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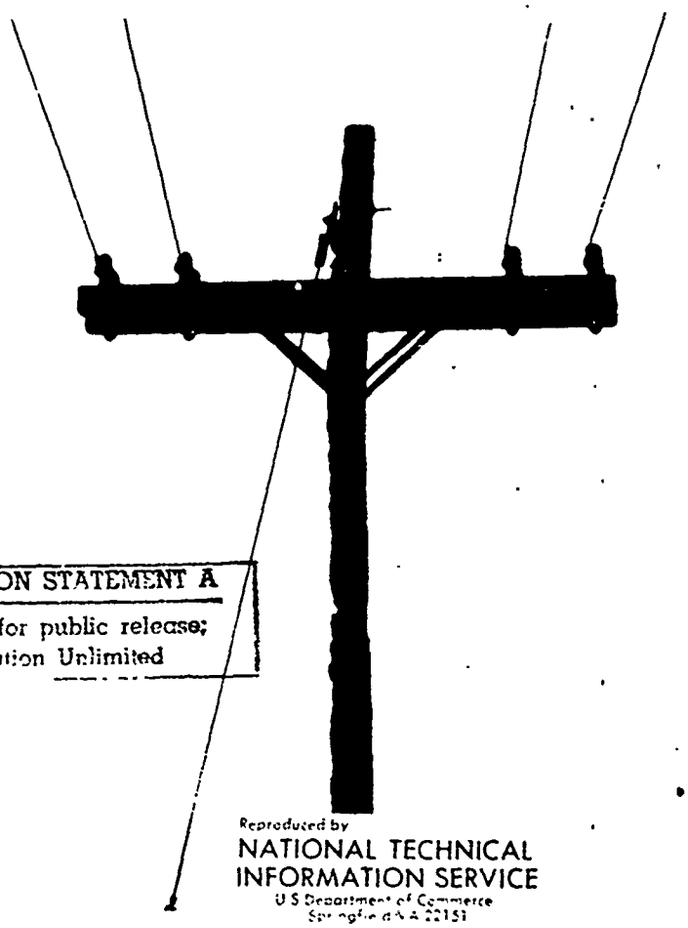

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Abstract

Telephone crossarms, differing in species, adhesive type, and preservative treatment, were tested for adhesive bond quality after field exposure. The results in six of the seven groups were considered to be quite good. The seventh group had been bonded with a urea resin, and, although bond strength was highly variable, the average strength was higher than would normally be expected. The reason for the unexpected results with urea was felt to be the water-repellent effect of the preservative treatment used.

EVALUATION OF ADHESIVE-BOND QUALITY IN TELEPHONE CROSSARMS AFTER 16 TO 23 YEARS OF EXTERIOR EXPOSURE

By

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Introduction

In the fall of 1946, the first experimental glue-laminated timber crossarms were produced for Bell Telephone Laboratories. This initiated a program of research designed to alleviate the problem of shortages of suitable lumber for producing solid-timber crossarms. The purpose of the Bell program was to develop and evaluate suitable designs for laminated crossarms which could be produced economically from available lumber, and to determine the specifications that would be required for laminated crossarms to meet telephone field requirements (1).[2]

The initial group of experimental crossarms was followed by others produced during the period of 1946-1954. These groups differed in species, preservative treatment, adhesive, and crossarm design. As a part of the experimental program, representative crossarms from the experimental groups were placed on outdoor exposure for long-term weatherability studies. The crossarms had weathered for periods ranging from 16 to 23 years when the exposures were terminated by Bell Laboratories. The weathered crossarms were then offered to the Forest Products Laboratory for evaluation because of the Laboratory's continuing general interest in the permanence of adhesive-bonded wood products.

This report describes the results from evaluations of 63 weathered crossarms for adhesive-bond quality by standard block-shear tests and wood-failure estimation.

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

[2] Underlined numbers in parentheses refer to literature cited at end of this report.

