# PRECAST CONCRETE HOMES for Safety, Strength and Durability

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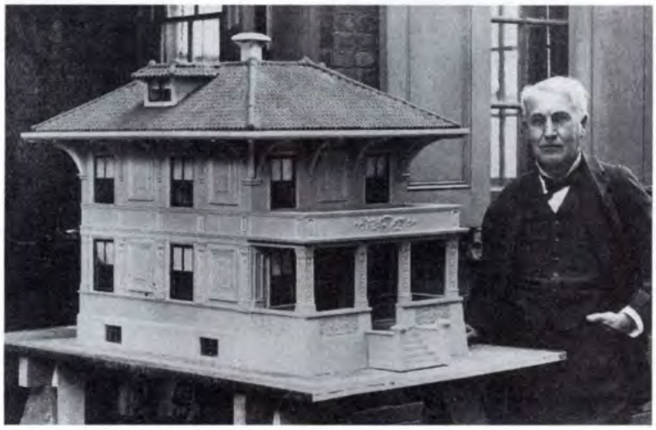
*Although concrete is a mainstay for foundations and landscaping amenities, buyers and builders in the United States have been slow to use concrete as a whole-house building material. Now, however, amid concerns over dwindling timber supplies, environmental conservation, and protection from natural disasters, there appears to be a new acceptance of concrete. This paper highlights some developments in the history of concrete as a homebuilding material and profiles four new precast concrete systems available today. Two are large-panel systems with integral insulation, suitable for erecting floors, roofs, and walls both above and below grade. The other two are based on transportable five-sided precast concrete box modules, which can be either stacked or laid out on one floor to produce a wide variety of homes. It is concluded that precast concrete housing satisfies environmental concerns while providing strength, durability, and protection from disasters at an affordable price.*

Widespread areas of South Florida were totally destroyed by the fury of Hurricane Andrew in August 1992. One of the most costly natural disasters to strike the United States, Andrew was followed a short time later by Hurricane Iniki which devastated the Hawaiian island of Kauai in the Pacific Ocean. Less than a year later, in the summer of 1993, floodwater destruction ripped vast areas of the Mississippi River Valley and its tributaries. As waters receded and restoration progressed in the midwest, raging firestorms hit the canyons of southern California in the fall. Only months later, on January 17, 1994, a major earthquake caused heavy damage in the Los Angeles area.

Rebuilding after disasters, such as these, all too often has involved restoring the same structures that were inadequate to handle the threats imposed on them. In the aftermath of the Southern California fires, a television interviewer asked how many jobs would be created by the rebuilding operation. "Oh, maybe about 500, pounding the nails and moving the

# The History of American Home Building is Cast in Concrete

The Horace Greeley Home (1856) remodeled from a barn.
*Courtesy: Portland Cement Association*



Thomas Edison's Housing Solution (1908).
*Courtesy: U.S. Department of the Interior, National Park Service, Edison Historical Site*

Fallingwater, Frank Lloyd Wright Classic (1935).
*Photo: Hedrich-Blessing. Courtesy: The Chicago Historical Society*

Two-Story Precast Concrete House (1935) - Revisited 1992. *Photo: Robert F. Armbruster*

Habitat '67 (1967). *Photo: Timothy Hursley*

Residence for Mr. & Mrs. Hans Keilhack which won the PCI Design Award in 1987.
*Courtesy: PCI JOURNAL*

Modular Precast Concrete Home (1993) *Courtesy: International Form Corporation*

2x4s," was the response. Fortunately, some progressive people are looking beyond the 2x4s to systems that will mitigate losses of life and property caused by such disasters in the future. Precast concrete offers a solution to the problem, as the four systems described herein show.

Fig. 1. *The Poor Man's Home and the Rich Man's Palace* was the title of a book George Barrett published in 1854 to describe construction of this concrete house in Spring Valley, Ohio. The sand, gravel, and lime mix was supplemented in some places with cobblestones to speed filling of the forms.

## HISTORICAL BACKGROUND

Concrete has been widely accepted throughout the rest of the world as an appropriate home building material, but markets in the United States have been slow to accept it on a large scale. Now, in light of attention to vulnerability of traditional frame houses to natural disasters, the tide may be turning in favor of concrete as a preferred material.

The trend is reinforced by environmental concerns as well as increased lumber and plywood prices. For example, 2x4s have increased in price as much as 44 percent in the past year.[1]

Although this paper does not attempt to present a complete history of concrete as a home construction material, some interesting forerunners of current developments will be cited. Even before the manufacture of portland cement in the United States, individual pioneers were trying out concrete as a home building material. George Barrett, an Ohio woolen miller who saw his frame home consumed by flames in 1852, wanted a new method of building. He set to work with sand, gravel, and lime to create what he called a "gravel wall house;" we

Fig. 2. An early precast concrete housing project in Youngstown, Ohio, included 281 units built between 1916 and 1920. A trestle track ran from the central mixing plant through the casting yard. Here concrete is being chuted from a sidegate car on the track into wood or concrete forms.

would call this material concrete today.

The Greek Revival style dwelling (Fig. 1), completed about 1854, still stands in Spring Valley, Ohio, providing shelter and displaying the longevity of concrete. A few years later, cement manufacturer Calvin Tompkins built his home in Rockland County, New York, using natural cement concrete. The 1858 structure, Boulderberg Manor, has stood in excellent condition throughout the 20th century, most recently housing a popular restaurant.

As concrete technology advanced, when mechanical engineer William Ward decided to build a concrete house in Port Chester, New York, he was able to import portland cement and add steel reinforcement. Neighbors at first nicknamed the home *Ward's Folly*, but as years passed and its comfort and durability were recognized, the name changed to *Ward's Castle*. Completed in 1875, the structure is still in use today.

In 1908, inventor and innovator, Thomas Edison, patented an elaborate system of cast iron molds for building concrete houses. Some say it was part of a strategy to extend the market for the output of his portland cement plant. Using these forms, Edison built concrete homes for workers in New Jersey, Pennsylvania, and Virginia. Many are still in use today. The Edison Portland Cement Company also constructed a precast concrete building (not a residence) in New Village, New York, in 1907.

Between 1910 and 1918, a number of precast concrete building systems were developed, primarily for industrial uses. One noteworthy residential project, reported by Schodek in the PCI JOURNAL,[2] included 281 units of housing in East Youngstown, Ohio, built over a 4-year period ending in 1920 (Fig. 2). Using traditional wood gable roofs and cast-in-place concrete foundations, these single- and multi-family dwellings were made of wall panels one story high and 16 ft (4.9 m) or more in length. Room size floor slabs were cast with a ribbed under surface. Interior wall panels had voids filled with granulated slag.

