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Concrete Sandwich Panels For Low Cost Housing Construction

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CONCRETE SANDWICH PANELS FOR LOW COST HOUSING CONSTRUCTION

By

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Among the most critical social and economic problems facing our society today is the almost overwhelming need for adequate urban housing and satisfactory low cost housing for disadvantaged groups. On examining this problem, we often see the fruits of our current technology overlooked in favor of time honored and traditional concepts. In many cases, we see aesthetic and human factors and long term maintainability sacrificed for low initial cost and expeditious construction. If our solutions are not to become problems themselves, it would appear that new concepts and systems must be exploited to a much greater extent than we now see.

One building system which may provide a very attractive alternative to traditional concepts is the concrete sandwich panel. The utilization of such panels in the United States is currently relatively uncommon and is usually seen in conjunction with curtain wall construction methods. In Europe, concrete sandwich panels enjoy wider acceptance and are frequently seen serving as structural elements. It is in the application of panels as load bearing elements that they become feasible for application in low cost housing construction.

In the development of a modular housing system SeaStone Corporation selected panels consisting of one inch inner and outer reinforced concrete shells with a 3-1/4 inch foamed polystyrene central core. Depending on the rigidity requirements for a particular panel, reinforcement is accomplished by three to seven layers of 3.4 diamond lathe steel mesh in each shell. In addition, four inch reinforced concrete shear connectors are included two to three feet on center to insure panel action. The concrete mix consists of Portland cement and fine silica sand with no additional aggregate.

The panels are manufactured in molds which consist of adjustable steel dams 5-1/4 inches high clamped to a steel flat. The flat may be textured to provide the desired surface on what will become the outside of the panel. Various architectural effects such as brick or stucco may be imparted. The production process begins with the pouring of a one inch (or greater for a particular surface treatment) layer of concrete into the mold. This is followed by the necessary layers of reinforcing mesh and finally by core inserts and shear connectors which are pressed into the wet concrete layer. The upper layer of reinforcing mesh is laid in place followed by a second charge of concrete about one inch deep. Throughout the process, mechanical shakers are utilized to insure complete filling of all voids in the panel.

After the second charge of concrete, the top surface, which will be the inside surface, is smoothed and textured to a sand finish or other desired surface.

Each mold is fitted with wooden frames which are cast in the panels for doors or windows that may be necessary. In wall panels, electrical conduit and junction boxes are held in position by the mold and are cast in place.

Completed panels are used for load bearing walls, floor and roof systems in modular housing units. Connections between panels are made using integral pins and structural adhesive grouting.

The panels described offer several distinct advantages which should be considered for the current housing crisis. First of all, in the manufacturing operation outlined above, extensive use of unskilled or semi-skilled labor can be made providing an extra incentive for self help projects and providing an economic as well as physical boost to underdeveloped or disadvantaged areas. In more highly industrial areas, the operations may be extensively automated leading to mass production and the attendant economic advantages. The panel production process leads to an almost finished product with the assembly installation of doors, windows, plumbing and wiring remaining.

Because of the heterogeneous nature of the concrete panels and the utilization of thick foam inserts, they offer excellent sound absorption, vibration isolation and thermal insulation. Each of these characteristics is of great importance in the design and construction of housing units that are satisfactory from the standpoint of human needs. When concrete sandwich panels are applied for inside and outside walls, roof and floor systems, significant improvement in the quality of life should result.

The long term stability of concrete offers the advantage of excellent maintainability. Housing units constructed from concrete sandwich panels are essentially fireproof and are unaffected by decay, corrosion or termites. Because of their relative light weight (approximately 20 pounds per square foot) panels or assembled modular housing units can be easily picked up and transported.

Perhaps the most significant advantage of concrete sandwich panel construction is the flexibility of design which it offers. Molds and surfaces can be modified quickly and inexpensively to provide an almost endless variety of architectural effects. It is particularly important that this flexibility be available to designers if massive housing programs are not to leave us with a legacy of sterile ghettos to deteriorate the lives of a future generation.

The authors' present systems are limited to single and two story applications primarily for small housing and commercial units. Current analysis, however, indicates that multi-story units may be feasible using sandwich panels as the primary structural systems.

