

Standing Technical Committee on Sewers and Water Mains: Materials and Standards Information and Guidance Sheet

GRP PIPES AND FITTINGS

1. INTRODUCTION

During the last few years, glass fibre reinforced plastics (GRP) pipes have become available in various forms of manufacture for duties undertaken by other materials. GRP is a thermosetting material, and the pipe is a composite structure made up from resins and glass fibre reinforcement. Around the world GRP pipes are used for sewerage, irrigation, water supply, and chemical process plant, although in the UK only limited use has been made for some of these purposes. Rather the material has been used for specialist purposes such as culverts and linings. The information contained in this sheet refers to the use of GRP pipes and fittings for water supply and sewerage.

2. COMPOSITION

GRP pipe is a composite, non-homogeneous structure made up of:

Resins	- polyester	BS 3532
	- epoxide	BS 3534
Glass fibre reinforcement (type E glass)	- rovings	BS 3691
	- chopped mat strand	BS 3496
	- woven fabrics	BS 3396
	- woven roving fabrics	BS 3749

and other materials, such as aggregates, inert fillers, additives and colorants.

Surface tissues may be used to produce resin rich surfaces, and pre-formed thermoplastic liners of uPVC (BS 3505, 3506) or polypropylene (BS 4991) may be incorporated.

The choice of these materials together with catalysts and/or hardeners is made such that the final product is compatible with the liquid to be transported in the pipe. In the case of compatibility with potable water this is particularly important as unless specifically designed, it is possible that a standard pipe may not be suitable for potable water. It would be necessary to ensure that a pipe required for this purpose was so classified.

The determination of suitability of a GRP pipe material for use with potable water is generally arranged by the manufacturer in consultation with the customer by an agreed testing procedure. This may involve testing by the customer to his own requirements, or by the manufacturer obtaining certification of the pipe's suitability from an independent body acceptable to the customer, or by NWC approval.

N.B. Standard testing procedures for effects of materials on water quality are currently being considered by a BSI Panel, as a common requirement for all materials.

3. CONSTRUCTION

The main methods of manufacture of GRP pipes are currently based on either a filament wound system or centrifugal moulding. The body of the pipe is made up of resin, and filler material, with the glass fibre providing reinforcement to resist loads.

Filament wound pipes may be made in a continuous length on a 'moving ribbon' mandrel, or on a fixed length mandrel to produce specific lengths. The filament may be wound in a helical manner (to develop resistance to load in circumferential and longitudinal directions) or in an orthogonal manner with each fibre or roving fabric developing load resistance in a specific direction.

Centrifugally cast pipes are manufactured from chopped strand rovings, resin and sand, arranged in distinct layers to develop the required pipe stiffness.

Curing of the pipe materials forms part of the production technique when automatic processes are employed. For non-automatic methods of manufacture, the curing process may be necessary as an extra operation. 'Maturing' of the pipe material is not normally a requirement but if it is necessary it only involves a matter of hours. The manufacture of a composite pipe structure should be carried out under controlled factory conditions of temperature and humidity.

The external surfaces of the pipe are usually finished in a particular fashion to ensure good wearing and impact resistance to provide durability. The internal surfaces are finished to minimise flow resistance, either by a resin rich surface or use of liners (Section 2).

4. APPLICATIONS

GRP pipes are available with or without thermoplastic liners for conveying, above or below ground, potable and non-potable water, foul sewage and storm water, and for pressure or non-pressure use.

5. BRITISH STANDARD CLASSIFICATION

A British Standard is being produced with the joint co-operation of manufacturers and users. Manufacturers are particularly aware of the need for standardisation in order that potential users of the material have some basis of judgement of the pipe properties, sizes and classifications available.

The British Standard BS 5480 - Glass fibre reinforced plastics (GRP) pipes and fittings for water supply or sewerage - consists of two parts:



Part 1 deals with classification, dimensions and materials, and was published in August 1977. Part 2 deals with performance requirements, and was issued as a draft for public comment in 1978. The comments received have been considered and Part 2 of the Standard has now been published.

In view of the variety of manufacturing processes and the diverse nature of design methods for GRP pipes, it is advisable for a customer considering purchase of this material to discuss the project at an early stage with potential manufacturers.

There are a number of other British Standards indirectly relevant to GRP pipes. These are concerned with properties etc. of materials of construction rather than the composite structure of the pipe itself. In BS 5480 Pt 1 reference is made to materials of construction and states that where appropriate, these meet the individual requirements of the associated standards (Section 2).

One other associated standard which is in preparation is the Draft Standard Specification for reinforced plastic pipes and fittings for process plant.

In view of the differing approaches to requirements in the water and process plant industries, this draft standard has been prepared by a separate BSI Panel which ultimately reports to the same parent Committee.

