U.S. Department of Housing and Urban Development
Office of Policy Development and Research

Innovative Structural Systems for Home Construction: Wood Structural Insulated Panels and Insulating Concrete Forms

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Prepared for

National Association of Home Builders
Washington, D.C. and

The U.S. Department of Housing and Urban Development
Office of Policy Development and Research

under HUD Cooperative Agreement No. H5932CA

Prepared by

NAHB Research Center
Upper Marlboro, MD

August 1995

Notice

Foreword

Wood has always been a favorite material for homebuilders in the United States because of its satisfactory performance, ready availability, and relatively low cost. In fact more than 90 percent of new single-family homes are framed with wood. However, recent unstable lumber prices have prompted interest in other structural materials.

In response to heightened interest, the U.S. Department of Housing and Urban Development (HUD) commissioned a review of available structural materials for housing construction. The result, *Alternatives to Lumber and Plywood in Home Construction*, published in 1993, identified several promising materials. Further study results released in 1994 (*Alternative Framing Materials in Residential Construction: Three Case Studies*)-provided insight into the installed cost of several systems.

HUD is continuing its research into new materials. This report, *Innovative Structural Systems for Home Construction*, presents two alternative technologies for conventional residential construction: wood structural insulated panels and insulating concrete forms. The report describes several variations on these systems and recommends actions designed to accelerate development, acceptance, and implementation by the homebuilding industry.

We hope that this report, by evaluating the design and construction of homes with alternative materials, will stimulate builders to investigate such options more thoroughly. Increased use of innovative construction materials should help to protect future homebuyers from price increases caused by too great a dependence on any one building material.

Michael A. Stegman
Assistant Secretary for Policy
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Acknowledgements

The Research Center recognizes the National Association of Home Builders (NAHB) and the U. S. Department of Housing and Urban Development (HUD) whose support made this publication possible.

Appreciation is also extended to several manufacturers whose product information was used by permission. While acknowledging the assistance of these organizations, we emphasize this in no way implies that NAHB or HUD endorses their products.

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INTRODUCTION

Lumber prices rose rapidly in 1993 and became very volatile thereafter. This increase and volatility was caused by a combination of shortages of mature timber, panic buying, and political decisions. As a result, the cost of building with wood-frame construction increased dramatically.

There are a number of innovative alternative systems appearing on the market as a result of the increase and uncertainty with lumber costs. This report focuses on wood structural insulated panels and insulating concrete forms. The purpose is to describe several variations of these systems, to identify their advantages and disadvantages, and to recommend actions that would accelerate acceptance in the home building industry.

As the cost of building with wood frame construction rises, alternative systems of this type will become more generally available and cost competitive. But a word of caution: many alternative products and systems are proprietary and are not necessarily covered by the building codes at this time. Therefore, builders interested in using such a product or system should first ascertain that it is acceptable to the local building official.

1.0 WOOD STRUCTURAL INSULATED PANELS

Wood structural insulated panels, also called foam core panels, consist generally of wood structural panel faces separated by a relatively thick, low-density core of plastic foam (see Photo 1-1). Faces are typically $^{3}/_{8}$- or ½- inch-thick plywood, flakeboard, or oriented strand board (OSB). The core is usually either expanded or extruded polystyrene, polyisocyanurate, or polyurethane foam.

The U.S. Forest Products Laboratory first began developing stressed skin structural panels in the 1930s that consisted primarily of plywood skins glued to each side of a wood frame or paper honeycomb core. The foam core sandwich panels developed more recently perform in much the same way as these earlier stressed skin panels.[1] However, the term "stressed-skin"

Photo 1-1
A 4¾-inch-Wide Foam Core Panel Sample

[1]Steve Andrews, *Foam-Core Panels and Building Systems: Principles and Practice Plus Product Directory*, Cutter Information Corporation, Arlington, MA, 1988, p. 6.

Photo 1-1
A 4¾-inch-Wide Foam Core Panel Sample

is used (and sometimes misused) to describe a wide variety of constructions. The following discussion focuses on structural panels with a plastic foam core and plywood, oriented strand board, or waferboard faces, and avoids the term stressed-skin.

Since the 1950s, foam core panels have been used extensively for refrigerated buildings because of their superior energy performance. Although a number of foam core panel systems have been developed and promoted for home building, they have not been widely accepted because of higher material costs, compounded by the normal resistance to change.[2]
However, as the cost of lumber increases, foam core panels offer a potentially competitive alternative method for building homes that reduces lumber requirements and offers several other advantages as well.

An excellent presentation of the current state-of-the-art of foam core panels may be found in *Foam-Core Panels and Building Systems* published by Cutter Information Corporation and available through the Structural Insulated Panel Association (see subsequent section).

Wood Structural Insulated Panel Systems

Although most of the manufacturers produce panels that are categorically similar, not all panel systems are manufactured or installed in the same way. There is no universal panel or construction technique. Typically, the core of wall panels is 3½ or 5½ inches thick, and the core of roof panels is 7¼, 9¼, or 11¼ inches thick, in order to coordinate with the sizes of conventional framing members. Panel sizes range from 4'x8' to 8'x24' or larger.

