Cover Story

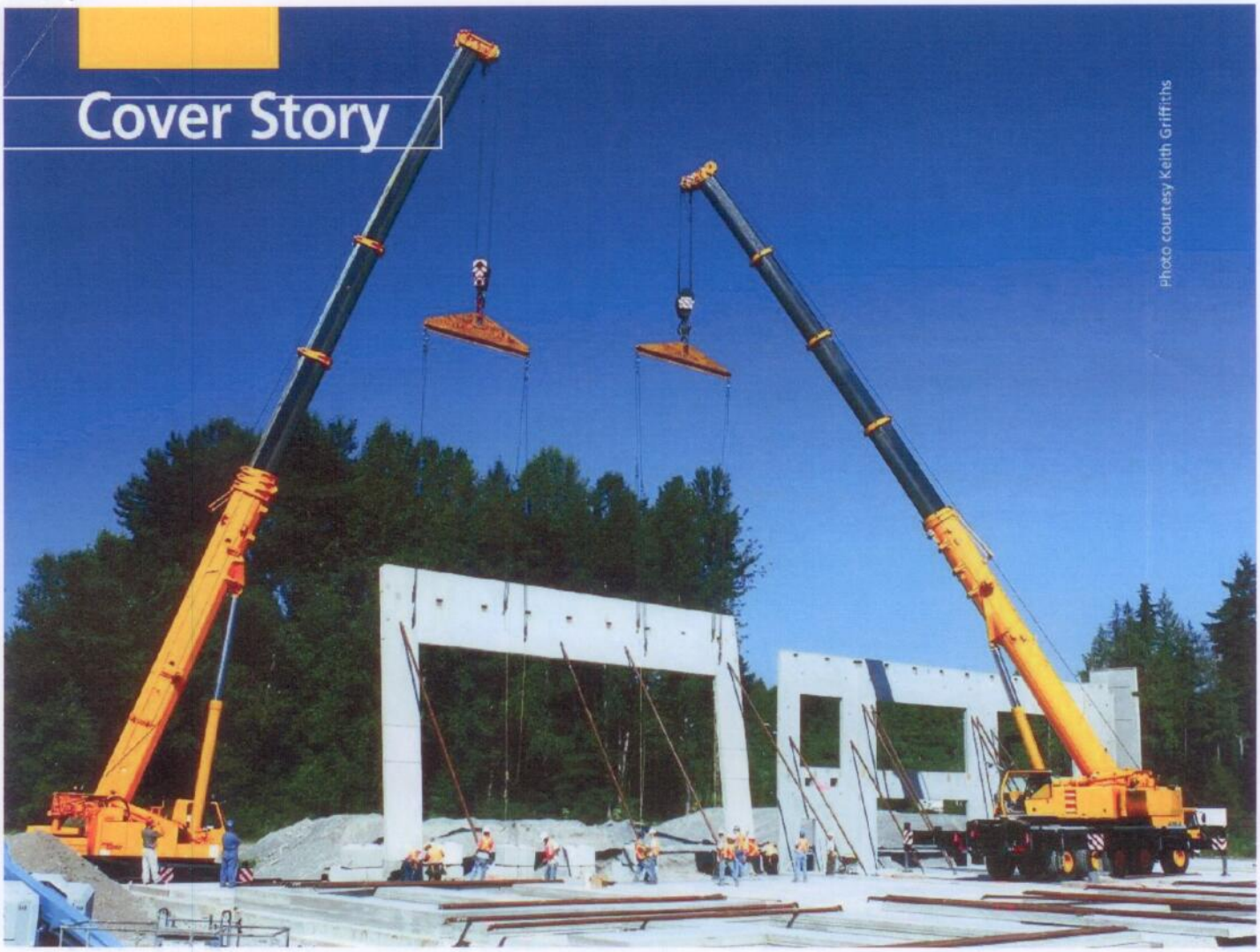

Photo courtesy Keith Griffiths

Look to the West

Tilt-up's rise in British Columbia

By Gerry Weiler, M.ASc., P.Eng., FCSCE, and Kevin L. Lemieux, M.Eng., P.Eng., Struct.Eng.

