

A HOUSE-FRAMING SYSTEM FOR LOW-COST CONSTRUCTION

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This publication has been prepared especially to provide advice to prospective home builders in Appalachia, a region that includes all of West Virginia and parts of Alabama, Georgia, Kentucky, Maryland, New York, North Carolina, Ohio, Pennsylvania, South Carolina, Tennessee, and Virginia. The information in this publication, however, is valid for the entire United States.

A HOUSE - FRAMING SYSTEM FOR LOW - COST CONSTRUCTION

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INTRODUCTION

Housing is needed by many people with low incomes in all parts of the country. Low-income persons usually cannot afford to pay for the labor to build their houses and they have difficulty in doing the building themselves because many of the construction methods and standard practices are too complicated. Simplification of the construction methods therefore seems to be a logical way to reduce the cost of a house.

There are three major ways that a builder can reduce the cost (cash outlay) for a structure:

1. Design for minimum amount of materials.
2. Select materials for maximum economy.
3. Reduce amount of hired labor needed.

The low-cost frame described in this report demonstrates the use of all of these concepts. Framing and foundation materials have been reduced one-third by an efficient system of posts, beams, and girts. Since the floor system is independent of the wall system, the frame and roof can be built before sewers and drains are installed. Curtain walls do not need to be as strong as structural walls, and they allow a wide selection of materials to be used both inside and outside.

Simple design and new and easy building techniques reduce the level of skill needed for construction and thus allow the builder to do some or all of the work himself. If a builder can reduce his labor cost by half, he can reduce his total cost by one-fourth, and if he can build the entire structure with his own labor, the house cost should be reduced by about half.

The simplified post-and-girt construction was developed to allow the do-it-yourself builder to provide himself with good housing at low cost. The prototype house provides:

1. Multiple use of the minimum living space.
2. Full use of economical materials.
3. Simplicity of construction to minimize hired labor.

A house was built in the fall of 1964 by the method described in this report (fig. 1). Space in the house can be arranged in many ways; the floor plan of the prototype is shown in figure 2.

The idea of using poles for both the foundation and the primary frame of a structure is not new. Some of the first structures built were of this type. The pole construction techniques have been neglected mainly because of the short life of wood set in damp soil. If the early settlers could have preserved wood products, as is possible now with a variety of chemicals, pole construction probably would have evolved as the primary building method for houses in this country.

Today, pressure-treated timber has an expected life as great as that of concrete. Sound timbers in installations throughout the world have been reported after 40 to 60 years of use.

In an effort to determine the exact cost of this structure and to eliminate estimates, an itemized record was kept for all purchases. This report will show the dollar value of materials used and it will indicate where savings could be made. It will also show where items need be added to complete the structure.

FRAME AND FOUNDATION

The house frame herein described was developed to meet the need for a low-cost, long-lasting structure. It has been tested in the laboratory and in prototype structures to determine its strength, its structural utility, and its cost advantage. This frame can be built with about two-thirds the material needed using conven-

tional methods. Fabrication techniques are simple and easy to follow. Calculations and tests have shown the frame to possess adequate strength to resist snow and wind.

The techniques described are of a general nature and they can be applied to a variety of house sizes and shapes. The spacing of posts and girts

can be varied to meet the demands of the house design. The spacing described in the following examples was selected to give maximum use of standard sizes of materials with a minimum of cutting.

Perimeter Walls

The prototype structure is 24 feet 8 inches by 33 feet 8 inches inside. It has a post-and-girt frame which consists of vertical supports linked together with horizontal girts. The vertical supports (square-sawed posts) rest on concrete pads which are in the soil at the bottom of postholes dug below the frost line.

The first step in building a post-and-girt frame is to prepare the foundation by digging a hole at the designated location for each post (14 re-

quired for prototype) and pouring a concrete pad at the bottom of each hole (fig 3).

The depth of the hole will depend on the depth of the frost line at the building location, and the diameter of the hole will depend on the bearing strength of the underlying soil and the weight supported by the footing. If the design calls for a roof load of 25 pounds per square foot and a post spacing of 8 feet 4 inches on center, each post must support approximately 2,800 pounds. If the allowable soil pressure is 4,000 pounds per square foot, then a concrete footing of 0.7 square foot will support the load. A 6-inch thick footing is recommended.

The posts are 4- by 6-inch square-sawed timbers 12 feet long. They were pressure treated with creosote to a density of 6 pounds per cubic foot. The post size depends on the wind load and the snow load which it must support. Calculations

