[F02-01] Integrating Insulation and Surface Finishes into Concrete Walls and Floors

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SUMMARY

Available concrete systems integrate insulation and concrete into one system. These systems have the benefit of providing thermal mass and continuous insulation to reduce energy loads. This combination reduces thermal bridging often found in steel or wood frame construction and provides continuous air and thermal barriers. Examples include insulating concrete form (ICF) systems and insulated precast sandwich panel walls.

Decorative finishes, when used in precast systems, are integral to the interior or exterior surface of concrete walls and the top surface of concrete slabs. Exterior decorative finishes eliminate the need for siding materials while providing a hard, durable exterior surface. Interior decorative finishes eliminate the need for gypsum wallboard and also provide a durable interior surface. Formed and colored or stained surfaces can closely match cut stone or other historic facades, and can mimic brick veneer.

Decorative finishes on floors eliminate the need for additional flooring finishes such as carpet or wood. Geometric patterns can be scored, stamped, rolled or inlaid into the concrete. The top surface can be ground to expose aggregate for an effect similar to terrazo.

These concrete systems are a resource efficient method of providing thermal mass and low air infiltration. In addition, concrete has low volotile organic compounds (VOC) emissions and does not degrade indoor air quality.

INTRODUCTION

Concrete is traditionally considered a structural element. However, available concrete systems integrate insulation and concrete into one system. These systems have the benefit of providing continuous insulation and concrete to reduce energy loads. This combination reduces thermal bridging often found in steel or wood frame construction and provides continuous air and thermal barriers. Examples include insulating concrete form (ICF) systems and insulated precast sandwich panel walls. These concrete systems are a resource efficient method of providing thermal mass, insulation, and low air infiltration.

In addition, decorative finishes, when used in precast systems, are integral to the interior or exterior surface of concrete walls and the top surface of concrete slabs. Exterior decorative finishes eliminate the need for siding materials while providing a hard, durable exterior surface. Interior decorative finishes eliminate the need for gypsum wallboard and also provide a durable interior surface. Decorative finishes on floors eliminate the need for additional flooring finishes such as carpet or wood. In addition, concrete has low VOC emissions and does not degrade indoor air quality.

WALLS

ICF Systems

Insulating concrete forms (ICFs) are hollow “blocks” or “panels” made of expanded polystyrene insulation (EPS) or other insulating foam that construction crews stack into the shape of the walls of a building. The workers then fill the center with reinforced concrete to create the structure. There are over 20 brands of ICFs in North America, each with some variations in design and materials. Flat panel systems, such as those shown in Figure 1, provide a continuous layer of insulation uninterrupted by framing or other thermal bridges.

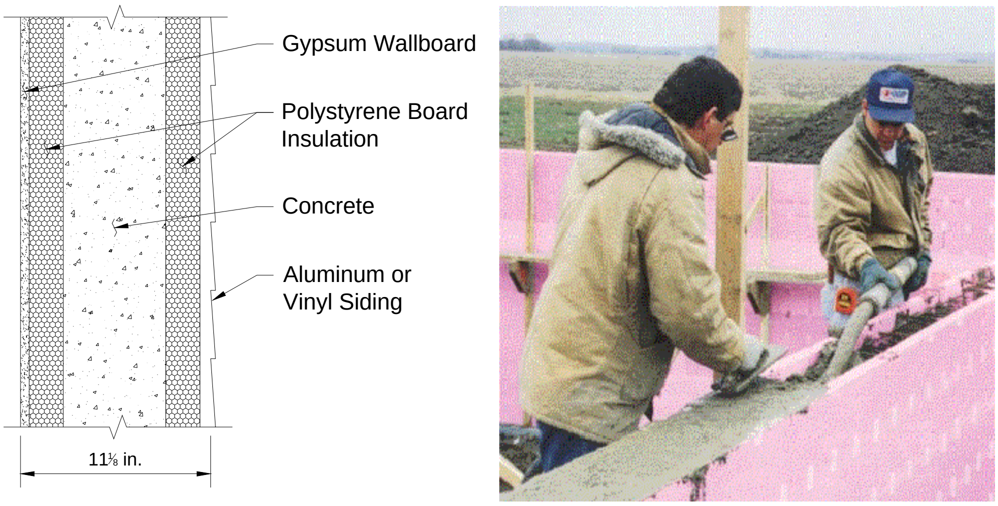

Figure 1. Insulating concrete form (ICF) walls (a) Cross-section of flat panel system (b) Filling the ICFs with concrete (Photos courtesy of the Portland Cement Association www.cement.org)

