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Shelly-Modular Housing System

Luis E. Mora

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by

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System design is a response to new technology of problem solving. Basically it comprises new ways of solving complex problems by dividing them into simpler systems, more in number, but simpler. With the advent of the computer systematic solution of complex problems has led us to thinking in terms of systems and sub-systems, equivalent to the mathematical solution of problems by organizing them into sets and sub-sets. Prefabrication has been the construction industries' way of systematic solution of their problems.

Prefabrication has been the basis of today's housing systems, as such it can be considered a child of the industrial revolution. Mainly developed in highly industrialized countries in Europe and the U.S.A., prefabrication, is and will be the key to the solution of most housing problems. It is by all agreed that this child has not come of age yet, its growth has been hampered by many events; mainly lack of attention.

In 1920-1945 period there was considerable attention focused in Prefabrication Industry because of the great need for housing that came after the Second World War. After 1960 another big boost was given to this industry, this time because of the high cost of housing. All efforts were focused in the use of new materials: mainly, aluminum and plastics.

There has been a new sociological development which has been the mobile home. This has opened our eyes to the space component idea, which is the basis of most housing systems on the news.

Prefabrication can be divided into two basic methods, these are:

A. The structural component: considered as the erector's set arrangement which may consist of wall blocks or wall panels. Considering variable thickness of members, this system has no limitation as to height. A box that is formed with Structural Components loses the advantage of rigidity at the corners.

B. The space component: which refers to boxes or units (often called modules), normally the height is limited to the capacity of the walls, if they are to be of standard dimensions. Because of their self-rigidity, one of their main disadvantages is their sensitivity to differential movements.

Most of new systems are a combination of A & B (structural components filled by space components).

The most classical and widely known example of a housing system using concrete boxes is the one designed by Architect Moshe Sofdie for Expo 67 at Montreal, Canada. Habitat 67, as the system was called, proved that the principle of repetition does not necessarily lead to the solution of the ideal housing system. This very primative concept, as an architect might consider it lacks totality.

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We, as children used to play with wooden blocks. We could build very high structures without collapsing the lower blocks. Those elements at the base will be carrying very small loads as compared to their structural capacity. Obviously this is considering the structure to be stable. But a box is not a strong as a wooden block. Their utilization is limited by their strength.

Each box wall will have to be different at each different level. The maximum utilization as to capacity of the wall is obtained when at any point in the wall, the maximum allowable strength is reached.

The principal mistake of the Habitat project was that the architect approached the problem completely neglecting most of the structural problems. It seems that, at that point, for that project, the structural issue was not considered very important.

Any housing system must be developed through the coordinated efforts of the architect, the structural designer and the construction engineer. They must all be integrated in the method of construction.

I have been through the experience of contributing in the developing of a housing system and the results have been the following: most manufacturing techniques, used in systems, have to operate on a give and take basis. The structural designer and the architect must yield to the manufacturing techniques without jeopardizing the safety or the esthetics of the structure.

The greatest contribution of Habitat was that the enthusiasm generated by the system produced similar ideas in other people's minds, most of which were very good and some very productive. One of them was the Shelly System.

Although the Shelly System does not offer technological ideas that are particularly exciting, it displays what is possible to do under existing technology*. It has achieved an optimized architectural, structural and construction integration.

The Shelly System is a unique method for building reinforced concrete structures utilizing precast box-like modules stacked in a checkerboard pattern. This system differs from other box construction methods in, that a usable space is created without the cost of double walls and double floors.

The boxes consist of a ribbed roof slab and side walls that are cast with a special steel mold and a floor slab producing an integral unit. The interior partition walls carry the weight of the floor slab to the roof beams as hangers. The roof beams convey the applied loads to the exterior columns of the box.

The monolithically cast box provides a very rigid structure able to resist bending moments and torsional moments

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which can be a very valuable asset against earthquake and hurricane wind forces. Handling and erection stresses are adequately resisted by the two rigid frames at the open ends of the box.

Load-bearing columns are an integral part of the box-like modules and when the boxes are stacked in the characteristic checkerboard pattern these columns match vertically thus carrying all gravity loads to the foundations without any appreciable eccentricity.

When wind stresses are of a considerable nature, as in high buildings, post-tensioning tendons are placed in vertical ducts running through the center of the end columns and are anchored to the foundation. The tensioning operation of the post-tensioning tendons is performed at the top of the boxes at the required level. Afterwards, the ducts are pressure-grouted to protect the tensioning rod. This post tensioning, provided mainly to resist lateral forces, also transforms the cluster of individual boxes into an integral structural unit.

In small buildings where wind stresses are not of prime consideration, steel dowels will protrude from the lower box and will be grouted into the upper box. Similar dowels may be used in the central columns for higher structures. Such dowels can be designed to transmit gravity loads as well as to take shearing forces.

Elastomeric bearing pads are placed at the contact surfaces of the columns between adjacent box-like modules to cushion the high bearing stresses generated at these points. These elastomeric bearing pads tend to decrease edge pressure due to manufacturing tolerances and contribute to the structures' high energy absorbing capacity.

The elastomeric bearing pads located between the box-like modules combined with the post-tensioning system render the structure insensitive to small differential settlement. The dead load of the Shelly System is very much lower than conventionally built structures because of its thin wall section. The decrease in dead load is approximately 25% where regular weight concrete is used and approximately 40% with the use of light-weight concrete. This advantage allows the system to be feasible where marginal soil conditions exist.

The thin concrete section at the box walls results in reduced dead load and consequently small seismic loads.

