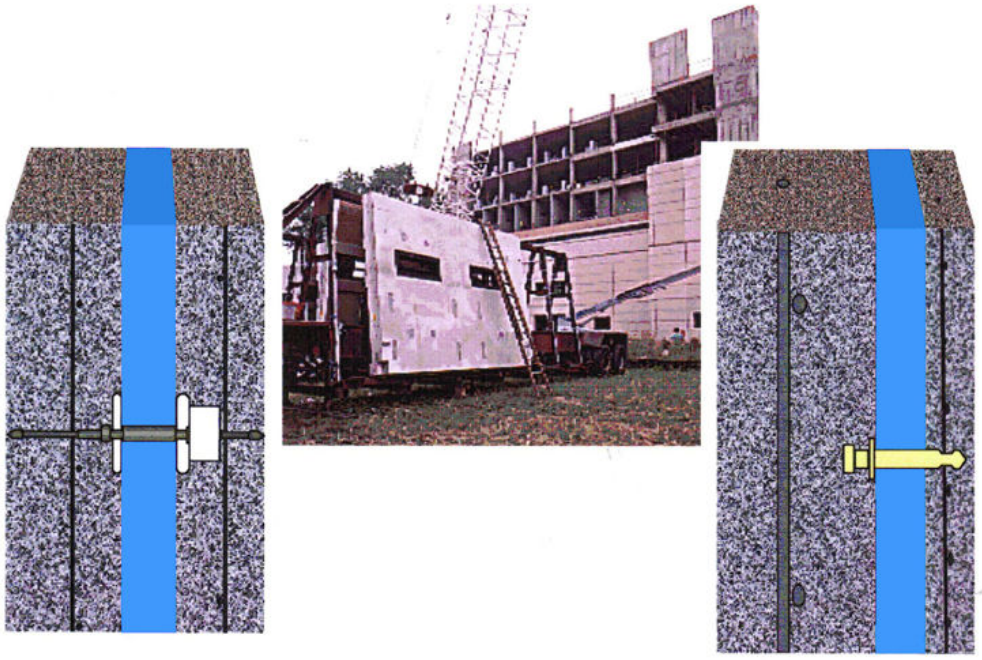
# BLU-CORE®

ISOFOAM ايسوفوم

# HK™ TIES

ISOBOARD® Extruded Polystyrene Insulation and Low-Conductivity Ties

Insulated Concrete Sandwich Panel Wall System



PRODUCT CONFORMITY

Underwriters Laboratories

ISO 9001 BUREAU VERITAS Certification Cert. No.: IND10.7766 UKAS QUALITY MANAGEMENT 008

مؤسسة محمد بن راشد لتنمية المشاريع الصغيرة والمتوسطة DUBAI SME

HK Composites

HK™ System Overview

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# HK™

## Insulated Concrete Sandwich Panel Wall System

Installation Instructions

# Polystyrene Insulation

and

Project List

# Low Conductivity Wall Ties

September 2007

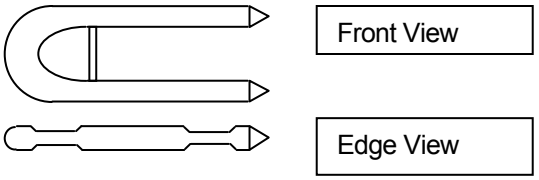
HK Composites

**May 2007**

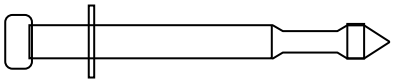
# HK™ Low-Conductivity Ties

HK Composites produces three types of HK™ ties. All ties are designed for use in insulated concrete sandwich wall panels, but each is best suited for a particular application. The ties are manufactured from different high-performance, heat and alkaline resistant, engineered polymers. HK™ ties minimize the energy draining effects of thermal bridging experienced when metal ties or solid concrete sections are used to connect the concrete wythes of sandwich panels through the insulation layer. The use of HK™ low-conductivity ties results in a sandwich panel with maximum thermal performance. Provided below are HK™ tie profiles and a brief description of the application for which the tie is best suited.

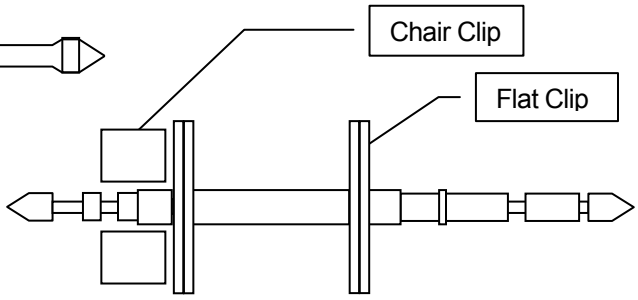
**Double Prong (DP)**




**Standard**



**Vertical Pour (VP) Tie**




| Tie Type | | Application |
|---|---|---|
| **DP Tie (Double Prong)** | **Horizontal Pour:** For site-cast or precast, tilt-up construction | For 38mm (1.5") thick insulation only. Pushed through the foam layer until properly seated, immediately after the bottom wythe of concrete is placed. |
| **Standard Tie** | | For insulation thicknesses between 50mm and 200mm (2" and 8"). Pushed through the foam layer until properly seated, immediately after the bottom wythe of concrete is placed. |
| **VP Tie (Vertical Pour)** | **Vertical Pour:** For modular precast & poured-in-place | For insulation thicknesses between 38mm and 100mm (1.5" and 4"0. Chair Clips are used to connect the tie to WWF in the exterior wythe, and Flat Clips hold the insulation in place on the tie while concrete is placed around it. |

**May 2007**

HK Composites

# HK Low-Conductivity Ties System Summary

This table defines the general system parameters in which HK Low-Conductivity Ties may be used. For specific application and properties data, please see related technical bulletins, or contact your HK Composites representative.

| Type | Color | Insulation Thickness | Wythe Thickness | | | | Resin (Heat & alkaline resistant engineered polymer) | Fiber Reinforced | Tie Spacing (standard) |
|---|---|---|---|---|---|---|---|---|---|
| | | | Exterior max. (unsupported, and modular precast, with no solid sections) | Exterior max. (supported) | Exterior min. | Interior max. | | | |
| **VP (Vertical pour)** | Semi glossy, beige is standard.<br><br>Other colors available for size identification if required. | 1-1/2 in. min. (38mm) 3 in. max. (75mm) | 3 in. (75mm)<br><br>(> 12 ft. (3.65m) high requires thermal expansion, contraction check) | 4 in. (100mm)<br><br>Contact HK Composites for additional information if greater thickness is needed. | 2 in. (50mm) | Unlimited<br><br>Assumes this wythe contains lifting hardware. | High Temperature Fiber Reinforced polymer, polyphthalamide (PPA resin)<br><br>Exceptional Elevated Temperature Performance Heat Deflection Temp-over 549°F (287°C) | Yes | 12 in. (305mm) o.c. |
| | | For >3 in. (75mm) consult HK. | Not Permitted unless approved by HK Composites | | | | | | |
| **Standard (Horizontal Pour)** | White, glossy Other colors available for size identification or as required. | 2 in., 2.5 in., 3 in., 4 in., 6 in., and 8 in.<br><br>(50mm, 60mm, 75mm, 100mm, 150mm, and 200mm) | 4 in. (100mm)<br><br>NOTE: If wythe is more than 3 in. (75mm), must check for creep on insulation thickness > 2 in. (50mm). Unsupported fascia not permitted for 6 in. (150mm) and 8 in. (200mm) insulation thickness. | | | | High Temperature polymer, polyphenylsulfone (PPSU resin)<br><br>Impact Resistant Outstanding Toughness Heat Deflection Temp-over 415°F (213°C) | No | 16-17 in. (406-433mm) o.c. |
| **Double Prong (Horizontal Pour)** | White, glossy | 1-1/2 in. (38mm) only | | | | | | | |

**May 2007**

HK Composites

# HK™ Low-Conductivity Ties, Tensile Strength

An independent test laboratory evaluated the tensile strength of HK Low-Conductivity Ties. All tests were performed on an Instron Model 4204 Tensile Test Machine using a 50 kN (10000 $lb_f$) load cell. All tests were run at a speed of 5mm/min. (0.2 in/min.) Tests were halted when it was obvious that the peak load had been reached even if fracture had not occurred. The data summarized in the table are the average of five tests for each tie type. The table shows ultimate strength loading minus 15%. In the full report, mean and standard deviation of the loads are provided.

Three types of HK ties, of varying sizes, were tested: Double Prong (DP), Standard, and Vertical Pour (VP). See related technical bulletins for a description of the different HK ties and the application for which they are best suited.

## HK™ Tie Tensile Strength[1]

| Tie Type | Ultimate Strength Loading | |
|---|---|---|
| | kN, min. | lb., min. |
| **Double Prong Tie (DP)** | | |
| 38mm (1.5") | 4.89 | 1100 |
| **Standard Tie** | | |
| 50mm (2") | 5.33 | 1200 |
| 75mm and 100mm (3" and 4") | 6.67 | 1500 |
| **Vertical Pour Tie (VP)** | | |
| 38mm to 75mm (1.5" to 3") | 7.56 | 1700 |

[1] A full report regarding the test procedures and the data summarized in this bulletin may be reviewed by contacting your HK representative.

HK Composites

**November 2004**

# HK™ Low-Conductivity Ties, Pullout Resistance

An independent test laboratory evaluated the concrete pullout resistance of HK™ Low-Conductivity Ties. Ties were inserted into freshly placed concrete until the foam and concrete came into contact (see Figure 1). The free end of the tie and the sides of the mold were tapped to consolidate concrete around the tie. The specimen was allowed to cure undisturbed until the concrete strength reached the appropriate value for testing. A standard 4000-psi concrete mix with 3/4-in gravel was utilized. No air or other additives were placed in the mix. The slump at the time of casting was 4 in. Concrete compressive strength was established by testing before and after the pullout tests were performed. Foam was removed from the specimens for testing. All pullout tests were performed on an Instron Model 4204 Tensile Test Machine using a 50 kN (10000 $lb_f$) load cell, at a speed of 5mm/min. (0.2 in/min.) Peak load was recorded for each test. Two types of HK™ ties, Standard and Vertical Pour (VP), of varying sizes, were tested as summarized in the table below.

**HK™ Tie Pullout Resistance[1]**

| Tie Type | Pullout Load (Minimum) | | Concrete compressive strength at test (Average) | |
|---|---|---|---|---|
| | kN | lb | MPa | psi |
| **Standard Tie** | | | | |
| 50mm (2") | 4.89 | 1100 | 21.71 | 3149 |
| 75mm and 100mm (3" and 4") | 6.67 | 1500 | 21.03 | 3050 |
| **Vertical Pour Tie** | | | | |
| 38 to 75mm (1.5" to 3") | 7.56 | 1700 | 21.03 | 3050 |

1. A full report regarding the test procedures and the data summarized in this bulletin may be reviewed by contacting your HK Composites representative.

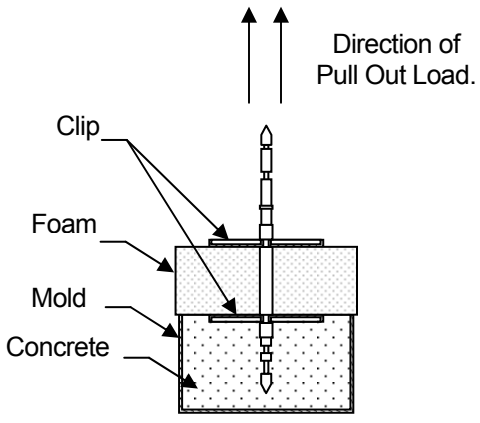


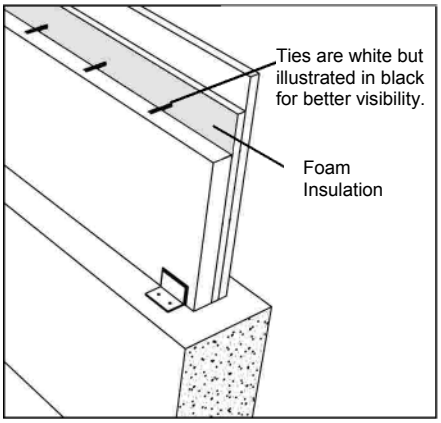

**Figure 1. Pull Out Test Sample Schematic for HK™ VP Tie.**

# Technical Bulletin

HK Composites

# HK™ Low Conductivity Ties for Tilt-up & Precast Structural Concrete Insulated Panels

**Figure 1**




**Available Sizes**

| | | |
|---|---|---|
| ☐ | 1.5 in | 35 mm Insulation & Ties |
| ☐ | 2.0 in | 50 mm Insulation & Ties |
| ☐ | 2.5 in | 60 mm Insulation & Ties |
| ☐ | 3.0 in | 75 mm Insulation & Ties |
| ☐ | 4.0 in | 100 mm Insulation & Ties |
| ☐ | 5.0 in | 125 mm Insulation & Ties |
| ☐ | 6.0 in | 150 mm Insulation & Ties |
| ☐ | 8.0 in | 200 mm Insulation & Ties |

## Description

HK ties are specifically designed for use in site cast or precast insulated concrete sandwich wall panels. This product provides a fast, efficient, cost-effective method of improving the thermal performance of commercial buildings. Typical concrete wall panels must be insulated after casting and erection. Using rigid foam insulation and HK ties, the panel is insulated during casting, prior to erection. Thus, the insulation is integral to the wall, which results in easier and faster construction. In addition, since the insulation is "sandwiched" between the interior concrete wythe and the fascia wythe, the panel maintains hard, durable concrete surfaces, both inside and out.

