The Long Term Stiffness of Black Max

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SUMMARY

Short and long term stiffness has been measured for a sample Black Max profiled wall plastic (polypropylene) drainage pipe, with a test duration of two years and four months. The best fit of a trendline to experimental data gives 50 year stiffness, 18% of the initial value. This result is similar to an early published value for polyethylene and much lower than values for polyethylene derived from data in AS 2566.1. Using the design method of AS 2566.1 with values for long term pipe stiffness above the actual stiffness of installed pipes will result in deflections greater than those predicted by the design.

INTRODUCTION

Black Max is a polypropylene pipe, supplied by Iplex Pipelines for non-pressure drainage, sewerage and irrigation applications [1]. The pipe has a structure comprised of a plain inner and profiled outer wall, fused together along the lines of contact. Black Max has been appraised by WSAA [2].

For the purpose of pipe stiffness measurement (eg "ring-bending stiffness" per AS 3752.10), a segment of pipe is loaded externally along diametrically opposite lines parallel to the axis. The stiffness is calculated from the force per unit length of pipe and the change in diameter along the line of the applied force ("deflection"). For the same pipe diameter and wall profile, pipe stiffness is proportional to the ratio of stress to strain ("modulus") for the material.

AS 2566.1 "Buried flexible pipelines – Part 1: Structural design" includes a table of "typical pipe material characteristics" (Table 2.1), including initial and long term (50-year) moduli. In one instance in particular, for polyethylene, the reduction in modulus from initial to 50 year values is much smaller than a typical value previously reported for the loss of stiffness of the corresponding pipe. From Table 2.1 of AS 2566.1, the residual modulus after 50 years ranges from 22% to 29% of the initial values, whereas an early publication relating to plastic pipe[3] reports a typical value of 16% for polyethylene.

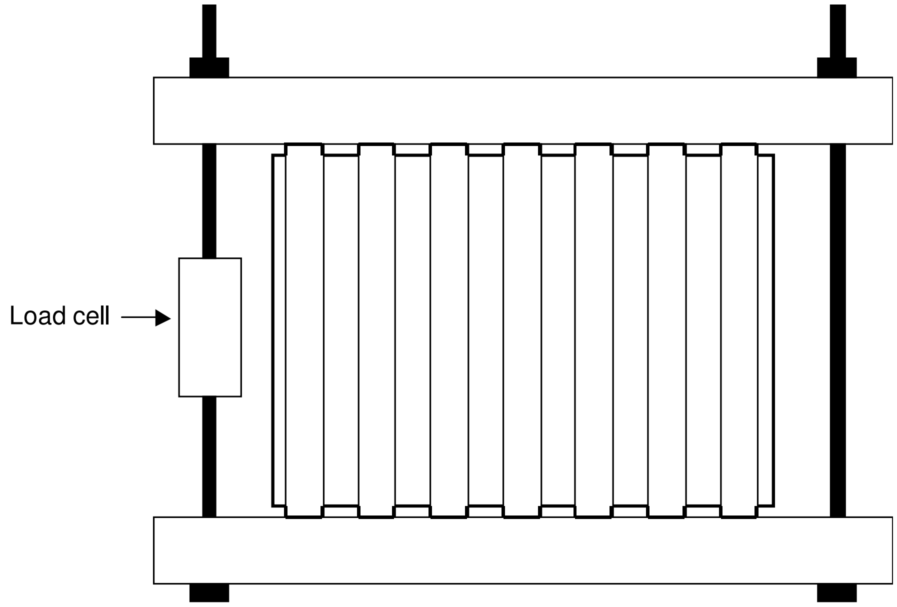
It was of interest to determine where the change in stiffness of Black Max, made from polypropylene, lies in relation to values for polyethylene.

TEST FOR STIFFNESS & STRESS RELAXATION

A 0.5 m long segment of DN 450 Black Max was deflected 4.4% using apparatus as shown in Fig. 1. This deflection was maintained and the load monitored over a period of two years & four months. The environment was air, indoors in Melbourne, without any heating or cooling.

