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Technical Note

Measurements of compression creep of wood at humidity changes

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Summary. Uniaxial compression creep tests of tubular spruce specimens loaded in uniaxial compression are reported. The relative humidity in the interior of the tube is varied in a controlled manner. The results indicate that creep is greatly increased in magnitude by simultaneous humidity changes of either sign.

Introduction

In a preceding paper (Bažant 1982), a theory for the effect of changes in environmental humidity on the creep of wood has been developed. This theory appears capable of explaining the test data available in the literature (Bažant 1982; Grossman 1978). However, except for Schniewind's tangential tension tests (1966), Ranta Maunus' shear tests (1973, 1975), and Byrd's fiberboard compression tests (1972), most of these data [see the preceding paper (Bažant 1982)] have been obtained on specimens subjected to bending. The interpretation of such data for the purpose of determining the constitutive equation is not as direct and clear as is the interpretation of tests of specimens in which the applied load does not produce nonuniform stress. An experimental program involving uniaxial compression creep tests was, therefore, inititated at Northwestern University to complement a simultaneous theoretical study (Bažant 1982). Although only a limited number of tests have so far been carried out, the results are interesting and are reported now since the program had to be interrupted due to funding situation and continuation is not in sight at present.

The test specimens, made of spruce, were hollow cylinders (tubes) of length 60 mm, external diameter 14.5 mm, and internal diameter 10.5 mm. The reason for choosing hollow specimens was to create a wall of small thickness (2 mm) which permits a rapid moisture exchange with the environment. The interior of each specimen was exposed to air of controlled humidity and temperature, which was

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circulated through the interior of the specimen. The external surface of the cylinders was sealed by vinyl jackets. Based on the known approximate moisture diffusivity of spruce across the grain, the drying time of a wall exposed on only one side was estimated as 4 hours, from the linear diffusion theory.

The relative humidity of the air was controlled by salts. To obtain the relative humidity of 52%, the air was circulated over crystals of calcium nitrate. To obtain a 100% relative humidity, the air was bubbled through a water bath. By exposing only the interior surface of the specimen, and circulating the air through thin tubing and a small glass tube with salt, the volume of air in the system was kept to a minimum. This allowed easy and precise control of humidity with a fast response. Prior to loading, the specimens were conditioned in the test chamber for one day at the test temperature and 100% humidity. Before that, the specimens were stored in a sealed state at a temperature of 25 °C. All tests were made at 35 °C.

The specimens were made of spruce and were manufactured at the Forest Products Laboratory, Madison, Wisconsin, from carefully selected timber. The cylinder axis was parallel to the grain of wood, and the specimens were cut from heartwood at the center of the tree trunk so as to minimize the effect of anisotropy. The tests reported here were made on green wood (i.e., wood never dried before the test). The mean short-time compression strength of the specimens in the green state was roughly 2500 psi. The specimens were provided with steel caps at their ends to transfer axial compression. The joint between the cap and the vinyl jacket was sealed with an O-ring.

A testing device which was originally developed for tests of creep of cement paste and mortar was used. It is described in detail in Bažant et al. (1976) and (1979). This device is triaxial; however, only uniaxial tests have been made so far. The axial load is provided by a hydraulically loaded piston. The deformation of the specimen was determined from the displacement of the loading shaft outside the chamber, measured by a pair of dial gauges. Based on previous calibration, a correction was made for the deformation of the loading system (shaft, test chamber, support columns, end caps); however, in the case of such a highly deformable material as wood, the necessary correction is unimportant.

The strains measured in two tests at different normal stresses (750 psi and 375 psi) are plotted as a function of load duration in Fig. 1; see the curves a-b. The relative humidity (R.H.) of the environment is also shown. Ideally, the part of total strain that is due to humidity changes (i.e., the shrinkage plus the increase of creep due to drying) would be obtained by subtracting from the strain of a loaded specimen the strain of a companion load-free specimen subjected to the same environmental history (as is done for concrete). This is, however, hardly possible in practice, due to the notorious large statistical variability of wood, which makes it impossible to produce an identical companion specimen. One way to circumvent this difficulty is to use bending tests, for which no companion tests are needed since environmental humidity changes produce no bending if the specimen is homogeneous. (This is one reason why only bending test data are found in the literature.) A different way to circumvent this difficulty was adopted here.

