GRP PIPE PRODUCTS FOR USE IN IRRIGATION PROJECTS

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ABSTRACT

Recent years have seen an increase in the use of glass reinforced polyester (GRP) pipes for irrigation projects in New Zealand. GRP pipes are available in diameters up to 4000mm and present a strong alternative to traditional materials due to their competitive up front cost and reduced whole of life costs.

Local and international standards with rigorous type and batch release testing exist for the protection of the consumer. These standards have been developed by the GRP pipe industry and are based on experience over the last 50 years with buried GRP pipes and flexible pipes in general.

The worldwide capacity to produce continuous filament wound (CFW) GRP pipe has increased significantly in the last 10 years. Copied production lines, without the robust technical backing of established manufacturers, have entered the global market in low cost economies. This is of concern as a lack of knowledge on materials and process will reduce product quality.

In the competitive irrigation piping market there is high demand for low cost options but the consumer and asset owner needs to be aware of how to evaluate the options being offered. Through knowledge of the requirements of the standards and the significance of consistency of raw materials the consumer will better be able to evaluate the long term performance and overall cost of asset ownership of GRP piping systems.

KEYWORDS

Glass reinforced polyester, pipe, irrigation, product evaluation

1 INTRODUCTION

GRP pipe has been in use internationally for almost 50 years. More than 70,000 kilometres of continuous wound GRP pipe has been installed in that time in diameters ranging up to 4000mm and pressures to 40 bar (4.0 MPa). GRP pipe has the advantages of being light weight, stiff and inherently corrosion resistant making it ideal for water and waste water applications. Major irrigation projects have been installed worldwide effectively utilising these properties.

Many international standards exist for GRP pipes and many suppliers claim compliance with these standards. This paper discusses the requirements of the standards and the significance of long term testing in evaluating pipe materials.

While there are a number of technologies available for the manufacture of GRP pipes this paper will focus on continuous filament wound GRP pipe as this is the current gold standard and the technology most likely to be used in irrigation projects.

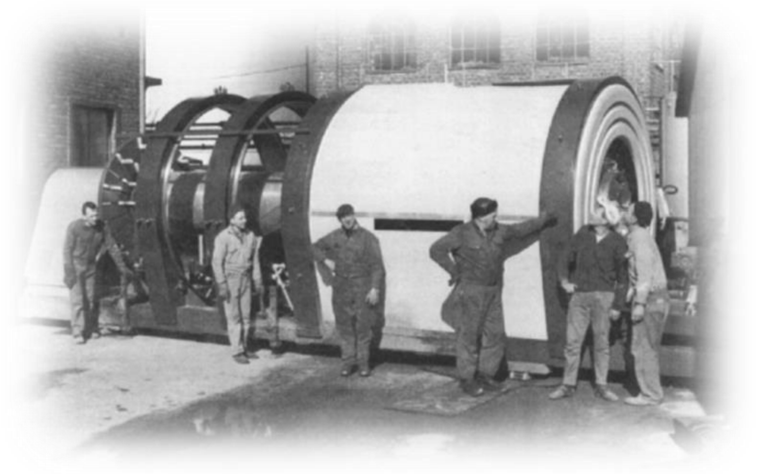
This paper will discuss the history of GRP pipes and the standards used to define their performance. The long term testing required will also be reviewed with the goal of informing the consumer on how to properly evaluate a GRP piping system, including joints, to give the best long term performance for a project and peace of mind for the asset owner.

2 HISTORY OF GRP PIPE

Glass fibre has been available for many years but it wasn't until the 1930s that glass fibres could be mass produced (Mallinson, 1988). These glass fibres were initially used to produce glass wool insulation and it wasn't until the 1940s that composites using fibreglass and thermosetting resins began to be produced (Murphy, 1994). As early as 1948 filament winding was being used to produce composite tubes (Peters et al.,1991) and in the 1950s filament wound and centrifugally cast pipes were developed.

The continuous filament winding process for GRP pipe was invented in Norway in 1967 by Vera Fabrikker and Danish company Drostholm. In 1968 Vera Fabrikker began manufacturing the first tanks and pipes made by the continuous winding process. Continuous filament wound pipes could be manufactured significantly faster than could previously be achieved and had the significant benefit of the strength of continuous glass fibres rather than less efficient short chopped fibres. This enabled GRP pipes to become an economical alternative for major pipelines.

