RESULTS OF ACCELERATED TESTS AND LONG-TERM EXPOSURES ON GLUE JOINTS IN LAMINATED BEAMS

Information Reviewed and Reaffirmed

March 1956

No. 1729

FOREST PRODUCTS LABORATORY
MADISON 5, WISCONSIN

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
In Cooperation with the University of Wisconsin

RESULTS OF ACCELERATED TESTS AND LONG-TERM EXPOSURES ON GLUE JOINTS IN LAMINATED BEAMS[1]

By

T. R. TRUAX, Technologist
and
M. L. SELBO, Chemical Engineer

Forest Products Laboratory,[2] Forest Service
U. S. Department of Agriculture

Abstract

A rapid method developed at the U. S. Forest Products Laboratory for determining the durability of glue joints in laminated beams intended for exterior service is described. The test is based on the principle that severe shrinking and swelling of laminated members produce stresses that cause checking of wood, failure of glue joints, or both. Vacuum and pressure are employed in bringing about the desired conditions of shrinking and swelling.

Results of the test are correlated with more extended laboratory exposures and with long-term soaking and weathering.

Introduction

The development of new glues and gluing methods has been more or less paralleled with the development of new or modified test methods for their evaluation. Testing of glues dates back many decades and undoubtedly was practiced much earlier than existing records indicate. With each new development in the field of woodworking glues there has arisen a need for new or modified test procedures that fully evaluate the new product -- its properties, application, and usefulness.

Through the years some form of joint test has been the common and generally accepted method of testing most glues for wood joints and the adequacy of such joints for different uses. Many types of joint tests have been devised and used

---

[1] Presented at the annual meeting of the Wood Industries Division of the American Society of Mechanical Engineers at Atlantic City, N. J., December 2-5, 1947.

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

with variations in the form of specimens, the exposure or treatment of the joints before test, and the method of applying the load or stress to determine the strength and performance of the bond. The block-shear and plywood-shear tests, developed at the U. S. Forest Products Laboratory during the World War I period, have been extensively used in determining the bonding strength of glues and the importance and limitations of gluing procedures.[3] When the specimens were subjected to various exposures before test, the two methods, and especially the plywood-shear test, have also been valuable in determining the durability of glues and wood joints.

Production of water-resistant plywood during and following World War I and its evolution into a type suitable for exterior use was preceded or accompanied by the development of accelerated test methods. The adequacy of plywood for exterior service was first established by subjecting unprotected panels to the variable conditions of outside exposure. The standards for its production were established, and the control of essential quality has been maintained by the use of accelerated test methods carefully correlated to the performance of the panels in service. Likewise, in laminated construction there is in progress the evaluation of glues and gluing techniques under different service conditions and of testing methods that will assure the development of suitable standards and the maintenance of adequate glue bonds in service.

Laminated structural members for interior or limited exposures followed the development of water-resistant plywood in this country, but in Europe they have been in service since about the beginning of the century.[4] Because of the form and size of material and essential differences in the details of construction of plywood and laminated members, however, the test methods and means of evaluating the two forms of construction must be varied. Furthermore, the methods in use for evaluation of the glue joints in interior laminated members are not adequate for judging the performance of joints under exterior exposure.

The necessity for test methods more discriminating in regard to durability of joints in heavy laminated construction than were provided by existing methods became apparent during the development of processes for laminating timbers for exterior use at the start of World War II. Laminated oak timbers that gave initial high strength in the block-shear test soon developed delamination of glue joints when exposed to the weather.[5] This led to the conclusion that test methods more nearly simulating service condtions would be necessary for evaluating the suitability of glue joints for exterior use.

Laminating for exterior use, like many other major developments, was prompted by an urgent need in time of war. The Navy needed immense numbers of ships and boats, the building of which soon brought on a shortage of available materials. White, oak, the foremost shipbuilding species, seasons slowly, especially in large dimensions. Nominal 1-inch oak lumber, however, can be dried in a

---

[3] Truax, T. R., "The Gluing of Wood," U.S.D.A. Bulletin No. 1500, 1929.

[4] Wilson, T.R.C., "The Glued Laminated Wooden Arch," U.S.D.A. Tech. Bull. No. 691, 1939.

[5] Dosker, C. D. and Knauss, A. C., "Laminating Lumber for Extreme Service Conditions," Mechanical Engineering, Vol. 66, No. 12, pp. 763-773, December 1944.

relatively short time. A process was therefore developed whereby boat and ship timbers of the desired shapes and sizes and timbers for other exterior uses were laminated from kiln-dried lumber with intermediate-temperature-setting phenol and later with resorcinol-resin glues.

In exterior use timbers are subjected to wetting and drying that cause severe stresses and a tendency to check. In laminated timbers these stresses are more or less concentrated at the glue lines. In addition, the laminations are usually relatively thick, in comparison with veneer used for plywood, and the requirements on glue line performance are even more rigid than in exterior plywood. Hence, accelerated tests that accurately predict the durability of laminated members under exterior exposure are of considerable importance.

The work of the U. S. Forest Products Laboratory on test procedures and test methods discussed in the following pages deals exclusively with types of glues, such as phenol, melamine, and resorcinol resins that, when properly used, have been found durable in exterior service.

Development of Accelerated Test Methods

During service, timbers used for exterior purposes may be expected to undergo considerable change in moisture content. To furnish dependable test results, stresses similar to those that might occur in service must therefore be induced during the test and, furthermore, the possible leaching or solvent effect of moisture upon the glue must be simulated. The two accelerated tests, described in the following paragraphs, were intended to simulate these conditions.

Soaking-Drying Cyclic Delamination Test (180-Day Test)

Sections 2 inches long were cut from laminated beams 8 by 10 or 6 by 6 inches in cross section and exposed to a repeating cycle of soaking for 30 days followed by drying in a room at 80° F. and 30 percent relative humidity for 30 days. The test included three complete cycles for a total test period of 180 days. Observations were made on the condition of the sections and, during the first week of drying in each cycle when the delamination was most in evidence, the total length of open glue joints on the sections was measured. This was expressed as a percentage of the total length of glue joints exposed and referred to as the percentage delamination. A low percentage of delamination indicates durable joints and a high percentage poor durability. Examples of good and poor durability as indicated by the 180-day cyclic test are shown in figures 1 and 2.

Vacuum-Pressure, Soaking-Drying Cyclic Delamination Test (21-Day Test)

The chief disadvantage of the 180-day cyclic test was its extended duration, and consequently attention was paid to development of a test method that would be less time consuming. It was found that by application of vacuum and pressure the moisture content of 6- by 6-inch beam sections 3 inches long could be brought well above the fiber-saturation point and often as high as 80 percent or more in a period of 24 hours. Since the checking in the wood and open glue joints usually were more pronounced during the first week of drying, it was assumed that the drying part of the cycle might also be shortened. Eventually the following test procedure was evolved:

The test sections were placed in an autoclave or other type of pressure vessel; they were immersed in water at room temperature and weighted down to keep them submerged. A vacuum of 20 to 25 inches of mercury was then drawn and held for 2 hours. The vacuum was released and air pressure of 75 pounds per square inch was applied for 2 hours. The vacuum-pressure cycle was repeated once, while the specimens remained immersed. The soaking was continued for an additional 16 hours at atmospheric pressure. The specimens were then dried in a room maintained at 80° F. and 30 percent relative humdity and provided with brisk circulation of air. The sections were placed at least 2 inches apart and with the end-grain surfaces parallel to the stream of air. The drying was continued for a total period of 6 days. The entire soaking-drying cycle was repeated twice for a total test period of 21 days. The total length of open glue joints (delamination) on the end-grain surfaces of the sections was measured during the part of the drying period of the third and final cycle when the checking of the wood and open glue joints were most in evidence (usually during the third or fourth day of drying). To facilitate measurement of delamination, the end-grain surfaces of the sections were cut or sanded smoothly prior to the start of the test. A magnifying glass was used as an aid in measuring delamination.

