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E. L. Hansen

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By

E. L. Hansen* and J. O. Curtis**

Precast concrete wall panels have many desirable qualities for use in housing such as durability, strength, waterproofness, vermin proofness, fire safety, appearance, low maintenance, and reasonable cost. Also, local materials and labor can be used.

Since 1964, the Department of Agricultureal Engineering at the University of Illinois, Urbana, has been developing a system that uses precast panels 4 feet wide and 5½ inches thick. These extend from footing to roof thus eliminating the conventional foundation. Up to 2 inches of a foam plastic insulation can be placed in the center of the panel.

Continuous wall insulation is achieved by extending the foam core to the edges of the panels and by anchoring the panels so that no columns are used. Figure 1 shows how this is done. The lower end of the panel is fixed in the notched footing and at least 12 inches above this point the panel is anchored to the concrete floor. This holds the panel erect without columns. The joint between panels is completed by inserting a piece of foam plastic in the center and placing mortar or caulking inside and out. This completes the section of wall-foundation, perimeter and wall insulation, and inside and outside surfaces.

Our goal was to work out equipment and procedures to provide interior and exterior surfaces in the casting operation which are acceptable for housing without added finishing operations on the job other than painting. We have succeeded in this. Also, we have developed handling equipment to make the operations of casting, handling and erection simple and economical.

DESIGN OF WALL PANELS

Design Loads and Analysis

Concrete wall panels, like other structural members, must be designed to resist the loads to which they may be subjected. Such loads include the wind, snow, and dead loads that are applied vertically or parallel to the panel face by roof frames; the wind load that acts perpendicularly to the panel; and erection loads.

The design loads that were used were those recommended in ASAE R 288.2 (1). A study of the different loads and combinations of loads that might reasonably be expected to act on the panels indicated that vertical loads from wind and snow as applied by the roof frames could safely be ignored in designing the panels. Thus the panels were designed to resist erection loads using the tilt-up method, and lateral loads caused by wind. Wind loads were based on a maximum wind speed of 85 mph at 30 feet aboveground.

The detailed procedures used to determine the critical design moments resulting from both wind and erection loads are straightforward and are therefore not presented here. The assumption was made that the insulated panels would be used in a closed building 32 feet wide with fairly large areas that could be opened. Thus, internal wind pressures were assumed, and two walls were considered to be effective in resisting the lateral wind loads. This assumption resulted in loads on the panels due to wind as shown in Figure 2.

Table 1 shows the moments used in the design. Critical moments in the panels due to tilt-up erection loads were of course at mid-height and those due to lateral loading were at floor level.

TABLE 1. DESIGN MOMENTS (FT-LB PER FT OF PANEL WIDTH)

Loading	Panel length (floor to eave) 8 ft	10 ft	12 ft
Wind	435	658	924
Erection	443	661	923

TABLE 2. VERTICAL STEEL REQUIRED IN A SANDWICH FOOTING-TO-ROOF PANEL (4 FT WIDE)

Wall height feet (floor to eave)	Number and size of deformed steel reinforcing bars in each face
8	6 - No. 3
10	8 - No. 3
12	11 - No. 3

Structural Design of Panels

The panels were designed in accordance with ACI Standards--ACI 318-63 (2) and ACI 525-63 (3)--in so far as they were applicable. Ultimate-strength design procedures were used. Values used for compressive strength of concrete and yield strength of reinforcement were, respective, $f_c = 4000$ psi and $f_y = 40{,}000$ psi. Only the reinforced concrete portions of the panels were assumed to be effective in resisting the applied loads. In other words, no credit was given for any composite action between the concrete and polystyrene portions of the panel. This assumption of course was conservative. Figure 1 shows the details of a sandwich footing-to-roof panel. Table 2 shows the vertical reinforcing steel required in the center of each face of the panels. Horizontal reinforcing steel should be No. 3 bars and should be spaced about 24 inches apart. These are placed on the inside of the vertical steel. Anchors are required at floor level and in the top of the panel.

BUILDING LAYOUT AND CONSTRUCTION DETAILS

One panel width plus a mortar joint equals 4 ft. therefore, one dimension of a rectangular building can be laid out in 4 ft. modules. The other dimension is 7½ inches more than the required 4 ft. modules because of the corner detail. (Fig. 3)

The edges of the panels have a slight taper for easier removal from the molds. This makes the outside width of the panel 3'-11 3/4" and the inside width 3'-11 1/2" resulting in mortar joints of 1/4" outside and 1/2" inside. (Fig. 3)

All panels are the same width. The only special panels are right and left corners. (Fig. 3) For these the foam insulation is cut 1 3/4 in. short of the edge and a 2" x 6" filler is placed in the mold to form a notch. Panels are made shorter to provide the proper rough openings for windows.

