

Technical Bulletin

CarbonCast® High Performance Insulated Wall Panels with C-GRID® carbon fiber epoxy grid shear connections



Precast insulated wall panels are a preferred enclosure system for providing outstanding thermal performance, structural characteristics and excellent aesthetic options. Factory fabricated with interior and exterior wythes of concrete that sandwich insulation, they offer a combination of speed and quality control.

CarbonCast High Performance Insulated Wall Panels use epoxy-coated carbon fiber composite grid shear connectors to provide a thermally efficient enclosure with full composite action. This paper will address many of the questions that frequently arise about CarbonCast High Performance Insulated Wall Panels and offer additional insight into their design, performance and materials.

Right: Tucker High School, Tucker, Ga.



Definitions

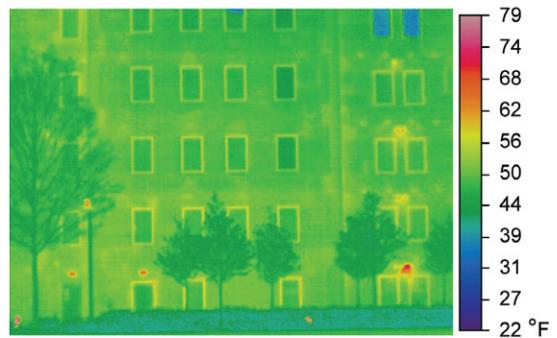
Insulated precast concrete wall panel system:

A horizontally or vertically oriented wall system comprised of two concrete wythes that sandwich a layer of insulation, often EPS or XPS, depending on the desired U-value or R-value. One wythe serves as the exterior face of the panel, the other as the interior surface. In CarbonCast® panels, they are connected with a patented shear truss system, or wythe connector (see below). The panels are fabricated in a factory environment by pouring a course of concrete to form the exterior wythe, adding the layer of insulation, then pouring an interior wythe. After initial cure, the panel is lifted from the mold and prepared for storage or transport.

Wythe connector: Mechanical devices used to connect the exterior and interior wythes of concrete through the insulation. (Also called a shear truss connector.) Historically, they were made from steel. But the market demand for large, lighter-weight panel assemblies without thermal bridging has led to the development of composite fiber connector systems to meet these changing sustainability needs. Carbon fiber and fiberglass are commonly used composite materials, carbon fiber being stronger by weight and more chemically resistant to alkali attack than fiberglass.

Composite action: Composite walls are insulated sandwich wall panels with wythes that act as a single unit in load-bearing and non-load-bearing conditions via transfer of horizontal shear forces through the wythe connector. The key to true composite performance is in how the wythes are connected, which makes a significant difference in design and cost requirements. In a CarbonCast panel, the C-GRID® truss placement and connector dimensions are dependent on the width of insulation and foam type utilized. Trusses are generally placed end to end on outer edges of the panel and continuous throughout the length of the panel. In the middle sections of the panel, the trusses can be placed intermittently as needed to accommodate structural performance as well as address window and door openings. The C-GRID trusses utilize the strength of the individual strands and connection crossover points to provide superior shear and pull-out strength in the sandwich panel. Embedment length of the grid in the panel is at least 3/4". Additionally, the design of the CarbonCast High Performance Insulated Wall Panel often incorporates an internal pilaster for additional strength and stiffness.

Continuous insulation: Continuous insulation is defined in ASHRAE 90.1 as "insulation that is continuous across all structural members without thermal bridges other than fasteners and service openings. It is installed on the interior or exterior or is integral to any opaque surface of the building envelope." The thermal performance of edge-to-edge insulated precast concrete sandwich wall panels with no or minimal thermal bridges and no solid zones maintains the R-values for continuous insulation as defined by ASHRAE 90.1, thereby lowering energy costs.



Above: Thermal Imaging Precast Wall System
Note: Red areas on left are lights, on right are bathroom vents.

Measurement of thermal conductivity of a single connector is generally insufficient to adequately determine what effect it might have on overall panel performance. One must evaluate – and set specifications for – the entire wall assembly to ensure optimal performance. One of the best measures for performance is actual thermographic measurement of the installed panel.

Carbon fiber grid: C-GRID® is an epoxy-coated composite grid made with cross-laid (non woven), superimposed carbon fiber. With the development of industrial-grade carbon fiber materials, advanced epoxy coating technology and new high-speed rotary-forming technology, carbon fiber has become feasible as an economical reinforcing and connecting material for precast concrete. It is four times stronger than steel by weight and has minimal thermal conductivity.