Examples of different degrees of durability as indicated by the vacuum-pressure 21-day cyclic test are illustrated in figures 3 and 4.

It is realized that variations in the 21-day test may be permissible without making the test less useful, and further work is planned with the idea of shortening the test period. For example, two cycles requiring 14 days instead of the three cycles requiring 21 days might be sufficient. Some available data, however, indicate that three cycles are preferable to two.

In table 1 the amount of delamination developed in each of 24 white oak beam sections after one, two, and three cycles in the accelerated vacuum-pressure, soaking-drying test is shown. The average delamination value for all sections after various cycles is shown graphically in figure 5. In general, the amount of delamination increased with each of the three cycles but the average rate of increase was greatest in the first cycle and less in each of the two succeeding cycles, with an indication that the amount of further delamination beyond the three cycles would be small, provided the test was continued further. Usually after a few cycles of severe soaking and drying the internal stresses are largely relieved, either by failure of the glue joints or by checking of the wood, and the amount of glue joint delamination brought about by further exposure is relatively small. On the other hand, if the test is carried through only two cycles where the rate of increase in delamination is still appreciable, there is less assurance that the results are true indications of the durability of the glue joints than when three cycles have been completed and the delamination has more nearly reached its maximum.

Long-Term Exposures

To be of value any test method for laminated members intended for exterior service should produce results indicative of durability in such service. Long-term weather exposures and continuous soaking tests of laminated beams were therefore started early in the work as a control for other tests.

Weathering Tests

For the weathering tests beams were made 6 by 6 or 8 by 10 inches in cross section and about 4 feet in length. To one end of each beam a protective coating was applied after which the beams were placed on racks and subjected to outdoor exposure with the unpainted ends directed south. At intervals of a year or less the unpainted end of each beam was inspected for delamination. At the time of the inspections block-shear tests were usually made on sections cut from the painted ends of the beams.

Soaking Tests

Laminated beams 8 by 10 inches in cross section and about 4 feet in length with a protective coating on one end were immersed in salt water (4 percent) for periods up to 3-1/2 years. They were examined for delamination at regular intervals and sections were also cut from them for block-shear tests. These sections were conditioned to about 12 percent moisture content before the block-shear specimens were cut and tested.

Correlation of Results From the Various Tests

The ultimate aim of the various tests was to determine the durability of the glue bonds under severe exposure conditions and the test method that might be the most dependable for predicting durability as well as being easily and quickly carried out. For this purpose a comparison of results from various test methods became necessary.

During the progress of the laminating studies beams were made up from time to time with different glues and under different curing conditions so that they represented considerable variation in glue bond quality. The beams were subjected to one or more of the four test procedures previously described and usually two of the testing methods were applied to the same beams. In other cases duplicate beams, made at different times with the same glue and gluing conditions but tested by different methods, afforded a basis for comparison of testing procedures.

Comparison of Continuous Soaking and Weathering Exposures

Results of continuous soaking for periods up to 3-1/2 years of 60 some beams (fig. 6) and weathering tests on a considerably larger number indicated that exposure to weathering produces delamination much more rapidly than continuous soaking. Only a few specimens among the beams exposed to soaking developed small amounts of open glue joints during the 3-1/2-year period; whereas beams similarly made and exposed to the weather in many cases developed large amounts of open glue joints. Shear blocks cut from beams during soaking and reconditioned to about 12 percent moisture content before testing in general showed no appreciable weakening, indicating that prolonged continuous soaking had very little deteriorating effect on the glue bonds. When beams that had been soaked for 3-1/2 years were dried, considerable delamination developed in some of them, but in others the glue joints remained intact even after severe drying. The beam shown in figure 7 had developed considerable delamination in practically every joint after 4 years of exposure to the weather; whereas a beam similarly glued and cured but exposed to continuous soaking was practically free from joint failure after 3-1/2 years' exposure. In the beams exposed to weathering, the glue joints that showed little or no opening during the first year usually remained in about the same condition throughout the several years of exposure.

Comparison of Results From the 180-Day Cyclic Test and the 21-Day Vacuum-Pressure Cyclic Test

As far as the time element is concerned the 21-day cyclic test is a great improvement over the 180-day test. The means of testing durability, by inducing stresses that would result in checking or delamination or both, was similar for both tests. The possible leaching or solvent effect might, of course, be greater for the longer soaking periods of the 180-day test. In the continuous soaking tests of beams and also in previous work with plywood,[6] it was established, however, that the effect of soaking on the types of glues that are durable under severe exposure is not appreciable, and for this reason it was considered that the shortening of the soaking period would probably not affect the results. In table 2 delamination values are shown for two different groups of test sections from beams similarly glued and cured, one group having been subjected to the 21-day test and the other group to the 180-day test.

There is no very close agreement between the results from individual sections of each pair, but the general trend indicated by the two tests is similar, and if average for groups of five sections are considered rather than results for individual sections, the similarity becomes more obvious. The results show that where the delamination is small the test values from the 21-day test are slightly higher than those from the 180-day test. With increased magnitude of delamination, however, the reverse trend is indicated. It is possible that with highly undercured glues, the longer leaching period of the 180-day test may be more damaging to the joints; on the other hand, the differences in results are somewhat inconsistent and are probably not significant.

---

[6] Wangaard, F. F., "Summary of Information on the Durability of Woodworking Glues." Forest Products Laboratory Report No. 1530 (Revised 1946).

Comparison of Results of the Weathering Test and the Accelerated Vacuum-Pressure, Soaking-Drying Test

Since exposure to weathering causes deterioration of imperfect glue bonds (made with phenol, melamine, or resorcinol resins), it was used as a basis of comparison for the accelerated vacuum-pressure, soaking-drying cycles. It is recognized that weather conditions vary in different localities and result in a more severe exposure in one part of the country than in other parts. In the Madison area where these tests were conducted, however, the climatic changes throughout the year are rather drastic, and the stresses induced in unprotected wood products due to temperature and moisture changes are quite severe. Consequently, it is believed that the glues and curing conditions that produced bonds that performed satisfactorily in unprotected outdoor exposure throughout the yearly cycle would be adequate for most exterior service; whereas appreciable delamination would indicate inadequate bonds. However, no attempt has been made to determine the relation of the severity of weathering period to the cyclic test in deterioration or delamination of glue joints.

In table 3 a comparison is made between results of the 21-day cyclic test and weather exposure on white oak beams. Percentage delamination (length of open glue joints) is shown in parallel columns for beam sections subjected to cyclic test and the beams exposed to the weather for approximately 1 year. Similar comparative tests were made using the 21-day cyclic and the weathering tests on groups of hard maple, southern yellow pine, and Douglas-fir beams. In most cases the specimen for the cyclic test was cut from the same beam that was exposed to the weather, and in every case the cyclic section represented the same species, glue, and curing condition that was used with the weather-exposure beam. In determining the amount of delamination in the cyclic test both end-grain surfaces of the specimen were examined and the condition of the glue joints recorded; whereas in the weathering test the amount of delamination in the glue joints was based on only the one end surface of the beam facing south. This may have been an important factor in determining the amount of delamination recorded in the two tests and may have affected to some extent the consistency of results.

The results on white oak beams (table 3) show considerable divergence between individual specimens, and the same was true for the other species. However, the general trend of increasing delamination in the cyclic test with increased delamination under exposure to the weather was exhibited in all the tests. This trend becomes even more apparent when the averages of groups of specimens are taken. Such averages of groups for the different species (southern yellow pine and Douglas-fir grouped together), shown in table 4 and presented graphically in figure 8, indicate the general relationship between the two types of test. The pattern of the data suggests the probability of a somewhat different relationship for the hardwoods and softwoods, but the indications are not yet sufficently definite to warrant positive conclusions.

The failure of glued joints is frequently the result of improper gluing techniques, and in the case of thermosetting glues to be used for exterior purposes improper cure has often been found to be an important cause of failure. The vacuum-pressure, soaking-drying cyclic test has been found convenient to determine the required curing temperature for different glues. Its use in determining the adequacy of joints in laminated white oak beams glued with two different intermediate-temperature-setting phenols is shown in figure 9, where percentage of delamination is plotted against the curing temperature.

