A Buyers' Guide To GRP Pipes For Water Supply And Seware Disposal

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Glass fibre reinforced plastic (GRP) pipes are bought over by various agencies to use them for transportation of water or sewage. In India, the purchase is mostly made by the engineers and administrators of government and local bodies and contractors. Since composites are relatively new materials, not much of information available to them on how to specify the pipes and how to evaluate the required durability and performance. Since GRP materials have certain behavioural differences from that of steel, it is not advisable to treat purchase and installation of GRP pipes in the same way being done for steel pipes. This helpline offers some guidance for the engineers for specifying, buying and installing GRP pipes. The aim is to give a broader understanding essential for carrying out the purchase and it is not intended to give an in-depth study of GRP pipe making technology. Those readers who want to learn more about the technology can read the relevant books or undergo courses.

Disclaimer

The guidelines presented in this article are offered for the users' benefit only and no guarantee is given about the correctness of information and data presented. By following these guidelines alone, there is no guarantee that the products can be defect free. The acceptance of these guidelines by the pipe buyers is purely voluntary and must be based on their discretion and judgment. No liability is assumed or implied either to NGN Composites or to its experts as a result of giving these guidelines.

Introduction To GRP Pipes

Application of Glass Fibre Reinforced plastic (GRP) pipes for water supply and sewerage lines is gaining wide scale acceptance in the country. It is estimated that India requires in the coming decade about 5000 km water supply and sewage lines added every year. A typical reciprocal filament winding machine can make about 30 km pipes in a year. Even with a 10 to 20% share of the total requirements, GRP pipe making requires several units in the country. The rapid increase in cost of steel and the manufacturing cost of corrosion resistant steel pipes make GRP pipes competitive. Next to wind energy sector, it is the piping sector that can be the largest outlet for GRP in India.

GRP are material systems made by combining the high strength glass fibre with a compatible thermoset resin system. Fibres are impregnated with the resin and the resin is then cured into a solid. In the case of pipes, the material is made into a cylindrical shell with required strength, rigidity and durability. GRP pipes can be made by hand moulding, filament winding and centrifugal casting. Pipe lines for long distance water supply and sewage disposal are made by the filament winding process. This article focuses on the filament wound pipes and their applications to water supply and sewerage lines.

GRP pipes were first made in USA in 1948 for transportation of oil. Pipes were in use in the chemical industry since 1960s. Application of pipes for water and sewage transportation started since 1980s. Today all countries in the world make and use GRP pipes. In India, GRP pipes made by hand lay up were in use for chemical plants since the 80s. The availability of indigenously made world class filament winding machines has given impetus for making filament wound pipes. With well proven design methodology and manufacturing, testing and quality evaluation processes, GRP pipe making, today, is a well proven technology.

Why GRP Pipes?

- Both glass fibre and the plastics used for pipe making are resistant to water, sea water, soil, many chemicals and the sewage. Steel is susceptible to corrosion under water and can be severely damaged by chemicals in the sewage and soil. Costly protective treatment is required for steel pipes to be used for water transport.
- Higher strength-to-weight ratio than steel and concrete. Hence the pipe walls are thinner and lighter.
- Light weight. Weight is only one-sixth of that of steel and one-tenth of that

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of concrete with similar load conditions. Transportation and erection at remote sites are much easier.

- Lower coefficient of friction. For the same rate of flow, GRP pipes require lesser diameter and pressure drops in long pipe lines will be less.
- Better dimensional stability
- Low maintenance cost. Since well made GRP pipes are not affected by the water, sea water, sewage or soil, very little maintenance could arise.
- The Standards for GRP pipes are written for 50 years life. Well made pipes can be durable even beyond 50 years.

Why Extra Care For Making Pipes?

