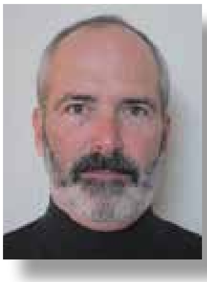
High Performance Precast: Integrating Structural and Envelope Systems

— By Degan Hambacher, P.E.

Maximizing the value of high-performance Total Precast Systems starts with understanding how to best organize the design and optimization process.

High-performance structures integrate and optimize several attributes on a life-cycle basis. This often requires the use of high-performance materials and systems. Precast concrete serves as a high-performance material and system for many reasons, especially due to its ability to serve both structural and architectural purposes at the same time. This provides a host of benefits, including reductions in materials, time, and costs while increasing usable interior floor space. Additional precast concrete attributes include fire, storm, and blast resistance; ability to resist earthquakes; and increased thermal performance, durability, and versatility in aesthetic and structural design.

Precast concrete structural systems, sometimes referred to as Total Precast Systems (TPS), have been successfully used over the past 50 years in almost every project type, from offices and retail centers to multi-family and institutional structures.



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Tucker High School, in Tucker, Georgia, used a total precast system including columns, beams, double-tees, stairs, and insulated wall panels to complete this 340,000 sq. ft. project. Photo credit: Photo courtesy of George Spence, Metromont

Basically, a TPS integrates the structural and envelope systems, sometimes referred to as core and shell, hence integrating architecture and structure. Structurally, precast concrete not only resists self-weight and lateral loads but also transfers and resists primary vertical loads, such as roof and floor loads. Architecturally, it offers versatility in aesthetic design options while also providing thermal performance and resiliency for the building's façade.

