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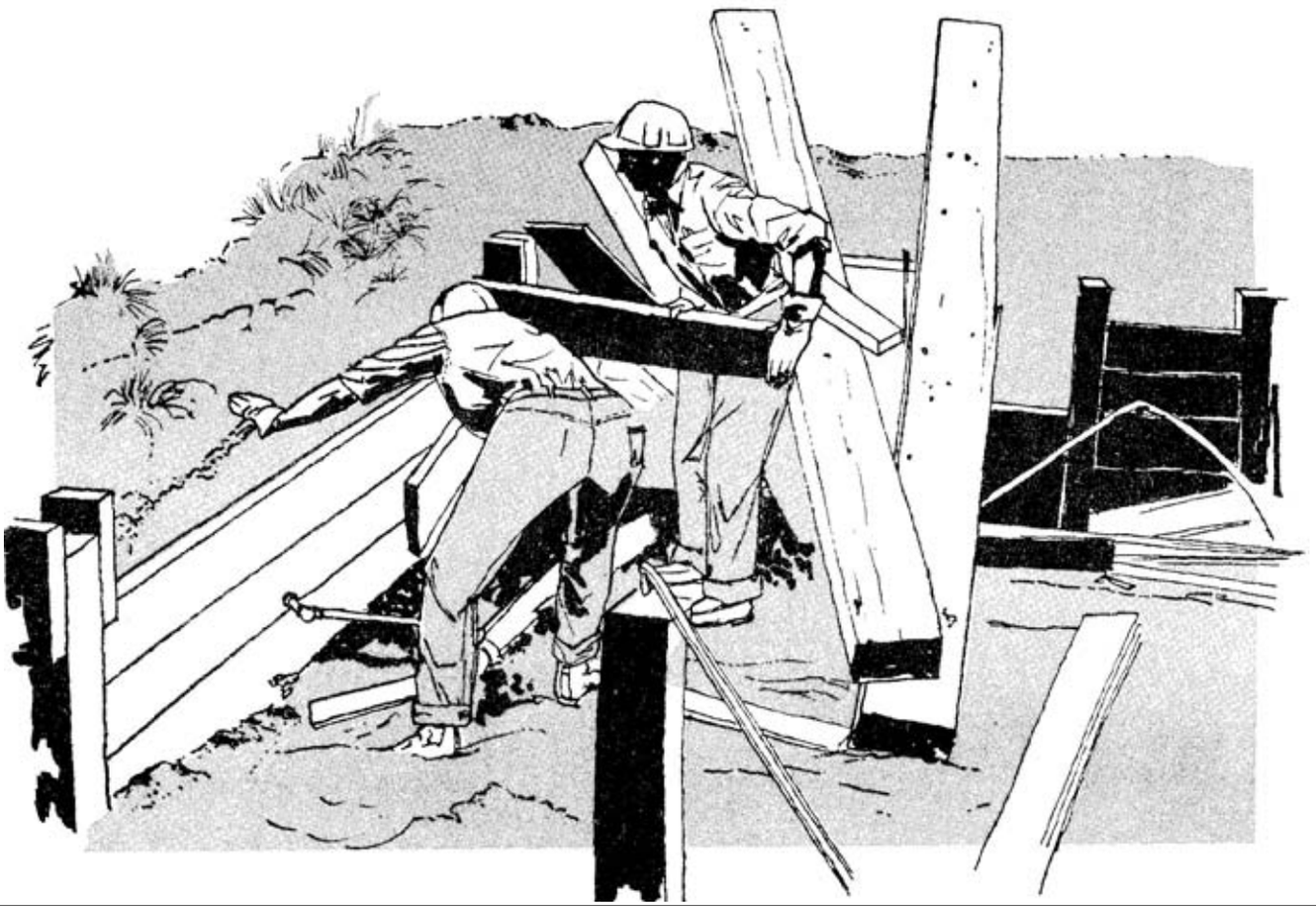
HOUSE FOUNDATION OF TREATED WOOD AFTER 30 YEARS' SERVICE



ABSTRACT

Mechanical properties were measured and decay was investigated on treated wood foundation materials from an experimental house that stood on the U.S. Forest Products Laboratory grounds for about 30 years. The results, coupled with visual observations, provide evidence that the foundation gave excellent service and met its requirements of use.

