AN EXPERIMENTAL WOOD FOUNDATION

Research Report 64-1

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March, 1964

This publication is a report of a study performed by the University of Illinois Small Homes Council-Building Research Council pursuant to an agreement for cooperative investigation between the University and the Koppers Company.

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ACKNOWLEDGEMENTS

The research was originated under the direction of Professor James T. Lendrum, director of the Small Homes Council prior to October 12, 1957. Additional studies were completed under the direction of Rudard A. Jones, Director, Small Homes Council; Research Professor of Architecture. The physical testing program was carried out by Donald H. Percival, Wood Technologist; Research Assistant in Forestry, Small Homes Council.

The publication was reviewed by a research committee of the Small Homes Council composed of Professor Frank M. Lescher, Professor William H. Kapple and the authors.

The cooperation of Dr. Stanley K. Suddarth and other staff members of the Wood Research Laboratory at Purdue University, Lafayette, Indiana, is gratefully acknowledged.

The last two paragraphs were typed with a typing plate behind the stencil.
I Background

During the design and planning stages of a residential remodeling project, a wood foundation was developed. A 24' x 28' frame structure was planned as an addition to a log cabin located in Nashville, Indiana, a village 40 miles south of Indianapolis. There are planning commission controls with restriction on the square foot area only.

Systems Considered

Before the final design evolved, other foundation systems were reviewed. A concrete block foundation and a poured concrete foundation were among those considered. However, due to the location and nature of the site, there was the opportunity to investigate a foundation using pressure-treated wood. Treated wood that can be used near soil, in concrete, and even buried in the soil, is on the market and available in many areas. First considered was a wood post-and-beam system. This system would consist of treated 4 x 4 posts spaced 6' apart around the 24' x 28' perimeter. The posts were to be imbedded in concrete in holes approximately 3' deep, to get below the frost line. Beams, girders and/or joists were to be positioned on top and between the posts to support the floor and structure (Standard platform framing and a trussed roof system).

The sloping topography influenced the decision to use a pressure-treated wood post-and-beam system. The major objective, aside from building the addition, was to evaluate the material and labor
costs and overall feasibility of such a system. If practical, the method could be used in more remote areas where there might be a minimum of equipment.

In reviewing background material, it was found that the proposed system had been used several times in constructing small buildings and other light frame structures, and that actual data and information were available. Therefore the design was changed from the proposed 4 x 4 post-and-beam system to a box-beam design. The design that evolved incorporates a prefabricated structural perimeter beam, 2 x 10 floor joists, and a plywood subfloor.

As co-sponsors of the project, the Koppers Company, through Mr. Bescher, Assistant Vice President of the Forest Products Division, agreed to furnish the treated lumber and plywood. All of the materials were to be pressure-treated with pentachlorophenol by the "Cellon" process. In this relatively new treating process, the pentachlorophenol is deposited in the wood with a liquid petroleum gas carrier. The gas eventually evaporates and leaves a residue-free surface. This has also shown to provide a deeper and more complete penetration of the wood.

A 25-guarantee was furnished by the Koppers Company for the durability of the chemical treatment of the wood, with the understanding that both the lumber and plywood would be field-cut and buried in part, or totally, in the soil or in concrete. A list of treated material is shown in Table I.
II Project Design

The proposal for the project was to design a foundation beam for this particular structure, perform basic strength and deflection tests on the beams, fabricate and construct the actual beams, and construct the foundation. During the fabrication and construction, a time and cost study was made and is recorded in this report. The foundation has been completed and is ready for plumbing, the exterior walls, and the roof. It has been left exposed, without heat, to check soil movements from freezing and thawing action.

Beam Design

A box beam, similar to those shown on Small Homes Council Instruction Sheet #22, "Nail-Glued Headers for Larger Openings," was developed. The beam consists of an 8-foot section with 2 x 4 flanges, stiffeners, support legs, and a 1/2-inch plywood web element. The beams have dual functions; they support the floor joists and serve as the skirt board for the crawl space.

Pilot Tests

Test beams, as shown in Figure 1 and 2, were fabricated and subjected to prescribed design loads for a 60-day period. The loads imposed on the beams simulated the generally accepted design loads for floor, wall, and roof, as shown in Figure 3. For this particular case, the joist span is 12 feet, the wall height 8 feet, and the truss span 28 feet. Design loads simulating half the floor area, the dead load of the wall, and half the truss length were calculated and applied to the test beams. The deflection
The design of the beams was not subjected to a mathematical analysis as the entire project was considered as exploratory at this time.
readings are shown in Table II and Figure 4.