## Insulation

Extruded polystyrene (XPS) foam insulation provides a stable R-value of 5.0 per inch. Since an uninsulated eight-inch layer of concrete has an R-value of less than 1, the addition of 1.5, 2 or 3 inches of XPS insulation (R-values of 7.5, 10 and 15 respectively) dramatically improves the thermal performance of a building. The tight, closed cell structure of XPS insulation also resists moisture penetration, which insures that the thermal performance is maintained over the life of the building. Lightweight properties mean ease of handling.

## HK Ties

Manufactured from a high performance, engineered thermoplastic resin, HK ties feature high strength and low thermal conductivity. Unlike other sandwich panel designs which rely on metal or solid concrete connections, the use of HK ties minimizes the energy-draining effects of thermal bridging and results in a sandwich panel with maximum thermal performance.

## Installation

HK ties are specifically designed for fast, accurate installation. The XPS insulation can be clearly marked with a 16-inch on center dot pattern to ensure accurate placement of the HK connector ties into the insulation. After casting the exterior concrete wythe, the XPS insulation and HK ties are placed in the fresh concrete. The design of the connector tip also ensures easy penetration through the foam, as well as a mechanical interlock into the concrete once it cures.

Once the insulation and HK ties are in place, construction of the inner concrete wythe continues. Reinforcement, imbeds and lifting inserts are all set in place on top of the insulation and then the concrete is poured. With a compressive strength of 25 psi (3,600 psf), the XPS insulation provides damage resistance from foot traffic and other abuse.

## Performance During Lifting

Because the lifting inserts are located on the inner wythe, the HK connector ties are designed to support the fascia wythe during the lift. A typical three-inch concrete fascia wythe weighs 37.5 lbs/ft$^2$. Suction force between the casting bed and the fascia wythe is approximately 25 lbs/ft$^2$. With the connector ties spaced 16-inches on center, each connector tie is required to support 111 lbs.

**Calculation for Stress on Connector Ties During Lifting**

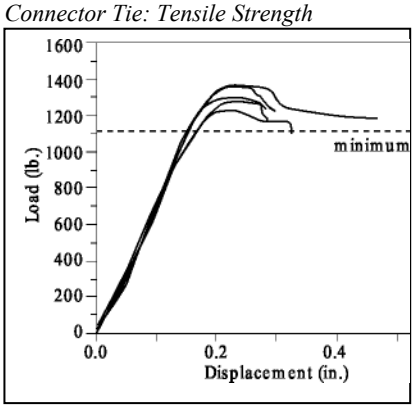
(37.5 lbs. + 25 lbs.) x 1.77 ft$^2$/tie = 110.63 lbs.

## Tensile Strength

A tie was placed in an Instron machine and tested until failure occurred. As shown on the graph below, the nominal tensile strength of each HK connector tie exceeds the 1,100 lbs. minimum performance, which provides a safety factor of 10 to 1. (Note that standard safety factors on wall panel lifting hardware are typically 5 to 1 or less).

**Graph 1**

*Connector Tie: Tensile Strength*



**Graph 2** - *Load-Deflection Curve for 4'x 8'Sandwich Panel in Shear*

### Tie Pullout in Concrete

The tie used in sandwich panel wall construction is subjected to tensile loads during the stripping and erection phases. The magnitude of loading depends on the thickness of the bottom concrete wythe, tie spacing and the suction forces present between the forming bed and the concrete surface.

There are two failure modes seen in tie pullouts. If concrete strength is not sufficiently developed, the tie may pull out with a concrete cone attached. With nominal concrete strengths, HK ties are designed to interlock mechanically in concrete and designed to fail at the minimum cross section when the pullout force reaches the ultimate tensile strength of the tie. Thus the pullout strength of the HK tie is typically equal to the tensile strength of the tie itself.

### Test Specimens

To investigate this, a series of pullout tests were conducted by Owens Corning. A total of thirty specimens were tested. For each sample, a PVC mold was used to form the concrete. The concrete molds had a diameter of 6 inches and a thickness of 2 inches (see Fig. 2). Twenty specimens were prepared by inserting ties through a 2-inch insulation board, following the standard HK tie installation procedure. The remaining ten specimens were prepared with a pre-drilled hole in the insulation for comparison with the standard installation of boards and ties. Concrete cylinders were cast to determine the strength of the concrete at the time of testing. The specimens were tested when the concrete reached approximately 2,300 to 3,000 psi.

### Test Results

The specimens were tested at two different intervals. The first batch of five pre-drilled and ten standard installation samples were tested after one day. The concrete strength at the time of testing was 2,300 psi. The remaining samples were tested after two days when the concrete strength reached 3,000 psi.

**Figure 2** – *Specimens before testing.*

**Figure 3** – *A test setup for pullout testing.*

The load was applied to the specimens using an Instron machine with a special jig attached (see Fig. 3). A summary of the concrete strengths and average ultimate pullout strengths at each day of testing are given in Table 1.

In each case, the average ultimate load, regardless of insertion method, was in excess of the nominal tie strength of1,l00 pounds.

**Table 1 – Summary of Test Results**

| Insertion Method | Concrete Age at Testing | Concrete Strength | Number of Specimens | Average Ultimate Load |
|---|---|---|---|---|
| Pre-drilled | 1 day | 2300 psi | 5 | 1215 lb |
| Standard method | 1 day | 2300 psi | 10 | 1110 lb |
| Pre-drilled | 2 day | 3000 psi | 5 | 1220 lb |
| Standard method | 2 day | 3000 psi | 10 | 1150 lb |

The tensile load on the ties during stripping and lifting depends on the concrete wythe thickness, tie spacing, and suction forces present in the casting bed. These can be quantified as follows for a 3-inch fascia.

**Assumption for Calculation of Stress on Ties During Lifting**

| | |
|---|---|
| Area weight of concrete (lbs/sf/in) | 12.5 |
| Thickness of fascia (in) | 3 |
| Suction force (lb) | 25 |
| Ties per square foot (16 in. spacing) | 0.5625 |

### Conclusion

These results confirm that the HK tie has a high factor of safety during stripping and lifting at the concrete strength commonly specified for concrete sandwich panels. A safety factor of approximately 10 is maintained whether the foam is predrilled or not.

### Shear Strength

As the wall panels are lifted from a horizontal to a vertical position, the load on the HK connector tie shifts from a tensile load to a shear or flexural load. Because a bond forms between the insulation and the concrete, the samples for testing shear strength were constructed in two different ways:

1. To measure the shear strength of the HK ties with the concrete-foam bond intact, 4 ft. x 8 ft. test panels were constructed by first pouring the three inches of concrete, then placing 2" thick XPS insulation on the fresh concrete and inserting 18 connector ties. Another three-inch layer of concrete was then poured on top of the foam in each test panel. Thus, the final assembly was representative of standard wall panel with XPS insulation.

2. In order to determine the strength of the HK ties alone (without the effects of the concrete-insulation bond), panels were constructed as above, but with two sheets of polyethylene between one concrete-insulation interface.

Application of the shear load on both types of panels was accomplished with a test apparatus that was custom-made for that purpose. A reinforced metal frame held the bottom wythe in place while a hydraulic ram applied pressure to the top wythe. The load was evenly distributed across the four-foot width of the top wythe.

Graph 2 shows the shear strength of the 18 connectors in the 4 ft. x 8 ft. panels, with and without the polyethylene film. A significant concrete-foam bond is formed in the conventional panel, without polyethylene. This bond eventually breaks at a displacement greater than 0.2 inches. While the bond can be seen as beneficial, the strength of the HK connector alone is sufficient to support the concrete fascia during lifting and installation.

**Graph 2** – *Load-Deflection Curve for 4' x 8' Sandwich Panel in Shear*

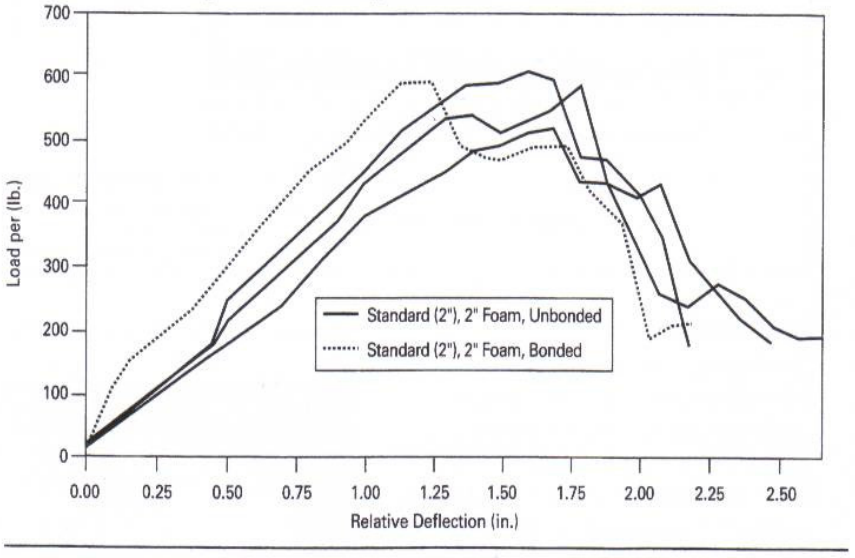
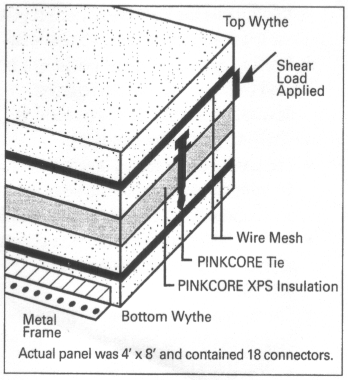



**Figure 4**

*Shear Testing Apparatus Illustration*




Actual panel was 4′ x 8′ and contained 18 connectors.

The weight of a 3-inch thick, 4 ft. x 8 ft. wythe is 1,200 lbs. During testing, the test panel exhibited a minimum shear strength of approximately 9,000 lbs. and a maximum of 11,000 pounds, with the variance depending on the presence or absence of the concrete-foam bond. Thus, the HK connector ties will easily support the weight of the concrete, whether or not the concrete-foam bond is considered.

**Full Scale Testing for Composite Action**

The primary function of ties in sandwich wall panel construction is to hold the two concrete wythes together. Composite action occurs when the ties are capable of transferring shear forces from one concrete wythe to the other. The degree of composite action varies depending on the stiffness of the ties and their capacity to transfer forces. This important property needs to be considered in the design calculations.