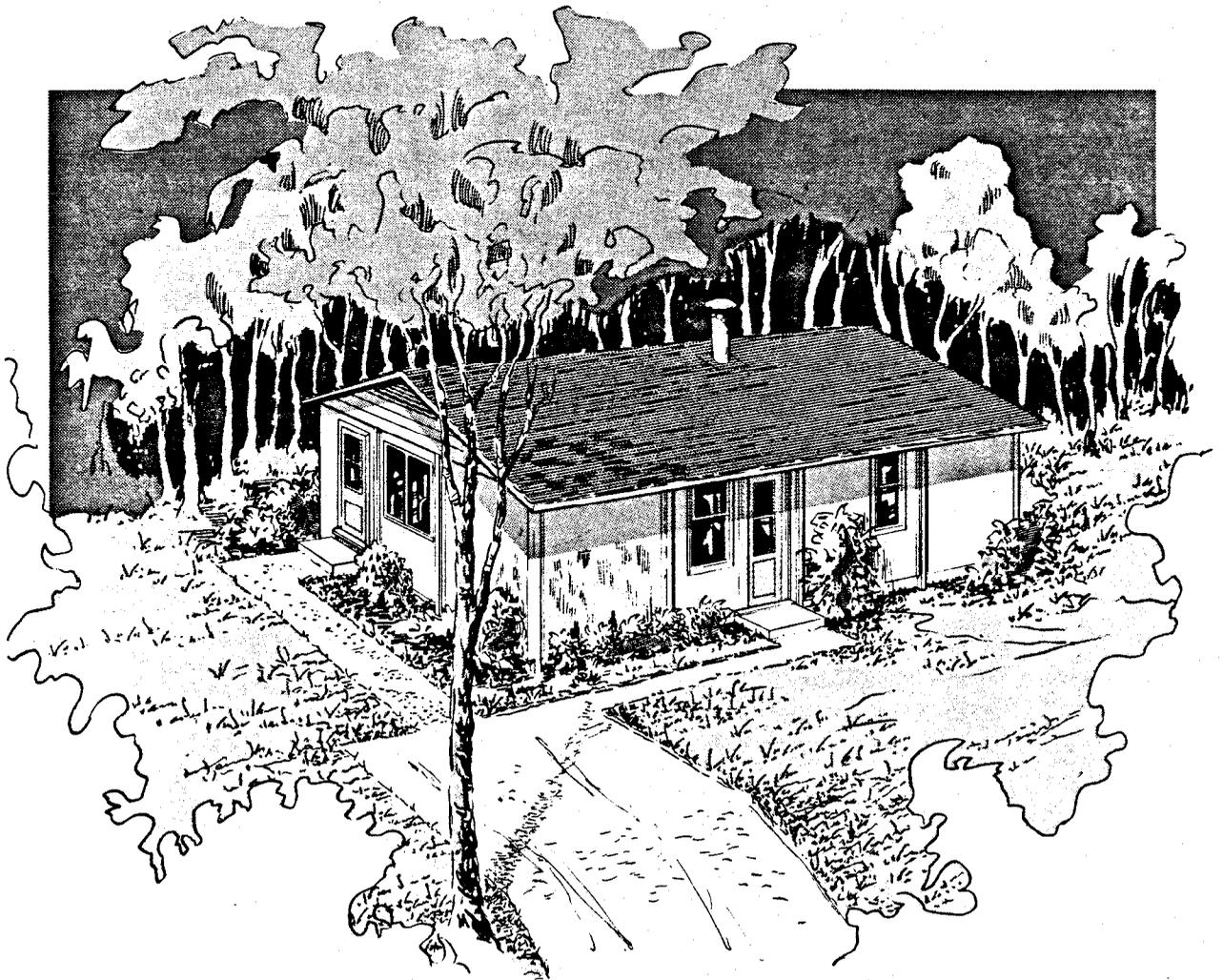


FIGURE 1.

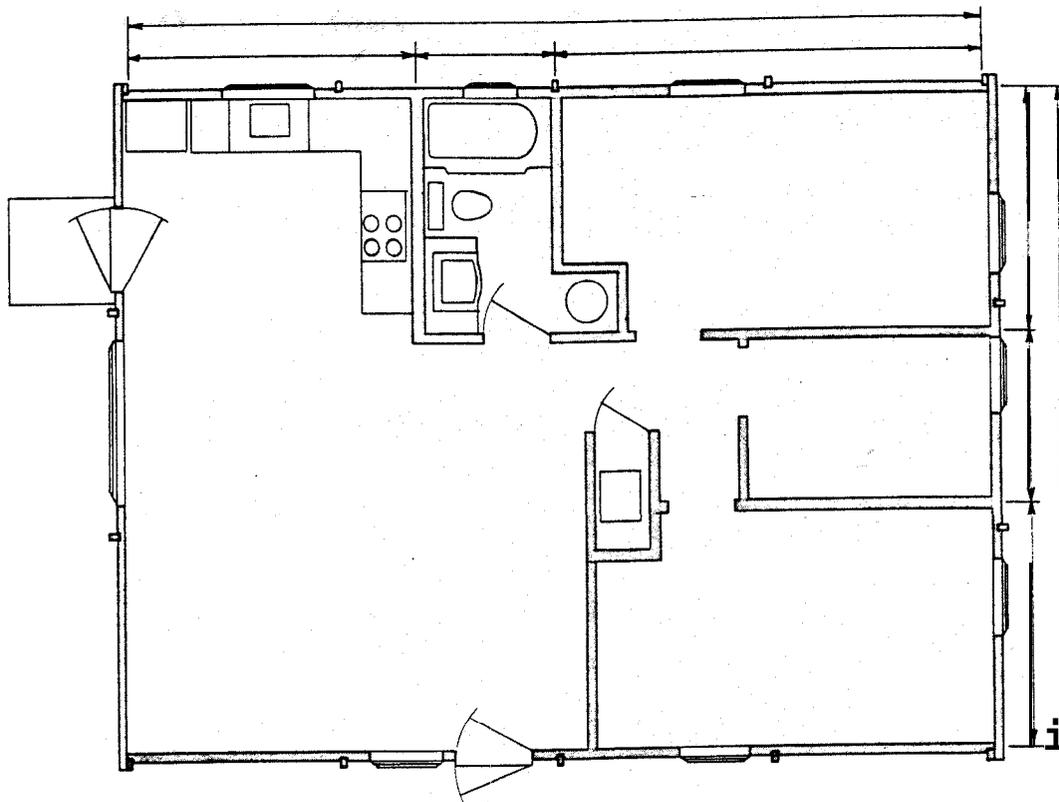


FIGURE 2.

indicate that a 4- by 4-inch post would support the load imposed upon it; therefore, this post is oversized for safety.

The post can be cut to length and notched to fit the plate beam before it is placed in the hole, or it can be cut and notched after the girts are in place. If the posts are precut, the elevation of each of the concrete footings must be determined before the posts are notched. The relative elevation of each footing is easily found by using a rod and level. Using the elevation data, cut the post to length and prepare a notch for the plate beam. Do not cut the bottom of the post; make sure that it is cut to length and notched on the top end. Cutting at any point below the ground line will reduce the effectiveness of the treated post.

Place the posts in the holes. Locate a vertical reference point on each post (fig. 4). This point can be found with a string level, a transit, and square, or other comparable equipment. If the posts have been precut to length, the top of the post can serve as a reference.

Now locate the position of the horizontal girts. The number of girts and their size depend on the span between posts and the wind or other loads which they must resist. In the prototype, with posts 8 feet 4 inches on center, 2 by 4 girts were spaced 2 feet on center. The most important

feature of this frame is the interlocking of members. Each girt is notched on each vertical support. The depth of this notch should be one-half the width of the girt (fig. 5.).

The notch must fit the post snugly for satisfactory results. The notch can be made at the building site or in a prefabrication shop. Each full-length girt should extend across two spans to support three posts (fig. 6).



FIGURE 3.

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FIGURE 4.