In AS 2566.1, the initial stiffness is the stiffness after three minutes of loading. With the equipment used in this test it was not possible to measure an initial load within this time and so an initial value was obtained by extrapolation. A second order polynomial was fitted to the data from the entire duration of the test and a load corresponding to three minutes taken from the curve so obtained. This load gives an initial stiffness of 13,000 N/m/m, well above the minimum of 1250 N/m/m required for application of AS 2566.1.

Figs. 2-4 are plots showing the variation of stiffness over time. In Fig. 2 the stiffness expressed as a percentage of the initial value is plotted against logarithm of time. Figs. 3 & 4 are plots against log (time) of the logarithm of percentage of the initial stiffness. Fig. 3 shows a second-order polynomial fitted to the data points as required by AS 3572.8, referenced in AS 2566.1 for measurement of long term stiffness. For some materials AS 2566.1 allows a linear approximation for the relationship between log (stiffness) and log (time). The data from this test fitted with a straight line are shown in Fig. 4.



Total applied load is twice the reading from the load cell

Figure 1. Test Arrangement

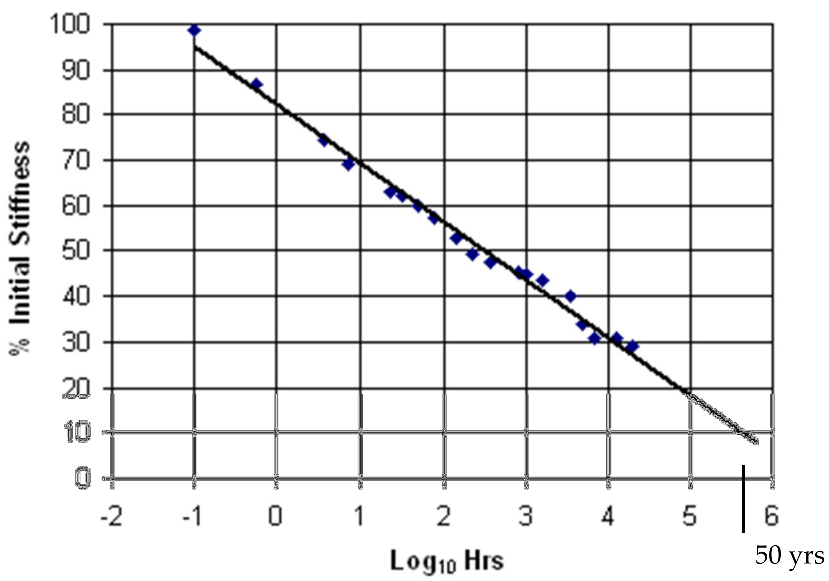


Figure 2. Percent of Initial Stiffness v. Log (time)