Many regarded the Youngstown project as the shape of things to come when it was presented at the 1920 national meeting of the American Institute of Architects. However, the period between World War I and World War II failed to bring to fruition many successful developments in concrete housing in the United States.

A notable exception was some work done by John J. Earley, a pioneer in architectural precast concrete. Earley is well-known for monumental structures such as the Baha'i Temple in Wilmette, Illinois, for which he cast the lacy exposed aggregate panels, and for the Lorado Taft Fountain of Time, in Chicago, where he precast all of the sculptor's 100 life-size figures in exposed aggregate concrete. Less remembered are the precast concrete houses he built in the mid-30s.

In 1934, the Earley Studio built an experimental house in Maryland, near Washington, D.C. The one-story, five-room house had a cast-in-place foundation and floor, and the exterior walls were 2 in. (51 mm) precast mosaic concrete. The roof and interior were made of conventional construction.

Fig. 3A. Erecting the walls of one of the Colesville Pike precast concrete houses, Silver Spring, Maryland, 1935. The completed Polychrome House is visible in the background (Courtesy: Reni Photographers).

Fig. 3B. Two-story precast concrete house in Silver Spring, Maryland, built in 1935 by the Earley Studio (Courtesy: Joseph W. Molitor).

Fig. 3C. Second ranch house built in 1935. This is the same house shown being built in Fig. 3A. The home was reported to be in excellent condition by Robert F. Armbruster when he took this photograph in 1992.

Fig. 3D. The two-story house shown above is the same house depicted in Fig. 3B. Robert F. Armbruster found this home, as well as all the other homes he inspected in 1992, to be in excellent condition.

Fig. 4. All-concrete home in Bel Air, California. Owner Edward K. Rice has never carried fire insurance, although he lives in an area vulnerable to firestorms and earthquakes.

The home's structural system was so simple that an average small builder could erect the precast concrete walls using only an A-frame and a chain hoist (Fig. 3A). Once the panels were erected, columns were cast in place to lock each precast slab to its neighbor with a weatherproof joint. The joints were designed to be flexible enough to permit slight movement in all directions as the slabs expanded and contracted with temperature changes.

Another unusual feature of the house was its color. Earley used crushed Oklahoma jasperite to impart a pinkish rose color to the walls, buff Potomac River gravel in the fluted corners and entrance pillars, and accents of ceramic material in other locations. The little building soon became known to local builders as the "Polychrome House." The Earley Studio built several homes of similar construction in the area, three of them two-story residences (Fig. 3B). In spite of the exciting promise shown by this forerunner of modern architectural precast concrete, wall panels for small houses never became an important part of Earley's business.[3]

In 1992, Robert F. Armbruster, director, Restoration of Baha'i National Center, inspected Earley's precast concrete homes. He reported that after nearly 60 years of use, the houses, today, are still being lived in and are all in excellent condition (Figs. 3C and 3D).

Since World War II, there have been a number of individual concrete successes, however, such as the all-concrete home built by prestressed concrete pioneer, Edward K. Rice, in 1962 (Fig. 4). Combining reinforced concrete masonry with a post-tensioned concrete roof, Rice built his home in Bel Air, an area prone to the California firestorms, and earthquakes as well. Interestingly, he has chosen not to carry fire insurance.

In 1967, Habitat at Expo '67 in Montreal attracted worldwide attention, although even that dramatic development did not start a new trend. Habitat '67 (described on pages 62-65) was assembled from precast concrete box units stacked and connected by post-tensioning cables.[5-7] It was built in a decade when "systems building" was a buzzword, and American presidents

Fig. 5. Aesthetic originality achieved with simple rectangular and double tee shaped precast and prestressed concrete units won a PCI Award in 1973. Structural components included 12x24 in. (300x600 mm) columns, 8x24 in. (200x600 mm) and 12x24 in. (300x600 mm) prestressed beams, and 24 in. (600 mm) double tee units 8 ft (2.4 m) wide with stems 4 ft (1.2 m) on centers. The components were fabricated at a nearby plant, transported to the site, and erected in only 3 days. Reference: PCI JOURNAL, November-December 1973, p.39.

(notably President Johnson in his quest for the "Great Society") were determined to provide improved housing for the inner cities.

In 1969, Housing and Urban Development Secretary, George Romney, announced Operation Breakthrough which would use industrialized techniques to achieve high volume, low cost housing.[4] The promise of large-scale systems building projects failed to materialize and few, if any, of the Operation Breakthrough building systems have survived.

Progress continued with individual homes, though. A precast, prestressed concrete house in Sarasota, Florida, was a winner in the 1973 PCI Awards Program. It displayed the potential for architectural drama attainable with simple precast and prestressed rectangular and double tee sections (Fig. 5).

Another handsome precast, prestressed concrete residence (Fig.6) was a winner in the 1987 PCI Awards Program. Situated in a beautifully wooded area of Charlotte, North Carolina, this home was framed with precast columns, beams, double tees and lintels.

Fig. 6. This prestigious, custom built home was built with precast, prestressed concrete in mind from the outset. Columns, beams, double tees and lintels framed the house. The project won a PCI Award in 1987. Reference: PCI JOURNAL, September-October 1987, p. 27.

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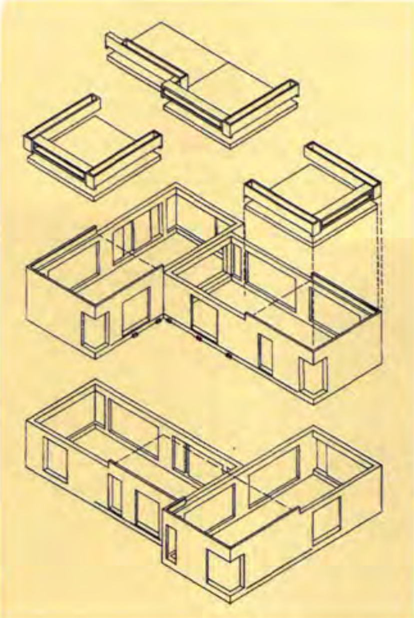


# HABITAT '67—
## Internationally Renowned Precast Concrete Housing Complex
### *A Retrospective Look*

Technical and aesthetic excellence have not in the past ensured the acceptance of concrete as a housing material. A landmark in the history of precast housing, Habitat '67 was built on the St. Lawrence River in Montreal, Quebec, Canada, at the time of the great world's fair, Expo '67.

