Prefabricated residential construction

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Not too long ago, an average American who needed to build a new home would probably design and build it himself, with his own hands, while one of the wealthy few would hire an architect and a team of laborers. Today, the wealthy few (only 5%) still hire an architect to design a new home. The average person, however, is much more likely to buy a tract home in a cookie-cutter subdivision than to design the home himself.

This paper examines prefabricated residential construction, or *prefab*. If its potential is realized, prefab could give the average person—in terms of both wealth and construction know-how—the ability to customize a well-designed home rather than settle for the generic.

First, we describe what prefab is, and explain its advantages and disadvantages compared with traditional construction techniques. We then offer reasons why it might become more prevalent in the U.S., thanks to new materials and a push towards productized architecture. We provide some details about a number of prefab materials. Finally, we describe the opportunities that prefab offers to entrepreneurial architects.

What is prefab?

The term prefab can apply to any construction method where a significant part of the construction takes place off-site in a factory that produces relatively large, complex pieces that are then assembled at the site into the finished building.

Since prefab is such a loosely defined term, it helps to show where prefab as we define it fits into the spectrum of construction methods ranging from completely off-site to completely on-site.

At the extremes, recreational vehicles are an example of completely off-site construction, while igloos and straw huts exemplify completely on-site construction. As more realistic examples, HUD-compliant manufactured homes (commonly called trailer homes) are brought to the site almost completely finished, while in traditional wood, steel or concrete construction, homes are built almost completely on-site from thousands of basic materials.

Prefab fits in the middle of this continuum: it bridges the gap between manufactured housing and traditionally built homes, offering many of the advantages and opportunities of each.

Why prefab?

Imagine a world in which there are only two ways to get a new computer. One way is to buy it from a manufacturer that offers a handful of models, each conforming to rigid specifications. Need more memory, or a faster graphics card? Sorry, no can do.

The other way, for those with a strong desire for customization and money to spare, is to hire a local computer architect to design a machine from scratch, and have it built from basic components like motherboards and hard drives (or even from raw silicon and sheet metal).

Buying a new computer in this fantasy world resembles the process of acquiring a new house in the real world. While building computers and building houses differ in many significant ways, it is safe to say that in the U.S., the residential construction industry lags behind other industries in adopting efficient methods to offer innovative, customizable products to the mass market.

The goal of prefab is to offer a third way—a way for an average person to get a well-designed house that is at least roughly tailored to his needs.

Compared with traditional methods of home construction, prefab offers a number of advantages:

- *reduced labor costs*. Fabricating most of a home's components at a central location can take advantage of economies of scale and specialization. For example, rather than paying a team of framers to travel to a job site, cut lumber, nail it into place and clean up, framing panels can be produced at a factory by people who do one job and do it well, in a facility that lets them work at maximum efficiency. Depending on the type of construction, a job that normally takes months to complete on-site can be finished in days or even hours of on-site work.
- *reduced material costs*. Again, off-site fabrication benefits from specialization and economies of scale. A company that manufactures certain products in large quantities can negotiate better prices from its own suppliers, and competition forces companies making similar components to pass these savings along to the customer.
- *higher quality materials*. Components produced off-site can often be manufactured to tighter specifications and using better raw materials than the same components built on-site. For example, as the overall quality of dimensional lumber declines, local builders are now stuck using lumber that they would once have tossed into the scrap heap, while off-site manufacturers located near sources of better wood can fabricate higher-quality components efficiently. And since manufacturers can use specialized tools and control the conditions under which the components are made, the resulting components can exceed the quality of anything built on-site.
- *environmental friendliness*. Off-site manufacturing processes can be

optimized to reduce the amount of waste generated during fabrication. Since on-site work is reduced to assembling prefab components, much less waste is generated at the job site than is typical of traditional construction methods. Some prefab components are also designed with energy efficiency in mind.

Why not prefab?

Prefab has a long history, stretching back at least to the days of the Gold Rush, when settlers brought prefab materials with them to construct homes in their new surroundings out West.

In the early 20th century, kit homes were a popular type of prefab. The homes were delivered to the nearest railroad station in thousands of carefully numbered pieces, which could be assembled by anyone with some amount of mechanical skill.

From 1908 to 1940, Sears Roebuck sold 75,000 prefab homes through its catalog. Customers could choose among good, better and best grades, and could order certain custom options.

One of the most famous prefab failures was Lustron Homes, which built steel-frame prefab homes that were clad in colored square steel panels. Established in 1948, they managed to sell only 3,000 homes before going bankrupt in 1950.

Today, companies like Lindal Cedar and Deck House produce partially-prefab custom homes, manufacturing components centrally and selling homes across the country through a network of local representatives. Both companies have been around for decades, placing them among the more successful prefab ventures, yet neither has taken the residential construction industry by storm.

