Q&A

Questions and Answers about Non-Composite **THERMOMASS®** Building Insulation Systems

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THERMOMASS®
BUILDING INSULATION SYSTEMS
By Composite Technologies Corporation

Non-Composite **THERMOMASS®** Q&A - 7th Edition

General Questions

What is the THERMOMASS® Building Insulation System?

The THERMOMASS Building Insulation System is a patented connector and insulation system for constructing tilt-up, precast, modular precast and poured-in-place insulated concrete sandwich walls.

High strength, low conductivity, and chemically resistant connectors structurally tie two layers of concrete together through pre-drilled, extruded Dow Styrofoam® insulation (R-5 per inch of thickness) or Dow ISO-CAST-R® insulation (R-6.5 per inch of thickness). In applications using a vertical set of forms, the connectors also position the insulation board in the wall during the pouring operation.

Composite Technologies Corporation (CTC), supplies both components of the system - the connector rods and the pre-drilled insulation. In addition, CTC is equipped to provide complete insulation layout drawings and precision-cut foam panels (a service referred to as "fabrication") incorporating openings and edge conditions. Additionally, we can recommend qualified wall panel producers in your area.

Why use the THERMOMASS Building Insulation System?

THERMOMASS places high-quality insulation between two layers of concrete and structurally connects the three layers in a single construction. This significantly improves the R-value of the constructed wall over concrete alone. An un-insulated, 200 mm (8 in) thick concrete wall achieves an R-value of 0.113 m^2•K/W (0.64 ft^2•h•°F/BTU) compared to 0.881 m^2•K/W or (5.0 ft^2•h•°F/BTU) for only 25mm (1 in) of extruded polystyrene insulation.

To be a viable building material in the majority of today's energy conscious regions, a concrete wall simply must be insulated. The THERMOMASS Building Insulation System provides building owners with cost-effective, durable, and energy efficient structures.

How does THERMOMASS differ from other insulated concrete wall systems?

The design of the system enhances the "purchased" R-value by eliminating thermal bridges otherwise created by highly conductive wythe ties and solid-thru concrete sections. Using the THERMOMASS Building Insulation System, a concrete wall can be insulated in a single operation, while maintaining over 99% of the insulation's R-value.

Why is it important to sandwich the insulation between two layers of concrete?

The concrete layers provide thermal mass. That is, the concrete is able to store significant amounts of thermal energy and delay heat transfer through the building walls. According to the Fundamentals Handbook of the American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc. (ASHRAE), this delay leads to three important results:

- First, the slower response time tends to moderate indoor temperature fluctuations under outdoor temperature swings.
- Second, in hot or cold climates, energy consumption is significantly reduced over that for a similarly sized low-mass building.
- Third, because the mass is adjacent to the interior the building energy demand can be moved to off-peak periods because energy storage is controlled through correct sizing of the mass and interaction with the HVAC system.

Composite Technologies Corporation can calculate the increased effect the thermal mass R-value will have for your projects using procedures developed by ASHRAE and other leading energy-efficiency organizations and confirmed by the Department of Energy.

What materials are the connectors made from?

The connectors are made from a fiber composite material consisting of continuous glass fibers and vinyl ester polymer. The materials have been thoroughly tested and proven to be extremely durable and strong.

How are the connectors made?

The connectors are manufactured under a strict quality control process, (independently monitored by a third party as required by International Code Council-Evaluation Service) using a proprietary process where glass fibers are pulled through a thermoset resin bath and a temperature-controlled die. The resin is heated to induce a chemical reaction that bonds the fibers together. In a separate process, a polymer collar is injection molded around the connector.

Why can't the connectors be fabricated using other materials?

The connector material must be compatible with concrete, thermally efficient and exceptionally strong. Compatibility will not exist if the connector is susceptible to alkaline attack, is hydrophilic, or has a thermal coefficient of expansion that is much larger than that of concrete.

Connectors made from incompatible materials may cause blowouts in the thinner, outer concrete wythe. It is even possible that the connectors will lose capacity. THERMOMASS connectors were carefully designed to be compatible with concrete and not lose capacity.

Why use a fiber composite instead of steel?

The fiber composite rod used in The THERMOMASS Building Insulation System has a thermal conductivity of 0.469 W•mm/h•m2•K (2.1 BTU•in/ft2•h•°F).

