BACKGROUND TO SUSTAINED LOAD TESTING OF PIPE
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1. Representation of Pipeline Service Conditions
A number of pipe materials lose strength with time, and due allowance for strength loss has to be made in setting acceptance levels for short-term performance tests. Long-term testing of strength properties is particularly important with pipes made from new materials, which have no long-term service history.

Tests as described in CPAA Technical Bulletin 01/87 (Reference 1) represent both the stress (loading) and the environment of a pipe in service. There is available a choice of tests which simulate one aspect or the other (i.e., stress or environment), which are appropriate if only one aspect has a significant effect, or if the two effects act independently. We can classify the types of test appropriate to various materials as follows:

1.1 Short Term Loading
Appropriate for materials where time-dependent and environmental effects are insignificant. Also for quality control or prototype testing, where time related effects can be taken into account by some other means. These tests can be simple, quick and graphic. However, there may be a strong temptation to take the results as conclusive, even when this cannot be justified.

1.2 Tests involving Long Term Loading in Air
Appropriate where environmental effects are not important. The Plastics Industry has recognised the need for and conducted such tests for a long time. Measurements can include creep or stress relaxation as well as long term strength.

1.3 Environmental Ageing Tests; No Stress
Appropriate where the environment acts independently of stress.

1.4 Long Term Loading in a Representative Working Environment
Better representation of the conditions of service than the other kinds of test, but generally more expensive. Essential where stress and the environment interact to produce more severe effects than either separately.

Figure 1 shows results of strength tests on polymer concrete immersed in water, with and without load applied (Reference 2). The strength loss is much less when there is no sustained load.

2. Examples of Test Methods from the Australian Pipe Industry
Our pipe industry provides a number of examples where long term effects are taken into account.

2.1 UPVC Pressure Pipe – Long Term Hydrostatic Pressure Test (Reference 3)
Test pipes are subjected to a sustained internal water pressure, with pressures chosen to give a range of tensile stresses in the pipe wall. Times to burst are recorded. A logarithmic plot of applied stress against time to burst is extrapolated to 50 years, and the extrapolated value must exceed a specified minimum. A safety factor of 2.1 is applied to the minimum 50 year strength to give the design stress for pipes.

While this is a combined sustained load/environmental test, it is now recognised that there is a significant effect from cyclic loads, particularly if there are any cuts or scratches in the pipe surface. The existing test does not take these factors into account.
2.2 Plastics Pipelaying Design (Reference 4)
The design method specified in this Standard is independent of the strength of the pipe material but does make use of the “creep modulus”, a long term analogue of Young’s Modulus. Creep moduli are typically a third or less of the short-term moduli. The Standard contains a table of creep moduli for various plastic pipe materials at a range of temperatures. Although there is a marked effect from the temperature, creep moduli for the types of material covered are essentially the same in air as in water, i.e. they are independent of environment.

2.3 GRP Pipe
The draft Australian Standard DR.87081, “Glass-fibre Reinforced Thermosetting Plastics (GRP) pipes – Polyester Based – Water Supply, Sewerage and Drainage Applications”, refers to four long term tests in which pipe specimens are subjected to a sustained stress or strain. They are long term stiffness, long term ring deflection, long term failure pressure, and long term resistance to strain corrosion. All tests involve setting specimens for periods up to and beyond 10,000 hours, and extrapolating to 50 years. The method of applying the data is more cumbersome than the method specified in the UPVC Standard, in that each result applies to a particular performance classification of pipe, rather than to the pipe material itself. Limits are set which the extrapolated values must exceed.

In the long term ring deflection test, specimens are placed in water under constant load either until they fail or until the rate of creep reaches a defined (high) value. An example of results from such a test is shown in Figure 2, which is of interest in showing deflections at failure becoming lower as the sustained load is reduced, and the rates of creep increasing with time for all levels of applied load – i.e. it is not valid to extrapolate creep values to a constant deflection or strain to predict failure times.

In the draft Standard the limiting values of deflection range from 24% to 9% for the common classes of pipe. Since the current laying code has a 5% deflection limit this results in a factor of safety for the installed pipes.

