

New Carbon Fiber Reinforcement Advances Sandwich Wall Panels

By Harry Gleich, P.E.

From schools to office buildings to warehouses to retail establishments, precast sandwich wall panels have a successful track record as a building envelope system. The sandwich design – two wythes of concrete encasing insulation – offers both strength and thermal benefits.

In addition, factory precasting enables architects and designers to choose from a variety of shapes, colors, finishes and veneers comparable to any field-applied finish. Factory fabrication usually offers superior precision compared with field-manufactured panels or masonry walls. Because they are delivered directly on-site and ready to erect, precast wall panels avoid the scheduling issues associated with coordinating various trades, weather delays, scaffolding costs, and site congestion caused by laborers and stored materials.

Sandwich wall panel technology has advanced gradually over the past four decades. However, the concept recently took a major leap forward with the introduction of carbon fiber shear reinforcement grids, which delivers benefits that promise to make sandwich wall panels a more viable option than ever.

Four Decades of Progress

Designs in the 1960s started with double tee sandwich wall panels that were fully composite with solid zones. The next innovation involved flat sandwich wall panels, again with solid zones of concrete to make the panel fully composite. Eventually, metal trusses were incorporated into designs to achieve a more effective thermal panel and still maintain the performance of fully composite sandwich wall panels. Still, thermally efficiencies were hampered by the conductivity of the metal or the concrete solid zones between panel wythes.

Non-composite panels were developed in the late 1980s using non-metallic ties. These panels were not structurally efficient, but they were thermally efficient. Slowly, improvements were made to those systems to create a partially composite panel that offered both structural and thermal benefits.

In 2003, AltusGroup – a national partnership of several leading precast manufacturers – introduced the first fully composite sandwich wall panel and fully thermally

efficient sandwich wall panel. Using a carbon fiber grid as shear reinforcement between the panels, these sandwich wall panels have redefined the limits of performance.

Carbon Fiber Connectors Enable Next-Generation Wall Panels

Thermally efficient panels require non-metallic shear connectors between the two wythes of concrete, regardless of the material used for wythe face reinforcement. AltusGroup precasters use a carbon reinforcement encapsulated in epoxy resin to replace conventional shear connectors, which conduct heat between wythes.

Non-corrosive carbon fiber grid is shaped to look like a truss, then cast into the panel. Carbon fiber has a relatively low thermal conductivity, and so does not readily transfer heat or cold between the wythes.

All three panel types – fully composite, partially composite and non-composite – are



This elementary school near Greenville, S.C., incorporates thin brick on panels that use carbon fiber grid as a shear truss between the inner and outer wythes of the panel.

made with either prestressed or conventional reinforcement in the wythes. Non-composite and partially composite panels can be prestressed in one wythe and conventionally reinforced in the other. However, fully composite panels are subject to bowing unless the same method is used in both wythes. When conventional reinforcement is selected for a fully composite panel, carbon fiber grid reinforcement can also be used on the outside wythe with conventional reinforcement on the inside wythe.

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Sandwich Wall Panel Technology Defined

The three sandwich wall panel design options mentioned – composite panels, non-composite panels and partially composite panels – differ significantly in both composition and function.

- The **fully composite panel** requires that both wythes act structurally together through the life of the panel. This allows thinner panels to be designed to perform the same task as a thicker non-composite panel. There are many advantages to the fully composite panels including reduced structural weight, more usable space inside the building, smaller (and less expensive) equipment to install panels, and possibly fewer pieces to erect.
- The **non-composite panel** means both wythes work independently of each other. This requires that at least one wythe be thicker and structural; this wythe will be thicker than wythes in fully composite panel. Some manufacturers consider these panels as composite for handling or until they are finally installed in the building. They accomplish this through the bond between the insulation and the concrete, in addition to minor help from the non-metallic connectors. The only structural positive of this system is that each wythe deflects independently due to thermal gradients, which slightly reduces the bow on the inside of the building.
- The **partial composite panel** incorporates non-metallic connectors that have some shear stiffness to create a panel that offers performance between the fully composite panel and non-composite panel. Several systems in the marketplace meet this definition. Their primary advantage is that the structural wythe can be thinner than a non-composite panel, which makes the panel less expensive than a non-composite panel. ■



The 332,000 square foot Cardinal Health office-warehouse features carbon-fiber-reinforced wall panels up to 51 feet in height. They deliver a healthy R-16.

