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UNIVERSITY OF TORONTO
JOHN H. DANIELS FACULTY OF ARCHITECTURE, LANDSCAPE, AND DESIGN

Tower Renewal Guidelines

For the Comprehensive Retrofit of Multi-Unit Residential Buildings in Cold Climates

Ted Kesik and Ivan Saleff
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Cover Photo: Jesse Colin Jackson

The Tower Renewal Guidelines project represents applied research conducted entirely at the University of Toronto that is aimed at assisting owners, designers, restoration contractors and regulatory officials, ensure the full benefits of tower renewal are realized. In terms of durability, much of the tower apartment building stock has performed admirably for the past half century, but within the context of high energy costs and global warming, a major makeover is needed now. The currently proposed cycle of renewal should restore reliable service and deliver sustainable performance for many decades to come. These guidelines seek to establish a framework for responsibly meeting our obligations to the future generations who will inherit this invaluable housing resource.

The Jetsons were on TV, Yorkville was electric, Neil was young, McLuhan was in fine form, Revell's City Hall design materialized complete with Moore's Archer, and the Beatles, the Stones and Zeppelin were in the air. The Maple Leafs were a dynasty. While our siblings south of the border experienced the '60s as turbulent times, Toronto optimistically embraced the decade as the beginning of a new world. A variety of lifestyle choices offering new directions appeared. High-rise living was one of them.
Ivan Saleff

Disclaimer

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Robert Wright and Graeme Stewart, Co-Researchers
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The following individuals generously volunteered their time and effort reviewing and commenting on the technical and practical relevance of these guidelines:

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Foreword

It is a great pleasure for me to write a foreword to the Tower Renewal Guidelines which has been prepared by Professor Ted Kesik, together with his colleague Ivan Saleff, and which includes contributions from a number of other members of the faculty, alumni and students of the John H. Daniels Faculty of Architecture, Landscape, and Design at the University of Toronto.

As noted in the Preface, this work began some years back in a research-based elective course offered by Professor Saleff, who was then joined in his work by Professor Kesik, and he in turn attracted a number of fellow faculty members and students to this important topic of architectural, landscape and urban research. Some of this complementary work is reflected in the contributions to the report by alumnus Graeme Stewart and by Professor Rob Wright.

By now, the influence of this important work has become widespread, and we can see it gradually beginning to influence policies of the City of Toronto and the Province of Ontario. Indeed, the Tower Renewal Guidelines must in my view be seen as one major culmination to this pioneering research investigation. Its ramifications for the future of our urban region are almost limitless, involving social and economic issues, industrial developments strategies, climate change, urban planning and transportation policy, etc.

I extend my deepest congratulations to my academic colleagues here at the Daniels Faculty, Professors Kesik, Saleff and Wright, as well as to the alumni and students who have worked with them on the production of this publication.

George Baird
Dean, John H. Daniels Faculty of Architecture, Landscape, and Design,
University of Toronto
June 2009

Preface

The idea of tower renewal in its broadest sense, and as it is presented in these guidelines, emerged from a series of architectural explorations initiated by Ivan Saleff shortly after the turn of the new millennium at what was then known as al&d, the Faculty of Architecture, Landscape, and Design, University of Toronto. His original elective course was attended by graduate students of architecture, engineering and landscape architecture, who were attracted to the idea of investigating building skin consciousness. Reinforced concrete-frame apartment buildings constructed across Canada, primarily during the 1960s and 70s, became the vehicle for this investigation of how the skin might be renewed to extend the service life of the buildings and to improve their environmental performance. As the course progressed, Ted Kesik examined the technical potential for energy and water conservation improvements, the corresponding reductions in greenhouse gas emissions, and the comparative life cycle costs associated with various renewal strategies.

The potential for improvements was found to be enormous, but one of the most significant findings to emerge from the early research was that these buildings were deteriorating rapidly. Their preservation was only achievable through an encapsulation of the building envelope on the exterior (overcladding), otherwise the precious embodied energy that was invested in the reinforced concrete armature (structural frame) would be lost, along with invaluable housing resources. Exterior retrofits also had the technical advantage of countering thermal bridging and improving thermal efficiency more cost effectively than any type of interior retrofit strategy offering equivalent performance. In terms of financial feasibility, exterior retrofits of the building envelope eliminate the need to displace tenants and this conserves revenues while it minimizes the dislocation of inhabitants.

All of this research and its significant findings paralleled efforts that were underway in continental Europe and the United Kingdom, and so it would appear that there was international consensus on appropriate strategies for the rehabilitation of high-rise, multi-unit residential buildings (MURBs). Subsequent research at the University of Toronto by the authors and their graduate students extended overcladding into the idea of tower renewal as a comprehensive, building-as-a-system retrofit that also opened opportunities for landscape restoration, urban intensification, renewable and district energy systems. Skin consciousness remained the trigger for a raised awareness of issues and opportunities that transcend the technical aspects of tower renewal.

These technical guidelines reinforce the view of housing as an essential resource to be sustained, not a commodity to be traded away, like stocks and bonds. Shelter is a primal necessity for human survival, and along with water and food comprise basic requirements for physical existence. Shelter, regardless of origin or form, is a critical driver of human advancement. Primitive shelter focused upon security and protection from the elements, whereas modern housing implies attributes and relationships that address the social, psychological and ecological connections between buildings and their inhabitants. Contemporary housing design criteria are of a high level of complexity, reflecting the modern condition and its expectations. In addressing these housing design challenges, it must be recognized that the essential “primitive” requirements for sustainable shelter cannot be compromised. Issues such as intergenerational equity necessarily emerge from this perspective to inform not just how we must rehabilitate our existing housing stock, but also how we must design our new buildings so that the future process of renewal is not compromised by outdated attitudes towards economics, ecology, technology and culture.

The tower apartment buildings that are the focus of these guidelines reflect a technology that corresponds to what in the future may be seen as the juvenile stage of our affluent, industrial society. Now that we are migrating towards a post-industrial society that inevitably will be forced to adapt to a post-carbon global culture, it is important to realize that static building systems are obsolete. These guidelines propose overcladding systems that have a maximum useful service life of 50 years, and may be easily replaced after they have expired. The critical environmental control layers and/or cladding attachment members should remain intact and serviceable for several cycles of cladding replacement. Accessible raceways and chases may also be incorporated into this new skin for the integration of building services and future ease of replacement or upgrading. The intent is to convert static, industrial era building technology into a biological model of a durable armature housing vital organs protected by a renewable skin. This anthropomorphic approach is consistent with the prosthetic function of buildings as an extension of human physiology.

This approach to tower renewal also gives cause to reassess the modus operandi of contemporary development, architecture, engineering and construction. If buildings are prosthetic interventions intended to enable human survival, then this implies a life cycle that mimics the creatures they shelter. “Green” movements have come and gone, reinvented periodically as a function of the fluctuation in energy costs and economic climate. The current movement, if sustained, will offer benefits enjoyed by many generations to come. Tower renewal will be a leading barometer of our collective will to mend the path to a sustainable future.

For all living things, there is but one alternative to renewal, and the same holds true for the artifacts that support living things. Tower renewal represents a single thread in the evolving tapestry of our built environment. Running along its weft are the eternal rhythms of civilization in all of their cultural dimensions. These human needs and desires intersect the ever changing warp of ecological carrying capacity, environmental impacts and the economic consequences that emerge as these intertwine. Weaving alongside tower renewal will be the revitalization of all the other building typologies and the municipal, transportation and energy infrastructure that now struggles to support them. The realities of the 21st century are demanding that we abandon a culture of conspicuous consumption and re-discover a reverence for cultivation and conservation. Adaptive renewal remains the only means to unfetter future generations who will otherwise inherit dysfunctional building technologies that tether the human imagination and diminish the earth.

This publication is a collaborative, interdisciplinary effort aimed at dealing with the regeneration of Canada’s tower housing stock. There is much more effort needed to realize tower renewal and extend it to other building typologies. It is hoped this modest beginning will inspire others to take up the challenge of maintaining the vitality of our built environment, so that is not a liability but a legacy to future generations.

Ted Kesik and Ivan Saleff
June 2009

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1. Tower Renewal Challenge

"In Toronto, an unusually large number of high-rise apartments poke above the flat landscape many miles from downtown….this is a type of high density suburban development far more progressive and able to deal with the future than the endless sprawl of the US…." [1]

Richard Buckminster Fuller, 1968

The tower renewal challenge can be described as a simple idea that is complex in its application. As such, it demands a highly structured and disciplined approach that must appreciate the preservation of this unique housing resource as being of foremost importance.

Canada contains a significant stock of high-rise housing constructed for the most part during the nation-wide economic and population expansion of the 1960s and 1970s. The majority of this housing typology is located in Ontario, primarily within the vicinity of the Greater Toronto Area and Hamilton (GTAH). From Oshawa to Hamilton there are more than one thousand high-rise apartment towers, clustered in neighbourhoods throughout the region. The concentration and scale of this tower apartment building inventory are unique in North America, and there are also many other Canadian cities that host large numbers of this housing form.

This aging form of housing has provided affordable shelter for countless numbers of people over the past 50 years, but has now reached a durability threshold in terms of its physical integrity, and a sustainability crisis relative to energy and water consumption and greenhouse gas emissions. It has been estimated that the collective greenhouse gas emissions of tower apartment buildings in the GTAH is nearly one megatonne annually. Notwithstanding this environmental burden, the reinforced concrete structural systems, also referred to as the building armature, continue to perform admirably except for exposed elements such as cantilevered balcony slabs. Suite sizes and configurations are generally much more accommodating than any new rendition of multi-unit residential buildings (MURBs), especially when compared to contemporary condominium apartment buildings that seldom cater to family living arrangements. The existing tower building stock also enjoys surrounding green space that is quite expansive in suburban locations. Most importantly, since the high-rise housing in question predates the condominium form of tenure, these buildings primarily constitute rental units, and this renders them highly relevant to maintaining a healthy mix of housing choices in the context of a rapidly expanding metropolitan setting.

Commentary on the quality and desirability of the tower building housing form versus any other housing form, has not been considered in this publication. Instead, these guidelines focus on the present reality of aging high-rise housing stock and attempt to identify opportunities associated with rehabilitation, enhancement and conservation.

Systematic analysis of human shelter reveals that it is comprised of a vast array of vital environmental, economic and societal systems having municipal, regional, national and international implications. Any successful program for the comprehensive revitalization of existing high-rise housing stock provides an opportunity for capitalizing on the direct and indirect positive benefits from all such arenas, as the ripple effects are widespread.

The key goal of these guidelines is to provide insights relative to the rehabilitation, retrofit and conservation of this vital housing resource. The pursuit of this objective reveals immense opportunities for the conservation of energy and water resources, the reduction of greenhouse gas emissions, and the diversion of solid waste from our landfills. Associated economic benefits include the stimulation of a sustainable manufacturing and construction industries sector and the implementation of retrofit industry education and training initiatives.

At the level of each household, tower renewal can cost effectively deliver superior comfort and indoor air quality that are in line with contemporary housing technology and consumer expectations. But the benefits also extend to the neighbouring communities because the resource conservation afforded by tower renewal fosters opportunities for suburban intensification without impacting existing infrastructure. These types of sensitive interventions can complement neighbourhood beautification, regional sustainability and many other such progressive agendas. But none of this is possible unless cost-effective means of conserving this housing stock while significantly improving its environmental performance are technically developed and responsibly implemented.

University of Toronto professors Ted Kesik and Ivan Saleff have spent nearly a decade generating research specific to the issues of system performance, component detailing and the logistics of tower renewal. They have shared their findings in both academic and professional venues, and extended their inquiry through the supervision of graduate student researchers. Kesik is a building science engineer and Saleff an architect who have combined their backgrounds to holistically address the tower renewal challenge. This guidelines publication goes beyond the interests of the principal researchers and is an example of proactive interdisciplinary collaboration in the fields of architecture, landscape and urban design that is essential to the success of any revitalization strategy.

Foremost among all of the ideas advanced in the research supporting these guidelines is the relationship between the building skin (envelope) and the armature (structural frame). The static view of building facades forming a permanent condition and identity for a building is shown to be dysfunctional when viewed from the perspective of revitalization. Like our own biological skins, the skins of buildings must be easily renewed when they wear out, taking advantage of ongoing technical advancements, and providing a convenient means of upgrading building services infrastructure. Assuming a 50 year service life for each skin, and several hundred years for the armature, there will be a large number of potential renewal cycles, hence heating, air and moisture management materials, and the connections between the armature and skin, must be designed with either the same service life and/or easy access for replacement. This realization, obtained by considering the life cycle of modern buildings, informs not only tower renewal, but also the design of new buildings. In this sense, the tower renewal challenge extends beyond existing buildings to the mass customisation of high performance building envelopes for new and existing buildings alike.

The tower renewal challenge seeks to improve the performance, economics, aesthetics, replicability and intelligence of our existing buildings. It will demand that the design, engineering, manufacturing and retrofit of existing buildings become a seamless process that can be broadly implemented with a highly predictable outcome. This transformation of conventional practice into an integrated design, fabrication and installation process represents an important contribution to our green economy.

[Photo Opposite Page: Jesse Colin Jackson]

Comprehensive Strategy

For decades now, tower buildings have been maintained and repaired in a largely makeshift manner, without an overview of the entire building asset and its life cycle. Research into rehabilitation strategies specific to vintage high-rise housing has identified the comprehensive retrofit to be the most advantageous. Envelope upgrades necessitate upgrades relative to other primary building systems, most critically environmental systems. Existing, robust solid masonry substrates provide the opportunity to overclad with new envelope systems from the exterior with minimal impact on existing inhabitants. Electrical, security, telecommunication and waste management system upgrades also benefit from overcladding as they may be integrated within new outboard cladding systems. Storm water management and surrounding landscape amenities also benefit from a comprehensive approach to tower renewal.

Subsequent chapters of these guidelines reveal comprehensive retrofit strategies to be the most economically feasible within the context of life cycle performance. Since the durability threshold of this vintage stock has been reached, action must be taken in the near future to conserve the structural integrity of the existing exterior walls in order to realize the benefits of overcladding. In some instances, (e.g., those clad in deteriorating glazed masonry) the durability threshold has already been crossed and restoration must precede any retrofit. The same holds true for the deterioration of exposed balcony slabs. Time is of the essence, and the renewal process must be comprehensive to take advantage of all the synergies available in the building as a system of systems.

Government and industry responses must also be comprehensive. Strategic alliances between public and private sectors are a vital component of any effective approach. Both sectors stand to realize mutual benefits and their coordinated mobilization is essential to assist owners with the regulatory and financial barriers to comprehensive retrofits of their buildings.

Based upon the research conducted at the John H. Daniels Faculty of Architecture, Landscape, and Design at the University of Toronto, the City of Toronto has launched their own proactive initiative. Tower Renewal was endorsed as an official policy direction by Toronto City council in the Fall of 2008, and is currently a focus of the Province of Ontario's Climate Change Secretariat and Ontario Growth Secretariat. It holds great promise as it unfolds and evolves to become part of business as usual in a green economy.

The pioneering work conducted at the University of Toronto is also gaining momentum in the private sector as industry leaders and private concerns have taken up the cause. A notable example is the recently announced Zerofootprint Building Re-Skinning Competition (May 12, 2009) that is based directly on the issues identified in earlier research and presented in these guidelines. It is anticipated that many other such initiatives will present themselves as opportunities are explored and synergies realized.

The focus of these guidelines is vintage high-rise housing, nevertheless they may also be applied to vintage low-rise concrete structures with solid masonry exterior envelopes because they are tectonically similar. On the other hand, historically significant vintage buildings may require other approaches to preserve their existing aesthetic. Many of the envelope concepts presented in the Tower Renewal Guidelines may also provide insights into appropriate design and building science practices associated with current and proposed renditions of these housing typologies.

Tower Renewal Guidelines is a stand-alone reference document of building science and architectural intent, unbiased by industry and government agendas, but highly responsive to many of their pressing issues, and supportive of their exploration of mutually beneficial opportunities. These guidelines were construed as national in scope, but use the Toronto area as a primary context for purposes of illustration, recognizing that the international proliferation of this housing typology lend the guidelines global relevance. As such, the tower renewal challenge is something that will have different dimensions based on its climatic and cultural context, most notably the value placed by society on primary shelter.

The following sections of the tower renewal challenge will examine:

- Modern Legacy;
- Current Challenges;
- Regional Assets;
- Opportunities;
- International Renewal; and
- Green Economy.

Figure 1.1. Jane Exbury Towers. [Photo: Archives of Uno Prii.]

[Photo Opposite Page: Jesse Colin Jackson.]

History of Tower Development in the GTAH

Canadian cities are unique. In general they are more compact than their American counterparts.[1] This is largely due to divergent forms of post-war growth experience by the two countries. While both built car-oriented suburbs, Canadian cities promoted high-rise housing, both private and public, as part of the housing mix.

In general, more Canadians per-capita live in high-rise dwellings then their American cousins. Of the top twenty cities in North America with the greatest number of high-rises (here defined as 12 stories and above), seven are Canadian.[2] A significant proportion (and in some cases the majority) of this high-rise stock in Canadian cities is made up of the post-war modern high-rise residential towers that are the focus of this document.

The Greater Toronto Area and Hamilton (GTAH) is Canada's post-war high-rise capital, containing over 1000 towers built between 1960 and 1980, particularly in the former municipality of Metropolitan Toronto.

Organized by a regional planning body during the period of explosive post-war growth, the area contains many experiments in modern planning, most significantly its legacy of high-rise "tower-in-the-park" apartment buildings spread throughout the region. Most are located in Apartment Neighbourhoods in suburban areas of the metropolitan region. *Apartment Neighbourhood* is defined as a cluster or collection of multi-unit residential buildings, typically tower buildings, that comprises the same population and/or number of dwellings as a conventional, low-rise residential neighbourhood. From a variety of influences, including the US and welfare state Europe, a hybrid form evolved, shaped by government regulation, but implemented by private developers that saw opportunity in the economic expansion of the period.

This section will look at where these towers came from and how they helped shape Canada's urban system, particularly the Greater Toronto Area.

Metropolitan Toronto

Although apartments were considered by Toronto's administrators to be a detriment to society prior to the Second World War,[3] the modern high-rise became a significant feature in the City's post-war urbanization, and for Canadian cities in general. This change in attitude resulted from the establishment of the Metropolitan Government. The process of Metropolitanisation was set in place almost immediately after the war with the establishment of Metropolitan Toronto on January 1st, 1954, which precipitated the regional administrative consolidation. Toronto thus followed New York City as the second regional government of its type in North America.[4]

The borders of Metro contained Toronto as well as several adjacent townships and villages, allowing for coordinated planning of the urban centre, suburban periphery and agricultural hinterland under one administration. Targeted for substantial economic and population growth, the form of development within its extensive yet finite boundary lead to several experiments in modern planning during the ensuing decades.

One of the key missions of Metro was the use of government intervention to ensure the "continued climate of economic expansion".[5] Planners would determine the overall framework and private developers would be the instrument of execution. As it was believed that significant apartment housing was needed in peripheral regions in order to achieve employment, transit and social objectives, the modern apartment tower played a prominent role in the shape of the Toronto Region.[6]

Developing Modern Communities

Although many towers were built in the central City, often near subway stops, the vast majority were built in new communities at the edges of the metropolitan area. Promoted as a more responsible use of land than single-family homes, fields for pasture rapidly changed to fields of towers.

As early as the 1950s, alternatives to typical subdivision sprawl were evident in Toronto's suburbs.[7] Several were planned as 'complete communities', providing industry, shopping, mixed-housing types and ample natural open spaces, as well as promoting modern design. Several of these communities were also loosely based on the 'satellite' or 'new' town, an idea popular during European reconstruction, where new development was organized in self-sufficient and physically separated communities. A departure from the typical sprawl of single detached homes found elsewhere in Toronto and elsewhere in North America, these planned communities offered a more compact and diverse form of outward growth.

The policies directing the development of these communities (known today as Apartment Neighbourhoods) were to provide self-sufficient macro communities within new suburban areas. In addition they minimized commuting by providing housing of all tenures in proximity to major employment, and were accessible by both private and public transit.[8] Significant apartment housing was a key element of the levels of densification needed to support transit.[9] As a result, high-rise housing became a feature in nearly all post-war neighbourhoods, and some were developed as Apartment Neighbourhoods containing high-rise housing exclusively.

Toronto's first such development was Don Mills, quickly followed by Thorncliffe and Flemingdon Parks, planned in 1953, 1955 and 1958 respectively. Situated along the new Don Valley Parkway, these privately developed communities offered employment, shopping, ample natural open space, and notably, mixed-housing types including high-density apartments. Whereas Don Mills apartments were mostly of the low and mid-rise type, Thorncliffe and Flemingdon were designed with multi-story high-rises.

Upon completion, these developments featured innovative and internationally published housing and cultural institutions by Toronto architects Irving Grossman and Raymond Moriyama, among others. These projects were of national significance with Flemingdon Park becoming the home of Toronto's new Science and Technology Museum (Ontario Science Centre), and a contender for the new headquarters of the Canadian Broadcasting Corporation.

These groundbreaking communities were the first developments of their kind in North America. Curbing sprawl and providing dense clusters in new suburban areas, in many ways these Apartment Neighbourhoods were 'smart growth' before the term was coined. They were also catalytic to the high-rise boom that followed.

[Photo Opposite Page: Lockwood Survey Corporation.]

The Modern Tower, A Brief History

The Tower in the Park is one of the defining housing innovations of the 20th Century. The idea of the tower in a genuine 'park' or 'landscape' setting became popular in Europe during post-war reconstruction. Open space around high-density developments was encouraged to provide breathing room, accessible community recreation space, and also to allow for unobstructed sunlight into apartment units. Felt to be the housing model that combined the best standard possible with a responsible use of land, the modern tower became a leading approach to urban growth the world over.

In Western Europe, these apartments were built in the wake of housing shortages during post-war reconstruction. In the Soviet Union, they represented nearly all new housing from the mid 1960's onward. In the United States modern towers were almost exclusively used to provide assisted housing for very low-income residents. In Canada, on the other hand, these buildings became popular to a wide range of income groups and both public and private builders. Readily accepted, the tower in the park was adapted to the Canadian context by the design and construction communities.

This typology was first introduced to Toronto through City Park apartments in 1954. Built downtown in response to density allowances granted as a result of the subway, it was heralded as a modern 'European' approach to city building.[10] This was followed by English/Canadian architect Peter Dickenson's Governor General award winning Regent Park, a social housing and urban renewal project in the downtown east side. Yet it would be in the expanding post-war communities that the modern tower gained its prominence.

Developers favoured modern concrete towers for their efficiency of construction and popularity within the booming housing market. The local invention of the 'flying form' technique of concrete construction made building these towers remarkably fast and cost-effective.

Toronto planners, particularly the Hungarian born architect/planner E.G. Faludi,[11] promoted the open space around multiple dwellings as best practice, ensuring what was felt to be a humane urban environment. In exchange for providing more open space, developers were permitted to construct larger buildings. The result is the multitude of tall apartment towers with up to 90 percent open space found across the Toronto region.

A convergence of planning ideology and an enthusiastic housing market created a wave of tower apartment buildings that spread across the entirety of the Metro region. Ironically, the towers in the Toronto area became symbols of both top-down planning and free market development.[12]

Modern Construction

With a high degree of similarity, these post-war apartments consisted of concrete structural frames efficiently built by the 'flying form' construction technique that was pioneered in Toronto. The concrete shear walls, spaced in six metre bays, easily accommodated one, two, three, and even four bedroom configurations. Projects became larger and larger until their sizes were ultimately limited in length by the maximum distance allowed between the fire stairs (located at either end of the building) and in height by the structural limitations of the concrete framing system (about thirty-six storeys).

Figure 1.2. Thorncliffe Park under construction. [Photo: Archives of Canadian Architect.]

Apartmentmania — Canada's Largest Housing Boom

Fuelled by the population and economic boom of the 1960s and 70s, hundreds of thousands of high-density units appeared through the region. Echoing today's condo market, these buildings were targeted at a growing consumer base of singles, young couples, empty nesters and young families.

When originally built, modern apartments were often marketed for their sophistication. Promoting a 'Jetsons' aesthetic, they offered for the first time panoramic views, underground parking, indoor pools and an alternative to the traditional Victorian house or walk up. For many, high-rise apartments symbolized a new world and a nation confident after the War.

Many of Toronto's leading architects, including, Peter Dickenson, Irving Grossman, and perhaps most notably Estonian/Canadian architect Uno Prii (famous for his swooping towers), provided their interpretations of modern housing. By the end of the period of rapid post-war growth, 'multiples' outpaced single detached homes by a ratio of 2:1. By 1966, at the peak of Toronto's first mass housing boom, nearly 40 percent of the city's housing stock and 77 percent of housing starts were modern apartments.[13] Nearly 30 000 high-rise units were built in 1968 alone.

As a result, the Toronto area contains the second highest number of buildings twelve storeys and over in North America. The majority of these buildings are the concrete apartments in question, making modern towers the definitive housing type of Toronto and Canada.

North American High-Rise Buildings:

New York	5,568
Toronto	**2,047**
Chicago	1,076
Vancouver	614
Miami	535
Los Angeles	467
Montréal	447
San Francisco	436
Honolulu	431
Philadelphia	336
Houston	331
Ottawa	284
Washington DC	272
Dallas	241
Edmonton	237

*Data from Emporis

Table 1.1. High-rise* buildings of all types, twelve storeys and over within metropolitan areas as of 2007. An estimated 1,000 high-rises in the Toronto area are the apartment buildings in question.

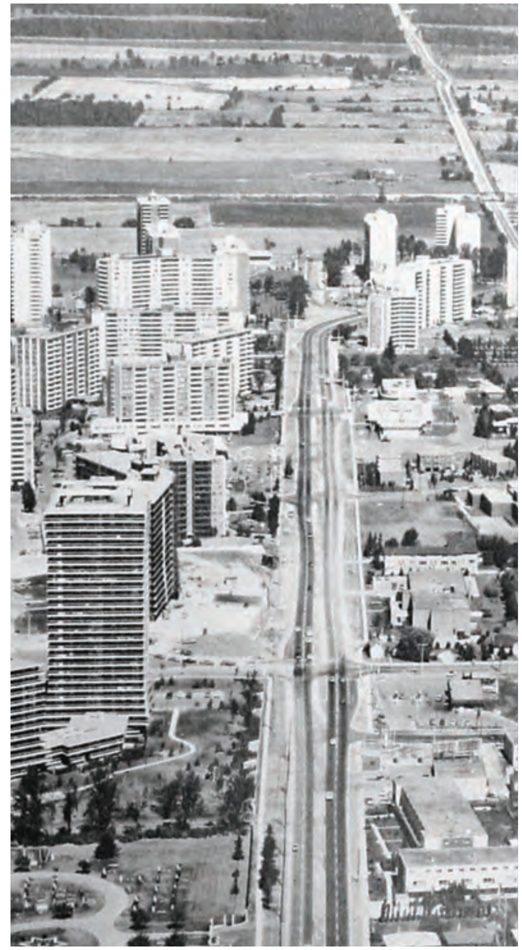

Figure 1.3. Bathurst and Steeles, towers and greenbelt, late 1960s. [Photo: City of Toronto.]

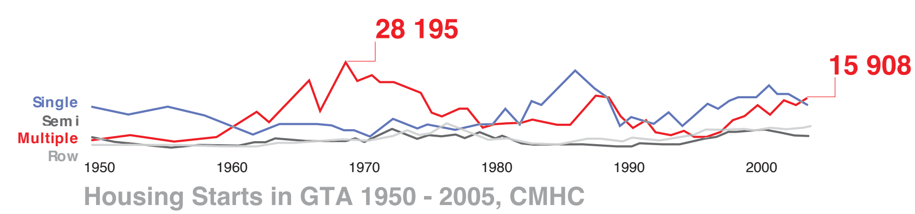

Figure 1.4. The graph above depicts multiple unit housing developed in the GTA over the past 50 years, illustrating the turn of the century condo boom, and mid century apartment boom. While the condo boom is, at the time of publication, the largest in North America, the previous apartment boom was significantly larger, overwhelmingly dominating the housing market for nearly 20 years.

Current Challenges

Environmental Sustainability

The private and public development of high-rise housing in Toronto's post-war communities has left Canadian cities with a unique inheritance. Built in an era of growth and optimism, they were developed under the premise of high-quality housing, and vibrant modern communities.

Today, however, as these communities approach their fifth decade, many are showing signs of disrepair and neglect. The quality of housing is in decline, and furthermore, these apartments have become among Toronto's most wasteful and ecologically irresponsible building types. As a result, aging Apartment Neighbourhoods sit at the centre of two of the greatest challenges facing Canadian cities: environmental sustainability and social inequity.

Aging, Inefficient Buildings

Deterioration of the buildings is widely evident, as is these building's increasing environmental impact on the region. From an energy use perspective, these buildings are extremely wasteful.
Although density is generally thought to aid sustainability, this stock of concrete slab apartments demands more energy per square metre than any other housing type, current data suggesting up to 20 per cent more than a contemporary single detached house (CMHC). Although certain efficiencies are gained from reduced land coverage and transit use, the buildings themselves perform poorly.

The towers were built in an era of cheap energy, when 'conservation' was not yet a consideration, and the principles of building science were not widely applied. Specifically, exposed slab edges (seen on walls and protruding balconies), minimal insulation, single-glazed windows and aging mechanical systems give these buildings an enormous environmental impact.

These inefficiencies compounded with the rising costs of energy, make these buildings significantly more expensive to operate than necessary and contribute to a degraded environment. With over one thousand such buildings in the Toronto region, their operating energy requirements collectively account for a significant percentage of regional residential greenhouse gas production, currently estimated at nearly one megatonne.

Underserviced Communities

Apartment Neighbourhoods are home to dense populations of thousands. Yet, despite the original intent to create self-sufficient communities, these areas of the city have become increasingly fragmented and disconnected.

In the past decades, places of residence and employment have become disjointed. Furthermore, many Apartment Neighbourhoods do not provide access to services and retail, such as childcare, healthcare or groceries. As a result, residents are increasingly travelling great distances for employment and daily errands.

With low car ownership, many apartment residents rely on public transit. However, current rapid transit routes are noteworthy for the lack of service they provide to Apartment Neighbourhoods. As a result, many communities remain isolated from the City at large.

Apartment Neighbourhoods are predominantly home to new Canadians. Yet they are not meeting the needs of these diverse communities. In recent years, many have been identified as suffering from chronic neglect, disinvestment and growing poverty. They are

Figure 1.5. Open space in St. Jamestown. [Photo: Brendan Martin.]

generally underserviced in terms of community facilities, amenities, retail and employment opportunities and other features that make communities thrive. These areas are not working for the people who live there.

A Neglected Resource

Poor site planning and lack of upkeep are preventing these buildings from performing as they could. In many cases buildings are years overdue for significant upgrade. The quality of public space in these neighbourhoods is often in decline. The hectares of land surrounding these towers are largely relegated to surface parking, and for the most part, are currently surrounded by chain-link fences. The 'park' areas adjacent to the worst of these buildings are abandoned spaces cluttered with unused swimming pools and clusters of disorganized dumpsters rather than the communal green space that was envisioned. These buildings are not providing the quality of life that was intended.

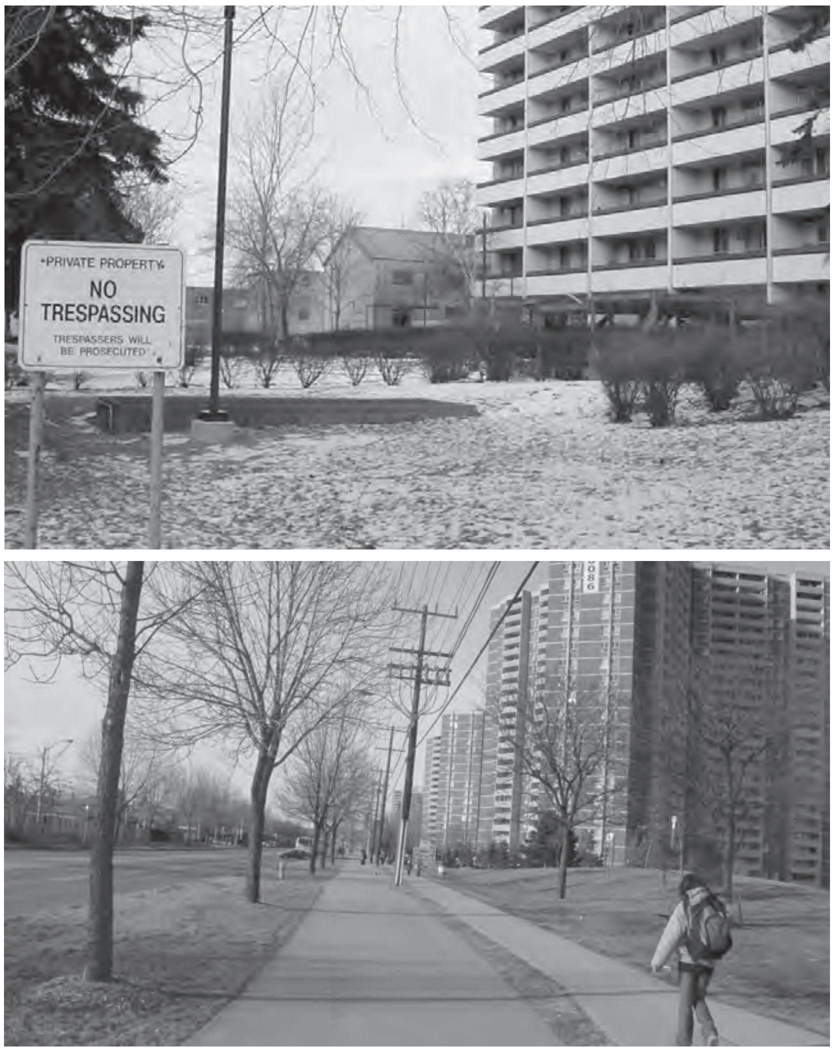

Figure 1.6. Open space of apartment properties, Kipling and Steeles.

Figure 1.7. Figure ground of Apartment Neighbourhood at Kipling and Steeles, showing property lines and chain linked fences. Here nineteen towers house thirteen thousand people.

Concrete Tower as Regional Asset

Despite these challenges, the heritage of the modern residential tower is an important built legacy, and a remarkable resource. Planned as integrated and complete communities, they contain a sound framework to meet the challenges of the 21st century. Collectively, these high-density modern tower blocks provide several advantages in achieving a prosperous, equitable and sustainable region.

These include, but are not limited to:

Existing Density

In Toronto, and many Canadian cities, post-war tower blocks provide high-density pockets throughout the urban region. In Toronto, these Apartment Neighbourhoods help give it twice the regional density of Chicago,[2] and even slightly more than that of Greater New York. With areas as far as 20km from the city centre housing up to 350 people per hectare, post-war planning has given the Toronto Area, particularly the inner-suburbs, a network of high-density nodes. By understanding and building upon the successes of these areas, and addressing their failures, these high density zones could be reinvigorated and reinvented as focal points for both new population and economic growth.

At the scale of the neighbourhood, the density found in high-rise apartment building developments provides the critical mass needed to make environmental upgrades and local services viable. At the scale of the city, these high-density clusters can be a catalyst for rapid transit and other infrastructure improvements.

Open Space: Room to Grow

There is room to grow. In Toronto, for instance, the city's highest concentrations of residential density corresponds with its largest areas of open space. Planned within modern guidelines requiring as much as 90 percent of the site to be undeveloped, residential towers sit within hectares of underutilised land, today largely relegated to surface parking and, in many cases, surrounded by chain-link fence.

This represents an enormous land resource, presenting a great opportunity for reengagement and reinvention. Allowed to evolve in response to the ambitions and needs of the resident community and stakeholders, this inherited open space provides a remarkable opportunity for the future of Apartment Neighbourhoods and the city at large.

Durable Infrastructure for Housing

These buildings are aging, yet can provide housing well into the future. Planned for now expired 30-year life spans, their single glazed windows, and aging sealants and mechanical systems have carried them to the end of their first life cycle. This building stock, however, is far from obsolete.

The durable concrete construction is sound and perfectly suited for upgrade to meet 21st century expectations of building performance and amenity. Properly upgraded, the tower apartments can continue to be a viable housing resource for many more generations.

Containing a significant percentage of two and three bedroom apartments, these buildings provide family sized multiple units, as well as affordable accommodation for working Canadians. As housing needs increase in our growing urban regions, updating existing housing will be a key concern.

When evaluated through the lens of ecological impact, the embedded energy contained within this extensive building stock is substantial. Demolition would be an incredible waste of resources.

Transit-Oriented Communities

The development of high-density suburban neighbourhoods coincided with the development of Toronto's metropolitan transit network. The extensive surface network which resulted is currently among the largest in North America and accounts for the most significant share of the City's transit riders; apartment dwellers, ranking among the highest users.

Apartment clusters provide the backbone of the transit system in suburban areas, enabling viable service in all areas of the city. High transit use also correlates with high levels of pedestrian activity. Thus it is not surprising that, in suburban areas, Apartment Neighbourhoods contain some of the lowest car ownership rates in the City. Building on this foundation with new investment in transit, pedestrian and cycling infrastructure, this inherited density could enable a truly connected and sustainable region.

[Photo Opposite Page: Lockwood Survey Corporation.]

Opportunities of Tower Renewal

Aging modern towers may be our greatest urban resource. These aging concrete towers present opportunities for significant greenhouse gas reductions, having the flexibility to adapt to new housing needs, having space for needed services, amenities and employment, containing dense populations to support vibrant communities and rapid transit, and having the durability to last several more generations. Thoughtfully managed, they may once again transform the region, enabling vibrant neighbourhoods, healthy communities and a sustainable built environment.

Several of the specific opportunities for renewal will be discussed in this section.

Going Green

Climate Change is one of the key issues facing cities in the 21st Century. Meeting these goals will not only require a high green standard when building new, but more importantly, addressing the existing built environment – making the existing city green. Aging apartment towers are among the most wasteful residential buildings in Canadian cities; yet with relatively straightforward modification, they could become their greenest.

Due to their straightforward concrete construction, as well as ample open space, these aging apartments are highly suited for green retrofits. Furthermore, the scale of these buildings, many containing several hundred units, provides the critical mass to make these green retrofits viable. Green retrofit will provide immediate and significant reduction in carbon output in addition to substantially reducing building operating expenses, at a fraction of the cost of building anew.

Through a variety of other green strategies, the energy footprint of apartment districts can be dramatically reduced. These include, but are not limited to:

- District energy installations
- Thermal over-cladding
- Low water use radiators
- Solar water heating
- Smart building sensors
- Grey-water recycling and storm water management,
- On-site waste management

Building upgrades can reduce energy needs by as much as 50%. If the energy used is from clean and renewable energy such as geo-thermal, green house gas production can be further reduced.

Investments are also possible at the neighbourhood level, such as district energy, auto-sharing, community gardens and on-site waste management. Furthermore, the addition of a mix of uses that provide local services and amenities will reduce the need for auto trips, and more importantly, will foster vibrant and self-sufficient communities.

Nation-wide upgrades will significantly reduce regional energy use and green house gas production, will improve the quality of existing housing and neighbourhoods, and will enable innovation and leadership in the growing green economy.

Overcladding

Thermal overcladding has been identified as one of the most effective strategies for tower block renewal. The fundamental challenge with the current buildings is the lack of a ‘thermal break’ between interior and exterior environments. A new ‘skin’, consisting of insulation, rain screen and exterior cladding, can be applied over the existing building surface. This approach extensively insulates the exterior of the buildings and covers thermally conductive slab edges. Furthermore, new operable balcony enclosures, consisting of an insulating double glazed enclosure would similarly improve building performance, provide a usable space in the winter and opening to the outside in temperate months.

Along with insulation, new building skins can include sun shading which responds to the light exposure on each building face. Furthermore, these assemblies can be integrated with services, ranging from geothermal heating, to gas, to high-speed internet, to garbage separation chutes. The new building surface itself could contain clean energy installations such as solar water heating and photovoltaic.

The key to the overcladding strategy is minimizing tenant disruption during the process of retrofit through phased upgrades applied from the outside in. This process would also offer the opportunity to update building appearance, creating unique and attractive neighbourhood landmarks.

Overcladding is the primary focus of this document and methods to achieve the best results will be discussed throughout the publication.

District Energy

Generally found in grouped clusters, Apartment Neighbourhoods contain the critical mass of people and buildings to support local resource networks, such as district energy.

Some options include geothermal heating and cooling, co-generation, turbine installations, solar hot-water heating, and so on. Applied at a district level, large installations based on these techniques could radically reduce the ecological footprint of these buildings and potentially take them off the City’s utility grid.

Carefully implemented, Apartment Neighbourhoods could become central to the creation of local green energy hubs. In addition to large apartment buildings, local energy networks could include nearby schools, shopping centres, nearby places of employment, and traditional housing. Taking these communities off the grid will free capacity for anticipated regional growth.

Figure 1.8. Opportunities for creating complete communities.

Figure 1.9. Conceptual low-rise infill between tower blocks.

Figure 1.10. Infill housing in Stockholm.

Figure 1.11. Infill housing in Marzahn, Berlin.

Creating Mixed-Use Neighbourhoods

The GTAH contains several dozen pockets of high-density Apartment Neighbourhoods in suburban areas. Many of these neighbourhoods have residential densities of over 250 people per hectare, in concentrations ranging from approximately 5, 000 – 25, 000 people (Statscan). However, despite these densities, the majority of these areas are underserviced and not meeting the diverse needs of their resident populations.

While primarily residential, many contain the capacity for mixed-use infill. The addition of new services, amenities and employment to these areas would reduce auto-trips, further support transit and address existing community-servicing gaps.

Allowed to evolve in response to the needs and aspirations of the resident community, these neighbourhoods could mature into the vibrant and dynamic 'urban villages' known to enable sustainable cities and a high quality of life.

Infill strategies include:

- New Housing
- Retail
- Social Services
- Transportation
- Employment
- Childcare / Senior Care
- Healthcare
- Language Training
- Job Training
- Libraries
- Food Markets
- Community Gardens

By design, these buildings can easily accommodate multiple uses from at-grade retail and office conversion to cottage industries. The concrete walls provide a natural fire break and the modular design is an infrastructure for uses which have yet to be considered.

New infill could give definition and form to areas, which today are criticized for their 'placelessness'. Thoughtfully designed structures providing a variety of uses could be integrated into existing buildings, arranged in a manner that defines private spaces, as well as facilitating an expanded and active public realm. Most importantly it would enable these communities to mature into lively, and diverse neighbourhoods.
The open space within these neighbourhoods presents the possibility for new housing.

Providing a Housing Variety

This would aid in reducing sprawl, but more importantly, would provide greater housing options within these communities. This could provide appropriate dwellings for the entire life-cycle, from young families to seniors.

Furthermore, in existing buildings themselves, the adaptability of the concrete structure lends itself to the possibility of layout alterations and building repurposing as the needs of residents evolve. Apartments could be combined both vertically and horizontally to create family sized dwellings. Alternations could include creating at-grade terrace units with street addresses, gardens, or conversion into communal areas or retail. They are a very flexible infrastructure.

Introduction of a variety of housing types into Apartment Neighbourhoods will help diversify the monolithic areas of apartment housing. Designed with sensitivity to the urban context, new housing could improve the built environment within Apartment Neighbourhoods, while providing needed housing options for current residents and the city at large.

Housing options include:

- Ownership
- Co-ops
- Rent to Own
- Assisted Housing
- Family-Sized Units
- Multi-Generational Housing

Enabling Locally Produced, Energy, Food and Culture

Beyond traditional mixed use, there also exists the possibility for permacultural, local and sustainable initiatives, including both environmental and cultural opportunities. Containing remarkable built, natural and human resources, these communities can become places of production to offset what they consume.

As an example, the open space found in Apartment Neighbourhoods was only a generation ago used for agriculture. Taking advantage of this potential for urban agriculture, onsite waste management and district renewable-energy installations, Apartment Neighbourhoods could manage local resource networks. This could take significant pressure off Toronto's grid, and foster engaged and green communities. Neighbourhoods could emerge as hubs servicing the City at large, with surplus energy sold to adjacent communities and yields from farming initiatives supplying local markets.

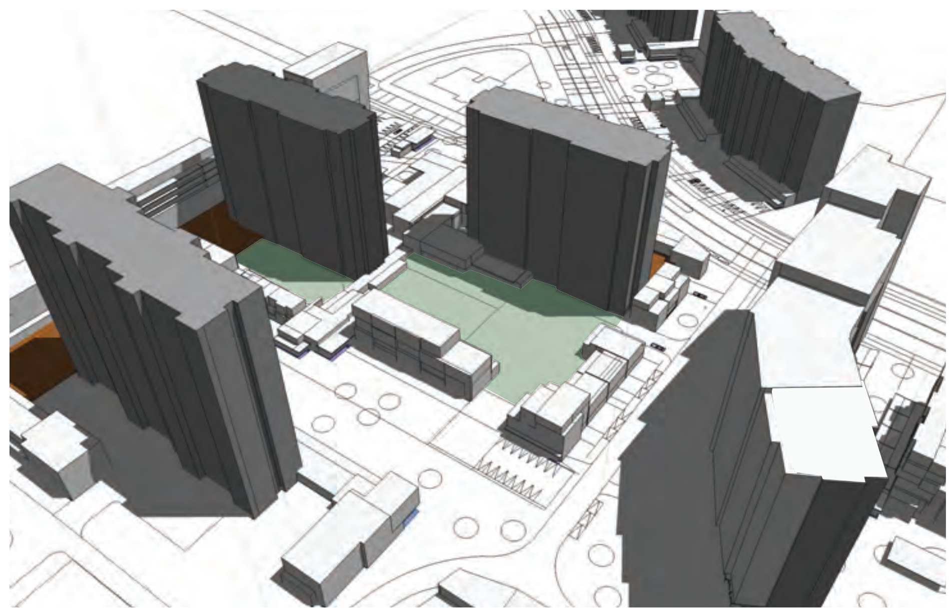

Figure 1.12. Conceptual infill strategy.

Figure 1.13. Conceptual infill strategies.

Regional Transformation

Tower Renewal has enormous transformative potential at both the local and regional scale. That a significant percentage of the GTAH housing stock consists of high-rise apartment complexes housing hundreds of thousands, already aids to regional sustainability. If these residents were housed in traditional single-detached homes, the region would be significantly more sprawling and transit would be impractical in many communities in suburban areas. Re-examined in today's context, Tower Renewal provides new possibilities for reinventing this legacy.

Currently, several regional planning studies are underway, examining the future of growth, transportation and energy in the GTAH. These initiatives aim to contain sprawl, improve transit options and foster vibrant and sustainable communities. Aligning these plans with the pockets of density created by tower blocks throughout suburban areas will provide significant advantages and unique opportunities. Regional opportunities include:

Tower Renewal has the potential to become a key feature in the Region's overall energy strategy.

Energy Planning

For urban regions to manage growth and energy needs into the future, new and existing communities must reduce the amount of energy required for operation, and the energy consumed must be made clean. Key in achieving these goals is the establishment of Community Energy Plans (CEP).

Establishing CEPs is the process of dividing Metropolitan regions into energy districts with long-term and sustainable energy strategies. The goal of CEP is to create districts that are self-sufficient in providing local energy needs, and that are able to accommodate growth without placing extra demand on existing systems.

In Toronto, nearly all proposed energy districts contain significant numbers of candidate towers for renewal. Comprehensively refurbished, Apartment Neighbourhoods could significantly reduce load on the existing system, creating the capacity to accommodate new growth. Additionally, positioned as clean energy hubs, Apartment Neighbourhoods could provide new clean energy within the district, emerging as net energy gainers.

Tower Renewal presents several opportunities for the Region's emerging energy challenges.

Furthermore, Tower Renewal presents the opportunity to accommodate growth and support transit.

Regional Transit and Growth

The proposed Regional Transit Plan will provide higher order transit lines along the busiest surface routes, creating a transit grid from the suburban arterial network that corresponds directly with many of the region's apartment clusters. The density of existing Apartment Neighbourhoods provides the ridership base to make new transit lines work. Introducing mixed-use infill within currently under–serviced neighbourhoods will further support transit, as well as enable these Apartment Neighbourhoods to emerge as hubs serving the local community.

New stations at the intersection of two or more transit lines adjacent to Apartment Neighbourhoods may emerge as larger scale regional hubs, providing the opportunity for significant investment, growth and employment.

Knit together by rapid transit, the GTAH's Apartment Neighbourhoods could quickly emerge as self-sufficient and sustainable communities, and may specialize as unique destinations within the network.

Investment in physical infrastructure, such as rapid transit, will be a catalyst for the new private investment needed in these areas, such as new housing, and building retrofit, corresponding with the goals of both the Regional Growth Plan and the Tower Renewal Project. Properly coordinated, these initiatives present a real opportunity for positive regional transformation.

Figure 1.14. Network of dense Apartment Neighbourhoods and major natural open space systems. Tower Renewal offers several opportunities at the regional scale.

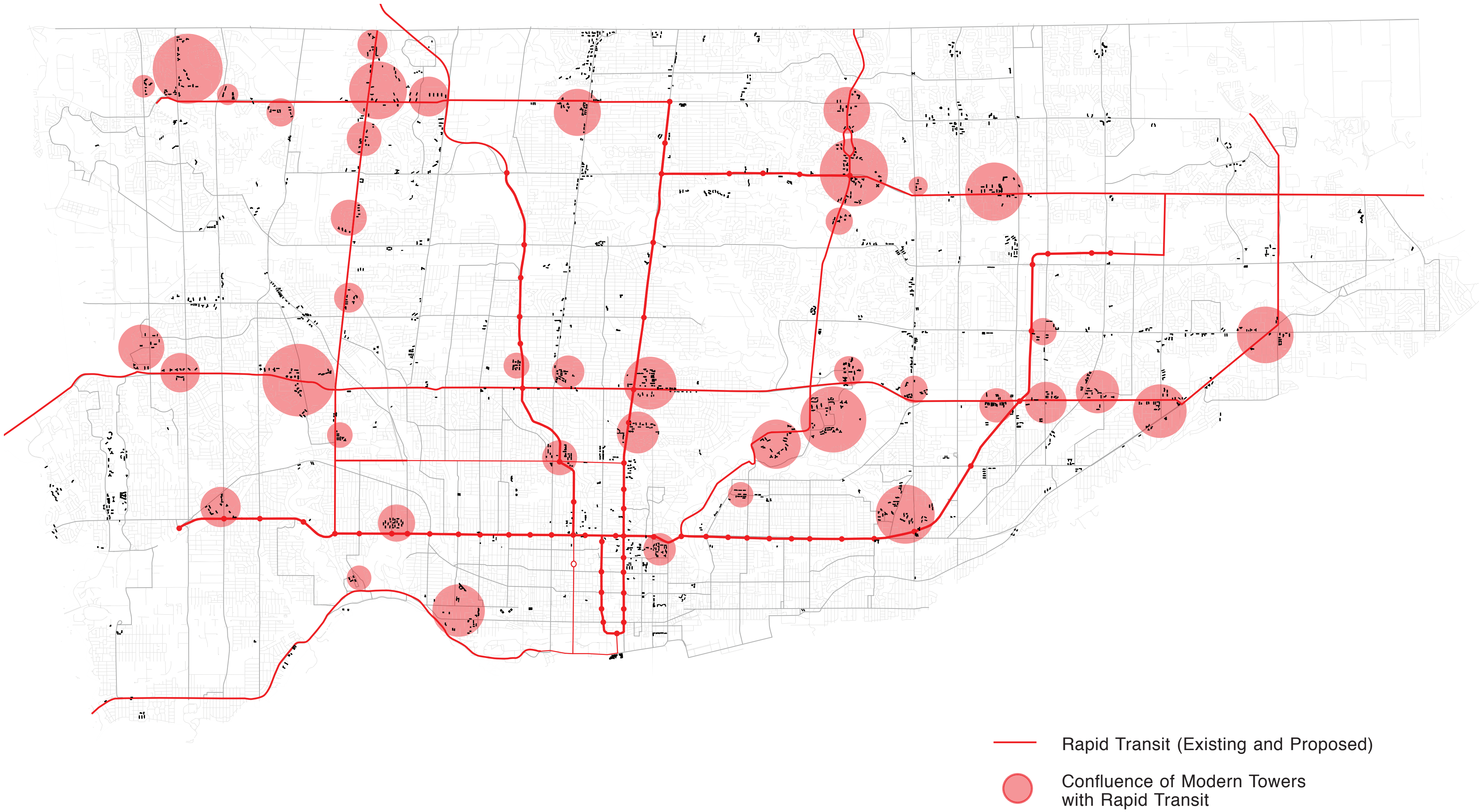

Figure 1.15. Toronto's Rapid Transit Plan intersecting with several of the region's underserviced high-density Apartment Neighbourhoods.

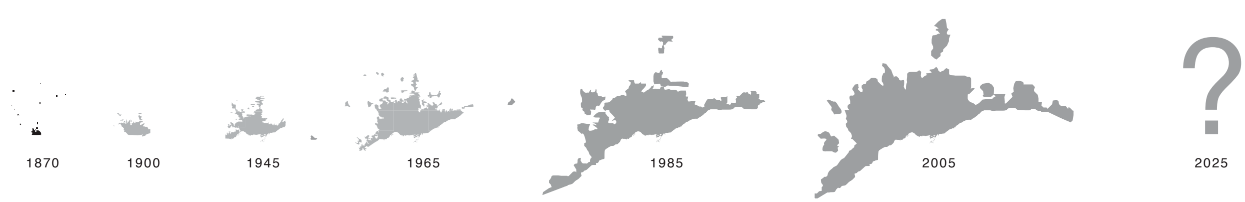

Figure 1.16. Growth in the GTA, 1870 - present.

Global Precedents

The challenges of aging tower blocks are not unique to Canada; it is an issue found the world over. From the Former Soviet Union to Western Europe, the Americas to East Asia, the modern tower block is truly part of the global landscape. A defining housing type of the 20th century, it has largely filled its mandate of providing well-serviced and equitable housing for tens of millions of people. Today, many of these buildings are reaching the end of their first life cycle.

There have been a variety of approaches to updating this housing stock for the 21st Century. In Europe, in particular, the community-building and carbon-cutting potential of aging towers has resulted in several innovative projects in building and neighbourhood renewal. Mixed ownership, massive scale redevelopment and liberalization of land use restrictions to encourage entrepreneurship are some of the strategies that have enabled apartment districts to evolve to meet today's housing and community needs.

One such example is the Bijlmermeer in south-east Amsterdam. Formerly a peripheral, underserviced and blighted community, integration with the Amsterdam Metro and Regional Rail was a catalyst for its development into an important regional employment, retail, growth and cultural centre. Containing refurbished post-war buildings and significant new development, the Bijlmermeer has emerged as an all-purpose hub within Metropolitan Amsterdam, rivalling the historic City. Other noteworthy examples include Marzahn (Berlin), Tower Hamlets (UK) and Topli Stan (Moscow).

Notable International Strategies Include:

- Environmental upgrade
- Building renovation and housing upgrade
- Urban design and enhanced public realm
- New permanent retail and outdoor markets
- Urban agriculture and enhanced green spaces
- Introduction of new housing and infill
- New housing ownership models (inclusive zoning)
- New investments in transit and other infrastructure

In Canada, we have an opportunity to learn from the best international examples, while developing cutting edge solutions best suited to the Canadian urban context and climate. There exists a great opportunity.

Figure 1.17. Though unique in North America, Toronto's post-war Apartment Neighbourhoods are similar to those found the world over; particularly those found in the European Union and the former Soviet Union. Although they were created in a different context and economy, Moscow (top), and Toronto (bottom), share a remarkably similar tower heritage, as well as related opportunities and challenges.


McDonald's
KIND
HÖRGERÄTE
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Figure 1.18. Internationally, over-cladding aging high-rises along with open space improvements has been a key strategy for carbon reduction and community renewal, especially in the European Union (EU). A leader in the field has been Germany, where the tower blocks of post-wall Berlin have been significantly upgraded as part of both environmental policy and unification.
Top, Left: Marzahn Berlin. Top, Right: Commercial Infill, Moscow. Bottom, Left: Social services infill, Tower Hamlets, London.
Bottom, Right: Halle Neustadt, Germany.

Figure 1.19. In Bratislava, the entire district of the Petrzalka, consisting of hundreds of tower blocks, is in the process of being over-clad as part of Slovakia's environmental agreement in joining the EU. Paid for in part by the EU Commission of the Environment, the municipality, and private investors (who gain development rights on adjacent properties), the project is not only making buildings more efficient, but is also breathing new life into this aging district through new mixed use and improved public space.

Building the Green Economy

The sheer scale of this tower building type (some 1000 throughout the GTA, with additional large clusters throughout Ontario and from Halifax to Vancouver), provides an enormous market for the clean economy and related industries.

While products and processes related to Tower Renewal exist internationally, specifically in the EU, there remains a need for home-grown solutions. As a result, there is an opportunity to develop processes and products appropriate to the Canadian context, which are produced locally, and create significant new employment in a variety of key sectors. This will help make Canada a laboratory for sustainable innovation, and a leader in the green economy.

Opportunities include, but are not limited to;

- Development of advanced products and processes related to clean and district energy, thermal over-cladding, smart buildings as well as building and neighbourhood renewal
- Job creation related to component design, manufacturing, assembly and installation
- Green collar job training and youth education programmes

Canada can position itself as a leader in a field that has global relevance, serving markets from China to South America. This will create tens of thousands of jobs for its citizens, as well as foster an improved and sustainable urban environment.

Figure 1.20. Examples of Building refurbishment, Top and Middle: Berlin, Bottom: London.

Figure 1.21. Refurbishment, repurposing and addition, Stockholm.

Synopsis

The environmentally responsible rehabilitation of existing high-rise housing stock represents a great step forward in Canada's response to climate change, healthy communities and sustainable economic development in the 21st century.

Mid-century apartment tower blocks have been selected as candidates for a comprehensive retrofit program based upon identified needs. From a societal perspective, these needs include the preservation of existing affordable rental housing stock, prevention of further building fabric deterioration, modernization of antiquated environmental systems, and the reduction of greenhouse gas emissions, energy and water consumption. For the building inhabitants, these needs translate into the enhancement of indoor air quality and thermal comfort to comply with contemporary standards, and the elimination of the social stigma associated with the declining aesthetic of tower buildings. Reinvestment in the comprehensive retrofit of tower buildings provides an opportunity to simultaneously address issues related to quality of life and environmental performance by directly responding to these needs.

The high-rise housing stock examined in these guidelines exhibits remarkable resilience and adaptability relative to its age. These characteristics are largely attributable to the material durability and robustness of the building envelope components that may now serve as a stable substrate for overcladding. Many contemporary examples of high-rise housing, such as condominium towers, may not accommodate overcladding strategies and will require the removal of their entire existing skins prior to retrofit. Only time will tell how today's newest housing stock will fare in terms of life cycle performance. Fortunately, the vintage tower buildings have many renewal cycles remaining provided the first and most critical renewal strategy is intelligently designed and properly implemented.

The associated benefits and opportunities of comprehensive rehabilitation are vast and transcend the individual artifact. These guidelines provide a reference point for many significant opportunities for the conservation of natural and housing resources. The next chapter looks at principles of tower renewal and how these may be applied to sustain our tower housing stock.

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[Photo Opposite Page: Jesse Colin Jackson.]


OF EDUCATION
OWNER'S EXPENSE
NO
TRESPASSING

2. Principles of Tower Renewal

Housing is a cultural resource to be preserved, not a commodity to be traded. As such it must be responsibly managed so that it will provide acceptable service over its useful life to successive generations. It should address environmental, social and economic realities while sheltering its inhabitants in safe, clean, comfortable and healthful environments. Post-war tower buildings, not just in Canada but around the world, have reached a critical point where their owners and the societies that support them must choose between a legacy of neglect or intergenerational equity. The nub of the current situation is summarized in founding work on sustainable development.[1]

> *Humanity has the ability to make development sustainable - to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs. The concept of sustainable development does imply limits - not absolute limits but limitations imposed by the present state of technology and social organization on environmental resources and by the ability of the biosphere to absorb the effects of human activity.*

Tower buildings and all manner of multi-unit residential buildings (MURBS) can be cost effectively rehabilitated so they are no longer addicted to wasting energy and water. Moreover, they can be regenerated to become much more durable and adaptable than their present condition, in some cases capturing sufficient energy and water to enable survival in the event of central infrastructure failures and extreme weather phenomena. Finally, through sensor technology and intelligent digital controls, this stock of buildings can be reincarnated as cooperative plug-and-play agents in the conservation, generation and distribution of energy throughout a decentralized smart grid. These are not fantastic ideas like flying cars, but very realistic possibilities that are within our current grasp. Towers and MURBS represent the future of sustainable urban settlements and lifestyles. This challenge is well documented in earlier work on the subject of urban regeneration.[2]

> *Half the world's peoples will live in urban areas by the end of this decade. Whether we achieve a greater degree of environmental sustainability over that time will therefore be determined largely by our cities. Surely, sustainability is not possible in the long term unless we can soon find ways to regenerate our urban ecosystems, keep them in good health, and adapt more sustainable urban lifestyles.*

The means are as important as the ends when it comes to the renewal of buildings and the revitalization of neighbourhoods. Conventional approaches to planning and design have not achieved their intended outcomes in many of our planned communities, and this is a particularly critical consideration in the renewal of tower buildings and their surrounding sites. Sequential planning and design processes parcelled out to individual disciplines are not an effective means of achieving high performance buildings and functional social amenities. The integrated design process (IDP) is a highly recommended alternative to what has been typically tower remediation carried out by contractors on behalf of building owners with practically no input from regulatory authorities and stakeholders. It is an holistic approach to design that begins with measurable performance objectives, and integrates a multi-disciplinary perspective on appropriate strategies for the conservation and renewal of housing resources.

Performance Objectives

Tower renewal is an opportunity to upgrade existing buildings and transform them into sustainable housing resources. The following principles may be used to inform the renewal process of tower buildings:

- **Performance** – achieving safe, healthy and sustainable housing through the conservation of resources, specifically, energy, water, and solid waste.
- **Economy** – sustaining housing stock through cost-effective measures that enhance the durability and adaptability of buildings without compromising their long term affordability and financial viability.
- **Aesthetics** – promoting sensitive and responsible architecture that contributes to an interesting and enjoyable shared urban landscape and the improvement of our quality of life.
- **Replicability** – advancing building technology and the skilled trades to improve the quality, reliability and durability of building retrofit methods and materials, and providing mass customization at a competitive cost with traditional practices.
- **Smarts** – implementing sophisticated control systems networked within the building system and interconnected to the supporting infrastructure of energy and water.

These objectives should be viewed as the minimum acceptable threshold of technical transformation for the building infrastructure. Additional requirements should also be fulfilled in relation to site and stormwater management.

Figure 2.1. Tower renewal must also focus on the site and urban landscapes if it is to achieve its full potential. Stormwater management, green spaces and recreational amenities are essential measures that speak to environmental responsibility and inhabitant well-being. [Photo: Jesse Colin Jackson.]

[Photo Opposite Page: Simon Pulsifer]

Tower Renewal Prime Directive

In the past, urban renewal was synonymous with the destruction of existing urban fabric and the massive displacement of inhabitants. The demographics of high-rise apartment towers in Toronto are largely skewed towards economically challenged tenants who cannot afford to re-locate to market housing during renewal activities. This limitation also applies to tower owners who cannot afford extended periods of vacancy while renewal work is being performed. In view of this reality, these guidelines focus exclusively on exterior retrofits according to what has been termed the Tower Renewal Prime Directive:

Zero displacement of occupants.

Limited intrusion into the day-to-day lives of tenants.

Minimal impact on vacancy rates.

Figure 2.2. St. Jamestown in the heart of downtown Toronto is an example of an area that is intensely populated by tower buildings. Unless appropriate planning and renewal strategies are adopted, areas like this could be disrupted for more than a decade as the retrofit work proceeds from one building to another. Noise, dust and traffic congestion are among the logistical challenges associated with tower renewal in urban cores. Disparity between the inhabitants of retrofit towers and those awaiting retrofit are social challenges stemming from several decades of benign neglect. [Photo: Simon Pulsifer]

Figure 2.3. Apartment blocks like this one, situated in the former Soviet Union, teach important lessons about coordinated renewal strategies. Each floor of this building has been addressed individually by its inhabitants in a makeshift manner that has not improved durability or energy efficiency, and has also failed to enhance architectural aesthetics. This extreme example underscores the need for architectural standards developed in support of tower renewal. [Photo: V. Menkov]

Figure 2.4. Token planter boxes containing weeds are representative of so many environs surrounding tower building. These suburban landscapes stand in stark contrast to the older and more established neighbourhoods in cities. Proper planning practices must encourage appropriate development to transform these wastelands into healthy, vibrant neighbourhoods. [Photo: Jesse Colin Jackson.]

Fundamental Principles

In planning, designing and subsequently carrying out tower renewal work, there are several key issues that must be carefully considered. These are related to notions of housing as a resource embodied in a physical building infrastructure, that is in turn nested within an urban landscape and its historical context. Tower renewal is as much a social as a technological intervention, and it is guided by several fundamental principles.

Armature Versus Skin: Preserving Inherited Infrastructure

A critical feature possessed by most post-war multi-unit residential buildings constructed across Canada is that the existing building enclosure is an ideal substrate for retrofit overcladding systems. This building typology possesses an extremely durable reinforced concrete structural system (armature) that can accommodate a succession of building envelope assemblies (skins) provided they are designed for obsolescence (i.e., ease of replacement and upgrading). Historically, architecture produced buildings with excellent durability characteristics. This was largely due to the traditional nature of the structural and envelope systems employed. As a prime example, load bearing masonry construction integrated armature and skin, hence the facade inherited the durability of the structure. Modern buildings have departed from this traditional approach, but designers have not yet fully appreciated that with a separation between armature and skin, building facades should be designed as sacrificial layers that will be replaced or rehabilitated several times during the useful life of a building. Magically, this DNA was inherited by Canada's multi-unit residential building stock.

Tower renewal measures should attempt to avoid compromising this robust quality. The building structure and the solid masonry enclosure between concrete structural elements must be preserved as a durable substrate that can support successive overcladding systems. Assuming a 50-year service life for skins, and a minimum 250-year service life for the armature, existing tower buildings will be re-clad at least 4 times before they are no longer fit for their intended purpose. The intelligent selection and arrangement of materials, and their corresponding assembly details, are most critical when the first retrofit is executed. Proper design and workmanship will facilitate ease of re-skinning for all successive retrofit cycles. Today's prudent investment will yield huge dividends, whereas substandard overcladding solutions may mask concealed deterioration of the armature that will burden future renewal efforts.

From the perspective of sustainability, albeit unintentionally, post-war high-rise housing in Canada employed a building envelope system with affordable first costs that could later accommodate retrofit strategies to upgrade performance. For social housing, it is especially important to consider the fairness of having one generation alone bear the economic burden of sustainability. Designing envelope systems that allow for a generational evolution from affordability, through efficiency, then up to sustainability is an important migration strategy for future housing needed to affordably accommodate immigration to Canada's large urban centres. Understanding how to design the armature and its first skin to support successive re-skinning of the building can help us afford the needs of today without compromising a sustainable future for succeeding generations. In this way, inherited infrastructure is a legacy rather than a liability.

Preservation, Conservation, Renewal and Regeneration

Cities are naturally engines of change, but as numerous 'urban renewal' projects across North America's cities have demonstrated, new ideas are not always better ideas. Multi-unit residential buildings have become an established part of most cities across Canada and much of the developed world. In cities like Toronto, this form of housing was originally discouraged and often viewed pejoratively, but tower living is now a welcome choice over suburban sprawl. In the process of revitalizing this invaluable housing resource, some critical issues need to be examined by planners and designers.

A common question that arises during discussions about tower renewal is, "Why not just demolish these buildings and start over again?" Aside from having to disrupt and relocate so many displaced inhabitants, it is not environmentally sustainable to destroy the embodied energy in the concrete structures forming tower buildings. Compared to contemporary high-rise condominiums, 1960s and 70s tower buildings offer a mix of 1, 2 and 3-bedroom apartment suites that support a variety of household demographics. From an historical and architectural perspective, existing tower buildings are unique and nothing comparable has been developed in the past quarter century. Preservation and conservation make sense from a number of perspectives, and are not mutually exclusive from renewal and regeneration.

In practical terms, these intentions translate into practices that seek to minimize demolition, and where it is necessary to some degree, to opt for de-construction methods that are conducive to re-use and recycling. Conservation of resources can also be promoted through designs that minimize waste and maximize the future potential for re-use. Landscaping and site work should seek to adopt a net zero cut and fill strategy to reduce material transportation.

One of the most tangible symbols of renewal and regeneration is the resurrection of fountains and outdoor pools as part of a comprehensive tower site stormwater management plan. Tower living was originally intended to provide a high quality aesthetic experience and many buildings featured water fountains and pools that have been mostly left in disrepair. Today, those features can be integrated within a rainwater harvesting system to provide both function and delight.

Lobbies and entranceways were often accorded a high standard of design. Some apartment buildings featured sculptural elements to grace their grounds. There is a great deal of restoration and reinterpretation needed to preserve the culture of tower living within our contemporary context.

Finally, regeneration must advance the urban sustainability agenda and explore the potential of renewable energy technologies in tower renewal projects. Solar hot water production, and the generation of electricity by photovoltaic panels and films, are two proven technologies that reduce greenhouse gas emissions, enhance the passive survivability of buildings, and are now cost-effective on a life cycle basis. The same holds true for stormwater management coupled to rainwater harvesting strategies.

Is it possible to renew and regenerate while preserving and conserving our tower housing resources? Demolition and building anew is a rapidly vanishing option in today's world. It is essential to make do with what exists, and to cultivate it so that it continually responds to our needs and evolving cultural context. Intelligent and sensitive interventions are not only technically possible, but as will be shown later, they are highly cost-effective investments.

Figure 2.5. Landscapes are among the lowest cost and most value added investments for the regeneration of tower building sites. Desire lines for pedestrian traffic and the state of original plantings suggest new directions for functional landscapes that can also enhance the aesthetic experience. [Photo: Jesse Colin Jackson.]

Cultural Resource Stewardship: Architecture, Landscape and Urban Design

The idea of tower renewal goes beyond overcladding, the retrofit of HVAC systems, and the revitalization of landscapes. Tower housing, in all of its multi-unit residential building forms, is a cultural resource, certainly a ubiquitous one in cities like Toronto. The issue of stewardship has many dimensions that involve not only building owners and the inhabitants, but surrounding neighbourhoods. In fact, this vertical housing form involves numerous stakeholders who deliver energy and water, manage solid waste and provide social services.

In this sense, cultural resource stewardship not only extends to include issues of architecture, landscape and urban design, but also aims to fulfill a social agenda that speaks to the centrality of healthful housing as a fundamental building block of a democratic society. While the focus of this publication is not on social policy, it is becoming evident from other jurisdictions that the battle for preserving viable social housing resources is being lost. The current situation is well documented in studies on the future of multi-storey housing in the United Kingdom.[3]

> *So serious is this interlocking nexus of seemingly intractable problems that many have concluded that the only solution is to demolish the estates and start again. All over Britain run-down multi-storey housing is being torn down. A good deal has already gone. But this draconian approach raises serious concerns. Will it really work? Does it provide value for money? Is there really no alternative? Why can't these generally substantial buildings be successfully adapted or re-used? The central question is whether such problematic multi-storey estates can be transformed; whether they can be modernized to provide good housing; or whether, indeed, the only solution is to consign them to oblivion.*

Therefore, it is important that all stakeholders appreciate the real need for tower renewal and its transformative potential. However, it must also be acknowledged this transformation may not yield desirable outcomes unless the tower renewal exercise is conscious of the need to address issues of architecture, landscape and urban design from a multiplicity of perspectives. The burden of democracy is balancing the rights of individual property owners (landlords) and the rights of the collective (society) to ensure that where there is conflict, the final decision observes the principle that benefits for the many outweigh advantages for the few.

Tower renewal brings into sharp focus those issues that have often been overlooked in the planning and design of new building developments. Unlike greenfield projects built far from established neighbourhoods, tower buildings reside within a rich and complex context. They will require owners, inhabitants, regulatory authorities, utilities, designers and contractors alike to full examine and comprehend the many impacts of their collective response to the tower renewal challenge.

Figure 2.6. Playgrounds without children are often indicative of tower living malaise. There is no life at the base of the tower buildings because it was assumed people would drive to a nearby centre for recreation, shopping or community activities. The stewardship needed to bring back the people overshadows all technical challenges associated with tower renewal.
[Photo: Jesse Colin Jackson.]

Figure 2.7. The view that tower buildings are just another form of infrastructure, in their particular instance affordable housing, no different than transmission towers in delivering an essential service, obscures their higher purpose. The Canadian perspective on core housing needs must be reaffirmed through appropriate policies and standards governing tower renewal projects.
[Photo: Jesse Colin Jackson.]

Integrated Design Process

There have been two significant developments since the 1960s and 70s that have advanced the design and construction of well performing buildings. The first is known as the *building-as-system-concept*, whereby the building artifact is viewed as a system of sub-systems that must be properly integrated to achieve a level of performance that is declared at the outset of design, rather than accepted as a default condition following construction. This concept is more fully discussed in *7. Tower Retrofit Strategies: A Systems Approach*. The second significant development is the integrated design process (IDP).

The integrated design process evolved relatively recently in response to the desire to design, construct and operate high performance buildings – that is, highly energy and water efficient buildings with superior indoor air quality, daylighting and optimized life cycle costs. Early on it was discovered that the design process depicted in Figure 2.8 was not appropriate, as this was suited to traditional buildings with no explicit performance criteria, designed and constructed with conventional materials and methods. The assembly line approach to architecture was found to be poorly suited to delivering high performance buildings with affordable life cycle costs.

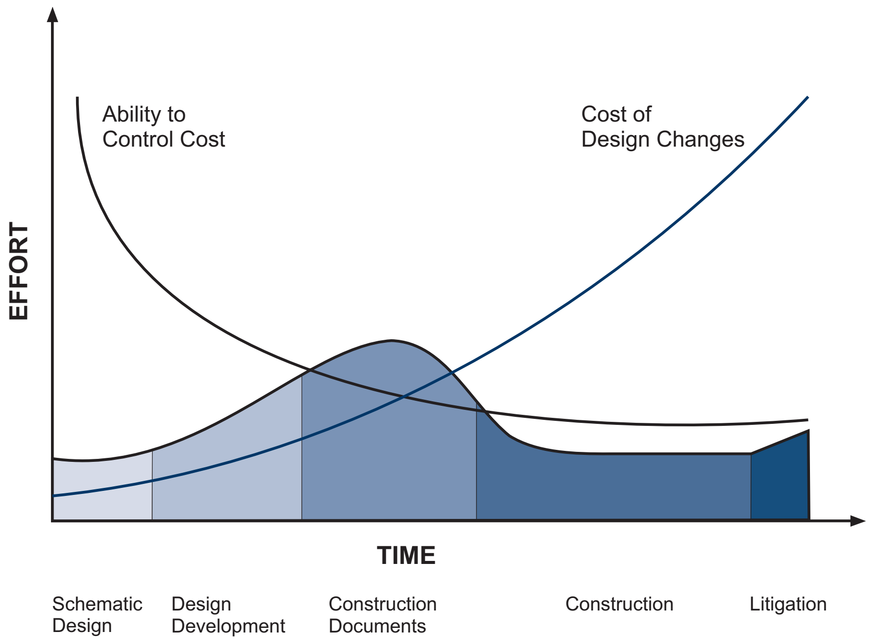

Figure 2.8. Conventional design practices tend to allocate the highest level of effort to the preparation of construction documents. This reduces the human resources available for schematic design and design development, when the design team has the greatest ability to control project costs. As a result, initial poor design decisions either incur very high costs for changes, or lead to litigation when poor performance is observed in the completed project. [Source: HOK]

The integrated design process is more akin to a quality circle in the automotive industry; every key member of the design team is involved at the outset, and throughout the project. The architect becomes the integrator of the various disciplinary perspectives through an extended schematic design and design development process, as depicted in Figure 2.9.

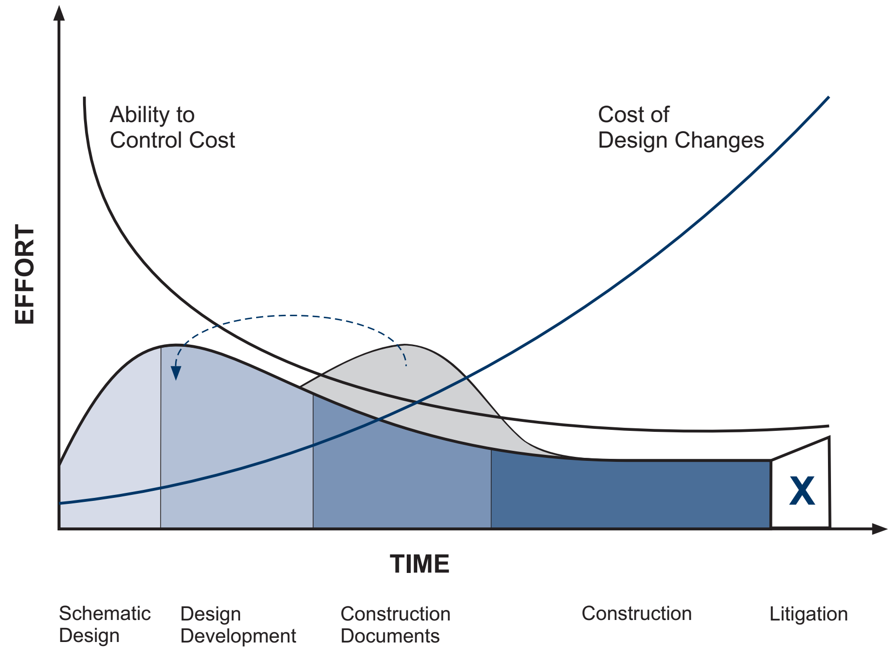

Figure 2.9. The integrated design process reallocates resources from construction documents to the formative stages of design in order to develop a better integrated system that meets pre-determined performance targets. Using the analogy of 'nature versus nurture' the integrated design process acknowledges that conceptual design creates the DNA of the building, which can later be nurtured through proper facilities management practices. Litigation is avoided through a process of quality assurance that constantly monitors and manages the design and construction phases to achieve the desired performance targets, on time and on budget. [Source: HOK]

A critical premise governing the integrated design process is that all key stakeholders are active participants during the various design stages. This implies that while the building owner (landlord) is certainly a key stakeholder, equally so are the inhabitants of the building. In many cases, it is speculated that minimum requirements for health and safety as found in our codes and standards will prove insufficient to guide the tower renewal process. In Canada, provincial governments have jurisdiction over building codes and standards, and these are in turn enforced at the municipal level where additional requirements may be prescribed. The integrated design process is a viable alternative to the evolution of building codes and by-laws needed to ensure that the interests of the building owners are fairly balanced with the interests and expectations of the inhabitants.

Returning to the planning and design of comprehensive retrofit projects, it should be noted that the retrofit and renewal of existing buildings and sites is different from the planning and design of new buildings because it is generally more highly constrained. The accommodation of the existing condition and the inhabitants is not a straightforward process, and there are very few contemporary precedents to inform practitioners. On the other hand, the integrated design process is best suited to deal with this challenge because it is premised on an overarching constraint: building system performance.

Building System Performance

The integrated design process as it relates to tower renewal is based on the concept of building system performance. The term "performance" may be defined as the level of service provided by a building material, component or system, in relation to an intended, or expected, threshold or quality.

These performance metrics drive a significant proportion of the design process and must be predicted with reasonable reliability at the design stage. Table 2.1 summarizes key performance metrics that may be employed at the design stage to inform the design, It is important to note that the performance metrics are strongly influenced by inhabitant behaviour, especially in the case of solid waste generation. Building energy and water consumption may be significantly moderated by technical intervention, but the observation of appropriate recycling and composting practices is almost entirely governed by effective public education of the inhabitants. Note that other important metrics, such as greenhouse gas emissions, may be derived from the key metrics listed below.

Performance Metric	Units	Description
Building Energy Use	kWh Btu J	Energy consumed annually in a building for heating, ventilation, and air conditioning (HVAC), indoor lighting, exterior lighting, service hot water (SHW), plug loads, elevators, and other building energy use. This is normally tracked on a monthly basis by energy source/fuel type for each of the end uses noted above.
Building Energy Use Intensity	$ekWh/ft^2$ $eBtu/ft^2$	Building Energy Use divided by the functional area of the building converted into an equivalent energy consumption per unit of building area.
Building Water Use	m^3	Annual volume of water consumed by the entire building for all uses, including irrigation.
Building Water Use Intensity	m^3/person m^3/suite m^3/m^2	Building Water Use divided by the number of occupants, the number of suites or the functional area of the building.
Solid Waste Generation	m^3	Annual volume of solid waste generated by a building, not including recycling and composting.
Solid Waste Generation Intensity	m^3/person m^3/suite m^3/m^2	Solid Waste Generation divided by the number of occupants, the number of suites or the functional area of the building.

Table 2.1. Key building system performance metrics combine the physical characteristics of the building and the behaviour of the inhabitants.

Life cycle affordability is a derivative of the actual building system performance achieved after the tower renewal work has been carried out. The lowest life cycle cost predicted at the design stage represents the best long-term investment on the part of the owner, and translates into the most affordable housing. The odds of attaining in actual operation the level of performance predicted at the design stage improve with the degree of rigour and comprehensiveness attached to the integrated design process. Figure 2.10 depicts the aspects of performance that must be successfully integrated by including all stakeholders from the outset.

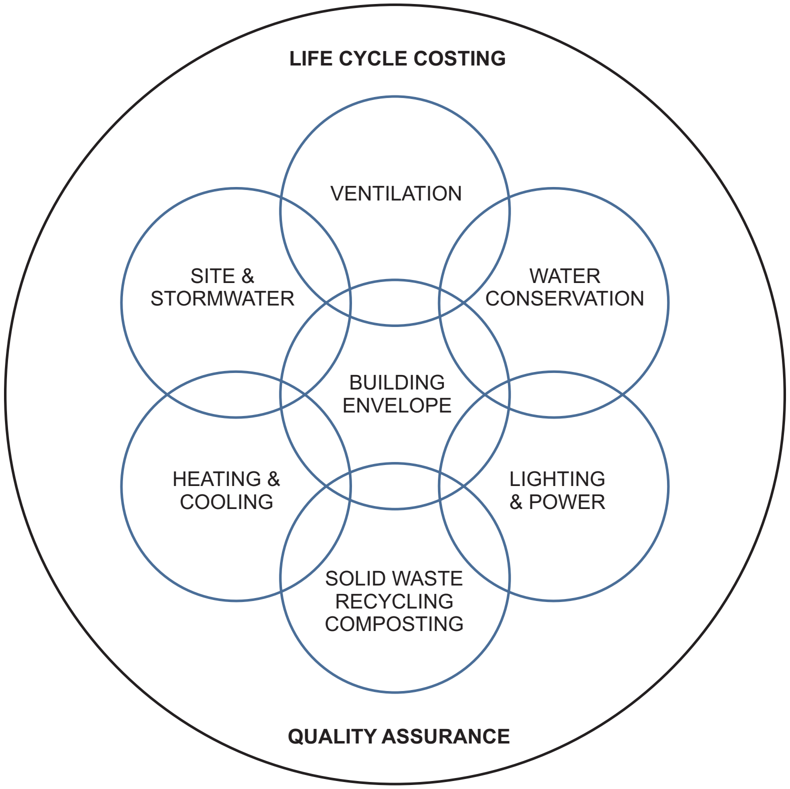

Figure 2.10. The building performance concept is based on the integration of building functional elements to attain the most sustainable level of performance as determined by life cycle costing. A corresponding quality assurance process must be implemented to ensure that the design promise is fulfilled in the comprehensively retrofit building and site.

In these guidelines, *9. Contract Documents and Administration* outlines the procedures and practices guiding design professionals in their exercise of due diligence for tower renewal projects. This traditional framework is not mutually exclusive from the integrated design process. In reality, the integrated design process reinforces the coordinating role of architects and the need to focus on measurable performance without compromising professional standards and the exercise of care.

The next part of these guidelines examines the anatomy of a typical comprehensive tower retrofit project from beginning to end. It assumes that the fundamental principles and considerations outlined herein have been assumed and applied.

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[1] G.H. Brundtland (Chair). *Our Common Future*. World Commission on Environment and Development, Oxford University Press, New York, 1987.

[2] *Regeneration: Toronto's Waterfront and the Sustainable City: Final Report*. Royal Commission On The Future Of The Toronto Waterfront (Canada), Minister of Supply and Services Canada, 1992.

[3] Towers, Graham, (2000). *Shelter is Not Enough: Transforming Multi-Storey Housing*. Briston: The Policy Press.

3. Anatomy of a Tower Retrofit

The comprehensive retrofit of tower apartment buildings is not a common type of building rehabilitation project in Canada. There are cases where one or more of the measures making up a comprehensive retrofit are undertaken, but typically, these are carried out individually on an as-required basis. In other jurisdictions, such as the United Kingdom and parts of continental Europe, more complete tower retrofits have been carried out, but these are not as comprehensive in nature as those proposed in these guidelines. A comprehensive retrofit involves a complete retrofit of the building envelope, HVAC systems and the surrounding site. It also considers measures for water conservation and the management of solid waste, recycling and composting while accommodating the potential integration of renewable and/or district energy systems. As a result of the relative novelty of comprehensive tower retrofits, it is important for owners and the professionals whose services they retain, to appreciate the process of tower renewal, in particular its duration, cost and critical considerations.

Duration

A limited survey of the building restoration industry indicated that most tower renewal projects are expected to have a duration ranging from twelve to eighteen months. For smaller buildings with less complex balcony arrangements, it may be possible to complete all work in just under one year, whereas extremely large and complex buildings may require close to two years. Additional considerations that may influence the project duration are accessibility to the site, space for material and equipment storage, and the weather.

Figure 3.6 indicates the duration and cost for a typical, comprehensive tower retrofit project. The time and cost projections are based on the 20-storey, 240-unit archetype tower building described in *11. Tower Renewal Case Study*, and economically assessed in *8. Tower Retrofit Analysis: Costs and Benefits*. Based on this example, the following durations may be used as a guide to planning a tower renewal project.

These durations do not include the time required for zoning by-law amendments, or the time needed to execute extensive repairs on existing building elements, such as balcony slab edges, before proceeding with the retrofit work proper.

- **Conditional Assessment and Pro Forma –** The inspection and review of the existing building, the compilation of operating costs (energy, water, maintenance), the development of an energy model, and the carrying out of a cost-benefit analysis that informs a tower renewal pro forma will normally require between four and six weeks. This phase may be impacted by situations such as inclement weather that makes it difficult to access the building for inspection, or the need to perform indoor air quality monitoring and infrared thermography.

- **Schematic Design –** This phase of the design stage is able to commence as soon as the pro forma is acceptable to the building owner. Assuming an integrated design process is adopted by the project team, this phase may be somewhat extended to arrive at an optimal design concept. The overcladding system design and its integration with the HVAC system form the primary focus of the schematic design exercise, which can range from two to six weeks before an acceptable design concept emerges.

- **Design Development –** The process of working out technical details and retrofit logistics commences after the design concept is accepted by the owner. The size and complexity of the existing building, and the performance ambitions of the retrofit, largely influence the duration of the design development process, which can range from weeks to months. Typically, time spent on integrated design in this phase reduces the time needed for contract documents.

- **Contract Documents –** The preparation of drawings and specifications, and coordination with all of the sub-consultants forms the legal basis of the renewal project. This phase typically ranges from two to four months, again largely dependent on the size, complexity and ambitions of the project. The tender usually takes place as soon as the contract documents are complete and adds between two to four weeks to the pre-retrofit stage of the project. See 9. Contract Documents and Administration for a more detailed description of the tasks and responsibilities.

- **Envelope Retrofit –** Tower renewal projects will normally begin with work on the envelope overcladding, preceded by repairs to elements such as balcony slabs, shear walls and brick veneer as required. The envelope retrofit will require as much as a year to complete depending on the materials and methods selected, seasonality and availability of human resources. The amount and strategic deployment of staging (scaffolding and/or climbing mast work platforms) also influence the amount of time needed to complete the envelope retrofit.

- **HVAC System Retrofit –** This phase of tower renewal is performed largely on the interior and requires the coordination of lifts and cranes for removing and replacing heavier HVAC equipment. The fitting of ductwork into the ceiling space of hallways on each floor level may require between one to two weeks per floor. All rooftop mechanical and electrical work is normally completed prior to re-roofing.

- **Commissioning –** This is a critical task that is typically carried out as a discontinuous process once the HVAC system has been completed and deployed under normal operating conditions, for example, prior to the beginning of the heating season. Approximately one month is required to commission all HVAC systems, with some intermittent tuning of the building automation system.

- **Miscellaneous Measures –** Items such as water conservation measures and parkade lighting controls are normally carried out as logistics permit. These are not time critical activities, but in the case of water conservation, fixture replacement must be coordinated with occupants.

- **Site Work –** Landscaping and stormwater management measures are usually the final step in tower renewal projects, carried out after the staging and office trailer/storage areas are no longer required. This work will usually require between one to two months under suitable weather conditions.

Each project will have its duration determined by the factors noted in the previous discussion. Smaller, less complex buildings may not necessarily differ from larger and more complex towers, depending on the quantity of staging and human resources that is employed. However, a common factor is that all sizes of renewal projects will not begin delivering appreciable savings in energy and water until the retrofit work is substantially complete.

[Photo Opposite Page: Nicobobinus]

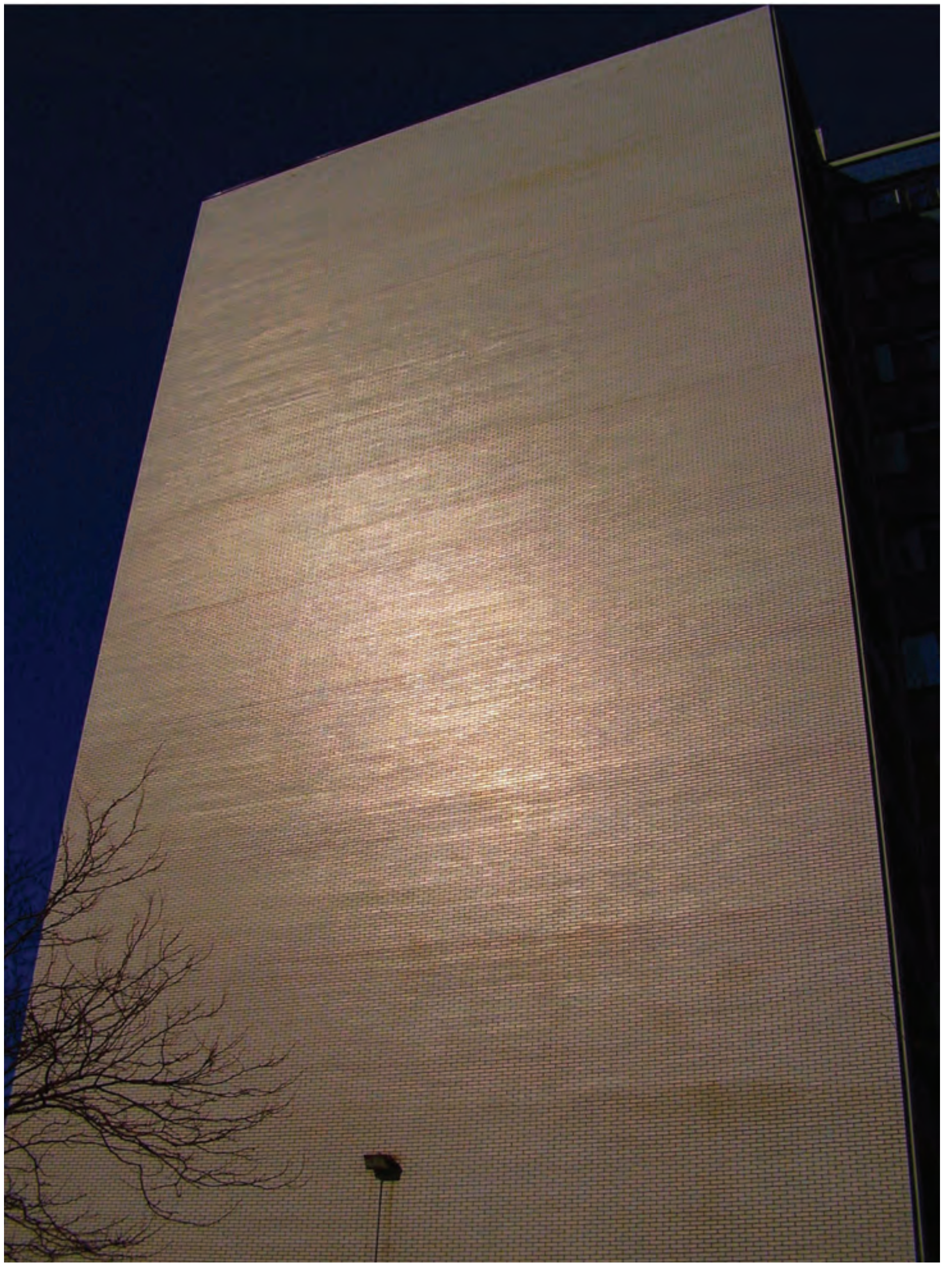


Figure 3.1. A brick clad shear wall without any window openings represents the lowest cost existing condition of the substrate for adequately supporting the new façade, and the cost of the materials selected for the overcladding. Repairs to the existing envelope may prove expensive, and durable materials with a high aesthetic appeal will further add to this cost. Retrofitting south-facing walls of this kind with photovoltaic and/or solar thermal panels will yield the lowest life cycle costs, and eventually revenue generation. [Phote: faculty x.]

Cost

The cost of tower renewal places a significant burden on the shoulders of building owners. In typical cases, the cost of the retrofit is recovered through energy and water savings. However, there may be a slight difference between the monthly payments to cover the retrofit loan and the actual savings that are realized. Marginal rent increases may be justified and this is important to forecast when preparing the pro forma for the proposed tower renewal project. A typical tower renewal project is examined in ***8. Tower Retrofit Analysis: Costs and Benefits***, and it forecasts payback periods ranging from 15 to 20 years, depending on the interest rates and the price escalation rates for energy and water. A sensitivity analysis is usually performed so that the owner is able to assess the risks associated with a proposed tower renewal scenario.

Based on estimates conducted in support of this guidelines publication, a comprehensive tower renewal project ranges from $25,000 to $30,000 per unit, inclusive of all interest charges, professional fees and permits. Approvals for re-zoning and repairs to deteriorated building elements are additional, variable costs that may be determined during the pre-retrofit stage.

The issue of cost must be reconciled with the need to retrofit buildings that are deteriorating and may incur repair and replacement costs that may be avoidable if the retrofit work is conducted in a timely manner. Building envelope expertise is needed to assess the building condition and provide an informed opinion on the amount of time available to the building owner before retrofit is cheaper than repairs that have no payback.

Figure 3.2. The cooperation of tower occupants for the removal of personal possessions and furniture from balconies is an important factor influencing the timely execution of retrofit work. Retrofit cost premiums may be compounded when an unusual geometry is combined with a high occupancy of balconies. [Photo: SolarWind – Chicago.]

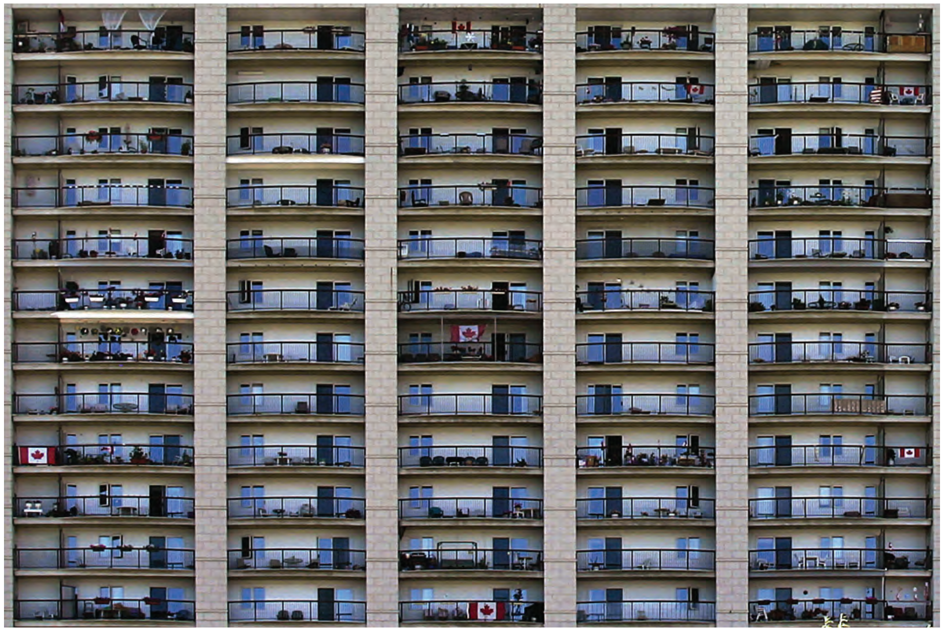


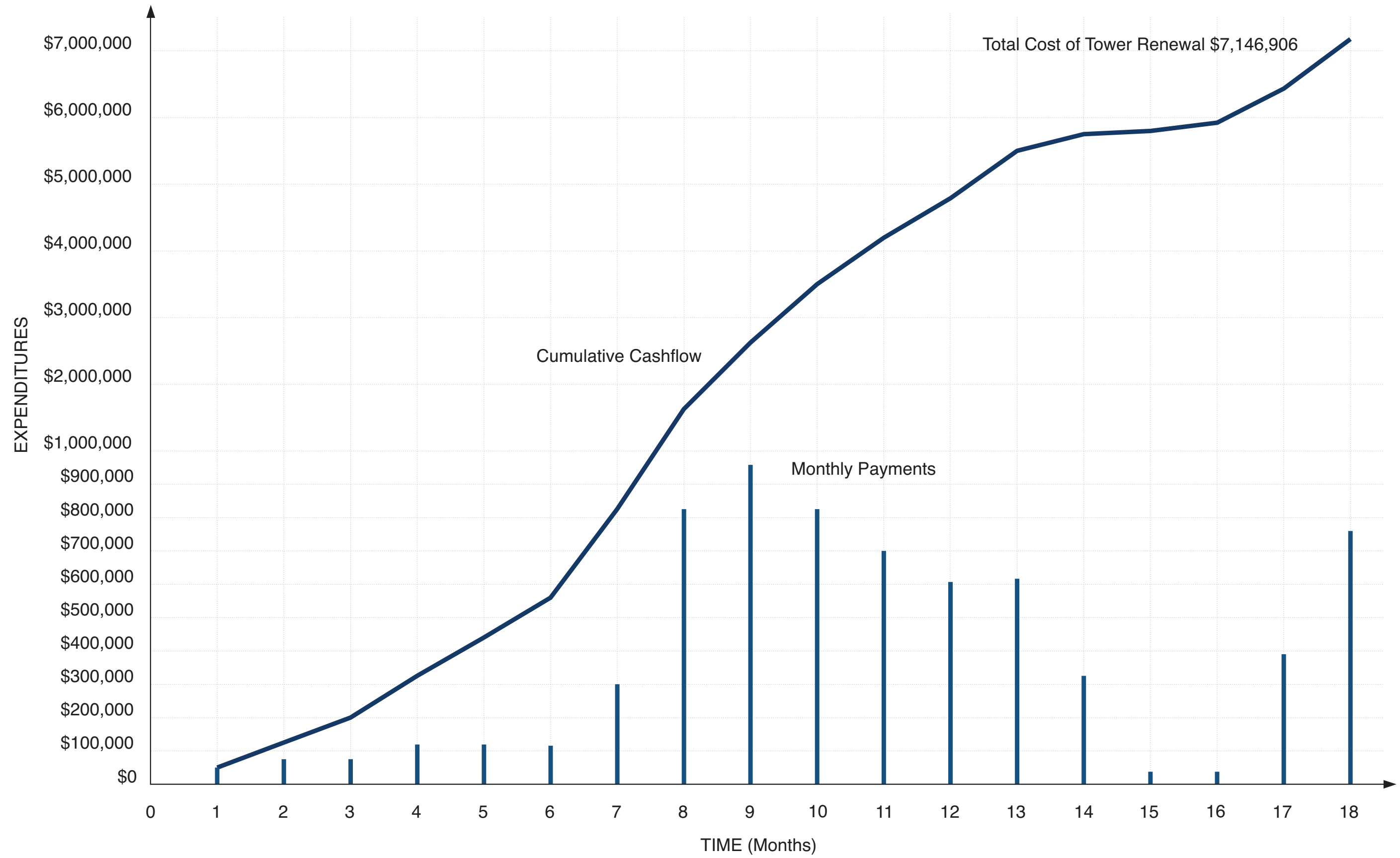
Figure 3.3. This high-rise apartment building in Winnipeg may look straightforward as an envelope retrofit, but the summer season here is much shorter here than many parts of Canada. Winter retrofit is often interrupted by inclement weather and labour productivity is lower in the cold. Weather protection and winter heating of the work enclosure all combine to add significant costs to out-of-season projects. [Photo: Daniel Hornseth.]

The influence of weather cannot be underestimated when forecasting retrofit costs. Unfortunately, the weather cannot be controlled, but the planning of the project can schedule work to be carried out under suitable weather conditions. The experience of local envelope restoration experts is a valuable source of information when forecasting costs.

Important Note: The cash flow analysis presented in **Figure 3.6** is different than the cost-benefit analysis presented in ***8. Tower Retrofit Analysis: Costs and Benefits***. In this cash flow analysis, all of the costs for goods and services pertaining to the comprehensive tower retrofit have been combined with all applicable fees. The assumed bridge financing interest rate of 5.5% per annum has also been applied over the 18-month duration of the renewal project. In the cost-benefit analysis, only the comprehensive retrofit costs were considered, exclusive of fees and interest. The reason for this difference is that professional fees, permit disbursements and monthly interest are depreciated differently than the building assets, and they are also subject to some degree of subsidy through grants and/or incentives. Since the costs and benefits associated with fees, interest charges and incentives may be accounted for in various and significantly different ways, these were not considered in the cost-benefit analysis, but rather appear here in the cash flow analysis. It is worth noting that the tax benefits and burdens associated with fees, interest charges and incentives will vary from owner to owner (individual or corporate) and should therefore be assessed by a qualified accountant within each specific context.

Figure 3.4. Fall is not an ideal time to commence building envelope retrofit work, as it will soon be halted by winter weather, but pre-retrofit work such as building condition assessment may be carried out conveniently in the fall after school has started. [Photo: dunescape.]

Figure 3.5. Winter is an ideal time to carry out miscellaneous retrofit measures that are not dependent on the weather. It is also a good time to execute design work and the development of contract documents. [Photo: Matthew Rutledge.]

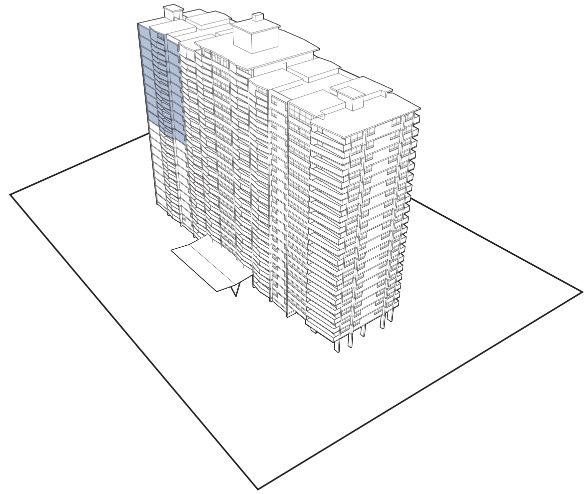


Tower Retrofit Bridge Financing Rate	5.5%	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
		Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Conditional Assessment + Pro Forma	$50,000	$50,000																	
Consulting Fees - Schematic Design	$75,000		$75,000																
Consulting Fees - Design Development	$75,000			$75,000															
Consulting Fees - Contract Documents	$300,000				$120,000	$120,000	$60,000												
Permits & Approvals Allownce	$25,000						$25,000												
Consulting Fees - Tender	$30,000						$30,000												
Consulting Fees - Contract Administration	$120,000							$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000
Replace Existing Roof	$294,600																		$294,600
Replace Windows, Overclad Walls, Enclose Balconies	$4,644,442							$290,278	$580,555	$580,555	$580,555	$580,555	$580,555	$580,555	$290,278			$290,278	$290,278
Replace Boilers	$540,000								$135,000	$270,000	$135,000								
Heat Recovery and Ducted Air Supply to Each Suite	$395,000								$98,750	$98,750	$98,750	$98,750							
Commissioning	$25,000											$10,000	$15,000						
Water Conservation (Fixtures and Washing Machines)	$120,000													$24,000	$24,000	$24,000	$24,000	$24,000	
Parkade Lighting Controls	$6,846																		$6,846
Site Work - Landscaping/Stormwater Management	$225,000																	$67,500	$157,500
Total	$6,925,888	$50,000	$75,000	$75,000	$120,000	$120,000	$115,000	$300,278	$824,305	$959,305	$824,305	$699,305	$605,555	$614,555	$324,278	$34,000	$34,000	$391,778	$759,223

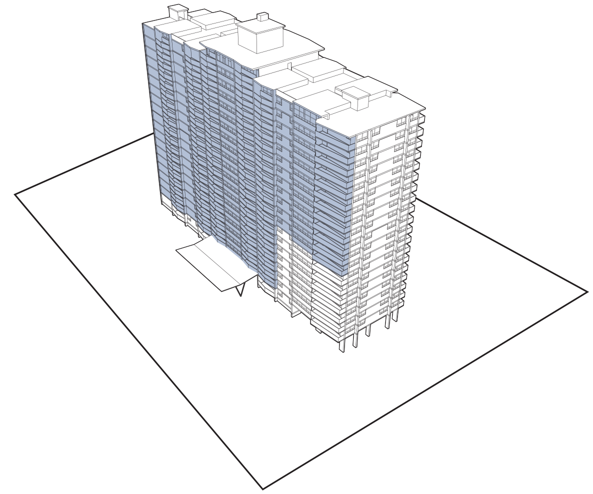
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Monthly Payment	$50,000	$75,000	$75,000	$120,000	$120,000	$115,000	$300,278	$824,305	$959,305	$824,305	$699,305	$605,555	$614,555	$324,278	$34,000	$34,000	$391,778	$759,223
Monthly Interest	$0	$229	$574	$919	$1,471	$2,023	$2,553	$3,932	$7,716	$12,130	$15,929	$19,151	$21,941	$24,771	$26,270	$26,433	$26,589	$28,386
Cumulative Interest	$0	$229	$803	$1,722	$3,193	$5,217	$7,770	$11,701	$19,418	$31,548	$47,476	$66,628	$88,569	$113,340	$139,610	$166,043	$192,632	$221,018
Cumulative Cost	$50,000	$125,229	$200,803	$321,722	$443,193	$560,217	$863,047	$1,691,284	$2,658,306	$3,494,741	$4,209,975	$4,834,681	$5,471,178	$5,820,227	$5,880,497	$5,940,929	$6,359,296	$7,146,906
Percent Complete	0.7%	1.8%	2.8%	4.5%	6.2%	7.8%	12.1%	23.7%	37.2%	48.9%	58.9%	67.6%	76.6%	81.4%	82.3%	83.1%	89.0%	100.0%

Figure 3.6. Cash flow analysis for a typical tower renewal project indicates that interest on bridge financing represents a significant disincentive, as does the lengthy duration of the project.

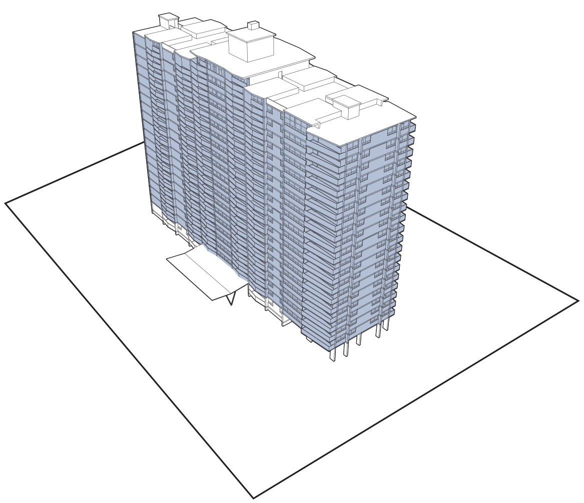
During the pre-retrofit stage, a condition assessment of the building is performed along with a cost-benefit analysis in order to develop a pro forma. This analysis of financial feasibility guides the scope and quality of the comprehensive tower retrofit measures incorporated into the contract documents.



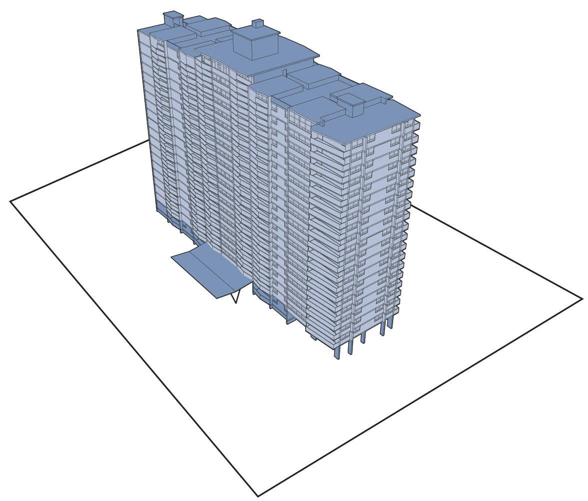
Overcladding of the building envelope commences from the top down to avoid damage and staining from falling debris. A critical consideration is the arrangement of staging (work platforms) and sequencing of the retrofit work.



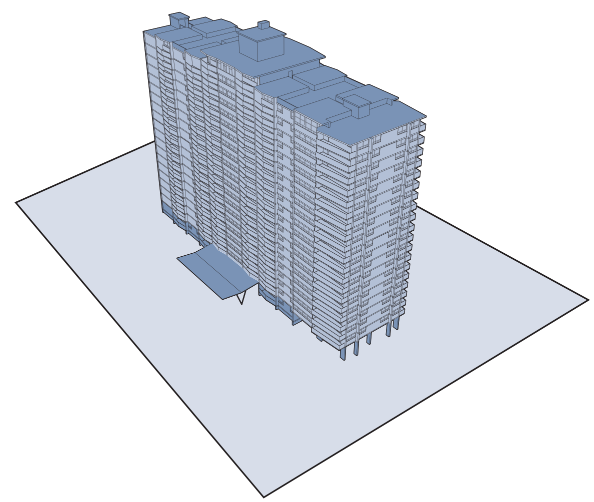
As overcladding work continues on the exterior, the HVAC system retrofit commences on the interior. The key measures include boiler replacement, exhaust air heat recovery and direct ducting of fresh air to each suite.



Overcladding and HVAC system retrofit work are completed at approximately the same time, except for the ground level where a more durable cladding system is recommended.



After the mechanical penthouses are reconfigured to accommodate the HVAC system retrofit, the roof replacement can proceed along with the ground level envelope retrofit.



Site work, water conservation and parkade lighting controls represent measures that can be implemented after all other retrofit work is complete.

Figure 3.7. A typical tower renewal project involves a comprehensive retrofit of the building envelope, HVAC system and surrounding site in the order listed.

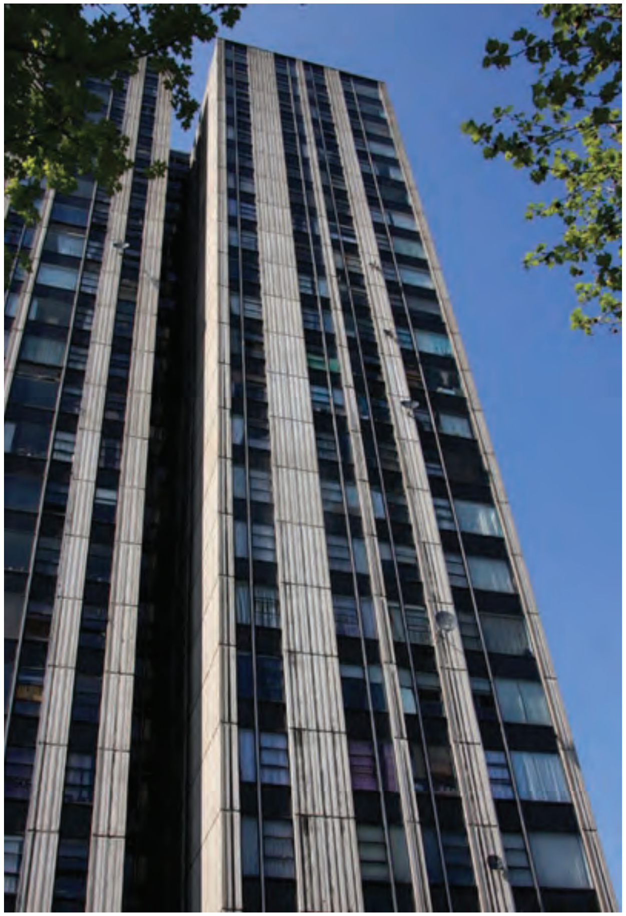
Critical Considerations

There are a number of critical considerations regarding tower renewal projects. From a practical perspective, the seasonality of the work is a major factor that can be addressed by scheduling to some degree. The staging required to provide work platforms for the envelope retrofit will occupy considerable space around the perimeter of the building, with special requirements at entrances. Impacts of envelope retrofits on traffic and parking are discussed in *6. Site Strategies*, and these are influenced by the size and configuration of the site.

From a logistical perspective, the cooperation of occupants is essential for a smooth running tower renewal project. There may be times when noise and dust will be unavoidable, and these should be scheduled away from evenings and meal times. Elevators may have to be used by workers to transport materials and equipment, preferably during the middle of the day so as not to interfere with morning and evening rush hours.

Financing considerations may well represent the most critical factor influencing an owner's decision to proceed with a tower renewal project. Bridge financing to cover the costs of retrofit work will incur significant interest charges unless favourable arrangements are available. Incentives, grants and tax credits may offset interest charges, hence a complete assessment of these is necessary at the pro forma stage. Equally important is determining any impacts on property assessment associated with retrofit measures such as balcony enclosure.

Additional considerations are the bonding of contractors and obtaining proper insurance to adequately protect the owner and occupants. In the event of construction accidents or extreme weather damaging the building during retrofit, it is prudent to ensure that proper insurance coverage has been extended for the duration.



An example of a typical tower apartment building prior to retrofit. Evidence of water damage is visible on the concrete façade elements.

Retrofit work proceeds in stages from the top down to avoid damage to finished elements from falling debris. Note the deployment of climbing mast work platforms.

The completed envelope retrofit includes a complete overcladding and window replacement.
[Source: www.building.co.uk.]

Figure 3.8. A typical tower retrofit project indicating the before, during and after stages.

Figure 3.9. The front façade of a tower retrofit is approaching completion. Note the deployment of climbing mast work platforms and their configuration to access the shear walls. The staging work area impinges on the street and requires special permits and procedures for pedestrian and vehicular traffic control. [Photo: Gary Easter.]

The process of tower renewal is lengthy, disruptive and costly. But it has several advantages. First, the timing of retrofit work can be scheduled to maximize convenience, whereas repairs have to be carried out when they are required, especially if these are related to issues of health and safety. Second, the retrofit work restores the service life of the building, while enhancing the property value, saving operating and maintenance costs, and reducing vacancy rates. Third, unlike deterioration leading to essential repairs, tower renewal provides a return on the investment, and eventual payback. Essential repairs leave the building no better off in terms of operating costs, and their occurrence is often unpredictable and inconvenient.

Properly planned, tower renewal projects can be carried out with minimal impact on the occupants' quality of life. Effective communications can encourage the cooperation of the occupants, who will understand the remarkable improvements to comfort and indoor air quality they will soon be enjoying in an aesthetically appealing building. The eventual benefits far outweigh the inconveniences of living in a building with performance problems, a blemished appearance and a revolving array of disruptive repairs.

This part of the guidelines is intended to provide an overview of the tower renewal process so that owners and the professionals that they retain, fully appreciate the nature, scope and duration of the retrofit work. It can also be translated into a means of explaining the proposed work to the occupants so that they understand the process and the benefits associated with its successful conclusion.

The next part of these guidelines examines tower building typologies and their current service condition. This represents the starting point from which all tower renewal projects will be assessed for their feasibility.

4. Tower Typology and Service Condition

This part of the guidelines is intended to provide an overview on the types of apartment buildings that will be the most likely candidates for tower renewal, and to summarize a general assessment of their condition. While the focus of this publication is the 1960s and 70s multi-unit residential building (MURB) within the Toronto context, many of the retrofit issues and techniques are applicable to a broad range of apartment buildings situated in cold climates like Canada. As noted earlier, Toronto is the focus of these technical guidelines not only because it has the second highest number of high rise apartment building in North America, estimated between 1,000 and 1,500 buildings depending on how apartment tower is defined, but also because of Toronto's climatic extremes with a 70 degree Celsius (126 degree Fahrenheit) seasonal temperatures range. Cold winters and hot, humid summers make Toronto an ideal laboratory for tower renewal measures that are suitable for climates extending across the entire northeastern region of North America and most of northern Europe.

Tower apartment buildings are not a new idea, and certainly not a Canadian invention. Apartment buildings rising 6 to 9 storeys were constructed in ancient Rome and there are references to large, multi-unit residential buildings prior to this period. In North America and Europe, apartment towers emerged at around the turn of the 20th century, made possible by new materials such as steel and concrete. Their design concepts were explored by renowned Modernist architects, and in addition to their ideological foundations, these buildings were distinguished from their predecessors primarily through the implementation of elevator technology, and some time later centralized heating, cooling and ventilation systems. After World War II, tower apartment buildings represented a rapid and affordable means of rebuilding destroyed European cities, and accommodating rapid growth in North America's urban centres. Until relatively recently, tower apartment buildings represented urban sophistication and many of these buildings continue to embody élite status. Regrettably, this housing form has also become associated with poverty, crime and failed urban planning experiments. Regardless, the multi-unit residential apartment building is an established housing typology that remains among the most reliable antidotes to urban sprawl, providing shelter to a broad and diverse spectrum of inhabitants.

Canadian Context

In order to appreciate multi-unit residential buildings, especially those taking the form of tower buildings, it is worthwhile examining how these came to become a socially accepted housing choice. According to housing geographer Richard Dennis, there was considerable debate about the desirability of apartment buildings, as noted in the abstract to one of his journal papers,

> *Apartment houses became fashionable in many North American cities in the early decades of the twentieth century. This paper focuses on one city, Toronto, where the construction of apartment buildings was fiercely contested, on moral, sanitary and economic grounds. Particular attention is paid to the language used to promote or denigrate apartments, and to questions of architectural style and design. Apartments were a key element in the creation of the landscape of modernity, but they were also indicative of the modernization of capital. As such, they illustrate the conjunction of cultural and economic dimensions to modernity.*[1]

Health and safety concerns, not just morality and economics, were also significant factors that influenced the design and construction of apartment buildings. The following excerpt from an article by Karen Jordan explains how these changes came about.

> *"We should not allow any buildings to be erected over seven storeys."*
>
> *That was the reaction, reported in the Toronto Star on April 21 1904, of then City Architect Robert McCallum, two days after the Great Toronto Fire.*
>
> *On the night of April 19, 1904 the city of Toronto suffered a disaster unlike any experienced before when a fire broke out in the wholesale and light-manufacturing district. It took nine hours and over 250 firefighters to bring it under control and the ruins left behind smoldered for weeks.*
>
> *The fire's aftermath left 5,000 people out of work, 2.5% of the population. A similar disaster using 2007 population numbers would leave over 60,000 out of work. Some of the unemployed found work cleaning up the ruins left by the fire, work which had to be done by hand.*
>
> *City Architect McCallum called for fire proofing measures in all apartment buildings, hotels and hospitals over three stories and businesses over four stories. Two years later the city of Toronto began using a high pressure water system.*[2]

Despite the controversy, apartment buildings like the one depicted below, were built all across Toronto to accommodate immigrants and rural Canadians who had migrated to urban centres like Toronto in pursuit of gainful employment.

Figure 4.1. Apartment building at 359 Davenport Road, Toronto in 1931. Three and four storey walk-up apartment buildings like this one, so named because they did not provide elevators, dominated rental income housing projects. These buildings employed solid masonry walls with hybrid wood and steel interior structures. Notches were commonly set into the sides of these buildings to deliver light and air to interior rooms. [Source: City of Toronto Archives.]

This construction typology for apartment buildings was all set to change after World War II, as the new infrastructure of industrial output to serve the war effort diverted its attention to a period of unprecedented immigration and economic growth.

[Photo Opposite Page: Jesse Colin Jackson]

Materials and Methods of Construction

This discussion ranges from mid-rise to high-rise apartment buildings constructed from the 1940s onward. Mid-rise apartment buildings are usually defined as buildings having 5 to 8 storeys and requiring an elevator. High-rise apartment buildings are therefore greater than 8 storeys according to this classifiction. It is important to note that from a building envelope retrofit perspective, both of these types are practically identical in terms of candidate overcladding and window replacement measures. The primary difference relates to the sophistication of mechanical systems. High-rise apartment buildings employed multiple elevators and mechanical ventilation, whereas their mid-rise counterparts tended to have a single elevator and operable windows providing the only means of ventilation.

There were also a large number of low-rise apartment buildings, typically 4 storeys or less, that were of very similar construction to their mid and high-rise counterparts, but did not provide an elevator. Many of the measures presented in these guidelines may also be applicable to this low-rise multi-unit residential building typology.

Figure 4.2. This 4-storey, 1950s apartment building has a hybrid steel and reinforced concrete structural system, and a brick veneer cladding. Operable windows are the only means of ventilation and there is no elevator service. Technically, it is not classified as a mid-rise apartment building, but unofficial estimates indicate this typology may be more prevalent than high-rise apartment buildings, based on the number of units or suites. Note the use of the cantilevered floor and roof slabs for balconies and awnings. [Source: City of Toronto Archives.]

Figure 4.3. Example of an apartment building ranging from 4 to 5 storeys in response to the sloped site. These sorts of contextual idiosyncrasies make it difficult to establish clear classification systems. This building features both single and double balconies, with combined masonry and steel tubing guard. Within less than a decade, the open shared balcony gave way to balcony dividers in the form of opaque, person-height privacy screens. [Source: City of Toronto Archives.]

Toward the late 1950's there are some examples of mid-rise apartment buildings employing steel columns and beams for the above-grade structure, with concrete over metal deck floors and roof assemblies. These typically had a single storey foundation and automobile parking was located above-grade on site. Several factors combined to render reinforced concrete frame structures the predominant system of choice: smaller parcels of land required underground parkades since there was insufficient space on the site to accommodate anything more than visitor parking; the multi-storey parking structures also served as the building foundations and were exclusively constructed using reinforced concrete; from a construction logistics perspective, continuing with the same contractor and trades for the above-grade structure was time and cost efficient; and the reinforced concrete frame structure provided superior fire safety. By selecting this system, it was simple and inexpensive to cantilever the floor slabs and create balconies that significantly enhanced the marketability of rental properties.