Habitat is a three-dimensional space structure in which all parts of the building, including dwelling modules, pedestrian streets, and elevator cores participate as load-carrying members. The 365 precast concrete modular units measure 17½ x 38½ x 10 ft (5.3 x 11.7 x 3.0 m) and weigh as much as 70 tons (63.5 t). With all fixtures and finishes installed at the on-site factory before erection, modules were stacked in an innovative 12-story configuration and connected by post-tensioning, high-tension rods, cables, and welding to form a continuous suspension system.

Three elevator cores provide vertical circulation to serve horizontal pedestrian streets. The streets are continuous throughout the project, and access to the dwellings is directly from these streets. Play areas for young children are also accessed from the streets. Although budget constraints limited Habitat to 159 dwelling units instead of the 1200 originally planned, there are 15 different living units all made from the one basic module. Residences range from 600 to 1700 sq ft (56 to 158 $m^2$).

Habitat was envisioned as a model for urban living. Architect Moshe Safdie planned it as a low-cost alternative to both suburbia and the rising towers of public housing, putting into a multistory high density structure the amenities of privacy, a garden, and open space.[5,6] Gardens were placed on the roofs of units below, with larger ones measuring 17 x 36 ft (5.2 x 11.0 m). The dwelling units were assembled in a three-dimensional pattern, forming an exterior membrane within which commercial and institutional facilities were provided, enabling a population density of 150 to 200 people per acre with all facilities provided.

Habitat '67 is alive and well today, continuing as an upscale community, one of Montreal's most desirable addresses, with many of the original residents remaining. Trees planted in 1967 have matured and gardens flourish on the terraces. Interestingly, similar housing projects designed later by Safdie were never built.

Although Habitat has been a local success, Moshe Safdie does not consider it successful as a universal solution to urban housing. He now has a different view of the solution to housing problems.[7] "Poor and middle class families should not be housed in high density complexes. The constraints on our economy and the distribution of income make it impossible to provide reasonable amenities in such buildings. A better approach is to build medium density projects close to the ground and on more land."

Nonetheless, Safdie maintains a belief in the validity of Habitat's fundamental objectives: to minimize inefficient field labor, and to divide a building into shippable, lightweight, and easy-to-assemble components. He concludes: "As we strive to bridge the gap between a desired ideal and what is affordable, we might consider that the verdict on Habitat is yet to be heard."[7]

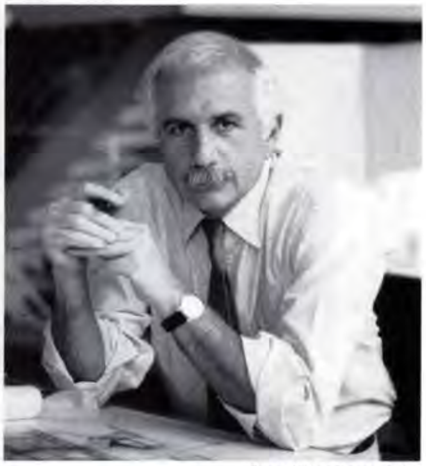
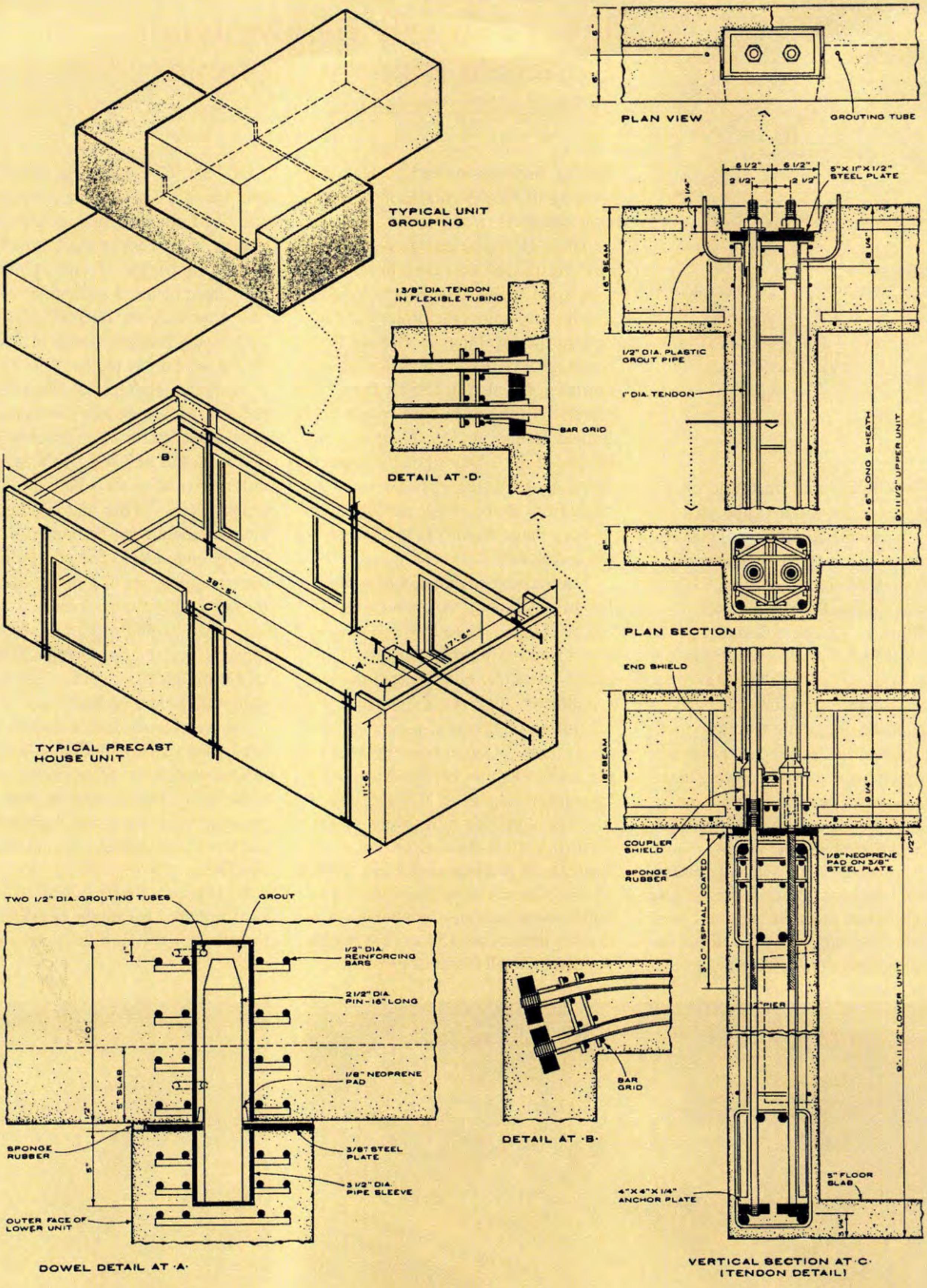
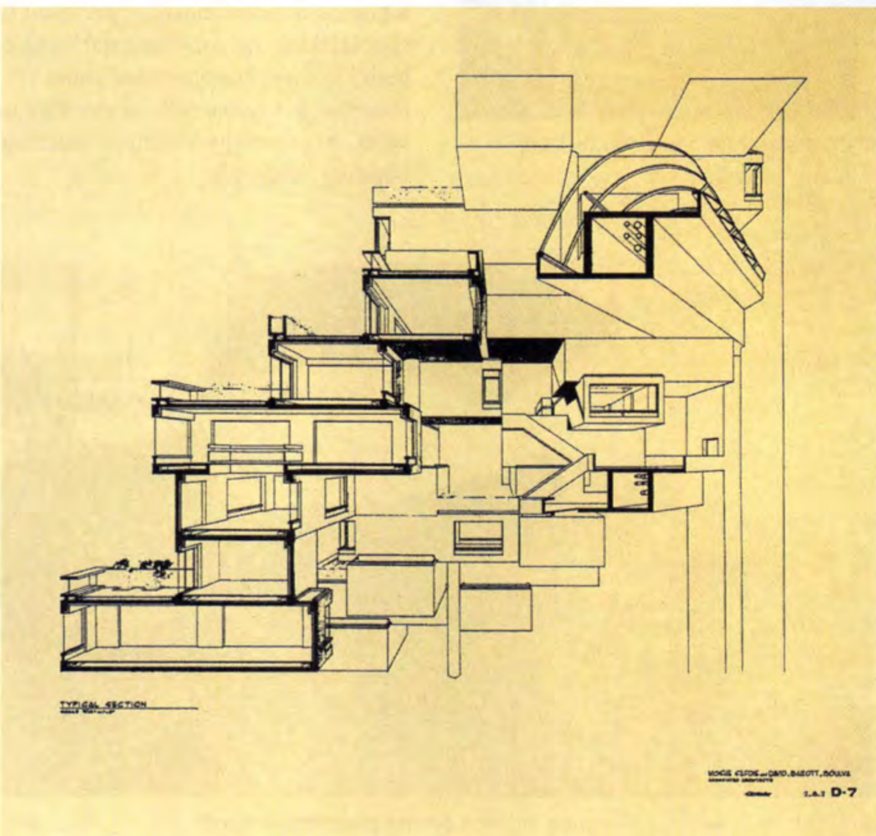