Since each of these prefab ventures has at best achieved only moderate success, it is worth examining the difficulties faced by prefab:

- *design limitations*. Although every type of construction has limits on what designs are feasible to construct, certain designs may stretch the limits of the prefab components chosen for a project. For example, while a prefab system intended for construction on a flat slab could be adapted for a steep slope, the amount of foundation work required may outweigh the advantages that are offered by that prefab system.
- *smaller pool of local builders and laborers*. Builders unfamiliar with a certain method of prefab construction may be unwilling to devote extra effort to learning it, especially if there is money to be made by building using traditional methods. Another difficulty is the lack of laborers skilled in the construction method. With less competition among builders bidding on a project, the overall cost may be higher or quality may suffer.
- *little or no cost advantage*. The labor and material cost advantages of prefab over traditional construction cited above depend on economies of scale, which

will not exist for a new prefab product. This presents a barrier of entry for bringing a new product to market, because the market will initially be limited to consumers willing to accept higher costs in exchange for other advantages of the product. Furthermore, traditional dimensional lumber construction can itself be done in a highly efficient manner, especially in large developments of thousands of new homes where a veritable mini-factory is established on the site. Prefab will always have a hard time competing with this kind of home construction.

- *labor unions and regulatory hurdles*. Labor unions are not eager to see local jobs for framers, roofers and pipe fitters replaced by faraway factories, and may thus exert pressure on governments to place restrictions on prefab construction. At the local level, planning and building departments unfamiliar with prefab often mistake it for HUD-compliant manufactured homes and impose the same zoning restrictions.

With all of these potential problems, are there still opportunities for prefab today? Prefab has certainly taken off in other countries. In Scandinavia, 70 to 90 percent of new homes are prefab, while nearly one third are prefab in Austria.

In the U.S., opportunities for broader use of prefab in residential construction could come from the development of new materials and fabrication techniques, and from efforts to productize the design and construction of prefab homes. The following sections will cover each of these topics.

Prefab materials

A number of new construction materials are starting to be used as components in prefab housing. Here we examine two of them: structural insulated panels (SIPs) and insulating concrete forms (ICFs). Other prefab materials include prefab foundation systems, steel framing, concrete framing, large-modular systems, and many others.

Structural insulated panels

A structural insulated panel (SIP, often called a sandwich panel) consists of a pair of oriented strand board (OSB) or plywood panels with a core of extruded polystyrene (EPS) foam in between, attached with an adhesive. Panels are available in a variety of thicknesses. They are usually produced in 8-ft-tall panels, but they can be cut to custom shapes at the factory, even with cutouts for windows and doors.

As the name implies, SIPs can be used structurally, with the OSB panels playing a similar role to the flanges of an I-beam, and the foam core acting as the web. Structural use of SIPs reduces the number of studs needed in a conventionally-framed house. SIPs can also be used as nonstructural walls in timber-frame and

post-and-beam construction.

One of the main advantages of SIPs is their insulating value, which depends on the thickness of the foam core. The foam core forms a continuous energy barrier, and the smaller number of studs leaves less opportunity for heat conduction.

SIPs are fabricated to very close (1/8 inch) tolerances, and the edge connections, which vary by manufacturer, are designed to fit snugly together. This property, combined with OSB's resistance to warping, results in a very tight structure whose walls are unlikely to shift and crack after construction. On-site labor can be further reduced by using SIPs with drywall preinstalled on one side.

Every material has disadvantages, and SIPs are no different. One of the biggest concerns about SIPs is their resistance to insects. While the EPS foam core provides no nutrition to insects, it offers an easy way for them to tunnel into the structure. Borate additives can be mixed into the foam during manufacture, providing some amount of insect resistance. Some manufacturers offer a 25-year warranty on their SIP products.

Although SIPs have been around for several decades, they have come into widespread use relatively recently, and questions remain about their performance in the long term. Delamination caused by failure of the adhesive is a major concern because it would affect the ability of structural SIPs to carry load. Fire resistance is also a concern, though manufacturers claim that as long as fire does not breach the OSB panel, SIPs perform just as well as traditional wood frames. There are also questions about the difficulty of remodeling buildings constructed with SIP walls.

SIPs are manufactured by dozens of companies; Premier Building Systems is one of the largest. They are growing in popularity for prefab construction, used by companies like Timbercraft Manufacturing of Washington for timber-frame construction and by architects such as Anderson Anderson for modernist prefab projects. The Structural Insulated Panel Association is an industry group that promotes the use of SIPs.

