An apparatus to measure the crosscut shearing strength of roots

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Loss of tree root strength after timber cutting is a principal mechanism leading to slope failure and landslides. Measurement of root shear strength changes can be useful in evaluating effects of logging on slope stability. The simple apparatus described measures shear strength directly on roots up to 50 mm diameter. Tests on live roots showed excellent correlation between measurements of shear strength and tensile strength.

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La perte de résistance des racines d'arbre après coupe est un des mécanismes importants qui conduisent à des affaissements de pente et des glissements de terrain. La mesure des changements de résistance au cisaillement peut être utile pour évaluer les effets de l'exploitation forestière sur la stabilité des pentes. L'article décrit un appareil simple qui mesure directement la résistance au cisaillement de racines allant jusqu'à 50 mm de diamètre. Les tests réalisés sur des racines vivantes ont montré une excellente corrélation entre les mesures de résistance au cisaillement et de resistance en traction.

[Traduit par le journal]

Deterioration of tree root strength has been identified as a major cause of reduced stability of steep forested slopes after logging.

Although roots generally tend to break in tension rather than shear during slope failure, root shear strength is much easier to measure and allows the study of considerably larger roots than tensile strength machines. Measurements of root tensile strength reported in the literature have been limited to root diameters less than 15 mm and most studies have been conducted on roots smaller than 4 mm in diameter.

Direct shear apparatus commercially available are either not suited to studying root strength or are prohibitively expensive. This note describes a device that is relatively inexpensive to manufacture, and satisfactorily measures the shear strength of roots from 1 to 50 mm in diameter. Over the past 2 years, we have sheared several thousand roots with this device.

The Apparatus

The apparatus (Fig. 1) consists of a stationary steel block which has been machined to allow the insertion of hardened steel dies. A hole is drilled in each die to hold a root of a desired diameter. For our studies the hole sizes were 2 mm, 5 mm, 10 mm, 17 mm, 25 mm, and 50 mm. The stationary block is held in place by two steel plates mounted on a steel rod framework. A movable steel block is machined to move closely against the stationary block along dovetail guides. A V-shaped hardened-steel cutting blade is welded on the top of the movable block. The movable block is pushed by a I0-ton-capacity mechanical jack.

The root to be tested is inserted through the hole in the die and protrudes at both ends. Stress is applied to the root at a shearing rate of 3.6 cm/min. The moving friction of the shear block and the maximum stress applied to each root segment at failure is measured with a proving ring and dial gauge positioned between the movable block and jack. The proving ring can be changed to match the range of anticipated stress applied. Both the moving friction and the maximum stress are converted to kilograms of force[2] using calibration curves developed for each proving ring. The net maximum force (shear strength) is obtained by subtraction. The proving ring capacities we used ranged from 90 kg for small roots to 2700 kg for large roots. Occasionally the maximum shearing force at failure on a root 50 mm in diameter would exceed 2700 kg.

Correlation with Tensile Strength

In early l976, a test was conducted to develop a correlation between direct shear strength measurements made with this apparatus and tensile strength measurements made with an apparatus developed by

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[2]The newton is the correct unit of force in the cgs system. The kilogram, a unit of mass, has been used by engineers and others as a force unit for years and is so used here. To convert: force (newtons) = mass (kg) x gravitational acceleration (9.807 m/sec^2).

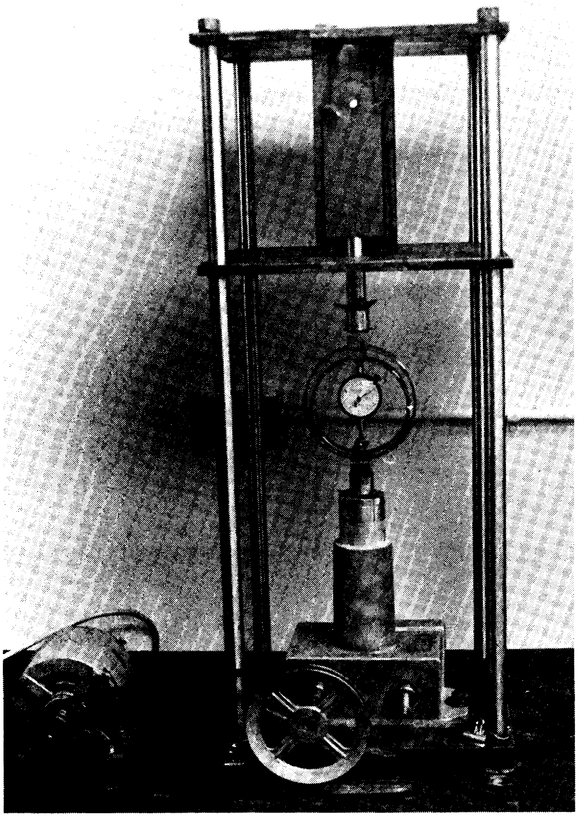

FIG. 1. The shear apparatus.

