Use of cylindrical specimens in evaluation of some mechanical properties of in-situ wood members

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Abstract

Method of testing compressive strength of wood using small diameter cores was developed. Special core drill was used to cut 5mm-diameter cores from wood members. Cores were drilled in the direction perpendicular to the fibers and were tested in concave jaws which applied the force in the direction along the fibers. Correlation between strength of cores and the strength of ASTM specimens in compression and tension was established.

Introduction

In-situ evaluation of structural members is gradually gaining practical importance with the aging infrastructure and number of buildings in service. Preservation specialists dealing with structures of historic importance, as well as practicing engineers, need the information about the mechanical properties of existing wood members.

Core drilling techniques have been used in wood structures for some time and purposes of it varied from assessment of wood preservation (5) to measuring the wood density, or shear strength of the glueline (2, 4). The technique presented in this paper uses small diameter cores to evaluate the compressive strength of the wood along the fibers.
Material and Methods

A special core drill was designed to cut cores of 5 mm (0.197 in) in diameter. The outside diameter of the drill is 9.5 mm (0.375 in). The tool creates a 10 mm (0.394 in)-diameter hole in the wood member. High strength tool steel was used for the drill to achieve high quality cores. The cores must be consistent to eliminate the effect of the variation in core geometry on the core strength. The drill is shown in Figure 1.

The testing device is comprised of a pair of cylindrical jaws which are used to apply compressive force along the diameter of the core in the direction along fibers. The length of the core should be sufficient to include a reasonable number of annual rings to avoid possible bias. The ASTM standards (1) require 50 x 50 mm (2 x 2 in) or 25 x 25 mm (1 x 1 in) cross section of the specimen. European standards use 20 x 20 mm (0.79 x 0.79 in) cross section. Therefore, the length of the cylindrical specimen should not be less than 20 mm. The testing device and a typical specimen are shown in Figure 1. The schematic of the testing apparatus is in Figure 2. The cylindrical specimen is inserted into the jaws so that the fibers are parallel to the direction of load. The concave surfaces of the device distribute the load over the surface of the specimen. The surface is only partially loaded due to the gap between the surfaces of the compression device. The gap is necessary to allow the specimen to deform. Currently, only the deformation of the cross head is used to establish the load-deformation curve. A new device which will allow the recording of the deformation between the two parallel surfaces has been developed and is currently tested. This will make possible to obtain information about the modulus of elasticity of the in-situ member.

To establish a correlation between the strength of a cylindrical specimen and the ASTM specimen, five species were tested: ash, maple, cedar, pine, and oak. Ideally, the relationship between core strength and ASTM-specimen strength should be only a function of the specimen geometry and test method - given that all other parameters (density, orientation, moisture content etc.) are equal for both methods. The species were selected to cover a wide range of densities and strengths. The location of individual specimens in the 50 x 50 mm (2 x 2 in) sample is shown in Figure 3. Cylindrical specimens were drilled in the vicinity of the ASTM specimens to reduce the effect of variability between specimens. All specimens were equilibrated at 22°C and 65% relative humidity environment. ASTM tension and compression tests were performed and correlated with the cylindrical specimens. The strength of the cylindrical specimen in compression was calculated as

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\sigma = \frac{F_{\text{max}}}{l} \frac{l}{d} \quad (\text{MPa, psi})
\]
where: $\sigma$ = compressive strength of the specimen; $F_{\text{max}}$ = failure load; $l$ = specimen length; and $d$ = diameter of the core.

**Results and Discussion**

A typical load-deformation curve is showed in Figure 4. There is no distinct yield point when a cylindrical specimen is used. This is due to the surface restraint, Poisson’s effect and shape of the specimen, which create a multiaxial stress situation. The value of the $F_{\text{max}}$ was established as an intersection of the straight line extension of two quasilinear portions of the load-deformation path and this is shown in Figure 4.

The correlation between the ASTM compressive strength and strength of the cylindrical specimen along the fibers is documented in Figure 5. Due to the inherent variability of wood and destructive nature of the test, perfect correlation cannot be expected. However, the correlation coefficient ($r^2 = 0.89$) indicates that the core drill method may be feasible for establishment of the compressive strength of the clear wood.

Tensile strength is compared with the strength of cylindrical specimen in Figure 6. As expected, the correlation coefficient is relatively low ($r^2 = 0.67$). One of the reasons of low correlation is the fact that the ASTM tensile test requires the cross section of the specimen to be $4.8 \times 9.5$ mm ($3/16 \times 3/8$ in). This leads to variable results, especially for species with wide annual rings. In future experiments, larger, non-standard cross sections will be used to avoid possible bias due to the nonbalanced proportion of early- or latewood.

The method can give a good estimate of compressive strength of small clear specimens when cutting of these is impossible. The relatively small outside diameter of the core drill will not cause structurally significant damage to in-situ members. The hole created by the drill can be easily plugged, thus somewhat preserving the integrity of the member. Possible drawbacks of the method are: 1. number of specimens needed to establish a reliable estimate of the clear wood strength. 2. determination of allowable stress based on clear wood values. The number of cores which need to be drilled per member should be sufficient to calculate the statistical parameters needed to establish a basis for allowable stress calculation. This may not always be possible. To estimate allowable stress values for in-situ members, one must know the extent and size of various defects. Therefore, a visual inspection of each member is necessary.

It appears, that the core-drill method can well complement some other nondestructive techniques such as stress wave method, which determines the global characteristics but may be weak in prediction of actual strength, moisture content or density. The core-drill method was successfully applied in conjunction with stress wave method and disperse wave analysis in determining the integrity of an underwater structure (3). The stress wave
method was used to isolate members different from the healthy control. The questionable parts of large 300 x 356 mm (12 x14 in) southern pine timbers were identified using stress wave analysis. Cores were drilled from the control and the identified members and their strength and density measured. Analysis of variance of the measured strength for cores and control was performed and the results were used to confirm the stress wave findings.

Future experiments will include: 1. establishing the correlation between ASTM modulus of elasticity in compression test (small clear specimens) and the core test, 2. establishing the correlation between the core test and ASTM bending test (small clear specimens), and 3. full-size members tests and core tests to establish the number of cores needed for strength and density estimates.

Literature


Figure 1: Core drill and testing device for cutting and testing cylindrical specimens

Figure 2: Schematic of the testing device.
Core samples

ASTM tension

ASTM compression

ends of tensile specimens
used for compression tests

Figure 3: Schematic of the location of specimens used to calibrate the procedure

Figure 4: Typical load deformation curve for a cylindrical specimen loaded in compression parallel to fibers.
Figure 5: Relationship between compressive strength of cylindrical and ASTM standard compression specimens.

Figure 6: Relationship between compressive strength of cylindrical specimens and ASTM standard specimens.