*Professor of Agricultural Engineering, University of Illinois, Urbana-Champaign
**Professor of Agricultural Engineering, University of Illinois, Urbana-Champaign

Window frames may be anchored to wooden wedges driven into the foam insulation on either side (Fig. 4). If only a fixed sash is needed this can be installed in the opening without a frame. Notches are cut into the foam; the glass is inserted and a knife grade putty or sealant is applied along the edges. (Fig. 5)

Footings

The bottom ends of wall panels must be fixed in the footing. A footing could be cast with a notch, but this is not too practical. Sections of footings may be precast as shown in Figure 6. An alternate method is shown in Figure 7. This is a very practical method. Small pads of concrete are placed level to support the panels then more concrete is placed in the trench to a height of one inch above the bottom of the panel. The trench should be dug a few inches deeper than ncessary and a layer of sand put in before setting forms or precast footings.

One or Two-Story Construction

Suggestions for one and two story construction are shown in figures 8, 9 and 10. Only the lengths of panels are changed.

Joints Between Panels

Figure 3 shows the joint between panels. It is ¼ inch wide outside and ½ inch wide inside. A wedge of plastic foam is placed in the joint. This insulates and acts as a stop when placing mortar.

A very satisfactory joint can be made with a cement-sand tuckpointing mortar which is placed with a caulking gun. These specially prepared mortars work in guns, they expand when they set and are strong and waterproof. There are many other sealants to choose from too. However first cost favors the mortar.

CASTING PANELS

Concrete Molds

One-piece concrete molds are used to cast panels flat. These molds are low-cost and hold their shape on any surface. Figure 11 shows a method of making a core first then casting a mold over the core. The core could be a wall panel.

The sides of the mold slope 1/8 inch in 5 1/2 inches so that the wall panels can be removed easily.

Liners for Molds

It is difficult to make a mold without imperfections. This makes it difficult to remove the wall panel. This can be overcome by using a thin liner in the mold. Another advantage of this is to give a variety of textures to the inside wall surface. For instance a silicone coated paper will expand and form wrinkles. Embossed steel sheets are now available in many patterns and in sizes needed. Hardboard form liners and textured plywood or boards can be used. A steel liner either smooth or embossed is very practical.

Steps in Fabricating a Panel

After the mold is set up, and a form coating applied, the bar which holds the two anchors at floor level is placed in the mold. (Fig. 12) Two short plugs are used instead of the anchors while the first layer of concrete is placed. After the first layer of concrete is screeded off (Fig. 13) these plugs are replaced with the anchors. Figure 14 shows anchors in the top of the panel. These are bolted to the end form during casting. The end form is made of 2" lumber bolted to the end of the mold.

A 1 3/4 inch layer of concrete is then placed in the mold. This must be vibrated enough to remove all air pockets on the surface. The steel reinforcement is then laid on the concrete and vibrated so that the vertical bar is in the center. The horizontal bars are next to the foam insulation which is now placed on top. This is notched for the anchors. The top layer of concrete is now placed and the steel vibrated to proper depth. Figure 15 shows an angle iron frame designed to place the steel accurately.

Finishing the Top Surface (exterior wall surface)

A variety of finishes can be used. However, one practical method is to use a vibrating screed followed immediately with a metal float, then a broom finish immediately. This is contrary to recommendations for finishing flat slabs, but it eliminates going back later for finishing and it gives more uniform surfaces with a minimum of labor and supervision. The texture is pleasing and the surface paints well.

Concrete Mix

The panel design is based on a 4000 psi concrete. Because the thickness of the concrete face is only 1 3/4 inches with No. 3 bars for reinformcement, it is necessary to limit the maximum size of aggregate to about 3/8 inch. A well graded aggregate from fine to 3/8 inch will help provide a surface next to the form liner without air pockets. With poorly graded aggregate a richer mix may be necessary.

HANDLING EQUIPMENT

Wall panels weigh about 200 pounds per foot of length. Equipment must have a capacity for lifting at least 2000 pounds for 10 ft. long panels and 4000 pounds for two-story panels, plus the weight of the vacuum lifter.

A vacuum lifter is ideal for removing panels from molds, stacking, loading and erecting. With a vacuum lifter panels can be handled horizontally and casting can be done under roof. With a two cable crane and two pickup points on the vacuum lifter the panel can be lifted into a vertical position for setting.

A transporter of some kind is needed to carry the lifter. Figure 16 shows a converted farm tractor. Fork lifts or other commercial carriers could be used. A fork lift would be useful for loading trucks too.

At the building site a two cable crane is ideal to unload panels in a flat position and to set them vertically.

ERECTION HARDWARE

When the panel is set on the footing a brace is needed to hold the panel safely in a vertical position while the vacuum lifter is removed. Figure 17 shows a stake made from two angle irons and a turnbuckle which hooks into the stake and fastens to a 2" x 4" brace which in turn is attached to a piece of strap iron bolted to the top of the panel. Final adjustment is easy to obtain.

References

1. Designing buildings to resist snow and wind loads. ASAE Recommendation: ASAE R 288.2. American Society of Agricultural Engineers. December 1969.

