High Performance Facilities

Challenging the Conventional with Prefabricated Precast Concrete Construction

Presented by:
Malcolm Hachborn, President,
M. E. Hachborn Engineering Limited
Agenda:

1. High performance and environmental attributes …
   … and why we need them
2. Prefabrication - Precast ‘Kit of Parts’ – architectural and structural options
3. Process – prefabrication of precast elements
   • Structural / architectural components
   • Aesthetic features – color, form, texture
   • Modular construction
4. Residential facility applications – case studies
### High Performance Attributes and Benefits of Precast

<table>
<thead>
<tr>
<th>VERSATILE</th>
<th>EFFICIENT</th>
<th>RESILIENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aesthetic Versatility</td>
<td>Site Efficiency</td>
<td>Structure Durability</td>
</tr>
<tr>
<td>Virtually any color, form, and texture</td>
<td>Minimal site disturbance</td>
<td>Long service life</td>
</tr>
<tr>
<td>Facade integration</td>
<td>Negligible waste</td>
<td>Barrier wall system</td>
</tr>
<tr>
<td>Historic compatibility</td>
<td>Accelerated construction</td>
<td>Functional resilience</td>
</tr>
<tr>
<td><strong>Structural Versatility</strong></td>
<td><strong>Energy and Operational Efficiency</strong></td>
<td><strong>Multi-Hazard Protection</strong></td>
</tr>
<tr>
<td>Load-bearing envelopes</td>
<td>Scalable performance</td>
<td>Storm resistance</td>
</tr>
<tr>
<td>Economical sections</td>
<td>Thermally efficient</td>
<td>Earthquake resistance</td>
</tr>
<tr>
<td>Long open spans</td>
<td>Low life-cycle costs</td>
<td>Blast resistance</td>
</tr>
<tr>
<td><strong>Use Versatility</strong></td>
<td><strong>Risk Reduction</strong></td>
<td><strong>Life Safety and Health</strong></td>
</tr>
<tr>
<td>Recyclable</td>
<td>Design assist</td>
<td>Indoor environmental quality</td>
</tr>
<tr>
<td>Deconstructive reuse</td>
<td>Reduced detailing and trades</td>
<td>Passive fire resistance</td>
</tr>
<tr>
<td>Adaptive reuse</td>
<td>Enhanced profitability</td>
<td>Meets FEMA 361</td>
</tr>
</tbody>
</table>
Environmental Footprint of Materials

<table>
<thead>
<tr>
<th>Material</th>
<th>MJ/kg</th>
<th>kgCO₂/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement</td>
<td>4.6</td>
<td>0.83</td>
</tr>
<tr>
<td>Concrete</td>
<td>0.95</td>
<td>0.13</td>
</tr>
<tr>
<td>Masonry</td>
<td>3.0</td>
<td>0.22</td>
</tr>
<tr>
<td>Wood</td>
<td>8.5</td>
<td>0.46</td>
</tr>
<tr>
<td>Wood: multilayer</td>
<td>15</td>
<td>0.81</td>
</tr>
<tr>
<td>Steel: Virgin</td>
<td>35</td>
<td>2.8</td>
</tr>
<tr>
<td>Steel: Recycled</td>
<td>9.5</td>
<td>0.43</td>
</tr>
<tr>
<td>Aluminium: virgin</td>
<td>218</td>
<td>11.46</td>
</tr>
<tr>
<td>Aluminium recycled</td>
<td>28.8</td>
<td>1.89</td>
</tr>
<tr>
<td>Glass fibre composites</td>
<td>100</td>
<td>8.1</td>
</tr>
<tr>
<td>Glass</td>
<td>15.7</td>
<td>0.85</td>
</tr>
</tbody>
</table>

ICE version 1.8a
Hammond G.P. and Jones C.I
2008 Proc Instn Civil Engineers
www.bath.ac.uk/mecg-eng/sert/embodied/
What is Resiliency

This term is defined by the globalization-focused Rockefeller Foundation as: making people, communities, and systems better prepared to withstand catastrophic events—both natural and manmade—and able to bounce back more quickly and emerge stronger from these shocks and stresses.
Resilient – Tornado resistance

