thermomass®
System NC

Q&A

Questions and Answers about System NC for Non-Composite Concrete Sandwich Walls

Topics include:

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Energy Efficiency in Concrete Terms™

General Questions

What is System NC?

Thermomass System NC is a patented connector and insulation system for constructing non-composite insulated concrete sandwich walls.

High strength, low conductivity, non-corrosive and chemically resistant connectors structurally tie two layers of concrete together through pre-drilled, extruded polystyrene insulation (R-5 per inch of thickness) or polyisocyanurate insulation (R-6.5 per inch of thickness).

Thermomass supplies both components of the system - the connectors and the pre-drilled insulation. In addition, Thermomass is equipped to provide complete insulation layout drawings and precision-cut foam panels (a service referred to as "fabrication") incorporating openings and edge conditions. Furthermore, Thermomass can recommend qualified wall contractors in your area.

Why use System NC?

System NC places high-quality, rigid 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 (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. System NC provides building owners with cost-effective, durable and energy efficient structures.

How does System NC differ from other insulated concrete wall systems?

By incorporating System NC, a concrete wall can be insulated in a single operation and will maintain over 99% of the insulation's "purchased" R-value. This is done by minimizing thermal bridges created by highly conductive wythe ties and solid-thru concrete sections inherent in other systems.

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 of the building, energy demand can be moved to off-peak periods. This is because energy storage is controlled through correct sizing of the mass and interaction with the HVAC system.

Thermomass can calculate the increased effective R-value attributable to the thermal mass in 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?

System NC utilizes MC/MS series connectors from Thermomass. These 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 are carefully designed to be compatible with concrete and not lose capacity.

Why use fiber composite instead of steel?

Thermomass connectors are better suited for sandwich wall construction because steel conducts heat energy at a rate over 50 times greater than that of fiber composite ties.

These ties have a thermal conductivity of 1.0 W/m•°K (6.9 BTU•in/ft²•h•°F).

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

Are the Thermomass MC/MS connectors code compliant?

Yes, the MC/MS connector series used in System NC have received an Evaluation Service Report (ESR-1746) and are compliant with the 2003, 2006 and 2009 International Building Codes, as well as the 1997 Uniform Building Code.

ICC-ES ESR-1746 is based on data submitted in accordance with AC320 (ICC-ES Acceptance Criteria for Fiber-Reinforced Connectors Anchored in Concrete). The AC320 requires seismic tests, creep tests, extreme temperature tests, static tension tests, shear tests and documentation for an ongoing third-party traceable quality control process.

Will the alkalinity of the concrete attack the connectors?

No. The vinyl ester resin matrix protects the glass fibers in the connectors 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 have Thermomass insulation systems been used in sandwich wall applications?

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

What building types are appropriate for Thermomass System NC?

Concrete is an architecturally significant building material that can take on virtually any appearance. Thermomass System NC 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, sports facilities, homes and residential developments.

Does Thermomass have systems for various concrete applications?

Yes, Thermomass has several insulation systems for a variety of concrete applications, including the following:

- Cast-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, 5 or 6-sided monolithic modules, vertically formed*

For more information please visit www.thermomass.com.

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

In recent years, System NC has been used extensively in prison facilities constructed with precast and tilt-up 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. 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.

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

No. Only the MC/MS fiber composite connectors should tie the two concrete wythes together. Insulation should extend to all panels' edges. Solid-thru concrete sections produce significant thermal bridges and 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 System NC are delivered with pre-punched 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 used with System NC: 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 does one determine which connector to use?

The type of connector to use depends on the concrete wythe thickness. If one or both concrete wythe thickness are less than 63mm (2.5in), MS connectors should be used. If both concrete wythes are 63mm (2.5in) or more in thickness then MC connectors should be used. See below for more information on wythe thickness.

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 extensively. A thickness greater than 100 mm (4 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 face wythe?

A minimum thickness of 50 mm (2 in) is recommended. The thickness of the fascia wythe should be increased from this minimum by adding the depth of any architectural reveals, rustication lines or thickness of brick.

What is the typical structural wythe thickness?

The thickness will vary as a function of the construction method and building loads. For plant precast 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. System NC can be used with any type of forming system, with or without form liners. Finishes can include natural concrete, paint, skim coat plaster, sandblasting, exposed aggregate, integral color, 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 and embossed logos in the finish are just a few examples. In fact, for a nominal charge, Thermomass can supply polystyrene molds for replication of almost any logo produced using a CAD drawing.

Details

Will solid concrete sections affect the panel?

Solid concrete sections 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 aesthetic 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 joints should be sealed with caulk to allow for movement. Other options are available through our technical department for specific conditions.

Engineering

Who provides engineering for the sandwich panels?

The structural capacity of the sandwich panel or structural wythe thickness should be determined by the project's design professional.

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 MC connector has an ultimate tensile strength (pullout capacity) of 12.5 kN (2820 lbs.).

Please refer to ESR-1746 for more detailed capacities.

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 in) 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 m^2	1.77 ft^2
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 MC/MS connector is approximately 4kN (910 lb) in double shear and 2kN (450 lb) in single shear.

Please refer to ESR-1746 for more detailed capacities.

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

The load on a MC/MS connector with a 75 mm (3 in) 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 m^2	1.77 ft^2
Therefore, shear 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 in) with 50 mm (2 in) insulation.

Can a heavy suspended fascia wythe be supported?

In the case where a fascia wythe, which exceeds 125 mm (5 in) 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 in), special connectors with higher shear strength can be placed in certain rows. The special connectors would serve to reduce displacement of the face wythe.

More information is available through our technical department.

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 (0.10 in) relative to the rear wythe. The project engineers or architects should determine the actual design parameters.

Composite Action

Does System NC act compositely in service?

No, a strong bond between the concrete and insulation exists initially, however, that bond will be eliminated 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.

While Thermomass does manufacture an insulation system that allows for composite action (System SC), our System NC should not be counted on to do so.

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 MC/MS 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 10×10^{-6} mm/mm/°K (5.5×10^{-6} in/in/°F). A 12.19 m (40 ft) long panel restrained at one end and subjected to a 38 °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 System NC installed?

The precast and tilt-up systems are both 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.

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- The pre-drilled insulation is then placed over the fresh concrete (which is placed at a 5 in – 7 in 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 inserted 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 plastic concrete to consolidate around the notch in the connector. In factory cast operations, additional consolidation may be achieved by bed vibration. Additionally, Thermomass 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 Thermomass for installation guides for specific applications.

What is most important about installation?

You must have concrete consolidation around the notch for the connector to develop its pullout 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 than 300 mm (12 in) from any panel's edge.

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 System NC?

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. Polyisocyanurates have slightly higher capacities (190 °F). 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?

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

Is System NC structurally proven?

All Thermomass insulation systems are exhaustively tested; System NC 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 System NC.

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 MC/MS fiber composite connectors to 1090 °C (2000 °F) temperatures for four 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).

In separate tests, MC/MS 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 R-value tests have been conducted to support your claims?

The most comprehensive study ever conducted on this issue was done on System NC by Construction Technology Laboratory in Skokie, Illinois. Additional tests have been conducted by The Department of Energy and Oak Ridge National Labs.

Additional Q&A brochures are available for Thermomass composite sandwich walls (System SC) and cast-in-place applications (System CIP).

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