Figure 4.4. This early 1960s apartment building employs a hybrid structural system comprised of steel and reinforced concrete. There is no underground parking and minimal site parking for this urban infill development. Note the absence of balconies and the use of single glazed, steel frame windows. The small windows serve bathrooms without means for mechanical ventilation.
[Source: City of Toronto Archives.]

With the introduction of underground parking, the foundation support spacing was rationalized as a multiple of parking spaces and this was reflected in the superstructure. Not only was the automobile shaping suburbia, but it also played a major role in shaping the size and form of high-rise apartment suites.

Figure 4.5. By the mid-1960s the reinforced concrete frame became the system of choice for mid-rise apartment buildings, like the one depicted above, as well as high-rise towers. The floor slabs are visibly exposed on the end walls because the infill masonry envelope spans from top of floor slab to underside of floor slab. Articulated canopies over the front entrance were common features.
[Source: City of Toronto Archives.]

Another distinguishing characteristic of the mid and high-rise apartment building stock is that virtually none of the buildings incorporated central air conditioning. Heating in these buildings was provided most commonly by hot water radiators located on exterior walls beneath the windows. In some cases, electric resistance baseboard heating was installed to reduce initial costs and permit better zone control than typical hydronic systems, many of which did not provide individual temperature control in each suite. Ventilation typically consisted of exhausts fans located on top of the building serving stacked bathrooms on a continuous basis. Make-up air to replace the exhausted air was drawn through unintentional openings in the building envelope (air leakage), thus reducing the potential for damage of the envelope assembly by exfiltration of exterior moisture. Kitchen ranges were not provided with exhaust hoods, and to control cooking odours the hallways on each floor were pressurized with tempered, outside air. This approach to heating, ventilation and air-conditioning predominated for roughly a quarter century until the shift in MURB housing markets toward condominium forms of tenure.

Figure 4.6. This photograph depicts handset-form method construction being used on a housing project in 1964. Unlike flying forms, traditional methods require the scaffolding and formwork to be disassembled and reassembled manually. The climbing crane delivered materials and had not yet been employed in the hoisting of large flying form sections. [Source: City of Toronto Archives.]

Key to the development of tower apartment buildings was the invention of flying form technology. This technique was a direct response to increasing labour costs and a decreasing number of skilled trades in relation to the growing demand for housing in Toronto. The lightweight aluminum frame and plywood liner formwork sections replaced the more labour intensive handset-form method. This earlier forming system used 0.6 metre (2 feet) by 1.2 metre (4 feet) sections that were disassembled after each floor and moved up and reassembled on the floor above. Flying forms came in up to 4.5 metre (15 feet) widths and typically 4.8 metre (16 feet) lengths, corresponding to the form plywood modular. The reduction in time required was so significant that additional Portland cement was added to the concrete mix so that the required strength needed to pull the formwork was reached much earlier than ever before. In an era of cheap fossil fuels, the cost of cement was a minor premium in comparison to the savings in time and labour costs.

In order to appreciate the impact of flying form technology, in a matter of several years following their introduction apartment buildings went from primarily 6 to 8 storey structures to towers typically ranging from 20 to 30 storeys. Flying form technology became so ubiquitous that practically all reinforced concrete building structures were erected by this method. The tower apartment building could not have been feasible without the climbing crane and flying form technology. If building typology was to be classified tectonically, most of the multi-unit residential buildings of the 1960s and beyond could be referred to as tower buildings, regardless of their height.

Figure 4.7. Concrete tower construction at Roselawn Avenue and Chaplin Crescent in Toronto. Aided by flying form technology, developers were able to “mass produce” housing with robust building armatures in response to Toronto’s explosive population growth. In Canada’s large urban centres, starting towards the early 1960s, concrete flying form technology was being invented. Reinforced concrete tower buildings were the ideal test bed for the technology, featuring repeated floor plans that could be sequentially erected one floor after another. To reduce labour costs, an aluminum framing system supported formwork that could be slid out sideways by the climbing crane after the concrete was set, and lifted in place on the next floor. The greatest economy was achieved when the floor plans were simplified and the building layout rendered symmetrical. Standardized dimensions were derived from a modular corresponding to Canadian lumber and plywood sizes to minimize cutting and waste. This highly rationalized system of construction was in reality a vertical assembly line that manufactured housing no differently than so many products manufactured in other sectors of the economy, such as automobiles and appliances. [Source: City of Toronto Archives]

For a fuller discussion of the methods and materials of concrete building construction during this period, refer to:

Concrete Toronto: A Guide to Concrete Architecture from the Fifties to the Seventies. Michael McClelland and Graeme Stewart, editors. Coach House Books, 2007.

Figure 4.8. The two photos above illustrate the densification of residential neighbourhoods, spurred on by construction of the Yonge subway line in Toronto, and made possible through flying form technology. [Source: City of Toronto Archives.]

Figure 4.9. A section of flying formwork is guided out of a building bay by workers, as it is pulled from above by the climbing crane. This section will be hoisted to the floor above in preparation for the construction of the next storey of the tower building.

Tower apartment buildings have delivered remarkable performance for several decades, the earliest approaching a half-century of reliable housing service. Despite their numerous limitations from a building science perspective, most notably unacceptable levels of energy efficiency, these buildings continue to provide impressive returns on the original investments that developed them. The first cycle of retrofit now being considered will undoubtedly be assessed in relation to this past precedent of performance. If the flawed technology of 20th century tower buildings has prevailed to the present, then it is reasonable to expect 21st century retrofit technology to surpass all aspects of past performance. The same motivations driving everyday consumer choices will surely guide tower owners seeking to cost effectively retrofit and extend the useful life of their real estate investments. This is the economic and technological challenge of tower renewal – to affordably extend durability, improve performance, and enhance quality of life, and the natural and built environment.

Tower Typology

Before describing the tectonics of the tower typology, it is noteworthy to appreciate the extent of this building type across Canada and its largest urban centre, Toronto. According to the 2006 census of Canada, there are 1,114,925 units in apartment buildings of five or more storeys, and of this total number, 710,785 units are located in Ontario.[3] Recent estimates indicate that some 478,555 units are situated in the Greater Toronto Area (GTA), with most of these having been constructed during the 1960s boom.

			Buildings by Date of Construction							
	# of Buildings	# of Units	Before 1946	1946-1960	1961-1970	1971-1980	1981-1990	1991-2000	2001-2007	Total
Apartments	1,379	306,268	38	246	626	137	47	51	5	1150
Condos	936	129,493	25	17	20	234	236	174	230	936
TCHC*	232	42,794								
Total	2,547	478,555	63	263	646	371	283	225	235	2086

* Toronto Community Housing Corporation.
Note: Date of construction could not be ascertained for 229 apartment buildings.
TCHC construction dates not provided.

Table 4.1. Inventory of high-rise apartment buildings in the Greater Toronto Area. (Defined as buildings having 5 storeys or more. Information provided by the Toronto Atmospheric Fund through TCHC and Urbanation.)

The characteristics of this generation of multi-unit residential buildings was surveyed in depth by graduate students of architecture and engineering at the University of Toronto starting in 2004 as a follow up to investigations into tower renewal that had been initiated several years prior by Professor Ivan Saleff. The findings of the survey have been summarized below.

The vast majority of Toronto's high-rise apartment stock constitutes rental housing predating the condominium form of tenure. The structural system employed was steel reinforced cast-in-place concrete arranged in a series of parallel shear walls including end walls, some of which were clad in brick veneer. Spanning perpendicular to the shear walls were one-way steel reinforced cast-in-place concrete floor slabs. This is consistent with the development of flying form technology. Roofscapes indicated poured concrete elevator cores and stairwells. Later versions of the typology began to articulate the end walls with more punched openings. Earlier, mid-rise versions utilized poured columns and beams often displaying corner windows. Contemporary versions tended to display a hybrid system of shear walls throughout the body of the building and flat plate slabs with concrete columns at the ends providing opportunities for corner and end wall glazing.

The predominant form seemed to be linear or bar buildings, followed by "Y" shaped and point towers. No matter what the plan geometry, all forms displayed common structural and envelope characteristics. The predominant envelope system was 100 mm (4") brick veneer with a 100 mm (4") concrete block back-up tied together by a regular rhythm of continuous header courses. On the interior face of the concrete block, asphalt impregnated building paper was laid up, followed by vertical wood strapping, over which an early version of mesh reinforced interior gypsum board and plaster was applied. The plaster was decorated with an oil based paint finish.
The solid non-load bearing masonry envelope more often than not simply sat on top of the exposed exterior floor slab perimeter. In many cases, buildings indicate exposed shear wall edges some of which actually projected +/- 1.2 m (4ft.) to 1.5 m (5ft.) beyond the exterior face of the masonry envelope to support balconies. About half of these shear walls continued down to grade while others cut back to the envelope at angles approximating 45°. These balconies were simple extensions of the interior structural concrete floor slab. Virtually all buildings from this era featured exposed balconies, most of which were linear in geometry and extensions of the structural floor slabs. Some were cantilevered while others were supported by flanking shear walls, as noted previously. Balcony guards were predominately painted steel frame with varying configurations of painted steel infill in the form of steel pans, pickets, etc., attached directly to the top or edge of the balcony slabs.

Openings in the envelopes were handled in different ways depending on their context. Glazed openings that addressed balconies tended to sit upon a typical masonry plinth and extended to the underside of the slab above. Glazed openings through the envelope not occurring at balconies were handled in one of three ways: 1) they were simple punched openings occurring in the body of the envelope sitting on masonry with loose steel lintels above carrying masonry to the underside of the slab above; or 2) they sat on masonry and extended to the underside of the slab above; or 3) they occurred in an opening which spanned from top of slab to underside of slab with a metal panel above and/or below the glazing.

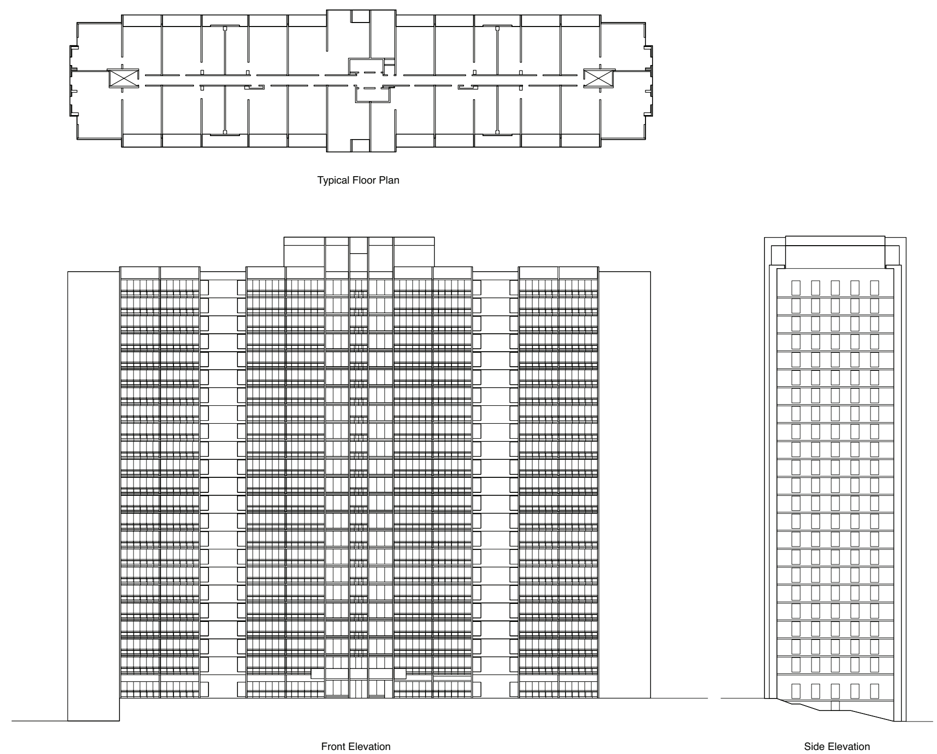


Figure 4.10. A typical tower apartment buildings of the 1960s and 70s era. Symmetrical and repetitive, the bar building form featured double loaded corridors and a relatively shallow building plate. Elevators were centrally located with internalized fire stairs at the ends of the hallway. Service shafts and chases for ducts, piping and wiring were tucked into residual bathroom and closet spaces to minimize obtrusiveness. Multiple levels of underground parking (not shown) minimized the footprint of tower development.

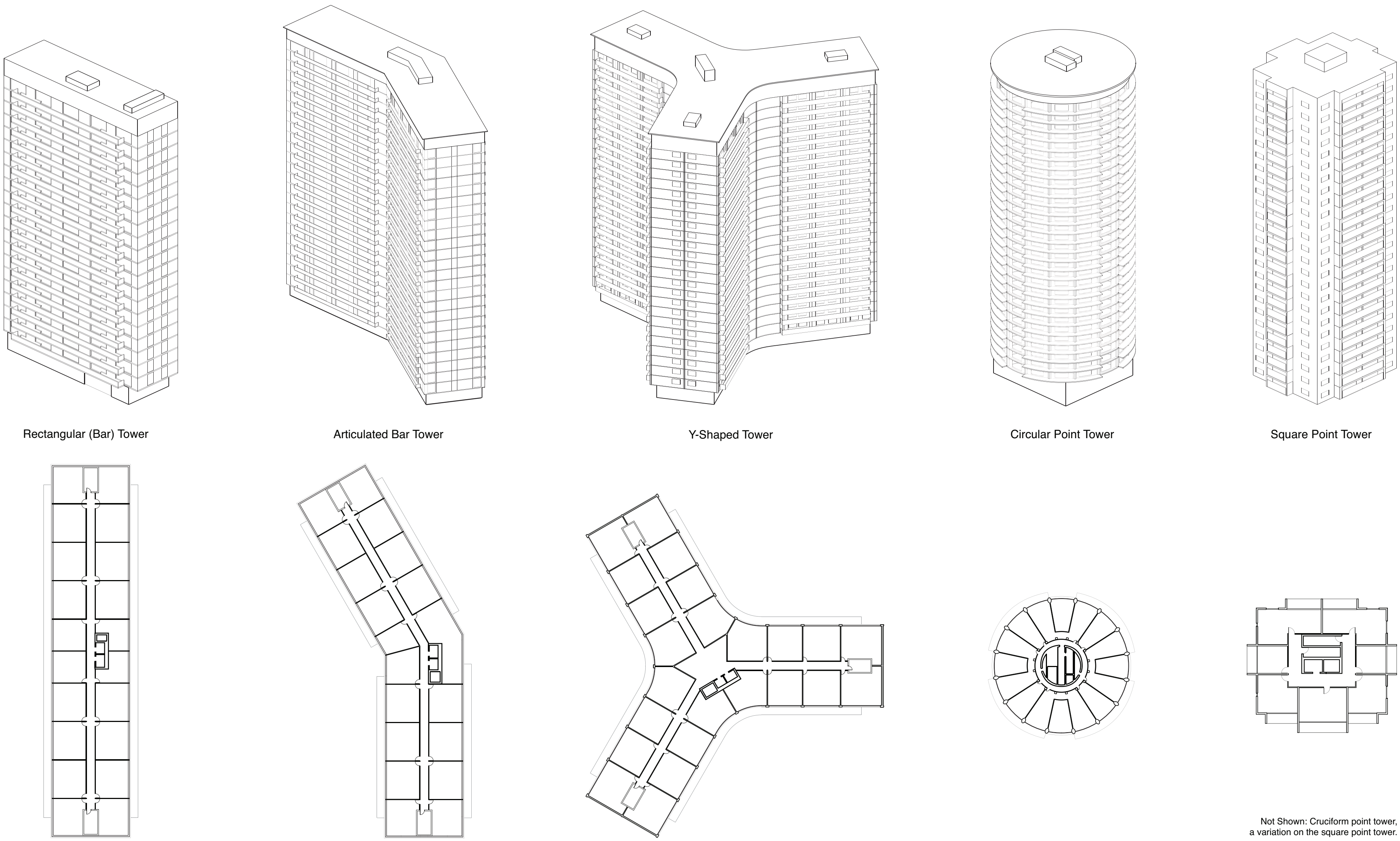


Figure 4.11. Commonly observed tower typologies of the 1960s and 70s.

Figure 4.12. A typical tower apartment building of the 1960s nearing completion. Many tower building owners lacked the sophistication to implement preventive maintenance practices, often assuming the selected materials were durable, "maintenance free" and made to last a lifetime.

Service Condition

This section focuses on the above-grade elements of tower buildings, acknowledging that significant performance problems exist with underground parking structures, but remain beyond the scope of these guidelines. Overall, the tower building stock has proven to be very robust, despite lacking design and construction measures that benefited from contemporary building science knowledge. The condition of this building stock has been surveyed on several different occasions. The earliest comprehensive survey occurred in the early 1980s, conducted on behalf of the Ontario Ministry of Municipal Affairs and Housing. This was followed by various research projects funded by Canada Mortgage and Housing Corporation in the 1990s. The most recent survey was conducted by graduate architecture and engineering students as part of technical research conducted by the University of Toronto. This section provides an overview into the typical condition of mid and high-rise apartment buildings to inform the condition assessments that must be carried out with due diligence for each individual building prior to proceeding with retrofit work. Part 5 of these guidelines presents a comprehensive review of condition assessment procedures and checklists.

The first comprehensive review of the condition of Ontario's high rise apartments was conducted in the early 1980s and published as Volume 10: Study of Residential Intensification and Rental Housing Conservation, "*Future Conservation Requirements and Costs for High-Rise Apartments and the Possible Impact on Rents and Tenants*" (prepared by Klein and Sears, Architects and Clayton Research Associates, 1983, on behalf of the Ontario Ministry of Municipal Affairs and Housing.

The following excerpts come from a discussion paper that followed the publication of the 1983 study.[4]

Conservation Needs in the High-Rise Rental Apartment Stock

As the term is used in this paper, conservation of the high-rise rental apartment stock refers to actions necessary to prevent the premature decay or loss of buildings, the replacement of major systems and the modernization of elements of the building structure and components as required as a result of the aging process. These measures are analagous to preventive maintenance actions on an automobile which, if not undertaken, may lead to more costly repair measures later or a significant shortening of its expected life.

All high-rise buildings can be expected to require conservation work over the next two decades, just as all automobiles require similar actions to ensure a long life. However, in some buildings, the necessary conservation work is more extensive due to other factors such as possible inadequate initial design and construction, deficient inspection and review procedures on the part of municipalities or lenders, or a lack of understanding on the part of building maintenance personnel and administrators regarding the conservation needs of high-rise buildings.

Examples of the types of conservation needs which have been identified in Ontario's high-rise rental apartment over the next two decades include: weather penetration of roofs, walls and windows; failing underground parking structures; obsolete or worn out electrical, heating, plumbing and ventilation systems; and upgrading of fire alarm and other safety systems.

The costs of this conservation work will be extensive. Estimates of necessary conservation work for five case study buildings indicate that costs (in 1982 dollars) could range between $ 3,600 and $ 9,500 per high-rise apartment unit over the next two decades.

[Note: This translates into between $7,200 and $19,000 in 2008 dollars, and does not include some 25 years of ongoing deterioration.]

Tower buildings are reinforced concrete structures largely exposed to the elements, and a 1990 CMHC study examined the potential for deterioration.[5]

Extent of Carbonation in Buildings in Toronto

Carbonation of concrete can cause serious structural problems. When it reaches reinforcing steel, the steel becomes susceptible to corrosion, and the cost of repairing corrosion damage is high. Diagnostic and preventative measures are therefore important. Carbonation is a reaction of concrete to carbon dioxide and occurs when the pH level falls below 9.0. A literature review in the late 1980s, commissioned by Canada Mortgage and Housing Corporation (CMHC), concluded there was a significant potential for carbonation in some of the major urban centres in Canada and recommended further investigation. CMHC subsequently commissioned this study to assess the impact of carbonation on concrete structures in Toronto.

The study showed that some of the buildings investigated will experience corrosion damage resulting from carbonation within their desired service life. Balconies in two buildings already had carbonation down to the steel reinforcements, and a third of all balconies examined had higher rates of carbonation penetration than desirable relative to service life expectancy.

None of the vertical cast-in-place components or pre-cast cladding panels had carbonation equal to cover depths. However, two buildings in each category had excessively high carbonation penetration relative to their service life expectancy.

Figure 4.13. Carbonation is the leading cause of balcony slab edge deterioration. The cost of repairs is relatively expensive because new guards are also usually installed. This type of necessary structural repair has no payback. Encapsulation of the concrete by overcladding or balcony enclosure is a preventive measure with payback due to energy savings.

In 1996, Canada Mortgage and Housing Corporation published a report authored by Gerald Genge and Jacques Rousseau on repair needs of high-rise apartments in Toronto that differentiated the nature and extent of necessary repairs by the age of the buildings, and used a repair needs typology to classify the work that needed to be performed.[6]

High-Rise Apartment Repair Needs Assessment
In a study performed for the City of Toronto on high-rise rental buildings, a different approach was used to evaluate the probable costs for repair. On the basis of the objective of understanding the scope of the repair needs and the overall costs for the population of 464 high-rise rental properties, a typology approach to repair needs was established. On the basis of the consultant's experience and recognizing that certain aspects of design resulted in certain typical repair requirements, buildings of different age groups were characterized and expected repair needs were assessed. From this, costs were applied and aggregate expenses were computed. The costs were assessed in terms of the initial costs to bring buildings back to a satisfactory level of performance and then the expected ongoing costs for maintaining buildings at that level. The characteristics found to most influence the repair costs were associated with specific elements of the building. In particular: cladding, windows, roofs, balconies, garage and exposed structural elements tended to dictate the level of expenditure. Other items, such as elevator control modernization, and heating system retrofits and replacement of domestic water systems were also included when appropriate; however, the cost of these items did not affect the overall costs to the same degree as the envelope issues.

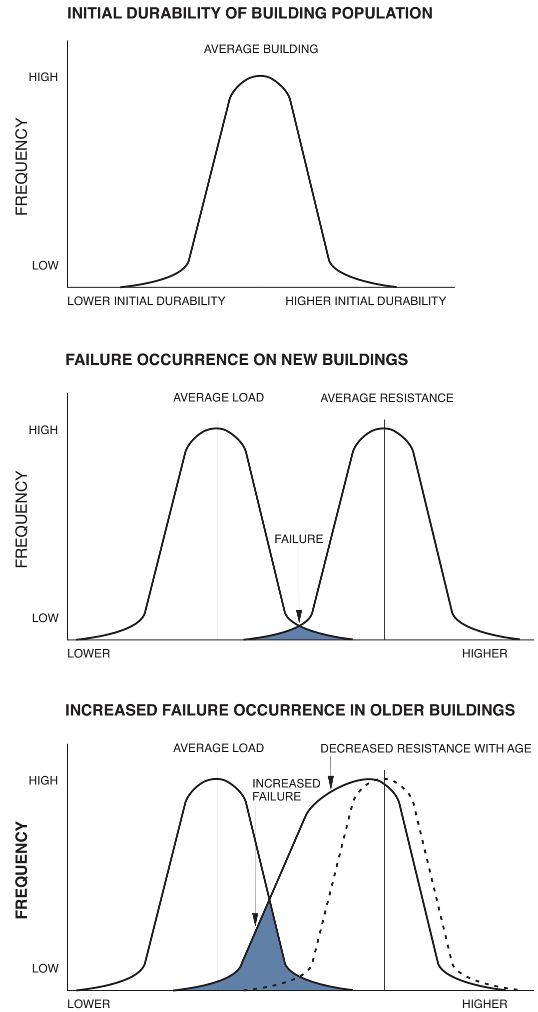


Figure 4.14. The research conducted by Genge and Rousseau explained how as buildings age, the likelihood or frequency of failures increases because the environmental loading on building components acts on materials with decreasing resistance to the imposed loads. Deferring necessary repair work implies higher future expenditures as the extent and severity of damage advances.

The situation over a decade ago was summarized as follows by Genge and Rousseau:

The majority of the housing stock has reached an age of 25 to 30 years and is in need of high levels of capital investment. The work is distinct from normal maintenance because, eventually, building components wear out or become deteriorated or become obsolete. Then major repairs and/or of components and systems must be performed in these aging buildings. A study performed for the Fair Rental Housing Organization (FRHO) in 1991 concerning Ontario high-rise housing determined that $350 million ought to be spent on an annual basis on private rental buildings. The majority of these buildings were constructed in the 1960s and 1970s.

Figure 4.15. Deterioration and obsolescence are commonplace in tower apartment buildings. The aging tower apartment stock has a pathology that reflects its common design and construction characteristics. Most prevalent are cladding failures and deterioration of cantilevered balcony slabs. Failure of cladding at grade due to uncontrolled moisture migration is widespread. Windows are typically leaky, exhibit poor thermal performance and in some cases, deterioration of the frames and sashes. Exposed concrete elements are beginning to reveal the onset of carbonation and the corrosion of reinforcing steel, in many cases leading to spalling of the concrete surface. Mechanical equipment is often obsolete and in poor condition, especially exposed equipment and ductwork located on rooftops. The major building services are often nearing the end of service life. Piping has deteriorated and its thickness has eroded over time. Ductwork is sound but requires thorough cleaning. Electrical wiring is normally serviceable, but cabling for television, telephones and telecommunications has spiraled into chaotic disorder and makeshift adaptation to ever changing tenant preferences and technological advances. Elevators, the lifeblood of high-rise apartment buildings, are typically in need of rehabilitation and their lack of reliability is frustrating to tenants who are pressed for time in meeting the demands of modern urban lifestyles.

Note on Underground Parking Garages

This guidelines publication is confined to above-grade building elements only, but recognizes an extensive body of research related to design, maintenance and repair by CMHC:

Deterioration of Parking Structures: Extent, Causes and Repair Considerations
http://www.cmhc.ca/publications/en/rh-pr/tech/2001-125.htm
Research Highlight: *Elastomeric Membrane Installations in Parking Garages*
http://www.cmhc-schl.gc.ca/publications/en/rh-pr/tech/00-142-E.htm
Cathodic Protection In the Rehabilitation of Reinforced Concrete Parking Structures
http://www.cmhc-schl.gc.ca/publications/en/rh-pr/tech/90248.htm
2001 Building Failures Study
http://dsp-psd.pwgsc.gc.ca/Collection/NH18-22-101-140E.pdf

Building envelope deterioration aside, in response to rising energy costs and concerns for indoor air quality, CMHC sponsored additional research in the area of MURB ventilation systems performance. A major concern regarding the overcladding of tower buildings is that the ventilation afforded in suites by air leakage will be practically eliminated as the envelope airtightness increases. The theory of corridor air ventilation systems is that the supply of outside air to the corridors will travel into each suite as it is drawn in by the continuously operated exhaust fan located in each bathroom. This theory was found to be unproven in research conducted by Unies Ltd. on behalf of CMHC and published in 1999.[7]

Corridor Air Ventilation System Energy Use in Multi-Unit Residential Buildings
The implications of this research are twofold. First, in existing buildings, corridor air systems represent a reasonable target for energy conservation efforts due to their impact on building energy use. Second, for new buildings, the functionality of corridor air systems should be questioned since significant amounts of the air provided do not flow as intended.

The implications of these findings for tower renewal projects are significant. Failure to address the need to mechanically supply tempered air directly to each suite will forfeit any possibility of heat recovery of the energy in the exhaust air stream, since the air being supplied to the corridors will not find its way into the suites, as these often have the gap under the entry doors weatherstripped, and large leakage paths are available to the pressurized air in the corridors through the various service and elevator shafts, leading to the roof. If tower building inhabitants open windows to ventilate their spaces then the opportunity for significant energy savings through an integrated ventilation system with heat recovery will be lost. Far worse, if they fail to open their windows and generate high levels of moisture in the space, indoor air quality and mold problems may result. This may eventually lead to building envelope performance problems if the moisture levels are high and chronic. Currently, the high-rise housing stock enjoys acceptable indoor air quality at the expense of energy and envelope durability.

University of Toronto Condition Assessment Survey

Field work conducted by graduate architecture and engineering students from the University of Toronto in the winter of 2004 focused on the service condition of 1960s and 70s tower buildings. Below is an abridged list of problem areas, most of which were common among all the buildings inspected. However, some buildings of the vintage studied were exceptional and exhibited few of these problems. Reasons for these exceptions were speculative. It was possible that a study of mechanical systems might reveal some answers, specifically whether or not the building in question was air conditioned in the summer months. These exceptional buildings also appeared to have undergone a window retrofit and regular maintenance. It was also speculated the good service condition was testament to the forgiving character of solid masonry walls. The ability of this “primitive” material assembly to survive countless cycles of energy, air and vapour movement with minimum deterioration was notable. It appeared that as long as enough heat was supplied to the building during the winter months, primary flashings were in place, and air conditioning was not provided, the service condition of the building envelope was very good. Notwithstanding this robust durability, energy consumption was reportedly high and becoming a grave concern.

For the vast majority of buildings surveyed, most envelope related failures appeared at the junctures of exposed structure and masonry envelope, balcony/envelope interface and window/envelope interface. Deterioration was also noted at the balcony/guard interface, underside of exposed balconies, mechanical vents and miscellaneous punctures in the envelope. Roof access was not available so roof membrane condition, parapet flashing and membrane interfaces were not reviewed or documented.

Figure 4.16. This 1960s apartment building is undergoing a major repair to the balconies and brick cladding that may have been largely avoidable if better maintenance practices were adopted. Again, there is no payback in these rehabilitation measures.

Notable performance problems observed in the field are summarized below.

- The most drastic masonry deterioration was evident wherever a brick façade with glazed exterior finish was used. The glazed face typically had popped off and efflorescence was present.
- Most brick deterioration was evident below window sills or at slab edges with associated mortar joint failure.
- Wherever the brick veneer of the masonry envelope came in contact with grade, deterioration of the brick was evident.
- Other areas which indicated envelope stress seemed to be at the junctures of concrete armature and envelope where a sealant was used to fill the joint. Sealant integrity appeared to be compromised due to either a lack of adhesion or a surpassing of the applied sealant’s stress-strain capacity. Many such junctures specifically between the masonry envelope and concrete armature had no sealant at all. Soft joints at the underside of slab/envelope junctures were also absent.
- Inadequate flashings, or lack thereof, also indicated localized areas of envelope failure. These were most evident at window sills, however base flashings at the masonry envelope and top of slab juncture were not documented in any of the case studies. This location was rarely observed as a consistent source of failure. Window openings were, however, consistently associated with localized envelope stress materializing in efflorescence, staining and masonry deterioration. Many of the buildings studied had yet to undergo a window retrofit and still possessed the original single glazed units, not to mention what appeared as the original sealant about their perimeter.

- Balconies in general represented a location where deterioration was evident. The junctures of steel balcony guards and slabs usually required immediate attention and often displayed exposed and corroded anchors and deteriorating concrete. The underside of said balconies often displayed surface and finish deterioration. Drip edges were inadequate or had been compromised by successive finish applications. Corrosion was also often evident wherever painted steel balcony guards had been employed.

It became evident that even such a cursory review of this building typology revealed many common areas of performance failures, and signaled that the predictions of earlier studies regarding the accelerated deterioration due to delay of repairs had come true. The commonality of the performance problems was to be expected since similar methods and materials of construction had been employed in Toronto's tower buildings. Performance shortcomings aside, this particular typology had performed admirably considering the available technology and building science theory of its time. Energy consumption had not been an issue some 40 years ago, and the envelope performed relatively well in a heating dominated climate. Air conditioning was a luxury at the time and not yet part of North American consumer expectations in housing, hence summer temperature and vapour pressure gradients were not at play.

One clear conclusion that emerged from the survey was that the buildings appeared structurally sound, except for the outer edges of the cantilevered balconies. The reinforced concrete armature was intact and was outperforming its non-load bearing masonry skin. The form of the armature still related to the programmatic spatial needs of contemporary personal shelter even though its grid was based upon below grade parking structures and the allowable span of 200 mm (8-inch) thick one-way reinforced concrete slabs. It was generally acknowledged that given the present condition and value of its structural armature, it was worthwhile investigating means of applying new skins periodically to continue sheltering many more generations of inhabitants. The early musings about how that could be best accomplished formed the basis of successive research leading up to the development of this guidelines publication.

A number of relevant issues were identified following the condition assessment. The replacement cost and construction time required to construct such an armature was recognized, as was the cost of demolition, environmental impact of material disposal, release of embodied energy, impacts of tenant displacement, infrastructure and parking reconfiguration. The economics of renewal versus demolition and re-construction, and how these may influence development densities in light of escalating costs of materials, construction, levies, permits, development charges and land values were identified as being critical to the rehabilitation of high-rise housing. As importantly, there was a palpable excitement generated by the architectural possibilities associated with the re-skinning of these rational, modernist buildings that so greatly influenced Toronto's urban landscape.

Synopsis

The common features of the tower building typology reflect similar materials and methods of construction that were employed over a relatively short period of time. The designers, builders and their trades were very familiar with this genre of housing and it was rendered quite consistently. As a result, the service condition and performance problems are common to a broad range of buildings, varying in severity but not in nature.

This is actually advantageous to building owners and housing agencies interested in tower renewal. Not only is it possible to develop standardized, replicable solutions, but it is also possible to engage industry to train skilled workers in the necessary techniques for retrofitting of this building stock. There are sufficient numbers of these buildings to make investments in the mass-customization of tower retrofit technologies economically attractive. The repetitive modularity of the initial tower artifact holds great promise for its subsequent revival.

But it is also important to recognize that each building will require careful assessment of its condition. The retrofit measures must be well suited to a particular building, realizing that there is a high likelihood some degree of repair will be necessary. These costs can be minimized by carrying out the renewal work as soon as possible, and coordinating the repairs to take advantage of the equipment and staging on site.

Practically all multi-unit residential buildings, including a large number less than 5 storeys, are suitable candidates for comprehensive retrofits to extend durability and conserve energy and water. It is important to note, however, that the measures covered in these guidelines are intended primarily for non-combustible building systems, typically rendered in masonry and/or concrete. Retrofit measures for low-rise housing using wood-frame construction is well documented in a number of authoritative sources and remains beyond the scope of this publication.

The next part of these guidelines examines in detail the process of building condition assessment, the essential first step of tower renewal.

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[1] *Interpreting the apartment house: modernity and metropolitanism in Toronto, 1900-1930.* Richard Dennis, Journal of Historical Geography, 20, 3 (1994) 304-322.
[2] *The Great Toronto Fire: An Unprecedented Disaster in the History of the City of Toronto.* Karen Jordan, July 21, 2007. http://canadianhistory.suite101.com/article.cfm/the_great_toronto_fire
[3] *Private households by structural type of dwelling, by province and territory.* Statistics Canada, 2006 Census of Population.
[4] *Conservation of Ontario's High-Rise Housing Stock. A Discussion Paper prepared by Clayton Rsearch Associates on behalf of the Ontario Ministry of Municipal Affairs and Housing, Housing Renovation and Energy Conservation Unit, May 1984.* [Note: This discussion paper is based upon Volume 10: Study of Residential Intensification and Rental Housing Conservation, "Future Conservation Requirements and Costs for High-Rise Apartments and the Possible Impact on Rents and Tenants" (prepared by Klein and Sears, Architects and Clayton Research Associates, 1983.)]
[5] *Extent of Carbonation in Buildings in Toronto.* Canada Mortgage and Housing Corporation, Ottawa, 1990.
[6] *High-Rise Apartment Repair Needs Assessment*. Gerald R. Genge and Jacques Rousseau. Canada Mortgage and Housing Corporation, Technical Policy and Research Division, Ottawa 1996.
[7] *Corridor Air Ventilation System Energy Use in Multi-Unit Residential Buildings.* Canada Mortgage and Housing Corporation, Ottawa, 1999.

[Photo Opposite Page: Jesse Colin Jackson]


Pay Here
Pay Here

5. Building Condition Assessment

The process of organizing and conducting a thorough building condition assessment is an important first step in every tower renewal project. The information gathered from existing records and field investigations serves many purposes. Original construction drawings of the building are necessary to estimate the effective thermal resistance values of the building envelope, and for quantity survey purposes to establish the areas of windows, walls, balconies and roofs. These data are also needed to perform energy modeling of the tower building. Energy and water consumption data are essential to performing accurate energy modeling that subsequently feeds into the cost-benefit analyses. A condition assessment of the building envelope is needed to itemize the repair work needed before the retrofit process can proceed. HVAC system and piping inspections are required to determine the extent of the upgrading work to be carried out. Simple, but important, procedures such as surveying the building to assess if it is plumb, level and square, assist in the development of appropriate details that can be adjusted if necessary to accommodate distortions in the existing building.

Building condition assessment is a procedure familiar to the building science engineering and consulting industry. It is commonly conducted for condominium buildings as part of the larger process of reserve fund studies, but will differ for existing tower buildings owing largely to the age of the buildings, and in many cases, a lack of detailed documentation in the form of drawings and specifications. However, the process of building condition assessment is the same in principle for all buildings and formal protocols have been established in Canada since 1993.[1]

In the publication, Protocols for Building Condition Assessment. Institute for Research in Construction, National Research Council of Canada, Ottawa, 1993, the condition assessment process is divided into eight categories: building structure, building envelope, mechanical systems, electrical systems, interior finishes, life safety, elevators, and function. Each section has its own building assessment protocol that defines the scope of the audit for that category, the audit procedure, and associated deliverables. Collectively, these eight protocols comprise the complete preliminary audit process.

Figure 5.1 positions the formal building condition process covered by these protocols within the broader context of condition assessment requirements for existing tower buildings. At the conclusion of the condition assessment process, a comprehensive report is prepared that can be referenced for energy modeling, cost-benefit analyses and eventually by the design team.

In cases where a recent condition assessment has been performed, it is not necessary to perform all of the procedures that are later outlined. Typically, critical elements are inspected to re-assess their condition. This is particularly important for structural elements and substrates to which overcladding elements and guards will be fastened. One critical item that will not usually constitute previous condition assessments of a building is the survey of building distortions. The Canadian experience in the latest techniques for assessing the plumb, level and square attributes of the building indicates these are widely available to conduct this survey efficiently and economically.[2]

It is also important to note the checklists that follow are comprehensive, across a broad range of building types, and not all of the items may apply to every tower retrofit project.

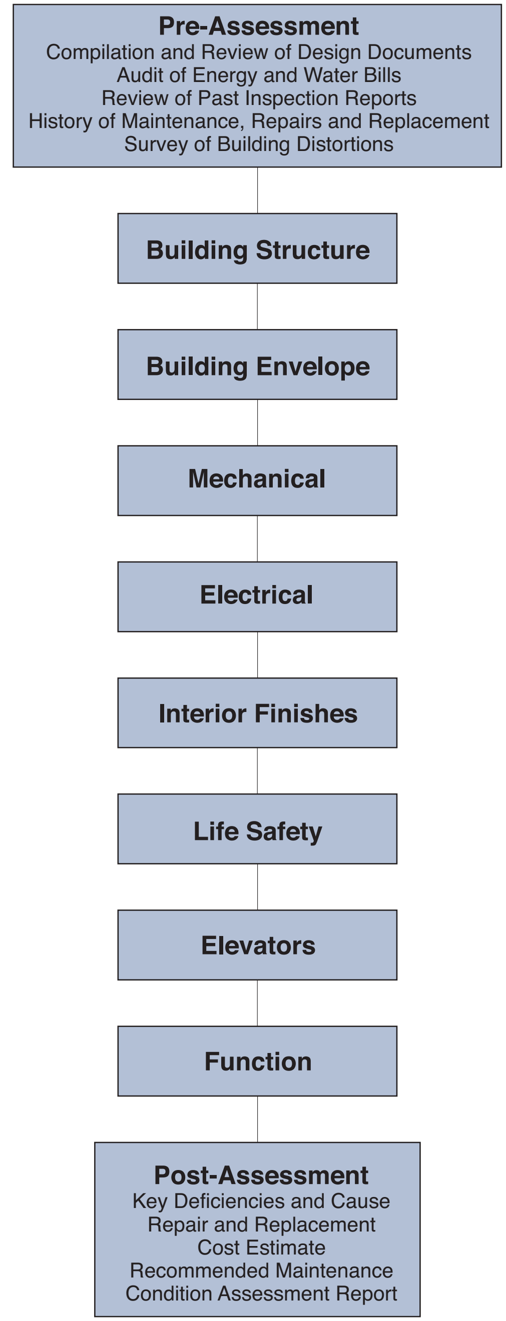

Figure 5.1. The building condition assessment procedure depicted above provides a systematic means of assessing the condition of the entire building, its components and equipment.

[Photo Opposite Page: Jesse Colin Jackson]

Condition Assessment Checklists

The checklists which follow are excerpted from the Institute for Research in Construction's Protocols for Building Condition Assessment. They are presented somewhat differently from the order depicted in Figure 5.1 to reflect the more likely sequence to be employed, and/or the inspection expertise required. Competent and qualified professionals commonly have developed their own checklists and procedures that may differ from those outlined here.

Building Structure

- underlying soils
- footings
- foundations
- retaining walls
- walls
- columns
- decking
- guards/railings
- beams
- trusses
- slabs
- shear walls
- elevator cores
- cladding
- joints
- windows

Building Envelope

- exterior walls
  - masonry
  - exposed shear walls
  - exposed slab edges
- balcony slabs
- windows and doors
- roofs
- foundation walls and slabs

Figure 5.2. Checklists for the assessment of structure and building envelope provide a framework for a more detailed procedures to be carried out in the field.

Figure 5.3. Photographs of the deficiencies are important for documentation purposes. The deteriorated exposed slab edge depicted above must be properly repaired prior to overcladding. Design details for the integration of existing grilles with the overcladding may begin to be investigated.
[Photo: Halsall Associates Ltd.]

Mechanical and electrical systems may often be inspected by a single firm that has both engineering disciplines in-house, but it is not unusual for separate consultants to be employed. In either case, it is important to coordinate these two categories because they are often interrelated, or occupy the same chases and bulkheads.

Mechanical

- heating, ventilating, air conditioning systems
- garage exhaust systems
- domestic hot and cold water supply
- sanitary equipment and sewers
- storm sewers and drainage
- fire sprinkler and standpipe systems
- specialized equipment such as garbage chutes and compactors

Electrical

- electrical supply and distribution
- lighting
- emergency lighting
- standby power system(s)
- telephone and communications
- cable and satellite TV
- security

Figure 5.4. For the purposes of tower retrofits, some of the items listed above may not apply. Often it is worthwhile performing a comprehensive assessment so that a complete, up-to-date record is available for future facilities management plans.

Figure 5.5. The service condition of the air-conditioning tubing depicted above is fair, but the penetration through the roofing system has not been properly addressed. This opportunity arises with roofing replacement where more appropriate measures may be employed, rather than relying on large quantities of caulking. [Photo: J. McBride and Sons Ltd.]

The assessment of interior finishes is not usually required for tower retrofits, since practically all of the work associated with overcladding takes place on the exterior. However, it is not difficult to combine an assessment of interior finishes when carrying out an assessment of the functional elements of the building.

Interior Finishes

- Common areas
  - walls
  - floors
  - ceilings
- Suites
  - interior walls and partitions
  - floors
  - ceilings
  - doors

Function

- Barrier free access
- Pedestrian circulation
- Garbage/recycling rooms
- Laundry rooms
- Mail rooms
- Kitchens, bathrooms, appliances
- Storage lockers
- Suite isolation (odour, noise, vermin)

Figure 5.6. Interior finishes and function are two categories of condition assessment that can be carried out simultaneously during the building inspection process.

The functional aspects of the building that should be assessed are listed in Figure 5.6. Barrier free access was not a Code requirement when most tower apartment buildings were constructed. The comprehensive tower retrofit offers an ideal opportunity to address barrier free access requirements.

Elevators are among the most critical services in tower apartment buildings. Their reliability and efficiency impacts the convenience of the building inhabitants. There is a significant potential for energy efficiency improvements with cost effective upgrades to older systems.[3]

Elevators

Review all major components:

- machines
- rotating sheaves
- hoist ropes
- controllers
- selectors
- motor generator sets
- governors
- hoistway equipment
- car fixtures including the car buttons and position indicators
- hall fixtures including the hall buttons and hall lanterns
- communication equipment
- door protective devices
- emergency alarm bell
- central control panel

Review the quality of adjustment with respect to industry standards.
Assess all functions on standard service calls and fire emergency modes.
Measure the following performance parameters:

- operating times
- running speeds
- car and hall call dwell times
- door open and close times
- door operation noise levels
- levelling accuracy
- fan noise levels
- door closing force
- machine temperature.

Review operation characteristics:
- acceleration
- deceleration
- ride quality
- controller dispatching (zoning, load weighing operations, etc.)

Figure 5.7. The inspection of elevators is a specialty field that can only be performed by licensed mechanics and certified inspectors. The list of items to be assessed is comprehensive and involves both safety and performance measures.

The assessment of life safety measures in tower buildings is normally well regulated and up-to-date inspection reports will usually be available. Many of the passive architectural elements will have been addressed in the past as a result of changes to codes, standards and insurance requirements. The emphasis in most tower retrofit projects will be on active mechanical and electrical elements. Comprehensive tower retrofits are an opportunity to upgrade these elements and improve the life safety of the building.

Life Safety

Passive Architectural Elements
- Occupancy classification
- Structural fire resistance
- Major fire separations
- Closures
- Means of egress
- Smoke control strategy
- Interior finishes
- Access for fire fighting

Active Mechanical Elements
- Sprinkler systems
- Standpipe and hose system
- Special extinguishing systems
- Water supply
- Fire pumps
- Supervisory switches
- Smoke control equipment
- Explosion relief devices

Active Electrical Elements
- Emergency power supply (NFC)
- Emergency lighting
- Smoke control (detection)
- Fire alarm system
- Voice communication
- Electrical vaults

Organizational Elements
- Fire safety plan
- Maintenance practices

Figure 5.8. Life safety requires inspection and review by qualified personnel. A comprehensive assessment is recommended for buildings that have not been thoroughly inspected in the recent past.

Note on IAQ Monitoring
Indoor air quality is not strictly speaking a life safety issue, but it is becoming a wider health concern. The sampling of exhaust air expelled from tower apartment buildings represents an opportunity to perform indoor air quality monitoring of the existing operating condition prior to retrofit. Subsequently, after the ventilation system has been upgraded, another set of samples may be obtained and analyzed to determine if there has been any change in the indoor air quality. Mold problems in tower buildings are quite common due to ineffective ventilation systems and when the overcladding is completed, the airtightness of the building envelope will have been dramatically increased. Monitoring affords a means of adjusting ventilation rates to achieve acceptable levels of indoor air quality and avoid health problems and damage to interior finishes in suites that generate high moisture loads. Air quality monitoring is now a widely available and affordable service that provides objective third party test data to building owners and HVAC system designers.

The checklists presented here outline the basic scope of a building condition assessment. It is intended more as a guide to building owners and facility managers who are arranging consultants for this service so they may appreciate the scope of the work. Special features of the building may require additional inspection and review. Building envelope inspections and testing of the soundness of the substrate (pull-out tests) often require a swing stage to gain access to the entire building envelope area. In some cases, sections of piping may have to be cut out to determine the wall thickness and remaining service life, and this will necessitate a temporary shutting down of water and/or sewage services. It is important to notify building occupants when and where inspections are being performed to minimize the intrusiveness of the inspection process. Scheduling away from peak rush hours and meal times is advisable.

Infrared Thermography

An important diagnostic tool for building envelopes is thermography. The infrared inspection of buildings for heat loss was one of the first commercial uses for thermography and today it is a widely available service provided by specialty consultants in this field. Thermography can yield qualitative and quantitative analysis of electrical and mechanical systems, and the building envelope.[4]

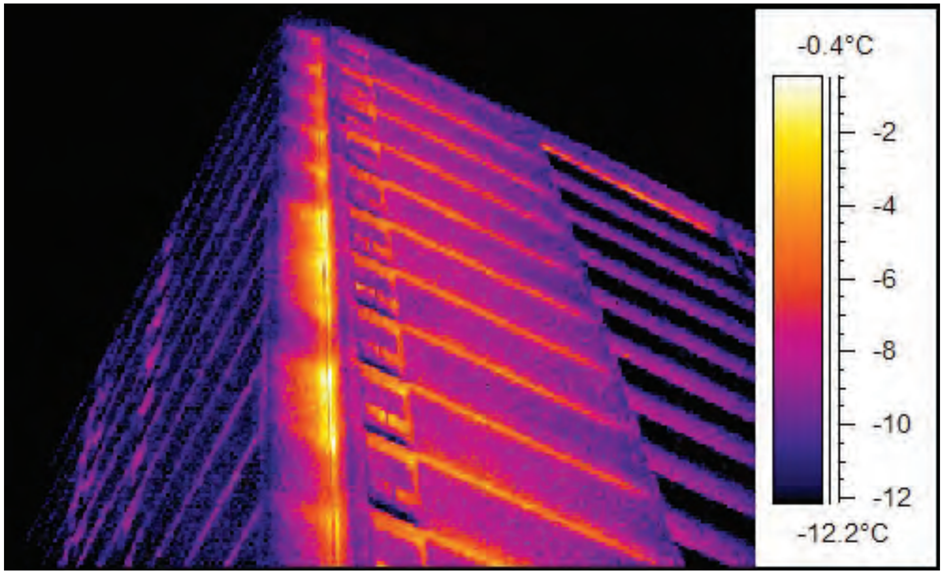

Figure 5.9. This thermographgic images indicates high rates of heat loss through exposed slab edges of a tower building. The intersection of the two corner shear walls produces the highest rate of heat loss because these act like efficient cooling fins. This image helps explain why interior retrofits of these buildings are not thermally effective. The thermal bridges denoted above by the red and yellow areas cannot be addressed by this insulation strategy. [Image: Boldstar Infrared Services Inc.]

Thermography can be employed during the condition assessment process to establish a qualitative reference level of thermal performance for the existing building envelope. Then the overcladding can be thermographically analyzed after it has been installed to ensure it has been properly and consistently applied. In some parts of North America, performance-based pricing is used to adjust payments for building envelope retrofits. Contractors are paid the percentage of the stipulated sum based on the percentage effectiveness of the installed assemblies according to a mock-up constructed according to the specifications and thermographically analyzed in a climate controlled test chamber. Thermography is more commonly employed as a means of identifying deficiencies that can be remedied before the warranty period expires. It is important to note that thermography is not a substitute for proper quality assurance procedures conducted in the field by qualified inspectors, as there are many aspects of overcladding installation that cannot be analyzed using thermography. However, the thermal performance of the overcladding strongly influences the energy savings realized, and hence the cost effectiveness of the investment in a comprehensive tower retrofit.

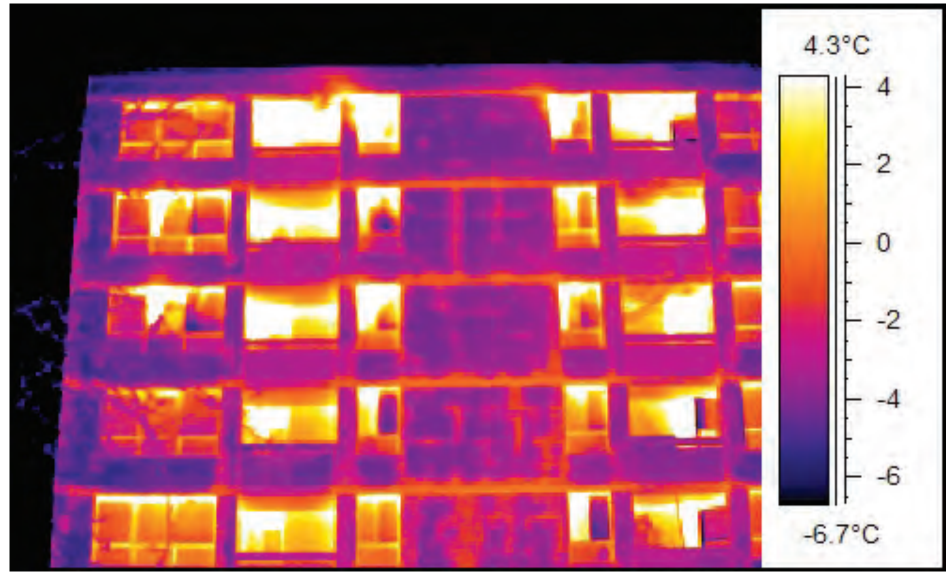

Figure 5.10. Single glazed windows typically represent the highest rate of heat loss in a tower building envelope. The uneven construction of the opaque wall assemblies is evident in this thermographic image, revealing the potential of this technology for quality assurance monitoring purposes. [Image: Boldstar Infrared Services Inc.]

Figure 5.11. The baseboard heaters beneath the second storey windows are evident in this thermographic image. Much of the heating in tower buildings travels directly to the outside without improving thermal comfort in the living spaces. [Image: Boldstar Infrared Services Inc.]

Assessment Audit Methodology

Referring to the previously outlined checklists, the methodology for the conducting of audits and inspections is briefly described below. It should be noted this may actually differ between organizations conducting the assessments. The discussion that follows is intended to provide a framework for the assessment process and deliverables.

Design Document Review and Post-Occupancy Evaluation

The condition assessment team is responsible for obtaining and reviewing all documentation in the form of original project briefs, original and updated working drawings and specifications, maintenance and operation reports. All utility bills for water, electricity and natural gas should also be compiled for use during energy analysis. Post-occupancy evaluation is a term used to describe the process of interviewing inhabitants, facility managers and building superintendents, as well as measuring building environmental conditions. The purpose of this evaluation is to gain an understanding of the operations, performance problems, comfort issues, and any other information pertaining to the behaviour of the existing building.

Building Inspection

A number of building walkthroughs will be conducted by a variety of experts corresponding to the condition assessment categories described in the checklists. Special testing and monitoring may also be conducted as required.

Costing

In order to perform a meaningful cost-benefit analysis of the proposed tower retrofit, costing of all necessary repair and replacement work must be assembled. The cost of various overcladding, window replacement and mechanical/electrical equipment alternatives should also be estimated at this time so that accurate, up-to-date information is available for cost-benefit analysis of the entire comprehensive tower retrofit project.

Reporting

A complete report will contain, as a minimum, the items noted below. It should be organized for convenient reference and include all documentation gained during the document review and post-occupancy evaluation process. Digital files of the documentation, report and photographs should be attached to the report, suitable for archiving and future reference.

Description of Existing Building Category

The existing inventory of each building category should be described in this section of the report. For equipment and services, the type, age, manufacturer and model numbers should be identified, as applicable. Capacities for HVAC and electrical equipment must also be noted.

Component Condition Summary

An assessment of the operating condition and remaining service life of all components should be clearly summarized. Items that will not be affected by the comprehensive retrofit should be differentiated from those that may be upgraded or replaced.

Key Deficiencies and Cause

The items that are deficient and require repair prior to the comprehensive retrofit are identified in this section of the report. It is important to identify the cause of the deficiencies so they may be considered by the retrofit design team.

Recommended Repair and Replacement

Deficient and deteriorated components that need to be replaced must be identified and listed in order of priority based on life safety and consequential damages arising. This list should differentiate critical items to be addressed prior to retrofit versus items that can be repaired or replaced without affecting the scheduling of retrofit work.

Cost of Retrofit Components and Equipment

Unit prices for components and assemblies along with estimates of total retrofit costs associated with each retrofit measure are necessary to perform cost-benefit analyses, and to estimate a retrofit project's cash flow requirements. The condition assessment team may have to consult with quantity surveyors, cost consultants and experienced contractors to obtain a reasonably accurate range of costs. Recent historical data on escalation rates for materials and labour should also be provided, where available.

Recommended Maintenance

There is no guarantee that the pro forma for the proposed tower renewal project will be feasible. This will depend on a large number of factors, and in some cases, it may be necessary for the owner to wait some considerable time before proceeding with the project. The recommended maintenance for the existing building is necessary to preserve its integrity. The recommended maintenance and recommended repair and replacement identified in the report will assist the owner in preserving the building asset regardless of whether or not the tower renewal project proceeds. This is the rationale behind conducting a comprehensive building condition assessment and having current information about the state of the building asset.

Condition assessment for buildings is akin to regular physical examinations for people. Small problems can be addressed before they become big problems. Mid to long-term planning to address deterioration and preserve the asset may be formulated well in advance of compliance orders by regulatory agencies. It is possible to go forward with complete knowledge of the available options.

Depending on the capacity of consultants employed by the owner to perform the conditional assessment, it may also be combined with the energy modeling and cost-benefit analysis. These may be integrated into a pro forma for the comprehensive tower retrofit. Regardless of the arrangements made by the owner in this regard, the completed condition assessment report and all supporting documentation should be conveniently packaged for archiving and future reference. This information is critical in the formulation of suitable design strategies for the site and building systems as discussed in the two chapters that follow.

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[1] Protocols for Building Condition Assessment. NRCC 36913, Institute for Research in Construction, National Research Council of Canada, Ottawa, 1993. http://irc.nrc-cnrc.gc.ca/pubs/catalogue/nrcc36913_e.html

[2] James B. Posey, W. Alan Dalgliesh, Andrew Little, and Chris Tucker. Variations in Position of Columns and Slabs. Proceedings of the 11th Canadian Conference on Building Science and Technology, Banff, Alberta, 2007. http://bricks-and-brome.net/44c11.pdf

[3] Harvey M. Sachs. Opportunities for Elevator Energy Efficiency Improvements. American Council for an Energy Efficient Economy (ACEEE), April 2005. www.aceee.org/buildings/coml_equp/elevators.pdf

[4] John Snell and Rob Spring. Testing building envelope systems using infrared thermography. Affordable Comfort 2005. Indianapolis, Indiana, May 16-21, 2005. http://www.affordablecomfort.org/images/Events/16/Courses/289/W2-SOLV_Infrared_Snell.pdf

6. Tower Site Strategies

The idea of tower renewal is often associated with the building itself, but in these guidelines it also extends to consider the site. There are two aspects of site strategies that should be addressed as part of a comprehensive tower retrofit. The first involves urban ecology, primarily through the management of stormwater. The second is not as enduring and relates to the management of traffic and parking during the course of the renewal works.

In each tower renewal project, it is important to consider the implications and opportunities afforded by site context. Each tower has its own unique site characteristics, such as site area, building footprint, building orientation, relationship to the public realm (streets and public space), parking, landscaping, etc. As well, each tower building site exists within a particular climatic zone, which has implications for its relationship to climatic variables such as solar access, wind exposure and precipitation.

Depending on the extent of renewal, or redevelopment, of a tower site, various planning and zoning regulations may apply, which may in turn invoke planning review processes such as site plan approval. There is an emphasis in today's planning reviews to more thoroughly consider the implications of the renewal of urban sites relative to environmental impacts. This trend is evident in the plethora of planning, design and engineering information relative to strategies for low Impact development (LID) and the evaluation of building projects using site criteria such as those found in the U.S. and Canada Green Building Councils' Leadership in Energy and Environmental Design (LEED) certification programs. Many municipalities are also enacting planning policy, site-specific standards and by-laws aimed at achieving ecologically sensitive site development measures.

Although much of the green development movement has been building "centric", there is an ever increasing body of research documenting the contributions to environmental goals by site design, as evidenced by the American Society of Landscape Architects (ASLA) recent draft guidelines, The Sustainable Sites Initiative: Guidelines and Performance Benchmarks.[1] As well, many cities are aggressively advocating a wide variety of site design considerations such as those embodied in the City of Toronto's Green Development Standard.

Given the emphasis of these guidelines on existing buildings and sites, this chapter focuses on what practical opportunities exist to alter existing site conditions to enhance urban ecology. Although the principles and approaches discussed in this chapter have general applicability, the main emphasis is on cold climate conditions with specific focus on data and situations typical to the City of Toronto.

Site As Infrastructure

Traditionally tower site development has tended to focus on site plan requirements such as access, servicing, parking, landscape and recreational amenities. Often site designs are purely the reflection of a set of minimum standard requirements. In other cases the site, especially the landscape features, have been almost entirely expressed in aesthetic terms. Contemporary thinking in site design is now shifting to where the site is seen as an opportunity to make a more substantial contribution to the servicing and environmental objectives of cities. This change has been strongly influenced by the opportunities that site design strategies can provide in support of goals based on sustainability, low impact development, and more ecologically sound landscape models. Tower sites are now seen as an important part of city infrastructure, integrating the building, site and city in a way that is more performative and ecologically based.

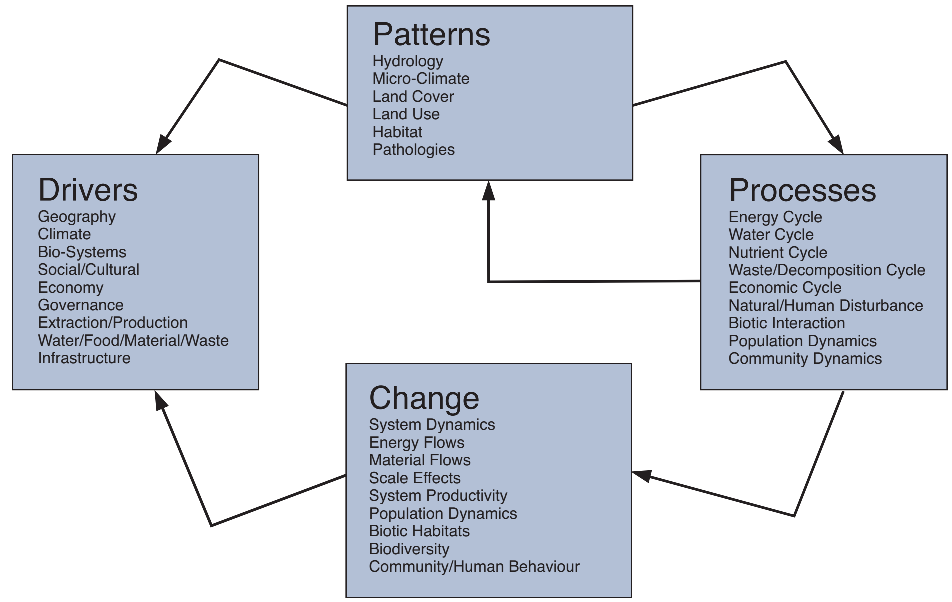


Figure 6.1. A conceptual model of urban ecology, adapted from the Urban Ecology Lab at the University of Washington, identifies some of the key concepts and relationships influencing contemporary site design strategies.

The importance in this type of reassessment of the role of site is nowhere more compelling than in the report, *Danger Ahead: The Coming Collapse of Canada's Municipal Infrastructure*.[2] The impending crisis in municipal infrastructure is identified as:

> *"Water supply, wastewater and stormwater systems are approaching the end of their service life, especially in older communities. The municipal infrastructure deficit for these categories stands at $31 billion [2006], a 47 per cent increase since 1996, when the deficit was estimated at $21 billion".*

This concern for degradation and collapse also extends to a city's natural systems.

> *"According to a study prepared for Urban Forestry Services (City of Toronto) the city's urban forest decreased in size by a staggering 24 percent in the decade between 1994 and 2004. We have a mere 17 percent canopy cover left for the entire city."*[3]

Engineers and landscape architects are actively pursuing how the design of urban sites can better address these issues. Perhaps the most significant of these identified to date are the role urban sites can play in the conservation of water resources and the reduction of stormwater loads on an aging and often over stressed infrastructure system.

[Photo Opposite Page: Jesse Colin Jackson.]

Stormwater Management

> *The trouble with weather forecasting is that it is right too often for us to ignore it, and wrong too often for us to rely on it.*
> Patrick Young

Stormwater is water that accumulates on land as the result of storms, and can include runoff from urban areas such as lawns, roofs and roads.[4] In the past, the strategy for dealing with stormwater was to collect and convey rainwater away from a site as quickly as possible. This approach has a rich history of drainage methods dating from the Indus civilization (2600-1900 BCE) to our present day systems. The objectives have remained essentially the same: use; convenience; and the prevention of damage to property (flooding). This attitude, especially in North America, resulted in a relatively sophisticated system of positive grading, swales, catch basins, channelization and piping intended to convey stormwater to natural waterways. From an urban perspective, rainfall was seen as a potential hazard and not as a resource. Figure 6.2 depicts 19th century municipal infrastructure that has not essentially changed to this day.

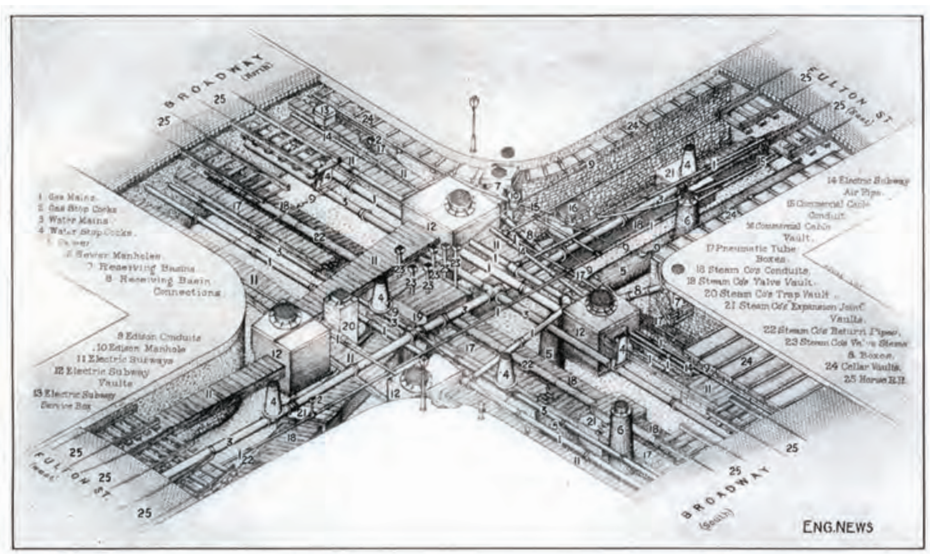


Figure 6.2. Isometric view of underground piping at the intersection of Broadway And Fulton Street, New York, New York,1890.[5] The inherited municipal infrastructure in our cities is being replaced in a piecemeal fashion as it fails, using the same dysfunctional technology that is the cause of our stormwater management problems.

It is now well documented that this system has many pitfalls, especially in urbanized areas. The effectiveness of stormwater infrastructure has often been compromised by the fast growth of cities, increasing demands, unevenness in the system due to various historic design standards (i.e. combined versus separated systems) and general deterioration of the system over time, in particular in older parts of the city. There are also increasing concerns over urban runoff quality, (e.g., vehicle oils, salt, increased sediment loads) resulting in the further impairment of the ecological functioning of watercourses and water bodies. Figure 6.3 illustrates some of the issues facing urban areas relative to stormwater impacts identified by the U.S. Federal Interagency Stream Corridor Working Group.

It would be difficult to identify the total number of books, journal articles or internet sites that are now aggressively dealing with approaches to the urban stormwater issue. Federal and provincial (state) environmental departments are playing a strong leadership role in this area. Most major municipalities through their engineering, public works, and conservation, agencies/departments have prepared stormwater management plans and development standards. The research underpinning this chapter is positioned within this context and specifically examines the potential for stormwater management approaches to the redevelopment of tower sites.

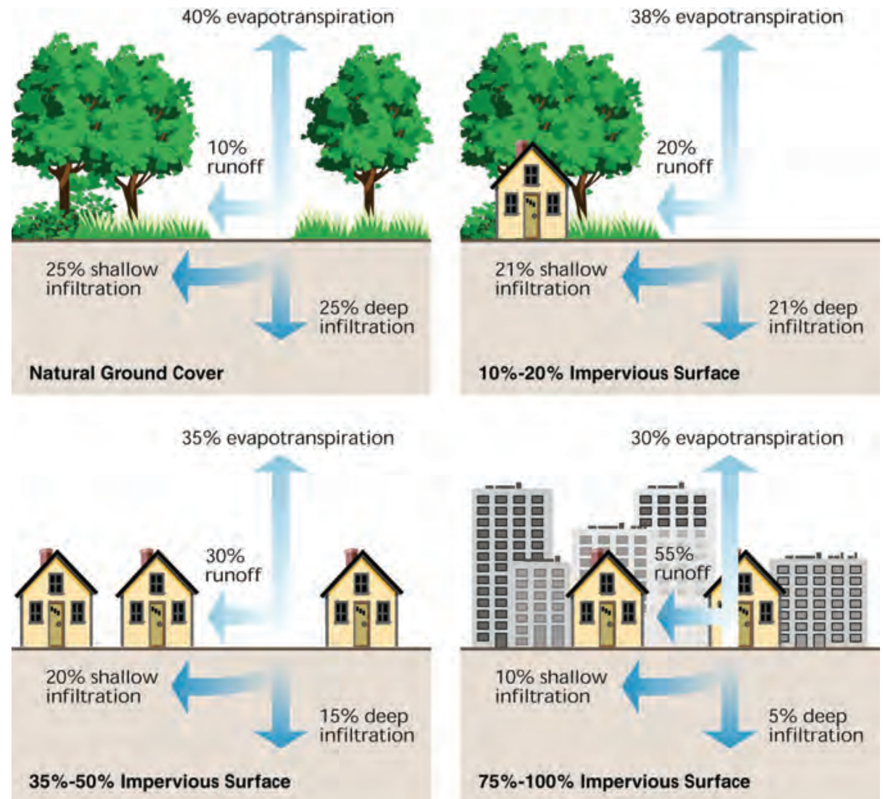


Figure 6.3. The relationship of stormwater runoff relative to the proportions of pervious and impervious surfaces that range from more natural sites to urban sites.[6]

Approach

The examples that follow are based on an evaluation of three existing prototypical tower sites within the Toronto area in terms of their stormwater contribution. It is important to note that the primary approach to the research was to allow flexibility for evaluating stormwater impacts in relation to best management practice (BMP) at the planning and design level. The emphasis here was to compare methods that would allow for more proactive decision-making. The approach to this evaluation consisted of the following steps:

1. Identify three sites with varying site area to building footprint ratios, typical of urban and suburban tower site conditions;
2. To evaluate pre-development and post-development stormwater flows;
3. To explore methods of hydrological assessment supportive of stormwater design decision making;
4. To investigate stormwater best management practices (BMPs) that can be practically implemented on tower sites; and
5. To evaluate the potential application and impacts of relevant BMPs to one of the prototypical sites.

This approach was guided by the intent and goals of The City of Toronto's Wet Weather Flow Management Guidelines (WWFMG).[7]

Method

The analysis and modeling of rainfall impacts in relation to runoff for small urban sites has been a topic of interest to hydrologists, hydrologic and civil engineers for well over 100 years. The level of sophistication of modeling approaches has grown along with the increasing capability of computers to handle complex rainfall statistical analysis and dynamic continuous modeling of urban hydrological processes. However, the majority of this work is mostly applicable to larger scale site areas (watersheds) and is not as useful or as easy to implement on smaller urban sites (i.e., less than 5 hectares). Approaches commonly used in urban areas vary from the Rational, Modified Rational, Hydrographic and Continuous modeling methods. The majority of methods focus on more static approaches based on precipitation events (5 year to 100 year storms) and intensity, duration frequency methods (IDF curves) for set time periods of rainfall (e.g., a 2 year storm with a 10 minute time of concentration). All three sites were modeled using the Rational, Modified Rational and Hydrographic methods, but for the purposes of these guidelines, two primary methods of analysis were employed:

- 5mm of rainfall over the whole site as recommended by the WWFMG, "*In most cases, the minimum on-site runoff retention requires the proponent to retain all runoff from a small design rainfall event - typically 5 mm (In Toronto, storms with 24-hour volumes of 5 mm or less contribute about 50% of the total average annual rainfall volume) through infiltration, evapotranspiration and rainwater reuse.*" [8]; and
- The Analytic Probability Models developed by Professors Barry J. Adams and Fabian Papa in their book Urban Stormwater Management Planning with Analytical Probabilistic Models (APM).[9] The APM method described by Adams and Paba in their book was chosen because of its ability to model the influences of both runoff coefficients and surface depression on urban runoff behavior. This was extremely useful in seeing the impacts of the variation of both these assumptions on urban runoff volumes and provided a cursory method of evaluating the potential impact on various BMP strategies for the prototypical tower sites.

The WWMFG technique is self-explanatory as it represents a total volume to be considered by site area regardless of runoff coefficients or surface depression. The APM method is based on the equation set out in Figure 6.4.

$$R = \theta E[\,Vr\,] = \theta \frac{\phi}{\zeta} e^{-\zeta Sd}$$

$R =$ *Runoff*

$\theta =$ *Average number of rainfall events*

$Vr =$ *Volume of runoff (mm)*

$\phi =$ *Runoff coefficient*

$\zeta =$ *Parameter of exponential PDF of rainfall volume* (mm^{-1})

$e =$ *Base of the natural logarithm*

$Sd =$ *Depression storage*

Figure 6.4 The equation governing the analytical probabilistic model of runoff considers storm pathologies, runoff coefficients and depression storage with the intent of making decisions that can effectively reconcile risk and consequences.[10]

Evaluations employing the APM model assumed that impervious areas, such as paved surfaces, have a runoff coefficient of 0.95 and pervious areas such as landscaped areas have a runoff coefficient of 0.25. Surface depression was assumed to be 1 mm for paved areas and 3 mm for landscape areas. Rainfall events were based on rainfall statistics of rain season, i.e., two-hour inter-event time definitions (IETD), for five Toronto weather stations, which most closely corresponded to Toronto IDF curve data and the 5mm WWFMG criteria.[11]

It is important to note the intent of these comparative evaluations is to gain an understanding of the impacts of the tower sites on stormwater runoff. Their primary purpose is to aid in decision making relative to the potential for BMP contributions to meeting the WWFMG objectives. Redevelopment of urban sites would require more thorough evaluation conducted by qualified professionals to determine effective stormwater management measures.

Tower Sites and Hydrological Analysis

Three tower sites were selected for the hydrological analysis of potential runoff volumes. Each site was analyzed in depth with landscape types broken down into five categories.

1. Pervious landscape areas of limited depth, 300 mm or less, where opportunities for infiltration are limited;
2. Pervious landscape areas of variable depth, over 600 mm, where opportunities for infiltration are significant;
3. Impervious, paved areas;
4. Impervious roof areas; and
5. Public areas, such as boulevards, with a combination of pervious and impervious surfaces.

Site plans and axonometric views of the three sites, Towers A, B and C, are depicted on the pages that follow.

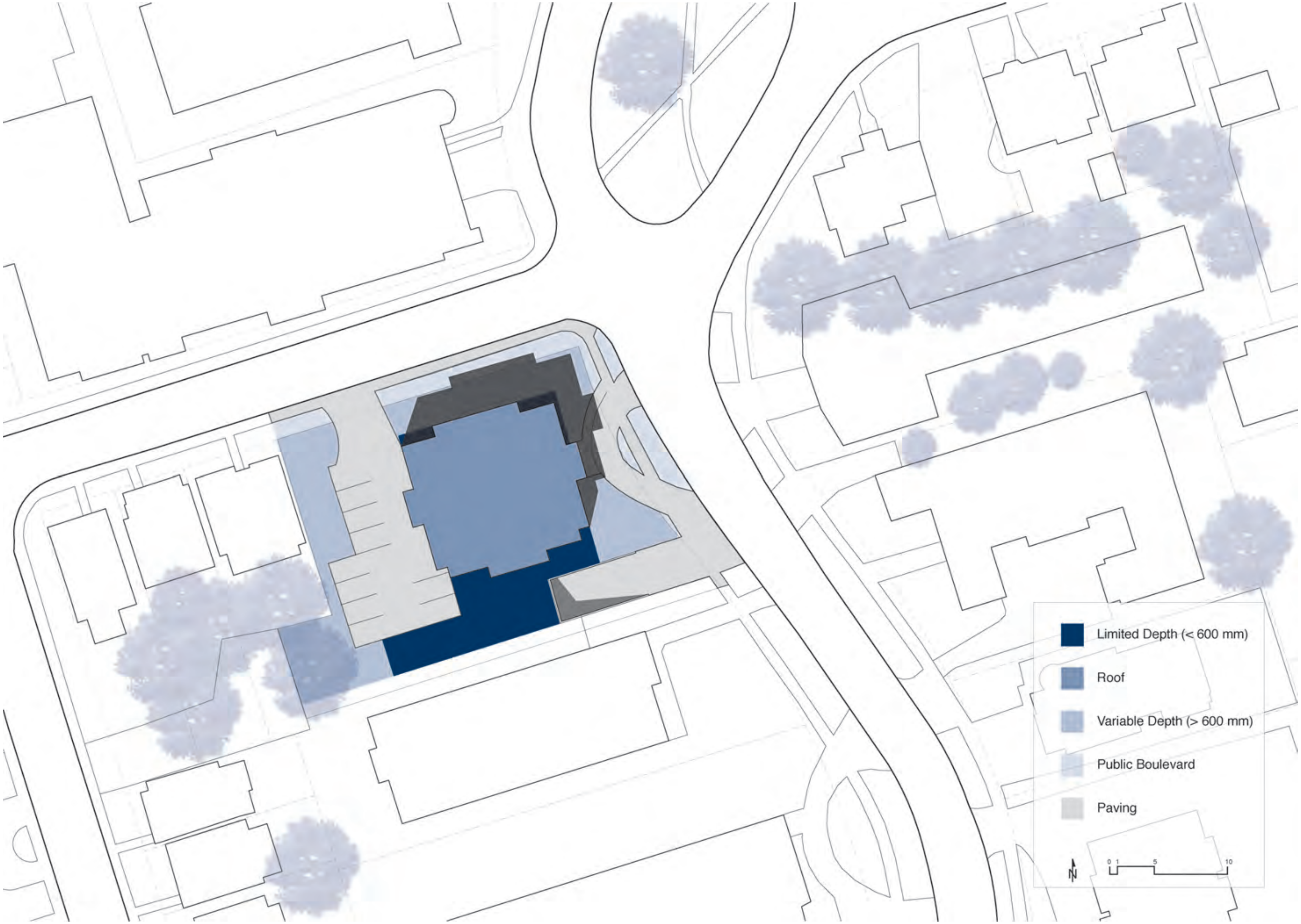


Figure 6.5. Tower A – Compact Urban Site is an example of tower buildings developed on small parcels of land in existing urban neighbourhoods.

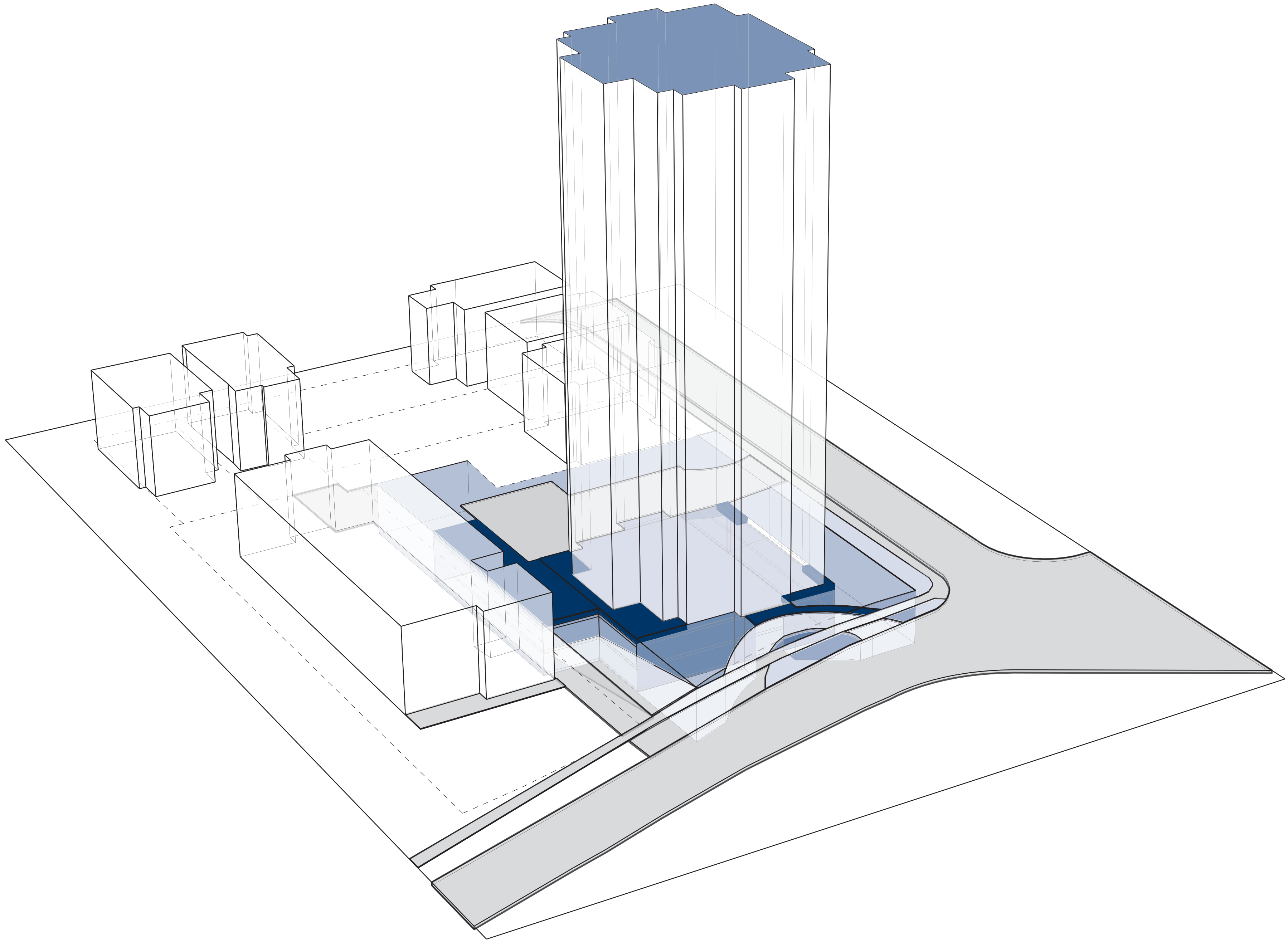


Figure 6.6. Axonometric drawing of Tower A indicating surface areas contributing to stormwater runoff. The full depth soils are limited in area and located at the perimeter of the property.

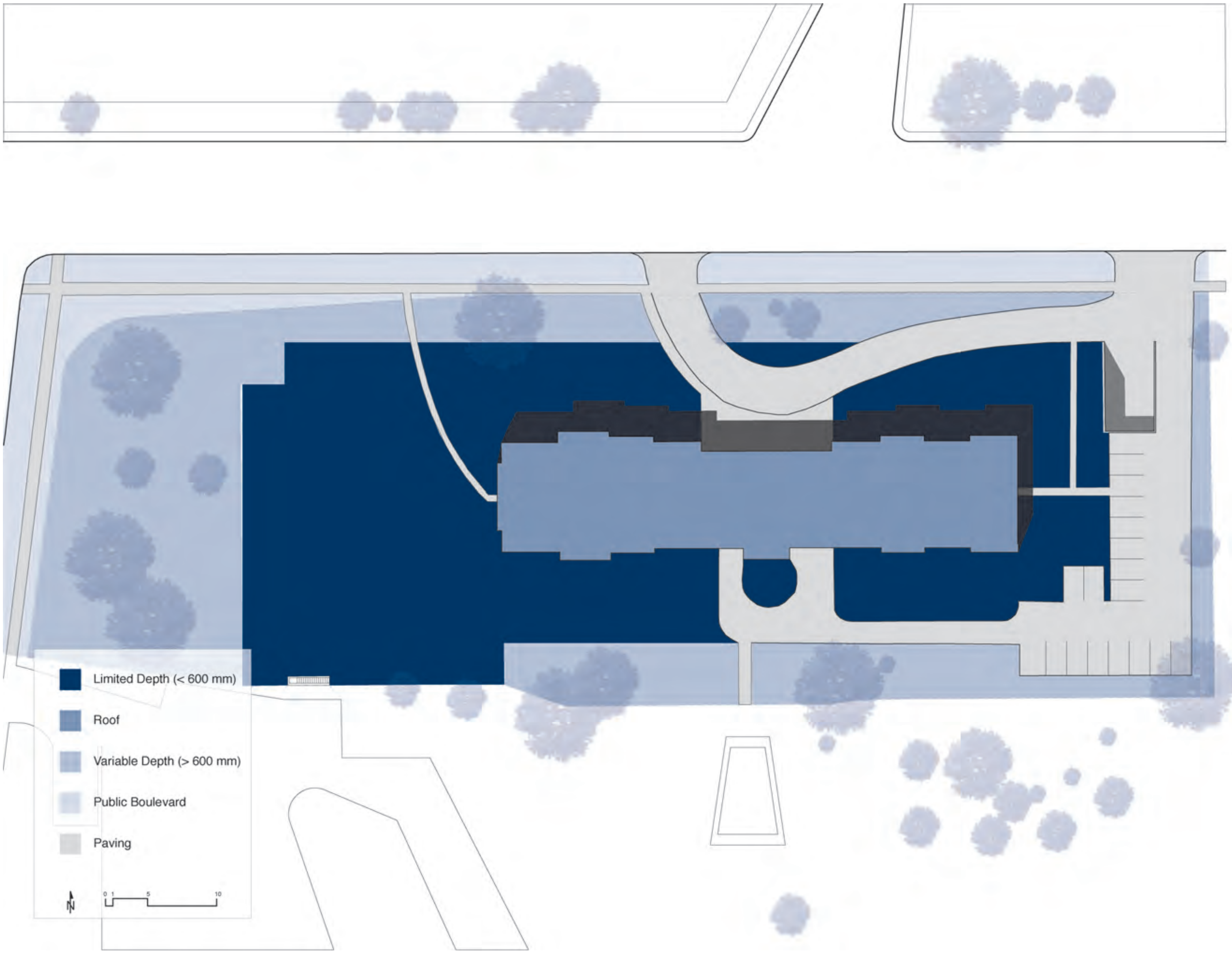


Figure 6.7. Tower B – Typical Suburban Site is an example of the most common tower development site found in many of the suburbs that sprang up after the 1950s. Extensive underground parking was preferred to deeper and more costly foundations having a smaller footprint.

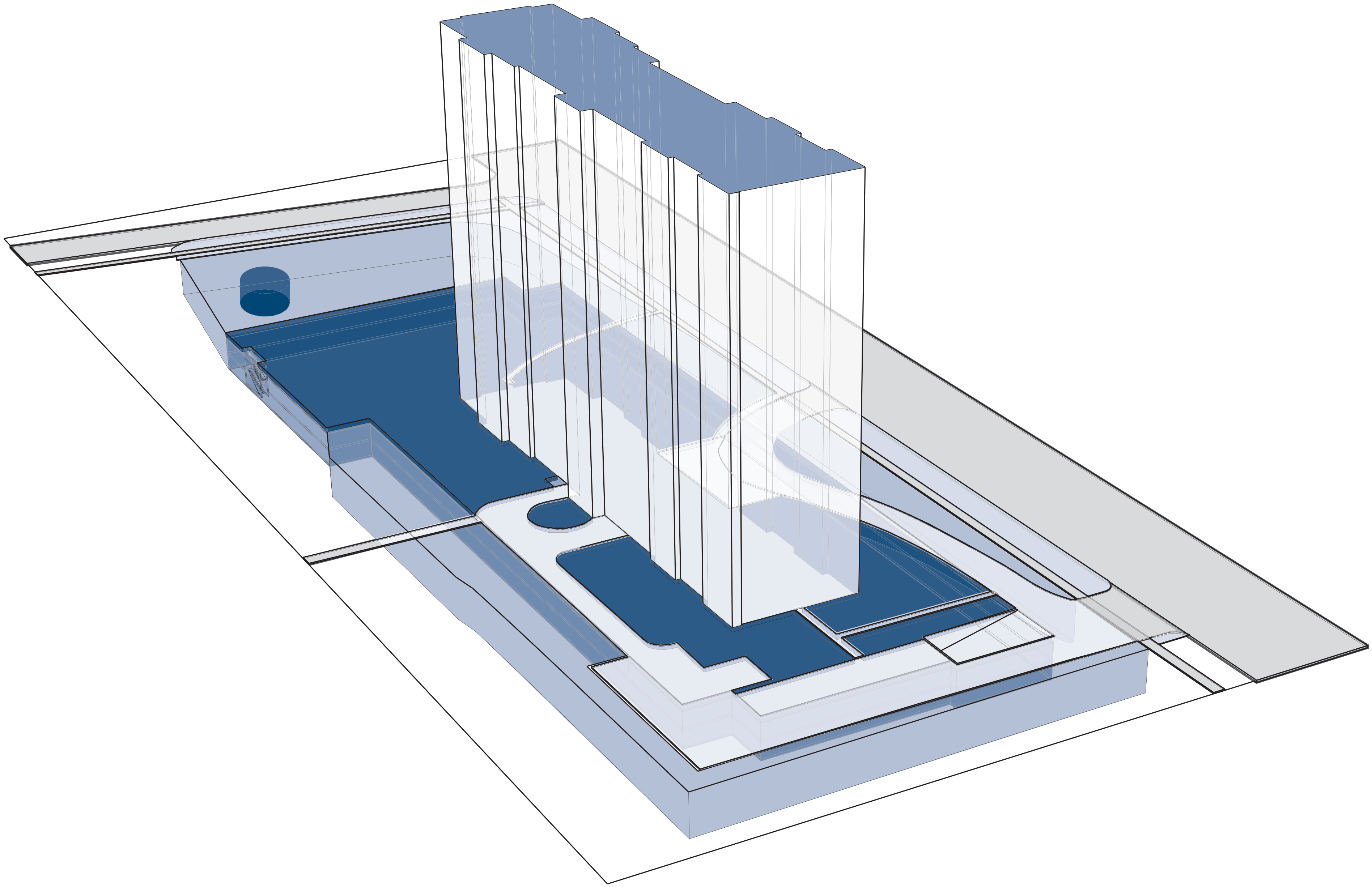


Figure 6.8. Axonometric drawing of Tower B indicating that much of the surface area is of limited depth soil covering the underground parking structure. Full depth soils are located around the perimeter of the site and strategies for storage or infiltration in these areas require relatively long conveyance paths.

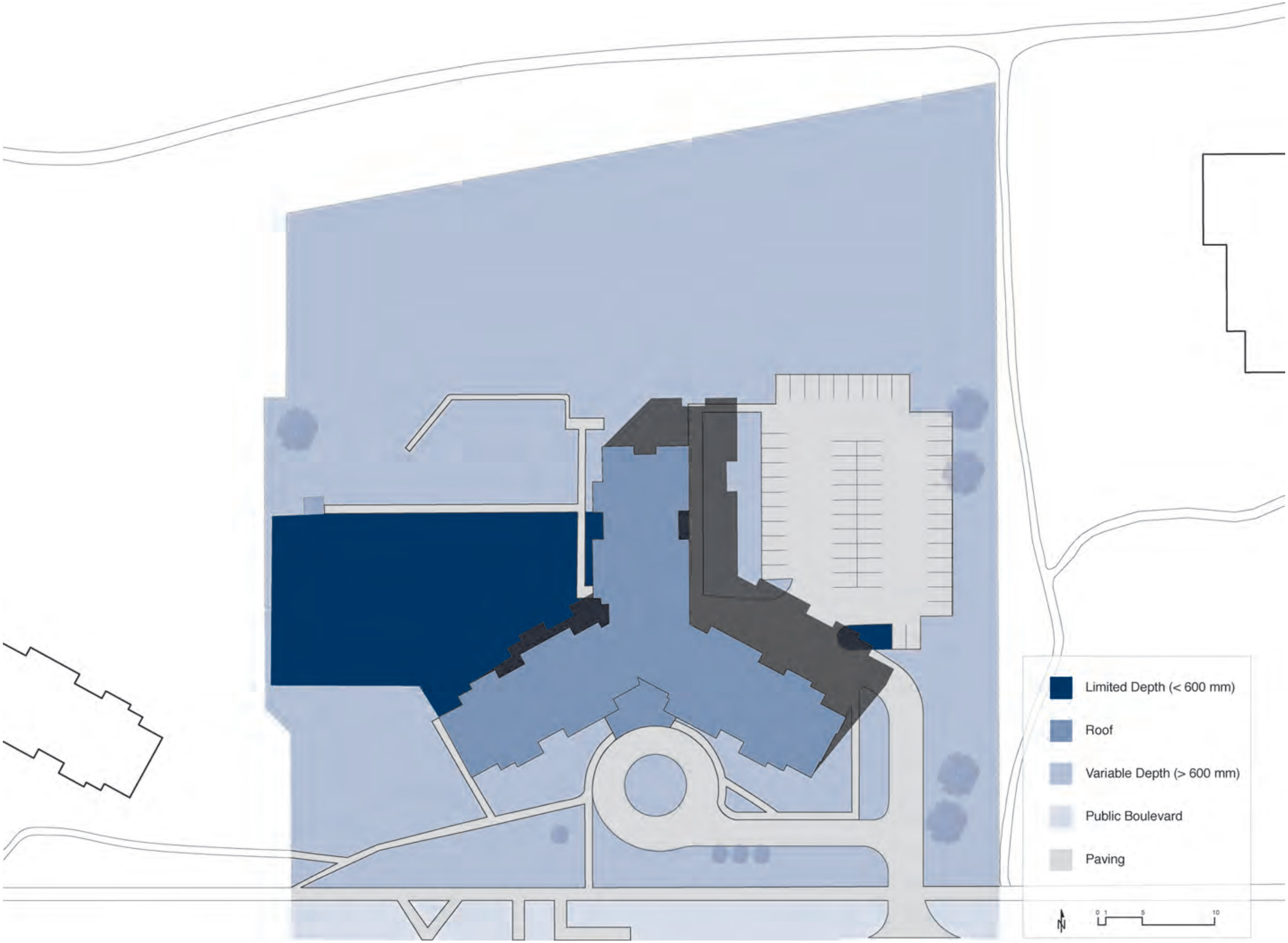


Figure 6.9. Tower C – Large Suburban Site is typical of developments that were located in low density areas where land prices were relatively low. Generous outdoor parking areas and ample green space frame the automobile-centric tower in the suburban park.

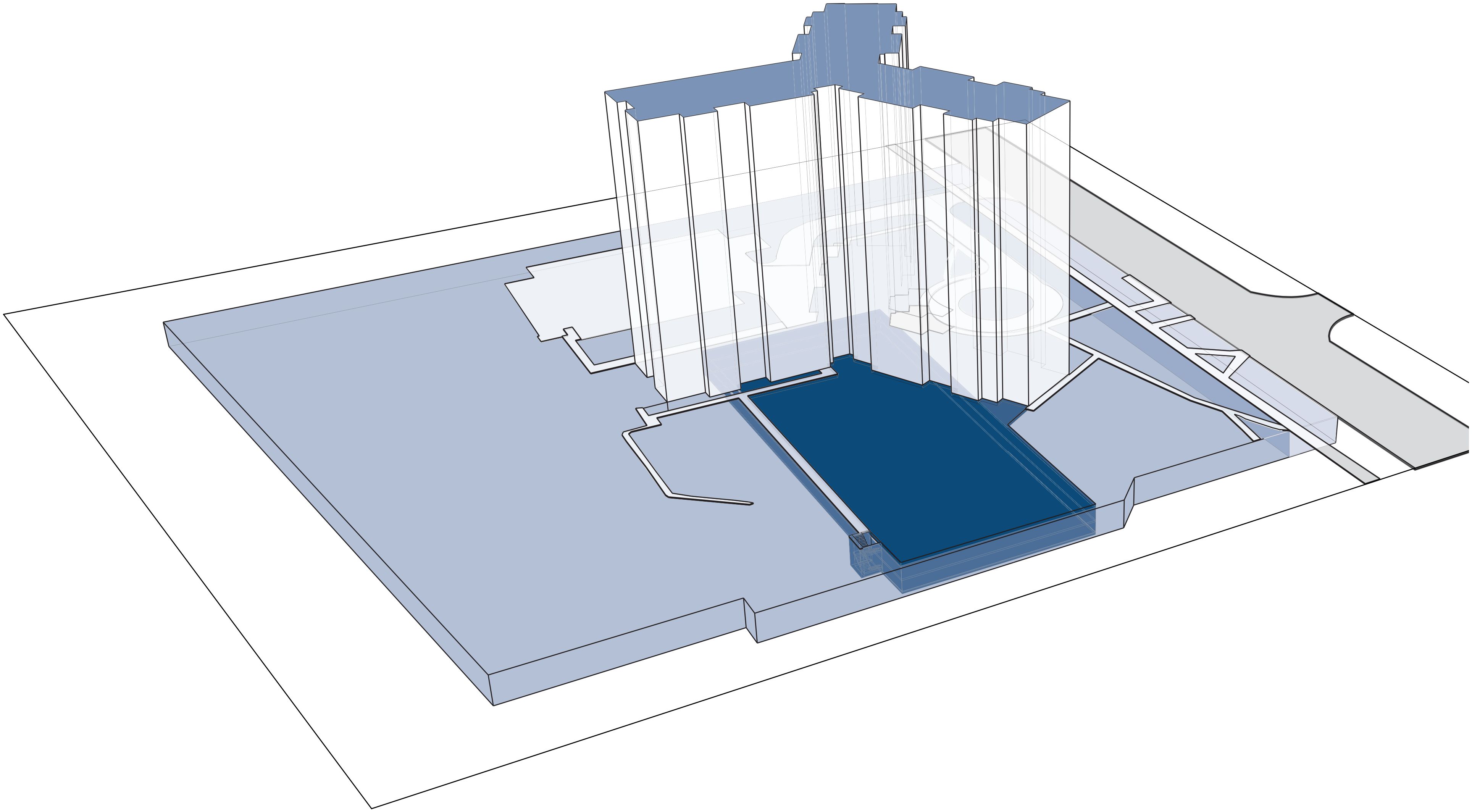


Figure 6.10. The Tower C site has more than enough full depth soil areas surrounding the building to receive stormwater for detention and infiltration, with surplus area available to accommodate urban agriculture and geothermal loops or wells. On some large suburban sites, there is sufficient capacity to host new development on the property without compromising stormwater management and green energy opportunities.

Comparison of Runoff Volumes

The critical mission for urban stormwater management is to reduce the quantity of water entering the municipal system and to improve its quality in terms of contaminants and suspended solids. Tables 6.1, 6.2 and 6.3 summarize the type and size of surface areas for tower sites A, B and C, respectively, and provide estimates of the quantity of runoff that must be stored and/or infiltrated according to the two calculation methods discussed earlier.

Tower A has a highly impervious site with just over one-third of the area comprising limited or variable depth soils. Based on the APM model, the required storage is estimated as 4.72 m^3, whereas the WWFMG predicts a maximum storage requirement of 8.99 m^3. It should be noted the most significant difference between the two methods is that the WWFMG model does not consider the runoff coefficient or surface depression storage.

Tower A - Compact Urban Site			APM Model 2 hr IETD	WWFMG 5 mm
Impervious Areas	m^2	ha	Required Storage m^3	
Parking Lot	331.66	0.03	1.26	1.66
Parking Lot Driveway	119.45	0.01	0.45	0.60
Front Entrance	40.75	0.00	0.15	0.20
Parking Ramp	118.75	0.01	0.45	0.59
Paths	74.09	0.01	0.28	0.37
Roof	439.44	0.04	1.67	2.20
Total Impervious	**1,124.14**	**0.11**	**4.27**	**5.62**
Pervious Areas				
Limited Depth Landscape	148.84	0.01	0.10	0.74
Variable Depth Landscape	525.49	0.05	0.35	2.63
Total Pervious	**674.33**	**0.07**	**0.45**	**3.37**
Percent Impervious	62.5%			
Total Site Area	**1,798.47**	**0.18**	**4.72**	**8.99**
Analytical Probabilistic Method employing 2-hour inter-event time definitions.				
Wet Weather Flow Management Guidelines - 5 mm depth of rainfall over entire site area.				

Table 6.1. Summary of physical site characteristics and runoff volumes for Tower A.

Tower B has just over two-thirds of the site comprising limited or variable depth soils, and its total surface area is slightly more than 5 times larger than the Tower A site. It may be noted that the required storage predicted by the WWFMG is purely based on site area with no consideration of runoff coefficients or surface depression storage. The APM model predicts a storage volume that is 3.30 times as large as that required for Tower A even though the Tower B site is 5.25 times larger than the Tower A site. The effects of the runoff coefficient and surface depression storage account for this attenuation of runoff.

Tower B - Typical Suburban Site			APM Model 2 hr IETD	WWFMG 5 mm
Impervious Areas	m^2	ha	Required Storage m^3	
Parking Lot	837.34	0.08	3.18	4.19
Parking Lot Driveway	682.22	0.07	2.59	3.41
Front Entrance	120.82	0.01	0.46	0.60
Parking Ramp	53.51	0.01	0.20	0.27
Paths	90.87	0.01	0.35	0.45
Roof	1,181.17	0.12	4.49	5.91
Total Impervious	**2,965.92**	**0.30**	**11.26**	**14.83**
Pervious Areas				
Limited Depth Landscape	3,558.66	0.36	2.36	17.79
Variable Depth Landscape	2,919.50	0.29	1.94	14.60
Total Pervious	**6,478.17**	**0.65**	**4.31**	**32.39**
Percent Impervious	31.4%			
Total Site Area	**9,444.09**	**0.94**	**15.57**	**47.22**
Analytical Probabilistic Method employing 2-hour inter-event time definitions.				
Wet Weather Flow Management Guidelines - 5 mm depth of rainfall over entire site area.				

Table 6.2. Summary of physical site characteristics and runoff volumes for Tower B.

Tower C has only 27.8% impervious surface areas, the lowest of the three sites. The APM model predicts 34.75 m^3 of storage required compared to the 113.20 m^3 using the WWFMG method. It is important to note that the WWFMG method was primarily aimed at addressing compact urban sites where the difference in storage between its predictions and those of alternate methods, such as the APM method, decrease as the size of the sites decrease and the percent impervious areas increase.

Tower C - Large Suburban Site			APM Model 2 hr IETD	WWFMG 5 mm
Impervious Areas	m²	ha	Required Storage m³	
Parking Lot	2,204.79	0.22	8.37	11.02
Parking Lot Driveway	1,093.53	0.11	4.15	5.47
Front Entrance	102.30	0.01	0.39	0.51
Parking Ramp	53.10	0.01	0.20	0.27
Paths	707.76	0.07	2.69	3.54
Roof	2,127.52	0.21	8.08	10.64
Total Impervious	**6,289.00**	**0.63**	**23.88**	**31.45**
Pervious Areas				
Limited Depth Landscape	2,271.81	0.23	1.51	11.36
Variable Depth Landscape	14,079.11	1.41	9.36	70.40
Total Pervious	**16,350.92**	**1.64**	**10.87**	**81.75**
Percent Impervious	27.8%			
Total Site Area	**22,639.92**	**2.26**	**34.75**	**113.20**
Analytical Probabilistic Method employing 2-hour inter-event time definitions.				
Wet Weather Flow Management Guidelines - 5 mm depth of rainfall over entire site area.				

Table 6.3. Summary of physical site characteristics and runoff volumes for Tower C.

Tower Sites Hydrological Analysis Discussion

The two approaches used in this report, specifically the APM method and the WWFMG method, are not directly comparable. The APM method includes landscape runoff coefficients, surface depression storage assumptions, and IETD rainfall data to calculate required runoff storage, while the WWMFG criteria is uniform over the site and does not take into account these factors. As well, each of these methods does not use pre-development runoff minus post-development runoff to determine design objectives for runoff storage. The preservation of pre-development runoff to native water bodies is a traditional approach when setting criteria for stormwater management on new development sites. This approach was also identified in the WWFMG water balance targets, "Retain stormwater on-site, to the extent practicable, to achieve the same level of annual volume of overland runoff (see Table 3 & Figure 2) allowable from the development site under pre-development (i.e. presently existing site conditions before the new proposed development) conditions".[12]

Table 6.4 shows a comparison of the storage volumes required for each of the tower sites assuming pre-development runoff (all landscape) versus post-development runoff (calculated with the Modified Rational Method (assuming 2 -year storms with a time of concentration of 10 minutes) as compared with the APM Model and the WWFMG 5mm assumptions. These comparisons show the variations possible on stormwater storage requirements resulting from assumptions intrinsic to the modeling methods chosen. In particular, assumptions based on the influence of landscape on infiltration (coefficients of runoff), surface depression storage and choice of rainfall event types. For initial planning and design purposes, the more conservative estimates (those with the largest storage requirements) may be chosen. In all cases this resulted from the WWFMG 5mm criteria. The higher costs associated with employing more sophisticated hydrological models will generally be more than offset by the lower cost of implementing effective detention/infiltration/storage measures.

Tower A - Compact Urban Site		
Site Area	1,798.47	m²
	0.18	ha
Q Pre-Development	0.011	m³/s
Q Post-Development	0.030	m³/s
Design Q	0.019	m³/s
On-Site Storage Requirements		
Mod. Rational Method	11.58	m³
APM 2-hr IETD	4.72	m³
WWFMG (5mm)	8.99	m³
Tower B - Typical Suburban Site		
Site Area	9,444.09	m²
	0.94	ha
Q Pre-Development	0.06	m³/s
Q Post-Development	0.11	m³/s
Design Q	0.05	m³/s
On-Site Storage Requirements		
Mod. Rational Method	30.54	m³
APM 2-hr IETD	15.57	m³
WWFMG (5mm)	47.22	m³
Tower C - Large Suburban Site		
Site Area	22,639.92	m²
	2.26	ha
Q Pre-Development	0.14	m³/s
Q Post-Development	0.25	m³/s
Design Q	0.11	m³/s
On-Site Storage Requirements		
Mod. Rational Method	64.76	m³
APM 2-hr IETD	34.75	m³
WWFMG (5mm)	113.20	m³

Table 6.4. Comparison of on-site storage requirements for three example tower sites based on three different hydrological methods.

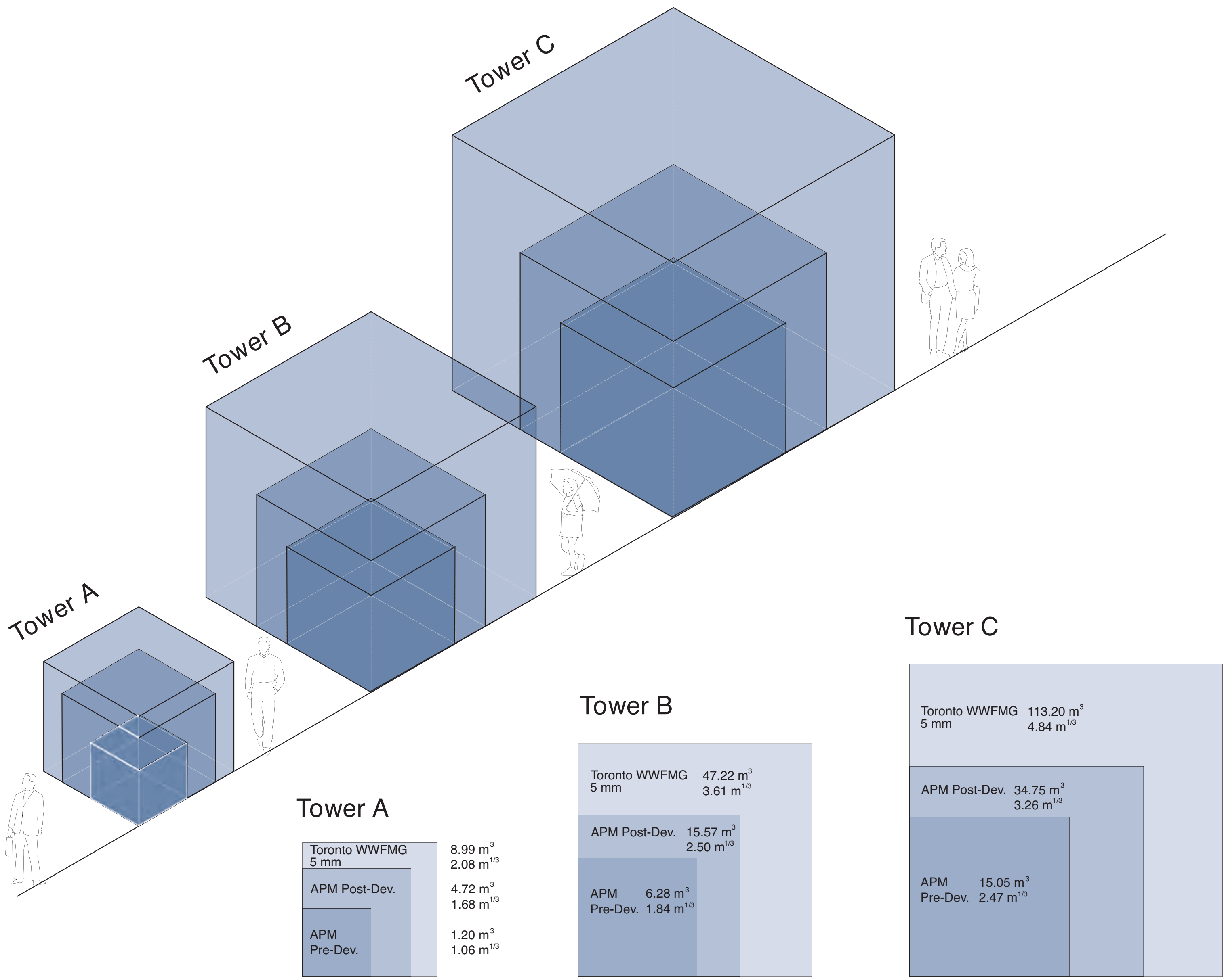


Figure 6.11. Comparison of storage volumes calculated using three different approaches. The smallest volume results when pre-development flows are maintained in conjunction with the APM model.

Best Management Practices for Stormwater on Urban Tower Sites

Methods for stormwater detention and control fall under two major classifications: source control; and downstream control. Source control is the use of smaller stormwater interventions located near the "top of a watershed" or in the case of tower sites, where runoff first occurs. Downstream controls are usually larger and structural in nature since they are collection points of many sources of stormwater. Figure 6.12 shows the conventional forms of runoff control from source to downstream. For small urban sites, the main emphasis is on source control measures for stormwater management.

Source controls for small urban sites rely primarily on methods of detention through the temporary storage of water. Detention strategies focus on quantity control and typically flatten (lower) the peak flow characteristics of storms and subsequently the demands put on downstream systems. Although not often expressly built for quality control (control of sediments and pollutants), source controls can have some effectiveness if they can temporarily store stormwater over longer periods of time, typically 12 hours or more. Small site detention approaches are generally based on increasing surface depression storage and promoting infiltration of rainwater into the ground as alternatives to contributing directly to the storm sewer system. Typically, these methods can be further subdivided into:

1. Retention in the form of storage tanks (cisterns);
2. Detention through dry ponds and dry swales;
3. Infiltration/storage via minor depressions, infiltration basins and infiltration trenches; and
4. Filtration devices such as sand/gravel filters (above or below ground), bio-retention basins (planted depressions) and filter strips (long narrow planted depressions).

Although not as frequent in use, other structural approaches, such as stormwater storage in pipes, or in-ground filtration through modified catch basins with oil and grit separators, may be more appropriate where conventional landscape approaches are not viable.

Designers and planners should not underestimate the potential for small sites to make significant contributions to stormwater management. Although each individual site's stormwater contribution may be low, this increases the opportunity for more modest landscape interventions that can effectively deal with these smaller temporary storage requirements. It must also be appreciated that the increasing stormwater infrastructure loads evidenced in cities today are the result of literally thousands of non-uniformly distributed small urban sites cumulatively contributing to the stormwater 'problem'. The 'mantra' for stormwater design on small urban sites may conscisely summarized in the acronym 'C3SR' which stands for Catch, Convey, Clean, Store and Release.

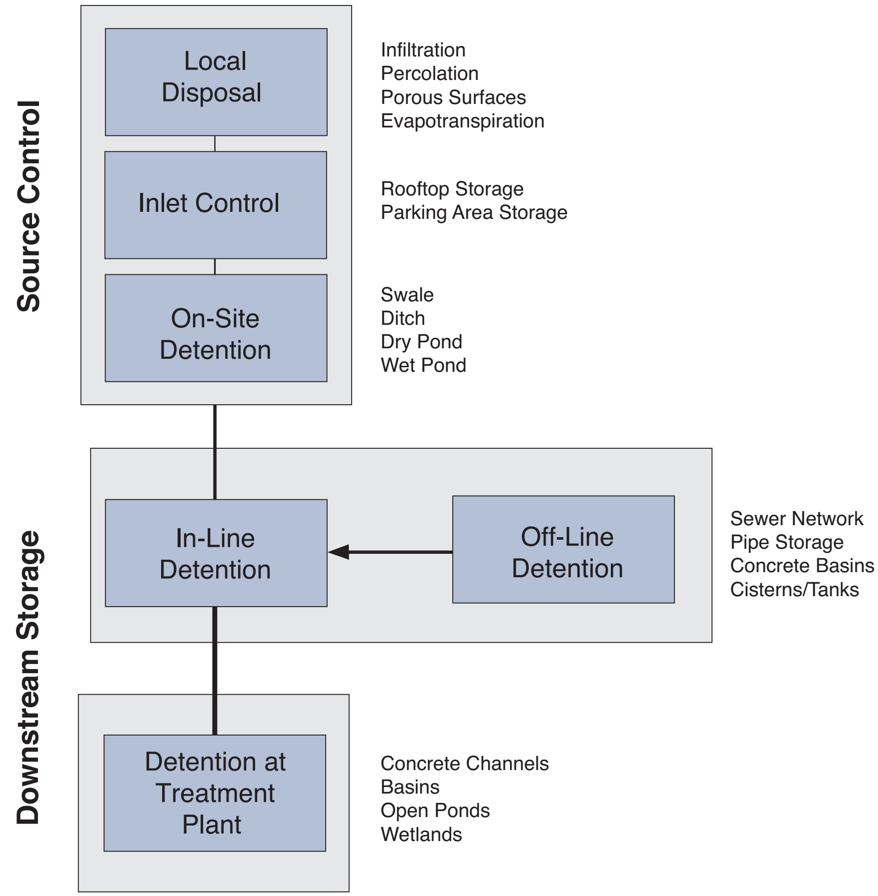


Figure 6.12. Classification of stormwater control and storage systems.[13]

Table 6.5 is a summary of BMPs for small urban sites. The practices highlighted in darker blue are those that will be typically favoured for stormwater management on tower sites. The matrix includes a qualitative index or these techniques in relation to their potential for addressing water quantity, water quality, physical requirements and environmental factors such as maintenance. One of the challenges with these sites is the relationship of pervious to impervious site areas. As can be seen in the hydrological analysis for the tower sites, the ratio of impervious to imperviousness is a good indicator of the opportunity for smaller landscape scale interventions. Tower A has a ratio of 60% imperviousness, Tower B, 46% and Tower C, 38%.

Stormwater Best Management Practices		Water Quantity		Water Quality				Physical Considerations						Community and Environmental Factors			
BMP	**Type**	**Flow Rate**	**Volume Control**	**TSS**	**P&N**	**Metals**	**FC**	**Soil***	**Water Table**	**Sites < 2 ha**	**Head**	**Area Required**	**Hotspot Runoff**	**Maintenance**	**Community Value**	**Cost**	**Habitat**
Retention	Wet Pond	H	L	P	S	S	S	A soils Liner	1 m	Limited	1-3 m	H	V	L	H	L	M
	Storage Pond	H	L	P	S	S	S	B soils testing	1 m	Limited	1.5-2.5 m	H	V	L	M	L	M
	Vault/Cistern	M	L	P	S	S	MR	NA	NA	Yes	1.5-2.5 m	L	Y	H	H	H	L
Detention	Dry Pond	H	L	S	MR	MR	MR	A soils liner-testing	1 m	Yes	1-3 m	H	V	M	M	L	L
	Pipes	H	L	M	MR	MR	MR	NA	NA	Yes	1.5-3 m	L	Y	L	H	H	L
	O&G Separator	L	L	S	MR	MR	MR	NA	NA	Yes	1.5-2.5 m	L	Y	H	H	H	L
	Dry Swale	M	L	P	S	P	MR	Any soil	1m	Yes	1-3 m	M	Y-Liner	M	H	M	L
Infiltration	Minor Depression	M	H	P	P	P	S	A and B soils	1m	Yes	0.1 m	M	N	M	M	L	M
	Infiltration Basin	M	H	P	P	P	S	C soils problematic	1m	Yes	1-3 m	H	N	M	M	M	M
	Infiltration Trench	M	H	P	P	P	S	D soils not recommended	1m	Yes	0.5-1.5 m	M	N	M	M	M	L
Wetland	Wetland	H	M	P	S	S	P	Any soil below water table	NA	Limited	0.5-2 m	H	Y	L	H	M	H
	Wet Swale	L	L	P	S	S	MR	Any soil below water table	Below water table	Yes	1-3 m	M	N	M	H	L	M
Filtration	Sand Flter	L	L	P	S	P	S	Any soil	1 m or 0 with Liner	Yes	0.5-1.5 m	H	Y-Liner	M	M	H	L
	Below Ground	L	L	P	S	P	S	NA	NA	Yes	1.5-2.5 m	L	Y	H	H	H	L
	Bioretention	M	M	P	P	P	S	Planting soil	1m	Yes	0.5-1.5 m	H	Y-Liner	M	M	M	M
	Filter Strip	M	M	S	MR	MR	MR	Any Soil	1m	Yes	0.1 m	M	Y	L	H	L	M

H = High P = Primary Y = Yes TSS Total Suspended Solids
L = Low S = Secondary N = No P&N Phosphorous and Nitrogen
M = Medium MR = Minor FC Fecal Coliform

* USDA Natural Resources Conservation Service classifies soils as A, B, C and D types. A has the highest infiltration rate (sand) and D has the lowest infiltration (clay).

Table 6.5. Summary of the suitability and performance of stormwater best management practices for small urban sites. [14]

Measures for Stormwater Management on Small Urban Sites

To visualize the potential for stormwater management on the tower sites, several measures were developed to address the surface depression and filtration potential of landscape areas. This is by no means an exhaustive set of measures, rather it examines techniques that are effective and economical. For a useful guide to measures for stormwater management on small urban sites in cold climates, refer to, *The Urban Small Sites Best Management Practice (BMP) Manual*, published by the Minnesota Metropolitan Council.[15]

In this discussion, it is assumed typical tower sites follow traditional site design standards for drainage. Generally, the sites have positive drainage away from the buildings using either sheet flow for landscape areas or more directed conveyance of water to catch basins in paved areas such as parking lots. These site drainage systems are often divided into small sub-watersheds intended to conveying water off the site via the shortest distance and in the shortest possible time. For existing sites, it is reasonable to assume that landscape interventions for stormwater management would take place at the time of tower renewal, or when modifications to the landscape were necessary due to maintenance or redevelopment. It is important for designers and planners to recognize that while landscapes may appear to be perpetually enduring, in an urban context they require regular maintenance and periodic replacement (commonly in the form of inter-planting). Natural landscapes are self-organizing systems, but artificial interventions are no different than the tower buildings themselves.

Parking lots are a particular challenge, as they must function seasonally and on a day-to-day basis. The design approaches must accommodate this use while manipulating surfaces to increase localized storage depressions (minor variations in the surface), increase porosity (permeable paving) or the more aggressive use of sub-surface areas for storage and infiltration. Refer to Design Guidelines for 'Greening' Surface Parking Lots by Toronto City Planning, November 2007 for a more complete set of appropriate measures.[16]

Initially, opportunities should be explored that vary the surface characteristics of parking lots to allow for increased surface depression. This approach assumes some inconvenience to users of parking lots, as the parking surface would be used for very short-term storage of small volumes of water (no greater than 150 mm in depth). Figure 6.13 shows three methods of short-term storage in parking lots indicating the storage capacity per linear metre. Note that the paved area where the water will accumulate is assumed to be permeable so that the detained water can infiltrate the soil beneath the pavement.

Another strategy for parking lots is to associate them with adjacent landscape buffers or strips to receive parking lot runoff. Since runoff from these types of surfaces is often of the lowest quality found on tower sites (sediments, oil, salt and other chemicals), it is preferable to intercept these flows with infiltration swales, usually vegetated for bioremediation. Figure 6.14 depicts two common approaches that have proven effective.

