Concrete Floor Systems In Residential Construction

Proliferation of homes built with insulating concrete forms inspires wider use of concrete floors

By Pieter A. VanderWerf and Cameron Ridsdale

Used widely in commercial construction for years, concrete floor systems have recently blazed trails into the residential market. The main reason is the growing popularity of stay-in-place insulating concrete form (ICF) homes.

An estimated 3,000 new homes were built in North America in 1995 using ICFs—hollow blocks, panels or planks made of rigid foam that are erected and filled with concrete to form the structure and insulation of exterior walls. Cost-competitive with wood-frame construction, ICF homes offer owners a variety of benefits including energy efficiency, comfort, durability and strength. (For a more complete overview of ICFs, see "Recommended Reading" on page 802.)

Until the advent of ICF home-building, concrete floor systems were rarely considered for houses because frame construction usually didn't provide the necessary structural support. A concrete floor works well with ICFs because concrete walls can carry the floor's greater weight without special provisions. In addition, the logistics of installing concrete floors in ICF homes are usually small, because the building crews already have experience working with concrete and reinforcing steel.


Hambro Structural Systems, a division of Canam Steel Corp.

Figure 1. Workers place concrete on a steel-joist floor.

Advantages of Concrete Floors

On average, the cost of a concrete floor is $1 to $3 more per square foot than a wood-frame floor. However, this cost differential narrows or disappears in designs with very long clear spans (over 20 feet). In addition, concrete floors provide the following benefits:

Strength. Concrete decks form a diaphragm that ties ICF walls together into an unusually strong structure. There is no bouncing or squeaking, as is sometimes experienced with frame decks.

Shallower depths. As floor spans increase, the required depth of frame decks increases rapidly, and they may become uneconomical. For the same span, concrete decks are often shallower.

Sound attenuation. Concrete decks have sound transmission coefficient (STC) ratings about 10 points higher than frame. This means that approximately two-thirds less sound passes through concrete floors than passes through frame floors.

Thermal mass. Concrete's higher thermal mass dampens temperature fluctuations, increasing comfort in the home. Mass is particularly useful in homes with passive-solar and hydronic radiant heating. And radiant heating ele-

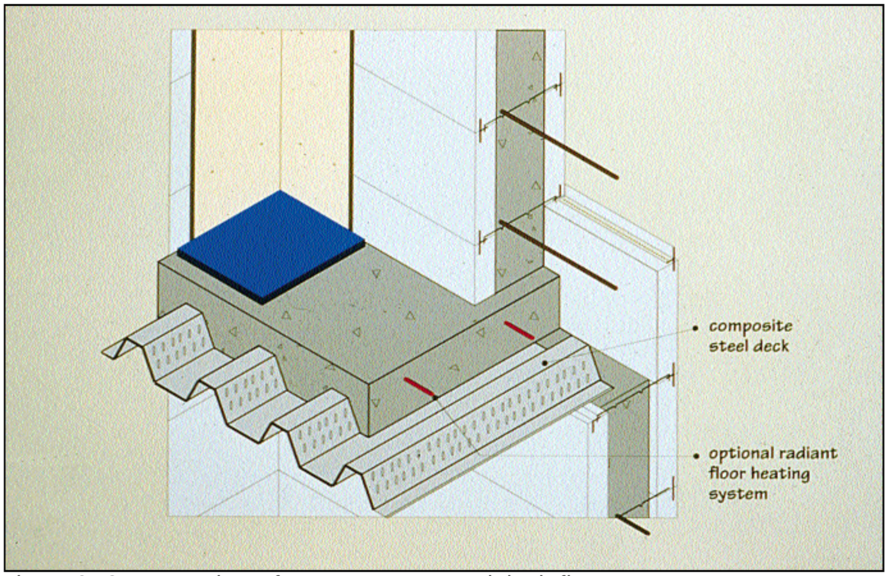

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Figure 2. Cutaway view of a concrete-on-steel-deck floor.

ments can be embedded within the concrete floor; with frame construction, a concrete topping is needed over the deck.

Fire resistance. Because concrete doesn't burn, many concrete floor systems have fire-resistance ratings of two hours or more. This compares with about one hour for typical wood-frame floors.

