Compact, Simple Stress–Relaxation Equipment

When measurements of creep or stress–relaxation extend over long periods and numerous replications are required, it is not practicable to appropriate a testing machine or other expensive equipment for the purpose. It is not difficult to design a simple system that maintains the load constant and allows measurement of creep deformation. Methods to measure the relaxation of stress of a test specimen at constant deformation are not quite so obvious. The author has previously described several systems suitable for the measurement of stress relaxation[1–3] and is offering another in this note.

A recent experiment required that test specimens of wood at constant deformation be exposed to a sequence of controlled environmental conditions for periods of several weeks. Uptake or loss of moisture and the load necessary to maintain the constant deformation had to be checked at regular intervals. The following requirements were therefore considered for the design of the test equipment:

(a) the unit holding the specimen in its deformed state had to be light enough to allow detection of a change in specimen weight of 0.1%, when the specimen was weighed with the unit;

(b) the unit had to be compact so that it fitted into a small environmentally controlled space, e.g. a desiccator;

(c) there had to be the means of measuring the reaction force exerted by the specimen.

METHOD

The deforming unit weighing ca. 180 g is illustrated in Figure 1. The specimen (S) is a strip about 200 mm (8 in.) long supported at its ends, its center loaded or deflected via a transverse cylinder (C), the movement of which is constrained by a slot.

Deflection of the cylinder, and thus at the center of the specimen, is controlled by a screw which is electrically insulated from the framework. A dial-gauge is used to measure the deflection with respect to reference surfaces (R). It should be noted that a constant setting of the screw maintains constant deflection of the specimen only if there is no thickness change due to swelling or surface indentation.

The specimen may also be loaded by a weight suspended from the ends of the cylinder. If such a load exceeds that needed for the given deflection, the loading cylinder separates from the screw and the circuit to an indicator lamp is broken.

In order to find the force needed to maintain the given deflection at any time during an experiment, one suspends a deforming unit by its screw head from a cross arm (Fig. 2). A weight exceeding the critical weight is hung from the loading cylinder and is partly supported on the pan of a balance. The operator can increase the share of the load carried by the specimen by raising the assembly. A helical spring in series with the weight ensures a gradual load transfer from balance to specimen. The required load is determined from the difference between the total mass of the suspended weight and the balance reading when the lamp turns off.

ACCURACY AND PRECISION

A strip of tool steel of 22.0 × 1.6 mm (0.866 × 0.063 in.) cross section was used to verify the accuracy and determine the precision of the method of finding the applied force.

The steel strip was loaded in the unit and the deflection was measured with the dial gauge, allowance being made for the spring force in the gauge. After removal of the load, the screw was turned until the strip deflected as before and the corresponding force was determined by the procedure described above. The process was repeated for several loads. The tests showed no difference between the freely suspended loads and those determined from the contact break. The limitation to the sensitivity of this comparison was the precision of dial gauge readings.

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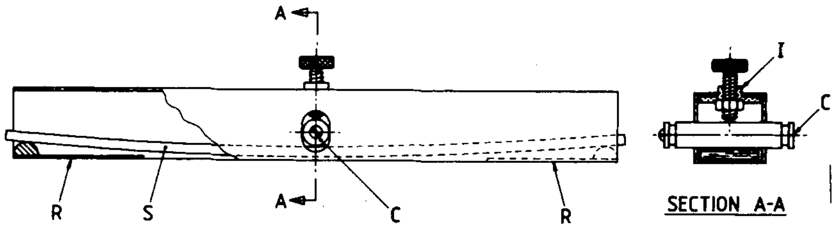

Fig. 1. Deforming unit: (S) specimen under flexure; (C) loading cylinder; (I) insulating grommet; (R) reference surfaces.

Repeated readings had a standard deviation of the order of 0.01 mm, and this corresponded to a deviation of about 80 mN or 8 g on the balance.

In order to determine repeatability, the steel strip was deflected, and at least five balance readings were taken when the light signalled contact break and at least five when contact was remade. This procedure was adopted for eight deflections ranging from 1 to 4.5 mm. The standard deviation of the sets of readings was 2–3 g for contact break and 4–5 g for remaking the contact. The difference between contact break and remake averaged 6 g.

Since the unit was designed for a maximum force of 45 N (10 lb), an error of 3 g in the balance reading corresponds to less than 0.1% of the full load. As the force decreases during a stress–relaxation experiment, the relative error will increase but remain tolerable for most applications.

APPLICATION

The method has been used on wooden strips of 20 × 4 mm (0.79 × 0.16 in.) cross section. These weighed about 10 g, and a commercial single-pan balance of 300 g capacity and 0.01 g sensitivity was used to determine changes in moisture content. A central deflection of 4 mm was maintained by means of the setting screw while units were placed into various consecutive atmospheres to cycle the moisture content of the wood between fibre saturation (above 30%)

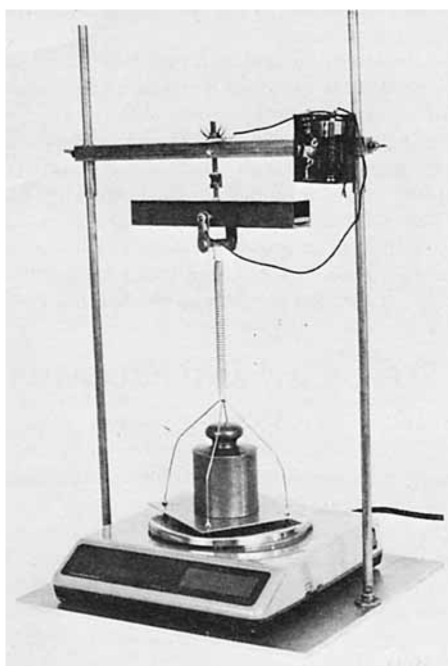

Fig. 2. Equipment for the measurement of the reaction load.

and 5%. The reaction load was initially of the order of 40 N (9 lb) and decreased during the process, reaching minima below a quarter of the initial value. The balance used to determine moisture content could also, in conjunction with appropriate suspended weights, be used to measure the reaction load.

Shrinkage and swelling of the specimens changed the deflection for a given screw setting by 4–5% and small screw adjustments had to be made to bring it back to the desired value.

The test specimens had to be removed from the atmosphere of controlled humidity for the several minutes needed to determine the residual reaction load. This caused no significant change in moisture content of the wood. The required temperature was maintained in the test room.

The method can be used for the study of stress–relaxation in many materials, but the dimensions of the specimens or even the deforming units may have to be adapted. The framework in the deforming unit must be sufficiently stiff by comparison with the specimen that its deformation can be neglected.

To illustrate the wider use of the equipment, a strip of PMMA of cross section 20.0×4.03 mm (0.787×0.159 in.) was tested at a temperature of 23°C. Since the sample was thinner and had a lower Young's modulus than the wood tested, the span was reduced to 120 mm (4.72 in.). The strip was deflected to 4.4 mm in the centre producing a maximum strain of 7.4×10^{-3} and the force needed to maintain that deflection was measured at intervals of time by the method outlined. It reduced gradually from 17.4 N after 1 min to 16.0 N after 95 min.

CONCLUSIONS

Stress–relaxation of large numbers of specimens can be observed over long periods without great equipment cost or space requirements.

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