PROCEEDINGS

SUSTAINABLE BUILDING ENVELOPE DESIGN AT VANCOUVER'S 2010 OLYMPIC VILLAGE

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ADDRESSING THE BUILDING ENVELOPE

ABSTRACT

The Village at False Creek is a mixed-use development including 1,100 residential units, commercial space, and a community center. In being certified LEED® Platinum for ND and LEED Gold for NC, the Village project addresses sustainable building envelope design features, including enhanced thermal performance of wall and roof assemblies, passive design, and durability of the building envelope. One of the buildings, a 68-unit affordable housing facility for seniors, is targeting net-zero annual energy consumption. Other features of the development include 50% vegetative roof coverage and rainwater harvesting.

SPEAKER

DAVID FOOKES, PENG — MORRISON HERSHFIELD LTD. - VANCOUVER, BC

DAVID FOOKES is a principal and technical director of the Building Science Division with Morrison Hershfield Ltd. (MH) and works out of the Vancouver office as a professional engineer specializing in material and building science. Fookes has a depth of practical experience in product evaluation and specification combined with academic training in materials science and engineering. He has valuable experience in providing technical expertise to clients through design and construction review, investigation, experimentation, representation, and facilitation of seminars with regard to material design, product selection, durability use, and life cycle. MH and David provided building envelope professional review services for the Village at False Creek project as required by the city of Vancouver.

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PROJECT BACKGROUND

The Village at False Creek is a mixed-use development that comprises 1.4 million sq. ft., including 1,100 residential units, commercial space, and a community center. The neighborhood was Vancouver's Olympic Village for the 2010 Winter Games and was occupied by 2,800 athletes and temporary services at that time.

The development is certified LEED® Platinum for Neighborhood (ND) through the USGBC and LEED® Gold for New Construction (NC) for the individual residential buildings through the Canada Green Building Council (CaGBC). The village project addresses sustainable building envelope design features including enhanced thermal performance of wall and roof assemblies, passive design, and durability of the building envelope. One of the buildings, a 68-unit affordable housing facility for seniors, is targeting net-zero annual energy consumption. Other features of the development include higher than typical thermal resistances of assemblies, 50% vegetative roof coverage, and rainwater harvesting. One of the early priorities in the concept design for the village was to emphasize passive strategies to achieve human thermal comfort. See *Figure 1*.

DESIGNING A SUSTAINABLE COMMUNITY

To meet the planning requirements established by the city of Vancouver for the Southeast False Creek (SEFC) neighborhood, the design team addressed all of the various sustainability requirements and became the first project to achieve LEED® Platinum Neighborhood Development from the USGBC. The project also attained LEED® Gold certification for all of the residential buildings and LEED® Platinum for the community center through the CaGBC. The design team went through a series of integrated design workshops in which the design and consulting team (consisting of over 30 firms and organizations) worked together to envision a strategy to meet the sustainable design criteria, as well as the complex requirements of the Olympic Village.

At the outset, the design team recognized that in terms of sustainability, a building's single greatest environmental impact is its energy use. While the recent wave of sustainable building design has often failed to prioritize energy systems, it was decided that for this project, energy systems were to be adequately addressed from the start of the design process. In order to address this issue appropriately, the team decided upon an approach that looked first at energy reduction. Instead of solving the energy reduction challenge through the use of complex technological fixes, the design team preferred to create energy systems that work with the environment and the laws of nature.

PASSIVE DESIGN

Passive design became a focus of this project, as well as hydronic radiant heating and cooling supplied through a neighborhood energy utility (NEU) as the primary strategy for achieving significant energy reduction. Waste-sewer heat recovery within the NEU and radiant capillary mats within the ceilings of the units were utilized to maximize energy efficiency. In addition, passive strategies were emphasized as a means of addressing human thermal comfort. Passive design is defined as an approach to building that reduces energy loads and improves thermal comfort while reducing reliance on mechanical systems. The goals of the passive design approach could only be achieved through integrated design, wherein architects, structural, mechanical, and envelope engineers all agree on the strategy and work together to achieve the desired outcome.