The comparison data for creep at constant environment can be generated by extrapolating the initial creep curve before the change of environment; see the curves a-c in Fig. 1. This extrapolation is possible in the log-time scale because in this scale the creep curve at constant environment is very smooth, of nearly constant slope, and because the extrapolation segment (the dashed lines in Fig. 1) is very short in the log-time scale. The effect of humidity changes is, therefore, represented by the difference between curves b and c in Fig. 1.

The curve a-b plotted in Fig. 1 shows the total strain, which includes the shrinkage or swelling strains, in addition to the mechanical (load-produced) strains. To assess how the environmental changes affect the mechanical strain alone (consisting of elastic strain plus creep, but without shrinkage or swelling), one needs to subtract the swelling strain from the strains observed during the wetting cycle. Due to the impossibility to use a companion specimen, the swelling strains to be subtracted may be roughly estimated as the cross-hatched strain difference s in Fig. 1, which are considered identical to the difference between curves b and c during the previous drying.

Although there is certainly some error in the values of s thus established, it is clear from Fig. 1 that the total strain (curve a-b) becomes *much larger* than the strain (curve r) which would be obtained by simple addition of the shrinkage or swelling strain and the creep (with elastic strain) at constant environment.

This proves that, similarly to bending creep, the creep in compression is greatly increased in magnitude by simultaneous humidity changes, of either sign. This conclusion qualitatively supports the theoretical model set up in the preceding work (Bažant 1982). Note that this conclusion is true, in particular, for wetting,

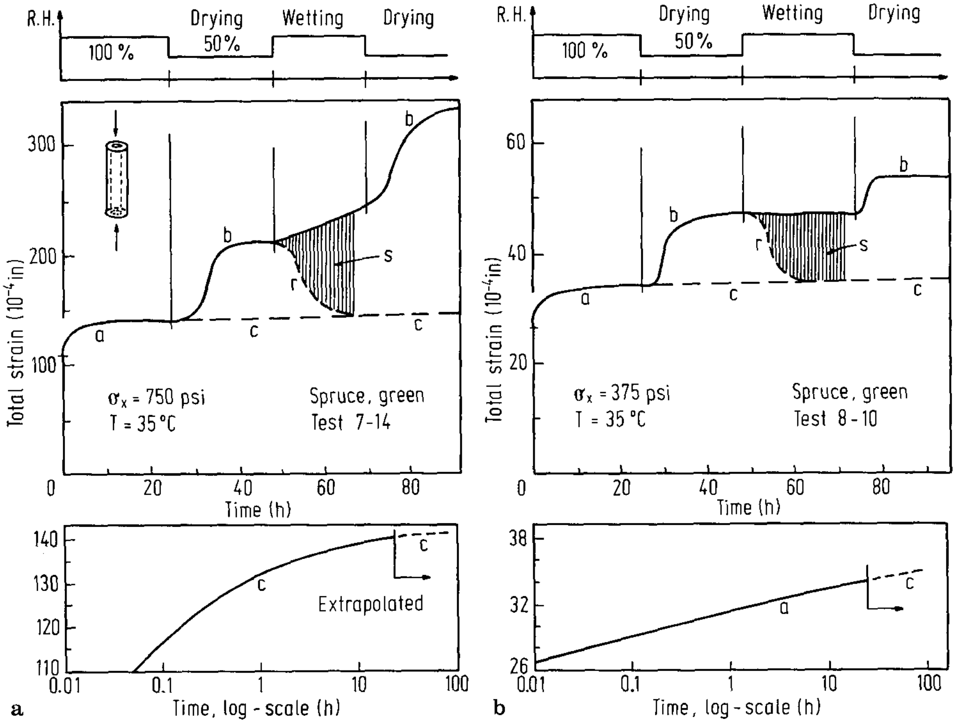

Fig. 1. Measured strains of wood specimens under constant axial compressive stress σ_x

even though the swelling caused by wetting goes *opposite* to the contraction caused by load. (From bending tests a similar conclusion cannot be drawn because one side of the beam cross section is always in tension.)

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