Deflection readings were taken before the long-term tests and compared to L/360, a deflection limitation commonly used as a criterion for wood beams. The deflections of the test beams proved to be less than the limit. They were, therefore, considered acceptable. The beams were nail-glued with a waterproof adhesive, "Penacolite" and aluminum nails. In any future consideration of the system, testing and evaluation will also include nailed-only designs. Stainless-steel threaded nails will be included. Both long-term, full-scale, design-load tests and short-duration, high-load, machine testing will be included if there is enough interest in the project.

Site Preparation

A bulldozer was used to grade, lower, and level the site. In the original post and beam system, grading would not have been necessary; however, in this instance, the bottom flanges of the box beams would be below grade at several points, which required a somewhat more level site. The job was not extensive, but the bulldozer did save considerable hand trenching and leveling. A hand-dug trench could be used. The perimeter was laid out by spotting hole locations, eight feet on center. Along each of the 28-foot sides, an additional four-foot section was required. Holes six to eight inches in diameter were dug at these points to an approximate depth of three feet.
III Construction

The material was treated at Orville, Ohio and trucked to the building site. The usual precautions were followed in handling the freshly treated material. Gloves were used during all of the handling operations to prevent the skin from coming in contact with the freshly treated wood. An additional precaution would be to prevent touching the face with the gloves or with the treated material. Flying sawdust was also a nuisance. It must be pointed out that the freshly treated wood had not been exposed to the air other than during the transportation period. After a 4-month exposure period, the characteristic "penta" odor is gone and the wood does not irritate the skin.

The 2 x 4 flanges, stiffeners, and support legs for the beams were cut and nailed together to form the framework. High-carbon galvanized helically threaded nails were used. Plywood panels were ripped to 2' x 8' pieces as the webs for the beams. The adhesive was weighed, mixed, and applied to the frames and the plywood nail-glued to the frames. Two-inch aluminum nails were used in the nail-gluing process. Other types of fasteners will be considered in the future. The beams were fabricated at the site where temperature and climatic conditions were excellent; however, a field-gluing operation, using waterproof or resorcinol adhesives, is not recommended without supervision and observing the specified gluing recommendations.
Beam Placement

After the recommended adhesive curing period had lapsed, the beams were positioned with the 2 x 4 support legs inserted into the pier holes. The 2 x 4 top plates were then nailed around the top flanges of the beams, and the support legs were nailed together. The beams, fastened together, were then leveled by using wood blocks as supports, a steel rod for moving the beams, and a surveyor's level for correcting height. The center girder posts were formed by nailing 2 x 4's together, and suspended in the holes ready for the concrete.

Concrete was mixed and poured around the beam support legs and around the girder posts. The center girder posts were leveled and cut to the prescribed height.

Girder

The girder was made up of 2 x 10's nailed together so that the joints of the girder would fall over the posts. The girder was positioned on the posts and held in place with metal post caps. The box beams were not used for the center supports. Due to time problems and indecisions on heating and plumbing plans, a double 2 x 10 girder was used so that future crawl space work could be done without obstructions.

Floor Joists

The 2 x 10 Western Hemlock joists, spaced 24 feet on center, were also "Seelon" treated. Metal joist hangers were nailed to each side of the girder to support one end of each floor Joist.
The joists were cut to 11'-10 3/8". They were set into position on the hangers at one end and placed on the top plates of the foundation, directly over a beam stiffener, or post, at the other end. The joists were nailed to the joist hangers and end-nailed through the plywood web of the perimeter beam.

Subfloor
The subfloor and/or work deck is 1/2-inch C-C exterior-type plywood, also "Celbon" treated. Some of the panels were cut to 4' x 4' sections while others were ripped to 2' x 8' sections. The plywood was positioned so that a row of 4 x 8 panels straddled the butt joints of the joists and the girder. The plywood was tacked down at the corners to facilitate future removal for plumbing installation, ground cover placement, and attachment of perimeter insulation. The completed installation is sketched in Figure 4.
A material and labor cost analysis is shown in Table III. Total costs for this system were $482.27. Comparative analyses were made for a concrete-block crawl-space foundation, including the joists, the girder, the headers and the subfloor, Table IV, and for a concrete slab of similar dimensions, Table V. Ground or soil poisoning or other termite control measures were not included in the analysis of these last two systems. The estimated cost of a block crawl space system was $627.17 and the estimated cost of a slab was $765.03.