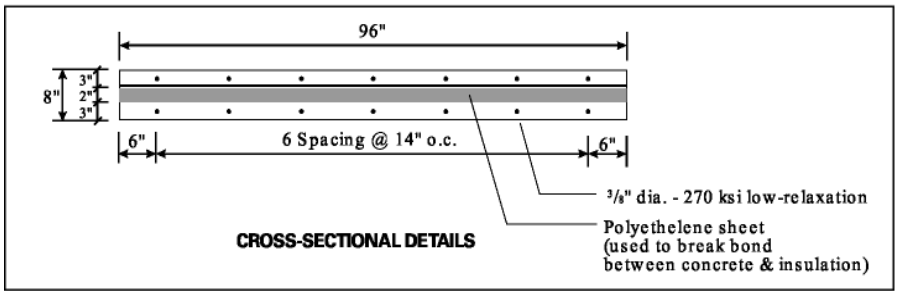
The Precast/Prestressed Concrete Institute's (PCI) Precast Sandwich Wall Panels Committee recommends designing a panel in three different ways, i.e. fully composite, noncomposite and semi- composite[1] depending on the manufacturer's testing of the system.

A higher degree of composite action provides a good shear transfer between the concrete wythes allowing a thinner panel. But it may also result in excessive bowing of the panel due to thermal deformations of the exterior wythe when subjected to varying temperature swings. Thus, for taller panels, noncomposite action is desirable where the growth of the outside wythe is independent and does not affect the panel deflections. Noncomposite ties are primarily used to resist tensile loads during the stripping, transportation and erection stages. Hence, to control deflections in a panel caused by thermal swings, a noncomposite panel would be ideal though it may not be structurally efficient.

To evaluate the load-deflection capacity of the panels with the HK system, full-scale testing on three panels was conducted by an independent testing laboratory. The panels were 8' wide by 30' 8" long with a 3"- 2"- 3" cross-section. A detailed description of the panels and the test methodology follows. A comparison of the test results to theoretical calculations is given at the end.

'PCI Committee on Precast Sandwich Wall Panels, "State-of-the-Art of Precast/Prestressed Sandwich Wall Panel," *PCI Journal*, V. 42, No. 2, March-April 1997, pp. 92-134.

**Figure 5** – *Typical Cross-Sectional Details of Test Panel*




**Panel Casting**

Three panels were cast by the precaster following the same procedure as their production panels. Figure 5 illustrates the typical cross-sectional details of the test panel. Descriptions common to all panels and the material strengths used are given below.

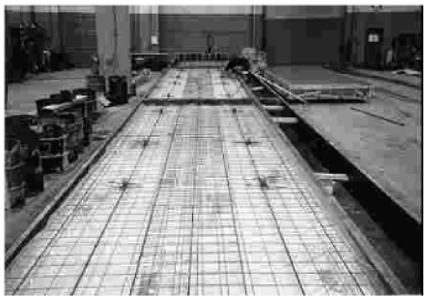
| | |
|---|---|
| Width | 8' |
| Length | 30' 8" |
| Thickness | 8" (3"- 2"- 3") |
| Concrete density: | Normal weight (145 pcf) |
| Concrete strength: | |
| At prestress transfer | 5,400 psi |
| At 28 days | 5,720 psi |
| Reinforcement per wythe: | |
| Prestressing strands: | 7 – 3/8" diameter 270 ksi low-lax |
| Welded wire fabric: | 6 x 6-W2.9 x W2.9 |
| Initial prestressing force: | 17.2 kip |
| Insulating system: | HK Ties & XPS foam |
| Lifting anchors: | Burke – 8 per panel with two U-loops for top lifting |

Two out of three of the panels were made with two slip-sheets (polyethylene) to break the concrete-to-insulation bond. The standard tie spacing of 16" on center was used for all panels. Table 2 summarizes the details of each panel tested. Figure 6 shows panel reinforcements on the precast bed before the concrete was poured.

**Table 2** – *Details of Test Panels*

| Panel Number | Bond Present | Tie Spacing |
|---|---|---|
| 1 | Yes | 16" |
| 2 | No | 16" |
| 3 | No | 16" |

**Figure 6** – *Test Panels During Casting*



The panels were stripped flat from the casting bed using 8 lift points after 6 days of curing and were moved outside for storage before shipping them to the test site. Panels were shipped with supports at lift points in flat-bed trailers stacking two on each trailer. The panels had been cured for 6 to 7 weeks when they were tested.

**Test Chamber and Setup**

A new steel vacuum test chamber specifically designed for testing these panels was built. The chamber was 5' deep to accommodate large deflections and to allow for visual inspection by personnel after the test was completed. The top and bottom of the panel were supported on steel channel beams which were allowed to rotate during the test. The panels were first flat-lifted with 8 lift points using a crane. Once airlifted, they were rotated to a vertical position using the two top U-hooks for positioning into the test chamber. The gap between the panel edges and chamber walls was sealed to make it airtight for testing. Two linear variable displacement transducers (LVDT) were attached at mid-height and quarter points to record the deflections. Strain gauges were also installed at various locations in the panel to measure the strain on the concrete surface. All instrumentation was connected to a data acquisition system using a computer for recording the data. Figure 7 shows a specimen in the test chamber before the load application.

**Figure 7** – *Full Scale Panel Subjected to Wind Loading During Test*

**Panel Testing**

A uniformly distributed load (udl) was applied using suction force in the chamber to simulate wind loads. The load was increased incrementally until a large midspan deflection occurred and released to let the panel recover back to its original position. Thus the load-unload was repeated for at least 4 cycles to record the load-deflection data. The panel could not be loaded to failure for safety reasons.

Several observations were made in addition to gathering test data:

- The panels experienced one to two cracks on interior concrete wythe near the mid span and cracks closed when unloaded.
- A small residual deflection was observed at mid-height after the test was completed.
- The insulation-to-concrete bond was broken at the top and bottom of the panel to one third of the height.
- No concrete spalling was observed during the test.
- The panel was intact in one piece even after being removed from the chamber and laid horizontally on the ground. The same test procedure was repeated for all panels and the recorded data was analyzed to evaluate the degree of composite action provided by the HK ties. The LECWall program[2]

[2]LECWall - Precast Concrete Wall and Column Design Program, Release 10, Losch Engineering Corporation, Palatine, IL, 1999.

(by Losch Engineering Corporation) was used to develop the theoretical load-deflection curves for comparison.

**Test Results and Evaluation**

The recorded data was used to plot load- deflection curves to compare with the theoretical results. The load-deflection curves for the three panels with 16" tie spacing are shown in Graph 3. Note that the curves are based on the raw data from testing and curtailed to fit the chart scale.

Using the LECWall program, a series of load-deflection curves were developed for various degrees of composite action (in increments of 10%) in addition to noncomposite and fully composite behavior. Actual material properties from the test specimens were used in the program. The program was run with suction loads increasing from zero to failure. Graph 4 shows a comparison of load-deflection behavior between actual data and the theoretical predictions using the program. The unbonded curve is an average of two panels tested with a similar configuration.

**In Service**

The tie is exposed to wind loads, and a highly alkaline environment while in service.

**Wind Loads**

Wind loads are derived from tables published by Factory Mutual.* For example, here is a typical wind load determination for central Ohio:

| Wind Force: | Central Ohio |
|---|---|
| 100 year max | 90 mph |
| Ground roughness | Type C |
| Building height | 30 feet |

From table: Wind pressure 27 lb/ft2.

Data Sheet 1-7, "*Wind forces on Buildings and other Structures*," Factory Mutual Loss Prevention.

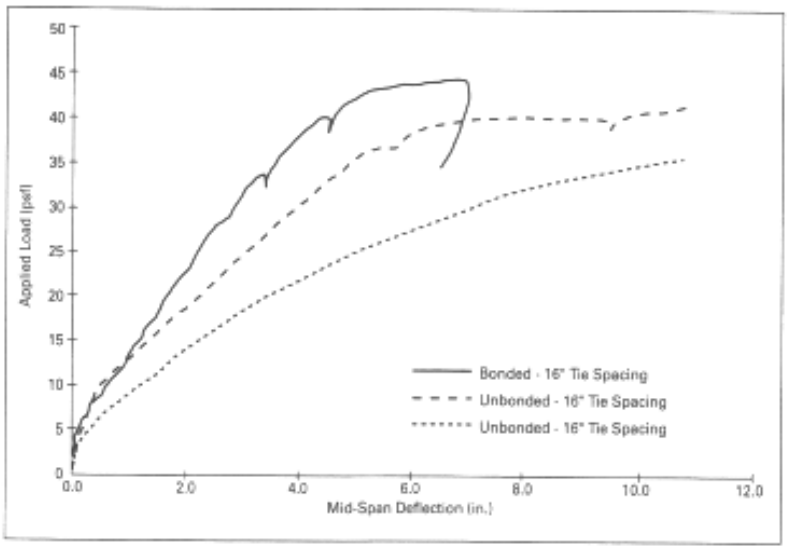
The maximum stress on the building comes at the comers. To calculate the corner stress, multiply the panel wind pressure by a factor of two; in this case, the result is 54 pounds per square foot.

**Maximum Wind Load Calculation**

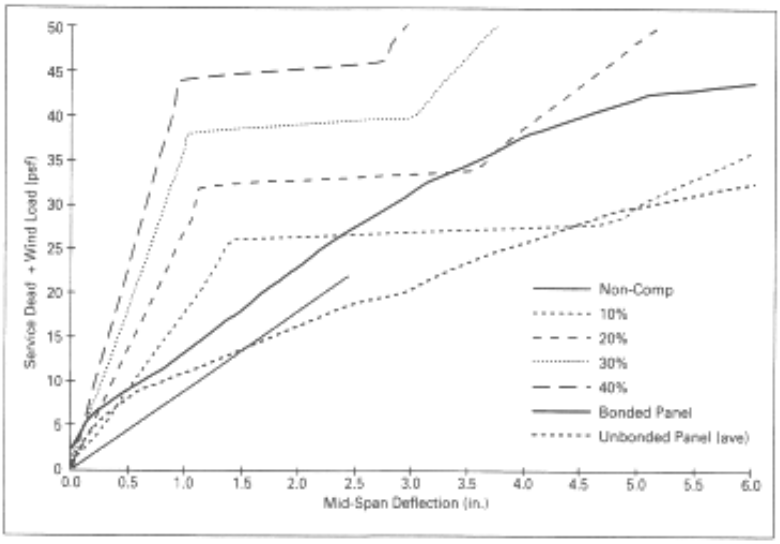
The calculation for maximum load on the connector tie becomes:

54 lbs/ft$^2$ 1.77 ft/tie = 96 pounds per tie

**Graph 3** - *Load-Deflection Curves from Testing*




**Graph 4 - Comparison** *of Load-Deflection Behavior between Actual Data and Theoretical Predictions*



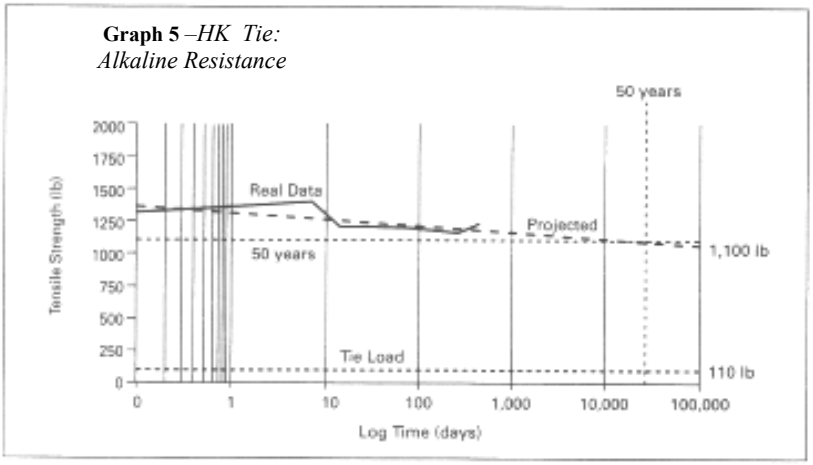

As these calculations show, HK ties allow for a safety factor in excess of 10: 1 in most parts of the United States.

**Alkaline Environment**

The tie must retain its strength even after being exposed to an alkaline environment while under stress. To simulate this condition, the HK connector tie was put in a jig which placed the tie under stress. The tie and jig combinations were then put into a bath of cement extract at an elevated temperature to accelerate the test.

At regular intervals of time, the ties were removed and tested for tensile strength. After 365 days of this accelerated testing, the tensile strength of the connector ties continued to be in excess of the nominal value of 1,100 pounds (Graph 5). In fact, extrapolation of this severe test confirms the exceptional alkaline resistance of this resin, as substantial safety factors are maintained for many years.