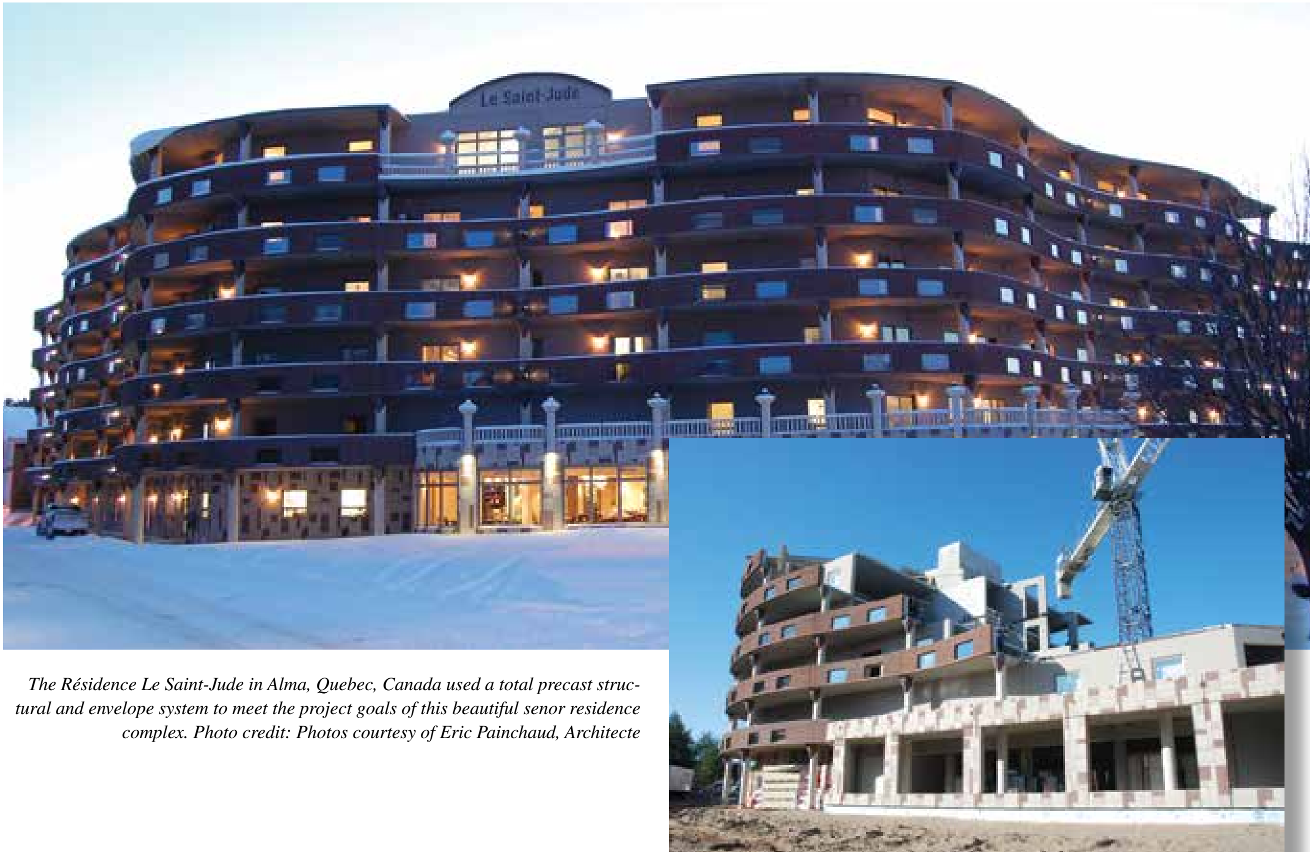
Aligned with BIM, IPD

Since the earliest days, TPS design compelled designers to reverse the traditional approach of Schematic Design (SD), Design Development (DD), Construction Documents (CD), and Construction Administration (CA), moving much of the CD effort related to core/shell to the SD phase. This change allows vital information to be collected sooner so decisions can be made earlier in the process, optimizing the design while saving time and money.

This is in-line with today's trend toward increased use of Building Information Modeling (BIM). More information is provided earlier in a project and then assembled in a model to identify challenges or concerns before construction actually begins. Modeling and BIM tools enhance the value available to designers when creating TPS projects.

It has become fairly common to bring key stakeholders to the table early in the design process. Owners are learning that this generates tremendous value and opportunity by allowing key contractors and subcontractors to optimize projects by taking advantage of each other's experience and expertise.

Examples include teams that work together to achieve LEED certification for projects or Integrated Project



The Résidence Le Saint-Jude in Alma, Quebec, Canada used a total precast structural and envelope system to meet the project goals of this beautiful senor residence complex. Photo credit: Photos courtesy of Eric Painchaud, Architecte

Delivery (IPD) approaches. This concept has long aligned with the use of TPS and fits well with the philosophy. Champions of this approach assimilate requisite talents and experience early in the process, developing and utilizing tools that allow for the creation of accurate and precise imagery during the SD phase of a project. Precast concrete manufacturers serve as an excellent resource to assist design teams in these early phases of design.

This early input maximizes the optimization of the three core aspects of a project: cost, time, and quality. It also helps identify any key requirements, concerns, or challenges early in the project, so they may be addressed before it becomes expensive to do so. Involving operations expertise in these discussions also provides great benefit.

Creating Value During Planning

High-level project planning can now precipitate the onset of conceptual design in parallel with high-level planning decisions being finalized. Resourceful inputs from this early design effort and operational input strengthen higher-level decision making. The goal is to capture added value at this stage and advance the project schedule. However, significant time can be lost if the finalization of financial/planning decisions cannot run in parallel with the commencement of the design process.

Key project design parameters and unique or special circumstances should be flushed out and carefully addressed as the team begins early SD efforts. For example, project location can present important system challenges, such as wind, earthquake, and special soil conditions. Project planning may generate onerous vertical-system requirements, such as heavy storage, vehicle loading, or heavy mechanical, electrical, or plumbing systems. Special security requirements may also include blast considerations. Knowing that some of these critical requirements are in play can add value in the early stages of SD work.

Foundation concepts based on soil observations, site conditions, and civil review should be available, and may present ways to increase the savings. For example, piers provide opportunities to integrate the precast system as grade-beam elements. Imagine the basic difference working with vertical panel elements as opposed to horizontal panel elements. Vertical elements requiring structural support at ground level would generate spread footings or grade beams. If the architecture can be accommodated with a horizontal panel concept, it is possible these panels could span across piers, omitting cast-in-place concrete grade beams.

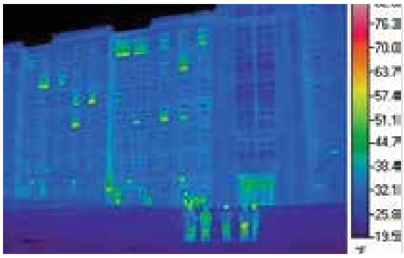
Precast foundation wall systems can accommodate a variety of excavation and soil scenarios, although the manner in which these systems are conceived will vary depending on the circumstances of each project. Early understanding of unique soil/site and foundation challenges reduces wasted design effort and helps leverage value creation.