BN-26461

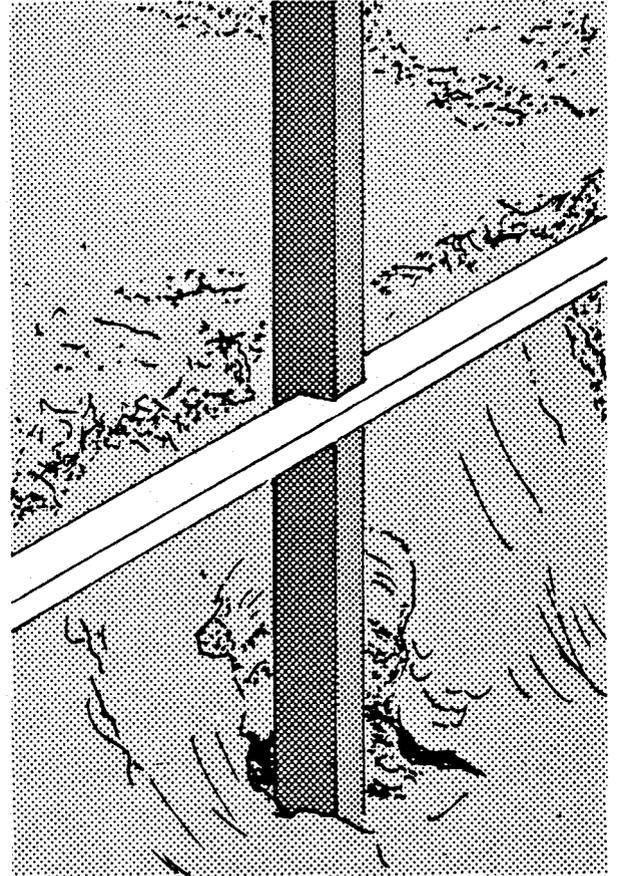


FIGURE 5.



FIGURE 6.

BN-26462

It is important that not all the girt joints occur on the same posts.

The girts in the prototype are made from 2 by 4's which are 18 feet long. It was impractical to calculate the strength and deflection of the composite wall panel. To determine the characteristics of this wall, a test frame was developed to support the wall panel as it would be supported in a post-and-girt structure. Tests were conducted on several test walls using sandbags as weights. Each panel was loaded to 20 pounds per square foot, and deflection measurements were taken at increments of 2.4 p.s.f. Panels framed with 2 by 4 girts placed 2 feet on center and notched over posts 8 feet $\frac{1}{4}$ inches on center deflected $\frac{7}{16}$ inch (approximately $\frac{1}{240}$ of the span) when loaded to 20 p.s.f. The girt patterns needed to form this frame are shown in figure 7. Where nailing the girts to the post is difficult, nail short 2 by 4 blocks to the post under the girts; then nail the girts to these blocks (fig. 8).

Two or three sixteenpenny nails are needed to fasten the girts at each post.

If the posts were not precut before they were placed on their footing, the next step is to cut the post off and prepare the notch for the plate beam (fig. 9). The notches are prepared only on side posts since the trusses transmit most of the roof load to the side walls. The plate beam fits into the notch and extends along each side of the structure at the top of the posts (fig. 10). The plate beam is usually built up, and its size and geometry will depend on the load which it must transmit to the post. The plate beam in the prototype was built up from a 2 by 8, a 2 by 6, and a 2 by 4, as shown in figure 11. It was placed on top of the post and fitted into the previously prepared notch as shown in figure 12.

When the plate is finished, the posts are alined and the building is squared. All posts are plumbed and held in place with braces (fig. 13).

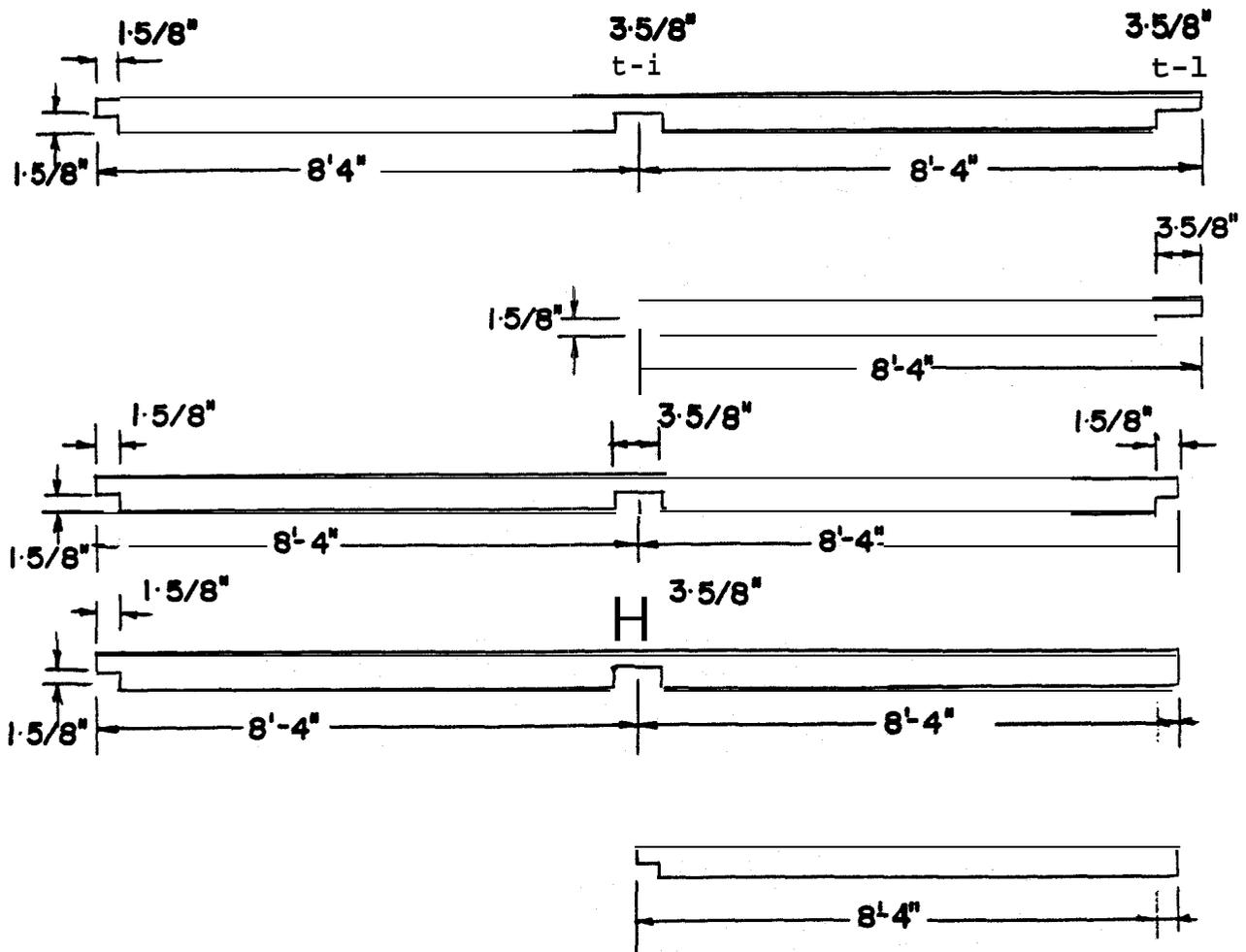


FIGURE 7.