Photograph 1: First continuous pipe winder in Sandefjord, Norway



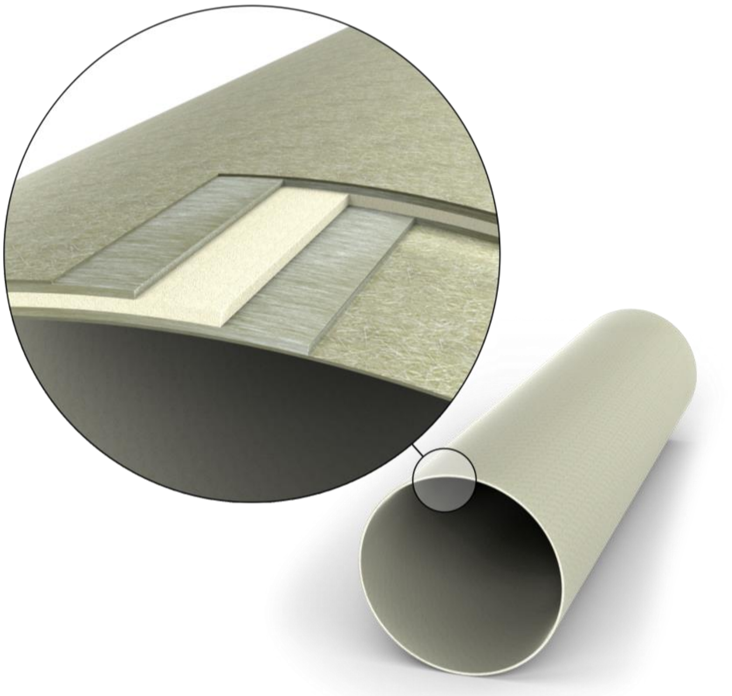
3 MANUFACTURING PROCESS

Continuous filament wound glass reinforced polyester (CFW GRP) pipes are manufactured using the continuous advancing mandrel process developed by Vera Fabrikker and Drostholm originally marketed under the Veroc brand and more recently as Flowtite®. All CFW GRP pipe plants around the world currently producing pipes are either licensed by Flowtite® or copies of their technology.

The process allows the use of continuous glass fibre reinforcement in the circumferential direction. For a pressure pipe the principle stress is in the circumferential direction. Incorporating continuous reinforcement in this direction yields a higher performing product at lower cost. A very dense laminate is created that maximises the contribution of the three basic raw materials, namely glass fibre, polyester resin and silica aggregate. Both continuous glass fibre rovings and chopped glass are incorporated for high hoop strength and axial reinforcement. A silica aggregate is placed near the neutral axis in the core to provide increased stiffness. The raw materials are placed on the continuous advancing mandrel to ensure optimum strength with minimum weight. The materials are applied in specific locations within the pipe wall to optimise pressure resistance and stiffness.

Once the materials have been applied the laminate is cured completely and cut to length as required in a continuous process. Most CFW GRP pipes are rubber ring jointed. Once the pipes have been cut to length and pressure tested a double bell coupling is fitted to finish the process.

Figure 1: Typical cross-section of CFW GRP pipe laminate



Photograph 2: The manufacturing process

4 STANDARDS

Continuous filament wound GRP pipe is a mature product and, as such, is the subject of a number of international standards. Listed below are a number of standards applicable to GRP pipes for both water and sewer and drainage applications.

For water applications:

AS 3571.2 -2009 Plastics piping systems—Glass reinforced thermoplastics (GRP) systems based on unsaturated polyester (UP) resin. Part 2: Pressure and non-pressure water supply (ISO 10639:2004, MOD)

ISO 10639-2004 Plastics piping systems for pressure and non-pressure water supply — Glass reinforced thermosetting plastics (GRP) systems based on unsaturated polyester (UP) resin

AWWA C950-13 Fiberglass Pressure Pipe

EN 1796-2013 Plastics piping systems for water supply with or without pressure. Glass-reinforced thermosetting plastics (GRP) based on unsaturated polyester resin (UP)

ASTM D3517 – 14 Standard Specification for “Fiberglass” (Glass-Fiber-Reinforced Thermosetting-Resin) Pressure Pipe

For sewer or drainage applications:

AS 3571.1—2009 Plastics piping systems—Glass reinforced thermoplastics (GRP) systems based on unsaturated polyester (UP) resin. Part 1: Pressure and non-pressure drainage and sewerage (ISO 10467:2004, MOD)