As plan layouts begin to take shape, function usually defines interior space requirements and the location of cores, anticipated story heights are established, and floor-framing concepts are determined. For TPS, an opportunity to increase value relates to careful study of the basic dimensioning and layout, especially an efficient use of floor framing. A TPS often allows greater open spans and a reduction in intermediate columns or supports relative to steel or cast-in-place. This allows for greater versatility in how a building's floor space can be used, or adapted for future use.

Specific attention to maximizing the

Catholic University of America, Opus Hall left the interior side of the precast envelope system exposed providing a durable, mold-resistant, interior finish. This approach also helps the structure take advantage of the thermal mass properties of precast concrete. Photo credit: Photo © John Cole 2009 / Image provided by Little

Continuous, edge-to-edge insulation is often used in precast concrete wall systems meeting ASHRAE requirements and helping to improve overall energy performance. Photo credit: Photo courtesy of Gate Precast Company



Thermal imaging validates that there are no thermal bridges in this precast concrete envelope system. Photo credit: Image provided by Little

design capacities of the structural elements is also of importance. Imagine a two-bay rectangular structure that requires one additional floor-framing piece in each bay at each end to close out the requisite interior space dimensionally. In a four-story structure, this could result in a swing of between $50,000 to $100,000 in overall costs.

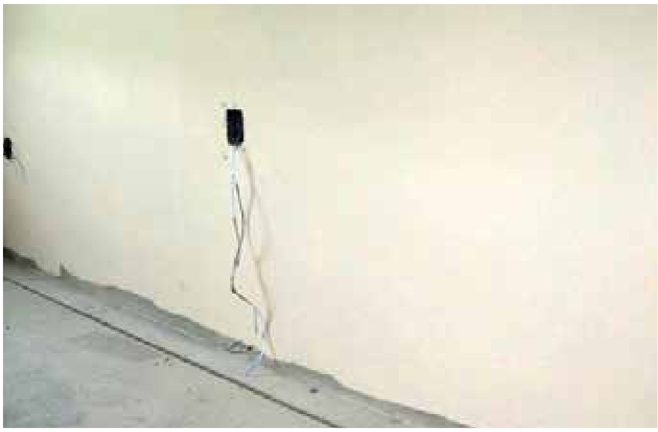
Opportunities to create walls will materialize in designing elements such as cores, usage separation, and shell development. With a basic layout in hand and an understanding of special loading circumstances and fire-separation requirements, the load-carrying capacity of walls can be studied in parallel with building-envelope requirements.

Integration of TPS

TPS provide opportunities for aesthetics to be designed for both external and internal sides of the envelope system. Often, the interior side of precast concrete sandwich wall panels is designed to be exposed and serve as the interior finish. This provides a durable interior surface while reducing waste materials, improving sound attenuation, and eliminating the potential for mold. It also improves the project's ability to take advantage of the thermal mass benefits associated with precast concrete.

Optimization of heating, venting, and air conditioning (HVAC) equipment based on the thermal mass of the precast concrete is important. Mass walls essentially provide a greater effective R-value, which allows for a reduction in heating and cooling loads relative to a standard non-mass wall structure. It also allows for smaller HVAC equipment, reducing first costs.

Many TPS use continuous, edge-to-edge insulation, which is required by most energy codes. These walls can also serve as a vapor barrier. Since precast concrete provides an air bar-



IlOften TPS incorporate part of the MEP systems such as electrical conduit, ductwork, or radiant heat into the panels and elements helping to save time and reduce work onsite. Photos credit: Image provided by Dukane Precast

rier as well, this effectively integrates the air, moisture, and heat management of the envelope system into the precast concrete. In addition, combining the architectural façade with the structural system reduces the need for additional connections. This also reduces thermal bridges in an envelope system.

Mechanical, electrical, and plumbing (MEP) systems are a large part of any project and therefore a critical element of SD. Early and extensive coordination needs to include the key core shell requirements, any challenges including vertical and horizontal system requirements, and the best layout for efficient MEP system delivery, clearances, and human-conveyance systems.

