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Standing Technical Committee on Sewers and Water Mains: Materials and Standards

Information and Guidance Sheet

GLASS FIBRE STRENGTHENED CONCRETE PIPES

1. INTRODUCTION

The pipe which is described and marketed as the 'Slimline Pipe' is a product of ARC Concrete Ltd, and is a centrifugally spun concrete pipe reinforced on both outer and inner face with a continuous length of an alkali resistant glass known as Cem-FIL sent in a thin layer of ordinary Portland Cement (OPC). Cem-FIL is a new material which was developed jointly by the Buiding Research Establishment and Pilkington Brothers Ltd. This information sheet reviews the development of the pipe, accelerated aging tests that have been used to assess the long term properties, and comments on the advantages and possible risks in using it.

2. DEVELOPMENT OF GRC

Portland Cement is highly alkaline and will normally attack glass. Development work in the 1950s and early 1960s on various combinations of glass fibre and cement matrices met with only limited success due to the problems of loss of the strength of the glass fibre under alkali attack. However, in 1967 the Building Research Establishment discovered that it was possible to produce an alkali resistant glass fibre by incorporating a high proportion of zirconia. This discovery made practical the production of a new composite material GRC (glass fibre reinforced cement), which combines both the high tensile strength of glass with the high compressive strength of cement. In 1968 Pilkington Bros Ltd, was licensed by the National Research and Development Corporation to develop GRC commercially in collaboration with the BRE, for use within the building and construction industry. By 1971 experimental production of building components had commenced and in 1972 the glass fibre was marketed by Pilkington as Cem-FIL. Selected companies have subsequently been licensed by Pilkington to develop and manufacture GRC products and components using Cem-FIL and powers have been retained by Pilkington and BRE to monitor its applications. The developers placed an embargo on its uses for structural applications and are undertaking a weathering programme to determine long term properties, strength and stress-strain behaviour, density and thermal movement, fatigue and creep. This embargo, together with other considerations, meant that the uses of GRC have mainly taken the form of cladding panels and sheet components which are factory produced from a sand-cement slurry matrix containing a recommended level of 5 per cent glass content, by weight. The glass fibre is usually a random chopped strand of 25 to 38mm length and the mix is usually dewatered.

By 1975 knowledge of GRC as a material, gained from experience in manufacturers and from experimental data, and their improved ability to evaluate its long term performance, enabled Pilkington to review its embargo. Resulting from this review Pilkington recommended that the embargo on the use of GRC in fully structural applications where, if failure were to occur, there would be risk to life and limb or of major loss or damage, should continue. However, it was recommended that GRC products or components could be used, with care in 'semi-structural' situations where failure would be very unlikely to cause danger to life or to cause serious damage, and where the material is subjected to low load producing stresses which could be closely defined and which would be well within the anticipated strength of 'aged' GRC. An example included within this category was: 'certain low pressure pipes'.

3. PROPERTIES AND DURABILITY OF GRC

The properties and behaviour of any composite material will depend on the proportional content, distribution and orientation of its constituent parts, together with the quality and method of manufacture. From 1969 onwards an extensive study of the properties of GRC has been made by Pilkington and BRE, and in June 1976 the results of a series of tests carried out on sheet material, which had been subjected to exposure to various environmental conditions, were published by BRE[1]. The majority of published results refer to the testing of a spray-dewatered type sheet material containing 5 per cent by weight of chopped fibre in OPC matrix.

Results of research have shown that after its initial cure the spray-dewatered GRC material has a bending strength (modulus of rupture) in the range 29 to 39N/mm² (4200 to 5650 lb/in²) and a tensile strain to failure of about 1 per cent. These properties are maintained for long periods in dry storage conditions, but in water storage conditions the tensile strength and modulus of rupture drop to around half of the initial values during the first two years, and the material becomes more brittle. Results that are available suggest that after this initial loss of strength a stable strength level is then maintained.

Storage in water at temperatures higher than ambient leads to a more rapid fall in strength which then stabilises at a lower level. Results of tests on

WRC ENGINEERING CENTRE
P.O. Box 85,
Frankland Road, Blagrove,
Swindon, Wilts. SN5 8YR.
Tel: Swindon (0793) 488301

GRC sheet material that has been immersed in water at 50°C show that a stable strength of 13 to 15N/mm² (1885 to 2175 lb/in²) is reached after about two months. Immersion in water at 50°C has been adopted as an accelerated aging condition to estimate long term performance.

Not enough is yet known to explain fully the chemical and physical changes that take place after the initial cure, nor is it certain that stability or equilibrium states have been reached. Research work is still in progress to determine the long term properties under load such as creep, fatigue and stress-rupture behaviour.

4. SLIMLINE PIPES

The Slimline Pipe consists of a normal concrete core which is 'sandwiched'[2] between an inner and outer layer of GRC. The GRC layers are integrally cast with the core and the inner layer is covered with a fine concrete lining. A centrifugally spun process is used and the glass fibre is a continuous roving Cem-FIL. After forming, the pipes are steam cured. The pipe is manufactured by ARC Concrete Ltd at its Meadow Lane Works, St. Ives, Cambridgeshire.

Concrete cover protection of the glass fibre against corrosion is unnecessary. The pipe has a rebated joint, i.e. within the pipe wall, which provides a lighter pipe and is therefore more easily handled. It also gives the additional advantages of flat bedding and easier alignment, and is easier to check the final position of the rubber joint ring and that the joint is fully made.