6. BS 5480 PART 1

Part 1 of BS 5480 relates to dimensions, fittings, joints, materials of construction, classification, beam strength and marking.

The preferred range of nominal diameters is shown in Table 1 with standard lengths of 3m, 5m, 6m, 10m and 12m. Other diameters and lengths may be supplied by agreement between manufacturer and customer.

Table 1. Preferred nominal diameters of pipe (mm)

25	125	600	1600	3000
32	150	700	1800	3200
40	200	800	2000	3400
50	250	900	2200	3600
65	300	1000	2400	3800
80	400	1200	2600	4000
100	500	1400	2800	

Pipes are classified by the maximum sustained working pressure for which they are suitable, as follows:

0.1, 2.5, 4.6, 10, 12.5, 16, 25, 40 and 64 bar

In addition there are stiffness classifications (relating to resistance to external load) viz:

Initial specific stiffness $\frac{EI}{D^3}$ in the classes

250, 400, 525, 650, 900, 1100, 4000, 8000 N/m²

where I = moment of inertia of pipe wall per unit length

E = bending modulus in the circumferential direction

D = diameter in m.

N.B. During preparation of the Draft British Standard, requirements for stiffness specified by certain Consultants, together with UK and USA recommendations for stiffness for flexible pipes, have resulted in an increased number of values being used in practice. Non-preferred stiffness values (together with the BS proposed figures) have therefore developed in general duty classifications as follows:

For light duty applications
250, 400, 525, 650 and 900 N/m²

For structural application
1500, 2000 and 2500 N/m²

For pipes subject to full external hydrostatic pressure
4000 and 8000 N/m²

The latter classification is dependant on internal strutting, and up to 10,000 N/m² has been quoted as a requirement in a few instances.

Whilst not normally produced to withstand end loads developed by internal pressure, GRP pipes can be so designed and would then be classified accordingly. Classification is also governed by the compatibility of the pipe material with liquids.

Due to loading which may arise during handling and laying, the ability of pipes to support beam loads may be measured by their longitudinal strength, as follows:

up to and including:	600mm diameter	:150N/mm
	600 to 1200mm	:200N/mm
	1200 to 2400mm	:250N/mm
	2400 to 4000mm	:300N/mm

These requirements should not be used for design purposes. e.g. pipes intended to withstand end load resulting from internal pressure or beam loads due to support on piers, will normally require higher longitudinal strengths.

7. BS 5480 PART 2

BS 5480 Part 2 contains type tests and quality assurance tests. Type tests are required on pipes or fittings representative of each duty, and must be repeated when significant alteration of designed basis or laminate structure is made.

Quality assurance tests are required at a frequency determined by procedures similar to those in BS 6001 Specification for sampling procedures and tables for inspection by attributes. The inspection level covers production lots up to 150 units. In certain instances 100 per cent testing is required by BS 5480.

Records of tests are required to be maintained by manufacturers which thus enable the customer to inspect quality control standards on a historic basis, as well as in relation to a specific production run.

Type tests are as follows:

- Compatibility with potable water
- Impact test
- Long term chemical resistance
- Long term hoop strength
- Long term semi-permanent set and ageing
- Diameter check (as in quality control tests, to a procedure laid down in BS 5480 Part 2).

Quality assurance tests are as follows:

- Dimensional check
 - in relation to requirements for straightness, out-of-squareness, and wall thickness already laid down in BS 5480 Part 1
 - of diameter, by a procedure laid down in BS 5480 Part 2.
- Leak tightness
 - Non-pressure pipes (ie 'O' bar rating).
 - On all pressure pipes.
- Initial specific stiffness - on a ring cut from the pipe barrel.
- Initial hoop tensile strength
- Initial longitudinal tensile strength (includes determination by beam test, tensile strip, or tensile plate test) for pipes designed to withstand

end load this strength requirement must be incorporated in pipe design procedures.

- (f) Chemical resistance (strain corrosion) to specific strain/life requirements.

Design limits are incorporated to ensure factors of safety on the various design stresses as determined from regression curves on test results, extrapolated to 50 years.

N.B. The '50 year' point is a design parameter, and does not reflect a limited life of the pipe material. On the basis of accelerated tests, the 50 year point is chosen as one at which the strength is appropriate for determination of long term minimum safety factors. Pipe, design procedures use conventional design formulae, and in common with other materials soil loading must be considered as well as any pressure loads.

BS 5480 Part 2 contains clauses relating to workmanship, certification and inspection, together with non-mandatory construction and cure tests which are based on existing British Standards relating to materials and other GRP composite structures.

8. OTHER CERTIFICATION

Some manufacturers have obtained independent certification from the Agrément Board for a particular pipe use and method of production. These certificates typically contain information as follows, although details vary:

- Part I Certification — the product; marketing; use; assessment; building regulations
- Part II Technical specification and design data — description; materials; manufacturers; identification; handling; installation; strength; durability; resistance to abrasion, damage and chemicals; toxicity; joint performance.
- Part III Technical investigations — summarises tests on which the issue of the certificate is based.