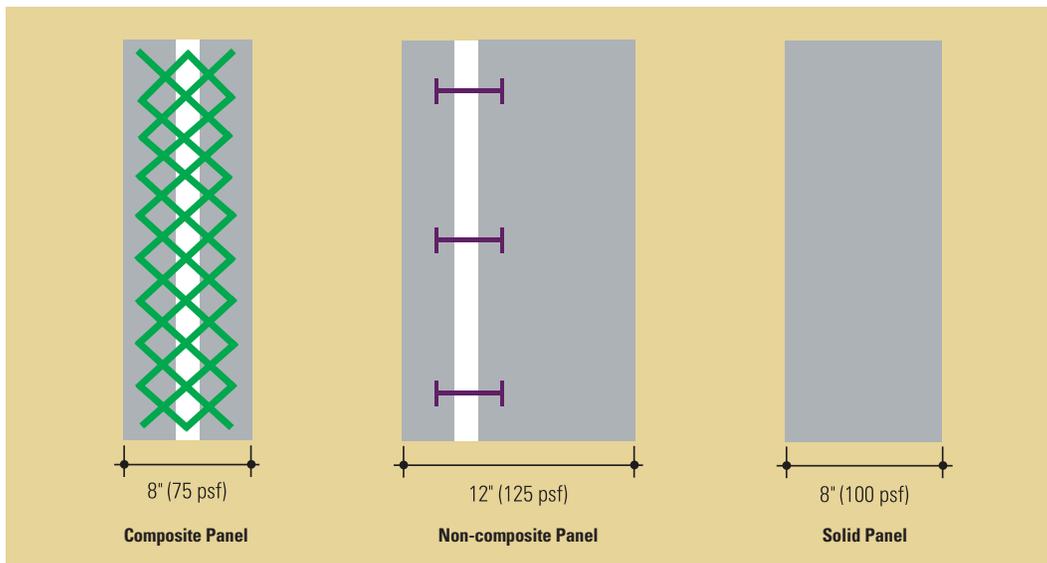
Composite and non-composite wall design

Composite panels: Both wythes act together as a single structure. This performance is attained through nonconductive shear connectors. Carbon fiber grid shear connectors have been proven to provide full composite action (AltusGroup® Technical Study, 6.5.1). The advantages are that the panels can perform the same structural function as solid or non-composite panels but can be lighter (reducing foundation and lateral costs), thinner (opening more usable space on the interior), more durable, and easier to handle and transport.

Non-composite panels: The wythes act independently and require one to be thicker to perform the structural tasks. Heavier and typically costlier, the wythes shrink and expand independently through temperature gradients

and may slightly reduce the bow inside the building. The additional concrete in the thicker wythe can lead to a larger environmental footprint.

Partially composite panels: The wythes act somewhat together due to non-metallic pin connections. The added stiffness results in performance somewhere between composite and non-composite. They are typically less expensive than a non-composite panel, but will not provide full true composite performance. Partially composite panels also use more materials to achieve the same objectives as composite panels and are, therefore, heavier. Again, heavier panels will generally have a more pronounced environmental impact with greater erection, handling and foundation costs.



Wythe connector systems

A variety of wythe connector systems for sandwich wall panels are available in the marketplace. Each provides different levels of performance in terms of composite action, thermal transfer, ease of installation and cost.

The thermal conductivity of wythe connector systems in sandwich wall panels depends on the thermal properties of the material itself and amount of surface area where it connects with the concrete wythes. Most mechanical connectors constitute a tiny percentage of the entire precast surface area on the inside of both wythes, making comparisons between thermal conductivity of connector materials inconsequential and difficult. What is important is designing a performance specification on the overall wall system rather than just the connector. A specification based on the overall wall system is one of the best ways of ensuring that the enclosure will meet the owner's standards.

Panel bowing: Bowing is a phenomenon exhibited by all precast sandwich wall systems. Bowing has many potential sources: deflection caused by differential wythe shrinkage, eccentric prestressing force, eccentrically applied axial load, thermal gradients through the panel thickness, differential modulus of elasticity between the wythes, or creep from storage of the panels in a deflected position. These actions can cause one wythe to lengthen or shorten relative to the other due to environmental expansion or contraction.