Enhanced building envelopes reduce energy loss and include high-performance rainscreen claddings, continuous insulation within the roofs and walls, and high-performance glazing systems. Buildings are designed and oriented to respond to their environment: for example, taking advantage of wind patterns and harnessing the winds for use in natural ventilation. Shading devices such as deep-balcony overhangs, operable exterior shades, and horizontal and vertical sunscreens are used to control heat gain by limiting the amount of sunlight and solar radiation to the windows. Suites are designed as single-loaded through units with exterior corridors, where possible, to allow cross breeze and improved circulation of air. See *Figures 2* and *3*.

The passive design strategies incorporated into the buildings comprised enhanced envelopes, including rainscreen claddings, air barriers, continuous insulation, and high-performance glazing systems; widened stairwells and public corridors with natural lighting; and ventilation shafts through suites and exterior corridors that maximize natural ventilation and provide fresh air for occupants. Heat gain is controlled using various types of operable

Figure 1 – The Village at False Creek sustainable community.

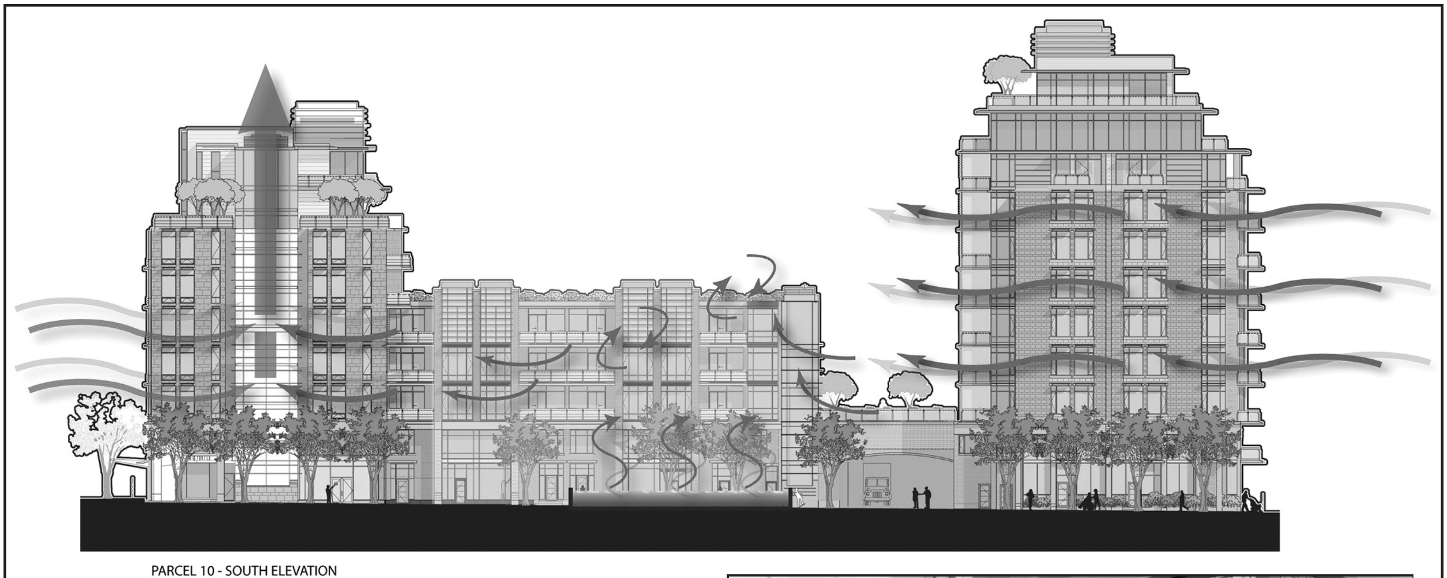


Figure 2 – Ventilation design includes through-units, operable windows, and radiant heating and cooling.

