Transverse Vibration Techniques — Logs to Structural Systems

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Abstract

Transverse vibration as a nondestructive testing and evaluation technique was first examined in the early *1960s.* Initial research and development efforts focused on clear wood, lumber, and laminated products. Out of those efforts, tools were developed that are used today to assess lumber properties. Recently, use of this technique has been investigated for evaluating a range of wood materials – from logs to wood-based structural systems. This paper presents the technique and its use to evaluate a variety of wood-based materials and systems.

Introduction

Low frequency vibration has been studied as a potential method for evaluating wood-based products for nearly 50 years. It was first examined as a potential nondestructive evaluation (NDE) method for structural lumber, as one of several ways to determine the modulus of elasticity (MOE) of lumber for the machine stress rating systems that were evolving. Since completion of the first research studies on the subject, equipment based on this method have been used numerous times in laboratory and field situations around the world, mostly to evaluate the mechanical properties of lumber products. Recently, use of transverse vibration methods have received considerable attention as a potential way to assess the quality of logs and structural systems.

This paper briefly describes this NDE method and its use for assessing a range of wood-based products - from logs to timber bridge systems.

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Fundamentals

Detailed descriptions of the fundamental concepts of this technique and an excellent summary of early research efforts are presented in the publications listed in the bibliography and detailed information about its use is included in ASTM Standard D6874-03. The following is a brief synopsis of the underlying concepts they present.

For a beam simply supported at its ends, as illustrated in **Figure 1,** the relationship between its MOE and frequency of oscillation is given by the equation:

$$\text{MOE} = \frac{f^2 W S^3}{2.46 I g}$$

where:

f = resonant frequency (Hz),

W = weight of specimen (lb),

S = span (in.),

I = moment of inertia (in.^{4}), and

g = acceleration due to gravity (386 in./s^2).

Three elements are essential to this type of test set-up: a support apparatus, an excitation system, and a measurement system.

Support Apparatus

The support apparatus should provide vertical support to the ends of the specimen yet permit rotation.

The specimen should be supported so as to prevent damage at the point of contact between the specimen and the reaction support. The reactions should be such that shortening and rotation of the specimen about the reaction resulting from deflection are not restricted.

Provisions should be made at the reactions to allow for initial twist in the length of the specimen. If the bearing surfaces of the specimen at its reaction are not parallel, the specimen should be shimmed or the bearing surfaces

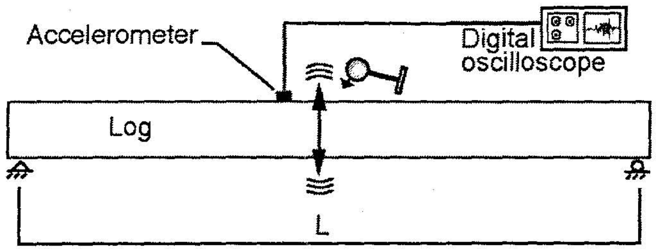

Figure 1.—*Typical transverse vibration test set-up used with a log.*

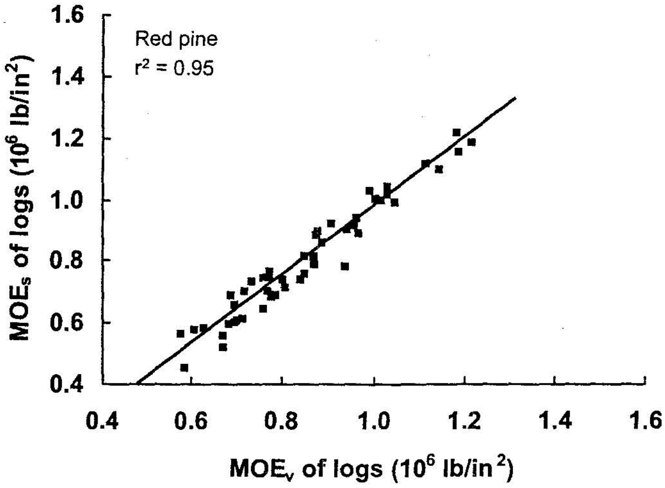

Figure 2.—*Typical statistical relationship observed between transverse vibration and static MOE.*

rotated about an axis parallel to the span to provide adequate bearing across the width of the specimen. No lateral support should be applied.

The specimen should be positioned such that an equal portion of the length overhangs each support. Excessive overhang may alter results. An overhang of approximately 1 in. (25.4 mm) on each end is often used in tests of dimension lumber. The amount of overhang may be influenced by the convenience of handling and positioning, but should be kept uniform from specimen to specimen.

Excitation System

The member should be excited so as to produce a vertical oscillation in a reproducible manner in the fundamental mode of vibration.

Manual deflection of the specimen will provide sufficient impetus for oscillation of many wood products. The deflection should be vertical with an effort to exclude lateral components.

Measurement System

Measurement of the frequency of oscillation should be obtained by a force, acceleration, or displacement measuring device.

Changes in force in response to the vibration at one or both supports can be used to obtain frequency of oscillation.