In panels with shear connectors, such differential wythe movement may result in curvature of the panel or bowing. Because nearly all sandwich panels exhibit

some degree of composite action due to shear transfer by either bonded insulation or the wythe connectors, bowing can occur in all types of sandwich panels.

It is important to realize that some bowing will occur in precast sandwich panels. The solution is to establish a reasonable, allowable limit for the magnitude of bowing, often based on experience and counsel with the precaster. Connections between the panels and the structural and nonstructural systems should be designed to compensate for the bowing and ensure that the wall's movement will not adversely affect building performance.



Right: Carbon fiber grid connectors and XPS insulation



Insulation

Three types of rigid foam insulation are generally specified for precast insulated wall systems: expanded polystyrene (EPS), extruded polystyrene (XPS) and polyisocyanurate (ISO). Each foam has unique properties. The choice depends on performance requirements and project budget. CarbonCast® technology enables you to use any of the three options.

Expanded Polystyrene (EPS)

Often known as “white board” or “beadboard,” EPS foam boards are available in a variety of thicknesses and in different densities, with correspondingly different R-values and permeance ratings per inch. Unfaced EPS foam generally costs less per point of R-value than XPS but has a lower permeance rating. EPS foam is more absorptive than XPS foam; however, EPS foam boards can withstand repeated cycles of wetting and drying without adversely affecting their performance. They will not support mold growth.

Depending on density, EPS foam will deliver R-values of 3.8-4.2 per inch. Though it has a lower permeance rating than other insulation types (0.9-2.5 per inch), the entire precast wall assembly (concrete-insulation-concrete) will generally have an overall permeance rating of 1.0 or less (2”/4”/2” configuration). This assembly delivers satisfactory structural, thermal and vapor drive retarding performance for many project requirements. (In fact, the roughened surface of EPS foam has shear value and actually contributes to the structural performance of composite panels.) It tends to be less expensive than XPS or ISO.

Extruded Polystyrene (XPS)

Extruded polystyrene foam (XPS) is a high-performance insulating foam made using environmentally friendly blowing agents that result in a very closed-cell structure. XPS foam boards are available in thicknesses up to 4” and

are generally available with a uniform R-value (about R-5 per inch) and permeance rating (1.1) per inch. In cases where high R-value is desired and wall panel thickness is constrained, XPS may be the best choice. And, in uses where high indoor humidity is present (e.g., natatoriums, cold storage facilities, hospitals) and where the wall panel is being relied upon to perform as a vapor retarder, XPS, or film-faced EPS, could be a better choice. Its surface tends to be smooth; however, it can be mechanically roughened to have some of the same structural properties as EPS.

Polyisocyanurate (ISO)

Polyiso is a closed-cell, rigid foam board insulation. Polyiso has trilaminate facers on either side. It has a low permeance and an R-value of R-6 per inch. It tends to be the most expensive option for continuous insulation in precast insulated wall panels. The facers provide a less-than-ideal surface for adhering to concrete in the wall panel, often resulting in the need for additional connectors. While it does deliver the highest R-value per inch of insulation, most precast insulated wall panels can achieve specified assembly R-value with a slightly thicker layer of lower cost EPS or XPS.

| Insulation Type | R-Value/Inch | Permeance |
|---|--------------|-----------|
| Expanded polystyrene (EPS or Beadboard) | 3.8-4.2 | 0.9-2.5 |
| Extruded polystyrene (XPS) | 5 | 0.8 |
| Polyisocyanurate | 6 | low |