- Both water supply and sewage lines are highly safety critical products. Their design and manufacture requires all care to make them safe.
- Just like the two blood vessel arteries of our body, water supply and sewerage lines form the two life lines of the society taking care of the needs of the people and their health. Like the red arteries take blood to all parts of body, the water supply lines bring potable water to all individuals of the region. Similarly, the sewage lines take away the waste water from the society either for disposal or for purification.
- The pipe lines are designed for 50 years life and the pipes and the pipe joints must provide trouble free service for the life period without any major failures.
- The pipes shall not contaminate the water by letting in ground water, leaching in chemicals or by degradation of the pipe wall. Similarly, the sewage lines shall not let out the wastes into the ground through which the pipes run.
- Since pipes once laid can not be easily accessed for inspection, maintenance and repair, greater care must be taken to see that the pipes must function well.
- Since steel pipes corrode, the coefficient of friction increases with time causing reduction in flow rate. Well made GRP pipes can retain the surface smoothness. Precaution must be taken to avoid any pitting away of surface due to erosion or degradation.
- The ultimate end users of the pipes are the public at large. They have no role or say in the making of the pipes or in the quality management. It is, therefore, the duty of the buyers namely, the government agencies, local bodies and contractors, who place order, purchase and install the pipes to make sure that the pipes fulfill the intended function for the entire life period so that the users should not suffer.
- Recognizing, the importance of the pipes and the pipeline for the society, the American Water Workers Association (AWWA), an industry association of USA has come forward to formulate an excellent standard for the piping system. This shows the concern and commitments of the industry to protect the society. The manufacturers of the pipes must show equal moral and legal responsibilities in making and installing the pipes.
- The Indian Standards specification is very similar to the AWWA C950 standards and every care must be taken by the authorities to strictly follow the IS Standards.
- It must be understood by the purchaser that the pipes are qualified based on extensive testing some of which can last 14 months. The purchaser must look for the results of such tests to make sure that the products fully satisfy the provisions of the standards. No manufacturer should be allowed to shortcut the testing and certification process.
- If the pipes are well designed, tested and made using the right materials and manufacturing processes, GRP pipes can certainly outlive the 50 years specified life and in several ways, GRP pipes are better than steel pipes.

What Precautions?

GRP are excellent materials for pipe making, but they have their own characteristic features and behavioural patterns that can be different from those of steel. Since composites are new material systems, engineers of most purchasers are not knowledgeable enough to understand these special features. They are experienced with steel and they tend to specify the pipes as if they do it for steel pipes. This can give a lot of room for suppliers to play with the materials and their design and manufacture. The buyers have to take a closer look and to adopt an approach different from that being pursued for steel pipes. Some of the precautions to be taken by the engineers and decision makers while purchasing and installing the pipes are given below. The details presented are no way exhaustive. The factors that must be looked into are listed here under four subtitles (i) General requirements,(ii) Material considerations, (iii) Manufacturing and (iv) Field installation.

General Requirements

- Many purchasers tend to give too much importance to the initial price offered by the manufacturers without critically looking into the quality of pipes they get. Cost must be considered as a factor only after the performance, safety, durability

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and quality level required are fixed.

- Most of the information about the use of GRP for pipe making comes to the purchaser from the material suppliers and pipe manufacturers. While many of them pass on the right information, it is likely that some would tend to give information that will project their material, business interest or processes and they may offer cheaper price. The buyer must critically assess the information to see the correctness of what they communicate. If help is needed, they can get good advice from experts in the field and they can cross-verify with other agencies.

- Detailed specifications with clear details of design, materials, tolerances, manufacturing methods, quality control procedures etc. must be prepared while calling quotations/ tenders so that there shall not be any room for the suppliers to play with the product quality and escape.

- The pipes are specified for 50 years life. The usual practice of giving warranty for one year is not adequate for such long lasting products. At least five to ten years' warranty must be insisted upon because most defects could be revealed within this period. In the wind energy field, the manufacturers generally maintain the turbines for the total life period of 20 years. A similar agreement for maintaining the pipe lines by the manufacturers for 50 years must be more appropriate.

- Most agencies verify the quality of products only when they are delivered to them. For steel pipes, this may be sufficient because the steel properties may not vary very much from pipe to pipe and the manufacturing defects can be assessed after completion of manufacture. In composites, the manufacturer can change the fibres, resins and chemicals from one product to other. They can be different from what was initially certified. It is difficult to find the quality and structure of these materials without destructive tests when product manufacture is completed.

- The purchaser must have arrangements to continuously monitor the materials used, pipe winding process and curing process during the manufacturing stage itself. If this is not done, it gives lot of opportunities for the manufacturers to play with the quality of materials.

- The pipe standards, due to obvious reasons, do not say which fibre or which resin should be used and what manufacturing methods and material structure must be selected. It is the manufacturers' responsibility to use the right materials and to make the product without loosing these properties during manufacture. The purchaser must clearly specify what materials to be used and they must ensure that these materials only are used in all pipes.

- Traceability. One of the basic necessities of such long lasting products is that if the product fails at a later stage, it is necessary to trace the cause of failure. It is not only to find who is responsible for such failure, but also to understand and eliminate such possible defects in future. Table 1 below gives the list of documents that must be prepared and preserved for pipe making. These documents must be preserved by the purchaser for the period that is mutually agreed between the manufacturer and purchaser.