Innovative designs and new building applications have marked the last two decades of tilt-up construction in British Columbia. Thanks to technology advances, the concrete building method has experienced great strides. While its growth remains solid on the West Coast, numerous opportunities exist within the rest of Canada. Although building codes still offer certain challenges for the industry, tilt-up holds numerous possibilities for continued growth and expansion beyond the B.C. border.

The tilt-up building method grew increasingly popular on the West Coast in the early 1970s, promoted primarily by developers and design-build contractors. However, it was not until the early 1980s that tilt-up gained acceptance and credibility in the building and design communities. Its establishment in British Columbia was due to the relatively mild climate, which allowed concrete to be poured in the winter without special precautions, thereby enabling tilt-up construction to proceed year-round with no significant restrictions.

The West Coast climate offered another contributor to tilt-up's acceptance. The warm ocean current brings an abundance of rain to British Columbia, especially to coastal areas. While other building methods—such as concrete block, concrete masonry, and artificial stucco—have experienced significant problems with leaks, tilt-up has been lauded for its durability and impermeability.

Moving outside the warehouse

Initially, there was reluctance to use tilt-up concrete for anything other than low-cost, simple warehouse construction. Eventually, architects realized the potential and design flexibility they could have with the method and stepped outside the traditional box-shaped warehouse designs. As a result, bold and innovative structures were created by making effective use of the large panel shapes and openings, and employing architectural treatments such as building set-backs, reveals, special finishes, and textures.

Facilitating the architectural innovations are technological advancements that make taller, wider, and heavier panels possible. These include high-capacity hydraulic cranes, larger braces for temporary support of panels, and skilled field expertise to handle increasingly innovative projects. In British Columbia, the result has been tilt-up projects beyond the traditional light industrial and warehousing applications—schools, recreational centres, shopping malls, theatres, churches, automobile dealerships, and office buildings up to four storeys high.

Owners and developers request the method for its look, durability, relative cost efficiency, and ease and speed of construction (there is no scaffolding to erect, brick to lay, or stucco to place). Well-designed tilt-up buildings are not only very structurally sound, but also provide excellent climatic protection and seismic safety. An automatic fire rating and excellent sound-insulating properties make the method even more appealing, especially in specific market segments.

Coming in from the cold

Although tilt-up has increased its market share in British Columbia and parts of Alberta over the last 15 or 20 years, it is not prevalent outside the West (The exception is Nova Scotia, where the technique has been used for 15 years.) For much of the country, precast concrete and structural steel continue to remain steadfast, particularly in Canada's colder regions, due partly to insulative requirements. However, it has been proven insulated tilt-up sandwich panels cannot only compete with these methods, but also offer many features otherwise not easily provided.

Sandwich panels

Sandwich panels consist of 51 to 102-mm (2 to 4-in.) thick polystyrene insulation between two layers of concrete. The outside layer is typically 65 mm (2.5 in.) thick and is the first to be cast. Pre-cut sheets of the insulation are laid atop the wet concrete and fibre composite connector pins are then pushed through pre-drilled holes in the insulation. These pins are non-corrosive with very low thermal conductivity and serve the purpose of tying the outer layer of concrete to the inner layer. The inside layer of concrete is then cast directly on top of the insulation, bonding to the connecting pins protruding through.

The outer concrete layer provides the exterior finish, serves as a weather barrier, and offers impact protection for the insulation. The inner concrete layer, on the other hand, is designed to support all structural loads from the building. Typically 152 mm (6 in.)

