Giannopoulos, I.P.

Creep and Creep-Rupture Behaviour of Aramid Fibres

Ioannis P. Giannopoulos

Over the past two decades aramids have been used as an alternative to steel for many civil engineering applications. However, uncertainty about their ability to carry significant loads for a long period of time (due to creep-rupture) has meant that engineers have been reluctant to adopt them. Many creep-rupture models have been proposed to explain the creep-rupture behaviour of aramids, but these models are based on data obtained at high load levels (min 70% Breaking Load), when creep failures can be expected in a short period of time. For lower load levels, extrapolation techniques have been suggested, but the reliability of these models is doubtful.

To improve the reliability of the long-term life models it is necessary to include creep-rupture data obtained at low load levels. However, creep-rupture data at low load levels cannot be obtained using conventional creep testing because failure takes place after years or even centuries. To overcome this problem, and to obtain creep-rupture data at low load level within a reasonably short time-scale, two accelerated techniques have been investigated. In these methods, heat and stress are used to accelerate the creep rate and thus reduce the time needed for a given amount of creep to occur.

Stepped Isothermal Method (SIM) testing involves loading a single specimen, under constant load, with the temperature increased in a series of steps to accelerate the creep. Careful choice of the temperature step and step duration allow the test to be completed in about 24 hours. At each temperature step a creep curve is obtained; these are then adjusted to compensate for the different temperature levels and a creep master curve at a reference temperature is produced. In Stepped Isostress Method (SSM) testing, a similar approach is adopted but the acceleration is obtained by increasing the stress in steps while keeping the temperature constant. Additional stress provides energy to the system in an analogue of the effect of heat in SIM.

In this thesis, SIM and SSM tests have been successfully applied to two slightly different aramid fibres, Kevlar 49 and Technora, for a wide range of loads (50-80% ABL). The test data are used to determine the creep and creep-rupture behaviour of the two materials. The creep master curves obtained by accelerated testing are compared with conventional creep tests at ambient conditions, and good agreement of the data is observed. A rheological model for the prediction of the creep and creep-rupture of the two fibres is established to facilitate and greatly increase the reliability of the prediction of the long-term behaviour.

This investigation allows more certainty about the creep-rupture relationships for different high modulus fibres, which will in turn allow more realistic safety factors to be applied when using these materials in engineering applications.

Key words: Accelerated testing, creep, creep-rupture, Stepped Isothermal Method, Stepped Isostress Method, continuous chain model, stress limits, Kevlar 49, Technora.