ICF construction sandwiches a heavy, high-strength material (reinforced concrete) between two layers of a light, highly insulated material (EPS or foam). This combination creates a wall with desirable properties: air tightness, strength, sound attenuation, insulation, and thermal mass. The R-value of ICF systems varies by producer. These systems typically use 50 mm of insulation on each side of the concrete for a total RSI-value of approximately 3.5. In addition, the corners of ICF walls are fully insulated, unlike conventional frame construction where corners have very little insulation. The insulation, air tightness, and mass of the walls reduce the amount of energy needed for heating and cooling by up to 40% compared to conventional wood frame construction. The high R-value combined with thermal mass means ICF walls exceed most energy code requirements. Most other wall systems are built to meet minimum energy code requirements.

ICFs are used for residential and commercial construction projects, as shown in Figure 2. Stacking ICF blocks is intuitive for most construction crews, and the cutting and leveling involved draw on standard carpentry skills. Most carpentry crews will have to brush up on the use of concrete, and electricians need to learn how to cut channels in the surface of the foam to house their electrical wire or conduits. ICF systems have strips for ease of attachment of interior finish systems such as gypsum wallboard and exterior finish systems such as brick or siding. Since insulating forms are light and power equipment moves the concrete, labor costs are often below those of frame construction. ICFs can take any shape as easily as wood or metal frame. Interesting architectural effects, such as curved walls and frequent corners, can be less expensive to build into an ICF wall. More information on ICF systems is available (ICFA 2008).

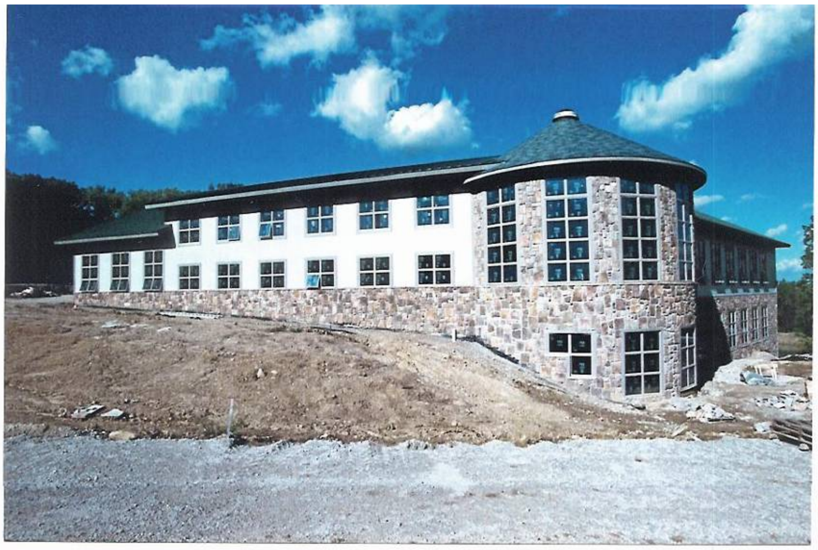

Figure 2. Completed ICF construction, Dental Ceramics Office Building in Richfield, Ohio (Photo Courtesy of Reward Wall Systems, www.rewardwalls.com)

Precast Concrete Sandwich Panel Walls

Precast concrete products are cast in molds in a factory setting. These products benefit from greater quality control achievable at a production plant. Cost savings are realized when shapes such as multiple wall sections are duplicated. Precast concrete sandwich panel walls utilize a layer of continuous board insulation between two concrete layers as shown in Figure 3.

Figure 3. Precast sandwich panel wall with a layer of insulation between two layers of concrete (a) with low conducting fiber composite connectors (Photo courtesy of Thermomass® Building Insulation System www.thermomass.com) (b) being set into place (Photo courtesy of Dukane Precast, Inc www.dukaneprecast.com).

Precast concrete construction is widely used in the U.S. for multi-family housing, hotels and motels, security facilities, schools, offices buildings, stores, warehouses, manufacturing facilities, and storage facilities. Precast concrete provides predictable quality and structural characteristics because of factory controlled conditions. Mass production as well as off-site production shortens project timeline, allowing earlier occupancy. For example, the walls of a building can be manufactured while on-site foundations are being built.

