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CASE STUDY: IMAGINATIVE BUILDING SOLUTIONS USING SLIM FRAMING & SLIM FLOORS/WALLS

Lemieux, D.[1,3], Tremblay, G.[2,4]
[1] Managing Director, Peikko Canada, Quebec City, QC, Canada
[2] VP Business Development, BPDL, Alma, QC, Canada
[3] dominic.lemieux@peikko.com
[4] gtremblay@bpdl.com

Abstract: This case study showcases the Luxenbourg Condos in Quebec City, QC. The three Luxenbourg condominiums are each five storeys, and 8,400 m^2 (90,000 ft^2). The challenge with this project was to have a slim-floor structure with long spans to facilitate two levels of underground parking. The developer also wished to have the building finished quickly to generate revenue earlier than a conventional construction system normally allows. All three condos use a Slim Frame System consisting of hollow trapezoidal-shaped beams and steel columns filled with concrete. The first challenge was floor depth; the project was limited in height and needed a shallow floor assembly. The project worked with a 250 mm (10 in) thick precast concrete hollowcore floor slab, with a typical bay size of 8 m x 11 m (26 ft x 36 ft). The long spans allowed for four parking stalls between each column while the shallow assembly was instrumental in meeting the height limitation. Using a slim frame system as the edge beam around the perimeter of each floor also allowed for easy slim wall precast concrete wall system fastening.

This integrated slim wall building envelope system offered unique architectural solutions including plant-insulated thin wall panels with pre-installed windows at the plant, and enhanced energy efficiency. Each balcony consisted of a "T" shaped solid prestressed concrete slab, 1.8 m (6 ft) wide with a 0.9 m (3 ft) cantilever. To minimize the thermal bridge, urethane foam was sprayed at the intersection of the balcony slab and the floor slab, and on the underside of the balcony slab within the interior living space. The corresponding top surface of the balcony slab is covered with a hydronic radiant floor heating system.

Innovation is the key to growth within the engineering and construction industries. The severity of climate change, and its accelerating implications, continues to garner greater exposure than any other time in the past. With that comes a very evident shift in demand for imaginative solutions that will contribute to an easing of these pressures in the short and long term. These solutions must meet the market demands for; resiliency, safety, energy efficiency, accelerated construction and of course aesthetic appeal and price. **This case study highlights many ingenious building solutions to create a beautiful structure that integrates resilience, safety, energy efficiency, accelerated construction and of course aesthetic appeal along with the Lowest Total Cost of Ownership.**

1 PROJECT OVERVIEW

The Luxenbourg Phase II & III are multifamily residential projects located in Quebec City, QC. The development comprises of two identical buildings, each containing 54 units with five storeys of residential and two levels of parking.

One of the primary objectives for the developer was to find ways to reduce the construction time in order to enclose the building before the winter, therefore, significantly reducing the impact of weather, and enabling interior finishes to continue during the more challenging weather conditions.

Adding to the site restrictions was the total permissible building height. To meet this restriction an innovative slim floor system was used in order to maximise the number of floors in the building.

2 INNOVATIONS

2.1 Innovation 1: Using a prefabricated slim-floor composite structure

One of the objectives of the developer was to build a non-combustible structure that would be quick to install with as little labour as possible. A new slim-floor system was developed to address these restrictions. The new system consists of composite beams and columns, and precast/prestressed concrete hollowcore slabs. The composite beams and columns are steel profiles with pre-installed reinforcement. Once these steel profiles were assembled on-site, they were filled with cast-in-place concrete to increase their strength and enhance their fire resistance.

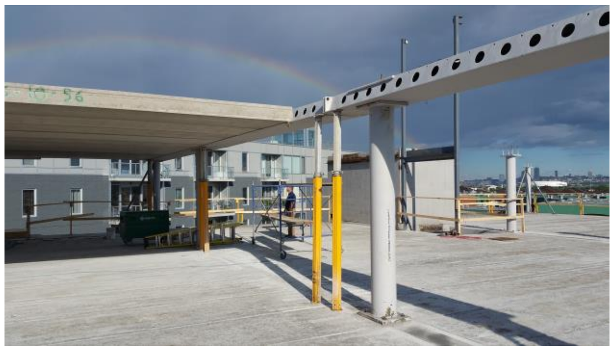

Figure 1. On-site assembly of the new slim-floor system

The use of precast/prestressed concrete hollowcore slabs minimized the on-site construction time by significantly reducing the shoring requirements. Only two shoring posts per beam were required during the erection which allowed other construction sequences to progress much faster than with conventional cast-in-place construction.