2. Building code requirements for reinforced concrete (ACI 381-63). American Concrete Institute, 1963.

3. Minimum requirements for thin-section precast concrete construction (ACI 525-63). American Concrete Institute, 1963.

4. Self-anchored, continuously insulated concrete wall panels. J. O. Curtis, E. L. Hansen. Transactions of ASAE (Vol. 9, No. 4) 1966.

5. Footing-to-roof, self anchored, continuously insulated concrete wall panels. J. O. Curtis, E. L. Hansen, Agricultural Engineering research report, Department of Agricultural Engineering, University of Illinois, Urbana, 1966.

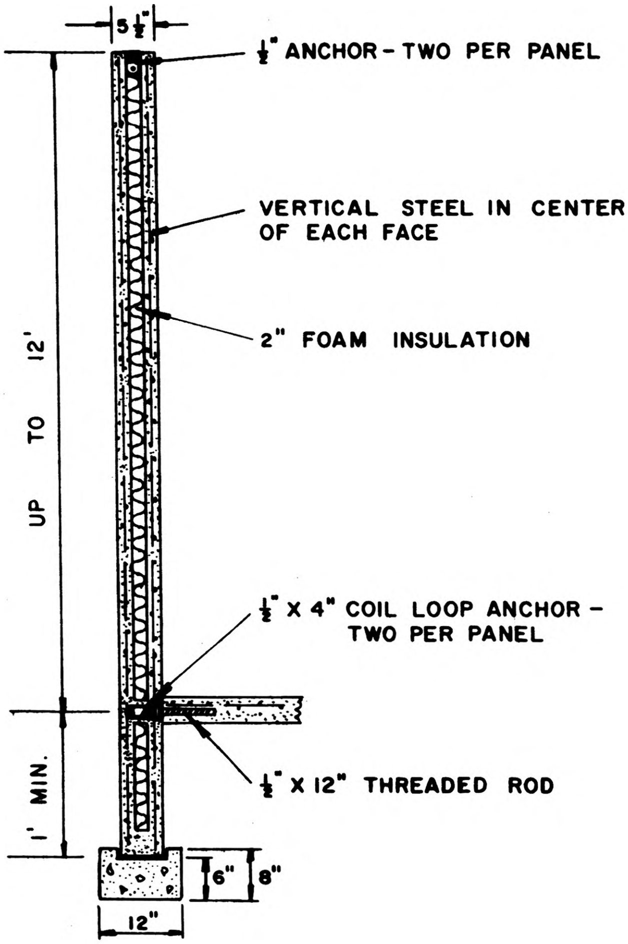


Figure 1. Details of sandwich footing-to-roof panel.

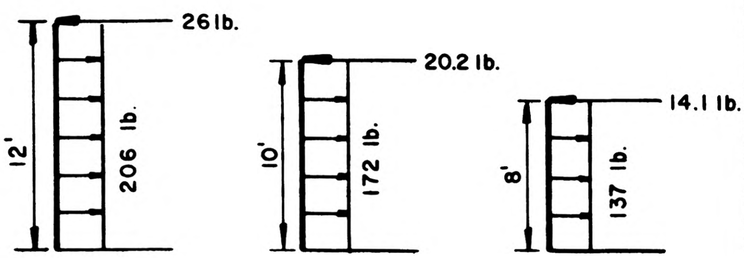


Figure 2. Lateral loads on panels due to wind. (pounds per foot of wall length)

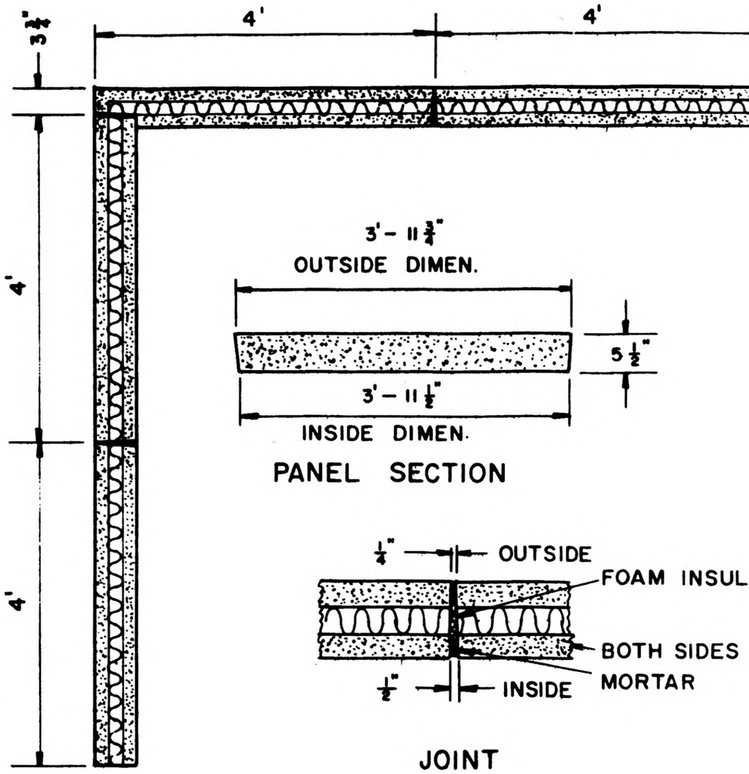


Figure 3. Layout details.