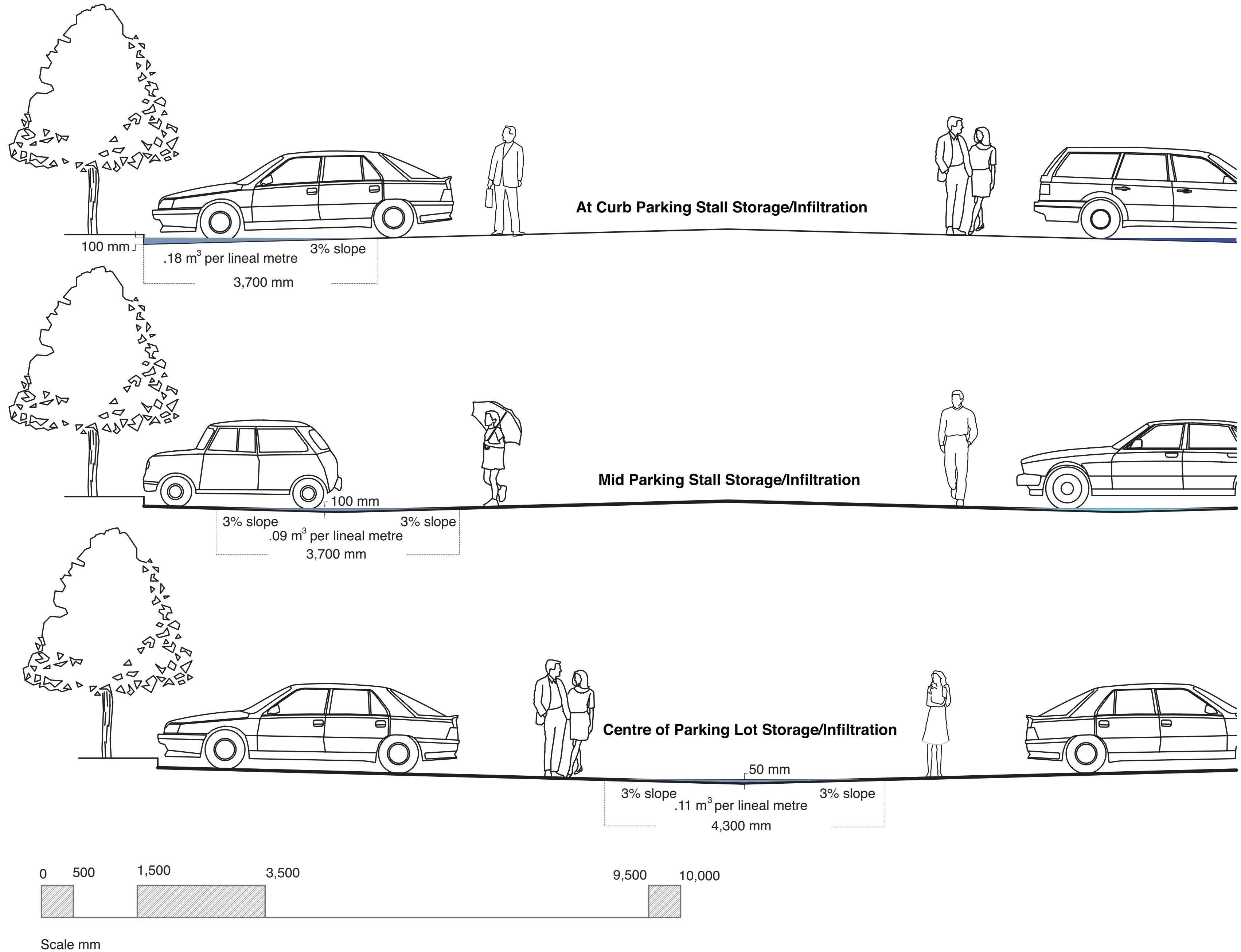
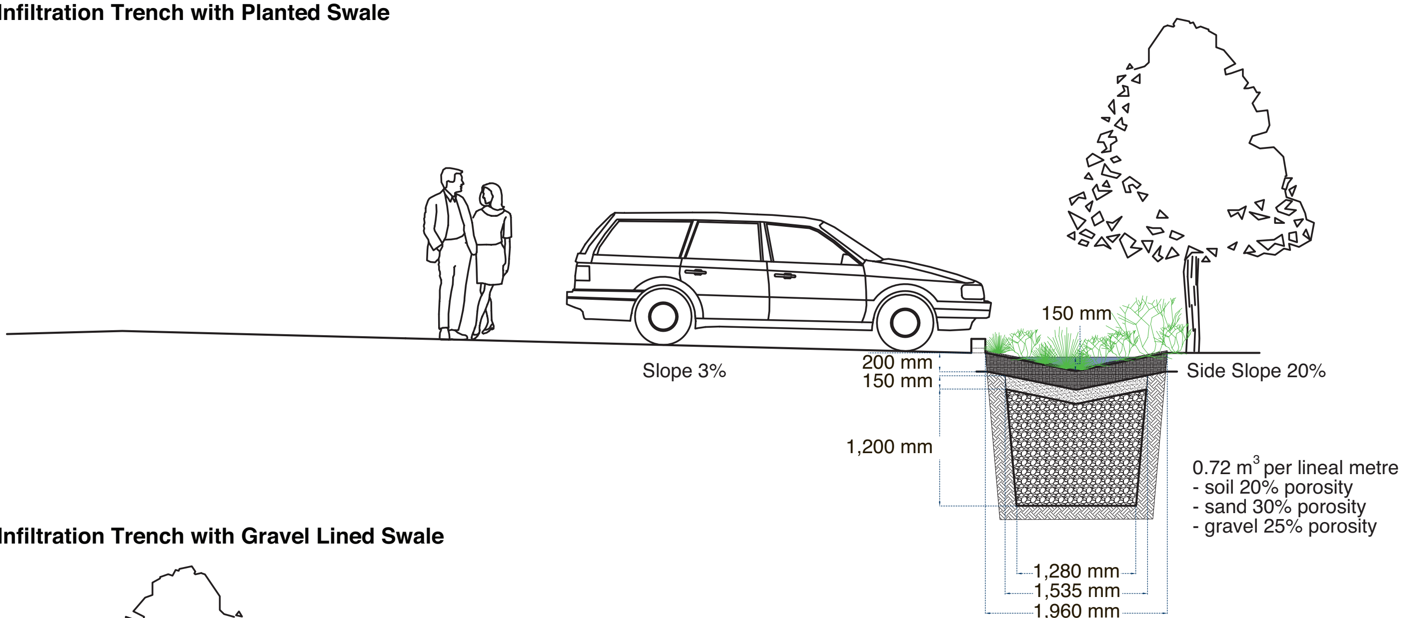


Figure 6.13. Examples of measures for the surface storage/infiltration of stormwater in parking areas. It is important to note that permeable pavement is required in the areas where the water accumulates to permit the infiltration of detained water.

Infiltration Trench with Planted Swale



Infiltration Trench with Gravel Lined Swale

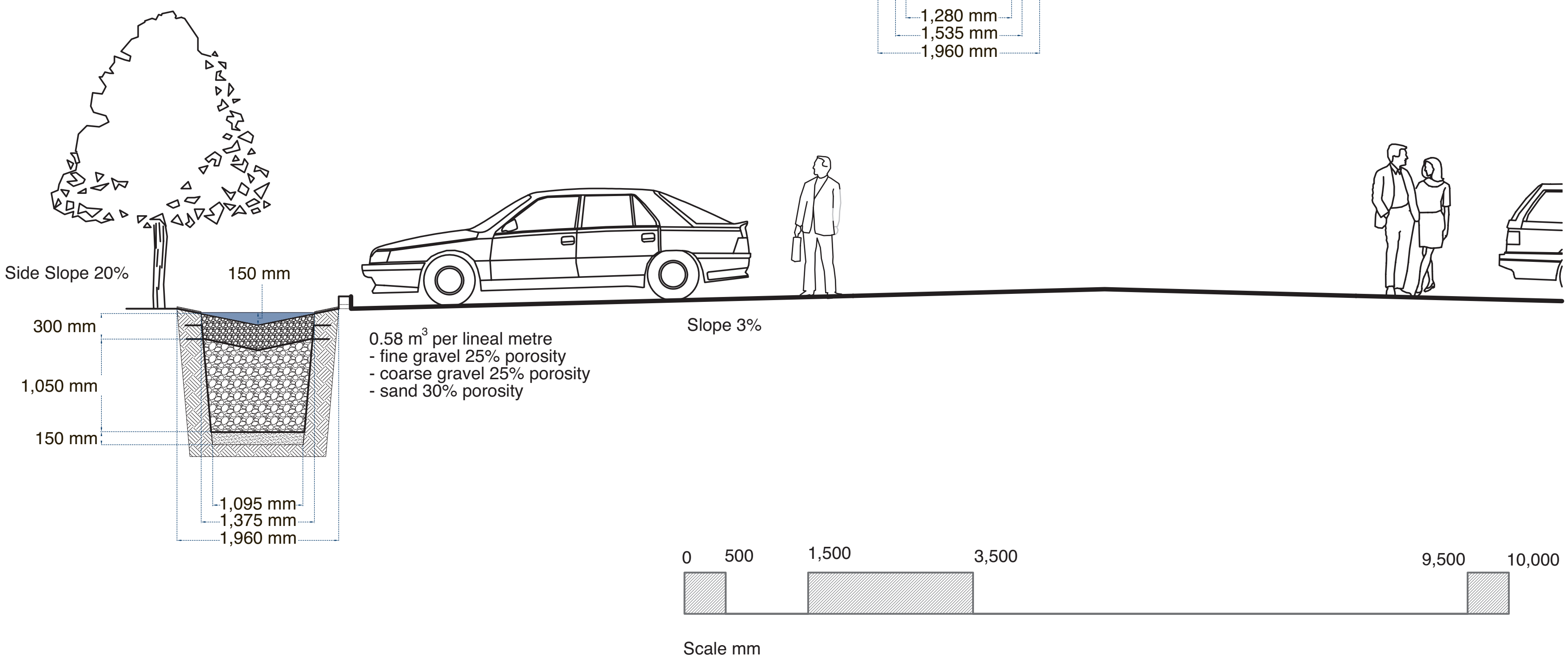


Figure 6.14. Examples of infiltration trenches located at the perimeter of parking areas. Cuts or gaps in the curbs allow water to flow into trenches that may be planted or lined with gravel or stones. Note that geotextile liners and cap sheets are normally required to prevent sediment from plugging the granular materials. Consult with an experienced geotechnical engineer for design assistance.

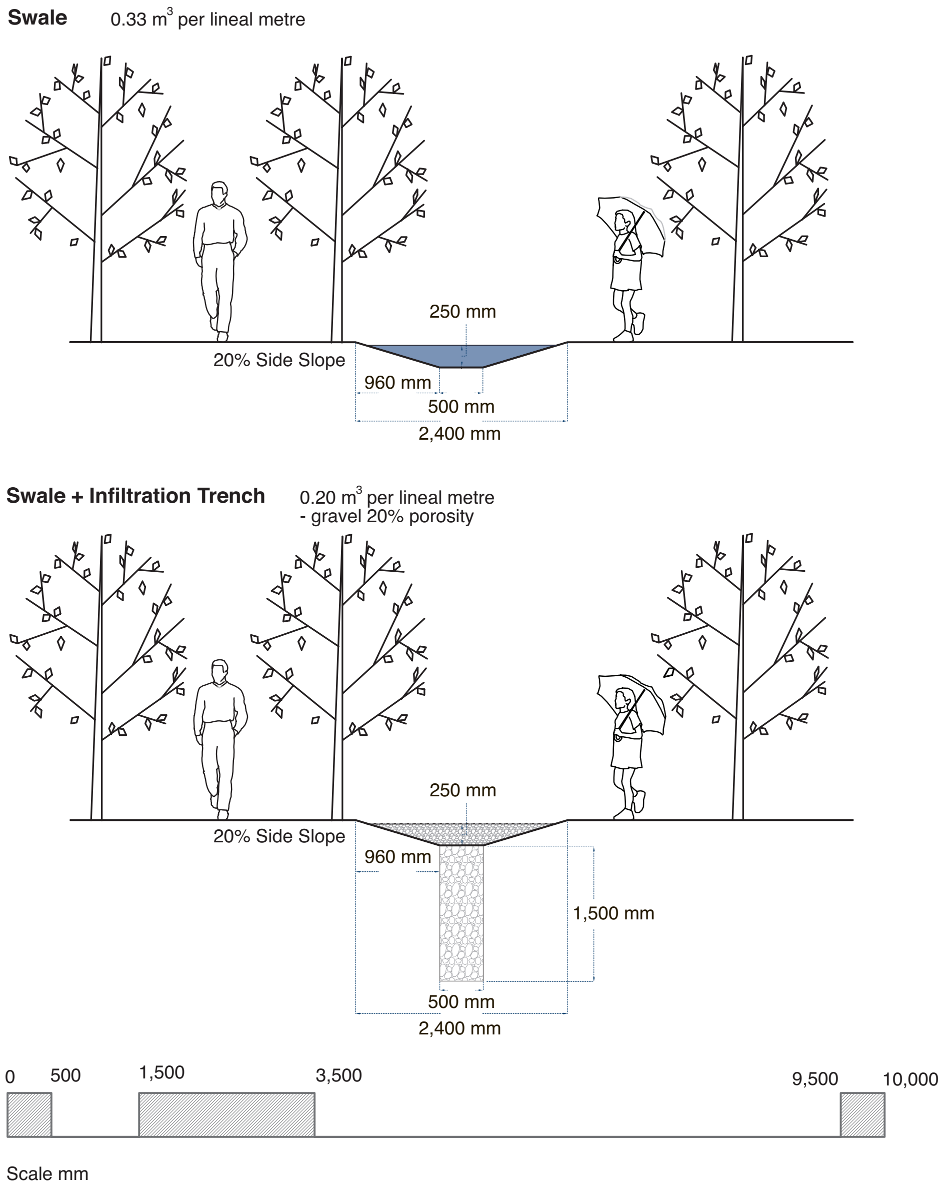


Figure 6.15. Swales in landscaped areas are another means of detaining stormwater that is then able to infiltrate the soil. Where native soils have high percolation rates, a simple swale may prove effective. In poor draining soils like clays, and infiltration trench may be constructed beneath the swale to receive infiltrating water.

The stormwater best management practices that have been depicted are relatively inexpensive when compared to the cost of tower renewal for the building elements. In all cases proper maintenance is required, and there are some particularly important design considerations for existing tower sites.

The use of depression storage/infiltration in parking areas must be assessed in terms of its seasonal performance. During winter and summer, there is virtually no difference between the performance of a parking area with surface depression storage/infiltration and a conventional parking area. But during the late fall and early spring, there may be times when the accumulated water can freeze before it infiltrates the soil beneath the permeable paving. This phenomenon may be observed in conventional parking lots when catchbasins are plugged or frozen, and the accumulating water freezes. For all types of parking areas, it is important to perform required landscape maintenance, snow removal and groundskeeping.

Infiltration trenches do not pose different challenges than parking area depression storage and infiltration measures, and they may prove difficult to implement on some tower sites. As noted earlier in the discussion of the example tower sites, landscaped areas consist of two types. Limited depth areas (soil depth less than 600 mm) and variable depth areas (soil depth greater than 600 mm). The reason for the differentiation is that limited depth landscapes are usually above underground structures such as parking garages. These areas need to be carefully assessed as the opportunities for increasing surface depression, infiltration or underground storage are limited, or practically non-existent. Typically, infiltration areas must be located at the perimeters of the existing tower sites where there is sufficient soil depth to absorb the infiltrating water. The conveyance of the water from the roof and paved areas must consider the path and means the water will take to reach the infiltration trenches. Opportunities are also associated with these measures. Trees planted alongside the trenches will receive sufficient water and their root structures will have access to saturated soils during periods of drought. This will provide a healthy tree canopy and avoid the need for irrigation.

Swales are the simplest measures to implement and these can also improve the aesthetics of the landscaped areas. Generally, these measures are confined to larger sites where there is sufficient variable depth soil to receive the accumulated water. Care must be exercised to ensure the soil is sufficiently permeable to percolate the water, otherwise an infiltration trench may have to be incorporated, as depicted in Figure 6.15.

Figures 6.16 to 6.19, inclusive, depict various stormwater best management practices. Table 6.6 is a convenient aid for determining the stormwater storage, detention and infiltration capacities of the various measures discussed in this section.

Figure 6.16. Infiltration trench with planted swale collects runoff from parking lot. The potential for phytoremediation of the water is governed by appropriate plant selection.

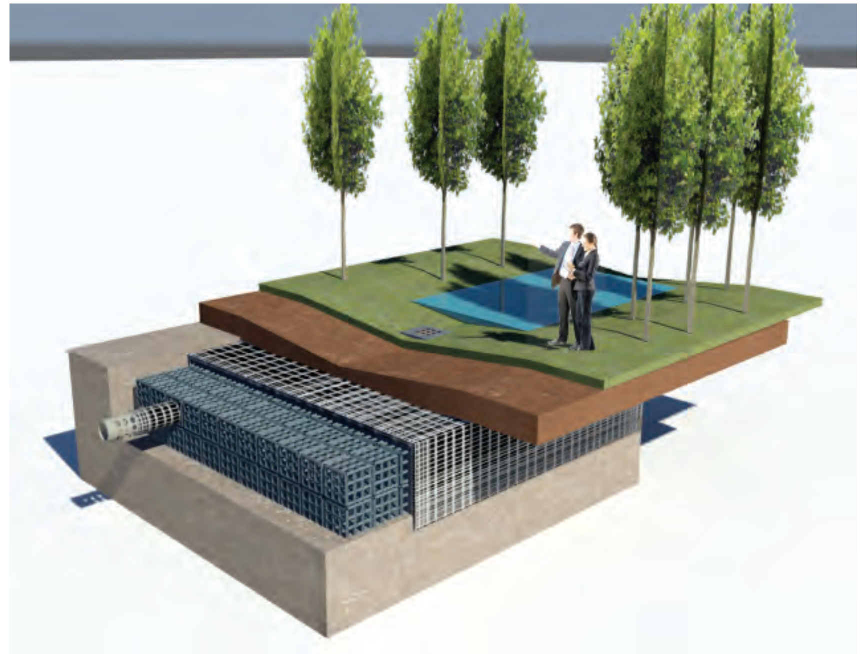


Figure 6.18. An alternative method of providing both infiltration and storage is to use manufactured storage cells located under the landscape depression swale.

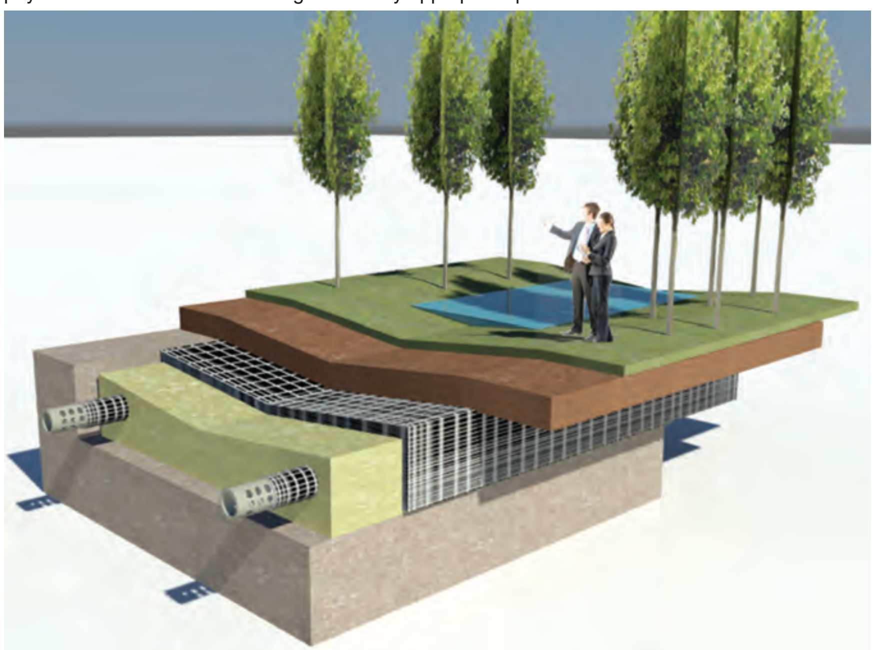


Figure 6.17. Landscape depression swale for stormwater detention and infiltration. Perforated sub-drains are optional where the runoff is conveyed to storage for later use.

Figure 6.19. Section through a catch basin with oil and grit separator, combined with infiltration trenches. The runoff is conveyed to infiltration trenches that can be varied in length and storage capacity.

	Surface Storage Parking Lot Pavement			Catchbasin with Infiltration Trench	Detention/Infiltration in Landscaped Areas			
Linear Distance	**At Curb Storage**	**Mid Stall Storage**	**Centre of Lot**		**Planted Infiltration Trench**	**Lined Infiltration Trench**	**Swale**	**Swale + Infiltration Trench**
m	**m^3 of Storage and or Infiltration for Linear Distance Indicated**							
1.00	0.18	0.09	0.11	3.50	0.72	0.58	0.20	0.44
5.00	0.90	0.45	0.55	17.50	3.60	2.90	1.00	2.20
10.00	1.80	0.90	1.10	35.00	7.20	5.80	2.00	4.40
15.00	2.70	1.35	1.65	52.50	10.80	8.70	3.00	6.60
20.00	3.60	1.80	2.20	70.00	14.40	11.60	4.00	8.80
25.00	4.50	2.25	2.75	87.50	18.00	14.50	5.00	11.00
30.00	5.40	2.70	3.30	105.00	21.60	17.40	6.00	13.20
35.00	6.30	3.15	3.85	122.50	25.20	20.30	7.00	15.40
45.00	8.10	4.05	4.95	157.50	32.40	26.10	9.00	19.80
50.00	9.00	4.50	5.50	175.00	36.00	29.00	10.00	22.00

Example Table Usage: For Tower B - Typical Suburban Site, 47.22 m^3 storage required. This can be achieved with 3 catchbasins each connected to 5 metres of infiltration trench - 3 x 17.50 = 52.5 m^3. Alternatively, use 25 metres each of at curb storage, planted infiltration trench, lined infiltration trench, swale, and swale + infiltration trench - 4.50 + 18.00 + 14.50 + 5.00 + 11.00 = 53.00 m^3

Table 6.6. Storage capacities of various surface storage, detention and infiltration measures.

Rainwater Harvesting for Irrigation

Another important measure that addressed stormwater management and water conservation is the use of roof water to supplement landscape irrigation on tower sites. This is referred to as rainwater harvesting and has been pioneered by many groups, but is exemplified by the work done through The Texas Water Development Board[17] and The Texas Rainwater Catchment Association (TRCA)[18]. For obvious reasons constituencies in more arid climates where water is already seen as a valuable renewable resource and a necessary requirement to the health and preservation of landscape and agriculture, have been at the forefront of pioneering methods of rainfall harvesting. However, there has also been an increasing use of landscape irrigation in more temperate climates fueled by the need for landscape watering over dry summer months, and increased efficiency and cost reductions over hand watering methods. In addition to landscape use, rainwater harvesting can be used to supplement non-potable water use (e.g., flushing toilets).

Before continuing with this discussion, it is important to realize that most urban landscapes are not well suited to sustainable development strategies. Put simply, if these were self-sustaining landscapes, there would be no need for rainwater harvesting for irrigation purposes. The discussion of landscape design on a water balance basis goes beyond the scope of these guidelines, but an examination of the least disturbed natural landscapes outside of urban areas provides an indication of the native species that would thrive without need for irrigation. Expansive green lawns are absent from this list of appropriate plant materials. The need for landscape irrigation aside, rainwater harvesting is important to consider for the following reasons:[19]

1. Rainwater is free with the exception of costs for collection and use;
2. The end use of harvested water is close to the source eliminating the need for complex and costly distribution systems;
3. Rainwater provides an easily accessible water source, reducing water demands on municipal systems;
4. The zero hardness of rainwater helps prevent scale on appliances or irrigation systems extending their use;
5. Rainwater is superior for landscape irrigation, and contains no added chemicals found in potable water such as chlorine or fluorides;
6. Rainwater harvesting reduces the storm water contribution and reduces non-point source pollution;
7. Rainwater harvesting reduces summer peak demands for water use; and
8. Rainwater harvesting can reduce consumer utility costs.

Rainwater harvesting potential is determined by the available area of clean surfaces, such as roofs, that can be used as catchment areas for precipitation. A performance evaluation of a rainwater harvesting system in Toronto has shown that, even in a low precipitation year, the system was capable of reducing stormwater by 36% and municipal water use by 73%. In a normal precipitation year, there was a 42% reduction in stormwater and an 89% reduction in municipal water use.[20] As can be expected, there was a requirement for municipal water augmentation during periods of extreme cold (freezing) in the winter and during periods of drought conditions in the summer.

In this assessment of the rainfall harvesting potential of tower buildings, only water collected on roofs was considered appropriate for use in irrigation. This is due to the fact that roof water generally is the highest quality of stormwater, as it does not have as many suspended solids and other contaminants, such as salt or oil, found in ground and paved surface runoff.

The rainwater harvesting strategy is to collect stormwater at times of high precipitation (low irrigation use), and to convey it to an on-site storage system for use later in more droughty months when irrigation loads are the highest. Typically, that storage could be accommodated in storage tanks located in the underground parking garages of the tower buildings. Irrigation loads for landscaping (typical landscape water demands for vegetation such as turf grass) are most often based on the rule of thumb that 25.4 millimeters (1 inch) of water is required each week (i.e., 101.6 mm per month) equally distributed over the entire landscaped area. The typical irrigation season in Toronto is from the beginning of May to the end of October.

More contemporary approaches to irrigation refine the irrigation system design by considering evapotranspiration, irrigation system efficiency and the minimum evapotranspiration stress factor for specific vegetation or landscape types. Evapotranspiration is defined as “the water lost to the atmosphere from the ground surface, evaporation from the capillary fringe of the groundwater table, and the transpiration of groundwater by plants whose roots tap the capillary fringe of the groundwater table”.[21] The Province of British Columbia has pioneered this approach and some municipal districts have implemented legislation that requires the use of evapotranspiration evaluations to determine water use allocations for irrigation. A typical formula for determining irrigation requirements is:[22]

$$IR_T = \frac{ET_O \times Cc \times As}{Ise}$$

IR_T = Irrigation Requirement (mm or inches)
ET_O = Reference evapotranspiration rate (mm or inches, for given location)
Cc = Crop coefficient
As = Allowable stress
Ise = Irrigation system efficiency

Typically, the crop coefficient for turf grass is 0.70, the allowable stress is 0.70 and irrigation efficiency can vary from 60% to 80%. Evapotranspiration data (ET) is usually identified in two forms: actual evapotranspiration (AET gathered from weather stations); or potential evapotranspiration (PET mathematically derived). In many cases, where direct evapotranspiration data is not measured by evapotranspiration instruments, both values can be calculated numerically from a variety of historic weather data. ET data can be extremely difficult to find and is usually published by meteorological agencies particularly in conjunction with departments of agriculture. Modern irrigation systems can have site specific “ET controllers” as part of the irrigation timers to ensure irrigation only takes place during appropriately droughty conditions. The use of these smart technologies is estimated to save as much as 20% to 30% of water use for irrigation.[23] In considering the potential impacts of AET values on irrigation requirements in Toronto, there are few sources of historical ET values available in the climate normals. This assessment utilized mathematically calculated values from The Canadian Climate Impacts Scenarios web site. Table 6.7 shows a summary of the estimated irrigation requirements for the three example tower sites.

Irrigation Required for Tower Site Landscape Areas m^3 (Based on 101.6 mm Per Month, or 1 Inch per Week)

					Irrigation Season								
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Tower A	0.00	0.00	0.00	0.00	24.97	25.15	25.32	18.93	18.78	29.70	0.00	0.00	**142.8**
Tower B	0.00	0.00	0.00	0.00	281.69	283.26	284.70	229.48	228.16	322.62	0.00	0.00	**1,629.9**
Tower C	0.00	0.00	0.00	0.00	710.98	714.95	718.59	579.20	575.89	814.28	0.00	0.00	**4,113.9**

Table 6.7. Summary of the irrigation requirements for the landscape areas associated with each of the three example tower sites. Climate peculiarities are evident in the calculations with October requiring much more irrigation than September because of the comparatively lower amount of precipitation. In Toronto, July has the highest monthly demand for irrigation.

With the irrigation requirements established, it is then necessary to determine the contribution of the roof to rainwater harvesting. For estimating rainfall, annual precipitation data was used (data was averaged over five Toronto weather stations, each having data for a minimum 25-year time period). When considering rainfall interception by roofs, it is critical to take into account that some of the water will be deflected (bounce) off the roof depending on rainfall intensity, and some water will pond in minor surface depressions. This will be dependent on the type of replacement roofing systems used for tower renewal. Most rainfall harvesting systems build in a “first flush” mode, where the initial rainfall collected from the roof, which has the highest sediment load, is diverted from storage to help maintain high stored rainwater water quality. The majority of rainwater harvesting estimation methods assume a rooftop catchment efficiency of 75% to 90%. In this assessment, a catchment efficiency of 75% was assumed.[24] Table 6.8 summarizes the roof contributions to landscape irrigation requirements for the three example tower sites. By comparison, Table 6.9 indicates the net irrigation requirements after accounting for the roof contribution.

Roof Contribution to Water for Irrigation m^3 (Assuming a maximum capture rate of 75%)

			Pre-Storage		*Irrigation Season*						*Pre-Storage*		
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Tower A	7.88	8.01	13.97	20.32	23.65	23.55	23.46	26.93	27.01	21.08	21.54	13.39	**230.8**
Tower B	21.17	21.53	37.54	54.61	63.56	63.30	63.05	72.38	72.60	56.65	57.89	35.99	**620.3**
Tower C	38.14	38.77	67.62	98.37	114.49	114.01	113.57	130.36	130.76	102.04	104.28	64.82	**1,117.2**

Table 6.8. Roof contributions to landscape irrigation requirements for the three example tower sites.

Net Irrigation Required After Roof Contribution m^3 (Irrigation Required Minus Roof Contribution)

			Pre-Storage		*Irrigation Season*						*Pre-Storage*		
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Tower A	-7.88	-8.01	-13.97	-20.32	1.32	1.60	1.86	-8.00	-8.23	8.62	-21.54	-13.39	**-87.9**
Tower B	-21.17	-21.53	-37.54	-54.61	218.13	219.97	221.65	157.10	155.57	265.96	-57.89	-35.99	**1,009.6**
Tower C	-38.14	-38.77	-67.62	-98.37	596.49	600.94	605.02	448.83	445.12	712.24	-104.28	-64.82	**2,996.7**

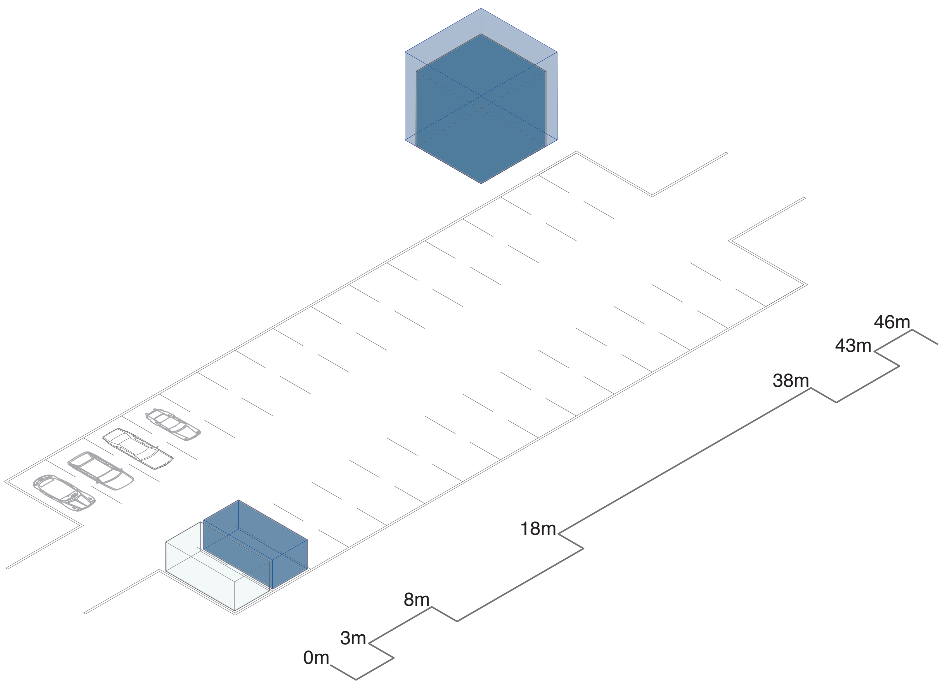
Table 6.9. Net irrigation required for the three example tower sites after taking into consideration the potential contribution of rooftop rainwater harvesting.

The key results from Tables 6.7 to 6.9, inclusive, have been graphically depicted in Figures 6.20, 6.21 and 6.22, for Towera A, B and C, respectively.

For compact tower sites, such as Tower A, where the landscape areas are modest, it is possible to provide practically all of the irrigation by means of rainwater harvesting. The rooftop will generally contribute more water on an annual basis than is required for irrigation purposes. One of the issues that emerges is the amount of storage required. Looking at the peak irrigation demand in July, and taking into account the rooftop contribution deficit in May, June and July, it is roughly estimated that a minimum 30 m^3 storage tank is needed. Many rainwater harvesting equipment manufacturers have developed sophisticated estimation tools for sizing storage requirements that are not based on monthly averages, but simulate historical rainfall data on a daily basis. In all cases, a qualified designer should be engaged to size the storage requirements, as well as specify suitable equipment coupled to the rainwater storage tank for use by the irrigation system.

Tower A - Annual Irrigation Requirements 142.8 m^3 (dark blue)

Tower A - Annual Rooftop Contribution to Irrigation 230.8 m^3 (light blue)



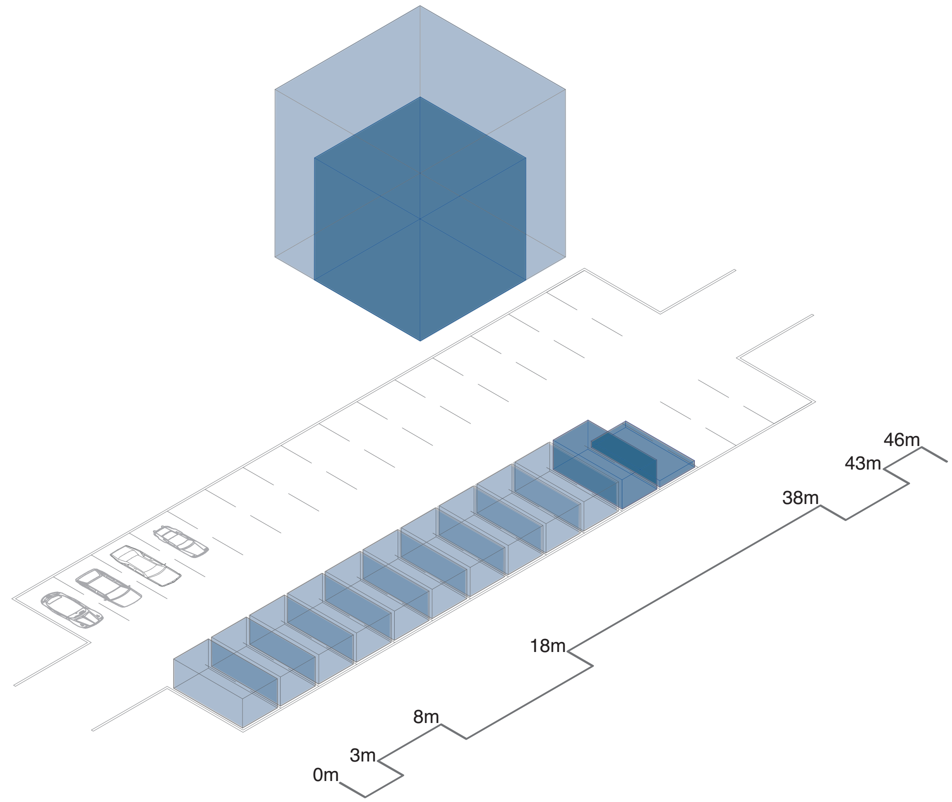
Maximum Monthly Irrigation Demand for Toronto - July

Tower A - Irrigation Requirement 25.32 m^3 vs Rooftop Contribution 23.46 m^3

Fig. 6.20. Tower A - Irrigation requirements versus rain harvesting opportunities, shown on an annual basis and visualized as storage tanks roughly equivalent in size to an underground parking stall. Due to the relatively small landscape area for the Tower A site, the roof can harvest more water every year than is needed to irrigate the landscape. In July, the month with the highest irrigation demand, the roof almost contributes the entire irrigation requirement.

Tower B - Annual Irrigation Requirements 1,629.9 m^3 (dark blue)

Tower B - Annual Rooftop Contribution to Irrigation 620.3 m^3 (light blue)



Maximum Monthly Irrigation Demand for Toronto - July

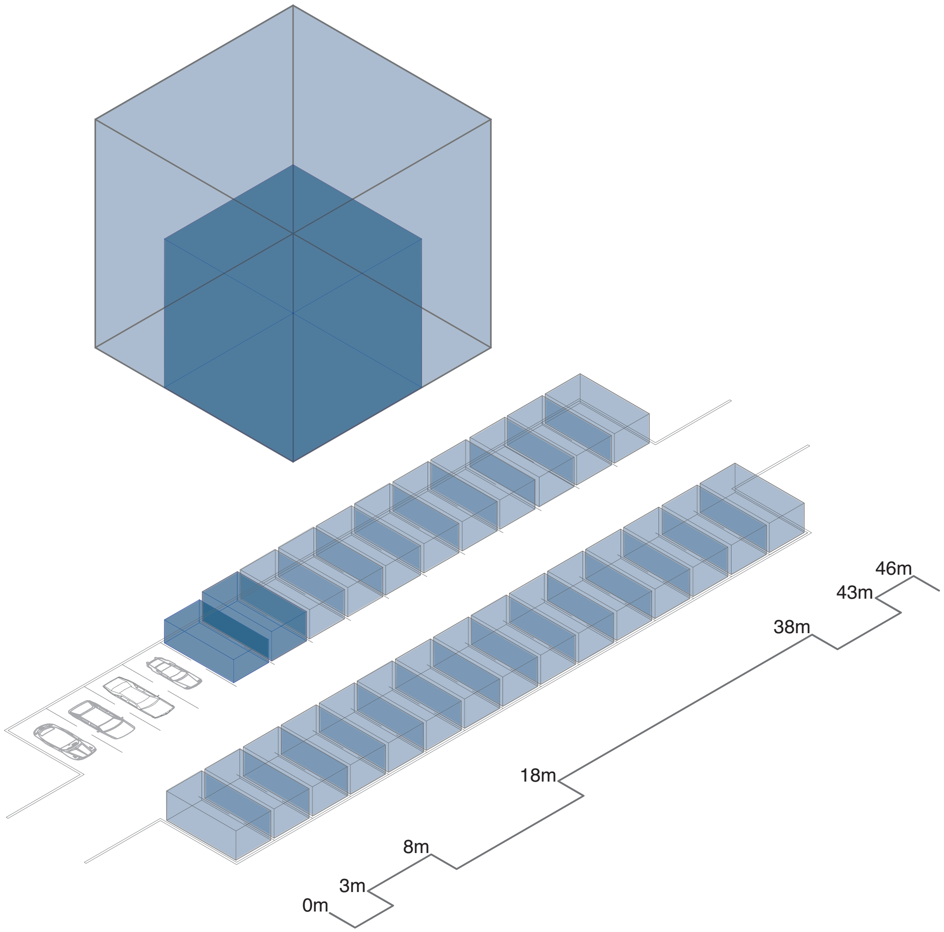
Tower B - Irrigation Requirement 284.7 m^3 vs Rooftop Contribution 63.05 m^3

Figure 6.21. Tower B – The irrigation requirements far exceed the rooftop contribution: however, rainwater harvesting has the potential to contribute 38% of the annual irrigation demand, assuming sufficient storage is made available.

Tower B simply has more landscape area than rooftop catchment area; hence it is not possible to satisfy all of the irrigation requirements with rooftop rainwater harvesting. However, the potential contribution accounts for 38% of the annual irrigation requirements and this is a significant benefit in terms of water conservation during periods of peak demand on municipal water supply systems.

Tower C - Annual Irrigation Requirements 4,113.9 m^3 (dark blue)

Tower C - Annual Rooftop Contribution to Irrigation 1,117.2 m^3 (light blue)



Maximum Monthly Irrigation Demand for Toronto - July

Tower C - Irrigation Requirement 718.6 m^3 vs Rooftop Contribution 113.6 m^3

Figure 6.22. Tower C - This site has extensive landscape areas that impose a high demand for irrigation. The roof area has the potential to contribute approximately 27% of the annual irrigation requirements, but the storage requirements pose a significant barrier.

Tower C represents the biggest challenge among the three example towers for the effective and economical implementation of rainwater harvesting on tower sites. The large suburban tower site has much less catchment area than the amount needed to collect all of the irrigation water needed on an annual basis. Assuming the collection surfaces could be increased by roughly four-fold, the issue of storage becomes a critical factor. The module of the underground parking stall was used to estimate the number of parking spaces that would be lost to storage tanks, and help visualize the magnitude of the challenge.

A comparison of irrigation requirements versus rainfall harvesting contributions for each of the three tower sites, as indicated in Table 6.9, emphasize the importance of the relationship between catchment areas and landscape areas. If instead of tower buildings, the housing took the form of low-rise development, then rainwater harvesting to meet irrigation demands could be easily achieved. By definition, high-rise, multi-unit residential buildings have a small roof area compared to the number of dwelling units. For large suburban sites, such as Tower C, which has a very large landscape area associated with the roof catchment area, substantial augmentation from the municipal water to meet traditional landscape irrigation requirements is unavoidable. In all cases, rainfall harvesting can make both a contribution to water reduction in landscape irrigation and a reduction in the total stormwater loads.

Returning to an earlier observation, it may be necessary to review the water balance on existing tower sites and reassess the landscape strategy accordingly. The predominance of turf grass in landscaped areas drives the demand for irrigation, and re-vegetating the sites is an option that may be explored.

Another strategy is to combine the stormwater best management practices with the landscape features so that the runoff is used to irrigate these areas, thereby reducing the need for potable water consumption by the irrigation systems. Employing more sophisticated drip irrigation systems with evapotranspiration controllers will further reduce potable water demand.

In the same way that tower buildings demand comprehensive retrofit strategies for the building as a system, landscape regeneration on existing tower sites and the incorporation of BMPs in a comprehensive strategy is recommended for effective and economical solutions. An example of this approach will be presented later in this chapter, but first an examination of the potential role of green roofs is reviewed.

Green Roofs

A full discussion of stormwater management and rainfall harvesting on tower sites necessarily deserves consideration of the potential for green roofs. Green roofs are an example of sustainable site technologies that are enjoying wider acceptance and application by designers and building owners.

Green roofs are an important measure in situations where there is little or no landscape area surrounding the building, as is often the case in the core of cities. For most typical tower sites, rainwater harvesting for irrigation is likely preferable to green roofs for several reasons. A large amount of HVAC equipment is mounted on tower roofs and it must remain accessible for inspection, maintenance, repair and replacement. As a result, there is not a large net area remaining for green roof surfaces on most tower buildings. As was pointed out earlier, the roof runoff is actually a valuable resource that avoids the consumption of potable water for irrigation; hence retention of the water on the roof is not as efficient as rainwater harvesting. The issue at play is the relative value of irrigating a landscape that is used by the tower building inhabitants versus the deployment of green roof technology that is unlikely to be accessible for recreational enjoyment. The arguments in favour of green roofs in densely built up areas of the inner city do not appear to be as compelling on most typical tower sites.

At the same time, it is interesting to note that many tower buildings constructed in the 1960s and 70s proved to be pioneers in the green roof movement. These buildings employed extensive green roofs over their underground parking areas, thereby reducing the obtrusiveness of parking requirements imposed by zoning by-laws. It is likely that tower buildings represent the highest deployment of green roofs of any other building type in Canadian cities. Regardless of their general suitability to tower renewal projects, green roofs do provide benefits that should be considered during the formulation of appropriate site strategies.

For compact urban tower sites, it is important to recognize that green roofs can contribute to stormwater storage and detention, offer potential for urban agriculture and provide an aesthetic dimension to untapped open space in dense urban form. Green roof technology and approaches come in many forms but are generally classified as intensive and extensive systems. Extensive roofs are the simplest of approaches and are generally less accessible and usable as outdoor areas. Intensive roofs are usually more elaborate and maintenance intensive, offering a variety of programmable uses. While extensive green roofs may be readily incorporated into most tower buildings, intensive green roofs, particularly those with large tree plantings, will require professional assessment of the structural capacity of the roof and appropriate moisture management measures for protection of the building envelope. The discussion of green roof technology in these guidelines is confined to their stormwater implications and remains for the most part focused on extensive green roof systems.

It is important to note that the energy conservation benefits of green roofs are not discussed because the high levels of thermal insulation recommended for roof retrofits of tower buildings render the contribution of the green roof media and plants relatively insignificant. The climate change impacts of green roof technology would be expected to stem more from reductions of the urban heat island effect (UHIE) than energy savings for either heating or cooling. The provision of habitat to encourage urban biodiversity is another benefit associated with green roofs that does not form part of this discussion.
A field study conducted by the National Research Council of Canada demonstrates the importance of green roof technology to stormwater management. In this report a controlled study of two extensive green roof systems and one control surface for a building in Toronto was evaluated. Rather than paraphrase, the following section on stormwater results has been excerpted from that document.[25]

"A reduction in runoff volume and/or runoff flow rate from the test plots, compared to the control roof, was expected. Such reductions could benefit stormwater management on both a lot-level and on a municipal sewershed basis. Flow volumes, from both test plots, provided an average annual reduction of 57% compared to the control roof. Maximum volume reduction (on an event by event basis) occurred during summer months when 100% reduction was achieved for certain rain events that totalled less than 15 mm, and that were preceded by six days of dry weather. Both test plots behaved similarly during these conditions, however, the SOUTH plot (Roof S) exhibited less of a reduction as the interceding dry period became shorter. During the typically wet spring and fall conditions, the NORTH plot (Roof G) consistently exhibited a reduction in volume, while the SOUTH plot (Roof S) periodically saturated and responded similar to the control roof. This may be the result of the thinner growing medium on the SOUTH plot (Roof S). Flow rates, from both test plots, were significantly reduced during all seasons compared to the control roof. Flow rates from the test plots during summer (Figure 7) typically showed a lag time (detention time) of 20 to 40 minutes, with a calculated peak flow rate reduction of 25% to 60% (when adjusted on a per m^2 basis). During late fall conditions (Figure 8), flow rates from the test plots showed a shorter lag time compared to summer. As the green roof media became saturated, the response rates behaved similar to the control roof. The peak flows rate reductions were not as dramatic, compared to summer conditions, but still exhibited a calculated peak flow rate reduction of 10% to 30% (when adjusted on a per m^2 basis)."

This discussion of green roof concludes that this technology offers many potential benefits that must be carefully considered along with other stormwater management measures. There are no general guidelines for the effective deployment of green roof technology for tower renewal projects, and it is the task of the designer to assess their feasibility within the context of each project.
It is important to realize that any stormwater management techniques applied to a tower site will rarely consider only one approach. The BMPs selected are often related to each other, or technically speaking, in series. This means that stormwater collected on a site may be collected by one system and then conveyed to another system before being released into the municipal stormwater infrastructure. It is the cumulative effect of these systems that offers the most potential for significant contributions to overall stormwater control and management.

Example of Stormwater Best Management Practices

As discussed earlier, the general approach to stormwater management is defined by the acronym **C3SR**, which stands for Catch, Convey, Clean, Store and Release.

Using Tower B from the previous discussions, Figures 6.23 and 6.24 depict an example of how these BMPs may be integrated on a tower site.
This includes the following BMP techniques.

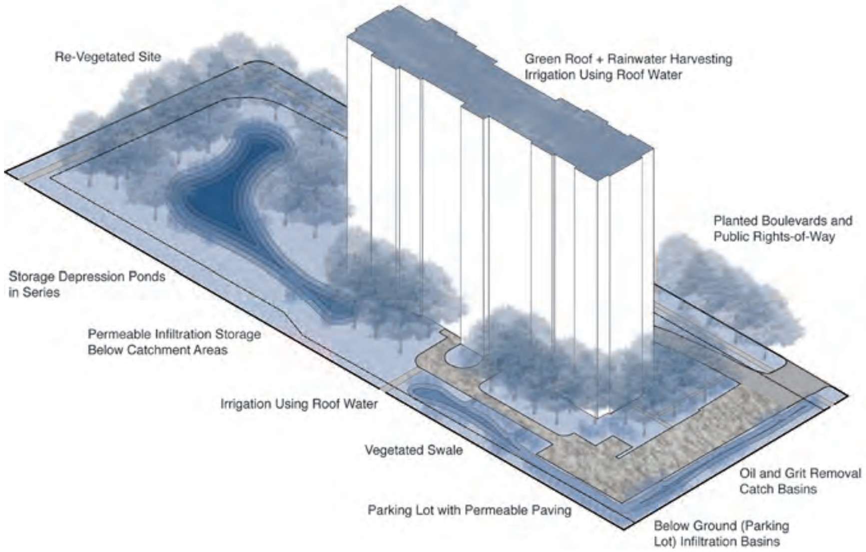


Figure 6.23. Axonometric view of the Tower B building site featuring BMPs in series.

1. A green roof with rainwater harvesting for landscape irrigation;
2. A permeable paved parking lot with sub-surface infiltration storage;
3. A vegetated swale associated with the parking lot;
4. A series of surface depression dry ponds linked in series;
5. Re-vegetation of the site along with public boulevards and rights-of-way; and
6. Subsurface infiltration beds associated with all the dry ponds.

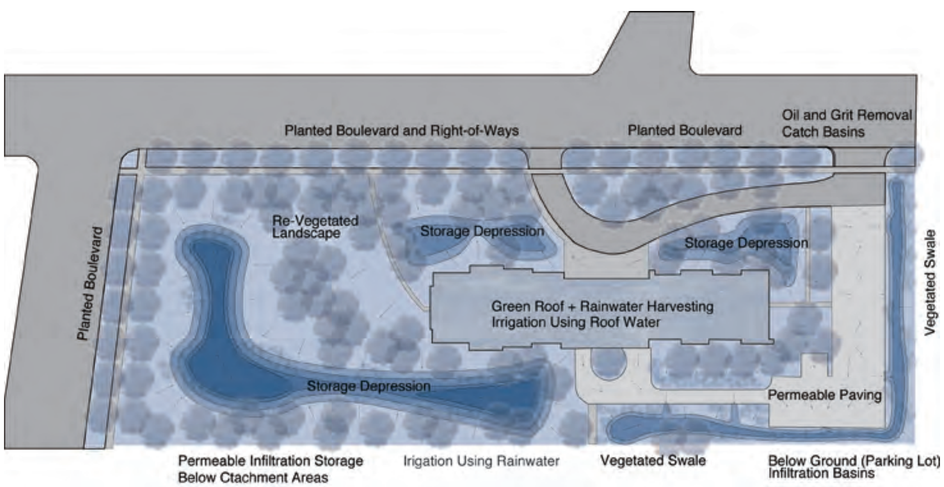


Figure 6.24. Plan view of BMPs in series applied to the Tower B building and site.

Stormwater Management Synopsis

At present, tower site landscapes are only treated in aesthetic or recreational terms, but based on the preceding discussion, it is obvious that the landscapes around tower sites can make a significant contribution to storm water management and water conservation. This ongoing contribution hinges on the recognition that landscapes have a finite life span and need to be renewed from time to time, similar to the buildings they serve. As it is likely the landscape will be compromised, possibly damaged, during the retrofit process, it seems this marks an appropriate opportunity to renew the landscape. When this work is undertaken, it should be approached from a landscape as infrastructure perspective. Landscape construction is relatively inexpensive, easy to carry out, and provides both an aesthetic and economic return.

Key to successful strategies is the need to consider the landscape water balance, and to minimize the contamination of runoff, so that the water resources falling on the site are put to their best and highest use. Parallel to this approach is an appreciation of detaining water and cycling it through the landscape for as long as possible to maximize its uptake by plantings. Finally, the selection and arrangement of plantings should be based on the resulting water balance to eliminate, or significantly reduce, the use of potable water for irrigation.

Tower site strategies have the potential to yield sustainable landscapes that provide effective stormwater management and help conserve potable water. Confirmation of this hypothesis will require monitoring of tower sites before and after renewal, so that theory can be refined to predict reality with an acceptable level of confidence. The need to exercise sound engineering research and practice is as evident in the performance of tower sites as tower buildings. There is a great deal of empirical work to be done in all aspects of tower renewal.

To this point in time, the limited research supporting this section of the guidelines indicates strong potential to achieve significant stormwater management and water conservation benefits by applying simple and cost effective landscape interventions. Previous studies on the cost effectiveness of the landscape as infrastructure approaches for new developments support this view.[26] It is reasonable to conclude that most of the tower building sites are as worn out as the buildings they surround, hence it would be prudent to consider how to revive the site aesthetically while improving its amenity and environmental performance.

The next section examines site impacts and strategies related to the retrofit construction work and its expected disruption on pedestrian and vehicular traffic.

Site Considerations During Retrofit Construction

During the course of retrofit construction, portions of the tower sites will be temporarily occupied by construction scaffolding and mast climbing work platforms. Access to the site by cranes for lifting equipment and deliveries of materials will also have to be made available periodically. All of the work must be carried out within safety setbacks from the building and there will also be requirements for the storage of materials and tools on site. The workers will require some parking for their own vehicles. These requirements will impact pedestrian and vehicular traffic to a lesser or greater degree, depending on the size and configuration of the tower sites.

The arrangement of the staging to carry out the work is critical to the efficiency and timing of the retrofit construction process, and has to be implemented in a way that causes the least inconvenience to residents. In the examples which follow, based on the Tower A, B and C sites from the earlier sections of this chapter, it has been assumed that a minimum 5 metre setback from all faces of the building is provided. In addition, a 5 metre by 10 metre accessible area has been designated for the storage of materials and tools. These are indicated in Figures 6.25, 6.26 and 6.27 by white zones and areas superimposed on the tower sites.

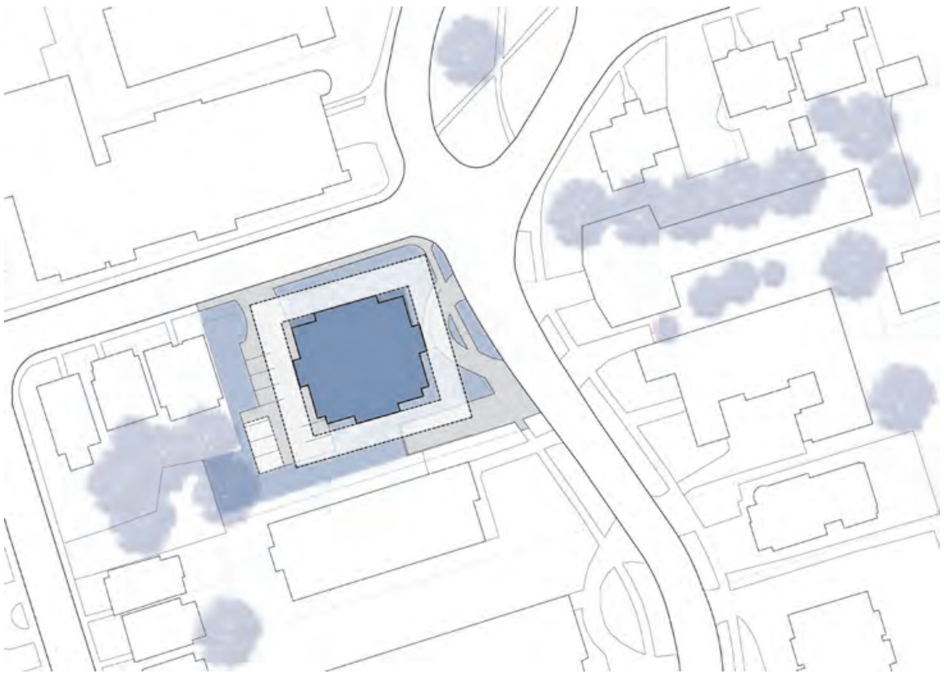


Figure 6.25. Tower A staging and storage requirements practically eliminate all visitor parking on this compact urban tower site.

Impacts associated with Tower A staging can be observed in Figure 6.25. Special measures will be needed to provide access beneath the staging to entrances. The ramp to underground parking will also have to be suitably protected. This case is an example of major impact by the retrofit construction on the tower site, but it should be noted that the surface parking area will be affected for approximately one quarter of the project duration. If this period coincides with winter weather and snowfall, special consideration must be made for snow removal. In all tower sites, access requirements for fire fighting must be observed.

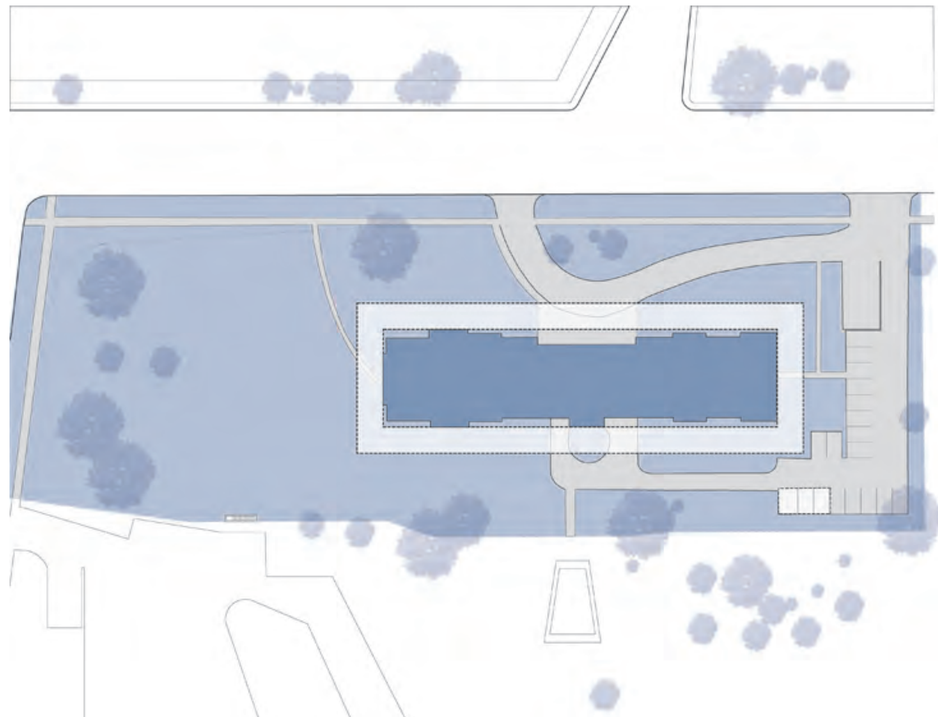


Figure 6.26. Tower B staging has moderate impact on the surface parking area.

In Figure 6.26 it is seen the retrofit construction impacts will mostly affect the perimeter of the building and the staging around Tower B will have moderate impact on the surface parking area. Again, measures for access to the entrances of the buildings will have to be accommodated. Tower B has ample surrounding space on the site to accommodate the storage of materials and equipment, in contrast to the Tower A site where careful coordination will have to be exercised.

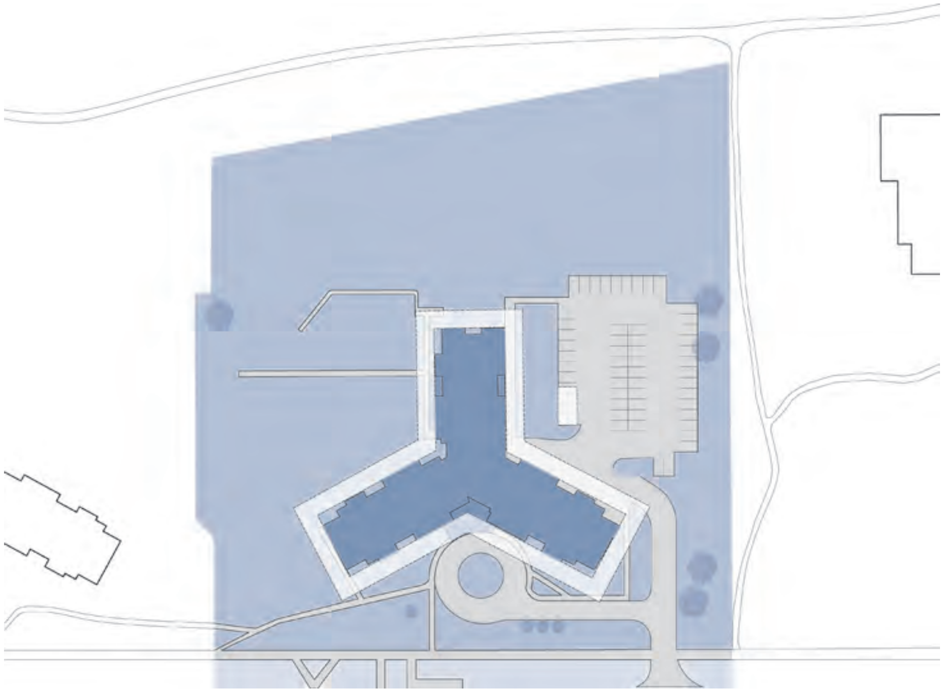


Figure 6.27. Tower C staging indicates very minimal impact on parking, vehicular and pedestrian access.

Tower C staging depicted in Figure 6.27 has minor impact on the parking area, but it does impinge on the turnaround circle at the main entrance to the building. The climbing mast work platforms operating in this area will usually be raised during working hours to permit the passage of vehicles, but at times they will unavoidably interfere with vehicular traffic. The relatively large size of the Tower C site does not pose any problems for the storage of materials and equipment, but the unusual shape of the building will pose staging challenges at the intersections of the angled walls.

One of the important conclusions that is derived from these three examples is that every site condition will have a different set of challenges and constraints. Even in the absence of any impacts on the pedestrian and vehicular traffic patterns, tower renewal activities will cause inconveniences to the inhabitants in the form of noise, dust and the temporary loss of access to balconies undergoing retrofit work. Loss of privacy for inhabitants during working hours will remain a constant concern and protocols for appropriate worker etiquette should be adopted.

Another critical consideration is the location of the tower building in relation to the street and the local traffic. Some tower buildings located close to public thoroughfares will require the staging to encroach on municipal sidewalks. Special measures and work permits will have to be arranged to control traffic at critical moments, such as the hoisting of equipment to the rooftop by a crane parked on the street. There are many additional factors to consider such as overhead electrical wires, proximity to health facilities, or buildings housing the elderly and young children. Health and safety requirements may be expected to factor into every tower renewal project, and in some cases these will prove a more significant challenge than staging and the efficient scheduling of work.

For tower projects where the site will also be revitalized, there is greater flexibility in using the landscaped areas for material and equipment storage. Temporary surfaces for vehicular traffic may be provided to least compromise driveways and parking areas. Security fencing can be erected to provide safety to the inhabitants and protect materials and equipment. In many ways, this is the preferred scenario whereby the gains in productivity from providing the contractor with unfettered access to the entire site may possibly offset the cost of a landscaping makeover.

In summary, the influence of the size and configuration of the tower site on the retrofit work, and conversely, the impacts of the staging and site access on the day-to-day lives of tower inhabitants must be carefully considered at the planning stages of renewal projects. It is important to reconcile these to the best advantage of everyone involved so that the work may be carried out safely and efficiently with minimum disruption.

Figure 6.28. This tower building contains a daycare centre on the ground level, and represents a situation where re-location would be recommended as the most prudent means of addressing retrofit construction impacts to the inhabitants. [Photo: Jesse Colin Jackson]

The next chapter examines tower retrofit strategies within the context of the building as a system.

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Convenience
Convenience
Open
24 Hrs.

7. Tower Retrofit Strategies: A Systems Approach

Tower renewal is a simple concept in theory, but it is technically complex and challenging in practice. Across Canada, after centuries of constructing new buildings which often experience performance problems, it is not reasonable to expect instant success with building envelope retrofits, unless the necessary time and effort are invested at the design stage, and due diligence is exercised during the renewal stage, including proper commissioning.

A major determinant of the cost and eventual performance of a tower renewal project is the suitability of the retrofit strategy. There are a number of key considerations that must be addressed at the outset of each tower renewal project.

- **Building as a System Integration** – Tower buildings were not designed as completely integrated building systems because the building as a system concept was not fully mature during the 1960s and 70s when most tower buildings were constructed. Tower renewal has the potential to upgrade existing buildings and convert them into 21st century building systems.

- **Code Constraints** – There is a significant number of tower buildings that are of the “legal, non-conforming” status. These were constructed before changes to building codes and related standards introduced requirements the existing buildings do not now satisfy. The most common building code compliance issues are related to limiting distances, allowable openings and requirements for non-combustible claddings associated with buildings located on small sites.

- **Building Envelope Retrofit** – The retrofit of the building envelope typically represents about 80% of the total cost of a comprehensive tower building retrofit. There are several basic approaches to building envelope retrofits with many options available to each approach. Each approach has cost and performance implications, hence it is important to develop an appropriate strategy.

- **HVAC System Retrofit** – Upgrading HVAC systems costs much less than retrofitting the envelope, but it can account for nearly half the potential energy savings in comprehensive retrofits. Air quality, heat recovery, cooling (air-conditioning) and controls are important considerations when retrofitting the HVAC system

- **Building Services Retrofit** – Piping and wiring normally have a longer service life than the building envelope and HVAC systems, but cabling for digital media (phone, TV, computers, etc.) is often obsolete. Plumbing fixtures and water consuming appliances are very cost effective to replace with efficient technology. Electrical systems can be sub-metered so that inhabitants pay for their own electrical energy consumption, greatly reducing demand and wastefulness. Elevators, building automation systems and emergency power generators often represent opportunities for further energy savings and improvements in safety, convenience and service.

- **Integrated Design for Future Adaptability** – The future is promising for renewable energy, combined heat and power systems, district energy systems and telecommunications. It is important to anticipate future developments and provide a means of migrating to these new technology platforms.

Each of these considerations are addressed in detail within the sections that follow. It is important to recognize that while technically challenging, these represent opportunities to transform existing buildings into sustainable housing and community resources.

Figure 7.1. An example of a cosmetic retrofit that does not address building system integration opportunities. Regrettably, neither the durability nor the energy efficiency of the balconies has improved. [Photo: Jesse Colin Jackson.]

[Photo Opposite Page: Jesse Colin Jackson]

Buildings have traditionally combined their building envelopes (skins) with their structures (armatures), typically employing loadbearing masonry construction. As a result, building envelopes inherited the durability demanded by requirements for structural integrity. When modern building technology separated armature and skin, the possibility of designing easily renewable building facades was not recognized. Only now that our buildings are deteriorating is the importance of skin renewal being appreciated. That we continue to design and construct buildings with 'permanent' facades is regrettably short sighted. But failing to conserve our existing building resources by not acting to implement appropriate retrofit technologies is recklessly irresponsible. As a society we must recognize that buildings are not disposable commodities, but renewable resources that must be sustainably managed.

The retrofit of building envelopes, sometimes referred to as overcladding, but more currently termed skin renewal or re-skinning, is recognized as among the most cost effective means of reducing greenhouse gas emissions and improving global energy productivity.[1]

Key Attributes of Comprehensive Building Retrofits
Opportunities to completely retrofit a building can only be afforded every several decades, for reasons of cost and disruption. Effective retrofit strategies have the five common characteristics or attributes described below.

Performance – energy and water conservation, durability, indoor air quality, comfort;

Economics – affordability and sustainable life cycle costs;

Aesthetics – pleasing façade, adequate daylighting, natural ventilation;

Replicability – retrofit components developed by economical mass customization; and

Smarts – building automation systems and future adaptability for intelligent evolution.

If it is not feasible or affordable to incorporate all of these attributes into a tower renewal project, the fundamental strategy must be re-evaluated and suitably revised. A future migration path should be incorporated into the retrofit design (i.e., rough-in for renewable energy equipment) for those items that can later help achieve the objectives of the renewal project. Buildings must be able to communicate, evolve and learn more like biological forms than inanimate objects.

The issues and procedures that are presented in the sections that follow assume realistic budgets that can support critical research and the exercise of due diligence. This is not a quantum leap, but an evolutionary process, that demands developing the right technology before transferring it through the training and education of skilled trades, designers and regulatory officials. Tower renewal is a special sub-set of building rehabilitation that has the potential to overshadow the new construction industry. Proper approaches adopted today will be critical to successful implementation at the broader scale tomorrow.

Figure 7.2. Entire neighbourhoods can be revitalized and made more sustainable through tower renewal projects that address the key attributes of comprehensive building retrofits, and bring this housing stock into the 21st century. [Photo: Jesse Colin Jackson.]

Building Systems Integration

Tower buildings were designed and constructed at a time when there was no explicit ***building as a system*** concept to guide the intelligent integration of building envelope, mechanical and electrical systems. Building design was largely based on successful past precedents. The allocation of funding for the research and development of innovative methods and materials, as reflected in Statistics Canada data on R&D spending, was not a priority for Canada's construction industry. To this day, the technology of tower buildings remains essentially unchanged, except that condominiums rather than rental apartments dominate the marketplace. Full floor to ceiling window walls have replaced punched windows and brick veneer with masonry backup wall assemblies. Air conditioning is now a necessary feature in today's highly glazed buildings, and corridor ventilation systems continue to be employed despite their negative cost and performance implications. Indeed, CMHC funded research currently in progress indicates that many of the new condominiums built in the past 10 to 15 years actually consume more energy than their 1960s and 70s counterparts. The prospect for building science innovation appears much brighter in the retrofit of existing tower buildings than the construction of new, glassy condominiums.

Historically, the building as a system concept emerged from research work conducted by the Division of Building Research, the predecessor to the Institute for Research in Construction (IRC) at the National Research Council of Canada. In addition to a broad range of pioneering research, it is the building science technology transfer publications that are the IRC's most enduring legacy. Remarkably, some 250 Canadian Building Digests (CBDs) were published between 1960 and 1990 about topics that reflected the diversity of the building industry and covered virtually every aspect of design and construction in Canada. A high percentage of the Digests are as relevant and meaningful as the day they were published. These are available at: http://irc.nrc-cnrc.gc.ca/pubs/cbd/index_e.html while a wide selection of related publications is available at: http://irc.nrc-cnrc.gc.ca/pubs/index_e.html, mostly as free downloads.

A brief survey of the Canadian Building Digests maps out the journey of innovation that followed World War II, when successful past precedents were discarded in favour of unproven methods and materials. As performance problems were encountered with foundations, walls, windows and roofing, CBDs were developed to provide designers and builders with scientific explanations of these phenomena and guidance toward best practices.

Unfortunately, by the time all of these building science contributions had been assembled into a cohesive building as a system concept, the Canadian tower boom had ended, leaving thousands of these buildings without appropriate measures for the control of heat, air, moisture and solar radiation. But these buildings were so soundly constructed and embodied such durable materials, they provided adequate service with few noticeable defects for decades. Long enough for the generation that created them to retire, leaving the succeeding generation oblivious to the building science knowledge that was available for the asking. Hence, all the mistakes of the 1960s and 70s were repeated, albeit using a higher proportion of unionized labour, in the 1980s and 90s. The new millennium has not witnessed any significant advances in buildings. This situation was recognized by the American Institute of Architects when it commissioned a guide to practitioners in 1986 to make them aware of the need for systems integration.[2] Some 20 years later, the root problem continued to fester in North America where building design and construction continue to be based on obsolete 19th century models of production.[3] It appears now that 'innovation' has completely eroded the collective memory of successful past precedents, never has the building as a system concept been so badly needed.

Fundamental Considerations

What makes for a system, and how do you know when you have one? A perfectly natural question for any curious person, yet not so easily answered when it comes to buildings. The founding fathers of modern building science approached the answer to this question incrementally, dissecting the building system to determine critical relationships. The first probes dealt with single components or assemblies and among the more famous is the work of Neil Hutcheon at the National Research Council of Canada. Over half a century ago he outlined the requirements for wall performance, applicable to all building envelope assemblies, as follows:[4]

1. Strength and rigidity.
2. Control of heat flow.
3. Control of air flow.
4. Control of water vapour flow.
5. Control of liquid water movement.
6. Stability and durability of materials.
7. Fire.
8. Aesthetic considerations.
9. Cost.

Since Hutcheon's time, additional objectives have been adopted, such as consideration of the environmental impacts associated with building methods and materials. A contemporary performance hierarchy is depicted in Figure 7.3. The objectives or requirements for acceptable wall performance were implicit within traditional methods and materials of construction. With the advent of modern building science, these objectives became more explicit in response to technological innovation. Currently, with the development of objective-based codes and standards, a formal hierarchy is being introduced to foster consensus standards and methodologies for the design and assessment of all aspects of building performance. It is now apparent that Hutcheon's originally proposed performance framework has expanded and reached the point where considerable time and expertise is needed to properly address envelope system design, let alone whole building systems integration.

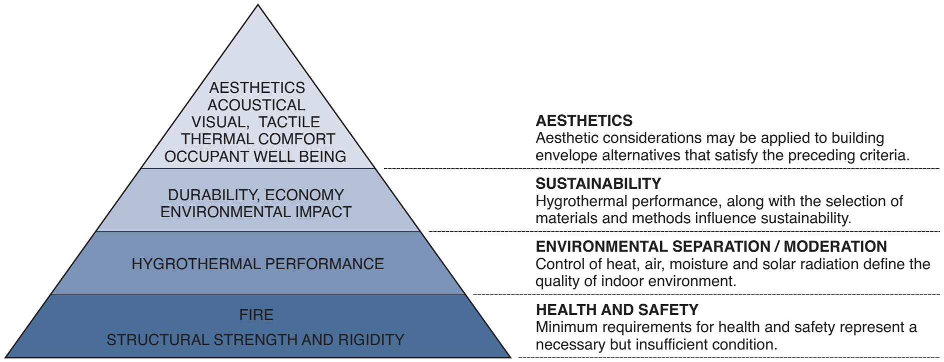


Figure 7.3. Performance hierarchy based on a building science approach to systems integration.

Before moving on to address the building as a system concept, it is important to appreciate that for tower renewal projects, the largest proportion of time and resources will be devoted to the building envelope. The building envelope retrofit strategy will largely determine the measures needed for the successful integration of the HVAC system, and will exclusively address long-term durability concerns. Table 7.1 summarizes the requirements and parameters to be considered when assessing the building envelope retrofit, recognizing many of these parameters also apply to the other building systems and services.

REQUIREMENT	PARAMETERS	
Structural Strength/Rigidity	Loadbearing/Non-loadbearing Wind Loading	Seismic Loading Thermal Effects
Control of Heat Flow	Effective Thermal Resistance	Thermal Bridging
Control of Air Flow	Stack and Wind Pressures Normalized Leakage Area	HVAC Influences Internal Partitioning
Control of Moisture Flow	Rain Penetration Vapour Diffusion	Air Leakage Condensation Potential
Control of Solar Radiation	Opacity/Emissivity Solar Orientation	Fenestration Shading Devices
Control of Sound Transmission	Airborne Sound	Vibration
Control of Fire	Fire Rating	Combustibility
Durability	Ultraviolet Degradation Corrosion Carbonation Freeze/Thaw Abrasion Fatigue Instability/Incompatibility	Biological Attack (mould, insects, animals, plants) Chemical Attack (soils, contaminants, pollutants) Efflorescence Subflorescence Spalling
Economy	Initial Cost Maintenance Cost	Operating Cost Life Cycle Cost
Environmental Impacts	Resource Depletion Environmental Degradation Reduction of Biodiversity	Greenhouse Gases Pollutants
Buildability (Ease of Construction)	Seasonality Tolerances	Coordination Sequencing
Aesthetics	Visual Tactile	Acoustic Olfactory

Table 7.1. Performance requirements for building envelopes and their corresponding performance assessment parameters.

Building As A System Concept

A significant advance in the field of building science is the development of the ***building as a system*** concept. Systems theory was applied to other fields long before it was introduced to building science, but its impact has arguably been the most significant in the buildings field. In its simplest form, the building as a system concept describes building behaviour as being determined by five constituent variables: the building envelope; the environmental control system; the inhabitants; the site and services infrastructure, and the external environment. From a design and construction perspective, the external environment is a given once a building is situated, notwithstanding weather variability, climate change, and transformative phenomena such as flooding or erosion. Hence in practice there are only four variables that can be manipulated to provide protection from the elements and a healthy and comfortable indoor environment, in response to external phenomena. Past experiments in social engineering indicate that this further reduces to three variables, seeing that the behaviour of building inhabitants is difficult to predict and control.

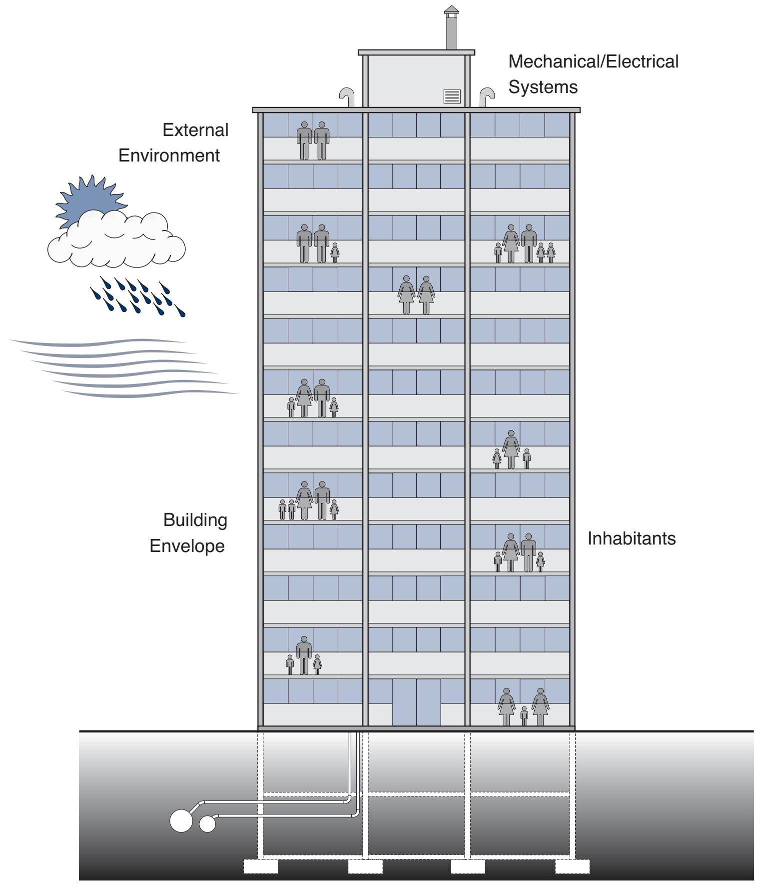


Figure 7.4. The building as a system concept recognizes all phenomena impacting the performance of buildings. In tower buildings, the highly conductive concrete armature, including projecting shear walls and cantilevered balcony slabs, strongly influences their thermal behaviour. Single glazed windows and high rates of air leakage compound energy demands. The mechanical systems for heating have to respond to these energy loads, rendering them very high in capacity and intensity, and typically they have poor controls. The corridor ventilation systems are largely disconnected from individual suites, hence inhabitants rely on air leakage and natural ventilation through operable windows for acceptable indoor air quality. All of these relationships are significantly impacted when the exterior of the building envelope is insulated, windows are replaced and an effective air barrier is provided.

Most of the building science research conducted in the 19^{th} and 20^{th} centuries focused on the enclosure and the environmental control systems, with the rational integration of these two elements becoming a subject of increasing interest in the past several decades. The environs (weather, site and services) were treated as an imposed condition that had to be resisted by the enclosure and environmental control systems. For the most part, the inhabitants were viewed very much like perishable goods that ought to be maintained within a narrow range of temperature and relative humidity, and provided with a minimum acceptable level of ventilation and daylighting.

This highly mechanistic view is now being displaced with a more holistic model of the building as a system, where the enclosure is seen as the primary, passive environmental moderator, and the environmental control system is a supplementary, active system that only delivers the difference between what is provided by the enclosure and what is desired by the inhabitants. These integrated elements are now understood as together being the environmental control system - one that may be modified by the inhabitants to accommodate their lifestyle choices. The environs are now viewed as an opportunity to harvest energy and water, treat waste and grow food to support life. Contemporary building science has gone full circle and returned to its biological roots and the recognition that building systems are simply prosthetic extensions of the human body and its supporting eco-system.

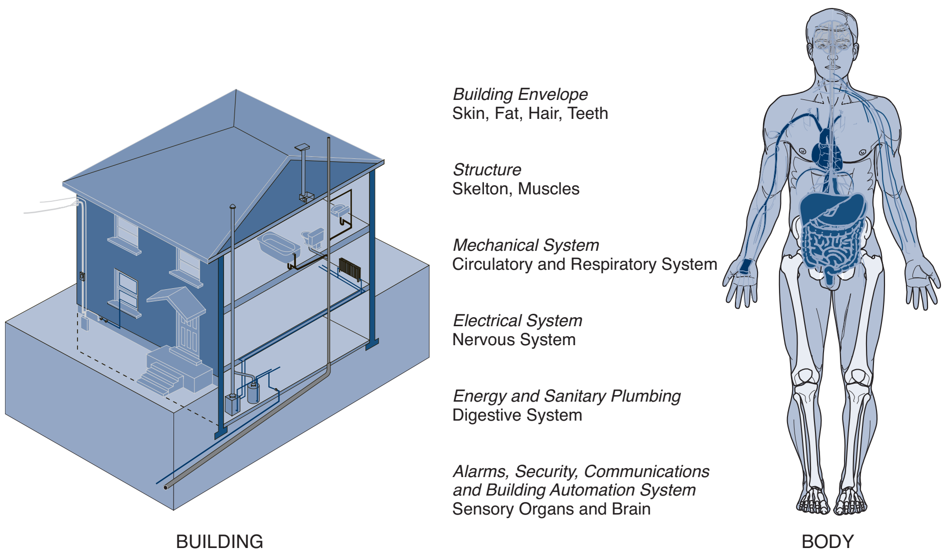


Figure 7.5. Buildings emulate all the functions of the human bodies they shelter.

As importantly, the relationship between buildings, the environment and human health, is being rediscovered in developed countries. This is particularly prevalent in large urban centres, where many inhabitants spend practically all of their time indoors. Modern urban inhabitants no longer spend as much time outdoors compared to their agrarian ancestors, hence the quality of the indoor environment is much more critical to health and wellbeing. The building as a system concept is an important design tool for achieving healthy buildings.

The building as a system concept hinges on the primary physical phenomena driving building behaviour, specifically: heat flow, air flow; moisture flow; and solar radiation. There are effective means for managing each of these phenomena individually; however, there are cases where unforeseen interactions between the various building systems result in performance problems.

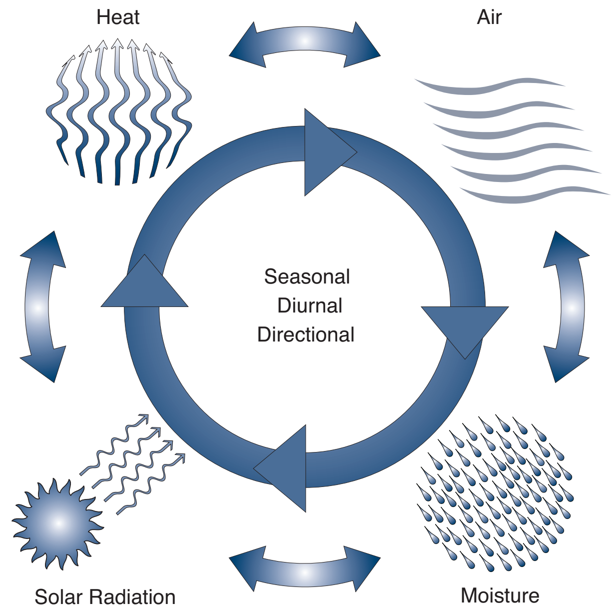


Figure 7.6. Building systems manage the flows of heat, air, moisture and solar radiation across the building envelope, and also through their mechanical and electrical systems, to deliver thermal comfort and acceptable indoor air quality. High performance building systems rely predominantly on a durable and efficient building envelope for passive environmental control, with minimal supplementary contributions from the active energy systems.

Building System Interactions

There are several building system interactions that have to be carefully considered when planning comprehensive retrofits of tower buildings:

- External insulation and cladding (overcladding) is the only feasible strategy for effective energy performance and envelope durability. Thermal bridging cannot be eliminated by insulating from the inside. This approach is also is too disruptive and requires the building to be vacated for the work to proceed. Overcladding protects the building envelope and armature from exposure to the elements, minimizes thermal bridging and maintains the building at a uniform temperature, significantly reducing thermal stress.

- The existing masonry building envelope and concrete structural armature function hygrothermally on a storage and drying basis. All wetting that occurs during the spring, summer and fall is stored in the large hygric buffer provided by the masonry and concrete, later driven out by the heat flow and air leakage during the heating season. Before overcladding is installed, it is critical to apply an effective air/vapour barrier on the outboard face of the existing envelope to prevent its wetting from exterior moisture sources, as its drying potential will be greatly reduced.

- Existing tower buildings have low cooling demands because the window areas are typically modest, the projecting balconies provide shading, and the exposed concrete armature and masonry envelope efficiently transfer heat build up through nighttime cooling. Overcladding and the enclosure of balconies will transform this behaviour unless careful attention is paid to shading devices, glazing optical properties and the design of the retrofit façade in relation to its solar orientation.

- The increased airtightness of the building envelope following its retrofit will adversely impact indoor air quality unless the corridor ventilation system is converted into a dedicated outside air system ducted to each suite. This is also the most practical means of effectively implementing heat recovery. Inhabitants will open their windows to ventilate their suites if the mechanical ventilation system is ineffective, and this will bypass the heat recovery loop, significantly reducing energy savings.

- Differences in space heating demands among solar orientations will be amplified after the envelope has been retrofit, hence heating system controls will have to become much more responsive than is typically the case in existing tower buildings.

Effective building systems integration must anticipate these interactions and manage them in order to achieve all of the performance objectives upon which a cost effective tower renewal project is based.

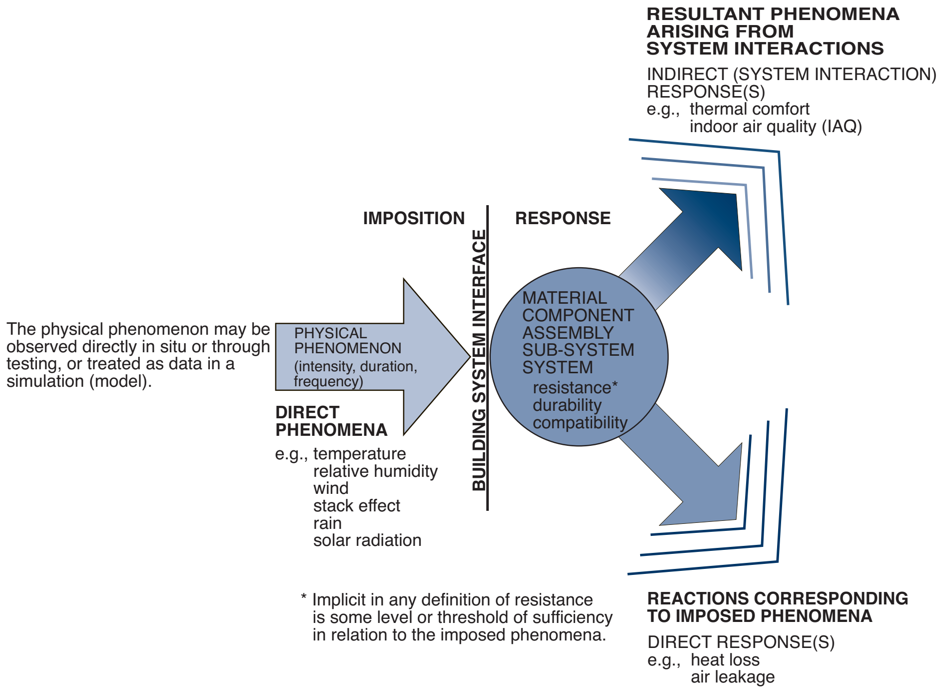


Figure 7.7. A phenomenological model represents building system interactions, both between the building and its external environment, and within the building system among its constituent elements. Failure to properly integrate the building as a system model impairs proper performance and minimizes the probability of attaining optimal performance.

Nowhere is the ***building as a system*** concept a more critical consideration than the comprehensive retrofit and rehabilitation of existing buildings. In nearly all cases, traditional building systems were based on a massive masonry envelope that acted as a hygric buffer, storing and then releasing water on a seasonal basis. Air leakage and high thermal conductivity (no explicit insulation material) were essential attributes of cold climate, masonry buildings. When coupled to oversized, heating-only HVAC systems, this approach resulted in durable buildings with acceptable indoor air quality. Building services were basic and telephone lines (sometimes door bells) were the only electronic technology provided. The cost of energy was insignificant when traditional building systems evolved and there was no awareness of impacts such as greenhouse gas emissions and climate change. People's expectations of building performance were also much lower than today. Retrofit and rehabilitation represent an opportunity for integrating traditional and contemporary systems into a superior hybrid building solution, but only if the principles of building system integration are observed. Realization of this enormous potential reinforces the importance of the building as a system concept.

The next section looks at the essential code constraints that must first be addressed before the critical retrofit strategies are formulated within the context of a building as a system approach.

Building Fire Safety

Tower renewal projects represent an opportunity to review the fire safety provisions in existing buildings and to investigate possible improvements as part of the retrofit work. As such, it is important to examine:

- Fire alarm and detection systems, and how these may be integrated with building automation systems;
- Provisions for firefighting, if there are any proposed changes to vehicular access;
- Lighting and emergency power systems, as an opportunity to consider a combined heat and power generator in lieu of a diesel generator; and
- Any additional requirements for high buildings that may apply.

Spatial separation for existing buildings is a special consideration that may be influenced by retrofit of the building envelope. Existing tower buildings fall into two categories in this regard: 1) buildings that fully comply with spatial separation requirements under the current Code; and 2) buildings that may have one or more exposing building faces non-complying with current Code requirements. This section of the guidelines looks at issues of spatial separation, acknowledging that all aspects of fire safety must be reviewed during the condition assessment of the building and the design of subsequent retrofit measures.

Balcony Enclosure Issues

When investigating the feasibility of balcony enclosure systems to deal with the durability and energy performance of the exposed, cantilevered balcony slabs, their potential impact on existing *limiting distance* criteria should be carefully considered. In most instances, existing open balconies project beyond the *exposing building face* of the building. Currently in such buildings, the exterior wall behind the outer face of the existing balconies constitutes the *exposing building face* from which *limiting distance* is derived and the percentage of allowable *unprotected openings* calculated.

Balcony enclosure causes the exposing building face to move outward. In general, as *limiting distance* diminishes due to the *exposing building face* moving forward to the proposed exterior face of newly enclosed balconies, the percentage of allowable *unprotected openings* is reduced. This reduction in allowable *unprotected openings* becomes a critical consideration when dealing with smaller sites of higher density or buildings with restrictive existing *limiting distance* dimensions. Specific *exposing building faces* of buildings on larger properties may also be impacted depending on their placement within the site. This relationship is illustrated in Table 7.3 which is excerpted from Table 3.2.3.1.A. of the National Building Code of Canada 2005.

As the *limiting distance* (m) increases, so does the percentage of allowable *unprotected openings*. As the *limiting distance* (m) decreases, so does the percentage of allowable *unprotected openings*. Table 7.3, is provided as a convenience in this section of the guidelines. Always refer to applicable codes and authorities having jurisdiction to assess compliance. If existing *suites* constitute *fire compartments* then their individual *exposing building face* may be substituted in the analysis model. There may or may not be benefits to this alternative method. However, such an approach should be explored if the allowable percentage of *unprotected openings* over the entire building face is found to be restrictive. The use of specific enclosing construction materials, i.e. glass block and wired glass provide the opportunity for increased day lighting while maintaining the percentage of allowable *unprotected openings*. The provision of a sprinkler system may also dramatically increase the percentage of allowable *unprotected openings*. Note the possibility that future high rise residential buildings may be required to be sprinklered to attain building code compliance, and this may influence the decision to provide sprinklering in existing buildings for marketability purposes.

The examples that follow are based on a hypothetical building where the enclosure of existing, unenclosed balconies is being considered at the design stage. The terms used in these examples are defined below.

Balcony Enclosure Limiting Distance Examples

Defined Terms

H	Height of Building
L	Length of Building
At	Total Area
Au	Area Unprotected
Ap	Area Protected
Aa	Area of Unprotected Allowable
DLe	Limiting Distance Existing
DLp	Limiting Distance Proposed

Limiting distance means the distance from an ***exposing building face*** to a property line, the centre line of a ***street***, lane or public thoroughfare, or to an imaginary line between two ***buildings*** or ***fire compartments*** on the same property, measured at right angles to the ***exposing building face***.

Exposing building face means that part of the exterior wall of a building which faces one direction and is between ground level and the ceiling of the top ***storey***, or where a building is divided into ***fire compartments***, the exterior wall of the ***fire compartments*** which faces one direction.

Street means any highway, road, boulevard, square or other improved thoroughfare 9m (29 ft 6 in) or more in width, which has been dedicated or deeded for public use, and is accessible to fire department vehicles and equipment.

Building means any structure used or intended for supporting or sheltering any use or occupancy.

Fire compartment means an enclosed space in a ***building*** that is separated from all other parts of the building by enclosing construction providing a ***fire separation***, having a required ***fire-resistance rating***.

Fire separation means a construction assembly that acts as a barrier against the spread of fire.

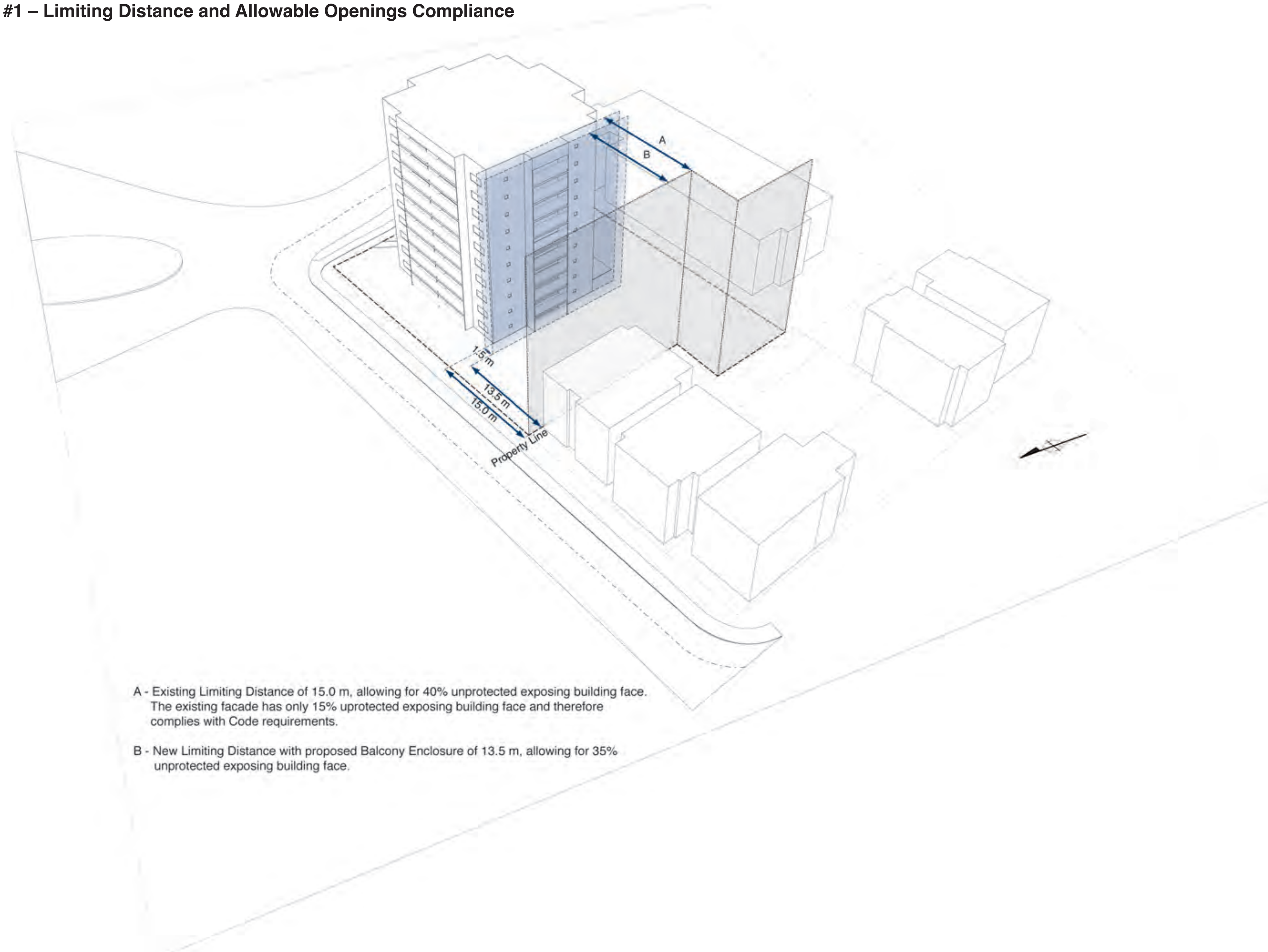
Fire-resistance rating means the time in minutes or hours that a material or assembly of materials will withstand the passage of flame and the transmission of heat when exposed to fire under specified conditions of test and performance criteria or as determined by extension or interpretation of information derived therefrom, as prescribed in the Code.

Unprotected opening (as applied to an ***exposing building face***) means a doorway, window or opening, other than one equipped with a ***closure*** having the required ***fire protection rating***, or any part of the wall forming part of the ***exposing building face*** that has a fire resistance rating less than required for the ***exposing building face***.

Closure means a devise or assembly for closing an opening through a ***fire separation*** or an exterior wall, such as a door, a shutter, wired glass or glass block, and includes all components such as hardware, closing devices, frames and anchors.

Fire protection rating means the time in minutes or hours that a ***closure*** will withstand the passage of flame when exposed to fire under specified conditions of test and performance criteria, or as otherwise prescribed in the Code.

Example #1 – Limiting Distance and Allowable Openings Compliance



A - Existing Limiting Distance of 15.0 m, allowing for 40% unprotected exposing building face. The existing facade has only 15% uprotected exposing building face and therefore complies with Code requirements.

B - New Limiting Distance with proposed Balcony Enclosure of 13.5 m, allowing for 35% unprotected exposing building face.

Figure 7.8. The limiting distance of the West elevation of the building depicted above decreases by 1.5 metres due to the proposed enclosure of existing balconies.

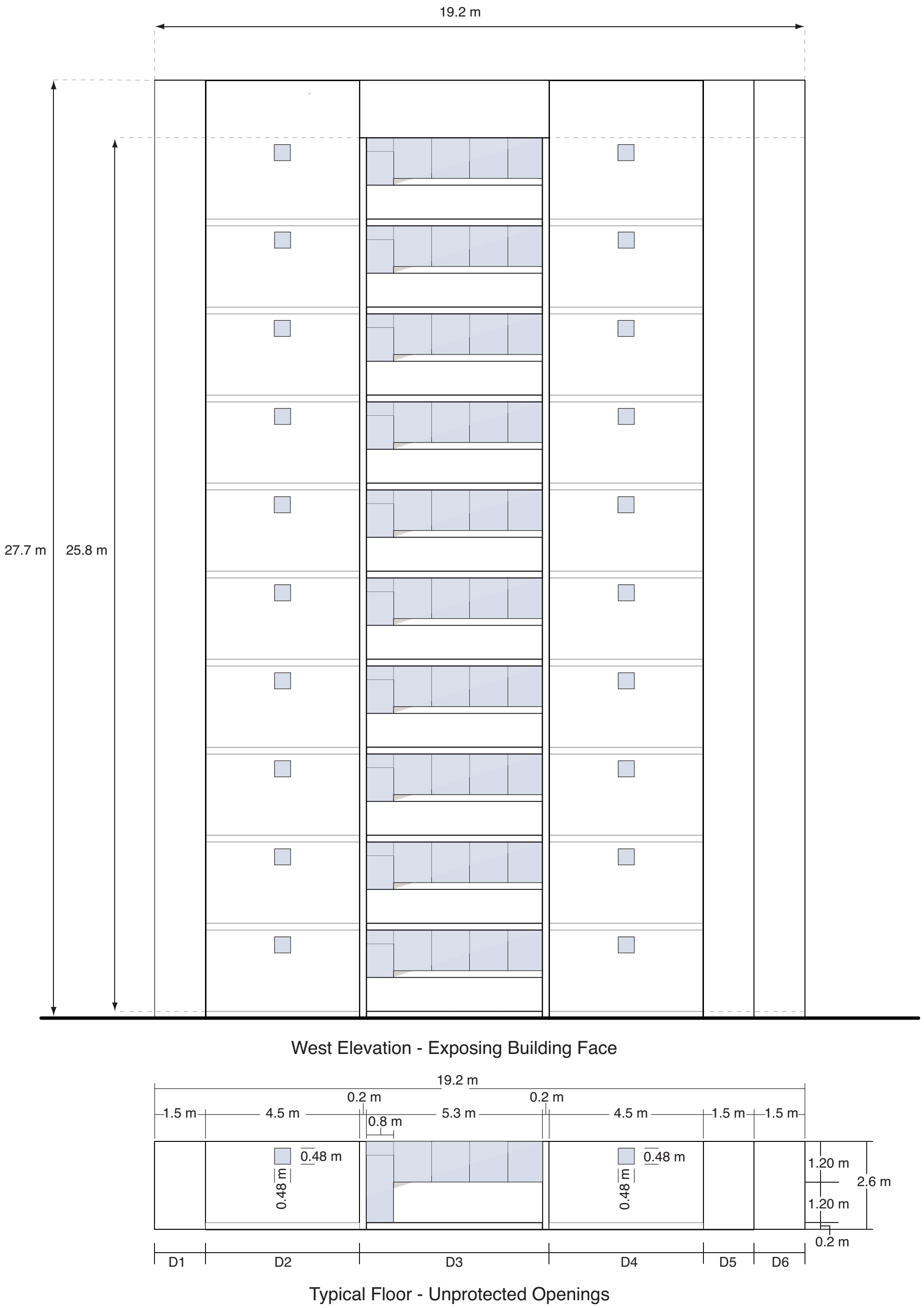
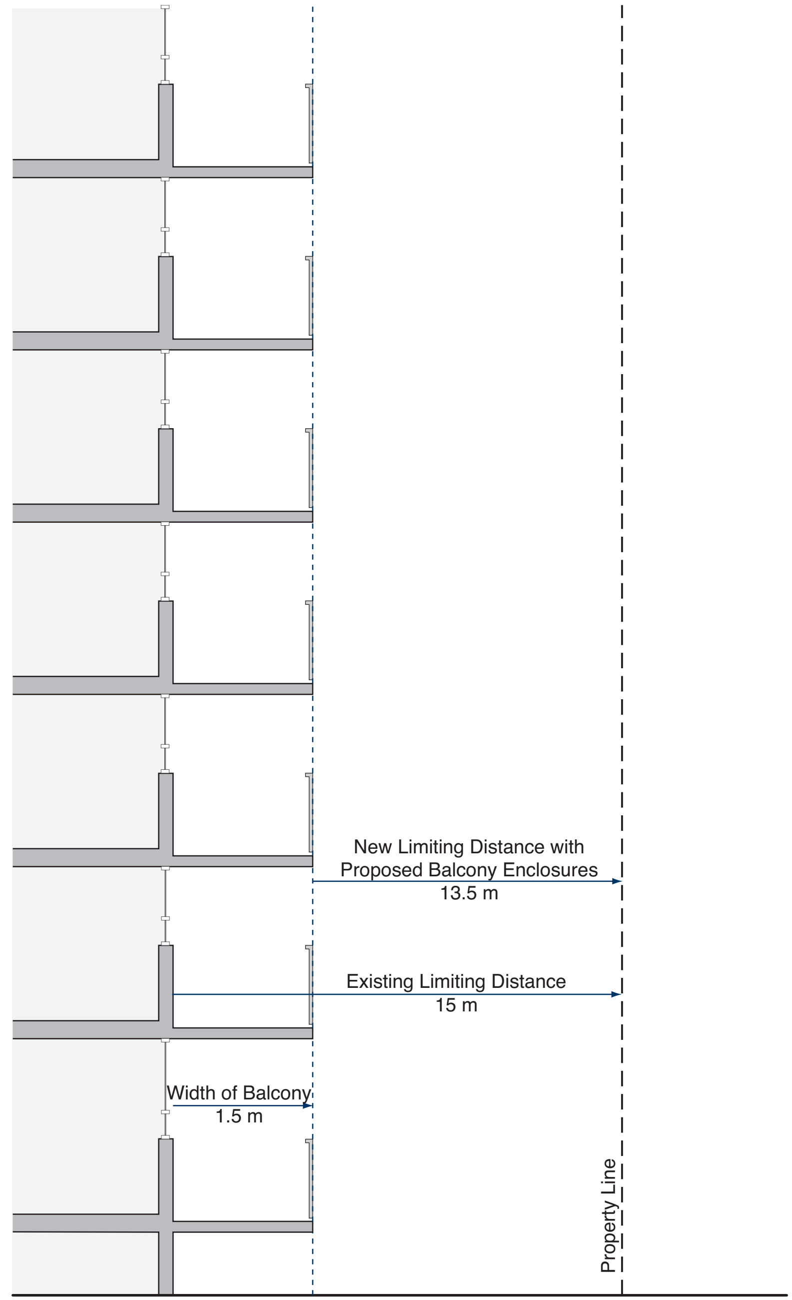


Figure 7.9. The dimensions of the West elevation exposing building face are required to calculate the areas used in the analysis of allowable unprotected openings.



Section Through Balconies on the West Elevation (N.T.S.)

Figure 7.10. A section through the building is used to establish the new limiting distance with proposed balcony enclosures. Note that an accurate survey is needed to properly determine the existing limiting distance.

Analysis of Limiting Distance and Uprotected Openings - West Elevation

Assumptions	
Floors	10
Height of Floor (including slab), m	2.6
Height of Tower **(H)**, m	25.8
Length of Tower **(L)**, m	19.2
Total Area of Exposing Face **(At)**, m²	495

Area	**Height (H) m**	**Length (L) m**	**Total Area (At) m²**	**Floors**	**Unprotected Area per Floor, m²**	**Unprotected Area (Au), m²**	**Protected Area (Ap), m²**	**Unprotected Openings, %**
D1	25.8	1.5	39	10	0.0	0.0	39	0%
D2	25.8	4.5	116	10	0.2	2.3	114	2%
D3	25.8	5.7	147	10	7.3	73.2	74	50%
D4	25.8	4.5	116	10	0.2	2.3	114	2%
D5	25.8	1.5	39	10	0.0	0.0	39	0%
D6	25.8	1.5	39	10	0.0	0.0	39	0%

Existing Exposing Building Face Area	**Height (H) m**	**Width (L) m**	**Total Area (At) m²**	**Floors**	**Unprotected Area per Floor, m²**	**Unprotected Area (Au), m²**	**Protected Area (Ap), m²**	**Unprotected Openings, %**
Total (D1+D2+D3+D4+D5+D6)	25.8	19.2	495	10	7.8	78	418	16%

Ratio		
H/L	1.3	**Larger value of H/L or L/H is used**
L/H	0.7	

Percentage of Unprotected Openings Allowable Based on Existing Limiting Distance
(Interpolation from Table 7.3)

42 % Existing exposed building face to property line currently 15 m **(DLe)**

Percentage of Unprotected Openings Allowable Based on Enclosure of Balconies
(Interpolation from Table 7.3)

35 % Based on 1.5 m deep balconies, exposing building face is now at a limiting distance of 13.5 m **(DLp)** to property line

Percentage of Unprotected Balcony Area Allowable Based on Adjusted Limiting Distance			
Total Area Exposed Building Face **(At)**	495	m²	
Percentage of Unprotected Openings Allowable	35	%	
Total Allowable Area of Unprotected Openings **(Aa)**	173	m²	
Area of Unprotected Openings to Remain	4.6	m²	(D2+D4+D5)
Remaining Possible Allowable Unprotected Area	169	m²	(Applicable to D3)
Total Balcony Area Possible	147	m²	
Unprotected Openings Allowable for Balcony Faces	> 100	%	**It is therefore possible for the balcony faces to be entirely glazed.**

Percentage of Unprotected Openings Allowable increases if sprinklers are provided.
For this example it has been assumed that the building is not sprinklered nor will it be after the retrofit.
Existing percentage of unprotected openings (16%) is smaller then the maximum allowed by Code (42%).

Table 7.2. The analysis of allowable unprotected openings for the proposed balcony enclosure is summarized in the above table. The first step is to calculate the existing percentage of unprotected openings, 16%, and then to compare this with what is allowable, 42%. Then the percentage of unprotected openings allowable under the new limiting distance of 13.5 m is determined from Table 7.3. Interpolating between 13 m and 14 m indicates 35% unprotected openings is allowable. Additional area calculations indicate the entire exposed balcony area may be glazed.

Exposing Building Face		**Area of Unprotected Openings, %**																									
Maximum Area, m^2 (ft^2)	Ratio (H/L or L/H) *	Limiting Distance, m																									
		0	1.2	1.5	2	2.5	3	4	5	6	7	8	9	10	11	12	13	14	16	18	20	25	30	35	40	45	50
350	Less than 3:1	0	7	7	7	8	8	9	11	14	16	20	24	28	33	38	44	50	64	81	99	100					
(3766)	3:1 to 10:1	0	7	7	8	8	9	11	13	16	19	23	27	32	37	42	48	55	69	85	100						
	Over 10:1	0	7	8	9	10	12	16	21	25	30	36	41	47	53	59	66	73	88	100							
500	Less than 3:1	0	7	7	7	7	8	9	10	12	14	16	19	22	25	29	33	37	47	59	71	100					
(5379)	3:1 to 10:1	0	7	7	7	8	8	10	12	14	16	19	22	25	29	33	37	41	52	63	76	100					
	Over 10:1	0	7	7	8	9	11	14	18	22	25	30	34	38	43	48	53	58	70	82	96	100					
1000	Less than 3:1	0	7	7	7	7	7	8	9	9	10	12	13	14	16	18	20	22	27	33	39	58	82	100			
(10758)	3:1 to 10:1	0	7	7	7	7	8	9	10	11	12	14	15	17	19	21	23	26	31	37	43	63	86	100			
	Over 10:1	0	7	7	8	8	9	11	13	16	19	21	24	27	30	33	36	39	46	53	60	82	100				
2000	Less than 3:1	0	7	7	7	7	7	7	8	8	9	9	10	11	12	13	14	15	17	20	23	33	44	58	74	93	100
(21517)	3:1 to 10:1	0	7	7	7	7	7	8	8	9	10	11	12	13	14	15	16	17	20	23	27	37	49	63	79	97	100
	Over 10:1	0	7	7	7	8	8	9	11	12	14	16	18	19	21	23	25	27	32	36	40	53	66	82	99	100	

Notes

* - Apply whichever ratio is greater.

L = Length of Exposing Building Face.

H = Height of Exposing Building Face

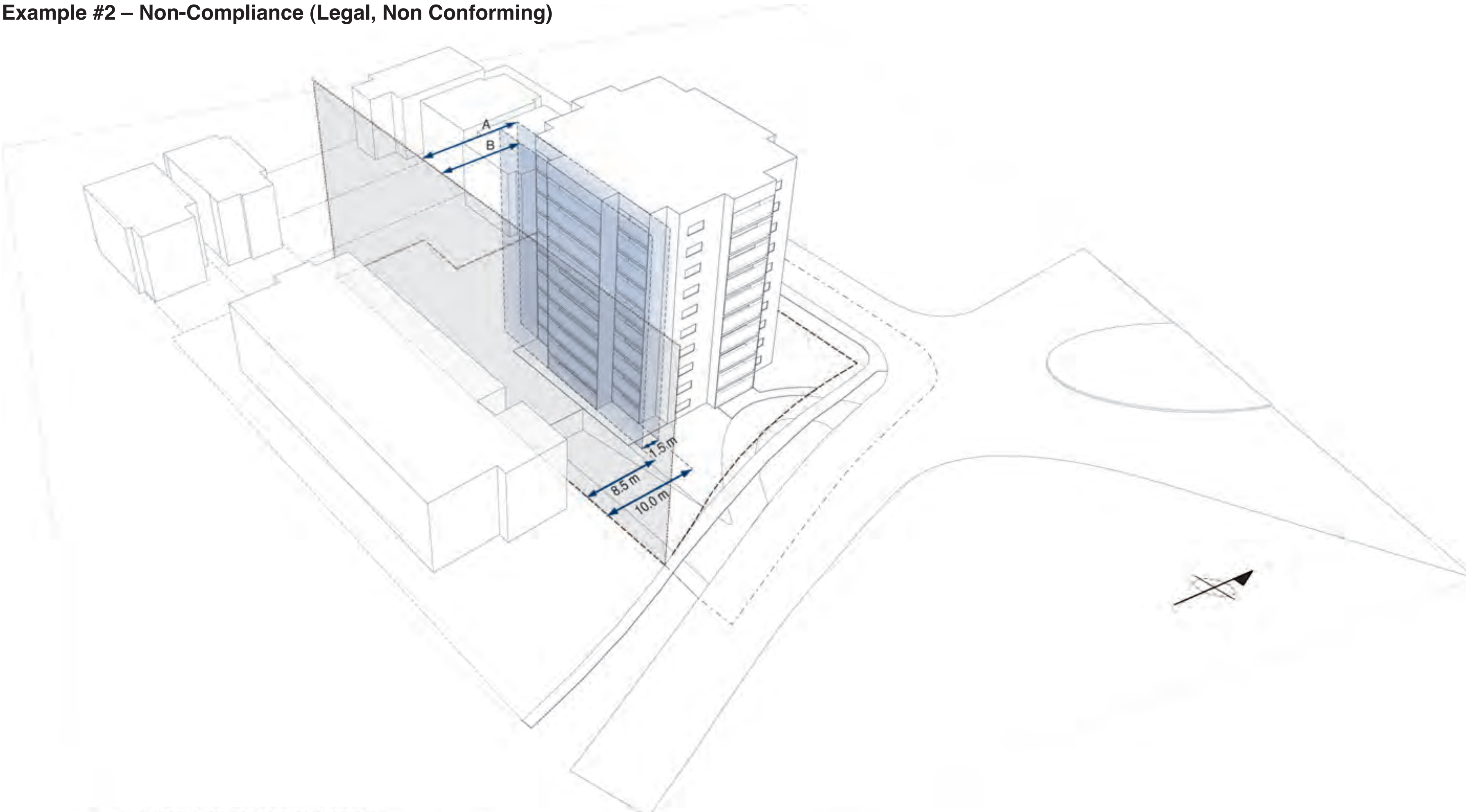
All values interpolated. Reference: Table 3.2.3.1.A., National Building Code of Canada 2005.

Table 7.3. The determination of the percentage allowable area of unprotected openings is indicated for the new limiting distance of 13.5 m with enclosed balconies. The maximum area and ratio of H/L or L/H, whichever is greater, establish the shaded row of values that apply. The limiting distance of 13.5 m is exactly half way between 13 m and 14 m, hence the mid-point between 33% and 37% may be interpolated as 35%. Note the same method was employed to determine the allowable openings using the existing limiting distance of 15 m, half way on the table between 14 m and 16 m.

This example represents what is likely to be the typical case for the vast majority of tower buildings located on large sites with generous setbacks from the property line.

The next example examines the south face of the building where there is concern the existing exposing building face does not comply with current Code requirements.

Example #2 – Non-Compliance (Legal, Non Conforming)



A - Existing Limiting Distance of 10.0 m,
allowing for 15% unprotected exposing building face.
This distance is smaller than what is required by Code
for the 39% unprotected exposing building face that currently exists,
and is therefore deemed non-compliant (existing non-conforming).

B - New Limiting Distance with Balcony Enclosure of 8.5 m,
allowing for 13% unprotected exposing building face.

Figure 7.11. The limiting distance of the South elevation of the building depicted above decreases by 1.5 metres, from 10.0 m to 8.5 m, due to the proposed enclosure of existing balconies. The existing 39% unprotected openings does not comply with current Code requirements.

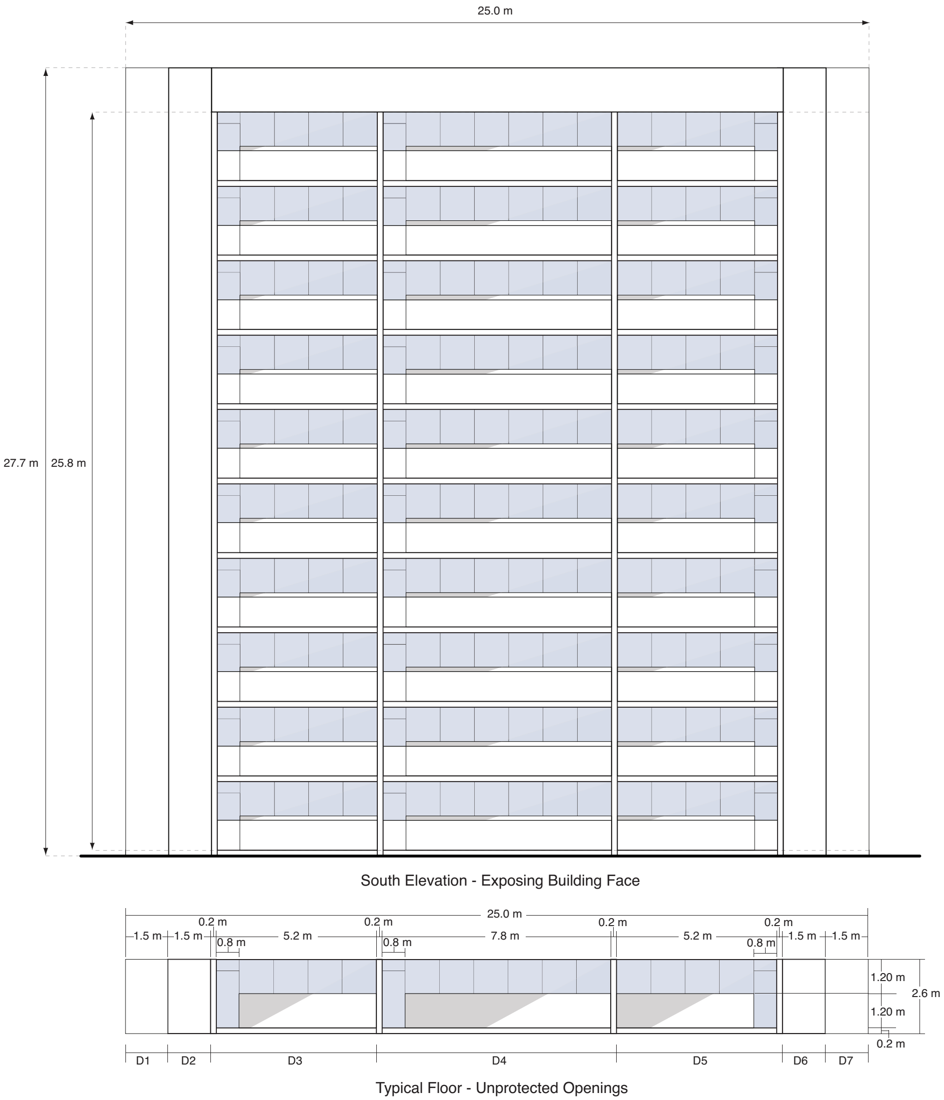


Figure 7.12. The dimensions of the South elevation exposing building face are required to calculate the areas used in the analysis of allowable unprotected openings. It may be observed that a much higher percentage of unprotected openings compared to the West elevation currently exists, signaling a potential issue in regards to spatial separation.

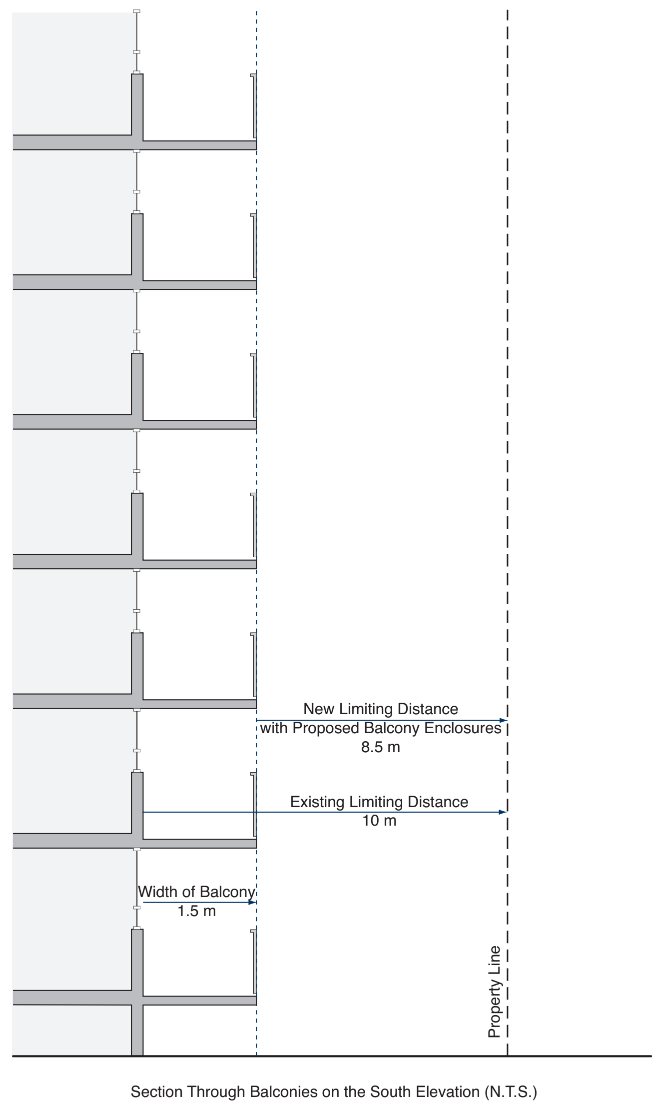


Figure 7.13. A section through the building is used to establish the new limiting distance with proposed balcony enclosures. A dramatic reduction in the area of allowable openings will tend to discourage balcony enclosure for reasons of access to daylight and natural ventilation.

Analysis of Limiting Distance and Unprotected Openings - South Elevation

Assumptions	
Floors	10
Height of Floor (including slab), m	2.6
Height of Tower **(H)**, m	25.8
Length of Tower **(L)**, m	25.0
Total Area of Exposing Face **(At)**, m²	645

Area	**Height (H) m**	**Length (L) m**	**Total Area (At) m²**	**Floors**	**Unprotected Area per Floor, m²**	**Unprotected Area (Au), m²**	**Protected Area (Ap), m²**	**Unprotected Openings, %**
D1	25.8	1.5	39	10	0.0	0.0	38.7	0%
D2	25.8	1.5	39	10	0.0	0.0	38.7	0%
D3	25.8	5.4	139	10	7.2	72.0	67.3	52%
D4	25.8	8.2	212	10	10.3	103.2	108.4	49%
D5	25.8	5.4	139	10	7.2	72.0	67.3	52%
D6	25.8	1.5	39	10	0.0	0.0	38.7	0%
D7	25.8	1.5	39	10	0.0	0.0	38.7	0%

Existing Exposing Building Face Area	**Height (H) m**	**Width (L) m**	**Total Area (At) m²**	**Floors**	**Unprotected Area per Floor, m²**	**Unprotected Area (Au), m²**	**Protected Area (Ap), m²**	**Unprotected Openings, %**
Total (D1+D2+D3+D4+D5+D6+D7)	25.8	25.0	645	10	24.7	247	398	38%

Ratio		
H/L	1.0	**Larger value of H/L or L/H is used**
L/H	1.0	

Percentage of Unprotected Openings Allowable Based on Existing Limiting Distance
(Directly from Table 7.5)
14 % Existing exposed building face to property line currently 10 m **(DLe)**

Percentage of Unprotected Openings Allowable Based on Enclosure of Balconies
(Interpolation from Table 7.5)
12.5 % Based on 1.5 m deep balconies, exposing building face is now at a limiting distance of 8.5 m **(DLp)** to property line

Percentage of Unprotected Balcony Area Allowable Based on Adjusted Limiting Distance			
Total Area Exposed Building Face **(At)**	645	m²	
Precentage of Unprotected Openings Allowable	12.5	%	
Total Allowable Area of Unprotected Openings **(Aa)**	81	m²	
Area of Unprotected Openings to Remain	0	m²	(D1+D2+D6+D7)
Remaining Possible Allowable Unprotected Area	81	m²	(Applicable to D3, D4 & D5)
Total Balcony Area Possible	490	m²	
Unprotected Openings Allowable for Balcony Faces	16.4	%	**It is therefore possible for only 16.4% of the balcony face areas to be glazed.**

Percentage of Unprotected Openings Allowable increases if sprinklers are provided.
For this example it has been assumed that the building is not sprinklered nor will it be after the retrofit.
Existing percentage of unprotected openings (38%) is larger then the maximum allowed by Code (14%). This exising building face is therefore non-compliant (legal, non-conforming).