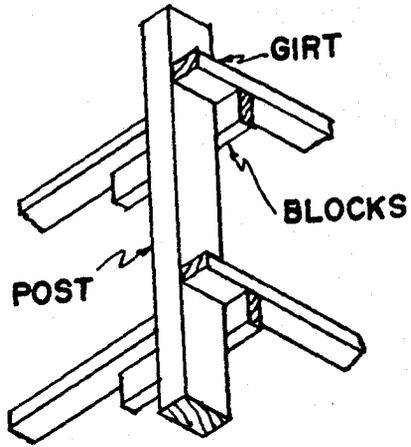


FIGURE 8.

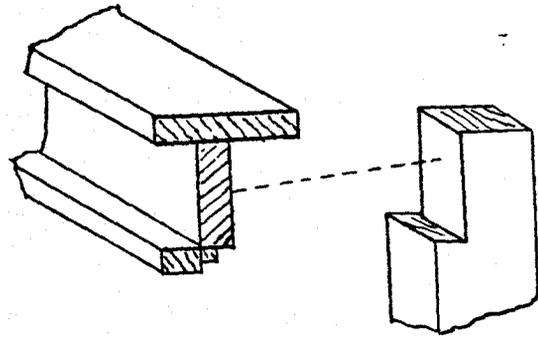


FIGURE 11.

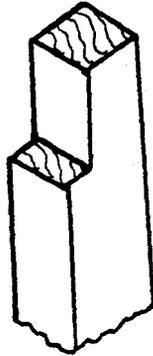


FIGURE 9.

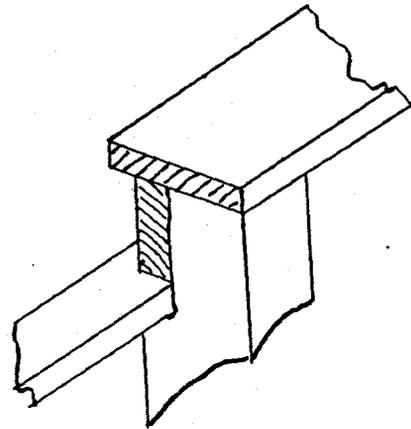
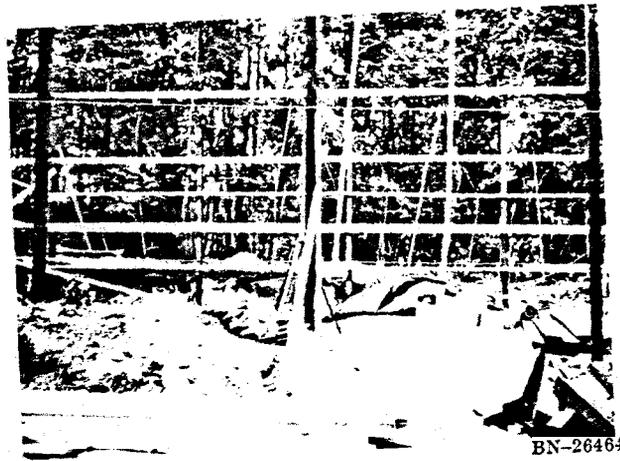


FIGURE 12.



BN-26463

FIGURE 10.



BN-26464

FIGURE 13.

Then all posts are fastened to the footing with anchor bolts or fixed at the base by tamping the soil.

Trusses

A truss was developed for this 24-foot 8-inch span with a 2-foot overhang on each eave. Figures 14, 15, and 16 show the truss solution, the nailing schedule, and the pattern for gussets and braces.

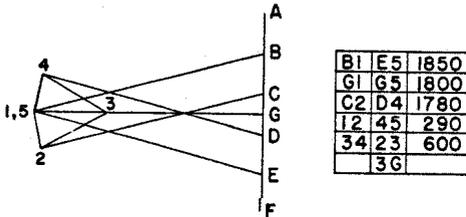
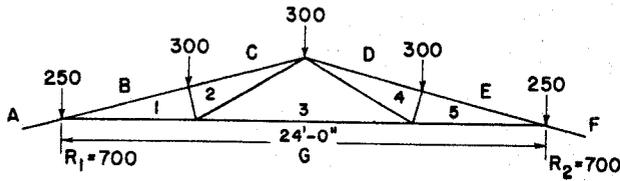


FIGURE 14.

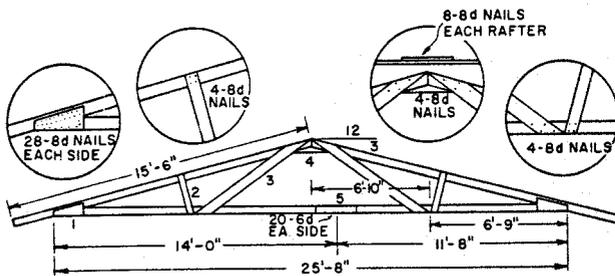


FIGURE 15.

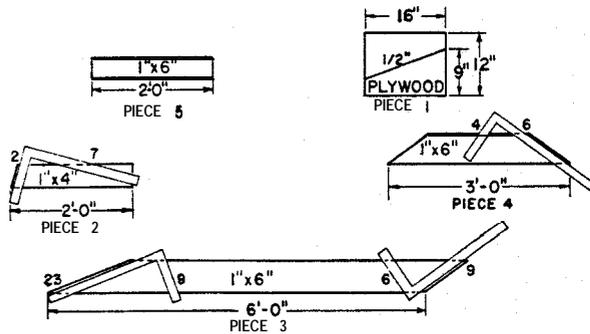


FIGURE 16.

The truss patterns are cut and fitted together. A jig built in the shop or at the building site will reduce the time and labor required and increase the uniformity of the trusses (fig. 17).

Trusses were spaced 2 feet on, center and nailed to the plate beam with twelvenny nails (fig. 18). When the trusses were in place, the frame achieved its dimensional stability and most of the temporary braces were removed.

The trussed roof allows complete freedom for building inside the structure. The final grading, the floor placement, and the partition location can be decided after the roof is in place. The ceiling can be covered as a single unit, thus eliminating much of the cutting and framing required when rooms are ceiled one at a time.



FIGURE 17.

BN-26465



FIGURE 18.

BN-26466

Sheathing and Weather Coat

This frame can be sheathed and weather coated to provide shelter during the remainder of the construction. The roof deck and the weather coating conformed to standard construction practices. The 2 feet between trusses was spanned with 1/2-inch plywood in 4- by 8-foot sheets. Eightpenny nails 8 inches on center held the plywood to the trusses. The weather coat was 210-pound asphalt shingles in a conventional pattern.