Figure 3 – Shading strategy: automated vertical shades on the west façade (left), and horizontal shades on the southern elevation (right).

and nonoperable exterior shading devices and deep-balcony overhangs. High thermal mass materials, such as concrete, were also utilized to help regulate indoor temperature. Blower testing of doors was conducted to measure the airtightness of the units. Testing was conducted to meet LEED® indoor-air quality requirements according to ANSI/ASTM 779-99.

The project paved the way for future sustainable design in Vancouver through an unprecedented agreement between the city and the developer. In order to encourage passive design strategies such as thicker walls for improved insulation, wider circulation areas, deep balconies for shading, and exterior corridors for improved air quality, the city granted area exclusions for any additional area required to meet passive design requirements. The developer was thus able to include passive strategies without forfeiting developable area.

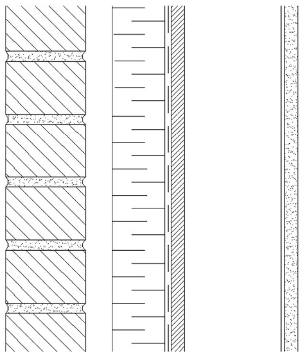
BUILDING DURABILITY

Moisture (and, specifically, rain penetration control) is the single biggest factor affecting durability in the Pacific Northwest. In order to establish the predicted service life of the building components, the designers drew from lessons learned from BC's recent leaky-condominium saga, best-practice guides, and their local experience in the climatic region of Vancouver. There are four key elements to effective moisture control: deflection, drainage, drying, and durability.

The Village at False Creek was built to meet a 50-year design service life (DSL). The 50-year DSL was established for the building and its components by the owner as identified in CSA S478, *Guidelines for Durability in Buildings*, as a minimum. Design for the building components and assemblies was undertaken so that the predicted service life (PSL) exceeds the DSL. Where component and assembly design service lives are shorter than the DSL of the building, design and construction of those components and assemblies were conducted so that they could easily be renewed. The DSL for each specific component was determined by the effect or consequence of failure. The PSL of structural components is typically required to be equal to the DSL of the building, while cladding and roofing assembly PSLs are typically required to equal half the DSL of the building. Building components were chosen with regard to their initial cost to the owners and the environment and their impact on maintenance, renewals, DSL, potential health effects, and sustainability (LEED®) implications.

A durability plan was developed including estimating the expected life of the various building envelope components and systems. The durability consultant performed design documentation reviews, mock-up reviews, and a final review of the building envelope components. Typical wall assembly performance and durability evaluations were developed for multiple assembly types (refer to *Table 1*). The durability specialist verified that other quality control tasks, such as regular field review and testing, were also performed. Quality assurance activities were also provided by the architect and the building envelope consultant. Mock-ups were constructed to ensure the performance characteristics of assemblies and to review the workmanship and quality assurance activities of the trade contractors, as well as the quality control activities of the construction manager and architect. An understanding of the workmanship and quality control activities assisted Morrison Hershfield (MH) in finalizing the PSL of materials and assemblies. MH provided a mock-up report as part of the regular site-

100% Exterior Insulated – Masonry Veneer



WALL ASSEMBLY	*THERMAL RESISTANCE*
90-mm brick veneer cladding	R - Value
25-mm air space (vented)	0.17
Brick ties	See note below
75-mm rigid insulation	15
1-mm SA membrane (air, moisture and vapor barrier)	0
13-mm glass-faced exterior sheathing	0.45
140-mm steel studs (structurally required)	0
13-mm gypsum wall board, taped and painted	0.45
360-mm total wall thickness	0.67
Air film	16.7*
TOTAL EFFECTIVE THERMAL RESISTANCE	

FUNCTIONAL ELEMENTS

Rain Penetration Control: (Most critical functional element in Vancouver)

Pressure-equalized, 1-in. rainscreen cavity. Water-shedding surface is exterior cladding, and moisture barrier is the impermeable membrane.

Air Leakage Control: Adhered impermeable membrane

Vapor Diffusion Control: Adhered impermeable membrane

Thermal Insulation: Exterior mineral wool (R-4 per inch typical)

*Note: Brick ties, shelf angles, and exposed slab expressions (balconies, eyebrows, etc.) may reduce the overall thermal resistance of the wall assembly.