[2] T. Michael Tool and Timothy D. Tonyan, "The Adoption of Innovative Building Systems: A Case Study", *Building Research Journal*, January 1992, p. 22.

There are several methods of joining panels, each with their own advantages. Splining methods include solid 2x studs, thermal-break studs, double-OSB splines, and cam-action locking devices. The solid 2x stud is a simple and effective method of joining, and is used by a number of manufacturers. Other variations may require more time for installation or cost more, but generally provide a desirable thermal break (see Figure 1-1).

Most manufacturers offer their panels with a built-in chase for wiring. Typically, the chase runs horizontally across the entire width of each panel at wall outlet height, about 14 inches above the floor. Some manufacturers also offer vertical chases, either built into panels or at vertical joints, or vertical chases can be made in the field by boring a hole through the top or bottom plate and the foam. A surface-mounted baseboard raceway is another alternative for wiring, but generally is less acceptable in residential construction. Larger chases for plumbing lines, etc., can be cut in the field.

Wall Construction

As with most new products or methods, foam core panel construction has some special installation requirements that must be carefully applied in the field. Typical construction details are shown in Attachment A. In this regard, foam core panels pose a learning curve for builders as well as their carpenters, electricians, and plumbers.

Panel erection requires some tools and equipment not normally used in conventional construction. For larger wall panels and roof panels, a small crane (12 ton) is recommended for installation. Also, some type of winch and strap system is often helpful to pull panel edges tight against each other. An extra large circular saw is necessary for the relatively thick panels, especially for cuts not perpendicular to the face. A router and special bits may be needed to cut chases and openings in panels. Also, special "hot wire" tools are often used to rout out the foam for top and bottom plates, for splines at panel joints, and for framing around openings (see Photo 1-2).

Figure 1-1
Splining/Joining Techniques Used with
Different Foam Core Panel Systems

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Photo 1-2
Hot Wire Tool Used to Rout Foam Core

Some manufacturers offer training for builders and their crews; others provide erection crews. Unless precut in the factory, placement of the panels starts by routing out the foam core to accommodate a 2x wood plate at the top and bottom of the panel. The bottom plate is attached to the floor. The first panel is then set with the wood skins extending down over the bottom plate, and is fastened to the plate through the skins. The second panel is set over the bottom plate in the same manner, connecting splines are inserted at the meeting edge (unless installed in the factory), and the panel is slid against the first panel and fastened at the spline joint and bottom plate. Since OSB and plywood can expand slightly with moisture, a small gap should be left between panel faces. The remaining wall panels are placed in similar fashion. To minimize air infiltration, sealants or caulks may be used at joints between panels as well as at top and bottom plates, etc.

Continuous 2x top plates are then set in the tops of panels and fastened through the skins as at bottom plates. Rough openings for doors and windows may be precut in the factory or can be cut on-site with a circular saw or chain saw. The foam core around the perimeter of the rough opening is normally routed out to a depth of 1½ inches to let in a 2x frame. Where required, structural headers are installed according to the manufacturers instructions. Conventional framing is often used for unusual or complicated conditions in exterior walls, such as at bay windows. Interior walls and floors are also framed conventionally.

Foam panels may be used with either platform or balloon construction (see Figure 1-2). With platform construction, as with most conventionally framed walls, foam core wall panels bear on the floor below, and the roof or floor above bears on the top of the panels. Balloon framing offers better thermal performance by avoiding interruption at each floor, but is generally more costly.

With true balloon construction, wall panels bear directly on the foundation sill plate and continue up to the roof. If there is a second-story, the floor is hung from a ledger anchored to structural elements in the panels. A modified balloon framing is more common where panels are one story in height. With this construction, first-story panels bear on the sill plate at the bottom and extend up to the second-floor surface; floor framing for the second level is then hung from the top of first-story panels, and wall panels on the second level bear directly on the wall panels of the first level.

Roof Construction

Foam core panels adapt best to straight gable roofs and often pose complications with other roof designs. Panels are typically installed from eave-to-ridge with double "rafter" splines between 4-foot-wide panels. This provides a flush ceiling, but also forms a thermal bridge which can promote lines of condensation on the inside face or "frost melt" lines on the outside in very cold weather. Panels may also be installed crosswise over roof beams, which can avoid the thermal bridge but adds further to cost. A crane is usually necessary for setting the large roof panels which are typically 4'x16' or larger. (see Photo 1-3).

Figure 1-2
Typical Balloon and Platform Construction
with Foam Core Panels

GraphicContainsDatafor

PostscriptPrintersOnly.

Photo 1-3
Crane Setting Large Roof Panel

Roof construction with foam core panels requires interior loadbearing walls or beams for support. Typically cathedral ceilings are used because there is no purpose in creating an attic space below the insulated panels, and because construction of redundant flat ceilings would add to cost. This type of roof construction requires insulated gable end walls and entails building interior partitions to fit up to the sloped ceiling. Such details tend to complicate construction and add to cost compared to conventional roof construction.