**Graph 5** –*HK Tie: Alkaline Resistance*




### Fire Performance of Concrete Sandwich Panels

The fire resistance of concrete is well understood. Major building codes allow for a calculated method of fire resistance when concrete construction is specified. This includes the fire resistance of multi-layered panels that have concrete in at least one layer. These calculated resistances may be used to satisfy building code requirements for all hourly fire ratings.

In addition, Owens Corning has performed testing at the Owens Corning Science & Technology Center in Granville, Ohio.

### Building Codes

All four national model building codes (UBC SBC NBC, and IBC) use the methodology for calculating fire resistances for concrete sandwich panels outlined in the Precast/Prestressed Concrete Institute's *Design Handbook*[3] and discussed in detail in the PCI's *Design for Fire Resistance of Precast Prestressed Concrete*[4].

This methodology allows for fire resistances to be established for each layer in the panel and for these resistances to be summed in such a way that results in the fire resistance of the whole panel. Use of these calculations is explicitly allowed as an alternative to fire tests of a specific wall assembly.

### The Rational Design Method

The Rational Design Method for fire resistance is based on research conducted at the Portland Cement Association (PCA). Essentially, the method has two steps. First, the fire resistance of each layer of material is established from tabulated test data. Second, the individual resistances are summed using the following calculation.

**Calculation of Fire Resistance for Multilayer Concrete Panels**

$$R = (R_1^{0.59} + R_2^{0.59} + \ldots + R_n^{0.59})^{1.7}$$

R is the fire resistance for the panel in minutes. $R_1$, $R_2$,..., $R_n$ indicate the fire resistance for the individual components of the panel in minutes.

The fire resistances for the individual layers of concrete may be calculated using the equation cited above, and the data from model code tables such as IBC table 720.2.1.2. Table 3 shows fire resistance calculated using the IBC table for siliceous aggregate concrete curve.

**Table 3** -*Approximate Fire Resistance of Concrete Layers*

| Thickness of Individual Concrete Layer | Fire Resistance in Minutes |
|---|---|
| 2” | 24 |
| 3” | 46 |
| 4” | 78 |
| 5” | 120 |
| 6” | 173 |
| 7” | 230 |

Data from the Precast/Prestressed Concrete Institute[3, 4] footnoted below, indicates that for polystyrene foam insulation, a fire resistance of 5 minutes is most appropriate for foam thicknesses greater than one inch. Note that, as a result, changing the thickness of the foam has no impact on fire performance.

### Fire Test Results

The hourly fire resistance rating for concrete walls is determined by the test standard ASTM E 119. In this test, one side of the full-size wall sample is exposed to the interior of the test furnace heated to an ultimate temperature of 2000 °F in 4 hours, while the other side is exposed only to ambient room conditions.

There are several criteria in the ASTM E 119 standard which determine the actual fire resistance rating for a given wall. However, the criterion which most often determines the rating for concrete walls is the temperature rise of the unexposed wall surface. This standard states that the surface temperature of the unexposed side cannot increase 250 °F above the ambient room temperature. Thus, if the ambient room temperature is 70 °F, the maximum allowable surface temperature is 320 °F. The time to reach this maximum temperature determines the hourly rating for the wall assembly.

As a way of confirming the PCI results and the performance of the HK System, Owens Corning selected a 2.5" exterior layer of concrete and a 5.5" interior layer of concrete with 2" of XPS insulation in between. According to the Rational Design Method described previously, this combination should produce a fire resistance, as defined by the E 119 criteria, greater than four hours.

The E 119 procedures were followed as closely as possible given the capabilities of the Owens Corning facility; the application of the flame, the temperature curve and instrumentation were all in accordance with E 119 protocol, except the size of the sample.

In fact, at the end of four hours, the temperature at the face opposite the furnace had risen only 13 °F above ambient, far below the 250 °F maximum.

[3] *PCI Design Handbook,* 4th Edition, Sections 9.3.6., 4-5, pg 9-33 - 9-34, Precast/Prestressed Concrete Institute, Chicago, IL

[4] *Design for Fire Resistance of Precast Prestressed Concrete,* 2nd Edition, MNL-124-89, Precast/Prestressed Concrete Institute, Chicago, IL

**Fire Resistance of Typical Panels**

Table 5 shows the results of performing the calculations described using the information from Table 3. Please note that changing the thickness of the insulation does not change the fire resistance calculation result.

When designing an insulated panel with a particular fire rating, the roof and the walls must both achieve that rating since the roof typically provides the rigidity of the building.

**Table 5**

*Calculated Fire Resistance for Typical Panel Cross Sections (in hours)*

| Thickness of Outside layer | Thickness of inside layer of concrete | | | | | |
|---|---|---|---|---|---|---|
| | 2 | 3 | 4 | 5 | 6 | 7 |
| 2 | 1.8 | 2.3 | 3.2 | 4.2 | 5.3 | 6.6 |
| 3 | 2.3 | 2.8 | 3.7 | 4.9 | 6.1 | 7.4 |
| 4 | 3.2 | 3.7 | 4.8 | 6.1 | 7.4 | 8.9 |

Based on fire resistances from Table 1

**Conclusion**

Concrete sandwich panels with XPS insulation and HK ties may be designed with any level of fire performance desired. The Rational Design Method gives the designer a way to design in fire performance.

**Thermal Performance**

Extruded polystyrene (XPS ) rigid foam insulation meets ASTM Standard Specification C-578, Type IV and has the thermal resistance of 5.0 F h $ft^2$/Btu per inch (R per inch).

**Table 4** – *XPS Insulation Thermal Performance*

| Thicknesses | | |
|---|---|---|
| IN | MM | R-value |
| 1.5 | 37.5 | 7.5 |
| 2.0 | 50.0 | 10.0 |
| 2.5 | 62.5 | 12.5 |
| 3.0 | 75.0 | 15.0 |
| 3.5 | 87.5 | 17.5 |
| 4.0 | 100.0 | 20.0 |

**Availability**

HK ties have been available for delivery since September, 1994. Shipments are made from the HK plant in American Fork, Utah, or from HK Composites' authorized distributors of HK™ connector products.

**Application Recommendations**

While the energy standard ASHRAE 90.1 is a United States standard, and has been adopted into building codes in many areas of the USA, it is completely appropriate for buildings anywhere in the world. A building constructed using ASHRAE 90.1principles – whether the code applies or not – will deliver the thermal performance the owner expects.

The requirements of Standard 90.1 call for increased energy efficiency in four primary areas:

- Lighting
- Building Envelope
- HVAC systems and equipment
- Service water heating

The answer to how much insulation a building needs and where should it be placed lies in the calculations that accompany ASHRAE 90.1. Using commercially available software, designers can measure the "tradeoffs" between insulating the walls and insulating the roof. And when the determination is made, the designer may very well be able to downsize the HVAC requirements thus saving even more on both first costs and life-cycle costs for the building.

Extruded polystyrene rigid foam insulation and HK ties create an opportunity for the architect/engineer to take advantage of the speed and low cost of insulated wall, while meeting owner and code demands for a thermally efficient building envelope.

In 65% of 211 major metropolitan areas studied by Owens Corning, no block wall or uninsulated block/concrete wall design met the ASHRAE 90.1 code requirement for maximum thermal usage with roof insulation rated less than R-45. ASHRAE 90.1 compliance can easily be met in all areas of the country with HK insulation and connector ties.

**Other Information**

Complete installation instructions for XPS insulation and HK connector ties (Pub. No. HK-ST-II) are available from your HK representative.

**Shipping**

Owens Corning's FOAMULAR® extruded polystyrene rigid foam insulation is shipped on open trucks. The insulation may be shipped to the distributor's yard, a precast plant (in the case of a precast order) or the job site (in the case of a tilt-up order). The following chart shows square feet of insulation per truck based on 4 ft x 8 ft sheets:

**Table 6** – *Loadout Data by Thickness for 4 ft x 8 ft Sheets*

| Insulation Thickness | Square Feet per Truckload |
|---|---|
| 1.5" | 24,576 |
| 2.0" | 18,432 |
| 2.5" | 14,745 |
| 3.0" | 12,288 |
| 3.5" | 10,532 |
| 4.0" | 9,216 |

The HK ties are packaged in cardboard boxes. For every 1,000 square feet of insulation, approximately 600 ties are needed. If a customer requires additional ties for the job, HK will charge for the additional boxes of ties.

HK ties are shipped separately from the insulation via ground carrier. The ties may be shipped to the distributor's yard or to a precast plant. For tilt-up orders, the ties will be shipped to the distributor and the distributor will arrange for delivery to the job site.

# XPS Rigid Foam Insulation and HK™ Connector Ties

**Related Services**
HK Composites can provide fabrication and drafting services related to insulated concrete sandwich panel jobs. Please contact your HK Composites distributor.

**Local Distributor:**
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**Disclaimer of Liability**
It is the sole responsibility of the contractor to install the XPS Foam Insulation and Low-conductivity HK Ties in accordance with these published instructions. The presence of an HK representative at the job site does not relieve contractor from the responsibility to follow these published installation instructions. HK COMPOSITES IS NOT RESPONSIBLE FOR ANY LIABILITY RESULTING FROM A FAILURE TO FOLLOW THESE INSTRUCTIONS


Pub. No. HK-280 Printed in U.S.A., September 2007 

Product Data Sheet

HK Composites

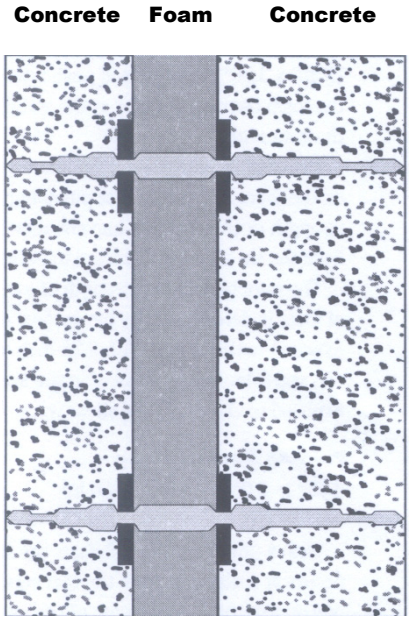
# XPS Rigid Foam Insulation and HK™ Ties for Vertical Pour Applications

## Description

HK™ panel ties for vertical pour (VP) applications are specifically designed for use in cast-in-place and modular precast applications. They provide a fast, efficient method of insulating concrete structures without compromising the low-maintenance/high durability of concrete walls.

Typical concrete wall panels must be insulated after casting and erection. Using rigid foam insulation and HK ties, the panel is insulated during casting, prior to erection. Thus, the insulation is integral to the wall, which results in easier and faster construction. In addition, since the insulation is "sandwiched" between the interior concrete wythe and the fascia wythe, the panel maintains hard, durable concrete surfaces, both inside and out.

**Drawing of Typical Panel Section**




## Insulation

Extruded polystyrene (XPS) foam insulation provides a stable R-value of 5.0 per inch. Since an uninsulated eight-inch layer of concrete has an R-value of less than 1, the addition of 2, 3 or 4 inches of XPS insulation (R--values of 10, 15 and 20 respectively) dramatically improves the thermal performance of a building. The tight, closed cell structure of XPS insulation also resists moisture penetration, which insures that the thermal performance is maintained over the life of the building. Lightweight properties of XPS insulation also provide easy handling.

## HK Ties and Clips

Manufactured from a high performance, glass fiber reinforced engineered thermoplastic, HK ties feature high strength and low thermal conductivity. Unlike other sandwich panel designs which rely on metal or solid concrete connections, the use of HK ties minimizes the energy-draining effects of thermal bridging and results in a sandwich panel with maximum thermal performance. HK clips are designed for easy installation and hold the insulation firmly in place while concrete is poured on both sides.

## Installation

HK ties are specifically designed for fast and accurate installation. The XPS insulation can be clearly marked with a 12-inch on-center dot pattern to ensure accurate placement of the HK ties.

- Place a clip on one end of the tie to allow easier insertion.
- Prior to placing the foam inside the vertical form, insert the ties into the foam.
- Push the ties through the foam at the locations marked by each dot.
- Place a second clip on the other side of the foam to firmly fix the tie in place.

The foam is now ready for placement in the vertical form.

## Performance

HK ties are designed to support the fascia or outer layer of concrete during casting, transport (if modular precast) and in-service situations. Primarily, this consists of withstanding the demands of the casting process and supporting the gravity load of the outer concrete layer.

