Composite Precast Concrete Sandwich Wall Panels:

Get More From Your Wall System Using Less

By Blake Johnson, PE

Precast concrete insulated sandwich wall panels, or sandwich wall panels, are composed of two concrete panels, or wythes, separated by a layer of insulation and connected by wythe connectors. These panels can be broken into two primary design categories: non-composite and composite. This article defines composite and non-composite design, reviews the evolution of the sandwich wall panel, and discusses the value added to projects when using composite design.

The basic variance between composite and non-composite designs is the ability for both wythes of the sandwich wall panel to act structurally together. In a non-composite sandwich wall panel design, each wythe works independently of the other. This requires that one "structural" wythe be thick enough to support the load criteria for the wall system while the "architectural" wythe is connected to it via a relatively flexible wythe connector. In a fully composite design, both sandwich wall panel wythes work together structurally through the life of the panel, sharing load between the wythes via relatively stiff wythe connectors. When the wythes work together across the insulation, there are significant gains in façade efficiency, which will be reviewed later in this article.

Figure 1 shows three different wall design configurations that would provide nearly the equivalent structural capacity of an 8-in.-thick solid concrete panel. It is important to note weight variance per square foot of each section. The composite sandwich panel wall design shown has a 40% reduction in weight when compared to a pin-type non-composite sandwich and a 25% reduction to a fully solid wall while providing a continuous insulation layer. The weight reductions are directly tied to the utilization of less concrete in the system using a fully composite wythe connection system. This is an especially important factor when considering the efficiency of the façade and its long-term high thermal performance.

Sandwich wall panel use in the United States dates to the 1960s when the use of precast/prestressed concrete became commercially available throughout the country. Initial panel designs were non-composite that used a thick structural wythe and a thinner architectural wythe. The structural wythe was sometimes hollow-core slabs, double tees, or single tees.

Initial composite panels utilized solid areas

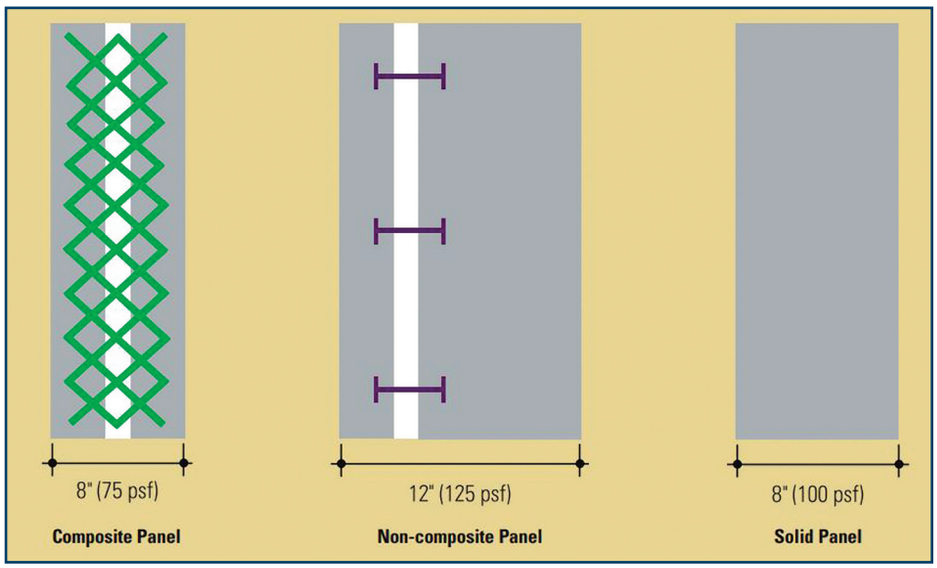

Figure 1. Three different wall-panel configurations with roughly equivalent structural capacity. Note: psf = lb/ft²