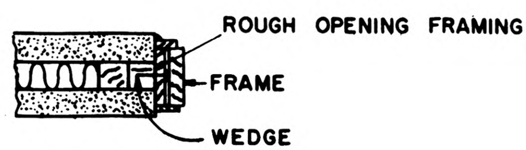


Figure 4. Door or window detail.

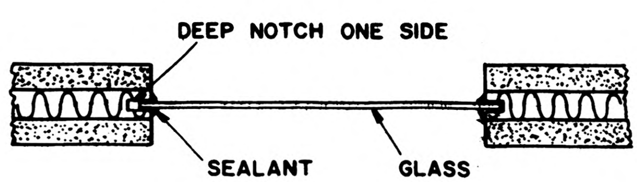


Figure 5. Fixed glass detail.

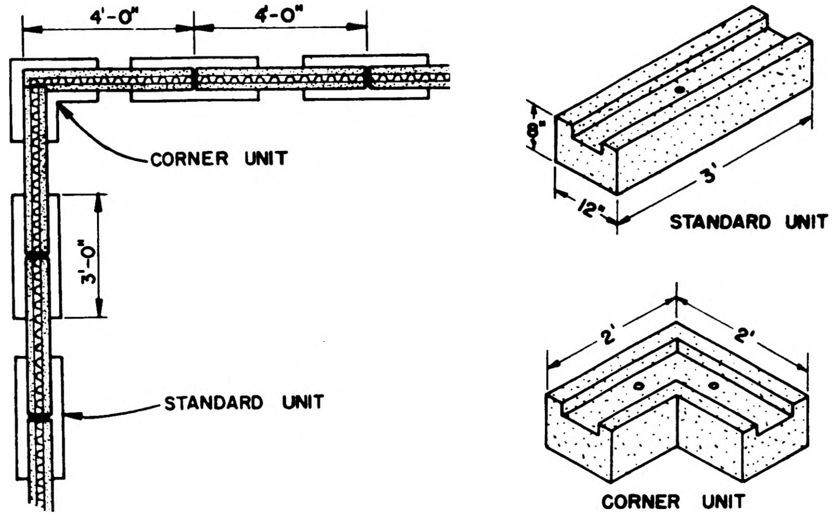
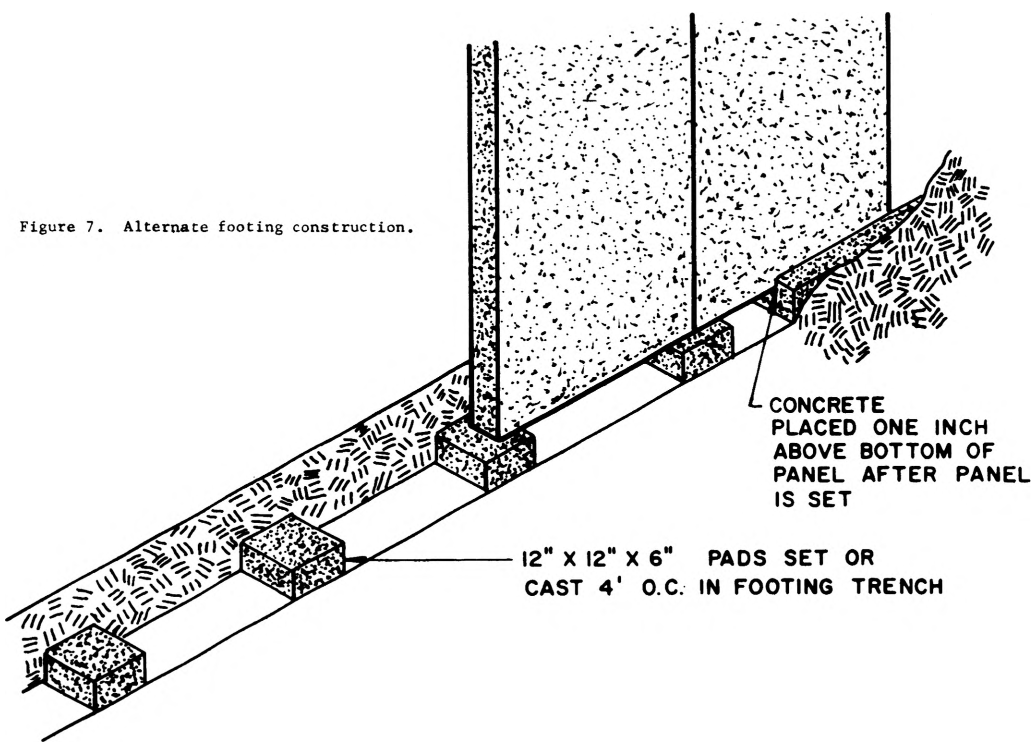


Figure 6. Details for precast concrete footings.

