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2008: Fibreglass for Corrosion Resistant Trade Sewers. Presented at NZWWA Trade Waste Conference. This paper presents design information, features and applications to give users a better understanding when using fibreglass.

Fibreglass for Corrosion Resistant Trade Waste Sewers

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ABSTRACT:
Fibreglass is widely used in trade waste sewers due to its corrosion resistance both inside and outside, its light weight and versatility in fabrication. Applications include pipelines, manholes, sumps, pumping stations, flumes, and storage tanks. Fibreglass was initially used in acid chlorine sewers in the pulp and paper industry, but use has now spread to most industry including those using acids such as food processing plants for CIP (clean in place) chemical waste streams. For applications to be successful, the fibreglass needs to be designed correctly, the right resin choice needs to be made, and appropriate international standards need to be followed. This paper looks at these issues to give users a better understanding so that fibreglass can be used with confidence and success.

1. INTRODUCTION
Worldwide, fibreglass has been used in the pulp and paper industry for more than 4 decades, especially for acidic chlorine solutions including waste streams. This industry almost single-handedly drove the development of resins with high chemical resistance such as bisphenol polyester resins, halogenated polyester resins, and more recently vinyl ester resins. Like mills in the rest of the world, the two New Zealand pulp and paper mills have used these resins since the late 1970s and they continue to use them today.

Fig 1: FRP pipes at Kinleith Pulp & Paper Mill

The New Zealand dairy industry, after years of difficulties with corroding chemical sewers, first tried fibreglass in 1988 at the Kauri site in Northland. Manholes and pipes made for this project are still in use today and are in excellent condition. The New Zealand Dairy Research Institute installed a test rig at the Hawera site in Taranaki between 1992 and 1994. This test rig was exposed to actual CIP wastewater chemicals, ie the many different concentrations and temperatures that dairy plants produce. The test report stated that the vinyl ester FRP pipe samples "appear to be completely unaffected" and "appeared to have excellent resistance to the dairy wastewater". The report also stated "many of the ceramic pipes that were readily available in New Zealand had softened significantly since installation".

Fig 2: 1988 Manhole (left) and 1992-4 NZ Dairy Research Institute CIP Wastewater Test Rig (right)

2. APPLICATIONS OF FIBREGLASS IN TRADE SEWERS

Fibreglass lends itself to a multitude of applications due to its unique features:

- Corrosion resistance inside and outside gives long low maintenance life
- Light weight makes it easy to transport and install
- Fabrication versatility means any shape or object or combination can be made.
- Joints can be made as strong as the original material, ensuring leak free.

The combination of these features means that often it is not only the material of choice, but also that it can be used at a lower cost than alternative materials. Some of the most common applications in trade waste sewers include:

2.1. Pipelines: Pipes are available in 6 metre lengths and sizes from 50 mm diameter upwards, and fittings available include the usual elbows, tees, flanges etc.

2.2. Manholes and Sumps: Manholes and sumps are designed to withstand ground pressures, high water tables and traffic loads. The units can be either thin wall liners that are reinforced externally with concrete, or full fibreglass manholes that are dropped into place, the pipe connections made, and then backfilled.

Fig 3: Fibreglass manhole liner (left), manholes and sumps are tailor made to each installation

A short sump is provided in each manhole below the invert of the pipe for three reasons. Firstly it acts as a trap for stones, nuts and bolts and tools that can cause damage to the invert of fibreglass pipes. Secondly the liquid retained in this sump acts as a buffer to extreme temperature and concentration fluctuations, thus protecting surfaces from shock. And thirdly, the sump enables the joints of the pipes to the manholes to be able to be made better with less chance of leaks.

2.3. Flumes: Fibreglass flumes include trapezoidal, Parshall and Palmer Bowlus styles for different applications. Fibreglass flumes are made from moulds so dimensional accuracy is secured and is repeatable from flume to flume.

Fig 4: Fibreglass flumes with integral manholes

2.4. **Pumping Stations:** Fibreglass pump stations are pre-fabricated offsite ready for installation. The light weight of fibreglass makes installation fast and easy, and the resulting installation is leak free, has easy to clean internal surfaces and its corrosion resistance gives it a long life.

Fig 5: Fibreglass pumping stations prefabricated off site

Puddle flanges can be used were required adjacent to manholes and pump stations to act as thrust blocks for stresses due to pipeline expansion and contraction when there are temperature fluctuations. This then avoids a local stress concentration and potential failure point at the vessel wall to pipe joint. Another potential problem is flotation of the unit during installation and subsequently. One solution is to use a circumferential anti-flotation ring near the base of the vessel. The soil load on this ring holds the vessel in place. Other solutions are to have anchor points and embed them in concrete during installation.

3. JOINTING OF FIBREGLASS

Pipe joints, joints of pipes to manholes, and joints between segments of manholes and pump stations are a common source of problems and leaks in traditional sewers using materials such as concrete lined manholes and ceramic pipes. All fibreglass systems like those described above effectively eliminate these problems. The manholes and pump stations are factory built and so all joints can be done in the factory under ideal conditions, and can be hydro-tested if required.

