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Introduction

The world of building construction is changing in response to concerns about urban sprawl, resource conservation, and sustainable development. In many communities you would now find homes and commercial structures being built with insulating concrete forms (ICF) as an alternative to traditional concrete basement walls and above-grade wood frame construction. (For more information about ICF construction methods and the advantages of ICF buildings see the Insulating Concrete Form Association web site at <http://www.forms.org>.) Mainstream production builders such as CENTEX Homes are offering ICF homes as an alternative to wood or masonry construction in selected markets ("Homebuilder gives," 1999). However, even the composition of ICF systems is evolving to include recycled material and cement composites to meet specific construction challenges and to provide a more environmentally friendly product. Educators and students graduating from Industrial Technology programs should be aware of new developments in alternative construction materials and methods and their impact on the use of plastics and composites in manufacturing.

After a quarter of century of dormancy, issues of energy efficiency, resource conservation, and sustainable development are again finding their way into debate at the national level. The purposes of this article is to provide an overview of ICF systems and some alternative concrete forming materials currently being utilized for both residential and commercial building construction, and to highlight the link between new construction practices and innovative material development.

Growing Demand For Insulating Concrete Form Systems

The National Association of Home Builders (NAHB) (1999) reported that insulating concrete form technology is the fastest growing alternative to wood-frame building for above-grade perimeter wall construction. Statistics gathered by the Portland Cement Association (PCA) indicated that the number of single-family homes built using ICFs jumped 70% from 1997 to 1998 and accounted for 1.7% of all new home starts (X'Cutter Information Corporation, 1999). Moreover, the PCA reported that awareness of insulating concrete form construction among the home buying public jumped from 22% in 1998 to 41% in 2000. The survey of homeowners also noted that 30% of respondents would consider an ICF home, making these systems the most popular option competing with traditional wood framing. An earlier study by the PCA (Portland Cement Association, 1998) found that 77% percent of homeowners said they would be willing to spend at least 1% more for a home that incorporates products and materials that are environmentally friendly and that 29% would be willing to spend at least 5% more.

Their environmentally friendly nature of ICFs comes from the fact that they improve the energy efficiency of the structure, reduce construction waste, and that the minimal waste foam generated in the erection process can potentially be recycled. Although most ICF systems are made from virgin polystyrene foam, use of recycled material is possible. Other advantages of ICF walls include improved sound attenuation, resistance to structural damage from flying debris associated

with high wind events, and concrete placement is feasible at lower temperatures without temporary heating. While ICF systems have many demonstrated advantages, the Journal of Light Construction (1999) noted that climate and site conditions may combine to create walls that are susceptible to burrowing insects when used below grade, and may also support fungus growth and retention of interior moisture. Proper materials, such as borate treated foam to resist vermin, and installation methods are a must to mitigate these potential problems.

To improve on an already environmentally friendly product, some manufacturers have developed alternative insulating concrete forms (“AICF” for the purpose of this article) systems that use materials such as recycled foam, wood fibers, or composites of portland cement. Recycled and composite form systems have the advantage of recycling construction waste and reducing industrial energy consumption. The global building industry consumes approximately 40% of all the mined, harvested, and dredged raw materials each year (Spiegel & Meadows, 1999). Given the tremendous amount of natural resources consumed in construction there is obviously an opportunity for significant improvement in recycling and resource conservation.

A serious consideration in contemporary building, therefore, is the issue of sustainability or sustainable development. Although there are a number of differing interpretations, one of the most cited was coined by the World Commission on Environment and Development who defined sustainable development as: “development which meets the needs of the present without compromising the ability of future generations to meet their own needs” (World Commission on Environment and Development, 1987, p. 43). ICFs and AICFs contribute to the goals of sustainability by the nature of their energy efficiency and their use of recycled materials. The Department of Energy (Spiegel & Meadows, 1999) estimated that improvements in the

energy efficiency of buildings, utilizing existing and readily available technologies, could save \$20 billion annually in the U.S., reduce dependence on foreign oil, and create 100,000 new jobs. ICFs are one of these technologies and can contribute to a more sustainable future.

Insulating Concrete Form Systems

ICF systems are comprised of lightweight modular units manufactured of insulating material such as polystyrene and are designed primarily for placement as foundation and exterior concrete walls. ICF wall assemblies typically have a thermal performance rating of at least R-22 and are designed with internal fastening strips that will accept virtually any interior or exterior finish system. These systems can be used for above or below-grade applications, however below grade use is prohibited in some regions, primarily the southeastern states. The modular shapes include blocks, planks, and panels. Block and plank systems are typically assembled by stacking the units in a running bond pattern. The erection of panel systems is very similar to metal or wood panel concrete forming systems. Because the forms are easier to manipulate during erection, walls generally require less labor to build.