Table 7.4. The analysis of allowable unprotected openings for the proposed balcony enclosure on the South elevation is summarized in the table above. The first step is to calculate the existing percentage of unprotected openings, 38%, and then to compare this with what is allowable, in this case 14%. The current unprotected openings do not comply with Code requirements. Then the percentage of unprotected openings allowable under the new limiting distance of 13.5 m is determined from Table 7.5. Interpolating between 8 m and 9 m indicates 12.5% unprotected openings is allowable. Additional area calculations indicate only 16.4% of the balcony face areas may be glazed.

Exposing Building Face		Area of Unprotected Openings, %																									
Maximum Area, m^2 (ft^2)	Ratio (H/L or L/H) *	Limiting Distance, m																									
		0	1.2	1.5	2	2.5	3	4	5	6	7	8	9	10	11	12	13	14	16	18	20	25	30	35	40	45	50
350	Less than 3:1	0	7	7	7	8	8	9	11	14	16	20	24	28	33	38	44	50	64	81	99	100					
(3766)	3:1 to 10:1	0	7	7	8	8	9	11	13	16	19	23	27	32	37	42	48	55	69	85	100						
	Over 10:1	0	7	8	9	10	12	16	21	25	30	36	41	47	53	59	66	73	88	100							
500	Less than 3:1	0	7	7	7	7	8	9	10	12	14	16	19	22	25	29	33	37	47	59	71	100					
(5379)	3:1 to 10:1	0	7	7	7	8	8	10	12	14	16	19	22	25	29	33	37	41	52	63	76	100					
	Over 10:1	0	7	7	8	9	11	14	18	22	25	30	34	38	43	48	53	58	70	82	96	100					
1000	Less than 3:1	0	7	7	7	7	7	8	9	9	10	12	13	14	16	18	20	22	27	33	39	58	82	100			
(10758)	3:1 to 10:1	0	7	7	7	7	8	9	10	11	12	14	15	17	19	21	23	26	31	37	43	63	86	100			
	Over 10:1	0	7	7	8	8	9	11	13	16	19	21	24	27	30	33	36	39	46	53	60	82	100				
2000	Less than 3:1	0	7	7	7	7	7	7	8	8	9	9	10	11	12	13	14	15	17	20	23	33	44	58	74	93	100
(21517)	3:1 to 10:1	0	7	7	7	7	7	8	8	9	10	11	12	13	14	15	16	17	20	23	27	37	49	63	79	97	100
	Over 10:1	0	7	7	7	8	8	9	11	12	14	16	18	19	21	23	25	27	32	36	40	53	66	82	99	100	

Notes

* - Apply whichever ratio is greater.

L = Length of Exposing Building Face.

H = Height of Exposing Building Face

All values interpolated. Reference: National Building Code of Canada (NBC)

Table 7.5. The determination of the percentage allowable area of unprotected openings is indicated for the new limiting distance of 8.5 m with proposed balcony enclosures. The maximum area and ratio of H/L or L/H, whichever is greater, establish the shaded row of values that apply. The limiting distance of 8.5 m is exactly half way between 8 m and 9 m, hence the mid-point between 12% and 13% may be interpolated as 12.5%. Note that it was possible to determine the allowable openings directly using the existing limiting distance of 10 m, corresponding to a value of 14% in the table.

In this example, it has been determined the maximum allowable unprotected openings for the balcony face areas is 16.4%. This is likely an insufficient allowance for daylighting and natural ventilation purposes. Looking at a balcony face with a typical floor to ceiling height of 2.4 m, the glazing area can be visualized as a continuous strip running the full width of each suite and approximately 400 mm in height. For this type of situation, balcony enclosures may not be a suitable retrofit strategy. There are additional considerations related to these to examples.

Overcladding System and Fire Separations

Residential occupancies are classified as Group C in the Code. Requirements pertaining to the combustibility and fire-resistance rating of the cladding as well as the fire separation between adjoining suites must be observed for any proposed retrofit.

The National Building Code of Canada 2005 contains the following provisions related to the combustibility and fire-resistance rating of the cladding.

3.2.3.7. Construction of Exposing Building Face
(1) Except as permitted by Articles 3.2.3.10. and 3.2.3.11, if a *limiting distance* shown in Table 3.2.3.1.A. or Table 3.2.3.1.C. for a Group A, B, C, D or Group F, Division 3 *occupancy* classification permits an *exposing building face* to have *unprotected openings* not more than 10% of the *exposing building face*, the *exposing building face* shall be
(a) of *noncombustible construction* having a *fire-resistance rating* not less than 1 h, and
(b) clad with *noncombustible* cladding.

(2) Except as permitted by Sentence (7) and Articles 3.2.3.10. and 3.2.3.11., if a *limiting distance* shown in Table 3.2.3.1.A. or Table 3.2.3.1.C. for a Group A, B, C, D or Group F, Division 3 *occupancy* classification permits an *exposing building face* to have *unprotected openings* more than 10% but not more than 25% of the *exposing building face*, the *exposing building face* shall
(a) have a *fire-resistance rating* not less than 1 h, and
(b) be clad with *noncombustible* cladding.

(3) Except as permitted by Articles 3.2.3.10. and 3.2.3.11., if a *limiting distance* shown in Table 3.2.3.1.A. or Table 3.2.3.1.C. for a Group A, B, C, D or Group F, Division 3 *occupancy* classification permits an *exposing building face* to have *unprotected openings* more than 25% but less than 100% of the *exposing building face*, the *exposing building face* shall have a *fire-resistance rating* not less than 45 min.

In the first example, the allowable area of unprotected openings was determined to be 35% of the exposing building face area. As a result, the requirement of Sentence 3.2.3.7.(3) apply, and the exposing building face must have a minimum fire-resistance rating of 45 minutes. In practical terms, virtually any combination of cladding and insulation materials may be used for the envelope retrofit.

The second example falls under Sentence 3.2.3.7.(2) because the allowable area of unprotected openings was determined to be 12.5% of the exposing building face area. The exposing building face must have a minimum fire-resistance rating of 1 hour, normally not an issue with typical tower buildings having brick veneer and backup masonry block walls. However, the cladding must be noncombustible and this will limit the number of available options for envelope overcladding systems.

Where balcony enclosure is permissible and feasible, it is also important to consider the requirements for fire separations between shared, enclosed balcony spaces. The minimum fire-resistance rating of the separator is 1 hour, and it must be tightly fitted to prevent smoke movement across the separator.

Fire safety requirements take a higher priority than durability and energy efficiency, but they are not exclusive of one another. There are a number of innovative products available that combine diffuse light transmission with thermal insulation, and are also considered non-combustible. Natural ventilation in balcony enclosure can also be accomplished with the intelligent arrangement of openings (high-low and cross ventilation patterns). The biggest challenge is to maintain a view, especially in situations where the existing building is found to be legal, non-conforming with respect to the limiting distance and allowable unprotected openings. As noted earlier, if existing suites constitute fire compartments then their individual exposing building face may be substituted in the analysis model. However, the provision of a sprinkler system is normally the most effective means of increasing the percentage of allowable unprotected openings, and the difference in cost between balcony enclosure versus balcony overcladding often more than pays for installation of the sprinkler system.

Building Envelope Retrofits

The retrofit of the building envelope is the most costly and critical component of tower renewal. The building envelope accounts for nearly two-thirds of the energy consumption in a typical tower building and this amount can be cost effectively reduced through the deployment of an appropriate retrofit strategy. But energy efficiency is not the only consideration driving tower building envelope retrofits. Deterioration of the building envelope can be addressed through overcladding, effectively encapsulating the existing building envelope with environmental control elements such as a continuous air/vapour barrier, thermal insulation and cladding over exterior walls. Overcladding may be extended to balconies or alternatively, these may be enclosed with a combination of insulated and glazed assemblies. Single glazed windows without thermal breaks can be replaced with double or triple glazed high performance window assemblies. Roofs can be entirely upgraded to current standards of energy efficiency and host a variety of innovative renewable energy and green roof technologies. This section focuses on the above-grade portion of the building envelope. It recognizes that underground parking structures may require rehabilitation, and also offer opportunities for energy savings, but these conservation measures have been dealt with in previous research and better practice guides for apartment building owners.

The process of developing an appropriate envelope retrofit strategy involves several critical factors that must be fully appreciated by the designer:

1. The relationship between skin heat loss versus air leakage and ventilation in multi-unit residential buildings is different from other types of buildings. MURBs have a relatively high demand for mechanical ventilation on a continuous basis. In typical existing buildings, air leakage and ventilation account for roughly half the space heating energy demand. Of that half, between one-quarter and one-third is accounted for by air leakage. The remaining demand involves ventilation and can only be addressed through heat recovery, not by envelope thermal efficiency.

2. Airtightness, air leakage and ventilation must also be fully considered in a comprehensive tower retrofit program. The air leakage will be reduced through the retrofit of the building envelope and this increased airtightness will adversely impact the ventilation rates in suites if the corridor ventilation system is not reconfigured. Fresh air must be directly ducted to each suite to compensate for the ventilation originally provided through the leaky existing envelope. This is the simplest means to enable effective heat recovery while maintaining acceptable indoor air quality.

3. Solar orientation of the tower building facades will normally require different façade treatments to effectively manage heat gains and daylighting, especially when balconies are enclosed as part of the overcladding measures.

4. There is always a need to assess the hygrothermal performance of the proposed envelope retrofit measures in terms of moisture balance and long-term durability. In general, exterior retrofits, also known as overcladding, provide the best heat, air and moisture management, provided the environmental control elements are properly selected and arranged.

In these guidelines, it has been assumed that interior envelope retrofits would prove too disruptive to tenants, and largely ineffective due to thermal bridging at each floor slab. Hence, only external retrofit strategies (overcladding) are explored. It is critical to the financial feasibility of tower renewal that tenants may continue to inhabit the building while work proceeds, in order to minimize disruption to their personal lives, and to maintain the landlord's cash flow.

MURB Energy and Water Use

There is a significant degree of variability in MURB energy and water use reported by various studies.[5,6,7] During the course of developing these guidelines, additional research was conducted by statistically analyzing tower buildings in the Toronto area in collaboration with the Toronto Atmospheric Fund. The averaged results for the CMHC studies and the recent research undertaken for these guidelines are summarized in Table 7.6 across both natural gas and electrically heated buildings.

Energy Use Intensity	322.5 ekWh/m^2
	30,823 ekWh/suite

Water Use Intensity	2.23 m^3/m^2
	239.4 m^3/suite

Table 7.6. Annual energy and water use intensities for typical tower buildings located in Toronto, Ontario, Canada. Space heating energy will vary in other geographic locations based on degree-days. Water consumption tends to vary based on household demographics.

These averages compare favourably to a detailed energy analysis performed on the archetype tower building which was developed to examine costs and benefits in Part 8 of these guidelines. Figure 7.14 indicates that the energy use intensity following a comprehensive retrofit was reduced from the existing value of 310 ekWh/m^2 to 94 ekWh/m^2 – a reduction of 69.7%.

An important factor affecting the actual energy consumption in rental housing was reported by Natural Resources Canada in a 2003 survey of household energy use:[8]

> *Low-rise apartments where someone other than the occupant (e.g. a landlord) was responsible for paying for at least one of the dwelling's energy sources had an energy intensity ratio of 1.62 GJ/m^2. This was in stark contrast to the energy intensity ratio of 0.68 GJ/m^2 for low-rise apartments where the household was responsible for paying for all of its energy consumption. This suggests that a household may have been more conscious of its energy efficiency if it was responsible for paying for all of its energy consumption.*

This factor cannot be ignored when estimating the energy saving benefits of a retrofit. Buildings where all of the utilities are included within the monthly rent may not achieve the projected reductions in energy and water consumption. Sub-metering is one approach to improving the energy consciousness of the inhabitants, but there are many issues related to this measure that must be carefully considered and negotiated.[9] Energy and water conservation education is a more socially oriented strategy for making inhabitants aware of how their consumption habits affect affordability and the environment. The important point to keep in mind is that unless there is a feedback loop between the landlord and the inhabitants, it is possible to achieve much lower energy and water savings than predicted, hence this should be reflected in a proper sensitivity analysis when assessing costs and benefits.

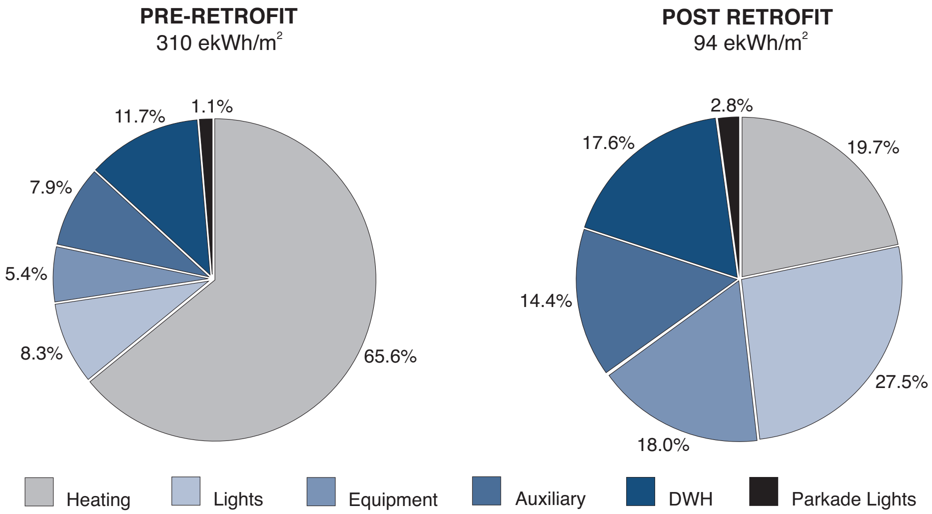


Figure 7.14. Breakdown of energy use in the archetype tower building before and after a comprehensive retrofit (refer to Part 8). The potential reduction in energy consumption is shown for a typical tower building located in Toronto. Approximately a two-thirds reduction is possible with an optimal overcladding strategy coupled to an appropriate HVAC system retrofit. It is important to note that in buildings heated with natural gas, the annual operating costs are only reduced by approximately one-half, due to the difference in the cost between natural gas and electricity. For electrically heated buildings, the annual cost reductions correspond directly to the energy consumption reductions.

CMHC undertook a study to examine the potential for energy conservation in MURBs and the findings are excerpted below.[10] This work suggests that significant opportunities, both present and future, are associated with the intelligent retrofit of the building envelope.

A research project was undertaken to evaluate the opportunities to reduce, recover and generate energy at the building envelope in existing multi-unit residential buildings. The research was conducted by a multi-disciplinary team of engineers, architects, building envelope consultants and representatives of the property management industry. The project reviewed new and emerging building envelope technologies that could help to reduce energy consumption in existing buildings, primarily based on experiences in European apartment buildings. Building integrated photovoltaics, solar water heating, solar air heating, insulation and window retrofits and double façade technologies were included in the review. For the most part, it was found that the current economics and risk associated with many of the available technologies can undermine the attractiveness of such technologies for property owners and managers. Two technologies (solar air heating and enclosing balconies) were found to offer attractive energy savings especially if the technologies are incorporated into a larger renovation project and the benefits derived from offsetting future repair costs are considered.

Enclosure Strategies

Strategies for retrofit of building envelopes range from the purely cosmetic to the entirely integrated systems approach. For the purposes of these guidelines, a building envelope retrofit is ideally defined as a process that improves the energy efficiency and durability of the building skin, notwithstanding its appearance. This reduces retrofit strategies into two alternatives: 1) an interior retrofit; and 2) an exterior retrofit. A third strategy is derived from a combination of these two approaches.

Interior retrofits have been demonstrated to be technically successful in cold climates; however, these are also disruptive to continuous occupancy, which is preferred by building owners for cash flow reasons and by tenants seeking to avoid displacement. Interior retrofits do not improve the public image of the building and nearly always imply a component of exterior retrofit work to manage deterioration, moisture and air leakage.

Exterior retrofits are the most common approach because they are least intrusive for occupants and can more cost effectively address improvements in energy efficiency and durability. It is interesting to note that the need to re-condition balconies is a major factor tipping the balance in favour of exterior retrofit measures, hence these guidelines focus exclusively on exterior building envelope retrofit strategies.

A typology of enclosure strategies is depicted in Figure 7.15. Modern building science research has demonstrated that face seal or barrier approaches do not have a high likelihood of acceptable performance, except for relatively arid climate zones. Pressure equalized rain screens, more correctly referred to as pressure moderated drain screens, manage moisture despite flawed workmanship and are commonly viewed as the most forgiving approach to building envelope design, especially for high-rise buildings. Within this context, overcladding in some form emerges as the preferred strategy for the envelope retrofit of high-rise housing. Acknowledging a wide range of available materials and methods, these guidelines consider the larger system selection and material arrangement strategies for walls, noting that these represent the highest proportion of the overall building envelope surface area:

- **Basic Overcladding** – air barrier/insulation protected by an exterior cladding applied to opaque wall elements, excluding balconies, combined with window replacement;
- **Comprehensive Overcladding** – air barrier/insulation protected by an exterior cladding applied to the entire opaque wall area, including balconies, combined with window replacement and appropriate enclosure of open balcony areas; and
- **Integrated Overcladding** – similar to comprehensive overcladding but incorporating a secondary framing system that enables the updating and integration of building services between the exterior insulation and existing façade, and the introduction of features such as double façade systems for natural ventilation and sound control.

Overcladding systems have the potential to significantly improve the hygrothermal performance of exterior wall assemblies. In the case of opaque wall areas, thermal insulation levels may be increased by more than RSI 3.5 (R-20), effectively reducing heat loss to approximately 15% of the existing rate. Air leakage may also be reduced to conform with modern standards when a comprehensive overcladding strategy is employed. The application of new glazing systems can improve thermal and air leakage performance, and in the case of integrated overcladding systems, reduce cooling loads while promoting natural ventilation. All of this is technically possible but relies on careful detailing of the envelope retrofit measures.

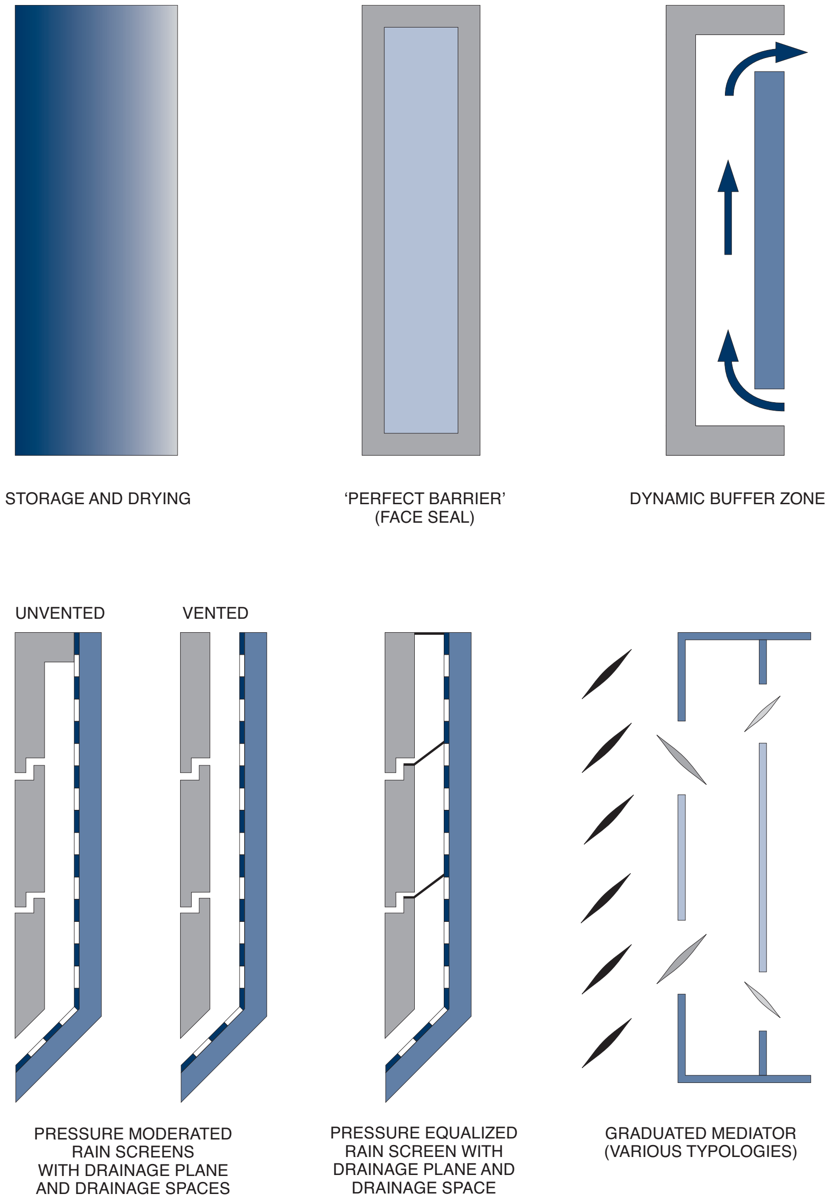


Figure 7.15. Most existing tower building envelopes rely on the storage and drying strategy for the management of moisture on a seasonal basis. The masonry façade is a hygric buffer that can store large quantities of water during the spring, summer and fall, which are then released outward during the winter, driven by the flow of heat. A number of overcladding strategies are technically possible, but only the pressure moderated and pressure equalized rain screens are practical for tower renewal projects. The graduated mediator approach is feasible, but requires careful integration with environmental control systems.

Material Selection and Arrangement

The basic requirements for acceptable building envelope performance are well established. Over the past decade, increasingly sophisticated tools for the design and performance assessment of separators have been developed to quantify their hygrothermal behaviour.[11] These advances are significant and ongoing, providing building science practitioners with valuable means of contributing to the improved reliability and performance of building envelopes.

Given this understanding, the key assumptions guiding material selection and arrangement are as follows:

1. Workmanship and materials are imperfect. Inaccuracy and inconsistency of workmanship and materials, in conjunction with variable weather conditions during construction, often result in buildings that only approximately fulfill their design intent.

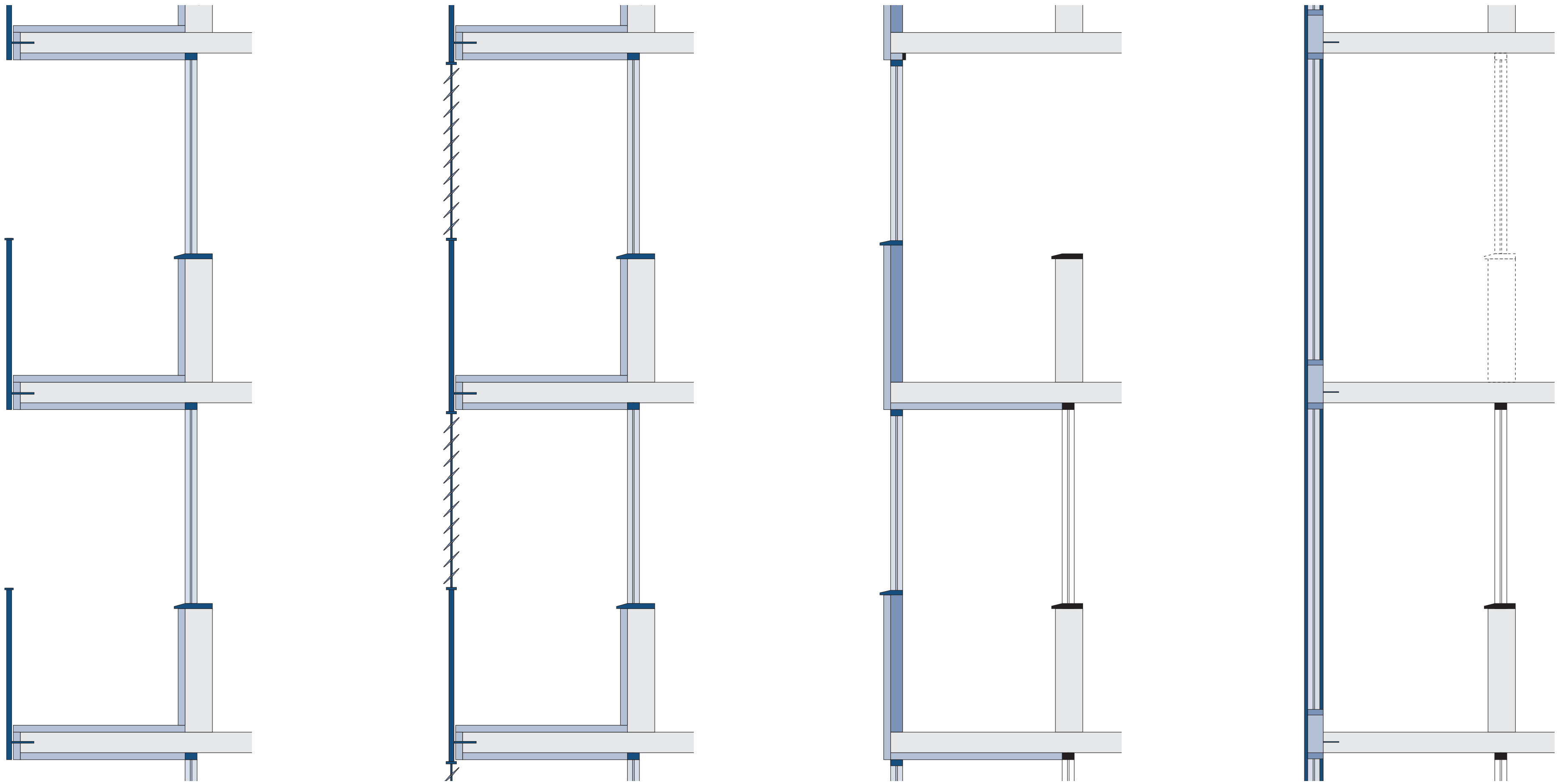
2. Building envelope design strategies employing redundancy of critical control functions are often superior to *'perfect barrier'* strategies. In general, they are less expensive and more forgiving to construct, since permissible variations in the quality of materials and workmanship are greater than those required by a *'perfect barrier'* approach.

3. In cold climates, experience indicates that when the requirements for the control of moisture migration have been satisfied, the other control requirements are either simultaneously satisfied, or more easily satisfied, than if moisture management is not addressed at the outset.

Keeping these assumptions in mind, the essential elements of an effective building envelope in a cold climate must address requirements for: structure; interior finish; vapour movement; heat flow; air leakage; and cladding (primarily exterior moisture management). Special requirements for fire and sound separation may also apply. The existing tower buildings provide structure and interior finishes; however, it is important to ensure the exiting substrate is sound and capable of supporting the overcladding system.

The basic strategies for overcladding are depicted in Figure 7.16. Each of these strategies should conform to the essential requirements for the control of heat, air and moisture management. Suitable measures for the control of solar radiation should also be employed corresponding to the solar orientation of the building façade.

As noted in the earlier section on building fire safety, the allowable area of unprotected openings and the combustibility of the overcladding may also have to be considered, depending on limiting distances.



Unenclosed Balcony
Overcladding
Replacement Window

Unenclosed Balcony
Overcladding
Replacement Window
Screen (Shading Device)

Enclosed Balcony
(Window Wall)

Enclosed Balcony
(Curtain Wall)

Figure 7.16. The basic overcladding strategies for tower buildings are identified in the schematic wall sections depicted above. For the unenclosed balcony types, the entirely unenclosed balcony is best suited to south-facing facades, while the unenclosed balcony with a screen, or shading device, is more appropriate for east and west-facing facades. The enclosed balcony types are generally less costly, but must carefully consider the arrangement of operable windows serving the enclosure, and the provision of suitable shading devices. Note how in the enclosed balcony cases, the existing exterior wall may be completely or partially disassembled. In all enclosed balcony cases, operable windows must be provided for natural ventilation.

Specific control strategies available to building envelope designers responsible for tower overcladding are summarized in Table 7.7. In most cases, an air/vapour barrier membrane will be installed over the existing masonry enclosure, followed by external insulation and a cladding.

CONTROL FUNCTION	PHYSICAL MECHANISM	CONTROL STRATEGY
Moisture Migration	***Bulk Water***	Shedding Conveyance Drainage Storage & Drying Drain-Screen Rain-Screen Dynamic Buffer Zone 'Perfect Barrier'
	Capillary Water	Capillary Barrier Capillary Break
	Vapour Diffusion	Vapour Barrier Thermal Insulation
	Air Leakage	Air Barrier System Thermal Insulation
Heat Transfer	***Conduction Radiation Convection***	Thermal Insulation Radiation Barrier Air Barrier System
Air Leakage	***Stack, Wind and Mechanical Effects***	Air Barrier System
Solar Radiation	***Heat***	Orientation Fenestration Shading Devices Thermal Resistance Glazing Reflectance and Emissivity
	Visible Light	Orientation Fenestration Shading Devices Glazing Optical Properties
Adapted from work by Bomberg, M.T. And Brown, W.C., 1993. *Building Envelope and Environmental Control: Part 1 - Heat, Air and Moisture Interactions.* Construction Canada, 35 (1).		

Table 7.7. Summary of control strategies available to resist physical mechanisms according to critical control functions for cold climate building envelopes.

The design of joints and drainage planes is essential to the acceptable long-term performance of overcladding assembles. Figure 7.17 depicts fundamental approaches to joints in cladding materials. In all cases, it is assumed a drainage plane is provided within the overcladding assembly to remove moisture that may penetrate under extreme phenomena. It is important to note these vary among overcladding system product manufacturers, and should be detailed, specified and installed accordingly.

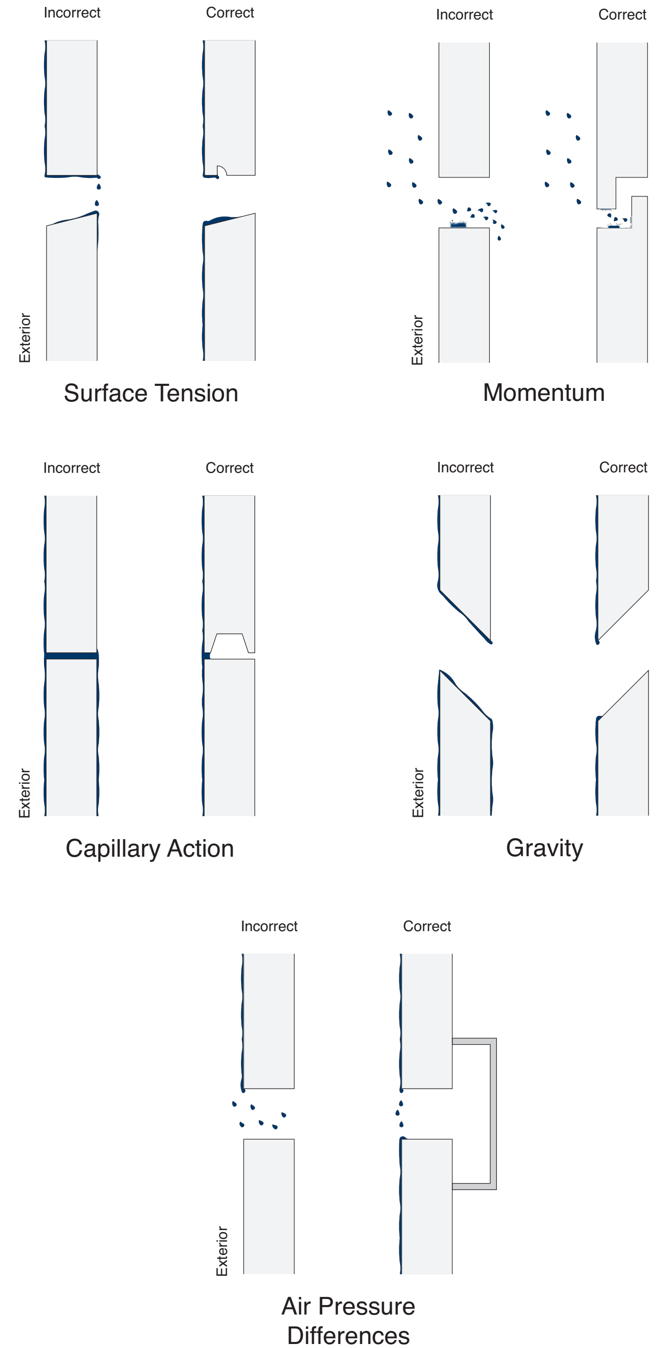


Figure 7.17. Proper approaches to joint design corresponding to moisture migration phenomena. [Source: Various publications – Institute for Research in Construction, National Research Council Canada.]

Differential Durability Considerations

In the process of selecting and arranging materials and components for overcladding, it is important to address durability concerns. *Differential durability* is a term used to describe how the useful service life of building components, such as structure, envelope, finishes and services, differs - both between components, and within the materials, assemblies and systems comprising the components.[12] The term may also be used to describe the whole building system by comparing between the service life of the building and its functional obsolescence.

An important term that is often absent in durability literature is service quality. This term goes beyond the purely functional performance of a product, component, assembly or construction to include attributes such as aesthetics. For example, two different roofing materials may have an identical service life, but exhibit different visual deterioration. One may appear unsightly after a fraction of its service life has expired, while the other may preserve its appearance until only a few years before becoming unserviceable. Functionally both keep out the water for as long a period of time, but the service quality of the latter is higher for longer, as depicted in Figure 7.18.

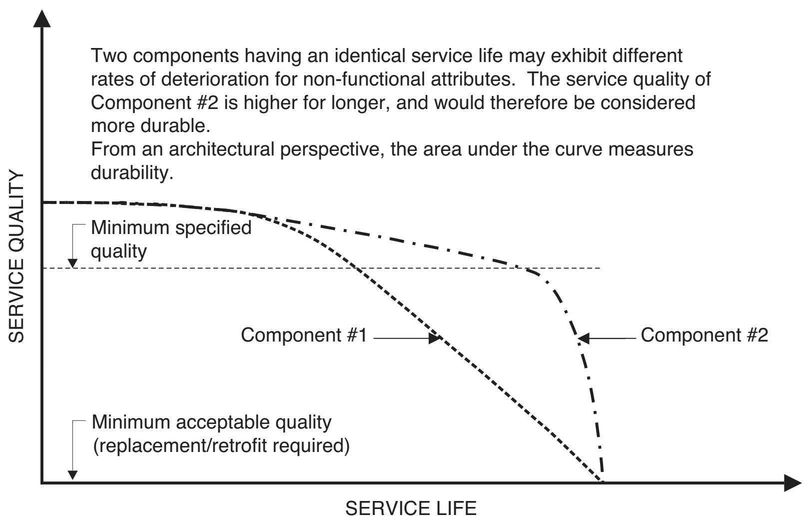


Figure 7.18. Service Quality X Service Life = Durability

A review of contemporary research generally indicates that with exception to structural elements, all of the other components require varying levels of maintenance, repair and replacement during the life cycle of the building. The extent and intensity of these recurring embodied energy demands vary significantly, depending on how appropriately the durability of materials, assemblies and systems are harmonized, and how accessible they are for periodic maintenance, repair and replacement.

Figure 7.19 depicts the key characteristics and relationships associated with differential durability concepts. As discussed earlier, durability may be expressed as a function of service quality and service life. There are three critical service quality thresholds related to durability: 1) the specified quality, established by the designer and/or minimum codes and standards, representing the typical new service condition; 2) the minimum acceptable quality indicating the need for replacement or retrofit; and 3) failure, where the material or assembly is considered completely unserviceable.

Failure may occur suddenly, as in the case of a lamp, pump or similar type of equipment, or it may result after gradual deterioration. Maintenance or restoration taking place prior to failure can extend the service life, whereas deferred retrofit or replacement beyond the minimum acceptable quality threshold can accelerate total failure. It is important to note that in some cases, the initial service quality of the material or assembly may exceed the specified quality based on codes and standards.

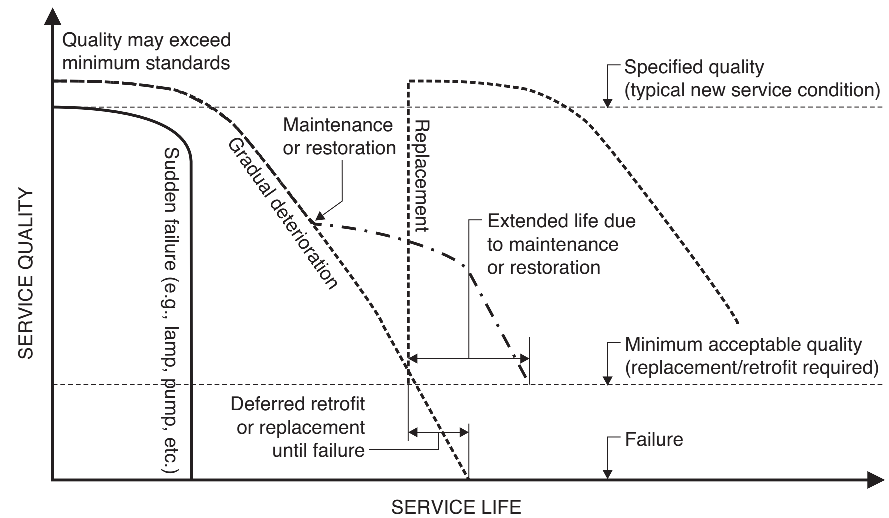


Figure 7.19. Durability characteristics and relationships as a function of service quality and service life.

Given these basic characteristics and relationships, it is possible to explore various aspects of differential durability. Figure 5 depicts the underutilization of durability in assemblies with interdependent components exhibiting differential durability. A practical example of interdependent durability is the case of bricks and brick ties, where the former often deliver a longer service life than the latter. When the inferior durability component reaches the end of its useful service life, the superior durability component is often replaced at the same time, resulting in an underutilization of its durability. The lesser the degree of durability harmonization, and the greater the degree of difference in initial service quality between components, the greater the underutilized or wasted durability (embodied energy) of the assembly. This underutilization has a direct impact on the recurring embodied energy demand over the building life cycle.

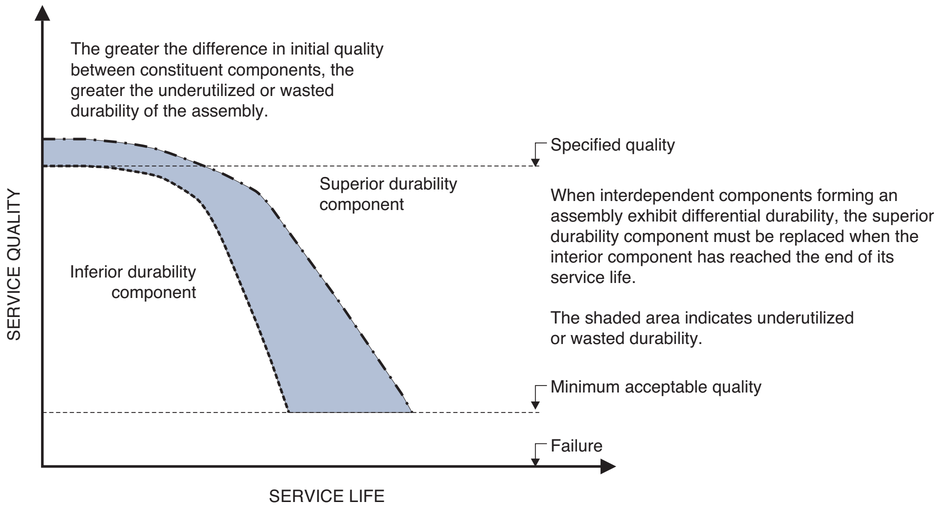


Figure 7.20. Underutilization of durability in assemblies with interdependent components exhibiting differential durability.

The magnitude of recurring embodied energy is compounded when the assembly is replaced at the end of the inferior component's service life, as depicted in Figure 7.20. This prematurely expended durability must be added to the underutilized durability when assessing the impacts of differential durability. This type of accounting, depicted in Figure 7.21, is not normally conducted in durability research related to the recurring energy content of buildings. At this time, it is difficult to accurately assess the magnitude of these compounding effects due to the scarce availability of verifiable data. However, a tour through any typical building demolition/reclaim yard indicates that many of the materials and components are serviceable. In the case of old windows where the glazing is serviceable long after the frames have deteriorated, the compound recurring energy for the glazing may easily approach 50%.

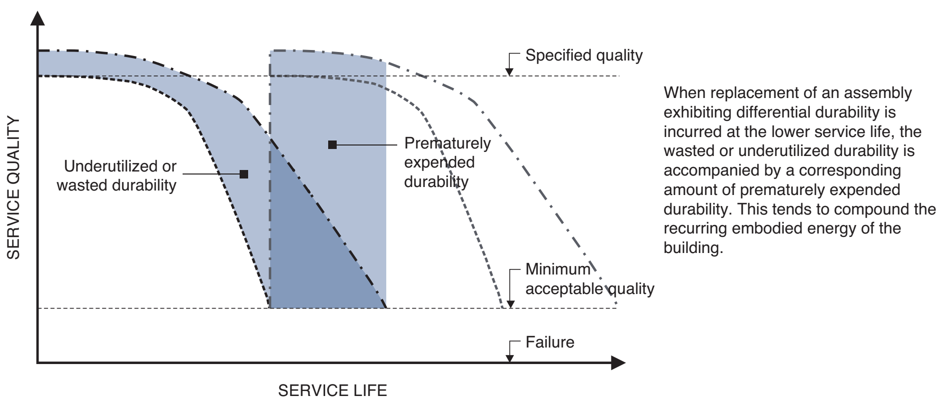


Figure 7.21. Compounding of recurring embodied energy due to underutilized (wasted) and prematurely expended durability.

The high-rise housing stock of Toronto exhibits differential durability among its primary systems: structure, envelope and building services. However, there is a remarkable harmonization of durability among the envelope components. Further, the envelope system chosen for this housing stock continues to provide a structurally sound substrate for various envelope rehabilitation strategies.

Why is differential durability a critical consideration in tower renewal? The existing tower buildings may be viewed as the armature for successive cycles of skin renewal. Protected by membranes and/or coatings, insulation and cladding, the tower armatures have an estimated useful service life of several hundred years. This translates into many successive cycles of skin renewal assuming a 50-year service life for each cycle. By selecting appropriate renewal strategies and harmonizing the durability of the overcladding, the cost and difficulty of successive cycles can be significantly reduced. Future innovations in cladding technology will be able to piggyback on properly formulated skin renewal strategies and provide generations of sustainable performance. A fundamental premise of these guidelines is to advise on the design of adaptive migration paths to affordable, cost effective tower renewal.

Differential durability is normally not desired within building envelope components and assemblies, where it should ideally be harmonized, but it can form part of a staged building sustainability strategy between systems. Selection of an extremely durable structural system (armature) can accommodate a succession of building envelope assemblies (skins) provided their components exhibit harmonized durability, and are designed for obsolescence (i.e., ease of replacement). Historically, architecture produced buildings with excellent durability characteristics. This was largely due to the traditional nature of the structural and envelope systems employed. As a prime example, load bearing masonry construction integrated armature and skin, hence the facade inherited the durability of the structure. Modern buildings have departed from this traditional approach, but designers have not yet fully appreciated that with a separation between armature and skin, building facades should be designed as sacrificial layers that will be replaced or rehabilitated several times during the useful life of a building.
From the perspective of sustainability, albeit unintentionally, post-war high-rise housing employed a building envelope system with affordable first costs that could later accommodate retrofit strategies to upgrade performance. For social housing, it is especially important to consider the fairness of having one generation alone bear the economic burden of sustainability. Designing envelope systems that allow for a generational migration from affordability, through adaptability, onto sustainability may be a feasible strategy for future high-rise housing needed to accommodate immigration to Canada's large urban centres.

Thermal Insulation

Another critical consideration for overcladding is the appropriate selection of thermal insulation. The selection of thermal insulation largely depends on its final use, and in most cases, good resistance to heat flow is not the only factor to consider. In specific situations, insulation may also need to possess some of the following physical properties:

- Thermal efficiency of the insulation (thickness available versus minimum required);
- Resistance to high temperatures (non-combustible);
- Resistance to moisture flow (effective management of water vapour movement);
- Resistance to air movement (integration within the air barrier system); and
- Compressive strength (ability to support foot traffic loads, withstand wind loads, etc.).

Matching material properties with a specific application also requires consultation with the manufacturer(s) to ensure the system will perform as intended and retain product warranties. It is also prudent to consider practical factors and review proposed retrofit measures with experienced contractors and trades to determine:

- Skill level of the installer;
- Need for special equipment (cutting, application, fastening);
- Forgiveness and ease of installation (conforms to irregular surfaces, joins together well);
- Seasonality (year round versus warm weather only);
- Coordination (number of steps/trades to complete envelope retrofit); and
- Availability of materials and trades (local versus imported).

Types of Insulation

The appropriate choice insulation will largely depend on how it will be used. Normally, different types of insulation are commonly used for insulating various building envelope assemblies such as walls, roofs and foundations. A description of the insulation materials commonly employed in the exterior retrofit of building envelopes is provided below.
This discussion is premised on the understanding that cold climate building envelopes normally comprise an exterior cladding to resist wind, rain and solar radiation, a drainage space to manage bulk water penetration, a sheathing or equivalent drainage plane on the inboard face of the drainage space, thermal insulation and an air/vapour barrier system. In some cases, a thermal insulation material is uni-functional, requiring a separate air barrier and vapour barrier. It may also be multi-functional, and effectively manage the flow of heat, air and moisture. For the purposes of tower retrofit projects, there are essentially two types of insulation that are suitable: rigid board insulation and spray-foam insulation.

Rigid Board Insulation

Board insulations are manufactured from glass fibre, mineral wool or foam plastic materials. These materials have a high insulating value per unit thickness. Insulating boards are lightweight and easy to cut and handle. Fitting them into irregular spaces, however, can be a tedious and time intensive process. Some board materials come with specialty facings or membranes and require their own system of attachment. Most board materials are manufactured in standard sizes but may also be ordered pre-cut to specific sizes for an additional cost.

Glass Fibre and Mineral Wool Boards

Two types of high-density, semi-rigid board insulation materials are commonly used in exterior wall applications: glass fibre and mineral wool (slag or rock wool). Glass fibre board insulation is usually manufactured from recycled glass and some types are classified as non-combustible – always check the manufacturer's specifications and product listings. Mineral wool board insulation is manufactured from slag or rock, and all types are considered non-combustible. The thermal insulation values vary depending on the thickness and density. The typical insulating values ranges from 0.028 RSI/mm (4.1-R/inch) to 0.031 RSI/mm (4.4-R/inch).

Expanded Polystyrene

Expanded polystyrene (EPS) is often referred to as "bead board" and it is commonly produced in two densities: low density, with an insulating value of 0.026 RSI/mm (3.7-R/inch); and high density, with an insulating value of 0.028 RSI/mm (4.0-R/inch). High-density board, specifically Type I Expanded Polystyrene Insulation Board (as per ULC-S701, and ASTM-C578) is commonly employed in exterior insulation and finish systems (EIFS). It must be protected from prolonged exposure to sunlight, solvents and some sealants – always check for material compatibility. Expanded polystyrene insulation requires covering with a fire-resistant material as it is considered combustible.

Extruded Polystyrene

Extruded polystyrene (XPS) is foam plastic board with fine, closed cells containing a mixture of air and refrigerant gases (fluorocarbons). It is manufactured in two densities: low density, with an insulating value from 0.033 RSI/mm (4.7-R/inch) to 0.035 RSI/mm (5.0-R/inch); and high density, with an insulating value of 0.035 RSI/mm (5.0-R/inch). It must be protected from prolonged exposure to sunlight or solvents. If joints and interfaces are sealed properly, XPS can perform as an air barrier, and certain thicknesses may perform as a vapour barrier. Extruded polystyrene insulation must be covered with a fire-resistant material as it is considered combustible.

Polyurethane and Polyisocyanurate Boards

These products consist of plastic boards made of closed cells containing refrigerant gases (fluorocarbons) instead of air. Usually these come double-faced with foil in a variety of sizes and have a typical insulating value of 0.040 RSI/mm (5.8-R/inch) to 0.050 RSI/mm (7.2-R/inch). Similar to extruded polystyrene products, these products can act as a vapour barrier when sufficiently thick, and as an air barrier if joints and interfaces are well sealed. Polyurethane and polyisocyanurate insulation boards must be protected from prolonged exposure to sunlight and water, and they must be covered with a fire-resistant material as they are considered combustible. This high performance insulation is generally limited to areas where a high thermal resistance is desired and space is at a premium.

Spray-Foam Insulation

This type of insulation is mixed on the job site by the contractor or installer. The liquid foam is sprayed directly onto the building surface using a spray gun driven by a pump. The foam expands in place and sets in seconds. The installation contractor should be trained in the application of the specific product and certified by a listed agency.

Polyurethane Foam

A foam of closed cells containing refrigerant gases (fluorocarbons), polyurethane foam used in exterior envelope applications is termed medium-density ranging from 24 kg/m^3 (1.5 lbs/ft^3) to 32 kg/m^3 (2 lbs/ft^3) and having a typical insulating value of 0.042 RSI/mm (6.0-R/inch). The insulation is sprayed onto surfaces in layers less than 50 mm (2 inch) thick and it hardens in seconds. Substrates must have a surface temperature no lower than 5 ^{O}C (40 ^{O}F) and no higher than 50 ^{O}C (120 ^{O}F) for proper adhesion and setting. Medium-density spray polyurethane foam insulation can be used as an air barrier, and is considered a vapour barrier for a 38 mm (1.5 inch) thickness or greater. It must be protected from prolonged exposure to sunlight and requires covering with a fire-resistant material as it is considered combustible.

Semi-Flexible Isocyanurate Plastic Foam
A combination of isocyanurate, resins and catalysts forms this open-celled, semi-flexible plastic foam insulation which has an insulating value of 0.026 RSI/mm (3.7-R/inch). There are some limitations on the thickness that can be applied. It can be used as an air barrier, but it is highly vapour permeable, hence a separate vapour barrier is required. Isocyanurate plastic foam insulation must be covered with a fire-resistant material as it is considered combustible.

	Critical Properties and Typical Applications						
Insulation Type	Thermal Resistance	Combustible	Air Barrier	Vapour Barrier	Walls (Exterior)	Roof (Exterior)	Below Grade
Glass Fibre Board	0.028 RSI/mm (4.1-R/inch) to 0.031 RSI/mm (4.4-R/inch)	Yes[1]	No	No	Yes	Yes	Yes
Mineral Wool Board		No	No	No	Yes	Yes	Yes
Expanded Polystyrene (EPS) Board	0.028 RSI/mm (4.0-R/inch)	Yes	No	No	Yes	No	Yes
Extruded Polystyrene (XPS) Board	0.035 RSI/mm (5.0-R/inch)	Yes	Yes[2]	Yes[3]	Yes	Yes	Yes
Polyurethane & Polyisocyanurate Board	0.040 RSI/mm (5.8-R/inch) to 0.050 RSI/mm (7.2-R/inch)	Yes	Yes[2]	Yes[3]	Yes	Yes	Yes
Polyurethane Spray Foam	0.042 RSI/mm (6.0-R/inch)	Yes	Yes	Yes[3]	Yes	Yes	Yes
Isocyanurate Spray Foam	0.026 RSI/mm (3.7-R/inch)	Yes	Yes	No	Yes	No	No

[1] Check with manufacturer specifications and product listing.
[2] Air barrier can be achieved with sealed/taped joints and interfaces.
[3] Vapour barrier can be achieved with sufficient thickness.

Table 7.8. Summary of suitable insulation types for tower retrofits, their critical properties and typical applications. Always check to ensure insulation products conform with applicable codes and standards, especially for novel offshore materials.

Unlike new buildings, where their minimum thermal efficiency is stipulated in applicable codes and standards, the minimum amount of thermal insulation for retrofit applications must be carefully considered by the designer. Beyond a certain amount, insulation does not offer significant performance benefits, as shown in Figure 7.22. Typically, insulation comes in standard thicknesses for semi-rigid and rigid board stock materials. In the case of spray foam insulation, standard size framing members will usually dictate the available thickness for application. Since insulation is a relatively inexpensive material compared to cladding and windows, it is prudent to specify the next higher standard thickness rather than reducing the amount, as this will account for inconsistent workmanship and the aging of insulation materials. Recommended minimum levels of thermal insulation for tower retrofits are summarized in Table 7.11.

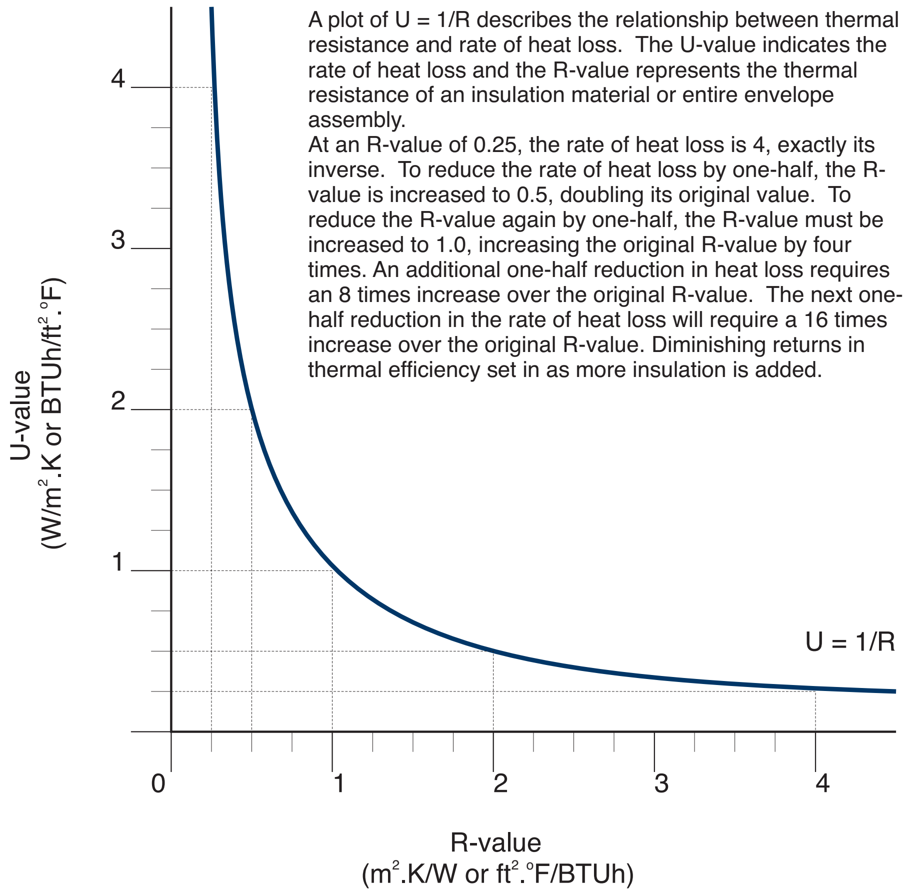


Figure 7.22. A plot of thermal conductance versus thermal resistance reveals how diminishing returns influence the optimal amount of thermal insulation. The optimal thickness of thermal insulation is guided by life cycle costs of the entire building system.

Windows and Glazing

Equally as critical as the thermal insulation is the proper selection of windows and glazing. Windows should be selected for durability and energy efficiency with a view to daylighting and natural ventilation. To reduce heating energy demand by maximizing solar gains, select the highest SHGC available for south-facing facades (usually 0.40-0.65 for the U-value ranges required in the Canadian climate). If cooling is a significant concern, as in the case of west facing facades, select windows with a SHGC less than 0.55. Optimal glazing selection is best determined through proper energy modeling. Some of the important windows and glazing terminology is provided below.

U-value - the rate of heat flow through a window or other building element. Also called the thermal transmittance. Reciprocal of thermal resistance, U = 1/R . Units W/m².°C (SI system), Btu/h.ft². °F (Imperial system). For windows, further differentiated for centre-of-glass (U_{cog}), edge-of-glass (U_e) and frame (U_f) regions. Overall total area-weighted U-value U_{tot} results.

U-value overall total area weighted (U_{tot}) - the area-weighted average thermal conductance of the complete window, including centre-of-glass, edge-of-glass and frame U-values.

Shading coefficient (SC) - the ratio of solar heat gain through a window to the solar heat gain through a single layer of 3mm clear glass under the same environmental conditions. Alternatively defined as the solar gain divided by the solar irradiance divided by 0.86, where 0.86 is the total fraction of solar energy incident on a clear 3mm pane of glass which is transferred through the glazing by all means (direct component plus inward-flowing fraction of absorbed component).

Solar heat gain coefficient (SHGC) - the solar gain divided by exterior solar irradiance. Thus it is composed of the solar direct transmittance plus the inward-flowing fraction of the solar absorptance (secondary inward heat transfer coefficient). For near-normal incidence only, SHGC = SC X 0.86. Also equal to the total solar energy transmittance (TSET).

Window-to-wall ratio (WWR) - the fraction of the total area of a building facade that is occupied by windows.

		Centre of Glass Properties			
# of Glazings	**Glazing Type**	**U-value**	**RSI**	**SHGC**	**Visible Transmittance**
Single Glazing	Clear Glass	5.91	0.17	0.86	0.90
Double Glazing	12.7 mm air filled	2.73	0.37	0.76	0.81
	12.7 mm air filled, e=0.20 on one surface	1.99	0.50	0.65	0.76
	12.7 mm air filled, e=0.10 on one surface	1.82	0.55	0.54	0.75
	12.7 mm argon filled, e=0.10 on one surface	1.53	0.65	0.54	0.75
Triple Glazing	13 mm air filled	1.76	0.57	0.68	0.74
	13 mm air filled, e=0.20 on one surface	1.42	0.70	0.60	0.68
	13 mm air filled, e=0.10 on two surfaces	1.02	0.98	0.41	0.62
	13 mm argon filled, e=0.10 on two surfaces	0.80	1.25	0.41	0.62

All values refer to centre of glass and have been summarized for comparative purposes only.
Use overall effective thermal resistance values for window selection and energy modeling.
All glass thickness 3 mm, normal angle of incidence for SHGC and Visible Transmittance.
Low-e coatings on surface 2 for double glazing, surfaces 2 & 5 for triple glazing.

Table 7.9. Most existing tower buildings have single glazing that is thermally inefficient, but provides high visible transmittance for daylighting. When selecting replacement windows, the SHGC and Visible Transmittance values of the glazing are important variables.
[Source: ASHRAE Handbook of Fundamentals.]

Optimizing the overcladding and replacement window systems is not a straightforward task. Designers often look to current codes and standards for guidance; however, these are often not based on a rigorous cost-benefit methodology. It is not advisable to optimize the thermal insulation and windows in isolation from the whole building system; however, it is also important to recognize the performance of the building envelope will strongly influence life cycle costs and environmental impacts, such as greenhouse gas emissions.

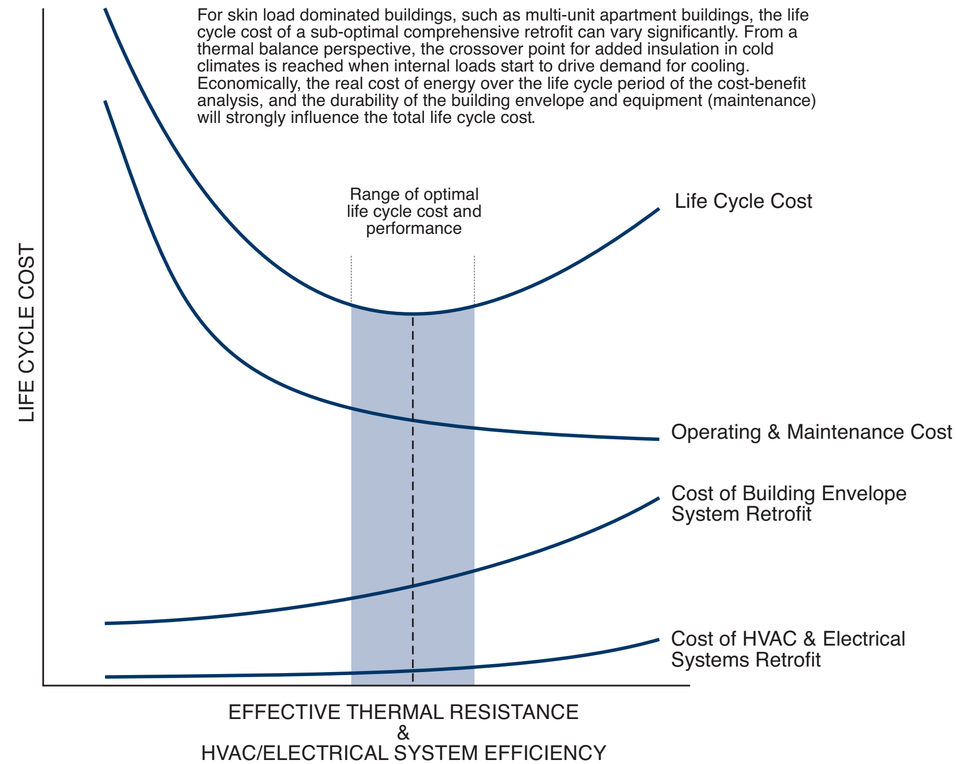


Figure 7.23. The optimization of the performance of the building-as-a-system over its life cycle must account for all of the system interactions over the useful service life of the asset. In the case of concrete frame tower buildings, several centuries of service life remain for the armature, which is capable of supporting many successive skins and HVAC/electrical systems. A life cycle cost assessment of the entire building system over a 50-year period is recommended in these guidelines. This should also be reconciled with intangible benefits such as enhanced thermal comfort, indoor air quality and the improvement of the aesthetic quality of the urban landscape.

Table 7.10 lists the overall, effective U-values of generic windows based on the types of glazing. This is intended as a convenient reference in the absence of product-specific ratings data provided from independent testing agencies. Refer to Figure 7.24 to determine the effective thermal resistance of the exterior wall assemblies based on the window-to-wall ratio and the amount of insulation provided with the overcladding.

Product Type	Glass Only	Operable					Fixed					Curtain Wall		
Frame Type	n/a	Alum w.o. Therm Break	Alum with Therm Break	Re-inforced Vinyl/ Alum Clad Wood	Wood/ Vinyl	Insul Fibrglas / Vinyl	Alum w.o. Therm Break	Alum with Therm Break	Re-inforced Vinyl/ Alum Clad Wood	Wood/ Vinyl	Insul Fibrglas / Vinyl	Alum w.o. Therm Break	Alum with Therm Break	Struct Glzg
Glazing Type	Cntr-of-Glass													
Single Glazing														
1/8 in. glass	5.91	7.21	6.13	5.11	5.05	4.60	6.42	6.08	5.56	5.56	5.34	6.93	6.30	6.30
1/4 in. acrylic/polycarbonate	5.00	6.47	5.45	4.49	4.43	4.03	5.62	5.22	4.77	4.77	4.60	6.13	5.45	5.45
1/8 in. acrylic/polycarbonate	5.45	6.87	5.79	4.83	4.71	4.32	6.02	5.68	5.17	5.17	4.94	6.53	5.91	5.91
Double Glazing														
1/4 in. airspace	3.12	4.94	3.69	3.24	3.12	2.78	3.92	3.58	3.18	3.18	3.01	4.49	3.86	3.58
1/2 in. airspace	2.73	4.60	3.41	3.01	2.90	2.50	3.63	3.24	2.84	2.84	2.73	4.14	3.52	3.24
1/4 in. argon space	2.90	4.77	3.52	3.12	3.01	2.61	3.75	3.35	3.01	2.95	2.84	4.26	3.63	3.41
1/2 in. argon space	2.56	4.49	3.29	2.90	2.78	2.44	3.46	3.07	2.73	2.73	2.56	3.97	3.35	3.12
Double Glazing, e=0.40 surface 2 or 3														
1/4 in. airspace	2.78	4.66	3.46	3.01	2.90	2.56	3.63	3.29	2.90	2.90	2.78	4.20	3.58	3.29
1/2 in. airspace	2.27	4.26	3.07	2.73	2.56	2.27	3.24	2.84	2.50	2.50	2.33	3.75	3.12	2.90
1/4 in. argon space	2.44	4.43	3.24	2.84	2.67	2.33	3.35	3.01	2.61	2.61	2.50	3.92	3.24	3.01
1/2 in. argon space	2.04	4.09	2.95	2.56	2.44	2.10	3.01	2.67	2.33	2.27	2.16	3.58	2.90	2.67
Double Glazing, e=0.20 surface 2 or 3														
1/4 in. airspace	2.56	4.49	3.29	2.90	2.78	2.44	3.46	3.07	2.73	2.73	2.56	3.97	3.35	3.12
1/2 in. airspace	1.99	4.03	2.90	2.50	2.38	2.04	3.01	2.61	2.27	2.21	2.10	3.52	2.90	2.61
1/4 in. argon space	2.16	4.20	3.01	2.61	2.50	2.16	3.12	2.73	2.38	2.38	2.27	3.63	3.01	2.78
1/2 in. argon space	1.70	3.80	2.67	2.33	2.21	1.87	2.73	2.33	2.04	1.99	1.87	3.24	2.61	2.38
Double Glazing, e=0.10 surface 2 or 3														
1/4 in. airspace	2.38	4.37	3.18	2.78	2.67	2.33	3.35	2.95	2.61	2.56	2.44	3.86	3.24	2.95
1/2 in. airspace	1.82	3.92	2.78	2.38	2.27	1.99	2.84	2.44	2.10	2.10	1.99	3.35	2.73	2.50
1/4 in. argon space	1.99	4.03	2.90	2.50	2.38	2.04	3.01	2.61	2.27	2.21	2.10	3.52	2.90	2.61
1/2 in. argon space	1.53	3.69	2.56	2.21	2.10	1.76	2.61	2.21	1.87	1.87	1.76	3.12	2.50	2.21
Double Glazing, e=0.05 surface 2 or 3														
1/4 in. airspace	2.33	4.32	3.12	2.73	2.61	2.27	3.29	2.90	2.56	2.50	2.38	3.80	3.18	2.90
1/2 in. airspace	1.70	3.80	2.67	2.33	2.21	1.87	2.73	2.33	2.04	1.99	1.87	3.24	2.61	2.38
1/4 in. argon space	1.87	3.97	2.78	2.44	2.33	1.99	2.90	2.50	2.16	2.16	2.04	3.41	2.78	2.50
1/2 in. argon space	1.42	3.58	2.50	2.16	2.04	1.70	2.50	2.10	1.82	1.76	1.65	3.01	2.38	2.16
Triple Glazing														
1/4 in. air spaces	2.16	4.09	2.90	2.50	2.44	2.16	3.12	2.73	2.38	2.33	2.27	3.58	2.95	2.67
1/2 in. air spaces	1.76	3.80	2.61	2.27	2.21	1.93	2.78	2.38	2.04	1.99	1.93	3.24	2.61	2.33
1/4 in. argon spaces	1.93	3.92	2.73	2.38	2.33	1.99	2.90	2.56	2.21	2.16	2.04	3.41	2.78	2.44
1/2 in. argon spaces	1.65	3.69	2.50	2.16	2.10	1.82	2.67	2.27	1.93	1.93	1.82	3.12	2.56	2.21
Triple Glazing, e=0.20														
1/4 in. air spaces	1.87	3.92	2.67	2.33	2.27	1.99	2.84	2.50	2.16	2.10	2.04	3.35	2.73	2.38
1/2 in. air spaces	1.42	3.52	2.33	2.04	1.99	1.70	2.44	2.10	1.76	1.70	1.65	2.95	2.33	1.99
1/4 in. argon spaces	1.59	3.69	2.50	2.16	2.10	1.82	2.61	2.27	1.93	1.87	1.82	3.07	2.50	2.16
1/2 in. argon spaces	1.25	3.41	2.21	1.93	1.87	1.59	2.33	1.93	1.65	1.59	1.53	2.78	2.16	1.87
Triple Glazing, e=0.20														
1/4 in. air spaces	1.65	3.69	2.50	2.16	2.10	1.82	2.67	2.27	1.93	1.93	1.82	3.12	2.56	2.21
1/2 in. air spaces	1.14	3.29	2.16	1.82	1.76	1.53	2.21	1.87	1.53	1.48	1.42	2.73	2.10	1.76
1/4 in. argon spaces	1.31	3.46	2.27	1.93	1.87	1.65	2.38	1.99	1.70	1.65	1.59	2.84	2.21	1.93
1/2 in. argon spaces	0.97	3.18	2.04	1.70	1.65	1.42	2.10	1.70	1.42	1.36	1.31	2.56	1.93	1.65
Triple Glazing, e=0.10														
1/4 in. air spaces	1.53	3.63	2.44	2.10	2.04	1.76	2.56	2.21	1.87	1.82	1.76	3.07	2.44	2.10
1/2 in. air spaces	1.02	3.24	2.04	1.76	1.70	1.42	2.10	1.76	1.42	1.42	1.31	2.61	1.99	1.65
1/4 in. argon spaces	1.19	3.35	2.21	1.87	1.82	1.53	2.27	1.93	1.59	1.53	1.48	2.73	2.16	1.82
1/2 in. argon spaces	0.79	3.07	1.87	1.59	1.53	1.31	1.93	1.59	1.25	1.19	1.14	2.38	1.82	1.48

Table 7.10. Overall, effective U-values of commonly available window assemblies (W/m^2.^{o}C). The lower the effective U-value, the better the energy efficiency of the window. Note how the centre of glass U-values are significantly lower than the overall, effective U-values of the entire window assembly. Do not use centre of glass U-values or R-values to calculate energy performance, as the results will be incorrect. To obtain the RSI-values corresponding to the U-values listed in the table, these are simply the reciprocal and may be calculated as 1/U-value. To convert to Imperial units, RSI-value x 5.678 = R-value. [Excerpted from ASHRAE Handbook of Fundamentals.]

Figure 7.24 indicates the effective thermal resistance of various exterior wall assemblies based on the window-to-wall ratio and the effective thermal resistance of the opaque overcladding. High window areas and/or inefficient windows significantly degrade the effective thermal resistance of exterior walls. Table 7.11 summarizes the recommended minimum thermal efficiency ratings for windows, walls and roofs that can be used as the departure point for a proper cost-benefit analysis using life cycle economics.

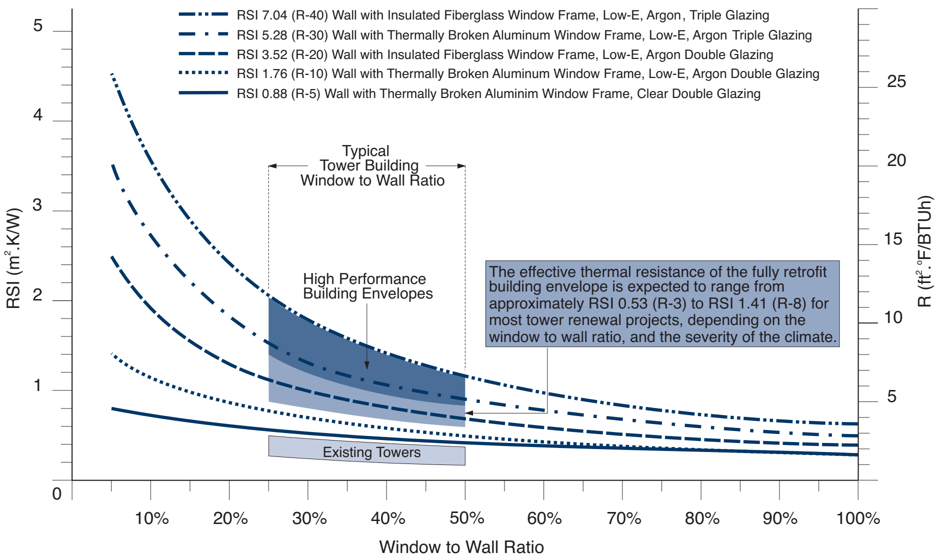


Figure 7.24. The typical tower building window-to-wall ratio (WWR) falls within a range of 25% to 50%. The vast majority of existing buildings fall within the 25% to 35% range. As a result, increasing the thermal resistance of the opaque wall elements is generally more cost effective than upgrading window performance. However, in all cases windows should be selected with a minimum level of thermal performance sufficient to avoid condensation under heating design temperature conditions.

The data in Table 7.11 may be used to begin the process of optimizing the tower building envelope retrofit. As an example, Toronto falls into the 3,500 to 5,000 degree-days Celsius range. The maximum recommended window U-value is 1.99 W/m².°C (hence, the minimum RSI-value is 0.50 m².°C/W). Looking at Table 10, a fixed window with a thermally broken aluminum frame and low-e double glazing, argon fill has a U-value of 2.21 (RSI 0.45), slightly higher than the recommended U-value rating. The data in Table 7.11 is generic, and there are aluminum window manufacturers producing more efficient units that could be specified. By comparison, the same glazing in an insulated fiberglass or vinyl frame has a U-value of 1.76. In the case of balcony enclosures where the existing building envelope is being retained, it is possible to use slightly less efficient windows for the enclosure since its thermal resistance is reinforced by the existing components.

Next, the thermal efficiency of the overcladding may be determined from Table 7.11. The effective thermal resistance of the overcladding assembly is given as RSI 2.82 (R-16) and due to the normally expected levels of thermal bridging, this translates into a nominal value of RSI 3.52 (R-20). This is the amount of insulation that should be specified in the overcladding assembly in order to achieve the minimum recommended effective thermal resistance. Note that the thermal resistance of the existing envelope is not factored into the values listed in Table 7.11 since it is typically insignificant. The relatively small contribution of the existing envelope to the overall, effective thermal resistance of the retrofit wall assembly roughly corresponds to the degradation of thermal resistance in the insulation materials over time, and loss of effectiveness due to imperfect workmanship and settlement/movement.

The effective thermal resistance of the replacement roof assembly is listed in Table 7.11 as RSI 3.52 (R-20), translating into a nominal value of RSI 4.23 (R-24) to account for thermal bridging and penetrations.

Based on Figure 7.24, the minimum effective thermal resistance of the retrofit wall assembly corresponds to the middle curve, and will range from RSI 0.53 (R-3) to RSI 1.06 (R-6). Figure 7.24 does not include thermal resistance of the roof. Normally, the contribution of the roof to the overall thermal resistance of the above-grade building envelope is negligible because the roof area is relatively small in comparison to the area of the opaque walls and windows.

	Window		Wall		Roof	
	U/RSI-value W/m².°C	U/R-value BTU/h.ft².°F	RSI-value m².°C/W	R-value h.ft².°F/BTU	RSI-value m².°C/W	R-value h.ft².°F/BTU
	U overall effective values.		Values indicate effective/nominal thermal resistance of assembly.			
Up to 3,500 Degree-Days	3.12/0.32	0.55/1.82	2.11/2.82	12/16	2.11/2.82	12/16
3,500 - 5,000 Degree-Days	1.99/0.50	0.35/2.86	2.82/3.52	16/20	3.52/4.23	20/24
5,000+ Degree-Days	1.42/0.70	0.25/4.0	3.52/4.40	20/25	4.93/5.64	28/32
	Solar heat gain coefficient (SHGC) of glazing to be selected according to solar orientation.					

Table 7.11. Table of recommended minimum effective thermal efficiency ratings for window, wall and roof assemblies to be achieved in comprehensive tower building envelope retrofits.

IMPORTANT NOTE: *It is extremely critical to recognize that the effective USI and U-values listed in Table 7.11 represent the performance of the entire window assembly including the effects of sash, frames and spacers in multiple-glazed units. The use of centre of glass thermal performance values is incorrect. Products from manufacturers who are unable to provide values from third party testing agencies and/or laboratories should be avoided.*

It is important to appreciate the recommended values in Table 7.11 are not prescriptive. As noted earlier, they simply serve as reasonable departure points for a thorough cost-benefit analysis. Actual values may vary slightly when the life cycle cost of the retrofit tower building is optimized. Refer to Part 8 for a detailed example and discussion of this process.

The section that follows examines a pivotal tower retrofit strategy related to balconies. The selection of appropriate overcladding and replacement windows does not directly address the issue of how to retrofit balconies, yet these distinguishing features of tower buildings represent a formidable technical and architectural challenge.

Balcony Enclosure

Balcony enclosure is one of the means available to reduce energy consumption, prevent continued deterioration of cantilevered balcony slabs and improve thermal comfort of balcony areas in tower buildings. Aesthetics, economics, durability, code requirements, and building as a system effects are among the issues that have to be carefully considered when selecting this approach to retrofit of the building envelope.

- Tower building aesthetics are strongly influenced by the type and arrangement of balconies, and the appearance of the retrofit building will be affected by balcony enclosure.
- The economics of tower renewal are determined to a great degree by improved energy performance and balcony enclosures address the weakest link in tower buildings. There is a potential to increase the liveable floor space with balcony enclosures and render this area comfortable for the whole year, or to extend the amount of time it is fairly comfortable. This measure may also affect property assessments and taxes.
- Exposed, cantilevered balcony slabs represent a liability that balcony enclosure can cost effectively convert into an asset that extends their service life.
- Balcony enclosure may not always prove practical for reasons of fire safety as the plane of unprotected openings projects outward from the building face.
- Building as a system effects associated with balcony enclosure can impact natural ventilation, daylighting and the potential for condensation in unconditioned enclosures.

From an aesthetic perspective, the appearance of the façade of tower buildings is strongly influenced by the arrangements of balconies. Existing balconies typically provide shading of the conditioned suites and render depth to the façade through an interplay of light, shade and shadow. Balcony enclosure affects the apparent massing of the building as the projecting balcony slabs and shear walls are obscured by the enclosure. Materiality and the rendering of surfaces also offer opportunities for re-invigorating tower facades and incorporating performative qualities, such as the collection of solar energy, or the display of art and media. While it is certain that overcladding will affect the aesthetics of tower buildings, it remains largely in the hands of the designer to determine whether this will prove beneficial or detrimental.

Tower retrofit economics encompass a broad range of stakeholder interests. Building owners seek to maintain the durability of their assets, hopefully improving their quality through appropriate retrofits. But their investments require reasonable returns if they are to be affordable. Improved resource conservation (energy and water) is able to deliver cost savings, but these must be accommodated by financial arrangements that recognize long-term performance benefits. A critical consideration remains the significant expenditures during the retrofit phase before any benefits are accrued during the investment recovery phase. From the tenant perspective, minimal disruption is tolerable if comfort and amenity are improved without unreasonable rent increases. In general, balcony enclosure has the potential to offer cost and performance advantages over unenclosed balconies, and may prove less disruptive since in most cases, the original façade enclosing the suite remains undisturbed. This retrofit option may also contribute to improved marketability by offering year-round amenity.

Figure 7.25. Balconies often influence and occasionally define the architectural quality of tower building facades. [Photo: Jesse Colin Jackson.]

Figure 7.26. Tower balconies come in a variety of types and arrangements that will challenge the design of pleasing and performative balcony enclosures. [Photos: Jesse Colin Jackson.]

Durability of balcony slabs and projecting shear walls is enhanced when a full balcony enclosure strategy is elected. In addition to minimizing the exposure of the reinforced concrete structure to the elements and atmosphere, the temperature regime of the structure is greatly moderated. This assumes that water shedding and thermal bridging are appropriately addressed in the enclosure construction details. While the advantages associated with balcony enclosure are also largely conveyed by the overcladding of unenclosed balconies, the probability of moisture penetration and thermal bridging at fasteners and material interfaces is lower in enclosed balconies. Balcony enclosures also provide both a thermal and dynamic wind buffer in a single application over the tower armature.

Figure 7.27. Exposed balcony slabs are the weak link in the existing stock of tower buildings. [Photo: Jesse Colin Jackson.]

Code requirements pertaining to balcony enclosures are for the most part related to limiting distance (spatial separation for reasons of fire safety). A more detailed discussion of this issue was presented earlier on, but it is important to recognize that as the plane of glazed opening extends outwards from the building, the allowable amount of glazing area may be significantly reduced. Normally, tower buildings with faces near adjacent property lines are affected, and there may be cases where the unenclosed balcony is the only practical option.

Building as a system effects are certain with the enclosure of balconies. The addition of a second enclosure may impact natural ventilation and daylighting of the main apartment suite. Depending on the climate and solar orientation, it may be necessary to condition, partially or fully, the enclosed balcony space to avoid condensation problems that may potentially range from nuisance to mold growth.

The next section examines the energy performance and condensation potential associated with various approaches to balcony enclosure.

Figure 7.28. In Canada, balconies provide seasonal amenity that can be extended by balcony enclosure. [Photo: Jesse Colin Jackson.]

Figure 7.29. The highest potential for balcony enclosures adversely affecting daylighting and natural ventilation is associated with recessed balconies. [Photo: Jesse Colin Jackson.]

Annual Energy Consumption and Condensation Potential

An extensive analysis of balcony enclosure performance was conducted employing computer simulation according to the parameters set out in Figure 7.30. The intent of the analysis was to assess the relative energy performance and condensation potential associated with a number of balcony enclosure strategies. Beginning with the existing condition having no balcony enclosure, 8 additional cases were considered. These were assessed according to the climates of 5 different urban centres across Canada that spanned a broad range of severity and duration of winter weather, as noted in Table 7.12 below.

	Degree-Days Below 18 °C	January Daily Average (°C)
Vancouver BC	2927	3.3
Victoria BC	3041	3.8
Toronto ON	4066	-6.3
Halifax NS	4367	-6.0
Montreal QC	4519	-10.2
Ottawa ON	4602	-10.8
Charlottetown PE	4715	-8.0
Fredericton NB	4751	-9.8
Calgary AB	5108	-8.9
Quebec City QC	5202	-12.8
Sudbury ON	5344	-13.6
Edmonton AB	5708	-13.5
Winnipeg MB	5778	-17.8

■ Indicates locations assessed for energy use and condensation potential.

Based on Climate Normals 1971 - 2000, Environment Canada using local airport data.

http://www.climate.weatheroffice.ec.gc.ca/climate_normals/index_e.html

Table 7.12. Range of degree-day and January daily average temperatures for Canadian urban centres, including those considered in the assessment of annual heating/cooling energy consumption and balcony enclosure condensation potential.

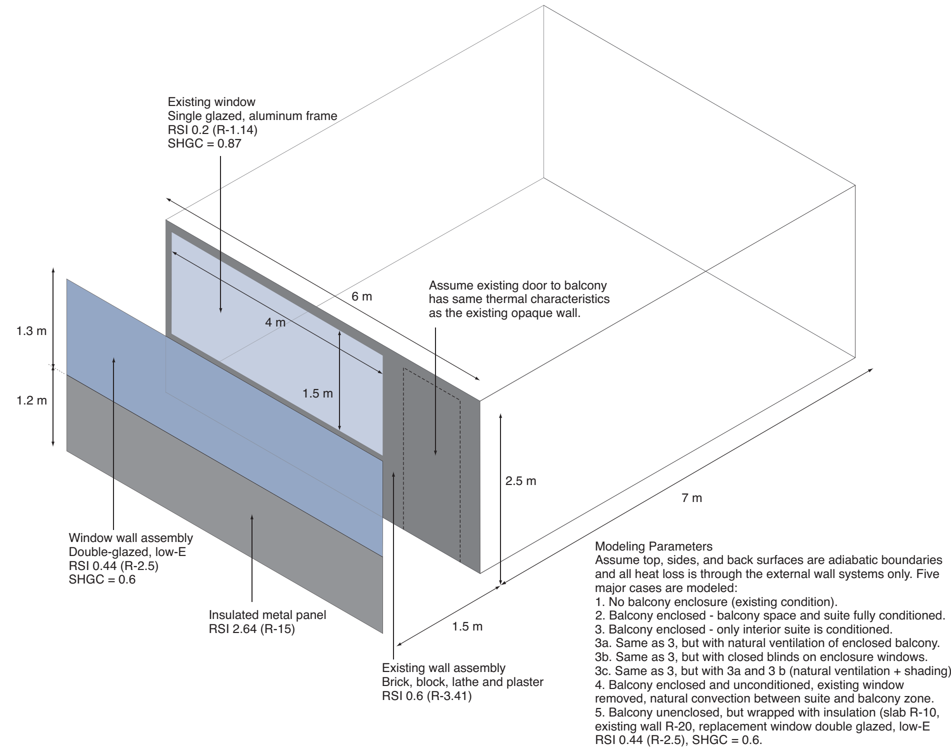


Figure 7.30. Modeling parameters and assumptions used in the computer simulation of energy consumption and condensation potential for balcony enclosures.

Case 1 assumes the existing balcony condition with no enclosure. A nominal ventilation rate corresponding to minimum Code requirements was applied to this and every subsequent case. Air leakage was adjusted to reflect increased airtightness for all balcony enclosure cases and Case 5 featuring comprehensive overcladding and window replacement.

Case 2 has the balcony enclosed with a window wall system having the characteristics noted in Figure 7.30, and it is fully conditioned, both heating and cooling. In this simulation scenario, the windows are assumed to remain shut except when outdoor temperature conditions are within the interior setpoint of 22 °C.

Case 3 has the balcony enclosed identically to Case 2, but the enclosed balcony space is not conditioned. The temperature here is allowed to float and again, the windows are assumed to remain shut except when outdoor temperature conditions are comfortable. Then, three separate cases are considered for Case 3.

Case 3a is identical to Case 3, but the operable windows are kept open at all times. It is unlikely this is how the balcony enclosure would be operated by occupants, but for modeling purposes it reveals the seasonal impacts of natural ventilation.

Case 3b is also identical to Case 3 but the windows are left closed at all times and shading devices (blinds) are fully drawn to reject solar gains.

Case 3c is a combination of Cases 3a and 3b, where the operable windows are left open, and the blinds are fully drawn at all times.

Case 3d is a hybrid of Case 3 and 3c, where the windows are shut and the blinds are not activated through the heating season, and the windows are open and the blinds full drawn during the cooling season. This resembles how the unconditioned, enclosed balcony would most likely be operated to conserve heating energy during cold weather, and cooling energy during hot weather.

Case 4 is identical to Case 3 where the balcony is enclosed and unconditioned, but it has removed the existing window that is between the suite and enclosed balcony areas. This allows natural convection of the heating and cooling to distribute heat to the enclosed balcony area.

Case 5 has no balcony enclosure, but the balcony slab and walls are overclad with an insulated assembly, and the windows have been replaced.

The results of simulations using ESP-r energy modeling software for all 8 cases are presented in Table 7.13 for Toronto, Ontario. Separate results are presented for each cardinal solar orientation.

Toronto ON

North

	1	2	3	3a	3b	3c	3d	4	5
Annual Apt Heating Energy (kWh)	6880.5	64.618	565.25	2511.1	721.28	2617.5	921.77	905.24	1796.1
Annual Balcony Heating Energy (kWh)	-	831.6	-	-	-	-	-	-	-
Total Heating (kWh)	6880.5	896.22	565.25	2511.1	721.28	2617.5	921.77	905.24	1796.1
Annual Apt Cooling Energy (kWh)	4.3779	316.23	639.27	39.507	312.56	13.258	13.258	663.22	0.60163
Annual Balcony Cooling Energy (kWh)	-	505.96	-	-	-	-	-	-	-
Total Cooling (kWh)	4.3779	822.19	639.27	39.507	312.56	13.258	13.258	663.22	0.60163
Combined Heating and Cooling Load (kWh)	6884.9	1718.4	1204.5	2550.6	1033.8	2630.7	935.03	1568.5	1796.7
Min Balcony Air Temp (C)	-	22	10.993	-13.1	10.514	-13.145	-3.3428	20.079	-
Max Balcony Air Temp (C)	-	25	35.412	31.935	32.11	31.616	31.616	26.697	-
Min Dbl. Glazing Surf Temp (C)	-	8.5384	3.3812	-9.3794	2.9884	-9.439	-0.094948	7.5732	-
Number of Hours Below 8 ^{o}C (Cases 3 and 4 only)	-	-	344	-	-	-	-	1	-

South

	1	2	3	3a	3b	3c	3d	4	5
Annual Apt Heating Energy (kWh)	5853.5	0	0	1721.2	74.7	1967.3	154.34	49.538	1098.3
Annual Balcony Heating Energy (kWh)	-	180.67	-	-	-	-	-	-	-
Total Heating (kWh)	5853.5	180.67	0	1721.2	74.7	1967.3	154.34	49.538	1098.3
Annual Apt Cooling Energy (kWh)	5.0479	1032.1	2212.8	222.16	1088.9	106.56	655.86	2254.2	1.8468
Annual Balcony Cooling Energy (kWh)	-	1918.3	-	-	-	-	-	-	-
Total Cooling (kWh)	5.0479	2950.4	2212.8	222.16	1088.9	106.56	655.86	2254.2	1.8468
Combined Heating and Cooling Load (kWh)	5858.5	3131.1	2212.8	1943.3	1163.6	2073.9	810.2	2303.8	1100.2
Min Balcony Air Temp (C)	-	22	15.451	-12.032	13.558	-12.246	-2.5695	20.605	-
Max Balcony Air Temp (C)	-	25	49.472	34.095	40.942	33.762	45.177	29.793	-
Min Dbl. Glazing Surf Temp (C)	-	11.786	9.9901	-7.8381	8.1524	-8.1828	1.3751	11.845	-
Number of Hours Below 8 ^{o}C (Cases 3 and 4 only)	-	-	0	-	-	-	-	0	-

West

	1	2	3	3a	3b	3c	3d	4	5
Annual Apt Heating Energy (kWh)	5725.2	6.9015	213.75	2095.1	394.96	2272.4	430.56	442.68	1290.8
Annual Balcony Heating Energy (kWh)	-	450.95	-	-	-	-	-	-	-
Total Heating (kWh)	5725.2	457.85	213.75	2095.1	394.96	2272.4	430.56	442.68	1290.8
Annual Apt Cooling Energy (kWh)	145.05	816.39	1845.9	282.35	1003.3	148.5	346.26	1950	225.88
Annual Balcony Cooling Energy (kWh)	-	1598	-	-	-	-	-	-	-
Total Cooling (kWh)	145.05	2414.3	1845.9	282.35	1003.3	148.5	346.26	1950	225.88
Combined Heating and Cooling Load (kWh)	5870.2	2872.2	2059.6	2377.5	1398.2	2420.9	776.83	2392.6	1516.7
Min Balcony Air Temp (C)	-	22	12.432	-12.678	11.622	-12.812	-2.8871	20.266	-
Max Balcony Air Temp (C)	-	25	51.589	34.305	43.086	34.059	46.399	30.282	-
Min Dbl. Glazing Surf Temp (C)	-	10.584	6.5015	-8.7575	5.5388	-8.9433	0.70855	9.7694	-
Number of Hours Below 8 ^{o}C (Cases 3 and 4 only)	-	-	47	-	-	-	-	0	-

East

	1	2	3	3a	3b	3c	3d	4	5
Annual Apt Heating Energy (kWh)	5764.6	18.67	318.74	2166.9	471.87	2327.3	537.6	564.48	1467.7
Annual Balcony Heating Energy (kWh)	-	552.27	-	-	-	-	-	-	-
Total Heating (kWh)	5764.6	570.94	318.74	2166.9	471.87	2327.3	537.6	564.48	1467.7
Annual Apt Cooling Energy (kWh)	103.57	774.4	1721.3	262.67	951.47	134.42	283.45	1832.8	154.07
Annual Balcony Cooling Energy (kWh)	-	1449.2	-	-	-	-	-	-	-
Total Cooling (kWh)	103.57	2223.6	1721.3	262.67	951.47	134.42	283.45	1832.8	154.07
Combined Heating and Cooling Load (kWh)	5868.2	2794.6	2040	2429.6	1423.3	2461.7	821.05	2397.3	1621.8
Min Balcony Air Temp (C)	-	22	12.58	-12.748	11.949	-12.819	-3.1917	20.223	-
Max Balcony Air Temp (C)	-	25	48.73	33.212	41.353	32.737	41.572	29.413	-
Min Dbl. Glazing Surf Temp (C)	-	10.169	5.5816	-9.2199	4.7971	-9.3189	0.047474	9.3286	-
Number of Hours Below 8 ^{o}C (Cases 3 and 4 only)	-	-	56	-	-	-	-	0	-

Table 7.13. Summary of computer simulations estimating annual energy consumption, seasonal temperatures and condensation potential for various balcony enclosure options in Toronto ON.

There are 4 performance parameters of interest in Table 7.13: the annual heating energy demand; the annual cooling energy demand, the annual combined heating and cooling energy demand; and the annual number of hours of condensation potential, signified by enclosure glazing temperatures at or below 8 ^{O}C. The greater the number of hours, the greater the risk of condensation on the glazing that may lead to deterioration of the balcony enclosure, and conditions conducive to mold growth. This condition may occur if air leakage occurs from the suite toward the outside, transporting moisture into the enclosed balcony area. Minimum values for energy demand are highlighted in shaded boxes, and the maximum number of hours with condensation potential is also thus indicated.

For north-facing balconies, the best energy performance results for Case #3 where the enclosed balcony is not conditioned and acts as a thermal buffer for the adjacent suite. However, the minimum surface temperature of the balcony enclosure glazing is far below the dewpoint temperature of the indoor air (assumed to be approximately 8 ^{O}C) and this results in some 344 hours where condensation is predicted to occur. The lowest cooling energy demand occurs in Case 5 where the balconies are unenclosed but comprehensive overcladding and window replacement has been applied. Without any enclosure, there is no build up of heat and the balcony slabs provide shading against morning and evening sunlight that strikes north facing facades during the summer. The lowest combined heating and cooling demand is provided by Case 3d where there is a near-ideal operation of the operable windows and shading devices in the balcony enclosure. In summary for north-facing balconies, the enclosed balcony with operable windows and shading devices is the best energy performing option; however, to avoid the potential for condensation, it should either have supplementary heating, or the existing enclosure should be opened up to allow for the circulation of heat during winter.

It is important to note that shading devices have not been included for the existing suite enclosure in all of the simulations. In the case where shading devices serve the balcony enclosure, they are effective because the heat that is generated between the blinds and the interior face of the glazing is removed by natural ventilation through operable windows. This does not occur to nearly the same degree where blinds are used inboard of the existing façade glazing. Exterior shading, such as provided by the cantilevered balcony slabs acting as awnings, is much more effective.

South-facing balconies exhibit the same performance pattern as north-facing balconies, except that there is no need for supplementary heating of the enclosed balcony area, or opening up of the existing enclosure. Note that the annual heating demand for the suite and enclosed balcony areas is 0, meaning that solar gains stored in the reinforced concrete armature are sufficient to passively heat south-facing zones. In summary for south-facing balconies, the enclosed balcony with operable windows and shading devices is the best energy performing option and has no significant potential for condensation no matter how it is configured.

The east and west-facing balcony options behave slightly differently than the north and south-facing orientations. The low sun angles render horizontally projecting shading devices ineffective, hence the potential for night cooling determines the lowest total cooling energy demand. At night, the reinforced concrete armature radiates heat gains outwards and also loses heat through convection through the cantilevered slabs. This explains why the existing balcony condition results in the lowest cooling energy demand. However, Toronto is a space heating dominated climate, hence Case 3d is the best overall performer, similar to the north and south-facing balcony orientations. There is some potential for condensation, less for the west orientation at 47 hours than for the east-facing orientation at 56 hours. The west orientation receives its solar gains immediately prior to the cold evening periods and retains the solar gains for a longer period of time. Approximately 2 days of condensation potential may be considered insufficient to require supplemental heating or the opening up of the existing enclosure to the balcony area. In summary for east and west-facing balcony orientations, the enclosed balcony with operable windows and shading devices is the best energy performing option and has no significant potential for condensation no matter how it is configured.

Does this mean that the comprehensive overcladding of balconies is not an appropriate option? If balcony enclosure is possible such that limiting distance for fire safety permits sufficient glazing areas for adequate daylighting and natural ventilation purposes, then balcony enclosure is the preferred strategy. However, limiting distance may prohibit or severely impair appropriate balcony enclosures, in which case overcladding is the best alternative. This is discussed in greater detail later on in this part of the guidelines publication.

How do the results for the other 4 cities compare with Toronto?

In Victoria, Ottawa, Quebec City and Winnipeg, the enclosed balcony is also the best energy performer. Balcony enclosures in Victoria offer the greatest flexibility of configuration as there is no risk of condensation in this region. But in Ottawa, an enclosed balcony with no supplemental heating or opening up between the suite and balcony areas, indicates 899 hours of condensation potential for the north orientation, 323 hours for the west orientation, and 439 hours for the east orientation. This suggests that at a minimum, a large proportion of the existing enclosure must be opened up and some means of supplemental heating may be required during the coldest periods to maintain comfort. For Quebec City and Winnipeg, supplemental heating is essential because the condensation potential increases dramatically with degree-days, and persists even after the existing glazing is removed to provide a generous opening interconnecting the suite and balcony spaces. In practical terms, supplemental heating would likely consist of an extension of the existing hot-water heating systems by adding a radiator beneath the balcony enclosure window, or moving the existing radiator forward to serve the balcony. In the case of electric resistance heating systems, an additional heater with a separate thermostat could be provided.

The next section examines the impact of the arrangement of balconies and projecting shear walls on the cost of balcony enclosure.

Wall Overcladding to Balcony Enclosure Ratio

The arrangement of balconies and the projection of shear walls are critical factors influencing the cost of the envelope retrofit. Figure 7.31 depicts 4 variations of balcony arrangements on an identical size building. The first building has 10 balcony projections on each of its long facades that serve a single corresponding suite. Based on the proportionate dimensions indicated on the plan view, the perimeter of the overcladding is 44 distance units and the balcony enclosure is 100 distance units. Note that the perimeter of these two elements is the critical parameter since this is multiplied by the typical storey height and then by the number of storeys to determine the gross overcladding and balcony enclosure areas for the building.

Looking at the second variation, it has 5 balcony slab projections on each of its long facades, resulting in a perimeter of 34 units for overcladding, and 90 units for the balcony enclosure. This arrangement requires 22.7% less overcladding than the first variation, and 10% less balcony enclosure area. However, 10 units of balcony separator are required for this arrangement, unless this function is provided by shear wall projections.

In the case of the third variation, it has 4 balcony slab projections on each of its long facades. There are 32 units of overcladding and 88 units of balcony enclosure required for this arrangement. Compared to the first variation, this arrangement requires 27.3% less overcladding and 12% less balcony enclosure. The number of balcony separators required is 16, an increase of 60% compared to the second variation.

Finally, the fourth variation has a single balcony slab projection on each of its long facades, resulting in a perimeter of 26 units for overcladding, and 82 units for the balcony enclosure. This arrangement requires 40.9% less overcladding than the first variation, and 18% less balcony enclosure area. There are now 24 units of balcony separator required for this arrangement, an increase of 140% compared to the second variation.

The significance of balcony arrangements and shear wall projections can be better appreciated by examining their impact on costs. Assuming balcony enclosures cost roughly twice as much as overcladding, the fourth variation costs 22.1 % less than the first variation as depicted in Figure 7.31, not accounting for the cost of the balcony separators. Assuming the balcony separators cost as much as the overcladding on a unit area basis, the difference is reduced to 12.3%. Clearly the arrangement of balconies and the configuration of shear walls in relation to the separation of balconies can affect envelope retrofit costs significantly.

Additional Considerations

An examination of the numerous types of existing apartment buildings reveals there are a number of additional considerations pertaining to a particular retrofit project:

- Balcony arrangements and shear wall projections influence the staging requirements and work flow associated with the building envelope retrofit.
- The overall cost of overcladding is strongly influenced by the number and size of windows to be replaced in the wall areas that will be overclad. Window replacement is generally much more expensive on a unit area basis than overcladding.
- Glazing on the sides of the balcony enclosures is more expensive than an insulated, opaque enclosure. Where the sides of balconies are comprised of projecting shear walls, the cost is generally lower than either of these two previous options.

The figures that follow depict examples of various balcony arrangements accompanied by commentary for cost and workflow implications.

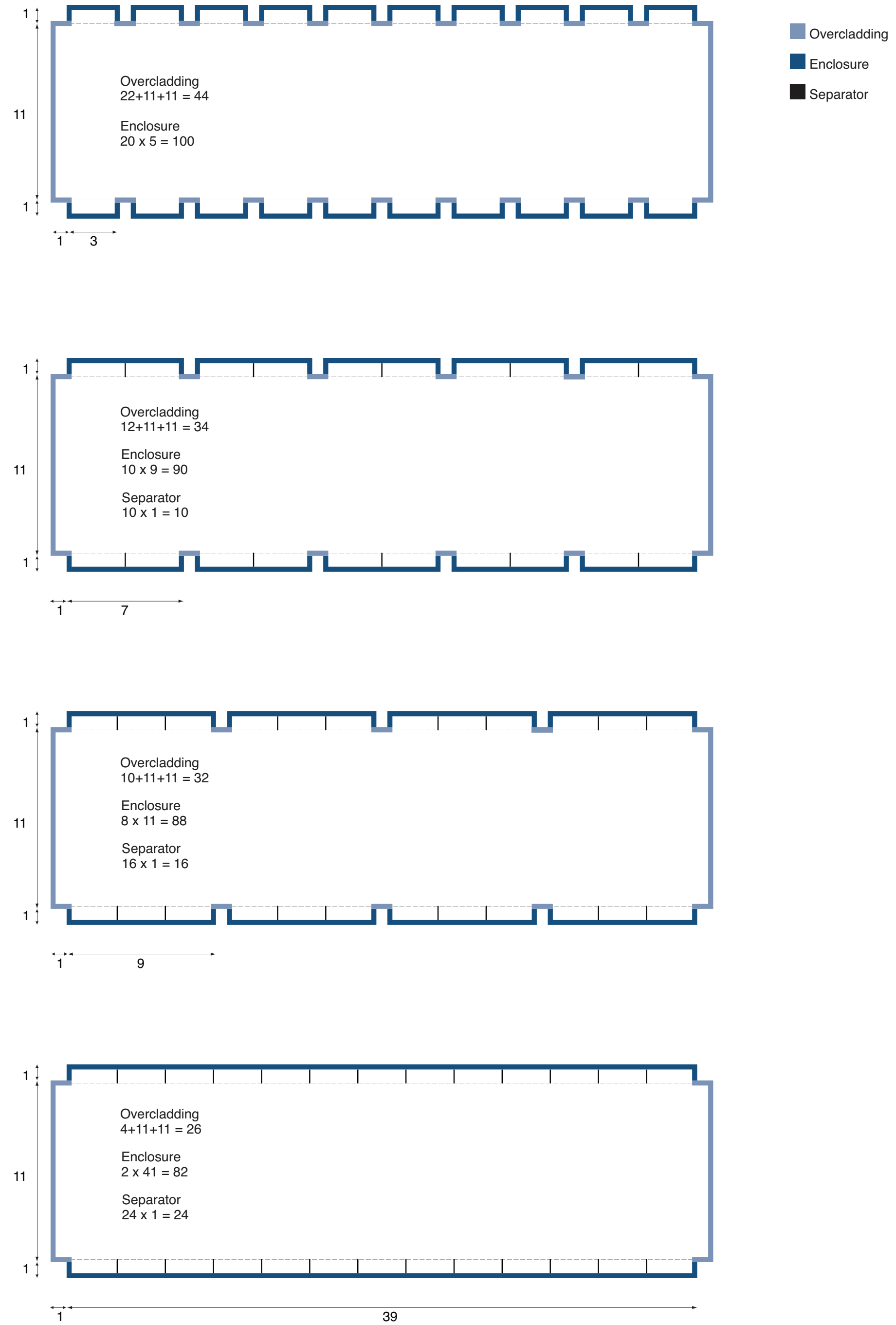


Figure 7.31. Parametric analysis of wall overcladding to balcony enclosure ratio for a typical tower building.

Figure 7.32. Example of a tower building where the projecting shear walls divide the balconies, serving as a separator and simplifying the balcony enclosure construction.

Figure 7.33. This apartment building has two types of balconies. The single balconies serve one suite and have one side enclosed by the projecting shear wall. The long, grouped balconies have metal dividers separating the balcony space allocated to each of the suites sharing the balcony.

Figure 7.34. Balconies on this apartment building vary, with some enclosed on two sides by projecting shear walls, and others having all three sides open. There may be cost advantages to considering a combination of balcony enclosure and balcony overcladding strategies for this type of building.

Figure 7.35. This building has balcony floor slabs spanning between projecting shear walls. Note that the balcony slabs are recessed from the outer edge of the shear walls, requiring the shear wall overcladding to be integrated with the balcony enclosure. Modest window openings on the end shear walls help make this portion of the overcladding easily executed and economical.

Figure 7.36. Example of a building where there is a low proportion of replacement windows in the exterior walls where overcladding will be applied. Note that the balcony guards have been removed and the doors to the balconies blocked from the outside for occupant safety. Remedial work on the existing envelope is underway before the remainder of the retrofit is performed.

Figure 7.37. There are two types of balconies on this apartment building. The centrally located balconies serve one suite and have one side enclosed by the projecting shear wall. The flanking balconies each serve one suite but are open on all sides. Special consideration must be given to the packages terminal air conditioning (PTAC) units located beneath the windows when designing the overcladding. Thermal bridging, future replacements of the PTAC units and management of the condensate dripping from the units when they are cooling the suites are among the chief concerns.

Figure 7.38. This building is an example of continuous balconies wrapping around the exterior of the building. Balcony enclosure will represent a much higher cost in this type of building than the types with individual, spaced balconies.

Figure 7.39. Mixed balcony arrangements are evident in this building. The balconies in the facing elevation are enclosed on one or both sides by projecting shear walls. Balconies on the side elevations are continuous and are fitted with metal partitions to subdivide the balcony space and allocate it to the individual suites.

Figure 7.40. This L-shaped apartment building has a combination of single and double balconies. The double balconies are divided with metal partitions that would have to be replaced when the balconies are enclosed with tight fitting, fire-rated separators.

Figure 7.41. Cast concrete guards at the outside of the single balconies separated by projecting shear walls make it practically much easier to enclose these spaces and to integrate the enclosures with the overcladding.

Figure 7.42. Point towers with continuous balconies and cast concrete guards, such as the one depicted above, are among the most costly to retrofit by any means.

The architectural character of 1960s and 70s tower apartment buildings is strongly influenced by their balconies. It is interesting to note that a very small proportion of this building stock was constructed without balconies. Apparently, convenient and private access to the outdoors was considered a desirable feature by the developers and their designers. This may have come about for reasons of marketability at a time when tower living was a bold experiment in Canada's major urban centres. Regardless, it is difficult to imagine having to wait for an elevator and then to travel down a dozen or more floors simply to stand beneath the open sky surrounded by fresh air. Yet, this is what some people propose as a solution to the tower balcony dilemma – the removal of the cantilevered balcony slabs altogether prior to overcladding. Looking at the preceding images, it is difficult to imagine tower living without balconies. It is equally difficult to imagine the urban landscape devoid of the classic tower typology that has left such a significant impression on our urban skylines.

The next sections in this part of the guidelines look at tower retrofit strategies that are technically based and much less architecturally controversial.

HVAC Systems Retrofit

These guidelines focus primarily on building envelope retrofits, acknowledging that the corresponding retrofit of HVAC systems is essential to cost effectively achieving optimal energy performance. It is not advisable to examine HVAC retrofits in isolation from building envelope upgrades since there are considerable savings to be realized by downsizing existing equipment as a result of a more efficient building envelope. Integration of the entire building as a system is the most reasonable means of carrying out a comprehensive tower retrofit.

There are numerous opportunities for upgrading the performance and reliability of HVAC systems in tower buildings. Many of these are examined in detail in the next part of these guidelines from the perspective of costs and benefits. The existing condition of typical tower building HVAC systems ranges from original equipment that has been maintained in operating condition, but with low energy conversion efficiency, to a mix of existing and replacement equipment. Central air conditioning is virtually absent in tower buildings with some tenants installing window air conditioning units where this is practical. Ventilation systems consist of make-up air units supplying corridor ventilation and rooftop mounted exhaust fans without heat recovery serving stacked bathrooms. Domestic water heating is often combined with large storage tanks to satisfy peak demand during morning and evening hours. Overall, much of the HVAC equipment is approaching obsolescence and required extensive servicing.

Statistics for MURB energy sources are not available for the 1960s and 70s tower building population. The Toronto Atmospheric Fund estimates that in the Greater Toronto Area, approximately 20% of MURBS are electrically heated, with the remainder using natural gas. Electrically heated buildings rely on baseboard heaters for space heating and electric water heaters for domestic hot water. Natural gas heated buildings employ boilers to serve both baseboard radiators and domestic hot water demand.

The key considerations when formulating an HVAC system retrofit strategy have been identified as follows:

- The building envelope and HVAC system must be designed in parallel so that the replacement HVAC system is properly sized for the reduced loads.
- It is not possible to achieve full energy conservation benefits without heat recovery on the ventilation air. The corridor ventilation system must be reconfigured to supply fresh air to each suite so that heat can be recovered from the exhaust air stream.
- Air conditioning is non-existent in virtually all tower buildings and the need for cooling may be reduced with the proper selection of glazing and the provision of effective shading devices. The reduced demand for cooling may be largely satisfied by dehumidifying and cooling the ventilation air during hot weather periods.
- Water conservation can reduce the demand for domestic hot water by upwards of 30% and it is feasible to combine space heating and domestic water heating equipment to take advantage of higher efficiency technology.
- Renewable energy systems, such as solar water heaters, are a reliable and proven technology that should be considered as part of integrated HVAC system. As a minimum, thought should be given to roughing-in conduits to accommodate a future migration to renewable energy technologies.

Another critical consideration for HVAC retrofits involves controls. In most tower buildings, there is no individual control of heating and ventilation. Two approaches to this situation are possible: 1) retrofit each suite with a dedicated HVAC system that is individually controlled and metered for energy use; and 2) improve the existing system controls so that the system is more responsive to weather conditions and solar orientation in the case of space heating. The first approach is generally more expensive and disruptive, but it provides the highest level of control and potential for energy savings. The second approach is much less costly and disruptive, but requires careful analysis and planning. Ideally, the space heating system should be zoned by solar orientation, so that heating is reduced in suites that are heated by the sun. Indoor/outdoor controllers should also be interfaced with the system to anticipate warming outside temperatures during the shoulder months (spring and fall) and reduce the amount of heat being delivered accordingly.

Recently, another promising technology that may be considered is a combined heat and emergency power (CHEP) system.[13] These systems use natural gas to power an electrical generator and harness the heat produced by combustion for use in the building. *CSA C282-05 UPD 2 Emergency Electrical Power Supply for Buildings* now permits the use of combined heat and power equipment fueled by natural gas to also serve as an emergency power supply. In the case of the existing high-rise apartment buildings, assuming the current diesel generators are original equipment from the 1970s, it is likely cost effective to consider CHEP as a replacement option that can also serve base domestic water heating loads.

Geothermal energy systems are another example of an innovative and proven technology that may prove cost effective over the replacement HVAC system life cycle. These are particularly attractive if they can be combined with renewable energy systems that feed into a district energy system serving a complex of buildings. However, it is important to recognize that district energy systems require a centralized, easily accessible and clearly delineated point of interface with the buildings they serve. It is therefore important to plan the services of buildings to accommodate future migration to district energy systems and currently many designers are not aware of this issue. More design aids and technology transfer programs are needed to bring the architectural, engineering and construction (AEC) industry up to speed with district energy systems. Further experience is needed with tri-generation systems that also provide cooling in addition to heating and electrical power to see where these can be most cost effectively implemented.

HVAC system retrofits are generally less costly than building envelope retrofits, and often these appear more attractive to building owners wishing to reduce operating costs. While the energy savings per dollar of expenditure are much higher for HVAC system retrofits than building envelope retrofits, it should be recognized that only a proper building envelope retrofit can address issues of deterioration and long-term durability. The HVAC system retrofit should be viewed as a complementary measure, not as a guiding approach to tower renewal.

Building Services Retrofit

Building services are those technologies that supply water and energy, handle sanitary waste and provide vertical transportation in tower buildings. They include emergency power, lighting and communications, and outdoor services like irrigation systems. These are best known to people when they fail or blackout, rendering the active system dormant and the building inhabitants inconvenienced.

Strategies for the retrofit of building services may be formulated after a condition assessment has been performed. In some cases, cut tests of piping may be required to estimate its remaining service life, but in general it is safe to assume most of the building services are approaching the end of their service lives, many of them already obsolete by contemporary standards.

Notwithstanding all services and systems related to life safety and health, there is some discretion available to building owners with the other building services. Key considerations when formulating a building services retrofit strategy have been identified as:

- Do not postpone the replacement or upgrading of services that will require the disassembly of envelope or HVAC retrofit measures, or potentially cause damage to these improvements. It is advisable to carry out intrusive and disruptive work in a single cycle of renewal where possible.
- Pumping is critical to the operation of high-rise buildings both for potable water and space heating. Considerable energy savings are possible with variable speed drive technology, while improving overall system reliability.
- The main electrical service to the building can often be downsized after a comprehensive retrofit, cost justifying a replacement system with a power harmonizer to further save energy.
- Energy efficient lighting in common areas, underground parking and outdoors is generally acknowledged as a cost effective upgrade with a relatively quick payback period. It is also possible to enhance aesthetics and security with this retrofit measure.
- Rainwater harvesting for purposes of irrigation is a simple, proven and low cost means of saving on water consumption. This can be integrated within a stormwater management retrofit plan.
- Elevator upgrades are highly visible and proactive means of retaining tenants while saving on energy and expensive repairs.

Elevators are among the most critical building services in tower buildings. Safety and reliability have always been primary concerns of landlords and tenants, but there is now good reason to examine their efficiency. It is estimated that elevators in high-rise buildings can account for between 5-10% of total, annual electrical energy consumption, and that somewhere between 30-40% of this can be saved with upgraded technologies.[14] Elevators are also known to contribute to air leakage in buildings that is reflected in higher space heating costs. Retrofit measures can also improve elevator performance with smarter controls and faster door operations. Most elevator manufacturers offer complete upgrade kits for existing elevator systems that enhance their appearance in addition to improving their performance. This is a retrofit measure that deserves careful consideration given the importance of this essential service in tower buildings.

Figure 7.43. For most multi-unit residential buildings, it is difficult to cope with solid waste. Programs for recycling and composting are not a priority for buildings overflowing with garbage. There are solutions available, but they involve education and cooperation more than any technological intervention. [Photo: Jesse Colin Jackson.]

Increasingly, solid waste management in buildings is becoming a controversial issue. In many urban centres, the cost of solid waste disposal is escalating dramatically, and these costs are being passed on to the building owner, hence ultimately the tenants.

The current thinking in design for waste diversion in existing tower buildings requires that facilities are conveniently located along tenant travel paths or within areas for garbage disposal. Additional resources have been developed to assist building owners and building superintendants cope with solid waste management problems[15]

The City of Toronto estimates that apartments and condominiums recycle only 13% of their waste, leaving 87% charged out at ever increasing rates for waste disposal. Much like elevators, solid waste management is a vital service in tower buildings and it deserves special consideration as part of the building services retrofit strategy.

Integrated Design for Future Adaptability

The future is difficult to predict and therefore leaving as many options open as possible is an ideal tower retrofit strategy. By opting for building envelope retrofits that have easily replaceable cladding and dedicated chases for the upgrading of services, it is possible to migrate toward renewable energy technologies that are integrated within the skin of the building.

Figure 7.44. Tower buildings may eventually become armatures for our individual domestic aspirations, free from the collective imperative. [Source: James Wines.]

Other opportunities, such as ducted wind turbines and district energy systems, will require further study as these are emerging technologies that have not benefited from widespread application and collective learning among designers and constructors.

One trend that is certain is the impending shortage of fossil fuels and the need to advance the renewable energy agenda. This pressure will be offset by intelligent building automation systems and a host of appliances and devices that use less and less energy with each development cycle. Pumps may never be as efficient as trees when it comes to moving water vertically, but they will eventually require much less energy. The same will be true of fans, refrigerators, stoves, televisions, and computers. Some day when all cars are electrically powered, underground parking garages may be used to temper outside air for ventilation.

These are all possibilities that should not be discounted when developing appropriate tower retrofit strategies that are adaptable to future opportunities. The key to successful strategies is ensuring that as few migratory paths to a sustainable future are blocked or destroyed in the course of implementing tower renewal.

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8. Tower Retrofit Analysis: Costs and Benefits

The analysis of costs and benefits associated with tower retrofits is critical to informed decision making by building owners, utilities, financial institutions and government agencies.

For building owners, investments in building improvements that extend service life, improve energy and water efficiency, and enhance aesthetics and marketability, must deliver reliable returns. Given the diversity of building types and owners, it is not possible to arrive at comprehensive generalizations. However, a key consideration is that the current cash flows cannot be compromised. If improvements can carry themselves, specifically, if the savings combined with modest, allowable rent increases, can cover principal and interest, then retrofit projects may be considered feasible.

Energy and water utilities are motivated to achieve reductions in peak demand in order to avoid the costs of expanding capacity. Conservation is generally more cost effective than expansion of capacity, and this strategy can respond more rapidly and flexibly than large infrastructure projects. Given the time required to conduct environmental assessments, prepare designs and specifications, carry out construction, and finally, commission the plant equipment and facilities, conservation is not only faster to implement, but also frees up the commitment of public funds to more pressing needs, such as health care and education.

Financial institutions are responsible for protecting the investments of their clients. Extending favourable financing is a sound business strategy for retrofit projects that preserve durability and conserve energy and water resources, provided the investments are secure and reliably deliver on their promise. Properties with low operating and maintenance costs represent sound, long-term investments that do not require as high a rate of return as more risky propositions. Financial arrangements hinging on savings repaying loans require that the predicted performance is actually realized over the entire amortization period.

Government agencies wishing to stimulate employment and promote affordable, healthy housing, may be willing to offer incentives and tax rebates for retrofit projects that attain these objectives. In times of sharply rising energy and water costs, resource conserving retrofit investments are a proven means of maintaining housing affordability. Properly designed, constructed, operated and maintained, tower renewal projects have the potential to improve comfort, indoor air quality and the well being of inhabitants.

The key to addressing all stakeholder concerns during the decision making process is the realistic consideration of costs and benefits, hence the need to predict performance.

Tower apartment buildings have delivered remarkable performance for several decades, the earliest approaching a half-century of reliable housing service. Despite their numerous limitations from a building science perspective, most notably unacceptable levels of energy efficiency, these buildings continue to provide impressive returns on the original investments that developed them. The first cycle of retrofit now being considered will undoubtedly be assessed in relation to this past precedent of performance. If the flawed technology of 20th century tower buildings has prevailed to the present, then it is reasonable to expect 21st century retrofit technology to surpass all aspects of past performance. The same motivations driving everyday consumer choices will surely guide tower owners seeking to cost effectively retrofit and extend the useful life of their real estate investments. This is the economic and technological challenge of tower renewal – to affordably extend durability, improve performance, and enhance quality of life, and the natural and built environment.

Figure 8.1. High-rise apartment towers, such as the one seen under construction in the image above, have proven to be robust investments in housing real estate. Proposed retrofits should build on this legacy and further enhance performance. [Source: City of Toronto Archives]

[Photo Opposite Page: Jesse Colin Jackson]

Forecasting Retrofit Benefits

Accurate and reliable prediction of the savings that will be realized by energy and water conservation measures in tower buildings is essential, but sometimes challenging. Building owners will base their business decisions on the estimated costs and forecast benefits of tower renewal.

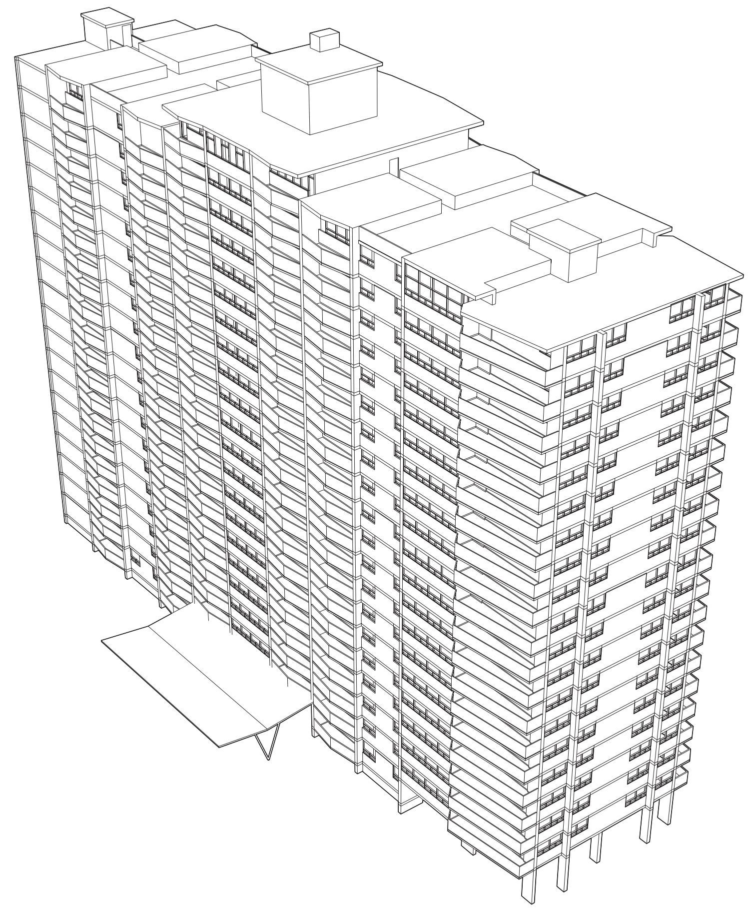
In order to perform a proper forecast, it is necessary to begin with current energy and water consumption for the tower building. Normally, electricity and natural gas utilities issue monthly bills that contain the amount of energy consumed and its cost. Public water works may only issue bills on a quarterly basis. It is important to recognize that when energy simulation software is used to forecast the benefits of various improvements, the results are based on a typical weather year. Climate data about a typical or average year is gathered by Environment Canada and published as Climate Normals, available online at: http://www.climate.weatheroffice.ec.gc.ca/climate_normals/index_e.html.

The local weather office or energy utilities can provide actual weather data corresponding to the period that reflects the energy bills being used to estimate annual consumption. If the actual weather data indicate a colder than normal winter, then the energy consumption obtained from bills for that period should be adjusted accordingly. A similar adjustment is needed when the winter is warmer than normal. Note that this adjustment applies to heating only, and a separate analysis of the summer weather is needed to adjust for air-conditioning use. In practice, the heating energy adjustment is most important. It is often difficult to perform an adjustment for cooling energy, since most tower buildings do not have central air conditioning that is separately metered. The electrical energy for cooling is mixed with the energy for lighting, appliances, fans, elevators, etc. and is therefore difficult to separate. Most areas of Canada do not have lengthy and severe air conditioning seasons, hence adjusting cooling energy demand is not critical for reasonably accurate modeling.

Water consumption may vary significantly depending on the amount of rainfall received and how extensively the landscape elements surrounding a tower building are irrigated. If there is little or no irrigation, it is not necessary to adjust the water consumption. However, if the grounds are extensive and frequently irrigated, an adjustment to water consumption is advisable. Water works utilities collect data and can provide a comparison between average water consumption levels and those that are associated with either very dry or very wet summers. This information can be used to adjust the water consumption from a particular year of water bills to reflect an average year's level of consumption. It should be noted that the forecast for annual savings of water consumption is needed for input to the energy model. This enables the energy model to estimate the energy reduction for service water heating (also termed domestic water heating) associated with the reduced water usage.