Precast concrete has many environmental benefits during construction and for the life of the structure. During construction, less material is required because precise mixture proportions and tighter tolerances are achievable. Less concrete waste is created due to tight control of quantities of constituent materials. Waste materials are more readily recycled because concrete production is in one location. For example, gray water is often recycled into future mixtures and hardened concrete is recycled (about 5% to 20% of aggregate in precast concrete can be recycled concrete). Less dust and waste is created at construction site because only needed precast concrete elements are delivered; there is no debris from formwork and associated fasteners. Fewer trucks and less time are required for construction because concrete elements are fabricated offsite; particularly beneficial in urban areas where minimizing traffic disruption is critical. Precast concrete units are normally large components, so greater portions of the building are completed with each activity, creating less disruption overall. Finally, less noise is generated at construction sites because concrete is made offsite (VanGeem 2006).

Environmental benefits of ICF and precast walls

During the life of the structure, energy savings are achieved in buildings constructed of ICF or precast sandwich panel walls by integrated combination of the thermal mass of concrete and insulation. In both wall systems, the concrete and insulation are usually continuous. Concrete acts as an air barrier, reducing air infiltration, and saving more energy. Buildings are more comfortable because they have a more even temperature throughout the day and night. They have virtually no “cold spots” and fewer drafts. In addition, concrete buildings generally allow the installation of smaller heating and cooling equipment because peak loads are often less than for a similar building of wood or steel frame construction.

Reinforced concrete structures are resistant to fires, wind, hurricanes, floods, earthquakes, wind-driven rain, and moisture damage. Experience shows that concrete structures are more likely to remain standing through fire than are structures of other materials. Concrete walls have also proven more resistant to allowing fire to pass from one side of the wall to the other. This is especially of interest in areas with brush fires that could spread into buildings, or fires from adjacent structures that jump to the next building. The rigidity of concrete construction reduces the flex in floors, and shifting and vibration from the force of the wind or the slamming of a door. The concrete acts as a strong barrier for locations where security is an issue.

As with all concrete, recycled materials such as fly ash, slag cement, silica fume, and recycled aggregates can be incorporated into concrete, thereby diverting materials from the landfill and reducing use of virgin materials.

Concrete has low VOC emissions and does not degrade indoor air quality. Table 1 presents VOC emissions of some common materials found in finishes. The level of VOCs in concrete construction can be further reduced by using low-VOC materials for form release agents, curing compounds, dampproofing materials, wall and floor coatings and primers, membranes, sealers, and water repellants.

Table 1. Concentrations and Emission Rates of Volatile Organic Compounds (VOC) for Common Materials (ECCO 1999)

Building Material	VOC Concentration, mg/m^3	VOC Emission Rate, mg/m^2h
Concrete with water-based form-release agent	0.018	0.003
Acrylic latex paint	2.00	0.43
Epoxy, clear floor varnish	5.45	1.3
Felt carpet	1.95	0.080
Gypsum board	N/A	0.026
Linoleum	5.19	0.22
Particle board	N/A	2.0
Plastic silicone sealer	77.9	26.0
Plywood paneling	N/A	1.0
Putty strips	1.38	0.34
PVA glue cement	57.8	10.2
Sheet vinyl flooring	54.8	2.3
Silicone caulk	N/A	<2.0
Water-based EVA wall and floor glue	1,410.0	271.0

Light or natural colored concrete reduces heat islands, thereby reducing outdoor temperatures and saving energy. About one-sixth as much sound gets through an ICF wall compared with an ordinary frame wall. This reduces the intrusion of noise from outside. More information on the environmental benefits of ICF and precast walls is available (VanGeem 2006) (Concrete Thinker 2008).

Exterior Finishes for Precast Concrete

Exterior and interior finishes can be formed into the outside and inside surfaces of architectural precast concrete. These can incorporate a full range of colors and textures ranging from simulated brick, masonry, stone or other historic facades to other patterns as shown in Figures 4 and 5(a). The inside can be finished without the need for additional gypsum wallboard as shown in Figure 5(b). These durable interior finishes are particularly beneficial in schools and other high-use areas. The integral concrete finishes eliminate the need for additional finish systems and their environmental impacts from extraction, production, and transportation. Textures are achieved by molded formwork, acid-etching, surface retarders, or sandblasting. Decorative finishes include a full palate of colors.