Number of tornadoes per year per 10,000 km²

- less than 0.5
- 0.5 to 0.9
- 1.0 to 2.4
- 2.5 to 4.9
- 5.0 to 7.4
- 7.5 to 10
- greater than 10
High Performance Facilities

Impact / storm resistance – wind-borne flying objects (tornado, hurricane, etc.)
Prefabrication

- **Precast Concrete** was one of the first materials to be prefabricated (or modularized) in the construction industry.
- Bridge beams,
- Double-T and Hollow core slab modularized floor systems
- Precast stairs added to the prefabrication list
- Introduction of cladding panels to the prefabrication offerings so walls systems could also be erected as modules.
Prefabrication

- **Precast Concrete Wall Panels** continue to evolve
- Introduction of insulated panels increased modularization -
  - entire wall system (building envelope) installed as one piece
  - natural stone or brick incorporated into a panel, wall system is further modularized
  - precast manufacturers installing windows in panels in their production facilities - modularize the entire wall assembly, enclosing a structure very rapidly.
Precast Components - Basic building blocks – “Kit of parts”

A. Load-bearing architectural spandrel
B. Exterior column
C. Double-tee or Hollowcore plank
D. Interior column
E. Inverted tee beam or composite beam
F. Shear wall
G. Stairs
High Performance Facilities

Precast components (custom vs. commodity products)

<table>
<thead>
<tr>
<th>Architectural Precast:</th>
<th>Structural Precast/Prestressed:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Architectural Wall Panels</td>
<td>Hollowcore Floor &amp; Roof Planks</td>
</tr>
<tr>
<td>Double Wythe insulated Wall Panels</td>
<td>Double Tees</td>
</tr>
<tr>
<td>Radial Panels</td>
<td>Structural Wall Panels</td>
</tr>
<tr>
<td>Spandrel Panels</td>
<td>Columns</td>
</tr>
<tr>
<td>Architectural Cladding</td>
<td>Beams</td>
</tr>
<tr>
<td>Column Covers</td>
<td>Spandrel Panels</td>
</tr>
<tr>
<td>Prison Cells</td>
<td>Horizontal Lite Walls</td>
</tr>
<tr>
<td>Modular Units</td>
<td>Raker Beams</td>
</tr>
<tr>
<td></td>
<td>Bleachers / Tread &amp; Risers</td>
</tr>
<tr>
<td></td>
<td>Bridge Girders</td>
</tr>
<tr>
<td></td>
<td>Piling</td>
</tr>
</tbody>
</table>
‘Total Precast’ Concrete Structures:

Solutions which integrate architectural and structural precast concrete components - to create the building structural frame and panelized façade or enclosure …

(sometimes in the same components).
Using precast concrete components together as a complete structural system creates a design in which the whole is greater than the sum of the parts.

For example, combining precast prestressed hollowcore plank or double tees with precast beams and columns creates a durable, fire-resistant structure that is quick to erect and cost efficient in part due to the compressed construction schedule.
Double tees provide excellent roof and flooring units, spanning considerable distances and providing quick erection to close in a structure more quickly. They can expand a designer’s options for floor layouts by eliminating interior columns and offering excellent fire resistance and durability.
High Performance Facilities

Prestressed hollow core plank

Hollowcore planks can span long distances and be erected quickly, helping to finish floors so interior trades can begin work faster. They provide acoustical and impact dampening.

They also offer strong fire resistance, especially when used together with an all-precast framing system.
High Performance Facilities

Integrated precast components

- Beam
- Column
- Exterior Shear Wall System
- Interior Shear Wall System
- Double Toes

Structural system components

Total precast system – Cross Wall

Total precast system – Exterior Wall
Concrete components are fabricated (cast), prior to (pre) being installed in their final location on the project. PREFABRICATED, PRECAST

Precast/prestressed concrete products are plant produced architectural and structural building components.

They are manufactured in quality controlled, CPCQA - Certified facilities where critical variables including mix design, consolidation, curing conditions, finishes and tolerances can be closely monitored and controlled.

This allows for safe, modularized construction with high-finish quality which exceeds tilt-up or cast-in-place concrete at the job-site.