The plotted values were obtained by applying the cyclic test to two 3-inch sections from each beam, while the remainder was exposed to the weather. Hence, each point on the graphs is based on results from two specimens. From the graphs it may be noted that the amount of delamination is closely related to temperature of cure and was found to correlate well with the amount of delamination that developed on the parts of the beams exposed to weathering.

Results of block-shear tests on the same white oak beams are also shown on figure 9. There was no significant difference in shear strength for the various curing temperatures. The wood failure values, however, decreased generally with lower curing temperatures and appeared to disclose incomplete cure and poor durability better than the strength results.

The appearance of beam sections and of the beams after the 21-day cyclic and weathering tests, respectively, are shown in figures 3, 4, 7, 10, 11, and 12. Figures 3 and 4 show white oak beam sections subjected to the vacuum-pressure cycle test, in which poor and good joint durability are indicated; figures 7 and 10 show two similar beams after exposure to the weather for 4 years with comparable results. Figures 11 and 12 show six white oak beams that represent a wide range in joint performance and durability when exposed to the weather, with the percentages of delamination obtained in the 21-day cyclic and weathering tests given in the titles of the figures.

Extensive block-shear tests were made on many of the beams immediately following their manufacture and at various stages during exposure in the other forms of test. Most of the results of such shear tests are not here presented because they were not found to indicate accurately joint performance under severe exposures. While the block-shear test is of value for the control of original joint quality, no close correlation exists between original joint strength and later delamination in weathering tests. Neither is block-shear strength after exposure as reliable an indication of joint durability as the percentage of delamination in accelerated cyclic tests. The estimated wood failures in the block-shear test have been found to be a better indication of durability under severe exposure than the shear strength values when glues of known durability are used. Estimated wood failures in the dry block-shear test, however, are of no value in distinguishing between durable and nondurable glues.

Conclusions

In conclusion it appears that the vacuum-pressure, soaking drying cyclic test gives a reliable indication of glue joint durability in laminated beams under severe exposure; that it is fairly comparable in severity and results obtained with a longer soaking-drying cyclic test; that wetting-drying cyclic tests are more severe than continuous soaking and more nearly comparable to weathering as an indication of joint performance in heavy timbers; and that the block-shear test, while of value in judging original joint strength, does not indicate joint durability under weather exposures as accurately as percentage of delamination in accelerated cyclic tests, but that details of the vacuum-pressure, soaking-drying cyclic test are not yet fully known, especially as related to different species.

Table 1.--Delamination in white oak beam sections after each of three vacuum-pressure, soaking-drying cycles

Cycle No.		
1	2	3
Delamination		
Percent	Percent	Percent
0.1	0.4	1.2
.3	1.1	1.5
.4	1.5	1.9
.6	1.6	1.8
.8	2.2	4.2
1.2	2.1	2.5
1.3	3.8	3.9
1.4	2.9	4.4
1.8	3.5	4.5
2.6	5.9	6.5
3.3	8.7	11.1
3.9	5.5	6.4
4.0	6.1	9.5
4.6	9.5	11.9
4.7	8.0	8.4
7.5	15.5	16.4
8.0	12.2	15.3
9.2	11.9	15.2
10.6	20.2	22.5
12.6	17.5	20.0
15.3	29.5	31.2
16.5	20.5	23.5
25.3	31.2	41.4
27.8	33.8	36.2
Av. 6.8	10.6	12.6

Table 2.--Delamination values in test sections taken from laminated beams similarly glued and cured, but subjected to different cyclic tests

Delamination developed in	
180-day test	21-day test
Percent	Percent
[1] 0.0	1.3
.0	2.1
.0	2.2
.0	2.6
.0	3.2
[2] .0	[2] 2.3
.1	3.5
.6	5.5
.6	1.0
.8	1.7
.9	5.8
[2] .6	[2] 3.5
1.2	2.4
1.9	4.3
3.9	2.2
4.2	1.8
4.4	2.5
[2] 3.1	[2] 2.6
5.5	4.1
6.5	4.1
11.1	6.1
11.9	6.0
14.8	16.5
[2] 10.0	[2] 7.4
15.2	8.4
15.8	20.3
16.4	10.2
22.5	23.5
31.2	20.0
[2] 20.2	[2] 16.5

[1] Reading down the left column the delamination values for the 180-day test are arranged in ascending order, and in the right column delamination values are shown for sections similarly glued and cured but subjected to the 21-day test.

[2] Average of 5 preceding values.

Table 3.--Amount of delamination developed in white oak beam sections subjected to the accelerated vacuum-pressure cyclic test (21-day test) and in beams exposed to the weather for approximately 1 year

Delamination		Delamination	
In vacuum-pressure cycle	Under weather exposure	In vacuum-pressure cycle	Under weather exposure
Percent	Percent	Percent	Percent
0.5	3.1	10.2	28.0
.6	4.1	11.9	12.5
.9	4.4	12.0	28.0
.9	9.6	14.8	42.8
1.1	7.0	16.0	54.0
1.2	5.9	16.5	40.0
1.3	11.4	17.8	37.8
1.4	9.9	19.2	27.0
1.7	10.9	22.1	55.4
2.0	14.0	25.5	46.6
2.2	11.7	29.4	44.0
2.2	13.0	48.0	100.0
2.3	18.7	76.0	95.0
2.4	5.7	78.0	96.0
2.7	6.7	92.0	95.0
2.9	5.9	100.0	100.0
2.9	13.3		
3.3	6.0		
3.6	7.2		
4.1	6.0		
4.1	20.5		
4.2	25.1		
4.3	4.0		
4.4	7.0		
4.4	23.9		
5.9	18.1		
6.0	27.0		
6.1	11.2		
8.2	13.5		
9.5	32.6		

Table 4.--Average amount of delamination by groups of beams in the vacuum-pressure, soaking-drying cycle and weathering tests

Grouping by amount of delamination in cyclic test	White oak			Hard maple			Southern pine and Douglas-fir		
	Number of beams	21-day cycle	Weathering	Number of beams	21-day cycle	Weathering	Number of beams	21-day cycle	Weathering
		Delamination			Delamination			Delamination	
Percent		Percent	Percent		Percent	Percent		Percent	Percent
0 to 1.0	4	0.8	5.3	3	0.8	4.5	28	0.2	1.0
1.1 to 2.0	6	1.5	9.8	7	1.7	6.8	7	1.8	2.2
2.1 to 5.0	15	3.3	11.6	8	2.3	12.7	9	3.0	4.0
5.1 to 10.0	5	7.1	20.5	2	6.6	18.8	5	7.0	10.7
10.1 to 20.0	8	14.8	33.8	4	11.7	33.6	4	12.6	13.0
20.1 to 30.0	3	25.7	48.7	0	....	....	2	24.8	27.6
Over 30.0	5	78.8	97.2	0	....	....	1	88.9	99.6