Summary of Framing

The designers attempted to make maximum use of each framing member. The roof load is transmitted through the trusses to the plate beam. The plate beam concentrates the load on the posts

which transfer it directly to the ground. This relieves the panels between the posts of their vertical load and allows the use of horizontal girts instead of vertical studs.

The girts are supported on the posts, eliminating the need for an expensive continuous foundation. The girts inter locked with the post provide a rigid, accurately dimensioned frame. There is about a one-third reduction in materials used compared to the conventional framing methods.

Another advantage is the basic simplicity and the flexibility of this frame. All of its parts can be precut. Only rough alining, plumbing, and squaring is needed when components are being assembled. Most alinement can be done just before the trusses are put in place. The position of the girts can be adjusted to suit window placement or other needs. Sewer and water lines can be placed without the inconvenience of working in mud, rain, or snow.

PLENUM WALL CONSTRUCTION

This house has a heating system which utilizes a crawl space 2 feet deep under the full house as a pressurized air chamber (plenum). To prevent air leakage from the crawl space a tight wall was constructed around the perimeter of the house below the floor level. The wall of this plenum serves a dual purpose-it supports the 2-foot earth fill around the chamber and it forms an insulated barrier to reduce heat loss at the ground line. Two methods of plenum wall construction were investigated. The first was to develop the wall in place and the second was to prefabricate the wall and then to nail it to the posts.

To build the wall in place, two rows of 2 by 6 timbers were nailed to the post (fig. 19). (These timbers were pressure treated with creosote to a density of 6 pounds per cubic foot.) Then 3/16-inch asbestos cement board was nailed to the outside of the 2 by 6's between the posts with 1-1/4-inch roofing nails (fig. 20).

The prefabricated wall was built on the bottom of the plenum chamber by placing two rows of 2 by 6's about 12 inches apart and parallel (fig. 21). Next, 2- by 8-foot sheets of asbestos cement board were nailed to the 2 by 6's.

When a 33-foot panel was completed, it was moved into position (figs. 22 and 23). The panel was fastened to the posts with twenty penny nails.

The plenum wall was fastened to the bottom girt with twenty penny nails. The nails were placed 8 inches on center as shown in figure 24.



FIGURE 19.

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The plenum wall was insulated with polystyrene foam 2 inches thick (fig. 25). The plenum was sealed with a 4-mil polyethylene film which was placed over the insulation (fig. 26). A 1/2-inch asphalt-impregnated fiberboard lining was nailed over the polyethylene film (fig. 27). Extra support was given to the plenum wall to help it resist the 2-foot earth fill by setting pressure-treated posts 4 inches by 6 inches by 4 feet, on the inside of the plenum wall midway between the main posts.

The bottom of the plenum was covered with a sheet of 4-mil polyethylene film (fig. 28) to prevent Just from being blown from the plenum floor into the house.



FIGURE 20.

BN-26468



FIGURE 21.

BN-26469

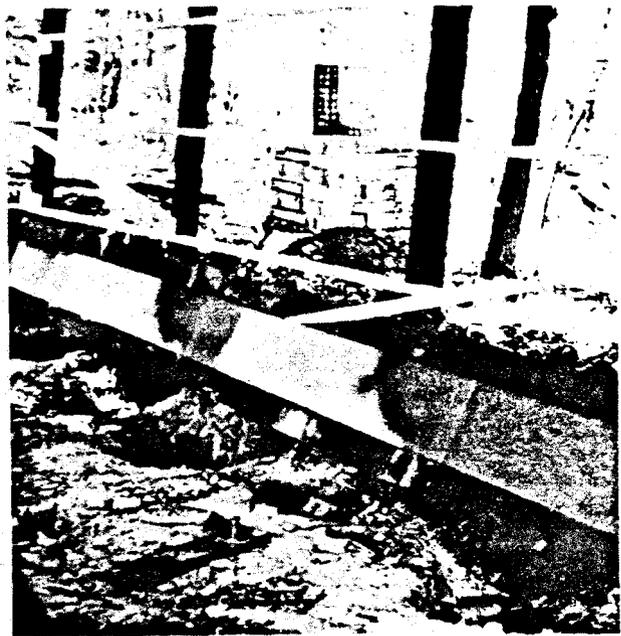


FIGURE 22.

BN-26470



FIGURE 23.

BN-26471

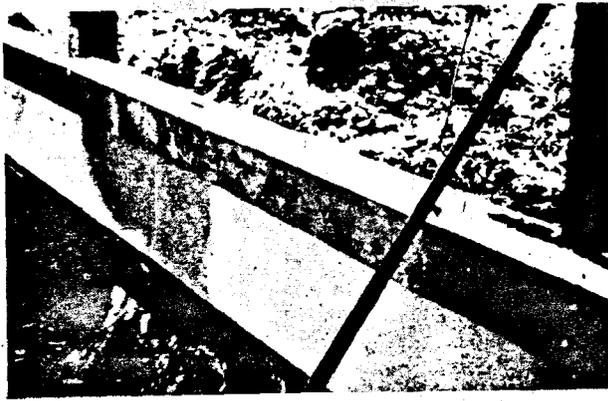


FIGURE 24.

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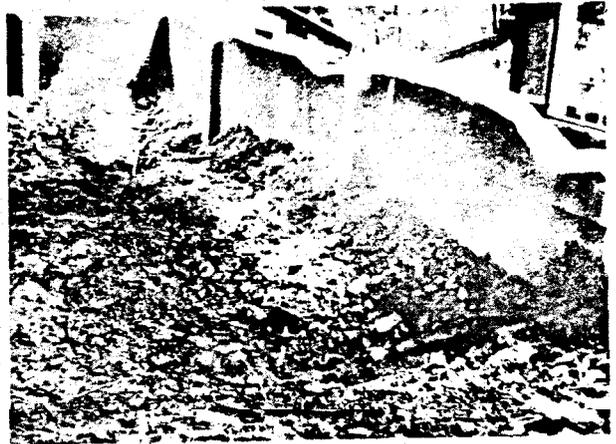


FIGURE 27.

