A.S.T.M. STRUCTURAL TIMBER GRADING STANDARD NOW APPROVED BY A.S.A. AS AMERICAN STANDARD

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(Report)

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ASTM STRUCTURAL TIMBER GRADING STANDARD NOW APPROVED BY ASA AS AMERICAN STANDARD[1]

By L. J. MARKWARDT, Senior Engineer

The recently adopted American Standard for Structural Wood Joist and Plank, Beams and Stringers, and Posts and Timbers approved by the American Standards Association last October (1939) is an excellent example of evolution and development rather than spontaneous origin.

Significant developments have been traced by J. A. Newlin[2] to a beginning as far back as 1891, when B. E. Fernow was chief of what was then called the United States Forestry Division.

The forestry program inaugurated at that early date outlined as one of its major objectives a more complete determination of the strength properties of American timbers.

The earlier studies on wood, some of which were quite comprehensive as regards properties investigated, were apparently more suggestive than conclusive because of limitations in the underlying purpose, and neglect of factors which are now known to influence the strength of wood. Even this previous work, however, had an important bearing on subsequent test procedure, and served to reveal the broader engineering purpose to be served. In the background also were the even earlier contributions from American and European investigators.

Function of Structural Grading Specifications

The development of structural timber grades is closely and intimately related to safe working stresses, because in designing a structure which must carry definite loads it is essential that the strength of the materials be definitely known and that any variation in the quality should be determinate.

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[1]Published in Industrial Standardization, Mar. 1940.

[2]1927. "Origin and Development of ASTM Tests and Specifications for Timber." Proceedings of International Congress for Testing Materials, Amsterdam, Vol. II, p.567-580.

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Newlin[3], who is responsible for much of the technical background on which the present grading of structural timbers is based, has emphasized that in most timber design it is the poorest timber likely to be found in any grade that is the controlling factor, and in that assigning working stresses primary consideration is given to the one-fourth of the pieces lowest in strength. Chaplin and Nevard[4], taking up the same thought, state that it cannot be overemphasized that the average breaking strength of a number of test specimens is not a quantity that the designer can apply directly, and that the working stress must be based on the strength of the weakest member that may be used, since the latter determines the strength and safety of the structure. Economy of material is obtained when all units are stressed to a figure approaching the allowable maximum, and this can only be done when the material is of uniform quality. Not only are there variations in the strength of clear wood, but also the strength is affected in varying degree by numerous features such as knots, shapes, cross grain, and moisture content.

It is the function of an efficient structural-timber grading specification to classify timber of any species into quality classes or grades by properly and adequately limiting the permissible defects and strength factors, to the end that definite minimum strength is assumed, and that maximum efficiency in utilization is obtained.

It is not practical and perhaps it would be too ambitious to expect to meet this desideratum in its entirety, but the present American Standard and ASTM specifications are far along in approaching this ideal. Far from dealing with an outmoded material, these standards, together with other research developments in modern connectors and in the laminated construction, have opened new horizons in timber construction.

Technical Background

Back of the preparation of grading rules and the assignment of working stresses must be adequate data and knowledge of the strength properties and variability of clear wood, of the strength of structural timbers containing defects, of the influence on strength of various defects of the influence of seasoning and of moisture changes in service, of manufacturing practice, of growth conditions, and of the mechanics of tree growth. Much of these data are now available and published in sources such as the following:

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[3] 1927. "Unit Stresses in Timber." Amer. Soc. Civ. Engrs. Trans 91; 400-407, illus (Discussion pp. 408-440).

[4] 1937. Chaplin, C. J. and Nevard, E. H. Strength Tests of Structural Timbers, Part 3, Forest Products Research Records No. 15. Department of Scientific and Industrial Research (England).

1. U.S. Department of Agriculture Technical Bulletin 479, Strength and Related Properties of Woods Grown in the United States.
2. Forest Service Bulletin 108, Tests of Structural Timbers.
3. U.S. Department of Agriculture Department Circular 295, Basic Grading Rules and Working Stresses for Structural Timbers.
4. U.S. Department of Agriculture Miscellaneous Publication 185, Guide to the Grading of Structural Timbers and the Determination of Working Stresses.
5. American Society for Testing Materials, Proceedings 24, Structural Timbers: Defects and Their Effect on Strength.

The importance in the specifications of adequate consideration of manufacturing practice in relation to mechanics of tree growth, taking into account factors such as the nature of knots and their method of formation, cannot be over-emphasized. Some individual manufacturers as well as lumber associations have contributed materially to insuring the practicability of the rules.