Unique finishes. In addition to being able to accept the common flooring materials used on wood-frame floors, concrete floor systems allow some unique, distinctive finishes possible only with exposed concrete. For example, pigment or stain can be used to add color, and impressions can be made with stamps to create attractive textures.

As with any technology, concrete floors have a few limitations. Since concrete structural elements above grade are not yet common in the residential market, building crews are likely to work slower at first until they have a few jobs under their belt. Also, most concrete floor systems penetrate through the inside foam layer of ICF formwork, which might reduce the effective R-value of the exterior envelope.

The concrete floor systems used in ICF home construction fall into four categories: concrete on steel joists, concrete on steel deck, concrete slab and joist, and precast concrete.

Concrete on Steel Joists

A 2½- to 4-inch thickness of concrete can be placed on a steel deck or ribbed pan supported by light steel joists (Fig. 1). Floors with a total depth of 10½ inches can span 20 feet. Deeper ones (28 inches) can span 40 feet.

A proprietary steel-joist system—marketed in the United States by Hambro Structural Systems, Ft. Lauderdale, Fla., and in Canada by Canam Hambro—is well-suited to residential applications. The joists are steel trusses with a special top chord. Instead of a permanent steel pan, sheets of plywood or steel are temporarily held up by roll bars that run crosswise between the joists. Steel mesh is laid on top, then covered with 2¾ inches of concrete. The top chords of the joists become embedded and act in unison with the concrete slab to provide great strength. The plywood or steel sheet and roll bars are removed from underneath and can be reused.

Because of the strength provided by the composite action between joists and concrete, steel-joist systems can be up to 10% lighter and 25% thinner than plain joist-and-steel deck designs.

Another key advantage is the price. Some contractors say the system's installed cost equals that of a frame floor. The joists and sheet materials are light enough for manual lifting and placement, saving on the cost of heavy equipment. In addition, the system uses less concrete than some of the alternatives, cutting material costs. And if plywood sheeting is used, it can be reused on the job as roof sheathing.

A downside of the system is that using less concrete decreases the floor's thermal mass when compared to heavier concrete floor systems. However, adding ½-inch-thick fire-rated gypsum board to the ceiling provides a

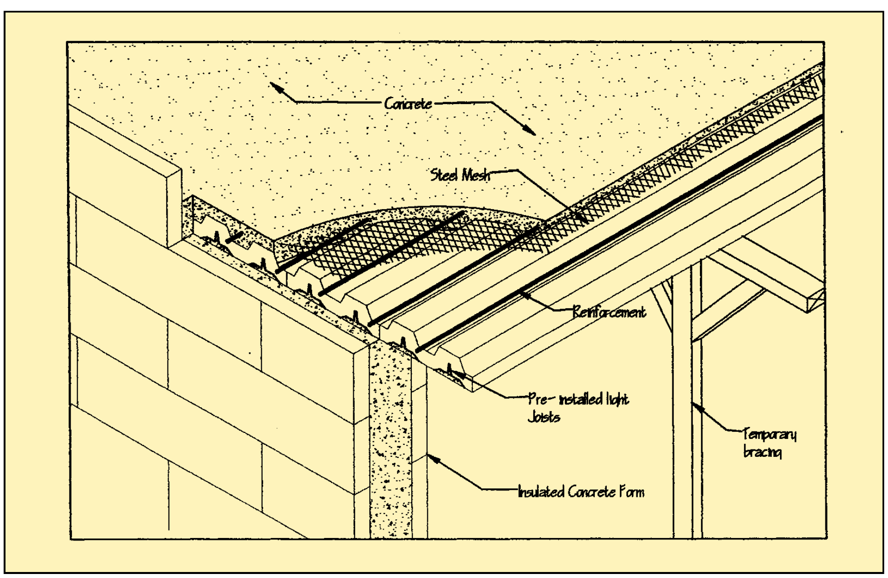

Figure 3. Cutaway view of a concrete slab-and-joist deck created with a foam form system.

