OCTAFORM™

A complete

Testing Report

A review of tests completed by Octaform

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Seismic Upgrade Using Octaform Restoration and Repair System

University of British Columbia (June 2010)

Objective of Test

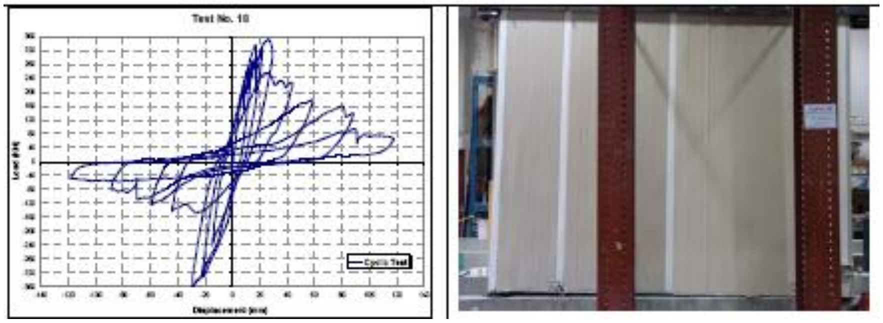
To test CMU walls retrofitted with Octaform under cyclic loading.

Significance and Main Findings

The Octaform System was used to seismically retrofit two concrete masonry unit (CMU) walls within the University of British Columbia's Innovative Retrofit Testing Program as a potential solution to the B.C. Seismic Mitigation Program. Retrofitted walls were subjected to cyclic loads applied through a lateral force along the top of the wall. The Octaform retrofitted wall reached a shear resistance of 450kN, well above all other retrofit strategies, and only experienced minimal hairline cracks.

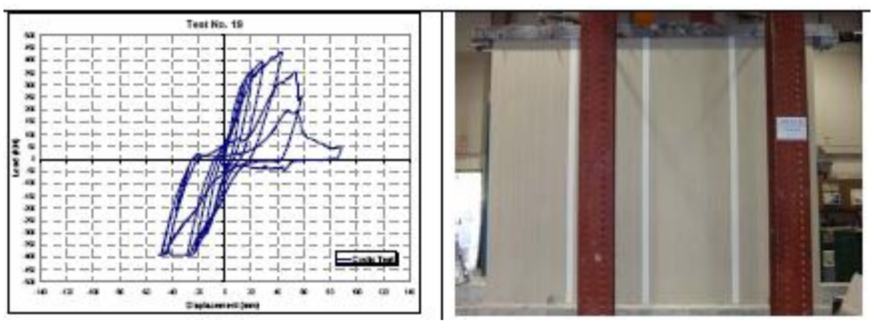
Detailed Findings

A steel plate was anchored along the top of the wall which attached to the loading arm. Displacement and loads were recorded as shown in the figures below:



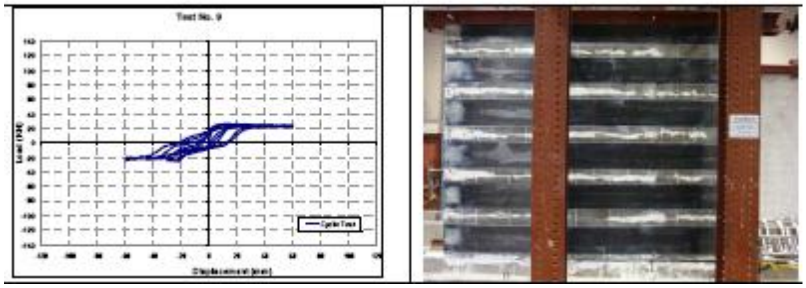
Load-Displacement Curve for Octaform Test Wall #1: Three anchor dowels at each edge

The first Octaform test wall lifted off the base due to insufficient anchorage between the Octaform wall and foundation, therefore the test was stopped before the capacity of the wall could be determined.



Load-Displacement Curve for Octaform Test Wall #2: Five anchor dowels at each edge

The second Octaform test wall contained additional anchors, and reached a maximum shear resistance of around 450kN, which was the maximum capacity the testing device could measure. The wall reached a ductility of about 3%, and showed only minimal hairline cracks along the mortar between the CMU blocks. In comparison, conventional unreinforced CMU walls typically only have a shear capacity of about 30kN, and a test wall retrofitted with Fibre-Reinforced Plastic (FRP) strips shown below only reached a shear capacity of about 20kN.



Load-Diplacement Curve for FRP Test Wall

Background of Test

- Two CMU block walls (stacked block pattern and running bond pattern) with dimension 3m x 3m (10 ft x 10 ft)

Method

The CMU blocks in the first wall were aligned using a stack pattern while the second had a running bond pattern. On both walls, PVC straps were attached to the CMU wall by metal fasteners and served as an attachment method for the Octaform connectors (2 inch) and panels. Steel reinforcing bars (10M) were placed, then grout was poured within the 2 inch wide space to bond the CMU wall to the Octaform System.

10 ft x 10 ft wall using grouted CMU construction block.

H-connectors were drilled into the wall with a 6" spacing between connectors.

2" connectors slid into H-connectors. Dowels were drilled into the concrete footing as anchors. Rebar was added.

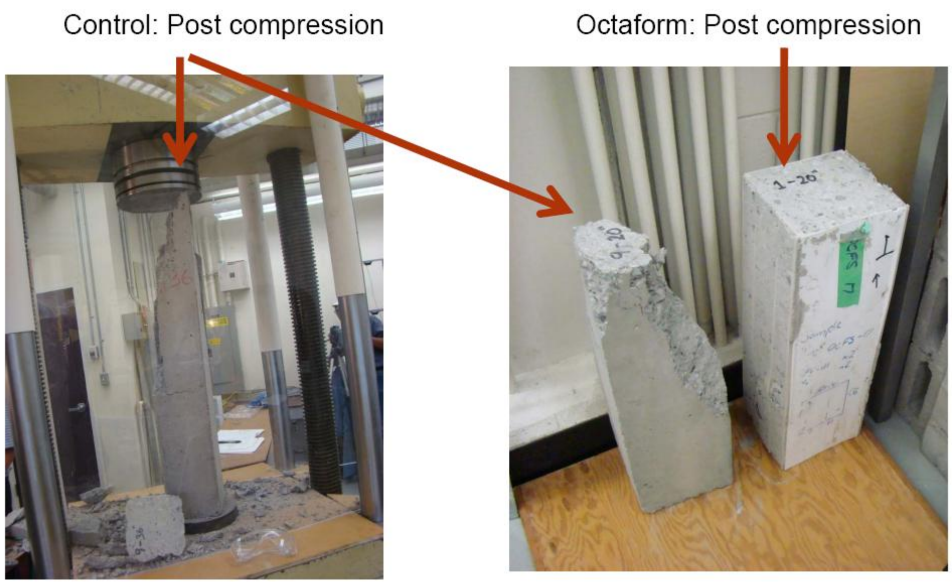
Octaform Finished Panels were slid into the 2" connectors.

