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IN-SERVICE DURABILITY OF uPVC WATER MAINS

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In order to determine whether uPVC pressure pipe performance is affected by time in service, sections of uPVC water mains of ages up to 16 years have been exhumed and tested. From a combination of quality and mechanical property tests it is shown that initial pipe quality is the overriding influence in determining pipe performance.

INTRODUCTION

uPVC pipes, which were first used as water mains over 25 years ago, currently have about 50% of the market share for pipe renewals and new works. This usage of uPVC is not spread evenly across britain, some engineers remain reluctant to specify it owing to its poor historical performance (1), whilst others are concerned that the pipes may age and become more susceptible to brittle failure with time in service. The work described in this paper was undertaken in collaboration with Severn Trent Water Authority, to determine whether the durability of uPVC water mains is affected by time in service.

uPVC is a viscoelastic material and therefore its properties are expected to change with time. Various research workers have investigated this phenomenon but they have used new pipes and artificially aged them by heat. In particular L C E Struik (2) found that the effect of artificial ageing on uPVC, using a variety of temperatures and times, is to make it stiffer and more brittle and to reduce the rate of stress relaxation of the material, whilst Schwencke (3) concluded that the effect of artificial ageing, which can be achieved by storing pipes at 60°C for 17 hours, is to increase their creep resistance and strength. A variety of preliminary tests carried out at WRc did not show artificially aged pipes to behave in the same way as pipes which had been in service for many years. It was decided that a study of properties of genuinely old pipes would provide results which could be interpreted more easily.

In this study pipes which had been in service for up to 16 years have been exhumed and tested in the ways described as follows.

In order to reduce the number of variables a single pipe size and class, 4 inch diameter class C (operating pressure 9 bar), from a single manufacturer was chosen for study. Pipes of a range of service ages which had experienced similar service conditions were exhumed. The manufacturer with the most extensive records of quality control and type testing for past production was chosen to allow this data to be compared with similar test data generated from tests on the exhumed pipes.

PIPES

Five 35m lengths of uPVC pipeline were exhumed from the Staffordshire area in the autumn of 1982. Their ages and operating pressures are given in Table 1. In addition samples of current production pipe were taken from Water Authority stockyards.

inhomogeneous regions up to 1.3mm were apparent, the larger ones being in pipes 1 and 4. Better gelled pipes would be expected to be more tolerant of defects, and therefore conversely pipe 4 with its low gelation and large defects would be expected to perform poorly. These differences in pipe quality must be borne in mind when examining the following mechanical test data.

The stress rupture results are shown in the standard format in Figure 3. The ductile and brittle failures are distinguished. Since it is not reasonable to relate the two failure types to a single regression line, only the ductile regression lines have been drawn. The dashed lines are regression lines of the original hydrostatic tests carried out by the manufacturer. It must be noted however that the manufacturer's test samples were end-restrained whilst those tested at WRc were unrestrained. For ductile failures, using Von Mise's yield criterion, it can be shown that pipe hoop stresses in restrained end tests are smaller than unrestrained by a factor of 0.87. Therefore to be directly comparable with the solid line, the dashed one should be shifted upwards. The dotted line shows this.

The slopes of the ductile regression lines and the manufacturer's lines are very similar for pipes 1 to 4 but there is substantial variation for pipe 5. If the samples of pipe 5 which are still on test and its tensile yield stress (see later) are taken into consideration it is clear that until further data is available, the line cannot be accurately plotted.

Still considering the ductile regression lines, the stresses which pipes 1 to 4 can withstand for a total lifetime of 50 years are slightly lower than those predicted from the manufacturer's regression lines but still significantly above the 23MPa required by BS 3505 (4). The scatter of the ductile failures about those regression lines is small such that the 97.5% lower confidence limit of the regression lines at 50 years is still greater than 23MPa. Until further data for pipe 5 is available it cannot be included in this comparison. The figures are given in Table 2.

Table 2 also compares the ductile regression line intercept with the tensile yield stress. The values are similar for pipes 1 to 4. The tensile yield stress for pipe 5 is close to the values for the other pipes which suggests that its ductile regression line will also be similar.