BN-26475

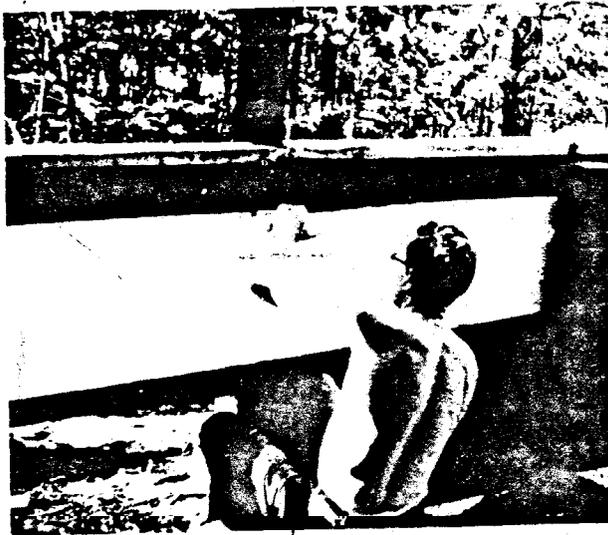


FIGURE 25.

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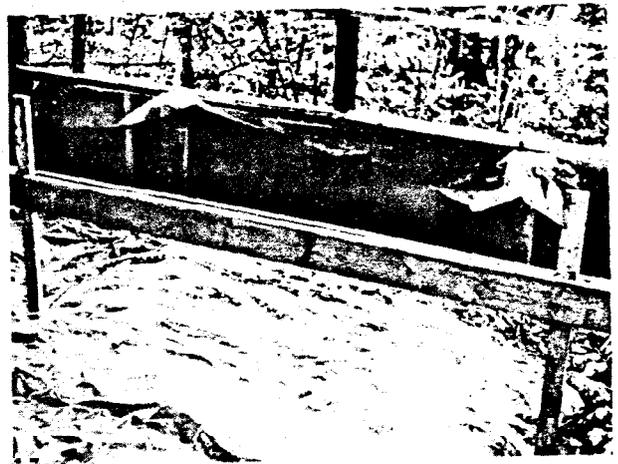


FIGURE 28.

BN-26476



FIGURE 26.

BN-23474

FLOOR

The floor was designed to support an evenly distributed load of 50 pounds per square foot and to meet a maximum deflection limitation of $1/360$ of the span. The load distribution was determined by the three moments equation which was developed by the method of conjugate beams, and the deflection was calculated by the double integration method. The floor framing utilizes continuous beams and cantilever overhangs to reduce the deflection of the floor joist and the main beams. This frame is independent of the side walls; it is supported on nine posts which are set on concrete footings (fig. 29).

The nine posts support three main beams built up from two 2 by 8 s (fig. 30). The overlapping joints are designed according to the theory de-

scribed by Kent and Teter.¹ The posts are built up from three 2 by 4's as shown in figure 31.

The base of each post was saturated with chlordane and pentachlorophenol. The solution was placed in a plastic bag which was stretched over the base of the post (fig. 32).

The main beams supported the floor joists which were placed 16 inches on center. The joists were also made continuous, with cantilevered ends (fig. 33).

The joists support a 1/2-inch plywood floor deck (fig. 34) nailed down with 1-3/4-inch serrated nails placed 4 inches on center. The floor finish was 1/8-inch asphalt tile on a 15-pound asphalt-impregnated felt.

¹ KENT, THOMAS E., and TETER, NORMAN C. *The design of nailed joints for continuous timber beams*, U.S. Dept. Agr., ARS 42-98, 10 pp. March 1965.



FIGURE 31

BN-26478



FIGURE 29

BN-26477

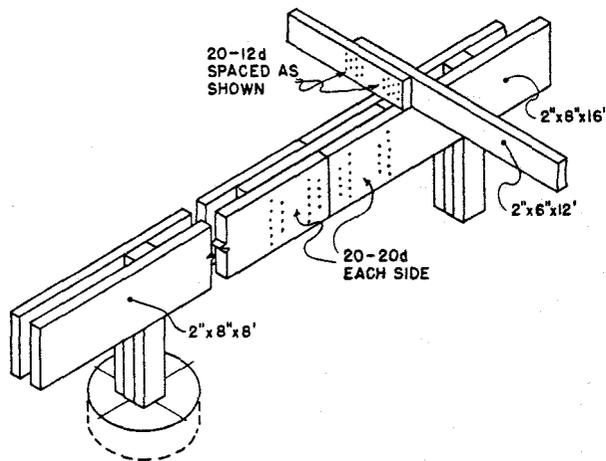


FIGURE 30



FIGURE 32

BN-26470



FIGURE 33.

BN-26480

roof and the ceiling load without interior support, the ceiling (1/2-inch gypsum board) was nailed in place before the partitions were built. This requires less cutting and fitting than ceiling each individual room.

PARTITIONS'

The partitions are curtain walls with horizontal girts. They were prefabricated at the construction site. The girts, sills, and plates were cut out and laid on the floor. Then the pieces were fitted together and nailed. The partitions were tilted up into place where they were nailed to the wall and floor (fig. 37). The partitions were held in place at the ceiling with wedges cut from short 2 by 4 blocks (fig. 33).

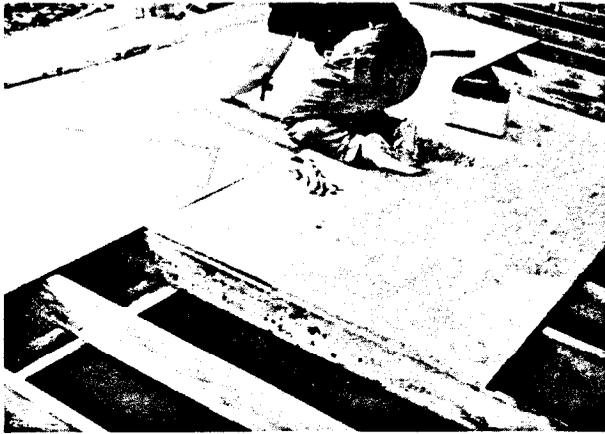


FIGURE 34.

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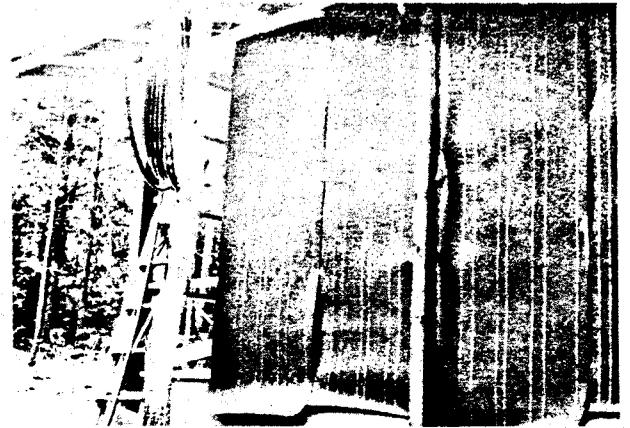


FIGURE 35.