Custom grouting mixture supplied by Vector was placed into the form.

The wall was left to cure for a week prior to testing.

Evaluation of the Compressive Strength Behaviour of the Octaform Concrete Forming System

British Columbia Institute of Technology (April 2009)



Objective of Test

To investigate the compressive strength and the additional load carrying capacity of columns encased with Octaform Forming Systems.

Significance and Main Findings (Phase 1)

Phase 1 tested square columns of three varying heights. Octaform Systems PVC encasement increased the compressive strength of columns up to a maximum of 31%, and on average by about 12% depending on the configuration type. Tests showed that configuration I and II were the strongest in resisting compressive loads. Although control specimens failed in a brittle manner, Octaform columns experienced minimal spalling and were able to continue to carry the load after the peak load was reached, indicating an enhanced energy absorption capacity.

Significance and Main Findings (Phase 2)

Phase 2 tested rectangular columns of one height rather than square columns in order to force bending to occur. During testing, the Octaform column moved away from the actuator axis, therefore the column needed to be re-loaded several times. This resulted in the Octaform column having lower compressive strengths than the controls for Batch 1. Batch 2 had a lower concrete compressive strength, and in this case Octaform configuration II reached a higher compressive strength compared to the control.

However, the failure modes were similar to Phase I as the the control specimens failed suddenly in a brittle and sudden manner, while Octaform columns remained in one piece due to the confinement that the PVC panels provide to the concrete.

<u>**Phase 1**</u>

Background of Test

- 15 unreinforced square columns tested for compressive resistance
- Three column heights: 500mm (20 inch), 915mm (36 inch), 1.8m (72 inch)
- Cross sectional dimensions: 150mm x 150mm (6 inch x 6 inch)
- 4 column configurations using Octaform Systems PVC panels
- Control specimens contained only concrete

Size	Height	Configuration Type
6" x 6"	20", 36", 72"	Control
		Configuration I
		Configuration II
		Configuration III
		Configuration IV

Properties

Concrete slump: 180mm (7 inch)
Air content: 2.8%
Concrete compressive strength (28 day): 38MPa (5.5 ksi)

Method

- Specimens cast vertically in plywood forms
- Concrete poured, vibrated
- Cylinders cast for compressive strength tests

<u>Phase 2</u>

Background of Test

- 6 unreinforced rectangular columns tested for compressive resistance to analyze behavior and used to model the stress-strain and load capacity
- One column height: 915mm (36 inch)
- Cross sectional dimensions: 150mm x 100mm (6 inch x 4 inch)
- Unsymmetrical columns were tested to force bending about one plane
- Two column configurations using Octaform Systems PVC panels
- Two types of concrete mixes: Batch 1 with concrete compressive strength two times that of Batch 2
- Control specimens contained only concrete

Size	Height	Configuration Type
6" x 4"	36"	Control
		Configuration I
		Configuration II

Properties

Concrete slump: 30mm (1.2 inch) (Batch 2)

Concrete compressive strength (28 day): 18MPa (2.6 ksi) (Batch 1), 9MPa (1.3 ksi) (Batch 2)

Water Resistance of Panel Snap-Tight-Lock 3 inch Width System

Intertek Testing Services (October 2008)

Objective of Test

To test the water tightness of an insulated Octaform concrete wall system under a water resistance test.

Significance and Main Findings

The Octaform Panel Snap-Tight-Lock PVC system when sealed with Chem-Calk 2020 withstood a maximum water pressure of 6psi and 68psi after a curing period of 24 hours and 96 hours, respectively.

Background of Test

- 4 to 5 PVC Snap-Tight-Lock panels were connected together, using different sealants on the joints (Chem-Calk 2020, NuFlex Silicone, Rubber Gasket)
- Water resistance was tested in accordance with AATCC 127-1998, with a modified procedure to accommodate the sample

Determination of Physical Properties: PVC Interlocking Hollow Forming Elements for Concrete

Cambridge Materials Testing Limited, & Intertek (March 2008)

Objective of Test

To investigate the mechanical properties of the PVC used in Octaform Systems. Tests included impact resistance, tensile properties, modulus of elasticity, heat deflection temperature, coefficient of linear thermal expansion, weatherability, and durability.

Significance and Main Findings

The impact resistance results on PVC samples prior to weathering are as follows:

Drop Dart Procedure A (Mean Failure Energy)	Room Temperature	-30 °C
Nominal Specimen Thickness	47.8 mils (1.21 mm)	47.6 mils (1.21 mm)
Mean Failure Height	6 inch	5.7 inch
Mean Failure Energy	48 in-lbf (5.42 J)	45.6 in-lbf (5.15 J)
Normalized Mean Failure Energy	1 in-lbf/mil (4.5 x 10^3 J/m)	0.96 in-lbf/mil (4.3 x 10^3 J/m)

Drop Dart Procedure B (Mean Brittle Failure Energy)	Room Temperature	-30 °C
Nominal Specimen Thickness	47.8 mils (1.21 mm)	47.6 mils (1.21 mm)
Mean Brittle Failure Height	6.75 inch	5.7 inch
Mean Brittle Failure Energy	54 in-lbf (6.10 J)	45.6 in-lbf (5.15 J)
Normalized Mean Failure Energy	1.13 in-lbf/mil (5.0 x 10^3 J/m)	0.96 in-lbf/mil (4.3 x 10^3 J/m)

Percent retention of impact resistance after exposure to outdoor weathering:

	Exposure Duration		
	6 months	12 months	24 months
Ohio	102	107	100
Florida	101	93	89
Arizona	107	97	48

To quantify the durability of the PVC, the percent retention of impact resistance after exposure to 2000 hours of accelerated weathering was found to be 109%. The CCMC Technical Guide specifies an 80% minimum retention of the original impact resistance. The high percentages indicate PVC's ability to retain its resistance and percentages above 100% show that the resistance increased after exposure to weathering. As shown in the table above, the PVC met the criteria in all exposure situations except for the 24 month exposure in Arizona.