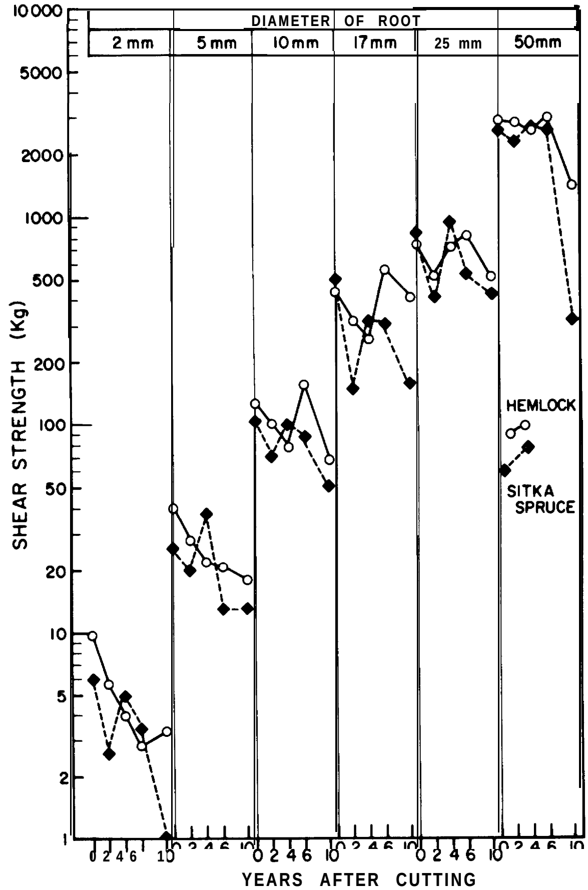

FIG. 2. Change in root shear strength with years after cutting for different root diameters of western hemlock and Sitka spruce.

Burroughs and Thomas (1977). Live roots of Douglas-fir (*Pseudotsuga menziesii* [Mirb.] France), redwood *(Sequoia sempervirens* [D. Don] Endl.), and Sitka spruce *(Picea sitchensis* [Bong] Carr.) were sheared about 25 mm from each end of the sample root segments. The mean of the two measurements was used as the maximum force required to shear the root. The same root was then placed in the tensile strength apparatus and broken in tension. The diameter of the roots ranged from 1 to 10 mm.

A linear regression using a total of 28 paired data points gave an excellent fit for the data:

Tensile strength = -7.6 + 2.2 (shear strength),

where the strengths are expressed in kilograms. The explained variance (r^2) was 0.97, standard error of the estimate was 15.09 kg, and the standard error of the coefficient was 0.07. No difference by species in the relationship could de detected.

Tensile strength measurements reflect the weakest point in the root segment. The weakest point, of course, fails first. Low tensile strength can be induced by bends in the root as well as by decay. When a bent root is pulled, individual root fibers break sequentially as the root straightens. Also, the probabilitv of finding a weak point in a straight root is a function of the segment length. The longer the root, the higher the probability of finding a weak point. Thus, a short test segment would have a higher strength, on the average, than a long test segment.

Shear strength measurements, on the other hand, are essentially independent of root segment length. A weak point in the root segment does not influence a shear measurement at an adjacent strong point. Consequently, we would expect average shear strength measurements to underestimate the loss of tensile strength in roots due to decay. Further study is needed to test this hypothesis.

Root Strength Loss After Cutting

About 500 western hemlock *(Tsuga heterophylla* [Raf.] Sarg.) and Sitka spruce *(Picea sitchensis*

[Bong.] Carr.) roots, collected from logged areas in southeast Alaska, where sheared (Ziemer and Swanston 1977). In uncut stands, hemlock roots were consistantly stronger than Sitka spruce. We found a linear relationship between the logarithm of live root strength and the logarithm of root diameter. As tree roots decay following cutting, residual hemlock roots were consistently stronger than Sitka spruce roots except 4 years after cutting (Fig. 2). Hemlock lost about one-third of its root shear strength and Sitka spruce lost about one-half of its root strength within 2 years following cutting. Large roots did not significantly lose shear streagth until after 6 years following cutting.

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