PLASTIC BENDING OF WOOD BEAMS

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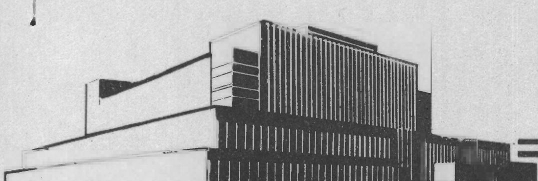

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UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
In Cooperation with the University of Wisconsin

PLASTIC BENDING OF WOOD BEAMS[1]

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Synopsis

Summarizes the historical development of plastic bending in wood beams.

Let us first define what we mean by a plastic material. A plastic material has a definite form of stress-strain curve. At small stresses, the strain is proportional to the stress. When the stress becomes equal to the strength, the strain continues to increase with no increase of stress. This is called creep. If the stress is reduced to values less than the strength, the reduction in strain is proportional to the reduction in stress. The proportionality factor is often very close to that which obtained when the stresses were small. Many materials act substantially in this way. They are said to be elastic-plastic materials. Dry wood acts substantially in this way when subjected to compression parallel to grain (12).[3] It acts differently

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[3]Underlined numbers in parentheses refer to Literature Cited.

in tension parallel to the grain. At small stresses, the strain is proportional to the stress and remains so until the stress becomes equal to the tensile strength when catastrophic failure occurs.

Such a stress-strain curve can readily be applied to beams by the method given by Nadai (4,5). He uses the assumption that planes perpendicular to the length of the unbent beam remain so after bending. Many experiments have proved this to be true even for non-Hookian materials, and proved necessary by MacCullough (3).

The first application of this stress-strain curve to wood was made by Neeley in 1898 (11). At that time very little had been done on the analysis of plastic materials and little use was made of Neeley's work. It was suggested again in 1917 by James S. Mathewson of the Forest Products Laboratory and used by J. B. Kommers and the writer in the analysis of wood I-beams and box beams in 1920. W. Prager (8) used it for the same purpose in 1933.

It was found that this method of estimating the bending strength of wood beams was unconservative when applied to beams that might fail in shear or in a combination of shear and tension. The method for overcoming this difficulty was developed by the writer and McKinnon (7) in 1946 and carried further by the writer in 1950 (6). This refinement was applied to the plastic bending of wood beams by Bechtel and the writer in 1952 (1). This work was divided into two parts. The first part showed that the method given by Nadai (4,5) can successfully be applied to wood beams. The second part shows that the strength of a wood beam can be predicted with reasonable accuracy by the use of the plastic-stress-strain curve in the method given by Nadai (4,5). In 1960, this method was applied to beams laminated of two species of wood by Ethington (2). The top and bottom laminations were of one species and the central lamination of another. The strength of wood I-beams and box beams can be calculated by use of the equations developed by also applying the method of transformed sections. In 1961, Ramos (9,10) measured the stress distribution in Douglas-fir beams by an ingenious method. He found the linear strain distribution assumed by Nadai (4,5) and a stress distribution substantially that of an elastic-plastic material.

It would seem that the linear distribution of strain in a beam and the elastic-plastic nature of wood subjected to compression parallel to the grain are very well established and should be considered in further investigations of and in the design of wood beams. The methods referred to in this paper apply to beams made of straight-grained clear wood. In such beams the tensile strength is greater than the compressive strength so that usually the plastic region is well developed before failure takes place. If the tensile strength is reduced by the presence of defects to a value less than the compressive strength, no plastic region will be developed and the formulas given will not apply. If this occurs, the usual elementary engineering formula using the reduced tensile strength for the modulus of rupture gives a good estimate of the bending strength.

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