Other properties of PVC tested are compared to the CCMC criteria:

	Average	Criteria	Criteria Met?
Tensile Strength	46.1 MPa (6690 psi)	> 37.7 MPa (>5500 psi)	Yes
Modulus of Elasticity	2970 MPa (431,000 psi)	> 2800 MPa (>377,000 psi)	Yes
Deflection Temperature	71°C (160 °F)	> 70°C (158°F)	Yes
Coefficient of Linear Thermal Expansion	3.8 x 10^{-5} cm/cm/ °C	< 6 x 10^{-5} cm/cm/ °C	Yes

Background of Test

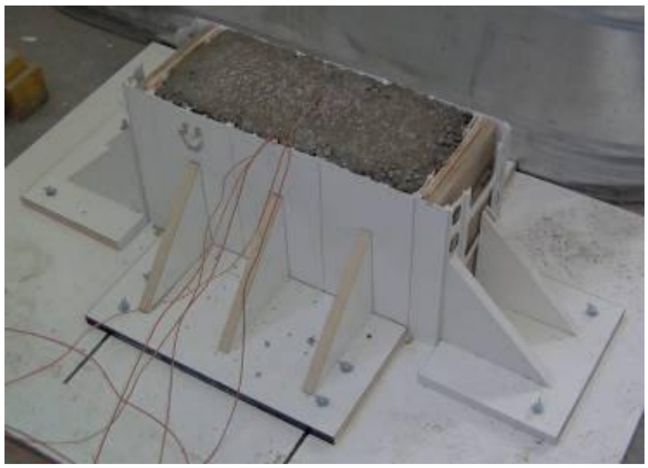
- 200 samples of PVC interlocking hollow forms of dimension 150mm x 150mm (6 inch x 6 inch) were tested
- Properties measured were impact resistance (Notched Izod and Drop Dart tests), tensile properties, modulus of elasticity, heat deflection temperature, coefficient of linear thermal expansion, weatherability, and durability

Method

- Testing was conducted according to the technical requirements found in "Physical Properties of PVC Elements" from the CCMC Technical Guide: PVC Interlocking Hollow Forming Elements for Concrete (Noncombustible Construction), Masterformat Section 03134 and ASTM methods

Effect of PVC Stay-In-Place Formwork on the Hydration of Concrete

Seattle University (August 2007)



Formwork Bracing System

Objective of Test

To investigate the effects of the Octaform PVC panels on the hydration of concrete and strength development.

Significance and Main Findings

The Octaform Finished Forming System acts as an insulator, allowing moisture and heat generated during the hydration of cement to be contained. In addition, fly ash with insulation used in combination with Octaform produces hydration conditions which yield higher compressive strength than a conventional wood formed wall with normal concrete mix and no insulation. This would make Octaform attractive in terms of cost and environmental advantages by requiring less cement material.

Tests showed that the difference in temperature development between normal concrete and fly ash mixes using conventional wood formwork is 49%, while for an Octaform System it is only 31%. This may indicate that the Octaform system may contain more moisture and develop more heat relative to wood formwork during the hydration process when fly ash is used.

Finally, the addition of the Octaform System eliminates the absorption of water by the form, which is typically common with wooden formwork.

Background of Test

- Walls (formed with Octaform Systems or conventional wood formwork) were subjected to thermal and compression tests
- Variables adjusted were formwork material, wall thickness (100mm (4 inch), 200mm (8 inch), or 300mm (12 inch)), concrete composition (with or without fly ash) and insulation (with or without)
- 8 wall samples were tested for temperature and strength

Method

- Temperature of concrete was monitored to measure the extent of the hydration process
- Strength of concrete was determined by measuring the compressive strength

Flexural Behavior of Octaform Concrete Forming System

University of Waterloo (July 2007)

Objective of Test

To investigate the flexural behavior of beams formed with Octaform Forming System in comparison to regular concrete beams.

Significance

Tests suggested that the Octaform System has properties which increase the ultimate load, cracking load, yield load and deflection. This allows structures produced with the Octaform System to carry more load and behave in a more flexible manner. Even Octaform beams without reinforcement showed greater load capacity in comparison to regular unreinforced beams, indicating that the PVC panels contribute to an increase in flexural strength.

Main Findings

The table below shows the percent increase in load and deflection for Octaform specimens with and without reinforcement and for varying beam depths in comparison to regular concrete beams:

	Increase in Cracking Load (%)	Increase in Ultimate Load (%)	Increase in Yield Load (%)	Increase in Maximum Deflection (%)
150mm (6 inch) without reinforcement	36	-	-	-
200mm (8 inch) without reinforcement	18	-	-	-
150mm (6 inch) with reinforcement	36	36	65	24
200mm (8 inch) with reinforcement	36	36	91	55

In terms of connector configurations, there was no difference in performance between the two types of connectors (middle connectors or 45 degree connectors) when used separately. However, Octaform specimens (without reinforcement) showed higher increases in maximum and yield loads when both types of connectors were used rather than just one type. The presence of both types of connectors increased the rigidity of the system.

Comparing the Octaform beams with and without reinforcement, the presence of steel reinforcement increased the number of cracks but decreased the width of the cracks, and increased the maximum load capacity by 197% (for specimens with both connectors or with inclined connectors).

Detailed Findings

Control specimens (concrete with reinforcement) had flexural cracks which appeared in the mid span of the specimen, load capacity increased steadily, followed by yielding of the steel reinforcement, and finally failure due to concrete crushing in compression.

Octaform specimens (without reinforcement) had flexural cracks which appeared in the mid span of the specimen, load capacity increased and dropped as new flexural cracks formed, followed by yielding of the tension PVC panel, and finally failure due to the tension panel rupturing.

Octaform specimens (with reinforcement) had flexural cracks which appeared in the mid span of the specimen, load capacity increased steadily, followed by yielding of the steel reinforcement, yielding of the tension PVC panel (at which point the load ceased to increase), and finally failure due to concrete crushing in compression and buckling of the compression PVC panel.