DURABILITY

Performance: The assembly relies upon all of the insulation being on the exterior of the steel studs to maintain a low relative-moisture content in the exterior sheathing to keep the steel studs warm. Continuity of the moisture-shedding surface and impermeable membrane (air/moisture and vapor barrier) is required at all transitions and penetrations.

Predicted Service Life: 50+ years (depending more on functional obsolescence than ono material degradation)

Maintenance Requirements: Depends on the selected masonry, repointing, cleaning, and sealing

Weak Link in System: Fasteners and penetration details

Table 1 – Typical wall assembly evaluation.

visit report documenting elements that conform to or contradict the specifications and noted suggested action(s) necessary to correct deficiencies. The various general contractors on the project were responsible for implementing a quality control plan and confirm in writing that the building envelope construction was in general conformance with design details.

ENVELOPE THERMAL PERFORMANCE

Energy use modeling was undertaken and defined thermal performance requirements for the building enclosure assemblies. The provided requirements are shown in *Table 2*.

The architectural teams were required to design wall systems that met these thermal performance requirements in addition to all the other aesthetic, performance, constructability, and budget restraints imposed on the design process. Many of the architects were surprised to learn that the wall systems that they had used in previous high-rise residential construction fell far short of the defined thermal resistance requirement, primarily because of the influence of thermal bridges and the requirement of effective and nonnominal assembly thermal values required to be used for the energy model. They obviously had questions

Assembly	U-value (W/m2 K)	U-value (Btu/hr ft^2 F)	RSI (m2 K/m)	R-value (hr ft^2 F/Btu)
ROOFS				
MNEBC ref.	0.47	0.083	2.13	12.1
Proposed design	0.24	0.042	4.2	24
EXTERIOR WALLS				
MNEBC ref.	0.81	0.143	1.23	7
Proposed design	0.38	0.067	2.64	15
VISION GLAZING				
MNEBC ref.	3.2	0.564	0.31	1.8
Proposed design	2.34	0.411	0.43	2.4
GLAZING				
Center of glass	1.65	0.29	0.61	3.4
Overall	2.33	0.41	0.43	2.4

Table 2 – Thermal resistances assumed by energy modeling.

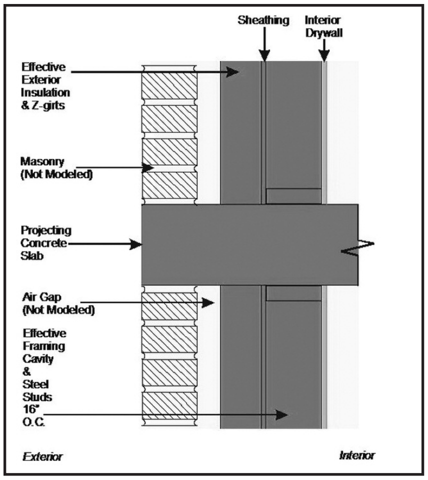


Figure 4 – Exposed slab edge.

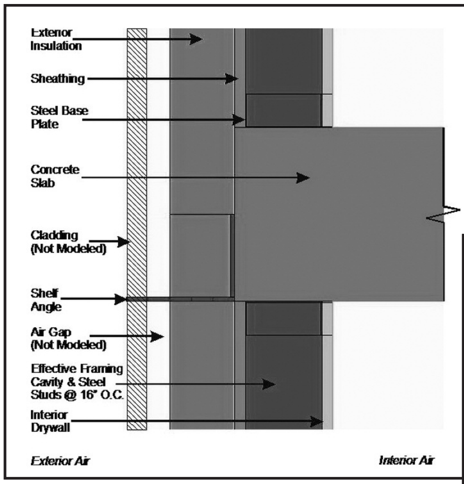


Figure 5 – Shelf angle bolted to slab.

Figure 6 – Shelf angle on brackets.

about whether they could simply modify the types of assemblies with which they had experience by, for example, adding insulation, or whether they had to make a dramatic departure from their initial design assumptions, and if so, to what?