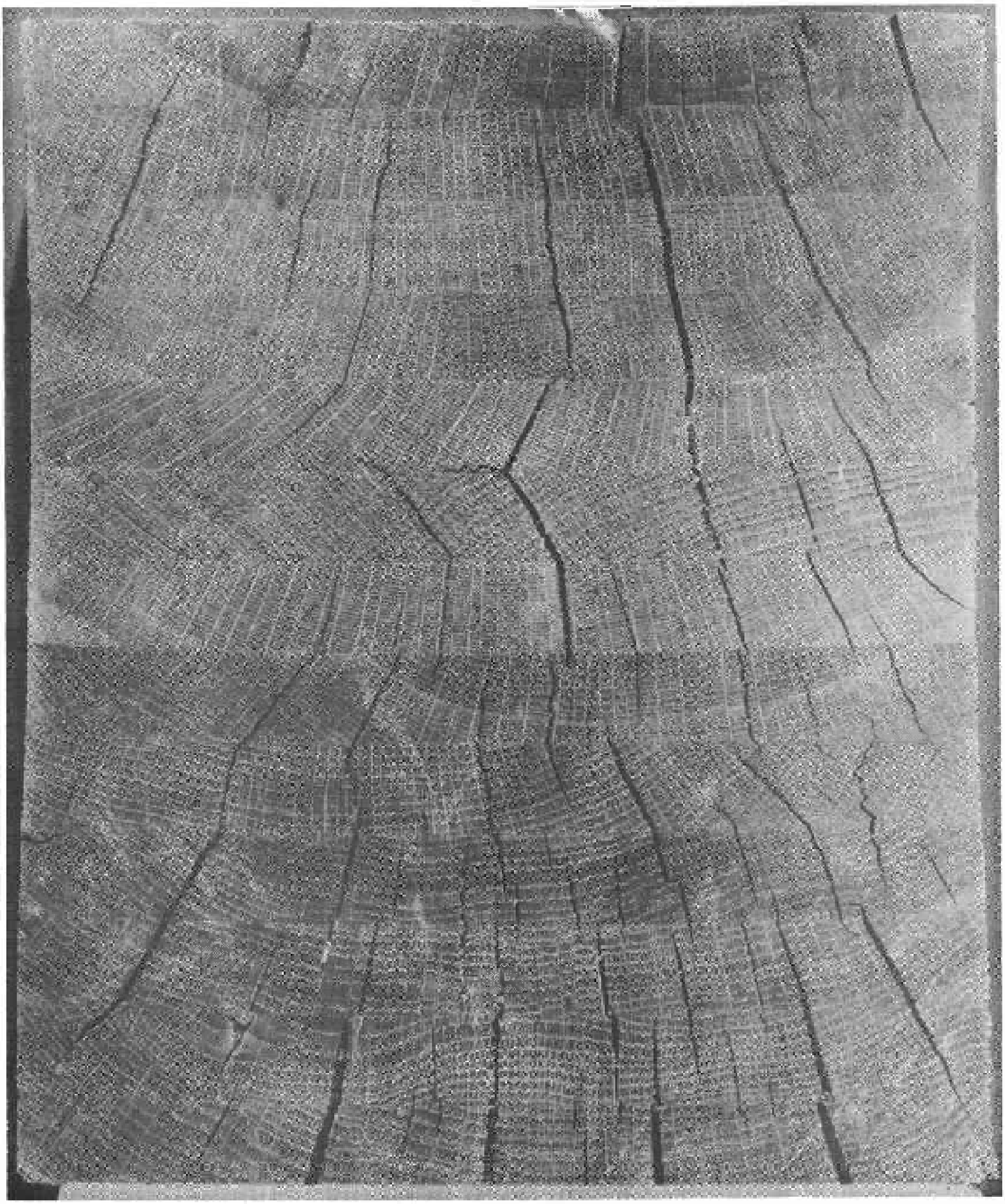


Figure 1.--Cross section of white oak beam, exposed to three cycles of the 30-day soaking -- 30 day drying test, indicates excellent durability of glue joints.

Z M 79273 F

Figure 2.--Cross section of white oak beam, exposed to three cycles of the 30-day soaking -- 30-day drying test, indicates poor durability of glue joints.

Z M 79274 F

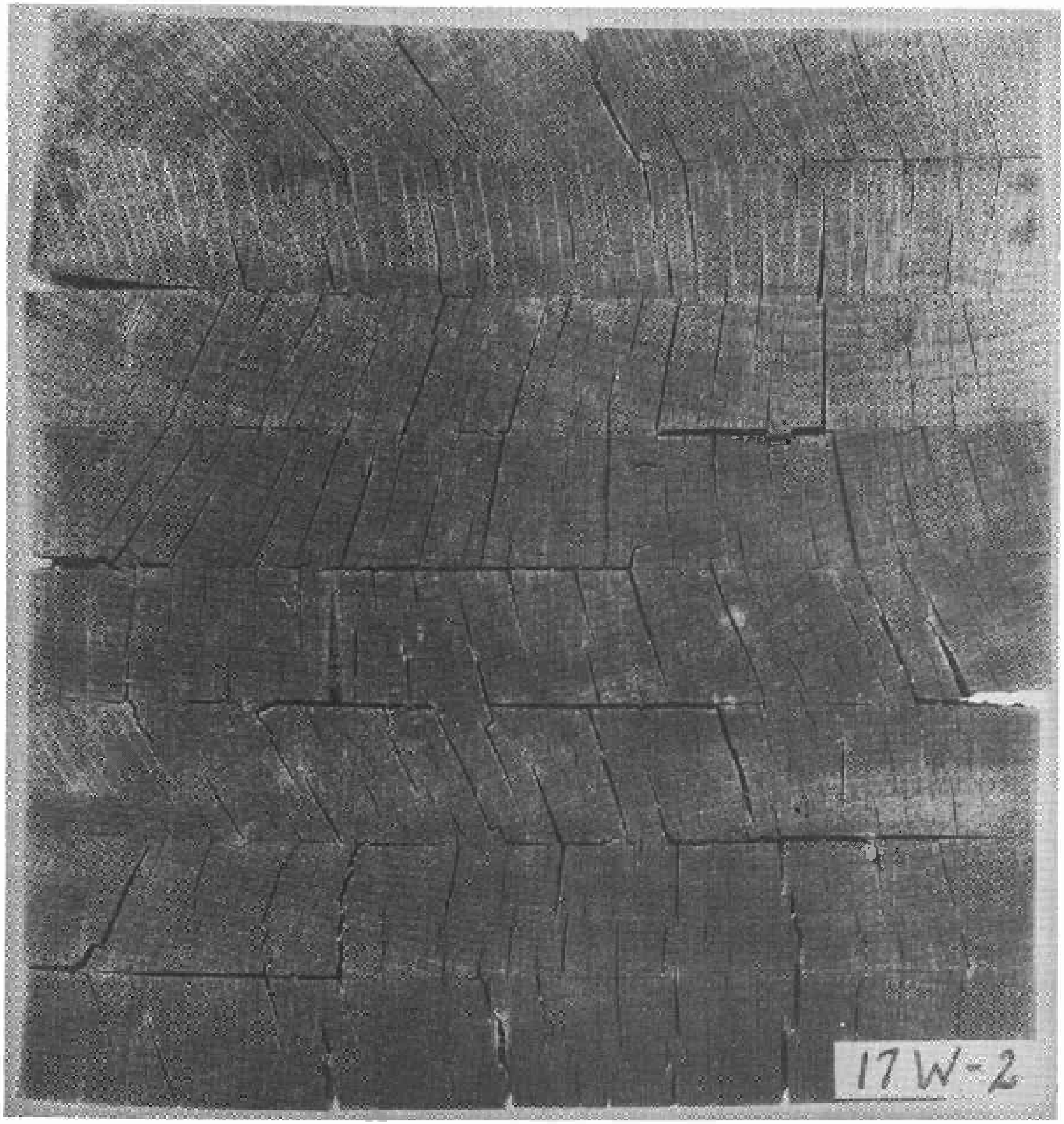


Figure 3.--Cross section of white oak beam, exposed to three cycles of the vacuum-pressure, soaking-drying test, indicates poor durability of glue joints.