Typical Rupture of Octaform Panels

Background of Test

- 24 beam specimens (12 combinations with duplicate specimens of each) subjected to four point bending
- 305mm (12 inch) wide by 2500mm (96 inch) long beams
- Variables adjusted were beam depth 150mm or 200mm (6 inch or 8 inch), steel reinforcement (none or 2-10M bars (#3 size bar)), connectors (middle connectors or 45 degree connectors)
- All control specimens contained reinforcement (placed on the tension side)
- Four point bending spanning 2100mm (83 inch) with loads placed 700mm (28 inch) apart

Properties

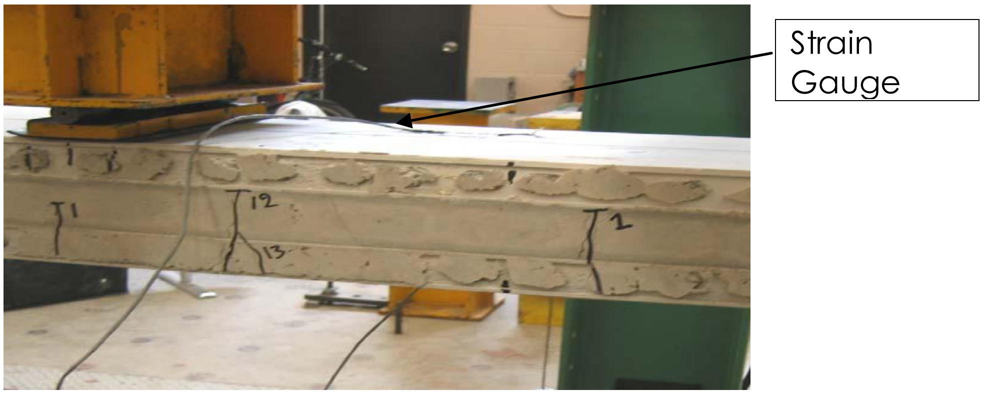
Concrete slump: 180mm (7 inch)
Concrete compressive strength (28 day): 25MPa (3.6 ksi)
Steel yield strength: 400MPa (58 ksi)

Method

- Specimens cast vertically in plywood forms
- Concrete poured, vibrated, then cured with wet burlap
- Load applied using a servo-hydraulic actuator, deflection measured with a Linear Variable Differential Transformer (LVDT), strain in panels measured using

electrical strain gauges

- Each specimen tested until failure (25% drop in load compared to maximum load achieved)



Strain gauge installed on the midspan section

Test Setup

Seismic Testing of Reinforced Concrete Squat Wall with Opening

University of British Columbia (July 2007)

Octaform System vs. Control Test Wall (painted white to view cracks)

Objective of Test

To investigate the behavior and seismic resistance of an Octaform System concrete wall under lateral loads.

Significance and Main Findings

Tests showed that the wall constructed with the Octaform System had a higher lateral load capacity, higher stiffness, less surface cracking, smaller crack widths, and resistance against spalling compared to a regular reinforced concrete wall. This makes the Octaform Finished Forming System a favorable choice for structures produced in high seismic.

Detailed Findings

The regular reinforced wall developed flexural cracks in the columns and beams at the location of the vertical reinforcements, surface spalling, and collapse occurred at 200% of the amplitude of the experimental earthquake due to a crack at the bottom of the clear length of a column. For the Octaform Wall System, the first flexural crack occurred at 225% of the experimental earthquake. Flexural cracks occurred at the location of the centre line of each Octaform panel and no cracks formed in the column.

Background of Test

- Two reinforced concrete squat walls of thickness 0.1m (3.9 inch)(one with and without Octaform System) were subjected to dynamic loads on a shake table test
- Wall dimensions: 2400mm x 2400mm (94 inch x 94 inch) with a centre opening of 1600mm x 1300mm (63 inch x 51 inch)
- 10M (#3 size bar) Horizontal and Vertical Reinforcement

Method

- Wall was bolted to the foundation with high strength threaded steel rods to produce a rigid connection
- Accelerometers and transducers measured the acceleration and displacements, respectively
- Walls subjected to a synthetically generated earthquake acceleration record and applied at increasing amplitudes

Properties

Concrete compressive strength (28 day): 32MPa (4.6 ksi)
Steel yield strength: 400MPa (58 ksi)

Static Resistance of Octaform Wall Panels for Blast Response Prediction

University of Missouri-Columbia (2007)

Load Tree Mechanism to Simulate Uniformly Distributed Load

Objective of Test

To determine the response of an Octaform wall under uniform loads in order to develop a model that predicts its blast resistance.

Significance and Main Findings

Tests led to computer analyses which showed that Octaform PVC panels provide increased blast resistance due to the energy absorption capability of the panels. The PVC panels act to provide additional strength and ductility. Octaform Systems will need to undergo further testing in order to verify and quantify the blast resistance performance.

Detailed Findings

Failure of the samples generally occurred with necking and tearing of the PVC tension panels. In most of the reinforced samples, the PVC failed before the reinforcement failed.

The resistance of the wall to blast loading is dependent on the equivalent mass of the wall and the equivalent static resistance of the wall.

Background of Test

- Wall systems (with and without Octaform) were tested under simulated uniform pressure to determine the static response of the wall panels and to evaluate its blast resistance
- Static resistance functions can be recorded to develop a simple dynamic model to predict dynamic response
- 4 different thicknesses used
- Specimens 457mm (18 inch) wide, 3.66m (144 inch) long, 3.0m (120 inch) span length
- 4 samples of each thickness made (2 with rebar, 2 without rebar), plus 4 control specimens (two were 150mm (6 inch) thick, two were 200mm (8 inch) thick)
- Reinforcement type: 13M (#4 size bar) and 16M (#5 size bar)

Properties

Concrete slump: 125mm (5 inch)
Concrete compressive strength (28 day): 27.8 MPa (4000 psi)

Method

- Uniform loading was achieved with a 16 point "Load Tree" which is a system that applies load at 16 different points
- Using the static resistance functions, two hypothetical explosion threats (1000 lbs and 450 lbs of TNT at 75 feet) were used to generate approximate dynamic analysis results