In an effort to assist architects, the authors undertook a program of modeling typical systems with the thermal modeling computer program THERM and created a method of transmitting results in a manner that aided the decision-making process of the architects.

Reducing heat loss in Vancouver's heating-dominated climate directly relates to maintaining energy efficiency. An effective envelope, therefore, plays an important role in achieving the building's energy performance targets. Buildings at The Village were expected to achieve thermal performance targets of R-15 for the opaque walls assemblies, a U-value of 0.41 (Btu/hr ft^2 F) for the complete window system, and R-24 for the roofs. The ratio of wall to window was a consideration (60% glazing overall) in developing good thermal performance, as large windows are valued by owners and occupants, but they reduce energy efficiency. In addition, the location and continuity of the insulation within the wall assembly had a significant impact on its thermal performance.

THERMAL PERFORMANCE MODELING METHODS

Thermal performance analysis was carried out using THERM, developed and maintained by Lawrence Berkeley National Laboratory. Modeling of building envelope assemblies was completed for a number of different steel stud wall systems and cladding support scenarios. Specific assemblies that were modeled included:

- With brick bearing on slabs (*Figure 4*)
- With brick bearing on ¼-in.-thick shelf angles bolted to slabs (*Figure 5*)
- With brick bearing on ¼-in.-thick shelf angles mounted on intermittent standoff 3- x ¼-in. steel brackets spaced at 24 in. (*Figure 6*)
- With vertical z-girts on 16-in. centers (*Figure 7*)
- With horizontal z-girts on 24-in. centers
- With thermally broken vertical z-girts on 16-in. centers (*Figure 8*)
- With vertical z-girts mounted on horizontal z-girts and two layers of insulation (*Figure 9*)

All cases were modeled with both 3½-in. and 5½-in. 18-gauge steel stud framing for both insulated and noninsulated frame cavities. Exterior insulation was modeled in a range of thicknesses and for several different insulation types. For each of the above cases, modeling was also carried out to determine the effective R-value of regions near concrete slabs. These R-values

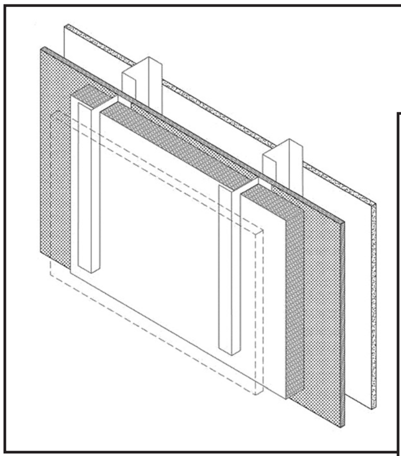


Figure 7 – Vertical z-girts.

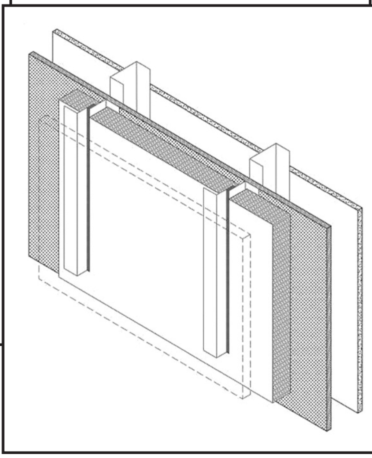


Figure 8 – Thermally broken vertical z-girts.

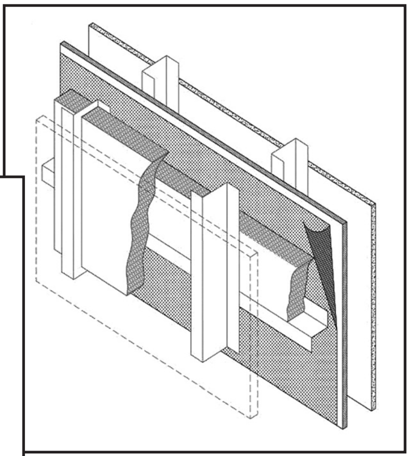


Figure 9 – Vertical and horizontal z-girts.