Model building codes define and provide prescriptive requirements for three types of ICF systems based on the shape of the resulting concrete wall: (a) flat, (b) waffle grid, and (c) screen grid.

Flat ICF systems result in a wall of uniform thickness similar to traditional cast-in-place metal or wood formed walls. Waffle-grid and screen-grid systems both have shaped interior foam cavities with a column and beam grid configuration. The difference between the two systems is that the waffle-grid produces a monolithic concrete wall, whereas the screen-grid results in an “interrupted grid” with foam filled spaces between the concrete grid components. Although other configurations exist, the NAHB reported that flat, waffle, and screen grid systems account for 95% of all ICF systems produced in the United States (National Association of Homebuilders, 1999).

Alternative ICF Products

Various sources indicate that there are approximately 40 - 50 manufacturers of ICF systems in North America, most of which produce forms made from virgin polystyrene foam. Of these manufacturers, only three were identified who produced forms made with recycled foam and/or composite materials. The list of AICF manufacturer’s identified is presented in Table 1. Descriptions and data for these systems were obtained from manufacturers literature.

The *Rastra*® building system is comprised of planks or panels made of a composite of cement and *Thastyron*®, which is produced from 85 percent recycled post-consumer

Table 1. Listing of Recycled and Composite ICF Manufacturers

System	Unit Type	Wall Type	Primary Material	Ties
Rastra® USA	Plank or panel	Screen-grid	Recycled polystyrene & cement composite	Foam/cement webs
K-X Faswall	Block	Post & Beam	Wood/cement composite	Wood/cement webs
Durisol	Block or plank	Flat	Recycled wood	Recycled wood

polystyrene waste. According to the manufacturer, *Rastra*® is a composite system that is durable, energy-efficient, and because of the high recycled material content, minimizes the impact on the environment. The *Rastra*® system is also suitable for industrial applications and can be prefabricated in the factory in lengths of up to 25 feet (7.5m). These panels can also be designed to include steel reinforcement, window and door openings, and even plumbing penetrations.

Another composite system, *K-X Faswall* uses a patented combination of fibrous waste material, including green-timber, agricultural products, and cement to produce strong and durable AICF systems. According to the manufacturer, *K-X Faswall* systems differ from pure foam or plastic systems because of the composite forms' superior ability to withstand flame, decay, and the passage of vermin and insects. While no technical data were presented, the manufacturer claims that the *K-X Faswall* system creates a permeable "breathing wall", in which a very slow exchange of air keeps the resulting wall dry so that no condensation or moisture collection takes place.

Durisol forms are made from recycled wood fibers and portland cement and is suitable for both above- and below-grade applications for the building industry. Because *Durisol* is made from recycled wood and requires no dangerous chemicals or produces no toxic waste during production, the waste from these forms can also be recycled. Furthermore, the *Durisol* system has been designed to have more insulation on the exterior wall, which keeps the interior surface warm and dry. The added exterior insulation also contributes to the vapor-permeability of the wall system and enhances the natural exchange of air within the wall forms.

Recycled Plastic in ICF Systems

The use of recycled polystyrene foam in ICFs reduces the energy demands of production without reducing the energy-efficiency of the product. The recycling process requires post-consumer plastic materi-

als to be melted and remold, which affects the chemical and physical structure of the foam. For example, the expansion characteristics of recycled foam differ from the natural bead of virgin foam (Hornberger, Hight, & Walawalker, 2000) and therefore require different treatment in manufacturing. Recycled and virgin foam ICFs must be manufactured using a closed-cell process to effectively resist the absorption of water. This is especially important for below-grade applications where the foam is continuously exposed to exterior soil moisture.

Of all the ICFs sold in North America, most are made of expanded-polystyrene (EPS) or extruded-polystyrene (XPS), although some systems use polyurethane and recent innovations are using cement-foam composite (Concretehomes, 1999). Each material has its own unique profile of properties. Table 2 presents the typical properties of plastic foams and composites.