This compares to values of 40.68 W•mm/h•m2•K (182 BTU•in/ft2•h•°F) for stainless steel and 81.59 W•mm/h•m2•K (365 BTU•in/ft2•h•°F) for mild steel, and 2.79 W•mm/h•m2•K (12.5 BTU•in/ft2•h•°F) for concrete, respectively.

Therefore, THERMOMASS fiber composite connectors eliminate the material components that would otherwise create a thermal bridge.

Will the alkalinity of the concrete attack the rods?

No. The vinyl ester resin matrix protects the glass fibers in the rods from chemical attack. Independent tests show that the connectors can withstand the concrete's alkalinity for up to 100 years.

How do the connectors hold the wall together?

The notches in the flexible, high-strength connectors develop a keying action within the concrete wythes. The pullout strengths of the embedded connectors are far greater than the forces experienced in normal loading conditions.

How long has THERMOMASS been used in sandwich wall applications?

The first building constructed using this system was a nine-story condominium completed in 1980.

What are the applications of The THERMOMASS® Building Insulation System?

- Poured-In-Place - *site cast, vertically formed*
- Precast - *plant cast, horizontally formed*
- Prestressed - *plant cast, including hollow core and double tees, horizontally formed*
- Tilt-Up - *site cast, horizontally formed*
- Modular Precast - *site or plant cast, 4 or 5-sided monolithic modules, vertically formed*

What building types are appropriate for the THERMOMASS system?

Concrete is an architecturally significant building material that can take on virtually any appearance. The THERMOMASS system allows the designer to take advantage of this strength and provide the owner with a highly energy-efficient facility.

The system has been used in a wide variety of building types since 1980 and should be considered for any building where low energy costs, long term durability, low maintenance, low fire insurance rates and low construction costs are important. Completed facilities fall under a wide variety of building types including retail stores and malls, churches, schools, hospitals, correctional facilities, manufacturing and distribution centers, warehouses, coolers/freezers, timber kilns, agricultural buildings, homes and residential developments and sports facilities.

Are there any “special use” type projects where this system should be a first choice?

In recent years, THERMOMASS has been used extensively in prison facilities constructed with conventional precast, tilt-up and modular precast where low operating costs, fire resistance and durability have been important considerations. THERMOMASS has also become a leader in concrete cooler/freezer-type applications where energy efficiency and durability are extremely important.

Thermal Performance

If the quantities of concrete and steel crossing the insulation are very small, then shouldn’t their effects be ignored?

No. Steel conducts energy 1,700 times faster than insulation. Concrete conducts energy 300 times faster than insulation and is a poor insulator. Energy loss attributed to the effect of steel and concrete thermal bridges can be greater than 70%.

Why is the effect of steel and concrete so large?

Heat flows from warm regions to cooler regions. As stated earlier, steel and concrete passing through the insulation create thermal bridges with high rates of heat transfer. In an insulated wall with thermal bridges, energy will tend to flow in paths parallel to the insulation until it reaches the bridges and is conducted rapidly from the warm side to the cold side of the wall. Because the energy effectively flows from a large area surrounding each thermal bridge, the total affected area is much larger than the cross-sectional area of the bridge itself.

Can the effect of thermal bridges be measured and predicted?

Yes. Significant research has been conducted at the Department of Energy’s Oak Ridge National Laboratory using guarded hot box testing. Full-scale examples of many popular construction methods, including insulated concrete sandwich panels, have been tested. The test data verify that one can predict the thermal bridging effect with mathematic equations such as the Modified Isothermal Planes Analysis Method published in the ASHRAE Handbook of Fundamentals.

More information can be found at: http://www.ornl.gov/sci/roofs+walls/awt/ref/techhome.htm

Should there be solid-thru concrete at the panel edges, inserts or openings?

No. Only the THERMOMASS connectors should tie the two concrete wythes together. Insulation should extend to all panels’ edges – eliminating thermal bridging. Solid-thru concrete sections not only produce thermal bridges, but they also restrain independent movement of the outer concrete layer due to temperature change.

Connectors

What is the connector spacing?

Typically, the connectors are spaced 400 mm (16 in) on center in both directions. Depending on panel dimensions and loading conditions, special spacing may be specified.