Table 1.--Summary of tests of glue bond quality of the laminated crossarms after long-term exterior exposure

Group	Number of crossarms	Number of observations	Species[1]	Adhesive[2]	Preservative[3]	Exposure period	Average shear strength	Wood failure	Shear strength: Standard deviation	Shear strength: Coefficient of variation
						Yr.	P.s.i.	Pct.	P.s.i.	Pct.
I	12	120	Sp	R	P	16	1,445	90	270	19
II	8	200	Sp	R	X	16	1,145	94	290	26
III	9	90	Df	R	P	23	1,270	100	320	25
IV	7	140	Sp	R	P	[4]17	965	98	325	34
V	5	50	Df	R	C	19	1,100	100	255	23
VI	9	150	Sp	Pr	C	19	1,280	87	430	34
VII	11	150	Sp	U	C	19	1,075	76	480	44

[1] Sp = Southern pine, Df = Douglas-fir

[2] R = Resorcinol, Pr = Phenol-resorcinol, U = Urea.

[3] P = Pentachlorophenol, C = Creosote, X = Unknown

[4] Estimated.

Description and History of the Crossarms

Two basic types of crossarms were included in the study--a 10-foot crossarm with a 3-1/4- by 4-1/4-inch cross section, and a 6-foot crossarm with a 3-1/2- by 5-inch cross section. All of the crossarms had been bored and machined for the fitting of hardware and attachments.

In some instances, available information regarding adhesive type and preservative treatment used was rather vague for certain groups of crossarms. In these instances, the information shown in table 1 was based on visual observations and best guesses based on past experience.

Group I

Group I consisted of 12 laminated 6-foot crossarms. The arms were made of three laminates of southern pine, and were intended to be used with the gluelines vertical. This group was manufactured in July 1954, using a radiofrequency-cured, resorcinol-resin adhesive. The preservative treatment was 8 pounds per cubic foot of penta-petroleum. The arms were placed on exposure in late 1954 at Chester, N.J.

Group II

Group II consisted of nine laminated 6-foot crossarms. The arms were made of six laminates of southern pine to be used with gluelines horizontal. This group was manufactured in 1954 using a resorcinol adhesive. The preservative, if any, is unknown. These arms were placed on exposure at Chester, N.J., in 1954.

Group III

Group III consisted of nine laminated 10-foot crossarms. These arms were made of three laminates of flat-grained Douglas-fir. The top laminates of these arms were one piece, while both the middle and bottom plies were made up of three shorter pieces finger jointed to obtain the required length. Figure 1 shows the type of finger joint used. The arms were manufactured in November 1946, using a waterproof, room-temperature-setting resorcinol resin. The preservative treatment was pentachlorophenol. These arms were first placed on exposure at Limon, Colo., in September 1947, and later moved to Chester, N.J., in July 1954.

Group IV

Group IV consisted of seven laminated 10-foot crossarms. The arms were fabricated from five laminates of southern pine glued with a resorcinol-resin adhesive and treated with pentachlorophenol. The estimated date of manufacture is 1952.

Group V

Group V consisted of five laminated 10-foot crossarms. The arms were made of three plies of Douglas-fir, bonded with a resorcinol-resin adhesive, and preservative treated with creosote. These arms were constructed in the same manner as those in Group III, with the top laminate one piece and the middle and bottom made up of shorter, finger-jointed pieces. These arms were placed on exposure in February 1951.

Group VI

Group VI consisted of nine laminated southern pine 10-foot crossarms. Six of the arms in this group were five-ply, and three were of three-ply construction. The latter three were made with the outer plies of 8/4 thick, and the inner ply of 4/4 material (see figure 2). The arms in this group were manufactured in 1951 using a phenol-resorcinol adhesive and preservative treated with creosote. These arms were placed on exposure at Chester, N.J., in late 1951.