NOMINAL WALL R-VALUE	*INSULATION THICKNESS (INCHES)*			*EFFECTIVE WALL R-VALUE FOR VARIOUS CLADDING ATTACHMENTS*			
	Mineral Wool	**EXPS**	**Spray Foam**	**Vert. Girts**	**Horiz. Girts**	**Broken Vertical Girts**	**Vert. & Horiz. Girts**
33.1	7.0	5.9	4.9	10.6			
28.9	6.0	5.0	4.2	9.8	13.5	14.6	16.8
24.7	5.0	4.2	3.5	9.0	12.3	13.4	15.0
20.5	4.0	3.4	2.8	8.2	11.0	12.1	13.2
16.3	3.0	2.5	2.1	7.3	9.5	10.5	11.3
12.1	2.0	1.7	1.4	6.1	7.7	8.6	8.8
7.9	1.0	0.8	0.7	4.8	5.6		
5.8	0.5	0.4	0.4	3.9	4.2		
3.7	0.0	0.0	0.0	2.6	2.6		

Table 3 – Summary of effective thermal resistances for exterior insulated walls (no insulation in frame cavity; slab effects ignored).

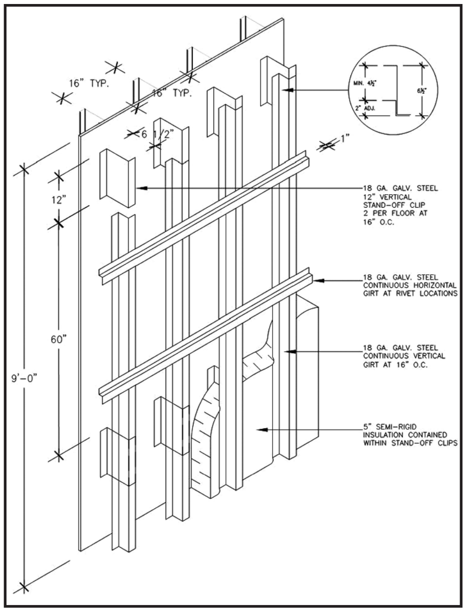


Figure 10 – Typical intermittent-layered girt panel back-up wall assembly.

were lower than those of the surrounding wall due to the thermal bridging effect of the concrete slab. Modeled slab data were averaged into the appropriate R-value tables, with the assumption of 8-ft. ceilings. The effects of different slab edge details on overall wall R-value may be seen in *Table 3*.

Important assumptions made in the modeling procedure include the following:

- Exclusion of exterior rainscreen cladding/masonry, due to the complex 3-D nature of convection and ventilation through the air gap between exterior insulation and cladding (note that it is the different connection details of exterior claddings that significantly influence envelope thermal performance, and not so much the cladding itself—either masonry or rainscreen). The contribution of either masonry or rainscreen cladding to envelope thermal performance is not greatly significant.
- Use of a 2-D model, when actual heat flow is in three dimensions. This approximation was necessary due to the 2-D limitation of the software used (THERM). As a result of the use of a 2-D model, R-values reported for wall sections containing a combination of materials represent an approximation of the actual heat-flow path and thermal resistance.
- Steady-state model (ignores thermal mass)
- Exclusion of membranes, vapor barriers, etc. from the model due to their negligible thermal resistances

See *Figure 10*.

NET-ZERO BUILDING

The term "net zero" is used to describe buildings that are designed to produce as much energy as they consume on an annual basis. Net-zero housing is a design approach that integrates five key principles of sustainable design: health, energy, resources, environment, and affordability. The Village at False Creek features Canada's first net-zero multiunit residential building. The Village project is a test bed to promote practical, cost-effective energy efficiency and on-site energy-production measures in a way that is transferable to future projects. The design team is working with the city of Vancouver and Canada Mortgage and Housing Corporation to support this project.

The net-zero building at The Village combines a high-energy-efficiency building envelope with integrated renewable energy options. The building is a 68-unit social housing project for seniors, approximately 6,900 m² in area. The building sits atop a ground-level supermarket. This structure demonstrates the application of strategies relating to human comfort, passive design, microclimate, thermal performance, and energy modeling.