Asphalt shingles installed on foam panel roofs tend to overheat in the sun and can seriously shorten their life. As a result, several shingle manufacturers have indicated that this application may void their warranty. Several panel manufacturers now provide details for adding air flow channels to help cool the roof. One "cold roof" approach is to lay 1x or 2x furring strips and a layer of structural sheathing over the foam core panel roof.

Considering the complications in design and construction and attendant costs with foam core roof panels, many builders that use foam core wall panels use a conventional trussed roof construction rather than roof panels.

Advantages and Disadvantages of Foam Core Panels

A major advantage of foam core panels is their enhanced energy efficiency. Typical R-values for nominal 4-inch-thick wall panels range from R-13 to R-22, depending on the type of insulating foam. Thicker panels have correspondingly higher R-values. R-values per inch for different types of insulation compared to fiberglass batts are as follows:

•Fiberglass batts	R-3 to R-3.8
•Expanded polystyrene (EPS)	R-4
•Extruded polystyrene (XPS)	R-5
•Polyurethane or polyisocyanurate	R-6 (aged value)

Since most panels incorporate little or no solid framing, heat loss through thermal bridging is also reduced. In addition, the large panels and integral insulation help to reduce infiltration losses. Further, the low moisture vapor permeance of <u>extruded</u> polystyrene and polyurethane foam core panels is superior to a conventional wood frame wall with batt or blown-in insulation and a separate vapor retarder. Although some limited research indicates that a separate vapor retarder may not be needed with <u>expanded</u> polystyrene panels, most manufacturers require conventional vapor retarders such as 4-mil polyethylene beneath the drywall, or foil-backed drywall.

Another potential advantage is speed of construction. The use of foam core wall panels can reduce the time required to enclose and finish a home. Besides incorporating the insulation and sheathing, the panels preclude the usual framing since they are designed to carry loads through the sheathing (stressed skin). Also, continuous structural sheathing on both sides of the wall simplifies attachment of siding on the outside and drywall on the inside. Although it may take one or two houses for carpenters to learn how to use the panels, the learning curve is relatively short because, for the most part, they are working with familiar materials, tools, and fasteners. However, even with increased speed of construction, higher material costs will likely result in foam core panels being less competitive than wood framing on a first cost basis.

Some building officials are skeptical of such a studless structure. However, foam core panels can be designed to meet virtually any structural requirement for residential construction. In fact, some structural characteristics, such as bracing (resistance to racking) under wind and seismic loads, are inherently superior to conventional wood-framed walls which have a structural sheathing on only the outside face. Builders should note that engineering design will likely be required for each house constructed with foam core panels; however, most manufacturers provide engineering requirements for standard construction details. Either way, approval is still at the discretion of the local building official.

Builders considering a panel system should be sure that the manufacturer has conducted structural tests and has well-documented performance data on the product. Builders should also ascertain that the manufacturer maintains a rigorous quality control program, particularly with regard to bonding of faces to the foam core. It is important to note that the structural properties of foam core panels are entirely dependent on the bond between the foam core and structural skins. The best assurance is a well-experienced manufacturer and a product that is covered by an Evaluation Report from one of the building code organizations. This type of information is extremely valuable in obtaining approval from the local building official.

One potential disadvantage is that foam core panels are susceptible to tunneling by termites, carpenter ants, and rodents that can destroy the structural integrity of the assembly. This is especially troublesome because the tunnels are difficult to detect. Where termites pose a threat, standard preventive measures should be used such as soil treatment or termite shields. At least one panel manufacturer has incorporated borate into their expanded polystyrene core as an insect repellent, but the effectiveness is not well-documented to date. Apparently other foam materials are not as receptive to treatment.

Another concern of foam core panels is fire resistance. Under intense heat, the plastic foam core can melt or become detached from the face, thereby destroying the structural integrity of the panel. Several manufacturers have conducted fire tests on structural panels covered with drywall with good results, but questions surrounding such issues as possible collapse during a fire and structural soundness of a building following a fire have not yet been totally resolved.

Finally, some asphalt shingle manufacturers claim that foam panel roofs result in overheating which can seriously shorten the life of their products. As a result, some shingle manufacturers reportedly do not provide a full warranty over foam panel roofs.

Structural Insulated Panel Association

The Structural Insulated Panel Association (SIPA), formerly the Foam Core Panel Association, was formed by panel manufacturers and related interests to represent the industry. SIPA has established a technical committee whose primary goal is obtaining acceptance of structural insulated panels (primarily foam core panels) by the model building codes. The committee is developing an ASTM Standard Test Method to Determine Structural Capacities of Insulated Panels (ASTM, 1994). This standard will define a testing protocol to be followed by all manufacturers to document the structural properties of their products.