An additional benefit of using carbon fiber reinforcement for shear connectors is that several rows of carbon fiber grid are positioned continuously through the panel, which increases the panel's tensile capacity and crack resistance.

Meanwhile, fully composite panels made with solid zones instead of carbon fiber create internal stresses from the solid zones being spaced 4 to 15 feet apart, which requires the panel to be designed for truss action and can contribute to cracking. Similarly, non-composite panels require special handling because the outside wythe is not normally structural.

Thermal Efficiencies Yield Improved R-Values

Composite sandwich wall panels with a thermally efficient system will decrease the energy required to heat or cool the structure compared with conventional walls systems. This is because the American Society of Heating, Refrigerating and Air-Conditioning Engineers' (ASHRAE) guidelines consider the mass of the wall system.

For example, when comparing a wood stud wall or a metal stud wall to an insulated concrete sandwich wall panel, the U-value required for the concrete panel will be higher, which means the R-value will be lower. Why? The concrete wythe inside the building will store thermal energy and thereby reduce the energy demand on the HVAC system. For example, compare a sandwich wall panel with an R-value of 13 to a 4-inch brick wall with metal studs at 16 inches o/c with R-19 insulation and sheet rock. According to ASHRAE, the latter system would really have an R-value of 7.1. As a result, concrete walls can decrease the energy cost by as much as 20 percent.

The use of carbon fiber grid as trusses has enabled significantly improved thermal performance. Again, because carbon fiber has relatively low thermally conductivity, inter-

wythe the transfer of heat is minimal. Therefore, the insulation between the wythes can deliver 100 percent of its rated performance without the hot spots or cold spots typically found with metal trusses.

As a result, carbon fiber technology has delivered concrete sandwich wall panels that have R-values as high as 32, with the more common values ranging from 11 to 16. Building owners can benefit from long-term energy savings and a smaller investment in HVAC equipment. In applications such as food storage or warehousing, the thermally efficient panels help ensure constant temperature and protect the quality of stored products.

Applications Underscore Versatility of Carbon Fiber Reinforcing

Since coming to market in 2004, carbon fiber connectors have been used in several million square feet of sandwich wall panels, including both commercial and institutional applications.

Office-warehouse: The 332,000 square foot Cardinal Health office-warehouse features carbon-fiber-reinforced wall panels up to 51 feet in height. The panels have a four-inch outer wythe and a four-inch inner wythe enclosing four inches of foam insulation to deliver a healthy R-16. (Other panels in the building were 3-4-3.) The high R value – provided at the same cost as conventional precast with R-12 or lower – significantly reduces Cardinal Health's costs to heat the warehouse. The panels feature ½-inch horizontal reveals throughout the facade, while the office exterior also incorporates several colors and articulations for stunning visual appeal. The load-bearing panels also support the structure's roof.

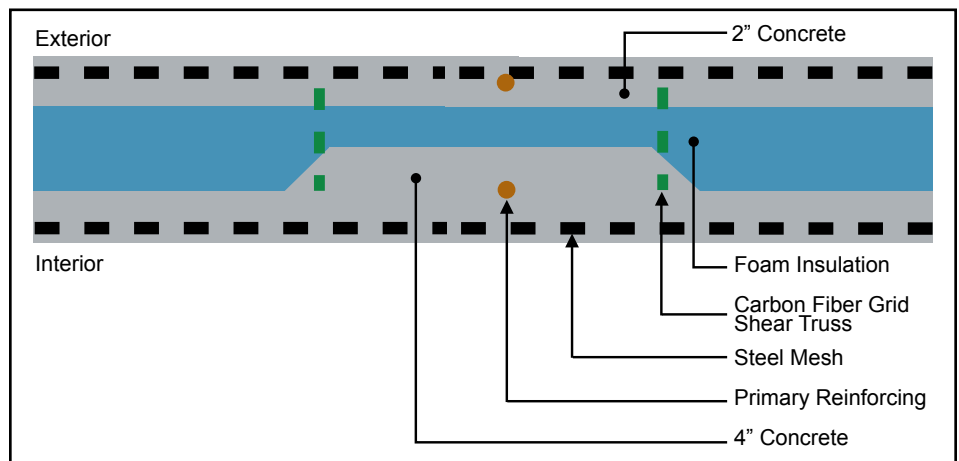
Cinema: With a 3-6-3 composition, wall panels used on a new Magic Theater also de-

liver R-16 insulation values, lowering energy bills and ensuring the comfort of moviegoers. Ranging up to 46 feet in height, the Magic Theater panels feature a ½-inch horizontal reveal and parapet in addition to alternating beige and taupe finishes.

