EVALUATION OF TIMBER PILES FROM FORT STREET BRIDGE

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TESTING AND RESEARCH DIVISION
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Samples of timber piling removed from the protective fender system at the Fort St bascule bridge, which was struck by the S. S. Silverdale, have been evaluated. This evaluation was requested by R. J. Eisenberg, of the State Attorney General's Office in order to obtain another opinion of the condition of the pile sections. Previously, portions of the same piles had been examined by S. B. Preston at the University of Michigan. The samples of timber piling were received at the Research Laboratory on December 4, 1980, from the Project Engineer's Office where they had been stored. The delivery of the piles to our laboratory was requested by the District Maintenance Office. The received short sections of piling were reported to have been removed from the remaining portions of four piles at approximately 12 ft below the waterline. Two of the samples were labeled as having been removed from piles installed in 1921 and the other two came from piles installed in 1949. The samples were reported to have been taken from the same piles, and adjacent to the samples evaluated by Mr. Preston at the University of Michigan. It had been previously determined by the examination performed at the University of Michigan that the section of piling installed in 1921 is red oak; whereas that identified as having been installed in 1949 is white oak. The length of the pile sections ranged from 5-1/2 to 6-1/2 in. Figure 1 shows a typical pile section.

Evaluation of the pile samples consisted primarily of performing the following operations:

1) Visually determining the amounts of 'sound' wood and deteriorated wood present in each sample,

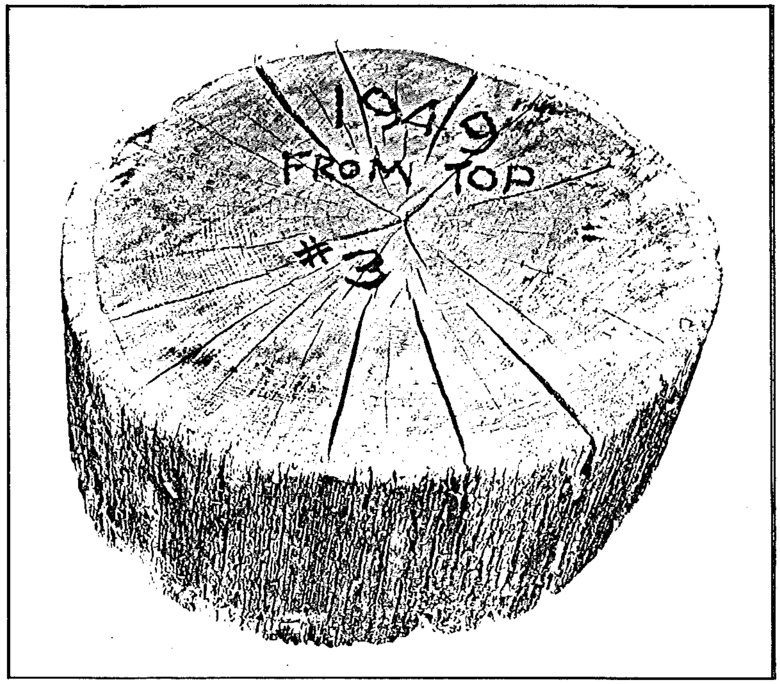
2) By tracing and measuring cross-sections and then using a planimeter, actual measurements of the areas of 'sound' and deteriorated wood were made and percentages of each computed,

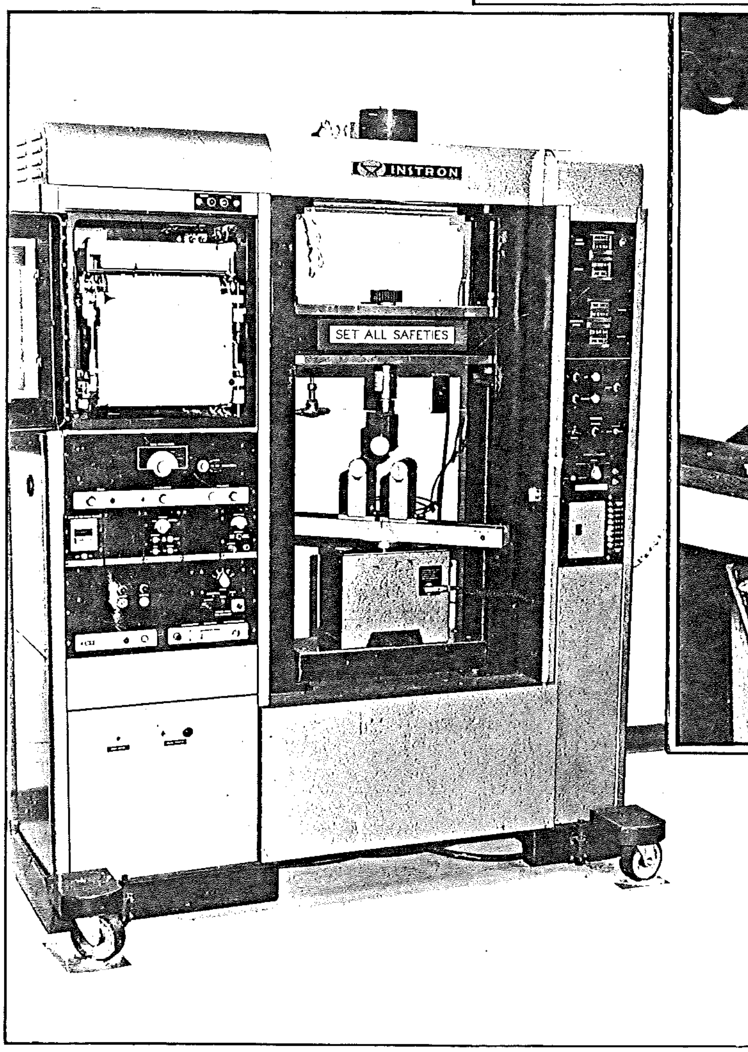
3) Verifying the visually determined 'sound' wood portion of the piles by performing static bending tests and computing the modulus of rupture,