TABLE 2

PIPE NO.	STRESS FOR 50 YEAR LIFE (MPa)			TENSILE STRENGTH (MPa)		
	DUCTILE LINE	97.5% LOWER CONFIDENCE	MANUFACTURER'S LINE	DUCTILE LINE INTERCEPT	MANUFACTURER'S INTERCEPT	TENSILE YIELD STRESS
1	29.8	26.1	32.0	47.1	52.2	48.0
2	29.3	27.8	30.8	46.9	51.3	47.4
3	28.3	26.6	33.0	46.7	52.9	46.2
4	30.0	27.5	35.7	48.6	50.4	48.8
5			36.4	54.9	50.1	48.6

Having noted the similarities of the ductile line with the manufacturer's line, the important difference must now be considered. For all pipes 1 to 5 there have been a considerable number of totally brittle failures at relatively short times under test. Such failures would not be expected in new good quality pipe. Pipes 1 and 4 have shown the most brittle behaviour. This is likely to be attributable to their large defects and poor gelation. On the basis of the present data the brittle failures cannot be attributed to ageing since extrusion because all of them have occurred at pipe hoop stresses which are lower than the hoop stresses used by the manufacturer during type testing. The data shows no correlation of pipe age with mechanical performance. It is the opinion of the author that the pipes' initial quality is the most significant factor in influencing their subsequent performance.

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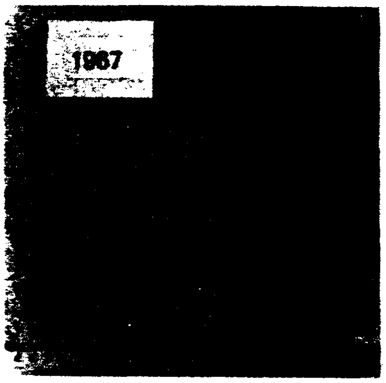
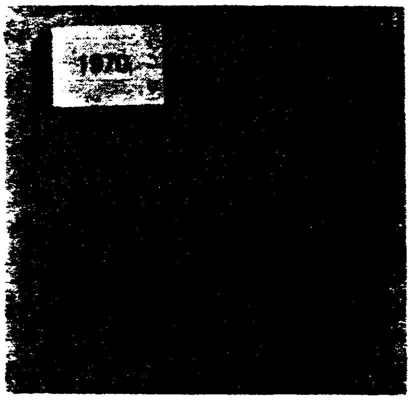
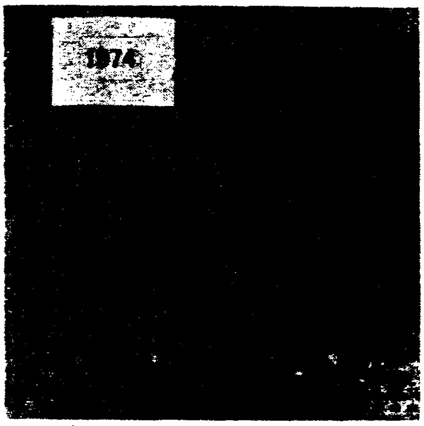


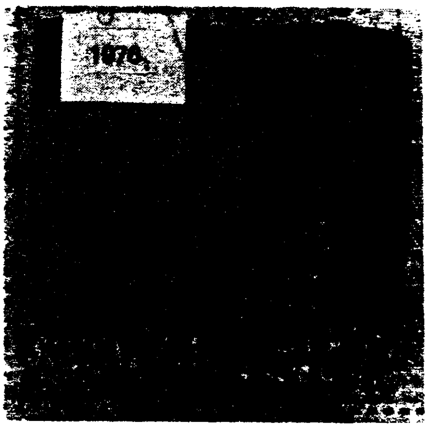
Pipe 1. Outside and middle of wall



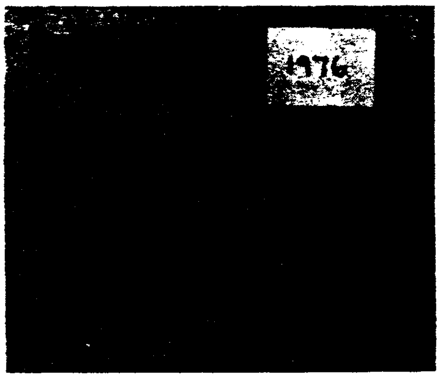
Pipe 2. Outside and middle of wall



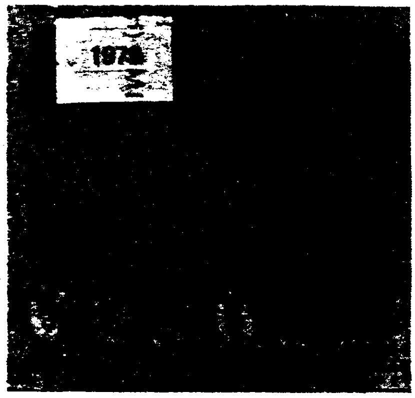
Pipe 3. Outside and middle of wall



Pipe 4. Outside and middle of wall



Pipe 4. Inside wall



Pipe 5. Outside and middle of wall

New pipe. Outside and middle of wall

Fig. 2. Pipes after tapering and immersion in methylene chloride at 20°C for 30 minutes.