The net-zero building required an ongoing integrated design process in order to meet its target. The building will substantially reduce energy consumption through the application of advanced building technologies and passive design techniques including enhanced envelope design (triple-glazed windows, R-20 walls, and R-30

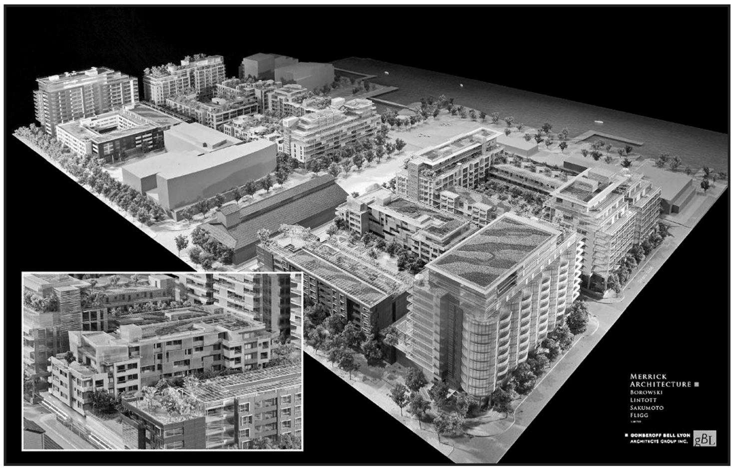
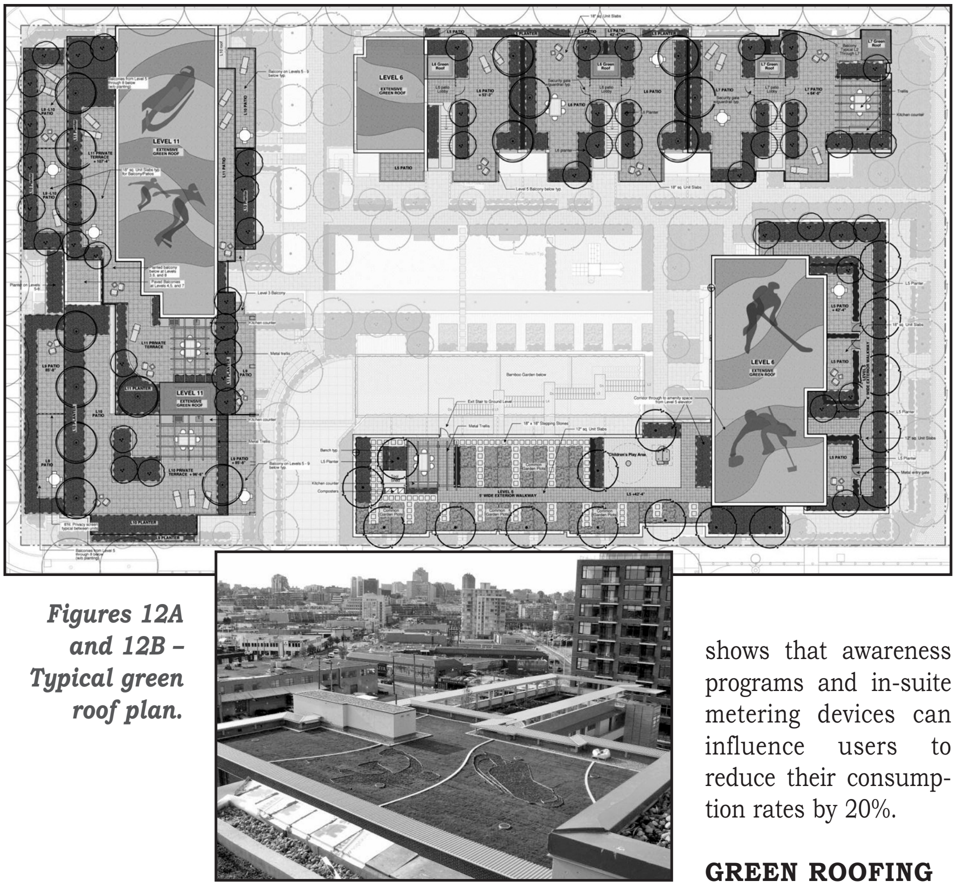


Figure 11 – The Southeast False Creek net-zero building in context of The Village at False Creek.