**Buzzwords:** Prefabrication, Offsite Construction
High Performance Facilities

Prefabrication – precast concrete plants

- Storage yard
- Raw materials storage
- Manufacturing facility (long line)
- Batch plant

Precast Plants are manufacturing facilities
Precast Concrete – batched of durable, high-strength concrete - water, sand, cement, aggregates and admixtures, mixed in controlled factory conditions to required design strengths - typically at least 35 MPa or 5,000 PSI.
In prestressed, precast concrete components, high-tensile strength steel strands (1860 MPa or 270 ksi+) are pretensioned and the concrete placed around them and allowed to cure.
The prestressed component is created by pulling the steel strand along the length of a bed or form and locking it into place at the fixed abutment end. Then the individual strands are elongated or stressed by hydraulic jacks to achieve the tension level required for the design specifications.
High Performance Facilities

Hollow Core (extruded)
High Performance Facilities

Structural beams …
High Performance Facilities

Wall panels - steel forms, wood forms and custom molds

Steel wall panel form

Custom wood wall panel form
High Performance Facilities

Wall panels – two basic types

**Single Wythe Wall Panel**
- Load bearing or non-load bearing
- Versatile - available in essentially any shape, colour and finish
- **Rain, air, and vapor barrier** (perfect barrier vs. rain screen)

**Double Wythe Insulated Wall Panel**
- Architectural surface
- Exterior wythe
- Rigid insulation (CI)
- Interior wythe = Thermal Mass
High Performance Facilities

Enclosure systems

Thermally efficient enclosures provide:
• Protection against moisture
• Continuous insulation, air and vapor barriers

<table>
<thead>
<tr>
<th>Material</th>
<th>Average leakage, cfm/ft² of surface at 0.3 in. H₂O</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solid precast concrete section</td>
<td>No measurable leakage</td>
</tr>
<tr>
<td>Extruded polystyrene insulation</td>
<td>No measurable leakage</td>
</tr>
<tr>
<td>½” fibreboard sheathing</td>
<td>0.31</td>
</tr>
<tr>
<td>Uncoated brick wall</td>
<td>0.31</td>
</tr>
<tr>
<td>Uncoated concrete block</td>
<td>0.41</td>
</tr>
<tr>
<td>1” expanded polystyrene</td>
<td>0.93</td>
</tr>
</tbody>
</table>

Barrier Wall (Two Stage Joint)
High Performance Facilities

Thermal mass

Thermal Mass Effect:

- Absorbs outside and inside heat and slowly releases
- Delays the onset of peak heating or cooling loads
- Reduces energy consumption and peak demand
- Enables downsized HVAC systems and smaller initial investment
- Reduces indoor temperature fluctuation to improve occupant comfort
Double wythe insulated wall panels

Thermally efficient envelope system – for higher energy efficiency and additional advantages.

These panels consist of a layer of precast that is placed into the form (architectural surface down in form), after which the insulation is placed and another layer of concrete is added.
High Performance Facilities

Double wythe insulated wall panels
High Performance Facilities

Double wythe insulated wall panels

- Concrete
- GFRP shear grid
- Wire mesh
- Insulation
Double wythe insulated wall panels

- Thermal efficient wall system
- Single trade, reduced materials + risk
- Barrier wall, face-sealed
- Continuous insulation, air & vapor barriers
Aesthetic versatility:

Through on-going enhancements to the fabricating processes, architectural precast can be produced in almost any Color, Form or Texture.
High Performance Facilities

Precast Concrete – versatile, plastic …

Composed of unique concrete mixture(s) with certain physical, architectural, and structural properties:

- Cement - white and/or gray
- Aggregates / Sand - define color, texture
- Pigments - if required to augment color
- Water and chemical admixtures
Color: Applied Coatings (stain)

PRECAST CONCRETE BUILDS ON...
Unlimited Aesthetics
High Performance Facilities

Color: Applied Coatings  Stains

Pick any color you want; there’s virtually no limit.
High Performance Facilities

Color Texture with Stains and Form Liners
Color & Texture with Stains and Form Liners used on the Interior
Molds - sculpture, form liner, lettering

Fig. 3.5.20 Recessed lettering.