After an average annual consumption for energy and water has been determined, it is possible to begin development of an energy model. The initial step in the process is to develop a model of the existing tower building that accurately predicts the average, annual energy consumption. An example of this baseline energy model development is depicted in Figures 8.3, 8.4, and 8.5. An online energy simulation software developed by Natural Resources Canada called Screening Tool was employed for this example. Refer to the Office of Energy Efficiency web site: http://screen.nrcan.gc.ca/index.htm for more information and to access this tool. A complete listing of suitable energy simulation software is available at http://apps1.eere.energy.gov/buildings/tools_directory/.

After gathering the energy and water consumption data, it is necessary to establish the schedule of energy and water costs. A complete area takeoff of the existing building must also be performed so that the area of roofs, windows and opaque exterior walls is obtained. An inventory of the mechanical equipment and lighting must also be conducted to obtain the efficiencies and operating characteristics required for modeling purposes.



Building Statistics

Gross Floor Area	23,360 m^2	Gross Wall Area*	12,016 m^2
Window Area	3,181 m^2	Net Wall Area	8,835 m^2
Window to Wall Ratio	26.47%	Roof Area	1,369 m^2
Parkade Floor Area	2,738 m^2	# of Suites	236

* includes projecting shear walls

Figure 8.2. 20-storey archetype tower building used in energy and water conservation forecasting examples.

After inputting the gathered data into the energy simulation model, the output is compared to the actual energy consumption, adjusted for weather if necessary. The results should fall within +/- 5% of the actual consumption. Normally several iterations are required to tune the existing building energy model. This process is explained along with a discussion of the input and results that follow.

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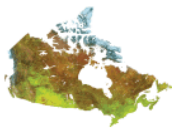

Screening Tool For New Building Design

Screening Tool Summary

Project Description

Your Project Description:

Existing Archetype Tower Building

Building Profile Summary

Proposed Building:	Multi-Unit Residential, 23360 m^2
Location:	Toronto (A), Ontario
Heating System:	Fossil

Utility Rates

Your marginal utility rates (including any taxes and fees):

$ 0.093 per kWh	$ 12.394 per GJ
$ 0.000 per kW	$ 0 per litre oil/propane

Building Shell

	Reference Building	Your Design
Average window-to-wall-area ratio:	26.47	26.47 %
Overall window USI-value:	3.2	5 W/m^2°C
Window shading coefficient:	0.736	1
Overall wall RSI-value:	1.818	0.6 m^2°C/W
Gross exterior wall area:	12016	12016 m^2
Roof type:	All other	All other
Overall roof RSI-value:	2.128	1.4
Gross exterior roof area:	1369	1369 m^2

Figure 8.3. Input of building profile, utility rates and building shell data in Screening Tool.

Key data is entered under the "Your Design" column. The reference building in Screening Tool automatically defaults to the requirements of the Model National Energy Code for Buildings MNECB). In general, the levels of thermal efficiency for the existing tower building envelope are much lower than current MNECB requirements.

The data entry for mechanical systems, lighting, parkade lighting and process loads follows the building shell. The values shown in the example below are typical for existing tower buildings that have not had the HVAC systems updated recently. Lighting is normally set to the default MNECB level for the building and the parkade (underground parking). Process loads refer to large energy draws that occur within the building, for example, a commercial establishment such as a restaurant or bakery. As these energy draws are usually separately metered, the process loads are normally set to zero.

Mechanical System

	Reference Building	Your Design
Heating efficiency:	80	60 %
Minimum outside air:	0.4	0.4 l/s/m^2
Demand control ventilation (DCV) type:	None	None
Percent of outside air controlled by DCV:	0	0 %
Percent of floor area cooled:	0	0 %
Cooling efficiency:	2.5	2.5 COP
Outdoor air economizer?	No	No
Efficiency of exhaust air heat recovery:	0	0 %
Service water heating fuel type:	Fossil	Fossil
Service water heating efficiency:	80	60 %
Service water savings:	0	0 %
Mechanical Efficiency Options (only applies to Your Design):		
Heating plant option:		On/Off
Variable speed fans:		No

Lighting

	Reference Building	Your Design
Average lighting density:	10	10 W/m^2
Lighting controls (select if applicable and enter floor area):		
None		0 %
None		0 %

Parkade lighting

	Reference Building	Your Design
Parkade floor area:	2738	2738 m^2
Average lighting density:	3.2	3.2 W/m^2
Percent of lighting load with occupancy sensor control:	0	0 %

Process Loads

	Reference Building	Your Design
Average process load density:	0	0
Percent served by electricity:	0	0 %

The thermal properties of the windows, walls and roof may be adjusted higher or lower than calculated values to tune the energy model if the difference between actual and predicted energy consumption is small. Heating and service water efficiency may be adjusted if the difference remains high, using the lighting density to further tune the model.

Building Performance Results

Based on the information you provided, your building design is not 25% more energy efficient than the reference building that meets the Model National Energy Code for Buildings.

Current Design Performance

Annual Energy Use (GJ)

Reference Building	12,627	
Your Design	26,065	
Energy Savings	**-13,438**	**-106.4%**

Annual Energy Cost Savings **$-174,642.89**

LEED© Canada Energy & Atmosphere (EA)

Does not qualify (EA Prerequisite 2 is not satisfied)

Emissions Savings

Carbon Dioxide (CO_2) -739,052 kg

Annual Energy Use Comparison

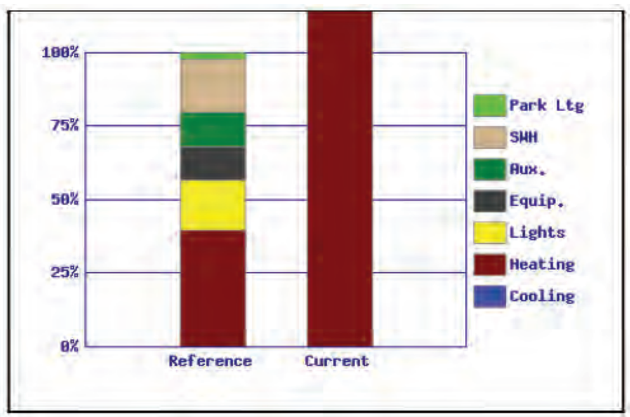

Figure 8.4. Summary of building performance results for archetype tower building.

The Building Performance Results screen of the Screening Tool software is primarily intended for new buildings that attempt to comply with or exceed the requirements of the MNECB. As can be seen from the results, the archetype tower building (Your Design) uses much more energy (106.4%) than a building complying with the MNECB (Reference Building). This inefficiency results in 739,052 kg more greenhouse gas emissions than a compliant building.

The final section of the Screening Tool software, depicted in Figure 8.5, presents a comparison of annual energy consumption and costs between the archetype tower building (Your Design) and an identical size building complying with the MNECB (Reference Building).

Your Design

Annual Energy and Costs				
End Use	**Electricity kWh**	**Fossil Fuel GJ**	**Total Energy GJ**	**Costs**
Cooling	0	0	0	$0
Heating	0	17,102	17,102	$211,920
Lights	599,616	0	2,159	$55,764
Equip.	392,953	0	1,415	$36,545
Aux.	571,404	0	2,057	$53,141
SWH	0	3,056	3,056	$37,871
Park Ltg	76,752	0	276	$7,138
Totals	1,640,726	20,158	26,065	$402,379

Reference Building

Annual Energy and Costs				
End Use	**Electricity kWh**	**Fossil Fuel GJ**	**Total Energy GJ**	**Costs**
Cooling	0	0	0	$0
Heating	0	5,032	5,032	$62,355
Lights	599,616	0	2,159	$55,764
Equip.	392,953	0	1,415	$36,545
Aux.	403,551	0	1,453	$37,530
SWH	0	2,292	2,292	$28,404
Park Ltg	76,752	0	276	$7,138
Totals	1,472,873	7,324	12,627	$227,736

Disclaimer

The information presented on this web page gives approximate values to help you make an informed decision about whether or not to proceed with an application for the validation of the design under the **ecoEnergy Initiative.** Because the input data are not as detailed as required under the ecoENERGY - New Buildings Design Validation Application, actual results will vary. Therefore, NRCan does not guarantee that the Screening Tool results meet the ecoENERGY criteria for validation of the design.

Press To Print

Figure 8.5. Detailed breakdown of energy consumption and costs for archetype tower building and reference building (MNECB).

The actual energy costs for the archetype building, adjusted for weather, were found to be $404,515, versus the predicted $402,379, hence the energy model is considered a good baseline model that can be used to forecast energy savings associated with various building envelope, HVAC and lighting system improvements.

Annual water consumption for this building is 52,122 m3, approximately 217 m3 per suite. Based on the City of Toronto water rates, this translates into an annual cost of $74,486. Savings due to reductions in water use through water conservation measures require two calculations: the first can be performed by the energy simulation software for reduced domestic water heating energy; and the second is calculated manually based on the reduction in the volume of water predicted. The detailed process of assessing costs and benefits with tower renewal can now proceed.

Economic Cost-Benefit Assessment Methods

Before performing an economic analysis of the costs and benefits associated with tower retrofits, it is important to understand an acceptable methodology for conducting a proper assessment. Cost-benefit analyses attempt to compare the costs and benefits associated with alternative decisions involving policies, technologies and investments using economic measures. The economic measures presented in these guidelines are familiar to economists and financiers involved in investment decisions. This section is aimed at assisting non-expert users of these guidelines to better appreciate the meaning and limitations of the various measures. Economic measures used in this study are based on ASTM Standards on Building Economics[1], and selected to reflect the economic perspectives of key stakeholders.

The various perspectives that are brought to bear on investments in building improvements require careful consideration if the results obtained from analyses are to prove useful to stakeholders. For tower retrofit projects in general, there exist three major perspectives to be considered, corresponding to the key stakeholders: owners (landlords); consumers (tenants); and society (government, utilities, financial institutions).

Figure 8.6. Mayor Phil White of Toronto is seen in this archive photograph speaking with new tenants at a recently completed tower apartment building. Safe and affordable housing was as important then as it is now. [Source: City of Toronto Archives]

Stakeholder	Primary Considerations	Study Period	Economic Measure
Owner (Landlord)	• Minimal impact on cash flow (ability of retrofit savings to repay retrofit loans + minimal impact on vacancy rates due to retrofit disruptions) • Improvement of building condition to avoid further deterioration and future repair/replacement costs that have no payback • Payback period that is less than the useful life of retrofit components • Favourable rate of return on retrofit investments	• Amortization period of retrofit loan or mortgage	• Payback • Internal Rate of Return (IRR)
Consumer (Tenant)	• Minimal impact on affordability • Improved health and safety, quality, comfort and amenity	• Duration of tenancy	• Annual monthly rent increase
Society*	• Conservation of housing, energy and water resources • Avoided costs of infrastructure expansion • Secure housing investment vehicles that promote sustainability	• Service life of envelope and equipment components • Useful life of tower apartment buildings	• Life Cycle Cost (LCC) using Modified Uniform Present Worth (MUPW)**

*Societal stakeholders include owners and tenants, but are confined in this instance to governments, utilities and institutions that represent societal stakeholders at large.
** Societal decision makers are gradually adopting the life cycle cost measure to assess the cost effectiveness of resource conservation measures. In its simplest form, the life cycle cost is expressed as the present worth or *net present value* (NPV) of all the costs associated with a particular proposal, which is then compared between alternatives. The lowest life cycle cost usually represents the best investment from a societal perspective, provided the non-monetary considerations are similar among competing alternatives. People will pay more for value, even when that value is non-monetary and intangible, such as matters related to health, the environment and global warming.

Table 8.1. Primary considerations and economic measures corresponding to key stakeholder perspectives.

These stakeholder perspectives are summarized in Table 8.1. Economics invariably involve a number of practical considerations, emphasizing the widely held view that money is simply a means to an end. Put another way, people have many priorities in life and while money is always a consideration, it is not the only consideration. Where money is among the important considerations, the economic measures in Table 8.1 typically apply.

Owners of tower buildings are landlords. They are primarily concerned with retrofit costs, sometimes referred to as capital costs or investments, and how these affect the profitability of their business enterprise. The carrying costs and opportunity costs associated with retrofit investments must result in substantial benefits, both short term (marketability) and long term (economic sustainability), if this stakeholder is to elect a tower retrofit investment. There is great diversity among tower owners. Some own one or several buildings with no intention of further acquisitions, while others include tower buildings in a broad portfolio of real estate assets, and venture to expand their holdings. Access to favourable financing arrangements may differ significantly between small and large landlords. For large landlords it is likely the rate of return on investments will be compared between retrofits versus further acquisitions. All landlords would ideally seek retrofit investments that pay for themselves through energy and water savings from the outset.

Tenants are primarily interested in the quality and affordability of their housing. Beyond health and safety, comfort and indoor air quality remain equally important to maintaining affordable rents that do not place an unreasonable financial burden on a household. Improvements to the buildings they inhabit are welcome provided they not do result in high rent increases. Similar to landlords, tenants are interested in expenditure-neutral improvements, and preferably improvements that counter rent increases due to spiraling energy and water costs, or costly repairs that cannot be deferred.

The societal perspective on investments in buildings is generally long term, taken over the useful life of the buildings. The primary concern is the viability of the building over its life cycle and how to maximize this benefit across all of society. A societal perspective implies that buildings are viewed more like natural and cultural resources, not simply as commodities, hence they must be conserved for succeeding generations. The construction of new buildings commits society to supply many forms of energy and services, on demand, for the useful life of the building (typically 75 years, plus). Roads, bridges, schools, hospitals, fire and police stations are among the many investments that society must make to support new development. Where building development exceeds the capacity of existing infrastructure, an escalation in the cost of municipal services normally results. The societal commitment to servicing new building development and dealing with all forms of effluent (storm water, sewage, products of combustion, etc.) must be economically assessed to properly compare between different standards of performance for parameters such as density, diversity, and energy and water efficiency. Tower renewal has the potential to preserve valuable housing resources while reducing energy and infrastructure demands, thereby extending the available capacity for new development and economic growth. This sort of comprehensive assessment is beyond the scope of these guidelines, but it is evident that municipalities, utilities, and financial institutions are societal stakeholders in tower renewal.

Municipalities avoid increasing the capacity of water and sewage treatment plants through water conservation. Increasingly important is the need to reduce solid waste by encouraging recycling and composting in tower buildings. Many of these buildings do not presently have suitable facilities in place for solid waste diversion and tower retrofits may potentially create opportunities. Appropriate measures addressing these issues as part of tower retrofits are in the best interest of municipalities, who may find it economically advantageous to provide suitable incentives.

Energy utilities, particularly electrical energy, are predicting problems meeting peak demands unless additional capacity is developed, or peak load management strategies are implemented. Tower retrofits can potentially reduce and/or shift peak energy demand. Utilities have an economic interest in encouraging peak load management through incentives that are less costly than expanding capacity.

Financial institutions, such as banks and pension funds, are interested in secure and reliable investments. Real estate is generally considered a secure investment but in the case of tower apartment buildings, it is critical the buildings are free of deterioration and in good condition. All building elements that may potentially incur large expenditures must be properly replaced or repaired. Otherwise, the cash flows from energy and water savings needed to repay retrofit loans will be disrupted. In extreme cases, where health and safety requirements must be addressed due to failing building elements, it may not be possible to cover these essential expenditures and payments on retrofit loans. Financial institutions must be assured the retrofit work fully addresses these issues and performs to provide predicted savings that underwrite the financing arrangements.

In summary, each of the stakeholders has a different perspective on costs and benefits, yet each stakeholder shares a common interest in sustainability on behalf of future generations. While it may not be possible to perform a comprehensive assessment, each stakeholder is connected within a complex economic, social and environmental cost-benefit matrix. This section of the guidelines focuses on the economic dimension of this cost-benefit matrix, acknowledging there are many intangible and non-monetary aspects of tower renewal that also deserve consideration.

The discussion that follows briefly presents each economic measure of costs and benefits and how these reflect the economic perspective of key stakeholders. Readers should appreciate that while these measures involve more sophisticated analytical techniques than are normally employed in day-to-day marketplace transactions, they still remain quite limited in their ability to fully reflect the economic complexity of building retrofits.

"Everything good that's happened to me and my family since I came to Canada is because of the investments I made in apartment buildings. When they were new, they were my pride and joy and I was proud to show them off to friends and relatives. Like me, they're getting a little old and tired, and I would like to fix them up. But I can't afford losing the monthly income. It's all tied up in all kinds of investments for my sons and daughters, and my lovely grandchildren. I have responsibilities to my family and they come before my responsibilities to anything else. Sure I want to do the right thing, but I need help to do it right so I don't screw up my family."

Excerpt from interview with tower apartment building owner.
(Conducted June 10, 2008, owner's name held anonymous upon request.)

Simple Payback and Payback Measures

The simple payback and payback measures used in these guidelines have been calculated according to the equations in Figure 8.7, taken from the corresponding ASTM standard[2]. Simple payback assumes there is no significant difference between the discount rate (interest rate) and the escalation rate (for example, the rate at which energy prices increase each year).

Consider the case where a building owner is evaluating replacement of the boiler system used to heat the building and make hot water for domestic purposes. Assume there are two options to consider: a 3-stage, modulating boiler system, having an annual fuel utilization efficiency (AFUE) of 82%, and a multi-stage, condensing boiler system with an AFUE of 93%. The 3-stage, modulating boiler system has a replacement cost of $425,000 and this results in annual energy savings of approximately $67,000. The multi-stage, condensing boiler system has a replacement cost of $540,000 resulting in annual energy savings of approximately $88,650.

Under the simple payback measure, the payback period is the cost divided by the savings. For the 3-stage, modulating boiler this is equal to $425,000/$67,000 per year or 6.34 years. The payback period accounting for the difference between the interest rate and the energy price escalation rate will be shorter if the energy escalation rate is greater than the interest rate. When the interest rate is 2.5% and the energy escalation rate is 6%, the payback period is 5.66 years, whereas when the rates are 4% and 9% respectively, the payback period is 5.44 years – almost a year less than the simple payback period. Looking at the multi-stage, condensing boiler system, the simple payback period is $540,000/$88,650/year or 6.09 years. For the two interest and energy price escalation rates considered above, the payback periods are 5.46 and 5.25 years, respectively. Based on payback considerations, the multi-stage, condensing boiler system is generally the preferred option, assuming the replacement cost can be afforded by the building owner.

Simple Payback

$$SPB = C_o/(B - \tilde{C})$$

where:

SPB = period of time, expressed in years, over which investments are recovered to the breakeven point

C_o = dollar value of initial investment costs, as of the base time.

$(B - \tilde{C})$ = initial value of an annual, uniformly escalating, net cash flow

Payback

when e is not equal to i:

$$PB = \frac{\log [1 + (SPB)(1 - (1 + i)/(1 + e))]}{\log [(1 + e)/(1 + i)]}$$

where:

PB = period of time, expressed in years, over which investments are recovered to the breakeven point

i = discount rate

e = escalation rate

SPB = PB when e is equal to i.

Figure 8.7. Formulas corresponding to the simple payback and payback measures.

It is interesting to note that the normally expected payback period sought by consumers is in the range of 3 to 10 years. This range is based on a series of studies conducted mostly during the 1980s.[3,4,5] There have been few, if any, comprehensive studies of consumer attitudes, let alone building owner attitudes, towards acceptable payback periods on investments in energy or water efficiency performed in the last decade.

Simple payback and payback measures have inherent limitations that are important to consider when making investments in buildings and building systems:

- Payback measures ignore benefits occurring after the payback period, and do not measure total savings. For improvements like added insulation, the higher energy efficiency continues almost indefinitely, long after the payback period. A tower building with lower operating costs has a higher market value, all other factors being equal, but this is not reflected in any of the payback measures.

- The payback period is affected by changes in energy or water efficiency afforded by other improvements. If more insulation is added to a building or the windows are replaced with more efficient units, the payback period will increase because the energy savings decrease.

- Payback measures do not consider the useful life of the building or building system. It is now commonly accepted that life cycle costing provides more appropriate economic measures than payback or internal rate of return measures.

In summary, critics of the payback method claim it is unsophisticated and theoretically incorrect because it ignores the time value of money, does not account for cash flows beyond the payback period, and is inconsistent with the owner's goal of maximizing wealth.

Why do building owners adhere to basing their investment decisions on the payback measure? One reason, perhaps, is that this is how products that save energy and water are marketed. Short payback periods are viewed as "no brainers" because these indicate the product pays for itself quickly. But the selection of improvements with short payback periods can backfire if the root cause of the high energy or water consumption is not addressed. This practice, known as "cherry picking" misleads building owners into selecting a host of improvements with short payback periods, not realizing these do not significantly reduce operating costs, and seldom address issues like deteriorating building envelopes and failing building services. Similar to cosmetic surgery, the effects are not long lived and they do not address the fundamental changes in lifestyle needed to achieve and maintain good health.

Internal Rate of Return Measure

In these guidelines, the internal rate of return (IRR) measure is applied according to the method set out in the corresponding ASTM standard on building economics[6]. Traditionally the IRR measure has been used in finance and economics to measure the percentage yield on investments. The yields from various investments are compared to determine the most attractive investment alternative.

Consider again the case where a building owner is looking to replace the boiler system used to heat the building and make hot water for domestic purposes. Assume there are two options to consider: a 3-stage, modulating boiler system, having an annual fuel utilization efficiency (AFUE) of 82%, and a multi-stage condensing boiler system with an AFUE of 93%. The 3-stage, modulating boiler system has a replacement cost of $425,000 and this results in annual energy savings of approximately $67,000. The multi-stage, condensing boiler system has a replacement cost of $540,000 resulting in annual energy savings of approximately $88,650.

Estimating Savings From Improvements to Equipment Efficiency

The annual savings resulting from improvements to equipment efficiency are calculated by comparing the current expenditures with the forecast expenditures. The case of the boiler system replacement being considered may be estimated as follows:

The energy savings are calculated by having the AFUE of the existing boiler system measured, typically by a heating system technician. The percentage savings is equal to [(1/AFUE existing – 1/AFUE replacement) / 1/AFUE existing] x 100%. For example, assuming the existing system is tested as having an AFUE of 60% and the case of the 3-stage, modulating boiler system with an AFUE of 82% is being considered. This would translate into: [(1/0.60 – 1/0.82)/1/0.60] x 100% = 26.8% reduction in energy consumption. The annual savings for this boiler system replacement option could be estimated as 26.8% of the annual amount currently being paid for heating energy. For the 93% efficient boiler system, the estimated annual energy savings are 35.5% of the current heating energy costs.

The internal rate of return is sensitive to the energy price escalation rate. The higher the energy price escalation rate, the higher the rate of return on an energy conservation investment. Another critical variable is the value of energy savings compared to the cost of the energy conservation measure. High cost measures that provide relatively low savings will tend to yield an unfavourable rate of return. In general, the replacement of low efficiency equipment with high efficiency equipment will yield a favourable rate of return, simply because the annual amount of energy savings is very high compared to the replacement cost.

Internal rate of return is not the only factor to consider when evaluating energy conservation measures. The building owner may not be able to afford the cost of the measure, or in some cases, the savings from the energy conservation measure may not be able to finance the measure. Assuming the previous two issues are not a concern, the rate of return will vary depending on the period of time over which it is assessed. For practical purposes, the time period is determined by the useful life of the energy conservation measure. In the case of boiler systems, and most HVAC equipment, this is typically assumed to be 25 years.

Internal Rate of Return

$$PVNB = \sum_{t=0}^{N} \frac{(B_t - \bar{C}_t)}{(1 + i^*)^t} = 0$$

where:

$PVNB$ = present value of net benefits (or, if applied to a cost reducing investment, present value of net savings).

N = number of discounting periods in the study period.

B_t = dollar value of benefits in period *t* for the alternative evaluated less the counterpart benefits in period *t* for the mutually exclusive alternative against which it is compared.

$\bar{C}_t$ = dollar costs, excluding investment costs, in period *t* for the alternative evaluated less the counterpart costs in period *t* for the mutually exclusive alternative against which it is compared.

i^* = interest rate for which PVNB = 0, that is, the IRR measure expressed as a decimal.

Figure 8.8. Formula used in calculating the internal rate of return measure.

For the example that compares the 3-stage, modulating boiler system with an AFUE of 82%, to a multi-stage, condensing boiler system with an AFUE of 93%, the rates of return over an assumed useful service life of 25 years, corresponding to different fuel price escalation rates, are summarized in Table 8.2.

3-Stage Modulating Boiler System Cost $425,000, Annual Savings $67,000				
Annual Fuel Price Escalation Rate	4%	6%	8%	10%
Internal Rate of Return	19.9%	22.2%	24.6%	26.9%
Multi-Stage, Condensing Boiler System Cost $540,000, Annual Savings $88,650				
Annual Fuel Price Escalation Rate	4%	6%	8%	10%
Internal Rate of Return	20.7%	23.0%	25.3%	27.6%

Table 8.2. Example of the sensitivity of rate of return to fuel price escalation rate and the relationship between the cost of an energy conservation investment and the annual savings it provides.

The rate of return on either investment improves with increasing energy price escalation rates. The multi-stage, condensing boiler provides a better rate of return in all cases, but it costs $115,000 more than the 3-stage, modulating boiler system option. Additional factors to consider are the reliability of the technology, warranties and required maintenance.

In general, given the current tends towards increasing energy prices, investments in energy conservation measures will tend to yield higher rates of return than other capital market investments. Improvements in the energy efficiency of assets also provide a hedge against sharp future increases in energy prices.

When using the internal rate of return measure for assessing cost effectiveness of investments in building improvements, it is important to keep in mind that the time period should correspond to the useful life of the component or equipment to which a cost premium (additional investment) is being applied. For building envelopes, 50 years is commonly used as a representative study period based on observed service life of façade materials and components. In the case of heating, ventilating and air-conditioning (HVAC) equipment, 25 years is typically set as a reasonable study period.

Life Cycle Costing

Life cycle economic assessments attempt to monetize various alternatives to compare their cost effectiveness. This approach normally involves estimating life cycle costs according to procedures outlined in the corresponding ASTM standard[7]. The most common methods of calculating life cycle costs involve the use of the uniform present worth (UPW) and modified uniform present worth (MUPW) measures, as noted in Figure 8.9. Under this approach, for a given life cycle period, all of the annual costs (or savings) are converted into a present worth using time-value of money economics.

Modified Uniform Present Worth

$$P = A_o \cdot \left(\frac{1+e}{i-e}\right) \cdot \left[1 - \left(\frac{1+e}{1+i}\right)^N\right]$$

Uniform Present Worth

$$P = A \cdot \left(\frac{(1+i)^N - 1}{i\,(1+i)^N}\right)$$

where:

P = present sum of money.

A = end-of-period payment (or receipt) in a uniform series of payments (or receipts) over N periods at I interest or discount rate.

A_o = initial value of a periodic payment (receipt) evaluated at the beginning of the study period.

N = number of interest or discount periods.

i = interest or discount rate.

e = price escalation rate per period.

Figure 8.9. Formulas corresponding to the modified uniform present worth and uniform present worth measures.

For example, how much money would a building owner have to set aside today to pay for all of their energy bills for a period of time, say 10 or 25 years? This will depend on how much interest the lump sum of money set aside earns, but also the rate at which the price of energy increases during this study period. Investments in buildings may be treated in a similar fashion. By adding the capital cost of a building improvement to the present worth of its predicted operating energy costs over the study period, meaningful comparisons among alternatives may be performed.

In the case of tower buildings, usually more than one improvement to conserve energy and water will be considered with several alternatives among each improvement. The existing building is normally set as the baseline. It has annual operating costs for energy and water, but the cost of improvements is set to zero since none have been performed. These annual operating costs can be converted into a net present worth using the modified uniform present worth equation to account for differences between the interest or discount rate and the energy price escalation rate.

For each proposed improvement, its present cost can be added to the net present value of operating costs over the selected study period. In general, the alternative with the lowest life cycle cost over the selected study period is the most cost effective choice. In order to conduct this assessment rigorously, costs for maintenance and repair should also be included in the annual operating costs, unless these are practically the same among all alternatives.

From a societal perspective, investments in resource conservation (energy and water) are assessed over the useful service life of the proposed resource conservation measures, regardless of how many times building ownership and/or tenants may change over this time period. This reflects the reality that the environmental burdens of resource depletion and greenhouse gas emissions affect everyone as long as the building is inhabited and operated.

Relationship Between Interest Rates and Energy Price Escalation Rates

The modified uniform present worth formula is favored by energy conservation analysts over the uniform present worth formula because it differentiates between the interest or discount rate and the energy price escalation rate. Figure 8.10 depicts the present value of savings for an initial annual savings of $100 over a range of study periods and several discount and escalation rates.

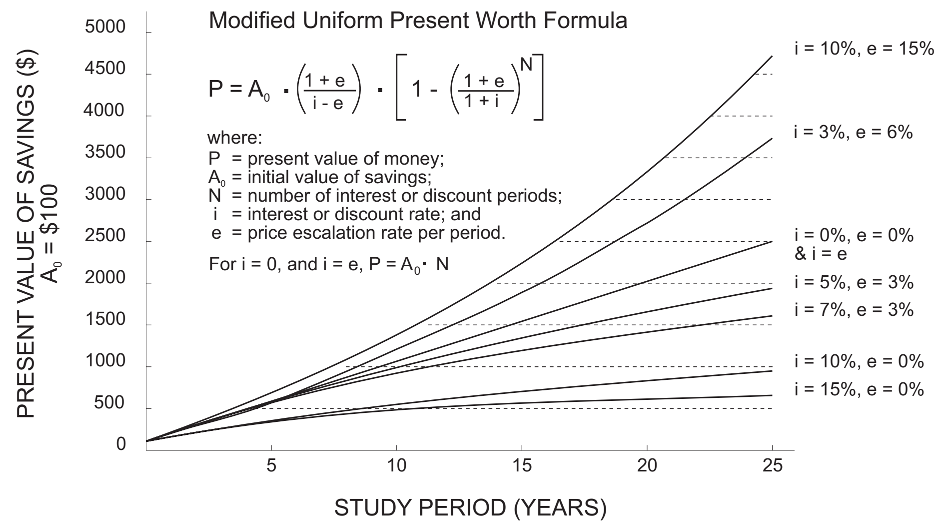

Figure 8.10. Sensitivity of modified uniform present worth measure to differences between the discount (interest) and energy price escalation rates.

Based on Figure 8.10, the following observations may be noted:

1. When interest rates are high, and the escalation rate of energy is low, investments in energy efficiency are not encouraging. Put simply, it is better to invest the money and earn more from interest than can be saved from energy efficiency improvements.

2. When the interest rate and the escalation rate are the same, the relationship is purely linear and there is not a preferred alternative.

3. When the escalation rate of energy exceeds the interest rate, investments in energy efficiency are very attractive - especially over long time periods. An investment that saves $100 in annual energy costs (as depicted above) has a present worth of nearly $4,800 when the interest rate and escalation rate differ by 5% over a 25-year study period. In other words, it is cost effective to invest almost $4,800 today to save $100 annually over the next 25 years under this economic scenario.

Life Cycle Costing Example

The use of the modified uniform present worth measure of life cycle cost effectiveness is best illustrated through a comparative example. This example returns to the case where a building owner is considering the replacement of the boiler system used to heat the building and make hot water for domestic purposes: a 3-stage, modulating boiler system, having an annual fuel utilization efficiency (AFUE) of 82%, and a multi-stage condensing boiler system with an AFUE of 93%. The 3-stage, modulating boiler system has a replacement cost of $425,000 and this results in annual energy savings of approximately $67,000. The multi-stage, condensing boiler system has a replacement cost of $540,000 resulting in annual energy savings of approximately $88,650.

Life Cycle Costing: Replacement Boiler System

Two interest rate and fuel escalation rate scenarios are considered in the analysis.

The boiler systems are examined over two study periods: 10 and 25 years.

	Energy Price Escalation Scenario	
Parameters	***Current***	***High***
Interest	2.5%	4.0%
Escalation	6.0%	9.0%
Study Period	10 years	10 years
	25 years	25 years

The selection of appropriate interest and energy price escalation rates is as much an art as a science. Historical interest rates may be obtained from the Bank of Canada, and there are relatively recent energy price trends available through Statistics Canada. It is advisable to consider a number of scenarios ranging from the most optimistic to the most pessimistic, and have the building owner select the level of risk.

			Present Worth of Operating Costs		***Present Worth of Boiler System and Operating***	
Boiler System	***Cost***	***Annual Operating****	***Current***	***High***	***Current***	***High***
Existing (60% AFUE)	0$	$476,865	$5,762,549	$6,230,187	$5,762,549	$6,230,187
			$18,991,432	$23,230,808	$18,991,432	$23,230,808
Modulating (82% AFUE)	$425,000	$409,837	$4,952,562	$5,354,468	$5,337,562	$5,779,468
			$16,321,985	$19,965,473	$16,746,985	$20,390,473
Condensing (93% AFUE)	$540,000	$388,209	$4,691,203	$5,071,900	$5,231,203	$5,611,900
			$15,460,635	$18,911,846	$16,000,635	$19,451,846

*Annual operating costs include natural gas, electricity and water. The difference in annual operating costs represents only natural gas and electricity (pump efficiency) savings. The condensing boiler has the lowest life cycle cost and after 25 years of service life, the net present value of energy savings is $2,990,797 under the current energy price escalation scenario, and $3,778,962 under the high energy price escalation scenario.

Table 8.3. Example life cycle cost comparison between two replacement boiler system options.

Based on the results of a life cycle costing assessment depicted in Table 8.3, the present worth of operaing costs for the existing boiler system over a 10-year study period is $5,762,549 under the current energy price escalation scenario, and $6,230,187 under the high scenario. Over a 25-year study period, the present worth of operating costs is $18,991,432 and $23,230,808, respectively. Note that for the existing boiler system, the values under the Present Worth of Boiler System and Operating are identical to the values under the Present Worth of Operating Costs, since the cost of the existing boiler system is $0.

Looking at the modulating boiler option, over a 10-year study period the present worth of energy savings are $809,987 compared to the existing system under the current energy price escalation rate scenario, and $875,719 under the high scenario. When the cost of the boiler replacement system is factored in, this difference is reduced to $384,987 and $450,719, respectively. Under the high energy price escalation rate scenario, the modulating boiler system replacement pays for itself more than twice over in 10 years. If the 25-year useful service life of the boiler system is considered, the net present worth of life cycle savings are $2,244,447 and $2,840,336, respectively. This represents savings that could be directed towards other investments, or conversely, these are the opportunity costs associated with keeping the existing boiler system for another 25 years. Normally, this is not an option since many boiler systems in tower buildings are original equipment often badly in need of replacement.

The condensing boiler system option proves to be the most attractive investment based on life cycle cost analysis. The condensing boiler has the lowest life cycle cost and after 25 years of service life, the net present value of energy savings is $2,990,797 under the current energy price escalation scenario, and $3,778,962 under the high energy price escalation scenario.

There are some notable limitations regarding the use of life cycle costing as a decision making tool. First, it is best suited to examining comprehensive and integrated building system performance. The boiler system is part of the building-as-a-system and its cost effectiveness varies as levels of insulation and the thermal efficiency of windows vary, among numerous other variables. Second, there are many costs that may not appear in life cycle costing if they are equal among alternatives. In this example, the cost of maintenance and repair were not factored into the present worth calculations because they were considered roughly equivalent, but this may not always be the case. Third, there are situations when the cost of the option with the lowest life cycle cost cannot be afforded or suitably financed. If every Canadian household could begin with a net zero energy house, it would likely prove the most cost effective in the long run, but the initial monthly payments might not prove affordable.

The preceding discussion has attempted to present how the various economic measures are employed in cost-benefit analyses of tower renewal. A key consideration by building owners is the cost associated with prolonged deterioration of their aging assets. In extreme cases, repairs of crumbling balconies and walls will render the building unfit and necessitate expenditures that cannot be fairly negotiated under duress. An ounce of prevention is worth a pound of cure. He who hesitates is lost.

…policy makers should be more aware that carbon reduction targets will rely on individuals using energy efficiently and those individuals operate in a social context and the influence of cultural, social and emotional influences cannot be underestimated. To that end, it would appear that the issue of learning and awareness, coupled with accessibility to simple technologies would be a central factor to formulating effective policy.

Towards a contemporary approach for understanding consumer behaviour in the context of domestic energy use. Adam Faiers, Matt Cook and Charles Neame. Energy Policy 35 (2007) 4381–4390.

Examples of Typical Cost-Benefit Assessments

The following examples were developed for these guidelines and use the economic measures presented previously. A series of 15 resource conservation measures are investigated in order to examine their cost effectiveness in the context of the archetype tower building. Energy, economic and practical considerations are also discussed to highlight their implications for decision makers. In all cases, the energy savings were estimated using the Screening Tool software, based on the archetype tower energy model presented earlier in this section of the guidelines. The capital costs of the retrofit measures were estimated using data obtained from a number of industry sources, and reflect average expected expenditures as of the last quarter of 2008 .The results for the analyses were summarized in a spreadsheet that allows key variables such as the energy escalation rates to be modified in order to perform sensitivity analyses and consider “what if” scenarios. Figure 8.11 provides a guide to the parameters, data and results for each measure.

Current energy price escalation scenario

High energy price escalation scenario

	Current	*High*
Interest Rate	**2.5%**	**4.0%**
Escalation Rate	**6.0%**	**9.0%**
Study Period (yrs)	**10**	**10**
	25	**25**
	50	**50**

3 study periods for each scenario

	Energy & Water Consumption	Capital Cost	Annual Operating	Present Worth of Energy & Water *Current*	Present Worth of Energy & Water *High*	Present Worth of Operating+RCM *Current*	Present Worth of Operating+RCM *High*
Existing Condition		**$0**	**$476,865**	**$5,762,549**	**$6,230,187**	**$5,762,549**	**$6,230,187**
Electricity (kWh)	1,640,726			**$18,991,432**	**$23,230,808**	**$18,991,432**	**$23,230,808**
Natural Gas (GJ)	20,158			**$62,956,496**	**$98,374,632**	**$62,956,496**	**$98,374,632**
Water (m^3)	52,122						

Baseline building (existing condition)
Annual resource consumption

Life cycle costs for 2 scenarios and 3 study periods

Cost of improvement

Annual operating cost for electricity, natural gas and water (maintenance/repair not included)

Differences in life cycle costs are compared between the existing building and the proposed resource conservation measure

Resourcece conservation measure number and description

RCM #1	**Replace existing roof with RSI 3.5 (R-20) roof**						
		$294,600	**$456,046**	**$5,510,965**	**$5,958,187**	**$5,805,565**	**$6,252,787**
Electricity (kWh)	1,628,500			**$18,162,296**	**$22,216,588**	**$18,456,896**	**$22,511,188**
Natural Gas (GJ)	18,570			**$60,207,914**	**$94,079,749**	**$60,502,514**	**$94,374,349**
Water (m^3)	52,122						

Payback (years)	11.42	@ Current energy escalation rate	**IRR =**	11.3%
	10.65	@ High energy escalation rate	**IRR =**	14.4%
Annual Savings	$20,819			
Annual CO_2 Credit	83,614	kg		

Annual greenhouse gas emission reductions

Annual operating cost savings

Payback periods and internal rates of return (IRR) for a 25-year study period and 2 energy price escalation rate scenarios

Figure 8.11. Guide to parameters, data and results for economic assessment of resource conservation measures applied to the example archetype tower building.

Cost-Benefit Assessment of Resource Conservation Measures - Archetype Tower Building

This analysis is based on NRCan's Screening Tool energy simulations and the assumptions contained therein. Refer to: http://screen.nrcan.gc.ca/index.html
Life cycle costing is based on ASTM E917 Practice for Measuring Life Cycle Costs of Buildings and Building Systems.
Costs associated with externalities not included. Benefits associated with improved health and comfort not included. Greenhouse gas credits not included.
* Cost premiums do not include design/consulting fees and permits.

Economic Assessment Parameters
Two interest (discount) rate and fuel/material escalation rate scenarios are considered in this analysis.

	Current	*High*
Interest Rate	**2.5%**	**4.0%**
Escalation Rate	**6.0%**	**9.0%**
Study Period (yrs)	**10**	**10**
	25	**25**
	50	**50**

	Energy & Water Consumption	Capital Cost	Annual Operating	Present Worth of Energy & Water *Current*	Present Worth of Energy & Water *High*	Present Worth of Operating+RCM *Current*	Present Worth of Operating+RCM *High*
Existing Condition		$0	$476,865	$5,762,549	$6,230,187	$5,762,549	$6,230,187
Electricity (kWh)	1,640,726			$18,991,432	$23,230,808	$18,991,432	$23,230,808
Natural Gas (GJ)	20,158			$62,956,496	$98,374,632	$62,956,496	$98,374,632
Water (m^3)	52,122						
RCM #1	**Replace existing roof with RSI 3.5 (R-20) roof**						
		$294,600	$456,046	$5,510,965	$5,958,187	$5,805,565	$6,252,787
Electricity (kWh)	1,628,500			$18,162,296	$22,216,588	$18,456,896	$22,511,188
Natural Gas (GJ)	18,570			$60,207,914	$94,079,749	$60,502,514	$94,374,349
Water (m^3)	52,122						

Payback (years)	11.42	@ Current energy escalation rate	**IRR =**	11.3%
	10.65	@ High energy escalation rate	**IRR =**	14.4%
Annual Savings	$20,819			
Annual CO_2 Credit	83,614	kg		

Figure 8.12. Life cycle cost assessment of roofing replacement.

The economic assessment of the resource conservation measures for the archetype tower building begins with the existing condition as depicted in Figure 8.12, in order to establish a baseline of energy and water consumption and costs. Results shown are based on the Screening Tool prediction, which was shown earlier in this section to accurately predict actual energy consumption. The existing building annually consumes 1,640,726 kWh of electricity and 20,158 GJ of natural gas. Separate from the energy analysis, the actual water bills indicate the building consumes 52,122 m^3 of water per year. Altogether, the energy and water account for an annual operating cost of $476,865. Looking at the Present Worth of Energy & Water, it should be noted these values are identical to the Present Worth of Operating + RCM. The existing condition includes no resource conservation measures, hence the capital cost is $0. It is interesting to examine the present value of energy and water costs corresponding to the various economic scenarios and study periods. Looking at 50 years, the present value of energy and water ranges from $62.95- to $98.37-million, in both cases exceeding the replacement cost of the entire building.

Resource conservation measure #1 (RCM#1) economically assesses the replacement of the existing roof with an inverted roof having a nominal thermal resistance of RSI 3.5 (R-20).

The capital cost of the replacement roof is $294,600 and this results in a reduced energy cost of $456,865, and an annual savings of $20,819. Under the current energy price escalation scenario, this improvement provides a payback of 11.42 years, and 10.65 years under the high energy price escalation scenario. The corresponding rates of return on the investment are given as 11.3% and 14.4%, respectively, assessed over a 25-year study period. It is important to note that the 50-year study period may or may not be applicable to the roof replacement even though it is indicated in the assessment. The 10-year, 25-year and 50-year periods have been automatically generated in the economic assessment spreadsheet to consider the full range of building component service life expectancies. In many cases, provided it is properly installed, operated and maintained, HVAC equipment can deliver a service life of 50 years even though it is usually ascribed 25 years. There are also some roofing systems that can provide acceptable service over a 50-year time period. Experience and judgment are needed to apply appropriate study periods in economic assessments.

Looking at the difference in life cycle costs over a 25-year study period between the existing roof and the insulated replacement roof, under the current scenario the present worth of savings is $534,536 and under the high scenario, $719,621.

Roof replacement may be necessary because of water leakage due to excessive deterioration before the owner is prepared to go ahead with a more comprehensive tower retrofit. In general, an inverted roof assembly is the preferred option because it can best accommodate any future reconfiguration of rooftop equipment. A durable roof surface of pavers can double as ballast for the insulation and a traffic surface that is needed by service people to access rooftop equipment for maintenance. Ideally, replacement of the roof is preferred to form part of a comprehensive retrofit so that it can be installed after any needed reconfiguration of the rooftop HVAC equipment has been completed.

RCM #2	**Overclad non-balcony/shear walls with RSI 2.1 (R-12) cladding system**						
		$860,844	**$440,136**	**$5,318,704**	**$5,750,324**	**$6,179,548**	**$6,611,167**
Electricity (kWh)	1,614,420			**$17,528,669**	**$21,441,519**	**$18,389,513**	**$22,302,363**
Natural Gas (GJ)	17,392			**$58,107,445**	**$90,797,595**	**$58,968,288**	**$91,658,439**
Water (m^3)	52,122						
	Payback (years)	17.07	@ Current energy escalation rate		**IRR =** 6.5%		
		15.55	@ High energy escalation rate		**IRR =** 9.5%		
	Annual Savings	$36,729					
	Annual CO_2 Credit	146,867	kg				
RCM #3	**Overclad non-balcony/shear walls with RSI 2.8 (R-16) cladding system**						
		$1,039,509	**$435,887**	**$5,267,361**	**$5,694,814**	**$6,306,870**	**$6,734,323**
Electricity (kWh)	1,611,380			**$17,359,458**	**$21,234,536**	**$18,398,968**	**$22,274,046**
Natural Gas (GJ)	17,072			**$57,546,512**	**$89,921,093**	**$58,586,022**	**$90,960,602**
Water (m^3)	52,122						
	Payback (years)	18.12	@ Current energy escalation rate		**IRR =** 3.4%		
		16.44	@ High energy escalation rate		**IRR =** 4.9%		
	Annual Savings	$40,978					
	Annual CO_2 Credit	163,858	kg				

Figure 8.13. Life cycle cost assessment of overcladding non-balcony walls.

Resource conservation measures # 2 and #3 reflect a common practice that is currently employed, where only the flat, continuous walls of the building are retrofit, and the balcony walls and shear walls are not retrofit. Typically, overcladding using either an exterior insulation and finish system (EIFS) or an insulation and rainscreen panel cladding system is applied. This partial approach is often taken because the cost and complexity of retrofitting balcony areas and shear walls are perceived as being prohibitive. In these two examples, it should be noted that the original windows are not replaced – only the easily accessible wall surfaces are overclad up to the edge of existing window openings in these walls, and up to the outer edge of projecting shear walls.

[**Important Note:** The thermal resistance values indicated for the overcladding options represent the effective thermal resistance values of the retrofit assembly, taking into account all thermal bridging due to framing and fasteners. Actual amounts of insulation installed will be higher to account for thermal bridging effects. In general, the existing walls of tower buildings have a thermal resistance value of RSI 0.6 (R-3.40), and this should be added to the effective thermal resistance of the overcladding for energy modeling purposes.]

In RCM#2, the RSI 2.1 (R-12) cladding system costs $860,844 to install and yields annual energy savings of $36,729. Under the current energy price escalation scenario, this measure has a payback of 17.07 years, and under the high scenario 15.55 years. The corresponding rates of return on the investment are 6.5% and 9.5%, respectively, over a 25-year study period.

RCM#3 uses an RSI 2.8 (R-16) cladding system that costs $1,039,509 to install and yields annual energy savings of $40,978. Under the current energy price escalation scenario, this improvement has a payback of 18.12 years, and under the high scenario 16.44 years. The corresponding rates of return on the investment are 3.4% and 4.9%, respectively.

This comparative example illustrates an interesting relationship between physics and economics. The diminishing returns associated with increasing levels of thermal insulation are the result of the first increment of insulation having a higher contribution to reducing the rate of heat transfer than successive increments (refer to page 115 in ***7. Retrofit Strategies: A Systems Approach***). In reality this effect can be amplified because the insulation is "short-circuited" by thermal bridging across uninsulated portions of the building envelope, but this is difficult to estimate in energy models.

The difference in cost between the two cladding systems is $178,666, but the difference in energy savings is only $4,249. Clearly, the relationship between the amount of insulation, its installed cost and the resulting savings, are not linear. Note that the payback periods for the two cladding options are similar, but the rate of return is much lower for RCM #3. However, from a societal perspective, looking at the 25-year and 50-year study periods, the life cycle cost for the RSI 2.8 (R-16) overcladding are lower than the RSI 2.1 (R-12) option. It is also important to assess the effect of higher insulation levels on peak load management. This assessment was not performed in these examples because it requires a highly sophisticated simulation tool that is not practically suited to economic assessments at the conceptual design stage. But it is widely understood that buildings having external insulation over high thermal mass internal elements can delay or shift peak loads and contribute to utilities' demand management programs. Further, higher effective levels of thermal insulation still provide good performance after losing some effectiveness to long term degradation, an especially important consideration as energy prices continue to spiral upward.

As importantly, the overcladding of walls without addressing future window replacements is problematic. At some point in the future, if the windows are replaced, it may prove difficult to remove the existing windows without damaging the new overcladding system. The breaching around the new windows will have to be repaired or somehow properly finished, adding additional expense to this future measure. Alternatively, a detail to accommodate the future replacement can be developed, but this will result in high levels of heat loss around the edges of the windows during the interim. Regardless, the cost of staging, that is the provision of working platforms to replace the existing windows, will be a separate additional cost, instead of being shared across all of the measures required to perform a comprehensive overcladding operation.

RCM #4	Replace existing windows with RSI 0.44 (R-2.5) units						
		$1,710,889	$378,389	$4,572,538	$4,943,605	$6,283,427	$6,654,494
Electricity (kWh)	1,488,358			$15,069,555	$18,433,468	$16,780,444	$20,144,357
Natural Gas (GJ)	13,356			$49,955,495	$78,059,513	$51,666,384	$79,770,402
Water (m^3)	52,122						
	Payback (years)	13.50	@ Current energy escalation rate		IRR = 9.2%		
		12.48	@ High energy escalation rate		IRR = 12.3%		
	Annual Savings	$98,476					
	Annual CO_2 Credit	382,650	kg				

RCM #5	Enclose balconies RSI 0.44 (R-2.5) glazing + RSI 2.64 (R-15) guard						
		$2,816,016	$386,271	$4,667,789	$5,046,585	$7,483,805	$7,862,601
Electricity (kWh)	1,583,375			$15,383,469	$18,817,455	$18,199,485	$21,633,471
Natural Gas (GJ)	13,279			$50,996,117	$79,685,570	$53,812,133	$82,501,586
Water (m^3)	52,122						
	Payback (years)	21.03	@ Current energy escalation rate		IRR = 4.3%		
		18.87	@ High energy escalation rate		IRR = 7.2%		
	Annual Savings	$90,594					
	Annual CO_2 Credit	363,279	kg				

RCM #6	Overclad walls RSI 2.8 (R-16) + overclad balconies RSI 1.76 (R-10) + new guards						
		$4,542,151	$359,509	$4,344,385	$4,696,937	$8,886,536	$9,239,088
Electricity (kWh)	1,556,687			$14,317,639	$17,513,705	$18,859,790	$22,055,855
Natural Gas (GJ)	11,320			$47,462,898	$74,164,627	$52,005,048	$78,706,778
Water (m^3)	52,122						
	Payback (years)	24.52	@ Current energy escalation rate		IRR = 2.7%		
		21.74	@ High energy escalation rate		IRR = 5.6%		
	Annual Savings	$117,357					
	Annual CO_2 Credit	469,271	kg				

Figure 8.14. Window replacements save money and improve comfort, but do little to improve building envelope durability. Overcladding of the flat, continuous wall areas of this existing tower building may partially reduce energy costs, but this partial measure fails to address the durability of the cantilevered balcony slabs and projecting shear walls.

The following three resource conservation measures provide interesting insights on how practical considerations, such as deterioration of the building envelope, can impact decisions. RCM #4 examines a complete window replacement with units having an overall effective thermal resistance of RSI 0.44 (R-2.5).

[**Important Note:** The effective U-value of window assemblies includes the effects of sash, frames and spacers. This value should not be confused with centre-of-glass R-values, which highly overestimate the actual energy efficiency of windows. Refer to Table 7.10 for typical window effective R-values.]

A complete window replacement costs $1,710,889 and results in annual energy savings of $98,476. The payback period ranges from 13.50 years under the current energy price escalation scenario, to 12.48 years under the high scenario. The return on investment ranges from 9.2% to 12.3%, respectively. This measure illustrates the relationship between the thermal performance of existing building components and the cost effectiveness of energy conserving improvements. The single glazed windows without thermal breaks in the aluminum frames perform so poorly that the replacement windows reduce their heat loss by more than half. By comparison, if the existing windows were double-glazed units with thermally broken frames, the reduction in annual energy consumption would be much lower, yet the cost of the window replacement would remain unchanged. As a result, the payback period would be much longer and the rate of return much lower. The need to accurately assess the condition and performance of existing windows cannot be overemphasized.

It is also important to realize that replacing windows without overcladding the walls can be problematic. In an overclad wall assembly, the replacement windows are pulled slightly forward from the existing window position to align the replacement window frame's thermal break with the inner region of the exterior insulation. Projecting replacement windows beyond the existing building face increases the risk of leakage – leaving them in their original position will compromise thermal performance after the walls are overclad.

In RCM #5, only the balconies are enclosed using a window-wall system with an RSI 2.64 (R-15) insulated, opaque portion up to guard height, and the remainder having RSI 0.44 (R-2.5) operable windows. In this case, the existing window and door leading to the balcony are retained, and therefore contribute to the thermal performance of the enclosure. The energy performance is similar to window replacement, but much more costly. However, it preserves the durability of the balcony slabs, which may be a critical consideration. All other wall surfaces continue to deteriorate.

Overcladding all of the walls, including a wrap over the balcony slabs (as opposed to balcony enclosure), but without window replacement, results in marginally better energy performance for RCM #6 than the two previous measures. However, it is extremely costly, yields the longest payback period and offers the lowest rate of return. Moreover, it will require special detailing and coordination to accommodate replacement windows in the future.

Most importantly, none of these resource conservation measures properly address all of the performance issues confronting tower buildings.

RCM #7	**Overclad walls RSI 2.6 (R-16) + overclad balconies RSI 1.76 (R-10) + new guards + replacement windows**						
		$6,253,040	**$302,612**	**$3,656,833**	**$3,953,589**	**$9,909,872**	**$10,206,629**
Electricity (kWh)	1,423,743			**$12,051,697**	**$14,741,946**	**$18,304,736**	**$20,994,985**
Natural Gas (GJ)	7,727			**$39,951,311**	**$62,427,164**	**$46,204,350**	**$68,680,203**
Water (m^3)	52,122						
	Payback (years)	23.28	@ Current energy escalation rate		**IRR =** 3.2%		
		20.72	@ High energy escalation rate		**IRR =** 6.2%		
	Annual Savings	$174,253					
	Annual CO_2 Credit	684,250	kg				
RCM #8	**Enclose balconies RSI 0.44 (R-2.5) glazing + RSI 2.64 (R-15) guard + overclad walls RSI 2.8 (R-16) + replacement windows**						
		$4,644,442	**$300,118**	**$3,626,689**	**$3,921,000**	**$8,271,131**	**$8,565,442**
Electricity (kWh)	1,489,544			**$11,952,354**	**$14,620,427**	**$16,596,796**	**$19,264,869**
Natural Gas (GJ)	7,032			**$39,621,990**	**$61,912,572**	**$44,266,432**	**$66,557,014**
Water (m^3)	52,122						
	Payback (years)	18.60	@ Current energy escalation rate		**IRR =** 5.6%		
		16.84	@ High energy escalation rate		**IRR =** 8.6%		
	Annual Savings	$176,748					
	Annual CO_2 Credit	703,412	kg				

Figure 8.15. Cost effectiveness of comprehensive overcladding and window replacement applied to the example archetype tower building.

Resource conservation measures # 7 and #8 provide a comparison between two building envelope retrofit strategies that address all of the durability, energy performance and thermal comfort issues associated with the current condition of typical tower buildings. These two examples do not include the replacement of the roof assembly as this will be considered in subsequent improvements that combine individual resource conservation measures.

RCM #7 involves a complete overcladding of the exterior walls and the balcony slabs are also overclad (wrapped), but with slightly less insulation. The existing guards are replaced with new guards and all of the windows are replaced. RCM #7 is effectively a combination of RCM #4 and RCM #6. The cost of this measure is $6,253,040 and it yields a payback of 23.28 years under the current energy price escalation scenario, and 20.72 years under the high scenario. The investment offers 3.2% and 6.2% rates of return, respectively. Annual energy savings are estimated to be $174,253. The capital cost shown in this example does not include any repairs that may be required for deteriorated balcony slabs. The installation of new guards requires that the outer edge areas of the balcony slabs are sound and capable of providing sufficient anchorage strength. The need for repairs must be addressed prior to any comprehensive overcladding since it is costly and disruptive to perform spot repairs afterwards. By restoring the full integrity of balcony, shear wall and exterior walls prior to overcladding, their continued service without further degradation can be preserved.

This comprehensive overcladding of the exterior walls and balconies, combined with complete window replacement, addresses concerns related to long-term durability, energy efficiency and occupant comfort. However, it is important to realize the increased airtightness of the exterior building envelope may adversely affect indoor air quality. The conventional ventilation system in tower buildings consists of exhaust fans operating continuously in bathrooms. Typically there is no kitchen range hood exhausting directly to the outdoors. Outside air is delivered to the hallways and it is assumed this will find its way into each suite through the undercut of the entry door. In reality, the gaps beneath doors leading from the hallway into each suite are weatherstripped to control unwanted odours and pests. Thus, the exhaust duct in the bathroom is drawing its make-up air through the leaks in and around the existing windows. When the envelope is tightened, the ventilation effectiveness is significantly reduced, possibly leading to moisture and indoor air quality problems. This may not become apparent if the household consists of one or two people who do not occupy the suite during weekdays because they are at work, and do not cook all of their meals at home. But in households where there are many occupants and frequent cooking and washing activities, moisture and/or indoor air quality problems are highly likely, especially if someone in the household is a smoker.

Looking at the life cycle costs for RCM #7, based on a 25-year study period, the present worth of savings is $686,696 under the current energy price escalation scenario, and $2,235,823 under the high scenario. Assuming today's energy price analysts are correct and we are actually living under the high energy price escalation scenario, which can only grow higher as non-renewable energy reserves are exhausted, the life cycle savings over the next 25 years are equivalent to receiving $2,235,823 the very same day the comprehensive overcladding retrofit is completed. In reality, these saving accrue incrementally, but the life cycle savings represent the amount of capital that is available to finance other investments, or draw income, over the next 25 years. When the 50-year study period is considered, the life cycle savings range from $16.75- to $29.69-million, depending on the energy price escalation scenario. The rate of return on investment for this 50-year period is not shown in the example assessment, but when calculated separately, corresponds to 7.5% and 10.5% for the two energy price escalation scenarios. Looking at these savings from the perspective of succeeding generations, this is the present value of economic burdens placed on the shoulders of future generations if comprehensive overcladding retrofits are not implemented.

For RCM #8, all of the measures are the same as in RCM #7, except that balcony enclosure is substituted for balcony overcladding. It is interesting to note that the window-to-wall ratio increases from 26.47% to 41.23% because in this example it was assumed that all of the balcony enclosure area above guard height is glazed. The existing building has smaller window areas in the balcony wall area. The capital cost is estimated as $4,644,442, roughly $1.6-million less than the previous approach. Energy savings are comparable, but the payback periods are shorter due to the lower capital cost. The rates of return range from 5.6% to 8.6%, depending on the energy price escalation scenario. Based on a 25-year study period, the present worth of savings is $2,394,636 under the current energy price escalation scenario, and $3,965,939 under the high scenario. Clearly, the balcony enclosure strategy is more cost effective than balcony overcladding, and it offers a more comfortable enclosed space. However, as explained earlier, balcony enclosure may not be an option for building faces with restricted limiting distances to unprotected openings.

RCM #9	**Replace boilers with 3-stage modulating 82% AFUE**						
		$425,000	**$409,837**	**$4,952,562**	**$5,354,468**	**$5,377,562**	**$5,779,468**
Electricity (kWh)	1,640,726			**$16,321,985**	**$19,965,473**	**$16,746,985**	**$20,390,473**
Natural Gas (GJ)	14,750			**$54,107,295**	**$84,547,037**	**$54,532,295**	**$84,972,037**
Water (m^3)	52,122						
	Payback (years)	5.66	@ Current energy escalation rate		**IRR =**	22.2%	
		5.44	@ High energy escalation rate		**IRR =**	25.7%	
	Annual Savings	$67,028					
	Annual CO_2 Credit	274,550	kg				
RCM #10	**Replace boilers with multi-stage condensing 93% AFUE**						
		$540,000	**$388,209**	**$4,691,203**	**$5,071,900**	**$5,231,203**	**$5,611,900**
Electricity (kWh)	1,640,726			**$15,460,635**	**$18,911,846**	**$16,000,635**	**$19,451,846**
Natural Gas (GJ)	13,005			**$51,251,922**	**$80,085,285**	**$51,791,922**	**$80,625,285**
Water (m^3)	52,122						
	Payback (years)	5.46	@ Current energy escalation rate		**IRR =**	23.0%	
		5.25	@ High energy escalation rate		**IRR =**	26.5%	
	Annual Savings	$88,657					
	Annual CO_2 Credit	363,139	kg				
RCM #11	**Heat recovery 70% efficiency + ducted air supply to each suite**						
		$395,000	**$402,071**	**$4,858,716**	**$5,253,006**	**$5,253,716**	**$5,648,006**
Electricity (kWh)	1,590,672			**$16,012,700**	**$19,587,147**	**$16,407,700**	**$19,982,147**
Natural Gas (GJ)	14,499			**$53,082,016**	**$82,944,956**	**$53,477,016**	**$83,339,956**
Water (m^3)	52,122						
	Payback (years)	4.79	@ Current energy escalation rate		**IRR =**	25.8%	
		4.62	@ High energy escalation rate		**IRR =**	29.4%	
	Annual Savings	$74,794					
	Annual CO_2 Credit	299,556	kg				

Figure 8.16. Cost-benefit assessment of boiler replacement and the provision of ventilation heat recovery and air supply ducted to each suite.

RCMs # 9 & 10 have already been discussed in detail in the preceding section on economic measures. To recap the discussion related to payback, rate of return and life cycle costing measures:

- Based on payback considerations, the multi-stage, condensing boiler system is generally the preferred option, assuming the replacement cost can be afforded by the building owner.
- The rate of return on either investment improves with increasing energy price escalation rates. The multi-stage, condensing boiler provides a better rate of return in all cases, but it costs $115,000 more than the 3-stage, modulating boiler system option. Additional factors to consider are the reliability of the technology, warranties and required maintenance.
- The condensing boiler system option proves to be the most attractive investment based on life cycle cost analysis. The condensing boiler has the lowest life cycle cost and after 25 years of service life, the net present value of energy savings is $2,990,797 under the current energy price escalation scenario, and $3,778,962 under the high energy price escalation scenario.

From a practical perspective, if the boiler system is replaced prior to a comprehensive retrofit, its heating capacity will be significantly oversized. It will also cost more than a smaller plant serving a more energy efficient building envelope.

RCM #11 considers the case where 70% efficiency heat recovery is provided for the ventilation system along with the installation of ductwork delivering ventilation air to each of the suites. This ductwork is fitted beneath a dropped hallway ceiling and enters above each door through a fire damper. The ductwork is fed by the existing ventilation air ducts currently serving the hallways and a small quantity of ventilation air continues to supply the hallways.

The capital cost of this measure is estimated as $395,000, not including savings that will be realized by a smaller sized boiler system. The annual energy savings are estimated at $74,794 and yield a payback ranging from 4.79 to 4.62 years, depending on the energy price escalation scenario. The corresponding rates of return over a 25-year study period are 25.8% and 29.4%, respectively. The life cycle savings over a 25-year study period are $2,583,732 under the current energy price escalation scenario and $3,248,661 under the high scenario. Over a 50-year study period, these life cycle savings climb to $9,479,480 and $15,034,675, respectively.

Adding heat recovery to the ventilation system will require some modifications to the current equipment and ductwork along with the provision and connection of heat recovery equipment. In order to realize the benefits predicted in this example, heat must be recovered from almost all of the air now being exhausted from the building, and that recovered heat must be used to pre-heat the outside air that is being supplied directly to each suite. The impressive cost effectiveness of this technology is only attainable if the system is properly designed and the installation carefully coordinated.

RCM #12	**Water conservation 30% reduction**						
		$120,000	**$443,795**	**$5,362,914**	**$5,798,121**	**$5,482,914**	**$5,918,121**
Electricity (kWh)	1,640,726			**$17,674,370**	**$21,619,744**	**$17,794,370**	**$21,739,744**
Natural Gas (GJ)	19,241			**$58,590,441**	**$91,552,316**	**$58,710,441**	**$91,672,316**
Water (m^3)	36,485						
	Payback (years)	3.37	@ Current energy escalation rate		**IRR =** 35.1%		
		3.28	@ High energy escalation rate		**IRR =** 39.0%		
	Annual Savings	$33,071					
	Annual CO_2 Credit	46,554	kg				
RCM #13	**Parkade lighting controls - occupancy sensors for two-thirds of fixtures**						
		$6,846	**$475,431**	**$5,745,212**	**$6,211,443**	**$5,752,057**	**$6,218,288**
Electricity (kWh)	1,625,299			**$18,934,294**	**$23,160,915**	**$18,941,140**	**$23,167,761**
Natural Gas (GJ)	20,158			**$62,767,083**	**$98,078,659**	**$62,773,929**	**$98,085,505**
Water (m^3)	52,122						
	Payback (years)	4.36	@ Current energy escalation rate		**IRR =** 28.0%		
		4.22	@ High energy escalation rate		**IRR =** 31.6%		
	Annual Savings	$1,435					
	Annual CO_2 Credit	3,780	kg				

Figure 8.17. Cost-benefit assessment of water conservation measures and parkade lighting controls.

The two resource conservation measures that are assessed in the examples above represent improvements that can be carried out at any time. Neither of these to measures interferes with building envelope or HVAC systems.

In RCM #12, it has been assumed that water closets and plumbing fixtures are replaced in each suite to achieve a 30% reduction in water consumption. The actual amount of water conserved in an apartment building will depend on the type of equipment, fixtures and faucets currently in use. If there has been no upgrading of washing machines, water closets and plumbing fixtures (taps and shower heads), then a complete changeover to the most water efficient equipment and fixtures can result in savings from 50% to 60%, depending on whether or not dishwashers are installed in each suite. Switching to a drip irrigation system over conventional irrigation equipment on a site with extensive landscaped areas can further improve water conservation. The savings shown in this example represent savings in energy for reduced domestic water heating and the forecast reduction in the quantity of water consumed. Note the water savings are calculated separately from the energy savings predicted by building energy software.

The capital cost of simply changing toilets, taps and showerheads is estimated at $120,000. This measure is forecast to reduce annual energy and water costs by $33,071, yielding a payback ranging between 3.37 and 3.28 years, depending on the energy price escalation scenario. The corresponding rates of return are 35.1% and 39.0%, respectively. Based on a 25-year study period, the life cycle savings are $1,197,062 under the current scenario, and $1,491,065 under the high scenario. It is important to appreciate that rates for potable water are rising sharply in Canada to address the high costs of maintaining aging municipal infrastructure, and the increasing energy costs associated with treating water and the resultant sewage.

RCM #13 is an energy conservation measure that is commonly employed in new building parkades (underground parking). There is typically no daylighting of underground automobile parkades, hence artificial lighting must be provided on a continuous basis. Most of the time the parkade is not occupied, and often only several tenants are arriving or leaving at any given time. Leaving all the lights on all of the time is clearly wasteful. Occupancy sensors controlling two-thirds of the lights turn lighting on and off on an as-required basis, triggered by people or cars moving through the parkade. Adequate lighting is provided only where needed and energy is saved. Looking at the example above, the addition of parkade lighting controls is estimated to cost $6,846, and results in annual savings of $1,435. Payback periods range from 4.26 to 4.22 years, depending on the energy price escalation scenario. The corresponding rates of return are 28.0% and 31.6%, respectively.

It is important to recognize that in this example, the existing parkade was assumed to have upgraded lighting, or lighting that meets today's efficiency standards. Many parkades in existing tower buildings have original lighting with much lower efficiency fixtures and lamps that deliver higher lighting levels than needed for vision and safety. In such cases, the cost effectiveness of both replacing fixtures and adding lighting controls may be examined.

RCM #14	**Combination of RCMs #1 + #7 + #10 + #11 + #12 + #13**						
		$7,609,485	**$218,861**	**$2,644,769**	**$2,859,395**	**$10,254,254**	**$10,468,880**
Electricity (kWh)	1,368,970		0.541	**$8,716,272**	**$10,661,968**	**$16,325,757**	**$18,271,453**
Natural Gas (GJ)	3,132			**$28,894,394**	**$45,149,834**	**$36,503,879**	**$52,759,320**
Water (m^3)	36,485						
	Payback (years)	20.25	@ Current energy escalation rate		**IRR =** 4.7%		
		18.22	@ High energy escalation rate		**IRR =** 7.7%		
	Annual Savings	$258,004					
	Annual CO_2 Credit	930,945	kg				
RCM #15	**Combination of RCMs #1 + #8 + #10 + #11 + #12 + #13**						
		$6,000,888	**$216,370**	**$2,614,664**	**$2,826,847**	**$8,615,551**	**$8,827,735**
Electricity (kWh)	1,368,970		0.546	**$8,617,056**	**$10,540,604**	**$14,617,944**	**$16,541,492**
Natural Gas (GJ)	2,931			**$28,565,494**	**$44,635,902**	**$34,566,382**	**$50,636,790**
Water (m^3)	36,485						
	Payback (years)	16.85	@ Current energy escalation rate		**IRR =** 6.7%		
		15.36	@ High energy escalation rate		**IRR =** 9.7%		
	Annual Savings	$260,495					
	Annual CO_2 Credit	941,149	kg				

Figure 8.18. Cost-benefit assessment of combined resource conservation measures.

RCMs #14 and 15 represent combinations of resource conservation measures that address entire building-as-a-system performance objectives. These examples combine roof replacement, boiler replacement, ventilation heat recovery, water conservation and parkade lighting controls with two comprehensive overcladding strategies: balcony slab overcladding; and balcony enclosure, both combined with overcladding of walls and the replacement of windows. The resulting retrofit towers are completely restored to current levels of technology and high levels of resource conservation efficiency.

First considering RCM #14, the capital cost of tower renewal is estimated as $7,609,485. Annual energy savings are $258,004, representing a 54.1% reduction in annual energy costs compared to the existing condition. The resulting paybacks are 20.25 years under the current energy price escalation scenario, and 18.22 years under the high scenario. The corresponding rates of return are 4.7% and 7.7%, respectively. Looking at life cycle savings over a 25-year study period, under the current scenario these amount to $2,665,675, and under the high scenario $4,949,355. Forecasting over a 50-year studio period, life cycle savings grow to $26,452,617 under the current scenario and $45,615,312 under the high scenario. On an annual basis, an estimated 930,945 kilograms of greenhouse gas emissions have been eliminated. The retrofit building is 36.2% more energy efficient than an identical building constructed to the requirements of the Model National Energy Code for Buildings.

A comprehensive retrofit of this nature is likely to provide approximately 50 years of service life with fewer replacement, repair, and maintenance costs than the existing building, assuming it was not retrofit in any manner. For all intents and purposes, it is like a new, high performance building that cost effectively provides safe, healthy, comfortable and environmentally responsible shelter.

RCM #15 is identical to RCM #14, except instead of overcladding the balconies, the balconies are enclosed using a window-wall system with an RSI 2.64 (R-15) insulated, opaque portion up to guard height, and the remainder having RSI 0.44 (R-2.5) operable windows. In this example, the existing window and door leading to the balcony are retained, and therefore contribute to the thermal performance of the enclosure.

The capital cost of this measure is estimated as $6,000,888. Annual energy savings are $260,495, representing a 54.6% reduction in annual energy costs compared to the existing condition. The resulting paybacks are 16.85 years under the current energy price escalation scenario, and 15.36 years under the high scenario. The corresponding rates of return are 6.7% and 9.7%, respectively. Looking at life cycle savings over a 25-year study period, under the current scenario these amount to $4,373,488, and under the high scenario $6,689,316. Forecasting over a 50-year studio period, life cycle savings reach $28,390,114 under the current scenario and $47,737,842 under the high scenario. On an annual basis, an estimated 941,149 kilograms of greenhouse gas emissions have been eliminated. The retrofit building is 40.9% more energy efficient than an identical building constructed to the requirements of the MNECB.

It should be appreciated that in all of the examples presented in this section of the guidelines, incentives and tax implications have not been factored into analyses. For the sake of simplicity, these have been assumed to offset the cost of design fees and permits.

The comprehensively retrofit tower building with enclosed balconies appears to be the most cost effective alternative, provided there are no restrictions on limiting distance. There may be cases where some tower buildings cannot elect balcony enclosure because of restrictive limiting distances and one or more building faces may have to employ balcony overcladding. While this will result in higher capital costs, there is not a significant difference in life cycle performance over the long term. From a societal perspective, comprehensive tower retrofits should therefore be assisted by whatever means necessary to achieve their economic, social and environmental objectives.

Table 8.4 summarizes the cost-benefit assessment of resource conservation measures examined in this section of the guidelines. It is followed by a review of additional considerations beyond the simple cost-benefit analysis presented herein.

Retrofit / Improvement	Cost-Benefit	Practical Considerations
Roof Replacement RCM #1	• Relatively inexpensive • Reasonable payback • Low lifecycle savings • Not visible for marketing	• Requires coordination to accommodate future replacement or modification of HVAC and other rooftop equipment • More expensive if carried out by itself, instead of sharing staging with other retrofit measures
Selective Overcladding RCMs # 2, 3, 5, 6	• Ranges from expensive to very expensive • Reasonable payback • Low to moderate life cycle savings • Visible for marketing, but draws attention to elements that have not been retrofit	• May not address balcony or shear wall deterioration • Requires coordination and special details to accommodate future window replacement and balcony retrofit • More expensive if carried out by itself, instead of sharing staging with other retrofit measures
Window Replacement RCM #4	• Relatively expensive • Reasonable payback • Moderate life cycle savings • Visible for marketing, but draws attention to elements that have not been retrofit	• Does not address balcony or shear wall deterioration • Requires coordination and special details to accommodate future overcladding and balcony retrofit • More expensive if carried out by itself, instead of sharing staging with other retrofit measures
Comprehensive Overcladding RCMs #7 & 8	• Very expensive • Reasonable payback • High life cycle savings • Visible for marketing • Improved occupant comfort	• Fully addresses balcony or shear wall deterioration • Requires coordination with HVAC to ensure adequate ventilation rates due to increased airtightness • Cost effectively shares staging with other retrofit measures

Retrofit / Improvement	Cost-Benefit	Practical Considerations
Boiler Replacement RCMs #9 & 10	• Relatively inexpensive • Rapid payback • Moderate to high life cycle savings • Not visible for marketing	• Oversized if replaced before comprehensive overcladding performed • Opportunity to improve controls and integration with HVAC system
Heat Recovery Ventilation and Ducted Air Supply to Each Suite RCM #11	• Relatively inexpensive • Rapid payback • High life cycle savings • Not visible for marketing • Improved indoor air quality	• Requires modification of existing ventilation system and coordination with HVAC system • Less effective if carried out by itself, before comprehensive overcladding improves airtightness
Water Conservation RCM #12	• Relatively inexpensive • Rapid payback • Low to moderate life cycle savings • Not visible for marketing	• Can be performed anytime without impacting other systems • Conservation improved with individual water metering of suites
Parkade Lighting Controls RCM #13	• Relatively inexpensive • Rapid payback • Low lifecycle savings • Visible for marketing but requires explanation to tenants	• Can be performed anytime without impacting other systems • Recommended to complement with safety features such as security cameras
Comprehensive Retrofit RCMs # 14 & 15	• Most expensive • Reasonable payback • Highest lifecycle savings • Highly visible for marketing • Improved aesthetics, durability, indoor air quality and occupant comfort • Low carbon footprint	• Requires professional planning, design and coordination • Disruption may increase vacancy rates during retrofit period • Scale of project and sharing of staging and equipment renders economical pricing
In practical terms, only water conservation and parkade lighting controls may be implemented anytime. Careful design and coordination is needed for all other retrofit measures.		

Table 8.4. Summary of the cost effectiveness of tower retrofit measures and practical considerations.

Critical Cost-Benefit Considerations

There are several additional considerations that influence decisions to proceed with tower renewal. These are discussed below with a view to establishing a context that goes beyond discretionary investments.

Avoidance of Physical Deterioration of Real Estate Assets

Many of today's tower buildings are experiencing performance problems ranging in consequences from routine maintenance to complete repair and/or replacement. A study conducted in 1996 examined nearly 500 apartment buildings in the Toronto area to assess their condition and repair needs.[8] The results of the study were not encouraging and in the 12 years since that time, much of the repair work identified in the study has been scheduled, initiated or completed.

Figure 8.19. Deterioration of essential components of tower buildings can lead to the need for costly repairs and replacement. Some of these repairs, such as balcony restoration, are expensive and do not have a payback since the energy and water conservation of the building has not been improved.

A major consideration influencing the decision to proceed with tower renewal is the avoidance of costly repair work. Normal deterioration in building envelopes and structural elements proceeds at a gradual rate and then rapidly deteriorates after the material integrity has been compromised. Interventions prior to this critical condition can avoid repair and/or replacement. For example, in the case of exposed, projecting balcony slabs, overcladding and enclosure may be performed without the need for extensive repairs of the slab edge. As long as the slab is not structurally compromised and the concrete near the outer edge of the slab can retain mechanical fasteners that have sufficient strength to attach items such as railings or glazed enclosures, the cost of slab edge repair and replacement can be avoided.

For the archetype tower building presented in this section of the guidelines, a complete slab edge repair and replacement carries a cost of approximately $750,000. Avoidance of chronic physical deterioration is a critical consideration that goes beyond the measures of payback, rate of return or life cycle cost.

Valuation of Real Estate Assets

The valuation of real estate, particularly assessing the market value of income properties, is a complex exercise that remains beyond the scope of this publication. However, it is an important consideration when exploring tower renewal opportunities. On the surface it may appear that spending between $5.7- and $7.6-million for a 15 to 20 year payback on a comprehensive tower building retrofit, that roughly yields between a 5% to 10% rate of return, may not be an attractive investment. As discussed earlier, this will vary depending on the nature of the building owner, and whether or not they are seeking to venture capital for the expansion of their real estate holdings, or into other investment vehicles.

In very general terms, an income property will have a valuation that ranges between 10 and 14 times the value of net annual income. The actual valuation multiplier will depend on the potential rate of return for other types of investments, and the condition of the building. Looking at the example building, assuming a mix of 240 suites with an average monthly rent of $1,000, the gross annual income is $2,880,000, assuming no vacancy. Operating costs, maintenance/repair, janitorial services, property management, accounting, insurance and vacancy represent approximately $750,000 each year. The resulting net annual income is $2,130,000. The fair market value of the property ranges between $21.30- and $29.80-million. After a comprehensive building retrofit, operating costs alone are reduced by approximately $250,000 per year and there will also be savings due to avoided maintenance/repair costs. On the basis of energy and water savings alone, the retrofit tower building is worth between $2.5- and $3.5-million more, hence the real cost of the retrofit is effectively reduced by about 50%. The enhanced marketability of the retrofit building is likely to influence vacancy rates, and this combined with the avoided costs of repair and replacement of the building fabric and major equipment resulting from ongoing deterioration. Put simply, this means the building owner's ability to qualify for financing of other investments, such as the expansion of real estate holdings, is not significantly impaired. This will highly depend on the valuation procedures and policies that are in place. Valuation of more sustainable real estate assets is being considered in other jurisdictions. The Vancouver Valuation Accord was signed on March 2, 2007 and addresses the interrelationship of sustainability and valuation. It recognizes the increasing need and demand for the business case for sustainability to be established, and acknowledges that valuation can play an important role.[9] Tower renewal hinges on the proper valuation of high performance buildings.

Financial Viability and Affordability

For building owners that are not interested in expanding their real estate holdings, or venturing capital into other investment vehicles, a real concern is financial viability of the retrofit and how this may effect affordability of the rents, hence marketability and vacancy rates. Table 8.5 indicates the monthly and annual payments required for each $100,000 borrowed on a 25-year mortgage at various interest rates.

	Payment per $100,000 Borrowed	
Mortgage Term & Interest Rate	Monthly	Annual
25 Years at 3%	$473.25	$5,679
25 Years at 3.5%	$499.27	$5,991
25 Years at 4.0%	$526.02	$6,312
25 Years at 4.5%	$553.47	$6,642
25 Years at 5%	$581.60	$6,979
25 Years at 6%	$639.81	$7,678

Table 8.5. Payments required to service principal and interest on a 25-year mortgage per $100,000 borrowed.

Looking at the annual energy and water savings associated with a particular retrofit scenario, it is possible to determine how much can be financed through conventional borrowing means. Table 8.6 shows the mortgaged loan amount that can be carried by annual operating cost savings. For the example building, post-retrofit energy and water savings approach $250,000. From Table 8.6, these savings can carry a mortgage ranging between $3.26- and $4.40-million, depending on the interest rate.

	Annual Operating Cost Savings				
Mortgage Term & Interest Rate	*$200,000*	*$250,000*	*$300,000*	*$350,000*	*$400,000*
25 Years at 3%	$3,521,747	$4,402,183	$5,282,620	$6,163,057	$7,043,494
25 Years at 3.5%	$3,338,207	$4,172,759	$5,007,311	$5,841,862	$6,676,414
25 Years at 4.0%	$3,168,447	$3,960,559	$4,752,671	$5,544,783	$6,336,895
25 Years at 4.5%	$3,011,304	$3,764,131	$4,516,957	$5,269,783	$6,022,609
25 Years at 5%	$2,865,658	$3,582,072	$4,298,487	$5,014,901	$5,731,316
25 Years at 6%	$2,604,940	$3,256,175	$3,907,410	$4,558,645	$5,209,880

Table 8.6. Amount of mortgage carried by annual energy savings at various interest rates.

Assuming financing can be arranged at 4.5%, then for RCM #15 with an estimated cost of $5.71-million, approximately $1.95-million cannot be carried by the energy and water savings. If the comprehensive retrofit was assessed as an allowable rent increase, the annual payment required would be $129,500 prorated among the 240 units. On average, this translates into a monthly rent increase of approximately $45 per suite. If financing was available at 3%, the average monthly rent increase would be reduced to $30 per suite. In reality, the rent increases forecast in this example would be lower after reduced repair/maintenance costs are factored into the economic assessment. The important considerations for the building owner are access to favourable financing arrangements, and how the marginal increase in rental rates may affect marketability and vacancy rates. From a consumer willingness-to-pay perspective, are comfort and superior air quality worth a premium of between $1 and $1.50 per day?

Marketability

The marketability of apartment housing has always being strongly correlated to its location, but the general appearance of the building, and the level of thermal comfort and indoor air quality it provides are also important factors. Safe, clean, well kept apartments that perform as well as new housing will likely be in greater demand than deteriorating buildings with poor appearances and moisture and indoor air quality problems.

It was not possible during the development of these guidelines to estimate the value of improved marketability. This assessment can be readily performed by building owners who have an intimate knowledge of their historical vacancy rates. The annual opportunity cost associated with vacancies can be sufficient to offset a large portion of the allowable rent increases that would result from financing a comprehensive tower retrofit.

Other costs are associated with high turnover rates in apartment buildings. In addition to costs for cleaning and painting, landlords must advertise their vacant units and take time out to show them to prospective tenants. The review of tenant applications is also time consuming and takes away time from other more important tasks, or must be delegated at a fee.

Societal Costs and Opportunities

Apartment buildings with higher net revenues enjoy higher market valuations, hence the influence of tower renewal on marketability is another important consideration for owners.

An earlier section of these guidelines examined the tower renewal challenge and identified potentially enormous social benefits with the improvement of housing conditions and their ripple effect on community health and well being.

Tower apartment buildings account for significant expenditures related to the provision of a host of social and essential services. Housing agencies incur high costs for necessary repair and maintenance of their deteriorating tower building stock. The cost of essential items such as energy, water and solid waste disposal are escalating rapidly and grow more burdensome over time. Utilities have strong incentives to avoid expansion costs to meet increased demand from urban growth, and financial institutions have a vested interest in protecting their investments. All stakeholders can benefit from reduced greenhouse gas emissions. Tower renewal represents an opportunity for government, utilities and financial institutions to minimize the costs and future risks associated with deteriorating and inefficient housing stock.

Societal stakeholders are pivotal players that can develop instruments such as tax credits, rebates and favourable financing arrangements to reduce barriers that are currently being faced by tower building owners. It is vital for societal stakeholders to explore creative means to shed costs and take advantage of opportunities that can be shared with owners and tenants.

Estimate of Greenhouse Gas Emission Reduction Potential
This estimate is based on data obtained through the Toronto Atmospheric Fund and derived from energy modeling conducted as part of the Tower Renewal Guidelines.

High Rise Buildings in Toronto
Defined as buildings having 5 storeys or more. Information supplied by TAF through TCHC and Urbanation.

	Buildings	Units	Date of Construction							
			Before 1946	1946-1960	1961-1970	1971-1980	1981-1990	1991-2000	2001-2007	Total
Apartment buildings	1,379	306,268	38	246	626	137	47	51	5	**1150**
Condominiums	936	129,493	25	17	20	234	236	174	230	**936**
TCHC	232	42,794								
Total	**2,547**	**478,555**								

Note: Date of construction could not be ascertained for 229 apartment buildings.

	Location						
	Toronto	Etobicoke	York	North York	East York	Scarborough	Total
Apartment buildings	432	175	92	349	47	229	**1324**
Condominiums	368	109	36	260	27	136	**936**
TCHC	N/A						

Note: Location could not be ascertained for 55 apartment buildings.

Annual Energy Consumption

	Avg. Apartment Building		TCHC*		Archetype Tower Building		Average per Unit
	Per Unit	Per sqft	Per Unit	Per sqft	Per Unit	Per sqft	
Natural Gas (m3)	1,468.57	1.85	2,000.00	2.40	2,254.27	1.84	1,907.61
Natural Gas (MJ)	54,717.45	68.93	74,518.00	89.42	83,991.67	68.51	71,075.71
Electricity (kwh)	10,512.15	11.98	9,500.00	11.30	6,836.36	5.58	8,949.50
Total Energy (GJ)	**92.56**	**0.11**	**108.72**	**0.13**	**108.60**	**0.09**	**103.29**

* Average of 37 buildings, 2005.
Average apartment building includes electrically heated buildings.
Archetype tower building heatedwith natural gas, average suite 1,226 f^{t2}, larger than average apartment unit.

Green House Gas Emissions Reduction Potential

Assumptions
Assume average annual per unit energy consumption for existing apartment building stock.
Based on the archtype tower building energy analysis, energy consumption reductions are: Natural Gas 85.46%; Electricity 16.56%

Only apartment buildings and TCHC buildings will be considered in this analysis because extent of retrofit measures implemented in condominium buildings is unknown. 349,062 units

Total natural gas consumed	24,809,828	GJ/year
Total natural gas reduction	21,202,446	GJ/year
GHG reduction potential for natural gas	1,076,391,599	kg/year
Total electricity consumed	3,123,931	GJ/year
Total electricty reduction	517,422	GJ/year
GHG reduction potential for electricity	126,768,294	kg/year
Total greenhouse gas emission reduction potential	**1,203,159,893**	kg/year
	1,203,160	tonnes/year
	3.45	tonnes/unit.year

Emissions Data (Ontario)

1 GJ	natural gas =	50.767	kg CO2e
1 MWhe	natural gas =	182.763	kg CO2e
1 kWh	electricity =	0.245	kg CO2e
1 MWh	electricity =	245	kg CO2e

CO2e of natural gas 1891.54 g/m³
http://www.ec.gc.ca/pdb/ghg/inventory_report/2004_report/ann13_e.cfm

1998-2005 average of electricity emission intensities 245 gCO2e/kWh
http://www.ec.gc.ca/pdb/ghg/inventory_report/2005_report/ta9_7_eng.cfm

Table 8.7. Estimate of greenhouse gas emission reductions for the City of Toronto associated with comprehensive tower retrofits.

Greenhouse Gas Emission Reductions

For all stakeholders, greenhouse gas emissions and their impact on climate change represent a serious concern. Among the many environmental benefits of tower retrofits, such as resource conservation, it is likely the most important pertain to greenhouse gas emission reductions, in terms of global warming and air quality.

The greenhouse gas emissions associated with tower apartment buildings are difficult to estimate precisely. This stems from the difficulty in determining the actual number of apartment buildings that actually exist in a municipal boundary. Assuming the number is known, it is possible to determine the aggregate energy consumption if the energy bills for each building can be obtained. If not, this can be estimated through computer energy simulation, but it is then necessary to determine the physical characteristics, such as building envelope properties, heating and ventilation systems and their efficiencies, fuel type, number of units, and whether or not there is underground parking, indoor pool, etc. A small population of typical buildings can yield a statistically significant result for current energy consumption by energy source, and this can be applied to all of the buildings, recognizing it may not be able to ascertain the extent of conservation measures that may have been implemented in these buildings. In a city like Toronto with more than a thousand candidate retrofit buildings, this is a challenging exercise that can only be accurately performed if an energy audit is conducted for each building. The greenhouse gas emission reduction potential that has been estimated in these guidelines is admittedly approximate, but based on the best available data. It should be noted that greenhouse has reductions associated with water conservation have not been considered. Municipal water works typically account for the single largest energy expenditure of any department, primarily in the form of electricity to pump vast quantities of water on a continuous basis.

Based on the data and assumptions noted in Table 8.7, a complete, comprehensive retrofit of Toronto's existing apartment buildings has the potential to reduce greenhouse gas emissions by approximately 1.2 million tonnes per year, or roughly 3.45 tonnes per year per apartment unit. The economic value of greenhouse gas emission credits has not been considered in this analysis. The marketplace for carbon credits is not fully established in Canada, but it is important to recognize the value of carbon credits may be a significant factor in electing tower renewal. Government agencies and utilities could assist owners by establishing an administrative framework for the eventual brokering of greenhouse gas credits.

The next page summarizes all of the costs and benefits associated with tower renewal that need to be kept in mind by all stakeholders choosing to participate in tower renewal.

Summary of Tower Renewal Costs

Before any of the benefits of tower renewal may be realized, it is important to appreciate the unavoidable costs (investments) that must be incurred.

- **Consulting** – All apartment buildings are unique and the physical condition of their various elements may differ considerably. Expert consulting is needed to conduct a conditional survey and assessment of remedial measures needed to address health and safety issues, durability of the structure and building envelope, and reliability of equipment and services. An accounting of annual energy and water consumption must also be conducted. Increasingly important is the need to assess solid waste management practices and potentials of the project.

- **Design** – A comprehensive tower retrofit project is no different than a new tower construction project in terms of the design expertise that must be integrated to deliver a cost effective and well performing solution. Using the results of the conditional survey, a design team of architects and engineers must work to find cost effective strategies for retrofit of the envelope, mechanical and electrical systems, water conservation, stormwater and solid waste management. Analysis of Code requirements and planning/zoning implications informs the design process. Contract documents (drawing and specifications) are subsequently developed for permit and tendering purposes. Design services typically include contract administration and an allowance for quality assurance.

- **Permits** – Tower retrofit work cannot proceed until all required permits and approvals are obtained. The time and cost associated with obtaining permits and approvals may be significant if variances to municipal by-laws are required, or compliance with Code requirements requires interpretation and a ruling.

- **Insurance** – Over the course of the renewal project, special arrangements for insurance will likely be needed. These arrangements will have to coordinated with insurance coverage provided contractors and trades. From an owner's perspective, risks pertaining to liability and property damage during retrofit must be responsibly managed.

- **Restoration/Retrofit** – The largest cost component for any tower retrofit project is associated with the rehabilitation of deteriorated elements and the retrofit of the various building systems. This specialized construction work demands material, labour, equipment and energy (electricity, winter heat). The energy and water conservation savings are not fully realized until this work is completed.

- **Commissioning** – Tower buildings are complex systems that must be properly commissioned to achieve their performance potential.

- **Construction Vacancy** – Retrofit work will cause some degree of disruption and inconvenience to inhabitants of the building. This may translate into an increased vacancy rate during the period when work is being carried out. A vacancy allowance represents an important cost to include in all estimates.

- **Bridge Financing** – The full benefits of energy and water savings are not realized until all of the work is complete. Bridge financing is needed to cover the cost of interest accumulated during the construction period on retrofit loans. The cost of bridge financing is critical to the economic feasibility of tower renewal projects.

Summary of Tower Renewal Benefits

The retrofit of existing tower buildings has the potential to deliver numerous benefits.

- **Employment** – A recent U.S. study indicates that in 2006, the annual sales by the renewable energy and energy efficiency industry exceeded the combined sales of America's top three corporations. Translated to Ontario, annual economic activity in this sector could reach $95 billion in annual sales by 2030 and create 838,000 jobs. Tower renewal would account for a significant proportion of this market. The labour associated with tower renewal represents jobs that cannot be outsourced. Overcladding cannot be carried out from an offshore call centre – it requires workers to be present on site as full participants in a green economy.

- **Innovation** – The mass customization potential of tower renewal is a significant opportunity for Ontario's building components manufacturing sector. Instead of constructing overcladding elements on-site, it is feasible to manufacture components under controlled factory conditions that are subsequently installed by highly qualified technicians and skilled trades. Manufacturers and contractors can become leaders in the rehabilitation of North America's urban building fabric, advancing technological innovation that would diffuse across Canada.

- **Conservation of Energy and Water Resources** – Reduction is the most important element of the 3Rs, and preliminary analyses indicate energy consumption in existing tower buildings can easily be reduced by at least 50% - more with the deployment of renewable energy technologies. Water consumption can be reduced by 30% to 50% by simply switching over to contemporary plumbing fixtures and water consuming appliances. Future economic growth hinges on sustainable supporting infrastructure, and conservation not only avoids expansion costs, but also makes essential resources available to new development.

- **Reduced Greenhouse Gas Emissions** – Energy is needed to heat, cool and light buildings. Water works and sewage treatment also consume energy. Most of this energy use results in greenhouse gas emissions. Reducing greenhouse gas emissions is good for the environment, and soon it will become good business as greenhouse gas credits become traded in Canada.

- **Affordability** – Higher energy and water costs are passed on to tower building tenants. Tower renewal improves the affordability of housing by investing in conservation measures that keep rent increases down.

- **Health and Comfort** – Properly air sealed and insulated buildings are more comfortable and less susceptible to mould and mildew. Tower renewal has the potential to improve the quality of life for hundreds of thousands of tenants.

- **Increased Market Value and Reduced Vacancy Rates** – Better performing buildings that have proactively reduced maintenance and repair costs carry higher market values than deteriorating energy hogs. Better health, comfort, affordability and aesthetics translate into lower vacancy rates.

- **Sustainable Urban Regeneration** – Rather than watch cash go up the chimney, down the drain or poured into avoidable repairs, comprehensive building retrofits can help finance redevelopment and urban regeneration that makes a community a better place to live and do business for everyone.

Cultural Resource Conservation and Stewardship

The concept of tower renewal transcends money, even though the predominant means of assessing costs and benefits is monetary. Tower apartment buildings are an important part of Canada's affordable housing resources. They require an appreciation of cultural stewardship that promotes the advancement of this architectural building form, the urban landscape it so strongly impacts, and its influence on future urban design and regeneration.

To this point in the assessment of costs and benefits, the importance of cultural resource continuity has not been discussed. It is now understood that the replacement cost of Toronto's stock of apartment buildings alone represents several hundreds of billions of dollars. This number more than doubles when all of Canada's apartment building stock is included. Replacement is clearly not an inviting option, particularly when the cost of renewal is far less than a tenth of this value. But replacement is inevitable unless the process of building retrofit is launched and supported by secure investment vehicles.

In exchange for these investments, whose costs and benefits must be fairly shared among the various stakeholders, it is possible to conserve affordable housing, preserve the urban landscape and foster the regeneration of our communities. This is an aspect of tower renewal that is difficult to assess in terms of conventional cost-benefit analyses. It will always be difficult to place a price on the future of our communities. As there can only be one future, it is vitally important to guide it towards a shared vision of sustainability.

Fig 8.20. High-rise apartment towers advertised features that were uncommon in single-family detached housing such as indoor swimming pools, sauna rooms and underground parking – penthouse suites afforded views of the city and less traffic noise. Tower renewal has the potential to restore these invaluable housing resources to their former status. [Source: City of Toronto Archives]

Sustainability is now understood as comprising environmental, social and economic dimensions that must be harmonized to achieve an equitable balance. The cost-benefit analysis of tower renewal presented in these guidelines is a methodology, not a definitive answer. However, it does strongly suggest that it is not possible for any single stakeholder to shoulder the economic burden alone. Building owners seeking to extend the useful life of their assets and hence their return on investment (income) stand to gain the most in the short term, and it seems reasonable they should carry the largest proportion of the initial cost. Tenants will enjoy a higher quality of life in their renewed towers and this necessarily comes at a cost they can afford, but also must be willing to pay.[10] Societal stakeholders must contribute by reducing unnecessary barriers, providing favourable financing and incentives to reduce the inherent risk in tower renewal propositions. Everyone also has to realize that housing is a social and cultural resource that demands stewardship guided by a long-term perspective. Tower renewal can only fulfill its promise if all stakeholders actively participate in preserving this iconic housing typology for successive generations of Canadians.

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[Photo Opposite Page: Jesse Colin Jackson]


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9. Contract Documents and Administration

This part of the guidelines focuses on the preparation of contract documents and the administration of the retrofit work. Due to the nature and scope of tower renewal, particularly with respect to comprehensive retrofits, it has been assumed that the prime consultant will normally be a licensed architect. This is in contrast to the common present practice of having building envelope consultants prepare technical details and specifications in the absence of architectural standards. Tower buildings form a significant component of the urban landscape and are among the most defining architectural features in many neighbourhoods and communities, hence this part of the guidelines is premised on the retrofit design being conducted by skilled practitioners and guided by appropriate architectural standards.

The following charts represent an abridged outline of a typical project process from conception to completion, as described earlier in ***3. Anatomy of a Tower Retrofit***. Charts listing project personnel and approvals that may be required have also been provided. They are intended as a convenience in an effort to illustrate project scope, phases and chronology.

The information presented is generic in nature with aspects that may vary under certain jurisdictions and in various locales. Most municipalities now provide a complete list of the required documentation for approvals and permits pertaining to buildings and site work. These should be observed and take precedence over the general outline presented in this part of the guidelines.

It is important to note that all assumptions pertaining to the work should be confirmed by due diligence. It is also recommended that all authorities having jurisdiction and experienced local professional consultants be engaged to determine a comprehensive project process specific to the retrofit's requirements and context. Tower renewal is a simple concept that is very complex in application. The retrofit of existing conditions is much more challenging than new construction simply because of the large number of fixed constraints. Occupied buildings also entail practical considerations. For example, the specification and detailing of overcladding and window replacements must minimize intrusiveness. Inhabitants are not well disposed to work procedures that involve repeated access by workers to the interior of suites. Processes that create dust and fumes should be avoided to the greatest extent possible. These are the sorts of critical considerations that are not listed in the charts that follow, but need to be seriously addressed in practice.

As noted earlier in these guidelines, the cost of contract documents and administration, inclusive of all consulting fees, will be higher than normal fee schedules for new construction, typically falling into a range from 8% to 12% of the total project retrofit cost. The actual fees for professional services will depend on the existing condition and the complexity of the retrofit. Note that permit fees are not included in this amount.

In many ways, contract documents and administration determine the quality of the completed retrofit. There is a tendency to dismiss the importance of design, quality control and administration in favour of obtaining lower prices from contractors who can work without proper instructions and supervision. This is not a recommended means of conducting tower renewal and it should be noted there are no cost effective substitutes for a comprehensive approach to contract documents and administration.

IMPORTANT NOTE: The project phases listed below and the charts that follow are not mutually exclusive of the integrated design process. This part of the guidelines provides a framework for the exercise of due diligence and the provision of professional services. Refer to ***2. Principles of Tower Renewal*** for a discussion of the integrated design process and how it may be deployed to attain sustainable building system performance.

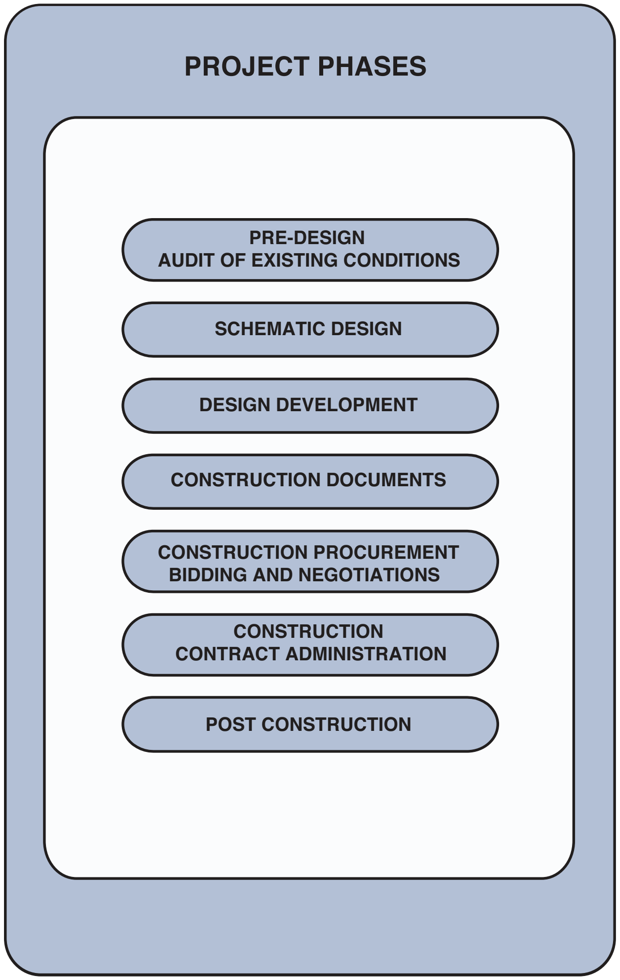


Figure 9.1. There are typically seven phases in a tower renewal project. In general, the time and effort expended during the first four phases will largely determine the success of the phases that follow. Intelligent design can easily pay for itself through savings in the retrofit costs.

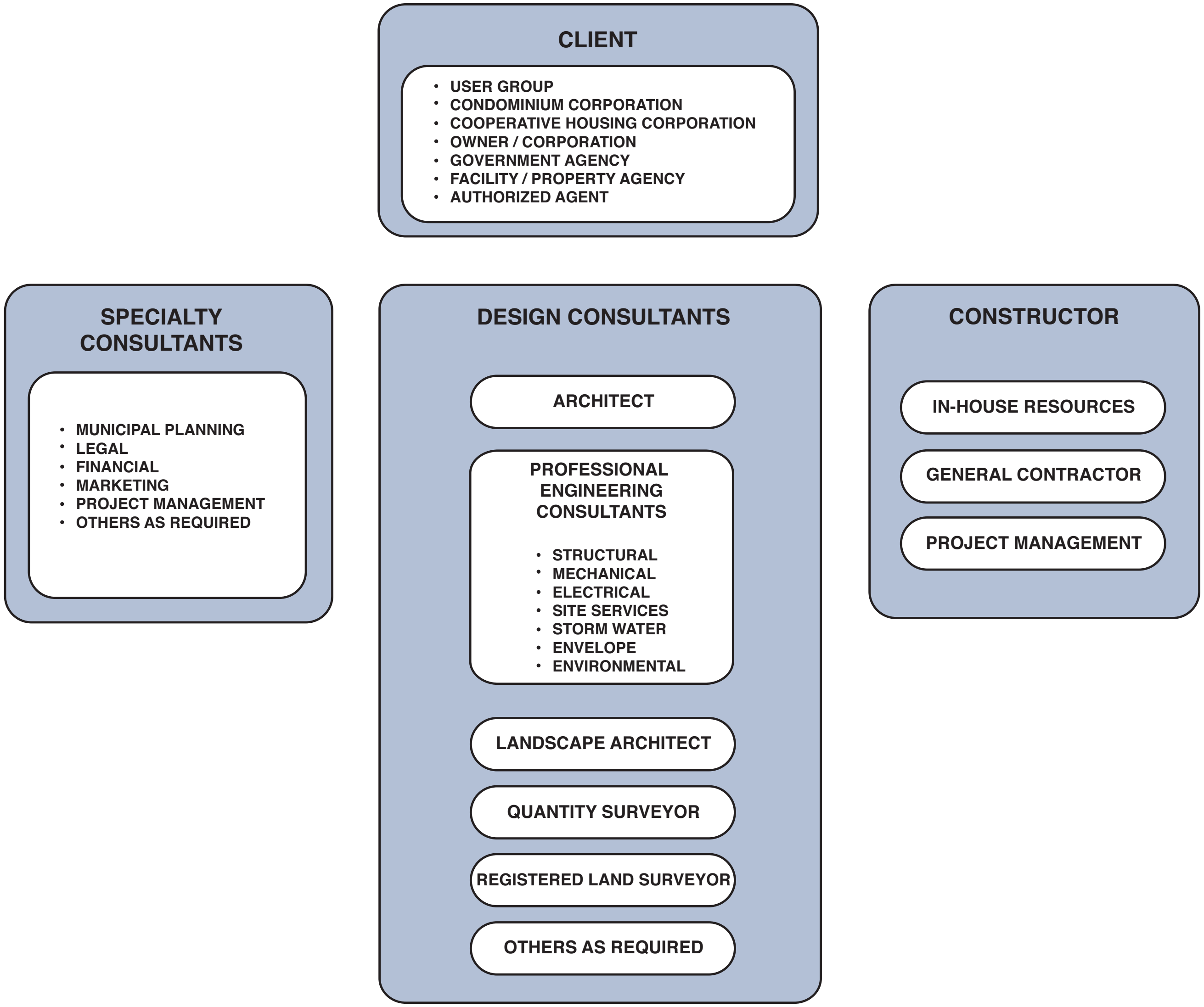


Figure 9.2. Project personnel involved in a comprehensive tower retrofit will usually involve a large group of people with diverse skills and backgrounds. The design consultant will normally be a licensed architect, who in turn will retain and coordinate a team of professionals. To avoid conflict of interest, the quantity surveyor, or cost consultant, is normally retained by the client directly, but works closely with the design consultants to estimate the value of the proposed retrofit work. There are essentially three options for construction. Some larger organizations may have in-house resources that can perform all or part of the retrofit work, but this is quite exceptional. In most cases, either a general contractor will be awarded the entire project, or the work will be parcelled out to the various sub-contractors and trades by a project manager representing the owner. Tower renewal projects demand a highly integrated design and construction team to ensure a successful project that is completed on time and on budget, and performs as predicted.

MUNICIPAL BY-LAWS
- PRE-APPLICATION LAW REVIEW
- PRELIMINARY ZONING REVIEW
- SITE PLAN APPROVAL
- SITE SPECIFIC ZONING BY LAW AMENDMENT
- COMMITTEE OF ADJUSTMENT
- PROVINCIAL MUNICIPAL BOARD OR EQUIVALENT
- OFFICIAL PLAN AMENDMENT

BUILDING PERMITS
- ARCHITECTURAL
- MECHANICAL
- ELECTRICAL
- PLUMBING

OTHER APPROVALS
- CITY PLANNING
- PARKS AND RECREATION
- WORKS AND EMERGENCY SERVICES
- LOCAL UTILITIES
- TRANSPORTATION
- REGIONAL AUTHORITIES
- PROVINCIAL MINISTRIES AND OTHER AGENCIES

PERMIT REGULATIONS
- NATIONAL BUILDING CODE
- PROVINCIAL BUILDING CODE
- LOCAL ZONING BY-LAWS
- OTHER APPLICABLE LAW(S)

CODES & STANDARDS
- HEALTH AND SAFETY
- FIRE PROTECTION
- STRUCTURAL SUFFICIENCY
- CONSTRUCTION MATERIALS
- PLUMBING AND MECHANICAL SYSTEMS
- ELECTRICAL SYSTEMS

LOCAL ZONING BY-LAWS
- LAND AND BUILDING USES
- BUILDING SIZE AND DENSITY
- LOCATION OF BUILDINGS AND OTHER STRUCTURES ON A LOT
- MINIMUM LOT SIZES AND DIMENSIONS, PARKING REQUIREMENTS AND BUILDING HEIGHT

OTHER APPLICABLE LAW(S)
- CONSERVATION AUTHORITIES LEGISLATION
- PLANNING LEGISLATION
- ENVIRONMENTAL PROTECTION LEGISLATION
- HERITAGE LEGISLATION
- LANDLORD - TENANT LEGISLATION

Figure 9.3. Approvals and jurisdiction related to tower renewal projects are dependent on the nature and scope of the work. It is advisable to review all applicable laws and by-laws, and to determine requirements for permits and other approvals in advance of all design work. Ensure that the correct versions of codes and standards are available for reference as the design work proceeds.

PRE-DESIGN
AUDIT OF EXISTING CONDITIONS

1. ASSEMBLE CONSULTANT TEAM AND DETERMINE FORM OF CLIENT-CONSULTANT CONTRACT(S).
2. RETRIEVE AND REVIEW EXISTING ZONING INFORMATION AND WHERE NECESSARY DISCUSS WITH AUTHORITES HAVING JURISDICTION.
3. PREPARE CURRENT PROPERTY SURVEY.
4. PREPARATION OF AS-BUILT DRAWINGS.
5. EXISTING BUILDING CONDITION DOCUMENTATION, ANALYSIS, REPORT AND RECOMMENDATIONS
    - ENVELOPE
    - STRUCTURE
    - MECHANICAL SYSTEMS
    - ELECTRICAL SYSTEMS
    - COMMUNICATION SYSTEMS
    - ENERGY CONSUMPTION
    - WATER CONSUMPTION
    - STORM WATER MANAGEMENT
    - WASTE MANAGEMENT
    - OFF-SITE AND ON-SITE UTILITIES
6. ESTABLISH PROJECT PROCEDURE PROCESS.

SCHEMATIC DESIGN

1. REVIEW AND EVALUATION OF PRE-DESIGN DATA.
2. ESTABLISH PRELIMINARY PROGRAM OF REQUIREMENTS AND SCOPE OF WORK.
3. ESTABLISH PRELIMINARY CONSTRUCTION BUDGETS.
4. REVIEW ALTERNATIVE DESIGN APPROACHES.
5. REVIEW TYPES OF CONSTRUCTION CONTRACTS.
6. ADDRESS ISSUES RELATING TO APPLICABLE STATUTES, REGULATIONS, CODES AND BY-LAWS AND WHERE NECESSARY DISCUSS WITH AUTHORITIES HAVING JURISDICTION.
7. PREPARE SCHEMATIC DESIGN DRAWINGS , OUTLINE SPECIFICATION AND OTHER SUCH DOCUMENTS ILLUSTRATING THE SCOPE AND CHARACTER OF THE PROJECT RELATIVE TO THE ABOVE.
8. PREPARE SUBMISSIONS AND MAKE APPLICATION AS REQUIRED RELATING TO ZONING CHANGES, VARIANCES AND OTHER SUCH LEGAL ISSUES.
9. PREPARE A PRELIMINARY STATEMENT OF PROBABLE CONSTRUCTION COST BASED UPON CURRENT DATA.

Figure 9.4. At the pre-design phase, the primary objectives are to accurately assess the existing condition and operating costs of the tower building and to organize the procedures for the integrated design of the retrofit measures. During the schematic design phase that follows, a number of strategies may be explored. At this time, a cost-benefit analysis may be performed to select among the competing alternatives. The schematic design phase ends with the production of schematic design drawings, outline specifications, and the assembly of all related documentation needed for approval applications. A pro forma of the proposed project is normally developed at this time so the owner can negotiate suitable financing arrangements before proceeding further.

DESIGN DEVELOPMENT

1. UPON SUCESSFUL COMPLETION OF THE SCHEMATIC DESIGN PHASE AND RECEIPT OF THE SPECIFIED APPROVALS SOUGHT AND REQUIRED BY THE AUTHORITIES HAVING JURISDICTION, PREPARE DESIGN DEVELOPMENT DRAWINGS OUTLINE SPECIFICATIONS AND OTHER SUCH DOCUMENTS APPROPRIATE TO THE CURRENT SCOPE OF WORK.

2. DEVELOP AND INCLUDE A PROJECT BRIEF DETAILING AREA CALCULATIONS, BUILDING SYSTEMS AND OUTLINE SPECIFICATIONS TO DESCRIBE THE SIZE AND CHARACTER OF THE ENTIRE PROJECT INCLUDING ARCHITECTURAL, STRUCTURAL, MECHANICAL, ELECTRICAL AND OTHER SYSTEMS, MATERIALS AND OTHER SUCH ELEMENTS AS MAY BE APPROPRIATE.

3. PREPARE A REVISED CONSTRUCTION COST ESTIMATE BASED UPON CURRENT DATA.

4. CONTINUE TO REVIEW APPLICABLE STATUTES, REGULATIONS, CODES, BY-LAWS AS THE DESIGN OF THE PROJECT IS DEVELOPED. OBTAIN APPROVAL OF THE AUTHORITIES HAVING JURISDICTION AS REQUIRED.

5. PREPARE MODELS, PERSPECTIVES AND OTHER SUCH PRESENTATION MATERIALS AS REQUIRED.

CONSTRUCTION DOCUMENTS

1. UPON THE RECEIPT OF THE APPROVALS SOUGHT IN THE PREVIOUS PHASE AND CURRENT STATEMENT OF PROBABLE CONSTRUCTION COST COMMENCE PREPARATION OF CONSTRUCTION DOCUMENTS CONSISTING OF DRAWINGS AND SPECIFICATIONS SETTING FORTH IN DETAIL THE REQUIREMENTS FOR THE CONSTRUCTION OF THE PROJECT.

2. ESTABLISH THE PROCEDURE FOR THE PREPARATION OF THE NECESSARY BIDDING INFORMATION, BIDDING FORMS, CONDITIONS OF THE CONTRACT AND FORM OF CONTRACT BETWEEN CLIENT AND CONSTRUCTOR.

3. CONTINUE TO REVIEW APPLICABLE STATUTES, REGULATIONS, CODES AND BY-LAWS APPLICABLE TO THE DESIGN AND WHERE NECESSARY REVIEW THE SAME WITH THE AUTHORITIES HAVING JURISDICTION IN ORDER TO APPLY FOR AND OBTAIN THE CONSENTS, APPROVALS, LICENSES AND PERMITS NECESSARY FOR THE PROJECT.

4. PREPARE AND SUBMIT APPLICATION FOR BUILDING PERMIT AND BUILDING CODE EQUIVALENCIES AS REQUIRED BY THE AUTHORITIES HAVING JURISDICTION.

CONSTRUCTION PROCUREMENT BIDDING AND NEGOTIATIONS

1. PREPARE BID PACKAGES TO OBTAIN COMPREHENSIVE BIDS OR NEGOTIATED PROPOSALS.

2. ESTABLISH CRITERIA FOR BID OR NEGOTIATED PROPOSAL EVALUATION.

3. ESTABLISH BIDDER ELIGIBILITY CRITERIA OR PRE-QUALIFICATION CRITERIA.

4. ISSUE BID DOCUMENTS.

4. PREPARE AND COORDINATE ADDENDA AS APPLICABLE.

5. ANALYSE BIDS OR NEGOTIATED PROPOSALS.

6. AWARD PROJECT AND PREPARE CONTRACT FOR CONSTRUCTION.

Figure 9.5. The three stages following schematic design are closely related. During design development, the architectural and technical aspects of the proposed retrofit are completely resolved, addressing all issues pertaining to required approvals, by-laws, codes and standards. In the construction documents phase, all of the preceding work is converted into a comprehensive set of drawings and specifications. The construction procurement, bidding and negotiations phase uses the contract documents as the basis for receiving tenders for the proposed work. This phase can be conducted by the architect in conjunction with the owner, or alternatively, the owner can retain a project manager to coordinate and administer the project.

CONSTRUCTION CONTRACT ADMINISTRATION

1. COORDINATE CONSULTANT CONTRACT ADMINISTRATION SERVICES AS PER CLIENT / CONSULTANT AGREEMENTS.
2. FORWARD INSTRUCTIONS TO CONSTRUCTOR.
3. CONDUCT CONSULTANT GENERAL REVIEW AND FIELD REVIEW OF WORK.
4. CONDUCT AND REPORT ON THE EXAMINATION AND EVALUATION OF REPRESENTATIVE EXAMPLES OF THE WORK.
5. MONITOR THE PROGRESS AND QUALITY OF THE WORK RELATIVE TO DEFICIENCIES AND DEFECTS.
6. RESOLVE CLAIMS AND DISPUTES ARISING RELATIVE TO THE WORK AS PER THE CONTRACT DOCUMENTS.
7. SCHEDULE AND CONDUCT ALL REQUIRED INSPECTIONS AND TESTING.
8. FOWARD THE REQUIRED DOCUMENTATION TO THE AUTHORITIES HAVING JURSIDICTION.
9. PREPARE, APPROVE AND CIRCULATE THE REVIEW AND APPROVAL OF ALL SUBMITTALS RELATIVE TO THE WORK.

CONSTRUCTION CONTRACT ADMINISTRATION

10. PREPARE, APPROVE AND CIRCULATE ALL CHANGE ORDERS AND CHANGE DIRECTIVES IN ACCORDANCE WITH THE CONTRACT DOCUMENTS.
11. PREPARE APPROVE, SCHEDULE AND CIRCULATE SUPPLEMENTAL INSTRUCTIONS.
12. MONITOR CONSTRUCTION BUDGET AND SCHEDULE ON A CONTINUOUS BASIS.
13. CONSULT WITH AND OBTAIN ALL APPROVALS FROM AUTHORITIES HAVING JURISDICTION.
14. RECEIVE AND REVIEW WRITTEN WARRANTIES AND RELATED DOCUMENTS.
15. REVIEW APPLICATION(S) FOR PAYMENT FOR CONSULTANT PERFORMANCE RELATIVE TO CONTRACT ADMINISTRATION AND ISSUING OF PAYMENT PER CONTRACT(S).
16. EVALUATE CONSTRUCTOR'S APPLICATION(S) FOR PAYMENT COMPLETE WITH SUPPORTING DOCUMENTATION AND DETERMINE AMOUNTS OWING.
17. ISSUE PAYMENT(S) IN THE VALUE PROPORTIONATE TO THE AMOUNT OF THE CONTRACT AND THE CONSTRUCTOR'S SCHEDULE OF VALUES, OF THE WORK PERFORMED AND PRODUCTS DELIVERED TO THE PLACE OF WORK.

CONSTRUCTION CONTRACT ADMINISTRATION

18. DETERMINE THE DATE OF SUBSTANTIAL PERFORMANCE OF THE WORK.
19. FULFILL REQUIREMENST OF LIEN LEGISLATION AND RELEASE HOLDBACKS PER CONTRACT(S).
20. EVALUATE AND VERIFY THE VALIDITY OF THE CONSTRUCTOR'S APPLICATION FOR FINAL PAYMENT INCLUSIVE OF ALL REQUIRED SUPPORTING DOCUMENTATION.
21. ISSUE FINAL PAYMENT(S).

POST-CONSTRUCTION

1. BUILDING MAINTENANCE SCHEDULES
2. COMMISSIONING
3. FACILITY MANAGEMENT PLAN
4. POST-OCCUPANCY EVALUATION
5. PROJECT TAKEOVER BY CLIENT/OWNER
6. TENANT IMPROVEMENTS

Figure 9.6. The construction contract administration phase begins after the work has been awarded, and may be performed by the architect or a project manager, depending on the type of contractual arrangement that is employed. The key objective of this phase is to ensure the owner receives value for monies expended, by ascertaining all work is carried out properly and conforms to the construction documents. A quality control plan must be established in advance of the construction so that inspections and testing may be effectively scheduled, The post-construction phase is intended to deliver the retrofit building in proper operating condition, complete with operating manuals, maintenance schedules and a facility management plan. A post-occupancy evaluation is advisable to confirm the proper functioning of the building as a system.

Figure 9.7. Many tower building inhabitants have no other housing alternatives. They are forced to endure retrofit work that may extend for over a year before everything is propelrly completed. Designers and contractors should endeavour to minimize the intrusiveness of the retrofit work being proposed. [Photo: Svenwerk.]

Practical Considerations

Tower renewal projects have the potential of transforming multi-unit residential buildings that are nearly half a century old into integrated systems that perform as efficiently as our best new green buildings. In order to achieve this level of performance, among the most critical aspects of retrofit projects that require careful management are changes and substitutions.[1] Materials that are approved for use in new building construction may not be suitable to retrofit work, or they may possess properties that make them incompatible with other materials forming a retrofit assembly. Special attention must be paid to any proposed substitution of windows. The overall, effective thermal resistance of the window assembly must not be compromised, and features such as the durability of operable window hardware must be assessed. Similar due diligence must be exercised for proposed substitutions to all equipment, building services and fixtures. The building as a system model should be kept in mind at all times when reviewing substitutions.

Another important consideration when preparing the contract documents is the use of life cycle cost analysis as the basis for decision making. According to Canada's Institute for Research in Construction, Canada's built environment represents a major investment that deserves sustainable design and management. Determining the appropriate quality and performance of a tower retrofit project requires achieving an adequate balance or trade-off between the following performance criteria over its remaining life cycle:

- Physical performance (e.g. safety, durability, functionality, risk of failure, service life, comfort)
- Economic performance (e.g. life cycle costs, return on investment, costs vs. benefits)
- Environmental performance (e.g. GHG emissions, contamination of air/water/soil)
- Social performance (e.g. health, safety of users, well being, user/disruption costs).

Assuming a 50-year life cycle for a comprehensive tower retrofit, life cycle analysis shows it is cost effective to invest in high quality materials and equipment. Using inappropriate economic measures like payback and rate of return will result in buildings that have not been optimized for sustainable life cycle performance.

Once a final design is achieved, it must be properly executed to fulfill its promise. There are a number of standard contracts available to owners and their authorized agents for use in Canada.[2] The importance of effective contracts and administrative procedures cannot be overemphasized, as this drives the work that transforms ideas into reality.

[1]*Change management in construction projects.* Hao, Q.; Shen, W.; Neelamkavil, J.; Thomas, R. July 15, 2008 NRCC-50325 http://irc.nrc-cnrc.gc.ca/pubs/fulltext/nrcc50325/nrcc50325.pdf

[2]Canadian Construction Documents Committee http://www.ccdc.org

10. Commissioning and Facilities Management

This brief chapter on one of the most important aspects of tower renewal is intended to provide a framework of understanding rather than a comprehensive discussion. A number of authoritative references have also been provided to obtain further information and keep abreast of commissioning and facilities management standards and practices.

After the comprehensive tower retrofit has been completed, it is prudent to conduct proper commissioning of the HVAC system and any other mechanical or electrical systems that have been upgraded. This is usually the first facilities management task following the completion of a comprehensive tower retrofit project. The commissioning process is intended to ensure that all of the components work properly as a system, but it is also a practical means of having a commissioning agent, who is independent of the contractor, review the entire system for compliance with the engineers' specifications and manufacturer's installation instructions. Further, the commissioning agent can ensure all documentation is complete and organized for use in the facilities management process, including preparation of a proper maintenance plan. Ideally, the commissioning process occurs during the holdback period so that sufficient funds are available to correct any deficiencies in the event the installing contractor is not willing or able to complete the work according to the commissioning agent's instructions. This situation is best avoided by setting aside an allowance for inspection of the work on a periodic basis as it proceeds. Regardless of the arrangement, it is important to properly commission all systems to ensure safe and proper installation and operation.