Figures 12A and 12B – Typical green roof plan.

roofs), rainscreens, glazing systems, and shading devices. See *Figure 11*.

CREEK SITE

The building relies on renewable energy systems to provide its own supply of clean, "green" power. Heating loads will be met using waste heat from an adjoining supermarket. The remainder of the building's energy use will be offset using two rooftop solar thermal arrays that were found to be both the most cost effective and appropriate technology for Vancouver's climate. The solar thermal collectors cover the roof of the net-zero building as well as the roof of a neighboring building.

Following occupancy, building energy performance is being extensively monitored for all buildings in The Village in order to evaluate the achievement of the project and to inform future projects. Building occupants are being educated about the building's systems and design so that they are aware of the goals for the building and how their individual choices can influence the building's performance. The Village suites will include metering devices that provide feedback on per unit energy and water consumption as well as the associated costs and greenhouse gas emissions. Research shows that awareness programs and in-suite metering devices can influence users to reduce their consumption rates by 20%.

GREEN ROOFING

Fifty-percent vegetative roof coverage was a requirement for the development of all buildings within the SEFC neighborhood of Vancouver. Green roofs are one of the most visible and easily recognizable green design features on a building and are widely known to include numerous social, economic, and environmental benefits. Third-party insurers threatened to derail the project as they were not willing to provide mandatory water ingress warranty coverage for residential buildings with widespread green roofs. The reluctance on the part of the home-warranty insurance providers stems from a number of interconnected issues. First, the use of extensive green roofs in multiple-unit residential construction lay in largely uncharted waters in our province; until recently, it was simply never done. As such, no underwriting principles exist for residential green roofing. Therefore, warranty providers don't yet know what components of a green roof (if any) should be covered by their insurance. For instance, would plants and growing media be insured or better exempt? What about irrigation systems? Compounding the matter further, no one in Vancouver wants another systemic building envelope failure as seen in the 1990s—a crisis that cost unfortunate condominium owners millions of dollars, and even more in time and grief.

The warranty providers for The Village acknowledged the roof guarantee program of the Roofing Contractors Association of British Columbia (RCABC), which covers green roofs, and required that the design of The Village green roofs follow the guidelines outlined in the RCABC Roofing Practices Manual and supporting advisory bulletins. Protected membrane assemblies with SBS modified-bituminous membranes were used on all landscaped roof areas over conditioned space consisting of two plies with a minimum of 180g/m^2 polyester or equal strength reinforcement. A root intrusion barrier with a minimum of 8-mil polyethylene was installed in a continuous plane directly above the roof membrane. Separation zones, free of growing medium and of vegetation with coarse aggregate on filter mat, were used at all perimeter and drain locations. Zones were a minimum of 12 in. wide and constructed with curbs or other physical barriers that separate and facilitate drainage. Proprietary drainage panels and grooved insulation provided a drainage layer to restrict ponding water on the roofs during periods of heavy rainfall.

Proprietary, noninvasive plantings were also required on all extensive roofs. Additionally, all intensive green roofs were to be identified as "planters." Planters on landscaped decks were to be isolated and separated from the roof membrane by 4-in. concrete curbs and covered with membrane. With that, the SEFC project green roofs received the green light. See *Figures 12A* and *12B*.

CONCLUSION

With so many architects, engineers, contractors, and subtrades involved in this large project, and with the city's goal of making this a real demonstration project for sustainability, many people became more familiar with emerging building envelope technologies. Education and the incorporation of new ideas to meet the sustainability requirements was definitely part of the project. The city wanted a high-profile project with high levels of performance using newer ideas and construction techniques. I believe this project demonstrates what can be accomplished in terms of building envelope performance and durability. It has definitely raised the bar.