Additional considerations

Moisture and dewpoint analysis

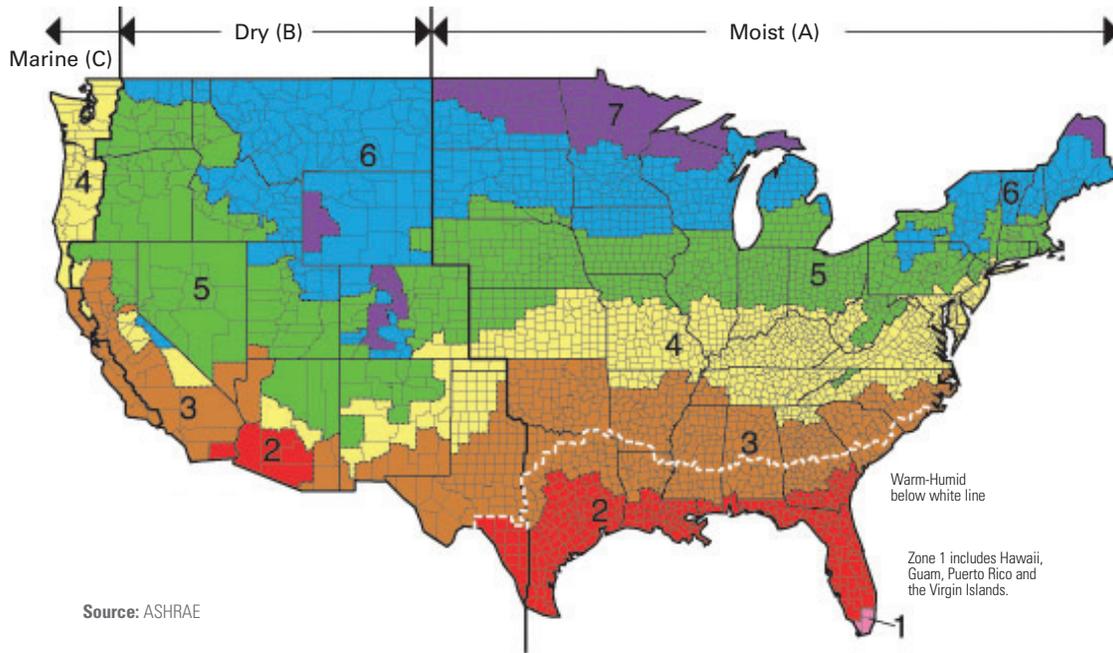
A common tool to ensure the proper design of sandwich wall panels is to conduct a moisture and dewpoint analysis covering various internal and external temperature and humidity conditions. A thorough analysis will ensure that the panels avoid condensation on the interior panel face. Your pre-caster or foam supplier can help with this analysis, depending on your panel design, foam and other components.

Thermal efficiency

A key benefit of insulated precast wall panels is thermal efficiency, a measure of how much energy used to heat or cool a building is lost through the wall panel. One of the ways to achieve thermal efficiency is to have continuous insulation (c.i.), which requires a connector system that has relatively low amounts of conductivity (like carbon fiber grid) as opposed to steel or solid zones.

Another important benefit of a concrete structure is its “thermal mass,” its ability to absorb and release heat. Concrete has a high specific heat, high density and low conductivity; therefore, a large amount of heat energy can be absorbed with little change in temperature. The high thermal mass provides thermal storage, reducing daily and seasonal temperature swings, absorbing heat during the day in summer and cooling the building by storing heat from the sun over the surface of the building rather than allowing it to flow into the building. This cycle reverses at night, during the cooler time of the day, when heat is released back out into the atmosphere. By damping and shifting peak loads to a later time, thermal mass reduces peak energy requirements for building operations.

In the United States, the ASHRAE Energy Standard provides minimum requirements for the energy-efficient design of buildings. Specifically, ASHRAE 90.1 designates minimum performance requirements for exterior wall assemblies.



ASHRAE 90.1 Building Envelope Requirements for Above-Grade Mass Walls

| Climate Zone | Assembly Maximum Residential | Insulation Minimum Residential | Assembly Maximum Nonresidential | Assembly Minimum Nonresidential |
|--------------|------------------------------|--------------------------------|---------------------------------|---------------------------------|
| 1 | U=0.151 | R-5.7 c.i. | U=0.58 | NR |
| 2 | U=0.123 | R-7.6 c.i. | U=0.151 | R-5.7 c.i. |
| 3 | U=0.104 | R-9.5 c.i. | U=0.123 | R-7.6 c.i. |
| 4 | U=0.09 | R-11.4 c.i. | U=0.104 | R-9.5 c.i. |
| 5 | U=0.08 | R-13.3 c.i. | U=0.09 | R-11.4 c.i. |
| 6 | U=0.171 | R-15.2 c.i. | U=0.08 | R-13.3 c.i. |
| 7 | U=0.171 | R-15.2 c.i. | U=0.071 | R-15.2 c.i. |
| 8 | U=0.052 | R-25 c.i. | U=0.071 | R-15.2 c.i. |

Seismic performance

Seismic design is an important consideration for wall panels in many sections of the world. In general, lighter panels are favored in high-seismic regions due to weight concerns. Your AltusGroup precaster can work with you and your structural engineering team to ensure proper seismic performance is achieved.