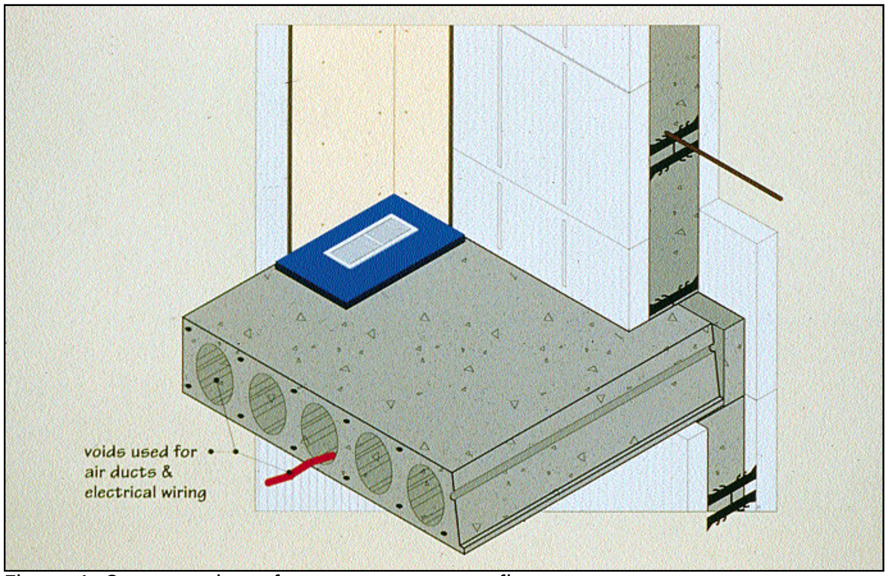

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Figure 4. Cutaway view of a precast concrete floor.

fire-resistance rating of two to three hours and an STC of 57 (an STC 57 floor transmits less than half as much sound as the minimum STC 50 floor required between dwelling units).

To locate additional manufacturers of steel-joist systems, contact the Steel Deck Institute or the Canadian Portland Cement Association (see "Sources for Further Product Information" on page 805).

Concrete on Steel Deck

Metal deck made from plain or galvanized steel sheet rolled into various ribbed profiles can be used to form concrete floor slabs (Fig. 2). For light construction, the material is generally made from 18- to 24-gauge sheets with 1½- to 3-inch-deep ribs. Steel decks can serve strictly as forms for the slab or can be fabricated to bond with the concrete and act with it structurally, creating a composite steel/concrete deck.

When the decking serves solely as a form, the concrete must be reinforced to carry all loads. A 1½-inch deck supporting 6½ inches of concrete above the flutes (for an 8-inch total thickness) can span about 15 feet if reinforced with #5 bars at 12 inches on-center in the direction of the span and #4 bars at 12 inches on-center in the perpendicular direction. Temporary supports must be installed under the deck at approximately 5 feet on-center and must remain in place until the concrete reaches 80% of its design strength. Some slabs of this type have fire-resistance ratings of up to two hours and sound ratings of about STC 52.

For a composite steel/concrete floor, a deck with dimples formed into the vertical flutes physically bonds to the concrete to perform the structural function of reinforcement. A 22-gauge deck 3 inches deep topped with 3 inches of concrete (for a 6-inch total thickness) can span 15 feet with no additional reinforcement. With a heavier deck or the addition of reinforcement, greater spans are possible.

Benefits of these types of systems include ease of use and a relatively thin finished-floor profile. The thin profile, however, makes it more difficult to install utilities. Small utility lines can fit beneath the deck between ribs, but to install large vents and pipes or crosswise utility runs, some form of strapping is necessary. Another drawback of these systems is the need for greater bracing and, in some cases, reinforcement.

The last three publications listed below provide detailed information about the design of composite deck floors. To locate manufacturers of the decking, contact the Steel Deck Institute or the Canadian Portland Cement Association.

Concrete Slab and Joist

Forms with deep ribs create floors that combine concrete slabs

Recommended Reading

1. W. Keith Munsell, "Stay-in-Place Wall Forms Revolutionize Home Construction," *Concrete Construction,* January 1995, pp. 12-19.

2. Pieter A. VanderWerf, Stephen J. Feige, Paula Chammas and Lionel A. Lemay, *Insulating Concrete Forms for Residential Design and Construction,* McGraw-Hill Inc., New York, 1997.

3. Pieter A. VanderWerf and W. Keith Munsell, *Insulating Concrete Forms Construction Manual: Successful Methods and Techniques,* McGraw-Hill Inc., 1996.

4. Pieter A. VanderWerf and W. Keith Munsell, *The Portland Cement Association's Guide to Concrete Homebuilding Systems,* McGraw-Hill Inc., New York, 1995.