How is this spacing achieved in the field or plant?

All insulation boards supplied with the THERMOMASS Building Insulation System are delivered with prepunched holes at the specified spacing. Instructions are available should holes need to be added in the field.

What does the connector designation mean?

There are two series of connectors: MC (Metric Common) and MS (Metric Short). The MC series connectors have 50 mm (2 in) embedment into both the interior and exterior concrete layers, while the MS series connectors have 38 mm (1.5 in) embedment.

The four digits following the two-letter designation indicate the insulation thickness. The first number is the insulation thickness measured in inches, multiplied by 10. The second number is the insulation thickness measured in millimeters.

For example, an MS20/50 connector would have an embedment of 38 mm (1.5 in) and would be used with 50 mm (2 in) thick insulation.

How do I determine which connector to use?

All connectors have a molded collar with a length corresponding to the insulation thickness. The MS series is designed for panels in which one or both concrete wythes are 50 mm to 63 mm (2.0 in to 2.5 in) thick (minimum recommended thickness). If both concrete wythes are 63 mm (2.5 in) or more in thickness, or if the depth of the reveals in the panels allow a net thickness 2.0 in or greater, then the MC series connectors should be used.

Insulation and Wythe Thickness

What thickness of insulation can be used?

Insulation thickness values ranging from 25 mm (1 in) to 250 mm (10 in) have been used successfully. The minimum recommended thickness is 38 mm (1.5 in) for horizontally poured panels and 50 mm (2 in) for vertically poured walls. A thickness greater than 75 mm (3 in) is typically built-up from multiple layers of insulation. The required thickness may be determined using a thermal analysis that considers the building's use, location and vapor drive potential.

What is the minimum thickness of a typical face wythe?

A minimum thickness of 50 mm (2 in) is recommended. This will provide 13 mm (.5 in) cover over the end of the shorter (MS) connectors. The thickness of the wythe should be increased from this minimum by adding the depth of any architectural reveals or rustication lines.

What is the typical structural wythe thickness?

The thickness will vary as a function of the construction method and building loads. For factory cast applications, the panel manufacturer must be consulted. For tilt-up applications, an initial thickness can be estimated by multiplying the un-braced panel length (in inches) by the inverse of the slenderness ratio of 50. The final thickness must be determined by the engineer of record considering erection, gravity and lateral forces.

Wall Finishes

What types of concrete finishes are possible?

It is up to the capabilities of your local wall producers. The THERMOMASS Building Insulation System can be used with any type of forming system, with or without form liners. Finishes can include natural concrete, paint, skim coat plaster, sandblasted, concrete exposed aggregate, colored concrete, thin brick or most forms of concrete treatment. Other materials may be secured to the wall with concrete anchors.

What about other design considerations?

There is no limit to the design possibilities when casting a panel in a form. Reveals, rustication, embossed logos and dimples in the finish are just a few examples. In fact, for a nominal charge, Composite Technologies Corporation can supply polystyrene molds for replication of almost any logo produced using a CAD drawing.

Details

Will solid concrete edges affect the panel?

Solid concrete edges will cause thermal bridges as discussed above. Perhaps more importantly, however, they will restrict the exterior face from moving independently of the interior face in response to temperature changes. This will create stresses within the exterior face resulting in non-structural cracking and may cause panel bowing.

What can I do if I must have a solid concrete section?

There are a variety of methods for reducing the potential for the two layers of concrete to become monolithically connected. Solutions are available through our technical department for specific conditions.

What covers the exposed insulation at openings?

Window and doorjambs can be used to cover the insulation wherever possible. They should be attached to one (usually the interior) wythe of the panel. The other joint should be sealed with caulk to allow for movement. Other options are available through our technical department for specific conditions.

Engineering

Who engineers the panels?

The connector system spacing is pre-engineered by Composite Technologies Corporation. The structural capacity of the panel or structural wythe thickness should be determined by the project structural engineer.

Tensile Strength

What is the tensile strength of the composite material used in the connectors?

The tensile strength of the connector composite material is in excess of 827 Mpa (120,000 psi).

What is the strength of one connector?

A single connector can carry up to 2,500 pounds of concrete.

How much tensile force is a connector subjected to in a typical panel?