Photo: Michal Ronnen Safdie

Architect: Moshe Safdie




POST-TENSIONING AND CONNECTION DETAILS BETWEEN BOXES



## CREDITS

Architect:
Moshe Safdie and David, Barott, Boulva, Associated Architects.

Structural Engineer:
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General Contractor:
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Precast Concrete Manufacturer:
Francon (1966) Ltd.

Photographer:
Timothy Hursley, Little Rock, Arkansas.

Illustrations are published through the courtesy of Moshe Safdie and Associates Inc., Architects and Planners, Somerville, Massachusetts.

Fig. 7A. Sloping roof is part of the five-sided precast module cast in this hydraulically operated form.

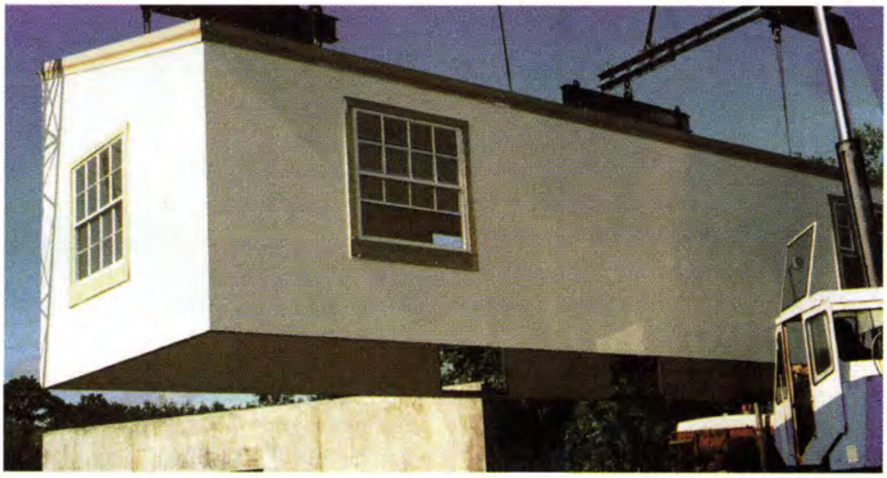

Fig. 7B. The box module ready for placement on a slab has been coated and sealed, with windows installed.

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## PRECAST CONCRETE HOUSING SYSTEMS

Admittedly, most of the major applications for single-family precast concrete housing have been outside the United States.[8] But here the potential remains large. The prospective benefits of improved durability and strength at reasonable cost are attracting home buyers as well as precasters and entrepreneurs.[9]

Four different approaches, currently emerging in the United States, are described in this paper. They include two systems based on box units and two systems based on large panels. Discussion is limited here to the single-family applications, but all of these methods will adapt to multi-family dwellings.

These systems afford interesting comparisons because of the background of their developers as well as the technology they embody. The box systems are based on five-sided modules. One is the work of a firm already well established in precast concrete production. The other box system was developed by a firm skilled in hydraulically adjustable forming equipment. One of the panel systems is the work of a home builder previously specializing in conventional "stick-built" homes, and the other panel system was the outgrowth of decades of work with energy-efficient concrete building methods.

Fig. 7C. Precast concrete roof module being lifted from its form.

Fig. 7D. With two box modules in place on the slab, precast roof is being lowered into position.