### Tensile Strength

To measure the tensile strength of the HK Vertical Pour (VP) ties, the ties were placed in an Instron machine and loaded until failure. The nominal tensile strength of the VP tie is 1,700 lbs.

### Pull-Out Strength

As the concrete cures, it forms a mechanical bond with the tip of the HK VP tie. The strength of this bond and the resulting shear cone must be sufficiently strong to allow the tie to develop its full tensile loading.

Samples were prepared by inserting a tie and clip assembly through 2-inch foam and placing the end with the clip into a 6-inch diameter, 3-inch deep cylinder of concrete. When the concrete had developed 2500 psi strength, the sample was placed in an Instron machine and loaded until failure.

# XPS Rigid Foam Insulation and HK™ Ties for Vertical Pour Applications

**Figure A**

**Load Displacement Curve from Pullout Tests**

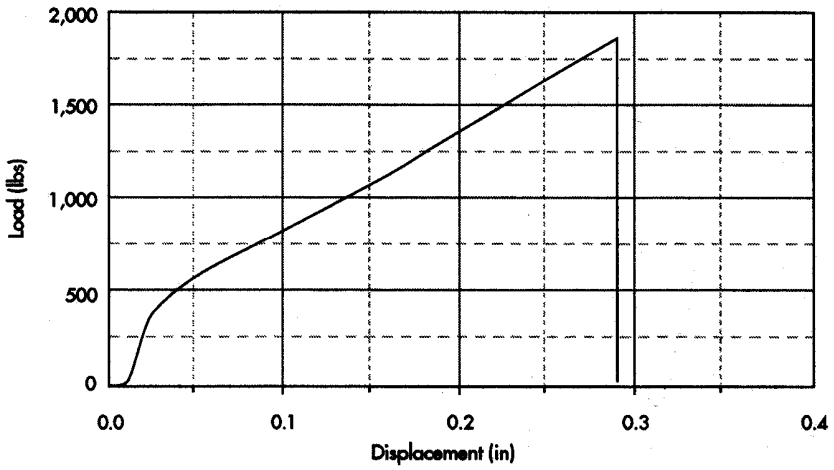
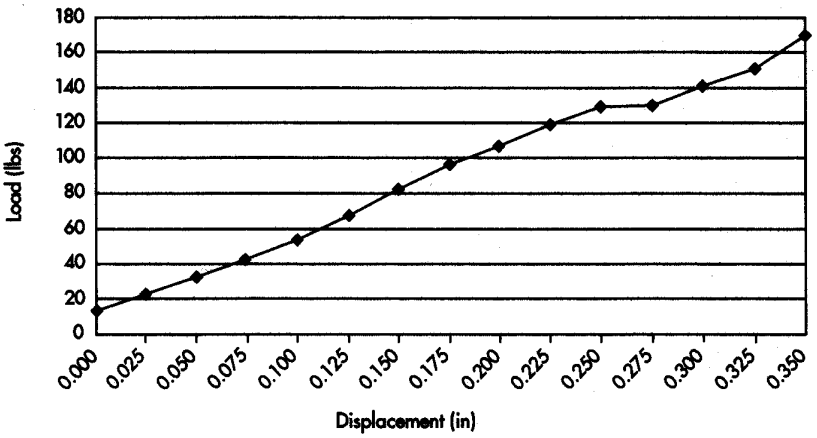



**Figure B**

**Load Displacement Curve from Shear Tests**




From the load-displacement curve in Figure A above, the average pullout strength was in excess of the 1,700 lb nominal strength of the tie.

### Bending/Shear Strength

After casting of the concrete, the HK VP ties are responsible for supporting the outer layer of concrete. The stress placed on the ties is a bending/shear stress. The stress calculation based on a 3-inch thick layer of concrete is shown below:

**Calculation of Stress on Ties due to Gravity**

37.5 lbs/ft$^2$ x 1 ft$^2$/tie = 37.5 lbs/tie

To measure the bending/shear strength of the HK ties with the concrete-foam bond intact, 4' x 8' test panels were constructed using 2 inches of foam insulation and 32 ties. The panel cross section was 3"-2"-3.5.

In order to determine the strength of the HK ties alone, two sheets of polyethylene were placed between each concrete-foam interface in some samples to prevent the formation of a bond between the two materials.

Application of the shear load was accomplished with a custom-made test. A reinforced metal frame held the bottom layer of concrete while a hydraulic ram applied pressure to the top layer. The load was evenly distributed across the 4-foot width of the top layer. Figure B shows the load vs. displacement curve resulting from the tests.

With a gravity load of 37.5 lbs, and the ultimate bending/shear strength of the tie being 165 lbs, the HK VP tie has a safety factor in excess of four (4) with a 3-inch fascia layer of concrete.

### Clip Strength – Vertical

As concrete is dropped on both sides of the insulation, the aggregate in the concrete falls onto the ties and clips. To simulate the aggregate striking the clip, a clip was placed on a tie and the tie held in place. The clip was attached to an Instron machine and pulled until it separated from the tie. The failure of the clip was at 100 lbs.

### Clip Strength – Horizontal

If the depth of the concrete differs from one side of the foam to the other during pouring, the concrete will exert a uniform loads on the foam and the ties. With a surface area of over 10.5 square inches (3.25"x3.25"), the clip will push against the foam bearing the weight of the concrete.

Two failure modes are possible: the load on the foam may exceed its punching shear strength or the clip may become unseated from the tie allowing the foam to move.

The punching shear strength of a section of foam is determined by the surface area exposed to the shear. With 3.25-inch square clip and 2-inch thick insulation the area exposed to the punching shear is:

**Punching Shear Load Area**

4.25" x 2.0" x4 sides = 34 in$^2$

With a punching shear failure, the failure occurs at a distance from the clip equal to one quarter of the foam thickness. With a punching shear capacity of 15 psi the ultimate punching shear load of the foam is 510 lbs.

**Punching Shear Ultimate Load Calculation**

$34\ in^2 \times 15\ lbs./in^2 = 510\ lbs.$

To test the strength of the clip/tie combination when under a load normal to the surface of the foam, a clip was placed on a tie and the combination was placed in an Instron machine. A load was applied to the face of the clip which would normally be in contact with the foam. The load was increased until the clip became unseated from the tie. The ultimate load was 385 lbs.

Given these results, one would expect the clip to become unseated prior to the punching shear limit of the foam being reached. Cutouts and other fabrication features may affect this conclusion.

## Wind Load

HK VP ties are designed to resist wind loads so that the fascia remains attached to the panel or cell.

Using the UBC wind load calculation, the design wind pressure may be calculated as:

Design Wind Pressure Calculation (UBC)

$P = C_e \times C_q \times q_s \times I_w$

$= 34.2\ lbs/ft^2$

Where:

| | | |
|---|---|---|
| $C_e$ | = 1.37 | gust factor coefficient (building height 50 ft) |
| $C_q$ | = 1.2 | pressure coefficient |
| $q_s$ | = 20.8 | wind stagnation pressure |
| $I_w$ | = 1.0 | importance factor |

The maximum pressure occurs at corners. To calculate the corner pressure, multiply the panel wind pressure by a factor of two; in this case, the result is 68.4 pounds per square foot.

Maximum Wind Load Calculation

The calculation for maximum load on the tie is:

$68.4\ lbs/ft^2 \times 1.00\ ft^2/tie =$

68.4 pounds per tie

With a nominal pullout strength of 1,700, pounds, the HK VP tie has a significant wind load safety factor.

## Alkaline Resistance

The tie must retain its strength even after being exposed to an alkaline environment while under stress.

The manufacturer of the engineered thermoplastic used in HK VP ties rates it as "Excellent" in resistance to alkaline exposure.

To confirm their results, a batch of ties was placed under stress and submerged in cement extract at 150ºF to accelerate the effects of alkaline exposure. After 28 days of exposure, the results indicated the ties will maintain tensile strength above the 1,700 lbs nominal.

## Thermal Performance

Extruded polystyrene (XPS ) rigid foam insulation meets ASTM Standard Specification C-578, Type IV and has the thermal resistance of 5.0 F h $ft^2$/Btu per inch (R per inch).

***XPS Insulation Thermal Performance***

| Thicknesses | | |
|---|---|---|
| IN | MM | R-value |
| 2.0 | 50.0 | 10.0 |
| 3.0 | 75.0 | 15.0 |
| 4.0 | 100.0 | 20.0 |

## Services

HK Composites provides foam fabrication for HK tie customers. HK Composites also provides scale drawings of the insulation portions of the job, showing haw foam will be fabricated and the locations of all ties.

## Availability

HK ties have been available for delivery since September, 1994. Shipments are made from the HK plant in American Fork, Utah, or from HK Composites' authorized distributors of HK™ connector products.

## Other Information

Complete installation instructions for XPS insulation and HK connector ties (Pub. No. HK-ST-II) are available from your HK representative.

## Related Services

HK Composites can provide fabrication and drafting services related to insulated concrete sandwich panel jobs. Please contact your HK Composites representative.

# XPS Rigid Foam Insulation and HK™ Connector Ties for Vertical Pour Applications

**Local Distributor:**
M/s. Isofoam Insulating Materials Plants W.L.L.
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**Disclaimer of Liability**

It is the sole responsibility of the contractor to install the XPS Foam Insulation and Low-conductivity HK Ties in accordance with these published instructions. The presence of an HK representative at the job site does not relieve contractor from the responsibility to follow these published installation instructions. HK COMPOSITES IS NOT RESPONSIBLE FOR ANY LIABILITY RESULTING FROM A FAILURE TO FOLLOW THESE INSTRUCTIONS

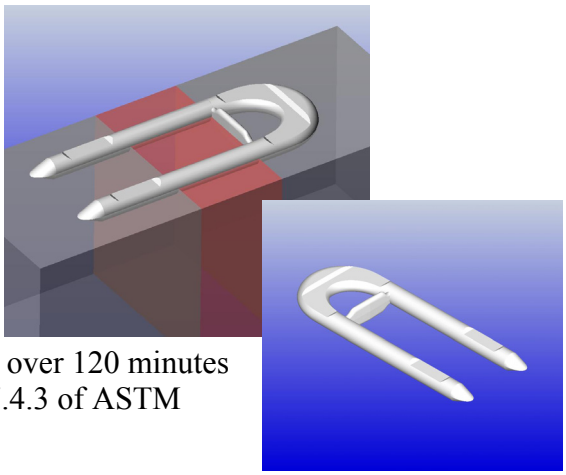

Pub. No. HK-VP-PDS Printed in U.S.A., September 2007 

# HK COMPOSITES INSULATED CONCRETE SANDWICH PANEL TIES

## PRODUCT SPECIFICATION

**Product:** HK™ Double-Prong Low-Conductivity Wall Tie

**Applications:** Pre-cast, pre-stressed, and tilt-up. Fascia may be supported or unsupported up to 3 inches thick and up to 4 inches thick supported.



| | |
|---|---|
| Insulation thickness: | 1.5 in. /38 mm |
| Fascia Thickness: | 2 to 4 in / 50 to 100mm |
| Tensile Strength: | 1,100 lb. / 4.89 kN |
| Pullout Strength: | 1,100 lb. / 4.89 kN |
| Panel Shear Capacity: | 500 lb. / 2.22 kN/tie |
| Alkaline Resistance: | Excellent |
| Impact Resistance: | Excellent |
| Thermal Conductivity: | 2.42 Btu-in/hr-ft$^2$ ºF<br>0.35 W/mºK |
| Fire Performance: | Resist 300-lb tension load for over 120 minutes when fire tested per Section 7.4.3 of ASTM E1512-01. |

| | |
|---|---|
| Tie length: | 4.75 in. /121 mm |
| Embedment Length: | 1.5 in. /38 mm |
| Diameter through Foam: | 2 x 0.354 in. / 2 x 9.0mm |

See installation instructions (Pub. No. HK-ST-II) before using.