ISO 10467-2004 Plastics piping systems for pressure and non-pressure drainage and sewerage — Glass-reinforced thermosetting plastics (GRP) systems based on unsaturated polyester (UP) resin

EN 14364-2013 Plastics piping systems for drainage and sewerage with or without pressure. Glass-reinforced thermosetting plastics (GRP) based on unsaturated polyester resin (UP). Specifications for pipes, fittings and joints

ASTM D3262 - 16 Standard Specification for “Fiberglass” (Glass-Fiber-Reinforced Thermosetting-Resin) Sewer Pipe

ASTM D3754 - 14 Standard Specification for “Fiberglass” (Glass-Fiber-Reinforced Thermosetting-Resin) Sewer and Industrial Pressure Pipe

Common to all standards is the requirement for the pipe manufacturer to prove compliance with the standard’s performance requirements. For GRP pipes these are both short term and long term and relate to both the raw materials used to manufacture the pipe and the finished product.

5 RAW MATERIALS

Continuous filament wound GRP pipes are constructed using chopped and continuous glass fibres, polyester resin and a silica aggregate. Compatibility of the raw materials with each other is essential for the long term performance of the pipe. To ensure their compatibility and performance, raw materials used for all types of GRP pipes must be qualified using an accredited laboratory to show compliance with the standards.

The polyester resin in a GRP pipe serves the purpose of keeping the glass fibres in the proper position to be able to withstand the applied loads. In addition the resin distributes the load to the glass fibres, protects the fibres, controls chemical properties and provides interlaminar shear strength between layers of glass. The adhesive bond strength of the polyester resin to the glass fibres is very important (Peters et al., 1991) and very much influenced by the type and quality of the glass fibres and their coatings. Short and long term testing must be performed on all raw materials intended for the manufacture of GRP pipe. The larger technology providers for continuous filament wound pipes have qualified a number of glass fibres and resin manufacturers.

By undertaking rigorous short and long term testing of raw materials it is possible to determine which raw materials satisfy the long term requirements of the standards and also those that do not. Substituting lower cost and/or inferior glass fibres and resins without performing the requisite testing in order to reduce product cost will have the effect of reducing the long term properties of the pipe and will lead to premature failure of pipes.

6 QUALIFICATION TESTING

Qualification testing is used to determine the long term performance of GRP pipes. Qualification testing must be performed on pipe samples using the same materials, design, composition and manufacturing processes as will be sold to customers. Any changes in any of these elements can make the testing not applicable to the product supplied. Of particular concern is the substitution of inferior raw materials and lack of adequate quality controls during manufacture.

Long term qualification testing consists of testing multiple samples at a variety of strain levels over a period of at least 10,000 hours (approximately 14 months). The results of the testing are analysed using the methods prescribed in the standards and extrapolated to 50 years. The value of 50 years is used for the purposes of statistics and does not mean the pipes only have a 50 year life. Extrapolating test results to 50 years and then applying the required factors of safety results in products which should perform for well over 100 years.

6.1 STRAIN CORROSION

For pipes subject to sanitary sewage there is the potential for the pipes to be exposed to sulphuric acid. This is generated from the hydrogen sulphide gas produced as bacteria decomposes the sewage in anaerobic conditions. Plastics are inherently more robust than both concrete and metals in acidic conditions. However, standardised long term test methods have been adopted where a number of pipe samples are exposed to sulphuric acid over an extended time period while subjected to artificially high tensile strain.

Photograph 3: Strain corrosion testing

Over 30 years Flowtite® has tested samples collected from all the Flowtite® manufacturing facilities. Analysis of the data has shown an estimated lifespan of 150 plus years. (Jonsson,2007)

6.2 LONG TERM STIFFNESS

The long term stiffness of a plastic pipe is a measure of the pipes ability to resist ongoing deflection under a constant load. This is also called the creep stiffness or creep factor. The long term stiffness is a measure of the pipes ability to resist vertical loads from back fill in combination with the soil embedment. For buried flexible pipes, the higher the pipe stiffness, the higher the allowable cover height.