NÇOIS

Close-up skew of lettering on a precast concrete panel with right angle shoulders.

Square shoulders of the V-recessed letter makes a sharp shadow, but the broken surface of the back causes an uneven shadow making the letter appear irregular.

Recessed letters with right angle shoulders and flat back stand out clearly, because the shadow cast by the outer angle against the flat back is strong and regular.
High Performance Facilities

Form – custom column and radial wall panel molds

Column cover form

Radial wall panel form and product
High Performance Facilities

SCAD Museum of Art - load-bearing, insulated precast building enclosure, historic adaptation...
Savannah, GA
Architect: Sottile & Sottile; Lord, Aeck & Sargent; Dawson Architects
High Performance Facilities
High Performance Facilities

Form – custom wood & fiberglass molds

Key to economy is repetition ...
Aesthetic options for buildings are ever-changing as developers and owners compete to attract the public with distinguishing features. Form liners and concrete colour stains can translate your designs into three-dimensional building facades.
Form liners

Fig. 3.5.11 Some of the available form liner patterns.
Stone textured form liners

Natural stone expressions can be achieved with custom-molded, flexible elastomeric form liners that use actual stone as the master pattern. Once cured, the flexible form-liner pieces are placed into the precast mold. The resulting pieces are sandblasted or acid-etched to create a remarkable stone-like appearance.
High Performance Facilities

Unity Christian High School
Hudsonville, MI
Architect: GMB Architecture & Engineering
High Performance Facilities

Artistic form liners

Kohl Center, Univ. of Wisconsin, Nichols-Johnson Pavilion
Madison, WI
Architect: HOK and Heinlein & Schrock (Ar)
High Performance Facilities

Texture – clay product-faced (thin brick)
High Performance Facilities

Texture – clay product-faced (ceramic tile)
Texture – stone veneer-faced

Terry Sanford Institute of Public Policy
Duke University, Durham, NC
Architect: Architectural Resources Cambridge Inc.
High Performance Facilities

Dubiski Career and Technology High School
Grand Prairie ISD, TX
Architect: Corgan Associates Inc.

$45 million, 260,000 SF
59,425 SF - 288 pieces of precast insulated panels of varying sizes

Best School
2012 PCI Design Awards
Texture – multiple finishes (double wythe insulated wall panel)

Precast plant forming/finish exercise
w/ PCI Foundation sponsored Precast Design Studios
at UNC Charlotte and Clemson University.
Modular construction is a process in which a building is constructed off-site, under controlled plant conditions, using the same materials and designing to the same codes and standards as conventionally built facilities – but in about half the time

Modular Building Institute
ABC is a paradigm shift in project planning, design, procurement, construction and commissioning that seeks to gain the benefits of minimizing the impact of on-site construction by placing a higher priority on **PRECONSTRUCTION, PREFABRICATION**, and **MODULARIZATION** processes and systems.
Accelerated Building Construction (ABC)

Modular and prefabricated elements for construction are used to replace traditional, inefficient on-site, in situ construction methods.

Modular and prefabricated elements address critical groups of activities that are either considered Fundamental or Comprehensive in nature.
This ABC ‘shift’ allows for the realization of intrinsic benefits such as:

- Lowering capital costs,
- Shortening overall timelines,
- Improving site safety and security,
- Gains in project quality,
- Enhancing project durability,
- Offering more opportunity to incorporate new technologies into the project,
- Reducing long-term operational costs,
- Limiting social impact costs, AND
- Limiting environmental impacts in the short and long term.
ABC improves:
• Complete design integration,
• Site constructability,
• Site security during construction,
• Total project delivery time,
• Project-zone safety for workers and the public alike,
• Project durability, AND
• Access to leading technologies for buildings.
Accelerated Building Construction (ABC)

Habitat 67 MONTREAL, QC. - COMPLETED 1966 Habitat, the central feature of Canada's Expo '67 World's Fair, is well known for its “original, bold design, which showcased construction techniques unheard of at the time.” In 2009, Habitat was designated as an historic monument by the Quebec government. Total Precast Modular construction.
High Performance Facilities

Hilton Palacio del Rio Hotel, San Antonio, TX ...