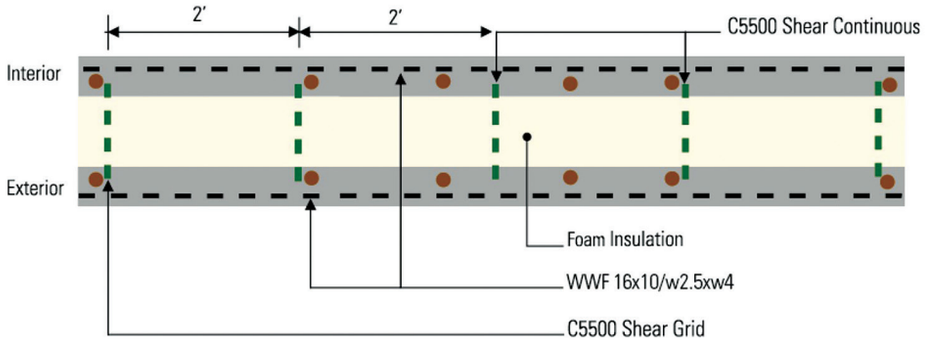

Figure 2. Typical section for a composite carbon-fiber wythe connection system for precast concrete panels.

of concrete to create the stiffness for the load transfer. These solid zones created issues with thermal bridging between the inner and outer wythes. With the advent of new wythe connectors, the solid zones were able to be eliminated while allowing for thinner flat wythes on both sides of the insulation. In the late 1980s, non-composite wall panels were developed using non-metallic ties. These ties significantly increased the thermal efficiency of the sandwich wall panel but utilized a non-composite design, which has significant downsides to project costs and logistics. Carbon-fiber grid was introduced into the sandwich panel market in 2003, by a national partnership of several leading precast concrete manufacturers to provide the first fully composite sandwich wall panel that still meets, or exceeds, today's ASHRAE 90.1 standard. **Figure 2** shows a typical section for a fully composite carbon-fiber wythe connection system.

When beginning to design a composite sandwich wall panel, there are several key criteria that should be considered, including:

- Owner's aesthetic needs
- R-value of the wall system
- Structural considerations
- Regional shipping impacts
- Jobsite impacts

Fully composite sandwich wall panel designs have a wide range of aesthetic capabilities, from a basic as-cast gray concrete finish, to embedded terra cotta panels, to digital imaged patterns using technologies such as graphic concrete which allows digitally printed images to be transferred into panel surfaces using high-resolution retarder images. **Figure 3** shows the level of detail available using graphic-concrete technology. From the composite perspective, with a focus on weight, it is important to consider any variances in wythe thickness due to reveals or form liner that may impact the structural capacity of the section and may require thickening, or added weight, to meet the structural requirements.

R-value requirements of building façades have continued to increase since the first significant code change in 1986 due to the impacts of the United States oil embargo. Since then, thermal efficiency criteria have continued to increase as awareness around the impacts of energy consumption increases. The latest developments in ASHRAE 90.1, including continuous insulation or edge-to-edge insulation, and a variety of climate zone criteria are easily navigated via the wide range of design options using a carbon-fiber-reinforced fully composite sandwich panel design.

In composite sandwich wall panels, using more insulation can result in the reduction of panel weight, environmental impact, and reduced manufacturing costs through labor. Due to these factors, many precasters prefer to use an expanded polystyrene (EPS) insulation, which has an approximate R-value of four per in. of thickness. **Table 1** outlines multiple insulation types, with an incremental insulation thickness to provide an R-16 sandwich panel. The increasing thickness of insulation in a lower-R-value product offsets concrete use in a fully composite sandwich panel design. A typical data-center panel that would be 30 ft. tall by 10 ft. wide, or 300 sq. ft., could recognize a reduction of panel weight of 3,875 lb using EPS in lieu of polyisocyanurate (polyiso) when maintaining the same overall panel thickness. In a 600-panel project, that adds up to a total weight reduction of 2.9 million pounds of concrete.