Z M 79275 F

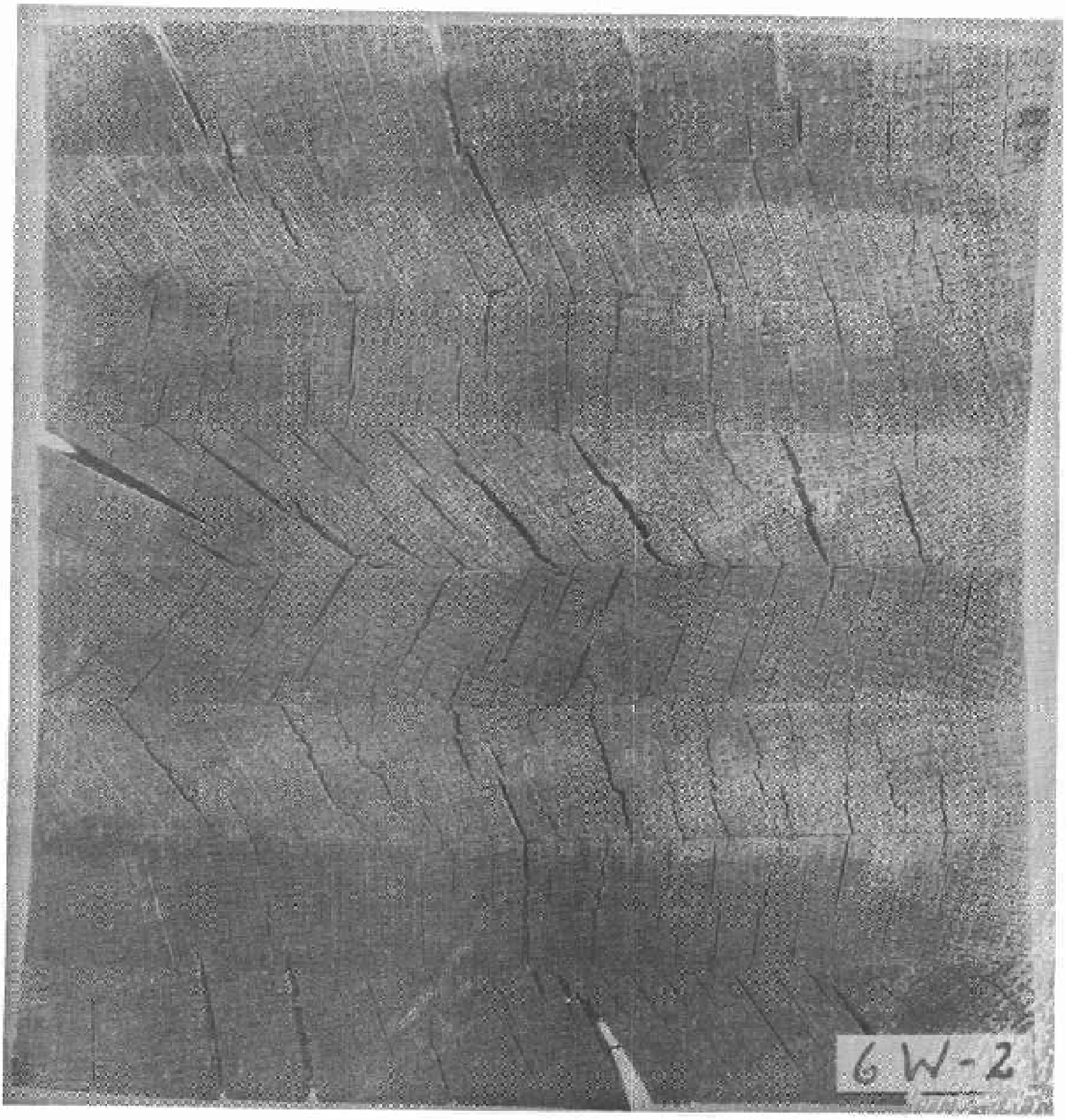
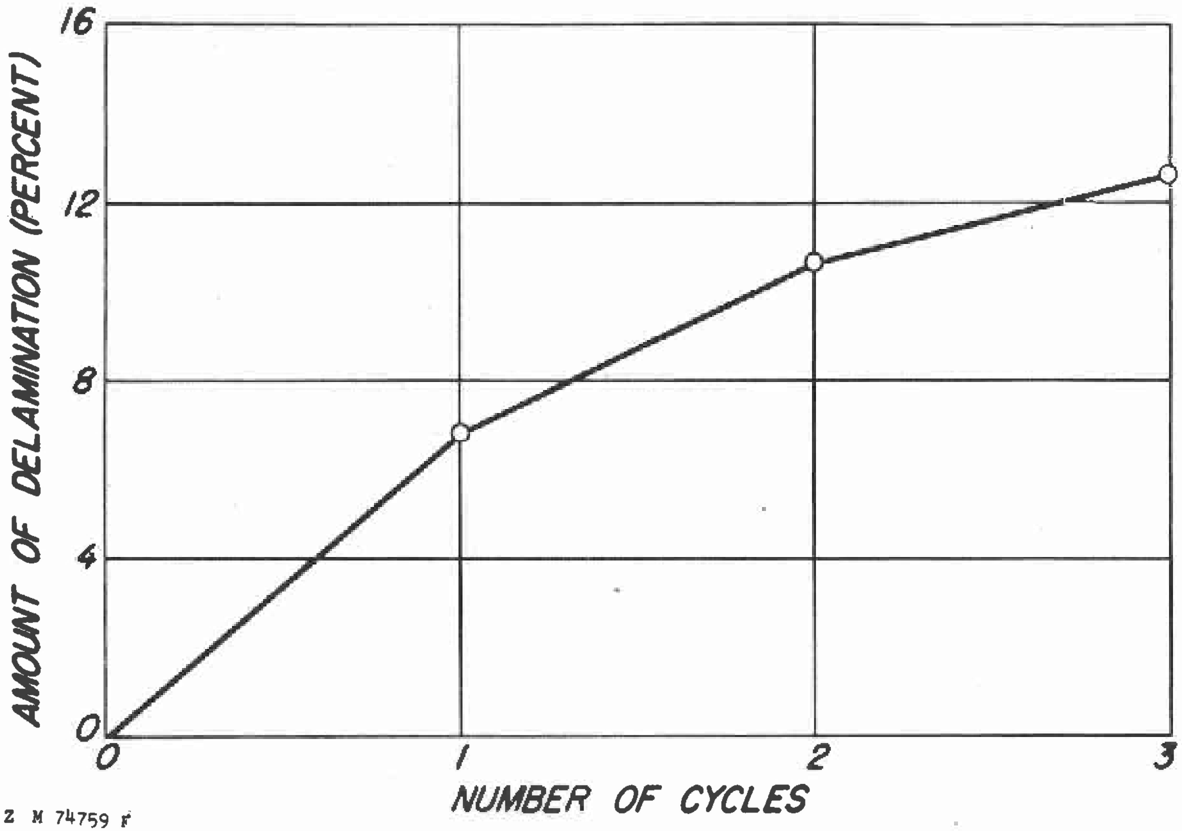


Figure 4.--Cross section of white oak beam, exposed to three cycles of the vacuum-pressure, soaking-drying test, indicates excellent durability of glue joints.

Z M 79276 F



Z M 74759 F

Figure 5.--Average amount of delamination in 24 white oak beam sections after 1, 2, and 3 cycles in the vacuum-pressure, soaking-drying test.