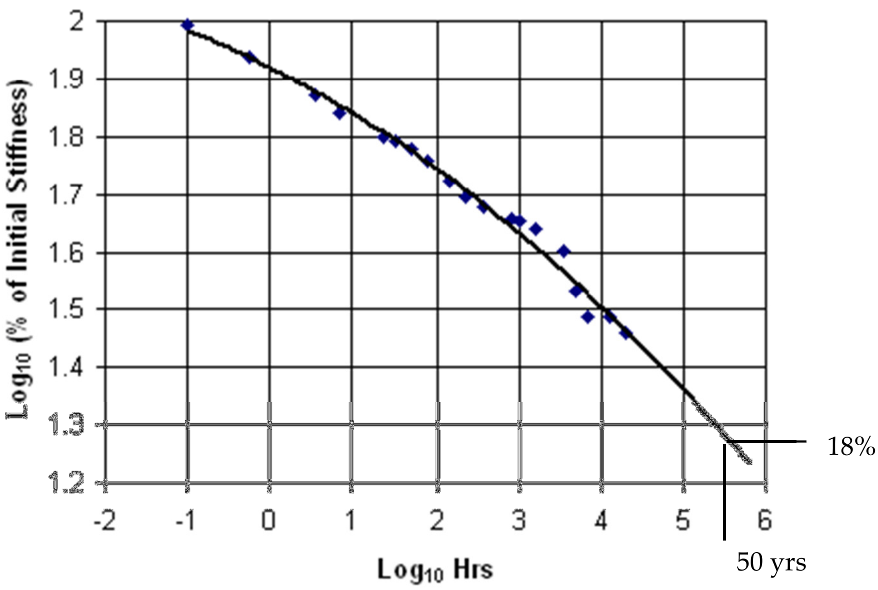


Figure 3. Log (% of initial stiffness) v. Log (time); Trendline Second Order Polynomial

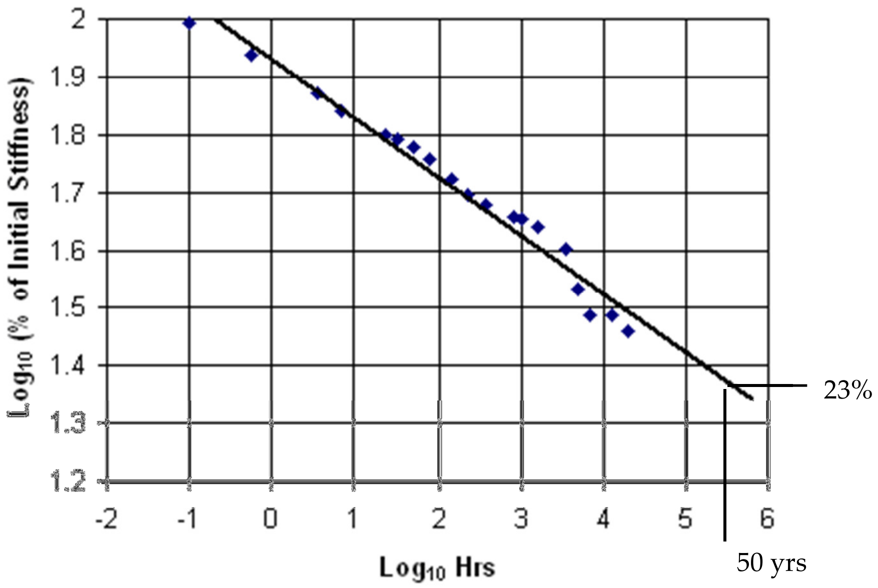


Figure 4. Log (% of initial stiffness) v. Log (time); Straight Trendline

Extrapolated to 50 years, the stiffness expressed as a percentage of the initial value, using the three types of plot, are as shown in Table 1.

TABLE 1. PERCENTAGE OF INITIAL STIFFNESS RETAINED AT 50 YEARS

Plot	Description	% at 50 years
Fig. 2	% initial stiffness v. log (time), straight line	10
Fig. 3	Log (% initial stiffness) v. log (time), second order polynomial	18
Fig. 4	Log (% initial stiffness) v. log (time), straight line	23

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The second order polynomial provides the best fit for the data, giving a result close to the early published value for polyethylene[3] . From these two results it would justifiable to take a range of say 15-20% as indicative for polyolefin, whether polyethylene or polypropylene. This is of course at variance with values for polyethylene tabulated in AS 2566.1.

The deflection of installed pipes is governed by both the pipe stiffness and the stiffness of the surrounding soil, and for plastic pipe the soil stiffness will usually have the greater influence. However using the design method of AS 2566.1 with values for long term pipe stiffness above the actual stiffness of installed pipes will result in deflections greater than those predicted by the design.

REFERENCES

1. Iplex website at www.iplex.com.au.
2. Iplex Pipelines Product Appraisal 03/05 "BlackMAX ™ and SewerMAX ™ Pipe Systems", Water Services Association of Australia, 15/12/03.
3. K Kienow & R Prevost, "Stiff Soils – An Adverse Environment for Low Stiffness Pipes", paper presented at the American Society of Civil Engineers "Pipelines in Adverse Environments" II Specialty Conference, San Diego, CA, Session No. 9, November 14-16 1983.