One of the first structural grading rules based on actual tests and incorporating all esential principles of a structural grade was that presented in Forest Service Bulletin 108, published in 1912. In these rules the beam was divided into three volumes or zones, representing different degrees of intensity of stress. Volume 1 comprised the lower one-fourth of the height of the beam at the center half of the length, where tension stress is most severe; volume 2 the upper one-fourth of the height of the beam at the center half of the length, where compressive stress is the most severe; and volume 3 the remainder of the timber. Larger knots were allowed on the compression side of the beam where they are less injurious than on the tension side, with the assumption that the beam would be used with this side up.

The next significant advance in structural grading was the establishment of the principles set forth in U.S. Department of Agriculture Department Circular 295, published in 1923. These principles covered the use both as beams and as posts. In beams no distinction was made between the upper and lower sides. These principles were incorporated in the structural grade examples adopted by the industry in connection with American lumber standardization, and published in Simplified Practice Recommendation R16-29 of the U.S. Department of Commerce, 1929. Concurrently the ASTM structural grades, sponsored by Committee D-7 and the corresponding AREA grades were established.

In 1934 structural grading received another contribution with the publication of "The Guide to the Grading of Structural Timbers and the Determination of Working Stresses", by T.R.C. Wilson. This guide is not a standard specification. It rather serves a threefold purpose of providing a technical basis for the establishment of specifications such as the present American Standard, permits the industry to establish grades of any desired strength-ratio, and gives the timber user a means of evaluating any material to establish the design stresses it is capable of taking.

Practical Considerations Involved

As previously mentioned, practical considerations frequently must be taken into account which limit the ultimate theoretical efficiency that might otherwise be possible in establishing a standard specification. For example, the compressive strength of wood is affected less by a knot of a given size than is the tensile strength. Hence larger knots could be used on the upper or compressive side of a beam with increased efficiency in utilization, but practical considerations suggest grading so that the beam can be used either side up, rather than in one definite position, the reversal of which might result in failure. Again, greater efficiency might be obtained with a more elaborate method of evaluating the size of knots, but such evaluation would be more complicated than the present simplified system, and hence less practical. A discussion of these factors is presented in the previously mentioned article entitled: "Structural Timbers: Defects and Their Effect on Strength" (ASTM, 1924)

Working Stresses

Safe working stresses are an essential corollary of structural grading. Tables of working stresses abound in engineering literature, and while marked improvement in them has taken place, there is still much room for modernization, and for correlating working stresses with structural grading.

Safe working stresses for timber are based both on tests of small clear specimens which afford average values of the inherent strength of the different species and a measure of variability, and on tests of large timbers which establish the influence of defects. The determination of safe working stresses involves further the adjustment of test values to meet the conditions of service. This adjustment requires consideration of (a) the loss in strength from defects, (b) the effect of long-continued loads, (c) the variability of individual pieces from the average, (d) the possibility of slight accidental overloading, and (e) species characteristics.

The effect of these factors is to necessitate a lower strength value for practical use conditions than the average value from tests of small clear specimens. Their combined effect may be embodied in a single factor, sometimes erroneously called a "factor of safety," which can be applied to averages from tests on small clear specimens to obtain safe working stresses, making in addition due allowance for species characteristics. It is evident that the larger part of this factor is required to correlate laboratory test results with actual conditions of use, and only a small part may be considered a true factor of safety.

The belief that a timber with a so-called "factor of safety" of 3 or 4 will carry three or four times the load for which it is designed is erroneous. As a specific example, the average modulus of rupture of green Sitka spruce, based on tests of small clear specimens free of defects, is 5,760 pounds per square inch and the basic working stress for extreme fiber in bending for a grade of material that permits defects that reduce the strength by one-fourth is 1,100 pounds per square inch, which shows a factor of 5-1/4. This factor of 5-1/4 is not a "factor of safety" but consists of successive reductions of one-fourth for defects, one-fourth for variability, seven-sixteenths for long-time loading, and two-fifths to provide an actual factor of safety of 1-2/3. The average timber has a factor of safety of about 2-1/4 for long time loading. The application of loads which would produce stresses only one and one-half times the working stresses would be expected to cause occasional failures if the loads were left on for any great length of time.