This church in Langley, B.C., made use of tilt-up construction. The top photo shows tilt-up panel exterior walls with exposed glulam wood roof beams. The panels also form part of the interior where the concrete arches were enhanced with a stucco finish to provide a traditional theme. The church's exterior with textured stucco and brick added to enhance the exterior finish of the panels, is pictured on the bottom—proof tilt-up has moved beyond the warehouse.

Pictured here is the main entry for a three-storey office with tilt-up concrete panel walls, curved cast-in-place concrete header beam, and structural steel floor and roof framing. Recessed portions of the panels allowed exterior glazing to run continuously between the floor levels.

Photos courtesy Gerry Weiler

thick or greater, it can also serve as an effective vapour barrier on the warm side of the insulation. With proper consideration to details, thermal bridging can be eliminated. The combined sandwich panel assembly can be lifted into place with standard tilt-up lift inserts cast into the inside concrete layer.

The cost premium for sandwich panels is essentially confined to the additional cost of the 'extra' (*i.e.* outside) layer of concrete and the insulation. There is only a small increase in forming and erection costs for sandwich panels compared to conventional tilt-up; usually, the same panel sizes (in terms of height and width) can be used.

In comparing costs of tilt-up sandwich panels to plant-cast precast panels, it is important to look at all aspects rather than just the particular component. Plant-cast panels can be produced quite efficiently, but since they have to be loaded on a truck and shipped to the site, there is a significant cost component. (This also severely restricts the architectural flexibility due to shipping limitations.)

Quite often, plant-cast panels are only designed to serve as exterior cladding, and the structural load-bearing system and lateral bracing for the building has to be provided by some other means such as structural steel. This not only adds cost, but also necessitates an excessive build-out of interior wall finishes.

Blankets and warming techniques

Sandwich panels are not the only method allowing tilt-up to be used outside the warmer climes of the West Coast. Even in colder parts of the country, the use of the tilt-up system has become possible during winter through specification of temporary glycol heating systems beneath floor slabs and selective use of insulating blankets. This practice has been used successfully and economically in Alberta to place floor slabs and tilt-up panels at temperatures below freezing.

The technique involves installation of a grid of polyvinyl chloride (PVC) lines in the gravel base immediately beneath the floor slab; connected to a portable heating unit, the system circulates warm glycol, concentrating the heat solely into the concrete component (as opposed to heating the air above it). The system also protects the sub-grade from freezing.

It is important to install the floor slab as early as possible before the ambient air temperature falls below freezing. (Sometimes, only a minimum amount of slab is placed to obtain sufficient area for tilt-up panel casting purposes.) Panels are then cast atop the floor-slab casting beds and selectively heated by the glycol. Initially, the fresh concrete is covered to retain the heat from below. Hard-trowel finishing of the surface is not usually needed unless a second panel lift is to be cast on top.

If the air temperature falls below –5 C (23 F) during the process, slight frost damage of the concrete surface sometimes occurs. Although this is not encouraged, it has very little effect on the final product since this surface is on the inside of the building and will eventually be covered by insulation or another finishing material.

Once panels have cured sufficiently under the blankets (usually a four- or five-day process), the heat can be turned off. The glycol

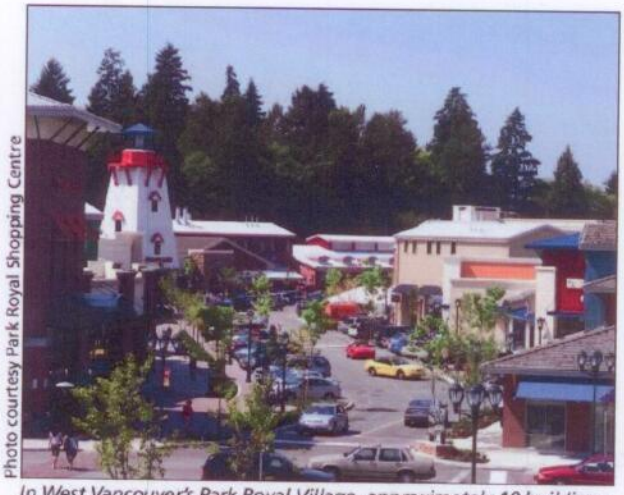

Photo courtesy Park Royal Shopping Centre

In West Vancouver's Park Royal Village, approximately 10 buildings were constructed with load-bearing tilt-up panels and structural steel roof and floor framing. The exterior surface was enhanced with various façade products such as textured stucco, metal cladding, and brick and stone facing.