Although the structural insulated panel industry is very fragmented at this point and may initially resist standardization, the entire building industry including manufacturers, builders, architects, engineers, and code officials will benefit from such standardization. Additional information may be obtained from SIPA in Washington, D.C. (202-347-7800). SIPA also offers the following publications:

- *Foam Core Panels and Building Systems: 2nd Edition* ($49)
- *Market Potential for Structural Insulated Panels in Residential and Light Commercial Buildings* ($15)
- *Structural Foam-Core Panels in Northwest HUD-Code Manufactured Housing: A Preliminary Assessment of Opportunities and Obstacles* ($10)
- *Side-by-Side Evaluation of a Stressed Skin Insulated-Core Panel House and a Conventional Stud-Frame House* ($10)
- *Strength and Energy Performance Properties of Foam-Core Sandwich Panels* ($5)

Manufacturers of Structural Insulated Panels

Because foam core panels are purchased directly from the manufacturers and not from building supply centers, availability of the panels is variable. Although this often results in only local or regional distribution channels, there is a movement toward affiliated manufacturers in an effort to share product certification costs and widen distribution regions. Builders should call manufacturers directly to determine the availability of their panels.

AFM Corporation
Shorewood, MN
612-474-0809

Alchem Industries
Anchorage, Alaska
907-243-2177

All American Modular
Arlington, TX
817-265-2345

Allied Foam Products, Inc.
Gainsville, GA
404-536-7900

Apache Products Co.
Union, MS
601-774-8285

Enercept, Inc.
Watertown, SD
605-882-2222

Engineered Panel Tech.
Nashville, TN
615-254-1381

Extreme Panel Tech.
Cottonwood, MN
507-423-5530

Fiber-Tech Ind., Inc.
Chatham, IL
800-307-9859

Fischer SIPs, Inc.
Louisville, KY
502-778-5577

Foam Laminates of Vermont
Maryland Heights, MO
800-824-2211

Great Lakes Insulspan
Blissfield, MI
517-486-4355

Korwall Industries, Inc.
Arlington, TX
817-277-6741

North American Panel Systems
Westmoreland, NH
603-352-9994

Perma "R" Prod., Inc.
Johnson City, TN
615-929-8007

Ray-Core, Inc.
Lock Haven, PA
717-748-6032

Schmucker Manufacturing
Derry, PA
412-694-8082

South & Sons Panels, Inc.
Franklin, OH
513-746-3544

Structall Building Systems
Oldsmar, FL
813-855-2627

Tectum, Inc.
Newark, OH
614-345-9691

The Murus Company
Mansfield, PA
717-549-2100

Thermal Foams, Inc.
Buffalo, NY
716-874-6474

Thermapan Industries, Inc.
Fonthill, Ontario, Canada
416-892-2675

URSA Structural Systems
Pasco, WA
800-577-6560

Vermont Stresskin Panel
Cambridge, VT
802-644-8885

W.H. Porter, Inc.
Hollard, MI
616-399-1963

Winter Panel Corporation
Brattleboro,VT
802-254-3435

Summary and Conclusions

Although still not widely used, structural foam core panels have been in existence for more than 25 years and have been used in thousands of homes. This history of experience is sufficient to demonstrate that properly designed, manufactured, and installed panels can provide an acceptable and, in certain cases, superior wall construction. However, several important concerns need to be resolved.

Structural panels having either polystyrene or polyurethane foam cores faced with $^3/_8$- to ½-inch- thick plywood, waferboard, or oriented strand board offer one of the most practical near-term alternatives for exterior wall construction in the home building industry. Perhaps the most practical and least costly variation has an EPS core with OSB faces, and uses a simple 2x4 or 2x6 spline to join panels. Light gauge steel studs provide a likely companion alternative for interior nonloadbearing walls. The case for foam core roof panels, however, is not so clear. Conventional roof construction, particularly with roof trusses, is extremely efficient and cost effective. The complications that foam core panels introduce to design and construction of a roof, as well as the attendent costs, suggest that they will remain a specialty for the foreseeable future.

One of the primary deterrents to acceptance by the industry in the past has been cost. Total installed costs of foam core wood structural panels have generally been somewhat greater than conventional wood frame construction with insulation batts and sheathing. Now, with the impending shortage of lumber, particularly of quality (straight) lumber, foam core panels should become more competitive. The superior strength of panels faced with a structural sheathing on both sides could contribute to their competitive position in the face of more demanding engineering requirements for home building. As the basic costs for panel vs. frame construction begin to equalize, other advantages of foam core panels—such as thermal efficiency and quality of construction—may well tip the scales.

The principal advantage of wood faced foam core wall panels over other alternative constructions such as steel, concrete, and masonry is that they are essentially wood products. Carpenters learn how to build with these panels in short order, using normal wood working tools and fasteners. And, as with most conventional building materials, the wood faced panels are easy to modify or adapt to special conditions that arise in the field. Also, foam core wall panels offer some potential labor savings in carpentry, as well as for higher quality, by avoiding the possibility of twisted, warped framing.

While foam core panels do not pose any special problems for carpenters, there are some problems for electricians. Electrical and communications wiring is normally run after all floor, wall, and roof framing is complete. While foam core panel systems generally provide wiring chases in the core, they typically require at least some wiring to be done during erection of the panels, which can be time consuming and is not in normal sequence for the electrician. This seemingly minor detail is, in fact, a major obstacle to acceptance of foam core panels, and a practical solution is needed.