A typical connector is subjected to approximately 0.5 kN (110 lbs.) of force during the lifting of a panel from the casting bed. That force can be calculated as follows for a 75 mm (3") face:

	kPa	**lb/ft2**
Face weight (based on normal weight concrete)	1.8	37.5
Suction	1.2	25.0
Total	3.0	62.5
Tributary area for connector	0.165 m2	1.77 ft2
Therefore, tensile force per connector	0.5 kN	110 lb

Uncertainties in concrete construction and other factors such as uneven distribution of forces during initial lifting dictate safety factors of the magnitude that is present with the system.

Shear Strength

What is the shear capacity of the connectors?

The shear capacity of each connector is approximately 4kN (910 lb) in double shear and 2kN (450 lb) in single shear.

What is the shear load on a connector in a typical application?

The load on a connector with a 75 mm (3") fascia wythe thickness would be approximately 0.30 kN. (66 lb) calculated as follows:

	kPa	**lb/ft2**
Face weight (based on normal weight concrete)	1.8	37.5
Suction	N/A	N/A
Total	1.8	37.5
Tributary area for connector	0.165 m2	1.77 ft2
Therefore, tensile force per connector	0.3 kN	66.4 lb

If the panel is suspended, how much fascia displacement can be expected?

A suspended 75 mm (3") fascia panel with the concrete/insulation bond completely broken would show a deflection of the face wythe relative to the rear wythe of approximately 1.05 mm (0.04") with 50 mm (2") insulation.

Can a heavy suspended fascia wythe be supported?

In the case where a fascia wythe which exceeds 125 mm (5") is suspended from the rear wythe, or where the displacement due to super-imposed loads on the face must be held below 2.54 mm (0.10"), special wide body connectors with higher shear strength can be placed in certain rows. The connector would serve to reduce displacement of the face wythe.

What is an acceptable allowable face displacement?

Design considerations at joints between panels, at doors, and at windows may make it necessary to restrict the total face wythe displacement to 2.54 mm (0.1 in) relative to the rear wythe. The project engineers or architects should determine the actual design parameters.

Composite Action

Does the THERMOMASS Building Insulation System act compositely?

While Composite Technologies Corporation does manufacture an insulation system that allows for composite action, our Non-composite THERMOMASS Insulation System should not be counted on to do so.

A strong bond between the concrete and insulation exists initially. However, that bond will reduce significantly over time. Therefore, we advise that panels be designed as non-composite under service loads.

It should be noted that the connectors and insulation continue to carry shear forces between the two concrete wythes even after the bond has been broken. A combination of bending of the connectors and a compression/friction force system in the insulation resist relative displacement between the concrete wythes and help to support the weight of the face wythe.

If the bond to the insulation is broken, do the connectors have the structural capacity to resist the forces of lifting and handling?

Yes. The shear capacity of the connectors far exceeds the weight of the face wythe.

Can both wythes be used to resist design loads?

Both wythes, acting independently, can be used to resist wind loads. Only one wythe should be used to resist vertical loading (such as roof or floor loading). This is usually the interior (thicker) wythe, but the exterior wythe can also be used.

Thermal Cycling

How much movement can be expected due to temperature change?

The coefficient of thermal expansion for concrete is 10 x 10-6 mm/mm/°C (5.5 x 10-6 in/in/°F). A 12.19 m (40 ft) long panel restrained at one end and subjected to a 56 °C (100 °F) temperature swing can be expected to expand (or contract) approximately 6.7 mm (0.26 in).

Can the connectors take that much movement?

Tests were performed on connectors in a wall with 50 mm (2 in) insulation. The wythes were displaced 11.2 mm (0.44 in) for 2,000 cycles with no deterioration of the connectors or their strength. This represents over 150 years of exposure in a climate with wide temperature swings.

Installation

How is the THERMOMASS system installed?

The precast, pre-stressed and tilt-up systems are all installed with nearly identical practices:

- The bottom layer of concrete is placed in the forms. This begins once the forms have been secured, the surfaces cleaned and treated with a bond release agent, and reinforcing has been placed. Reinforcing for the thinner (outer, lower) concrete layer is typically 6x6 – W2.9xW2.9.
- The pre-drilled insulation is then placed over the fresh concrete (which is placed at a 5” – 7” slump). This should be done immediately after the bottom layer has been consolidated and leveled to thickness, but in any event, within 15 to 20 minutes after placement of the concrete to ensure the concrete mix is still plastic.
- The connectors should immediately be inserted through the pre-drilled holes.