9. CODES OF PRACTICE

No standard code of practice for GRP pipes exists, but some manufacturers have produced documents covering design procedures, specifications for installation and handling, instructions for jointing and repair work, storage/stacking requirements and so on. Whilst each document refers to a particular manufacturer's product, all contain much technical information. The code of practice for thermoplastics pipes (CP 312) states that 'thermosetting materials are outside its scope', and hence GRP is excluded.

Repairs to GRP pipe installations can be carried out either by in-situ patching, or by cut-out and replacement. Section cut-out and replacement would be used for pressure installations. Where in-situ patching is implemented on non pressure installations the work should be carried out by skilled operatives.

Where installations are expected to experience surge or fatigue conditions the customer is advised to inform the manufacturer. The major manufacturers have carried out cyclic testing of their products to verify design criteria, and can either design pipes to accommodate such loadings or provide higher classifications than would otherwise be needed for static pressure conditions.

For site pressure testing it is necessary that the pressure applied does not exceed the works test pressure, otherwise strain damage may occur to the pipe. This may not cause failure during the site test, but due to the nature of material properties and

design based on strain rather than stress, could give rise to failure later during service.

10. FITTINGS

Fittings for use with GRP pipes may be made from GRP or other conventional materials. The requirement of BS 5480 Pt 1 is that fittings of all materials must be equal or superior in performance to GRP pipe of the same classification and in addition fittings of materials other than GRP must also comply with requirements of relevant British Standards.

Specials and fittings for the larger sizes in pressure classifications are often made of coated steel. A range of fittings is available in GRP comprising 'T's, bends, Y junctions, tapers, etc, and these are fabricated from sections cut from complete pipe lengths, or made by hand lay up process.

BS 5480 Pt 2 requires that a leak tightness test be carried out on every GRP pressure fittings. For GRP 'non-pressure' fittings the Quality Assurance frequency requirements of paragraph 7 apply.

Although GRP pipes are currently made primarily in the larger sizes, and hence might not normally be expected to have small off-takes connected, facilities are provided by some manufacturers for this purpose. For non-pressure purposes the use of a 'saddle' type of connection can be made. For pressure purposes the use of a 'T' piece is normally recommended.

11. JOINTS

Joints may be of rigid or flexible type. BS 5480 Pt 1 refers to rigid joints such as flanged, butt and overlap, socket and spigot with bonding compound and screwed joints. Flexible joints are referred to as rolling, or restrained O ring, or clamped type.

Rigid joints are required to be equal or superior in performance to pipe of the same classification in both circumferential and longitudinal directions. Flexible joints have a similar requirement in the circumferential direction only, up to the limits of angular deviation or draw indicated by the manufacturer.

In common with certain other materials, joint interchangeability is not usually possible between different manufacturers' products. However interchange fittings and specials are available to facilitate jointing between different GRP pipes, and to other pipe materials.

12. SUMMARY AND CONCLUSIONS

GRP pipes and fittings are available in this country for use in water supply and sewerage. The present estimate of penetration in the UK market is up to 5 per cent. Standard sizes, lengths and classifications are available.

Automated production techniques are:

Type of construction	Typically available from	Trade name
Centrifugally cast with chopped strand rovings and sand layers	Johnston Pipes Ltd	Armaflo
Filament wound	Redland Pipes Ltd	Fibaflor
Filament wound with sand layers	Stanton and Staveley	R.P.M.

Advantages, particularly for large diameter water and sewerage system, are:

High strength to weight ratio
Resistance to internal and external corrosion
Design flexibility for standard and non-standard situations.

Manufacturers also claim advantages of:-

- Ease of handling and laying
- Good and maintained flow characteristics (C value 150 in Hazen Williams flow formula)
- Durability
- Long term safety factors.

Whilst ease of handling and laying may be achieved in good soil conditions, the flexibility of the pipe could in some conditions be considered a disadvantage through requirements for special precautions in laying and back-fill.

It is considered that there is a need for a code of practice relating to BS 5480, particularly if the pipes are to be widely used in the UK.

On the basis of cost comparison it is generally considered that GRP pipes are competitive in the larger sizes. It is suggested that GRP compares with some other materials for similar duties (e.g. concrete) on a production cost in sizes from around 1000mm diameter upward. In conditions where advantage can be taken of the ease of handling and laying the installed cost break-even comparison could be in sizes from around 500mm upwards.

In addition to manufacturers' technical literature, a comprehensive reading list is available from the Water Research Centre on a range of topics including marketing information, commercial production, practical experience, and materials investigation and testing. The document is Enquiry Report ER 454.