**HK COMPOSITES, INC.**
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Pub. No. HK-150 September 2006

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U.S Patents:5,519,973; 5,830,399;5,987,834;5,809,723;6,112,491; Canadian Patent 2,187,284; Australian Patent 687,367; European Patent 0754265; Mexican Patent 201,274; Chinese Patent ZL 95192498.2; Japanese Patent 3,604,144

# INSULATED CONCRETE SANDWICH PANEL TIES

HK Composites

## PRODUCT SPECIFICATION

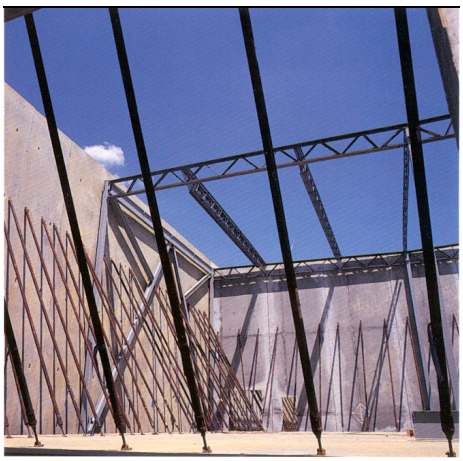
**Product:** 2" Ties for insulated concrete sandwich panels.

**Applications:** Pre-cast, pre-stressed, and tilt-up. Fascia may be supported or unsupported up to 3 inches thick.

| | |
|---|---|
| Insulation thickness: | 2 in. /50 mm |
| Fascia Thickness: | 2 to 4 in / 50 to 100mm |
| Tensile Strength: | 1,100 lb. / 4.89 kN |
| Pullout Strength: | 1,100 lb. / 4.89 kN |
| Shear Strength: | 910 lb. / 4.04 kN |
| Panel Shear Capacity: | 500 lb. / 2.22 kN/tie |
| Alkaline Resistance: | Excellent |
| Impact Resistance: | Excellent |
| Thermal Conductivity: | 2.42 Btu-in/hr-ft$^2$ ºF<br>0.35 W/mºK |
| Fire Performance: | Resist 300-lb tension load for over 90 minutes when fire tested per Section 7.4.3 of ASTM E1512-01. |

| | |
|---|---|
| Tie length: | 5.31 in. /135 mm |
| Embedment Length: | 1.5 in. /38 mm |
| Diameter through Foam: | 0.5 in. /12.5 mm |

See installation instructions (Pub. No. HK-ST-II) before using.



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Pub. No. HK-200 September 2007

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# HK COMPOSITES INSULATED CONCRETE PANEL TIES

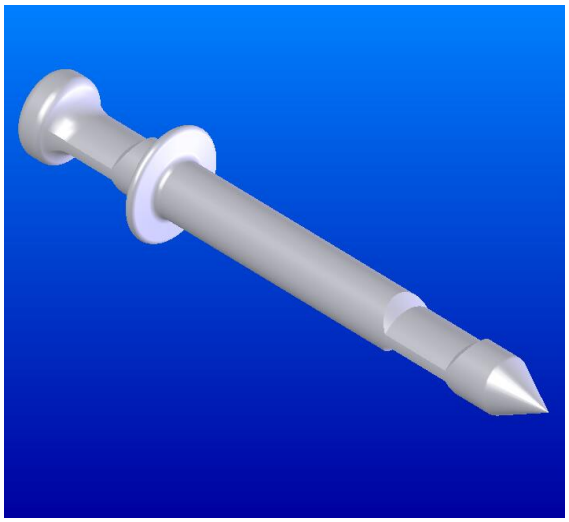
## PRODUCT SPECIFICATION

**Product:** 2.5” Ties for insulated concrete sandwich panels.

**Applications:** Pre-cast, pre-stressed, and tilt-up. Fascia may be supported or unsupported up to 3 inches thick.

| | |
|---|---|
| Insulation thickness: | 2.5 in. /60 mm |
| Fascia Thickness: | 2 to 4 in / 50 to 100mm |
| Tensile Strength: | 1,100 lb. / 4.89 kN |
| Pullout Strength: | 1,100 lb. / 4.89 kN |
| Shear Strength: | 910 lb. / 4.04 kN |
| Panel Shear Capacity: | 500 lb. / 2.22 kN/tie |
| Alkaline Resistance: | Excellent |
| Impact Resistance: | Excellent |
| Thermal Conductivity: | 2.42 Btu-in/hr-ft$^2$ ºF |
| | 0.35 W/mºK |

| | |
|---|---|
| Tie length: | 5.75 in. /145 mm |
| Embedment Length: | 1.5 in. /38 mm |
| Diameter through Foam: | 0.5 in. /12.5 mm |



See installation instructions (Pub. No. HK-ST-II) before using.

**HK COMPOSITES, INC.**
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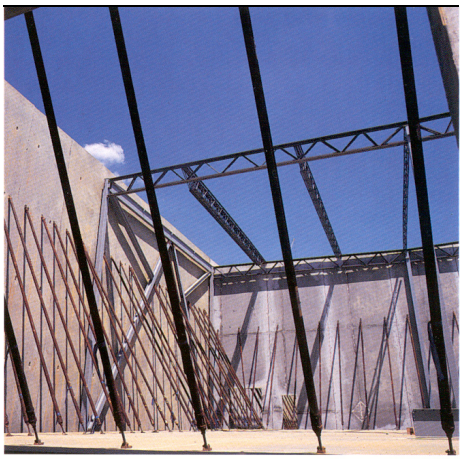
(801) 763-0907

Pub. No. HK-250 September 2007



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U.S Patents:5,519,973; 5,830,399;5,987,834;5,809,723;6,112,491; Canadian Patent 2,187,284; Australian Patent 687,367; European Patent 0754265; Mexican Patent 201,274; Chinese Patent ZL 95192498.2; Japanese Patent 3,604,144

# HK COMPOSITES INSULATED CONCRETE PANEL TIES

## PRODUCT SPECIFICATION

**Product:** 3” Ties for insulated concrete sandwich panels.

**Applications:** Pre-cast, pre-stressed, and tilt-up.

| | |
|---|---|
| Insulation thickness: | 3 in. / 75 mm |
| Fascia Thickness: | 2 to 4 in. / 50 to 100mm |
| Tensile Strength: | 1,500 lb. / 6.67 kN |
| Pullout Strength: | 1,500 lb. / 6.67 kN |
| Shear Strength: | 1,700 lb. / 7.56 kN |
| Panel Shear Capacity: | 800 lb. / 3.56 kN/tie |
| Alkaline Resistance: | Excellent |
| Impact Resistance: | Excellent |
| Thermal Conductivity: | 2.42 Btu-in/hr-ft$^2$ ºF<br>0.35 W/mºK |

| | |
|---|---|
| Tie length: | 6.25 in. /160 mm |
| Embedment Length: | 1.5 in. /38 mm |
| Diameter through Foam: | 0.57 in. /14.5 mm |

See installation instructions (Pub. No. HK-ST-II) before using.

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Pub. No. HK-300 September 2007

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# HK COMPOSITES INSULATED CONCRETE PANEL TIES

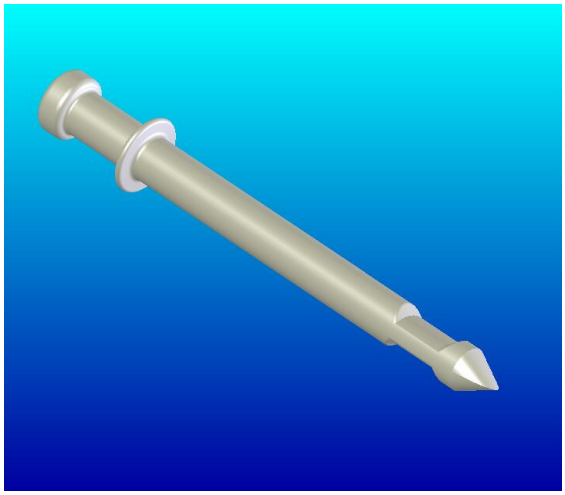
## PRODUCT SPECIFICATION

**Product:** 4” Ties for insulated concrete sandwich panels.

**Applications:** Pre-cast, pre-stressed, and tilt-up.

| | |
|---|---|
| Insulation thickness: | 4 in. /100 mm |
| Fascia Thickness: | 2 to 4 in. / 50 to 100mm |
| Tensile Strength: | 1,500 lb. / 6.67 kN |
| Pullout Strength: | 1,500 lb. / 6.67 kN |
| Shear Strength: | 1,700 lb. / 7.56 kN |
| Panel Shear Capacity: | 800 lb. / 3.56 kN/tie |
| Alkaline Resistance: | Excellent |
| Impact Resistance: | Excellent |
| Thermal Conductivity: | 2.42 Btu-in/hr-ft$^2$ ºF |
| | 0.35 W/mºK |

| | |
|---|---|
| Tie length: | 7.25 in. /184 mm |
| Embedment Length: | 1.5 in. /38 mm |
| Diameter through Foam: | 0.57 in. /14.5 mm |



See installation instructions (Pub. No. HK-ST-II) before using.

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Pub. No. HK-400 September 2007

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U.S Patents:5,519,973; 5,830,399;5,987,834;5,809,723;6,112,491; Canadian Patent 2,187,284; Australian Patent 687,367; European Patent 0754265; Mexican Patent 201,274; Chinese Patent ZL 95192498.2; Japanese Patent 3,604,144

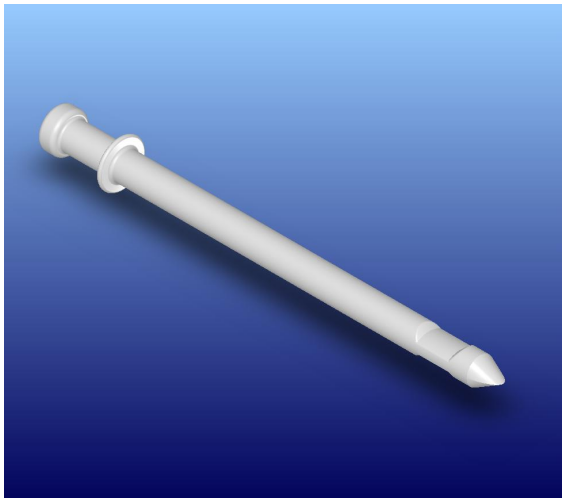
# HK COMPOSITES INSULATED CONCRETE PANEL TIES

## PRODUCT SPECIFICATION

**Product:** 6” Ties for insulated concrete sandwich panels.

**Applications:** Pre-cast, pre-stressed, and tilt-up.

| | |
|---|---|
| Insulation thickness: | 6 in. /150mm |
| Fascia Thickness: | 2 to 4 in. / 50 to 100mm |
| Tensile Strength: | 1,500 lb. / 6.67 kN |
| Pullout Strength: | 1,500 lb. / 6.67 kN |
| Shear Strength: | 1,700 lb. / 7.56 kN |
| Panel Shear Capacity: | 800 lb. / 3.56 kN/tie |
| Alkaline Resistance: | Excellent |
| Impact Resistance: | Excellent |
| Thermal Conductivity: | 2.42 Btu-in/hr-ft$^2$ ºF |
| | 0.35 W/mºK |
| Tie length: | 9.25 in. /235 mm |
| Embedment Length: | 1.5 in. /38 mm |
| Diameter through Foam: | 0.57 in. /14.5 mm |



See installation instructions (Pub. No. HK-ST-II) before using.