Detailed cost analysis have been made to determine the economic feasibility of using concrete sandwich panels in the mass production of modular housing units. Current estimates indicate that with a minimum capital investment of $350,000, panels could be produced in the Southeast for approximately $.75 per square foot at a production rate of 10,500 square feet per eight hours shift. This production would be sufficient to manufacture 2,300 housing units per year.

Because of the familiarity of the building community with reinforced concrete and the straight forward analysis and design concepts employed for panels, little difficulty has been encountered or is expected in winning wide acceptance of panels and in satisfying local building codes or other regulations.

In summary, it would appear that concrete sandwich panels offer excellent characteristics which should make them attractive for application

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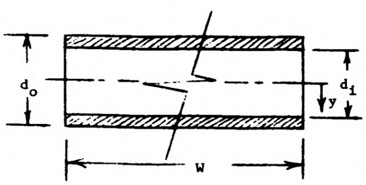
in low cost housing construction. They combine low cost with structural utility, environmental and aesthetic advantages which are an absolute necessity in the solution to the housing crisis.

APPENDIX

For purposes of structural design, the most significant characteristic of concrete sandwich panels is flexural rigidity. The failure criteria applied has been the appearance of the first crack of the concrete shell in tension due to flexure. The cracking stress for the mixtures used has been approximately 300 psi which correlates well with experiments performed by Pfeifer and Hanson (1).

It has been found that an elementary composite beam model predicts the cracking load quite well for design of symmetric panels. Consider a panel of depth d_o as shown below:



The flexure formula indicates the stress at a distance y from the center line. The moment at a section is given by

$$M = \sigma y dA = \int_{\substack{\text{Area of}\\ \text{Concrete}}} \frac{E_c y\, dA}{\rho} + \int_{\substack{\text{Area of}\\ \text{Reinforcement}}} \frac{E_s y\, dA}{\rho} \qquad (I)$$

Where: $\sigma = \frac{Ey}{\rho}$

ρ is the curvature at a given section

E_c and E_s are elastic moduli of concrete and steel

We will define the panel rigidity as $(EI)_{section}$ such that

$$M = \frac{(EI)_{section}}{\rho} \qquad (II)$$

Thus, after integration of I, we find that

$$(EI)_{section} = \frac{W\left[E_c(d_o^3 - d_i^3) + 2Na_s d^2(E_s - E_c)\right]}{12}$$

Where: N is number of layers of reinforcement mesh per shell

d is average depth from center of panel to mesh

a_s is area of steel per unit width for one layer of mesh

W is the panel width

Failure of floor or roof panels in flexure would be predicted when

$$M = \frac{\sigma_{(cracking)}\, 2(EI)_{section}}{E_c d_o}$$

Panels are designed to withstand the ACI(2) load test of structures (.3 dead load plus 1.7 design live load applied) with a minimum safety factor of two.

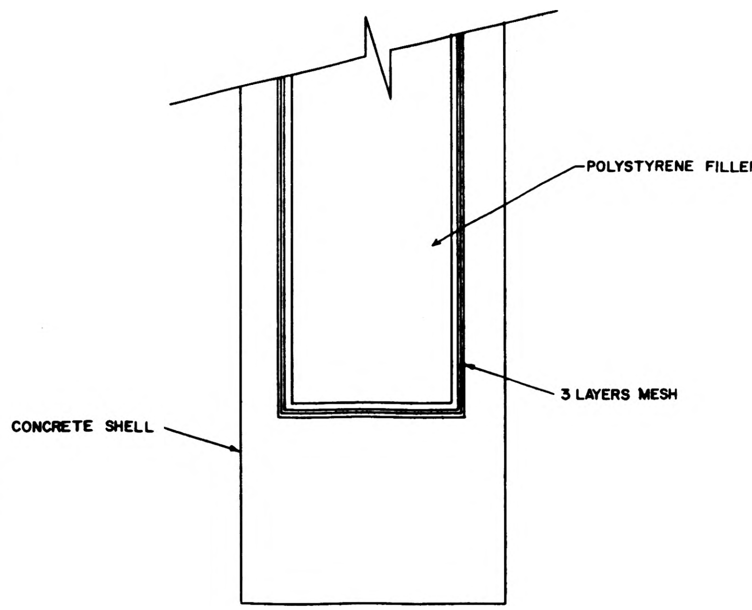
With regard to load bearing walls, panel stability is the critical factor and consequently panel rigidity is again significant. Current designs are based on assumptions of simple supports on top and bottom edges of walls with free verticle edges.