Expanded-polystyrene (EPS) is comparatively inexpensive, resistant to air and moisture infiltration, moderately strong, and available in either molded or sheet form, Concretehomes (1999). Extruded-polystyrene (XPS) foam is typically twice the cost of EPS, but carries about a 25% higher insulating value, greater resistance to water, and higher strength. Polyurethane has a higher insulating value than either of the polystyrenes with comparable strength, but is generally most expensive of the three plastic foam materials. Composite materials tend to be stronger, heavier, and perhaps more durable than foam forms. However, composite systems typically require more effort to

place and generally have a lower insulation value because of material density.

Composite Materials

The use of composite materials in insulating concrete forms has increased in the same way, and for many of the same reasons, that product manufacturers have opted for recycled plastics. Unlike recycled plastics, composite ICFs are not actually pure foam but an amalgam of materials including recycled wood fibers, portland cement, post-consumer plastics, and foam scrap waste (Concretehomes, 1999).

As with almost all materials, using composite materials has a number of advantages and disadvantage. Because of their density, most composite systems are highly resistant to the passage of termites, vermin, or other nesting insects (Journal of Light Construction, 1999). In addition, the systems generally will not entertain mold, support fungus growth, rot, or decay. Depending on the proportion of combustible materials to cement, some composite systems may carry a four-hour fire rating. Composite ICFs also provide an excellent mechanical and chemical bond for finish materials because the material accept nails or screws anywhere; therefore there is no need to locate fasteners at nailing strips. In the negative column, composites contain cement and are heavier than pure foam forms, require more effort to cut, and carry a lower insulating value (Concretehomes, 1999). Compared to most foam ICFs that are highly resistant to water penetration, composite systems tend to have to higher moisture content because of the

Table 2. Typical Properties of Plastic Foams and Composites

Property	EPS	XPS	Polyurethane	Composite
Density (lbs/cu.ft.)	1.35 - 1.80	1.60 - 1.80	2.00	21.00
R-value per inch	4.17 - 4.35	5.00	5.90	3.00
Water absorption (%)	< 3.00	< 0.30	2.00	NA
Retail cost (\$/bd.ft.)	\$0.17	\$0.35	\$0.70	NA ¹

Table reproduced by permission from Concretehomes (1999). Available On-line <http://www.concretehomes.com>.
¹Cost estimates are unavailable since the material comes only as completed, molded units.

retention of water in the wall material. In practice, even though most ICF systems are resistant to water penetration, dampproofing or waterproofing coatings are typically applied to the surface in contact with the soil to mitigate potential moisture problems. Composites would need similar treatment to repel hydrostatic pressures.

Summary and Conclusion

The increasing role of plastics and composite materials is changing traditional building methods and requiring new knowledge and skills of builders and educators preparing graduates to work in this new environment. The construction industry, long wary of change, appears to be willing to accept ICFs and competing alternative products as one way to address a host of building challenges — from demands for more energy efficient structures to shortages of skilled labor. Industry surveys indicate increasing acceptance of stay-in-place insulating concrete forming systems by designers, builders, and building owners. Manufacturers have responded with a steady stream of new materials and innovative products from which construction designers and owners can select to achieve green building and increased labor productivity. To summarize:

1. It is estimated that there are approximately 40 - 50 producers of ICFs in the United States and Canada. At this time, only three manufacturers produce forms made with recycled and/or composite building materials.
2. Major advantages of ICFs are increased energy efficiency, reduced labor cost of installation, increased sound attenuation, and greater moisture resistance when compared to competing wall systems.
3. Alternative ICF systems using composite materials overcome

- some of the shortcomings of pure polystyrene ICFs by providing increased resistance to burrowing insects, enhanced air exchange between the forms and concrete thereby reducing entrapped moisture, and reduction of post-construction waste materials through recycling.
4. Compared to foam ICFs, cement based composite materials are heavier and required greater labor cost for installation.
5. Alternative systems using recycled materials contribute to environmental waste reduction and the development of sustainable products for the building industry.
6. Although recycled foam does not have the same expansion characteristics as virgin foam bead and requires different treatment during processing, it appears to be a viable material for composite materials.

Recycled and composite materials in insulating concrete forms appear to address some of the shortcomings of virgin foam ICFs such as the potential for insect infestation. Further, the use of recycled materials in AICFS contributes to waste reduction and supports the goals of sustainability in building materials and appear to justify continued interest and investment by manufacturers, contractors, and homeowners. As noted previously by Spiegel & Meadows (1999) there is a still lot of opportunity for reducing the amount of resources and energy dedicated to construction processes. While it would be imprudent to pass judgment without the benefit of long-term perspective, recycled polystyrene and cement-foam composites appear to provide a positive alternative for the construction of environmental friendly and energy-efficient buildings.

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