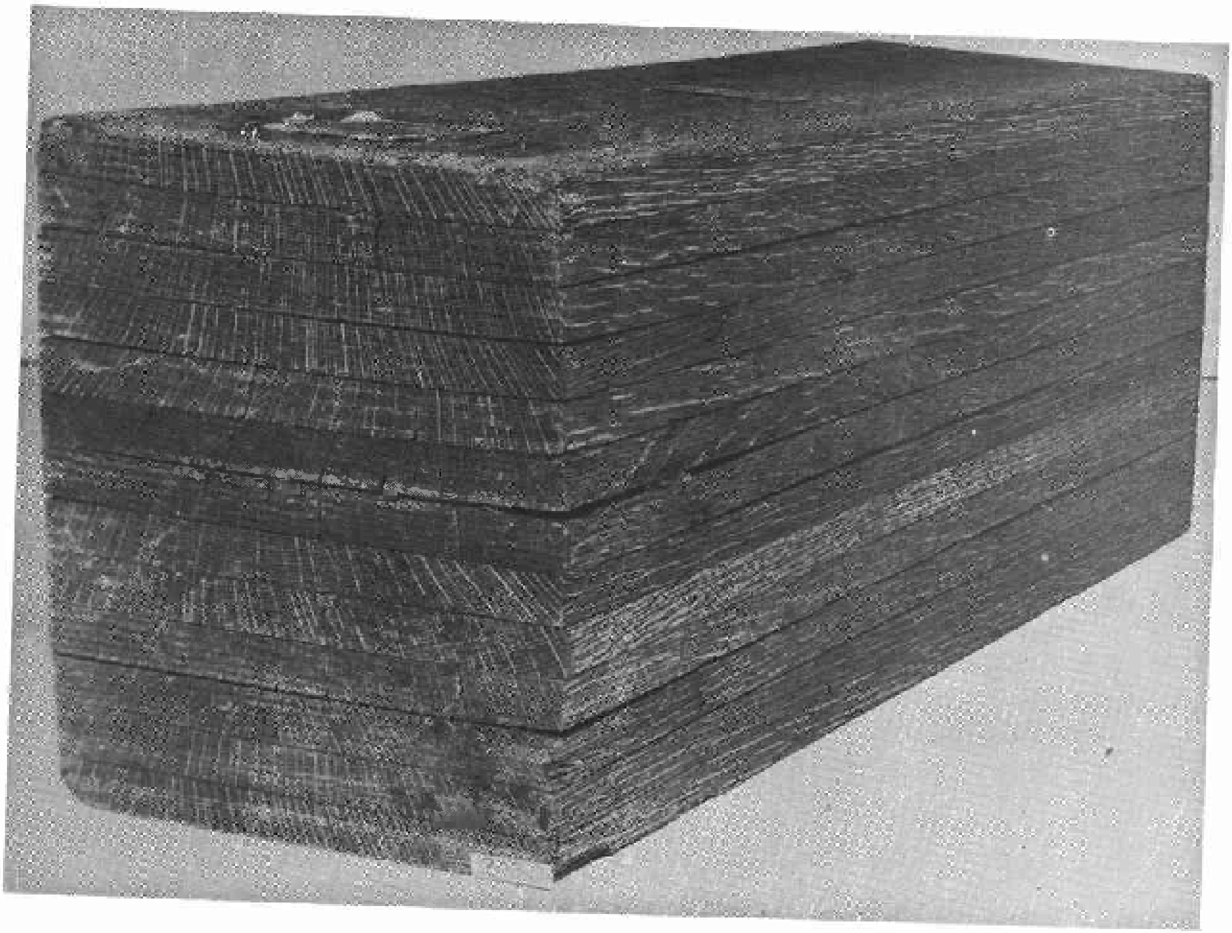
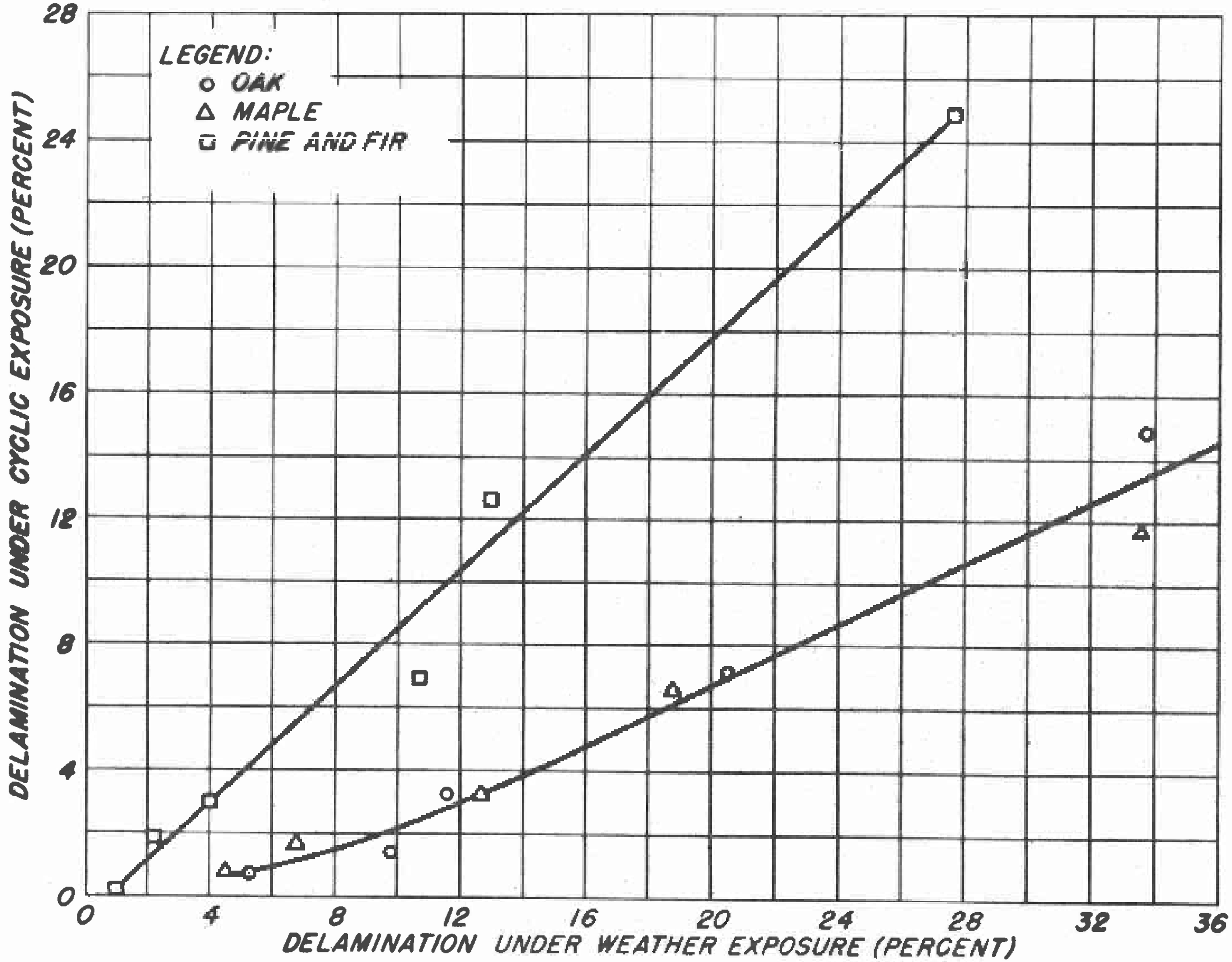
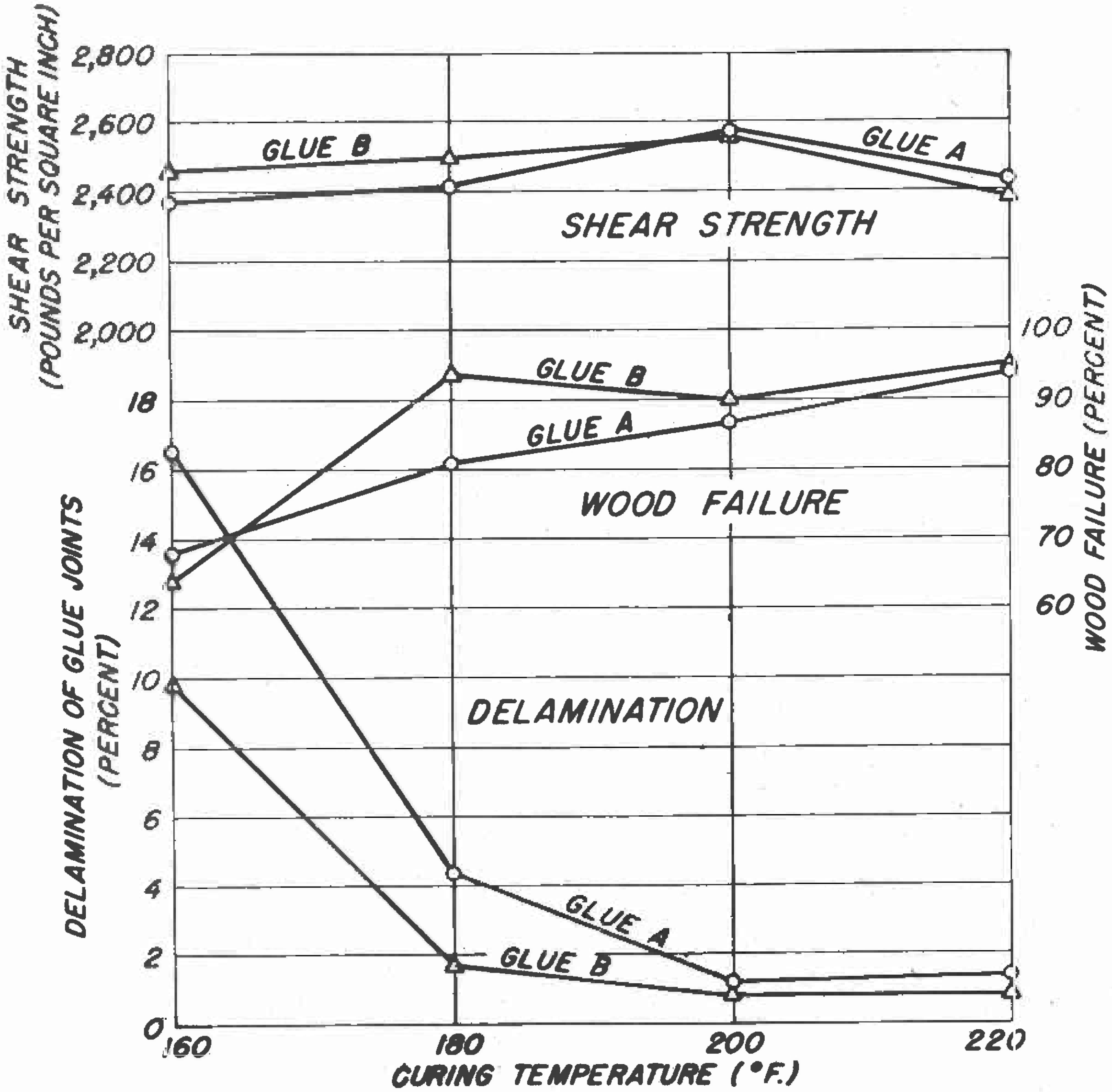