5. DEVELOPMENT AND TESTING OF THE SLIMLINE PIPE

ARC Concrete Ltd decided in 1971 to commence work on the development of a 750mm diameter GRC/concrete pipe designed to meet the performance requirements of BS 556[3]. During the following year the first pipe was produced from a pilot plant and by 1975, a 750mm diameter test pipe line, installed with measuring equipment to monitor movement and deflection, had been laid under the access roadway to its St. Ives works. In 1976. Agrément Board Certificate No. 76/378 relating to the 750mm diameter Class M pipe was granted and in 1977 this was replaced by Certificate No. 77/499 which covers the diameter range 600 to 1200mm. Also in 1977, a full scale production plant was commisioned.

Throughout the development Pilkington has approved the suitability of the application and use of Cem-FIL and an assessment of the performance of GRC in the Slimline Pipe was submitted by Pilkington to the Agrément Board in support of ARC's application for a certificate relating to the 750mm diameter pipe.

This information submitted to the Agrément Board included the results of hydraulic and load tests carried out in accordance with the requirements of BS 556[3], together with results of load tests to assess strength retention. These were carried out on coupons, 350mm long x 50mm wide, cut from a 750mm diameter pipe and artificially aged in water at 50°C for up to 90 days, and at 35°C for up to 12 months. Results of load tests on short lengths of pipes which had been similarly aged in water at 50°C and 35°C were also submitted. Subsequent to the submission similar tests were witnessed by the Agrément Board representatives. Testing has been carried out by either ARC or Pilkington.

The results show that the Slimline Pipe meets the test requirements specified in BS 556[3]. The results of tests on the accelerated aged specimens indicate that the initial bending strength (modulus of rupture) is lower than that of GRC sheet material being 10 to 11N/mm² (1450 to 1600 lb/in²) compared with 29 to 39N/mm² (4200 to 5650 lb/in²). This strength level, however, remains fairly stable and there is not the rapid loss of strength that is characteristic of GRC sheet material.

6. CERTIFICATION ASPECTS

(i) The Agrément Board Certificate No. 77/499 which was granted contains the following statements:

(a) 'The pipes are equivalent to conventionally reinforced concrete pipes in terms of strength, hydraulic flow characteristics and durability...'

(b) *Resistance to loading:* 'Pipes and fittings may be considered to be equivalent to BS 556: Part 2: 1972.'

(c) *Durability:* 'The design strength, and composite action of the materials will be adequately maintained during the life of the pipes.'

(d) 'When used in accordance with the recommendations contained in this Certificate, the product will have a life similar to that of conventional spun concrete pipelines'

(ii) It should be noted that BS 556[3] does not refer to this type of reinforcement in concrete pipes and the British Standards Institution says of (b) above: 'We consider the use of the British Standard in this way for an article for which no standard has been drawn up is misleading'.

(iii) BSI has published a Draft for Development, No. DD76 in 1981, on *Precast concrete pipes of composite construction;* Part 1 deals with *Precast concrete pipes strengthened by continuous alkali resistant glass rovings*. The following two paragraphs are reproduced from the foreword of this document:

Concrete pipes are normally expected to remain in service for 50 years to 100 years, so the introduction of new materials makes it necessary to assess long term durability. For glass fibre strengthened pipes, the accelerated aging tests developed by the Building Research Establishment and by Pilkington Brothers Limited for GRC composites have been used. The results obtained from these tests have been examined by a study group set up by the BSI committee responsible for all standards relating to concrete pipes and fittings.

A full explanation of the differences in performance between pipes strengthened by continuous glass rovings and other products made from glass reinforced concrete is not yet available, but the Committee considers that the absence of any significant change in strength shown by pipe sections subjected to these accelerated aging tests is a reasonable indication that the strength of the pipes will be maintained. However, it is recognised that this performance may be a function of the design and manufacture of the pipes and hence a type test using the accelerated aging procedure has been included in this Part. Pending further research, some of the available evidence suggests that the continuous glass fibre rovings strengthen the pipes by arresting crack propagation by redistributing stress around the cracks.

Drafts for Development are reviewed every two years. During this time comments of the document are required from users, specifiers and manufacturers with a view to renewing the draft or developing a British Standard. A questionnaire prepared by BSI is available on request from the Secretary to Committee CAB/12, British Standards Institution, 2 Park Street, London W1A 2BS. When completed, these forms should be returned to the Technical Secretary of STC Sub-committee 4, WRC Engineering Centre, PO Box 85, Swindon, Wiltshire.

7.CONCLUSIONS

The Slimline Pipe offers advantages over its traditional counterpart in weight, bedding requirements, ease of handling and jointing, all of which lead to reduced pipeline construction costs.

The cost of the pipes themselves are at present comparable to the cost of conventional steel reinforced pipes, but with the rising cost of steel reinforcement the Slimline Pipe may become more cost competitive in the future.

The Slimline Pipe has been subjected to a range of standard and accelerated testing to assess its structural strength and some of these tests have been included in the Draft for Development to provide a sound basis for design. The Agrément Board certification also includes a regular level of quality assurance which is carried out by the QA Department of BSI. However, only limited investigations have been undertaken to assess the suitability of the pipe for use in a drainage system where it may be subject to the effects of a variety of industrical effluents. While further testing would be desirable, further accelerated tests are unlikely to provide any greater assurance than that obtained from the present evidence, and as with all new materials, the ultimate test of suitability will be dependent upon time in service in actual operational situations. It is suggested that slimline pipes could now be used in appropriate situations where there are benefits and other advantages.

Referring to the Draft for Development, it is important that comments are made on this document and the water industry users and specifiers should be encouraged to use the Draft and make appropriate comments in order to assist its review after its two year life.

[1] A Study of the Properties of Composite: current Paper 3876 Building Research Station.

[2] Although it is convenient to refer to the composite material as a 'sandwich', there is no discontinuity between concrete and GRC in the construction of the pipe.

[3] It should be noted that BS 556 Part 1 has been withdrawn and Part 2 will remain in use only for a limited period and will be replaced by BS 5911 Part 1.