The bending strength and stiffness of southern pine plank material averaged only slightly lower than the average of four major southern pine species. Loss in compressive strength was observed in some posts, but it was limited to instances where treatment was erratic or virtually nonexistent.

Decay, when present, was predominantly by the soft-rot fungi. Creosote retentions were consistently low in the plank material, and they ranged from substandard to very good in the posts. In the planks, decay was essentially limited to the surface in contact with the soil, and the maximum depth of penetration was 6.5 millimeters. Where treatment was thorough, there was no evidence of decay.

HOUSE FOUNDATION OF TREATED WOOD AFTER 30 YEARS' SERVICE

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INTRODUCTION

Interest is intensifying regarding the use of wood as a material for the construction of foundations where the wood is required to simultaneously support the weight of the structure and to act as a retaining wall to resist the lateral pressure of the soil. There is ample evidence to indicate that satisfactory performance can be obtained from treated wood in contact with the ground; for instance, in applications such as posts, poles, and piles. However, none of these is strictly applicable to the rather unique use of wood in a basement foundation where only one side of the members is exposed to the soil, In order to encourage the use of wood for foundations, information is needed regarding the performance of wood under these conditions.

Accelerated tests for wood have been developed for many exposure conditions, but it is generally recognized that the best evaluation of durability is obtained from observations of material in actual service. In 1937, a 24- by 36-foot experimental prefabricated house was constructed on a wood foundation at the Forest Products Laboratory site in Madison, Wis. (fig. 1). New construction at the Laboratory in 1966 required that this building be moved to a new location. Thus, an opportunity was available to evaluate a woad foundation after approximately 30 years of actual service. The soil at the site is characteristic of that near Lake Mendota, that is, it consists of a heavy clay loam, a soil type capable of holding substantial moisture.

Before the move, the house was used to provide office space and performed well. At the time it was moved, inspections showed that the floors were flat and level and the entire building was in good condition--evidence that the wood foundation was still functioning as a sound structural assembly. This study is concerned with the determination of the presence of decay and with evaluating the strength properties of the wood foundation components to determine if and how they were affected by decay.

[1]Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

Figure 1.--The foundation of the one-story prefabricated house in the foreground was the subject of this study. The 24- by 36-foot house was built in 1937 and moved in the summer of 1966. Soils near Lake Mendota in the Madison, Wis., area are characteristically clay loam types.

M 34209

METHODS AND MATERIALS

The foundation consisted of 6- by 6-inch Douglas-fir posts, spaced 4-1/2 feet on center. Each post rested on a wood pad buried approximately 2 feet beneath a 3-foot-deep excavated crawl space. Nominal 2- by 8-inch southern pine planks, either 4-1/2 or 9 feet in length, were nailed on edge to the outside perimeter of the posts with the joints of the planks staggered at the posts. The retaining wall consisted of five courses or tiers of planks, The top course was approximately one-half exposed on the outside and the bottom course one-half covered on the inside. Figure 2 shows a diagram of a typical wall section, and figures 3 and 4 show the building site after the house was removed and dismantling of the foundation was under way.

All of the Douglas-fir and southern pine material was pressure-treated with creosote, using an empty-cell process, Although formal treating records no longer exist, we believe that average retentions were approximately 9 and 11 pounds per cubic foot in the Doughs-fir posts and the southern yellow pine planks, respectively.

Moisture contents of planks in the north and the south walls were obtained, prior to their removal, with a resistance-type moisture meter. This work was conducted inside the crawl space of the building. Each plank (except for those in the top tier which had already been removed) was sampled at a point located centrally with respect to its length and 2 inches from its lower edge. The readings were taken with the probes penetrating to within 1/4 inch of the opposite (soil) side.