Figure 7.--Laminated white oak beam exposed to the weather for about 4 years shows a high percentage of open glue joints.
Z M 79277 F



Z M 74760 F

Figure 8.--Comparison of delamination values obtained with the vacuum-pressure, soaking-drying cycle and exposure to weather.



Z M 74761 F

Figure 9.--Results of vacuum-pressure, soaking-drying cyclic tests and block-shear tests on white oak beams glued with two different adhesives cured at various temperatures.

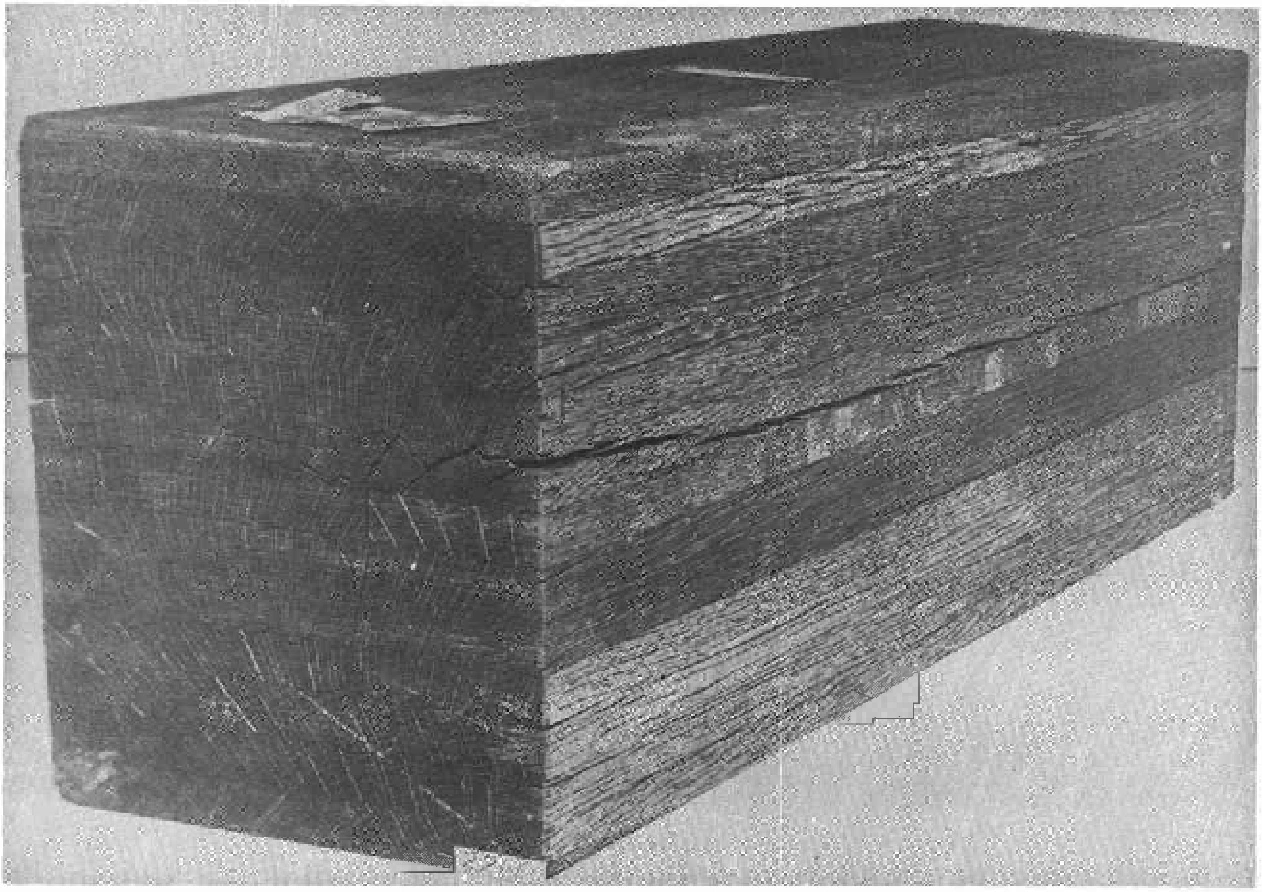


Figure 10.--White oak beam exposed to the weather for about 4 years shows excellent durability of glue joints.