Value-added coordination at this stage may include designing repetitive MEP details into the TPS development. For example, piping, drains, and supports can all be cast into the precast concrete, which saves time and resources onsite. In some projects, the HVAC delivery systems have been included within the TPS envelope (utilizing framed spaces in lieu of ducting). Also, if roof loads are increased in specific areas related to MEP equipment support, this should be provided in the TPS roof design. Additional topping or reinforcement can be used to address these needs.

Coordination between TPS and MEP can result in major savings and improve the overall financial success of a project.

TPS Structural Options

The next step is to determine the best approach to vertical and lateral load resistance. A TPS can be designed as simple or special shear-wall structures. They can also be designed as basic frame systems or take the shape of special moment-resistant frames.

Incorporating the perimeter shell system into the lateral structural system may provide additional value. Imagine an architectural skin comprising window box–type architecture. Many times, these are conceived as cladding systems or simply vertical load-bearing systems. In these situations, interior cores, frames, shearwalls, or a combination of these components typically are provided.

Given these internal solutions are isolated to minimize impact on interior space planning, loads tend to concentrate, requiring additional concrete and steel for element design, as well as foundations to resist overturning. Diaphragm design can also become more onerous, as it must span and connect the cores and shearwall elements.

These challenges are readily resolved if the architectural precast envelope system also serves as part of the structural system. By including the perimeter architectural precast as part of the lateral system in the SD phase, concentrated lateral loading is minimized, and internal cores, frames, shearwalls, and diaphragms can be made more efficient.

TPS can utilize an exterior loaded wall system. These are essentially "punched- window" type walls that can be used as exterior shear walls. Specific attention to more common shear-wall type structures allows design teams to utilize intermediate versus ordinary shear-wall designs. For example, most precast shearwall structures, conceived in SD/DD/CD phase of design, are ordinary, or R=3 for load generation (where 'R' is the response modification factor used in seismic design).

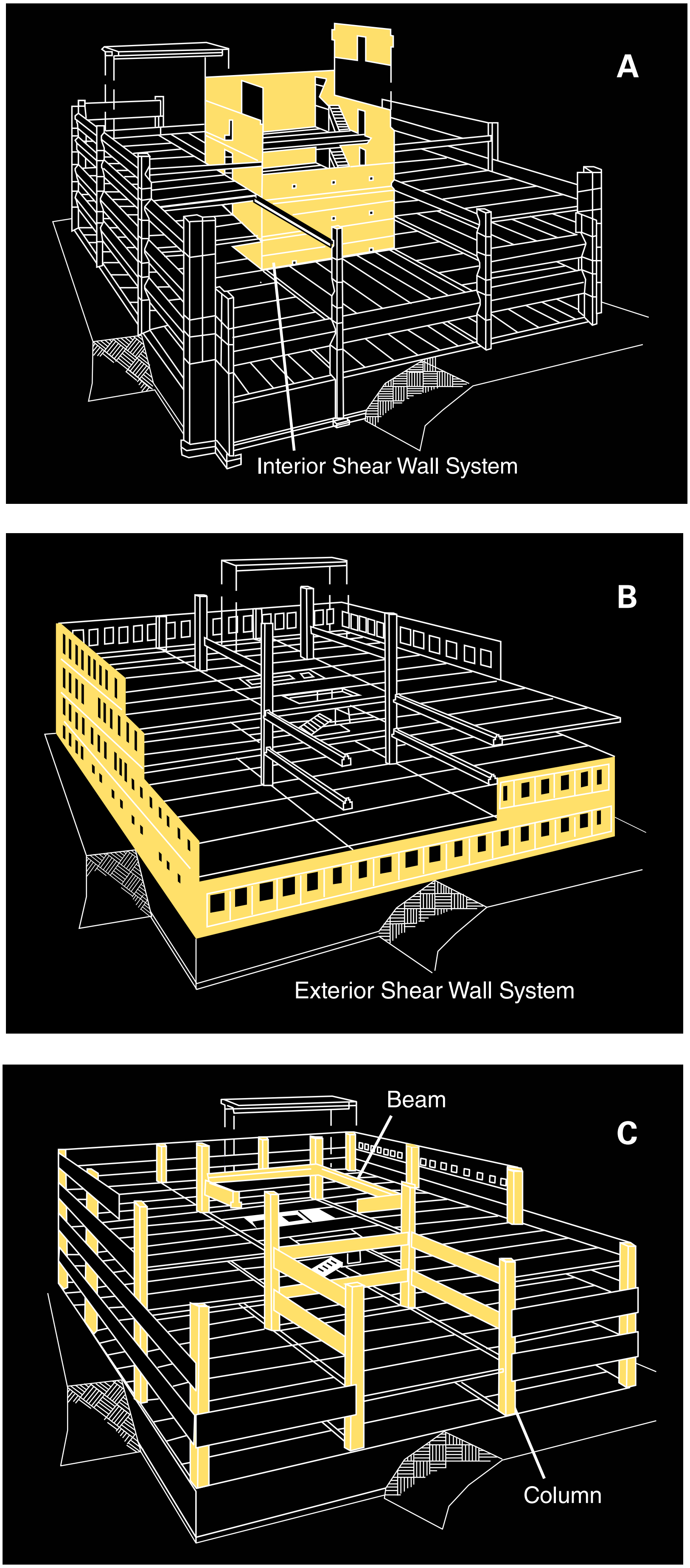
With some prior understanding of precast system requirements to generate intermediate shearwall designation (not a stretch, nor of measurable cost impact in my experience), the design effort can proceed with R=4 for load generation. This reduces overall lateral loads for seismic design by 25%, as R occupies the denominator in load calculations. This facilitates a more efficient assessment of all lateral system loading, including the foundations.