## Form Specialists Patent Modular Precast System

One Florida company has patented new technology for erecting a 1500 sq ft (140 $m^2$) or larger home every two days. Key to the operation is the form, which has a hydraulically controlled shrinking inner core and roll-back outside panels (Fig. 7A). Each form can turn out one 13x40 ft (4x12 m) module per day. Form units may be set up in a precasting plant or on site for a multi-dwelling development.

Reinforcing steel, a combination of bars and wire mesh, is installed upward from the base or pallet of the form, surrounding the internal form, with door and window blockouts accurately bolted to the inner core, forming openings that will receive the actual frames later. After the reinforcement is set, the hydraulic control pump, which has expanded the inside core tight against the base, then rolls the outside form panels inward and secures the corners to make the form tight and ready for the concrete pour. Concrete is either pumped through valves on the form or placed from above. A lower slump concrete is used for the integral sloping roof.

Vibrators built into the form take care of consolidation. After approximately 24 hours, the inner core and outer forms are backed off hydraulically from the casting, and the five-sided module is lifted by crane and placed on a supporting cradle where it will be coated and/or sealed and continue curing. At full strength it will be transported (Fig. 7B) to the cast-in-place slab on which it will finally become a major portion of a complete home.

Two of the 13 x 40 ft (4 x 12 m) modules are set in place and anchored to the base slab at a distance equal to the width of the central great room of the home. The third module, a precast concrete roof element (Figs. 7C and 7D) is placed by crane and anchored structurally to the interior walls of the two box modules. By varying the distance between the two boxes, homes of different sizes can be built, with central roof modules of the proper size cast to fit. Interior partitions are nonloadbearing and can be configured to any desired floor plan. Partitions can be made of appropriate local materials.

Fig. 7E. The completed concrete home. This prototype erected for a builders show in 1993 has been contributed to Habitat for Humanity.

Exterior walls may be insulated and finished with dry wall if desired, or insulation may be placed on the outside of the walls, with protective finish over it. Plumbing and electrical services are brought up through the slab in the desired locations. Where insulation is added to the inside of exterior walls, electrical conduit will be run through it.

Alternatively, conduit can be set within the reinforcing bar cage before casting, and located to connect to conduit in the slab. The precast roof is fully functional and requires only a coloring/waterproofing sealant coating. However, conventional roofing materials may be attached to the concrete if desired. By adding patterned form liners to the outside forms, a textured wood, stone, or brick appearance can be achieved.

The firm has opened a precasting facility to produce single-family homes in Puerto Rico, but major emphasis will be on licensing the technology and providing forming equip-

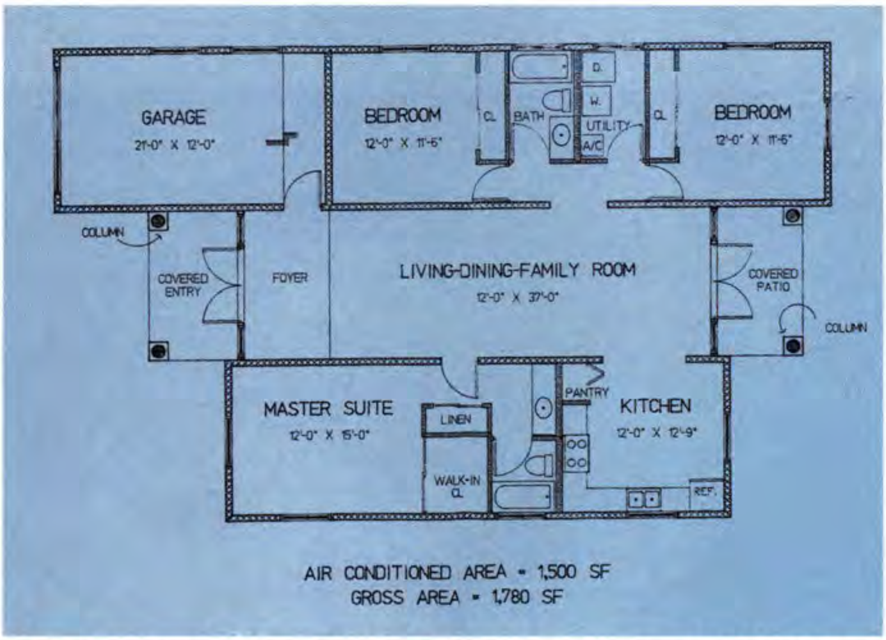


Fig. 7F. Floor plan for 1500 sq ft (140 $m^2$) home shows how two 13x40 ft (4x12 m) modules are aligned with an offset, and spaced 13 ft (4 m) apart. The gap between is spanned by the precast concrete roof. A block-off in the standard form enabled casting a half module for the garage addition.