A typical rectangular roof panel reinforced with three layers of mesh in each shell and spanning a 14 foot by 12 foot area will carry approximately 120 pounds per square foot. This meets the ACI load bearing test requirement if the design live load is 20 pounds per square foot with the specified factor of safety. Typical 8 foot wall panels will withstand approximately 1,000 pounds per foot of thrust which is well within structural requirements.

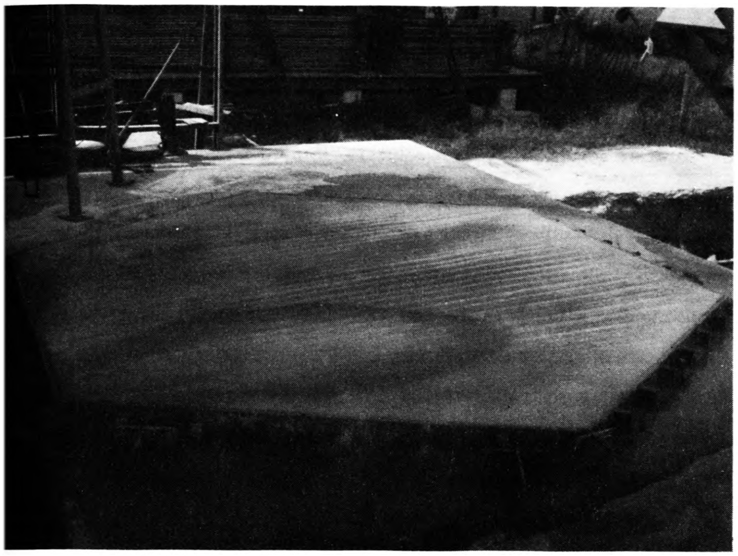
REFERENCES

1. Pfeifer, D. Ward, J. A. Hanson: "Pre Cast Concrete Wall Panels: Flexural Stiffness of Sandwich Panels" PCA Research Report, Bulletin D99 (1965)

2. "Load Test of Structures": ACI Standard - Building Code

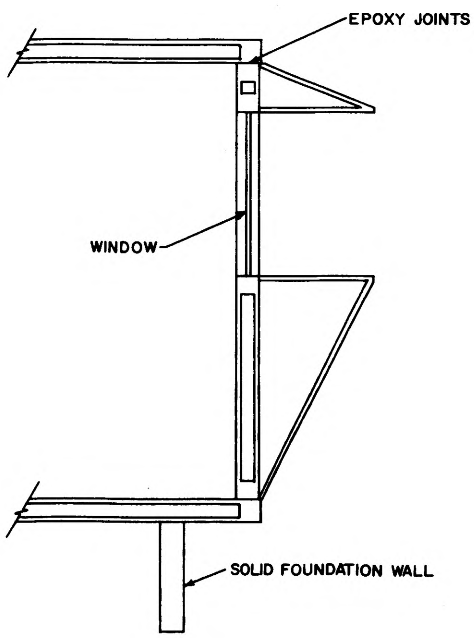


TYPICAL WALL PANEL DETAIL
scale—½"=1"

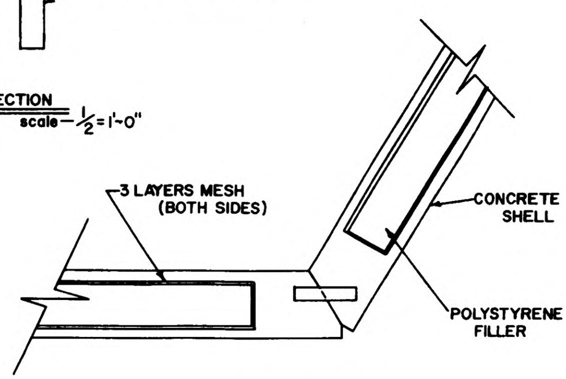


HEXAGONAL FOURTEEN FOOT DIAMETER ROOF PANEL BEING CURED IN PLACE AFTER MOLDING

TYPICAL SURFACE TREATMENT AS CAST ON OUTER SURFACE OF A WALL PANEL



TYPICAL WALL SECTION
scale— 1/2 = 1'-0"



EXTERIOR CORNER DETAIL
scale— 1/8" = 1"