Concrete Drop Test in Octaform Concrete Forming System

Intertek Testing Services (November 2006)

Core Sample

Objective of Test

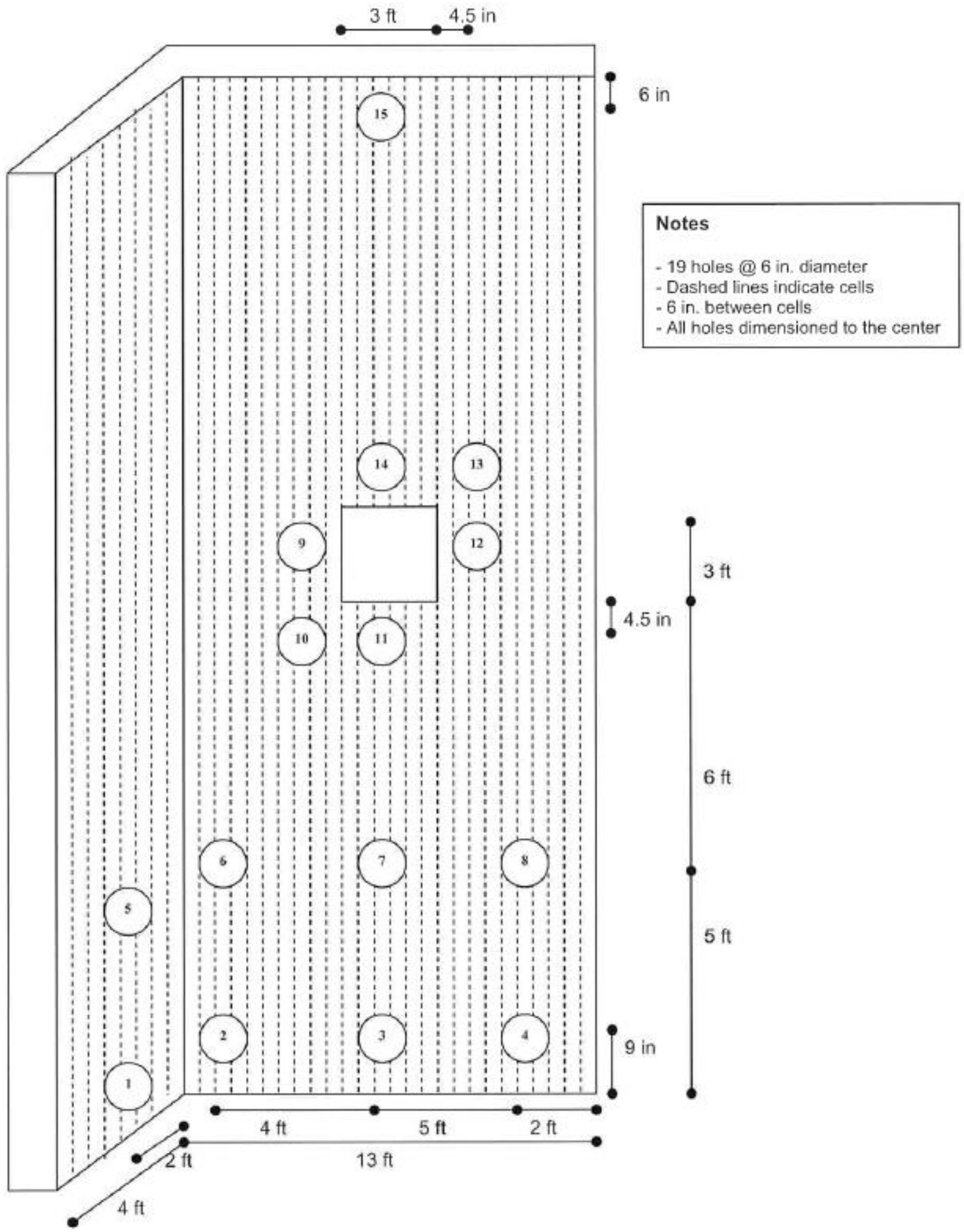
To observe concrete consolidation through the thickness of the Octaform wall system.

Significance and Main Findings

The test showed the cores were continuous with no visible segregation of aggregates, and most samples contained minimal air voids that were less than 6.4mm (1/4 inch) in diameter. The detailed results of each of the core samples are found in the report.

Background of Test

- 200mm (8 inch) thick concrete filled Octaform wall system
- Wall dimension 4.0m x 2.4m x 7.6m high (13ft x 8ft x 25ft high)
- 150mm (6 inch) core samples of the wall were taken at 15 locations after curing for no more than 28 days in order to observe the concrete consolidation



Core Sample Locations

AIR-INS inc.
1320, boul. Lionel-Boulet, Varennes (Québec) J3X 1P7 – Tél. : (450) 652-0838 • Fax : (450) 652-7588 • info@air-ins.com

Performance Evaluation of Octaform Systems Inc. PVC Forms as per CCMC Technical Guide for PVC Interlocking Hollow Forming Elements for Concrete Masterformat Section 03134

Air-Ins Inc. (June 2006)

Octaform Wall with Water Bags Enclosed Between Wall Cavities

Objective of Test

To ensure the Octaform wall system does not exceed the maximum deflection under the required design pressure from the CCMC Technical Guide.

Significance and Main Findings

The Octaform PVC form system met the requirements of the CCMC Technical Guide noted above for an 86 kPa (12.5 psi) factored design pressure applied over 2 hours. The maximum deflection did not exceed the L/360 limit.