In addition to the cost analysis of the wood foundation, a detailed list of the operations are included in Tables VI and VII.
V General Observations

Reference points were located on the foundation for subsequent level measurements during periods of freezing and thawing. Final grading has not been completed. However, readings were taken in December after several freezes had occurred. For beams with no soil contact, no movement was observed. Along one side, where the bottom flanges of the beams rest on the soil between the supports, an average upward movement of \(\frac{1}{16}\)-inch was observed at the center of the beams. No movement was observed on points located directly over the support leg positions.

The plywood subfloor was nailed only at the corners. Due to a series of timing problems, completion of the structure was not feasible until the following spring and summer. The plywood was left loosely nailed to allow for installation of the plumbing, insulation around the perimeter, and laying a ground cover.

An identification strip printed on the treated wood will serve as a reminder to carpenters of the precautions to be observed in handling the material. Because of the nature of the chemical used in the treatment, the wood has no outstanding color. The workers, on occasion, became careless and forgot the gloves which resulted in some skin irritation. Normally, treated materials are stacked for air drying, but due to time problems, it had to be fabricated before the airing period. In checking the material after a 4-month period, the wood has lost the odor and it doesn't seem to cause skin irritation.
The advantages of a wood foundation system of this type are numerous, and include:

1. Allows construction throughout the entire year since the small amount of concrete required is easily protected from freezing.

2. The prefabricated wood system is lighter in weight and more easily handled than unit masonry or precast concrete grade beam systems.

3. Eliminates one skilled trade or subcontractor.

4. Minimum of equipment and water supply required for construction on remote sites.

5. Provides better job control through shop fabrication, and increases possibilities for labor utilization during inclement weather.

Several items could be considered for any future experimental work:

1. The beams could be fabricated with stainless-steel threaded nails and subjected to the various tests. This change would eliminate gluing, which carries temperature and fabrication limitations. However, stiffness and deflection characteristics would dictate design changes.

2. The system may have application as a permanent concrete form for a breezeway between a house and garage or patio and for the perimeter of garages with an earth or gravel floor.

3. Investigating a box-beam-type central support, in lieu of the girder used in this case, would be suggested.
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1) American Wood-Preservers Association
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   University of Illinois, Urbana, Illinois.
HISTORY OF PROJECT

Following is a discussion of data collected during the construction of an experimental wood foundation: During the design and planning stages of a residential remodeling project, a wood foundation was developed. A 24' x 28' frame structure was planned as an addition to a log cabin located in Nashville, Indiana, a village 40 miles south of Indianapolis. There is a planning commission operation with restriction on the square foot area only.

Before the final design evolved, other foundation systems were reviewed. A concrete block foundation and a poured concrete foundation were among those considered. However, due to the location and nature of the site, there was the opportunity to investigate a foundation using pressure-treated wood. Treated wood, that can be used near soil, in concrete, and even buried in the soil, is on the market and available in many areas. First considered was a wood post-and-beam system. This system would consist of treated 4 x 4 posts spaced 6' apart around the 24' x 28' perimeter. The posts were to be imbedded in concrete in holes essentially 3' deep, to get below the frost line. Beams, girders and/or joists were to be positioned on top and between the posts to support the floor and structure—(Standard Platform framing and a trussed roof system).

The sloping topography more or less dictated the decision to use a pressure-treated wood post-and-beam system. The major objective, aside from building the addition, was to evaluate the cost, labor, and overall feasibility of such a system. If practical, the method could be used in more remote areas
where there might be a minimum of equipment. In reviewing background material, it was brought to the attention of the author that the proposed system had been used several times in constructing small buildings and other light frame structures, and that actual data and information were available. During a discussion with Mr. Ralph Bescher, Assistant Vice President of the Forest Products Division of Koppers Company, Pittsburgh, Pennsylvania; Professor Rudard A. Jones, Director of the Small Homes Council; and the author, suggestions were made to change from the proposed 4 x 4 post-and-beam system to a box-beam design. The design that evolved incorporates a prefabricated structural box-beam system as the perimeter and 2 x 10 floor joists and a plywood subfloor. All of the materials were to be pressure-treated with pentachlorophenol by the "Cellon" process.