Long term stiffness testing consists of applying a predetermined constant load to a pipe submerged in water and measuring deflection with time. The test must continue for at least 10,000 hours (approximately 14 months). The 50 year stiffness calculated from the 10,000 hour testing should be between 60% and 75% of the initial stiffness for a correctly manufactured continuous fibre wound GRP pipe. GRP pipes made without continuous fibres and only short chopped fibres, such as centrifugally cast pipes, can have values as low as 30% of the initial stiffness.

6.3 ULTIMATE LONG TERM RESISTANCE TO FAILURE IN A DEFLECTED CONDITION

As well as measuring the long term stiffness of the pipe the standard requires the performance of the GRP pipe to be evaluated as it deflects. Both routine short term and long term type tests are used. Long term resistance to failure in a deflected condition is calculated by testing a minimum of 18 samples over a period of at least 10,000 hours. The samples are loaded with sufficient weight to cause them to rupture periodically over the 10,000 hours for statistical accuracy. The extrapolated ultimate ring deflection must be greater than 150% of the stated allowable long term deflection when buried.

For a GRP pipe with a short term pipe stiffness of 10,000 N/m/m the allowable long term deflection once buried is normally 6%. Therefore, the tested long term ultimate ring deflection must be greater than 9%.

Routine short term testing must be performed on pipe samples. The pipe samples are deflected to 150% of the allowable long term deflection and can show no signs of damage to the internal surface or structure or the pipe. They are then deflected to 250% of the allowable long term deflection and testing must show no signs of damage to the structure of the pipe.

6.4 LONG TERM FAILURE PRESSURE

The long term failure pressure is also called the Hydrostatic Design Basis (HDB). The approach used for testing for long term failure pressure is similar to that used for long term deflection in that at least 18 pipe samples are pressurised to different levels to create failures within a 10,000 hour period. The time to failure is determined as the passage of water through the pipe wall which is typically evidenced as weeping with a CFW GRP pipe rather than a burst which might be seen with other materials or construction methods of GRP.

Photograph 4: Hydrostatic Design Basis (HDB) testing

A factor of safety is applied to the extrapolated 50 year pressure and the resultant value must exceed the stated design pressure for the pipes being tested. Minimum safety factors are prescribed in the various international standards and a minimum value of 1.8 is common.

Routine short term testing is used to verify the mechanical properties of the pipe laminates in both the circumferential and axial directions.

6.5 CYCLIC PRESSURE RESISTANCE

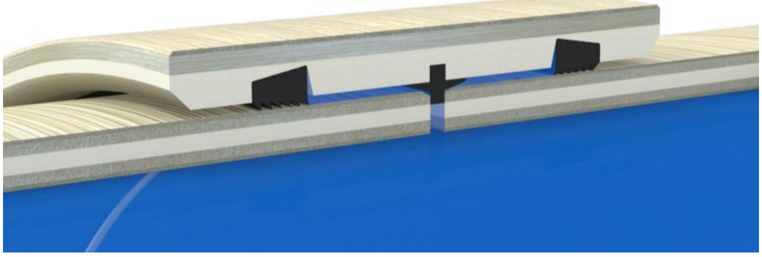
Cyclic pressure resistance is a requirement of some of the international standards mentioned earlier. Both the ISO and Australian Standards include the requirement for cyclic testing.

As compared to thermoplastics, the cyclic pressure used for testing exceeds the pressure class of the pipe. The pipes are subjected to a cyclic pressure of 0.75 x PN to 1.25 x PN for at least 1,000,000 cycles. On completion of the testing the test piece must not show any signs of leakage or weeping. The ability of CFW GRP pipes to be able to withstand cyclic loads without the need for deration, as is the case with HDPE pipes, is a major benefit when designing pumped pressure irrigation systems.

6.6 JOINT PERFORMANCE

CFW GRP pipes are typically rubber ring jointed using a double socket coupling. The type of joint depends on the manufacturer with the most common design being the REKA gasket design as shown in Figure 2 which was introduced to CFW GRP pipes in 1979. The REKA gaskets are preferred as the couplings can be manufactured relatively quickly on the same production line as the pipe with excellent control over the internal diameter and composition. This is essential for high pressure performance. Every coupling is pressure tested prior to assembly to verify performance.

Figure 2: REKA coupling



One manufacturer has opted to use a narrower coupling with a fully moulded internal gasket rather than the REKA coupling. Where a standard requires a minimum angular deflection and draw this narrow coupling will have difficulty complying. It is also difficult to verify the quality of manufacture without routine quality control testing such as pressure testing.