The combination of hollowcore slabs and shallow trapezoidal composite beams (called Deltabeam®) created a floor assembly of only 250 mm (10 in) thick while allowing for spans of over eleven metres. This compact floor assembly allowed the developer to maximize the number of floors per building.

2.2 Innovation 2: Accelerated construction using plant-insulated thin precast concrete walls with pre-installed windows

Weather conditions can significantly impact typical on-site construction, especially during winter. The costs of heating and hoarding buildings under construction can sometimes increase the cost of construction significantly. To avoid these additional heating and hoarding costs, the developer decided to use insulated precast concrete panels as their building enclosure. Additionally, all windows were pre-installed in the precast concrete panels before they were shipped on-site. This resulted in tremendous time and cost savings for the developer. In addition to providing a higher quality and more durable building enclosure, having pre-glazed windows resulted in less on-site labour, safer environment, and fewer material shipments to the job site.

Figure 2. Installation of precast concrete walls with pre-installed windows at the factory

The type of precast concrete wall system used in the Luxenbourg projects was called Slenderwall™. The panel's exterior wythe thickness was 50 mm (2 in) of molecularly bound Polyvinyl Alcohol (PVA) fiber and welded wire reinforced high-strength architectural precast concrete. The integrated interior frame is made of 14 & 16-gauge, G90 galvanized steel studs spaced vertically at 600 mm (2 ft) on centre. The architectural concrete is connected to the steel-stud frame utilizing stainless-steel fasteners, allowing for continuous insulation, therefore, greatly reducing thermal bridging within the walls. The frame is filled with factory-applied closed-cell foam insulation.

While this type of wall gives full architectural freedom on the exterior of the building for reveals and brick finishes, it also provides great flexibility on the interior side for wires and conduits to be installed on-site.

2.3 Innovation 3: Designing cantilever precast balconies without a thermal bridge

One of the most significant structural and building science challenges in residential construction is designing cantilever balconies without a thermal bridge. Since the concrete slab is partially inside and partially outside, eliminating the heat loss through the concrete and reinforcement is very challenging.

In the Luxenbourg projects, the thermal bridge was eliminated by using solid prestressed concrete slabs with an integrated 900 mm (3 ft) cantilever. A 50 mm (2 in) gap between the cantilever balcony and the interior slab was filled with insulation to provide the thermal break. Once the slabs were installed, urethane was sprayed under the slabs and a polystyrene foam was used over the slabs, therefore, eliminating the thermal bridge. The polystyrene was then used to anchor the pipes for the radiant floor system.

Figure 3. Thermal proofing of the cantilever balcony: polystyrene boards placed on top (left photo) and the urethane sprayed underneath (right photo)

3 LESSONS LEARNED

3.1 Lesson learned 1: "The more precast concrete prefabricated elements the better"

The only part of the exterior envelope that was not prefabricated were the corners of the building, which consisted of a field installed aluminum-framed glass curtain wall. Not only did these small sections of the envelope take longer than the rest of the building to install, they also led to unintended condensation issues after occupancy, during winter. Because of this, the developer has now decided that the next phase of Luxenbourg will have corner windows using precast concrete elements, similar to phase I. With the current labour shortage situation, there is the added benefit of eliminating the curtain wall system, and utilizing the precast concrete accelerated building construction technique that requires less on-site labour and is simpler to manage.

3.2 Lesson learned 2: Long spans = greater flexibility

The combination of precast concrete hollowcore slabs and composite beams created a large open space, giving full flexibility to the interior design team. Originally the Luxenbourg Phase II & III were intended to have units of similar areas as the Phase I. However, after a year of occupancy of the Luxenbourg Phase I, the owner realized that the monetary yield was greater with smaller units, so the design team was instructed to fit one more unit per level in the Phase II and III. Since the entire 1,200 m^2 (12900 ft^2) floor plate was supported by only six columns, they were able to add an eleventh unit on each floor without making major changes to the structure. The only change required was to add a second cantilever balcony on one of the precast solid slabs at the perimeter of the building.

3.3 Lesson learned 3: Designing precast cantilever balconies without a thermal bridge is possible

The precast concrete cantilever balconies of Luxenbourg Phase II & III were a successful improvement over the previous Phase I design that utilised an independent structure for each of the balconies. Although the first phase also eliminated the thermal bridge, it required bringing a crane back to the job site a second time, just to install balconies, which proved to be more costly and time consuming.

4 CONCLUSION

The Luxenbourg projects have been a great success because of the successful implementation of construction innovations and overall quality of the building. The next four phases of the Luxenbourg project will continue to incorporate the lessons learned and best practices from it's first three phases, but one could simply sum it up as "the more pre-planning with prefabrication the better".