Being originated in an island where earthquakes and hurricanes are of common occurrence the Shelly System has been designed to resist the highest lateral loads. The almost total elimination of welded, bolted, or any other conventional connection and a minimum amount of "in-place-grouting" make the Shelly System structure less expensive to build. In addition the System provides complete fire and corrosion resistance, with minimum maintenance costs.

The combined effects of short span modules and their staggered position as well as their flexible joints localize movements due to temperature changes and differential settlement, thus reducing cracking and permitting the erection of long buildings without construction joints.

Due to their inherent stability, the box-like modules do not require temporary bracing, guys or shoring during the production, transportation and erectional operations. Only in case of a sudden hurricane precautions should be taken and this will consist of providing temporary stressing of the post-tensioning rods as required.

The precast concrete boxes can be produced in a portable or fixed plant. The boxes are cast in specially designed, mechanically operated steel molds which were built to very strict specifications with respect to tolerances on production of the monolithic box.

Once poured in place proper vibration of the concrete is achieved by external high frequency vibrators attached to the steel molds. A rail traveling portal crane is used for the fabrication and handling of the precast boxes which weigh approximately 36 tons.

Concrete strength, used in the boxes, varies between 3,000 and 5,000 psi at 28 days depending on structural requirements. Regular weight aggregate concrete or cellular concrete, may be used for the structure. Heat curing of the concrete allows for early removal from the forms and provides the necessary strength for early transportation to the finishing area normally located in the adjacent grounds to the casting yard. Here finishing work is completed including painting, installation of doors and windows, fixtures and electrical and mechanical installations. Connections are provided for the final electrical and mechanical integration of the structure which is done through the pipe chase. Quality control of workmanship and materials is simple because of this industrialized production system.

The Shelly System provides great architectural diversity and flexibility. Buildings may vary from one to over twenty stories even in the same building as would be the case in a pyramid-like structure. The facades may also be greatly varied by using longer modules which could cantiliver out from the buildings, or by stacking the boxes at an angle with the axis of the building or by alternating boxes of different widths, thus creating very pleasing irregular patterns.

All this can be achieved with the basic standard modules without extensive or costly alterations.

The facilities for horizontal and vertical transportation, garbage disposal system and other public facilities can be combined with the basic Shelly System box. For horizontal transportation, cantiliver corridors are provided along the building. Elevator shafts which are completely prefabricated including guard rails, are set up adjoining and connecting with the corridors. The elevator machinery rooms may be completely prefabricated and equipped at the ground floor and then hoisted into place. Such erection of elevator facilities will eliminate the costly delays usually experienced of elevator facilities in high-rise construction. The garbage disposal system may also be incorporated as a part of the prefabricated elevator shaft. Stairways are also prefabricated and connect directly to the cantilevered corridors.

Another important housing type for which the Shelly System may be used is the temporary and mobile home needed especially for relocated persons. In this case factory finished concrete modules may be transported by trailers to the site. They will provide an inexpensive fire-proof, hurricane proof, vandal-resistant temporary home in a very short period of construction time. These units can be moved and restacked at another site for another use or may be made into permanent dormitories or homes for the elderly.

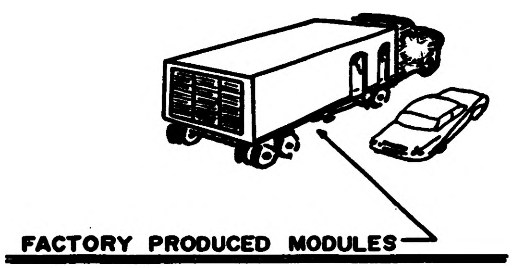

FIGURE 1

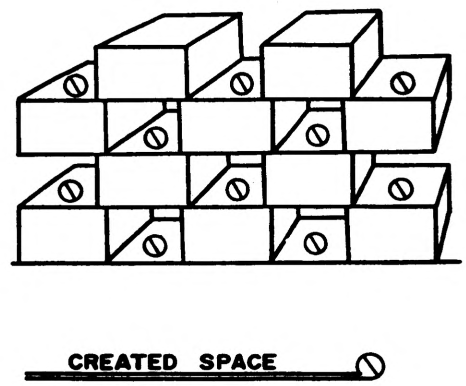

FIGURE 2

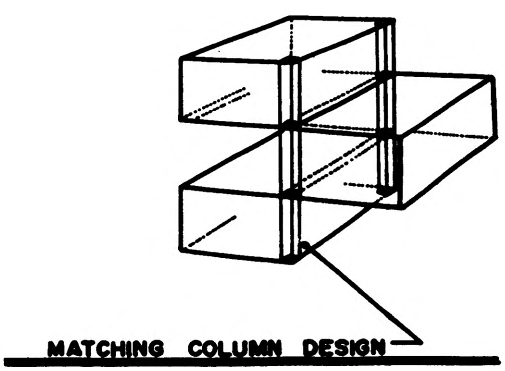

FIGURE 3

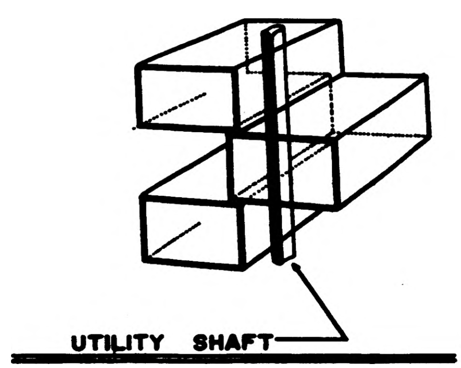

FIGURE 4