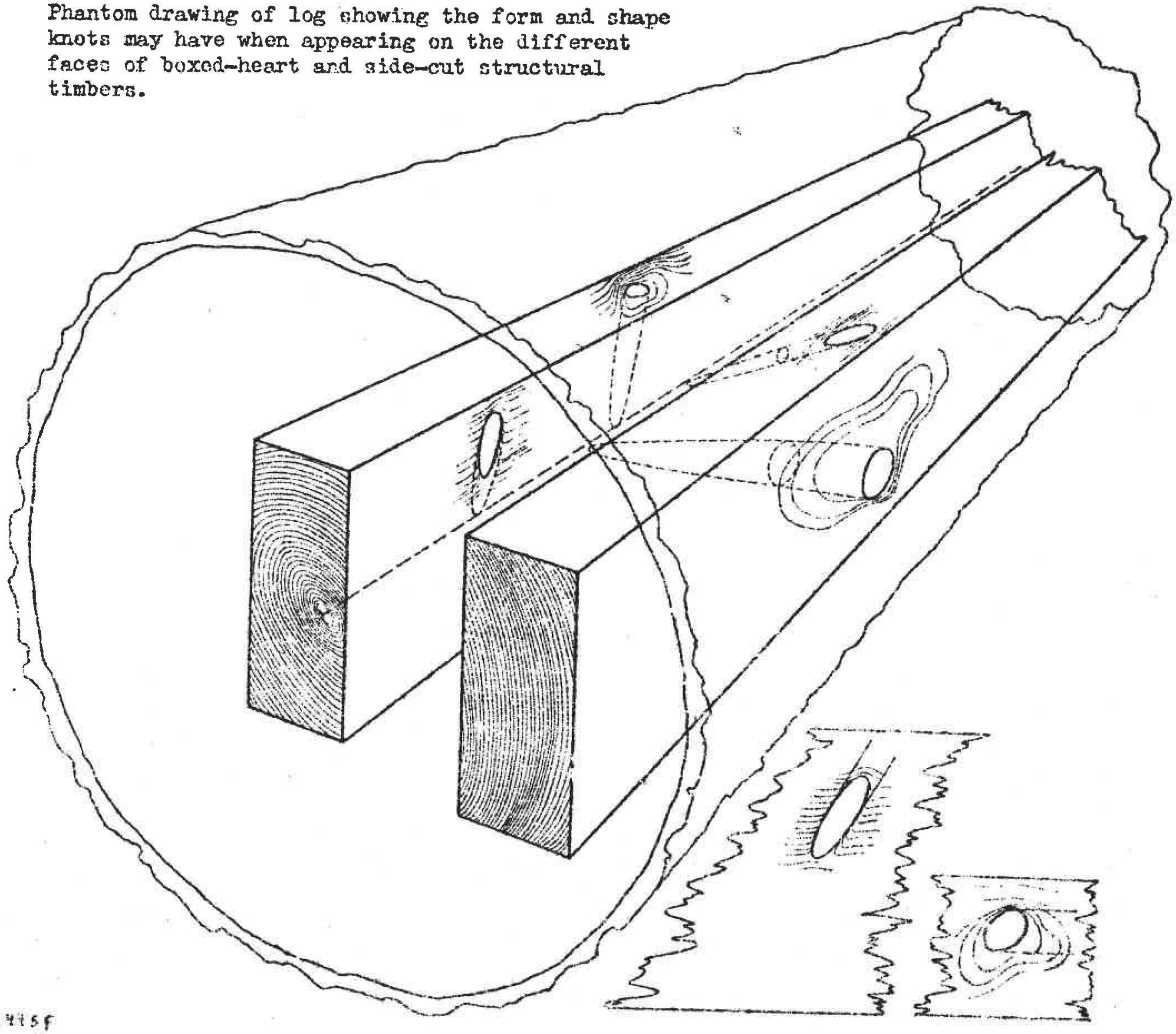
The structural grades incorporated in the standard are designated by the extreme fiber stress they are designed to carry, by the kind of timber according to use (joist and plank, etc.) and by the species name, the latter sometimes with a prescript. Within limits, it is possible to set up grades for any species to take any desired stress by appropriately varying the defects permitted to meet any desired grade-strength ratio. While the standard establishes a variety of stress grades for the more important species, it could be extended at will to cover other species and other grade-strength ratios.

It should be noted that the stresses for the various American Standard structural grades apply to timbers used in continually dry locations, or used under other conditions where deterioration is not expected. Higher initial strength than would otherwise be required is desirable in timbers exposed to decay or other deterioration and to delay replacement. It may be provided by arbitrarily increasing the size of timbers, or by using lower design stresses. This factor is mentioned because of its importance, but it is not the purpose of this paper to discuss it fully.