Another trade that is affected by foam core panels is plumbing. However, plumbing is not normally required in exterior walls, and is already precluded from exterior walls in many areas with freezing climates. Thus, it is not an especially critical factor in design. Furthermore, it is not necessarily a problem to cut a plumbing chase in a foam core panel where there is no practical alternative.

Two other potential problem areas exist for foam core panels that need final resolution: 1) susceptibility to attack by termites and carpenter ants; and 2) fire resistance relative to structural integrity. Panels are being produced by at least one manufacturer with an expanded polystyrene core that contains an insect repellent. This may offer a practical solution to the former concern, but it needs to be evaluated and verified by a credible third party. Similarly, several manufacturers have produced panels demonstrating a reasonable degree of fire resistance. However, the fire resistance of a particular panel needs to be evaluated and verified by a credible third party.

A final, more general, concern is the question of long-term performance of structural panels that depend on a glue bond to an otherwise nonstructural foam core. The answer to this broad issue probably lies as much with growing experience as with specific tests. However, development of nationally recognized test standards for structural foam core panels will do much to allay such underlying concerns.

The fact that foam core panels are not addressed in building codes poses a serious constraint to local approval. Ideally, a generic prescriptive requirement could be developed and introduced into the model building codes. However, since manufacturers each produce their own panel system variation(s), this may not be possible. A more promising approach to model code approval may be to reference an appropriate standard in the code, such as the ASTM Standard Test Method to Determine Structural Capacities of Insulated Panels being developed by SIPA as the basis for acceptance.

In the meantime, the primary means for individual manufacturers to obtain recognition of wood structural insulated panels is to get an Evaluation Report from one or more of the model code organizations. This does not constitute approval as such, but indicates that the product meets the intent of the code and is acceptable to most local officials.

Recommendations

Wood structural insulated panels appear to offer a viable alternative for construction of exterior walls in the home building industry. Therefore, the building industry should support efforts to accelerate development and implementation of this technology, as follows:

- Conduct field studies to evaluate practical construction requirements.
- Conduct a special study of electrical wiring alternatives and solutions.
- Perform cost analyses to quantify cost/benefit of foam core panel systems.
- Study and evaluate the termite/carpenter ant issue and document solutions.
- Study and evaluate the fire resistance issue as related to structural integrity.
- Study and evaluate the long-term durability/performance issue.

- Work with foam core panel manufacturers to sponsor demonstration houses in different regions of the country.
- Work with manufacturers to obtain Evaluation Reports from the model code organizations.
- Investigate alternative approaches for obtaining model code approvals, e.g., prescriptive provisions vs. reference to standards.
- Participate in development of standards and other activities to bring uniformity and quality assurance to the foam core panel industry.

The above activities should be conducted in close coordination with SIPA and/or individual panel manufacturers, and be funded by them to the extent possible. However, at the same time, it would be appropriate for NAHB and/or HUD to fund certain activities that are basic to acceptance of foam core panels, with particular reference to the termite/ant, fire, and long-term durability issues.

2.0INSULATING CONCRETE FORMS

In general, residential concrete construction has been limited to foundations of cast-in-place (poured) walls. Home builders, many of whom were once carpenters, generally have negative reactions to concrete for above-grade construction. They view concrete as difficult to work with, and are concerned about such things as changing the location of a door or window, installing electrical systems, insulating, and attaching finish materials. Another major consideration is the difficulty of insulating concrete walls.

However, there are several variations of innovative concrete form systems that offer solutions to some of these concerns, particularly the question of insulation. Insulating form systems utilize rigid plastic foam that is left in place following placement of the concrete. The concept of forming and insulating at the same time has captured the imagination of many inventors and entrepreneurs. At this time, there are at least 25 companies making or selling different variations of stay-in-place foam form systems.

There are two basic variations on the concept. One variation utilizes hollow core foam blocks—typically made of expanded polystyrene—that are stacked up and filled with concrete to form a structural wall (see Photo 2-1). The other variation utilizes special ties with rigid foam panels that serve as concrete forms (see Photo 2-2). The foam board is generally extruded polystyrene. Both of these variations permit the contractor to insert vertical or horizontal reinforcing bars in the cavities to meet structural requirements.

Foam Block Form Systems

Foam block forms generally have an interlocking design to hold the units in alignment. Most manufacturers use blocks that are larger than standard concrete masonry units, such as 1 foot high by 4 feet long, to provide more wall area per block. The large foam blocks are very light in weight, and require minimal labor to form a wall. However, they must be braced extensively with steel or wood supports before pouring concrete. Typical construction details are shown in Attachment B.

Foam block forms that have foam webs connecting the two faces typically produce a structural grid of concrete within the form. This reduces the required amount of concrete but introduces variations in structural characteristics between different systems, depending on the grid configuration. Also, an "open" grid of concrete does not provide a continuous fire barrier. Some other foam block forms have steel or plastic webs connecting the two faces so that the plastic foam does not extend through the wall, which provides a continuous concrete fire barrier (see Figure 2-1). Some of these webs are configured to provide a nailing flange or "furring strip" on the face of the block to which siding or drywall can be screw attached (see Figure 2-2).