Photo courtesy Gerry Weiler

Pictured here is panel for a three-storey office in North Vancouver, overlooking the city skyline. The 9 x 12-m (30 x 40-ft) panel weighs nearly 45,000 kg (100,000 lb).

Photo courtesy Gerry Weiler

Tilt-up construction was used to build this two-storey office/warehouse building in Coquitlam, B.C.

system can be set up so heat is directed to selected areas only to conserve energy. On completion, the underslab lines are usually disconnected from the heating unit and abandoned.

Reaching new heights

Although tilt-up has matured in Western Canada, the technology is far from standing still, thanks to advances. For example, there is a stigma the building method cannot be used to construct buildings higher than a few storeys. This was because of restrictions with temporary bracing of high panels. Earlier brace systems had relatively low capacity and limited lengths, and it became prohibitively expensive when bracing panels over 12.2 m (40 ft) high.

There was also a limitation in cranes that could erect taller panels. As panel height increased, so did the weight. At the same time, however, the length of the crane boom had to increase, reducing the maximum lift weight achievable. Consequently, there was a reluctance to construct three- or four-storey buildings in tilt-up, not because of technological limitations, but because of the perceived economic disadvantage.

Today, the available capacity of mobile cranes for tilt-up is two to three times what it was 20 years ago. Further, a new generation of high-capacity braces, connecting anchors, and lifting inserts have been developed, making multi-storey buildings more economical.

The argument against tall tilt-up structures has been disproved by recent projects, such as a six-storey self-storage facility in Vancouver, where some of the panel shear walls and the elevator shaft exceed 22 m (72 ft) high. Another example of a tall B.C. tilt-up structure is a new cultural centre starting construction in Chilliwack—the main atrium area will consist of several panels extending more than 24.4 m (80 ft) above grade. Office buildings with three or four storeys and film studios with 15.2-m (50-ft) high panels are now becoming commonplace in the province.

A good, traditionally underused tilt-up application is for heavy industrial facilities. Not to be confused with warehousing applications, the industrial market includes manufacturing plants and bulk distribution facilities where there is a need for very durable buildings with hard walls and good structural flexibility to accommodate various applications.

Tilt-up has been used in a number of industrial projects in British Columbia, including plastics manufacturing plants, lumber storage facilities, fertilizer plants, and chemical plants. The authors' firm partnered with a B.C. construction company to complete a concrete-pipe-manufacturing facility project using the method. A unique aspect of this particular project was very little ready-mix concrete had to be brought in to the project, because the facility required its own concrete plant for use in manufacturing the pipes.

This was set up in the early stages of the construction schedule to supply concrete for most of the foundations, the floor slab, and the tilt-up walls. An enclosed concrete tunnel system for the high-humidity, pipe-curing line was constructed entirely with site-cast panels, including the concrete slab on top, which was designed for second-floor warehouse storage.

As tilt-up has achieved acceptance in British Columbia, the method has also brought changes in the way structural engineers prepare their drawings. While there has been a trend in recent years by many designers to avoid providing dimensional information and other detail on their drawings and to rely on the contractor to determine details onsite, drawings for tilt-up buildings must be fully detailed.

These buildings are a combination of components, and everything must be specified on the drawings before going into the field for the project to run smoothly.