Figure 7. Alternate footing construction.



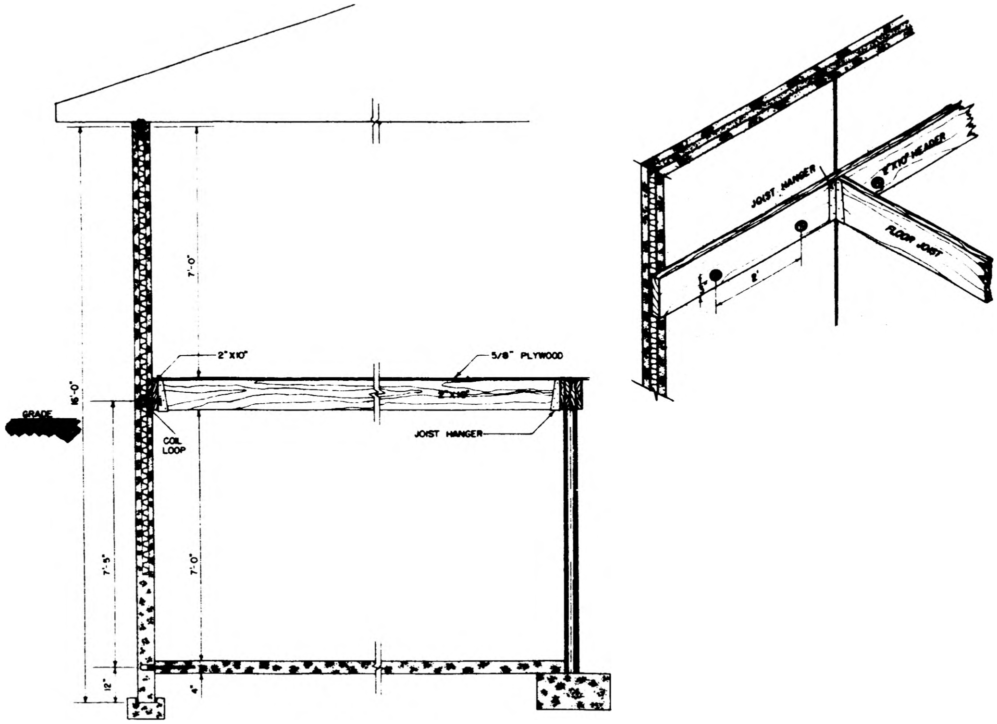


Figure 8. Details for two story or basement and first floor.

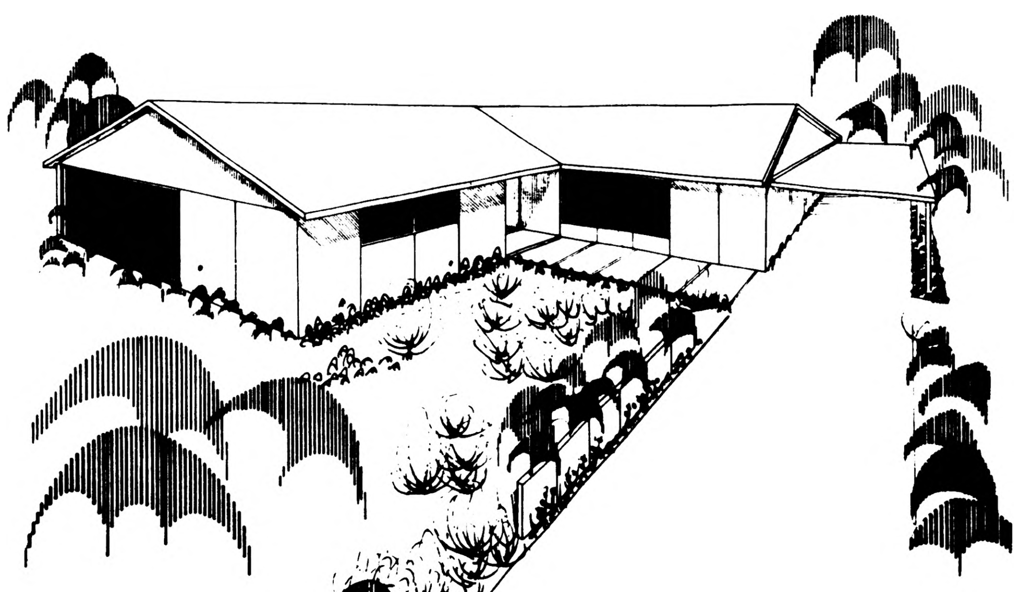


Figure 9. A conventional home built of concrete panels, showing window walls and privacy windows. Only the length of panels is changed.