The most popular pipe jointing system is the "butt and strap" joint. This is done by butting two pipe ends together, preparing the surfaces and wrapping the joint with a fibreglass bandage that is the same material as the pipe and to approximately the same thickness as the pipe wall. The joint is generally left to cure overnight, although the application of heat can speed this process. The end result is a joint that is leak free and is stronger than the pipe itself.

Rubber ring joints can be used, but it must be realised that the expected life of the rubber ring is probably less than 10 years, whereas the fibreglass pipe has an indefinite life. Therefore rubber ring joints, if they are used at all, are used where the joint can be accessed in the future to change the rubber ring. It is not recommended that rubber ring joints be used underneath concrete floor slabs.

4. FIBREGLASS – A COMPOSITE MATERIAL

Fibreglass is a composite material made up of a thermoset resin and reinforcing. The resin protects the reinforcement and transfers loads to the reinforcement. Vinyl ester resins have proven the most effective in trade sewers, as they are better able to handle widely fluctuating temperatures and chemical concentrations. They have a tensile elongation to yield of 5% to 6% and thus are more flexible than other options. The reinforcing used gives the composite its strength and is generally in the form of chopped strands, woven fabrics, or continuous filaments. For trade sewers, glass reinforcing is the most cost effective and thus the most commonly used. The reinforcing can be positioned purposely to carry the loads imposed. Other materials used include core materials to give a laminate stiffness and thus resist buckling due to soil and traffic loads.

Three fibreglass manufacturing methods used are:

- **Contact Moulding:** Layers of chopped strand mat and glass reinforcing are applied to a mould to the thickness required. This is often called "hand lay-up". Core materials can be incorporated in this manner. This method produces a laminate with a resin content of approximately 70% to 75%, and as it is the resin that gives the laminate its chemical resistance, this manufacturing method provides the most chemical resistant laminate.

- **Filament Winding:** Continuous glass filaments are wound onto a mandrel and produce a laminate that has the highest tensile strength so is ideal for pipes with an internal pressure. The resin content is lower at approximately 50% and lower. With the continuous glass filaments, chemicals can track along these should the laminate be compromised, and finding the leak or problem can be difficult. Thus it is generally accepted that this gives a lower chemical resistance than contact moulding.
- **Centrifugal Casting:** The fibreglass materials are placed inside a revolving mould and the centrifugal action compresses and compacts them outwards against the mould. Sand fillers are often incorporated to give the pipe stiffness at a low cost. The internal surface is sprayed with resin to give a chemical resistant and smooth finish.

5. FIBREGLASS – STRESS, STRAIN AND CREEP

With fibreglass the yield and ultimate strength are the same. This is very different from common metals and plastics (see fig 6). For a fibreglass laminate under tensile stress, when failure does occur it can be sudden and dramatic, and initiates from the point of maximum stress. This was never more evident than in Americas Cup yacht races with the Australian fibreglass hull failure (1995) and New Zealand fibreglass mast failure (2003).

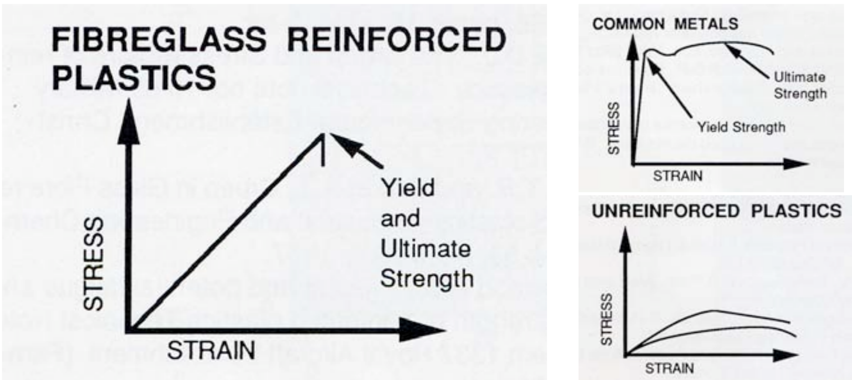

Fig 6: Stress-strain relationships for fibreglass, common metals and plastics

For fibreglass, the ultimate strength reduces with both increasing temperature and time. For fibreglass under constant load, such as tanks and pressure pipes, the ultimate strength of fibreglass reduces by approximately 50% over 10 years (see fig 7). This can lead to failure some years after installation. The reduction in the ultimate strength depends on the service temperature and the HDT (heat distortion temperature) of the resin. It is good practice to choose a resin with a HDT of at least 20ºC above the service temperature.

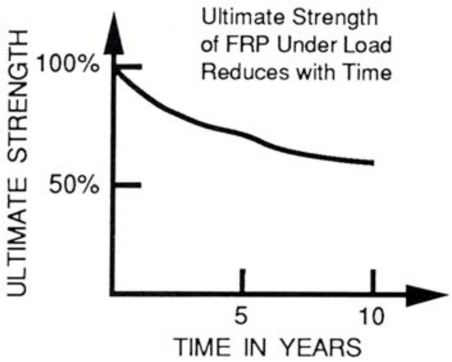

Fig 7: Ultimate strength reduction with time

The two pictures in fig 8 are of failures of a fibreglass tank that split open when full and a plastic sump that failed under buried load at temperature. The fibreglass tank failure sounded like a "rifle shot" to a neighbour hundreds of metres away.