As co-sponsors of the project, the Koppers Company, through Mr. Bescher, agreed to furnish the treated lumber and plywood. In this relatively new treating process, the chemical, pentachlorophenol is deposited in the wood with a liquid petroleum gas. The gas eventually evaporates and leaves a residue-free surface. In other treatment methods, an oil or water is used to carry the chemicals into the wood. The new process known as the "Cellon" treatment has also shown to provide a deeper and more complete penetration of the wood. A 25-year guarantee was furnished by the Koppers Company for the durability of the chemical treatment of the wood, and with the understanding that during the construction of the foundation, both the lumber and plywood would be cut and buried in part, or totally, in the soil or in concrete. The tentative proposal for the project was to design a foundation beam for this particular structure, perform pilot strength and deflection tests on the beams, fabricate and construct the actual beams, and construct the foundation. During the fabrication and construction, a time and cost study would be made and is recorded in this report. The foundation has been completed and is ready for plumbing, the
exterior walls, and the roof. It has been left exposed, without heat, to check soil movements from freezing and thawing action. (Material costs are listed in Table III.)

BEAM DESIGN

A box beam, similar to those shown on Small Homes Council Instruction Sheet #22, "Headers for Larger Openings," was developed. The beam consists of an 8-foot section with 2 x 4 flanges, stiffeners, support legs, and a ½-inch plywood web element. The beams have dual functions; they support the floor joists and serve as the skirt board for the crawl space.

PILOT TESTS

Test beams were fabricated and subjected to prescribed design loads for a 60-day period. Load-deflection data are included on Figure 1. The loads imposed on the beams simulated floor, wall and roof loads generally accepted as theoretical design loads. For this particular case, the joist span is 12', the wall height 8' and the truss span 28'. Design loads simulating half the floor area, the dead load of the 8' wall and ½ the truss length were calculated and applied to the test beams. (For this case - joists and trusses both do not rest on beams)

Deflection readings were taken previous to the long term tests and compared to \( \frac{L}{360} \), a deflection limitation commonly used as a criterion for wood beams. The actual deflections of the test beams proved to be less than the generally accepted \( \frac{L}{360} \). It was, therefore, considered acceptable, and the project progressed. The beams were nail-glued with a waterproof adhesive, "Penacolite" and aluminum nails. In any future consideration of the system, testing and evaluation will also include a non-glued or nailed only designs. Stainless steel threaded nails will be included. Both long term, full scale, design load
tests and short duration, high-load machine testing will be included providing there is enough interest in the project.

SITE PREPARATION

Due to the change, from the 4 x 4 post system to the box beam system, and because the author's wife changed her mind to provide a step down from the present structure into the addition, lowering the site was required. A bulldozer was used to grade, lower and level the site. In the original post and beam system, grading would not have been necessary; however, in this instance, the bottom flanges of the box beams would be below grade at several points, and requires a somewhat more level site. The job was not extensive, but due to the changes, the bulldozer did save considerable hand trenching and leveling. A hand-dug trench could be excavated where a bulldozer is not available. The perimeter was laid out by spotting hole locations, 8' on center. Along each of the 28' sides, an additional 4' space was required. Six to 8 inch diameter holes were dug at these points to an approximate depth of 3 feet.

BEAM FABRICATION

The material was treated and trucked from Orville, Ohio and unloaded at the building site. The usual precautions were followed in handling the freshly treated material. Gloves were used during all of the handling operations to prevent the skin from coming in contact with the freshly treated wood. An additional precaution would be to prevent touching the face with the gloves or with the treated material. Flying sawdust was also a nuisance. It must be pointed out that the freshly treated wood had not been exposed to the air other than during the transportation period. After a 4-month exposure period, the characteristic "penta" odor is gone and the wood does not irritate the skin.

The 2 x 4 flanges, stiffeners and support legs for the beams were cut and
nailed together to form the framework. High-carbon galvanized helically threaded nails were used. Four by eight plywood panels were ripped to 2 x 8 foot pieces as the webs for the beams. The adhesive was weighed and mixed, and applied to the frames and the plywood nail-glued to the frames. Two-inch aluminum nails were used in the nail-gluing process. Other types of fasteners will be considered in the future. The beams were fabricated at the site where temperature and climatic conditions were excellent; however, a field-gluing operation, using waterproof or resorcinol adhesives, is not recommended without supervision and observance to the specified gluing recommendations.

CONSTRUCTION AND BEAM PLACEMENT

After the recommended adhesive curing period has lapsed, the beams were then positioned with the 2 x 4 support legs inserted into the holes. Two by four top plates were then nailed around the top flanges of the beams, and the support legs were nailed together. The beams, fastened together, were then leveled by using wood blocks as supports, a steel rod for moving the beams, and a surveyor's level for correcting height. The center girder posts were formed by nailing 2 x 4's together. These were placed in the holes ready for the concrete.