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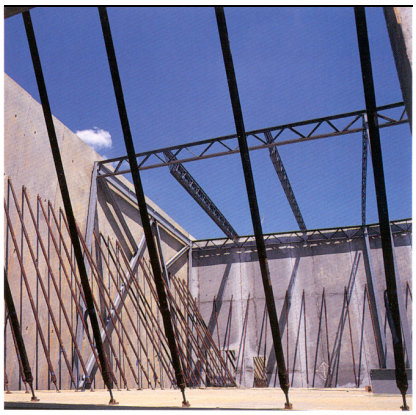
Pub. No. HK-400 September 2007



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# HK COMPOSITES INSULATED CONCRETE PANEL TIES

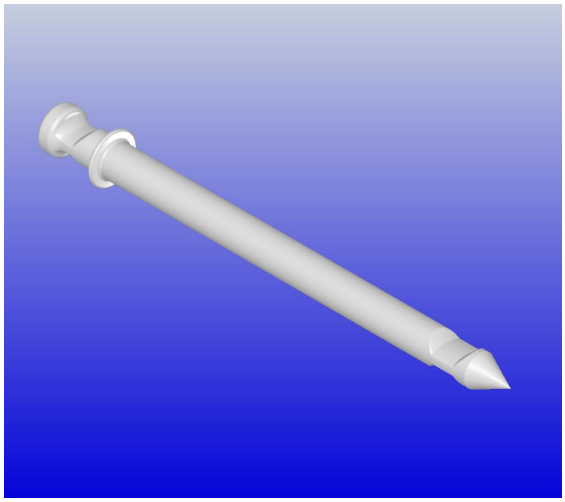
## PRODUCT SPECIFICATION

**Product:** 8” Ties for insulated concrete sandwich panels.

**Applications:** Pre-cast, pre-stressed, and tilt-up.

| | |
|---|---|
| Insulation thickness: | 8 in. /200 mm |
| Fascia Thickness: | 2 to 4 in. / 50 to 100mm |
| Tensile Strength: | 2,300 lb. / 10.23 kN |
| Pullout Strength: | 2,300 lb. / 10.23 kN |
| Shear Strength: | 2,300 lb. / 10.23 kN |
| Panel Shear Capacity: | 1,000 lb. / 4.44 kN/tie |
| Alkaline Resistance: | Excellent |
| Impact Resistance: | Excellent |
| Thermal Conductivity: | 2.42 Btu-in/hr-ft$^2$ ºF<br>0.35 W/mºK |

| | |
|---|---|
| Tie length: | 11.38 in. /289 mm |
| Embedment Length: | 1.5 in. /38 mm |
| Diameter through Foam: | 0.75 in. /19 mm |



See installation instructions (Pub. No. HK-ST-200) before using.

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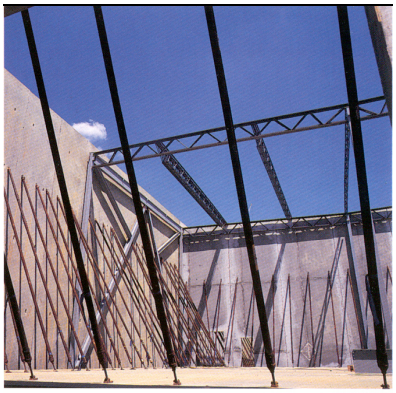
Pub. No. HK-800 September 2007



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U.S Patents:5,519,973; 5,830,399;5,987,834;5,809,723;6,112,491; Canadian Patent 2,187,284; Australian Patent 687,367; European Patent 0754265; Mexican Patent 201,274; Chinese Patent ZL 95192498.2; Japanese Patent 3,604,144

# INSULATED CONCRETE SANDWICH PANEL TIES

HK Composites

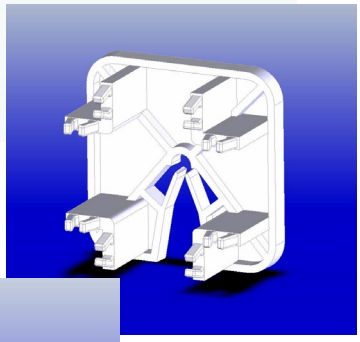
## PRODUCT SPECIFICATION

**Product:** HK™ Vertical-Pour Low-Conductivity Wall Ties.

**Applications:** Modular Pre-cast and Poured-in-Place for insulated concrete sandwich panels.

| | |
|---|---|
| Insulation thickness: | 1.5 - 4 in. /38 -100 mm |
| Fascia Thickness: | 2.5–4 in. / 64–100mm |
| Inside Wall Thickness: | 2.5–10 in. / 64–254mm |
| Tensile Strength: | 1,100 lb. / 4.89 kN |
| Pullout Strength: | 1,100 lb. / 4.89 kN |
| Panel Shear Capacity: | |
| 1.5”-2” Insulation: | 200 lb. / 0.89 kN/tie |
| 3” Insulation: | 150 lb. / 0.67 kN/tie |
| 4” Insulation: | 140 lb. / 0.62 kN/tie |
| Alkaline Resistance: | Excellent |
| Impact Resistance: | Excellent |
| Fire Performance: | Resist 300-lb tension loads for over 90 minutes when fire tested per Section 7.4.3 of ASTM E1512-01. |
| Thermal Conductivity: | 2.58 Btu-in/hr-ft$^2$ ºF<br>0.37 W/mºK |
| Tie Length: | 6.5–15 in. /165–381 mm |
| Embedment Length: | 2.38–9.88 in. /60–251 mm |
| Diameter through Foam: | 0.5 in. /12.5 mm |

See installation instructions (Pub. No. HK-VP-II) before using.



U.S Patents
5,673,525
5,996,297

Canadian Patent
2,237,793

European Patent
0954652

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Pub. No. HK-VP September 2007

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Technical Update

# XPS Rigid Foam Insulation and HK™ Ties

## Spalling Force

### Description

The outside layer of concrete in a sandwich wall panel will experience temperature swings throughout the year. The concrete and everything in the concrete will expand and contract during these thermal cycles. A concern may arise that the thermal expansion or contraction of the HK tie will exert a force on the fascia causing the concrete to fail resulting in surface spalling.

An analysis based on the material properties of the tie and the concrete shows the HK tie provides a safety factor of over 5.0 for a 100ºF temperature change in a typical 2-inch fascia. As the fascia thickness increases, so does the factor of safety.

### Approach

The dimensional change of a material as a result of temperature change is a function of:

| | | |
|---|---|---|
| $\Delta T$ | = | temperature change |
| L | = | original length |
| $\alpha$ | = | coefficient of linear thermal expansion (CTE) |

Expressed mathematically as,

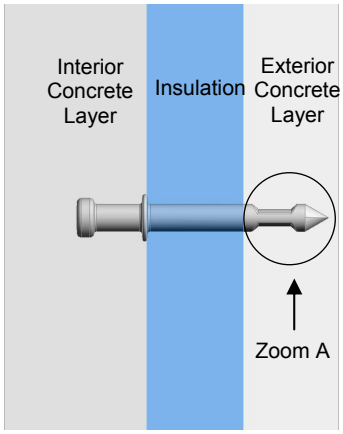
$\delta = \Delta T * L * \alpha$

When the temperature of the fascia increases, the volume of the HK tie and the concrete would increase if they are not restrained. The CTE of the tie is greater than that of the concrete so the thermal growth of the tie is partially restrained. As the concrete around the tie restrains the tie elastically, the tie also compresses the concrete to an equilibrium position (see Fig. 1).

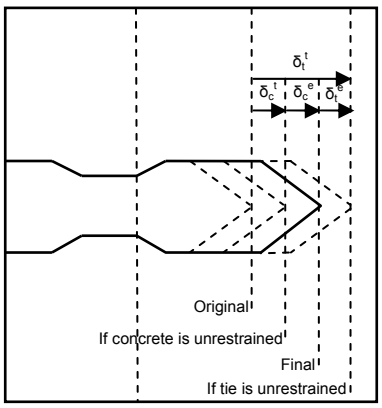
Referring to Figure 1(b), the equilibrium position of the tie after the temperature increase can be described as:

$$\delta_{equil} = \delta_t^{\,t} - \delta_t^{\,e} = \delta_c^{\,t} + \delta_c^{\,e}$$

**Figure 1 – Thermal Expansions of Tie and Concrete**




**(a) HK Tie in Concrete Sandwich Panel**




**(b) Zoom A**

With this equation, we can now substitute the following terms.

| | | |
|---|---|---|
| $\delta_t^{\,t}$ | = | $\Delta T * L_t * \alpha_t$ |
| $\delta_t^{\,e}$ | = | $P * L_t/(A_t * E_t)$ |
| $\delta_c^{\,t}$ | = | $\Delta T * L_c * \alpha_c$ |
| $\delta_c^{\,e}$ | = | $P * L_c/(A_c * E_c)$ |

Where,

| | | |
|---|---|---|
| $\Delta T$ | = | temperature change |
| $A_t$ | = | cross-sectional area of tie |
| $A_c$ | = | area of concrete over which load is applied |
| $E_t$ | = | compression modulus of tie |
| $E_c$ | = | compression modulus of concrete |
| $L_t$ | = | length of tie restrained by concrete |
| $L_c$ | = | length of concrete compressed by tie |
| $\alpha_c$ | = | coefficient of linear expansion of concrete |
| $\alpha_t$ | = | coefficient of linear expansion of tie |
| P | = | spalling force |

After substitution and solving for P in the equilibrium equation, we get the following equation to calculate the spalling force.

$$P = \frac{\Delta T * A_c * E_c * A_t * E_t * (L_t * \alpha_t - L_c * \alpha_c)}{(L_c * A_t * E_t + L_t * A_c * E_c)}$$

### Spalling Force Calculation

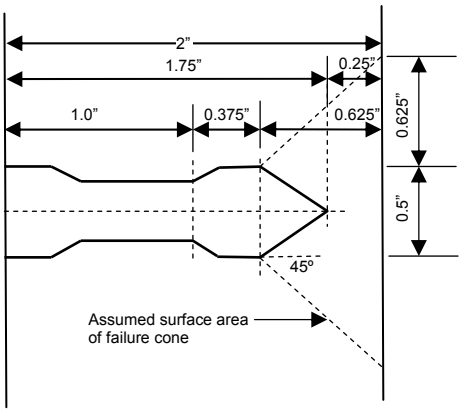
The following example shows the spalling force generated due to tie elongation with a 2 in. exterior concrete layer. The values to plug into the equation are:

| | | |
|---|---|---|
| $\Delta T$ | = | 100ºF |
| $A_t$ | = | 0.196 $in^2$ |
| $A_c$ | = | 0.196 $in^2$ |
| $E_t$ | = | 251,000 psi |
| $E_c$ | = | 3,156,000 psi |
| $L_t$ | = | 0.75 in. |
| $L_c$ | = | 0.625 in. |
| $\alpha_c$ | = | 6.2 x $10^{-6}$ in./in.ºF |
| $\alpha_t$ | = | 31.0 x $10^{-6}$ in./in.ºF |

# XPS Rigid Foam Insulation and HK™ Connector Ties

The spalling force, P, equals 119 lbs. This force is to be distributed over the assumed failure surface which is taken to be that of a 45º truncated cone, as per PCI Design Handbook*, and is shown below in Fig. 2.

**Figure 2 – Assumed Failure Surface Area of the Cone**




## Safety Factor

In order to calculate a safety factor, the following equation for basic concrete breakout strength from the American Concrete Institute's Building Code Requirements for Structural Concrete (ACI 318-05) was used to determine the allowable load, $P_{allow}$.

$$P_{allow} = 24\sqrt{f'_c}\, h_{ef}^{1.5}$$

Where,

$h_{ef}$ = the effective anchor embedment depth

$f'_c$ = compressive strength of concrete

For 3,000 psi concrete with a 2.0 in. fascia, $P_{allow}$ equals 650 lb.

For a 2.0 in. fascia made from 3,000 psi concrete experiencing a 100ºF temperature increase over ambient casting temperature, the HK tie will exert a force of 18% of the allowable force, i.e. a factor of safety of 5.4. The safety factor increases to 13 when the exterior layer thickness in 2.5 in.

This analysis confirms that the differential thermal elongation of the tie has a high factor of safety and should not be a concern to the designer.

## Other Information

Complete installation instructions for XPS insulation and HK connector ties (Pub. No. HK-ST-II) are available from your HK representative.

*PCI Design Handbook, 4th edition, Precast/Prestressed Concrete Institute, Chicago, IL, 1992, pp. 6-7.

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HK ties are distributed in the U.S. and Canada by Owens Corning as PINKCORE ties.

Pub. No. 71521 Printed in U.S.A., September 2007 

**Disclaimer of Liability**

It is the sole responsibility of the contractor to install the XPS Foam Insulation and Low-conductivity HK Ties in accordance with these published instructions. The presence of an HK representative at the job site does not relieve contractor from the responsibility to follow these published installation instructions. HK COMPOSITES IS NOT RESPONSIBLE FOR ANY LIABILITY RESULTING FROM A FAILURE TO FOLLOW THESE INSTRUCTIONS

# Installation Instructions

HK Composites

# HK™ TIES FOR TILTUP & PRECAST INSULATED CONCRETE PANELS

## Description

HK™ panel ties are specifically designed for use in tilt-up, and precast panels.

Each sheet of insulation should be marked on one side with dots on 400mm to 435mm (16 to 17-inch) centers, indicating where ties would normally be inserted into the foam.