Five vertically adjacent planks were removed from two separate locations on each of the four sides of the foundation (40 planks in all). Although purely arbitrary, the selection was made so that a variety of exposure and drainage conditions

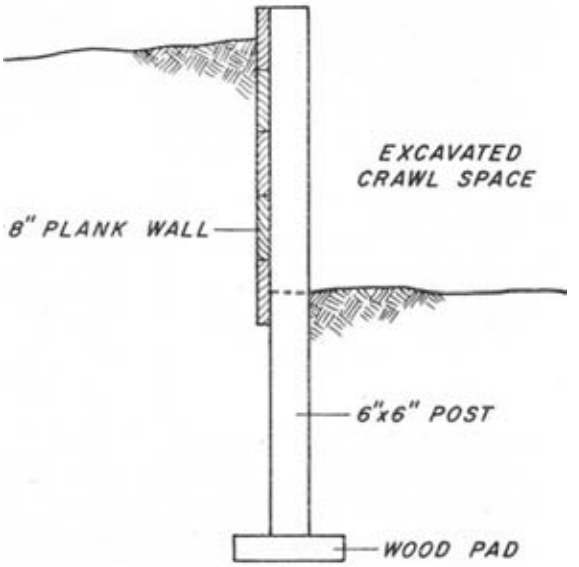

Figure 2.--Wall detail. Typical foundation wall section. M 135 210

Figure 3.--Dismantling of the foundation wall in progress. Moisture content readings of planks in the north and south walls were obtained prior to their removal. The two large timbers leaning against the foundation were not part of the foundation wall M 131 268

Figure 4.--Foundation post being removed by crane. Markings on past and planks were used to identify locations of specimens. M 131 267

were represented in the sample, Eight posts were selected from the foundation. one near each location from which planks were removed.

The following test specimens were cut from each plank:

(a) Two 30-inch static bending specimens, 2 inches wide and the full thickness of the plank.

(b) Two 15-inch static bending specimens, 1 by 1 inch in cross section.

(c) Two toughness specimens, 0.79 by 0.79 by 11 inches.

The 1-inch static bending and the toughness specimens were removed from near the center of the plank in both the width and thickness directions, so they were as closely side-matched to the full-thickness static bending specimens as possible. Specimens were adjusted in a lengthwise direction to avoid strength-reducing growth characteristics such as knots and cross grain. After preparation, the specimens were conditioned to approximate equilibrium (12 percent equilibrium moisture content) in an atmosphere controlled at 75° F. and 64 percent relative humidity. Tests of these minor plank specimens were conducted according to ASTM procedures for the evaluation of small clear specimens of wood.[2] The loads on the 2-inch static bending specimens were applied in the width direction of the plank so that the depth was always 2 inches.

[2] American Society for Testing and Materials. Standard Methods of Testing Small Clear Specimens of Timber, ASTM D 143-52.

Two full-sized specimens approximately 24 inches long for compression parallel to grain tests were cut from each post, one from above and one from below ground level. They were loaded to failure in a 1 million-pound testing machine. Strain was recorded with two dial gages over a 12-inch gage length (fig. 5).

After completion of the full-sized post tests, a 2- by 2- by 8-inch specimen was removed from six of the eight above-ground post sections. (Fractures and lmots prevented obtaining specimens from the other two sections.) These specimens were tested in compression parallel to grain according to standard procedures.[2]

Creosote retentions were determined[3] for the outer 5/8 inch of both faces of five individual planks. This permitted comparisons between the amounts of creosote retained in those plank faces which had been in contact with the soil with the amounts retained in those which had been exposed to the air. The planks were selected to represent a cross section of the foundation with respect to vertical position. One-eighth-inch-long sections were also removed from four of the six posts from which minor specimens were taken and were analyzed for creosote retentions. These samples represented each of the four foundation walls.