In the long term pressure test, the test pressure for each pressure classification is the nominal working pressure divided by a parameter which corresponds to the retained strength ratio (defined in Technical Bulletin No. 01/87) and then multiplied by a safety factor. Safety factors vary with the pressure class but are all close to 2.

Details of the tests for long term stiffness and long term resistance to strain corrosion are not relevant to the present discussion.

3. In Conclusion
3.1 The conditions of service of drainage pipe are well represented by water immersion and a sustained load.
3.2 Plotting times to failure of pipe samples set at a range of loads and extrapolating to the design lifetime is an accepted way of determining the long term strength of pipe or pipe material relative to initial strength.
3.3 It is also accepted that, in setting test loads, a safety factor must be applied as well as the allowance for strength loss.
3.4 To determine the long term strength of a pipe material, it is not sufficient to measure the change in strength with time of test specimens immersed in water but not subject to sustained load.
3.5 Long term strength cannot be determined by extrapolating creep measurements.

References:
Fig. 1 Strength of Polymer Concrete in water.

- Beams
- X Sustained load
- O Immersion only

Fig. 2 Long Term Ring Deflection Test Results for GRP Pipe ring samples

(From "Advances in Underground Pipeline Engineering," p.373, Ed. J. K. Jeyapalan, American Society of Civil Engineers, 1985.)
INTERPRETING RESULTS FROM SUSTAINED LOAD TESTS

1. INTRODUCTION
The purpose of sustained load testing is to determine the long term strength of a material, and it is inevitable that a result will be required for a longer period than the actual period of testing; i.e. the results have to be extrapolated. The extrapolation is carried out by fitting a line to the experimental points and extending the line to the period for which an estimate of strength is required.

2. FITTING THE LINE
There is no one “right” way of determining the shape and position of the line, but experience can show which procedures give lines that match the experimental points best, and which give estimates of long term strength that vary least as the period of testing becomes longer. Both these criteria are important – a method giving a good fit to early data is unsatisfactory if the fit becomes progressively worse, and the projected long term strength changes markedly, as the tests run for an increasing period of time.

Examples of different ways of fitting lines to data are shown in Figures 1 and 2. In both cases the source of the data is an Amdel report on the sustained load testing of cellulose FRC pipe (Reference 1). In Figure 1, the line is fitted to the data according to the original Humes specification for this kind of test (Reference 2), and in Figure 2 according to the method now more generally favoured and expressed in one of the draft Australian Standards for testing glass reinforced plastic pipe (Reference 3). Both lines fit the points equally well (correlation coefficients similar) but the latter gives a somewhat lower 100 year retained strength ratio. Refer to Table 1 for a summary of the influence of plotting technique on the determination of retained strength ratio and, consequently, on the calculation of the factor to be applied to design load to obtain an acceptable test load.

Table 1. Influence of Plotting Technique on Retained Strength Ratio

<table>
<thead>
<tr>
<th>Figure</th>
<th>Reference</th>
<th>Method of Plotting</th>
<th>Dependent Variable</th>
<th>Retained Strength Ratio at 100 Years</th>
<th>Test Load Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>Log - linear</td>
<td>Strength</td>
<td>0.32</td>
<td>4.7</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>Double - log</td>
<td>Time</td>
<td>0.26</td>
<td>5.8</td>
</tr>
</tbody>
</table>

* Design load is multiplied by this factor to obtain minimum ultimate test load (Reference 4).

3. RELIABILITY OF EXTRAPOLATION
Extrapolated strengths from sustained load testing will be unreliable if any of the mechanisms of strength loss is prevented from becoming effective during the test period. For materials susceptible to water this can be “arranged” by coating the samples so as to keep water out during the test period. Polymeric coatings are permeable to some degree but are able to keep water out of the body of the pipe material for the relatively short periods (often less than two years) employed in sustained load testing.

REFERENCES
03/87

Fig. 1 **Strength of FRC (Cellulose) under sustained load in water.**
Rings cut from 600mm pipes.

Strength axis linear.
Time axis logarithmic.
Strength treated as dependent variable in determining position of line.

Fig. 2 **Strength of FRC (Cellulose) under sustained load in water.**
Same data as Fig. 1.

Strength and time axes both logarithmic.
Strength treated as independent variable in determining position of line.