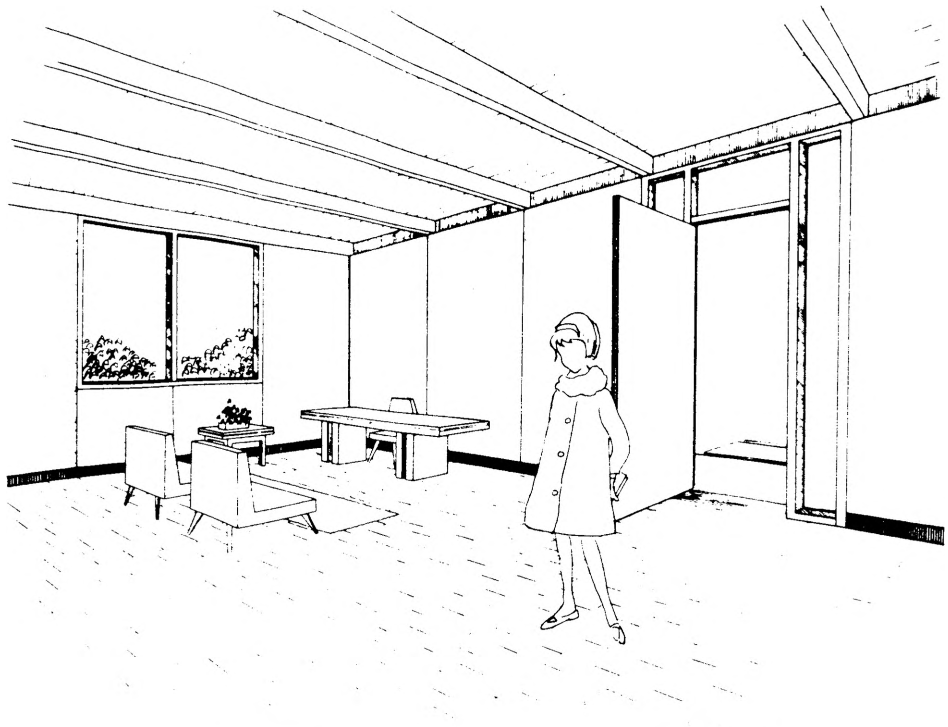
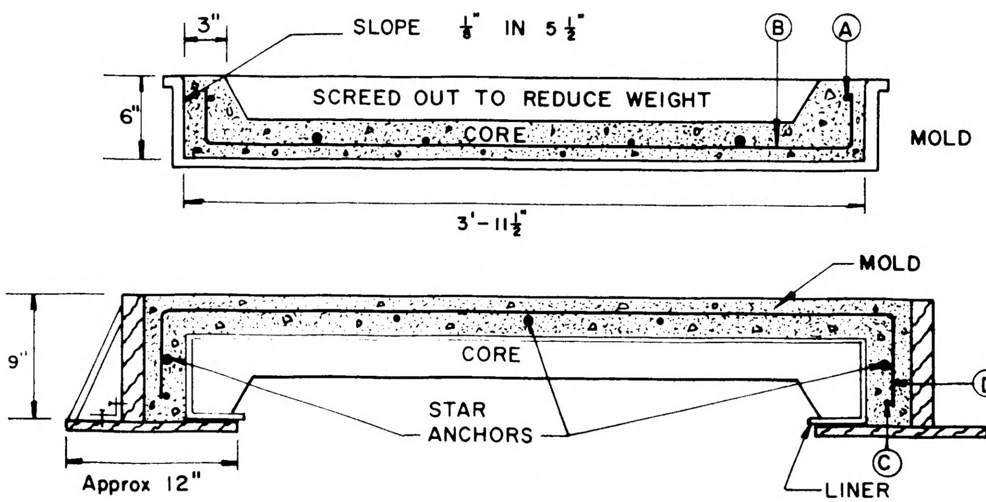


Figure 10. Interior surfaces may have a variety of textures depending upon the mold liner used.



STEEL SCHEDULE				
MK	SIZE	SHAPE AND DIMENSION	NO.	TOTAL FT.
A	NO.3	9'-8"	6	60
B	NO.3	3 1/2 3'-9" 3 1/2	11	60
C	NO.3	9'-8"	6	60
D	NO.3	6" 4'-4" 6"	11	80

Figure 11. A method of making a concrete core and casting a mold over it.