Decay determinations were made on 10 planks from each of the four foundation walls by bath visual examination and probing. Where decay was found, the affected wood was scraped from the surface until sound wood was reached, and then the depth of decay penetration was measured. To determine the type of degradation involved, sections were cut from representative planks and examined microscopically. No detailed observations were made on the post material, which appeared generally sound.

RESULTS

Strength Tests of Plank Material

Table 1 shows the results of toughness tests on specimens removed from the planks. These

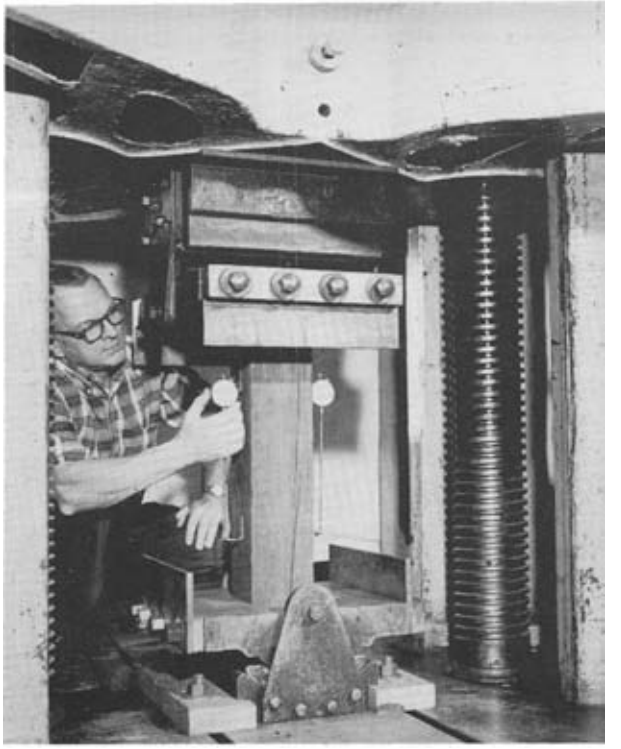

Figure 5.--Full-sized post specimen in compression parallel to grain test in 1 million-pound testing machine. M 132 101

tests were conducted because the toughness test is known to he sensitive to decay, even in the incipient stages. The results indicate that decay, when present, had not progressed to the interior of the planks. In fact, the average of all specimens tested is higher than the average for four major southern pine species (at 12 percent, moisture content)[4] There is considerable variation between the five courses (or distance from surface line) of planks and between planks from the four sides of the building, but the toughness test by nature is quite variable and no consistent trends are apparent, For instance, in course No. I (top course), the south side has the highest average toughness value. However, when each course is considered for the highest average value, each side is represented at least once.

The results of static bending tests are shown in table 2. Again, no consistent trends are evident with respect to distance from surface line ox between sides of the building. There is some indication that the material from the top course is stronger and stiffer than remaining courses,

[3]The authors are indebted to Henry G. Roth, Forest Products Laboratory, for all creosote analyses, which were conducted according to standard procedures of the American Wood Preservers' Association.

[4]U.S. Forest Products Laboratory. Wood Handbook. U.S. Dep. Agr., Agr. Handb. No. 72. 1955.

Table 1.--Results of toughness tests on specimens cut from foundation planks

Course and average for wall	Toughness by specimen location				Average by course
	South	West	East	North	
	In.-lb.	In.-lb.	In.-lb.	In.-lb.	In.-lb.
Course 1 (top)	259.2	103.2	208.6	152.6	.....
	309.0	309.0	137.8	78.2	.....
	309.0	152.5	227.2	210.4	.....
	243.5	214.8	142.8	158.5	.....
Average	280.0	195.0	179.0	150.0	201.0
Course 2	137.0	(1)	242.6	170.0	.....
	120.7	172.2	247.0	165.4	.....
	172.2	35.4	266.5	177.8	.....
	114.4	161.9	242.6	230.5	.....
Average	136.0	123.0	250.0	186.0	177.0
Course 3	(1)	122.1	194.2	245.4	.....
	73.4	158.5	205.8	128.6	.....
	160.8	264.1	154.9	168.9	.....
	205.8	198.4	67.9	46.9	.....
Average	147.0	186.0	156.0	147.0	160.0
Course 4	239.7	133.2	194.2	309.0	.....
	297.4	150.2	115.7	307.9	.....
	211.9	109.2	122.1	309.0	.....
	173.4	124.5	218.8	309.0	.....
Average	231.0	129.0	163.0	309.0	208.0
Course 5 (bottom)	159.6	127.1	141.7	77.5	.....
	242.6	156.0	85.5	139.3	.....
	198.4	(1)	157.3	204.7	.....
	282.0	217.9	145.4	119.5	.....
Average	221.0	167.0	133.0	135.0	164.0
Average by direction	206.0	162.0	176.0	185.0	.....