The ISO and Australian Standards require a minimum draw and angular deflection for the pipe rubber ring joints. The maximum allowable angular deflection should not be less than the values shown in Table 1.

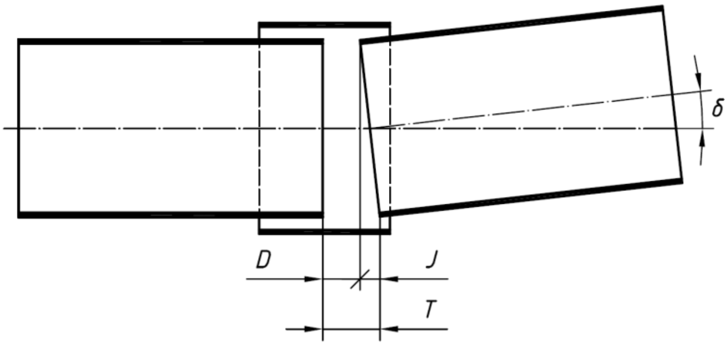
Table 1: Maximum Angular Deflection

Pipe Diameter	**Maximum Angular Deflection**
Equal or less than DN500	3^o
Greater than DN500 but equal to or less than DN900	2^o
Greater than DN900 but equal to or less than DN1800	1^o
Greater than DN1800	0.5^o

Total draw (T) is the distance the pipe can pull out of the joint without compromising the long term performance of the joint. The total draw takes into account the movement of the spigot end due to rotation of the joint as well as the shortening of the pipe under pressure (Poisson contraction) and temperature effects. For a pressure pipe the maximum allowable draw (D) shall not be less than 0.3% of the laying length of the longest pipe for which it is intended to be used.

Figure 3 shows the total draw (T) made up of the draw (D) and the longitudinal movement arising from angular deflection of the joint.

Figure 3: Joint movement (AS3571.2 Figure 1)



Depending on the diameter of the pipe and corresponding bend angle the total draw requirement can vary from 56mm to 71mm for a 12m pipe length which typically requires quite a wide coupling. When evaluating the draw of a coupling it is important to consider the chamfer on the pipe end as this total draw available will reduce by the length of the chamfer.

The performance of the coupling design is verified through type testing. A range of tests are conducted on the joints and must be representative across the entire diameter range. Testing is conducted with the joint in a number of configurations including angular deflection and draw as well as with a simulated misalignment. The joint must be able to resist angular deflection and draw at twice the design pressure for a minimum of 24 hours.

7 CONCLUSIONS

The use of GRP pipe in water and irrigation projects is growing with a number of projects already installed in New Zealand, including the Christchurch area. The demand for larger diameter pipe and increased volume in the irrigation market has meant a number of manufacturers and vendors have entered the market looking for opportunities.

As GRP pipe for larger diameter water pipelines is relatively new to some customers there is a need for education on what to look for in regards to product quality, especially when it comes to lower cost options from relatively new and unproven players. Many manufacturers have entered the market by simply buying a copied production line with no depth of knowledge in the manufacturing process or how to support the products in the market place.

The value of design support should not be underestimated. Whether for buried pipe design or thrust restraint, the ability to talk directly to an engineer from the supplier with an in depth knowledge of the product can help eliminate potential future problems and provide ongoing support.

Customers should be mindful of the long term cost of a purchasing decision. As the saying goes, the bitterness of poor quality remains long after the sweet taste of low price is forgotten.

REFERENCES

Standards Australia, AS 3571.2 (2009) Plastics piping systems—Glass reinforced thermoplastics (GRP) systems based on unsaturated polyester (UP) resin. Part 2: Pressure and non-pressure water supply (ISO 10639:2004, MOD)

Jonsson, H., (2007) “Chemical Resistance of Fiberglass Pipes Measured over 33 Years” *Pipeline Technology Conference 2007*, Hannover, Germany

Mallinson, J.H., (1988) Corrosion-Resistant Plastic Composites in Chemical Plant Design, Marcel Dekker, New York, 7

Murphy, J. (1994) Reinforced Plastics Handbook, Elsevier Advanced Technology, Oxford, 1,2

Peters, S.T., Humphrey, W.D. and Foral, R.F. (1991), Filament Winding, Composite Structure Fabrication, Society for the Advancement of Material and Process Engineering, Covina, iii, 2-4