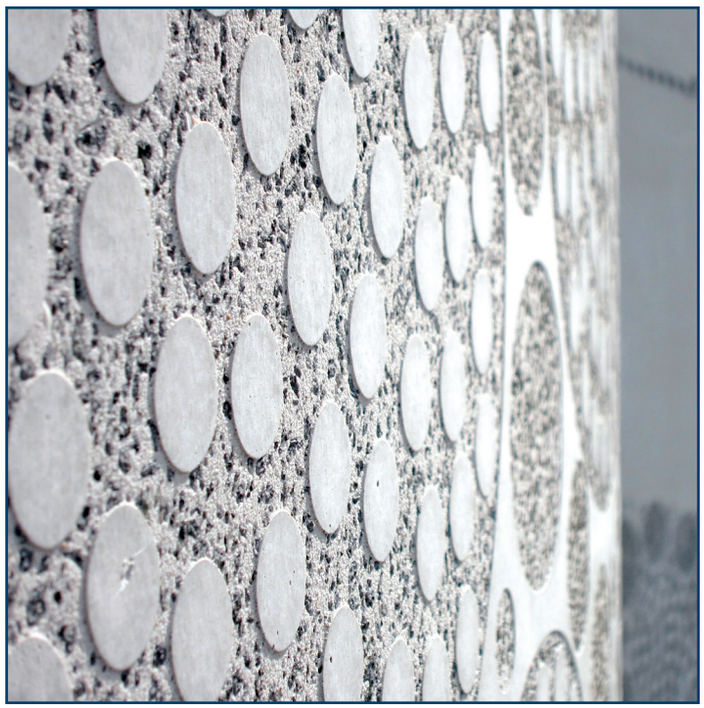

Figure 3. This photo shows the level of detail available using graphic-concrete technology.

Type	Classification	Density, lb/ft³	R-Value Per Inch of Insulation	Thickness Required, in.*	Pounds Per Square Foot Reduction+
Expanded Polystyrene (EPS)	ASTM C578 Type II	1.5	4.4	4.0	12.9
Graphite Polystyrene (GPS)	ASTM C578 Type II	1.35	5.0	3.5	6.5
Extruded Polystyrene (XPS)	ASTM C578 Type IV	2	5.4	3.0	—
Polyisocyanurate (Polyiso)	ASTM C1289	2.5	6.0	3.0	—

*Insulation thickness based on ½-in. thickness increments.
+ Reduction compared to use of polyiso.

Table 1. Typical insulating foam properties and thickness impacts.

Figure 4. Roughened XPS insulation is placed in the formwork prior to concrete placement.

Figure 5. This close-up shows non-roughened EPS insulation and a close-up of the carbon-fiber wythe connectors.

Example of Freight Impacts of Panels with Composite Panel Detail:

Panel size:	30 ft. by 10 ft. by 10 in. (Wythe thickness of 3 in./4 in./3 in.)
R-value (typ.):	16.89 (EPS insulation)
Panel weight (typ.):	23,250 lb
Standard trailer capacity:	48,000 lb
Delivery requirement:	20 panels per day

Freight Impact:

- 2 panels per truck (600 ft.^{2} of wall panel per load)
- 30 trailers required (10 loading – 10 transit – 10 staged)

Example of Freight Impacts of Panels with Non-Composite Panel Detail:

Panel size:	30 ft. by 10 ft. by 12 in. (Wythe thickness of 6 in./3 in./3 in.)
R-value (typ.):	16.39 (XPS insulation)
Panel weight (typ.):	34,875 lb
Standard trailer capacity:	48,000 lb
Delivery requirement:	20 panels per day

Freight Impact:

- 1 panel per truck (300 ft.^{2} of wall panel per load)
- 60 trailers required (20 loading – 20 transit – 20 staged)

	Composite	Non-Composite
Section (wythe thicknesses)	3 in./4 in./3 in.	6 in./3 in./3 in.
Concrete (yd.^{3})	3,333	5,000
Insulation	EPS (3.92 R-value/in.)	XPS (5 R-value/in.)
R-value (typical)	16.89	16.39
Loads	300	600
Material cost	Baseline	+8.9%
Freight cost	Baseline	+200%
Project variance	Baseline	+16.3%

Reductions in worker hours are also recognized using EPS foam in lieu of XPS or polyiso, as the beaded surface of the foam and carbon-fiber-grid wythe connectors provide the necessary shear transfer for composite design. XPS designs require the surface of the insulation to be roughened and often require an increased quantity of carbon-fiber wythe connectors. **Figure 4** demonstrates manually roughened XPS insulation with carbon grid, and **Figure 5** is standard "non-roughened" EPS foam being installed.