Frequency of oscillation can also be determined by measuring midspan displacement, velocity, or acceleration.

It is essential that only the frequency associated with the fundamental vertical oscillation mode be used.

The span-to-depth ratio should be greater than 60 unless special precautions are taken to permit higher frequency measurements. Best results are obtained when the frequency of oscillation is less than 30 Hz.

Assessment of Log Quality

The past several years has brought an increasing awareness of the health of forest ecosystems in the United States. There has been a marked increase in the number and severity of wildfires, with consequent loss of life and structures. This situation has arisen due to a variety of manmade and natural factors that have combined to produce forests containing a very high proportion of small diameter, low value trees. In an effort to provide economically viable uses for these trees, the USDA Forest Service initiated research and development activities to find uses for logs obtained from them. A series of research studies were completed to examine the potential of using transverse vibration NDE techniques to assess the quality of logs obtained from small-diameter trees from a variety of species.

Figure 2 shows typical results obtained. Note that a very high degree of correlation was observed between transverse vibration and static bending MOE values.

Lumber Property Evaluation

Investigations of the use of transverse vibration NDE techniques to evaluate mechanical properties of structural lumber were conducted as early as the 1960s. Excellent relationships were observed between transverse vibration and static bending MOE values for lumber obtained from a variety of wood species.

Evaluation of Glued Laminated Timbers

An experiment was designed to examine the contributions transverse vibration grading can make in the design and evaluation of laminated beams. The objective of the study was twofold: first to study the technical feasibility of using transverse vibration to analyze laminated beams and their components and second to demonstrate the possible benefits to be derived from the application of nondestructive testing to the production of laminated beams. Randomly selected lumber specimens were nondestructively evaluated using transverse vibration, ranked according to predicted strength, and segregated into three strength categories: high, median, and low. Fifty-five-foot-long laminae for the these categories were made by end-jointing appropriate lumber specimens. Individual laminae were evaluated using transverse vibration

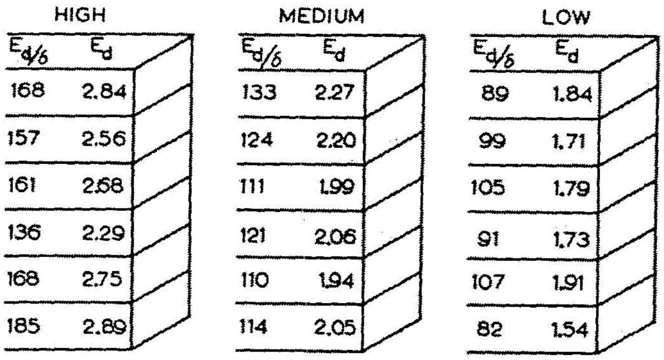

Figure 3.—*MOEs of glued laminated timbers.*

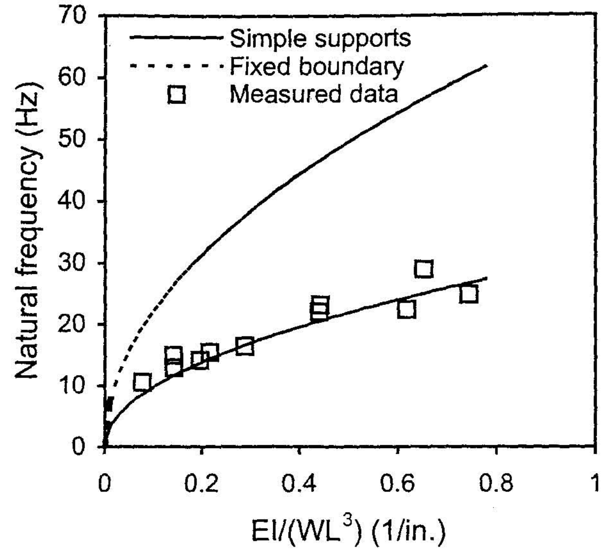

Figure 4.—*Results obtained from testing several in-place floor systems.*

NDE and fabricated into three laminated beams; one for each of the three strength categories **(Fig. 3).** The three beams were then tested nondestructively. Static bending tests were then performed on each beam. Results showed that the vibration parameters were proportional to static mechanical properties.

Condition Assessment of Structural Systems

Methods currently used to determine the condition of in-service wood (probing, stress waves, ultrasound) focus on evaluating individual members or small areas within members. Recently, an extensive theoretical and experimental research program was conducted to examine the feasibility of testing, in-place, entire structural wood systems. The results to date have shown that it may be possible to assess the in-place stiffness of some types of structural systems (e.g., short-span timber bridges and floor systems within buildings) using transverse vibration NDE techniques. **Figure 4** illustrates the results obtained from testing several in-place floor systems using a forced transverse vibration technique. Note that strong agreement was observed between predicted and test results.

Summary

The following can be summarized from the literature:

- Excellent agreement has been shown to exist between experimental observations and theoretically derived dynamic properties.
- An extensive database exists on the use of this method to evaluate the mechanical properties of wood-based materials.
- Transverse vibration NDE can be used on a variety of wood-based products, including structural systems.

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