Fig 8: Fibreglass tank failure is sudden and dramatic (left) compared to plastic failure (right)

6. FIBREGLASS – DESIGN, SAFETY FACTORS AND STANDARDS

It is good design with fibreglass to use relatively high safety factors in order to stay away from the ultimate strength and yield point, and to allow for a reduction in the ultimate strength with time and temperature. Safety factors of 10 are usual for fibreglass tanks and pipes under constant internal pressure, and a minimum safety factor of 5 is usual for structural fibreglass.

A variety of Australian/New Zealand, British, American and European standards are available for tank and pipe design and fabrication especially. One standard used for years is AS2634 as this provided an easy to use guide for fibreglass chemical plant equipment including pipes and tanks. This has been withdraw now and is in the process of being superseded by European Standards.

In any design with fibreglass, the most important design point is to avoid stress concentration points. This can be achieved by spreading loads over a greater area, providing curved corners instead of square ones (such as at the base of a tank), and providing additional fibreglass laminate in the areas of high loads. Finite element analysis is an invaluable tool for stress analysis. One typical example of a stress concentration point is around a manhole in the side of a tank; the local stress concentration point immediately above and below the manhole has been the cause of many tank failures including one in Patea, New Zealand in the early 1980s that resulted in a fatality.

7. FIBREGLASS - CHEMICAL RESISTANCE

As discussed before, it is the resin that provides the chemical resistance. Resin manufacturers publish extensive results of testing of the chemical resistance of their resins at various concentrations and temperatures. Table 1 shows the versatility of vinyl ester fibreglass in handling a wide range of chemicals.

Table 1: Chemical resistance of fibreglass to selected chemicals found in trade waste sewers

Materials	Carbon Steel 1020	Stainless 316	FRP Vinyl Ester
Hydrochloric Acid Dilute	NR	NR	R
Hydrogen Sulphide	NR	NR	R
Lactic Acid	NR	R	R
Nitric Acid Dilute	NR	R	R
Phosphoric Acid Dilute	NR	R	R
Salt Water	NR	NR	R
Sodium Hydroxide Dilute	NR	R	R
Sodium Hypochlorite	NR	NR	R
Sulphuric Acid Dilute	NR	R to 5%	R

R = Resistant, NR = Not Resistant. Above subject to temperature limitations

The full potential of the chemical resistance of the resin is only achieved if the laminate is cured fully. In some instances this may require post curing at an elevated temperature that exceeds the final service temperature.

8. FIBREGLASS – QUALITY ASSURANCE

Standard quality assurance procedures also apply to fibreglass, including ISO 9000 procedures, materials traceability, design audits and quality assurance checks during manufacture. The standards have specific limitations on air inclusions and other defects.

The cure of the resin can be checked with a Barcol Hardness instrument and comparing this with the minimum requirements from the resin manufacturer. For vinyl ester resins, a minimum Barcol Hardness of 32 is generally required. The Barcol Hardness tester can be used to check the laminate after a number of years in service, but the results are not always meaningful as a slight surface softening of a laminate in service is not uncommon.

The thickness of a fibreglass laminate can be measured accurately with an ultrasonic thickness tester (see Fig 9). This technique is most useful for monitoring the wall thickness of a fibreglass laminate as it is fabricated, and when it is in service.

Fig 9: Ultrasonic Testing of FRP

Testing of standard laminates is specified in AS 2634. In this test a manufacturer prepares standard laminates of varying thicknesses and has the ultimate strength of each measured. This is then compared to a table of minimum requirements in the standard. One such test done by the author's company is given in Table 2. It can be seen that all thicknesses of laminates meet the minimum requirements of the standard and thus these standard laminates can be used to fabricate the items covered in the standard to the minimum wall thicknesses stated.

Table 2: Armatec Standard Fibreglass Laminate Testing

Laminate Thickness, mm	AS 2634 Minimum Ultimate Strengths	Armatec Standard Laminate Ultimate Strengths *	Exceeds Minimums By:
3.1	57 MPa	103 MPa	+ 80%
4.6	68 MPa	127 MPa	+ 87%
5.9	77 MPa	107 MPa	+ 39%
9.7	100 MPa	124 MPa	+ 24%
10.3	100 MPa	167 MPa	+ 67%

** By Materials & Testing Laboratories Ltd to AS 1145*

9. CONCLUSIONS

Fibreglass made from vinyl ester resin is an ideal material for use in trade sewers. It has an outstanding corrosion resistance to the wide range of chemicals found in trade waste sewers, and in particular for CIP waste streams, and is able to handle the large temperature fluctuations. Successful applications include pipes, manholes, sumps, flumes, pump stations, and storage tanks. Knowledge of the unique engineering properties of fibreglass and the applicable standards is essential in designing and building successful applications.