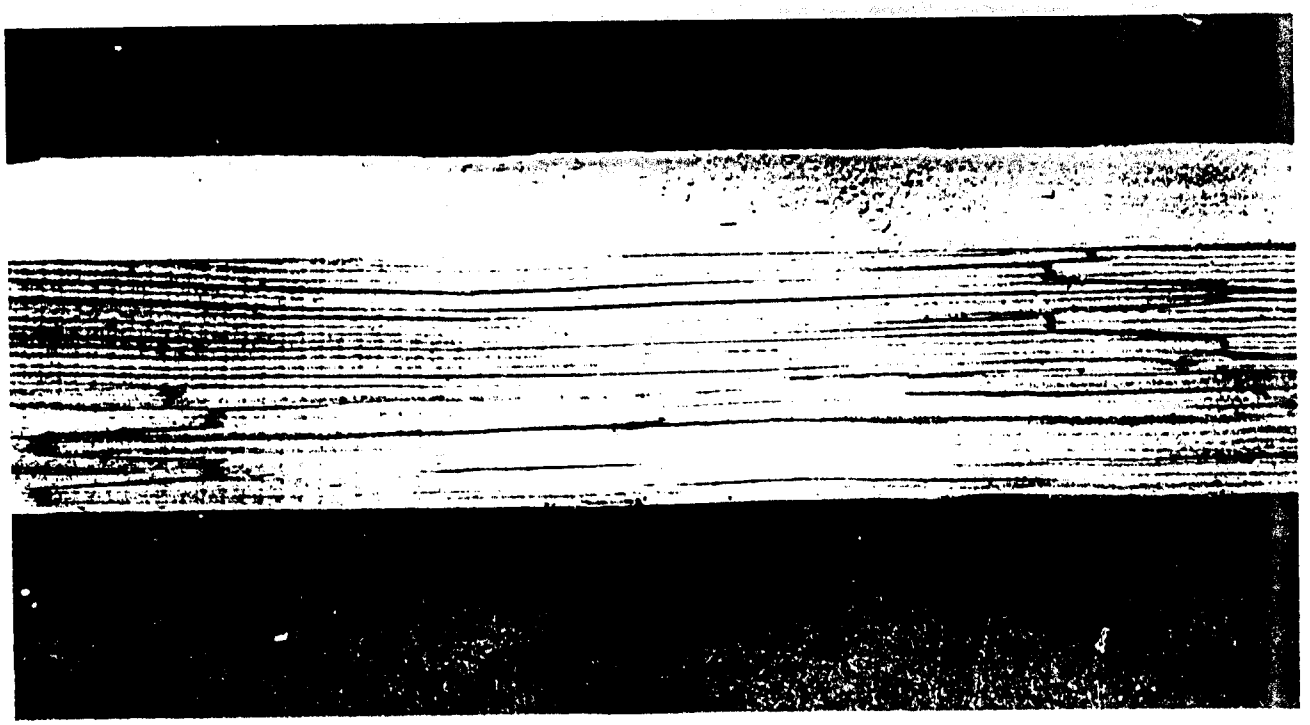

Figure 1.--Side view of a section of a crossarm from Group III showing type of finger joint used in the middle and bottom laminate.

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Group VII

Group VII consisted of 11 laminated southern pine, 10-foot crossarms. Eight of the arms were three-ply, and three were of five-ply construction. This group of crossarms was manufactured in 1951, using a urea-resin adhesive, and were treated with creosote. The arms were placed on exposure at Chester, N.J., late in 1951.

Crossarms of Groups I, II, III, and V were removed from exposure racks in 1967 and stored in outdoor ventilated stacks until sent to the Forest Products Laboratory in March 1970. Groups IV, VI, and VII remained on exposure until September 1969, when they were sent to the Laboratory.