Sustainability and carbon footprint

The members of AltusGroup have funded a third-party cradle-to-gate analysis of greenhouse gas emissions (in kgCO₂e). Produced by Verus Carbon Neutral, Atlanta, Ga., the Life Cycle Assessment (LCA) methodology followed ISO 14040 standards. Based on the data examined, CarbonCast products have a lower cradle-to-gate CO₂e impact than comparable conventional steel-reinforced precast concrete products. CarbonCast products with precast finishes also have lower CO₂e impacts than almost all of the generic competing enclosure products modeled. And, CarbonCast enclosure products made with thin brick veneers have substantially lower CO₂e impacts than enclosure assemblies using full-depth bricks.

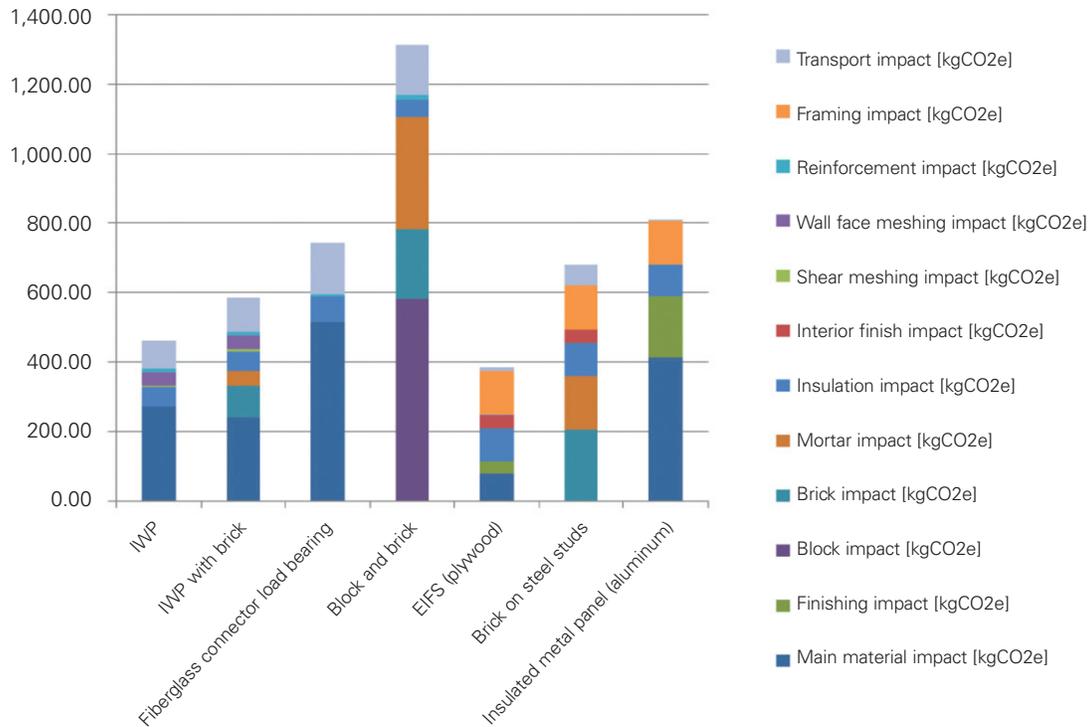
The ability to make load-bearing insulated wall panels with thinner interior wythes offers additional potential to reduce concrete usage and, therefore, the carbon footprint.

ICC/ES status

CarbonCast® High Performance Insulated Wall Panels have received International Code Council Evaluation Service (ICC-ES) acceptance criteria for the C-GRID® carbon fiber grid truss system used to connect the inner and outer wythes of the precast concrete wall panels. The official criteria is called AC422 – Proposed Acceptance Criteria For Semicontinuous Fiber-Reinforced Grid Connectors Used In Combination With Rigid Insulation In Concrete Sandwich Panel Construction.

The acceptance criteria means the ICC-ES has approved a method for evaluating product samples from each AltusGroup® precaster licensed to fabricate the system. Successful completion of the tests – such as load capacity and freeze-thaw cycling – will result in ICC-ES issuing an Evaluation Service Report (ICC-ESR) number certifying that the manufacturer is producing the CarbonCast precast sandwich wall panel system using C-GRID® according to established standards. Some municipalities and building jurisdictions require an ICC-ESR certification before allowing use of a structural building product.