Insulating concrete forms

Insulating concrete forms (ICFs) are a prefab construction material consisting of hollow EPS foam blocks that are stacked and glued together on-site, creating a form that is filled with reinforcing bars and concrete. The unique property of ICFs is that the foam blocks are not removed after the concrete hardens; instead, they help insulate the building, while the concrete provides structural integrity.

Although ICFs are really a hybrid prefab material, since installing rebar and pouring concrete is done on-site, they offer many of the cost and environmental benefits of pure prefab. Compared with traditional concrete construction, it is faster to stack ICF foam blocks than to build a wood form, and since the foam blocks are not removed, there is much less waste. Some manufacturers offer large

prefab foam panels rather than blocks, which further reduces the amount of on-site labor.

Manufacturers claim that ICFs provide much better thermal insulation than conventional framed construction. Four inches of polystyrene foam plus a typical five-inch-thick concrete wall is rated at R-17, and since the wall is solid, there is no possibility of convection within the wall. Sound transmission is also much lower than conventional frame walls with fiberglass insulation.

One of the disadvantages of ICFs is the potential for improper installation due to problems with the concrete. The concrete must be fluid enough to fill the foam blocks without leaving air pockets, which would severely detract from the structural integrity of the finished wall, yet must be solid enough not to exert too much horizontal pressure on the foam, which can cause the forms to fail. Manufacturers seem to gloss over these problems when they claim that almost anyone can install ICFs easily.

As with SIPs, questions have been raised about the fire and insect resistance of ICFs. Since ICFs are often used both for the foundation and as walls, foam comes in direct contact with the soil, providing an easy vector for insects to invade the structure. However, insect-resistant additives can be mixed into the polystyrene foam, and manufacturers claim that fire-retardant additives make ICFs perform much better than traditional wood-frame walls in fires.

ICFs have been used for three decades, and originated in Europe where concrete and masonry are the most common forms of residential construction. Many manufactures provide ICF products. American Polysteel of New Mexico is one of the largest. The Insulating Concrete Form Association is a good resource for information about products and manufacturers.

Productizing architecture

In recent years, architects have been paying more attention to prefab as a legitimate construction method. Hoping to avoid the mistakes of past attempts to popularize prefab, some architects have been teaming with builders and entrepreneurs not only to focus on the design of finished buildings, but also to create improved processes for generating buildings. Their goal is to productize architecture, just as cars and computers have been productized, and prefab plays a significant role in this effort.

Earlier we referred to prefab as a third way, lying between the extremes of commodity mass production and one-off customization. Returning to the example of the computer industry, this third way is exemplified by companies like Dell Computer. Dell has nearly perfected the art of offering consumers just the right amount of customization in their products, in a timely and cost-effective way.

The third way has been called mass customization. The key to mass customization

is to allow choices, but to narrow them from an infinite range to a manageable matrix, so that design and manufacturing processes can be kept as simple as possible and economies of scale can be realized. For example, Dell allows customers to choose the amount of RAM, various sizes of disks, and the type of operating system when they order a computer. They do not allow the customer to specify the color of the case, the shape of the mouse, or any of the infinite other customizations one can think of, even if they are technically possible, or even easy, to achieve.

Some architects have already followed this approach in offering prefab products. Michelle Kaufmann's Glidehouse, introduced several years ago in collaboration with Sunset Magazine, is available in any of a handful of standard configurations, with a fixed set of exterior finishes. Any customization beyond those offered as standard—even something as simple as moving a wall by a few feet—incurs custom design fees. If the majority of orders fit into the standard production process, the more efficient the process and the greater the economy of scale.

In addition to limiting choices, a number of other factors are important when considering the process of a productized architecture. These factors include:

- *careful selection of materials and manufacturers*. The number of manufacturers, their stability, and their ability to ramp up production as demand increases, are all important considerations when selecting materials.
- *attention to marketing*. Contrary to popular myth, good designs do not sell themselves. Reputation of the producer, how the product fits into the lifestyle, transparency of the process, and many other marketing factors affect how well a product is received.
- *teaming with and educating local builders and governments*. As mentioned earlier, local builders, planning and building departments need to be educated about new materials and methods, especially prefab, which is often confused with trailer homes.

Conclusion

Walking through the Michael Graves teapots-and-toasters section of any Target store makes it clear that demand exists for good design, and that it is possible to sell good design to the mass market. The residential construction industry in the U.S. has done a poor job of modernizing itself the way many other industries have, to meet the demands of design-conscious consumers who cannot spare the money and time to build a home the traditional way.

Prefab offers one way to satisfy this demand, through the use of new materials and through an effort to productize the design and construction of homes. The good news for architects is that this market gives them an opportunity to expand their skills and play some role in revolutionizing an industry.

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