- The concrete around the connectors should then be consolidated. Walking on the insulation near each row of connectors and applying foot pressure on each side of the connector can do this effectively. This will cause the still fluid concrete to flow into the notch in the bottom side of the connector. In factory cast operations, additional consolidation may be achieved by bed vibration. Additionally, Composite Technologies Corporation provides a vibration device for use where insulation thickness exceeds 75 mm (3 in).
- The reinforcement and hardware for the second concrete wythe shall be placed.
- Finally, the top wythe of concrete is placed. (Note: If the top concrete wythe cannot be poured immediately, then it must be poured after the bottom or lower concrete wythe has fully set.)

Contact Composite Technologies Corporation for installation guides for specific applications.

What is the most important thing to remember about installation?

You must have concrete consolidation around the notch for the connector to develop its strength.

How can good consolidation be attained?

Walking along or exerting foot pressure on each side of the connectors (often called the "THERMOMASS Shuffle") causes fresh, plastic concrete to flow around the notches in the connector. Good consolidation can be achieved by placing the insulation, inserting connectors and "walking" the insulation immediately after placing the lower concrete wythe (within 20 minutes under normal conditions).

Note: Setting time varies as a function of many factors, including (but not limited to) mix design, concrete temperature, ambient temperature, casting surface temperature, and mix time. The installer must ensure that the concrete has not reached initial set before connectors are installed.

What if a row of holes is removed while trimming an insulation board to fit?

A new row of holes should be drilled into the insulation by drilling holes with a $^{7}/_{16}$ inch diameter drill bit. The new row of holes should be no closer than 100 mm (4 in) to and no farther then 200 mm (8 in) from the edge of the insulation.

What should be done if a connector hits a reinforcing bar or piece of aggregate?

Remove the connector and reinsert it at an angle to bypass the obstruction.

Will applied curing heat affect the THERMOMASS Building Insulation System?

The connectors won't be affected. However, some insulation will soften at approximately 71 °C (160 °F). Extruded polystyrenes will expand and expanded polystyrenes can melt. Curing temperatures (the combination of heat of hydration and applied curing heat) in the lower concrete wythe should be carefully monitored near the center of the panel and not allowed to exceed 60 to 65 °C (140 to 150 °F).

Testing

What types of tests have been performed on the connectors and walls?

The connectors have been independently tested for tensile strength, compression strength, shear strength, fatigue and cyclic loads, both high and low temperature stress, fire resistance and flexure.

Have tests been performed to confirm alkaline resistance?

Tests were performed on the rods according to accepted standards to simulate over 100 years of alkaline exposure. There was no significant loss in the strength of the rods.

Is the THERMOMASS system structurally proven?

THERMOMASS has proven itself in the laboratory and in the field. Construction Technology Laboratories (CTL) of Skokie, Illinois, performed flexural load tests on the basic wall configuration in 1984. Since then, years of successful application as well as additional structural and fire testing at CTL, Iowa State University, the University of Kaiserslautern, Stork Twin City Testing Corporation, and Southwest Research Institute have verified the outstanding structural capabilities of the THERMOMASS Building Insulation System.

How do the connectors perform in fire?

A test performed at a leading fire testing agency in the United States subjected a panel constructed with THERMOMASS fiber composite connectors to 1900 °C (2000 °F) temperatures for 4 hours with no degradation. The temperature, measured on the surface of the wall opposite the fire, rose only 20.8 °C (37.6 °F) during the testing period. The standard for passing the test was a temperature rise of 121 °C (250 °F). The THERMOMASS Building Insulation System actually improved the overall fire resistance of the wall versus a solid cast concrete wall.

In separate tests, THERMOMASS connectors installed in only 75 mm (3 in) of concrete were exposed to a standard time-temperature profile while subjected to high tensile loads. Even under these extreme conditions, the connectors withstood over one hour of fire exposure!

What about R-value testing to support your claims?

The most comprehensive study ever conducted on this issue was done on The THERMOMASS Building Insulation System by Construction Technology Laboratory in Skokie, Illinois.

Additional Q&A brochures are available for composite panel and poured-in-place applications.

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