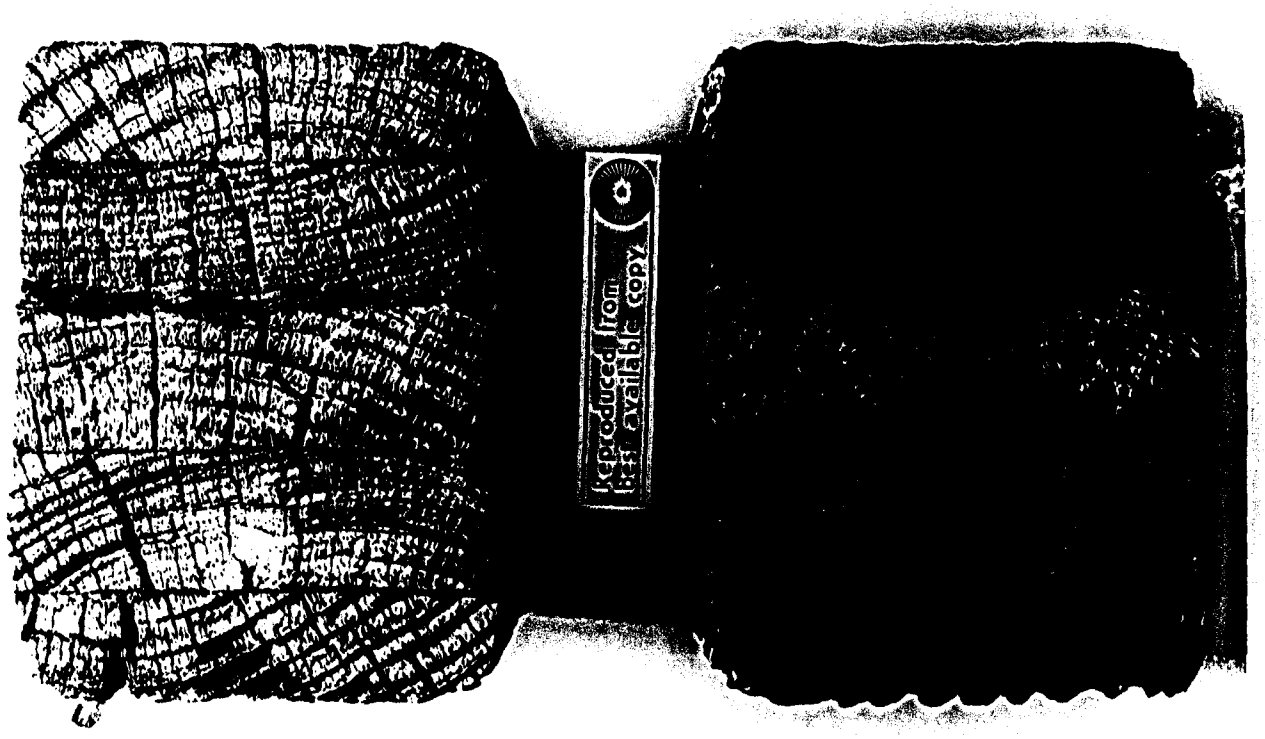

Figure 2.--End view of two crossarms; the arm on the left was treated with a preservative in light oil; the one on the right with a preservative in heavy oil. The heavy oil apparently acted as a water repellant and significantly reduced checking.

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Testing Procedure

When the crossarms were received at the Forest Products Laboratory their moisture content as determined by a resistance-type meter was between 9 and 12 percent.

Five stair-step-type shear blocks, as described in ASTM D 2559 and shown in figures 3 and 4, were taken from each crossarm. The 10-foot arms were first cut in half with the shear specimens taken from one-half and the remaining half held in reserve. The half arm to be tested was then planed to remove nearly an equal amount from each side and to reduce its thickness to 2 inches. After planing, shear specimens were cut from locations between the insulator-pin holes bored in the crossarms and between the finger joints in samples from Groups III and V.