Regional shipping constraints can often play a significant role in the cost of delivery and duration of project installation. Composite panel design reduces panel weights, which in logistics planning allows for the following items to occur:

- Increased square footage of sandwich wall panel to be provided per truck
- Reduced fuel consumption in the delivery of wall panels to site
- Increased shipping range for competitive bids by precast manufacturers
- Reduced crane requirements for installation
- Decreased project schedules through reduction in installation duration

Following is more detail on the 600-panel case noted previously in the article. Using a composite design on a 30-ft. by 10-ft. by 10-in. sandwich wall panel, two 23,250-lb panels could be shipped per 48,000-lb standard trailer. Given a target of 20 panels per day, this would require 10 deliveries per day. With panel staging at the jobsite and trailer pre-loading, this would require 30 trailers to be allocated to the project. The same panel layout in a non-composite design would weigh 34,875 lb per panel and would be single-panel shipments requiring 20 deliveries per day and 60 trailers allocated to the project. If the driver or trailer availability is limited, this would translate into an increased

Figure 6. Double precast concrete composite panel ready for shipment.

Figure 7. Composite precast concrete panel installation.

installation duration with reduced daily shipments. Additionally, if the project were 150 miles from the plant, this would increase the distance traveled by 90,000 miles with round-trip deliveries. See **Example of Freight Impacts of Panels with Composite Panel Detail.**

Understanding the owner's expectations of the jobsite and time domain for their project is another primary consideration. Whether using a composite or non-composite system, the following values should

be factored into evaluating the costs of a precast sandwich wall panel:

- The entire building enclosure is produced off site.
- Building enclosure trades are consolidated.
- Sandwich wall panels are produced in a 100% controlled plant environment.
- Fewer people are needed on site, and there are fewer deliveries. A single crane and an ironworker/installation crew of about half a dozen people can handle the installation for an entire building façade.
- The building enclosure can be produced in parallel with or before site work, which can speed construction.
- Once site-cast footings and foundations are completed, precast concrete sandwich panels can be installed in all weather conditions.

In summary, composite wall design for insulated precast concrete sandwich panels adds value to projects at many levels, including providing high levels of thermal efficiency, wide ranges of aesthetic capabilities, and a reduction in environmental impact due to increased delivery and installation reliability, all while providing a resilient building façade. Engage with your local precast manufacturers early in the design phase to learn about their unique product offerings, design approaches, and manufacturing and logistic limits to help guide your design on your next composite sandwich wall panel project. IIBEC

Blake Johnson, PE

Blake Johnson is a commercial director with Knife River Construction's prestress division. He has a passion for building. After receiving a degree in marine engineering and shipyard management from the United States Merchant Marine Academy, he began a career focused on modular construction and the benefits that it brings to projects. Johnson's experiences in modular construction range from industrial heat recovery and power generation to precast concrete datacenter façades.

Opportunities for Women in Construction Perceived to Be Increasing

In a workforce survey of over 700 women in construction, 71% of respondents felt that job opportunities for women in construction were increasing, while 28% felt that opportunities were about the same. The survey was released by the National Association of Women in Construction (NAWIC) and Safe Site Check In. NAWIC Executive Director Crissy Ingram noted that the gender pay gap in construction is also much less significant than in the general workforce.

"On average, women in construction earn 99.1 percent of their male colleagues," said Ingram.

When asked "On a scale of 1-100, how does your employer rank in treating men and women equally?" more than half of the respondents rated their employer at 80 or above. 24% ranked their employer below 60.

Survey respondents were also asked about the effect of COVID-19 on their employment, and what safety procedures are in place. Most (96%) stated that their employer encourages employees to stay home if they feel sick, 90% are utilizing social distancing, while 76% see frequent handwashing.

According to NAWIC, "The survey was conducted in February 2021, and 718 NAWIC members participated. Survey participants represent all areas of the construction industry across private and public sectors."

— NAWIC, ConstructionDive, ForConstructionPros.com

NAWIC
The National Association of Women in Construction