4) Determining moisture content and specific gravity as per applicable ASTM specifications.

The relatively short lengths of pile sections which were received precluded the use of standard size static bending specimens. However, guidelines outlined by ASTM were followed in determining an appropriate sample size and testing fixture requirements. The specimen size chosen for determination of modulus of rupture was 7/16 by 7/16 in. in cross-section. The length of the specimens varied from 5-1/2 to 6-1/2 in. In all cases,

Figure 1. Typical pile section.





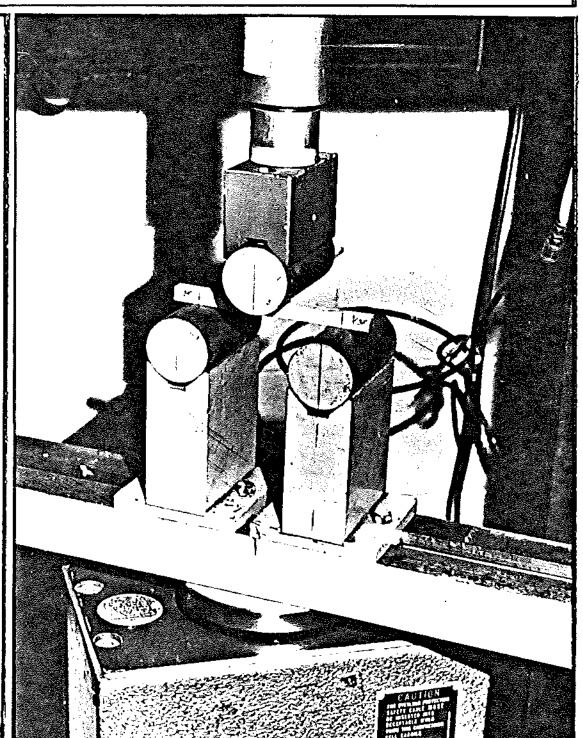


Figure 2. Instron testing machine (left) and loading fixture with specimen ready to load (above).

the span length used when determining flexural strength was 4-1/2 in. The ratio (a/h) of specimen thickness to one-half the span length was 5.1:1. This is within the recommendations of ASTM D-198, "Static Tests of Timbers in Structural Sizes," which recommends a/h ratios from 5:1 to 12:1 and reasonably close to the requirements of ASTM D-143, "Testing of Small Clear Specimens of Timber," which requires two standard specimen sizes with a/h ratios of 5.6:1 and 7:1.

Generally, modulus of rupture values increase with decreasing moisture contents. The "Wood Handbook" (1) gives modulus of rupture values at 12 percent moisture content and in a 'green' condition (64 to 83 percent moisture content) and are as follows for oak.

		Modulus of Rupture, psi
Red Oak:	'Green'	8,300
	12 percent moisture content	14,300
White Oak:	'Green'	8,300
	12 percent moisture content	15,200

The coefficient of variation for these values is 16 percent. Correction of modulus of rupture book values to moisture content other than 12 percent is accomplished by the relationship:

$$S_{Rx} = S_{R12} \left(\frac{S_{R12}}{S_{Rg}} \right)^{-\left(\frac{x - 12}{13} \right)}$$

where: S_{Rx} = modulus of rupture at moisture content x

x = the moisture content of the tested specimen

S_{R12} = modulus of rupture at 12 percent moisture content

S_{Rg} = modulus of rupture in 'green' condition.