Background of Test

- 200mm (8 inch) thick Octaform wall system was constructed to be tested in accordance with "CCMC Technical Guide for PVC Interlocking Hollow Forming Elements for Concrete, Masterformat Section 03134"

- Wall dimension 2.7m (9 feet) wide by 2.4m (8 feet) high
- Wall cavities were filled with bags of water to create hydrostatic pressure on the wall and the displacement of the wall was monitored
- The desired horizontal pressure on the wall was achieved by connecting the bags to a water supply and booster pump

Effect of PVC Stay-In-Place Formwork on the Mechanical Performance of Concrete

Seattle University (May 2006)

Octaform Cube Under Axial Load

Control Cube Under Axial Load

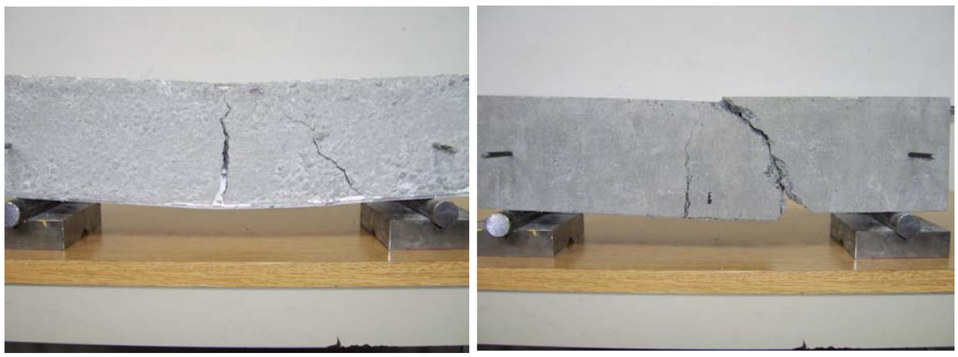
Objective of Test

To investigate the effect of the Octaform System on the mechanical properties of concrete (flexural, compression, hydration).

Significance and Main Findings

Tests showed that Octaform Systems enhance the mechanical properties of concrete due to the presence of the PVC panels and connectors. Results indicated an increase in the moment capacity and toughness by over 50%, and an increase in the compressive strength by 30% compared to systems without Octaform. The increase in compressive strength is likely due to the PVC panels acting to confine the concrete.

The results in this preliminary test did not show any enhancement in the hydration process with the use of Octaform (however further testing proves otherwise in Seattle University's research in 2007). The results did not differ significantly between different configurations.

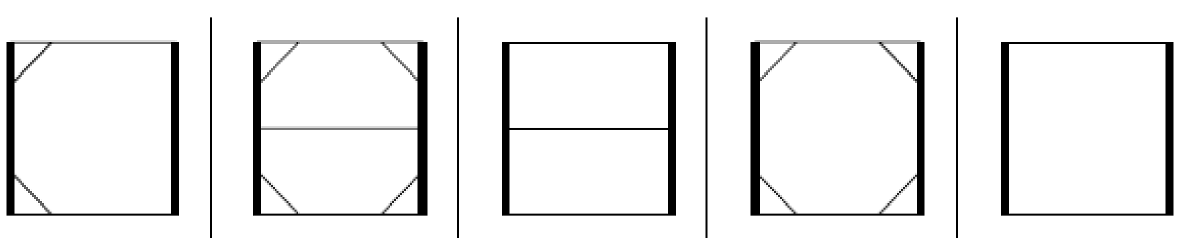


Octaform (left) vs. Control Beam in Flexure and Shear Cracking in Reinforced Specimens

Background of Test

- Tested for compression, flexure, thermal properties, and the influence of formwork on the hydration process
- 5 different Octaform configurations and a control specimen
- A typical test series contained 6 replications of each configuration
- 1 test series was for compression tests and 2 test series were for flexural tests (one series with reinforcement)
- Compression cubes of dimensions 150mm x 150mm x 150mm (6 inch x 6 inch x 6 inch)
- Flexural beams of dimensions 150mm x 150mm x 600mm (6 inch x 6 inch x 24 inch)
- 10M (#3 size bar) reinforcement used where applicable

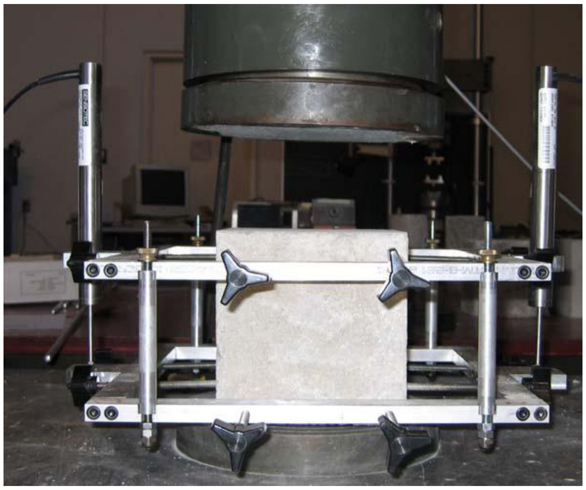
Configuration Types:



Method

- Compression tests were performed on concrete cubes
- Flexure tests were performed on concrete beams (with or without steel) under

3 point bending (load applied at mid span)
- Thermal tests were performed by monitoring temperature in concrete cubes during casting over a 72 hour period



Compression Test Fixture to Measure Modulus

Sound Transmission Loss Test and Classification of an 8 Inch Thick Concrete Filled Octaform Wall System

Intertek Testing Services (May 2006)

Objective of Test

To determine the sound-insulating property and to rate the ability of an Octaform wall system to reduce the overall loudness of ground and air transportation noise.

Significance and Main Findings

There is no pass-fail criteria for these tests and the values obtained for the Octaform wall system are as follows:

Sound Transmission Class (STC) = 54
Outdoor-Indoor Transmission Class (OITC) = 46

These values can be used in order to compare the sound and noise reducing properties with other materials and building elements. In general, higher values indicate higher sound insulating properties.

The STC value describes the decibel reduction in noise that a partition can provide. Typical interior walls in residential wood stud frame buildings using 25.4mm (1 inch) drywall have an STC of about 33. In comparison, concrete walls of thickness 100mm to 200mm (4 inch to 8 inch) have higher STC values ranging from 40 to 50. An STC value of 54 for the 200mm (8 inch) thick Octaform concrete wall indicates that the PVC contributes in attenuating sound. An STC value of 54 is equivalent to a partition constructed of a single layer of 12.7mm (½ inch) drywall glued to a 200mm (8 inch) thick concrete block wall and painted on both sides.