Average all specimens.	182.0
Average of four major southern pine species[2] . .	145.0

[1] Specimen culled because of knots or cross grain in a critical section.

[2] U.S. Forest Products Laboratory. Wood Handbook. U.S. Dep. Agr., Agr. Handb. 72. 1955.

Table 2.--Results of 1—by 1- and 2- by 2-inch static bending tests on specimens cut from foundation planks[1]

Course	South		West		East		North		Average by course (2" x 2" only)
	1" x 1"	2" x 2"	1" x 1"	2" x 2"	1" x 1"	2" x 2"	1" x 1"	2" x 2"	
	MODULUS OF RUPTURE (P.S.I.)								
1	15,200	16,200	15,100	13,300	14,100	11,800	12,000	11,000	13,100
2	11,100	10,400	11,300	11,200	13,100	11,700	14,000	11,800	11,300
3	10,000	9,500	13,100	12,500	12,000	10,700	13,400	10,900	10,900
4	14,200	12,300	11,700	9,400	12,100	9,900	15,100	13,600	11,300
5	13,900	12,900	12,300	12,000	9,600	10,800	11,600	10,300	11,500
Average by direction....	12,900	12,300	12,700	11,700	12,200	11,000	13,200	11,600	.....
Average all 2 by 2's.									11,600
Average all 1 by 1's.									12,700
Average of four major southern pine species[2]									14,000
	MODULUS OF ELASTICITY (1,000 P.S.I.)								
1	2,230	2,160	2,270	2,080	1,710	1,420	1,800	1,750	1,850
2	1,330	1,460	1,690	1,800	1,970	1,900	1,890	1,730	1,720
3	1,280	1,280	1,800	1,850	1,540	1,510	1,760	1,520	1,540
4	1,990	1,900	1,510	1,450	1,560	1,530	2,160	2,060	1,740
5	3,040	1,980	1,800	1,810	1,220	1,640	1,520	1,440	1,720
Average by direction....	1,780	1,760	1,810	1,800	1,600	1,600	1,830	1,700	.....
Average all 2 by 2's.									1,710
Average all 1 by 1's.									1,750
Average of four major southern pine species[2]									1,900

[1]Except for several instances where a specimen was culled because of knots or cross grain in a critical section, each value In the table is an average of 4 tests.

[2]U.S. Forest Products Laboratory. Wood Handbook. U.S. Dep. Agr., Agr. Handb. 72. 1955.

although there are notable exceptions to this in material from the north side. There was no matching of the material in the original installation, however, and the variation between course and sides of the building is within the natural variation Mat can be expected in a species. Also, the variation may be increased because identification of the material tested is limited to We southern pine group and several species may be represented.

Because the toughness tests gave no indication of decay in the interior of the planks, the 1- by 1-inch static bending specimens can be considered as controls for comparative purposes. The average modulus of rupture of the 2- by 2-inch specimens (which represent the full thickness of the planks) is approximately 1,100 pounds per square inch less than the 1- by 1-inch controls. However, if the average values are adjusted for size effect,[5] the difference is reduced to less than 200 pounds per square inch. (Estimated strength of a 2- by 2-Inch specimen = $\frac{\text{the strength of a 1- by 1}}{1.08}$.) Modulus of elasticity values for the two different groups are also essentially the same.