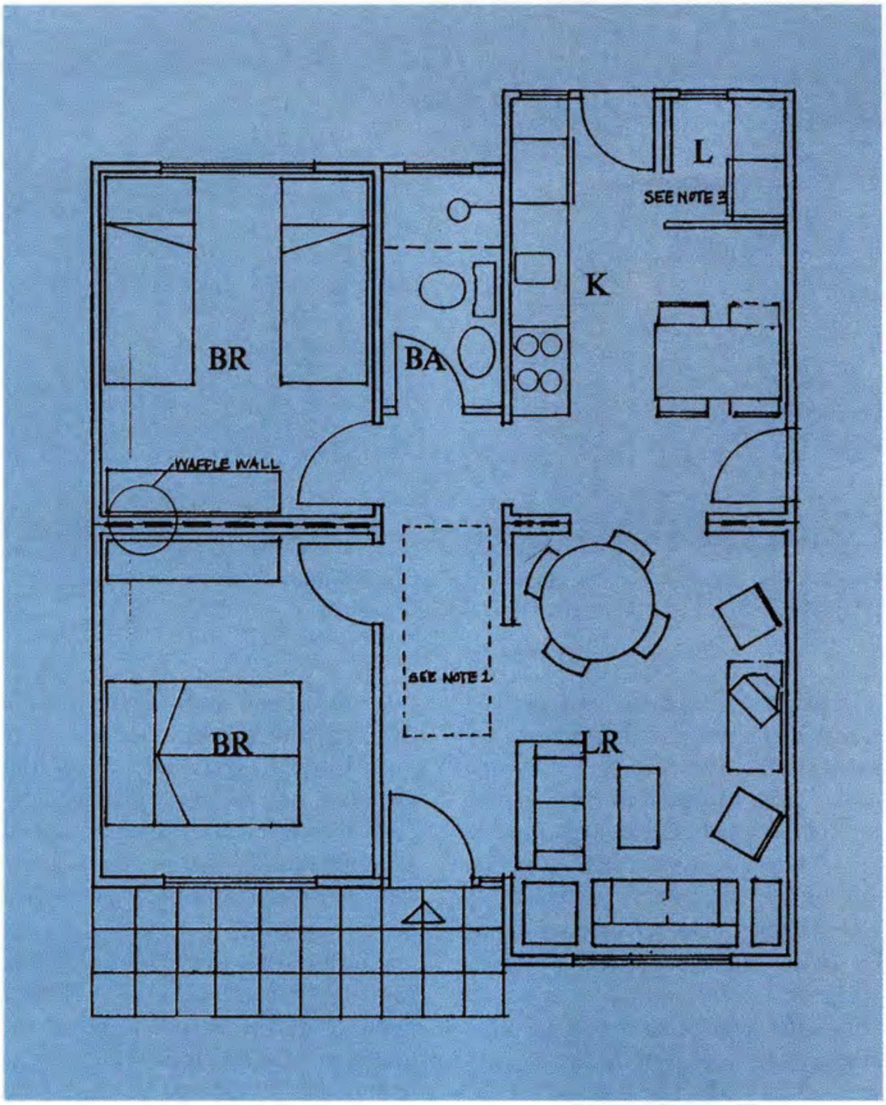


Fig. 8A. Floor plan of 512 sq ft (48 $m^2$) house made with two sizes of room modules. Door-size window in the kitchen permits future expansion.

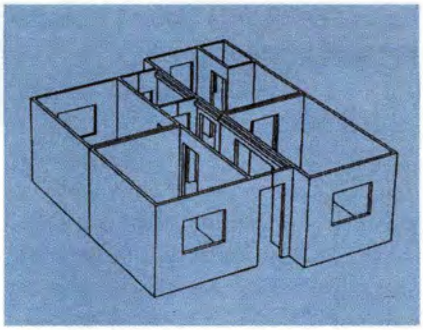

Fig. 8B. Cutaway view of assembled modules shows how extensions cast with the boxes permit enclosing a portion of the central corridor to create a bathroom.

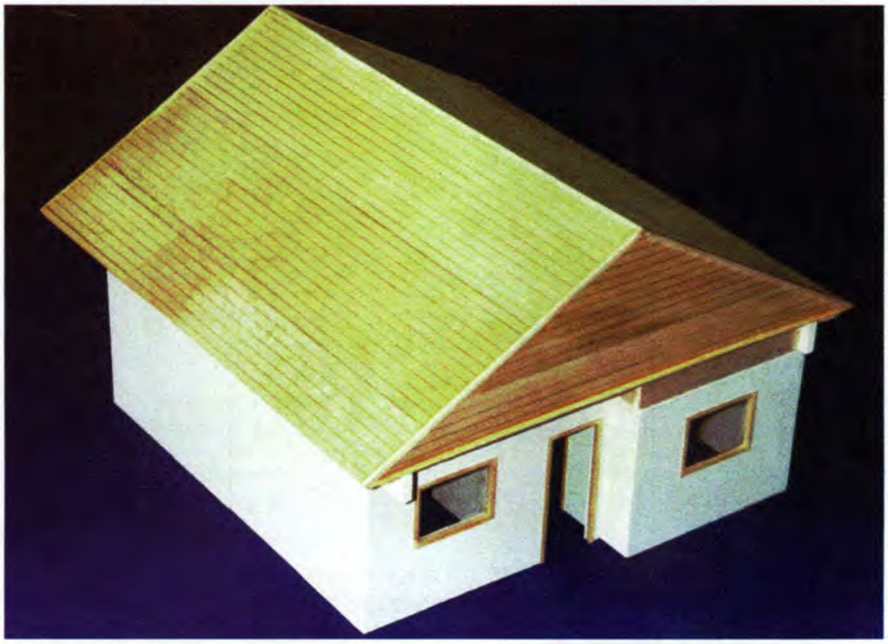

Fig. 8C. Model of the single-family dwelling with wood framed roof installed.

ment. The form manufacturer reports that the system can produce a finished 1500 sq ft (140 $m^2$) house (Figs. 7E and 7F) for about \$30 per sq ft (\$323/$m^2$). One module per day can be cast in the hydraulically controlled form with a crew of eight.

## Precaster Introduces Modular Homebuilding System

An established New England precaster has developed prototypes for its new system, and awaits patent approvals before entering the field of home construction in the United States. With an extensive background in production of prison housing units, the firm has also done residential housing work internationally.

The modular box system is based on three-dimensional coordinated components, sized to provide for ease of combination in varied designs. Modules range up to 300 sq ft (28 $m^2$) or larger. The system is flexible enough to provide a range of housing, from single-space emergency shelters to large and elegant single-family residences, multi-family housing and hotels. In low- and mid-rise construction, no additional structural support is needed to meet American code requirements for hurricanes or seismic loading.

This system uses its smallest modules in single-family housing. The four primary modules are:

- The basic five-sided box, 8 x 12 x 8 ½ ft (2.4 x 3.7 x 2.6 m), is light enough to be handled by a forklift or small crane, and small enough for transport over narrow winding roads. It can be stacked, or joined to an adjacent module at the open side to form a single large room.

- The tunnel module, a four-sided box, also 8 x 12 x 8½ ft (2.4 x 3.7 x 2.6 m), can be attached at its open ends to other units.
- A stair module, also 8 x 12 x 8½ ft (2.4 x 3.7 x 2.6 m), provides floor-to-floor access. It is constructed and delivered to the site complete for attachment to the other modules.
- Roof modules of varied configuration — sloped, arched, canted, etc. — create roof form and provide space for equipment. Conventional roofing may also be applied to the top slab of box modules, where a flat roof meets the design and cost criteria.

Fig. 8A shows the floor plan of a small home assembled from two of the basic box modules and two slightly larger room modules. The cutaway view (Fig. 8B) shows how extensions cast with the basic box modules provide for enclosure of a bathroom in the central hallway. Fig. 8C is a model of the completed structure where a wood framed roof was used instead of the concrete module described above.

The concrete modules will be available with or without insulated walls. They can be erected over basements or on a slab, and the units can be stacked to three stories. Utility services and foundations must be in place before the precaster delivers and erects the concrete shell. Local labor installs plumbing, electrical and mechanical appliances, and finishes. This is consistent with the housing authority desire to provide local jobs.