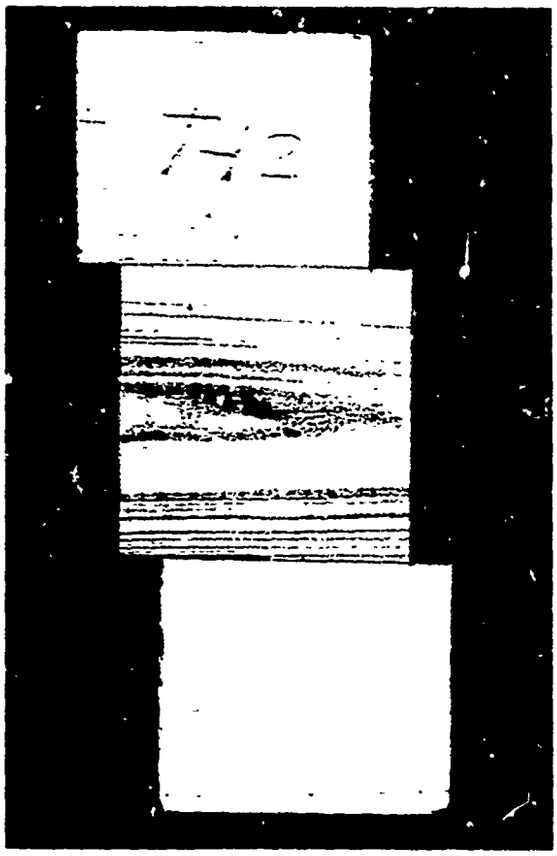

Figure 3.--Stair-step-type shear block from a crossarm made with three laminations of nominal 2-inch lumber.

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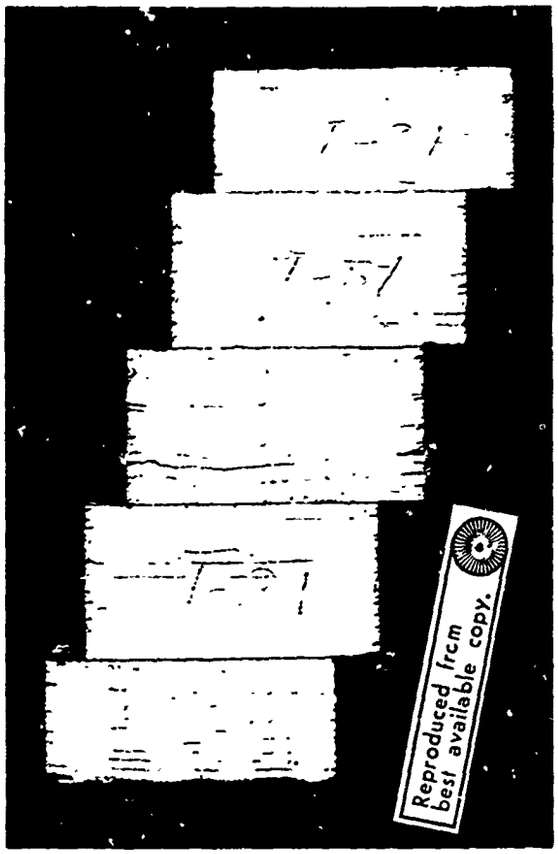

Figure 4.--Stair-step-type specimen from a crossarm made with five laminations of nominal 1-inch lumber

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The 6-foot crossarms were handled in the same manner with the exception that they were not cut in half. The length of the arms and the location of the insulator-pin holes made it impossible to obtain the desired number of specimens from only half of each laminate.

At the time the specimens were cut, each was marked so that the top lamination could be determined at the time of testing with the exception of Group I crossarms which had been exposed with the gluelines vertical. No attempt was made to mark the location of individual specimens with respect to their positions along the length of the arm.

After cutting and coding, the specimens were conditioned at 80° F. and 65 percent relative humidity before testing for shear strength.

The shear tests were made in accordance with ASTM D 2557. The total load at failure, and the estimated percentage of wood failure, were recorded for each glueline in each specimen tested.