Facilities management can be simply defined as a means of maintaining the building and all of its sub-systems, components and equipment in safe and proper operating order by conducting routine maintenance to achieve optimal performance and service life. In some cases, owners act as their own facilities managers, while in other cases this role is assigned to professional service providers, often known as property managers. Property managers may also act on behalf of the owner in landlord/tenant transactions and relations. In addition to possessing the necessary qualifications and experience, facilities managers must be able to maintain good working relationships with owners, tenants and the numerous trades that will help maintain a good building service condition. Commissioning is among the first of several critical tasks that must be undertaken by the facility manager after the comprehensive retrofit work has been completed, and the process must be coordinated with the designers and contractors.

Note on Information and Documentation Coordination
Commissioning and facilities management must be carefully coordinated with the design team, and the condition assessment process. The documentation assembled during the condition assessment must be transmitted to the design team, who in turn must pass on this and all design drawings and specifications to the facility manager (owner). Requirements for contractors to provide all installation and operating instructions, warranties and service contacts, and to cooperate during the commissioning process must be embedded in the contract documents, and followed up during contract administration. All of the historical and comprehensive retrofit information must be assembled in an orderly fashion and properly archived for future reference. Thorough commissioning and effective facilities management cannot be achieved unless all of this information and documentation is well organized and made accessible immediately following the substantial completion of a tower retrofit project.

Commissioning

It is not possible to review the extensive procedures and checklists associated with commissioning, but these are published and available from several recognized sources of information for building commissioning. The most widely recognized guideline for HVAC systems is:

American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE) *Guideline 1-1996: The HVAC Commissioning Process.* These may be purchased online and downloaded from ASHRAE directly.

There are a number of useful resources available free of charge. A complete guideline for building commissioning may be downloaded from:
http://www.energydesignresources.com/Portals/0/documents/DesignGuidelines/EDR_CommissioningHandbookComplete.pdf

Recently, a best practices guide was published and made available online.
Best Practices in Commissioning Existing Buildings. Building Commissioning Association, Portland, Oregon, August 18, 2008.
http://www.bcxa.org/downloads/bca-ebcx-best-practices.pdf

Recommended Minimum Qualifications

Comprehensive retrofits on tower apartment buildings are not as common as new building construction, hence it is important to select a commissioning agent who is suitably qualified and experienced. The recommended minimum qualifications are outlined below to assist in selecting a suitable commissioning agent:

- Experience in design, specification or installation of commercial/institutional building systems including HVAC, mechanical, electrical, lighting, communications, control systems and other systems being commissioned.
- History of responsiveness and proper references (at least 3 positive references).
- Meets owner's liability requirements.
- Experience working with project teams, managing projects and conducting scoping meetings.
- Experience commissioning at least two projects of similar size and of similar equipment to the current project; one in the last three years. This experience includes the writing and execution of verification checks and functional test plans.
- Experience in design installation and/or troubleshooting of direct digital controls and energy management systems, as applicable.
- Demonstrated familiarity with metering and monitoring procedures.
- Knowledge and familiarity with air/water testing and balancing.
- Experience in planning and delivering O&M training.
- Overall understanding of all building systems including building envelope, structural and fire/life safety components.

The importance of proper commissioning cannot be overstated and this should always be performed by someone other than the installing contractor.

[Photo Opposite Page: Jesse Colin Jackson]

Facilities Management

This section deals exclusively with those aspects of facilities management pertaining to the proper operation and maintenance of buildings, facilities and grounds. To put the role of the facility manager into perspective, a typical 200-unit tower apartment building has an approximate value of $50-million, likely more depending on its location and features. A comprehensive tower retrofit adds between $5 and $10-million to this asset and it is intended to extend the useful service life by 50 years. There are few assets having this value today, for example jet airliners, that would not require a highly qualified professional to operate and manage them. The business plan for every tower renewal project hinges on achieving an estimated level of operating cost savings, and maintaining the overcladding and window replacements in good condition over the projected service life. Facilities managers must deliver the best achievable performance from comprehensive tower retrofit to ensure a reasonably attractive return on the investment.

Facilities managers are usually assisted by a superintendent and a janitorial staff, hence their primary focus is on establishing an effective framework for operations and maintenance. A key function is to establish an inspection and maintenance plan for the tower building. In order to gauge when maintenance or adjustment is required, it is necessary to develop performance indicators. When an assembly, component or item of equipment falls below the threshold established in the performance indicator, appropriate action must be taken.

Most performance indicators are visual, such as worn out floor finishes in lobbies and hallways. Others are quantitative and relate to energy and water consumption, solid waste disposal, and vacancy rates. Each of these must be closely monitored to reduce operating costs, minimize vacancy rates and identify corrective measures. Issues of health and safety take priority over aesthetic and are normally assigned the highest priority.

Preventive maintenance begins with daily inspections to the building, facilities and grounds. Figure 10.1 provides an example of a daily inspection list that should be carried out by the superintendent or designated staff.

Daily Inspection Checklist

- water pipes and pumps
- gates and locks, fire doors and closers
- intercoms and TV signaling, lights and fittings
- hose reels, nozzle boxes and alarm glass
- letter boxes and storage lockers
- security TV and cameras, timer switches
- surface water channels, drains, manholes covers
- club facilities, swimming pools, saunas
- flower beds and planters, playground equipment
- staircases, lobbies, laundry rooms
- mechanical and electrical rooms, elevators
- underground parking, lighting and ventilation
- building structure, cladding, windows and finishes

Figure 10.1. An example of daily inspection checklist to be performed by the superintendent of a typical tower building. Note that not all of the items may necessarily apply to a particular building, such as club facilities and swimming pools.

The daily inspection is often carried out informally as a part of regular housekeeping procedures, but it is advisable to keep a formal reporting system in place, at least once a week, so that a record of the conditions is available for reviewing and adjusting maintenance schedules.

In addition to daily inspections, there are seasonal inspections and special inspections. An example of a seasonal inspection is checking the underground parking ramp de-icing system prior to winter. Figure 10.2 highlights critical special inspections for tower buildings.

Special Inspections

- fire safety
- emergency power
- HVAC system
- elevators
- building envelope and balcony guards

Figure 10.2. Special inspections are periodic and in some cases these are determined by regulatory authorities, in other cases by equipment manufacturers and/or the commissioning agent. The condition assessment and design processes will usually provide recommendations on the inspection of the building envelope and balcony guards.

It remains the responsibility of the owner to provide sufficient resources to carry out required maintenance and address any deficiencies identified during the inspection process.

Effective facilities management of tower buildings, facilities and grounds requires proper resources and organization to ensure the following:

- Proper housekeeping procedures;
- Comprehensive maintenance plan;
- Daily, seasonal and special inspections;
- Monitoring of energy and water consumption;
- Management of solid waste, recycling and composting;
- Record keeping and strategic planning; and
- Mechanisms for obtaining tenant feedback.

For additional information on facilities management and helpful resources for the management and maintenance of multi-unit residential buildings, consult the following:

TowerWise Program, Toronto Atmospheric Fund http://www.towerwise.ca/

Highrises and Multiples, Canada Mortgage and Housing Corporation
http://www.cmhc-schl.gc.ca/en/inpr/bude/himu/

Housing is a resource that must be monitored and maintained to ensure its continued health and viability. Readers of these guidelines are urged to conserve our precious housing resources through better design, retrofit, commissioning and especially, facilities management practices.

[Photo Opposite Page: Jesse Colin Jackson]

Appendix A – Overcladding Design and Detailing

The most critical components of a comprehensive tower renewal project are the overcladding and window replacement. Together they represent the highest cost of any resource conservation measure forming part of the tower renewal work. This appendix was developed to illustrate generic means of integrating overcladding and windows to achieve durable, thermally efficient building envelopes. It is an exercise in building science intent that does not imply specific products or advocate any architectural aesthetic. The approach was to simply depict means of achieving a high performance building envelope retrofit using commonly available materials and components. Innovation rests with industry.

This appendix is not a comprehensive examination of all possible methods and materials. It is somewhat colloquial in that it assumes current practices employed by Canada's building envelope restoration industry, chiefly the use of the mast climbing work platform as the predominant alternative to stationary scaffolding. However, it presents the two most common approaches to the overcladding of tower building envelopes: exterior insulation and finish systems (EIFS) with a rear drainage plane; and panelized cladding accommodating a variety of exterior finishes, and employing a pressure moderated drain screen approach. Unlike the pressure equalized rain screen, the pressure moderated drain screen recognizes wind pressures will not be perfectly equalized in the drainage cavity, hence moisture penetration will occur and should therefore be properly drained to the exterior. Similarly, EIFS best practices now recognize that face sealed systems will inevitably suffer moisture penetration due to imperfect materials and workmanship. Rear drainage planes between the exterior insulation and the existing building envelope ensure that moisture penetration does not accumulate and is properly conveyed to the exterior of the building envelope. The key to both approaches advocated in these guidelines is redundancy of critical moisture control measures to reduce the probability of moisture problems to an acceptable level of risk, congruent with prudent architectural and engineering practices.

Users of these guidelines should appreciate overcladding design and detailing can be addressed by a generic approach, unlike HVAC systems. While it is important to address HVAC systems, in particular mechanical ventilation ducted to each suite and coupled to heat recovery, it is beyond the scope of these guidelines to advise on HVAC system design. The reason for this dichotomy is that while the tower building armature and skin typologies are virtually identical across all tower buildings, HVAC systems vary considerably among the existing buildings. A separate appendix would be required to address each type of HVAC system, in addition to the hybrid combinations that are evident in the tower building stock. The subject of optimal HVAC control system strategies would constitute a major document in its own right, as would the various renewable and district energy systems with which it would interact. HVAC systems retrofits must therefore be dealt with on a case-by-case basis requiring the expertise of qualified professionals and contractors.

During the development of these guidelines it was recognized that computer simulation of building performance would play an important role in retrofit strategies. The heat, air and moisture behaviour of the building envelope can be well predicted through the deployment of hygrothermal modeling software. Building system energy performance, including the building envelope and HVAC systems, can also be assessed using energy modeling software. In all cases this will require highly qualified and experienced users of the simulation models. This becomes especially critical in the development of innovative building envelope and HVAC systems where there is insufficient field evidence to calibrate the simulation results. Laboratory testing conducted in parallel with the simulation work is essential for new products. This appendix is confined to overcladding systems with proven past performance.

The sections which follow have been arranged to provide users of these guidelines with an overview of the architectural aspects of tower renewal. They are presented as follows:

- **Archetype Tower Building** – This section provides an overview of the tower building typology by examining an archetype tower building. This building was used as the basis for the design and detailing of the example overcladding systems, window and roofing replacements.
- **Navigation Guide** – This section provides a convenient guide for navigating through the plan, section and axonometric detail drawings, and assembly sequence renderings.
- **External Insulation and Finish Systems** – The most common elements of tower building retrofits using a generic EIFS overcladding system are depicted in a series of detail and sequence drawings.
- **Panel Cladding Systems** – This section illustrates the use of a panel cladding system for the same tower building retrofit elements as in the previous section on EIFS. It also depicts the integration of balcony enclosures with the panel cladding system, and these are also extensible to EIFS applications.

Roof retrofits have not been addressed in depth because roofing replacements represent common industry practice, unlike integrated overcladding systems. There is a wide variety of roofing materials and assemblies available for tower renewal projects, and their suitability will depend on a number of factors and criteria specific to each tower renewal project. In these guidelines, inverted roofing systems have been depicted along with the overcladding system assemblies. Inverted roofing systems represent the proper arrangement of materials from a cold-climate building science perspective (structure, moisture protection, insulation, exterior cladding) that is consistent with the wall overcladding systems. These systems also provide a serviceable walking surface for convenient access to rooftop-mounted equipment. Green roofs are highly proprietary systems that have not been detailed in these guidelines, and users should contact manufacturers of green roof systems for appropriate design guidance.

The drawings that are presented are deliberately generic in this publication and do not favour or recommend any proprietary systems. Specific materials and dimensions have not been included as these will vary based on the materials and components selected by the designer. Guidance on building science principles and optimal levels of thermal insulation and replacement window thermal efficiencies has been provided in *7. Tower Retrofit Strategies: A Systems Approach*.

The focus of the overcladding sections is on the key elements of the building envelope and the corresponding assemblies and details and assemblies that most influence the performance of the building envelope retrofit, as well as the duration and cost of the retrofit work.

The next section presents an overview of an archetype tower building that was used as the basis for the example overcladding systems.

[Photo Opposite Page: Jesse Colin Jackson]

Archetype Tower Building

A reference archetypical building example was developed and utilized to illustrate various conceptual and technical aspects of these guidelines. This archetypical example is consistent with vintage high-rise residential towers of medium complexity and exhibits a diverse sampling of common attributes. It should be noted that the building statistics presented in the appendix differ slightly from those noted in Figure 8.2. The latter data were generated for the purposes of energy modeling and differ slightly from architectural conventions for presenting building data.

Figure A.1. Axonometric rendering of archetype tower building.

Building Statistics

The data listed in Table A.1 reveals a moderately large site consistent with the majority of suburban tower developments from the 1960s and 70s. The compact and efficient floor plates of this typology were capable of establishing high density development with relatively low coverage, generating maximum open space and surface parking. Smaller urban sites supported high unit counts and increased densities at the expense of residual open space and surface parking.

Building Data	m^2	ft^2
Lot Area	9,515	102,365
Building Area	1,221	13,140
Building Gross Floor Area (GFA)	24,300	261,430
Plan Dimensions 240 feet x 60 feet (73.2 m x 18.3 m)		
Building Height	190 ft (57.9 m)	
Number of Storeys	21	
Site Density (Bldg. GFA/Lot Area)	2.55	
% Coverage (Bldg. Area/Lot Area)	12.84%	

Table A.1. Summary of key building data for the archetype tower building.

Floor Areas	m^2	ft^2
Ground Floor	825	8,880
Typical Floors (Floors 2 through 20)	1,221	13,140
Penthouse	269	2,890
Total Floor Area	24,300	261,430

Table A.2. Floor areas of the archetype tower building.

Figure A.2 depicts other configurations associated with this typology including, but not limited to, *slab*, *bent slab*, *'Y'* and *point* towers. Examples of other variations on the theme would include *cruciform* and *'L'* shaped towers. It is important to recognize that tower plan dimensions and structural grid geometry had an intrinsic relationship to the functional and spatial requirements of the below grade building program, specifically parking stalls and drive aisles. It should be noted that below grade aspects of this typology are beyond the scope of this document. Figure A.3 illustrates the typical floor plans of the reference archetype, which constitutes the most common configuration of the typology.

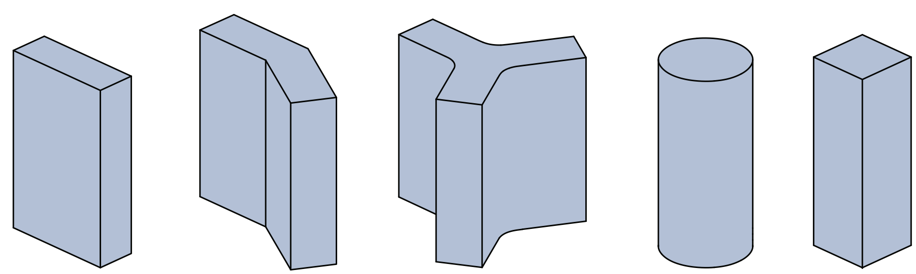


Figure A.2. Examples of common tower typologies constructed during the 1960s and 70s.

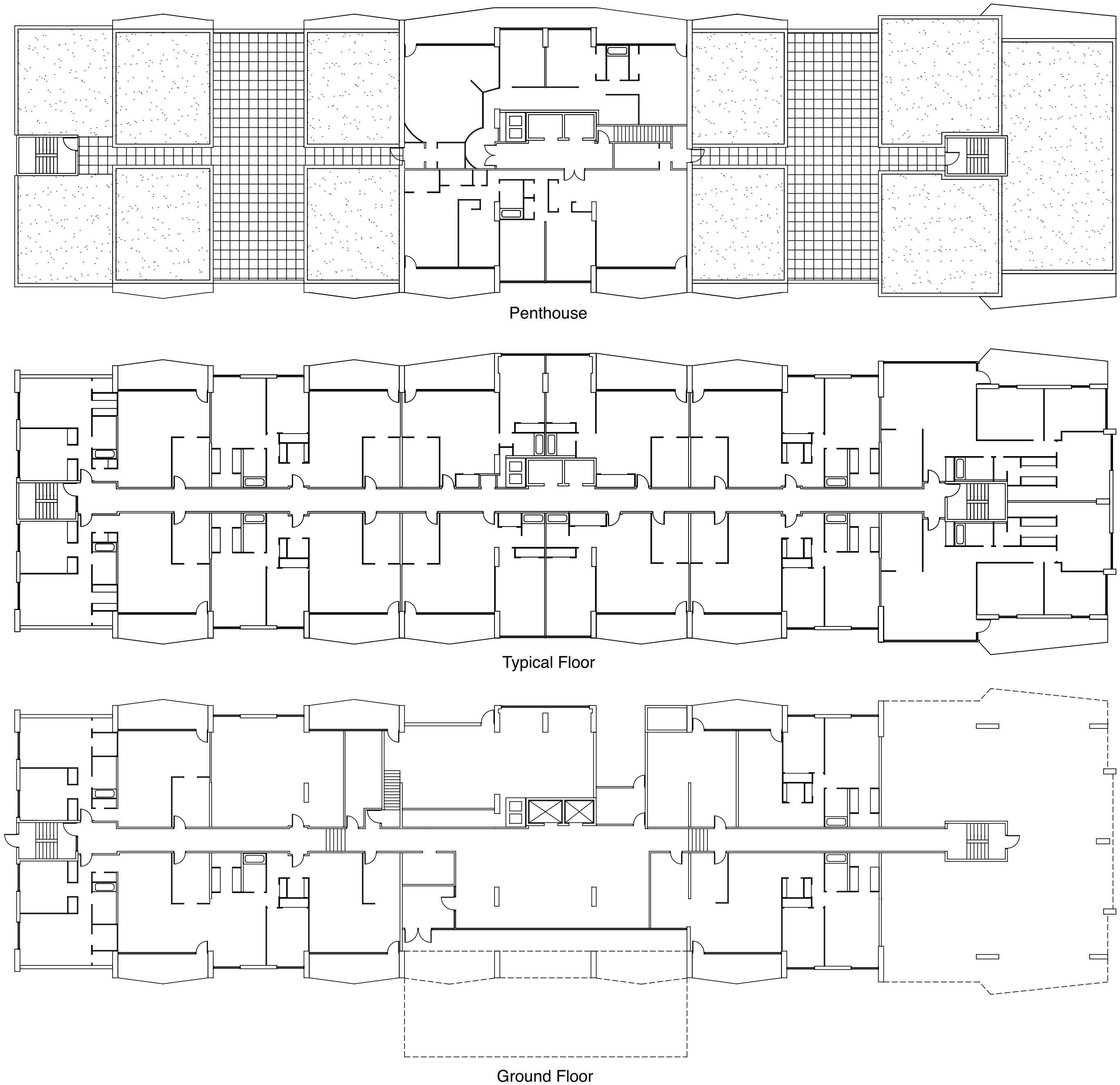


Figure A.3. Floor plans of the archetype tower building indicate that tower buildings provided a diversity of apartment units suited to singles, couples and larger family households.

Floor Plans, Unit Types and Functional Area Allocation

Figure A.3 illustrates the three floor plans that comprise the archetype tower building. Note the recessed entry and covered open space of the Ground Floor Plan, which accounts for the reduction in its gross floor area (GFA). The Typical Floor Plan is by far the most efficient of all the floors and produces the maximum GFA. The Penthouse Floor Plan produces the least GFA of all floors. It shares the roof space with rooftop mechanical penthouses that are a common feature in practically all tower buildings. Penthouse apartments are generally less common than mechanical penthouses. Figure A.1 indicates increased floor-to-floor heights for portions of the uppermost typical floor that articulate the roofscape.

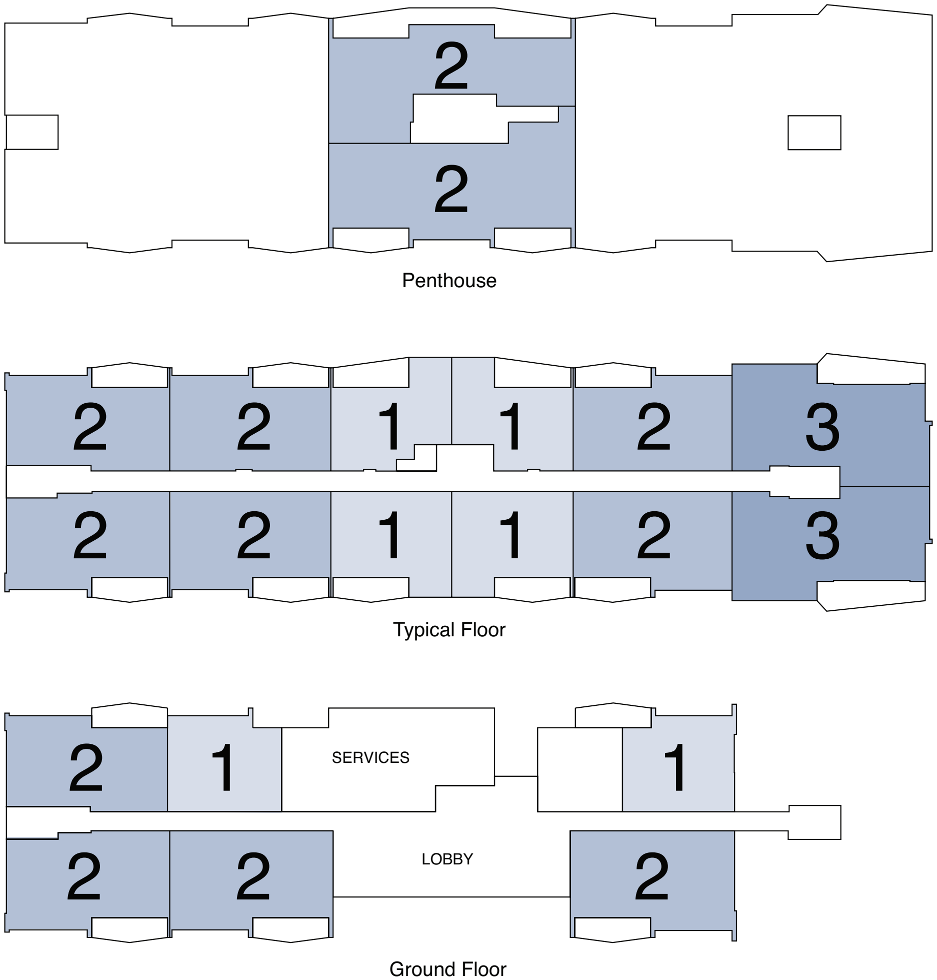


Figure A.4. Examples of common tower typologies constructed during the 1960s and 70s.

	Unit Types				
	Bachelor	1-Bedroom	2-Bedroom	3-Bedroom	
Ground Floor	0	2	4	0	
Typical Floors	19 x 0	19 x 4	19 x 6	19 x 2	
Penthouse	0	0	2	0	Total Suites
Totals	0	78	120	38	236
% of Total	0.0%	33.1%	50.8%	16.1%	100.0%

Table A.3. Summary of key building data for the archetype tower building.

The number and types of apartment units on each floor are identified in Figure A.4. Note the provision of 3-bedroom units comprising nearly a sixth of the total units, and conversely the absence of bachelor units. This mix of apartment units mix was common to this era of the typology and reflects the ability to accommodate a diverse range of tenant housing requirements. Contemporary examples of this typology, the tower condominium, rarely provide as high a proportion of 3-bedroom units, if at all, and contain an increased proportion of 1-bedroom units, with the addition of bachelor units. The vintage high-rise residential towers that form the focus of this document are crucial to maintaining a diverse rental housing inventory rarely reflected in current multi-unit residential building developments.

	Area Functional Breakdown (ft^2)			
	Public	Building Services	Suites	Balconies
Ground Floor	2,507	1,355	5,018	580
Typical Floors	19 x 1,390	19 x 55	19 x 11,695	19 x 1,565
Penthouse	490	45	2,355	590
Totals	29,407	2,445	229,578	30,905
% of Total GFA	11.2%	0.9%	87.8%	11.8%

Table A.4. Summary of key building data for the archetype tower building.

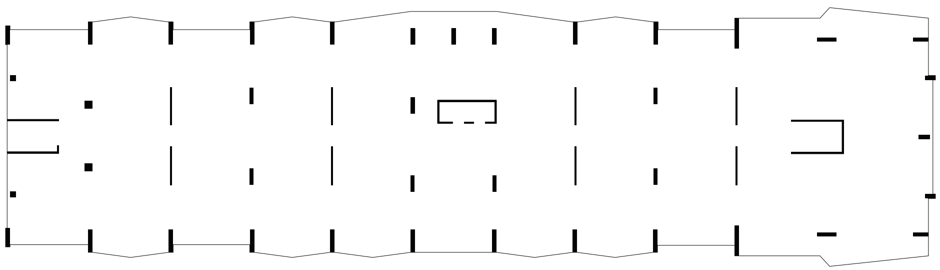
A functional breakdown of building areas for the archetype tower building is provided in Table A.4, which may be cross-referenced with Figure A.4. The Ground Floor Plan indicates a reduction in GFA and unit count as well as an increase in common public areas and common building service areas. As noted earlier, this reduction is due to the recessed entry and covered open area. The increase in non-habitable floor space is accounted for by the ground floor lobby area and common services area, that typically deals with waste management, loading and unloading of tenant contents, storage facilities, rental office, mailroom, etc.

The Typical Floor Plan is an exercise in spatial utilization efficiency. A continuous double-loaded corridor is anchored by enclosed exit stairwells at either end. The elevator lobby is central and compact adjacent to vertical service shafts. Suite areas requiring the delivery of comprehensive services, including electricity, potable water, sanitary drainage, roof drainage, and ventilation, are served by chases flanking the central corridor walls and superimposed in plan and section for the entire height of the building. Suite configurations accommodate the redundant placement of poured concrete shear walls spaced at approximately two to three parking stall widths (+/- 20 to 28 feet,or 6 to 8.5 metres), on center.

The Penthouse Floor Plan is one of countless variations occurring within the tower apartment building typology. These apartments were often occupied by the original owners who developed the buildings, but they also offered premium executive accommodation overlooking, and in many cases having access to, enhanced roofscapes. These served to add diversity not only to the unit types, but the demographics of tower building inhabitants.

Structural System

One of the primary reasons for the success and proliferation of high-rise residential buildings was their economical and rapidly erected structural systems. The development of flying forms to enable rapid cast-in-place, reinforced concrete structural systems revolutionized high-rise residential construction. The impact and attributes of this technology are discussed in *4. Tower Typology and Service Condition*, and it is important to recognize that these made possible vertical building assembly lines deploying standardized modular formwork. This common modularity has provided a distinct advantage in the retrofit of 1960s and 70s tower buildings since they are ideally suited to vertical retrofit assembly line processes made possible by mast climbing work platforms. This typology is also conducive to mass customization of unitized systems for integrated overcladding and window replacement solutions.



Structural Plan

Figure A.5. The structural plan of the archetype tower building shows the use of shear walls arranged according to a spacing that reflects the optimal utilization of below grade space for parking stalls and drive aisles.

Figure A.5 illustrates a simplified rendering of the archetype tower building's structural plan. It is typical of the structural systems found in most tower buildings. In concept, vertical, steel-reinforced, poured concrete shear walls of 200 mm (8 inch) thickness spaced between approximately 6 to 9 metres (roughly 20 to 28 feet) apart extended from the foundations to the roof slab. Openings in the shear walls occurred as required to accommodate circulation within the suites and corridor. These shear walls were superimposed one on top of the other for the height of the building and provided bearing for the floor slabs. There were many variations of this approach, primarily to accommodate internal programmatic requirements. From a structural engineering perspective, each variation was similar in concept.

Spanning horizontally between shear walls were steel-reinforced, poured concrete one-way floor slabs of 200 mm (8 inches) in thickness. The dimension from top of slab to underside of the slab above was 8 feet, reflecting the standard size for plywood used in the construction of forms. Floor slabs often extended beyond the exterior envelope to form balconies. Some of these projections spanned between projecting shear walls, which also extended beyond the envelope as continuations of the one-way slab system, while others extended as cantilevered structural anomalies. Exposed concrete balcony slabs remain the Achilles' heel of tower buildings in terms of durability, but their saving grace in terms of liveability.

Building Envelope

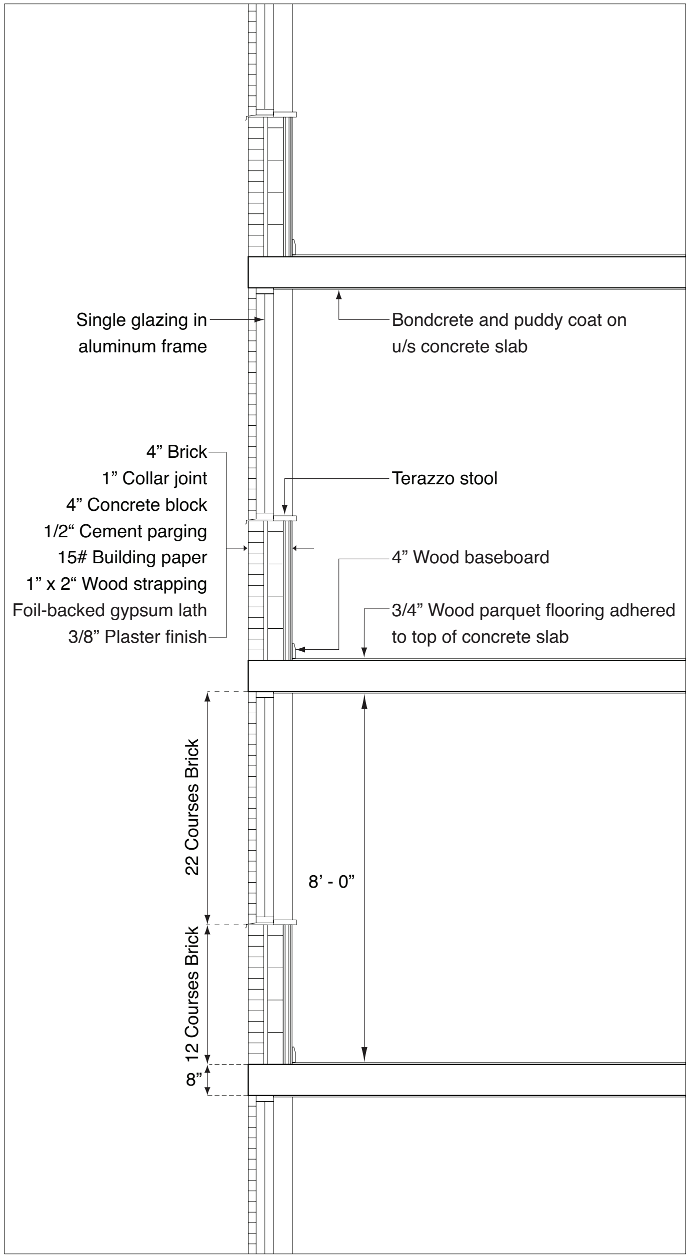
The typical building envelopes of the tower building typology are an example of simplicity and durability, but unfortunately not of energy efficiency and sustainability in the comprehensive contemporary sense. Figure A.6 was derived from actual construction drawings for a typical tower building. All of the original terminology and dimensions found on these drawings has been retained in the drawings and discussion which follows. It should be noted that these buildings were constructed before the adoption of the metric system, hence all dimensions and nomenclature are based on the Imperial system of units (feet, pounds). It will be interesting to see if this system of measurement and its modularity will be retained for retrofit purposes, or if the metric equivalents will be employed.

Referring to the typical wall and balcony sections in Figure A.6, it is observed that the double wythe, solid masonry exterior walls were simply constructed utilizing 4-inch clay brick as the exterior wythe bonded by header courses to an interior wythe of 4-inch hollow concrete block. The block subsequently supported the interior finish system of cement parging followed by asphalt impregnated building paper, wood strapping, gypsum board lath, and multi-coat plaster finish. This was typically finished with alkyd-based paints, or ceramic tile in bathrooms. Masonry units simply sat above exposed concrete slab edges without base flashings, control joints or soft joints at the underside of slabs above to allow for movement. The consequences of this form of envelope construction in terms of heat, air, and moisture management are discussed in earlier sections of this publication and numerous documents referenced herein. This selection/arrangement of materials is the primary cause of the numerous deterioration concerns witnessed in tower building envelopes today.

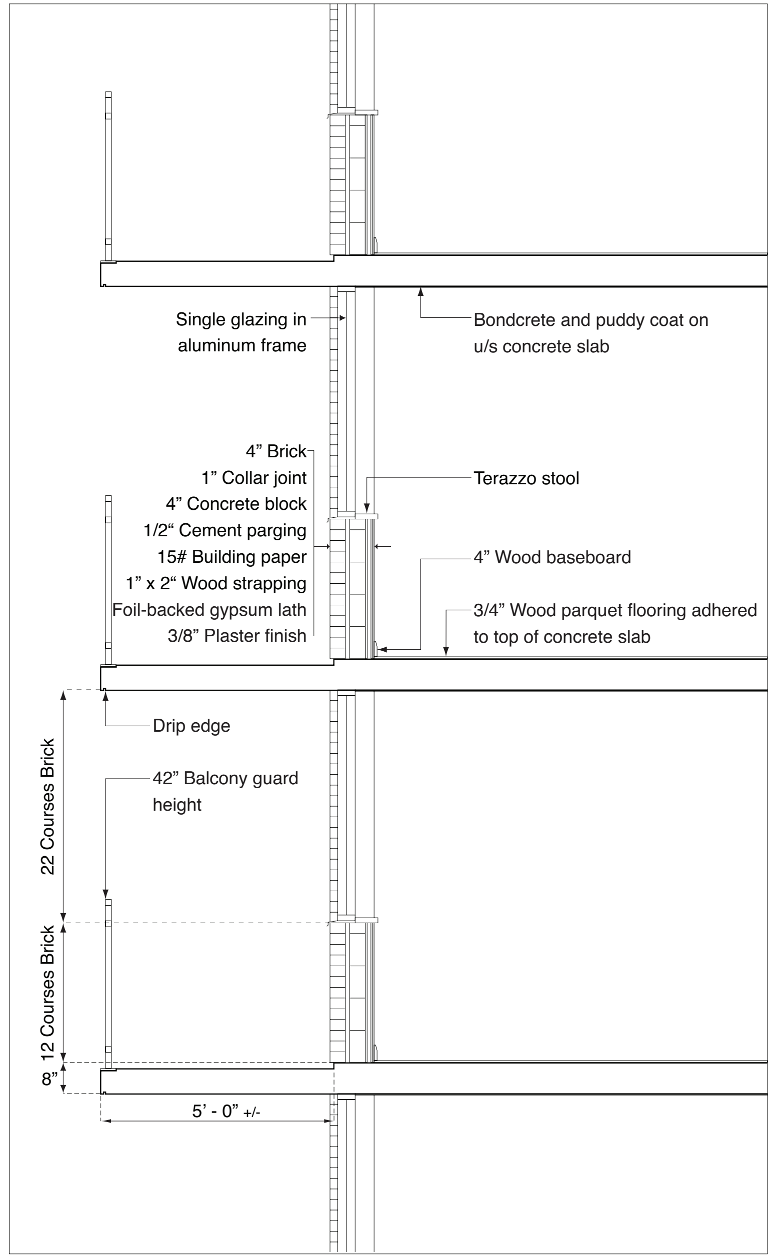
In particular, the deterioration of exposed concrete balcony slabs has become a serious problem in many tower buildings and requires expensive repair that does nothing to improve the thermal performance of the building envelope. The proliferation of exposed concrete balcony slabs has had an enormous adverse effect on heat transfer across tower building envelopes due to thermal bridging, which is aggravated when winter winds increase the rate of convective heat transfer.

Window systems rival exposed balcony slabs in their poor thermal performance. In tower buildings, windows were typically comprised of single glazed units in metal frames without thermal breaks. Operable windows were commonly sliders that exhibited increasing rates of air leakage as the weatherstripping abraded and failed to be replaced. The breaching around the windows was also poorly air sealed and contributed to the high rates of air leakage measured in tower buildings. This condition was attributable to window design and installation practices. Window placement was centered upon the collar joint of the solid masonry wall with metal window sills below. There were no air or vapour barrier membranes to tie into the window system and maintain a continuous seal. Vintage systems relied upon inferior caulking technologies and overly generous construction tolerances.

The choice of durable building envelope materials, combined with a hygrothermal cycle that was conducive to the management of moisture migration across the building envelope in cold climates, has resulted in an existing tower building stock with a robust substrate for overcladding, except where deterioration has gone on far too long in the absence of prudent maintenance and repair practices. But the spiraling cost of energy, and the need to encapsulate the existing building envelope for continued durability, demands effective solutions that are economical, aesthetically relevant, and integrated within the *building-as-a-system* concept. The next section provides a guide to the example details and assembly sequences that have been devised to convey the building science intent of overcladding systems for comprehensive tower retrofits.



Typical Wall Section



Typical Balcony Section

Figure A.6. Typical sections derived from actual construction drawings illustrate the lack of building science applied to building envelope design. Ease and speed of construction by available trades was a more important consideration than building envelope performance.

Navigation Guide

The remainder of this appendix on overcladding design and detailing presents examples of typical assemblies and components according to the two primary types of overcladding alternatives – EIFS and panel systems. The illustrated guide depicted below is intended to assist users in conveniently locating details and assembly sequences of interest.

There are five major assemblies and components constituting a typical tower overcladding retrofit. For each of these, a set of details and assembly sequences has been provided by the figures indicated in the navigation guide. In actual tower retrofit projects, it is reasonable to expect many additional details will be required to reflect the particular context of each building.

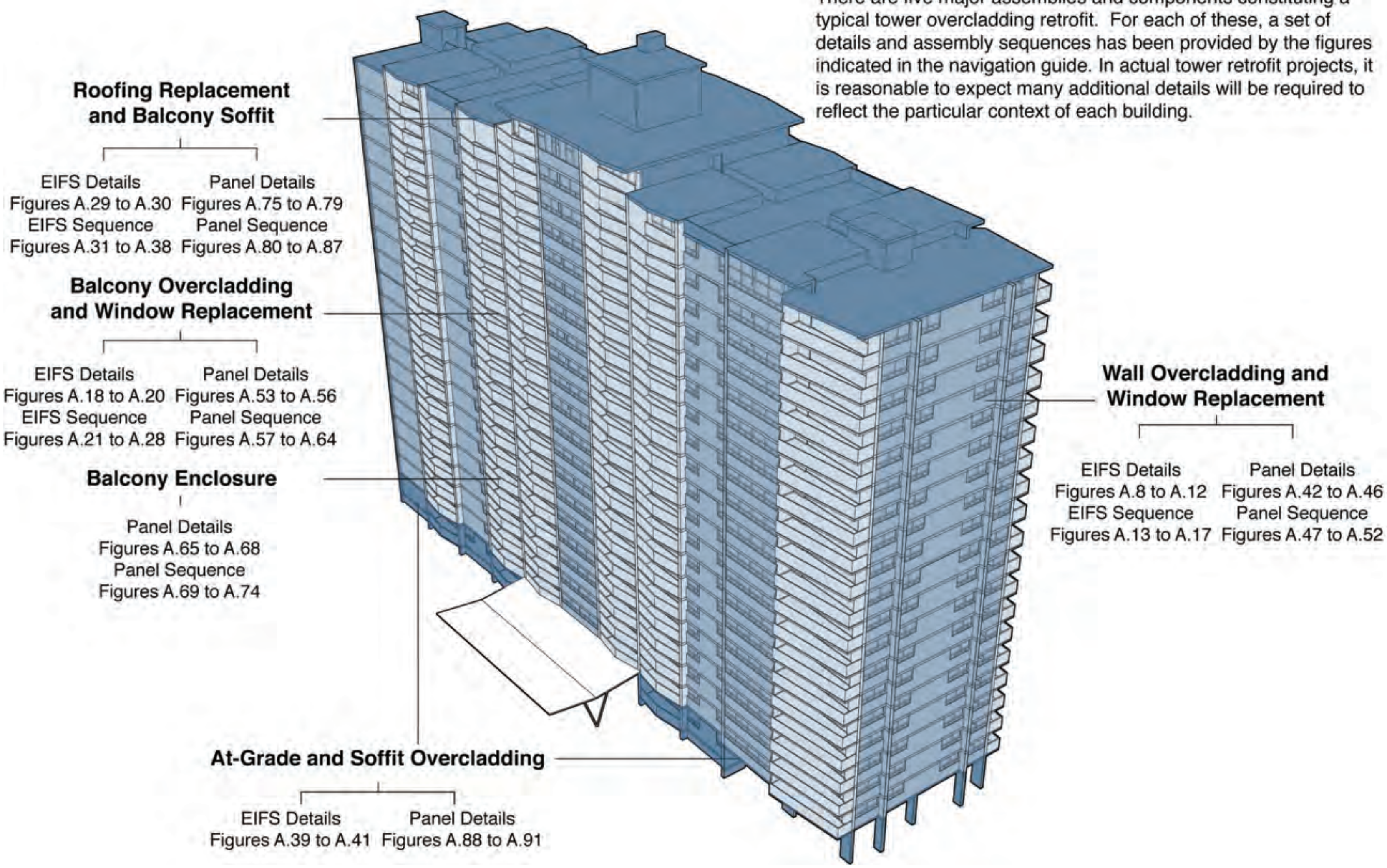
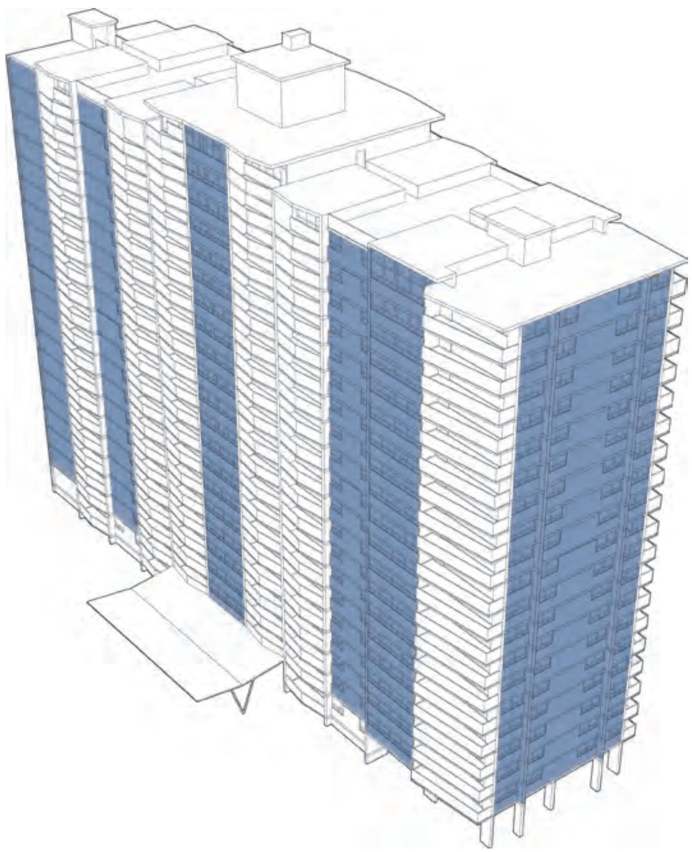


Figure A.7. Navigation guide to overcladding details and assembly sequences.

EIFS Wall Overcladding and Replacement Windows

This section of details and sequence assemblies depicts the design of external insulation and finish systems (EIFS) overcladding and window replacements for plane wall elements without balconies or projections. The shaded areas on the archetype tower building represent typical locations for these types of overcladding and window replacements.



A comprehensive discussion of EIFS technology is beyond the scope of this document, and it is assumed most design professionals are familiar with EIFS for new building applications. In the case of tower retrofits, it is important to ensure that the existing substrate is sound, and that if found to be otherwise, appropriate repairs must be carried out prior to the commencement of retrofit work. In Canada, the EIFS Council of Canada has recently launched the EIFS Quality Assurance Program to ensure the highest quality of materials, design, workmanship and inspection of EIFS projects. This is a voluntary program and there a number of critical requirements under the program that should be observed for all EIFS overcladding projects. The details and assembly sequences that follow conform to EIFS industry best practices, but these are not comprehensive. Building envelope designers and cladding engineers are ultimately responsible for the proper design and specification of overcladding systems, and it sound practice to work collaboratively with EIFS suppliers and contractors to develop appropriate and effective solutions.

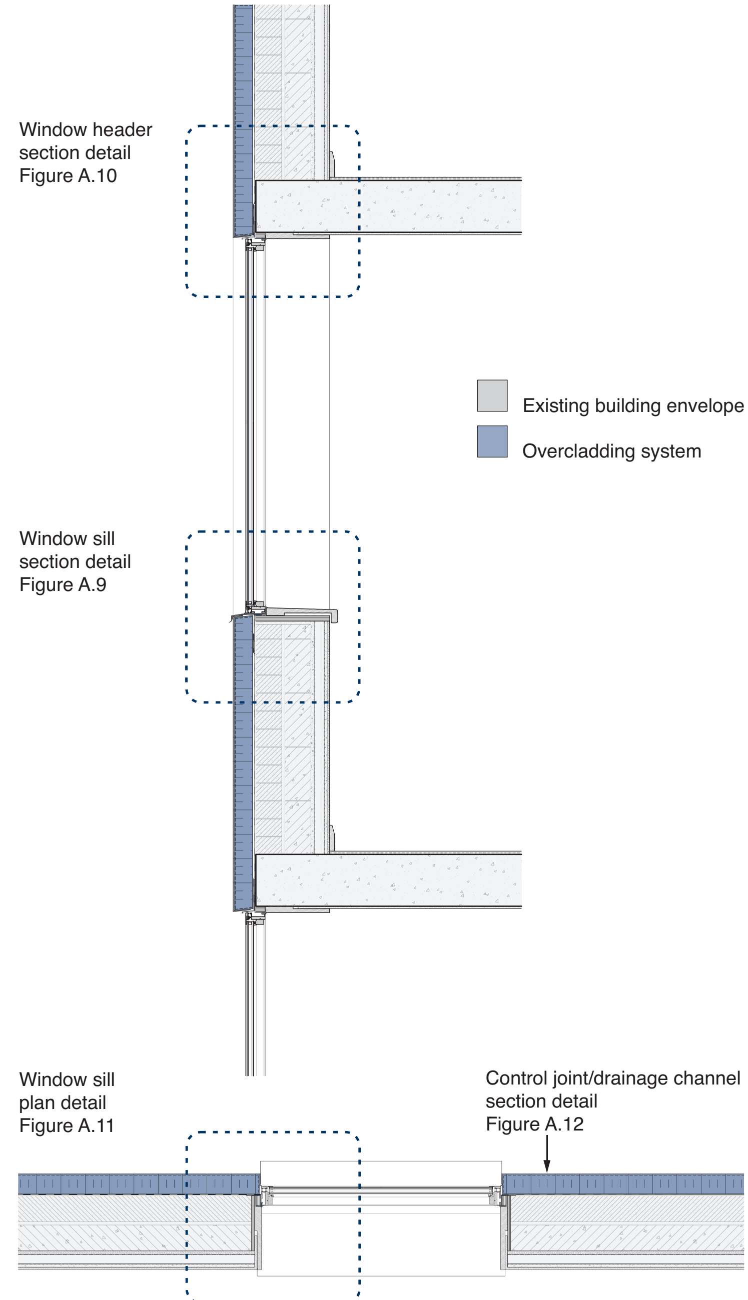


Figure A.8. Section and plan views of a typical wall and window assembly with corresponding detail drawings denoted.

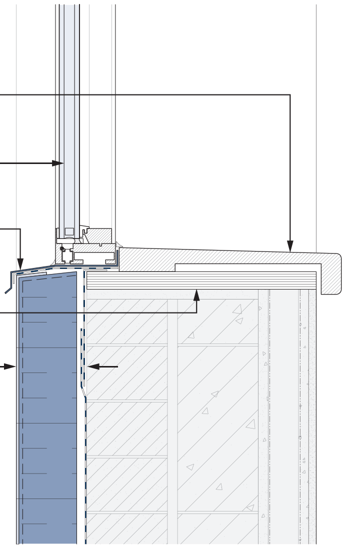


Figure A.9. Sill detail indicates critical flashing and moisture protection membranes. The pre-fabricated sill is one approach to avoid sanding and painting in the suite, and the associated time and cost of cleaning. The sill profile shown can be used with shims over the plywood blocking, or installed over an existing sill when no blocking is required.

IMPORTANT NOTE: A critical measure for EIFS system is the rear drainage layer, or drainage plane, required to convey moisture penetration out of the wall assembly. Depending on the EIFS manufacturer, this drainage layer may be achieved by a variety of approved methods. It is common to use a notch-trowelled insulation board adhesive as both an air/vapour barrier and drainage layer, thus achieving all three functions with a single material application. For some EIFS systems, such as those required in non-combustible construction (not shown here), an air/vapour barrier membrane or coating may be employed prior to the attachment of non-combustible insulation boards. In this case, the drainage layer is created at the interface between the inboard face of the non-combustible insulation and the air/vapour barrier. It is always necessary to ensure that the entire EIFS system complies with these basic moisture protection requirements. Do not mix materials and components from different manufacturers' systems as this may result in poor performance and a void warranty. From a practical perspective, the system should be detailed and installed so that it is much easier for the water to get out of, rather than into, the overcladding assembly.

Window Alignment: Replacement windows must be correctly aligned with exterior insulation such that the thermal break in the window frame is adjacent to the warm side of the insulation as depicted in the figures on this page. This better practice improves thermal efficiency and reduces condensation potential.

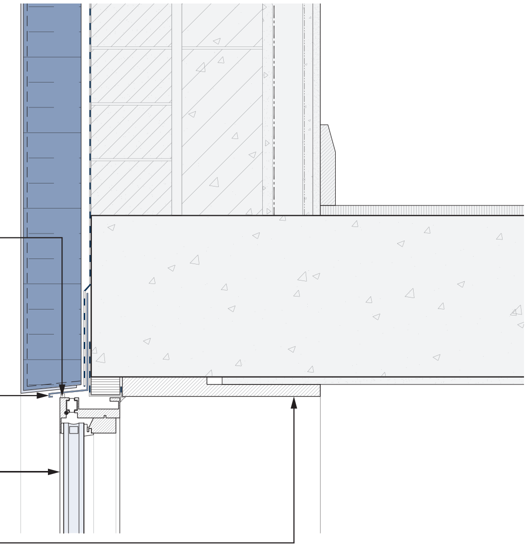


Figure A.10. Replacement window header detail indicating the use of flashing to convey potential moisture penetration during extreme weather phenomena outboard of the wall and window assembly. Not shown is the foam sealant around the window prior to installation of the window jamb extension.

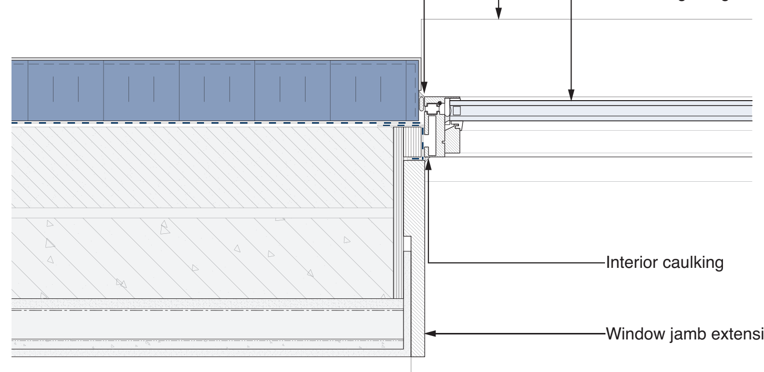


Figure A.11. Pre-finished window jamb extensions complement the pre-fabricated window sill to facilitate interior finishing of the retrofit window opening within a single visit, minimizing tenant disruption.

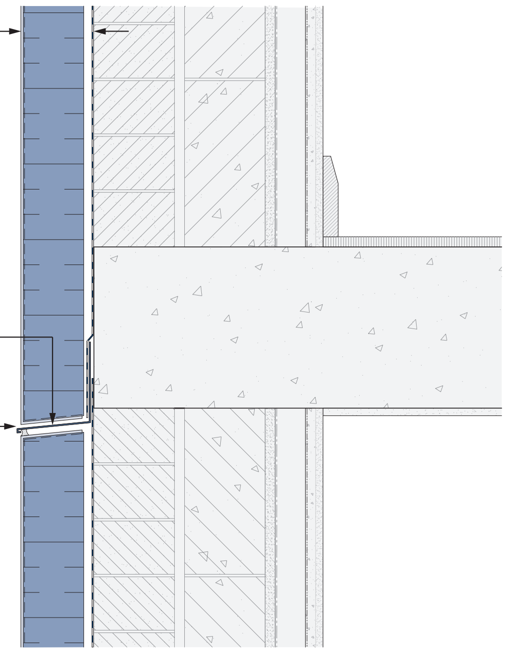


Figure A.12. Well designed EIFS assemblies will incorporate control joints that also serve as drainage channels every several storeys. In the event of a moisture problem, such as can occur when wind borne projectiles damage the EIFS assembly during extreme weather phenomena, the potential moisture damage is confined to a few floor levels. The flashing and drainage channel will prevent the water from running behind the entire EIFS assembly. Control joints may impact aesthetics by creating straight horizontal joints that run continuously across the building façade.

EIFS Wall Overcladding and Replacement Window Sequence

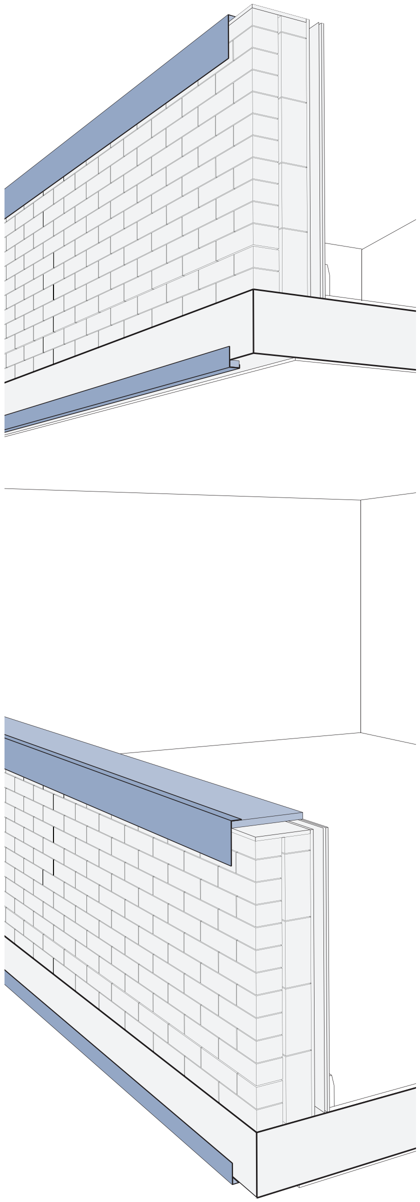


Figure A.13. The process of wall overcladding and window replacement begins with the removal of the existing window(s). The existing rough opening has blocking installed on the window sill, followed by the placement of air/vapour barrier membranes that will subsequently overlap and tie into the air/vapour barrier system. Normally, this process begins at the top of the building and proceeds downwards so that debris and falling objects do not damage the newly installed components below. Note that the backing on the air/vapour barrier strips is retained until these later overlap and tie into the wall air/vapour barrier.

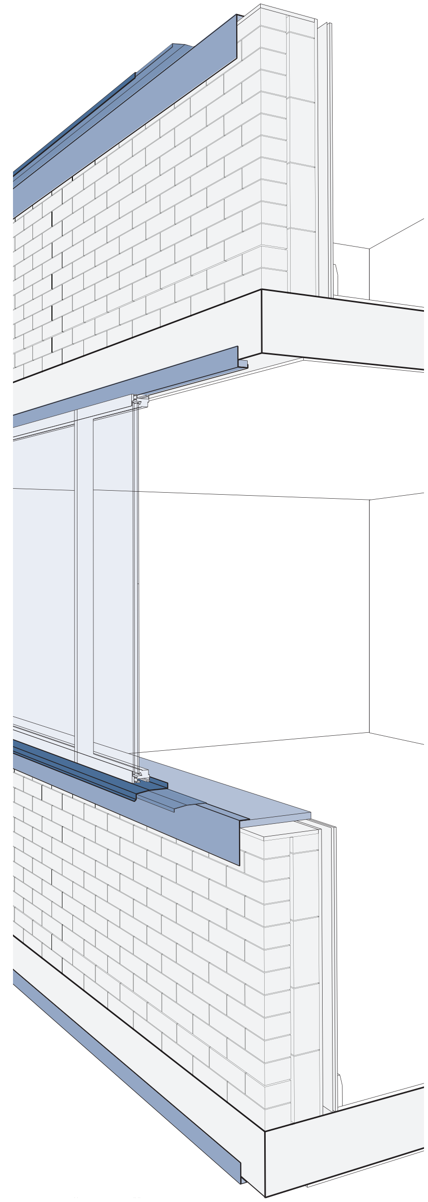
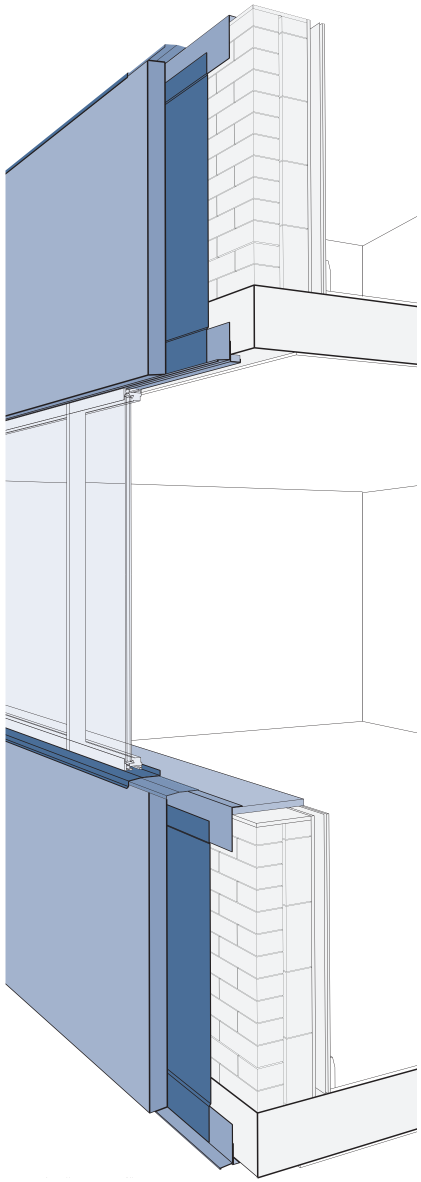


Figure A.14. The replacement window is installed along with the end dam and subsill flashing. The removal and replacement of the window(s) must be scheduled so as to be completed in a single day to avoid exposure of the suite to the elements and minimize disturbance to the inhabitants. Interior finishing of the rough opening can be scheduled at a later time, ideally to be completed within a single visit at a convenient time for the inhabitants.



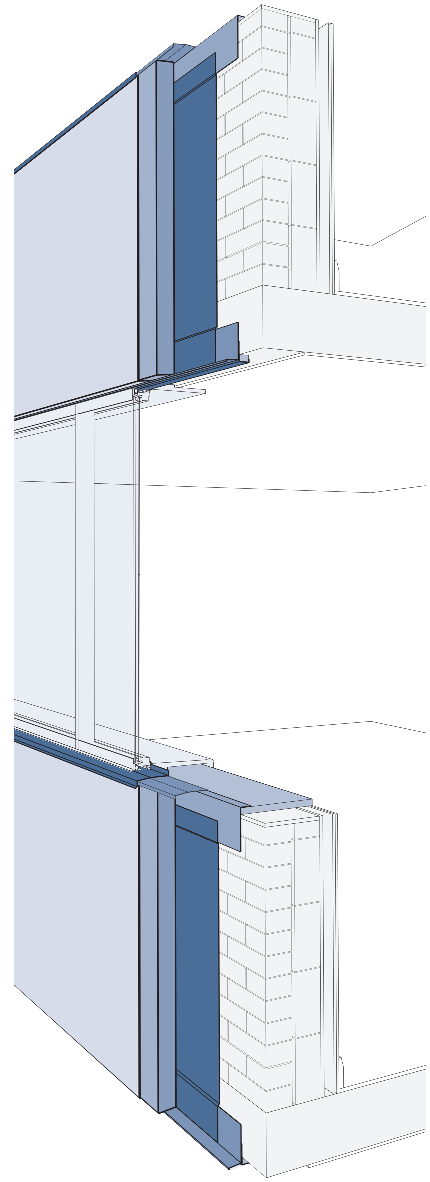


Figure A.15. With window replacement complete, the EIFS system application commences. Depending on the type of EIFS system, there are commonly two options. An air/vapour barrier membrane or coating may be applied over the existing envelope, and then the insulation board may be adhered/fastened to it. Alternatively, the insulation adhesive can double as the air/vapour barrier (shown above). In both cases, a proprietary rear drainage plane is created by the adhesive and air/vapour barrier interface, or by grooves, dimpling or other drainage channels rendered with the adhesive itself. The air/vapour barrier membranes installed prior to window installation must be properly tied into the air/vapour barrier serving the EIFS overcladding. Continuity and compatibility of the air/vapour barrier system components are essential to long term durability.

Figure A.16. The final steps in the process involve application of the acrylic stucco beginning with the base coat in combination reinforcement mesh over areas as specified, followed by the finish coat. Caulking is applied as specified and this generally concludes the overcladding and window replacement sequence. Note that EIFS stucco finish coat is normally butted up to caulking adhered to the base coat. Caulking does not adhere to the finish coat and typically separates to compromise performance.

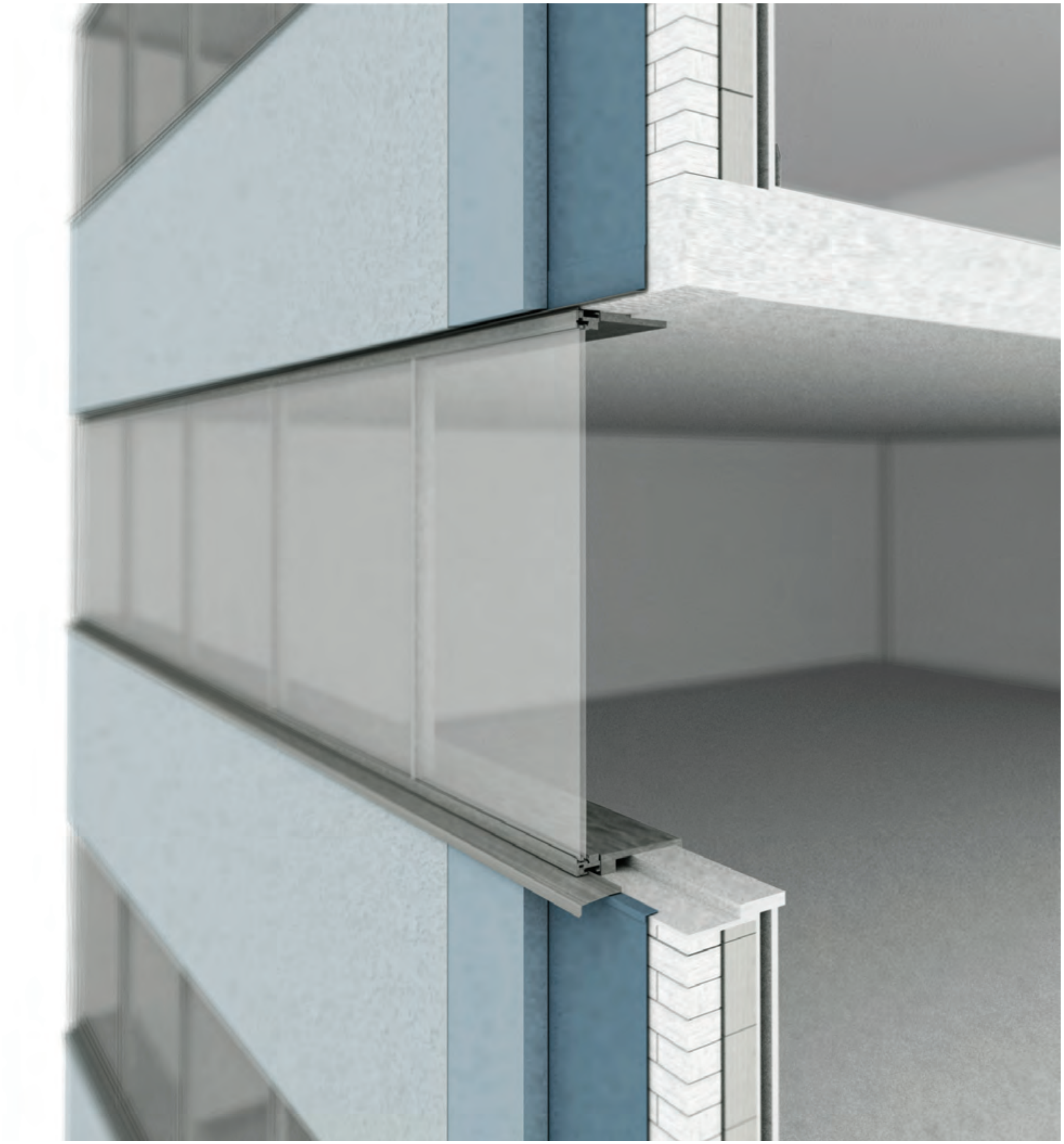
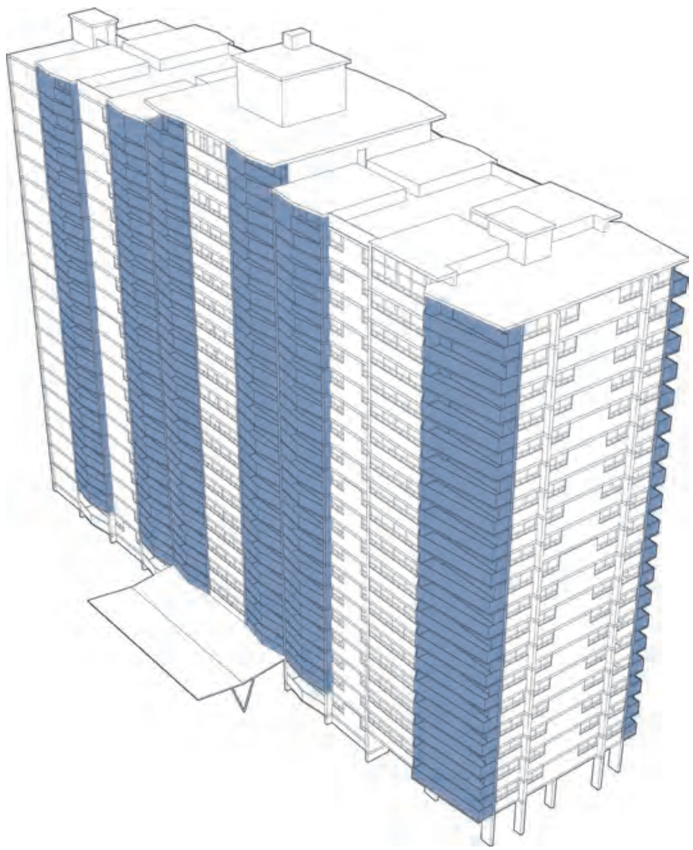


Figure A.17. Cutaway rendering of the completed EIFS wall overcladding and window replacement. Note in this rendering the existing sill with no blocking is depicted. The sill profile is also adaptable to plywood blocking used after the existing window sill has been removed, as shown in the previous details.

EIFS Balcony Overcladding

Balcony overcladding, as it is presented in this section, presents one of two alternatives for addressing projecting concrete balcony slabs. Figure A.18 indicates a complete encapsulation of the balcony slab that is integrated with the wall overcladding and window replacement. Alternatively, the balcony may be enclosed with insulated panels and glazing, an approach that is presented under Panel Overcladding Systems. The shaded areas on the archetype tower building below represent typical locations for EIFS balcony overcladding.



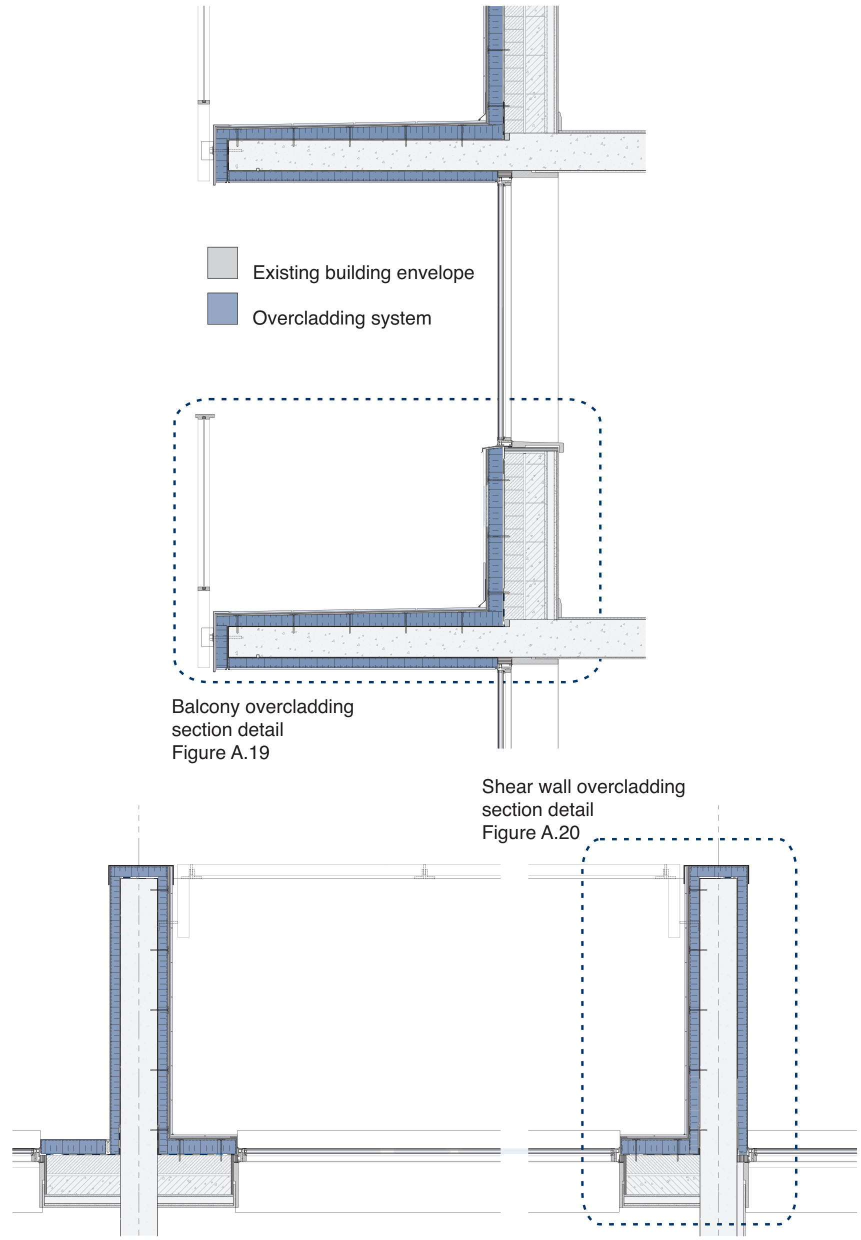


Figure A.18. Section and plan views of a balcony overcladding assembly with corresponding detail drawings denoted.

Balcony overcladding is a preferred strategy if there is a need or desire to keep the balcony space open to the outdoors. As discussed in ***7. Tower Retrofit Strategies: A Systems Approach***, there may be cases where limiting distance requirements for fire safety do not practically permit the enclosure of balconies. That is, they may be enclosed, but the proportion of glazing (unprotected openings) permitted will be insufficient for daylighting and natural ventilation purposes. There may also be cases where unenclosed balconies are preferred for the sake of aesthetics and quality of life reasons. In the former case, a non-combustible EIFS assembly will be required (not shown here) where typically the foam insulation board is replaced with mineral fibre board stock. Expanded metal lath is attached over top of the insulation by mechanically fastening it to the existing building envelope substrate. The stucco is rendered over the metal lath similar to conventional EIFS applications, which are the focus of this section on balcony overcladding.

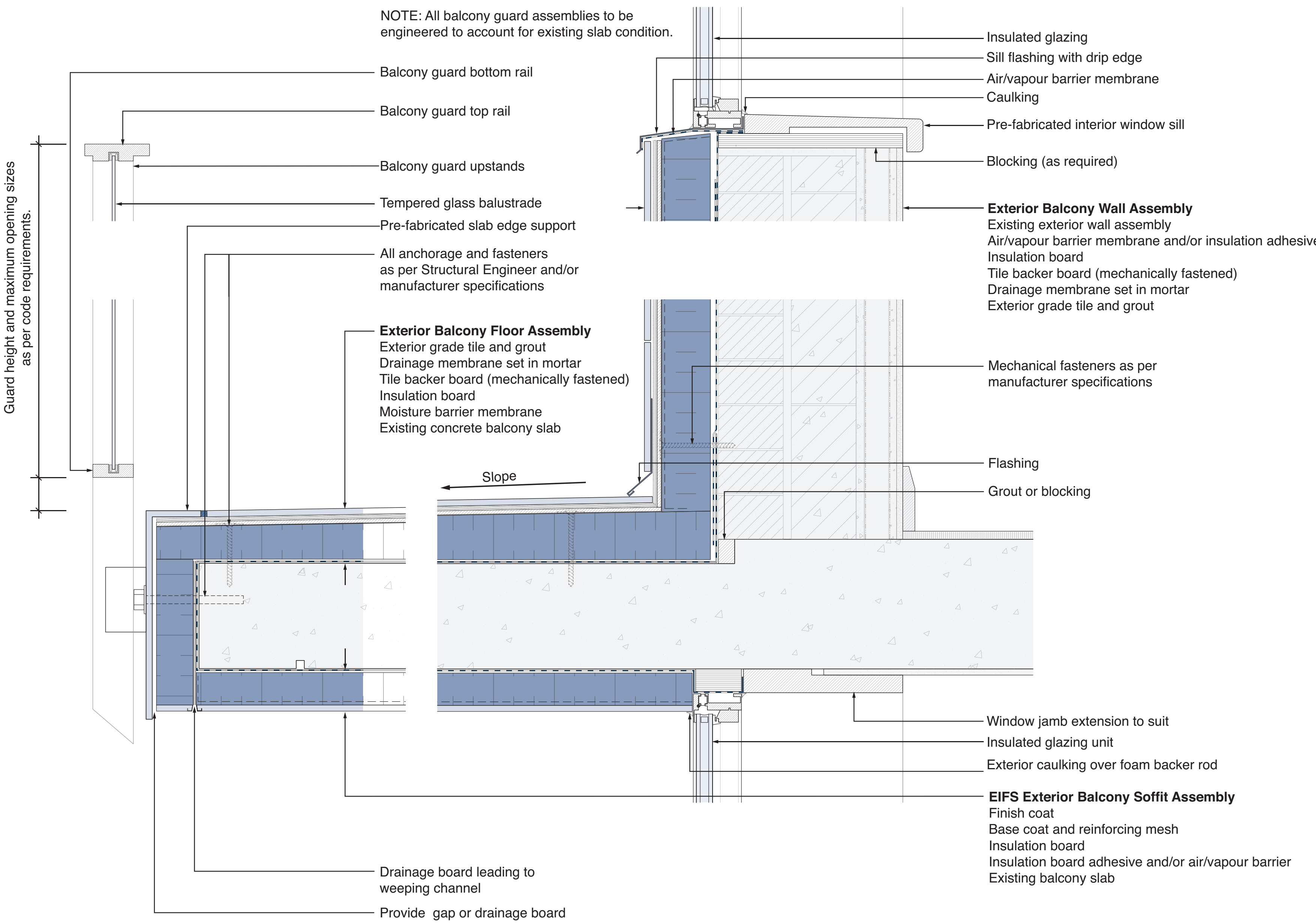


Figure A.19. Section through balcony slab overcladding indicates the use of a tile product as an exterior wall finish and floor traffic surface. Multiple lines of defence against moisture migration are essential for long term durability. The thermal resistance of the insulation material for the slab edge and floor areas should not decrease appreciably under wet conditions. All materials should be corrosion resistant and capable of withstanding freeze–thaw cycles. Alternative products and assemblies providing equivalent wear resistance and durability may be substituted for the tile cladding assembly. Note the use of a combined insulation adhesive and air/vapour barrier to attach the insulation to the existing wall.

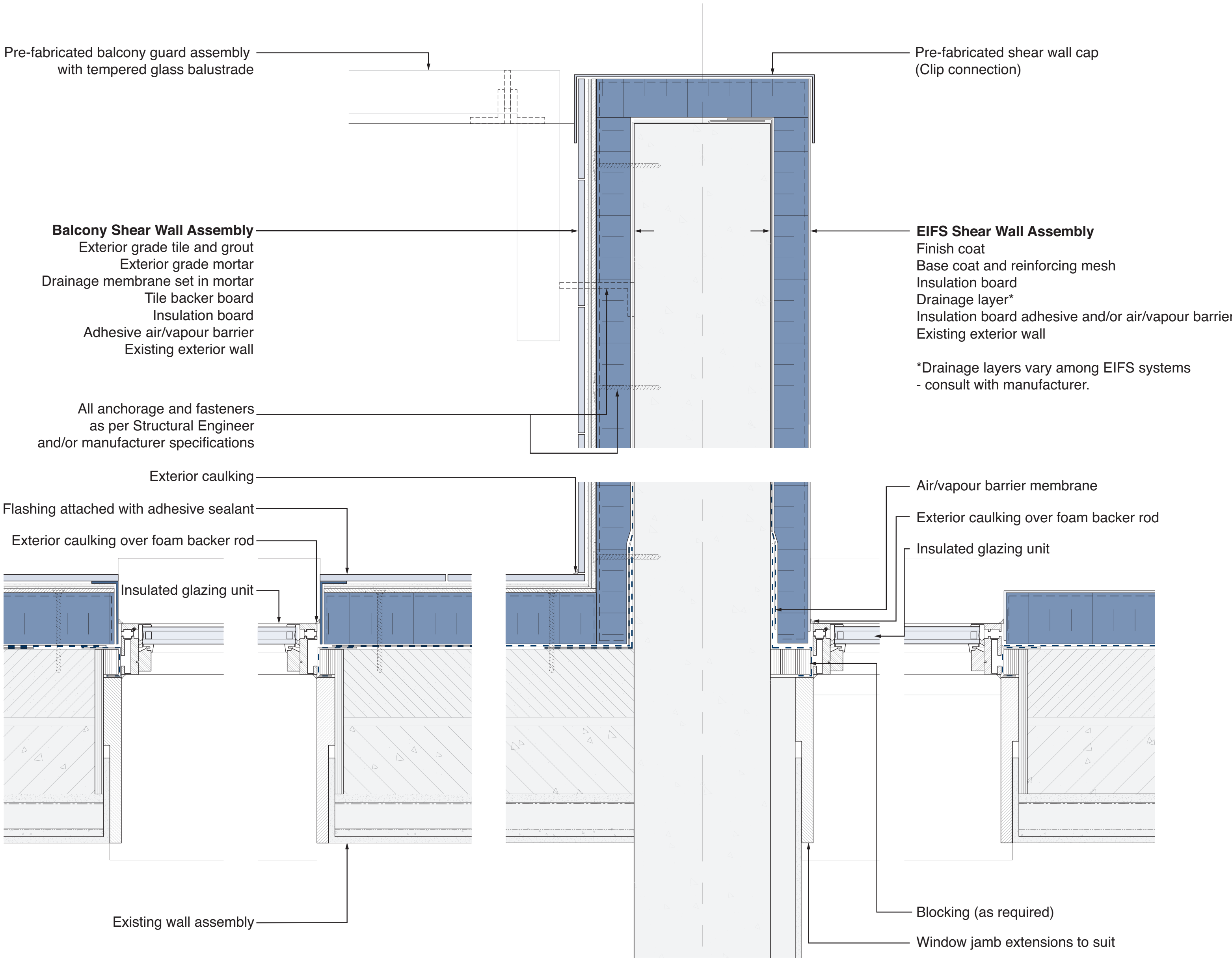


Figure A.20. This plan detail depicts the transition from the tile cladding system to the EIFS overcladding. The shear wall end cap can be extended to serve as a chase for building services, and rendered in a variety of materials. Two replacement window conditions are depicted. The conventional punched window appears on the left, while the window that originally abutted the shear wall appears on the right. It requires additional blocking or an adjustable bracket to properly align and attach the window frame at this location. Foam sealant of the breaching to fill voids between the window and the rough opening is recommended, but not shown, to maintain the clarity of the drawing.

EIFS Balcony Overcladding and Replacement Window Sequence

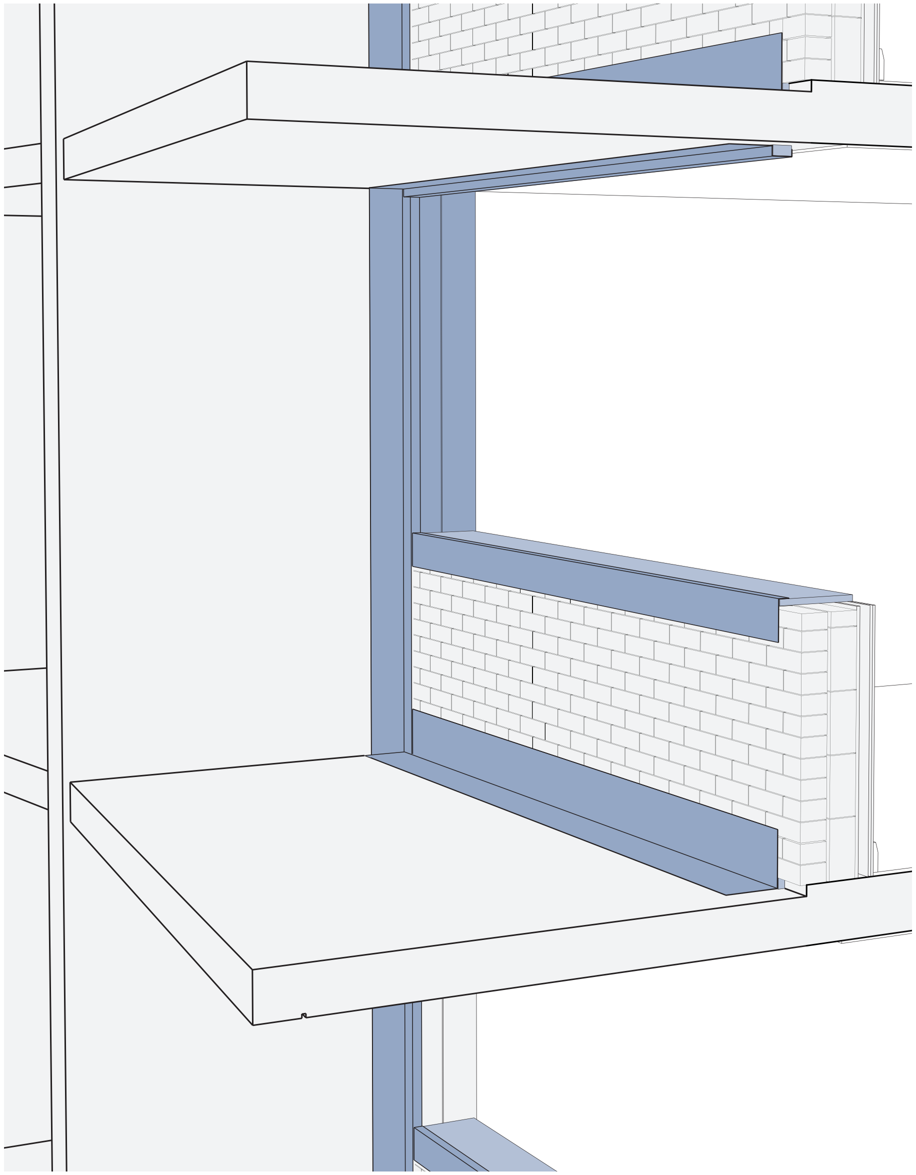


Figure A.21. Similar to previous sequence for the regular wall elements, the existing rough opening has blocking installed on the window sill, followed by the placement of air/vapour barrier membrane strips that will later be tied into the air/vapour barrier system. A strip is also placed over the length of the shear wall/ balcony wall intersection. Note that the backing on the air/vapour barrier strips is retained until these later overlap and tie into the wall air/vapour barrier. This is not required if a combined insulation adhesive and air/vapour barrier is trowelled over the entire surface, as depicted in the sequences that follow.

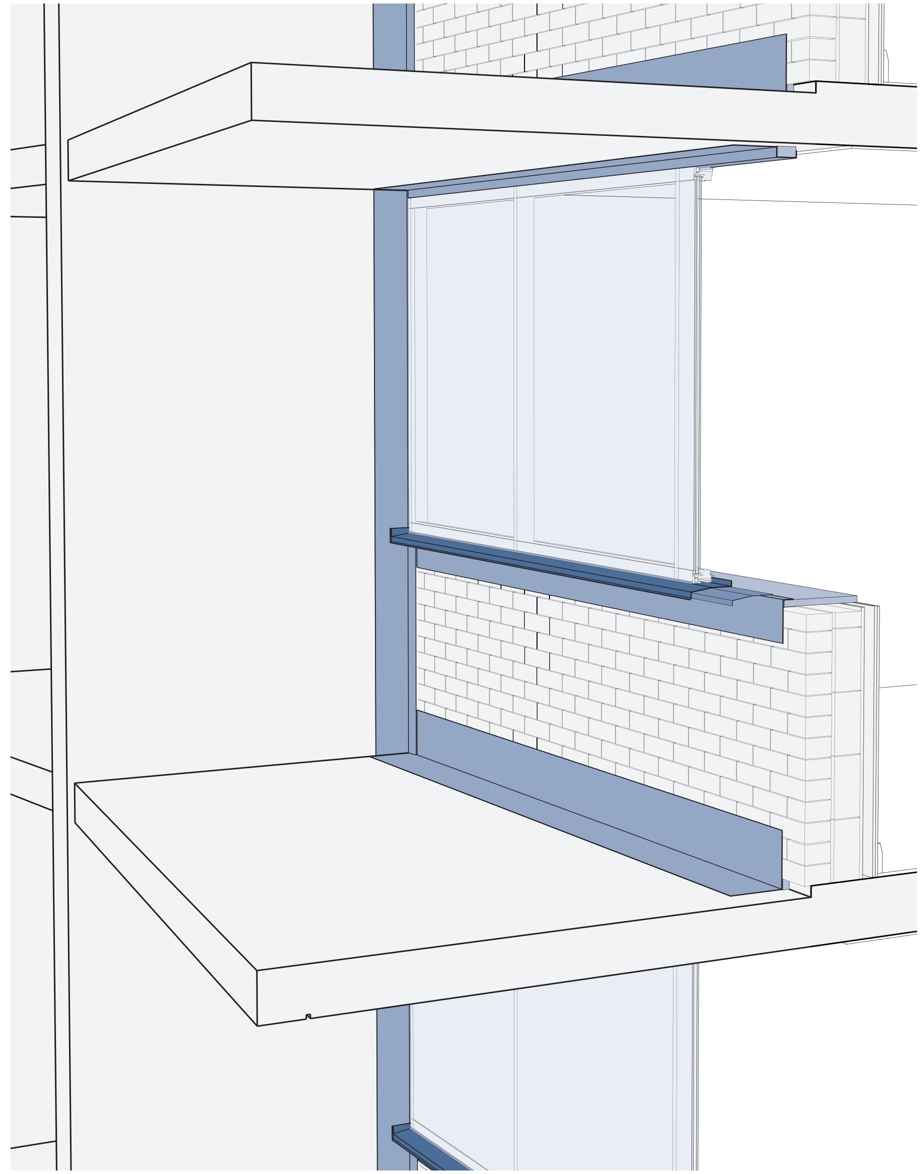


Figure A.22. The replacement window is installed along with the end dam and subsill flashing. The removal and replacement of the window(s) must be scheduled so as to be completed in a single day to avoid exposure of the suite to the elements and minimize disturbance to the inhabitants. Interior finishing of the rough opening can be scheduled at a later time, ideally to be completed within a single visit at a convenient time.

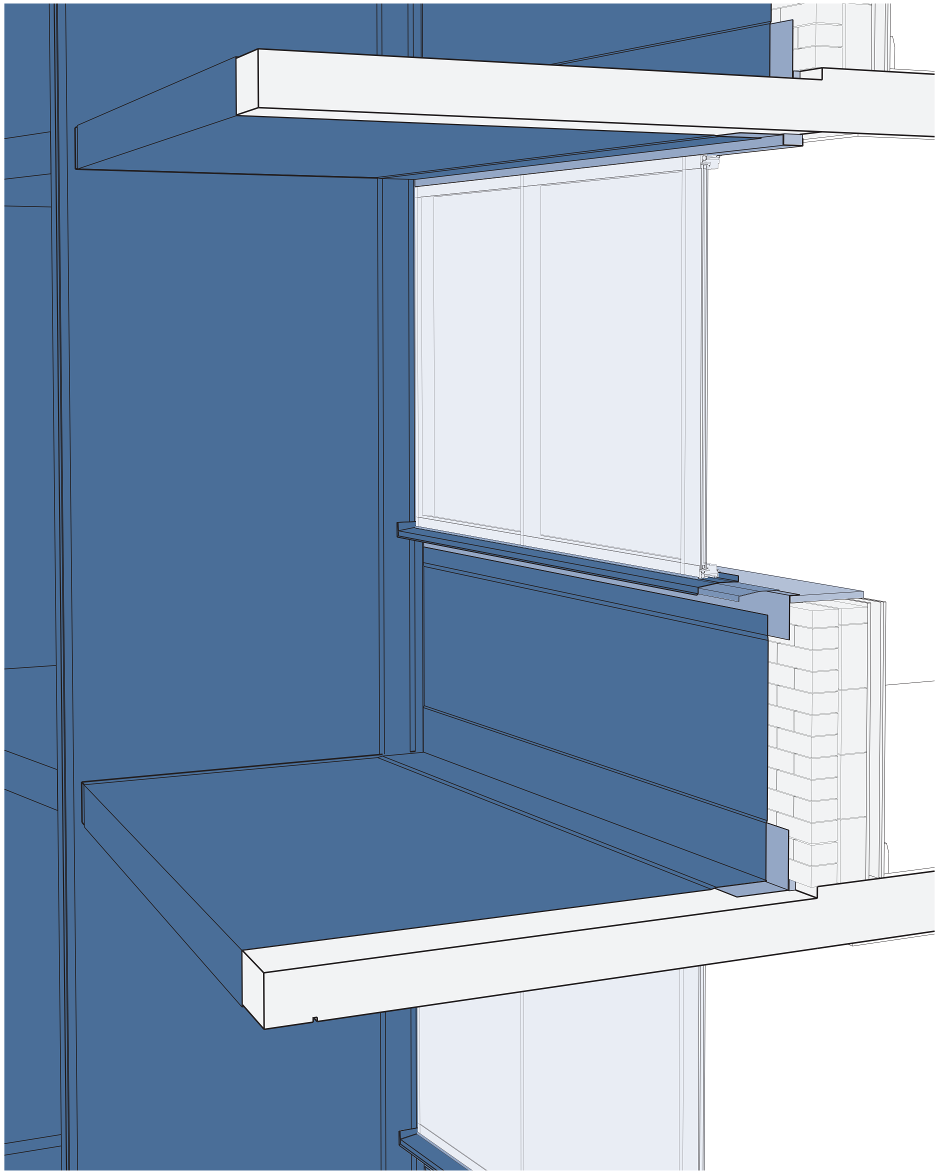


Figure A.23. An air/vapour barrier membrane or coating is applied over the entire exposed surfaces of the balcony slab, balcony wall and adjoining shear wall. The air/vapour barrier may also take the form of adhesive used to attach the exterior insulation, as depicted above.

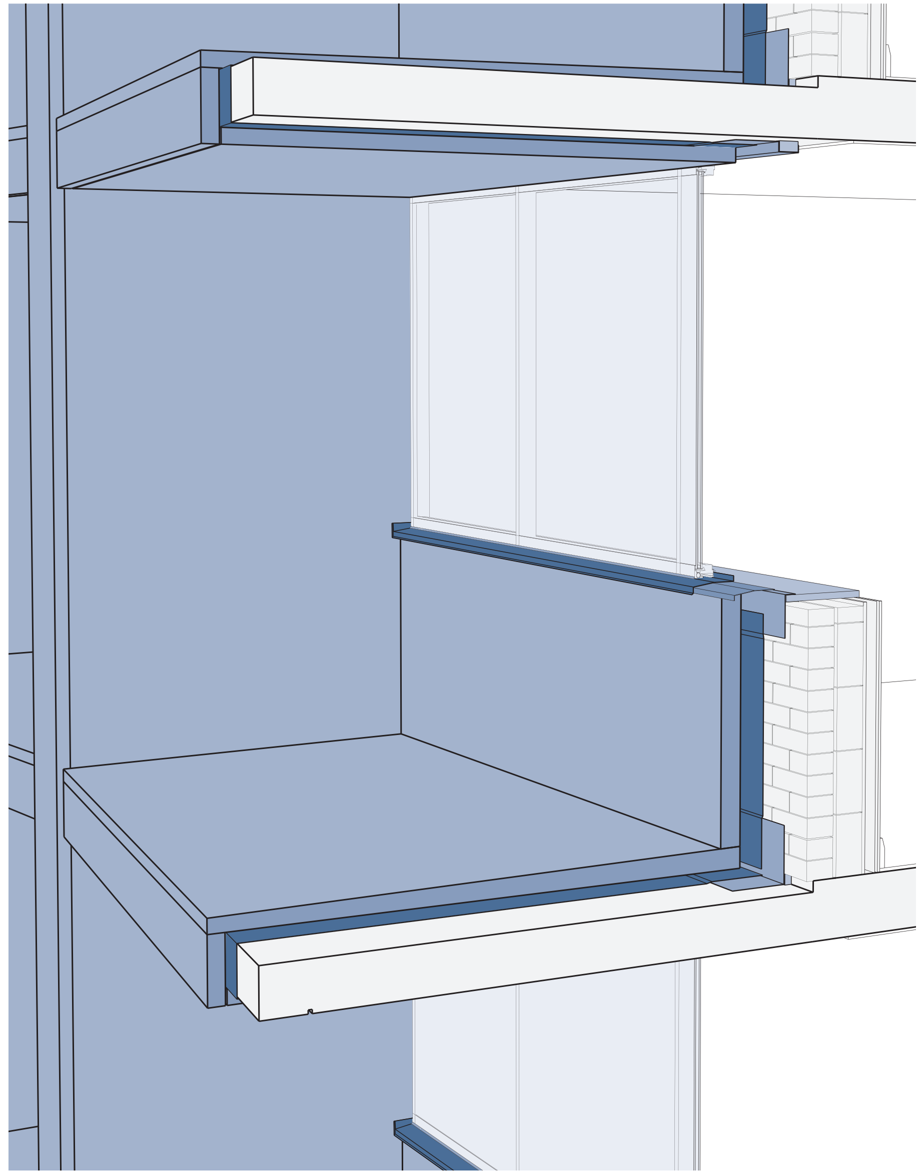


Figure A.24. Exterior insulation is subsequently installed over the entire exposed surface areas of the balcony slab, balcony wall and shear wall.

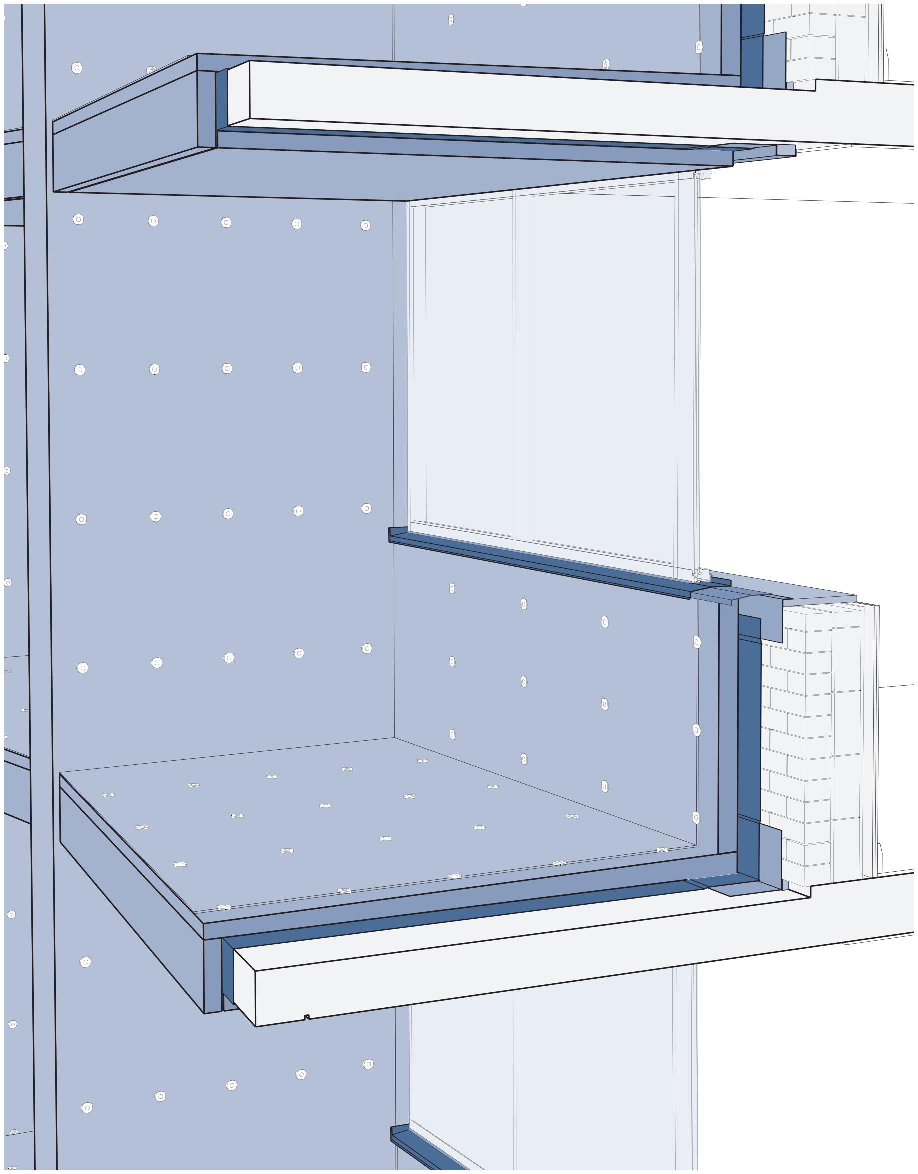


Figure A.25. Fibre-reinforced cement board is mechanically fastened in all areas receiving tile surfacing. The type and number of fasteners for this application must be properly specified.

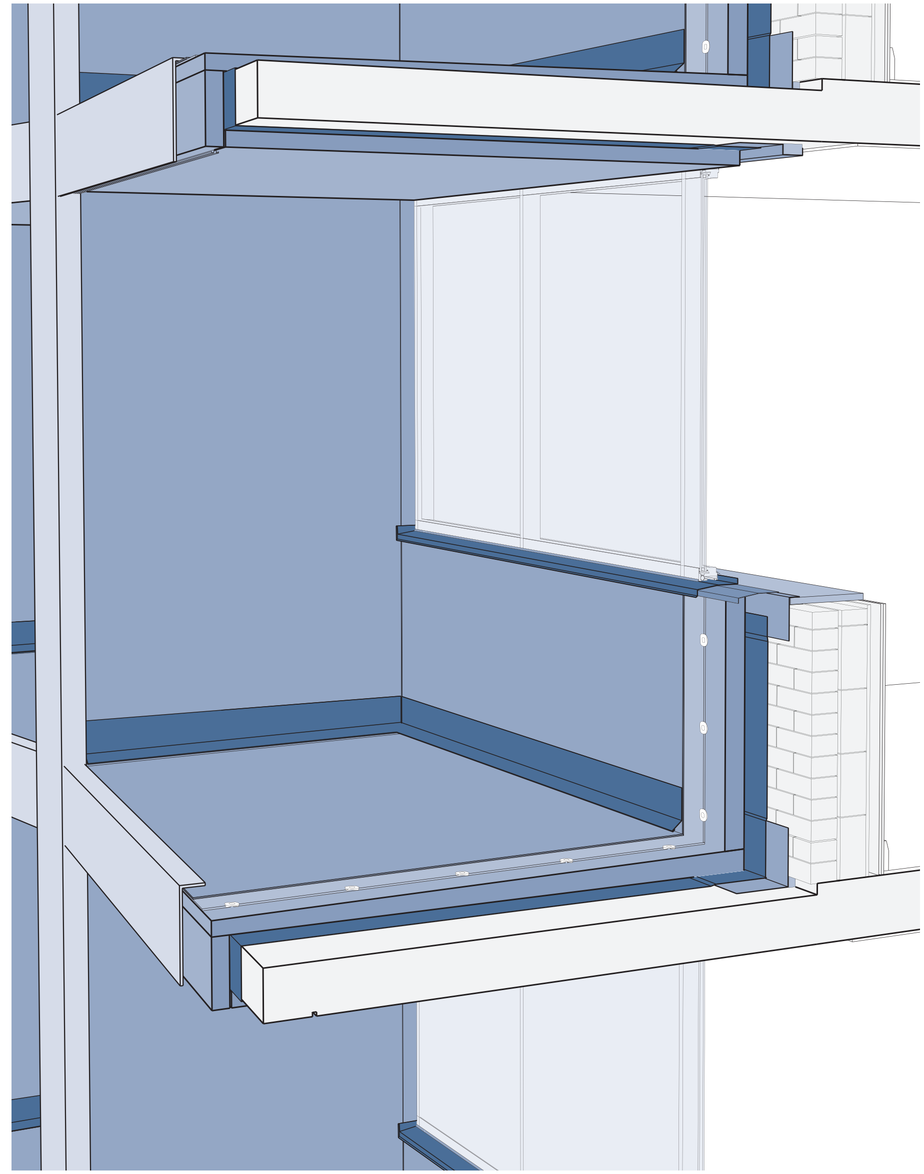


Figure A.26. A drainage membrane is applied over the cement board surfaces. A dimpled plastic sheet material is commonly used for this purpose, and it adhered to the cement board with proper overlap between sheets and over the base flashing. A slab edge support for the guard is installed prior to the setting of the tile finish.

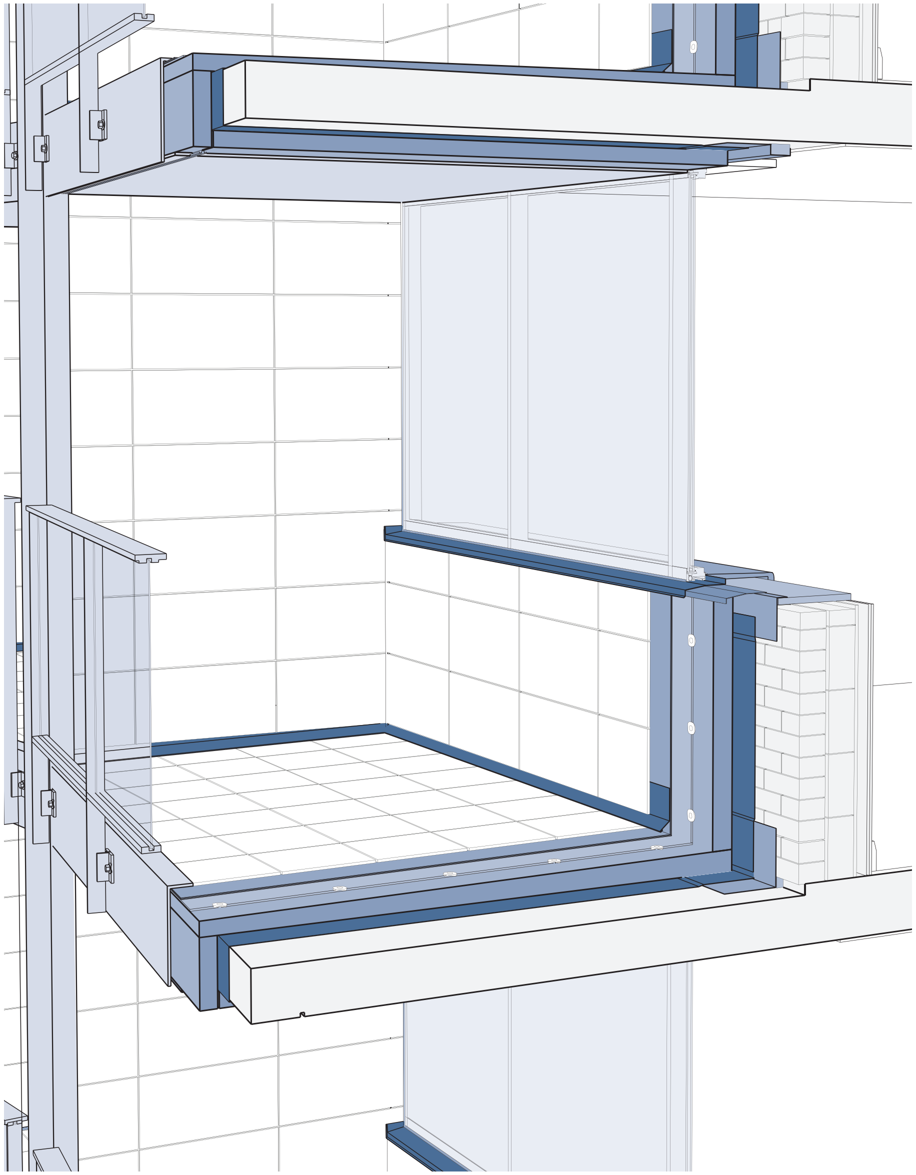


Figure A.27. Installation of the tile and grout proceeds, followed by caulking as specified. A new balcony guard is installed to complete the balcony overcladding assembly.

The overcladding of balconies is typically more expensive than balcony enclosure, and there may be a tendency to specify more economical materials to compensate for higher cost. The example depicted in this sequence does not advocate this particular material selection, rather it is intended to illustrate several important principles.

First and foremost, more than one line of defence against moisture migration must be provided. The continuous air/vapour barrier over the existing building envelope is the first line of defence against moisture penetration since this barrier also resists bulk water migration. The second line of defence is the drainage membrane beneath the tile and mortar in which it is set.

Second, water that enters the assembly must be provided with a drainage path out of the assembly. The air/vapour barrier conveys water to a drainage board running along the length and width of the slab edge. The drainage board conveys water to a weeping channel that allows the water to drip out by gravity. The drainage membrane beneath the tile conveys water to a gap or drainage board located between the slab edge support and the exterior insulation covering the slab edge.

Third, the materials must be suited to the environment in which they are located. Unenclosed balconies are exposed to all of the elements. Solar radiation and freeze/thaw cycles are two critical considerations related to the climate. The finished surfaces must also be durable, resistant to abrasion, and easy to clean. Insulation materials used for the slab area must have a high compressive strength and be able to maintain their thermal resistance when exposed to moisture. Mechanical fasteners should be corrosion resistant and all of the materials must be compatible with one another.

Given these three basic considerations for balcony overcladding assemblies, there are many materials and system available that satisfy these requirements and are capable of delivering a long service life. Care must be exercised in the selection and detailing of the systems to enable straightforward maintenance of the balcony overcladding on a periodic basis.

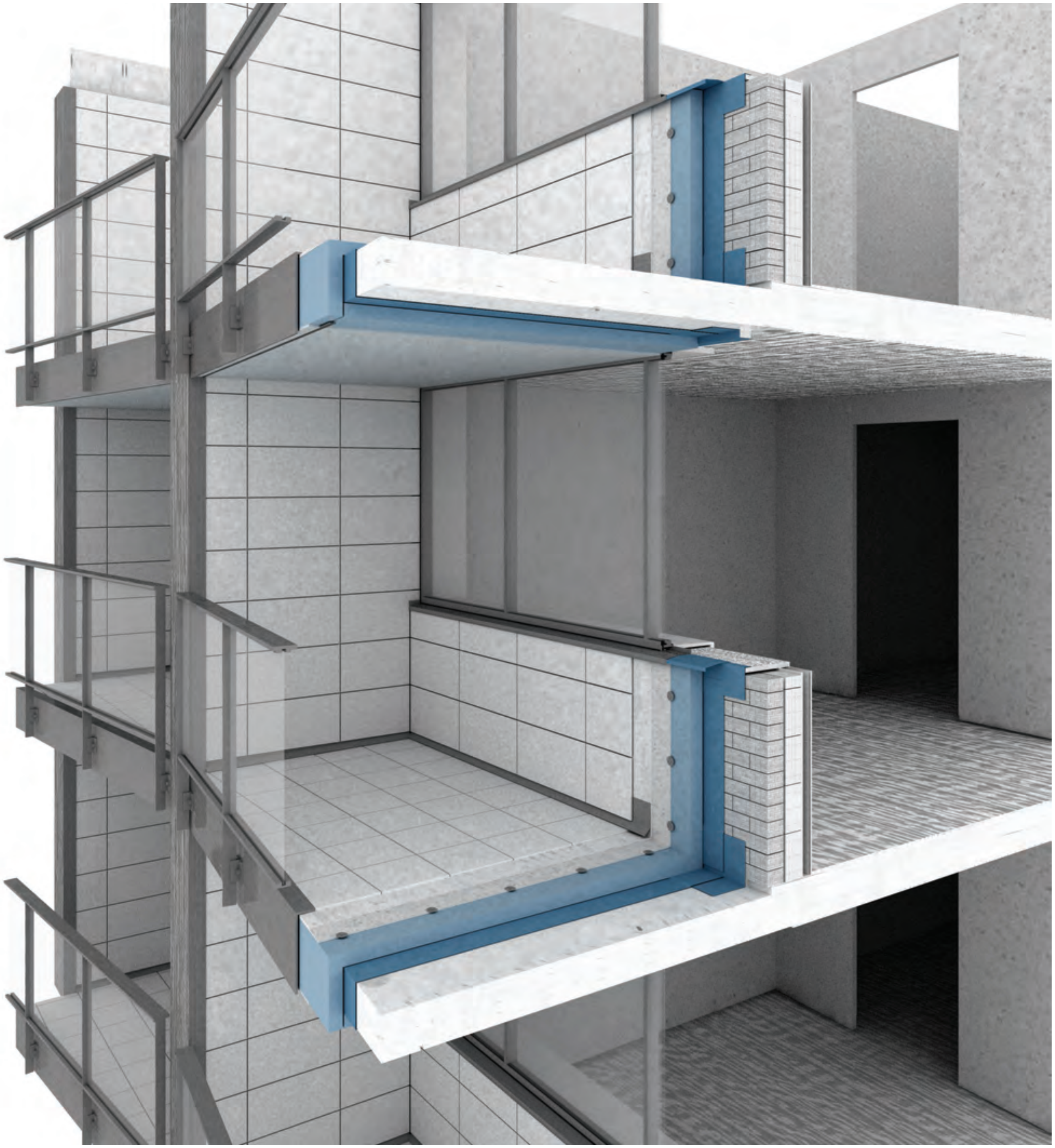
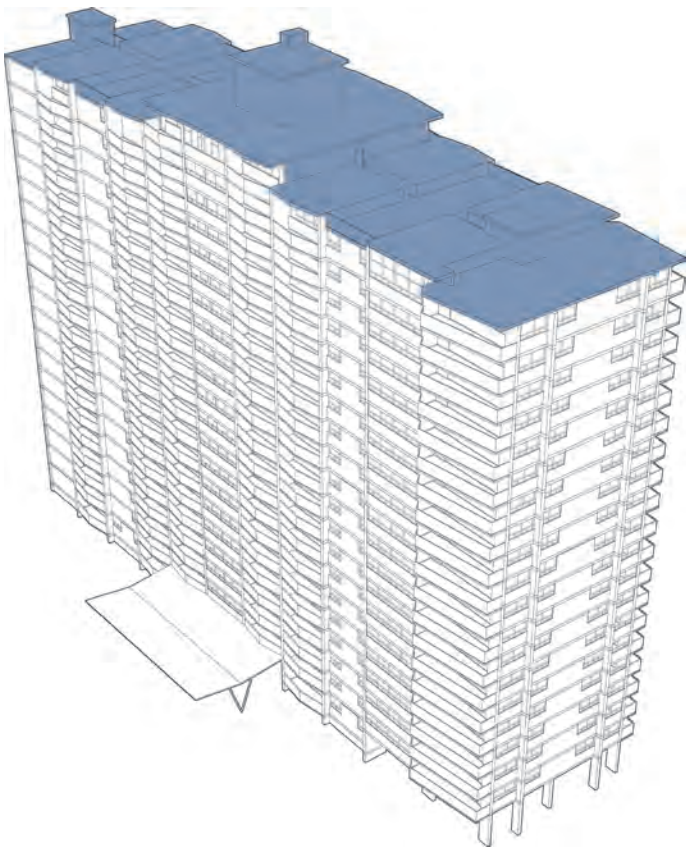


Figure A.28. Cutaway rendering of the completed EIFS balcony overcladding and window replacement. Note that the EIFS rendering is confined to the undersides (soffits) of balcony slabs and the outer surfaces of shear walls adjacent to regular wall elements.

EIFS Roofing Replacement and Balcony Soffit

Roofing replacement is a common and well understood procedure that is routinely carried out on existing buildings. It is not common to integrate overcladding of balconies with roofing replacement over the projecting roof slab. This section deals with this particular condition and discusses key considerations for design and the coordination of the overcladding and roofing replacement assemblies. The shaded areas on the archetype tower building below represent the locations of this condition.



The selection of roofing assemblies must consider that in typical tower retrofit projects, the roofing replacement will usually be carried out after all the overcladding has been completed, with exception to the at grade overcladding assemblies. Ideally, the mast climbing work platforms can be used to transport materials to the roof and possibly retrieve the existing roofing materials that have been removed. This affords a wider selection of roofing system options and reduces both time and costs. When this coordination is not possible, roofing systems that have components that can be cold applied and easily moved up using the building's elevators may be a preferred option. From a sustainability perspective, roofing systems that have the highest proportion of reusable and recyclable materials are preferred to systems that end up entirely in the landfill. Durability, water shedding and thermal effectiveness are essential requirements for any roofing system.

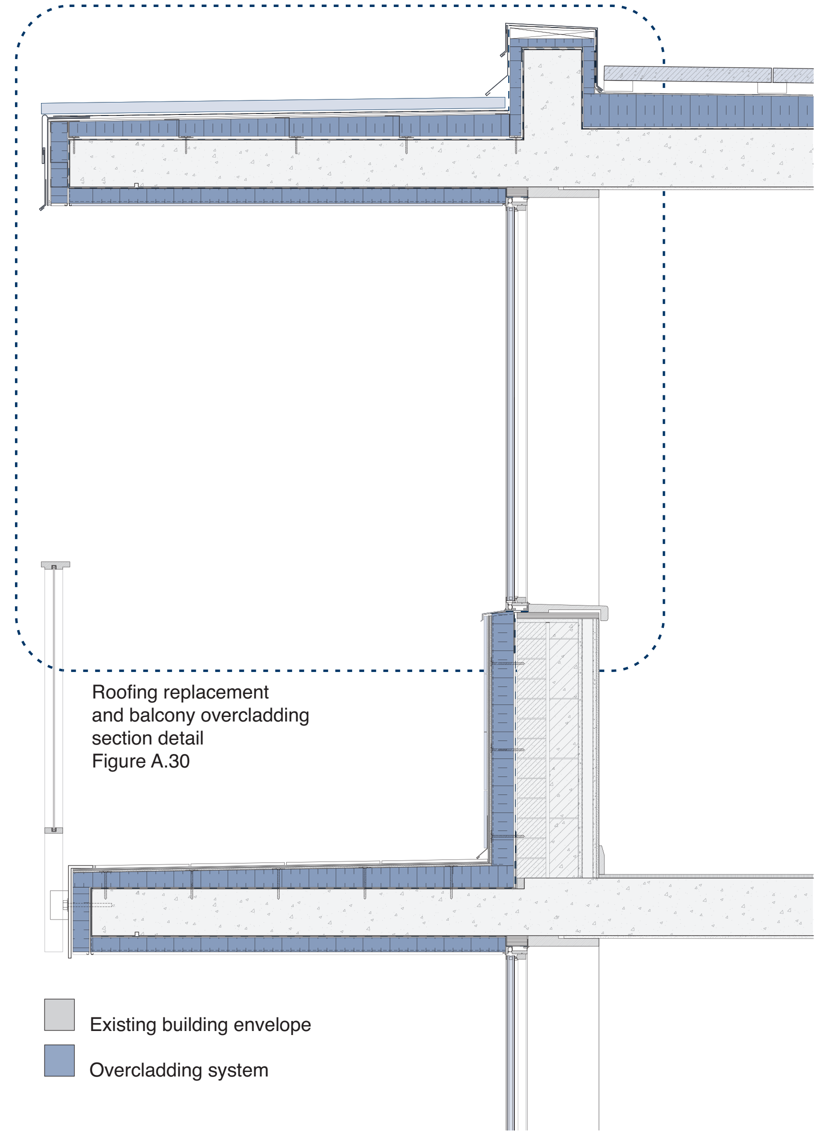


Figure A.29. Section view of a roofing replacement and balcony overcladding assembly with corresponding detail drawing denoted.

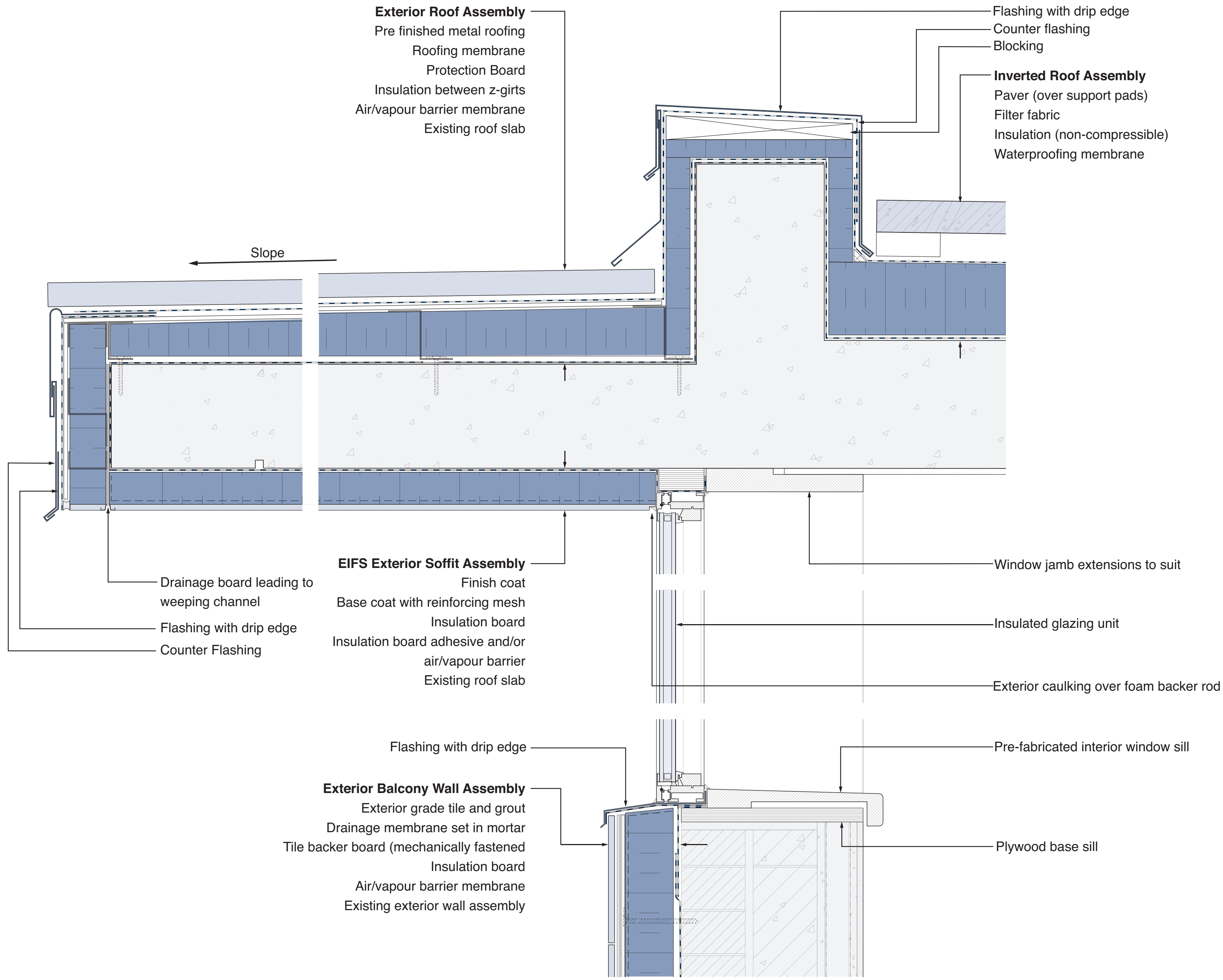


Figure A.30. Two roofing systems are depicted in the above detail. An inverted roof system is shown for the main roof area, and a metal roofing system is shown for the cantilevered roof slab. EIFS is applied to the soffit and the balcony wall and window replacement are the same as detailed in the previous section.