ABC has history on its side.
Accelerated Building Construction (ABC)

The ABC process was touted by the Modular Building Institute (MBI) for this hotel built in San Antonio TX in 1968.

Only one short block from the convention center stands a 21-storey example of modular construction that has become a part of the historical landscape of San Antonio, as well as an early and ever-present example of the engineering feats modular construction can undertake.
Accelerated Building Construction (ABC)

The Hilton Palacio del Rio Hotel is proudly pointed out to visitors as a ‘modular’ hotel with a history worthy of landing it on the famed Riverwalk boat tour for review and discussion. This original story written in 1968 about the project upon its construction. Interestingly, the piece is timeless in that the application could happen just as easily today.
Recent (ABC) Projects

Toronto South Detention Centre
Recent (ABC) Projects

Toronto South Detention Centre

Modular precast concrete jail cells before stacking

Cells were delivered with beds, desks, and sinks and toilets pre-installed
Recent (ABC) Projects

Innovationen Tower, a 125-metre high tower formed of stacked precast concrete modules, has completed as part of an OMA-designed housing development in Stockholm.
Recent (ABC) Projects

Innovation Tower completed in 2018
High Performance Facilities

Precast Concrete Case Studies
Case Study: **Champagne - Quarry Calgary, Alberta**

- Champagne - Quarry Park in Calgary is a recent example of what is happening in many parts of the country where former industrial lands along waterways near city cores are being rejuvenated as self-contained communities.
- In this case, over 162 hectares [400 acres] of a former brownfield site in southeast Calgary near the Bow River, which once included a gravel extraction facility for Lafarge Canada, has been master planned as a mixed-use community with many amenities.
Case Study: Champagne - Quarry Calgary, Alberta

The project comprises five individual four- and five-storey buildings located on top of two levels of interconnected underground parking. The architecture is French provincial, which is supported with details such as natural stone and steep-pitched roof lines. It has balconies and large windows, and arched detailing over the top windows.

Colour palettes, construction materials and specifications differentiate this property from any other in Alberta. Precast was chosen for its resilience and inherent fire resistance - both being key requirements for this property. The interior uses long-span concrete hollowcore floor slabs supported by precast concrete shearwalls.
One Forty Nine is a seven-storey total precast apartment building consisting of (73) one & two bedroom units ranging from 530 to 800 square feet. The city of Hamilton required the building finishes to match the surrounding properties therefore a stone & brick formliner was proposed for the project. The end result is a modern building with a traditional historic look.
Total precast was an economical solution for this project due to the tight site restrictions and access. Furthermore, the erection timeline was far quicker than the traditional superstructure with a brick and stone veneer. One entire level (9,000 square feet of precast hollow core floors & 7,600 square feet of precast walls) was erected in just five working days.
FWBA Architects worked with precaster to replace the traditional building method of this care facility with an innovative total precast concrete building solution. Since its inception, the project has been a rewarding journey of integrated design, collaboration, value engineering and cross-functional brainstorming meetings. The structure, supplied by Armtec, is comprised of architectural double wythe insulated wall panels, solid interior wall panels, precast columns, stair stringers, steel Deltabeams and hollowcore floor and roof slabs.
Case Study; St. Teresa Place Supportive Living Facility Calgary, Alberta

This building method facilitated a fabrication and installation schedule of mere months – starting with precast production in June, precast installation starting in August and completion by the end of November.

This aggressive schedule is very much in line with the province of Alberta’s commitment to building an inventory of 2,000 continuing care beds as soon as possible. Building these facilities with traditional construction materials would not be possible under these tight and accelerated schedules. Total precast construction provides a state-of-the-art solution for continuing care needs by delivering a safe, fast, sustainable and resilient building.
Case Study; St. Teresa Place Supportive Living Facility Calgary, Alberta
The Onyx at Barrel Yards, Waterloo
High Performance Facilities

The Onyx at Barrel Yards, Waterloo
In comparison to a similar nearby traditional project also under construction, the Barrel Yards Precast Concrete Project started six months later and finished four months earlier, which greatly reduced construction and financing costs.
QUESTIONS

Precast Concrete Builds on ... Accelerated Building Construction (ABC)

For more information: www.cpci.ca