In 2013, it is expected that additional testing will result in ICC broadening the AC422 acceptance criteria to include the entire precast assembly, not just the carbon fiber grid connector. The CarbonCast High Performance Insulated Wall Panel would be the only structural precast sandwich wall panel of similar nature and use on the market to earn that level of accreditation. Tests are being conducted at North Carolina State University in conjunction with accreditation testing and inspection agencies.



Source: Verus Carbon Neutral, LLC



Above: Savannah College of Art and Design and Museum of Art, Savannah, Ga.

Calculating and comparing R-values

Whenever one system or method is compared to another, it is important to make sure the comparison is of sound judgment and of equal benefit. Comparing terms that relate constructability or results of non-standardized calculation methods creates unequal comparisons. ASHRAE 90.1 defines a method of calculating R-values for assemblages of mixed materials, and many methods have been developed and tested that comply with this code requirement.

Although the standard recognizes thermal effect in its definition of mass wall, it provides little to no guidance on the creation of comparative calculation techniques. It has been shown that there is a significant advantage when using a mass wall construction method and that precast sandwich panels can enhance performance.

The industry standard for thermal performance comparison should be a comparison of steady state R-values. The method used to calculate the steady state R-value of the assembly follows the "Characteristic Section Method." The method is an excellent predictor of R-values with variations in material thickness, solid zones or thermal shorts. It has been adopted by the PCI Handbook as the preferred method of calculating R-values for complex assemblies.

Material and performance specifications

When developing initial specification during enclosure technology evaluation, architects will want to outline expectations to ensure accurate comparison among systems. The following components are recommended for CarbonCast enclosure products. (Complete three-part Master Format specifications for all CarbonCast products are available at altusprecast.com.)

- Wythe connector systems should be made of composite material (carbon fiber epoxy), having low thermal conductivity compared to steel or other conductive materials to eliminate cold bridging and thermal transfer.
- Panel system should be either load-bearing or non-load-bearing, depending on attachment and connection to building frame.
- Panel system must feature continuous, edge-to-edge insulation per ASHRAE 90.1 requirements.
- Either EPS or XPS rigid insulating foam may be used to achieve a specified R-value. (Indicate if there is a foam preference.)
- Fully composite wall panel design is preferred. (Or indicate if a partially composite or non-composite panel is preferred or acceptable.)

AltusGroup Producers

- **Blakeslee Prestress**
Branford, Conn.
blakesleeprestress.com
- **Central Pre-Mix Concrete Company**
(an Oldcastle company)
Spokane, Wash.
centralpremix.com
- **CHOMARAT North America LLC**
Anderson, S.C.
carbongrid.com
- **EnCon United**
Denver, Colo.
enconunited.com
- **Enterprise Precast**
Omaha, Neb.
enterpriseprecast.com
- **Gage Precast**
Sioux Falls, S.D.
gagebrothers.com
- **GPRM Prestress**
Kapolei, Hawaii
gracepacificcorp.com
- **Heldenfels Enterprises, Inc.**
San Marcos, Texas
heldenfels.com
- **High Concrete Group LLC**
Denver, Pa.; Springboro, Ohio;
Paxton, Ill.; Buena, N.J.
highconcrete.com
- **International Precast Solutions, LLC**
River Rouge, Mich.
psi-hci.com
- **Knife River-Northwest Oregon Region, Prestress Division**
Harrisburg, Ore.
kniferiverprestress.com
- **Marxuach & Longo, Inc.**
San Juan, Puerto Rico
mlprecast.com
- **Metromont Corporation**
Atlanta, Ga.; Greenville, S.C.;
Charlotte, N.C.; Nashville, Tenn.;
Richmond, Va.; Bartow, Fla.
metromont.com
- **Oldcastle Precast Building Systems**
Baltimore, Md.; South Bethlehem, N.Y.
oldcastleprecast.com

- **The Shockey Precast Group**
Winchester, Va.; Fredericksburg, Va.
shockeyprecast.com

- **Wells Concrete**
Wells, Minn.
wellsconcrete.com

International Affiliate Partner:

- **Verheyen Betonproducten**
(Belgium precaster)

Innovation Partners:

- **BASF Admixtures, Inc.**
- **High Concrete Accessories**
- **JVI**
- **Meadow Burke Products**
- **Owens Corning**

For more information about AltusGroup, CarbonCast precast concrete components and C-GRID technology, call 866-GO-ALTUS or visit altusprecast.com.

 See us on sweets.com
in section 034500/ALT.