The average modulus of rupture and modulus of elasticity are somewhat lower than the average for four southern pines.[4] However, here too, precise comparisons are not too meaningful

[5]Bohannan, Billy. Effect of Size on Bending Strength of Wood Members. U.S. Forest Serv. Res. Pap. FPL 56, Forest Products Laboratory, Madison, Wis. 1966.

Table 3.--Results of compression tests on full-sized post sections and on minor specimens removed from post sections

Location	South	West	East	North[1]	Average
MAXIMUM CRUSHING STRENGTH (P.S.I.)					
Below ground line	4,110	3,360	3,340	3,110	3,530
Above ground line	4,320	4,970	4,460	4,410	4,540
Average of all full-sized specimens.... 4,020					
Average of six minor specimens..... 7,700					
Average of Douglas-fir (Coast Region)[2]..... 7,240					
MODULUS OF ELASTICITY (1,000 P.S.I.)					
Below ground line	1,980	1,870	1,930	1,460	1,810
Above ground line	1,700	2,100	2,330	1,815	1,990
Average of all full-sized specimens.... 1,900					
Average of six minor specimens..... 2,060					
Average of Douglas-fir (Coast Region)[2]..... 1,950					

[1] Values for one post. All other values represent average of two.

[2] Average values at 12 percent moisture content from Wood Handbook.

because of the natural variation both within and between species, Also, the results of the 2- by 2-inch tests are subject to more than normal error because of the difficulty in measuring the cross sectional dimensions with accuracy due to surface irregularities in the planks. This comparison, together with the comparison between the 2- by 2- and 1- by 1-inch results indicates that decay had not affected strength to an important degree.

Strength Tests from Post Material

The results of full-sized post tests and tests of minor specimens removed from the posts are shown in table 3. One post (north side) was excluded from the table because the bottom section was decayed to the extent that realistic area measurements could not be obtained However, the maximum load carried by this section was 35,750 pounds, indicating it was still capable of carrying a substantial load. Visual observations of the cross section of this post showed that treatment was very erratic or practically nonexistent.

No pronounced directional effects were noted between the four sides of the foundation. However, the averages for the lower sections were about 20 and 10 percent lower in crushing strength and stiffness, respectively. than averages for the same properties En the upper sections. This is at least partially due to moisture content differences. Because of creosote treatments, moisture contents could not be determined by the normal oven-drying technique, but moisture meter readings indicated that the top sections averaged about 14 percent moisture content while the bottom sections averaged about 17 percent. If maximum crushing strength values are adjusted for this 3 percent moisture content difference by the approximation method,[4] the values for the upper and lower sections differ by only about 200 to 300 p.s.i.

The average crushing strength of all post sections was substantially lower than the average value for clear material. However, this can be attributed to strength-reducing growth characteristics because the minor compression specimens removed from six posts averaged above normal for the species (table 3).

Pathological Considerations

There was little difference in the moisture contents of boards comprising the north and south foundation walls, In most cases. moisture contents were below the fiber-saturation point (table 4), that is, below 30 percent moisture content based on ovendry weight of the wood.

The creosote concentrations in all planks (table 5) were well below the minimum of 8 to 10 pounds per cubic foot recommended for wood in contact with the ground. Retentions in the posts ranged from 1.2 to 12.8 pounds per cubic foot. There is no way of determining from these data the original creosote retentions, because the rate of loss of creosote from wood can be influenced by several factors. These include the dimensions, or surface-to-volume ratio, of the pieces; the type of creosote used (whether of high or low volatility) ; and the exposure conditions, such as moisture, ventilation, etc. Creosote depletion has been reported to be as great as 45 to 65 percent in the underground portions of 3/4-inch stakes following exposure of 9 to 10 years. [6]

[6] Colley, R. H., Henry, W. T., Leutritz, J., Jr., and Stasse, H. L. The 1948 Cooperative Creosote Project: 3/4-inch Stakes. Proceedings of the American Wood Preservers' Association 58: 181-208. 1962.