EIFS Roofing Replacement and Balcony Soffit Sequence

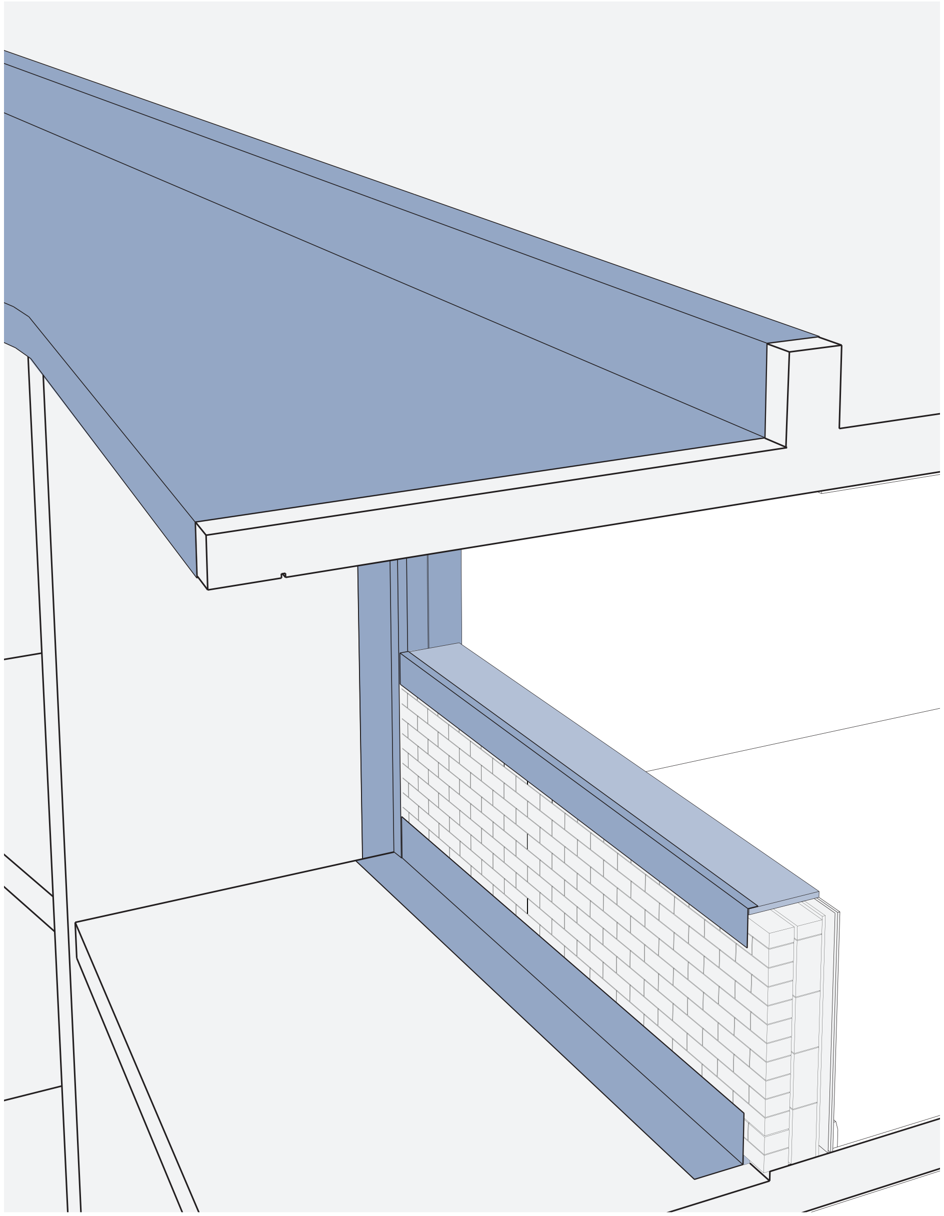


Figure A.31. The balcony overcladding sequence is the same as described in earlier sections, hence the focus of this sequence will be the replacement roofing assembles. Following removal of the existing roofing, the replacement roofing begins with the applications of an air/vapour barrier that also serves as the waterproofing membrane. Refer to the previous section on balcony overcladding for related notes.

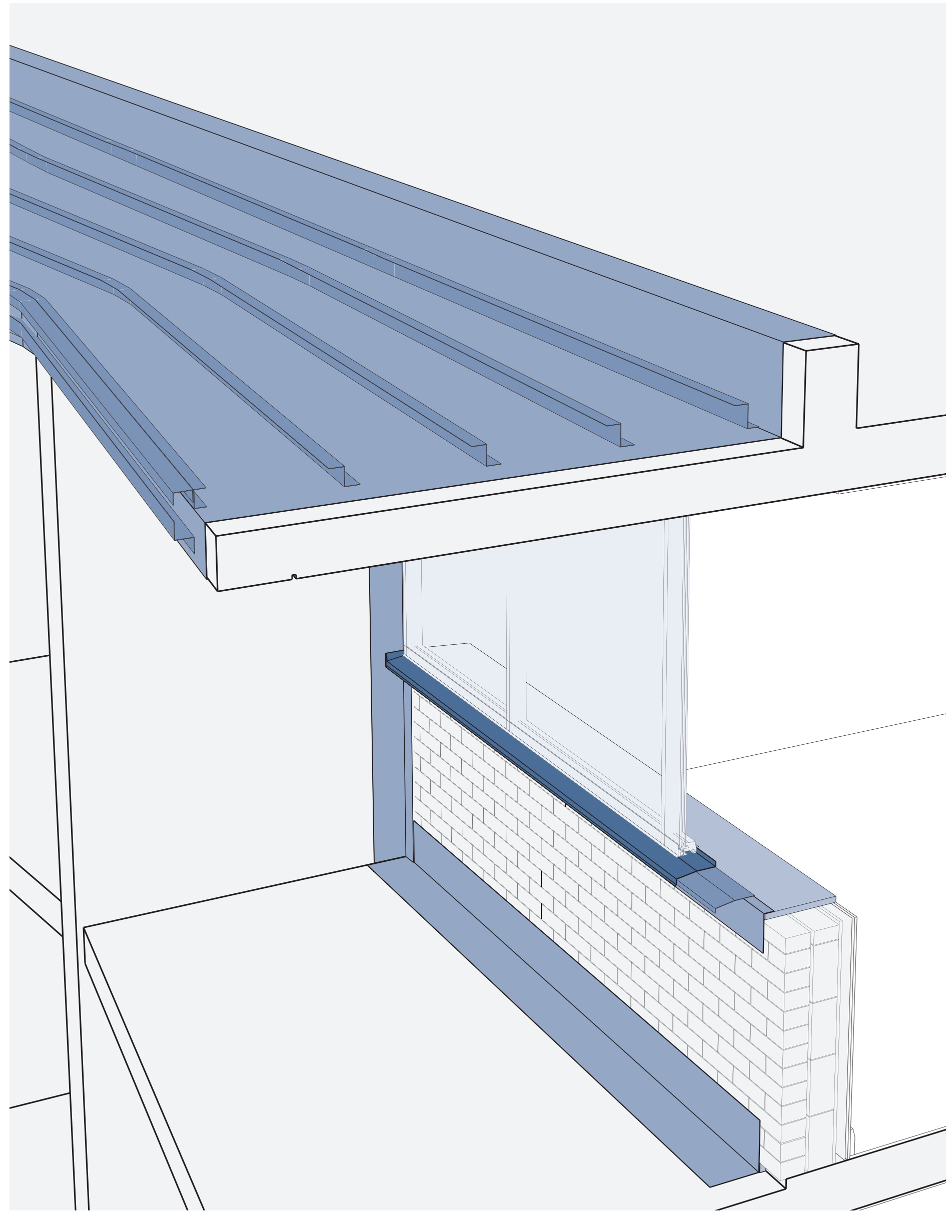


Figure A.32. On the projecting portion of the roof, Z-girts or other suitable channels are installed to eventually receive the fasteners to attach the corrugated metal roofing.

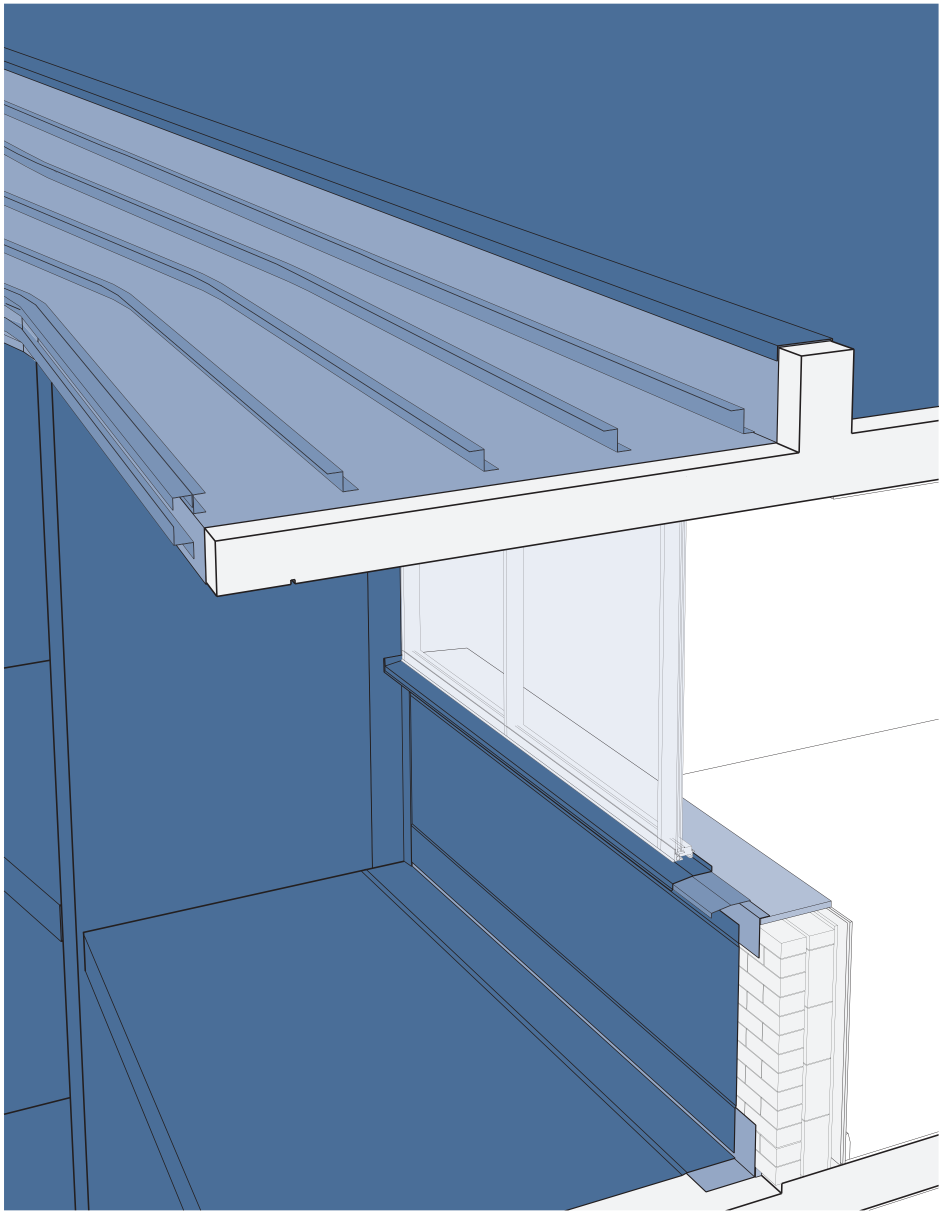


Figure A.33. A waterproofing membrane(s) is applied over the main roof section overlapping the projecting roof at the parapet.

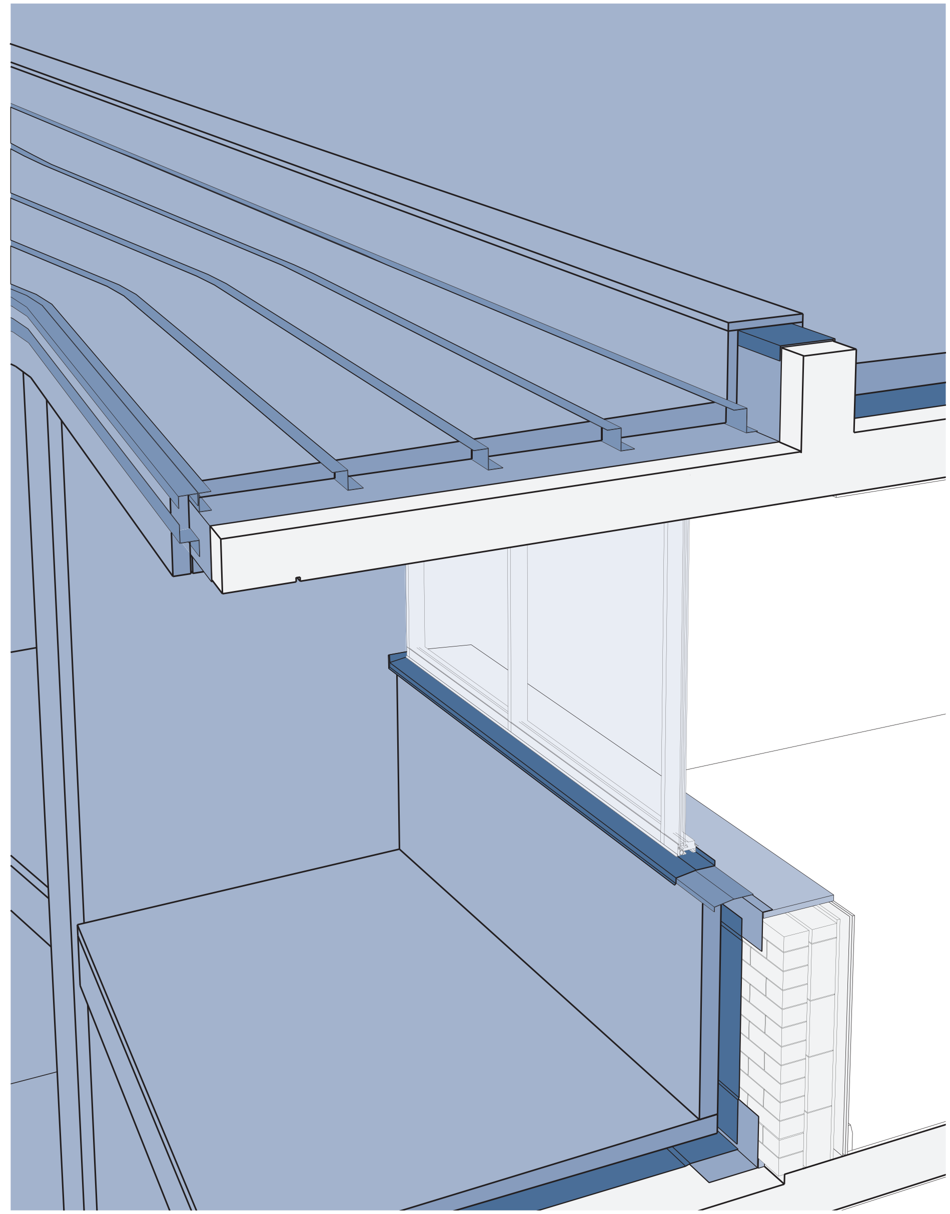


Figure A.34. Insulation is installed over the entire roof areas. Proper fitting of the insulation between the Z-girts is necessary to maintain thermal effectiveness of the assembly.

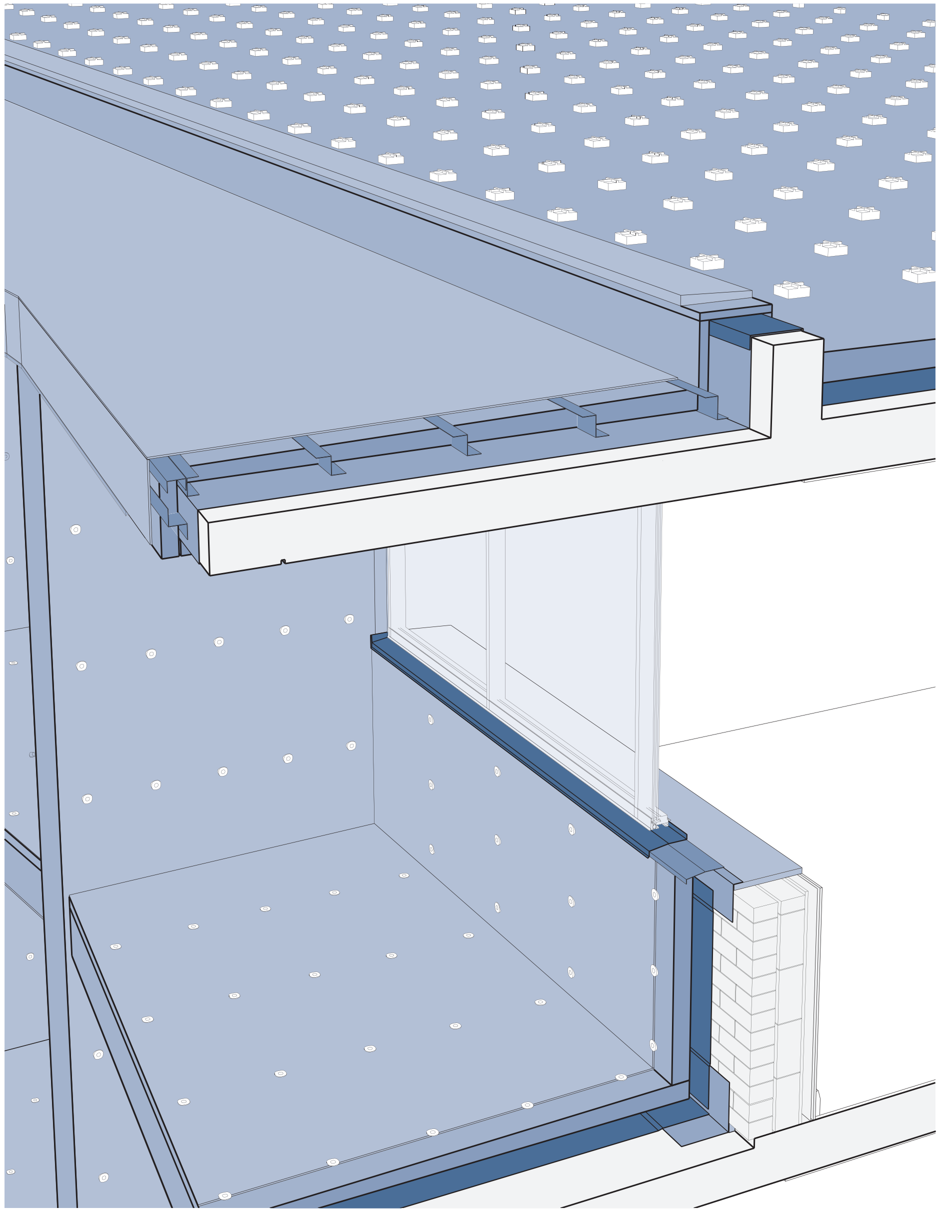


Figure A.35. Protection board is fastened to the Z-girts over the projecting roof area. On the main roof area, a filter cloth is laid over the insulation, followed by spacers to support the pavers.

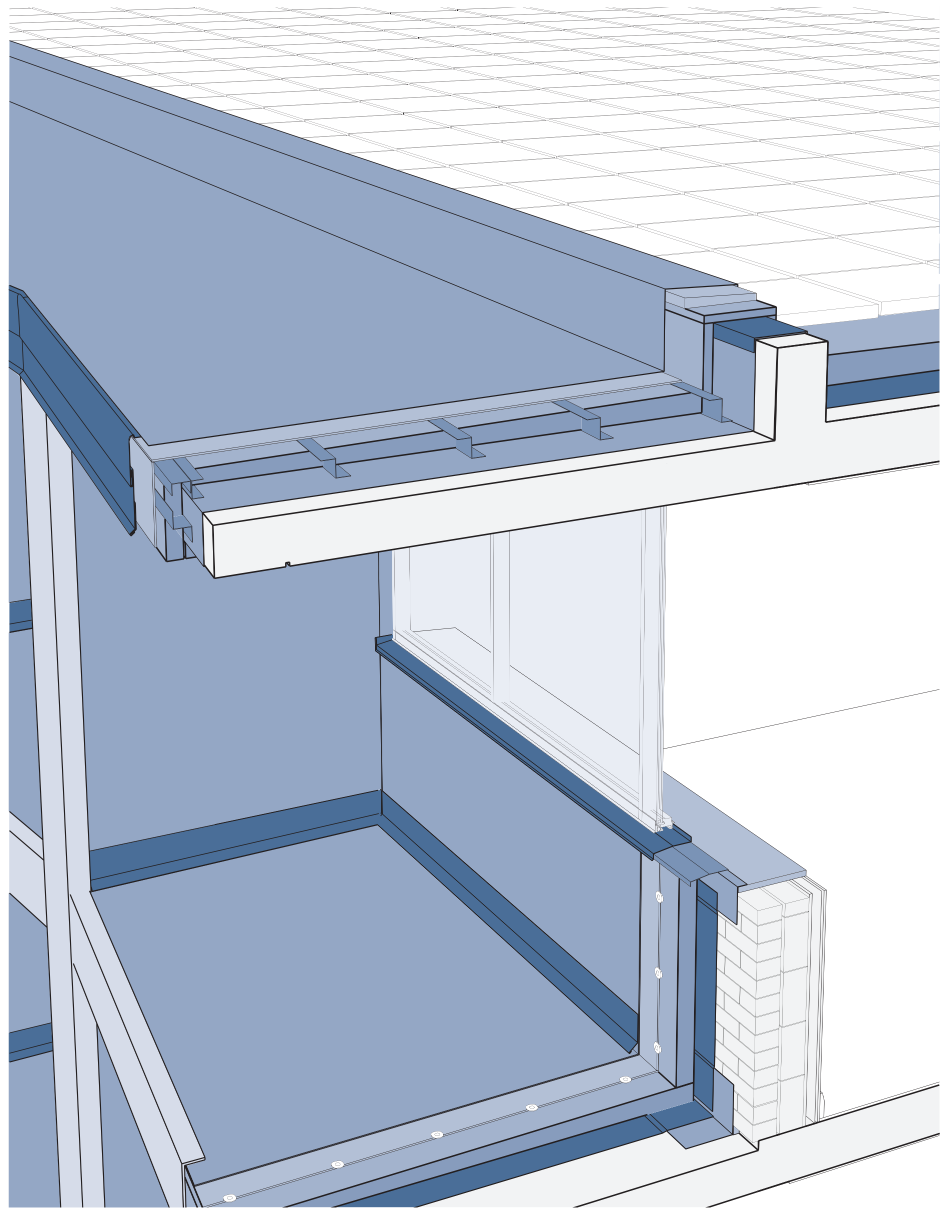


Figure A.36. Flashings are installed at the projecting roof slab edge. A roofing membrane is laid over the projecting roof area and lapped over the parapet and the flashing. Pavers are laid on top of the spacers in the main roof area.

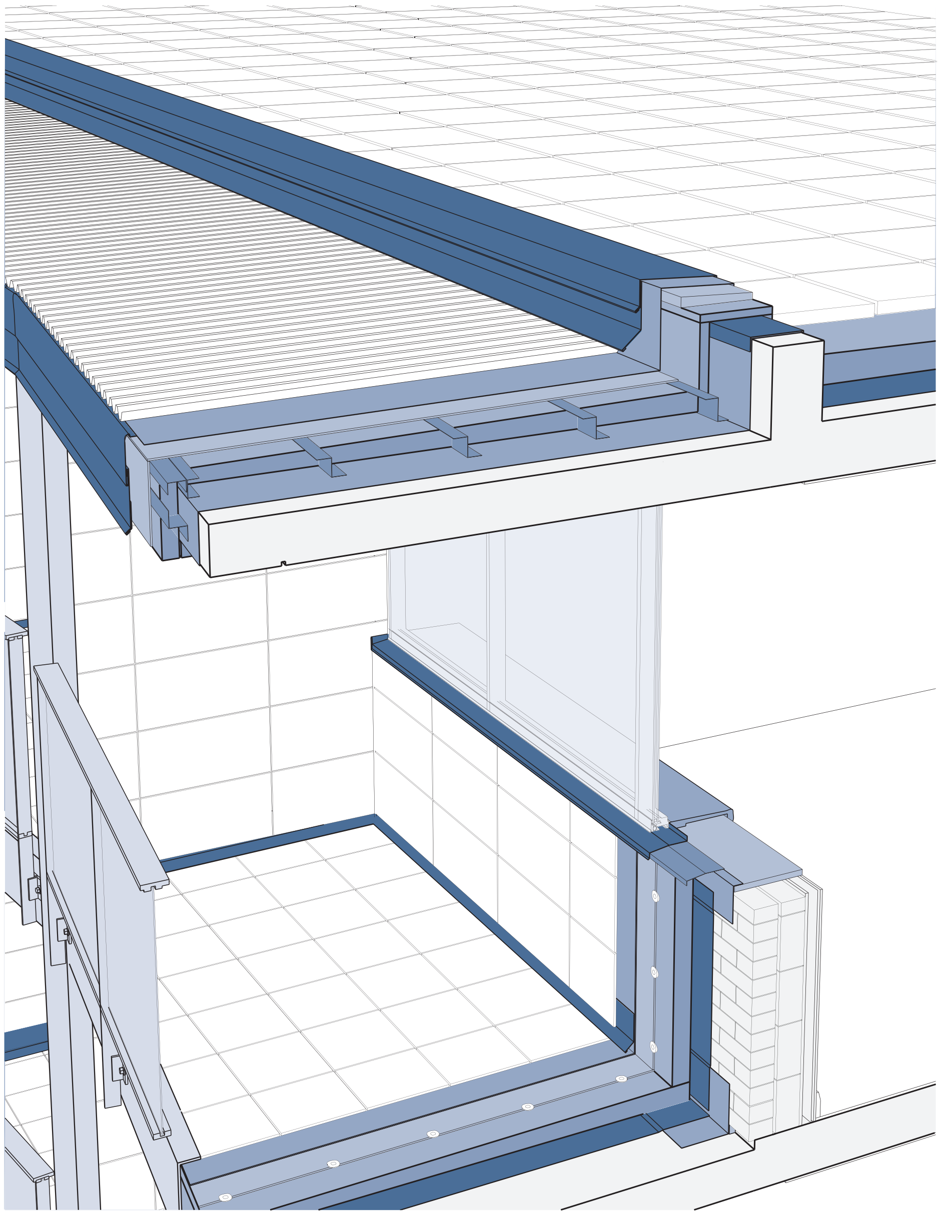


Figure A.37. The corrugated metal roofing is installed over the projection roof area, followed by the parapet flashing which completes the roofing replacement sequence.

The roofing replacement sequence and the balcony overcladding with window replacement have been illustrated together in order to assist users of these guidelines appreciate the need for coordination of these two aspects of a comprehensive tower retrofit.

For the wall and balcony elements retrofit contractor, the ideal process starts at the top of the building and proceeds downward so that debris and falling objects do not damage the overcladding below. The roofing replacement normally occurs toward the end of tower retrofits after the last of the mechanical and electrical work associated with the HVAC system upgrading are complete. This means that the roofing over the projecting portion of the roof will occur after the wall and balcony overcladding have been completed. This explains why in the detail and assembly sequence shown here, a corrugated metal roofing assembly with cold applied or peel-and-stick membranes was depicted. This type of roofing is more likely to minimize the potential for hot liquid spills or splatters damaging the finished overcladding below. If a different replacement roofing system was selected, it would be prudent to complete the projecting portion of the roof before proceeding with the overcladding. In this case, a temporary parapet flashing membrane could be installed until such time as the roofing replacement of the main roof area is carried out. For buildings that have recently received roofing replacements prior to the tower retrofit work, suitable details will have to be developed to tie the overcladding into the roofing assembly.

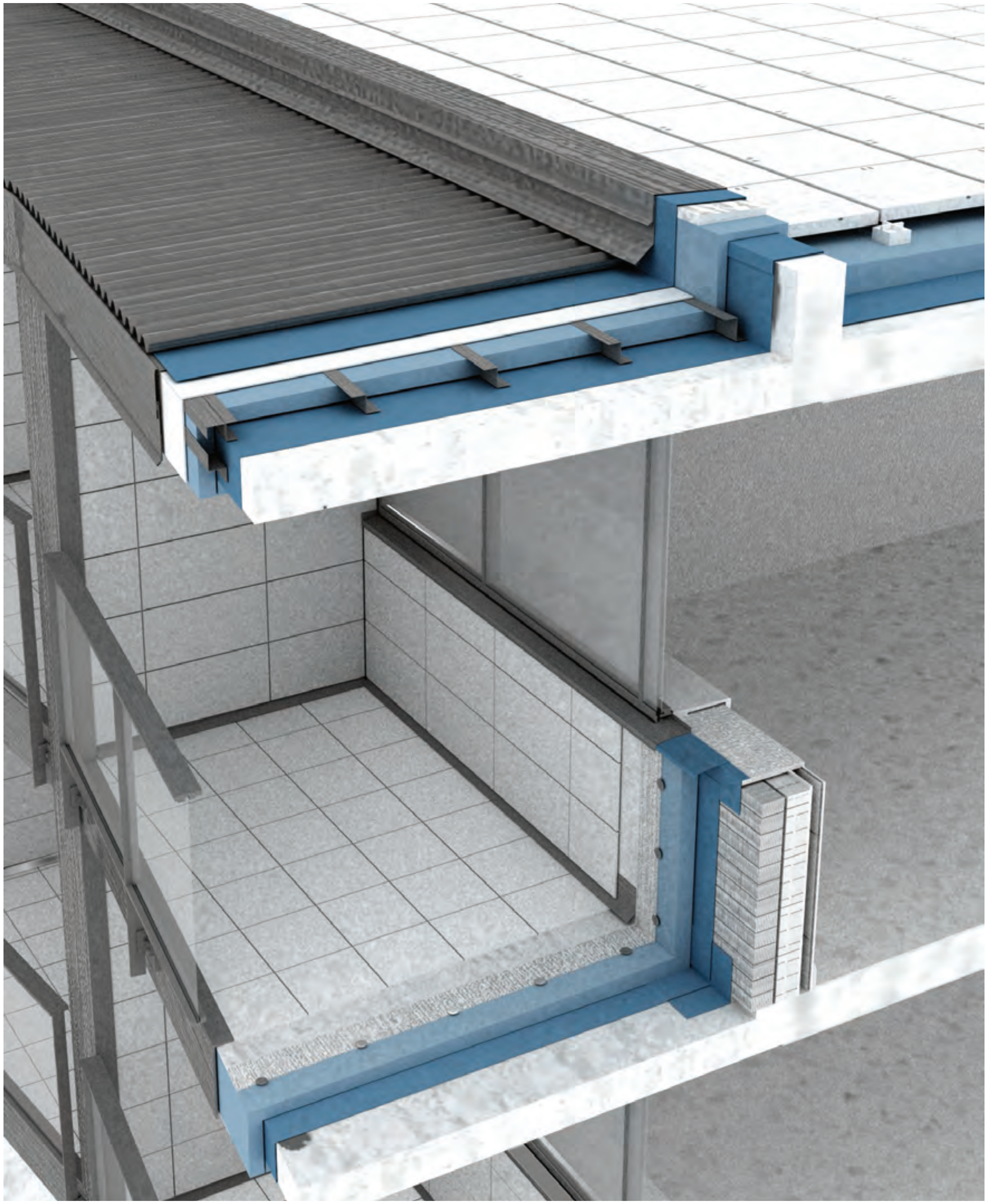
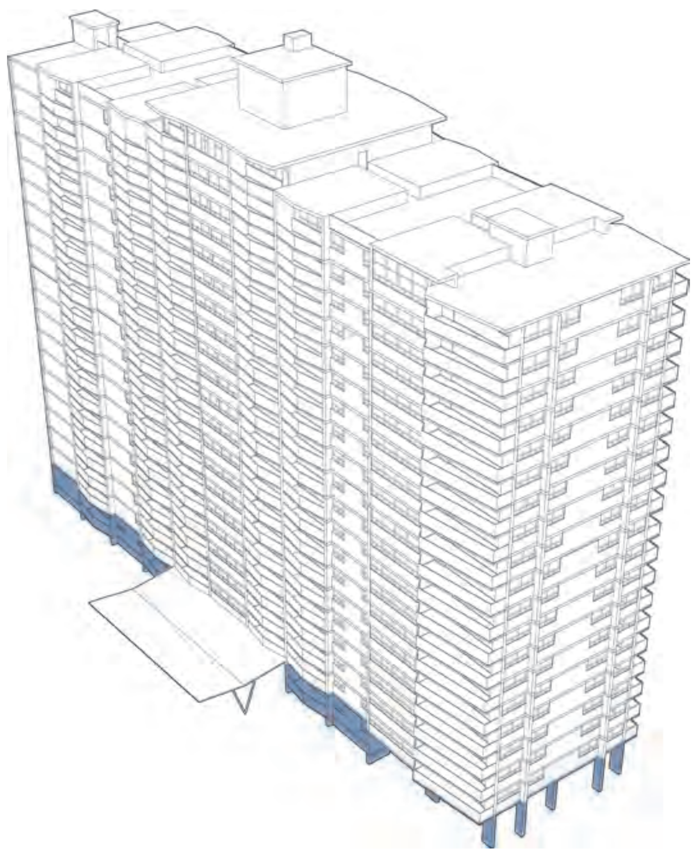


Figure A.38. Cut-away rendering of the completed roofing replacement, balcony overcladding and window replacement at the uppermost storey of the archetype tower building.

EIFS Soffit and At-Grade Overcladding

All tower buildings will have an at-grade condition, and some may have soffits under raised portions of the building as shown in the archetype tower building. EIFS systems, along with a number of other overcladding products, are not well suited to at-grade applications. Typically, the ground level of any building must be able to resist exposure to abrasion, mechanical impact, de-icing salts, soils and other organic matters, in addition to the normal exposure to the outdoor environment. This section deals with the at-grade condition and soffits. The shaded areas on the archetype tower building below represent the locations of this condition.



Differentiating at-grade overcladding from the storeys above is an architectural opportunity that holds potential for integrating the often graceful tower building entrance canopies with the at-grade overcladding. From a practical perspective, the at-grade overcladding will usually be the last stage in the overcladding process. Access to the façade at grade level permits selection of the widest range of materials since size and weight are less critical than overcladding assemblies handled by mast climbing work platforms. A primary consideration is the susceptibility of the surface finishes to absorption of pigments (graffiti) and the ease of cleaning. In all cases, pressure moderated drain screens represent the preferable at-grade overcladding strategy.

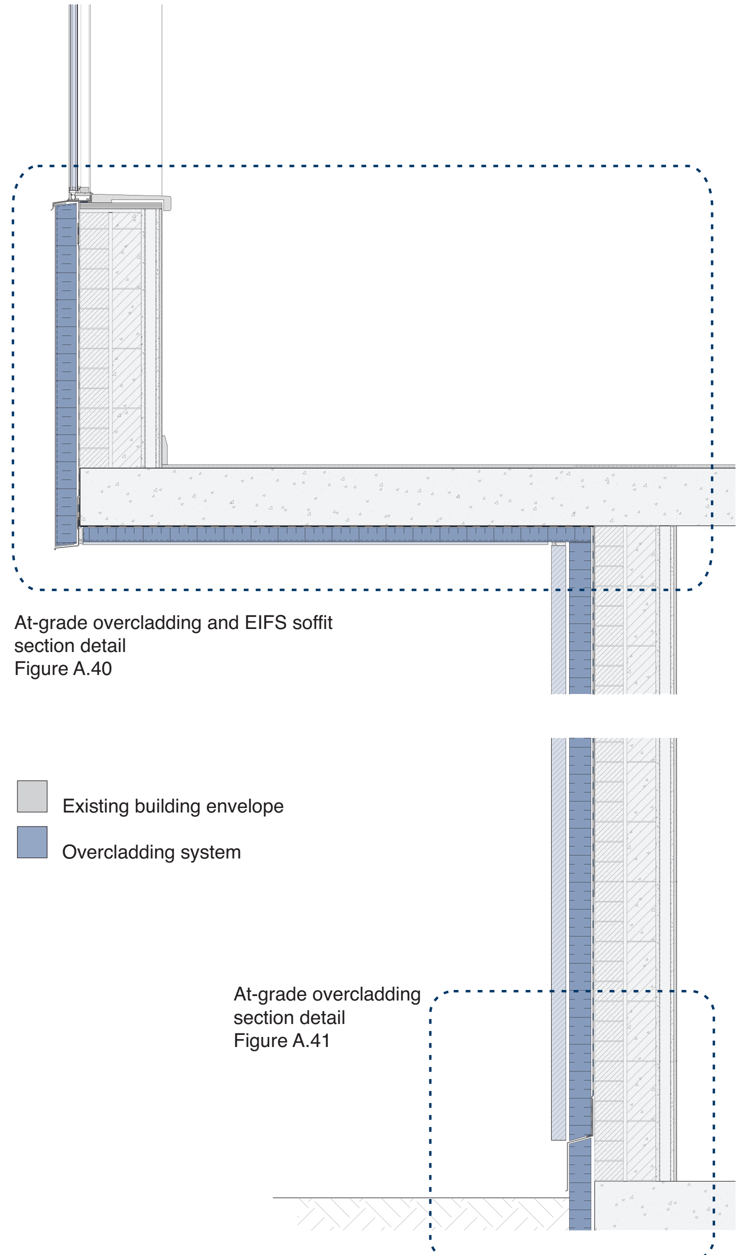


Figure A.39. Section and plan views of a roofing replacement and balcony overcladding assembly with corresponding detail drawing denoted.

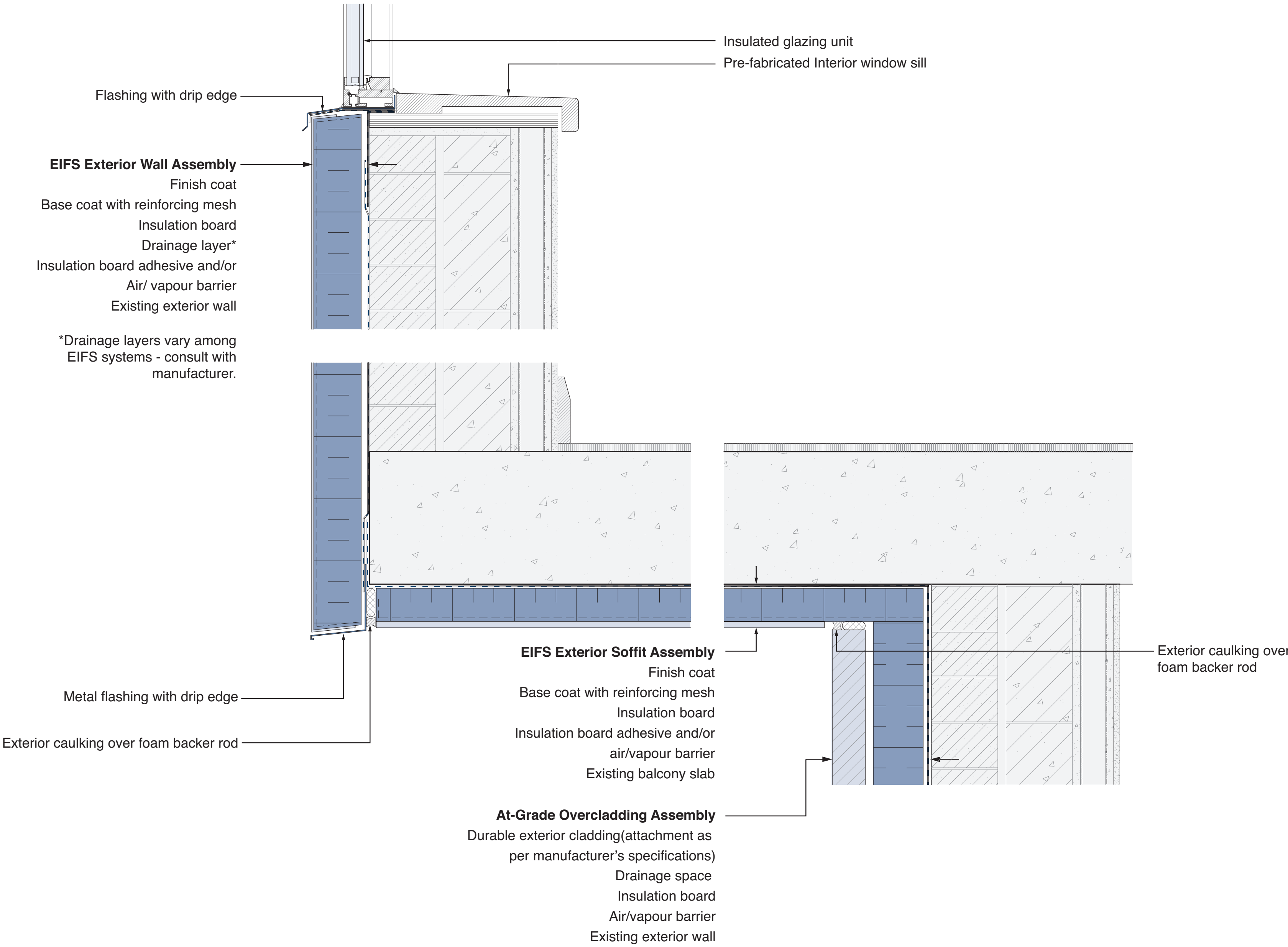
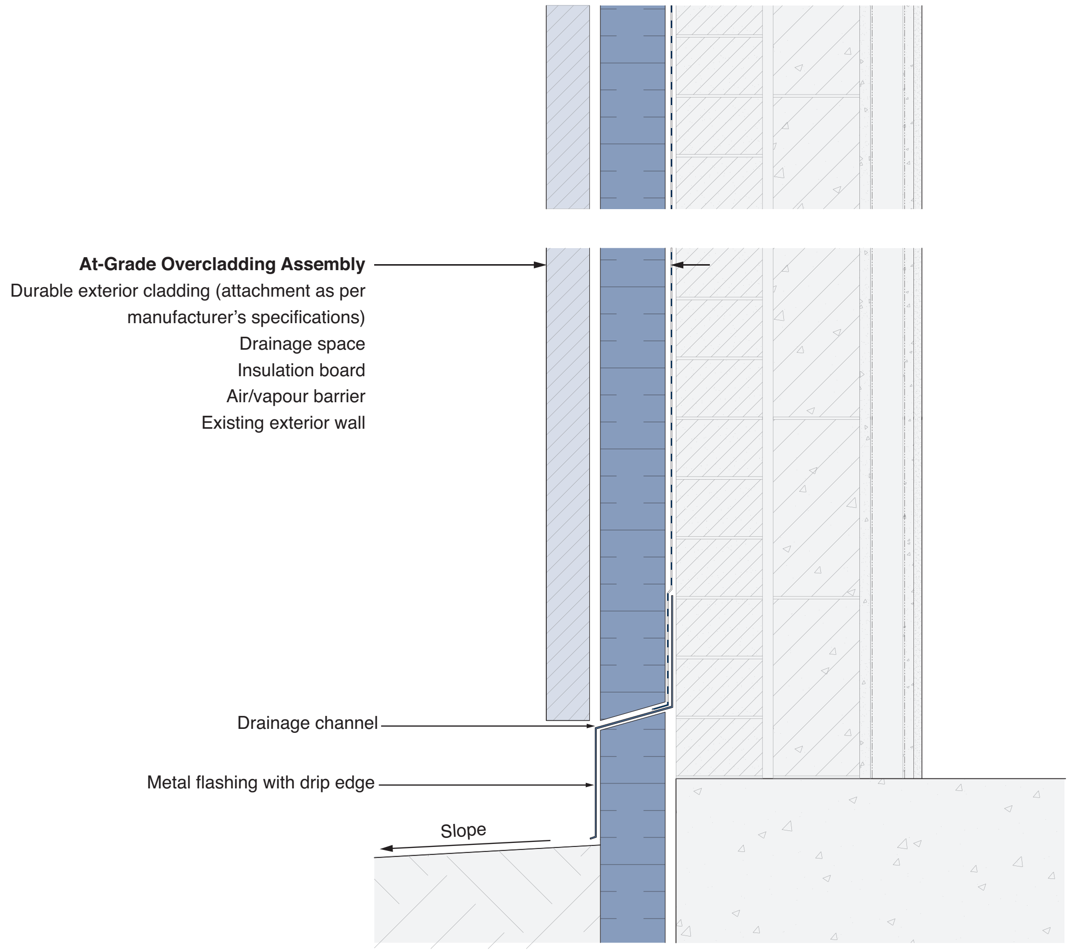


Figure A.40. The integration of EIFS wall and soffit overcladding with the at-grade overcladding is depicted above. The critical detail for the EIFS wall overcladding occurs at the intersection with the soffit. The flashing, which is required to be effective, durable and aesthetically pleasing, must be properly installed so that it is aligned with the finished EIFS surfaces.

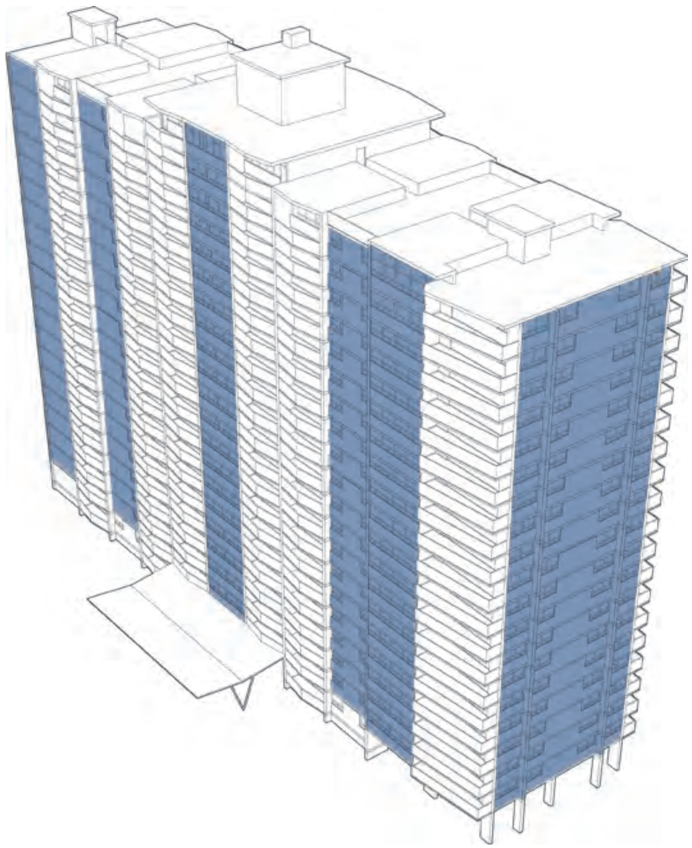


Note: Depth of insulation below grade as specified by designer. Minimum depth to provide full coverage over slab at grade.

Figure A.41. A pressure moderated drain screen overcladding is depicted above. Due to the wide range of possible overcladding systems suitable to the at-grade condition, the detailing of this overcladding with the replacement windows has not been shown. The principles presented in the earlier assembly details should be observed along with manufacturer's recommended installation requirements.

Panel System Wall Overcladding / Window Replacement

This section of details and sequence assemblies depicts the design of a panel system wall overcladding combined with window replacements for plane wall elements without balconies or projections. The shaded areas on the archetype tower building represent typical locations for these types of overcladding and window replacements.



Panel cladding systems are available in a wide variety of configurations, materials and finishes, and the technology is familiar to building envelope designers. This section focuses on critical aspects related to the overcladding of existing tower buildings. For this and all panel system overcladding sections that follow, the use of spray polyurethane foam insulation has been assumed. Typically, panel overcladding systems are mechanically fastened to the existing building envelope, hence it is important to ensure that the existing substrate is sound. Deficient and deteriorated elements must be properly repaired prior to the commencement of retrofit work. The details and assembly sequences that follow are entirely generic and intended to illustrate building science principles. Actual panel overcladding systems are proprietary and specific product applications must be coordinated with the manufacturer. Building envelope designers and cladding engineers are ultimately responsible for the proper design and specification of panel overcladding systems.

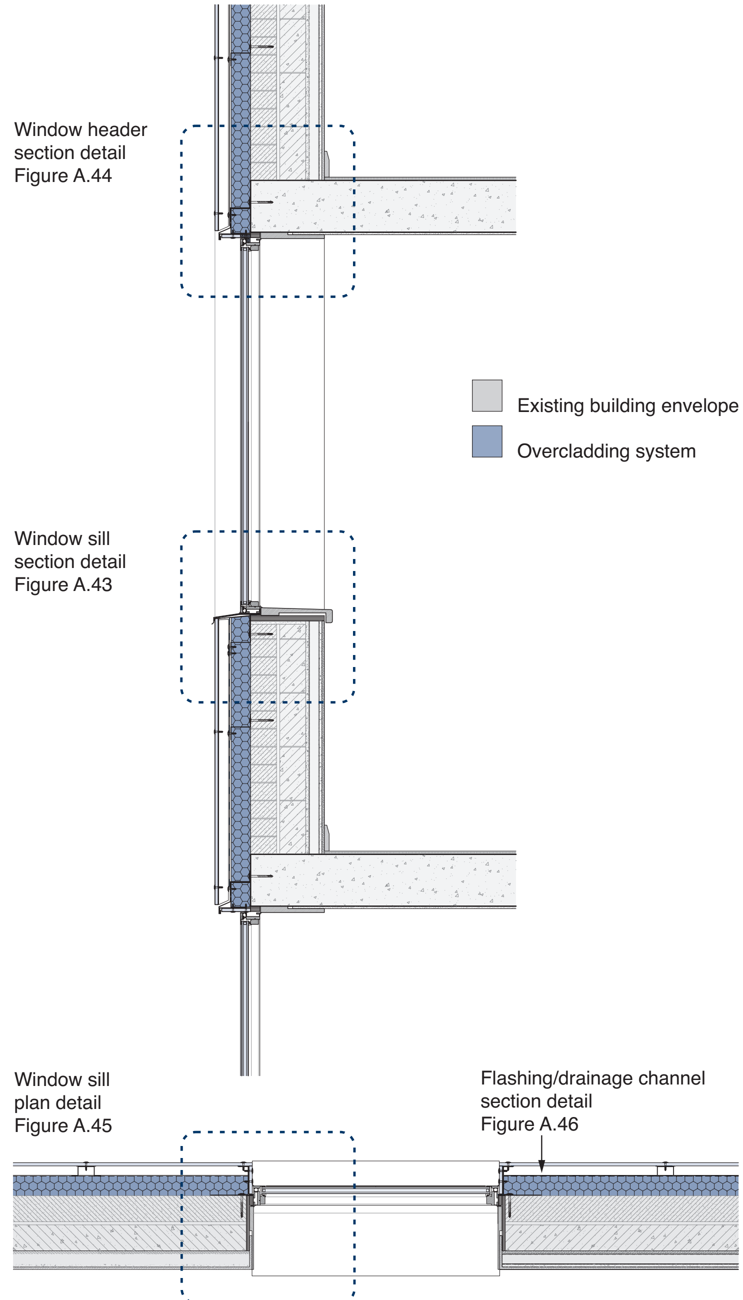


Figure A.42. Section and plan views of a typical wall and window assembly with corresponding detail drawings denoted.

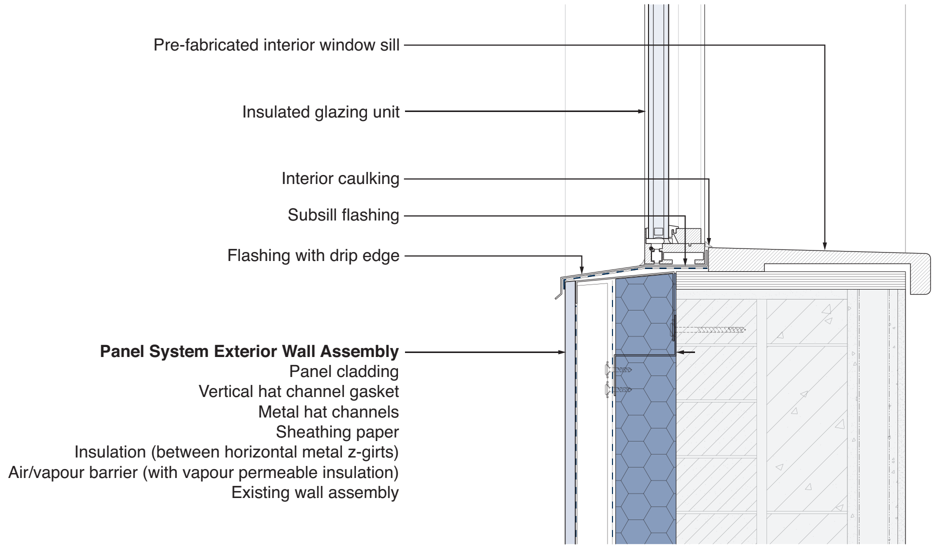


Figure A.43. Sill detail indicates critical flashing and moisture protection membranes. The pre-fabricated sill is one approach to avoid sanding and painting in the suite, and the associated time and cost of cleaning. The sill profile shown can be used with shims over the plywood blocking, or installed over an existing sill when no blocking is required.

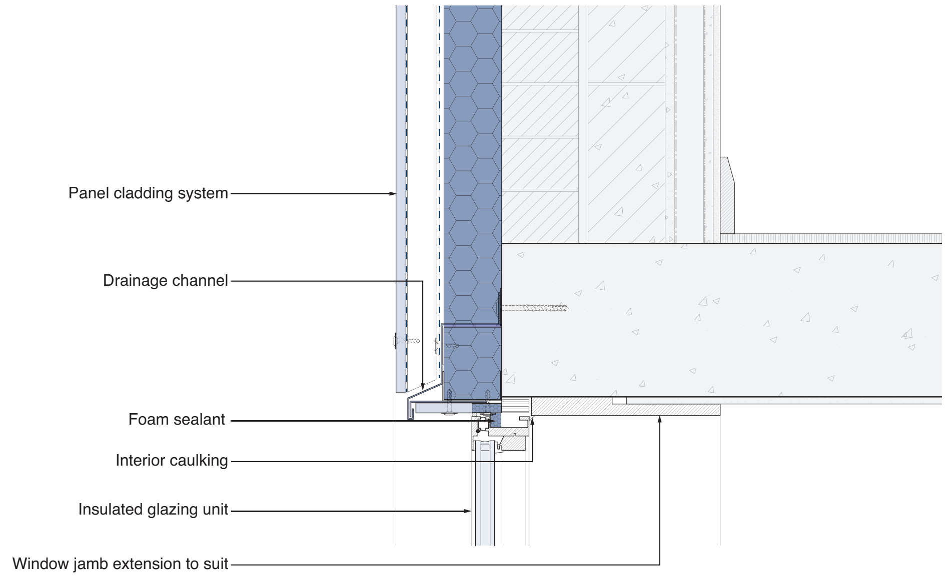
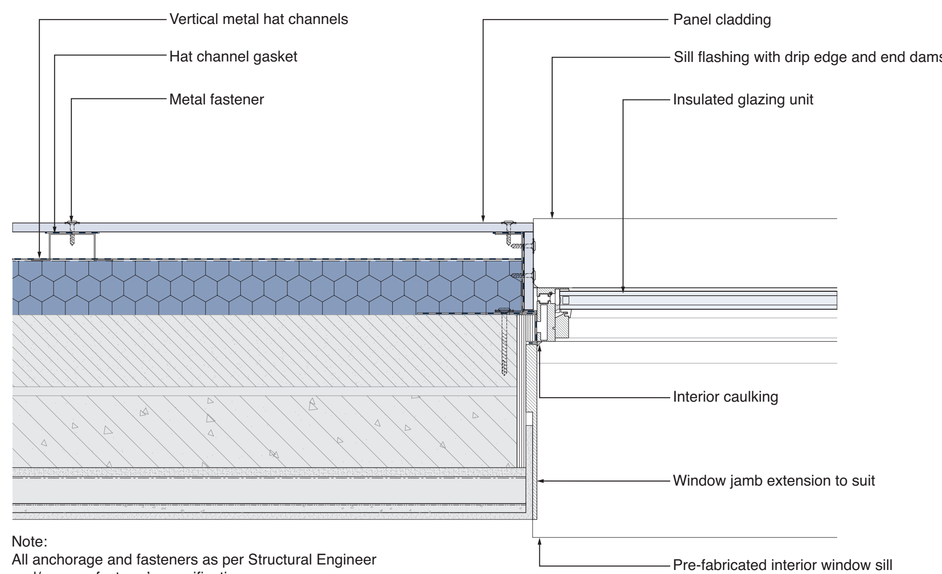


Figure A.44. Replacement window header detail indicating the use of flashing to convey potential moisture penetration during extreme weather phenomena outboard of the wall and window assembly. Note the use of the foam sealant around the window prior to installation of the window jamb extension.

IMPORTANT NOTE – Type of Insulation: Panel overcladding systems employ a range of insulation materials. For non-combustible cladding applications, a mineral fibre insulation board is commonly combined with non-combustible cladding panels, fasteners and girts/furring channels. For conventional overcladding applications, there is an increasing use of medium density, closed cell, spray polyurethane foam (SPF). The critical difference between the two types of insulation is their vapour permeability. For vapour permeable insulation materials, such as mineral fibre wool, an air/vapour barrier membrane or coating is required over the exterior surface of existing building envelope prior to installation of the insulation. For low vapour permeable insulation, such as spray polyurethane foam, the vapour barrier function is provided by the insulation. Properly detailed and applied, the spray foam insulation can also serve as the air barrier system, but depending on the retrofit details, it may have to be combined with other air/vapour barrier materials around breaches and transitions in the building envelope. In these guidelines, the use of air/vapour barrier membranes and coatings in these areas is recommended as a better practice when spray polyurethane foam is employed, so that a more durable and effective interface is provided between envelope elements and the SPF insulation. This is consistent with the durability provided by air/vapour barrier systems used for vapour permeable insulation applications.

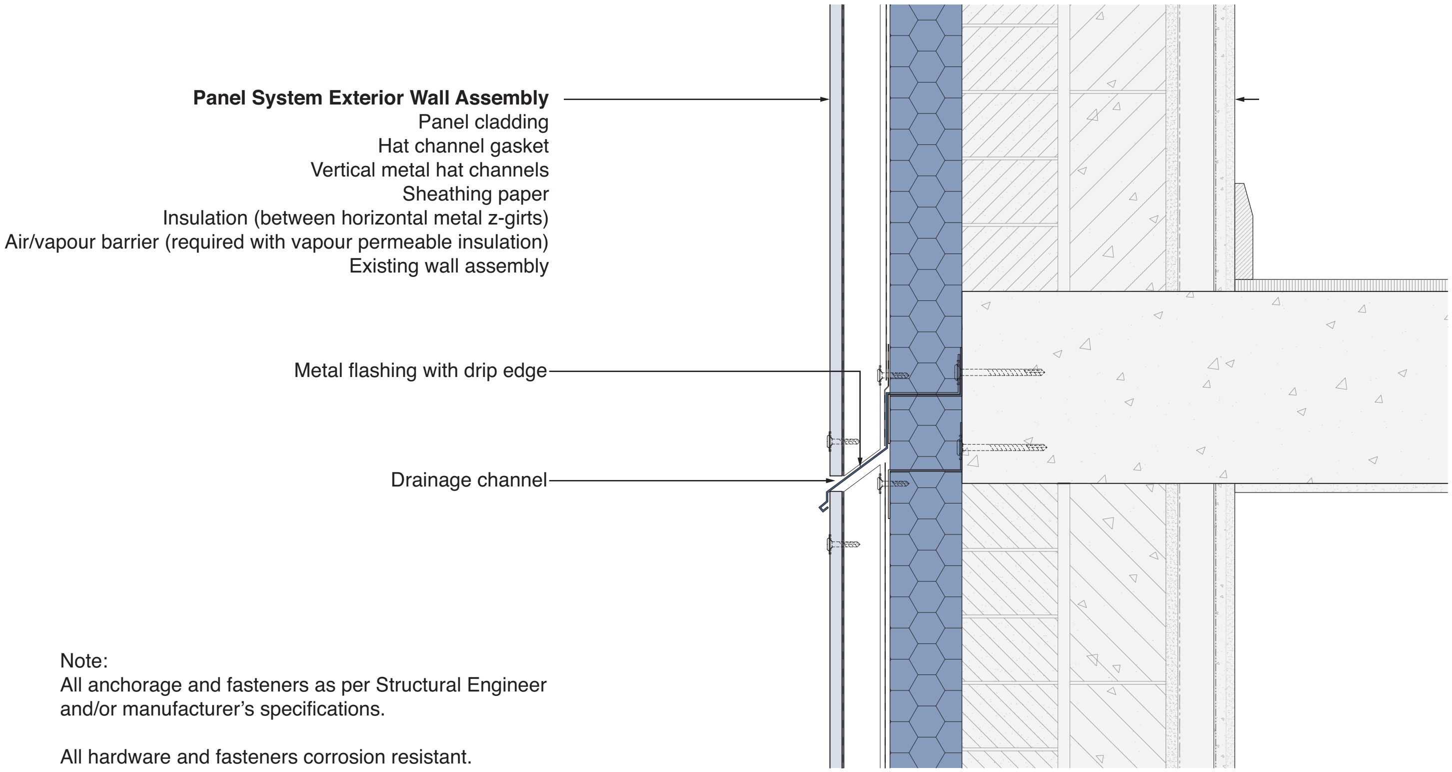
Window Alignment: Replacement windows must be correctly aligned with exterior insulation such that the thermal break in the window frame is adjacent to the warm side of the insulation as depicted in the figures on this page. This better practice improves thermal efficiency and reduces condensation potential.



Note:
All anchorage and fasteners as per Structural Engineer and/or manufacturer's specifications.

All hardware and fasteners corrosion resistant.

Figure A.45. Pre-finished window jamb extensions complement the pre-fabricated window sill to facilitate interior finishing of the retrofit window opening within a single visit, minimizing tenant disruption.



Note:
All anchorage and fasteners as per Structural Engineer and/or manufacturer's specifications.

All hardware and fasteners corrosion resistant.

Figure A.46. The use of flashings leading to drainage channels every several storeys is advisable to effectively manage water penetration in pressure moderated, drain screen overcladding systems. For continuous wall surfaces on tall buildings, the air space behind the panel cladding near the bottom of the building may not be able to convey the cumulative water penetration during extreme weather phenomena. Flashings may impact panel cladding aesthetics by creating straight horizontal joints that run continuously across the building façade.

Panel System Wall Overcladding / Window Replacement Sequence

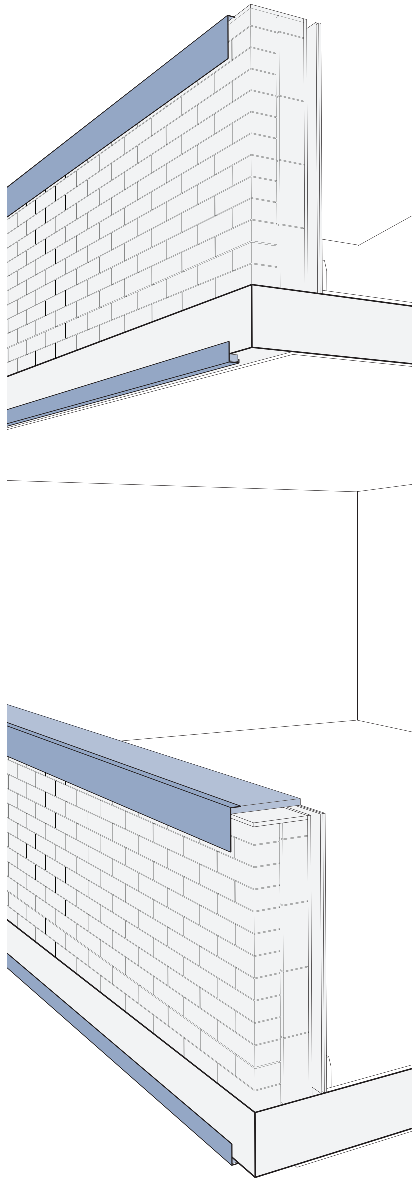


Figure A.47. The process of panel system wall overcladding and window replacement begins with the removal of the existing window(s). The existing rough opening has blocking installed on the window sill, followed by the placement of air/vapour barrier membranes that will subsequently overlap and tie into the air/vapour barrier system. Normally, this process begins at the top of the building and proceeds downwards so that debris and falling objects do not damage the newly installed components below. Note that the backing on the air/vapour barrier strips is retained until these later overlap and tie into the wall air/vapour barrier, unless a spray polyurethane foam insulation is employed.

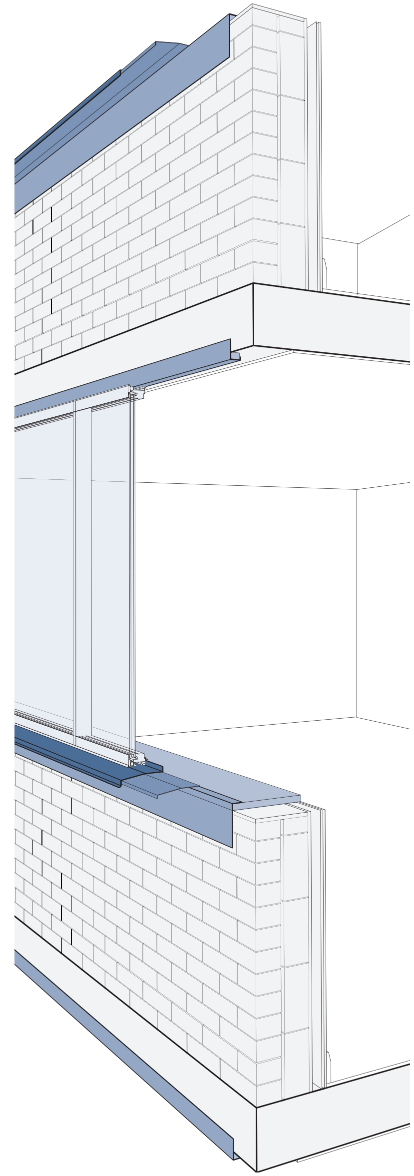


Figure A.48. The replacement window is installed along with the end dam and subsill flashing. The removal and replacement of the window(s) must be scheduled so as to be completed in a single day to avoid exposure of the suite to the elements and minimize disturbance to the inhabitants. Interior finishing of the rough opening can be scheduled at a later time, ideally to be completed within a single visit at a convenient time for the inhabitants.

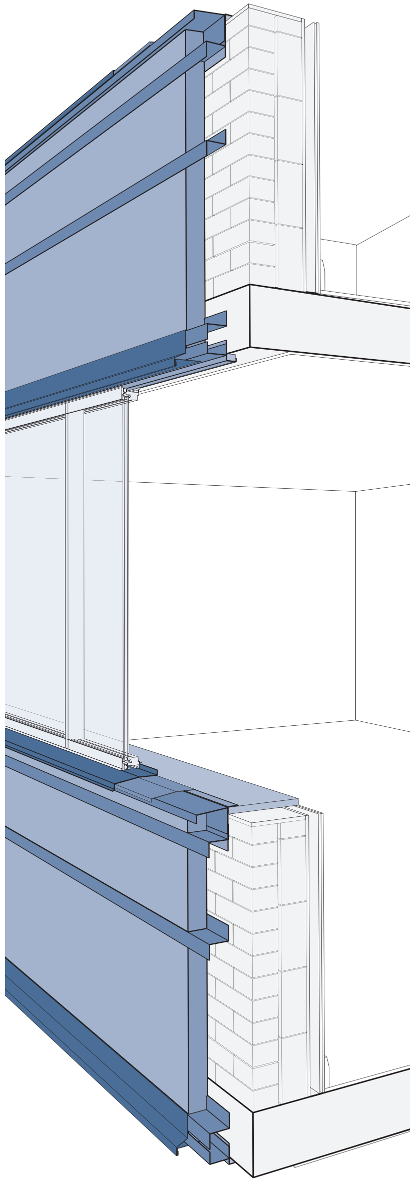


Figure A.49. With window replacement complete, the panel overcladding system application commences. Depending on the type of insulation employed, there are commonly two options. For vapour permeable insulation, an air/vapour barrier membrane or coating must be applied over the existing envelope prior to installation of the insulation. Alternatively, spray polyurethane foam insulation may be applied (shown here) to provide the air/vapour barrier function. The air/vapour barrier membranes installed prior to window installation must be properly tied into the wall air/vapour barrier. Continuity and compatibility of the air/vapour barrier system components are essential to long term durability.

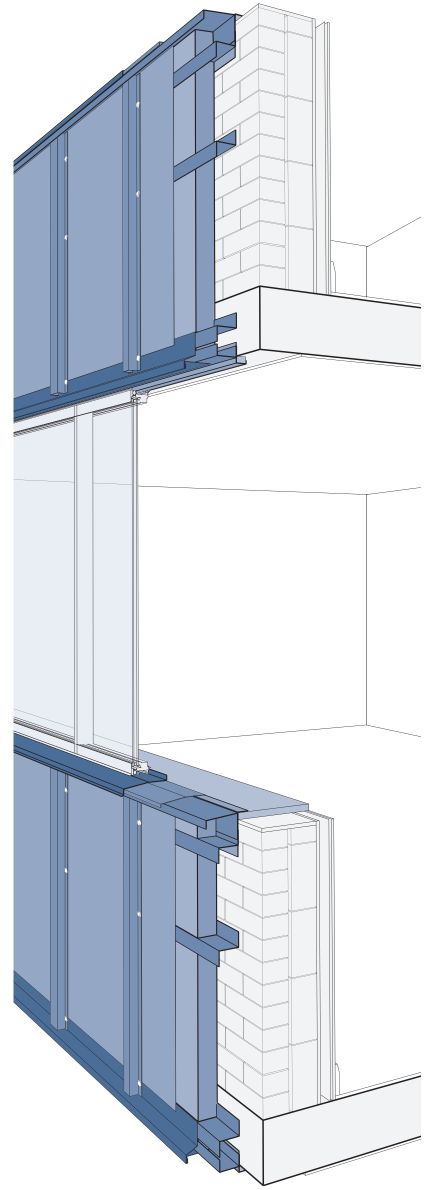


Figure A.50. A sheathing paper is applied over the insulation and horizontal z-girts to serve as a drainage plane in the cavity behind the panel cladding. Joints in the sheathing paper should be lapped and taped, ideally located behind the vertical hat channels that are fastened over top.

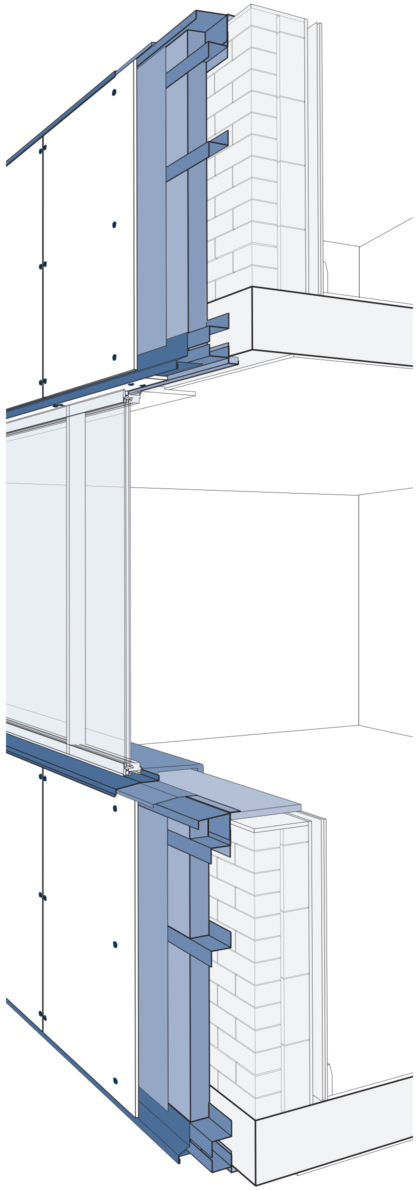


Figure A.51. Gaskets are applied over the vertical hat channels prior to the installation of the cladding panels. The panels are subsequently fastened according to the manufacturer's installation instructions and as approved by the cladding engineer for resistance to wind loads.

IMPORTANT NOTE – Sheathing Paper Over SPF Insulation: The use of sheathing paper over spray polyurethane foam insulation, when it forms a part of an open face, pressure moderated, drain screen panel cladding system, is considered a better practice that is highly recommended. In addition to forming a smooth drainage plane, the sheathing paper also protects the SPF insulation from ultraviolet degradation during construction. The application of SPF is imperfect as with any material, and often cracking of the insulation after curing may occur. The surface of the sprayed insulation is often not smooth and particulates in the wind and rain will eventually plaque over this surface and accumulate. Given that these guidelines advocate a 50-year service life for the overcladding system, the use of sheathing paper is seen as an economical preventive measure for long term performance and durability.

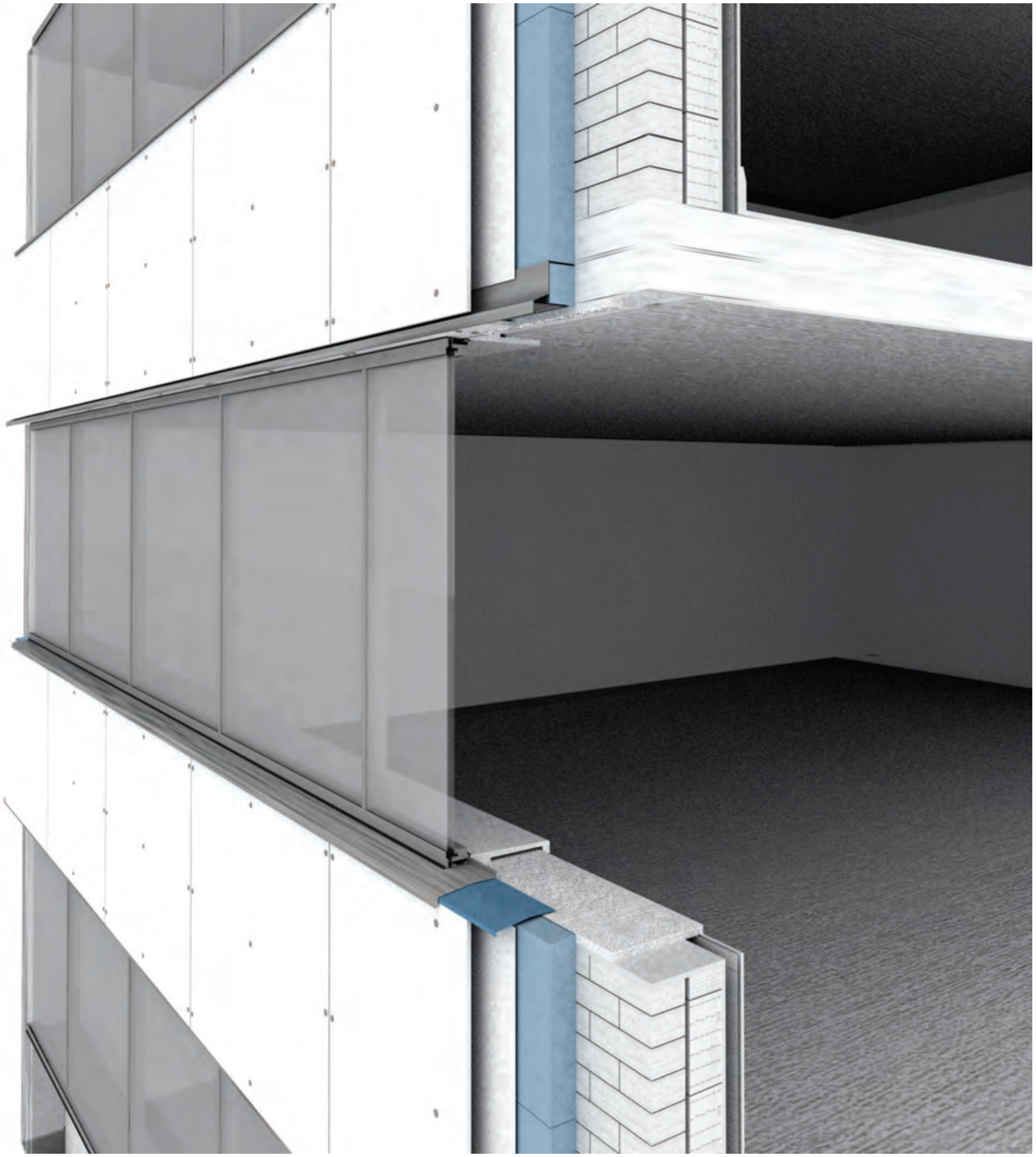
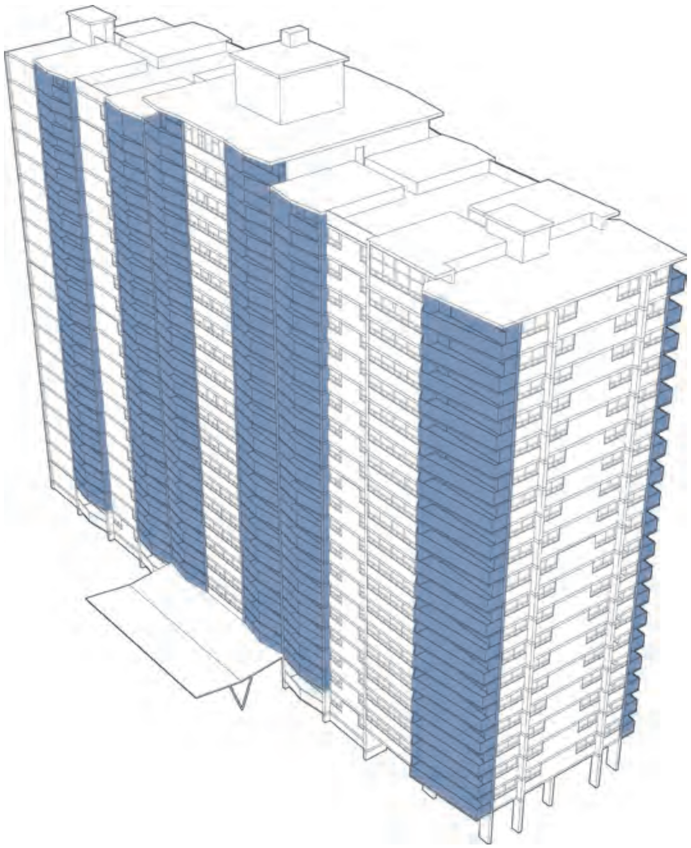


Figure A.52. Cutaway rendering of the completed panel overcladding system and window replacement. Note that the air/vapour membrane strips used to tie in the window assembly to the wall air/vapour barrier are not depicted. in this rendering the existing sill has been removed and replaced with blocking (sub sill). The pre-fabricated sill profile is also adaptable and may be installed over the existing window sill if it is retained.

Panel System Balcony Overcladding

Balcony overcladding, as it is presented in this section, presents one of two alternatives to addressing projecting concrete balcony slabs. Figure A.53 indicates a complete encapsulation of the balcony slab that is integrated with the wall overcladding and window replacement. Alternatively, the balcony may be enclosed with insulated panels and glazing, an approach that is presented in the section that follows. The shaded areas on the archetype tower building below represent typical locations for panel system balcony overcladding.



Balcony overcladding is a preferred strategy if there is a need or desire to keep the balcony space open to the outdoors. As discussed in ***7. Tower Retrofit Strategies: A Systems Approach***, there may be cases where limiting distance requirements for fire safety do not practically permit the enclosure of balconies. That is, they may be enclosed, but the proportion of glazing (unprotected openings) permitted may be insufficient for daylighting and natural ventilation purposes. There may also be cases where unenclosed balconies are preferred for the sake of aesthetics and quality of life reasons. In the former case, a non-combustible panel cladding assembly will be required (not shown here) where typically the spray foam insulation is replaced with mineral fibre board stock. The cladding panels, fasteners, girts and furring channels are also non-combustible for this type of application. Conventional panel system applications to balcony overcladding are presented here.

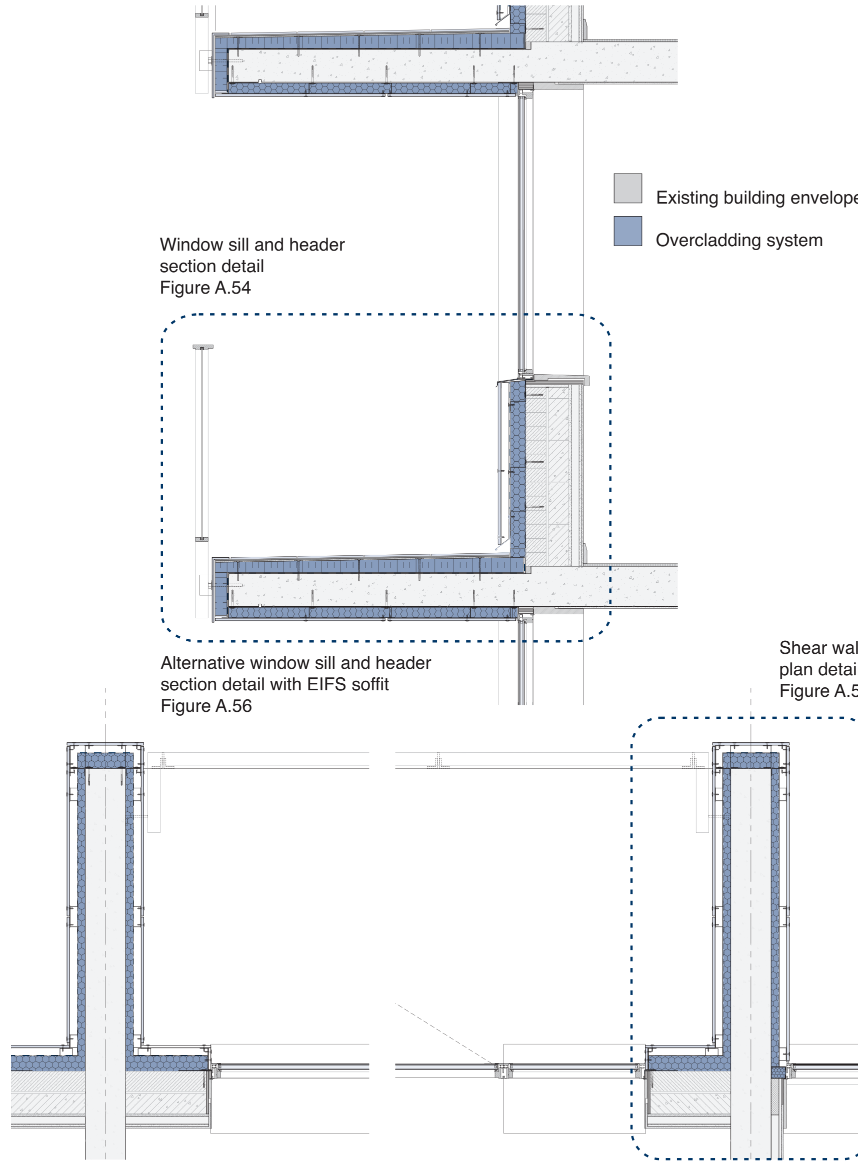


Figure A.53. Section and plan views of a balcony overcladding assembly with corresponding detail drawings denoted.

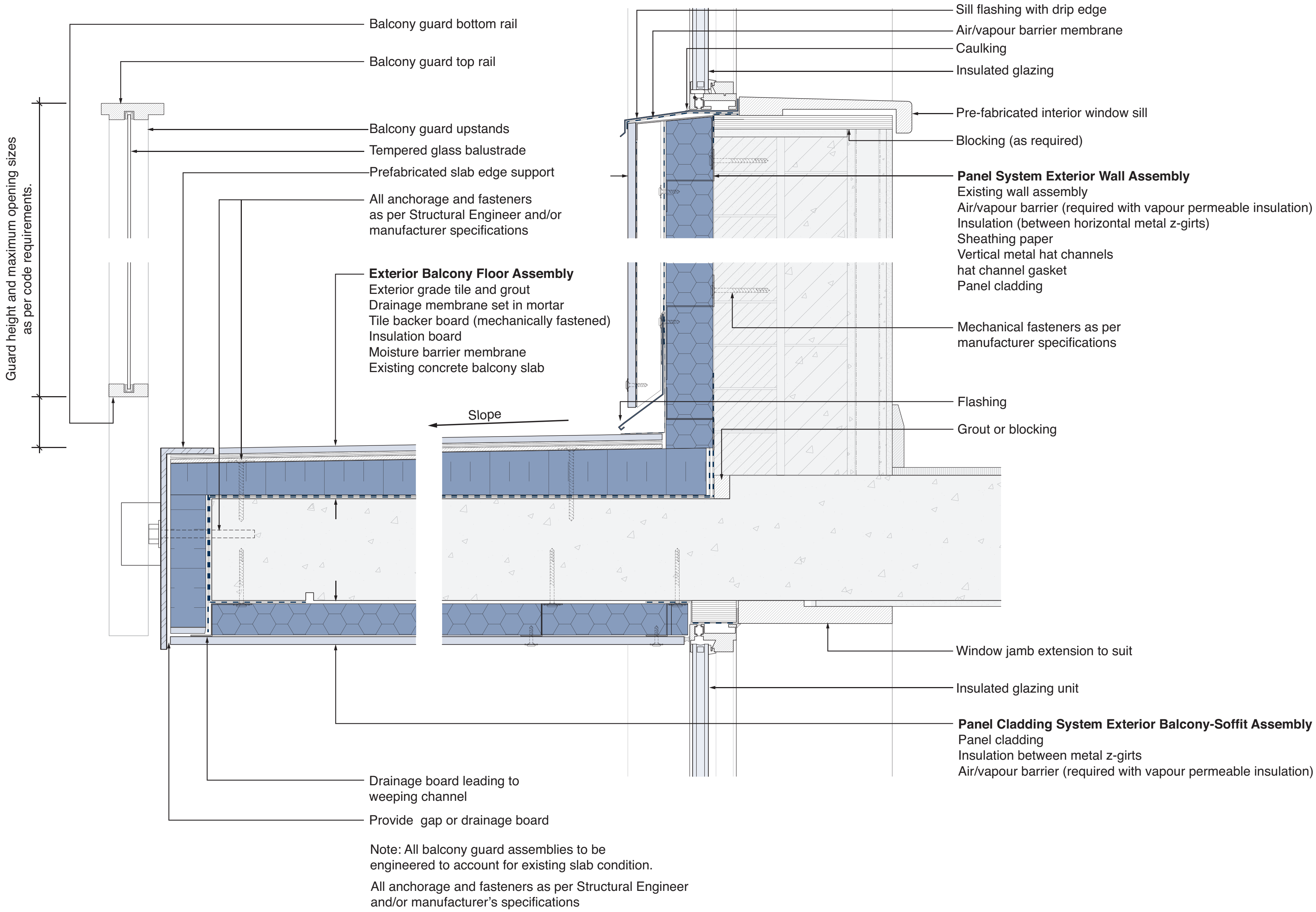


Figure A.54. Section through balcony slab overcladding indicates the use of a tile product as an exterior floor finish and traffic surface. Multiple lines of defence against moisture migration are essential for long term durability. The thermal resistance of the insulation material for the slab edge and floor areas should not decrease appreciably under wet conditions. All materials should be corrosion resistant and capable of withstanding freeze–thaw cycles. Alternative products and assemblies providing equivalent wear resistance and durability may be substituted for the floor tile cladding assembly. The wall and balcony soffit have been overclad with a panel system.

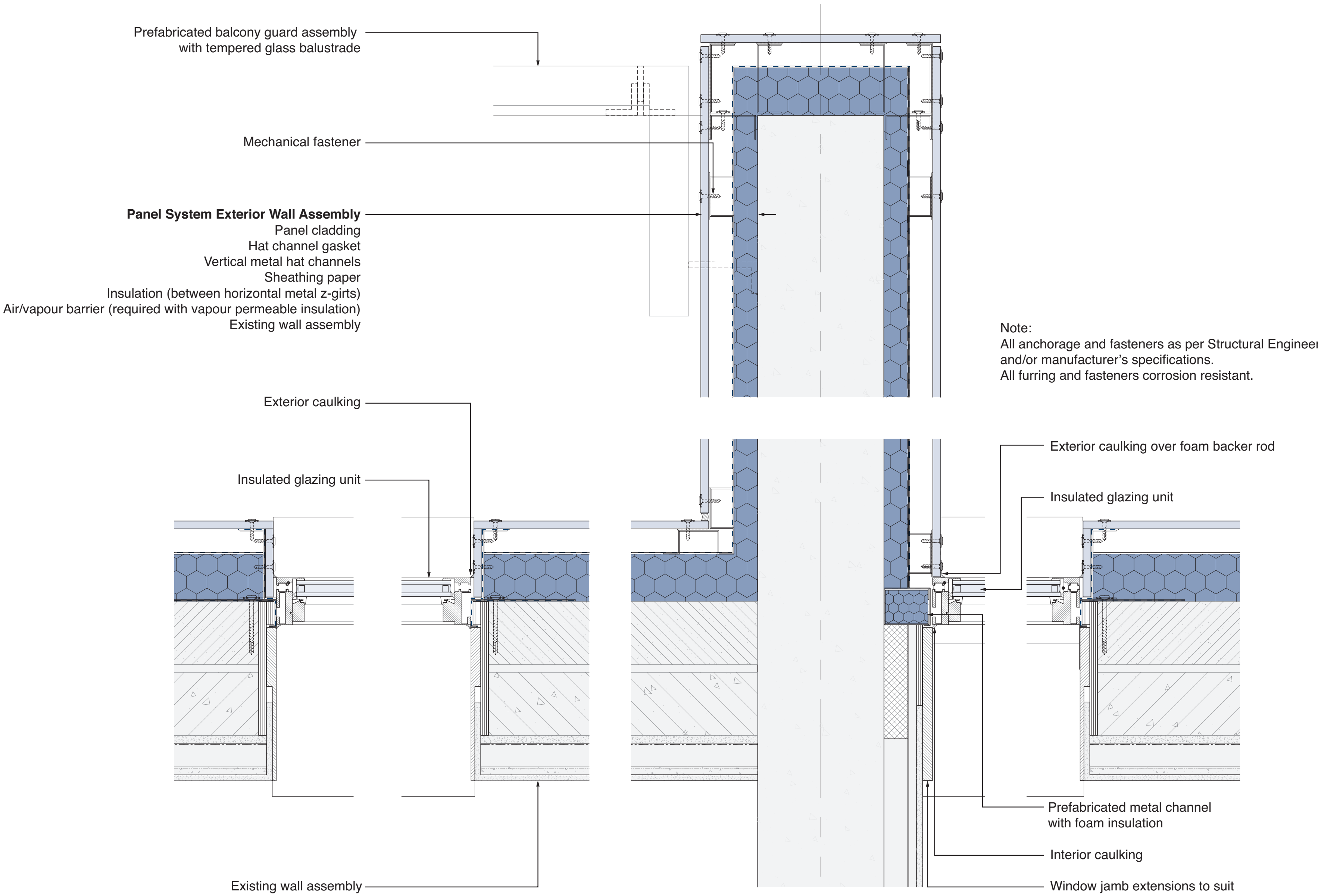


Figure A.55. This plan detail depicts the panel overcladding of the projecting shear walls. Panel overcladding systems are well suited to the integration of building services located in the air space immediately behind the cladding panels. Two replacement window conditions are depicted. The conventional punched window appears on the left, while the window that originally abutted the shear wall appears on the right. It requires additional blocking or an adjustable bracket/channel to properly align and attach the window frame at this location. Foam sealant of the breaching to fill voids between the window and the rough opening is recommended.

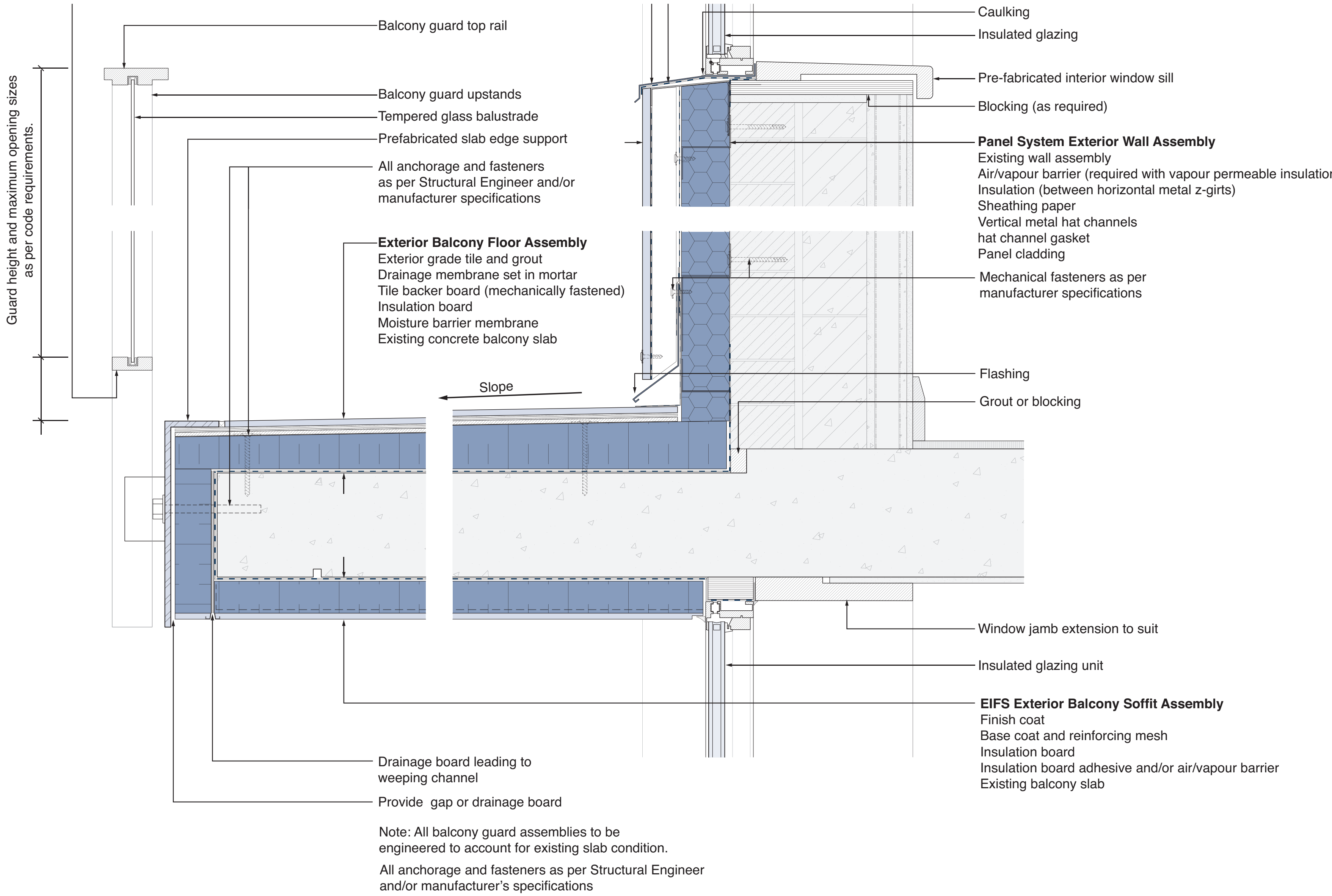


Figure A.56. The use of an EIFS soffit finish is shown as an alternative to the panel overcladding system depicted in Figure 54.

Panel System Balcony Overcladding / Window Replacement Sequence

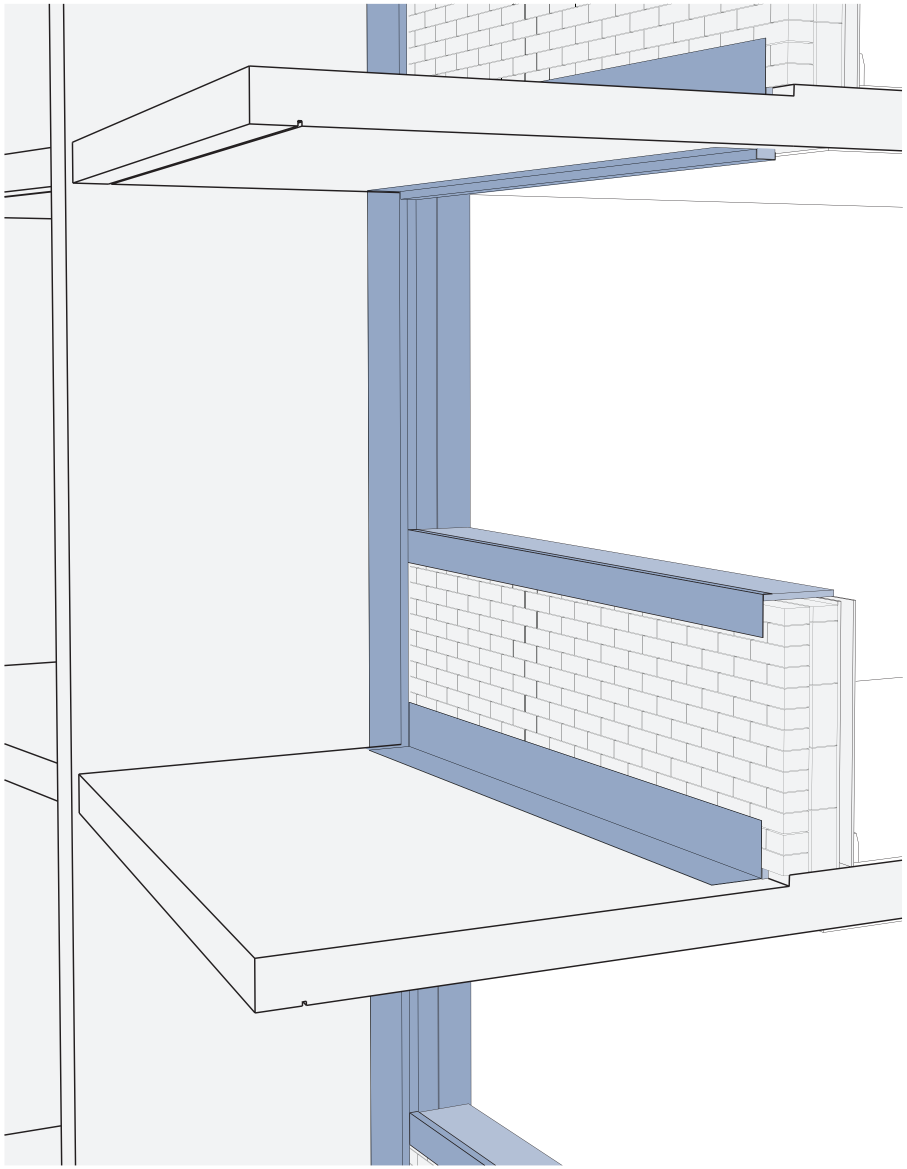


Figure A.57. Similar to the previous sequence for the regular wall elements, the existing rough opening has blocking installed on the window sill, followed by the placement of air/vapour barrier membrane strips. A strip is also placed over the length of the shear wall/balcony wall intersection. Note that the backing on the air/vapour barrier strips is retained until these later overlap and tie into the wall air/vapour barrier when a vapour permeable insulation is employed. The strips may be adhered to the existing envelope when spray foam insulation is being applied.

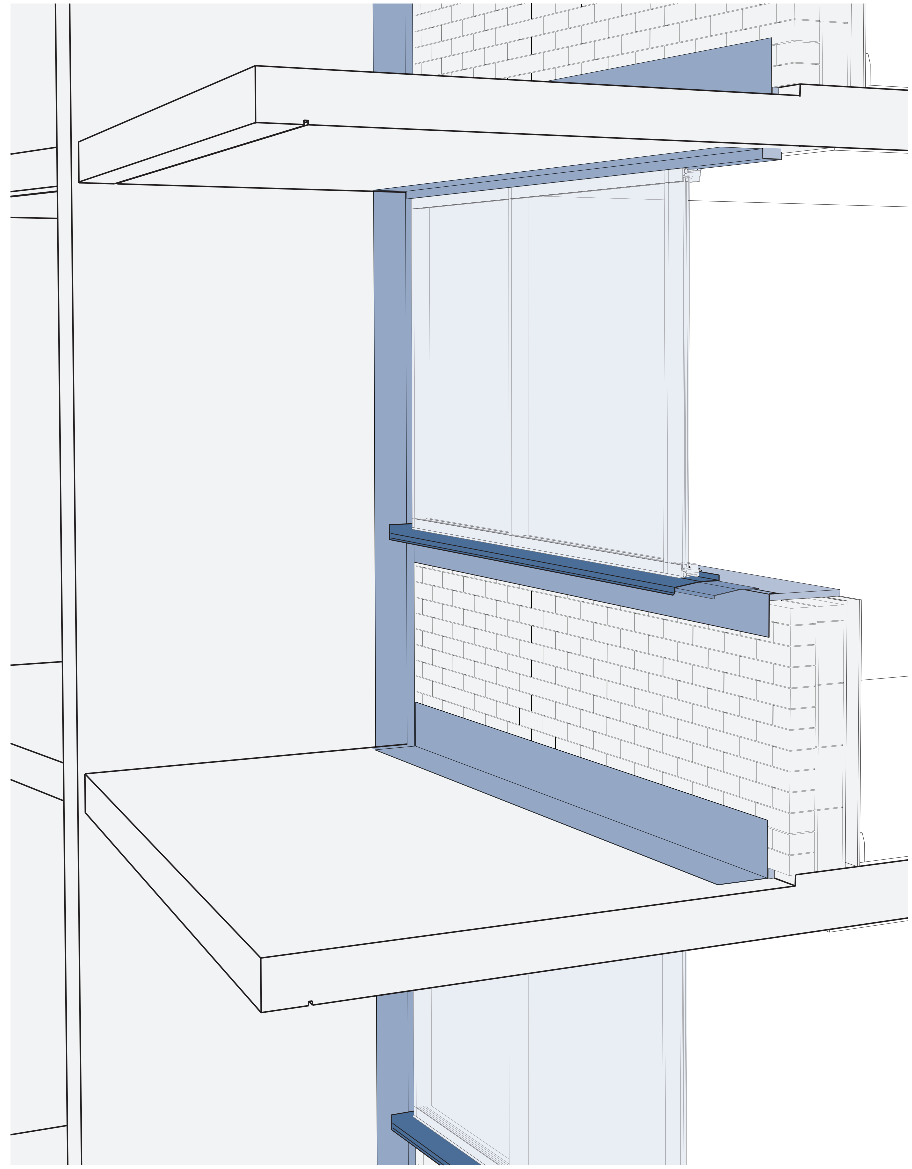


Figure A.58. The replacement window is installed along with the end dam and subsill flashing. The removal and replacement of the window(s) must be scheduled so as to be completed in a single day to avoid exposure of the suite to the elements and minimize disturbance to the inhabitants. Interior finishing of the rough opening can be scheduled at a later time, ideally to be completed within a single visit at a convenient time.

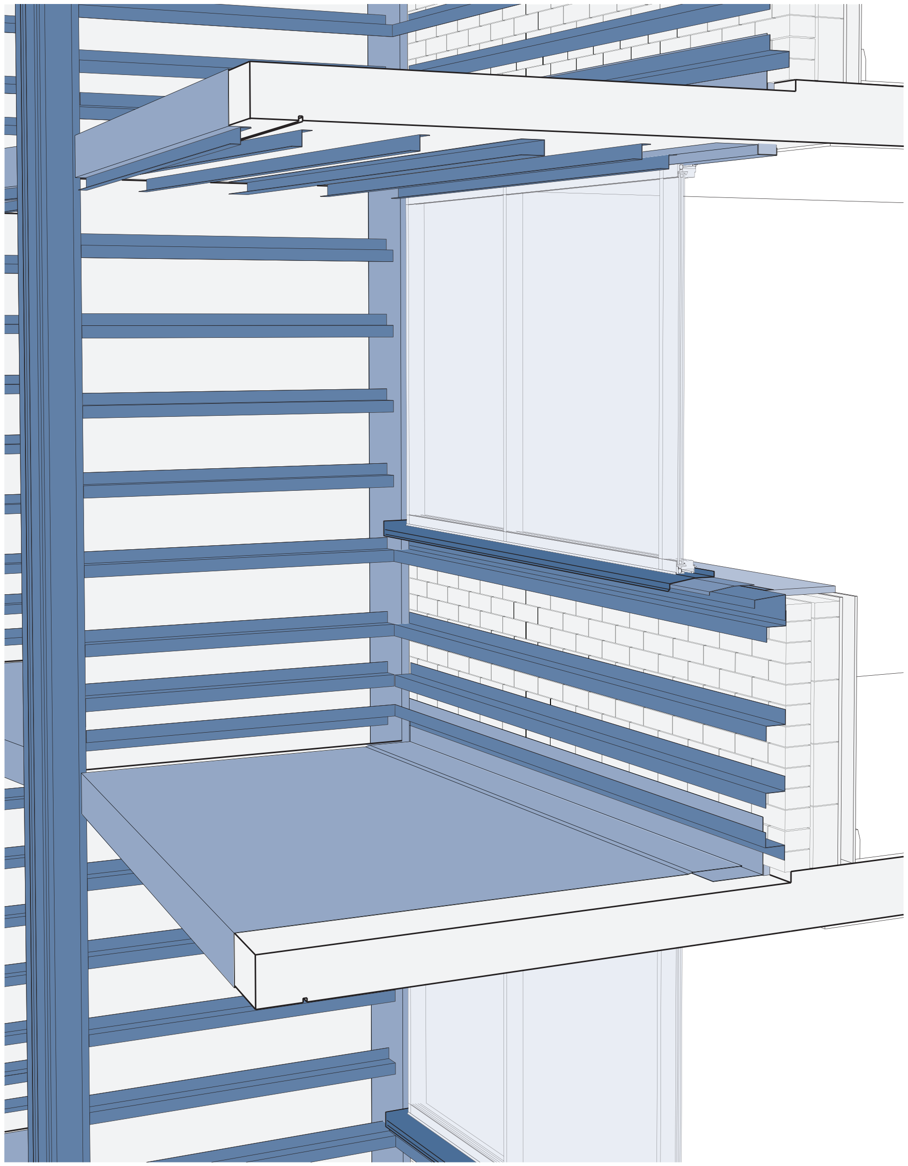


Figure A.59. An air/vapour barrier membrane or coating is applied over the entire exposed surfaces of the balcony slab. Horizontal z-girts are mechanically fastened to the existing envelope elements. The remaining surfaces will have spray polyurethane foam applied to serve as the insulation and air/vapour barrier system.

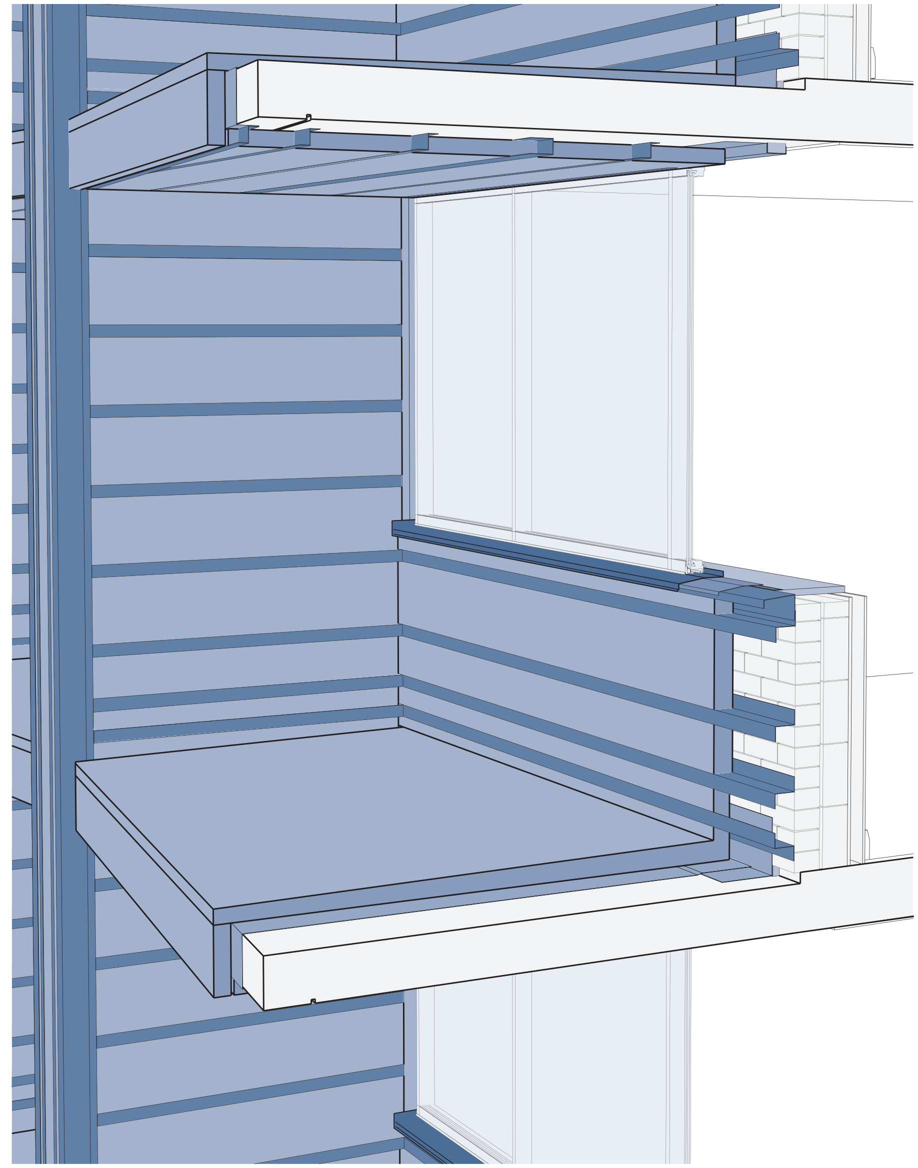


Figure A.60. Exterior insulation is subsequently installed over the entire exposed surface areas of the balcony slab, balcony wall and shear wall. Incompressible board stock insulation has been assumed over the top and edge of the balcony slab. The remaining areas have spray polyurethane foam insulation applied continuously.

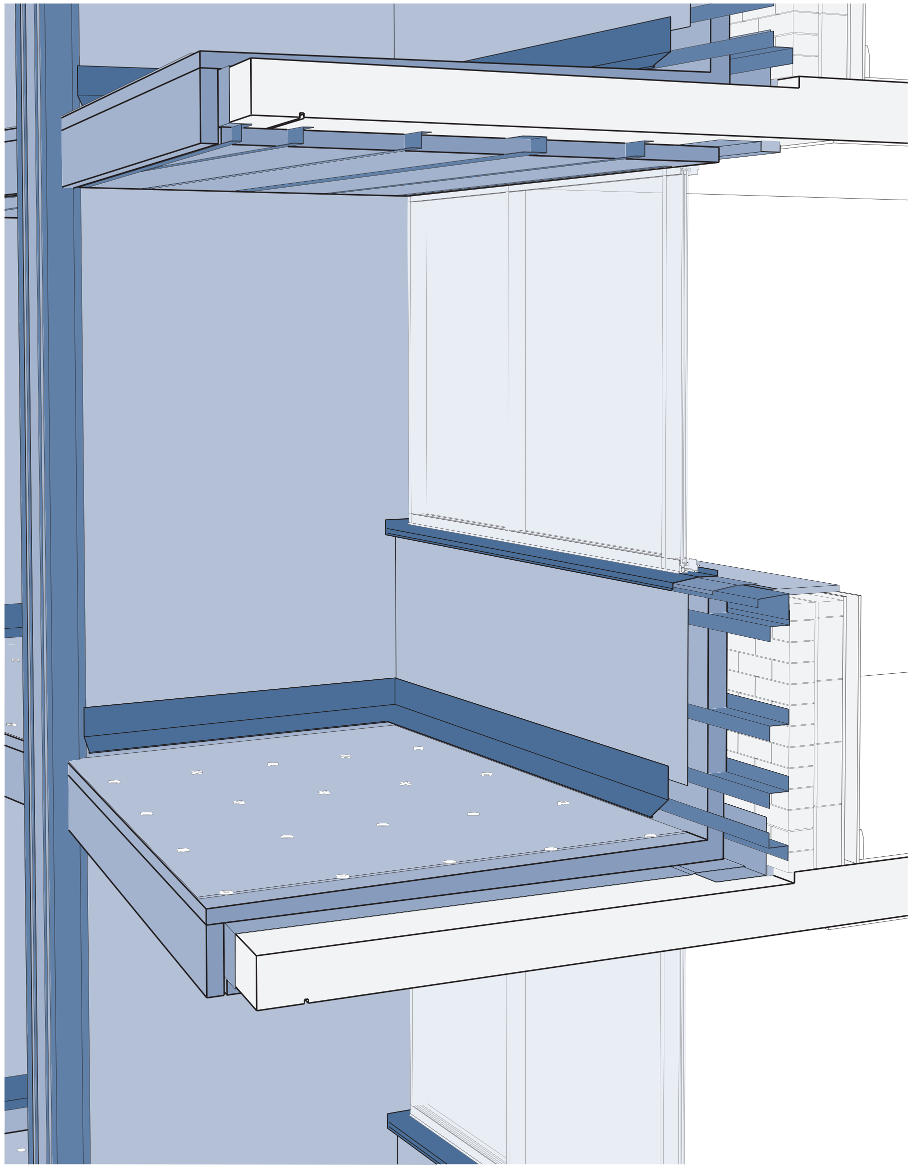


Figure A.61. Fibre-reinforced cement board is mechanically fastened in all areas receiving tile surfacing. The type and number of fasteners for this application must be properly specified. Sheathing paper is applied over the wall elements, followed by a base flashing. If the vertical leg of the base flashing is sufficiently high, it is not necessary to lap the sheathing paper over the flashing, as depicted above. Otherwise, lapping is recommended.

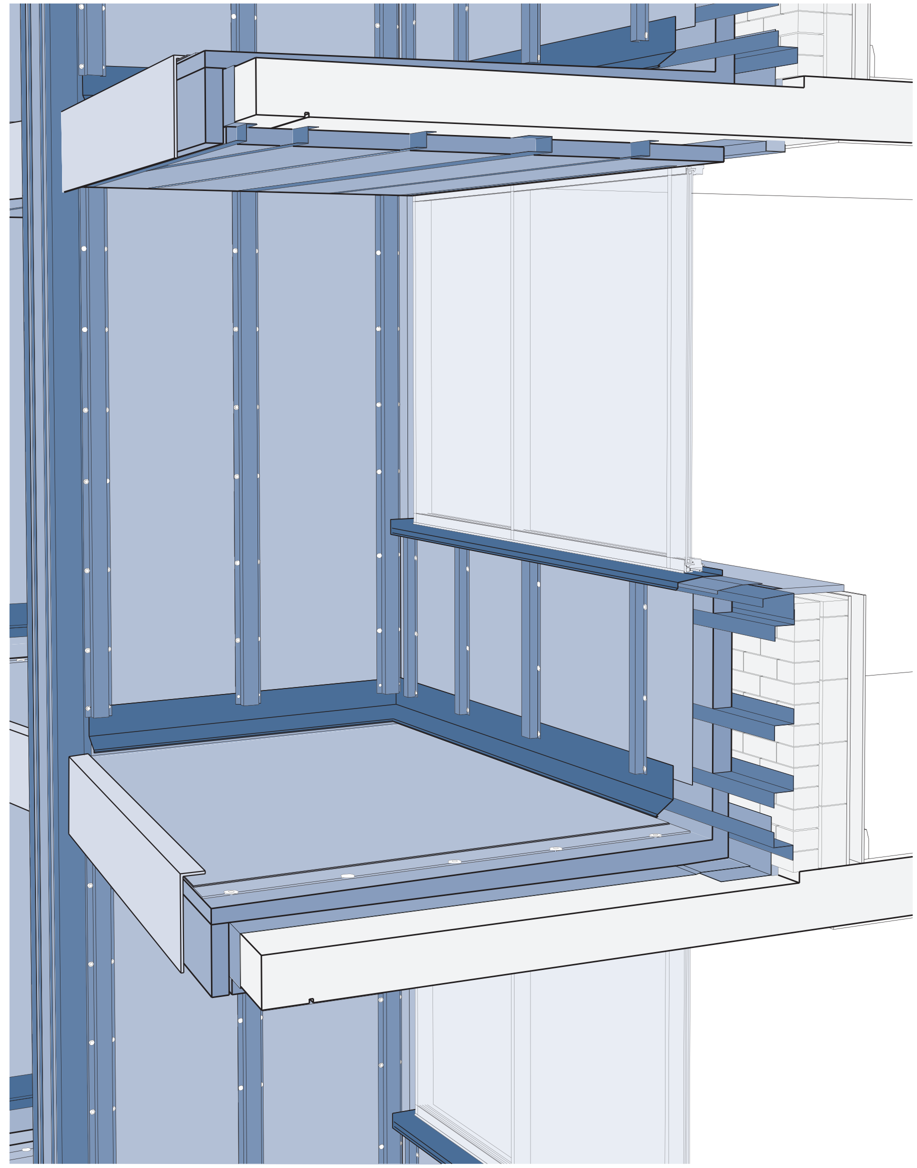


Figure A.62. A drainage membrane is applied over the cement board surfaces. A dimpled plastic sheet material is commonly used for this purpose, and is adhered to the cement board with proper overlap between sheets and over the base flashing. A slab edge support for the guard is installed prior to the setting of the tile finish. Vertical hat channels are mechanically fastened to the horizontal z-girts to receive the cladding panels.

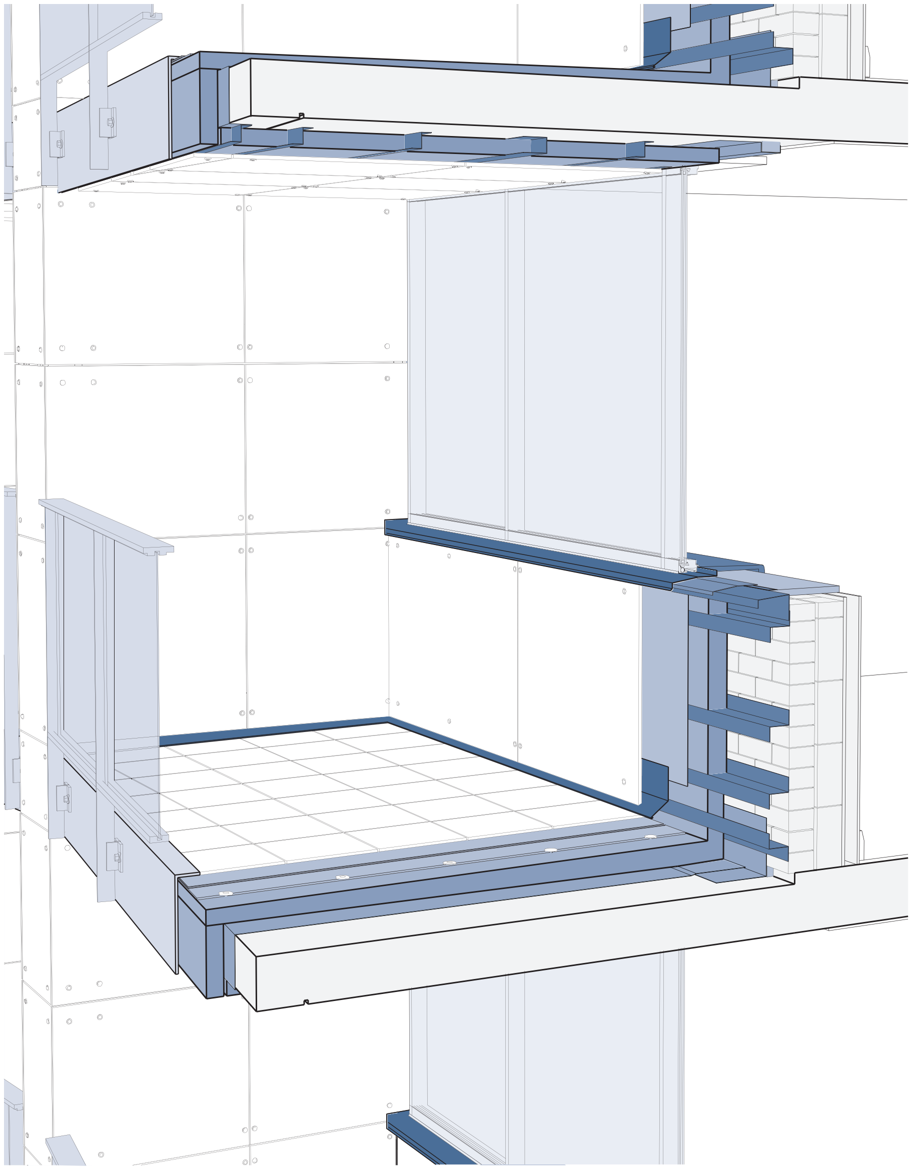


Figure A.63. Installation of the tile and grout proceeds next, followed by caulking as specified to complete the floor assembly A gasket is applied over the vertical hat channels and then the cladding panels are installed over the wall and soffit areas. A new balcony guard is installed to complete the balcony overcladding assembly.

The discussion that follows is repeated from the corresponding section on EIFS overcladding. Overcladding balconies is typically more expensive than enclosing balconies, and there may be a tendency to specify more economical materials to compensate for higher cost. The example depicted in this sequence does not advocate this particular material selection, rather it is intended to illustrate several important principles.

First and foremost, more than one line of defence against moisture migration must be provided. The continuous air/vapour barrier over the existing building envelope is the first line of defence against moisture penetration since this barrier also resists bulk water migration. The second line of defence is the drainage membrane beneath the tile and mortar.

Second, water that enters the assembly must be provided with a drainage path out of the assembly. The air/vapour barrier conveys water to a drainage board running along the length and width of the slab edge. The drainage board conveys water to a weeping channel that allows the water to drip out by gravity. The drainage membrane beneath the tile conveys water to a gap or drainage board located between the slab edge support and the exterior insulation covering the slab edge.

Third, the materials must be suited to the environment in which they are located. Unenclosed balconies are exposed to all of the elements. Solar radiation and freeze/thaw cycles are two critical considerations related to the climate. The finished surfaces must also be durable, resistant to abrasion, and easy to clean. Insulation materials used for the slab area must have a high compressive strength and be able to maintain their thermal resistance when exposed to moisture. Mechanical fasteners should be corrosion resistant and all of the materials must be compatible with one another.

Given these three basic considerations for balcony overcladding assemblies, there are many materials and systems available that satisfy these requirements and are capable of delivering a long service life. Care must be exercised in the selection and detailing of the systems to enable straightforward maintenance of the balcony overcladding on a periodic basis.

IMPORTANT NOTE: It should be recognized that the overcladding of existing exposed balconies requires the reconfiguration of the door threshold providing access to the balcony. The increased height of the overclad balcony traffic surface may also have implications in barrier-free suites. Enclosed balconies provide a viable alternative for barrier-free suites.