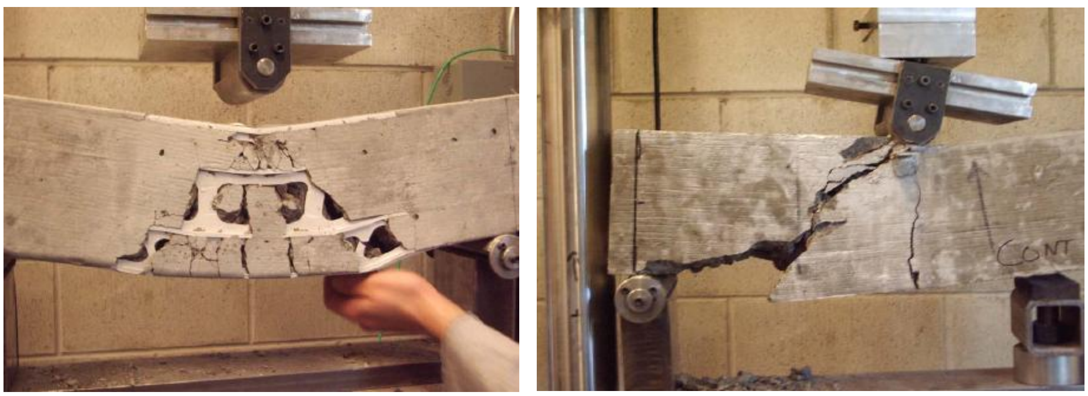
The OITC standard is used to rate the transmission of sound between outdoor and indoor spaces, and targets lower sound frequencies (down to 80 Hz) that capture ground and air transportation noise. It is a newer rating system used to assess exterior partitions that are exposed to traffic noise. For example, glass windows typically have an OITC range of 20 to 30. A typical 89mm (3.5 inch) steel stud wall with insulation and 12.7mm (½ inch) drywall has an OITC of about 40. In comparison, the 200mm (8 inch) thick Octaform concrete wall has an OITC of 46.

Background of Test

- Sample 200mm (8 inch) thick concrete filled Octaform wall system was constructed to be tested in accordance with ASTM E90-2004, ASTM E413-2004, and ASTM E1332-90 in order to determine the Sound Transmission Class (STC) and Outdoor-Indoor Transmission Class (OITC)
- Wall dimension 1140mm (45 inch) wide by 1650mm (65 inch) high
- Higher values of the STC indicate greater sound insulating properties
- Values of OITC are used as a rank ordering device

Evaluating the Performance of Octaform Concrete Forming Systems Under Cyclic Loading

University of British Columbia (April 2006)



Octaform Beam vs. Control Beam Under Point Load

Objective of Test

To investigate how Octaform System beams perform under flexural cyclic and quasi-static loading.

Significance and Main Findings

Tests showed that specimens containing PVC configurations exhibited higher values of strength under quasi-static loading compared to cyclic loading. This is explained due to a slower load application under quasi-static conditions, therefore allowing the beam to adjust to the conditions. There is evidence that the addition of PVC can add to the overall bending strength of the system. Different configurations of the PVC panels were found to have varying effects on the flexural strength.

Detailed Findings

Results showed that beams with only 45 degree corner sections had a greater resistance to quasi-static loads compared to cyclic loading but were more susceptible to shear failure rather than flexural failure. On the other hand, beams with midpoint connectors had a greater resistance to cyclic loading rather than quasi-static loads, and kept their structural integrity.

Background of Test

- 22 beam specimens constructed with 5 different PVC configurations and a control specimen (using conventional wood forms) for cyclic loading and quasi-static loading tests in order to determine the strength of each configuration and the flexural behavior under such conditions
- 3 identical beams for each of the 5 configurations plus 7 control beams
- Beam dimensions 150mm x 150mm x 600mm (6 inch x 6 inch x 24 inch)
- Beams reinforced with 10M (#3 size bar) main reinforcement bars and 4M bar stirrups
- 3 point loading

Properties

Concrete compressive strength (28 day): 40MPa (5.8 ksi)
Steel yield strength: 400MPa (58 ksi)

Finished Product Testing: PVC Interlocking Hollow Forming Parts

Cambridge Materials Testing Limited, & Intertek (April 2006)

Objective of Test

To investigate the properties of the PVC used in Octaform Systems, namely the wall thickness, colour match, hardness (Shore D), ash content, shrinkage, rate of burning, and impact resistance.

Significance and Main Findings

The properties of the PVC tested are shown below:

	Value	ASTM Standard
Wall Thickness	1.232mm (0.0485 in)	N/A
Hardness (Shore D)	80	D2240-04
Ash Content	14.70%	D229-01
Shrinkage	2.70%	D3679-04a
Rate of Burning	---	D635-03

A durometer was used to determine the hardness of PVC by measuring the depth of indentation created by a standardized pressure. Shore D corresponds to the D Scale for harder plastics while the A Scale is for softer plastics. The D Scale has a range of values from 0 to 100, with higher values indicating a harder material. The PVC hardness value of 80 indicates the material is relatively hard.

The ash content of a plastic is found by burning the sample to determine the amount of filler left after the polymer has burned off. The ash that is left is weighed and divided by the weight of the original sample to obtain the ash content.

The shrinkage test determined by ASTM D3679-04a states that the maximum shrinkage allowed is 3%, therefore a 2.7% shrinkage of the PVC is allowable.

During the rate of burning test, the material did not burn to the first reference mark, so the rate of burning according to ASTM d635-03 could not be determined.

Background of Test

- Samples of PVC interlocking hollow forms - dimensions 150mm x 300mm (6 inch x 12 inch), 150mm x 610mm (6 inch x 24 inch),150mm x 915mm (6 inch x 36 inch) were tested
- Properties measured were the wall thickness, colour match, hardness, ash content, shrinkage, rate of burning, and impact resistance

Method

- Testing was conducted according to the technical requirements found in "Physical Properties of PVC Elements" from the Canadian Construction Materials Centre (CCMC) Technical Guide: PVC Interlocking Hollow Forming Elements for Concrete (Noncombustible Construction), Masterformat Section 03134 and ASTM methods

Pilot Scale Fire Test Program Conducted on Vinyl Encompassed Concrete Wall System

Intertek Testing Services (July 2002)

Exposed Octaform Wall After Fire and Hose Stream Tests

Objective of Test

To see if the Octaform wall system meets a 2 hour fire rating.

Significance and Main Findings

The Octaform wall system met the standards for a 2 hour fire rating.

Detailed Findings

During the fire endurance test, the vinyl on the exposed side was consumed in flames and burned away completely, leaving the concrete exposed. The concrete however did not crack or spall. No burn through occurred to the unexposed side of the wall.