A gasoline engine concrete mixer was brought to the site. Concrete was mixed and poured around the beam support legs and around the girder posts. The center girder posts were leveled and cut to the prescribed height.

GIRDER

The girder was made up of 2 x 10's nailed together so that the joints of the girder would fall over the posts. The girder was positioned on the posts and held in place with metal connector post caps.
FLOOR JOISTS

Two-by-ten joists, spaced 24 feet on center, were planned in the design of the structure. The joists, Western Hemlock 2 x 10's were also "Cellon" treated. Metal joist hangers were nailed to each side of the girder to support one end of each floor joist. The joists were carried to the saw horses, measured and cut to 11 feet 10 3/8 inches. They were set into position on the hangers on one end and placed directly on the plates over a beam stiffener at the other end. They were nailed to the joist hangers and through the plywood flanges at the other.

SUBFLOOR

The subfloor and/or word deck is 1/2-inch C-C, exterior-type plywood, also "Cellon" treated. Those plywood panels to be cut were carried to the saw horse. Some of the panels were cut to 4 x 4 sections while others were ripped to 2 x 8 sections. The plywood was positioned so that a row of 4 x 8 panels straddled the butt joints of the joists and the girder. The plywood was merely tacked down at the corners. This was done to facilitate future removal for plumbing installations, ground cover placement and attachment of a perimeter insulation.

DISCUSSION

A material and labor cost analysis is shown in Table A. Total costs for this system were $482.27. Comparative analyses were also made for a concrete block crawl-space foundation, including the joists, the girder, the headers and the subfloor, and for a concrete slab of similar dimensions, Table C. Ground or soil poisoning or other termite control measures were not included in the analysis of these last two systems. The estimated cost of a block crawl space system was $627.17 and the estimated cost of a slab was $765.03.

In addition to the cost analysis of the wood foundation, Table A, a detailed list of the operations are included in Tables G, D, and E, L, E and F.
building the foundation. In Table "b", a hypothetical cost analysis for a foundation and subfloor is shown. This was done using the same rates and floor dimensions to be used as a comparison to the experimental wood foundation. Table "c" included a hypothetical cost analysis for a slab floor system as a comparison.

**Discussion**

Reference points were located on the foundation for subsequent level measurements during periods of freezing and thawing. Final grading has not been completed. However, readings were taken in December after several freezes had occurred. For beams with no soil contact, no movement was observed. Along one side where the bottom flange of the beams rest on the soil, between the supports, an average movement upward of 1/16-inch was observed in the center of the beams. No movement was observed on points located directly over the support leg positions.

The plywood subfloor was nailed only at the corners. Due to a series of timing problems, completion of the structure was not feasible until the following spring and summer. The plywood was left loosely nailed to allow for installation of the plumbing, insulation around the perimeter and laying a ground cover.

An identification strip rolled on the treated wood will serve as a reminder to carpenters handling the material. Because of the nature of the chemical used in the treatment, the wood has no outstanding color. The workers, on occasion, became careless and forgot the gloves which resulted in some skin irritation. Normally, treated materials are stacked for air drying, but due to time problems, it had to be fabricated before the airing period. In checking the material after a 4-month period, the wood has lost the odor and it doesn't seem to cause skin irritation.

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The advantages of a wood foundation system of this type are numerous, and include:

1. Allows construction throughout the entire year since the small amount of concrete required is easily protected from freezing.

2. The prefabricated wood system is lighter in weight and more easily handled than unit masonry or precast concrete grade beam systems.

3. Eliminates one skilled trade or subcontractor.

4. Minimum of equipment and water supply required for construction on remote sites.

5. Provides better job control through shop fabrication, and increases possibilities for labor utilization during inclement weather.
Several items could be considered for any future experimental work:

1) The beams could be fabricated with stainless steel threaded nails and subjected to the various tests. This change would eliminate gluing which carries temperature and fabrication limitations; however, stiffeners and deflection characteristics would dictate design changes.

2) Because of the cost differences in favor of the treated wood system, an attempt would be made to interest others in widely scattered areas to investigate its use on an experimental basis.

3) The system may have application as a permanent concrete form for a breezeway between a house and garage or patio and for the perimeter of garages with an earth or gravel floor.

4) The treated wood foundation system has merits for use in more remote areas where a limited amount of equipment is available.

5) Investigating a box-beam-type central support, in lieu of the girder used in this case, would be suggested.
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   829 17th Street, N.W.  
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