Photo 2-1
Foam Block Forms Being Installed

Photo 2-2
Foam Board Forms Being Installed

Figure 2-1
Foam Block with Steel Webs Provides
Continuous Concrete Fire Barrier

Courtesy of I.C.E.Block™ Building Systems, Inc. Used by permission.

Figure 2-2
Foam Block with Integral Steel or Plastic Flanges
For Attaching Finish Materials

Courtesy of Polysteel Forms® Used by permission.

Even though the foam block forms are very light, they are bulky and, therefore, relatively costly to ship. One system solves this by using hinged ties to connect the two faces of "blocks" that allow them to be folded flat for shipping. Several other products solve the problem by using plastic webs that are inserted in the field to connect the two faces of the blocks. An additional advantage of these systems is that different wall thicknesses can be formed with the same faces simply by using different web-ties.

Foam Board Form Systems

Typical foam board form systems use large panels of 1-inch to 2-inch-thick extruded polystyrene foam board for inside and outside forms, connected by special plastic or metal ties. These systems are comparable to conventional systems that use plywood forms and metal ties, except that ties must be spaced much closer (as close as 12 inches apart vertically and horizontally) because of the lower strength of the foam board.

The ties pierce the foam board and have large washer-like retainers on the outside (see Photo 2-3). The retainers may also be used as a means to screw attach interior or exterior finish materials to the wall. Different lengths of ties are used to cast different wall thicknesses. One system uses 8-inch-wide strips of foam board joined by ties that are placed over the edge of strips to align them and hold them in place (see Figure 2-3). Plastic or metal H-shaped sections are used to join panels at the edges.

The uniformly thick concrete walls that foam board form systems produce have the same strength characteristics as conventionally formed walls, which minimizes the necessity for engineering design and helps in obtaining acceptance from code officials.

Photo 2-3
Foam Board Ties Have Large Flanges That Provide for Attachment of Finish Materials

Finishing the Walls

Either foam block or foam board stay-in-place form systems allow pipes and wires to be run by cutting chases in the plastic foam with a hot wire, router, or knife after the wall is poured (see Photo 2-4).

Photo 2-4
Hot-Wire Tool Used to Rout Channels in Foam for Pipes and Wires

Figure 2-3
This Design Uses 8-inch-wide Strips of Foam Board Joined by Ties Along the Joint

GraphicContainsDatafor

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Courtesy of AAB/Demand Products. Used by permission.

With either type of system, the exposed plastic foam on the interior must be covered with a fire resistant facing such as ½-inch-thick drywall attached to furring or adhered to the foam with a recommended cement. On the exterior, conventional mesh and stucco, or synthetic stucco finish systems such as Dryvit®, may be applied over the foam. Conventional siding products may be attached to the nailing flanges or retainers (where provided) or to furring strips installed over the foam.

Advantages and Disadvantages of Foam Forms

The principal advantage of foam block or foam board concrete form systems from a performance standpoint is that they integrate insulation with a concrete wall to overcome one of the major deficiencies associated with concrete construction. The principal advantage from a construction standpoint is that the systems can be installed rapidly with minimal labor, especially considering that they do not require subsequent removal, and that the labor for installing insulation is included. Also, the insulating forms make it possible to place concrete in colder weather than with conventional forms.

Foam block systems are more of a specialty product than foam board systems and, therefore, tend to be somewhat more costly per square foot of wall surface. Also, block forms are not available in many localities and are bulky and costly to ship. Block forms that can be shipped flat and opened or assembled at the site are easier to ship, but may add to labor for assembly at the site. On the other hand, foam board systems are often assembled from a locally available foam board product that is less costly because it is a standard commodity. However, the on-site labor is somewhat higher than with most block forms, and the ties are a relatively costly specialty product.

Foam form systems are very light and easy to set and, therefore, offer potential labor savings compared to conventional concrete forms. However, since they are relatively fragile, they require extensive bracing at corners and openings, as well as along walls, which offsets some of the labor savings. This bracing is critical for supporting the walls while the concrete is being placed in order to avoid "blow outs" and to assure accurate walls. Standard plywood forms also require bracing, but plywood form bracing is somewhat less critical and easier to install. The net result is that the current material premiums for any foam form system appear to exceed the savings in labor. In addition, any concrete system requires a concrete pumper or other means to fill the forms for above-grade walls, which adds to the in-place cost of concrete.

Foam products used on the outside of foundations and exterior walls are especially vulnerable to tunneling by termites and carpenter ants. Thus, either foam block or foam board form systems are subject to attack. Although the insects do not eat the plastic foam, it provides a protected, out-of-sight pathway to wood members elsewhere in the structure. For this reason, building officials in several states do not allow foam insulation on the exterior of the foundation above grade. In response to this concern, at least one manufacturer produces an expanded polystyrene product incorporating a borate insect repellent; however, the effectiveness is not yet well-documented.