During the hose stream test, the test assembly met the required standards and no openings developed.

Background of Test

- Fire endurance and hose stream tests were conducted on an Octaform concrete wall system in order to determine eligibility for a 2 hour fire resistance rating
- Tests were in accordance with UBC 7-1, ASTM E119-98, NEPA 251, CAN/ULC S101-M89
- 100mm (4 inch) wall thickness used

Thermal Analysis – EPS Insulation

Intertek Testing Services (August 2000)

Objective of Test

To measure the U-Value and R-Value of an Octaform wall system insulated with expanded polystyrene insulation blocks and a regular built-up wood stud wall system.

Significance and Main Findings

The following results were obtained from the centre of an Octaform wall insulated with expanded polystyrene insulation blocks and a regular built-up wood stud wall system.

	Octaform Wall System	Built-up Wood Stud Wall System
U-value	0.066 Btu/hr/ft2/°F (0.37 m2 °K/W)	0.050 Btu/hr/ft^2/°F (0.28 m^2 °K/W)
R-value	15.2 hr-ft^2 °F/Btu (2.7 m^2 °K/W)	20.2 Btu/hr/ft2/°F (3.56 m2 °K/W)

Expanded polystyrene insulation blocks have an R-Value of about 4.5 hr-ft^2 °F/Btu (0.79 m^2 °K/W) per inch of thickness, which is lower than the R-Value for polyisio foam used in the test done in 1997. In addition, the insulation thickness was reduced from 89mm (3.5 inch) to 76mm (3 inch), which explains why the R-Value for the entire wall has decreased for this test in comparison to the 1997 test.

Background of Test

- Sample insulated Octaform wall system of low density concrete was modeled using Frame 4.0 computer software under ASHRAE winter conditions (0°F outside

temperature and 70°F indoor temperature)
- 76mm (3 inch)thick expanded polystyrene insulation blocks were placed on the exterior side of the concrete wall
- Wood wall system consisted of 3/8" thick fir plywood sheathing, 6 mil poly vapour barrier, 2"x6" spruce studs @ 24" o/c, R-20 fibreglass insulation, 1"x4" spruce strapping @ 24" o/c and 30 ga high tensile painted steel siding
- Wall systems were modeled only for the central wall area

Flame Spread Test Program Conducted on Extruded PVC Concrete Wall Forming System

Intertek Testing Services (February 2000)

Objective of Test

To observe the rate of progression of a flame along a sample of the PVC Octaform panels in a 7.6m (25 foot) long tunnel.

Significance and Main Findings

The flame spread classification for the PVC panels was found to be 35 and 20 (for ASTM and CAN/ULC standards, respectively). This value is relative to the flame spread classification of red oak flooring and asbestos-cement board which have values of 100 and 0, respectively.

The smoke development classification for the PVC panels was found to be 120 and 175 (for ASTM and CAN/ULC standards, respectively). This value is relative to the smoke classification of red oak flooring, which has a value of 100.

Background of Test

- Surface burning characteristics of extruded PVC Octaform panels were tested in accordance with ASTM E84-98 and CAN/ULC S102.2-M88 "Standard for Surface Burning Characteristics of Flooring, Floor Covering and Miscellaneous Materials and Assemblies"
- In total, 4 runs were conducted
- PVC sample lengths of 3.66m (12 feet), width 152mm (5.97 inches)

OCTAFORM™

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Product Evaluation Conducted on Vinyl Panels

Intertek Testing Services (July 1998)

Objective of Test

To measure the exact thickness of the PVC panels.

Significance and Main Findings

The vinyl panels have an average thickness of 1.224mm (0.0482 inches).

Background of Test

- Thickness measurements were made on twenty samples of vinyl extruded panels

Water Tightness Test

Intertek Testing Services (September 1997)

Objective of Test

To test the water tightness of an insulated Octaform concrete wall system under a water resistance test.

Significance and Main Findings

The Octaform PVC form system met the requirements of ASTM E-547 at the specified pressure difference of 750 Pa (15.6 psf). No leakage was observed.

Background of Test

- Sample Octaform wall system was constructed to be tested in accordance with ASTM E-547 "Test Method for Water Penetration of Exterior Windows, Curtain Walls, and Doors by Cyclic Static Air Pressure Differential"
- Wall dimension 2235mm (88 inches) wide by 1981mm (78 inches) high
- 89mm (3.5 inch) thick polyiso foam insulation blocks were placed on the exterior side of the concrete wall
- Silicone caulking was used to seal the perimeter of the test sample
- Uniform spray of water applied to the test sample

Thermal Analysis – Polyiso Insulation

Intertek Testing Services (September 1997)

Objective of Test

To measure the U-Value and R-Value of an Octaform wall system insulated with polyisio foam insulation blocks.

Significance and Main Findings

The following results were obtained from the centre of an Octaform wall insulated with polyiso foam insulation blocks:

U-value	0.0324 Btu/hr/ft2/°F (0.18 m2 °K/W)
R-value	30.8 hr-ft^2 °F/Btu (5.4 m^2 °K/W)

For concrete, a typical R-Value is about 0.09 hr-ft^2 °F/Btu (0.016 m^2 °K/W) per inch of thickness. Assuming a 200mm (8 inch) thick concrete wall, the R-Value would be 0.72 hr-ft^2 °F/Btu (0.127 m^2 °K/W). The polyiso foam insulation contributes the most to the modeled R-Value. The typical R-Value for 89mm (3.5 inch) thick polyiso foam insulation is about 19.6 hr-ft^2 °F/Btu (3.45 m^2 °K/W). For rigid PVC, typical R-Values range from 0.69 to 0.98 hr-ft^2 °F/Btu (0.12 to 0.17 m^2 °K/W) per inch of thickness. Using this value, the addition of the 1.2mm (0.047 inch) thick PVC Octaform panels would theoretically increase the R-Value by 0.03 to 0.05 hr-ft^2 °F/Btu (0.005 to 0.009 m^2 °K/W).

Background of Test

- Sample concrete insulated Octaform wall system was modeled using Frame 4.0 computer software under ASHRAE winter conditions (0°F outside temperature and 70°F indoor temperature)
- Wall system was modeled only for the central wall area
- 89mm (3.5 inch) thick polyiso foam insulation blocks were placed on the exterior side of the concrete wall.

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