The HK™ ties are designed to keep a 76mm (3") fascia layer of concrete affixed to the panel without the benefit of solid sections of concrete.

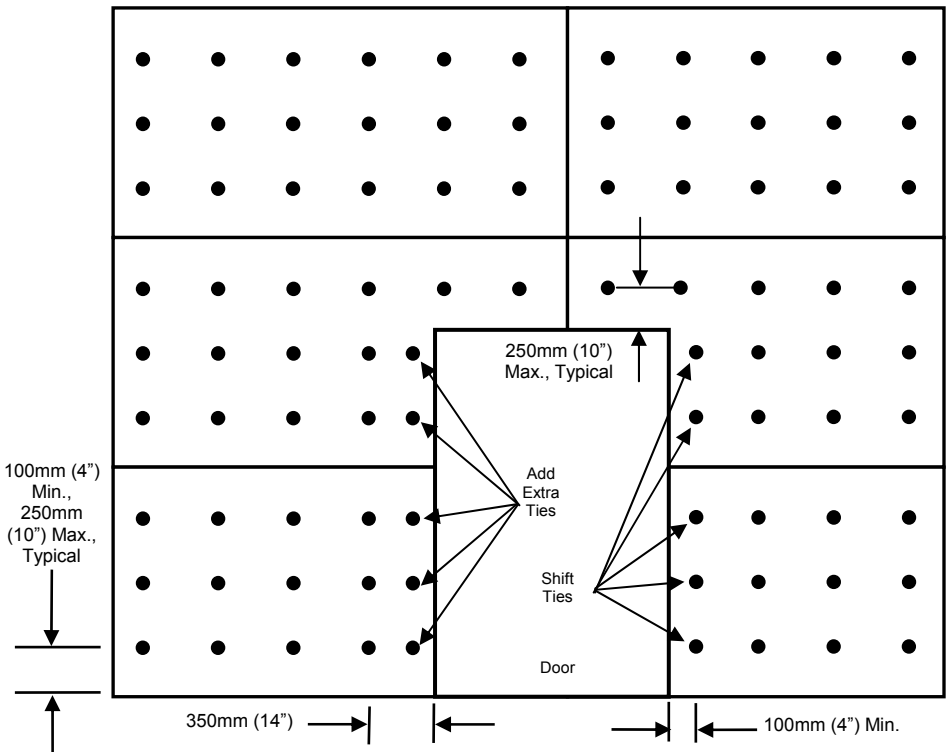
## Applications

The HK™ ties may be used in most tilt-up and precast applications where:

- The fascia is 100mm (4") thick or less
- The panels do not extend beyond 12.5m (50') above grade
- The concrete compressive strength at the time of lifting is at least 17.2Mpa (2,500 psi)
- If the fascia is suspended, the rigid foam insulation has a density of 27.23 kg/m$^3$ (1.7 lb/ft$^3$) or greater and fascia is 75mm thick or less.

## Installation

- Place foam insulation board on freshly poured concrete immediately after screeding (within 15-30 minutes). The concrete should be level enough to contact the entire surface of the insulation board.
- Insert the HK ties immediately after placing the insulation board on the wet concrete. Push the pointed end of the tie through the insulation board into the fresh concrete until the embedment stop is even with the top surface of the insulation board. Optionally, ties may be pushed through insulation board before placing it on the concrete, while it is stacked on top of other insulation boards. Place ties on 400mm (16-inch) centers.




To promote concrete consolidation around the tie, apply repetitive foot pressure on the insulation board near each tie, or otherwise vibrate the tie or the area around the tie. Do not use this system while it is raining or if rain is imminent.

### Around Openings/At Panel Edges

Ties should be no closer than 100mm (4") and no further than 250mm (10") from the edge of the foam. In these cases, you may need to either shift ties away from the panel edges or openings or add extra ties so this spacing is maintained.

# HK™ LOW CONDUCTIVITY TIES FOR INSULATED STRUCTURAL CONCRETE PANELS

**More Information**

For more information on HK ties please contact your local distributor to request the Product Specification.

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HK Composites

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U.S. Patents: 5,519,973; 5,830,399; 5,987,834; 5,809,723 and 6,112,491.
Canadian Patent: 2,187,284.
Australian Patent: 687,367.
European Patent: 0754265.
Mexican Patent: 201,274.
Chinese Patent: ZL 95192498.2.
Japanese Patent: 3,604,144.



Pub. No. HK-ST-II, September 2007

# Installation Instructions

HK Composites

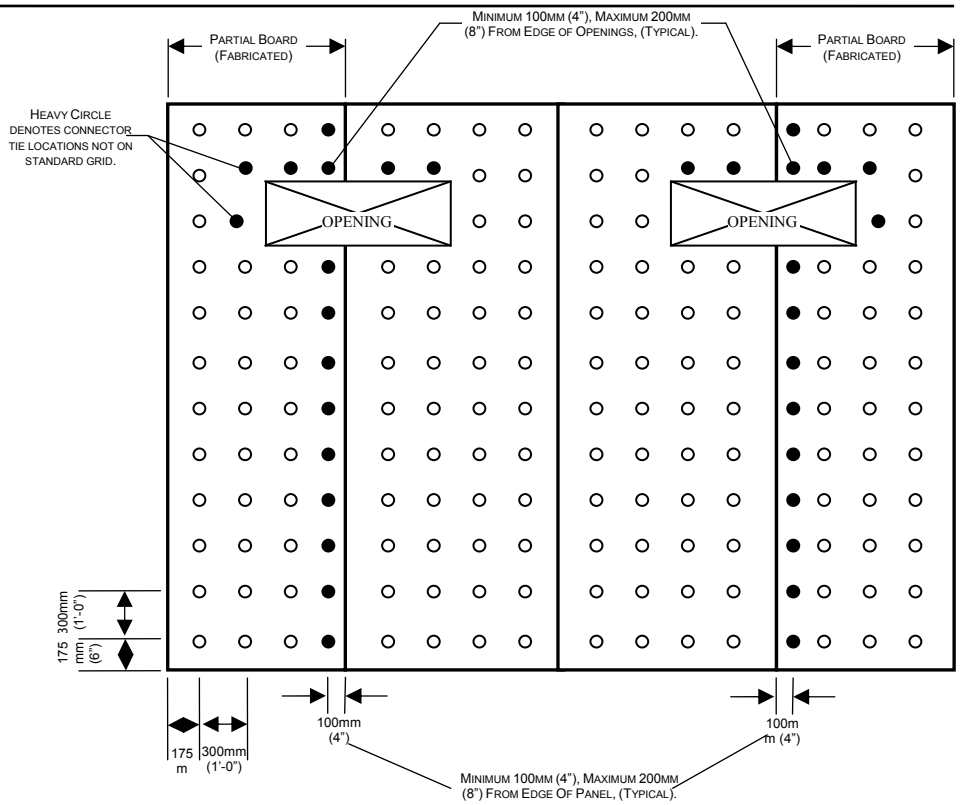
# HK™ TIES FOR FOR VERTICAL POUR APPLICATIONS FOR INSULATED STRUCTURAL CONCRETE PANELS

## Description

HK™ panel ties for vertical pour (VP) applications are specifically designed for use in cast-in-place and modular precast applications. They provide a fast, efficient method of insulating concrete structures without compromising the low-maintenance/high durability of concrete walls.

Each sheet of insulation should be marked on one side with dots on 305mm (12-inch) centers, indicating where ties would normally be inserted into the foam.

The HK™ VP tie is designed to work with two clips per tie to hold the foam in place during casting. The clips fit into recessed areas on the tie.




## Applications

The HK™ VP ties may be used in most modular precast and cast-in-place applications where the following conditions apply:

- The fascia, or outside layer, is 75mm (3") thick or less for modular precast applications.
- Fascias 10 feet or taller are unsupported, if wall section has 50mm thick foam, or use VPT ties for tall walls (fascias less than 10 feet tall may be supported or unsupported).
- The concrete compressive strength at the time of lifting is at least 17.2Mpa (2,500 psi).

## Installation

- Attach one clip to the tie. The clip slides into the recessed area on the tie from the side. The two retention arms of the clip will snap into place first. Positive retention is ensured when you hear a second "click" and the clip is properly seated on the tie.
- Push the tie with one clip through the foam insulation at a location marked by a dot.
- Move to the other side of the foam insulation and slide the second clip into the recessed area on the tie, just protruding from the foam. The tie is now installed.

Repeat the above steps for each tie.

## Around Openings/At Panel Edges

Ties should be no closer than 100mm (4") and no further than 200mm (8") from the edge of the foam. In these cases, you may need to either shift ties away from the panel edges or openings or add extra ties so this spacing is maintained.

## Concrete Placement

While placing the concrete inside the forms, place the concrete on either side of the foam as equally as possible. Make certain the concrete level on one side does not vary from the level on the opposite side by more that18 inches.

# HK™ TIES FOR INSULATED STRUCTURAL CONCRETE PANELS

### Follow These Instructions

It is the sole responsibility of the contractor to install the HK ties in accordance with these published instructions. The presence of an HK Composites representative at the job site does not relieve contractor from the responsibility to follow these published installation instructions. Failure to follow these instructions could cause injury, death or property damage. In no event shall HK Composites be responsible for any loss or damage caused by improper installation or misuse of the products or systems described herein. Our recommendations should not be taken as inducements to infringe on any patent or violate any law, safety code or insurance regulation

### More Information

For more information on HK ties please contact your local distributor to request the Product Specification.

**Local Distributor:**
M/s. Isofoam Insulating Materials Plants W.L.L.
P.O. Box 23053, Safat, 13091, Kuwait

**Kuwait:**
Tel.: # + 965 4763820/1/2/3
Fax: # + 965 4763819
E-mail: insulations@isofoamkw.com

**UAE:**
Tel.: # + 9714 2861082
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HK Composites

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U.S. Patents: 5,519,973; 5,830,399; 5,987,834; 5,809,723; 5,673,525; 5,996,297; and 6,112,491.
Canadian Patents: 2,187,284 & 2,237,793.
Australian Patent: 687,367.
European Patents: 0754265 & 0954652.
Mexican Patent: 201,274.
Chinese Patent: ZL 95192498.2.
Japanese Patent: 3,604,144.

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March 2007

HK Composites

# HK™ Insulated Concrete Sandwich Panel Wall System
# Partial Project List

**HK™ Low Conductivity Ties have been used successfully in many and varied projects. A partial list is provided in the table[1].**

| Project | Location |
|---|---|
| Barton Fruit | Yakima, WA |
| Blackfoot Telephone Co-Op Garage | Missoula, MT |
| Blue Grass Auto | Louisville, KY |
| BMW Dealership | Halifax, NS |
| Boeing Solid Fuel Rocket Facility | Huntsville, AL |
| Butler County Jail | Elderado, TX |
| Cache County Sheriffs Complex | Logan, UT |
| Cintas | Wichita, KS |
| Clean Uniform Company | Joplin, MO |
| Dust & Son | Charleston, IL |
| Federal Correctional Institute | Herlong, CA |
| Federal Correctional Institute | Yazoo City, MS |
| Frisco Sports Complex | Frisco, TX |
| Great Lakes Cheese Factory | Fillmore, UT |
| Greenville County High School | Greenville, SC |
| Harman Music Group | Sandy, UT |
| Maintenance Work Bays | Ardmore, OK |
| Mary Hill Winery | Goldendale, WA |
| Mercer Wine Estates | Prosser, WA |
| Morris County Correctional Facility | Morristown, NJ |
| National Beef | Emporia, KS |
| Nordstrom | Phoenix, AZ |
| Northwood Paper Converting Inc. | Beaver Dam, WI |
| Paul Thomas Winery | Sunnyside, WA |
| Rouche Racing Facility | Charlotte, NC |
| Snowkist Refrigerated Storage | Yakima, WA |
| Sydney Home for Special Care | Sydney River, NS |
| The Home Depot | Reynoldsburg, OH |
| The Home Depot | Westerville, OH |
| United States Penitentiary | Hazelton, WV |
| United States Penitentiary | Coleman, FL |
| Watts Brothers Dairy | Paterson, WA |

[1] Owens Corning supplied insulation and ties for many of these projects. HK ties are distributed in the U.S. and Canada by Owens Corning as PINKCORE ties. **See Owens Corning project profiles for more in-depth details regarding selected projects.** PINKCORE is a registered trademark of Owens Corning.