- Markings. All standards specify that certain markings must be made on each pipe. It is necessary to identify who has made the pipe and the date of manufacture. These markings will help to link the pipe with the documents prepared in case of a failure.

- Installation of pipes at the field also requires special considerations compared to that being used. Since installation process can spoil the performance of otherwise good pipes, the purchaser must opt for those who make and install. If that is not possible, the manufacturer and supplier must be jointly made responsible for the total performance and there must be a joint warranty.

Table 1

List of documents to be prepared, maintained during production and preserved

1. The tender documents and the work order/ purchase order issued by the purchaser.
2. Pipe design report which shall contain the name of designer, rating and the agency issued the certification of rating.
3. Material Estimation which must take note of the layer by layer winding details.
4. Product and manufacturing specifications and QA plan.
5. Detailed working drawings.
6. Day by day work report and Check list of quality monitoring. The names of materials used, their suppliers, the material certification documents etc. must form part of this document.
7. Prototype testing and the report
8. Field erection report
9. Final certification.

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Material Considerations

The choice of right fibres, resins and chemicals is very important for achieving both performance and 50 years life. Some of the areas where problems can arise are listed below;

Glass Fibre: Glass by nature is a durable material. They are inert to most chemicals. However, glass fibre can have a gradual reduction in strength due to both static and dynamic fatigue. Since the pipes have to have 438000 hours of life and 657 million cycles of pressure fluctuations, the glass fibre used must be able to survive under water, sewerage and soil and the pressure and cyclic loads. Attention must be given to the following;

- Glass fibre comes in different compositions. E and ECR compositions are ideal for pipe making. C glass and other compositions must not be used. E, ECR and C glass fibres are being imported into the country and some of them are substandard in quality. The purchaser must take care to see that such poor quality fibres will not get into the pipes both in mat and roving form.
- The strength of glass fibre is very much dependent on the fibre diameter. The purchaser must get the fibre diameter of roving and mat included in the test certificate. Generally, the direct roving used in filament winding is of higher diameter (about 24 microns) and the strength can be much less than that of 15 micron fibres (can be even half). The actual strength of fibre roving must be obtained from test certificates and not from the published literature of the fibre manufacturer. This strength only must be used in the pipe design calculations.

Moisture on glass fibre surface can aggravate stress corrosion under load. Pipe is a product which is always in contact with water and hence, the glass fibre must be protected from water getting on its surface for which good bond between fibre and resin must be ensured. The coupling agent used in the glass fibre size must be polyester resin compatible.

Resins: The choice of resin is much more critical in pipes than even that of fibre. The durability of pipe depends on the durability of resin and on the degree of curing or cross linking achieved during manufacture. Polyesters and vinylesters are commonly used for pipe making. However, it must be understood that the properties and durability of each batch of resin can vary considerably depending upon the constituent chemicals and their proportions used. To ensure the quality, the purchaser must take the following precautionary steps.

- The 50 years of durability of pipes can not be ensured without ensuring the 50 years durability of the resins used. The purchaser must get assurance from the manufacturer that the resins that they use will last 50 years. The tests specified in the standards like the long term hydrostatic strength tests must be conducted by the pipe manufacturer as specified in the standards. Only such pipes that pass the tests must be accepted.
- The constituent chemicals and their proportions used for the resin batch that used for the pipes for rating must be standardized. This resin must be made in the presence of the surveyors and the composition must be certified by them. Only resins made by the same constituents and procedures must be used for all subsequent batches. If there is any doubt, the resin quality can be tested and compared with standard property.
- Some poly4esters like orthophthalic resin can undergo degradation due to water induced hydrolysis. Since pipes are constantly in contact with water, such resins shall not be used for pipe making. The resin manufacturer must declare in writing that the resin will not undergo hydrolysis.
- The resin used for pipes meant for drinking water supply shall be non-toxic and shall not contain heavy metals. Any solvents or excess styrene used may leach out and contaminate the water. Tests are specified in the IS standards for verifying the water contamination and the resin and pipe wall made of the resin must pass the water contamination tests. No solvents other than styrene must be used in the resin and styrene content must be just sufficient for cross linking.
- The resin used for the inner gelcoat and the chemical barrier shall not erode away by the flowing water or sewerage. Erosion occurs due to the break down of plastic molecules and if it occurs, the eroded plastics and glass fibre can get into the water.
- The viscosity of liquid resin must be controlled for allowing fibre wetting without dripping of resin during winding. Since the viscosity of vinylester can be very low, thixotropic agents may become necessary for increasing viscosity and creating void free construction.
- The percentage elongation at break of resin is an important property that affects the resin cracking under internal pressure. Since the fibres in filament winding are closely packed, strain magnification even upto 14 times that of the average strain in pipe wall can occur in the matrix within the filament wound layers. This can initiate resin cracking in resin which can lead to leakage of water and loss of fatigue strength. A higher elongation at break equal to or more than 4% is good for pipe making. Such elongation occurs in vinylesters and some modified