High volume projects are necessary for economy, but this system is readily adaptable to scattered site housing, where a housing authority has numerous vacant sites at different urban locations. The shell can be put up and enclosed in a day, leaving a secure building. This is important in inner city neighborhoods where theft and vandalism from traditional exposed construction at a project site is common. To enhance the economy of this system, it has been designed for compatibility with standard off-the-shelf products such as dry wall, windows, and ordinary roofing.

Fig. 9A. Sandwich panels trucked to the site are lifted by crane for assembly of a home.

Fig. 9B. Workers guide panel into position on precast foundation wall.

Fig. 9C. Second-story panel goes into place for larger home.

Fig. 9D. A completed 2800 sq ft (260 m$^2$) home, ready for landscaping.

able outdoor living in warm weather.

Since the sandwich panels are manufactured off site in temperature controlled casting beds, then transported to the site and lifted into place by crane, there is minimum disruption of site vegetation. From the time a house plan is selected, panels can be manufactured and erected within two to three weeks. The owner chooses a general contractor to finish the home.

Radiant hot water heating in the cast-in-place floor slab is a comfort feature that leads many buyers to opt for exposed concrete floors. As to energy efficiency, the builder reports an annual heating cost of $170 for a 4000 sq ft (372 m$^2$) home in the Salt Lake City area. Including design and engineering, prices quoted in 1993 for a completed home ranged upward from $62 per sq ft ($667/m$^2$), depending on the buyer's choice of finishes and amenities for the completed home.

### Homebuilder Successful With Sandwich Panels

An experienced designer/builder of conventional custom homes in Utah has found a new direction with precast concrete as the basis of environmentally sound homes. Throughout Utah and the Intermountain West, large panel assemblies are being combined to produce homes to either standard plans or custom designs (Figs. 9A, 9B and 9C).

The heart of the system is a 9 in. (230 mm) thick sandwich wall panel which includes a structurally reinforced 4 in. (100 mm) concrete layer, 3 in. (75 mm) of polystyrene insulation, and a 2 in. (50 mm) thick fiber-reinforced concrete outer layer with a stucco-like finish. The inner and outer concrete layers are structurally connected with a patented glass fiber composite connector to minimize heat loss. Corner panel intersections are detailed to provide continuous insulation, with no cross connections of concrete. The same panels are used for basement or foundation walls as well as above grade.

The homes are designed to withstand Zone 4 earthquakes (8.5 on the Richter scale) and have concrete floors and interior partitions of fire-resistant construction. The buyer can choose precast or cast-in-place concrete for a flat roof, or wood framing for a pitched roof. When concrete roofs are provided, the sandwich base is 5 in. (125 mm) of concrete topped by 4 in. (100 mm) of foam insulation, a waterproofing membrane, and an added layer of concrete as the wearing surface for a useable deck. These roof panels are engineered for massive snow loading as well as for comfort-

Fig. 10A. Prototype structure being erected with site-cast laminated panels. Precast panel used for sloping roof.

Fig. 10B. Prototype structure after application of exterior finishes.

The cost per square foot of concrete panel is equal to or slightly less than the cost per square foot of a completely finished 2 x 6 ft (0.61 x 1.83 m) wood framed wall.

The developer of this sandwich panel system first used it in individual homes he was building (Fig. 9D). As demand increased, he began supplying the panels to other builders. Now he is licensing the technology to others for precasting in different regions. The company will also provide services related to marketing and interfacing with homebuilders.

### Laminated Panel System Designed for Site Casting

An innovator who has worked for the past two decades with modular systems of insulated stay-in-place forms for concrete has patented a building system based on a laminated panel which can be cast at the site and then assembled to make both single-story and multistory buildings. Developed as an economically and environmentally sound alternative to wood construction, the panel is designed as a structural unit to include the architectural face, insulation, interior finish, and provisions for electrical and mechanical components. The panels, in several configurations engineered to meet local code requirements for wind and earthquake, serve as inside and outside walls, roof (Figs. 10A and 10B), and also floors in multistory buildings.

The system is sold as a complete package including a panel fabrication facility, complete with the casting mold, prepackaged concrete admixtures, and all necessary hardware. Complete structural details are provided as well as a panel erection procedures manual.

The panel consists of two concrete layers, connected across an interior of insulation by galvanized truss-shaped bridging. Fig. 10C shows a typical panel cross section; interior bearing walls have added concrete webs across the panel and exterior walls have stiffening ribs. The spacing and type of webs and ribs determine the strength of the completed structure.

The developer reports that panels in production have typical R-values of 20 for the walls and 30 for the roof. Panel

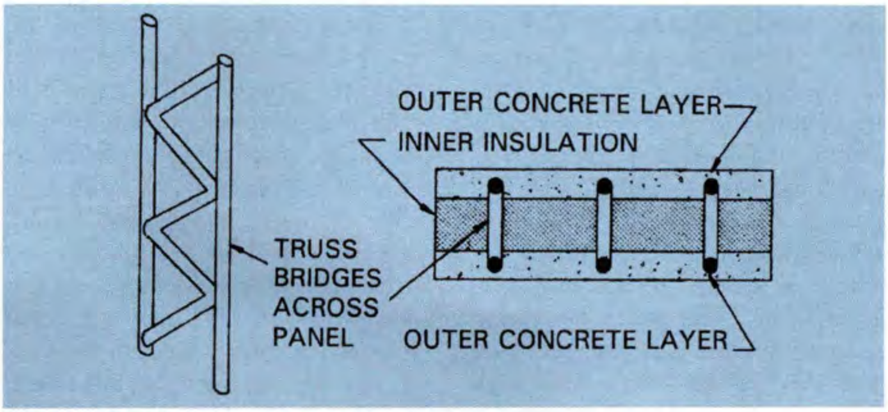


Fig. 10C. Cross section of laminated panel.