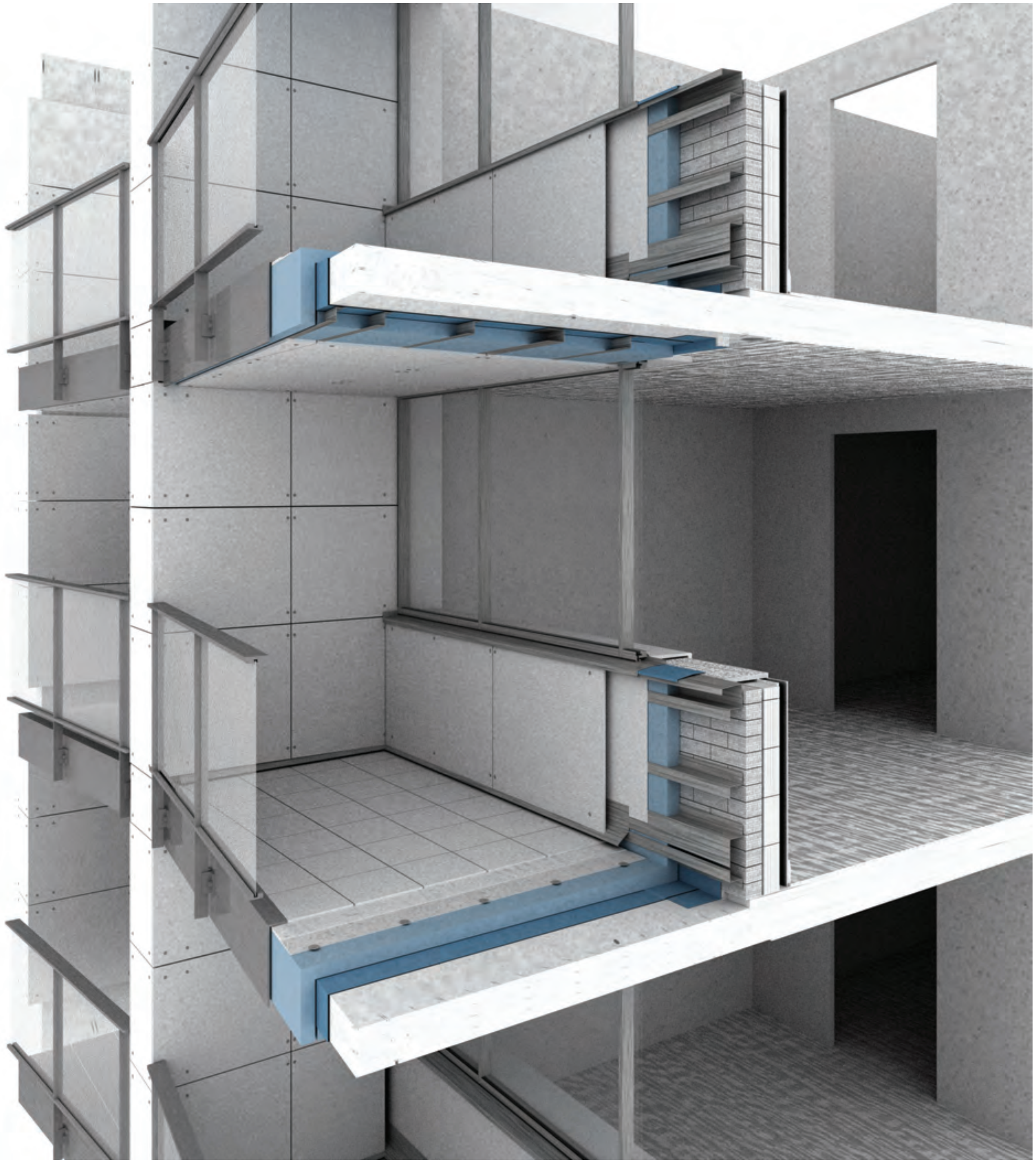
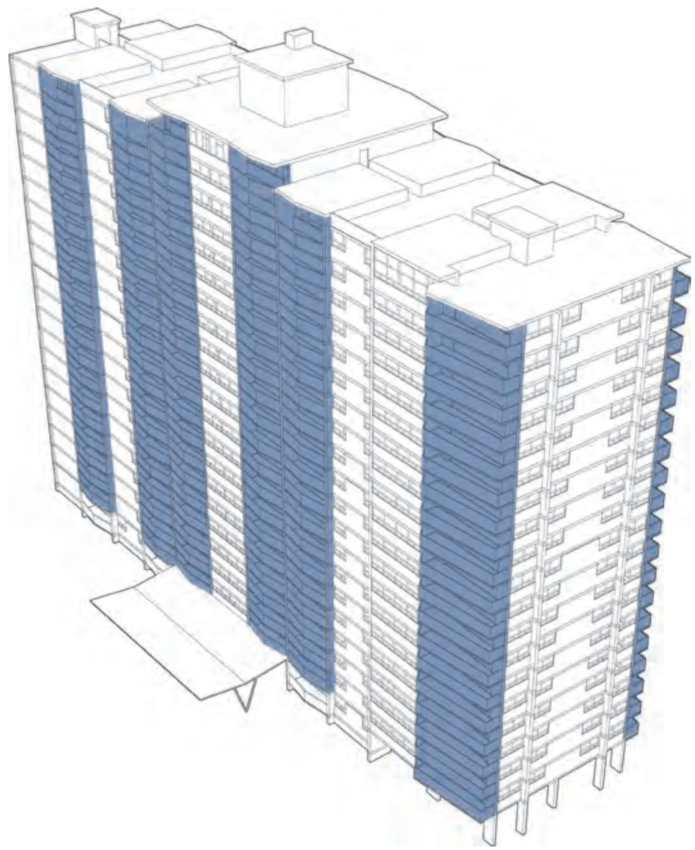


Figure A.64. Cutaway rendering of the completed panel system balcony overcladding and window replacement.

Panel System Balcony Enclosure

This section focuses on balcony enclosure using a panel cladding system and high performance window wall assemblies, as an alternative to balcony overcladding. The shaded areas on the archetype tower building below represent typical locations for balcony enclosures.



Balcony enclosure has economic and thermal advantages over balcony overcladding, but it must be properly integrated within the building system. As discussed in ***7. Tower Retrofit Strategies: A Systems Approach***, there may be cases where unconditioned balcony enclosures lead to severe condensation problems, and appropriate measures must be adopted to avoid deterioration and indoor air quality problems. The arrangement of window openings for natural ventilation is also a critical consideration, along with the need for shading devices on east, west and southern exposures. In cases where the enclosed balcony spaces are unconditioned, it may be advisable to modestly insulate the underside of balcony slabs so that if the windows in a balcony above or below a suite are left open during cold weather, the adjoining balconies are not significantly affected in terms of heat loss and thermal comfort.

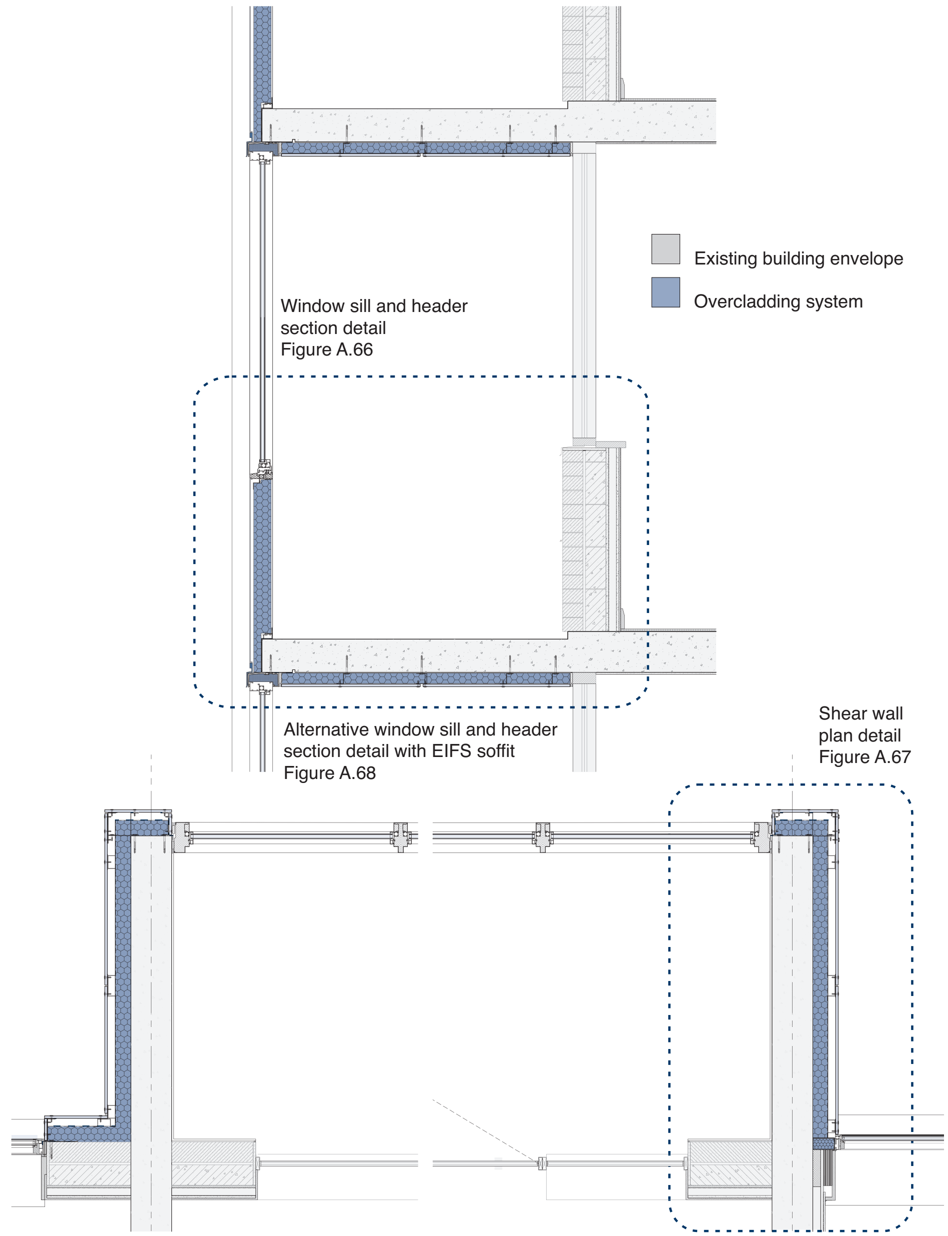


Figure A.65. Section and plan views of a balcony enclosure assembly with corresponding detail drawings denoted.

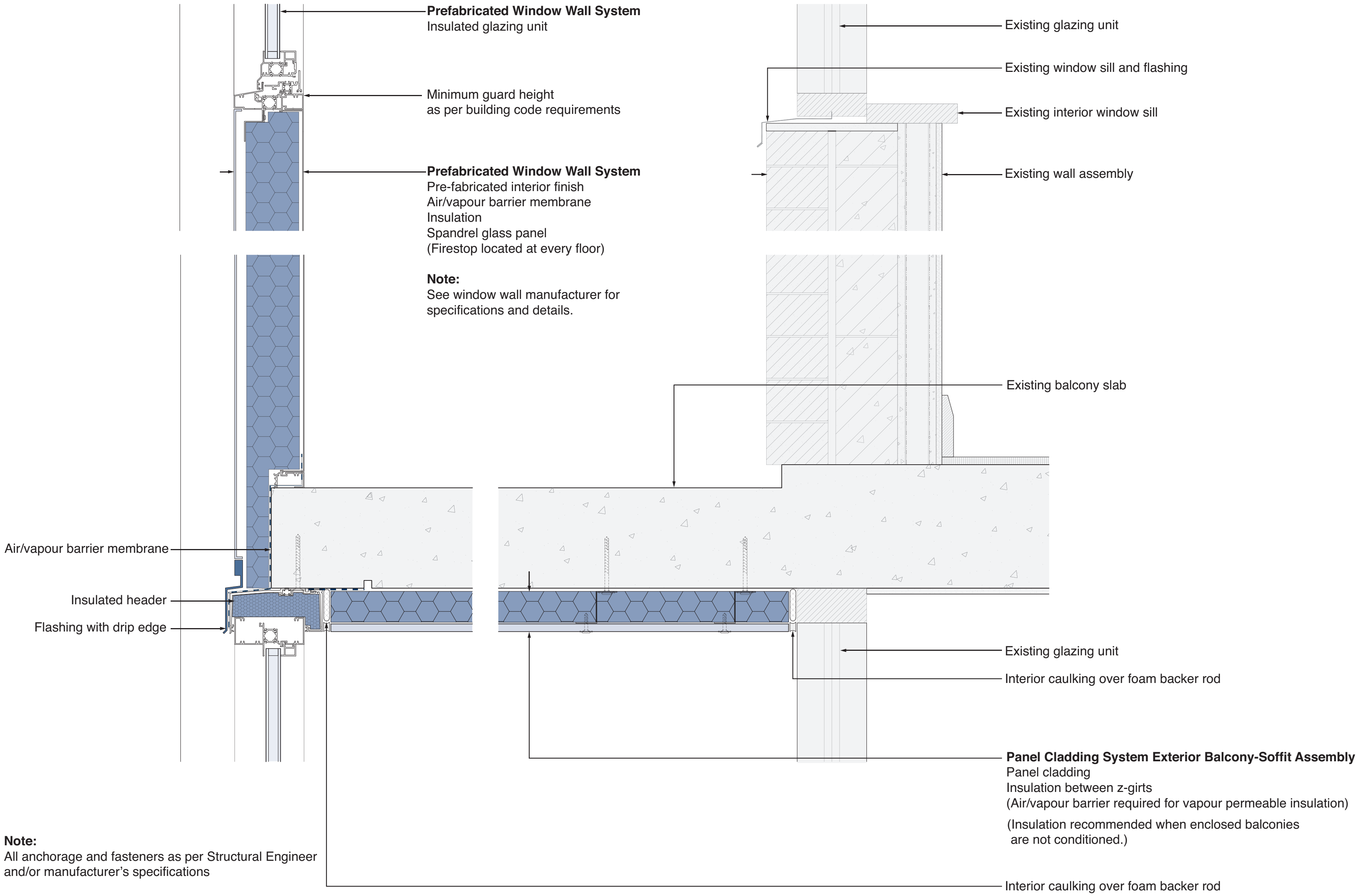


Figure A.66. Moisture control, drainage and continuity of the insulation and air/vapour barrier assembly are depicted in the balcony enclosure assembly above. Minor changes to currently manufactured window wall assemblies are needed to improve thermal performance and reduce condensation potential. It is advisable to obtain third party testing data to ensure specified levels of performance are achieved. Note that the panel cladding interior finish of the enclosed balcony space is optional.

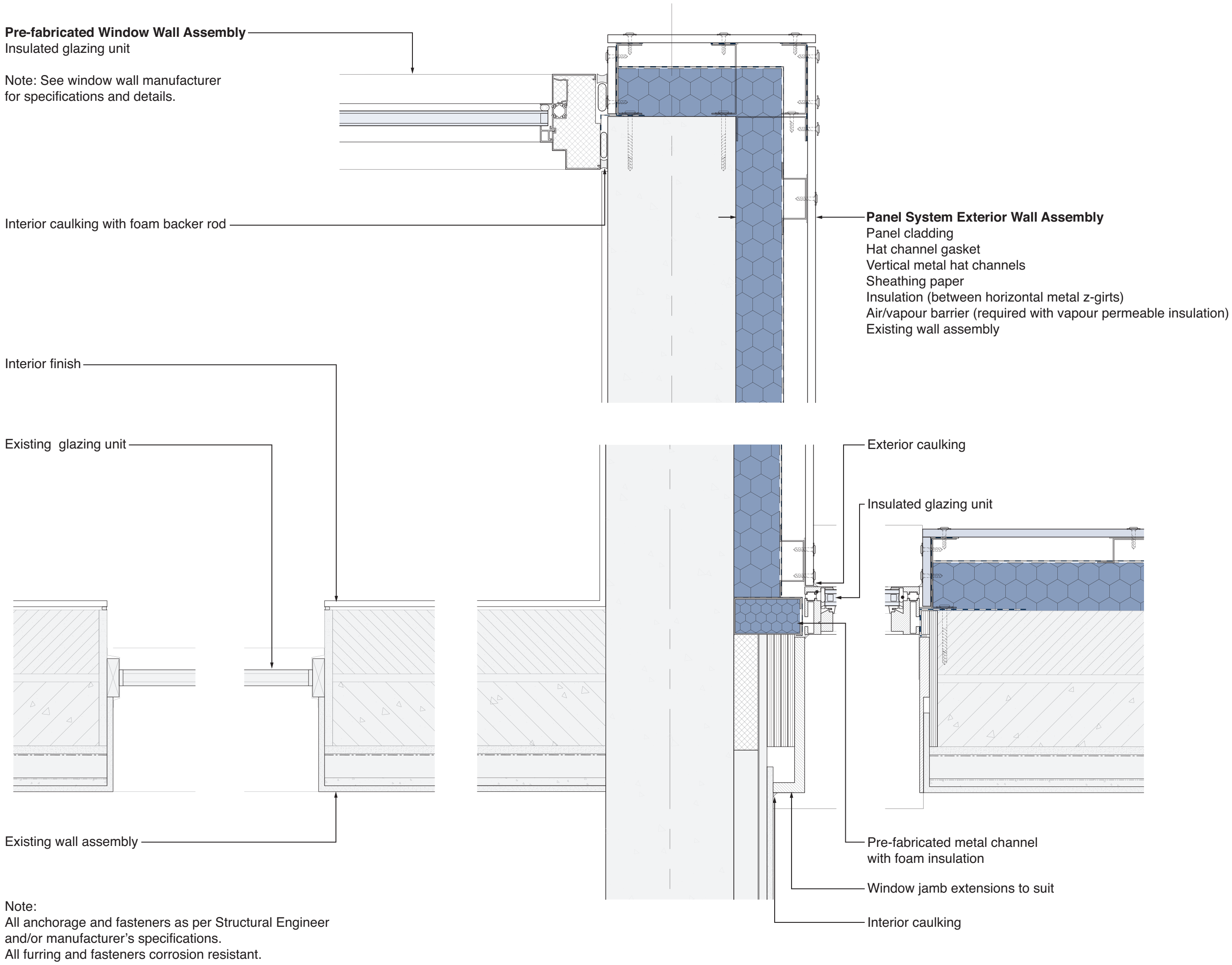


Figure A.67. The alignment of the thermal break in the enclosure window assembly with the exterior insulation is critical to achieve proper thermal performance. Detailing of the panel system overcladding and the balcony enclosure should be carefully coordinated with suppliers and installing contractors. Optional panel cladding interior finish not shown.

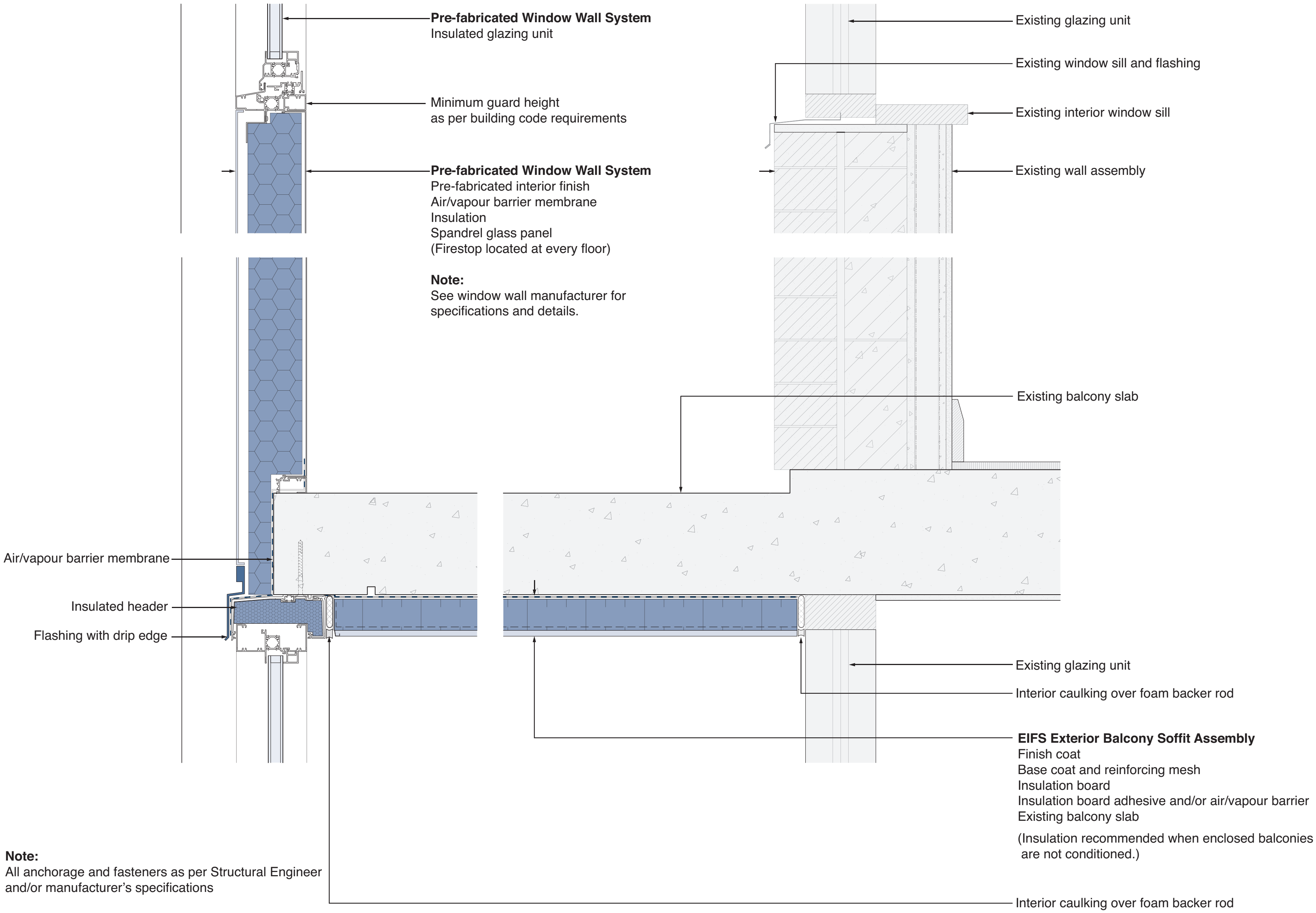


Figure A.68. EIFS soffit overcladding alternative to panel overcladding system depicted in Figure A.66.
Optional panel cladding interior finish not shown.

Panel System Balcony Enclosure Sequence

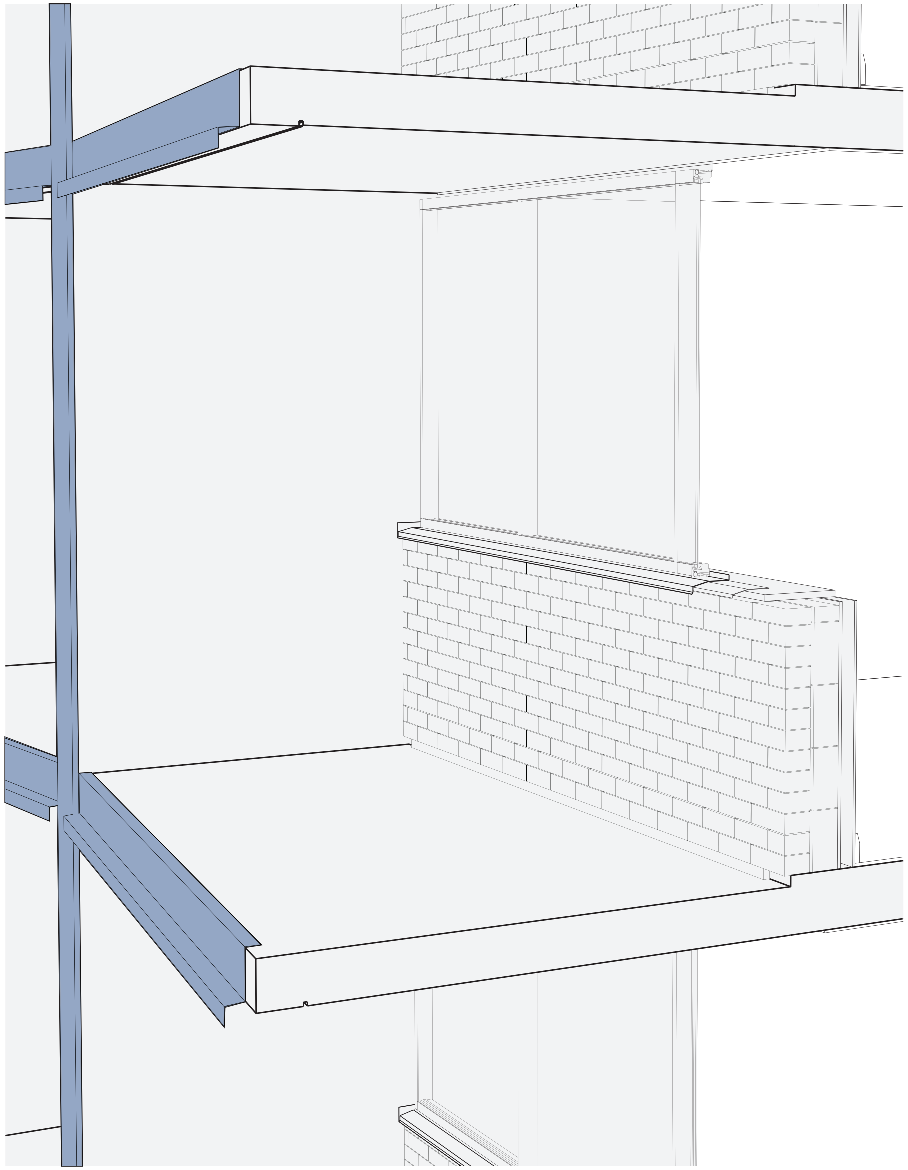


Figure A.69. For balcony enclosures, the existing window is normally left intact, but there are many options available on how to treat this existing condition. Flashings and air/vapour barrier membrane are applied to the existing balcony slab edge and shear wall faces. Condition assessment and remedial action, if necessary, of existing balcony slab edges is critical to ensure adequate bearing capacity for the new window wall enclosure system.

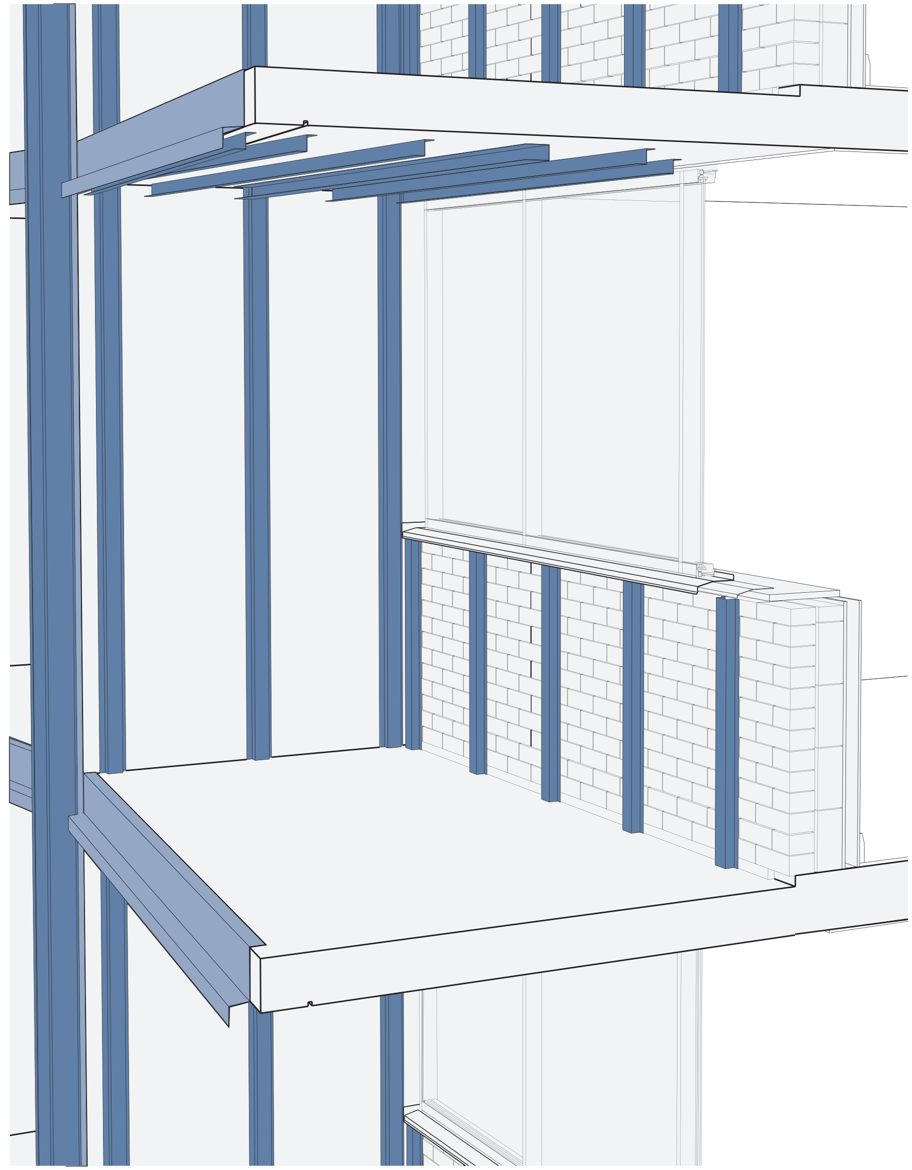


Figure A.70. Girts and furring channels are mechanically fastened to the existing building envelope elements if a panel cladding interior finish is selected.

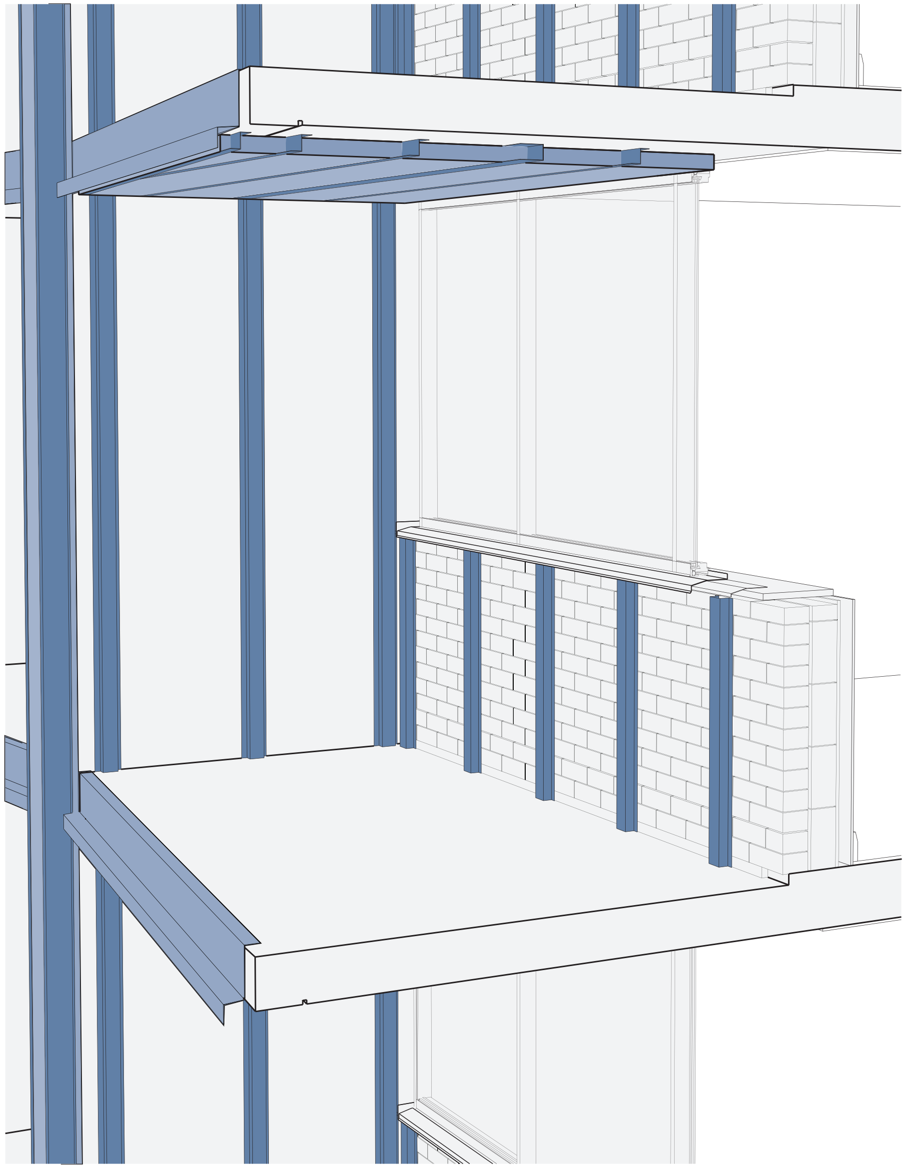


Figure A.71. The underside of the balcony slab is optionally insulated for retrofits that do not condition the enclosed balcony spaces in the building.

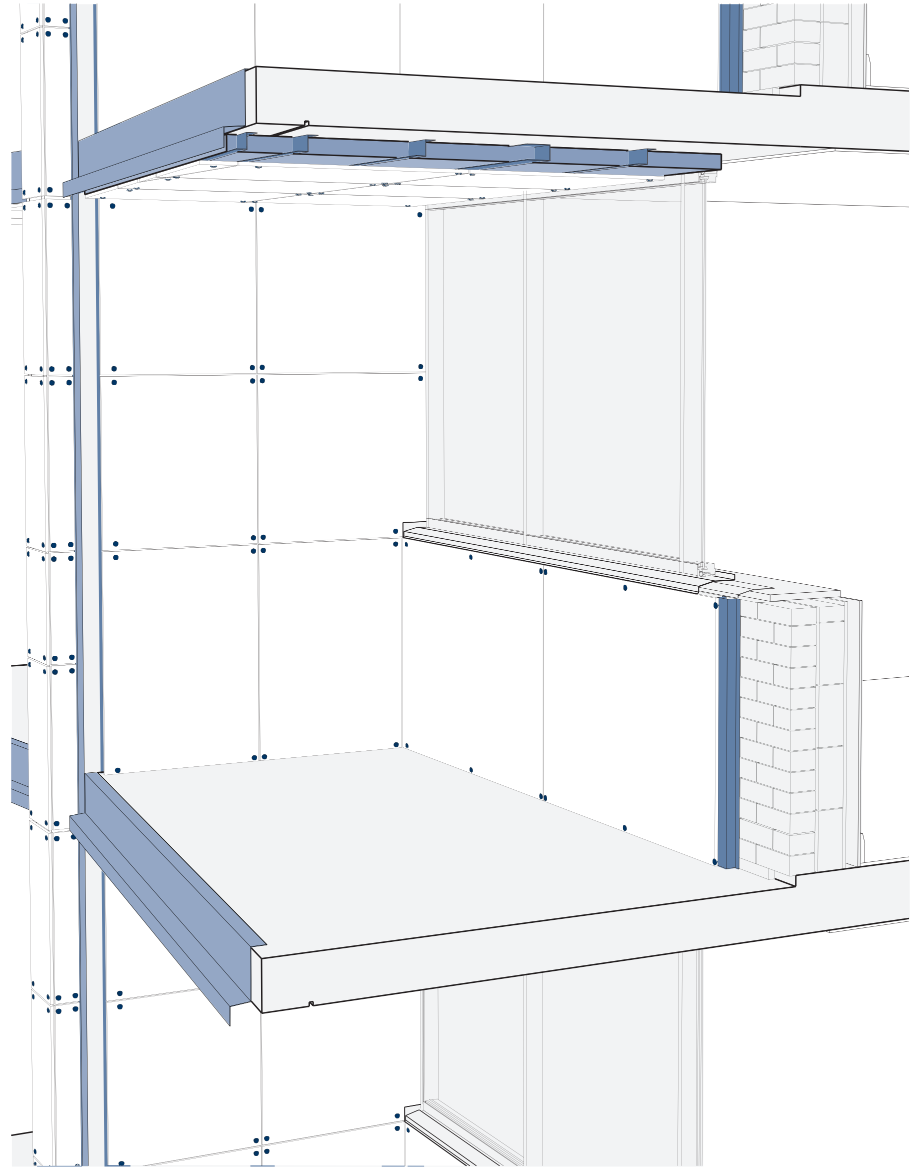


Figure A.72. The panel cladding is installed as an interior finish (optional). Note that a pre-fabricated sill flashing extension will be required at the bottom of the existing window sill to transition to the panel cladding.

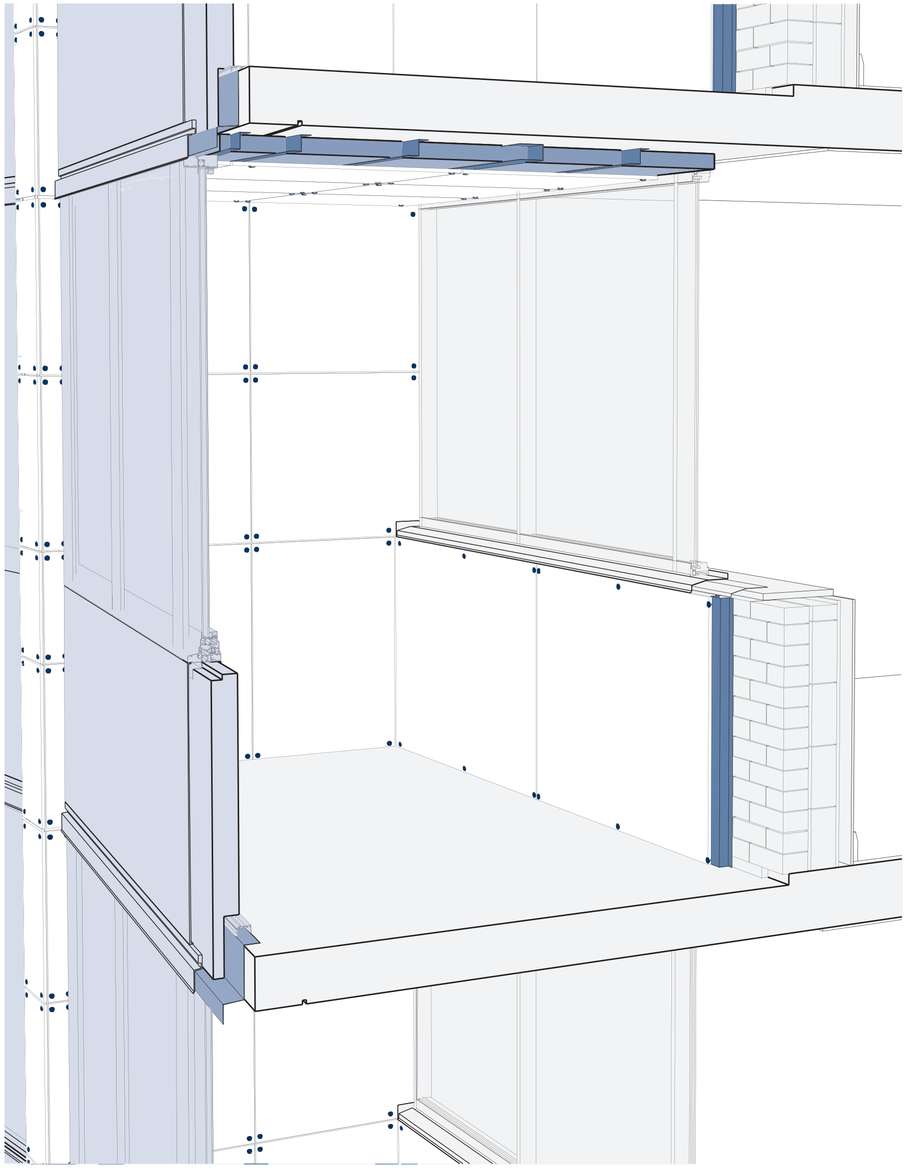


Figure A.73. The final procedure is the installation of the window wall assembly, followed by the application of required sealants and caulking.

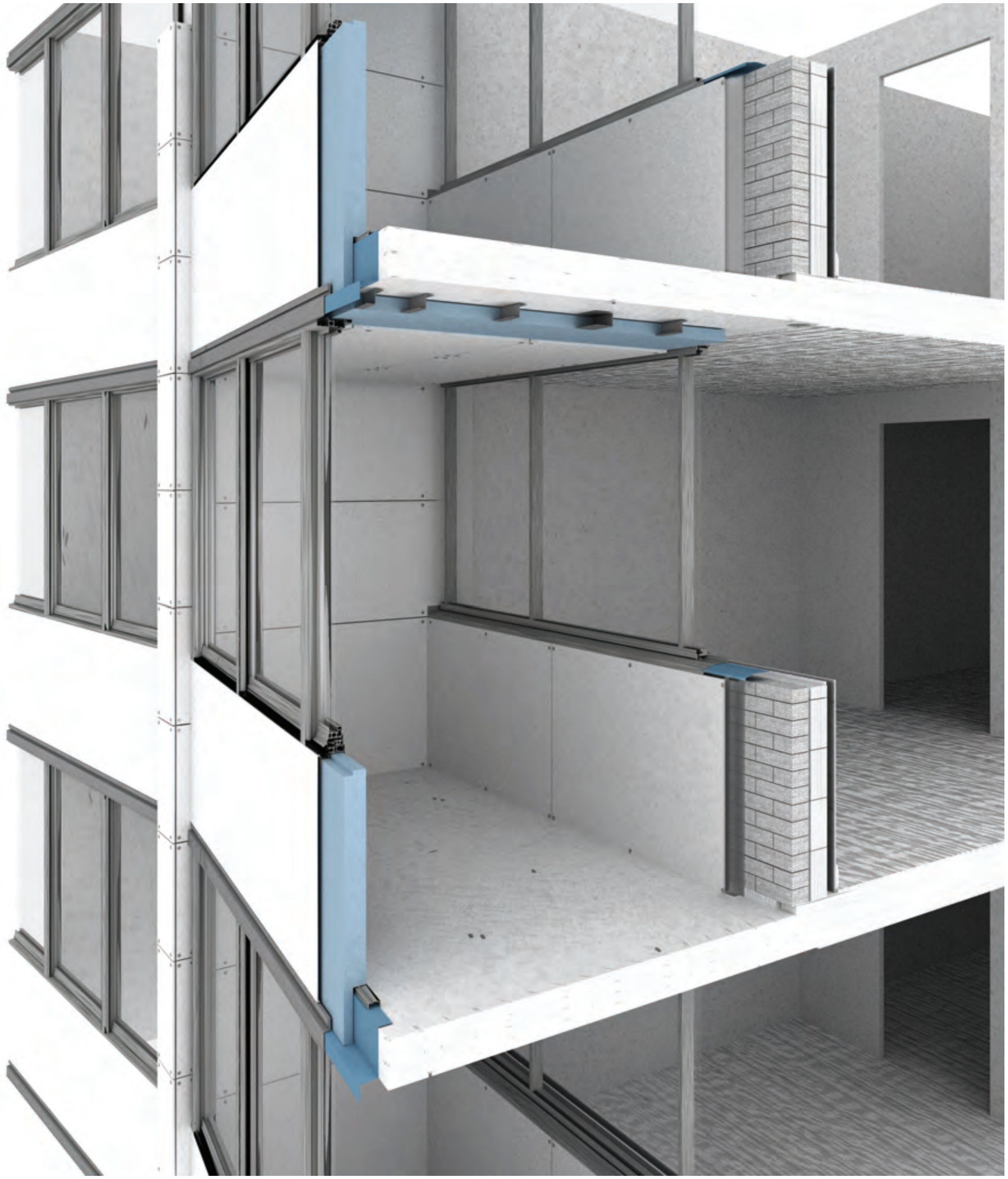
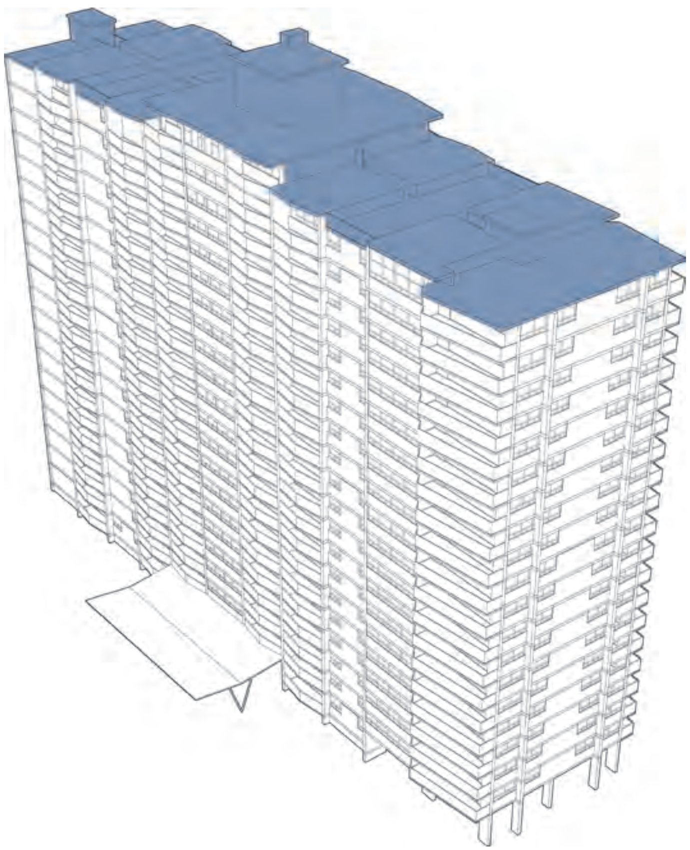


Figure A.74. Cutaway rendering of the completed balcony enclosure assembly, integrated with the panel overcladding system.

Roofing Replacement and Panel System Balcony Options

Roofing replacement is a common and well understood procedure that is routinely carried out on existing buildings. It is not common to integrate overcladding of balconies with roofing replacement over the projecting roof slab. This section deals with this particular condition and discusses key considerations for design and the coordination of the overcladding and roofing replacement assemblies. The shaded areas on the archetype tower building below represent the locations of this condition.



The selection of roofing assemblies must consider that in typical tower retrofit projects, the roofing replacement will usually be carried out after all the overcladding has been completed, with exception to the at grade overcladding assemblies. Ideally, the mast climbing work platforms can be used to transport materials to the roof and possibly retrieve the existing roofing materials that have been removed. This affords a wider selection of roofing system options and reduces both time and costs. When this coordination is not possible, roofing systems that have components that can be cold applied and easily moved up using the building's elevators may be a preferred option. From a sustainability perspective, roofing systems that have the highest proportion of reusable and recyclable materials are preferred to systems that end up entirely in the landfill. Durability, water shedding and thermal effectiveness are essential requirements for any roofing system.

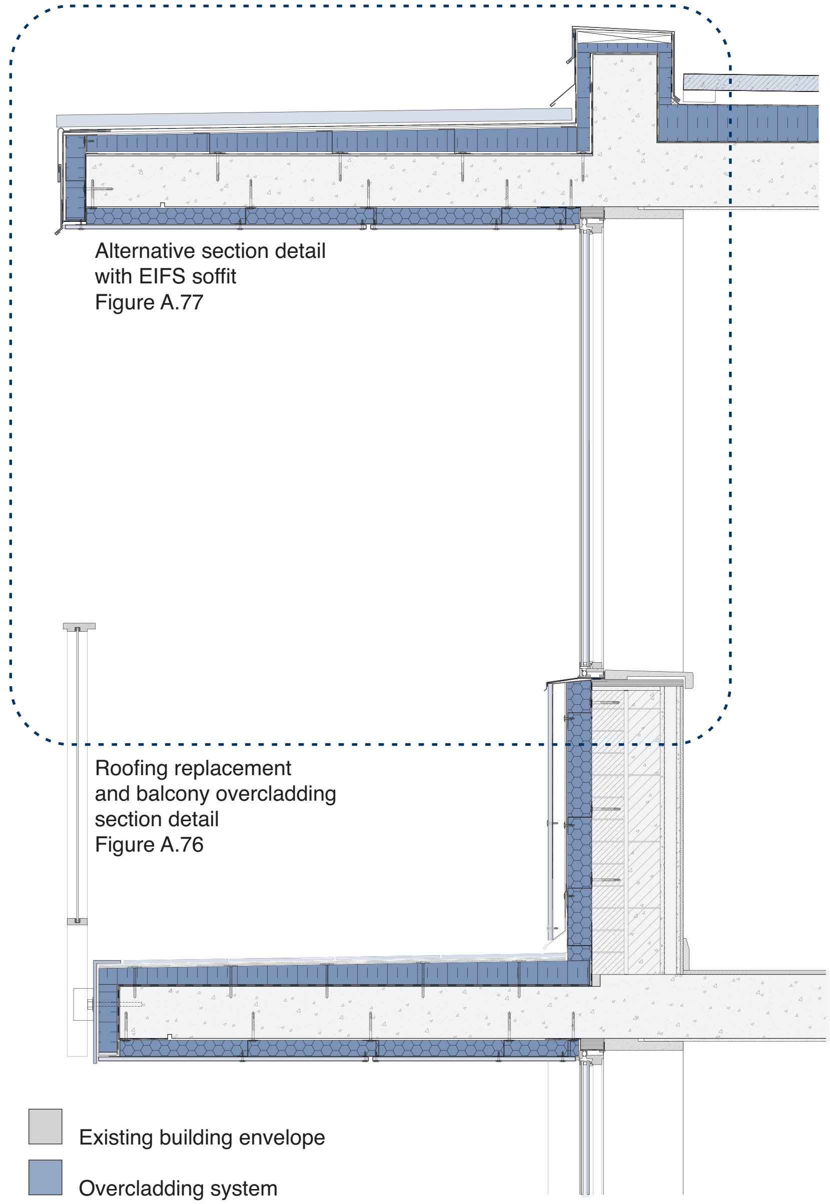


Figure A.75. Section view of a roofing replacement and balcony overcladding assembly with corresponding detail drawings denoted.

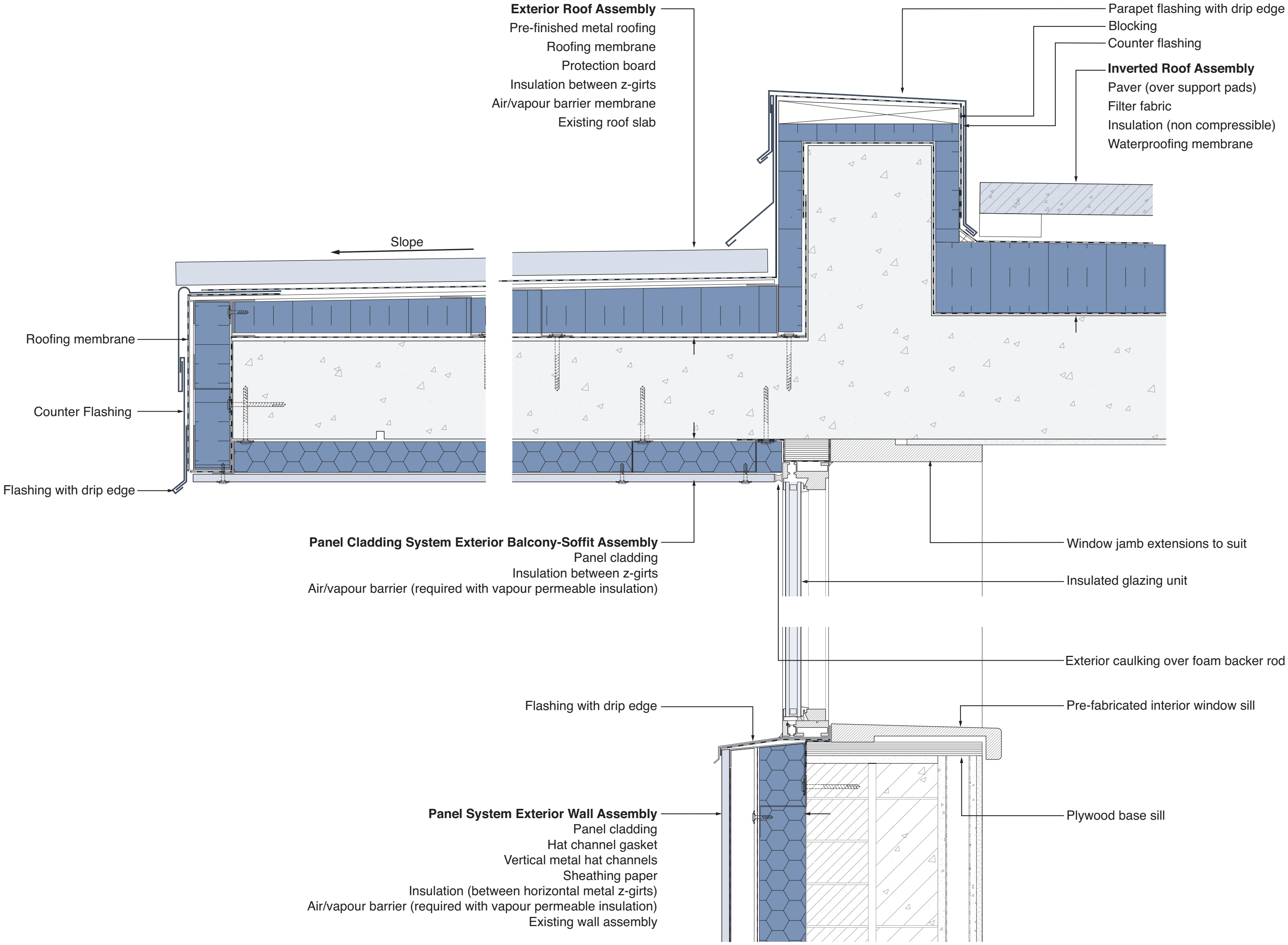


Figure A.76. Two roofing systems are depicted in the above detail. An inverted roof system is shown for the main roof area, and a metal roofing system is shown for the cantilevered roof slab. EIFS is applied to the soffit and the balcony wall and window replacement are the same as detailed in the previous section.

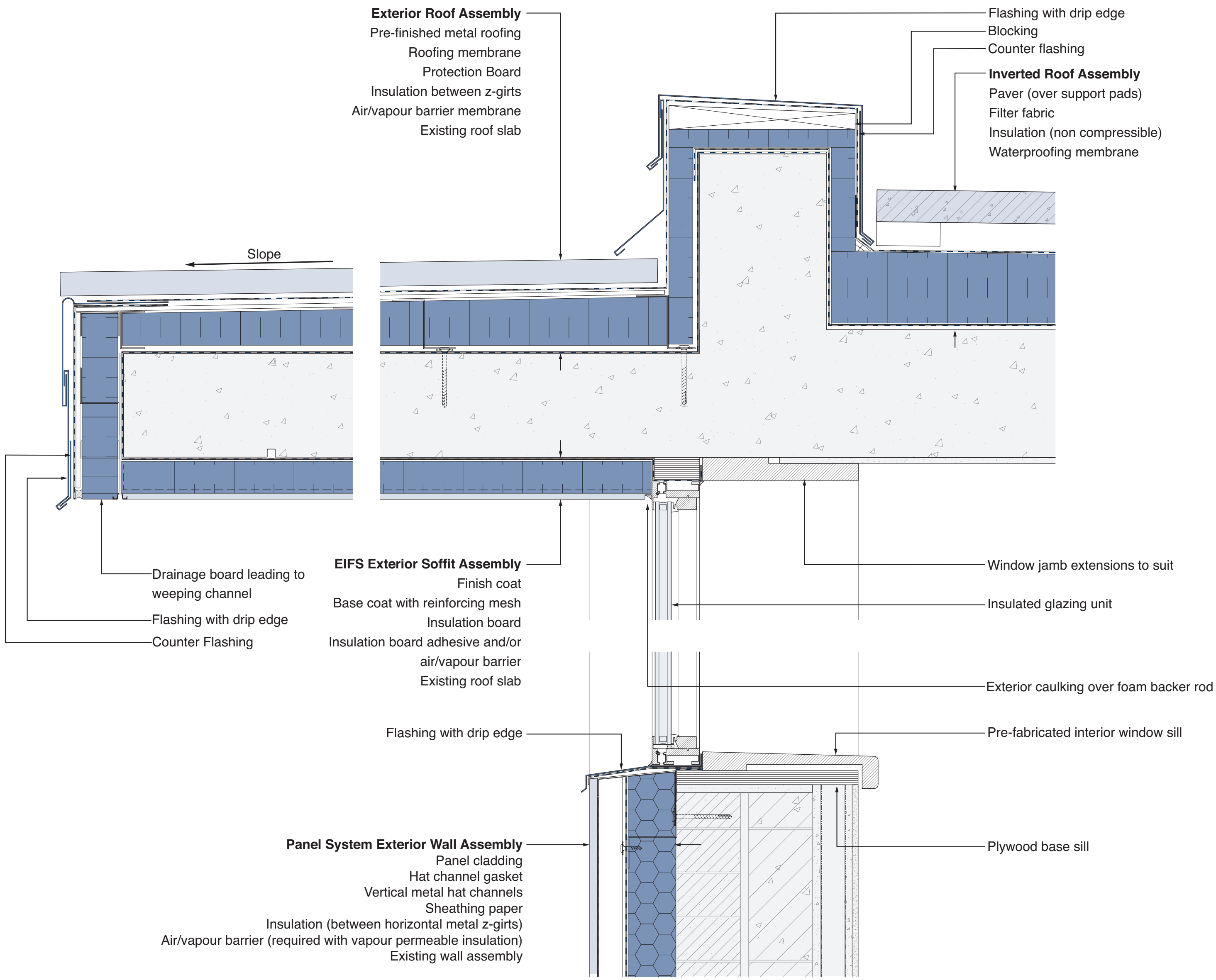


Figure A.77. Two roofing systems are depicted in the above detail. An inverted roof system is shown for the main roof area, and a metal roofing system is shown for the cantilevered roof slab. EIFS is applied to the soffit and the balcony wall and window replacement are the same as detailed in the previous section.

The enclosure of balconies must be properly integrated with the roofing replacement both for acceptable performance, but also for construction coordination purposes. It is advisable to retrofit the cantilevered portion of the roof slab and the uppermost enclosed balcony at the same time. This may not prove possible and it will then be necessary to develop appropriate details that can accommodate various sequences to provide the contractor with the greatest flexibility.

It is important to recognize that in some tower retrofits, different orientations will be given different treatments. Some balconies may be overclad while others are enclosed. The overclad balconies may have screen elements to shade and shelter from the wind. The details that are presented at key junctures, such as the roof and uppermost balconies, will therefore have to be carefully considered to account for cost, schedule and technical feasibility.

This final aspect becomes important when pre-fabricated overcladding and enclosure systems are being considered. It is well known that existing tower buildings are not dimensionally consistent and some minor deformation has also occurred since these buildings were constructed. Flexible and adaptive systems that are well suited to mass customization will certainly emerge as cost effective options provided they can accommodate the required tolerances and be easily installed by available trades.

Balcony enclosures are a promising candidate for mass customization that can accommodate a variety of natural ventilation, screening and shading strategies, that respond to the different solar orientations within the context of privacy from adjacent buildings.

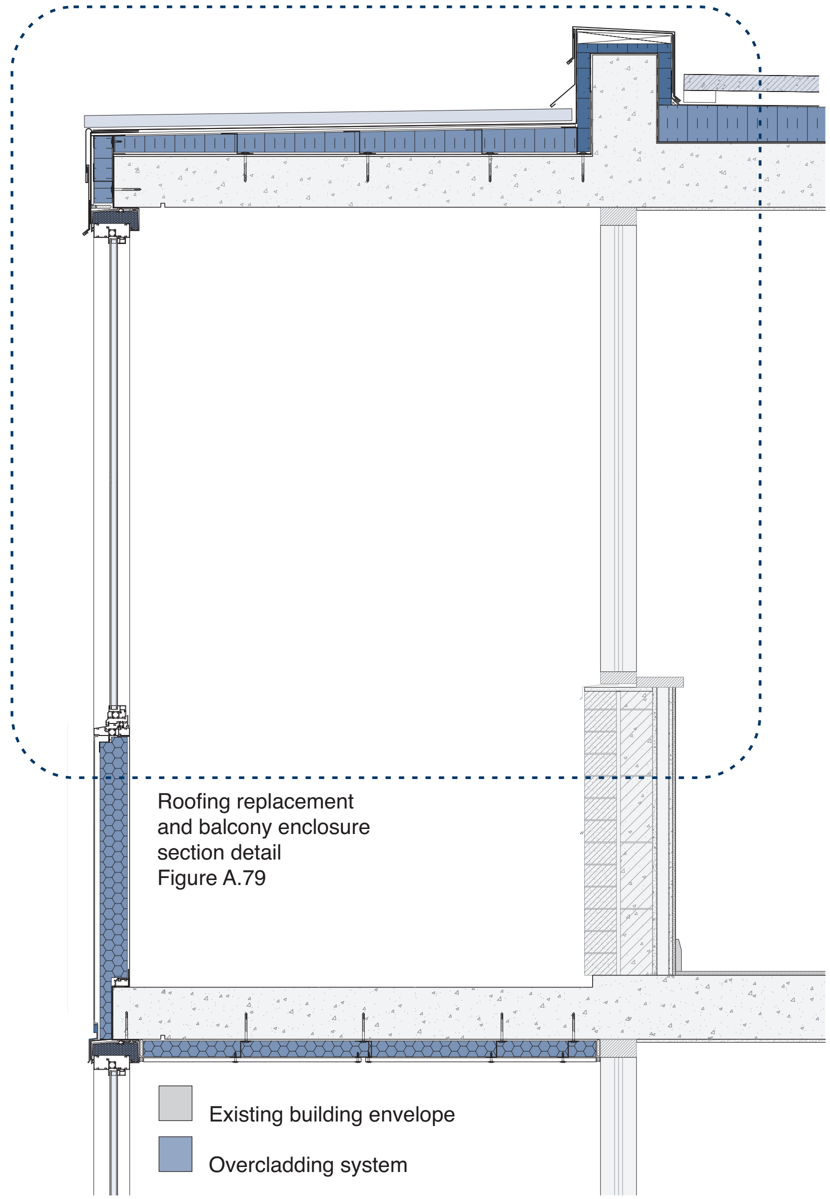


Figure A.78. Section view of a roofing replacement and balcony enclosure assembly with corresponding detail drawing denoted.

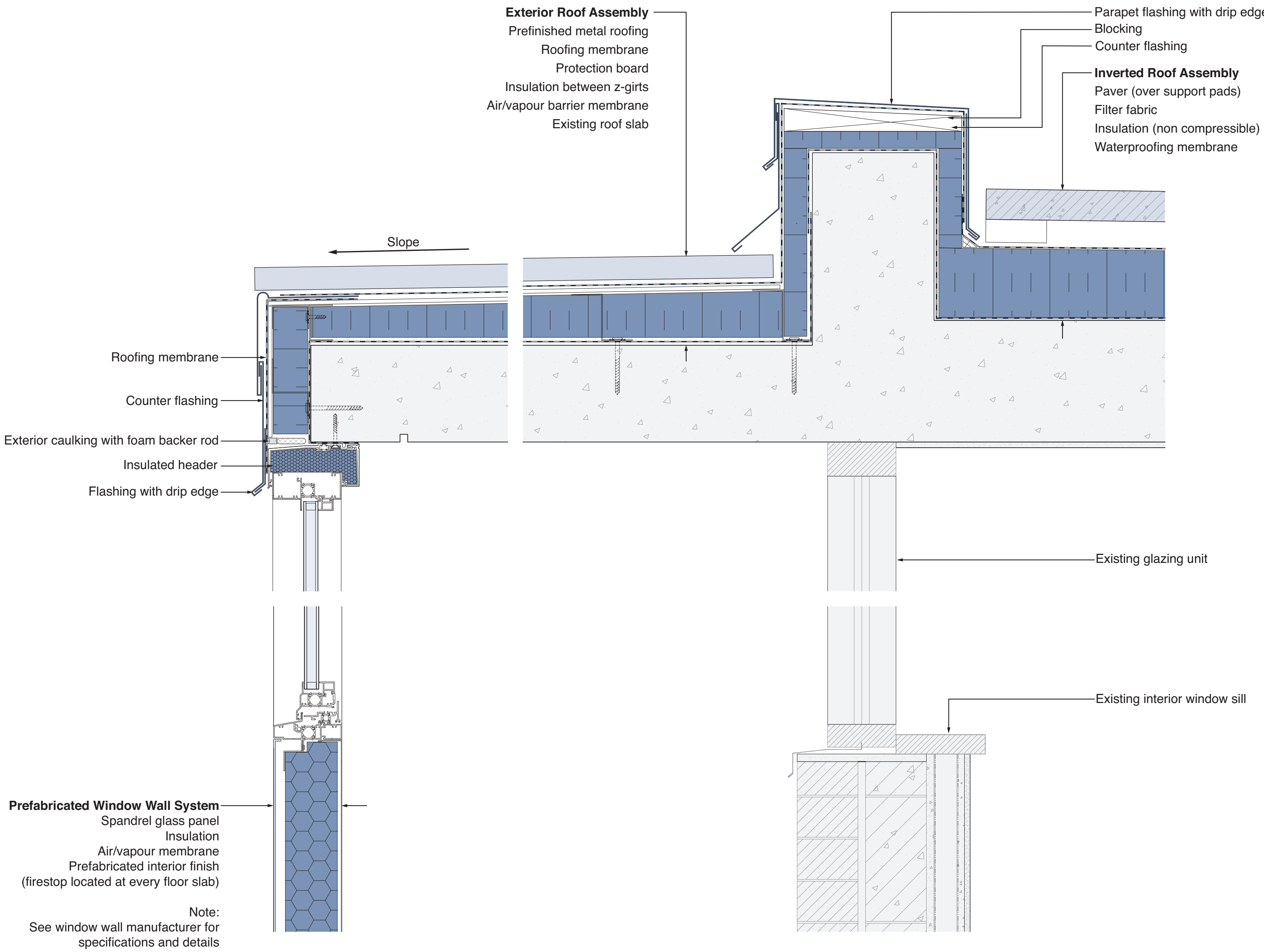


Figure A.79. Section detail of enclosed balcony and replacement roofing. The projection on the flashing over the top of the balcony enclosure glazing should be designed to convey the water away from the enclosure face to avoid staining and potential leakage through open windows.

Roofing Replacement and Panel System Balcony Enclosure Sequence

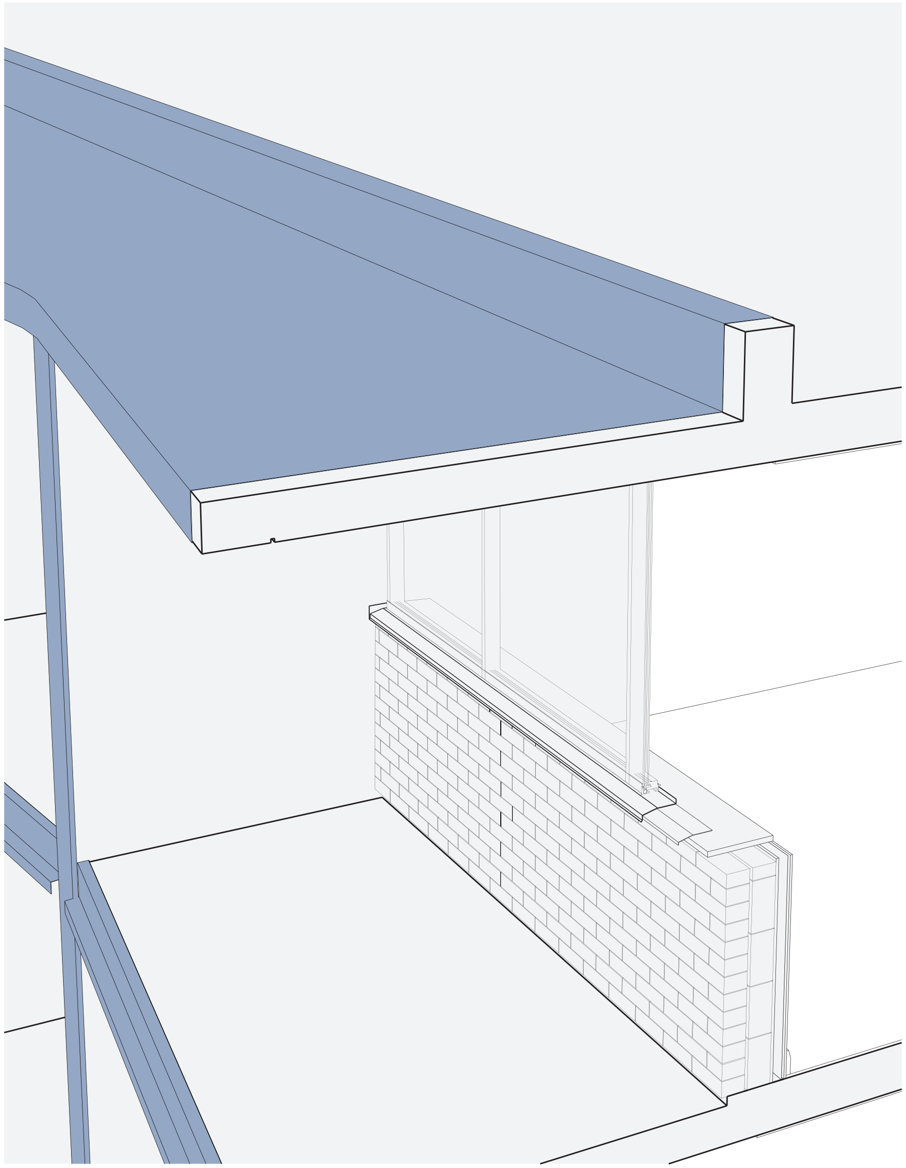


Figure A.80. The balcony enclosure sequence is the same as described in earlier sections, hence the focus of this sequence will be the replacement roofing assembles. Following removal of the existing roofing, the replacement roofing begins with the applications of an air/vapour barrier that also serves as the waterproofing membrane. Refer to the previous sections for related notes.

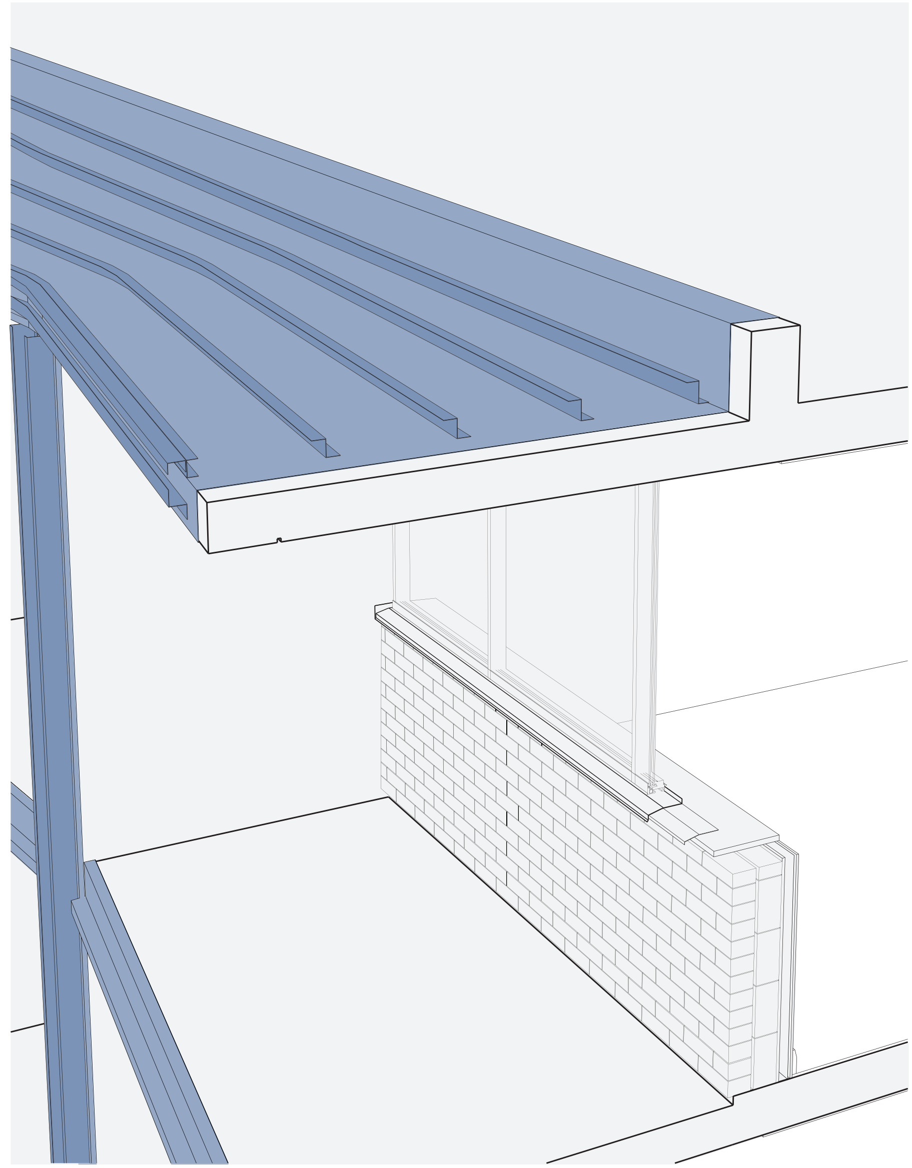


Figure A.81. On the projecting portion of the roof, Z-girts or other suitable channels are installed to eventually receive the fasteners to attach the corrugated metal roofing.

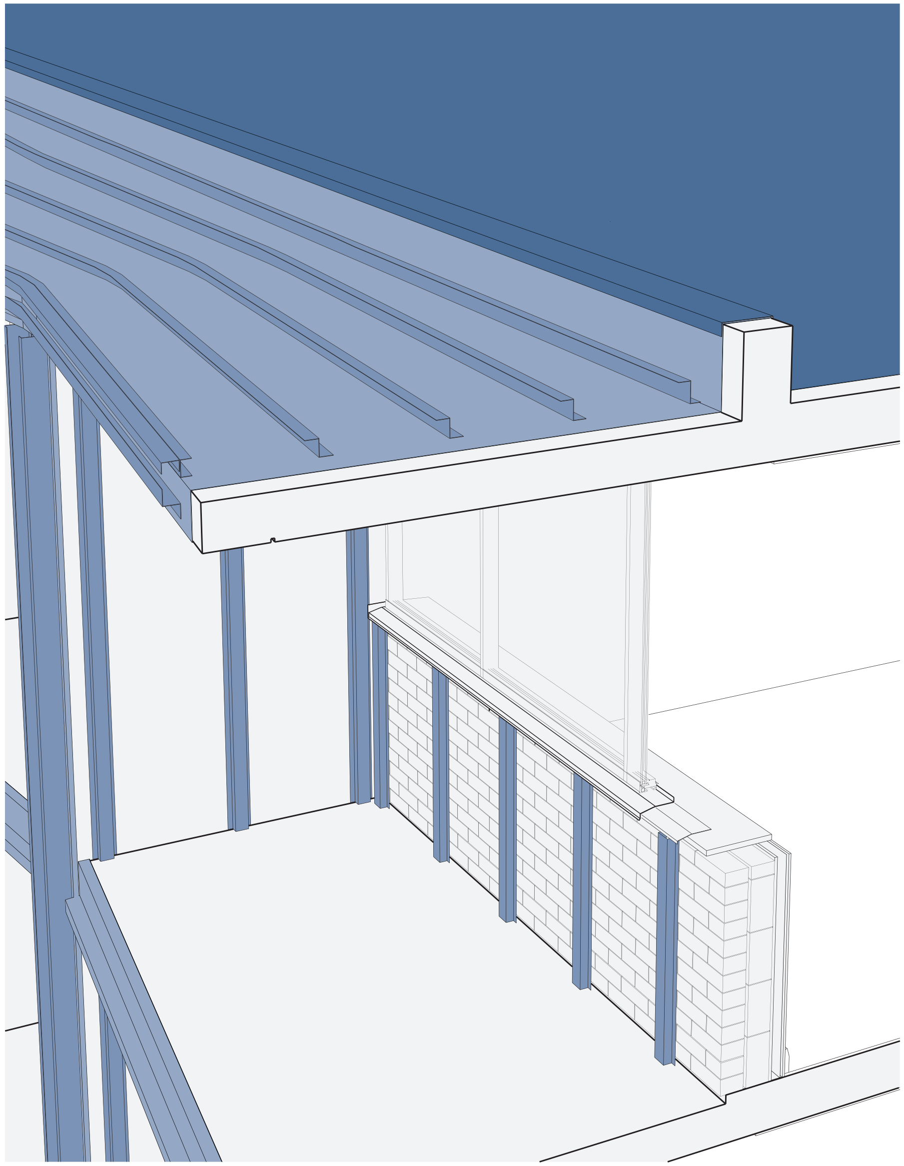


Figure A.82. A waterproofing membrane(s) is applied over the main roof section overlapping the projecting roof at the parapet.

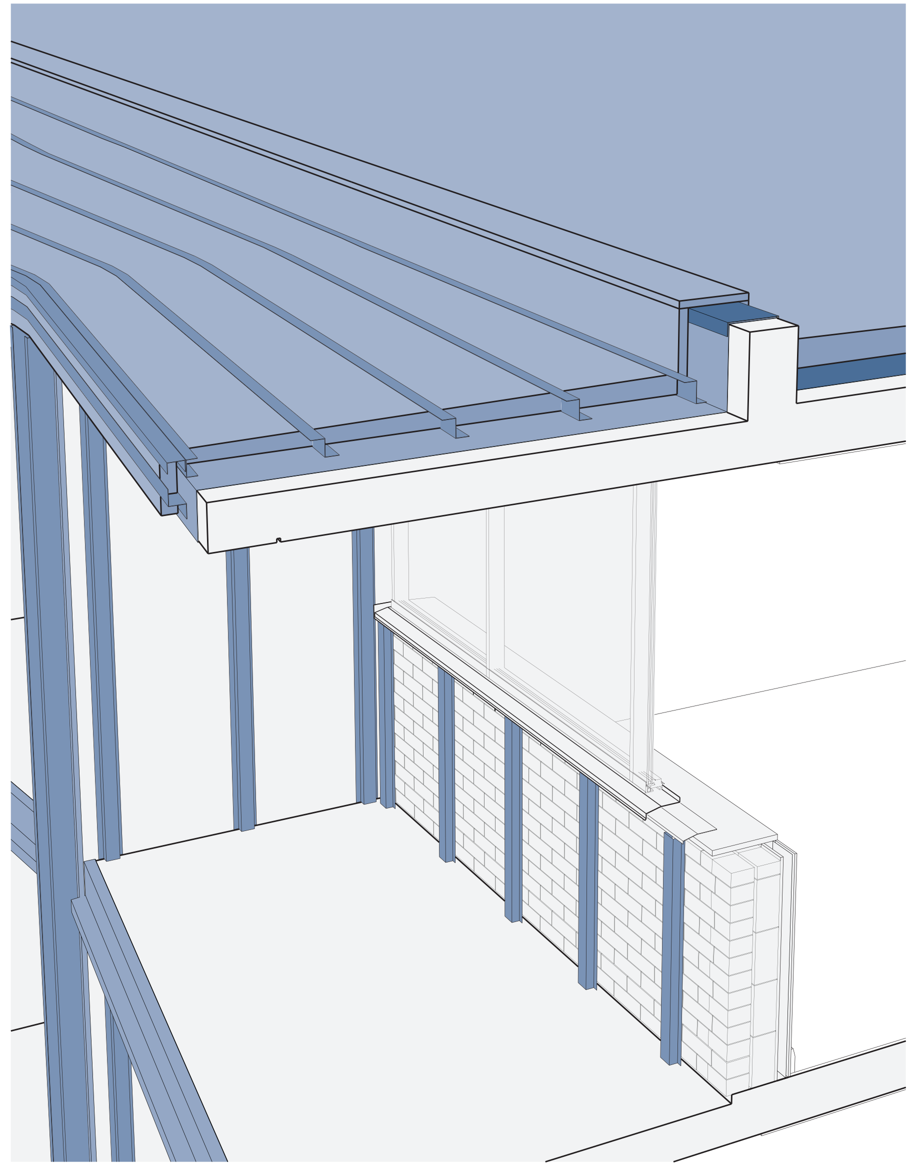


Figure A.83. Insulation is installed over the entire roof areas. Proper fitting of the insulation between the Z-girts is necessary to maintain thermal effectiveness of the assembly.

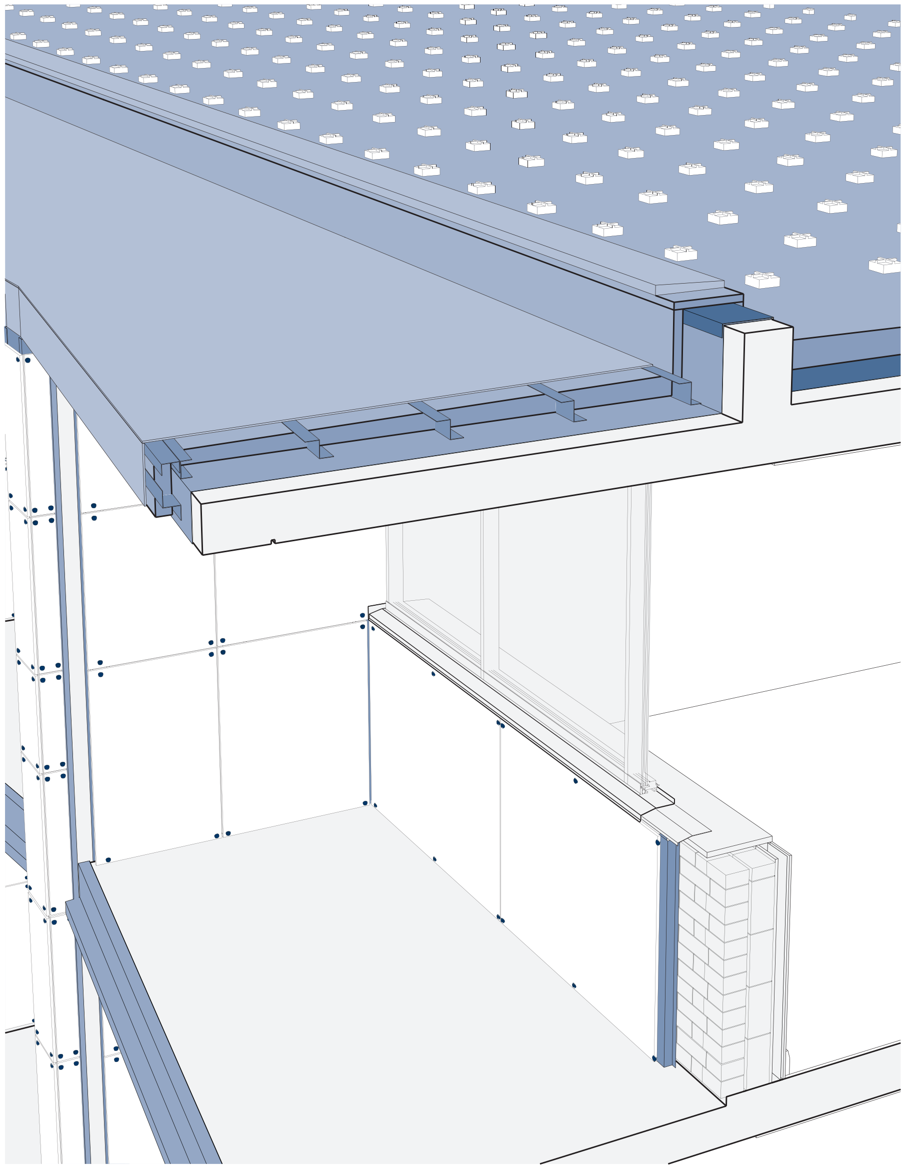


Figure A.84. Protection board is fastened to the Z-girts over the projecting roof area. On the main roof area, a filter cloth is laid over the insulation, followed by spacers to support the pavers.

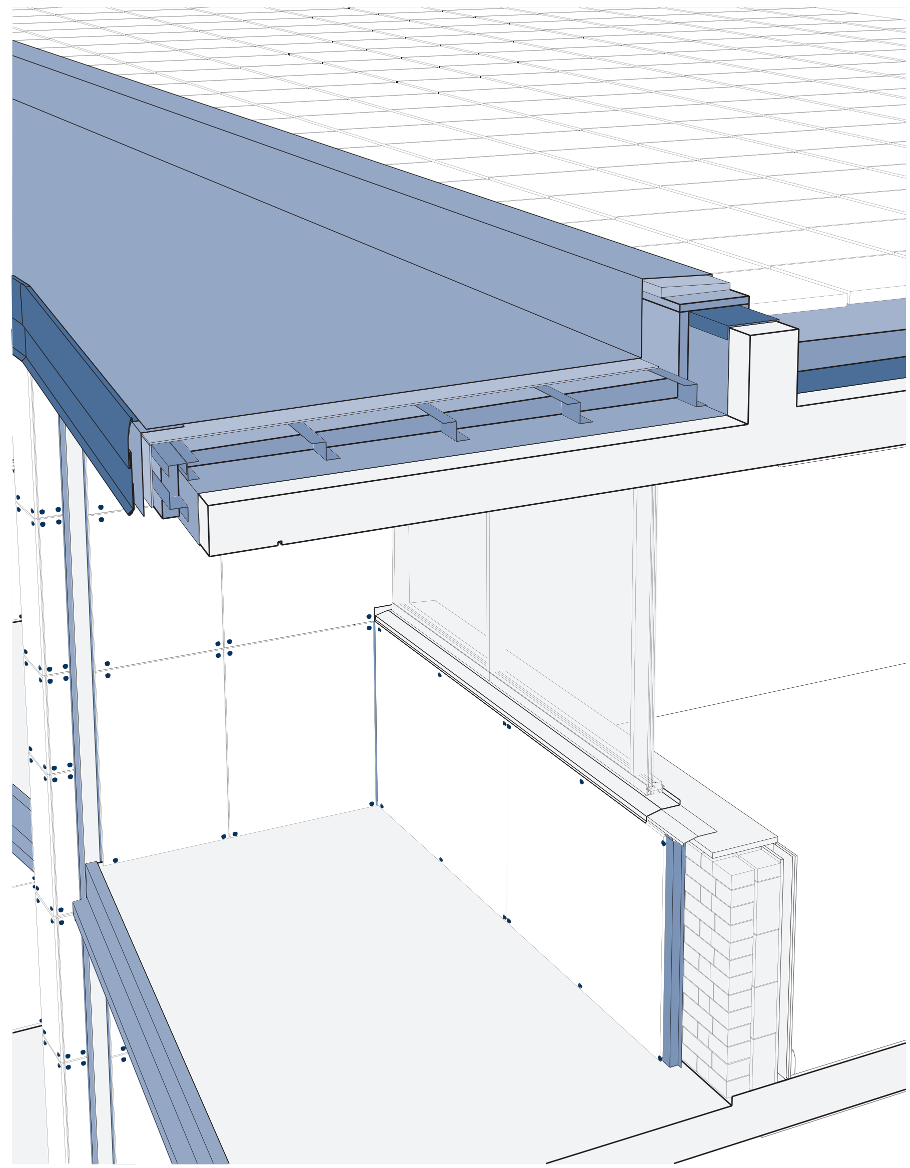


Figure A.85. Flashings are installed at he projecting roof slab edge. A roofing membrane is laid over the projecting roof area and lapped over the parapet and the flashing. Pavers are laid on top of the spacers in the main roof area.

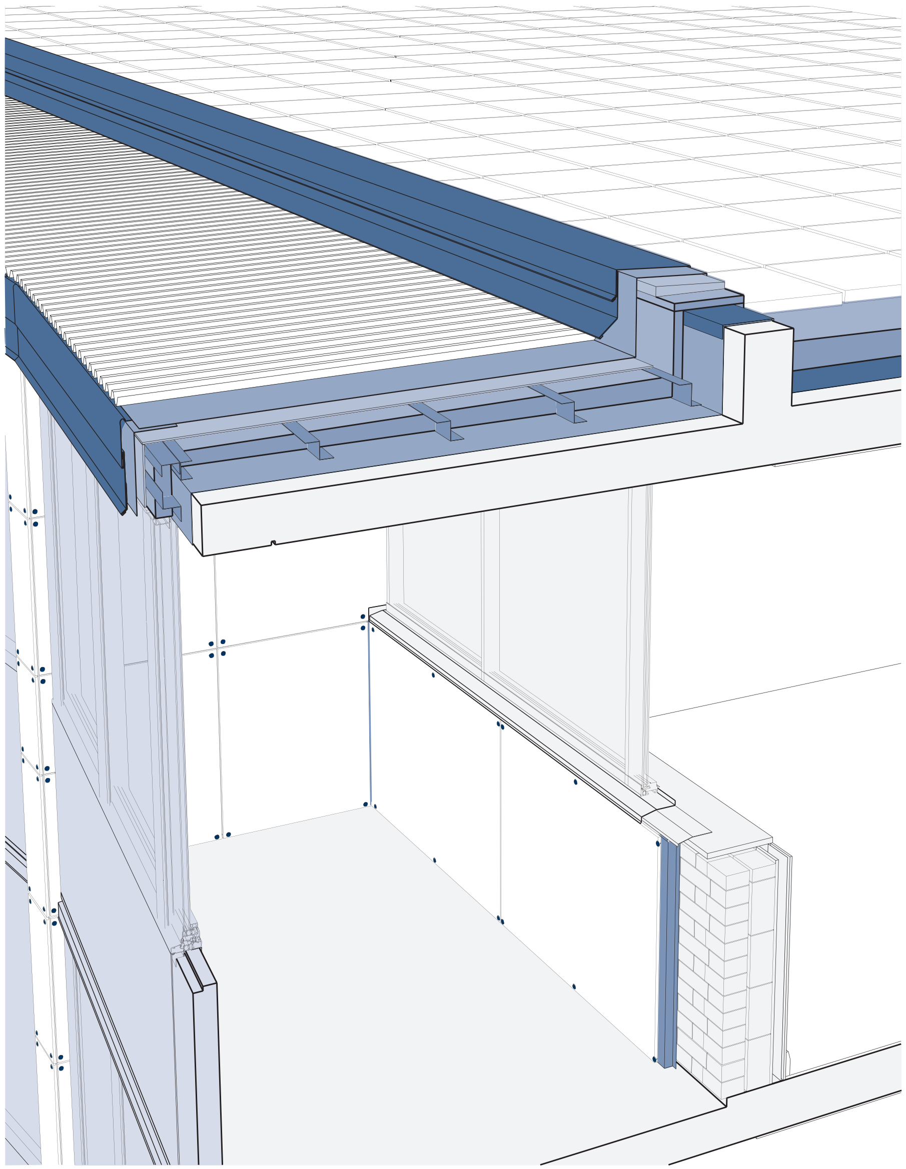


Figure A.86. The corrugated metal roofing is installed over the projection roof area, followed by the parapet flashing which completes the roofing replacement sequence.

The roofing replacement sequence and the balcony enclosure options have been illustrated together in order to assist users of these guidelines appreciate the need for coordination of these two aspects of a comprehensive tower retrofit.

For the shear wall and balcony elements retrofit contractor, the ideal process starts at the top of the building and proceeds downward so that debris and falling objects do not damage the overcladding below. The roofing replacement normally occurs toward the end of tower retrofits after the last of the mechanical and electrical work associated with the HVAC system upgrading are complete. This means that the roofing over the projecting portion of the roof will occur after the wall and balcony overcladding have been completed. This explains why in the detail and assembly sequence shown here, a corrugated metal roofing assembly with cold applied or peel-and-stick membranes was depicted. This type of roofing is more likely to minimize the potential for hot liquid spills or splatters damaging the finished overcladding below. If a different replacement roofing system was selected, it would be prudent to complete the projecting portion of the roof before proceeding with the balcony enclosure. In this case, a temporary parapet flashing membrane could be installed until such time as the roofing replacement of the main roof area is carried out. For buildings that have recently received roofing replacements prior to the tower retrofit work, suitable details will have to be developed to tie the balcony enclosure into the roofing assembly.

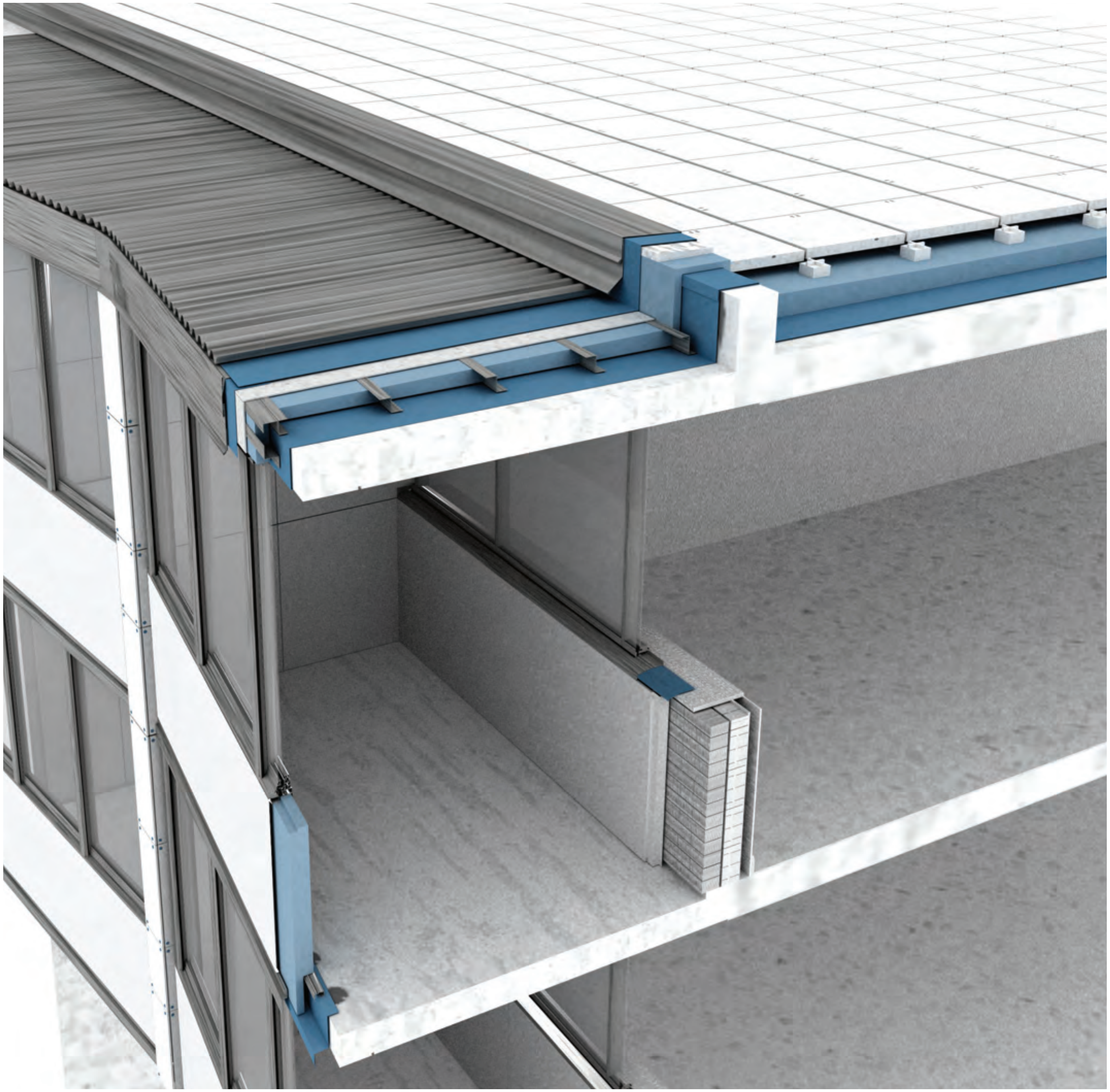
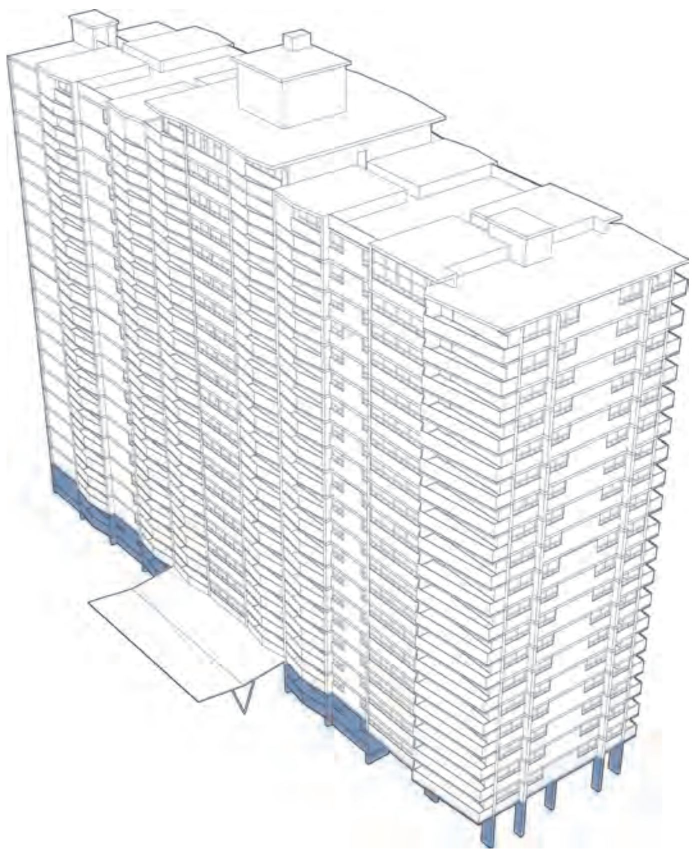


Figure A.87. Cut-away rendering of the completed roofing replacement and balcony enclosure at the uppermost storey of the archetype tower building.

Panel System Soffit and At-Grade Overcladding

This discussion also appears under the corresponding section for EIFS. All tower buildings will have an at-grade condition, and some may have soffits under raised portions of the building as shown in the archetype tower building. Not all panel cladding systems will be well suited to at-grade applications. Typically, the ground level of any building must be able to resist exposure to abrasion, mechanical impact, de-icing salts, soils and other organic matters, in addition to the normal exposure to the outdoor environment. This section deals with the at-grade condition and soffits. The shaded areas on the archetype tower building below represent the locations of this condition.



Differentiating at-grade overcladding from the storeys above is an architectural opportunity that holds potential for integrating the often graceful tower building entrance canopies with the at-grade overcladding. From a practical perspective, the at-grade overcladding will usually be the last stage in the overcladding process. Access to the façade at grade level permits selection of the widest range of materials since size and weight are less critical than overcladding assemblies handled by mast climbing work platforms. A primary consideration is the susceptibility of the surface finishes to absorption of pigments (graffiti) and the ease of cleaning. In all cases, pressure moderated drain screens represent the preferable at-grade overcladding strategy.

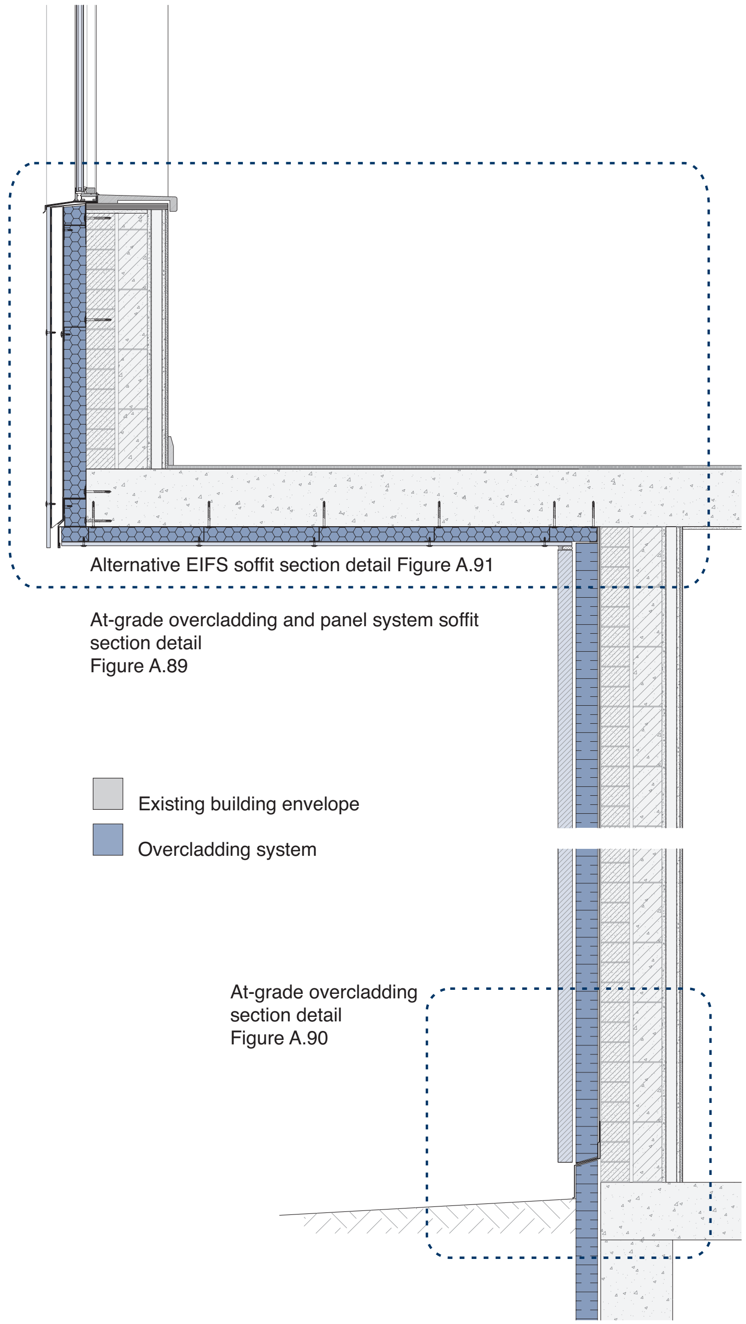


Figure A.88. Section and plan views of a roofing replacement and balcony overcladding assembly with corresponding detail drawing denoted.

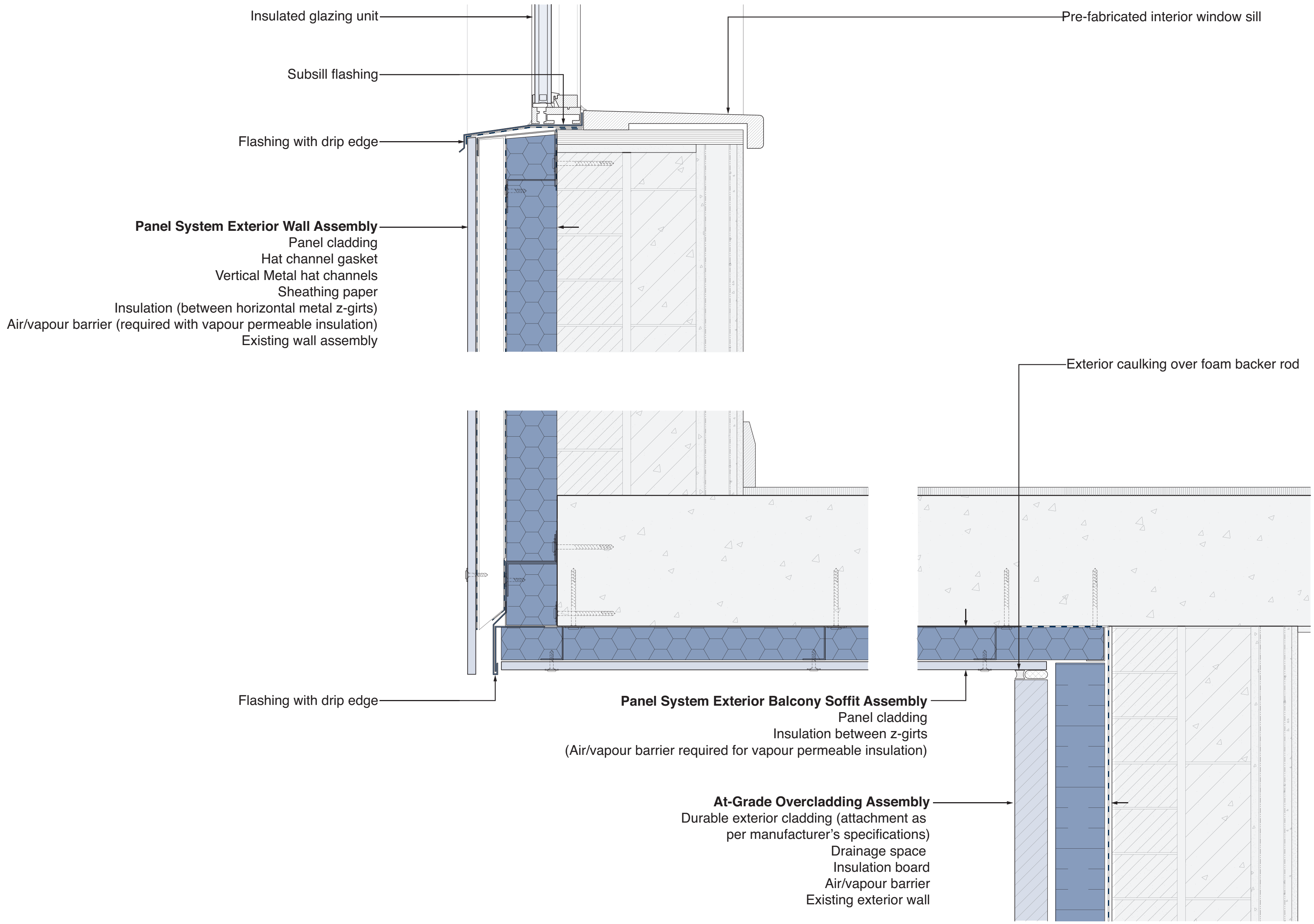


Figure A.89. The integration of the panel overcladding system at the wall and soffit with the at-grade overcladding is depicted above. The critical detail for the panel wall overcladding occurs at the intersection with the soffit. The flashing, which is required to be effective, durable and aesthetically pleasing, must be properly installed so that it is aligned with the panel soffit cladding.

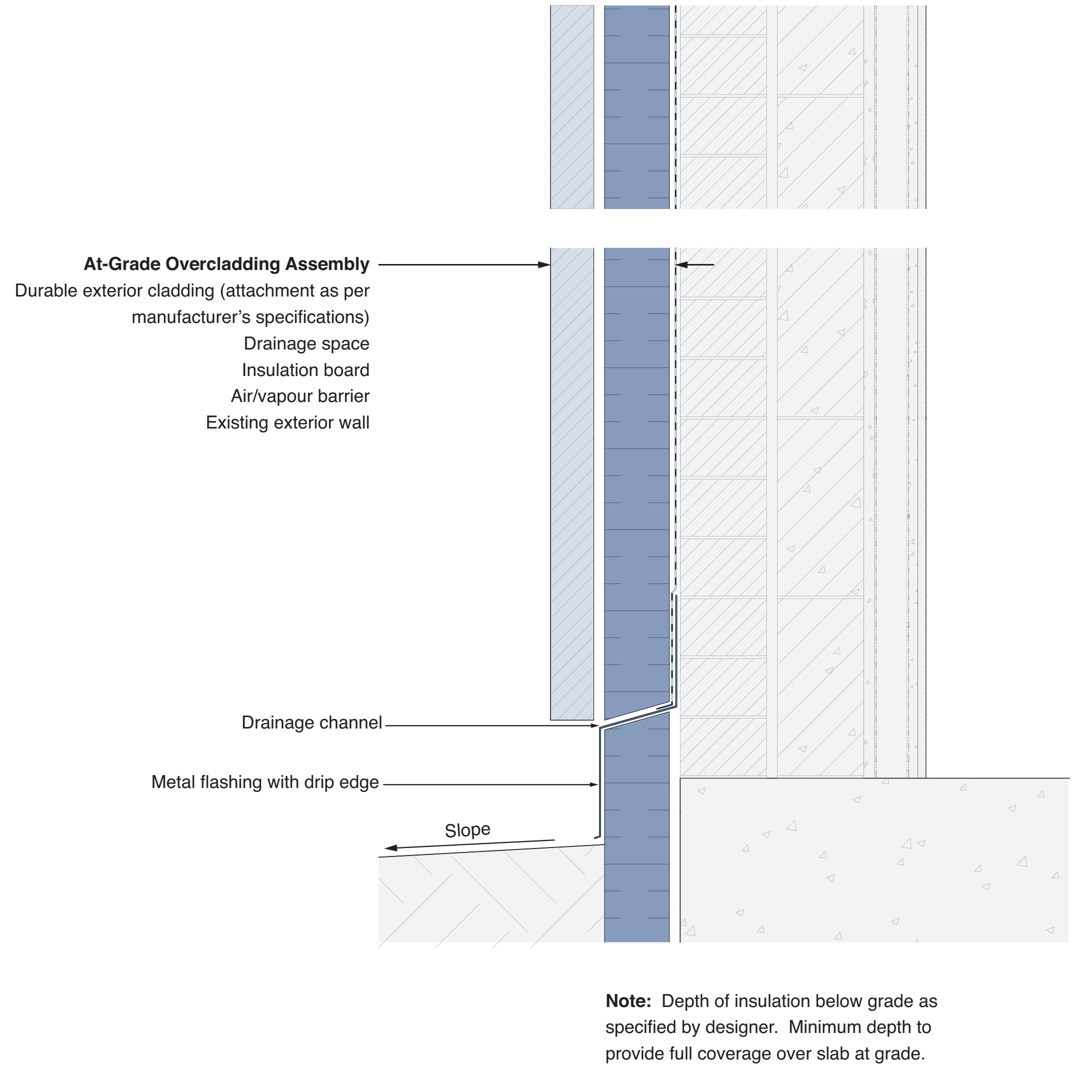


Figure A.90. A pressure moderated drain screen overcladding is depicted above. Due to the wide range of possible overcladding systems suitable to the at-grade condition, the detailing of this overcladding with the replacement windows has not been shown. The principles presented in the earlier assembly details should be observed along with manufacturer's recommended installation requirements.

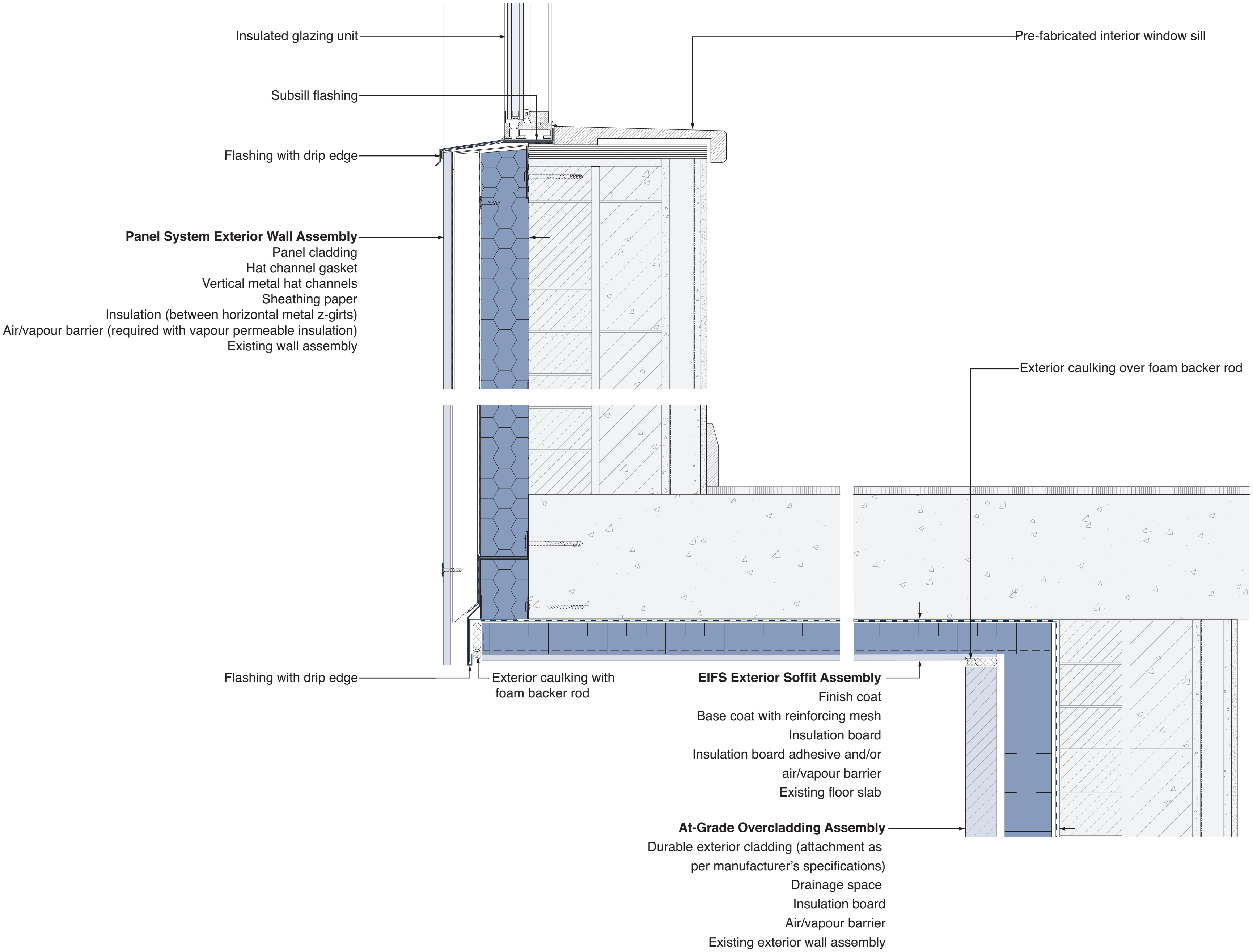


Figure A.91. EIFS soffit overcladding alternative to panel soffit shown in Figure A.89.

Appendix B – Tower Visions

The following schematic drawings provide generic insights into the visual impact overcladding may provide to tower buildings. These representations are not meant to suggest any specific design attitude. They are included only to illustrate the transformational potential of overcladding.

Design opportunities are abundant within the concept of comprehensive retrofit. Over-cladding denotes the application of new exterior finish and glazing systems. Balcony treatments, whether enclosed, wrapped, or combinations of both, provide formal design and massing opportunities. Material and colour selections are relatively unrestricted within the context of the systems illustrated in this guide. An appropriate durable material and finish however is recommended close to grade. The retrofit construction budget and life cycle costing are ultimately affected by the design decisions made and their relationship to the tectonics of the systems employed.

Some existing generic architectural attributes and considerations are noted below. Refer to the preceding sections of this guide for more information.

Windows

Punched masonry openings accommodating windows are common throughout the typology located primarily in bedroom areas, however later examples of the typology began using metal panel and window prefabricated modules which spanned vertically from top of slab to underside of slab above. This eliminated the need to provide steel lintels to carry masonry above, or employ masonry infill below the opening. Some have brick infill below only and are placed tight to the underside of the exposed slab edge above. Windows typically are anchored into the flanking masonry jams or butt up against exposed shear wall projections.

The majority of existing windows employ single glazing and aluminum frames without a thermal break. Designers should refer to local building codes for any and all window and frame related requirements (i.e., combustibility of window frame materials, area of venting, lateral loading, guards, spatial separation, etc.). It should be noted that new retrofit double or triple glazed windows with thermally broken frames will be relocated within the new building section of the overclad envelope, positioned so that the thermal break is aligned with the new insulation layer. Window relocations imply responding to a deeper interior sill, jam and head condition. Any solution must consider impacts on the inhabitants of the suite in terms of aesthetics and amenity.

Strip windows are also a common configuration occurring most often in dining and living room areas with sill heights typically ranging from 0.9 m to 1.05 m (36” to 42”) fronting onto balconies beyond.

Typical existing operable windows are sliders with outboard insect screen. Those servicing rental units often contain window stops which restrict opening size to 100 mm (4”) for safety considerations.

[Photo Opposite Page: Jesse Colin Jackson]

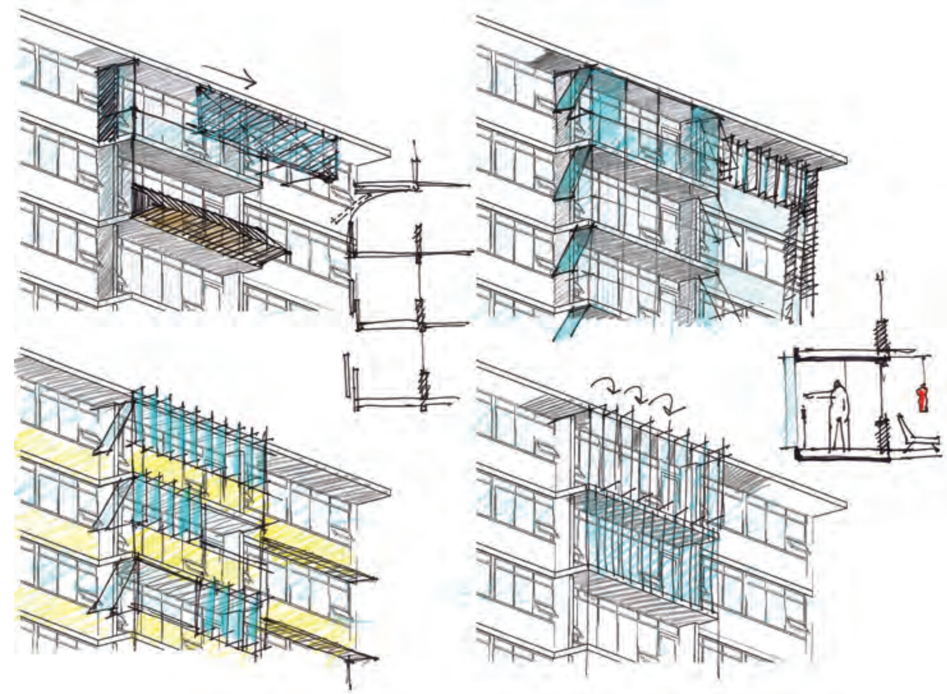
Balconies

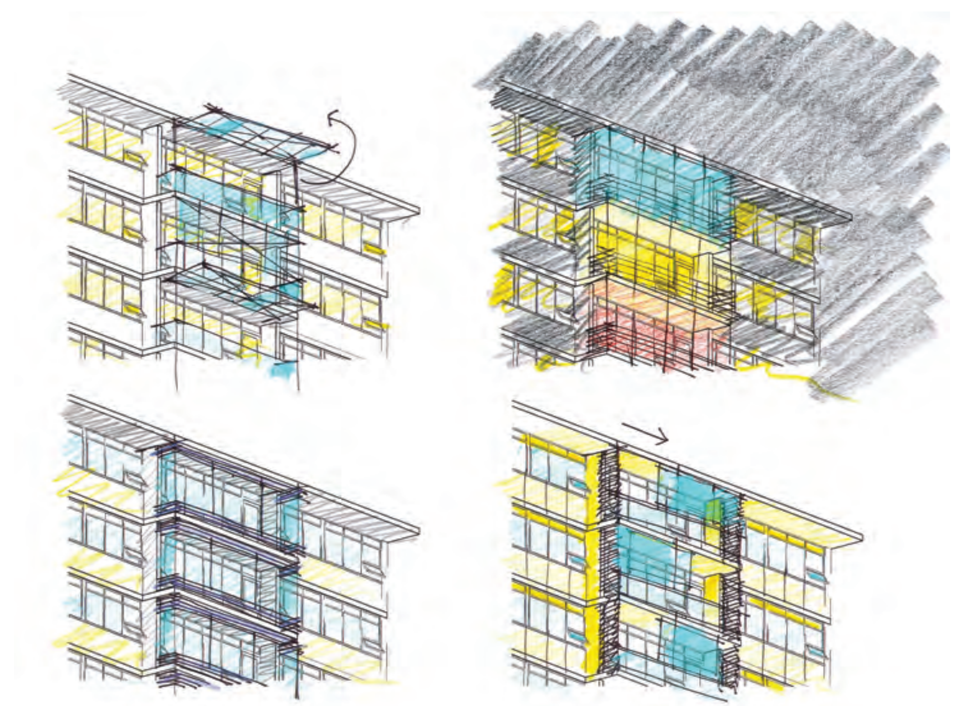
The vast majority of buildings within the typology studied contain exterior balconies. Generally these balconies are sections of the concrete floor slab that cantilever beyond the existing masonry exterior walls creating a massive thermal bridge. This document recommends either balcony enclosure, or an insulated overcladding of existing balcony slabs when open balconies are to be maintained. A completed retrofit may exhibit either or any combination of the above depending on factors ranging from building orientation to design intent.

New balcony enclosures may provide varying degrees of environmental separation responding to seasonal climatic fluctuation. Natural venting and daylighting remain prime considerations although portions of new enclosures may be insulated translucent or opaque panels used in conjunction with clear vision panels. Either type may be operable or fixed.

The size of opening in any balcony enclosure will be specific to each design. Full height openings must be provided with guards that meet applicable building code requirements. Guards may be outboard to the opening or be on the interior face protected from the elements when the opening is closed.

Existing balconies are typically configured as continuous bands which span across several units, as horizontal bands compartmentalized by projected exposed shear walls, as singular components relating to individual suites, or a combination of all of the above. When enclosing balconies which form a continuous band, it is important to observe the new required fire separations for the partitions that separate the enclosed balconies of adjacent suites.





Wall Overcladding Systems

Generic panel and EIFS overcladding wall systems have been investigated in preceding sections of this guide. They may be used individually or in conjunction. Colour choice is relatively unrestricted, however issues such as context, fading due to ultraviolet exposure, and maintenance are a consideration. The recoating of certain panel materials is more feasible than others. Specialty coatings are available for the recoating of EIFS systems which also provide opportunity to change colour. Durable materials to clad enclosed balcony interior surfaces are recommended.

A variety of materials may be employed as the exterior finish of the generic panel cladding system ranging from pre-finished metal to exterior grade composite wood panels to integrated photovoltaic solar panels. Fire resistance ratings must comply with local building codes. Panel systems may provide a higher level of adaptability once their life cycle has been reached depending on the engineered ease of panel replacement without impacting the system components behind, (i.e. system armature, insulation and air/vapour barriers).

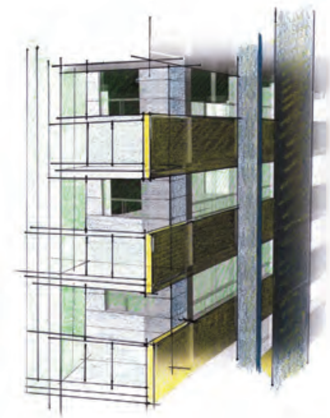
Wall cladding systems may also be utilized as cladding components of enclosed balconies. Existing exposed shear walls may be clad as part of the panel system, or if flanking an enclosed balcony, may be wrapped by the balcony enclosure spandrel material.

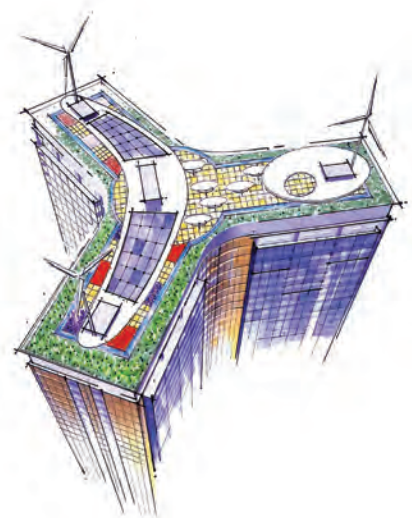
Roofs

Comprehensive retrofit provides opportunities for rooftop amenities, renewable energy systems, rainwater management and roof membrane protection.

Summary

The benefits of the comprehensive retrofit of vintage high-rise housing stock have been explored in depth throughout this guide. Most of the discussion has revolved around building science, economic and environmental concerns. This section illustrates the associated benefits relative to addressing the stigma of their declining aesthetic. Overcladding provides relatively unbounded possibilities for a rejuvenated tower aesthetic. The following photos and representations provide before and after views of potential tower transformations.





[Photos on Following Pages: Jesse Colin Jackson]


Apartments
Available