isophthalic (ISO) and orthophthalic (GP) resins available in developed countries. The ISO and GP resins made in India may not have such high elongation to failure and hence if such resins available in India are used, a lower allowable strain must be considered in design which will increase the wall thickness and cost.

Sand Addition: The author frequently gets queries asking how much sand can be added to pipes. It appears that the industry is very much obsessed with sand addition hoping that it will help them to reduce cost or to increase profit. The continuous pipe making and centrifugal casting processes use sand addition. ASTM standard also mentions about mortar pipes. The pipes made by these processes are generally good for underground pipes used for gravity flow. Although they can be made for higher pressures, they are not very much suitable for pressures more than say 6 bars. Such pipes do not have high axial strength because of their method of construction.

Addition of sand helps to increase the buckling strength under external soil pressure of under ground pipes. They are also good in compression like concrete pipes. Under internal pressure, pipe walls are in hoop and axial tension. The resins within fibre layers experience strain magnification as explained earlier and the effect is to cause resin cracking while pressurized even at one-twentieth of the percentage elongation at break of resin. When sand is added, even this strain at failure of resin gets reduced which in turn cause resin to crack even at lower strain level. Sand addition can thus increase the chances of pipe to leak. Only by adding more thickness it can be compensated. Whatever cost reduction expected can thus be lost.

Optional additives: The pipe manufacturer can use several additives which are chemicals in small percentages (less than 5 %). They include abrasion resistant fillers in the inner gelcoat, air releaser, ultra violet resistant stabilizers etc.

Manufacturing, Testing and Quality Control Measures

Reciprocal winding and continuous pipe making are the two filament winding processes used for pipe making. Questions are being asked frequently about the relative benefits and limitations of the two methods. In reciprocal winding fibres are wound from one end of the mandrel to another and then wound back. This to and fro winding process is repeated until the required thickness is built up. The pipe is then extracted from the mandrel and post cured. In continuous pipe making, on the other hand, pipes are continuously made and pushed out of the machine. They are then cut into required lengths and post cured. The two processes can be assessed as follows;

- The reciprocal winding is a batch process and is slower than continuous pipe making. While it is possible for winding about 30 km of pipes in the reciprocal method, it is possible to make about 100 km in the continuous process in a year.
- The continuous pipe making machine is at least 5 times costlier than reciprocal winding machine.
- While reciprocal machine can wind pipes with various winding angles, continuous winding winds only in hoop direction and the axial strength is provided by randomly sprayed chopped fibres.
- Reciprocal winding consumes less quantity of resins whereas the continuous winding because of the random mat layers consuming more resin. Sand addition is used here to reduce the resin consumption. Such sand addition is not good when fibres are wound at 67 % fibre content.
- The axial strength of pipe in continuous winding is much less than that of reciprocal winding.
- The addition of sand in reciprocal winding with close fibre packing can cause strain concentration and resin cracking at very low strain level. Sand addition is not good for such a product. Stiffness can be increased by incrddeasing the thickness or by providing stihhner

Installation Considerations

Pipes when made are designed and evaluated for specific nominal diameter, nominal pressure and stiffness class. By a series of qualification tests, pipes are rated for these classifications. When these pipes are used for field applications additional loads may occur and the soil conditions and supports may also cause additional stresses. Pipes have to therefore be redesigned to see that they can withstand the additional loads and stresses. If they are not able to bear additional loads, pipes of a higher rating must be selected and used.

The pipe installations can be differently treated for above ground and buried conditions.

The joining of pipe is generally done by many in India by over wrapping chopped and woven mat layers. If the soil is wet or if soil gets into pipe surface where joining is done, the resin cure at the joint may not be proper. Spigot and socket or collar joint with water tight seal is ideal for field joining. *(To be continued).*

The readers are welcome to give their comments and suggestions so that these guidelines can be made more effective. The author can be contacted on ngnair@ngncomposites.com