Another concern to some building officials is the possibility of fire spreading through the "space" behind the wall finish material that is occupied by the foam. Although this concern does not seem to be well-founded, fire stops spaced not more than 10 feet vertically and horizontally have been required in the foam in some localities.

Plastic foam insulation of any kind must be covered by a fire resistive material such as ½-inch gypsumboard on the interior and by a weather-resistant material on the exterior. Attachment to foam form concrete systems is obviously more difficult than with a wood structure. Foam form systems with integral "furring strips" or other provision for attaching gypsumboard, sheathing, or siding materials have an advantage. Otherwise, fasteners must extend through the foam and into the concrete, or furring strips may be used which are attached through the foam and into the concrete. The choice of an exterior covering on a foundation wall that extends above grade is particularly troublesome. A totally satisfactory solution has not yet emerged, but a stucco-type coating is often used. Also, foam board forms are sometimes removed on the above-grade exterior of the foundation wall to expose the concrete.

Concrete walls have traditionally been limited to foundations in residential construction. The more recent requirement to insulate basement walls suggests special potential for foam form systems in this application. The insulating value of these systems ranges from about R-8 for blocks with 1-inch-thick expanded polystyrene faces on both sides, to R-20 for 2-inch-thick extruded polystyrene boards on both sides. Other plastic foams that have greater R-values may be used, such as polyisocyanurate or polyurethane, but they are more costly.

The requirement for insulation is even more critical for above-grade walls. Therefore, foam form systems would appear to increase the potential feasibility for above-grade concrete walls in residential construction, where they have not been considered in the past. Because of the association of concrete to masonry, the greatest potential would seem to be in regions where masonry construction is common. This applies in particular to regions where wind or seismic loads are a primary design requirement, because reinforced concrete walls offer an attractive structural option in these regions.

Construction of above-grade concrete walls faces significant obstacles in most other regions of the country where wood frame construction and the associated trades and professions have been the norm for 50 to 100 years. A major departure of this type will require a lengthy period of time for designers, builders, and subcontractors to learn how to deal with the special characteristics, and detailed construction requirements of these systems and for home buyers to accept them. Successful introduction under these conditions typically requires one or more innovative builders operating under a particularly favorable competitive situation, such as a severe and protracted shortage of lumber.

A major impediment to the use of reinforced concrete walls of any type, including foam formed walls, is the requirement for engineering design. Since reinforcing is a practical necessity in the use of foam forms, some form of engineering design must be provided. The building official may require each job to be designed by a professional engineer registered in that state. However, many foam form manufacturers provide standard design tables for typical installations, usually prepared by a professional engineer, that should be acceptable to most building officials.

Even where acceptable engineering design is provided, building officials may be reluctant to approve foam forms because of some of the concerns discussed above, or just because they are new and different. Building codes do not address specific products, such as the various foam form systems, and there is presently nothing in any of the codes that addresses this type of system in a generic sense. The only effective means for manufacturers to gain acceptance of their product under these circumstances is to obtain an Evaluation Report from one or more of the model code organizations, which provides implicit approval of a product when installed as provided in the report. Most foam form manufacturers have obtained such reports.

Insulating Concrete Form Association

A new trade association was recently formed to represent the interests of companies that manufacture stay-in-place, insulating forms in North America. Called the Insulating Concrete Form Association (ICFA), the organization will promote code acceptance and act as a clearinghouse for technical information. ICFA is working closely with the Portland Cement Association (PCA) to gain acceptance of this new technology. For more information, contact ICFA, Glenview, IL (708-657-9730).

Manufacturers of Foam Form Systems

Because foam block and foam board form systems are usually purchased directly from the manufacturers and not from building supply centers, availability of the panels is variable. Although this often results in only local or regional distribution channels, there is a movement toward affiliated manufacturers in an effort to share product certification costs and widen distribution regions. Builders should call manufacturers directly to determine the availability.

Block Systems

AAB Building System
1009 South Atlantic Avenue
Beach Haven, NJ 08008
310-539-2221 or 609-492-3398

American Conform Industries
1820 South Santa Fe Street
Santa Ana, CA 92705
714-662-1100

American Polysteel Forms
5150 F. Edith N.E.
Albuquerque, NM 87107
505-345-8153

Branch River Foam Plastics
15 Thurber Boulevard
Smithfield, RI 02917
401-232-0270

Cubic Industries
4931 Meinders Road
McFarland, WI 53558
608-838-6607

Ener G Corporation
4203 West Adams
Phoenix, AZ 85009
602-470-0223

Energrid
6421 Box Springs Boulevard
Riverside, CA 92507
909-653-3346

Featherlite Building Products
301 West Hills Road
New Canaan, CT 06840
203-966-2252