Acknowledgments

The present American Standard, being a development extending over many years, includes contributions from a great number of individuals and organizations. Any attempted enumeration is most certain to be incomplete. Among the more important, however, are the National Lumber Manufacturers Association, the West Coast Lumbermen's Association, ASTM Committee D-7 on Timber, AREA Committee VII on Wooden Bridges and Trestles, the Central Committee on Lumber Standards, and the Forest Products Laboratory. Among individuals, Dr. Hermann von Schrenk, Professor C. E. Paul, C. J. Hogue, J. A. Newlin, T. R. C. Wilson, W. E. Hawley, and Arthur T. Upson may be mentioned, but many others also made important contributions.

Phantom drawing of log showing the form and shape knots may have when appearing on the different faces of boxed-heart and side-cut structural timbers.



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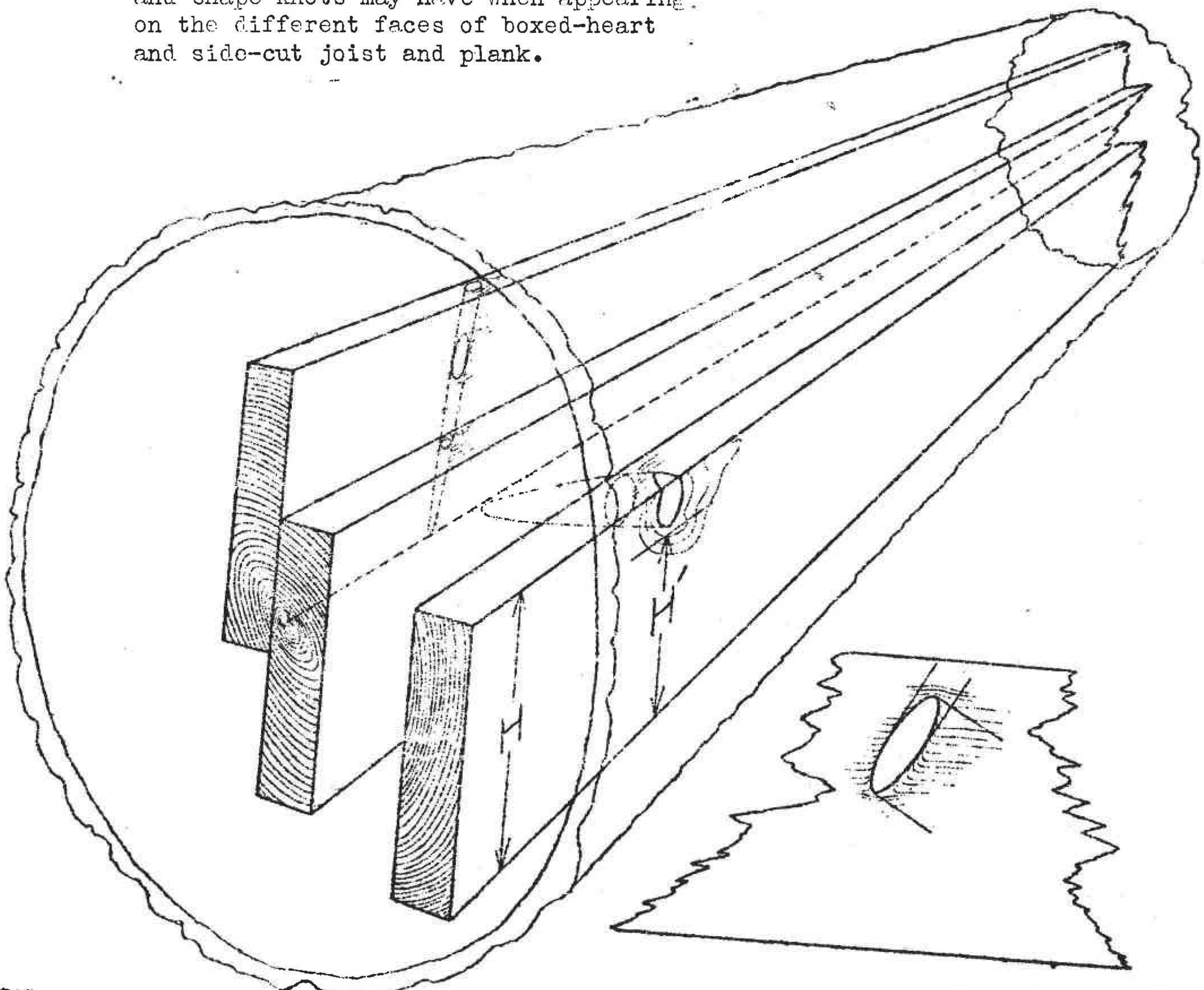
Phantom drawing of log showing the form and shape knots may have when appearing on the different faces of boxed-heart and side-cut joist and plank.



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