The mechanical properties of various wood species listed in the "Wood Handbook" are based on a variety of sampling methods and reflect tests performed over a period of years. Values given in the book are intended to estimate the average clear wood properties of the species.

In our evaluation, we made no attempt to obtain clear wood specimens. Consequently, the modulus of rupture values of some of the specimens were

TABLE 1
RESULTS OF EVALUATIONS PERFORMED

Sample No.	Date Installed	Wood Species	Modulus of Rupture, psi	Moisture Content, percent	Specific Gravity	Sound Wood, percent	USDA* Modulus of Rupture, psi
1A	1921	Red Oak	21,763	5.6	0.67	73	18,652
1B			22,584	4.0	0.66		20,015
1C			24,277	4.8	0.64		19,310
1D			23,816	5.1	0.72		19,070
1E			23,406	5.0	0.73		19,150
1F			17,657	4.9	0.69		19,230
2A	1949	White Oak	20,942	5.6	0.68	78	20,849
2B			26,280	5.5	0.80		20,952
2C			22,584	4.8	0.66		21,689
2D			20,531	4.9	0.79		21,582
2E			14,783	5.3	0.68		21,160
2F			19,710	5.0	0.77		21,475
3A	1949	White Oak	20,941	5.3	0.71	82	21,160
3B			25,048	5.1	0.73		21,370
3C			22,584	6.1	0.72		20,340
3D			20,531	5.9	0.72		20,542
3E			22,995	5.6	0.71		20,849
3F			21,352	4.9	0.74		21,582
3G			23,159	6.9	0.73		19,552
3H			24,719	7.1	0.73		19,360
3J			22,748	7.2	0.75		19,265
4A	1921	Red Oak	18,889	5.0	0.68	84	19,165
4B			21,763	4.6	0.72		19,480
4C			23,406	5.4	0.67		18,856
4D			18,889	4.9	0.72		19,270
4E			18,889	5.3	0.69		18,959
4F			22,174	4.7	0.74		19,375
4G			19,299	7.2	0.68		17,470
4H			20,941	6.7	0.70		17,838
4J			20,777	6.7	0.69		17,838

* From U. S. Department of Agriculture, "Wood Handbook," corrected to corresponding moisture content as per equation on the preceding page.

adversely affected by such defects as small knots and cross-grain. In all instances, the sample was oriented such that loading was applied from the direction corresponding to what would have been the outside of the pile.

Loading of the modulus of rupture specimens was performed in an Instron machine equipped with autographic printout. Load was applied through a rounded loading block attached to the movable head of the machine. The specimen supports, located on the fixed load cell were round-edged and adjustable to accommodate the chosen 4-1/2-in. span. Load and deflection measurements were obtained directly from the output chart. Calibration of the load cell was checked immediately prior to loading the specimens, both electronically and by use of calibrated weights, and rechecked upon completion of the specimen loadings. Figure 2 shows the testing machine and loading fixture equipment.

The portions of piling received contained soft rot in the outside 1/2 to 1 in. The USDA "Wood Handbook" states, "Soft rot typically is relatively shallow; the affected wood is greatly degraded and often soft when wet, but immediately beneath the zone of rot the wood may be firm," (p. 17-4). This was found to be true of the pile sections examined. The average loss of usable cross-sectional area attributed to soft rot was approximately 21 percent.

Results of the evaluations performed are given in Table 1. Figure 3 shows the locations where the modulus of rupture specimens were taken from each pile section.

The results obtained were, as an average, 9 percent higher than the "Wood Handbook" values after correcting the book's values to the same moisture content as the specimens at the time of testing. Correction to the same moisture content is necessary since the mechanical properties of wood are significantly affected by the moisture content, and this allows direct comparisons of test results and "Wood Handbook" values.

As shown by the results of static bending tests, that portion of the pile section which was not soft rotted was found, structurally, to be as strong on the average as would be expected for new material at the time of installation.

Based on findings of this evaluation we believe the following to be a fair assessment of the structural integrity of the protective fender system on the Fort St bridge.

1) On the basis of computations of section modulus of the pile cluster; taking into account the amount of deterioration present in the pile samples