BN-28482

SIDE WALLS

The walls of the house are built on the 2 by 4 girts. Fifteen-pound asphalt felt was stapled to the outside edge of the girts (fig. 35). The 1/2-inch plywood sheets were nailed to the girts with 1-3/4-inch serrated nails spaced 8 inches apart (fig. 36). Fiberglass blanket insulation 3 inches thick was placed between the girts. Then a 4-mil polyethylene vapor barrier was fastened to the inside of the girts. The inside wall paneling was nailed over the plastic film.

CEILING

The ceiling was insulated with 3-inch fiberglass insulation which was stapled to the bottom chords of the trusses. Since the trusses carry the



FIGURE 36.

BN-26483

Wall coverings were easily applied to the horizontal girts since it was not necessary to have studs spaced at exact intervals and there are no long unsupported joints requiring headers.

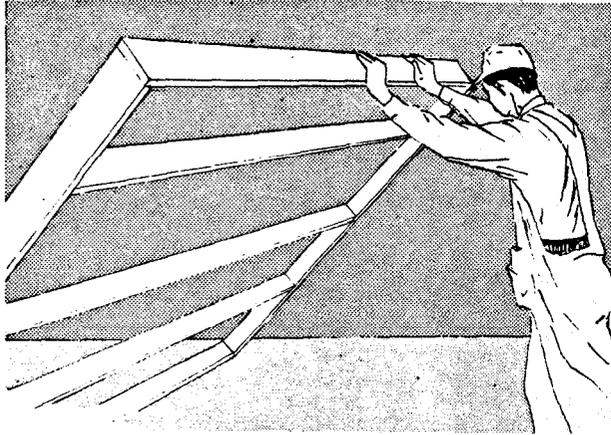


FIGURE 37.

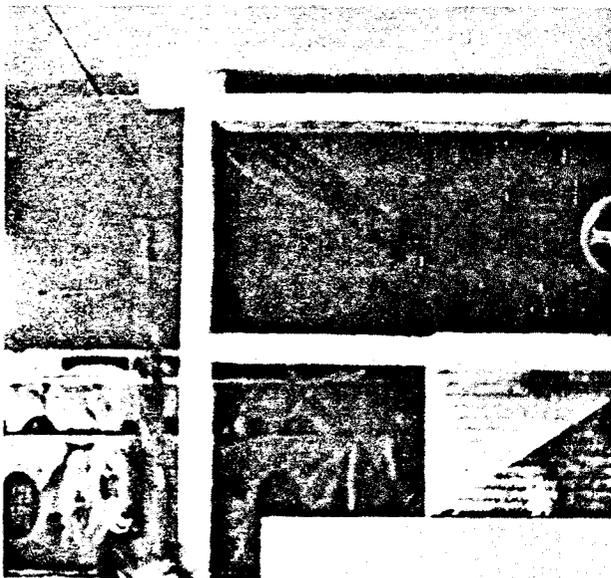


FIGURE 38.

BN-26484

WINDOWS

With curtain walls between the post supports, the window construction is flexible and simple. Some of the windows were installed in this structure after the outside siding was in place, and others were installed after the wall was complete. Once the window size is known an opening can be cut in the wall, and blocking is placed around the opening to support the interior wall finish.

A shadow box is built and fitted in the opening where it is nailed to the siding (fig. 39). Then an aluminum three-track combination storm sash is placed over the opening on the outside of the wall.

HEATING SYSTEM

The heating system in the prototype house is a hot-air system which utilizes the crawl space of the structure as a distribution plenum. The air is allowed to escape from the plenum through a narrow slot under the baseboards along the outside walls of the house. The furnace is located near the center of the house in a bottomless closet. A metal box on the base of the furnace extends through the floor into the crawl space where it discharges hot air from the furnace.

Air from the living area is returned to the closet through grills in the closet walls. The blower on the furnace can be adjusted to take air intermittently or continuously from the living area and force it over the furnace bonnet into the plenum and through the perimeter slot into the living area.

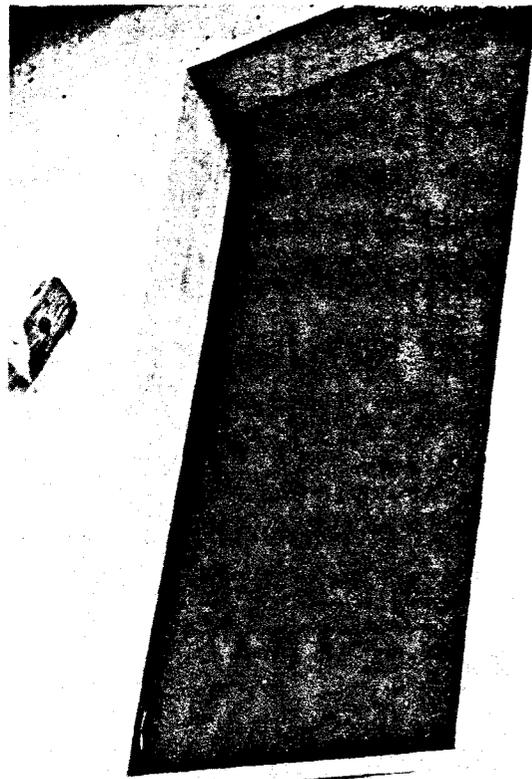


FIGURE 39.

BN-26485

BILL OF MATERIALS FOR THE LOW-COST DWELLING

Materials for this house were purchased on the open market from June to November in 1964 at retail prices. No attempt was made to obtain discounts other than those available to the general public for cash payments or quantity purchases. 411 materials were purchased from outlets in eastern West Virginia and western Maryland. The actual costs of the materials included in this structure are presented in the following tabulation:

Foundation :	
1 gal. chlordane -----	\$ 5.67
Plastic bags ---	.61
1 gal. pentachlorophenol ----	3.86
5 bags sand -----	1.28
Sand and cement -	3.65
Total	15.07
Plenum :	
Asbestos cement board -----	42.03
Treated lumber -----	82.85
14 pieces 4" x 6" x 4'	
12 pieces 2" x 6" x 18'	
4 pieces 2" x 6" x 10'	
1/2" insulation board -----	15.28
Calking -----	.28
Roofing nails -----	2.56
Dry foam --	32.40
4-mil polyethylene -----	15.50
Total	190.90
Framing :	
Nails -----	4.63
Lumber -----	130.09
8 pieces 2" x 8" x 18'	
4 pieces 2" x 8" x 12'	
36 pieces 2" x 4" x 18'	
6 pieces 2" x 4" x 12'	
10 pieces 2" x 4" x 10'	
15 pieces 2" x 4" x 10'	
4 pieces 2" x 6" x 10'	
Treated posts 4" x 6" x 12' -----	66.00
Total	200.72
Flooring :	
Nails -----	11.83
Felt paper -----	4.43
Plywood -----	119.00
Tile -----	42.00
Adhesive -----	6.98
Lumber -----	150.00
40 pieces 2" x 6" x 18'	
12 pieces 2" x 8" x 14'	
Total	334.24

Note: Tile not included for kitchen, bath, bunkroom, and bedrooms.