5. *Concrete Housing Handbook,* Canadian Portland Cement Association, Toronto, 1995.

6. *Standard for the Structural Design of Composite Slabs,* American Society of Civil Engineers, New York, 1994.

7. Richard B. Heagler, Larry D. Luttrell and W. Samuel Easterling, *Composite Deck Design Handbook* (No. CDD1), Steel Deck Institute, Canton, Ohio, 1991.

8. *Criteria for the Design of Composite Slabs,* Report CSSBI S3-88, Canadian Sheet Steel Building Institute, Willowdale, Ontario, November 1988.

and joists in one continuous casting of material. Removable metal or fiberglass forms are available, as well as steel forms that bond to the concrete to act as reinforcement. Typical systems create 8-inch-deep ribs 2 to 3 feet on-center. Additional concrete depth on top is 2 to 3 inches, for a total floor thickness of 10 to 12 inches. The deeper floor profiles of these systems enhance sound attenuation and thermal properties and reduce the amount of temporary bracing required.

Usually one reinforcing bar is placed near the bottom of each rib, and wire mesh is placed in the top slab. With composite forms, spans of 16 to 26 feet are achievable without further reinforcement, depending on the depth of the floor and the reinforcement schedule.

Several U.S. and Canadian manufacturers are developing systems that use foam forms to create concrete slab-and-joist floors. Such systems have long been sold by European companies and are installed in thousands of buildings abroad. Hollow-core foam planks with periodic ribs stay in place permanently. They have built-in reinforcement to hold them stiff during installation and concrete placement (Fig. 3). After concrete is placed, they are braced below with temporary supports every few feet. As with ICF wall systems, attachments for finishes can be incorporated into the foam. Many of these new systems are being designed specifically for use with ICF walls.

Contact the Insulating Concrete Form Association for manufacturer and product information.

Precast Concrete

Precast, prestressed hollow-core concrete planks for residential floors are usually 4 feet wide and 6 or 8 inches thick (Fig. 4). The planks are set on walls by crane and anchored with bent reinforcing bars set into the shear key joint between the planks. Grouting the joints completes the installation.

Most of these precast planks have evenly spaced voids, or cores, running the length of the slab, with prestressing tendons in between. They can be cut to any specified length at the plant. Widths and shapes can also be customized to accommodate stair openings or other special situations. Holes for utilities can be formed at the plant or cut onsite with concrete drills or saws.

Precast products are consistent in depth, with relatively flat tops and smooth undersides that require minimal finishing. A thin grout or concrete topping is required under thin flooring materials such as vinyl. The cores can be used to distribute air and/or wiring.

While precast systems can be very fast and simple to install, a crane is required to set them in place. Also, there is less flexibility in routing utility lines and making changes in the field.

To locate manufacturers of these systems, contact the Post-Tensioning Institute or Precast/Prestressed Concrete Institute. In Canada, contact the Canadian Portland Cement Association or Canadian Prestressed Concrete Institute.

A Promising Future

Although concrete floor systems are relatively new to the low-rise single-family residential market, interest in these systems will grow as the ICF homebuilding trend continues. Concrete has benefits that buyers are seeking and are increasingly willing to pay for. And as the features of these floor systems are fine-tuned and as building crews become more familiar with concrete-floor construction, the installation costs are likely to fall.

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Sources for Further Product Information

Canadian Portland Cement Association
60 Queen St., Suite 206
Ottawa, ON
Canada K1P 5Y7
(613-236-9471)

Canadian Prestressed Concrete Institute
196 Bronson Ave., Suite 100
Ottawa, ON
Canada K1R 6H4
(613-232-2619)

Insulating Concrete Form Association
960 Harlem Ave., #1128
Glenview, IL 60025
(847-657-9730)

Steel Deck Institute
P.O. Box 9506
Canton, OH 44711
(330-493-7886)

Portland Cement Association
5420 Old Orchard Road
Skokie, IL 60077
(847-966-6200)

Post-Tensioning Institute
1717 W. Northern Ave.
Suite 114
Phoenix, AZ 85021
(602-870-7540)

Precast/Prestressed Concrete Institute
175 W. Jackson Blvd.
Chicago, IL 60604
(312-786-0300)

PUBLICATION #C970798