Table 4.--Moisture contents of foundation wall planks (based on readings taken within 1/4 inch of the face abutting soil)

Wall location	Vertical position of plank in wall[1]	Moisture content percent: Range	Moisture content percent: Average (eight planks)
North	[2]	--	--
	2	17-20	18
	3	17-44	21
	4	18-21	19
	5	20-45	26
South	[2]	--	--
	2	18-23	20
	3	19-21	21
	4	18-22	20
	5	20-30	22

[1] Vertical position is identified by numerical sequence starting with (1) at the top.

[2] The top planks were removed prior to initiation of moisture readings and were not included in this part of the study.

Table 5.--Creosote content of foundation planks and posts

Location in foundation[1]	Position of sample in plank	Amount of creosote present: Pct.	Amount of creosote present: Lb. per cu. ft.[2]
	PLANKS		
South - 5	Inner 5/8 inch	6.0	2.1
	Composite of cross section	6.0	2.1
	Outer 5/8 inch (facing soil)	4.2	1.5
South - 2	Inner 5/8 inch	17.5	6.3
	Composite of cross section	16.6	6.0
	Outer 5/8 inch (facing soil)	15.7	5.7
North - 2	Inner 5/8 inch	6.3	2.3
	Composite of cross section	6.1	2.2
	Outer 5/8 inch (facing soil)	6.0	2.1
North - 4	Inner 5/8 inch	8.3	3.0
	Composite of cross section	7.6	2.8
	Outer 5/8 inch (facing soil)	4.2	1.5
East - 1	Inner 5/8 inch	10.3	3.7
	Composite of cross section	10.9	3.9
	Outer 5/8 inch (facing soil)	13.5	4.8
	POSTS		
South wall		10.1	3.0
North wall		3.9	1.2
East wall		19.9	6.0
West wall		42.6	12.8

[1] Vertical position of plank is identified by numerical sequence starting with (1) at the top.

[2] Computed by using 36 lb. per cu. ft. for density of southern pine and 30 lb. per cu. ft. for Douglas-fir.

Although the stakes were smaller in size and subject to more severe moisture conditions than the foundation material considered here, this is somewhat offset by the much longer period that the foundation was in use. Therefore, the creosote losses in the foundation material may be somewhat comparable to those reported for the stakes.

No consistent differences in prevalence of decay were found between planks located in the north, east. and west foundation walls (table 6). However, somewhat less decay was present in the south wall. Eight of the 50 planks examined contained no decay. Six of these planks were located in the south wall. Decay, when present, was generally confined to the surface in contact with the soil, and its greatest depth of penetration in the planks was 6.5 millimeters (table 6). No consistent differences in depth of decay were found between planks situated in different positions vertically in the foundation walls (table 6).

If the moisture contents of the planks (table 4), as determined in May just prior to their removal, are considered representative of those which generally prevailed during the three decades they were in use, then it is understandable why decay progressed so slowly. Wood is not considered to be liable to serious decay when its moisture content is below the fiber-saturation point. However, we cannot be certain that moisture contents were not higher at times during the 30 years.

Fungi capable of causing wood decay are generally divided into two broad groups, the typical wood-rot: fungi (Basidiomycetes) and the soft-rot fungi. The former are capable of relatively rapid and thorough disintegration of wood and are responsible for the majority of decay encountered in wood products. The latter are a heterogeneous group of fungi, which generally

Table 6.--Depth and type of decay present in foundation wall planks

Wall position	Vertical position of plank in wall[1]	Depth of visible decay in millimeters[2]			Type of decay present	
		Plank No. 1	Plank No. 2	Average	Soft rot	Typical wood rot
North	1	3.5	5.0	4.3	×	
	2	5.0	4.0	4.5	×	
	3	4.0	4.0	4.0	×	
	4	5.0	5.5	5.3	×	
	5	4.0	5.0	4.5	×	
South	1	3.5	0	1.8	×	
	2	2.5	0	1.3	×	
	3	0	0	0	×	
	4	4.0	0	2.0	×	
	5	5.0	0	2.5	×	
East	1	3.0	3.5	3.3	×	×
	2	4.5	3.0	3.8	×	
	3	6.5	3.0	4.8	×	
	4	6.5	3.0	4.8	×	
	5	3.0	3.0	3.0	×	
West	1	0	0	0		
	2	6.5	2.5	4.5	×	
	3	5.0	3.5	4.3	×	
	4	5.0	6.0	5.5	×	
	5	6.0	3.0	4.5	×	

[1] Vertical posit-ion is identified by numerical sequence starting with (1) at the top.

