Tensile creep rupture testing for long-term strength

Introduction

Creep is defined as continuing deformation with time when the material is subjected to a constant load. Creep can occur as a result of long-term exposure to high levels of stress that are still below the yield stress of the material. CIPP and spray liners are susceptible to creep. A creep retention factor was utilised to consider the long-term reduction of material properties of CIPP liners. The creep retention factor is defined as the ratio of 50 years predicted modulus to short-term modulus in ASTM D2990 (2001), and was derived based on standard creep testing conducted with controlled temperature and humidity. However, creep retention factor was found to not correlate well to strength reduction and Young's modulus reduction in CIPP and spray liners (see Tensile creep tests and creep retention factor – fact sheet.docx). Therefore, testing such as creep rupture (ISO 899-1 2017) and hydrostatic design basis (ASTM D2992 2018) are recommended to determine long-term properties (long-term tensile strength or long-term burst pressure, specifically).

This fact sheet provides information on initial creep rupture testing of spray and CIPP liners, and shows that initial testing is promising to conduct full creep rupture curves.

Tensile creep rupture testing at Monash University

Tensile creep rupture tests were conducted on an Instron loading frame with 2kN and 50kN load cells (for spray and CIPP respectively). Loads were ramped to the stress level within 5 seconds (ISO 899-1 2017). The stress levels were held until the specimens failed in creep rupture. An example of a creep rupture strain curve for spray liner is shown in Figure 1.

Tensile creep rupture testing was conducted at various stress levels in specimens of CIPP and spray liners from flat plate samples (in hoop direction for CIPP). As creep rupture testing can be highly variable, a minimum of 3 repetitions of each stress level should be examined. Stress levels are a percentage of maximum stress (short-term tensile strength). To conduct testing requires good knowledge of how long a specimen may take to fail in creep rupture. Constant loads need to be held until failure occurs in the specimen, therefore, testing should be conducted initially at high percentages of maximum stress. For example, if running a creep rupture or hydrostatic design basis test at 60% maximum stress, the test may last for well over a year. Therefore, it is critical to run trial testing at higher stress levels before running a test that may take too long to get the required information.

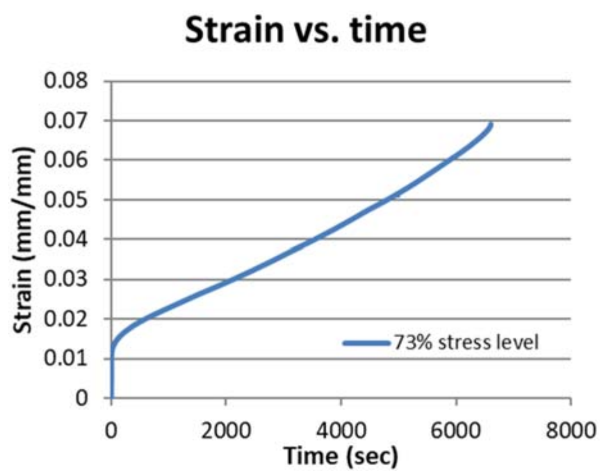

Figure 1. Strain vs. time curve of a tensile creep rupture test for spray liner subjected to a stress of 73% maximum tensile stress.

As testing was conducted on an automated loading frame, the initial tests were all at >70% maximum stress. Multiple tests were conducted on a spray liner and few tests were initiated on a CIPP liner.

Results and discussion

The following results are shown for spray liner tested under tensile creep rupture (Figure 2). Figure 2 shows the normalised stress (creep rupture stress/maximum short-term tensile strength) vs. time (hours). The results indicate that the normalised stress of the spray liner would be expected to decrease at a rate indicated from the logarithmic trendline shown. To extrapolate the strength of the spray liner at 50 years based on the trendline, the 50 year maximum tensile strength would be approximately 37% of the maximum short-term tensile strength (note: further testing should be conducted for a more accurate prediction).