Results and Discussion

General Appearance After Weathering

The general appearance of most of the crossarms was good. The arms treated with a preservative in a heavy oil exhibited less checking than did the arms treated with a preservative in a light oil carrier (fig. 2). Group III, which had been treated with penta, showed decay present at finger joints and in insulator-pin holes.

In Groups I through VI, very little delamination was present, and that which was present was never more than 3/8 inch deep. In Group VII, those bonded with urea-resin, the top ply in two of the arms was completely delaminated, and delamination was also present at the ends of several of the other arms.

Shear Strength and Wood Failures

A summary of the results of the tests in the laminated crossarms is presented in table 1. No attempt was made to make comparisons between groups of crossarms, species, preservative treatments, or adhesives. The study was not designed to do this originally and it is impossible to make statistically meaningful comparisons now.

In computing the average shear values and the standard deviations, zero values were included for gluelines which had delaminated during exposure, or which had failed during the cutting of the specimens.

The average shear strength and percentage of wood failure for the first six groups indicated that the adhesive bonds were in good condition after extended exterior exposure. However, since information was not available on the original bond quality of this material, it was impossible to determine how much, if any, bond degradation had occurred. Only indirect comparisons can be made between the values obtained here and previous tests made on similar material or with the published shear strength of solid wood of the same species.

Selbo (2,3,4) reported average block-shear values for southern pine, both penta and creosote treated, ranging from 1,550 to 1,750 pounds per square inch. In the same studies, the average shear strength of treated Douglas-fir ranged from 1,300 to 1,350 pounds per square inch. This material was all selected to be clear, straight-grained, and of high density.

The average shear strength parallel to the grain for solid loblolly pine at 12 percent moisture content is 1,370 pounds per square inch. The shear strength of coast-type Douglas-fir under the same conditions is 1,130 pounds per square inch. The above values were determined from ASTM D 2555-69.

Based on the preceding data, the average shear values obtained for Groups II, IV, and VI are lower than would be expected for southern pine. In an attempt to find a possible cause for the low shear values, it was noticed that the wood used in these groups tended to be of low density. Pieces that contained 60 to 90 percent earlywood in their cross section were not uncommon, whereas the material in Group I contained 50 percent and more latewood. The belief that wood density was primarily responsible is further substantiated by the high percentage of wood failure obtained in conjunction with the low shear strength. The presence of preservatives in the laminates precluded any measurement of the weathered wood density.

Group I specimens had the highest average shear strength, and exhibited the least variation of any of the groups tested. This group was the only one in which the adhesive had been cured with radiofrequency energy. Although this group performed quite well, it is felt that this was primarily a reflection of the quality of the wood used rather than the method of curing the adhesive.

Groups III and V, laminated from Douglas-fir, had average shear strength close to the published average for the species. These two groups also exhibited excellent wood-failure results, both averaging 100 percent. The only group with a lower coefficient of variation than these two was the southern pine Group I.

The Group VII crossarms were fabricated using 3/4-inch southern pine bonded with a urea-resin adhesive and treated with creosote. After 19 years of exterior exposure, they still exhibited a notable average shear strength and percentage of wood failure. However, two of the crossarms in the group had one ply (the top one) completely delaminated, and several others had some delamination at the ends of the arms. The delamination present and the associated zero shear strength values are reflected in the high coefficient of variation shown for this group.

With the exception of the Group VII crossarms, the data did not indicate the existence of any trends in shear strength between the top and bottom gluelines in the crossarms.

Conclusions

Based on the results obtained in this study, it can be concluded that the bond quality in six of the seven groups tested was still very good after 16 to 23 years of exterior exposure. Nothing in the data conclusively indicated any advantage for a particular preservative treatment or species. While a urea-resin adhesive would not be recommended for laminated crossarms because of the highly variable shear strength and the prevalence of delamination, this study does suggest that a preservative treatment using a heavy oil carrier provides a measure of protection resulting in a performance far exceeding that normally expected of a urea-resin adhesive.

Acknowledgment

The author would like to thank Bell Laboratories for supplying the material and background information for this study.

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