Precast can also be used in traditional framing systems using a beam and column approach. Often, the envelope system will consist of spandrel panels, but other configurations could also be used. In this approach, shear forces are still resisted by internal shear walls or the core(s) of the structure.

Special hybrid moment frames have been constructed in TPS. They provide lateral stability to extreme earthquake events, incorporating some of the exterior-shell architecture and returning the structure to the original shape and dimensions following a significant event. These systems are accepted in building codes and perform very well.

TPS Aesthetic Benefits

As these decisions are being made, architectural and functional designs should also be progressing in parallel, generating specific inputs to the core/shell system development. Precast concrete provides incredible aesthetic versatility in color, form, and texture. This offers the designer a wide array of options, from exposed concrete to thin-brick and other traditional finish materials. These can also be combined into one panel, reducing detailing, joints, and the number of trades



These diagrams show examples of the versatility of precast structural systems: (A)–interior shear wall system, (B) - exterior shear wall system (C) – rigid frame system. Photo credit: Images by Ed Derwent, PCI

onsite. The Precast/Prestressed Concrete Institute (PCI) offers extensive resources on this subject.

Virtual 3D mockups (VMUs) can be of great value for this design process. Providing the requisite design expertise on the TPS team, combined with virtual imagery through VMUs, enhances the team's ability to collaborate and finalize key aesthetic and functional challenges in early SD stages over normal design processing. More robust physical mockups, which can be beneficial to projects, can follow and mimic these virtual cousins.

As the design/construction team moves to finalize SD and move into DD/CD planning, the TPS team accelerates. Armed with the above information, in a high-quality model format, final choices for a precast concrete supplier can be solidified, and shop-drawing efforts can be scheduled to run concurrent with DD/CD efforts.

Scheduling leverage with TPS allows for CDs to be finalized and issued while precast fabrication is in final stages of planning. The entire team benefits from this as a result. More precise and accurate input on the core/shell system is at the design team's fingertips, while the precast shop-drawing development accelerates support to the design team. These more thorough and accurate early inputs allow the design team to finalize issues related to the TPS and core/shell, reducing the amount of work required to produce the construction documents.

The effort roughly outlined above provides the design team with the opportunities to include significant areas of value in the continuing DD/CD efforts. Much of what's been noted can be readily integrated into the SD phase of planning and design. The results of this leveraged effort are generous input on the most efficient structural systems, coordinated MEP, and integrated core/shell architecture.

In my 30 years of practice in this rather specialized field, I have witnessed fabulous success stories where the team utilized the TPS method of design and construction. Total Precast Systems offer an incredible array of opportunities to optimize projects saving time and money, while increasing the delivered value to project owners. ■

For more information on these or other projects, visit www.pci.org/ascent.

The MGM Grand Hotel and Casino in Las Vegas used a precast concrete structural and envelope system to create the world's largest hotel at that time.
Photo credit: Photos courtesy of FDG