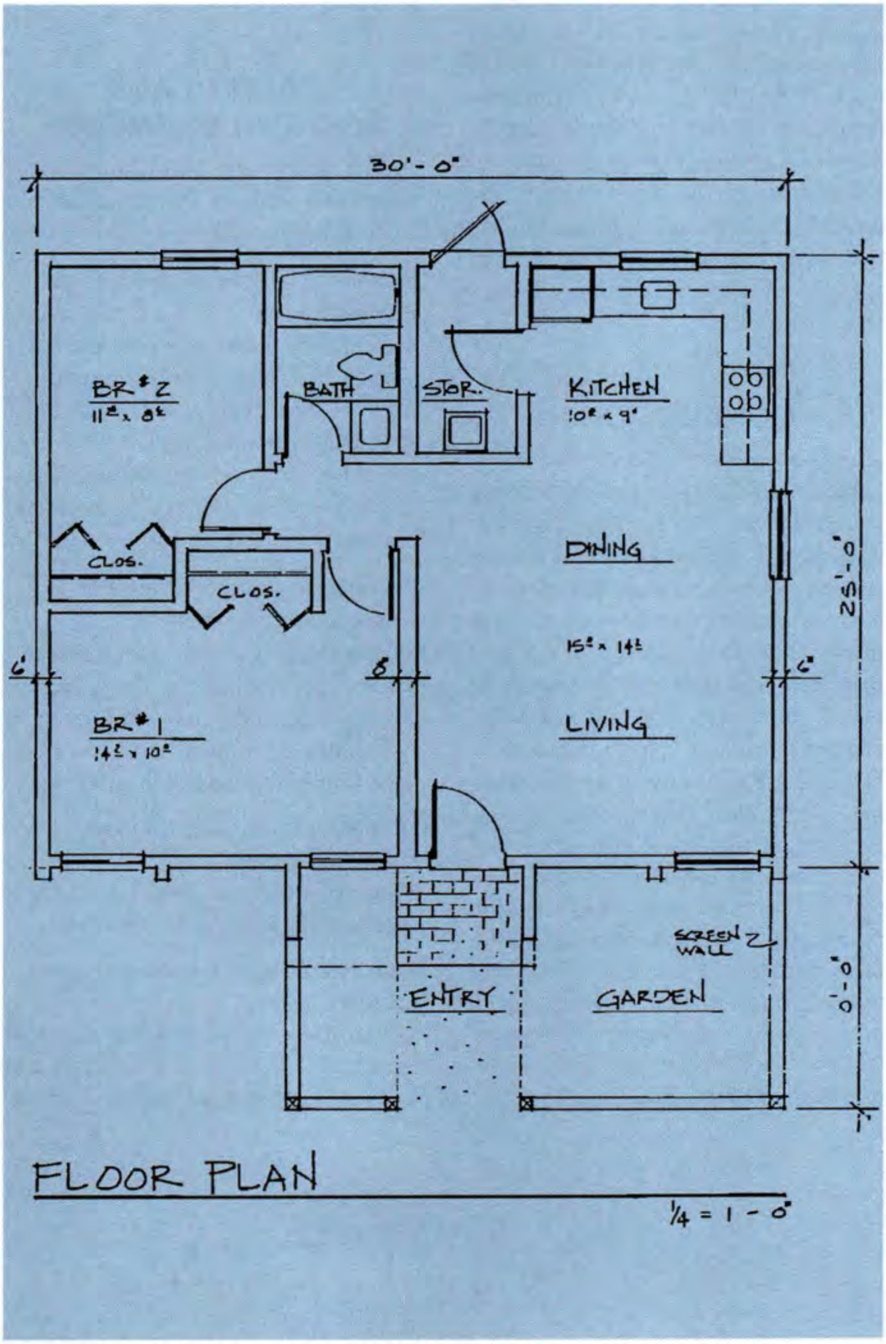


Fig. 10D. Floor plan of small residence designed with a single panel comprising each of the four basic exterior walls.

sizes ranging up to 8 x 25 ft (2.4 x 7.6 m) are stack-cast at a rate of one per hour or faster. Roller imprinting tools are used to provide a desired surface texture, and integrally colored concrete can be used where desired. For example, walls may be given a brick or stone pattern, and roofs may be imprinted with a three-dimensional Spanish tile or split shake pattern. One project under construction in Jamaica uses three stack molding setups to turn out panels for one 750 sq ft (70 $m^2$) house per day (Fig. 10D). For large projects or for placing homes on scattered sites, a temporary central casting area may be used.

The system makes large use of local materials and labor. Unskilled workers may be trained to produce the panels on site, or production may be done in an existing plant. Because of efficiencies of the panel system, the developer estimates a home can be built in Michigan for 20 to 25 percent less than a comparably equipped wood frame residence.

## CONCLUSIONS

Although concrete has only slowly gained acceptance as a homebuilding material in the United States, there is new promise today born of increasing concern for preservation of timber resources, for both environmental and financial reasons. In recent decades there has been growing acceptance of manufactured (factory built) housing, primarily because it has offered comfort and affordability in an era when the middle class citizen could not afford the average house. Yet recent natural disasters have raised serious questions about strength, stability and durability of the conventional manufactured home. Precast concrete provides a solution that addresses both problems — conservation of resources and provision of strength and durability at an affordable price.

The precast concrete systems described here, and others like them, represent a new beginning that will offer increasing options to the home buyer. They are open systems that can be used at isolated sites as well as in large developments, and they permit numerous local options for finishing with local labor. Both site and plant precasting will have their place, and prestressing will contribute to the variety of components that can be offered. Buyers will benefit additionally from the varied forms and textures available in one of construction's most durable materials — concrete.


## CREDITS AND ACKNOWLEDGMENTS

The developers and designers for the precast concrete systems described are as follows:

**Form Specialists Patent Modular Precast System**
System Developer: International Form Corporation, Jacksonville, Florida.
Architectural Design: Gambach Sklar Architects, Miami, Florida.
Structural Engineering: Spronken and Company, Inc., Calgary, Alberta, Canada.

**Precaster Introduces Modular Homebuilding System**
System Developers: The Rotondo Companies, Precast Concrete Products, Rehoboth, Massachusetts, and Monacelli Associates, Inc., Architects and Planners, Cambridge, Massachusetts.

**Homebuilder Successful With Sandwich Panels**
System Developer: Rod Irwin, Concept Homes, Salt Lake City, Utah.

**Laminated Panel System Designed for Site Casting**
System Developers: Thermal Laminar Incorporated, Livonia, Michigan and Laminar International, Miami, Florida.

**Photographs and Illustrations**
Photography and illustrations have been provided by the following:
Fig. 1, Richard W. Steiger
Fig. 3C, 3D, Robert F. Armbruster
Fig. 4, Edward K. Rice
Figs. 7A – 7F, International Form Corporation
Figs. 8A – 8C, The Rotondo Companies and Monacelli Associates, Inc.
Figs. 9A – 9D, Concept Homes Figs. 10A – 10D, Thermal Laminar, Inc.

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**NOTE:** Limitations of time and space have precluded total coverage of all precast concrete systems for homebuilding in the United States. The author and editors will welcome comments and information regarding other systems currently available.