Electric System :

Entrance -----	39.43
Roof flange	
#2 wire	
2" conduit	
Straps	
Weather head	
1 breaker box	
2"-2-1/2" reducer	
Ground clamp	
Ground rod	
1-1/4" clamp	
Breakers -----	19.64
2-wire conductor #12 -----	32.96
Receptacles and boxes -----	25.59
Ground clips -----	.12
Bulbs, etc. -----	5.28
Stove circuit -----	13.02
Light fixtures -----	14.90
Total	150.94

Plumbing :

30 ft. 4" pipe -----	8.67
Adapter -----	1.13
Fiber T -----	2.42
1 cast-iron pipe -----	1.78
1 closet flange -----	.46
Copper fittings -----	80.00
Sewer -----	5.00
Septic tank -----	81.55
Total	187.01

Note: Bathroom fixtures to be added at a later date.

Heating System :

Chimney (insulated) -----	72.54
Furnace -----	316.94
Thermostat -----	10.40
Plenum for fan -----	5.77
Oil line -----	5.64
Stove pipe (insulated) -----	61.71
Total	473.00

Insulation and barrier:

2 rolls felt -----	5.87
Staples -----	1.03
Fiberglass -----	99.20
Polyethylene -----	12.00
Total	118.10

Roof:

Shingles -----	87.57
Nails -----	16.99
Plastic cement -----	3.93
2 pieces 2" x 4" x 16' -----	3.29
Plywood 1/2" x 4' x 8' -----	162.37
Lumber (trusses) -----	141.50
44 pieces 2" x 4" x 16'	
20 pieces 2" x 4" x 12'	
20 pieces 2" x 4" x 14'	
Total -----	<u>415.65</u>

Porches :

Reinforcing 3/8" rods -----	5.66
60 blocks -----	11.75
Mortar -----	1.19
Sand, gravel, cement -----	10.40
Total -----	<u>29.00</u>

Interior finish :

Gypsum -----	102.15
Nails -----	6.25
Staples -----	2.40
Baseboard -----	6.17
Door and hardware -----	13.96
9 sheets 3/8" plywood -----	35.58
6 sheets hardboard -----	14.95
Total -----	<u>181.46</u>

Note: One additional door will be needed.

Partitions :

Framing -----	<u>74.43</u>
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Exterior finish :

Storm door, back -----	21.88
Storm door, front -----	30.78
29 sheets plywood -----	126.81
Calk -----	3.09
11 windows -----	151.61
1 kitchen window -----	24.90
1 window frame -----	12.60
Total -----	<u>371.67</u>
Total Cost -----	<u>2,742.19</u>

With a materials cost of \$2,742.19 one would expect a labor cost of \$2,700 or a total cost of \$5,442.19. Adding the lot cost to this total should give the cost of a new structure. Since the prototype house is not completely finished, there will be certain costs which should be added to the above cost. And since some of the items included in this structure are more expensive than those required, the price of some items can be adjusted downward. The following adjustments can be made to more accurately reflect the minimum cost.:

Plenum :

The plenum wall height might be reduced to about 6 inches, making the plenum wall essentially a buried asbestos cement board with insulation extending into the soil. The following savings would result:

Two-thirds of the treated lumber -----	\$56.00
One-half of the asbestos cement board -----	21.00
All insulation board -----	15.28
Savings -----	<u>-\$ 92.28</u>

Electrical system :

The cost of the electrical installation was high but it is not easily lowered when meeting codes. However, some materials were left after installation was completed.

Unused electrical materials -----	-30.00
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Plumbing :

The plumbing cost could be reduced by \$40 by using plastic fittings. However, the cost of the bathroom fixtures and the hot water tank would increase the cost by about \$160. We must add to the plumbing cost:

Fixtures less savings on fittings -----	\$120.00
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Heating :

The heating system is much more elaborate than those generally used in a low-cost house. Such a house is usually heated with a coal, wood, gas, or oil radiant heater. Most of these heaters would require a chimney. Therefore we would need :

One chimney at -----	\$67.77
Heater -----	60.00
Total -----	<u>127.77</u>
Substitute chimney and heater for furnace system (-\$173 + \$127.77) -----	<u>-345.23</u>

Roof:

The plastic cement. was not used -----	<u>- 3.93</u>
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Interior finish :

The only features above the minimum quality are the 6 sheets of hardboard and the 9 sheets of 3/8-inch plywood, which cost \$50.53. These materials could be replaced with 15 sheets of gypsum board at \$1.61 per sheet (\$24.60).

Substitute gypsum board for plywood and cardboard -----	-25.93
Add the cost of one door and hardware -----	<u>+13.96</u>
Savings -----	<u>-11.97</u>

Exterior finish :

Three windows were not used	-48.00	
Storm doors could be eliminated	-52.66	
Savings		-100.66

Flooring :

Asphalt tile for the entire house, 768 square feet at 4.5 cents per 9- by 9-inch tile, would be \$69.12. This quality of tile would be satisfactory and is

recommended for low-cost construction. Tile cost listed is \$42.00.

Add to cost of flooring _____ +27.12

Total Adjustment

-436.95
No adjustment on foundations, framing, insulation and barriers, porches, or partition framing.

With the materials cost reduced by \$436.95, the bill of materials is \$2,305.24 and the finished structure (including labor) should cost between \$4,400 and \$5,000, plus lot cost. Other reductions may be possible under particular circumstances.



U. S. DEPARTMENT OF AGRICULTURE

CAUTION

If pesticides are handled or applied improperly, they may be injurious to humans, domestic animals, desirable plants, and pollinating insects, fish, or other wildlife, and may contaminate water supplies. Use pesticides only when needed and handle them with care. Follow the directions and heed all precautions on the container label.

HOW TO ORDER WORKING DRAWINGS

Working drawings may be obtained from the extension agricultural engineer at your State university. Ask for plan number 5997. There may be a small charge to cover cost of printing.

If you do not know the location of your State university, send your request to Agricultural Engineer, Federal Extension Service, U. S. Department of Agriculture, Washington, D. C. 20250. He will forward your request to the correct university.