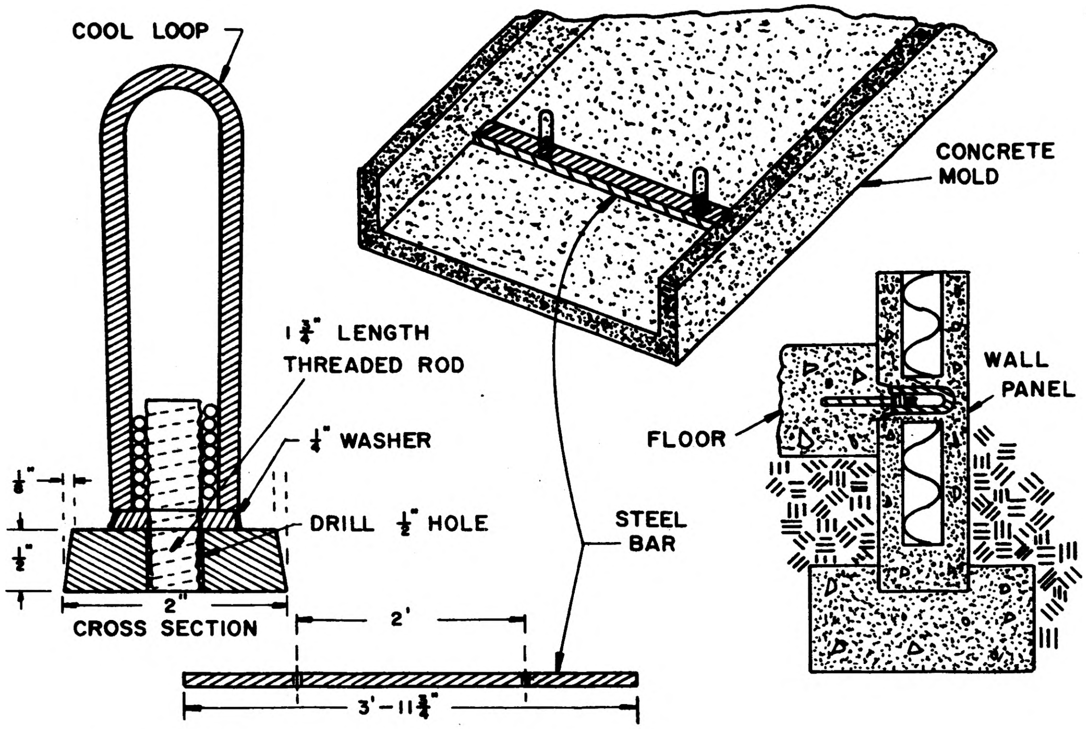


Figure 12. Casting details for locating anchors at floor level.

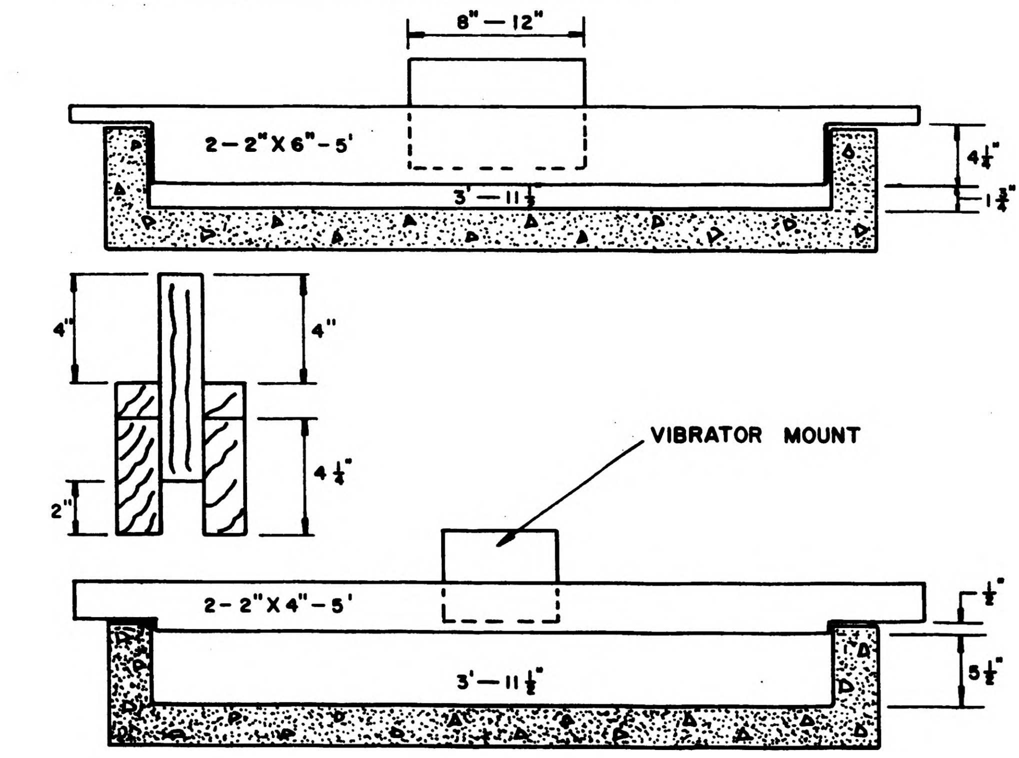


Figure 13. Wooden screeds for bottom and top courses.