Greenblock Company
P.O. Box 749
Woodland Park, CO 80866
408-625-1898

ICE Block
570 South Dayton-Lake
View Road
New Castle, OH 45344
800-423-2557

Keeva International, Inc.
1854 North Acacia Street
Mesa, AZ 85213
602-827-9894

PDQ Building Blocks, Inc.
P.O. Box 395
Pablo, MT 59855
406-675-2525

Polycrete
7951 Rue Vauban
Ville d'Anjou, Quebec H1J 2V1
514-493-6954

Precision Forms
182 Caldecott Lane, #118
Oakland, CA 94618

Reddi-Form, Inc.
593 Ramopo Valley Road
Oakland, NJ 07436
800-334-4303 or 201-405-2030

Thermoformed Block
Corporation
1777 S. Bellaire, Ste 430
Denver, CO 80222-4306
303-584-0330

Board Systems

AFM Corporation
"Diamond Snap Form"
Affiliated Foam Manufacturers
24,000 W. Highway 7, Ste 201
Shorewood, MN 55331
612-474-0809

Lite-Form, Inc.
1210 Steuben Street
P.O. Box 774
Sioux City, IA 51102
712-252-3704

R-Forms, Inc.
10999 Prosperity Farms Rd.
Palm Beach Gardens, FL 33410
407-624-2515

Summary and Conclusions

Foam block form systems and foam board systems both have potential for reducing costs because they are easy to erect and do not require removal; they combine insulation and form work in one operation and they generally provide superior insulation compared to conventional practice. Also, the insulating forms make it possible to place concrete in cold weather. They appear to have special potential for foundation walls and, to a lesser degree, for above-grade walls. However, there are several other factors affecting cost that must be considered.

The total installed cost for walls with most foam stay-in-place form systems is currently higher than for conventional insulated foundation walls or wood frame walls, primarily because of the high cost of the forms and/or special ties. Also, the fact that foam forms must be braced extensively with wood or steel supports prior to pouring the concrete offsets some of the potential labor savings. Further, a concrete pumper is normally required to fill the forms where they extend more than 2 or 3 feet above grade, which adds to cost.

Another factor that must be considered is the cost of finish surfaces, particularly on the exterior. Foam form systems that have special provision for attaching finish materials, such as siding, have an advantage. Otherwise, finish materials or furring strips must be anchored through the foam form to the concrete. Foam-form systems used for foundations present a special challenge because they require an exceptionally durable treatment for the above-grade portion of the wall.

There is also concern that foam forms are prone to tunneling by termites and carpenter ants. Although this does not pose a structural hazard to the wall itself, it can provide access for termites and ants to wood members. At least one company adds borate to their expanded polystyrene product to deter insects, and other companies are studying incorporation of various insect repellents in their products. However, the effectiveness of such treatments has not been well-documented to date.

Some code officials have expressed concern that fire could spread in the space between the wall finish and the concrete, which is occupied by the foam. As a result, fire stops are sometimes required to provide a break in the foam layer, usually in the form of metal flashing, every 10 feet horizontally and vertically in the wall. This requirement appears to be misdirected and needs to be resolved.

Model code acceptance of foam form systems is being pursued by ICFA and will likely resolve some of the issues in the process. The structural design issue for systems that produce a grid or other irregular wall configuration is being addressed through a computer design program developed by the Portland Cement Association. This is a valuable engineering tool, but it is not clear how this could be incorporated into a code provision. Foam form systems that produce a wall with a uniform thickness do not pose a special engineering requirement, but will still require engineering design for reinforcing.

In the meantime, the primary means for individual manufacturers to obtain recognition of insulating concrete forms to get an Evaluation Report from one or more of the model code organizations. This does not constitute approval as such, but indicates that the product meets the intent of the code and is acceptable to most local officials.

Recommendations

Foam block and foam board concrete form systems appear to offer a viable alternative to conventional cast-in-place concrete and concrete masonry foundations and, in some cases, above-grade walls. Therefore, the building industry should support efforts to develop and implement this technology, as follows:

- Conduct field studies to evaluate practical construction requirements.
- Perform cost analyses to quantify cost/benefit of foam form systems for basement walls and for above-grade walls.
- Evaluate exterior finish alternatives, particularly for above-grade foundation walls.
- Study and evaluate the termite/carpenter ant issue and document solutions.
- Study and evaluate fire/firestop issues.
- Work with manufacturers to get Evaluation Reports from model code organizations.
- Investigate alternative approaches for obtaining model code approvals.

These activities should be conducted in coordination with the Insulating Concrete Form Association or individual manufacturers and be funded by them to the extent possible. However, there are several common issues critical to long-term performance that would be appropriate for NAHB or HUD to fund, including the termite/ant issue and exterior finishes for foundation walls.

ATTACHMENT A

FOAM CORE WOOD STRUCTURAL PANEL SYSTEM
TYPICAL CONSTRUCTION DETAILS

COURTESY OF AFM CORPORATION
EXCELSIOR, MN
USED BY PERMISSION

ATTACHMENT B

FOAM BLOCK CONCRETE FORM SYSTEM
TYPICAL CONSTRUCTION DETAILS

COURTESY OF REDDI-FORM, INC.
OAKLAND, NJ
USED BY PERMISSION