DECORATIVE FINISHES FOR FLOORS

Decorative flatwork, as shown in Figure 6, allows the designer and owner to use the concrete as a finished floor without the need for additional flooring materials such as carpet, wood flooring, or tile. This eliminates the additional finish systems and their environmental impacts from extraction, production, and transportation. Concrete floors have a long life, low VOC emissions, and are moisture resistant. Special techniques are available to make concrete slip-resistant. Concrete floors with no additional finishes also provide the thermal mass for passive solar and other buildings. Their use helps reduce energy use by moderating the effect of changes in outdoor temperatures.

Figure 4. Exterior finish as part of exterior precast wall (a) Simulated brick (Photo courtesy of Thermomass® Building Insulation System www.thermomass.com) (b) Simulated wood (Photo courtesy of Dukane Precast, Inc www.dukaneprecast.com)

Figure 5. Exterior and interior finishes as part of concrete wall system (a) Simulated masonry during final stages of construction in precast plant (b) Interior concrete wall in residence (Photos courtesy of Dukane Precast, Inc www.dukaneprecast.com)

Geometric patterns can be scored, stamped, rolled or inlaid into the concrete. Other interesting patterns are obtained by using divider strips to form panels of various sizes and shapes - rectangular, square, circular or diamond. The top surface can be ground to expose aggregate for an effect similar to terrazo. Variations in the color and texture of concrete surfaces are limited only by the imagination of the designer and the skill of the concrete craftsman.

Textures

An exposed aggregate finish gives traditional concrete a more natural look. Texture is achieved by brushing and washing away surface mortar as the concrete begins to harden, so the stone or gravel in the concrete becomes visible. Any attractive stone can be imbedded into the surface – marble, granite chips, pebbles, or even shells for beachfront property.

Semi-hardened concrete can be pattern-stamped (Harris 2004), as shown in Figure 7, with special tools to create the custom look and feel of slate, cobblestone, brick or tile. Typically, these textures can be done at a fraction of the cost, and offer long-term performance. Using decorative concrete is two to ten times less expensive than actual brick or flagstone.

Fig. 6 Decorative flatwork combining plain concrete, textures, exposed-aggregate, pattern stamping, divider strips, and borders (Photo courtesy of the Portland Cement Association, www.cement.org, Nos. 9046)

Figure 7. Pattern-stamped concrete (Photos courtesy of the Portland Cement Association, www.cement.org, Nos. 5077 and 7054)

Colors (Pigments and Staining)

Concrete can be cast in a wide variety of colors (Harris 2004) as shown in Figure 8. Pastels and earth tones are produced by mixing mineral pigments throughout the concrete. For deeper tones, finishers use the dry-shake method – sprinkling powdered, prepackaged color-hardeners onto a freshly cast concrete slab, then trowelling it into the surface.

CONCLUSIONS

ICF wall systems and insulated precast concrete sandwich panel systems integrate concrete's thermal mass and insulation in one energy-efficient system. These systems commonly have a continuous layer of concrete (reducing air infiltration) and a continuous layer of insulation (reducing thermal bridging). Further integration is obtained when exterior and interior finishes are formed into the outside and inside surfaces of concrete. This eliminates the need for additional finish systems, such as siding or brick on the exterior or gypsum wallboard on the interior, and their environmental impacts from extraction, production, and transportation.

Figure 8. Stained concrete on interior floor. (Photos courtesy of the Portland Cement Association, www.cement.org, Nos. 5074 and 15195)

Decorative finishes such as stamping and staining allow concrete to be used without the need for additional flooring materials such as carpet, wood flooring, or tile. This eliminates the additional finish systems and their environmental impacts from extraction, production, and transportation. Concrete floors have a long life, low VOC emissions, and are moisture resistant. Concrete floors with no additional finishes also provide the thermal mass for passive solar and other buildings.

REFERENCES

Concrete Thinker. 2008. www.concretethinker.org

ECCO. 1999. *What's Your IAQ I.Q?*, Environmental Council of Concrete Organizations, www.ecco.org, Publication No. EV20.

Harris B. 2004. *Bob Harris' Guide to Stamped Concrete*. Portland Cement Association, www.cement.org , Publication No. LT284.

Harris B. 2004. *Bob Harris' Guide to Stained Concrete Floors*. Portland Cement Association, www.cement.org , Publication No. LT283.

ICFA. 2008. Insulating Concrete Form Association, www.forms.org.

VanGeem, M. 2006. Achieving Sustainability with Precast Concrete. *PCI Journal*, January/February 2006. www.pci.org