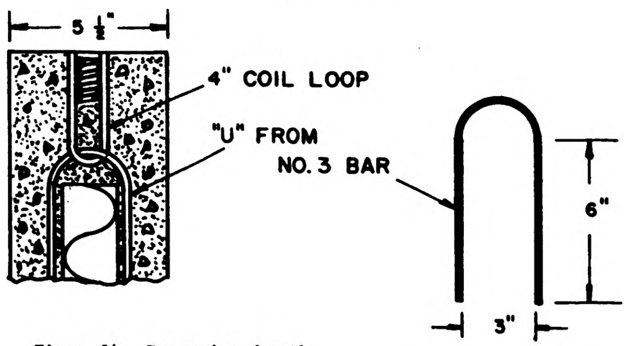


Figure 14. Top anchor detail.

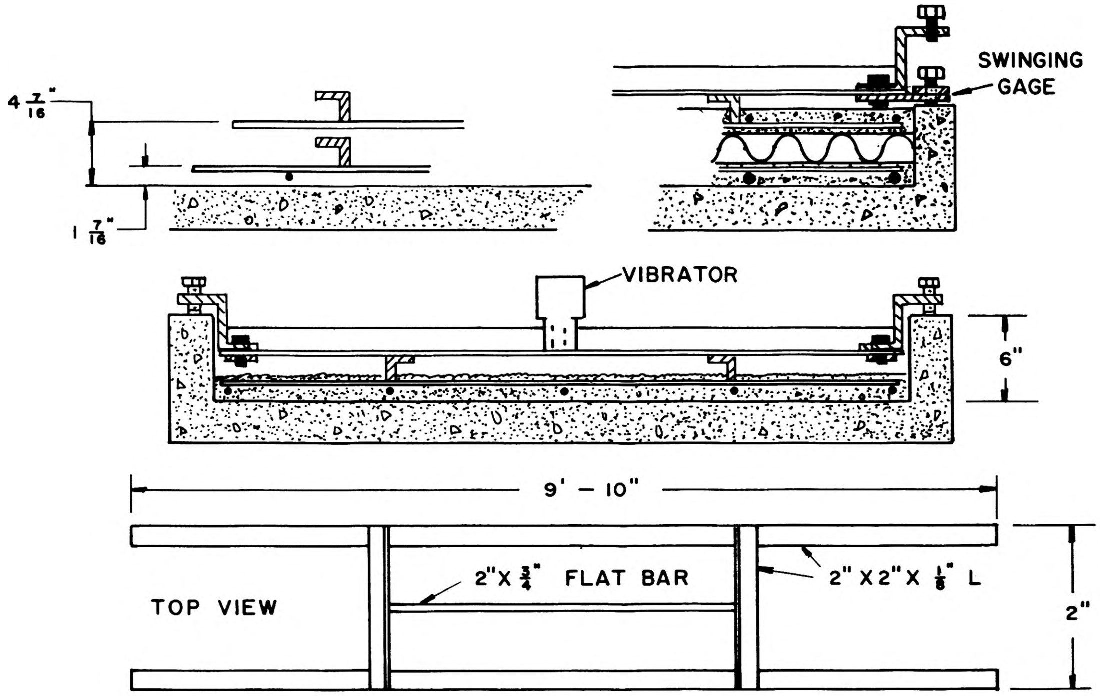


Figure 15. Angle iron frame for placing steel in both sides of panel.

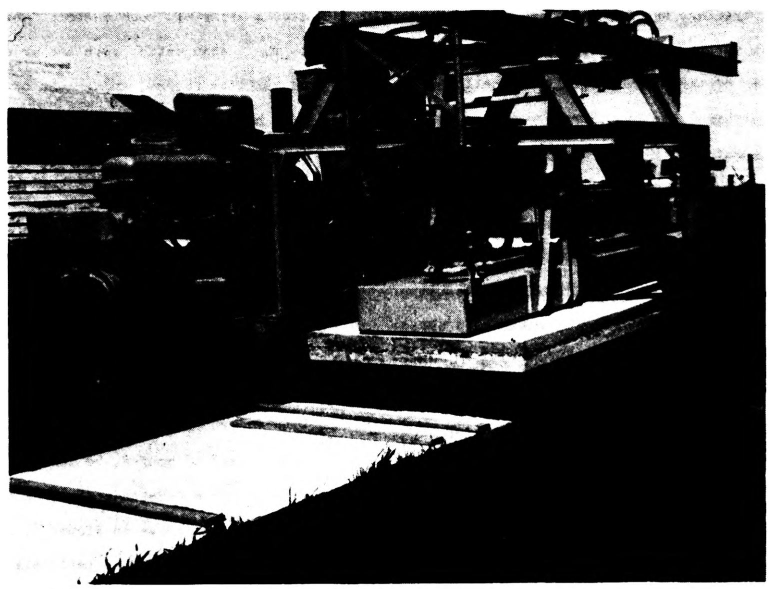


Figure 16. A converted farm tractor to carry vacuum lifter and panels.

Figure 17. A stake and a turnbuckle which is attached to a 2 x 4 brace for holding panels erect.