Z M 79278 F

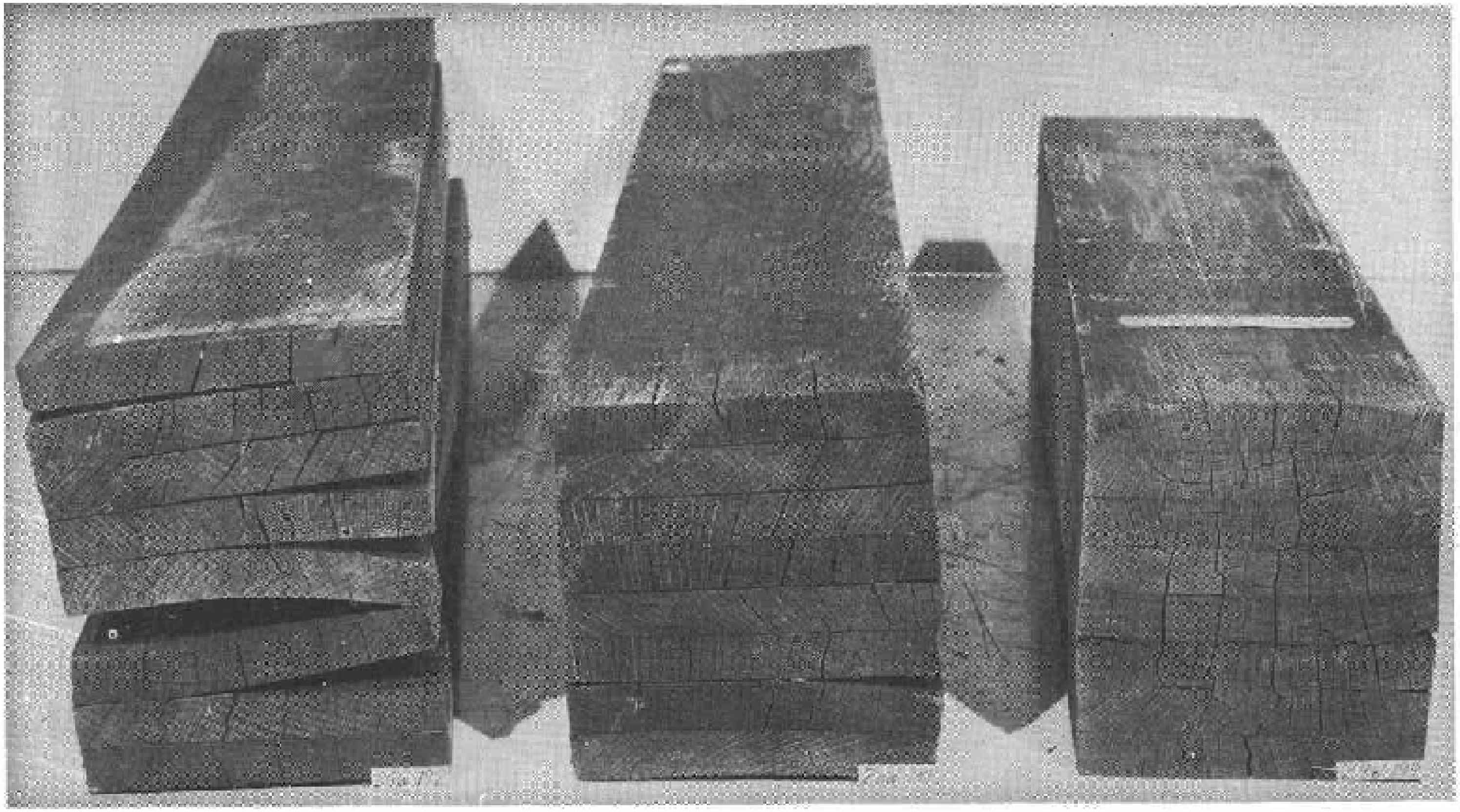


Figure 11.--Laminated white oak beams exposed to the weather for about 2 years showed, from left to right, the following percentages of delamination: 100, 95, and 9.3.

Delamination values obtained in the 21-day cyclic test on sections cut from these beams were as follows: 92, 76, and 3.6.

Z M 79279 F

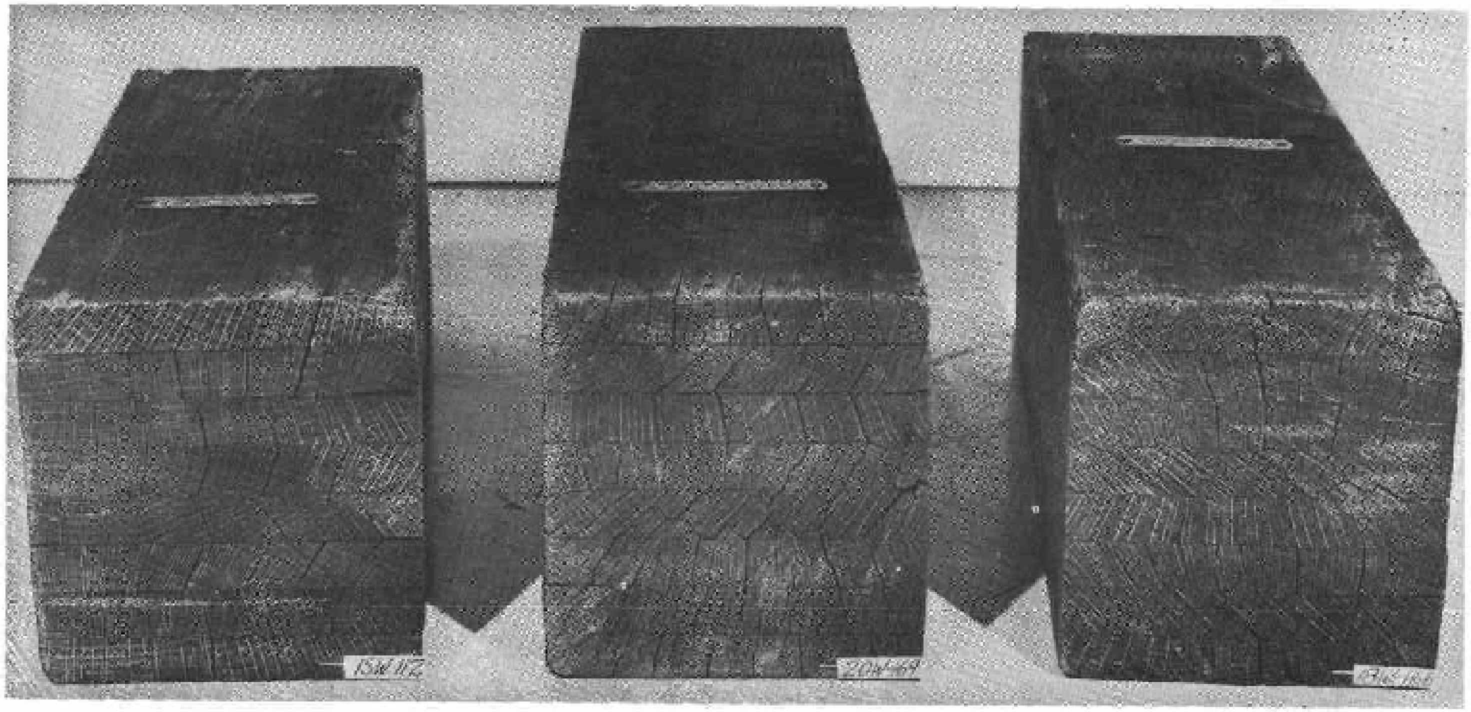


Figure 12.--Laminated white oak beams, glued with three different glues and exposed to the weather for about 3 years showed, from left to right, the following percentages of delamination: 15.7, 11.8, and 8.5.

Delamination values obtained in the 21-day cyclic test on sections cut from these beams were as follows: 6.1, 3.6, and 1.5.

Z M 79280 F

SUBJECT LISTS OF PUBLICATIONS ISSUED BY THE

FOREST PRODUCTS LABORATORY

The following are obtainable free on request from the Director, Forest Products Laboratory, Madison 5, Wisconsin:

List of publications on Box and Crate Construction and Packaging Data

List of publications on Chemistry of Wood and Derived Products

List of publications on Fungus Defects in Forest Products and Decay in Trees

List of publications on Glue, Glued Products, and Veneer

List of publications on Growth, Structure, and Identification of Wood

List of publications on Mechanical Properties and Structural Uses of Wood and Wood Products

Partial list of publications for Architects, Builders, Engineers, and Retail Lumbermen

List of publications on Fire Protection

List of publications on Logging, Milling, and Utilization of Timber Products

List of publications on Pulp and Paper

List of publications on Seasoning of Wood

List of publications on Structural Sandwich, Plastic Laminates, and Wood-Base Aircraft Components

List of publications on Wood Finishing

List of publications on Wood Preservation

Partial list of publications for Furniture Manufacturers, Woodworkers and Teachers of Woodshop Practice

Note: Since Forest Products Laboratory publications are so varied in subject no single list is issued. Instead a list is made up for each Laboratory division. Twice a year, December 31 and June 30, a list is made up showing new reports for the previous six months. This is the only item sent regularly to the Laboratory's mailing list. Anyone who has asked for and received the proper subject lists and who has had his name placed on the mailing list can keep up to date on Forest Products Laboratory publications. Each subject list carries descriptions of all other subject lists.