[2] Decay was generally confined to the plank surface butting on soil, hence the values given here represent the depth of decay present on that plank face,

cause an erosion-like decay of wood surfaces. They are most apt to be dominant in wood which is insufficiently treated with preservatives. or which is otherwise placed under environmental conditions not conducive to invasion by Basidiomycetes, such as poor aeration, high moisture, or where frequent drying is encountered. In the present study, typical wood rot was present and dominant in only one of the boards examined Soft-rot organisms were responsible for the remainder of the decay encountered in these boards (table 6). The dominance of the latter fungi was most likely due to their greater tolerance to low concentrations of creosote than that. of most Basidiomycetes.

SUMMARY

The moisture content of the foundation material, measured prior to removal, was in general below the fiber-saturation point. Creosote retentions were consistently low in the southern pine plank material, and they ranged from substandard (1.2 pounds per cubic foot) to very good (12.8 pounds per cubic foot) in the Douglas-fir posts. In the planks, decay was essentially limited to the surface in contact with the soil. The maximum depth of penetration of decay in the planks examined was 6.5 millimeters. Decay was predominantly by the soft-rot fungi, probably because they have greater tolerance to low creosote retentions than do the more destructive wood-rot fungi. Also, the soft-rot fungi may be somewhat more tolerant of low moisture contents in wood. No detailed observations were made on the posts, but decay seemed more variable. Where treatment was thorough, there was no evidence of decay. In two posts where creosote determinations were low, decay was prevalent. In one instance, the cross section of the post was reduced to about one-half its original dimension.

The strength properties of the plank and post material were not significantly reduced when compared to apparently sound core material and to the average strength properties of clear material for the species involved. The comparison would probably be somewhat less favorable for the foundation material if stress was calculated using the dimensions that prevailed before the occurrence of decay. The cross section of some planks and posts had been reduced by surface deterioration, and the stresses obtained reflect only the strength of the remaining material. It is quite evident, however, that even after 30 years of use, this wood foundation was giving excellent service and effectively meeting its requirements.

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- Fungus and insect Defects in Forest Products
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- Glue, Glued Products, and Veneer
- Growth, Structure, and Identification of Wood
- Milling and Utilization of Timber Products
- Mechanical Properties and Structural Uses of Wood and Wood Products
- Modified Woods, Paper-Base Laminates, and Reinforced Plastic Laminates
- Sandwich Construction
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As our Nation grow, people expect and need more from their forests--more wood; more water, fish and wildlife; more recreation and natural beauty; more special forest products and forage. The Forest Service of the U.S. Department of Agriculture helps to fulfill these expectations and needs through three major activities:

* Conducting forest and range research at over 75 locations ranging from Puerto Rico to Alaska to Hawaii.

* Participating with all State forestry agencies in cooperative programs to protect, improve, and wisely use our Country's 395 million acres of State, local, and private forest lands.

* Managing and protecting the 187-million acre National Forest System

The Forest Service does this by encouraging use of the new knowledge that research scientists develop; by setting an example in managing under sustained yield, the National Forests and Grasslands for multiple use purposes: and by cooperating with all States and with private citizens in their efforts to achieve better management, protection, and use of forest resources.

Traditionally, Forest Service people have been active members of the communities and towns in which they live and work They strive to secure for all, continuous benefits from the Country's forest resources.

For more than 60 years, the Forest Service has been serving the Nation as a leading natural resource conservation agency.