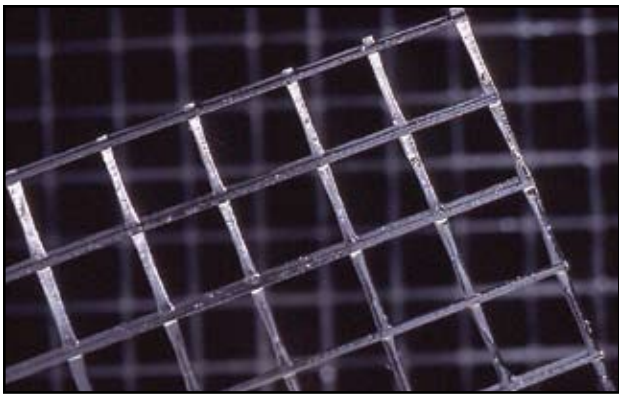


With R-values as high as R-24, this 138,400 square-foot beverage distribution center uses carbon fiber-reinforced panels to reduce the energy expended by the refrigeration system.

Schools: elementary and high schools can be constructed using fully composite carbon-fiber-reinforced panels. Type of panel could be 2.5-4-2 in construction, These panels could be as wide as 13 feet 4 inches and up to 42 feet high, providing a three-story exterior. The load-bearing panels support double tee floor decks. R-values range from R-12 to R-20 can be achieved by varying the insulation thickness, an improvement from the R-8 to R-10 levels found in precast panels that do not use carbon fiber. Aesthetically, the panels feature brick veneer, tile medallions and ½-inch reveals.



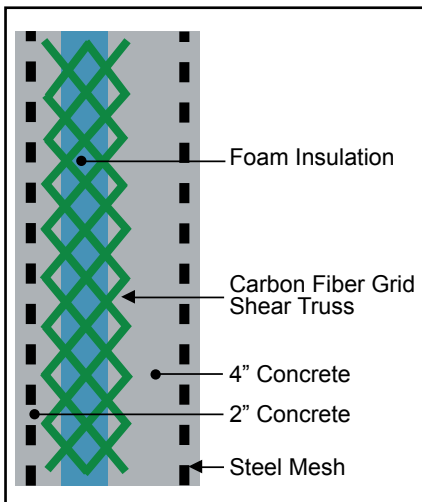
Horizontal section of insulated wall panel with carbon fiber reinforcing and internal pilaster.



Because of its relatively low thermal conductivity, carbon fiber provides excellent thermal performance when used as a shear connector in insulated wall panels.

Beverage distribution center: Boasting R-values as high as R-24, a 138,400 square-foot beverage distribution center uses carbon-fiber-reinforced panels to reduce the energy expended by the refrigeration system. The company had used masonry-based systems for other distribution buildings, but found that the insulation qualities of the carbon-fiber-reinforced panels provided a lower-cost option. There are no insulation blockouts anywhere, creating an even thermal profile. Panel thickness ranged from 12 inches in the storage area (2.5-7-2.5) to a conventional eight-inch thickness (2.5-4.5-2) in other sections of the building, delivering an R-14 value. These panels also served as support for the steel roof, which saved the owner money on the structural system.

Acceptance of carbon fiber reinforcing as shear grid has grown rapidly as applications like those above. With the promise of fully composite structural action and improved R-values, the carbon fiber technology is leading an evolution that will make precast sandwich wall panels an even more popular exterior envelope option. ■



Vertical section of insulated wall panel with carbon fiber reinforcing.

Harry A. Gleich, P.E., FACI, FPCI, Vice President of Engineering, Metromont Corporation, is an active member in the Precast/Prestressed Concrete Industry (PCI), having served on the several PCI Design Handbook Committees, currently as Chairman of the Parking Structures Committee and currently Chairman of ACI 533 Precast Panels. He is a member of the technology committee and board of directors for AltusGroup, a partnership of precast concrete manufacturers that have collaborated to expedite the commercialization of carbon fiber reinforced precast concrete. He can be reached at HGleich@metromontusa.com.



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