Code challenges

Across North America, many structural engineers who design with tilt-up have expressed concern that building codes have traditionally ignored this type of construction. (Seismic issues have been particularly challenging.) However, the Canadian Concrete Code Committee and the Cement Association of Canada (CAC) now provide specific design requirements and guidelines for tilt-up, alleviating some concern.

Seismic design

A research program, currently underway at the University of British Columbia (UBC), looks at the performance aspects of tilt-up buildings subjected to seismic forces. This is an area traditionally given very little attention in engineering research, but has recently come to the forefront due to the relatively large amount of interest and activity in the construction market of Western Canada. The focus is on trying to evaluate interaction between the very stiff tilt-up wall panels and other building components, particularly steel bracing systems and the steel deck roof diaphragms. The research will also delve into the suitability of the connection systems tying these buildings together.

Southwestern British Columbia and southern Vancouver Island have the highest seismic risks in Canada. Ottawa and parts of Quebec are also in a relatively high-risk zone. The 2005 *National Building Code of Canada (NBC)* re-addressed seismic provisions for buildings, adopting a new focus for seismic design where the expected ground accelerations due to an earthquake have increased by more than a factor of two in some areas. At the same time, the code expects buildings to be more resilient. One of the results of the code changes is many areas in Canada not previously required to consider earthquake forces (*e.g.* Toronto) must now do so.

Seismic requirements have changed the focus on structural design priorities. Simply making the building strong enough to resist a prescribed force is no longer adequate. It must now have a combination of minimum strength and the ability to absorb significant deformation without collapsing. The application of these principles is a major problem facing tilt-up design engineers, and it will take much more research and experience to adequately develop this.

Unsurprisingly, *NBC*'s near-doubling of seismic design forces has had a ripple effect on tilt-up building design, where smaller openings in the panels, increased amounts of concrete, more interior shear walls, and added connections have become more common. The West Coast has many of the same seismic issues as California, and professionals involved with the Canadian codes have worked with the Tilt-up Construction Association (TCA), American Concrete Institute (ACI), and other U.S. organizations to help address their concerns. The authors' firm is working with UBC and Montreal's McGill University and École Polytechnique in actively pursuing more seismic-related research for tilt-up

Photos courtesy Gerry Weiler

Mall montage: From Linens 'n Things to The Shoe Company, it seems as if everybody's shopping with tilt-up. The top two photos feature retail complexes in Coquitlam, B.C., and the bottom two show malls in Langley, B.C. Concrete offers advantages for power centres.

buildings. The result of such studies is expected to be more economical buildings and simpler designs that will meet the new code requirements.

Energy efficiency

Code changes to produce more environmentally responsible buildings have also influenced tilt-up design. A case in point is the *British Columbia Building Code (BCBC)* that recently introduced an amendment in an effort to increase energy efficiency for many building types. This will affect some buildings more than it will others, but tilt-up warehouses and manufacturing facilities are particularly impacted.

The code calls for new insulation standards for all commercial and industrial buildings, but the question remains over how to meet the new requirements while ensuring tilt-up is still economical and efficient. Unfortunately, the consequences of the revised *NBC* have not yet been completely worked out. It is unclear whether the requirements call for minimum levels of insulation for particular components (*e.g.* tilt-up walls) or are looking for overall system performance where additional roof insulation can be used to avoid wall insulation in some cases.

To address the new insulation requirements, more insulated sandwich panels may have to be used. As with any type of construction that has not been used extensively in a geographical area, the cost of sandwich panels will likely come down as the design and construction community becomes more familiar with the details and techniques.

The future

In the future, tilt-up promises to expand into new building applications while strengthening its presence in existing markets. Expansion into the heavy industrial market is likely, as opportunities for growth remain plentiful in this area. Other applications, such as car dealerships, can benefit from both the concrete esthetic and the clean, hard surface needed for service areas.

Opportunities are expected in applications such as parking structures, small restaurants, and other commercial properties. Hotels hold huge potential for tilt-up, and even two to three-storey residential projects may see more tilt-up work in the future.

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