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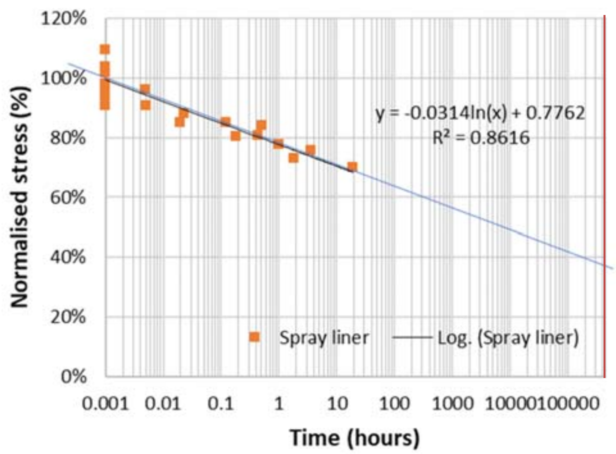

Figure 2. Normalised stress (%) (Creep rupture stress/maximum stress), vs. time (hours) in a log scale for spray liner tested. Curve was extrapolated for 50 years (red line).

The results of the CIPP specimens (Figure 3) in hoop direction also show a different trend with that observed in spray lining. In this case the long-term strength at 50 years would be predicted to be higher (~50%). A plateau in normalised stress may be seen in CIPP where fibres take more proporational stress (fibre-matrix decohesion) than the resin (see blue dashed line). However, as there are not enough data points for an accurate prediction, further tests are required for CIPP.

Tensile creep rupture tests seem promising to determine the long-term tensile strength of CIPP and spray liners. Further testing is required and creep rigs that can transmit a higher stress may need to be built when testing at lower nomalised stress values (<70%), due to the time it will take to creep rupture. The correlation between specimen testing (creep rupture) and pipe testing (hydrostatic design basis) may need to be established.

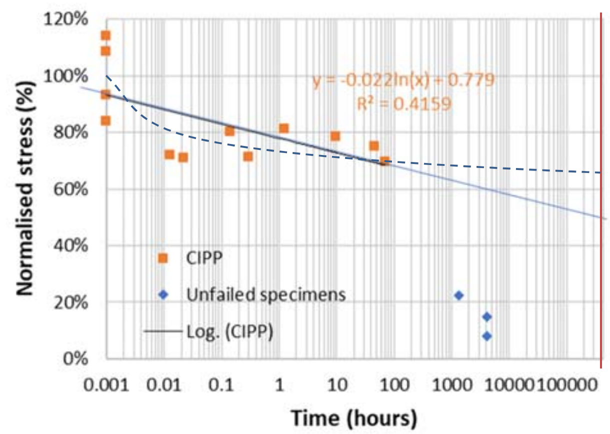

Figure 3. Normalised stress (%) (Creep rupture stress/maximum stress), vs. time (hours) in a log scale for CIPP liner tested. Curve was extrapolated for 50 years (red line). Blue dashed line proposed normalised stress vs. time curve.

Conclusions and recommendations

The long-term tensile strength can be examined through the use of creep rupture testing. Creep rupture or hydrostatic design basis testing should be a prerequisite of the standards for determining the service life of the liner used in pressurised water pipes. Further testing at longer time intervals are required for extrapolation of data up to a service life of 50 years. Testing for creep rupture of saturated specimens may be considered for further testing.

References

ASTM D2990-01, Standard Test Methods for Tensile, Compressive, and Flexural Creep and Creep-Rupture of Plastics, ASTM International, West Conshohocken, PA, 2001.

ASTM D2992 (2018). Standard practice for obtaining hydrostatic or pressure design basis for "fiberglass" (glass-fiber-reinforced thermosetting-resin) pipe and fittings. In ASTM D2992. ASTM International, West Conshohocken, PA, USA, pp. 1–10.

ISO 899-1 (2017). Plastic - Determination of creep behavior - Part 1: Tensile creep. International Standard Organization, Geneva, Switzerland, pp. 1–14.