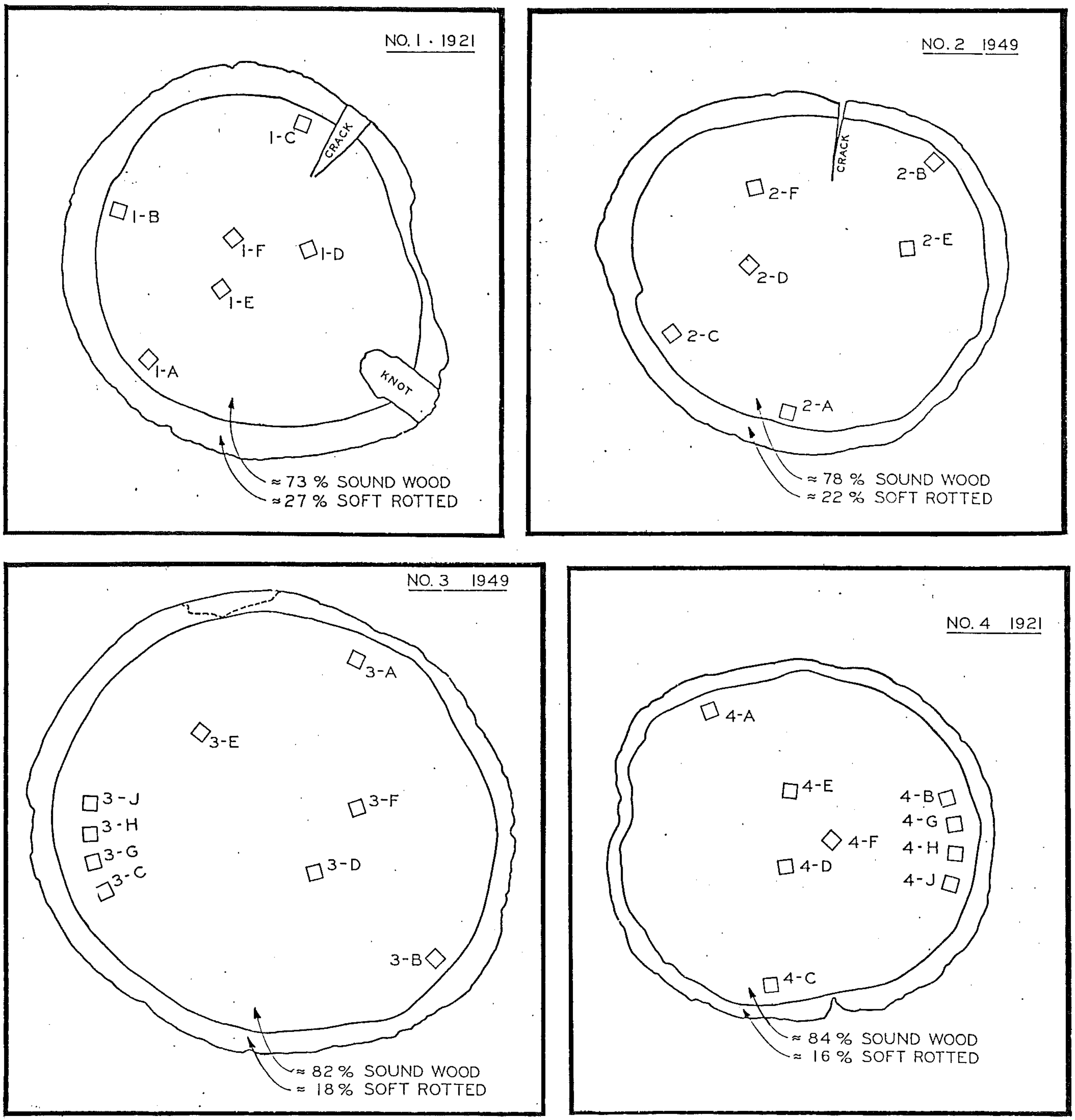


Figure 3. Timber pile cross-section and location of removed static bending specimens.

received, assuming the deterioration of each pile in its pile cluster to be approximately the same; and assuming the minimum material specification requirements at the time of installation were met, then the structural capacity of the pile cluster should have been approximately 85 percent of the minimum originally required.

I = πD⁴/64
S = πD³/32.

2) Individual piles installed in 1921 and reconditioned in 1949 showed a net section modulus of 'sound' wood approximately 24 percent greater than the minimum originally required.

3) Individual piles installed in 1949 showed a net section modulus of 'sound' wood approximately 22 percent less than the minimum originally required by specifications in effect at the same time of installation. These specifications required larger pile cross-sections than those required in 1921.

4) We concur with Mr. Preston's comments that the above water portions of the individual piles and wale timbers were probably 100 percent deteriorated. This would account for a 12 percent decrease in length of individual 50-ft piles installed in 1921 and reconditioned in 1949 and a 14 percent decrease in length of the 35-ft piles installed in 1949. There was no loss in length from the pile cluster since deterioration in the above water portion was replaced with a concrete cap. However, since the maximum bending stress in the pile occurs well below the waterline, the loss of the above-water sections of the pile should have little effect, if any, on the performance of the intended function of keeping a ship away from the bridge.

REFERENCE

1. "Wood Handbook," U. S. Department of Agriculture, Forest Products Laboratory, 1974.