FARASSAN

Farassan Manufacturing & Industrial Company

Comparison of GRP Pipes with Steel & Polyethylene Pipes

Contact Us:

Address: No 249, 22 Ave ,Eram, Blvd, Shiraz, Iran
Phone: (+98)7132291918 – (+98)7132293350
Fax: (+98)7132272697
Email: info@farassan.org - bmr@farassan.org
Website: www.farassan.com

Chapter 1: An introduction to GRP Pipes produced by Farassan Company under Faratec Technology

1.1. Introduction

Pipe material selection is one of the most important issues in designing water delivery, transmission and distribution systems. Different factories manufacture pipes with various materials. In recent years, plastic and specially fiberglass pipes have been considered significantly in water projects. The term "GRP" stands for **Glass fiber Reinforced Plastic.**

The GRP pipe was first introduced in 1948 in the oil industry. Choosing a GRP pipe as a cost-effective, corrosion-resistant material is a better method than metal pipes. In the late 1950s, high-diameter pipes entered the market, and GRP pipes were used in the chemical industry. Because the pipe has good corrosion resistance, it was accepted in urban water and sewage from 1960 to 1990. The efficiency of GRP pipe is related to its life time, strength and corrosion resistance. Another advantage of GRP pipes is the lack of environmental problems. The production and use of GRP pipes in various fields of industry, construction projects, etc., does not pose any environmental risk. This is because that all raw materials used for this kind of pipes are neutralized after chemical reactions.

Also, in a water supply or sewage transmission network, various fittings such as Tee, Elbow, Reducers, etc. are used as needed. Therefore, it should be said that in GRP pipes, it is possible to produce fittings in different forms, which in addition to increasing their installation capability, makes it possible to reduce the number of fittings used and also produce fittings with the least pressure loss and friction against fluid passage.

Farassan Manufacturing & Industrial Company, a leader in the development of GRP pipe technology, as a member of the country's industrial society, is proud to have been continuously operating in the composite industry for more than 33 years since 1986. It started in 1996 and during its activity in the mentioned fields, it has been able to transfer and localize the production technology and equipment of GRP lines to establish its position as one of the leaders in designing, producing and supplying GRP pipes at the international level. The production of kilometers of GRP pipes in the range of 15 to 4000 mm with a working pressure of 1 to 100 bar for use in hundreds of projects. Industrial in water and sewage, industrial waste waters, irrigation, oil and gas, petrochemicals and other industries is only a part of the company's record.

In Farassan Industrial Manufacturing Company, GRP products are made with a special type of resin reinforced with glass fibers. Very high, long life, easy and fast installation as the top generation of pipes and in comparison with other pipes has a special and worthy position and is the most economical option compared to other pipes, so there are various applications for them, most of which are :

- Water supply lines,
- Sewerage and wastewater collection and transmission lines
- Surface water collection lines
- Chemical, oil, gas and petrochemical industries.

In this report, we have tried to consider the technical and economic issues regarding the use of Faratec GRP pipes as an alternative for polyethylene or steel pipes. Farassan Company is ready to hold technical briefing sessions in this regard and to answer the questions in person. In general, the company can provide its services to customers in the following ways:

A) Providing all engineering services alongside and in line with esteemed customers

B) The company has the ability to carry out the project in the form of EPC and EPCF

C) Technical and complete training of the desired forces of the employer or the respected consultant of the project

D) Sending consultants and technical inspectors to the site and reviewing any problems in implementation and cooperation to solve it.

1.2. Introduction of GRP pipes produced by Farassan company under Faratec technology

Fiberglass pipes were first used in the United States by Perault Fiber Cast Company to deal with extreme corrosion in the oil extraction industry. In the production of the mentioned pipes, manual production method was used on wooden molds.

One of the first experiences of using high-quality GRP pipes (1600 and 1700 mm) in the world is the water transmission line from Karun River to Imam Khomeini Port (Khuzestan Province, Iran) to supply water to the region's petrochemical facilities, which was started in 1976 by the American company Owens-Corning. This line is now in service with a maximum capacity after 45 years of operation. It is worth mentioning that in 2008, in order to increase the water supply capacity in this project, due to the increase in water demand in petrochemical projects in the special economic zone of Mahshahr (parallel to the previous line), a new GRP pipeline has been supplied and installed by Farassan Company and is in operation.

Faratec Company now offers technological services for GRP pipes to companies in South Korea, Turkey, Romania, etc. GRP pipes are commonly referred to as engineered pipes. In other words, according to the need of the project and its specifications, GRP pipe is designed and produced. In other words, the application of engineering principles in all stages of the project, including the production, supply and implementation of these pipes will play a direct role in the final efficiency of the project. The choice of Faratec pipes depends on the conditions and type of application.

Since the Faratec pipes are composed of a combination of fibers and resins with special ratios, choosing the right ingredients and the accurate amount of materials and choosing the right process and arrangement, can results in pipes with the desired properties. Also, in each type of produced pipes, by changing the composition and amount of resin and fibers, products with different resistance and specifications can be produced. Here are some of the features and benefits of Faratec GRP pipes:

- High resistance against corrosions caused by fluid and soil around the pipe
- Suitable friction coefficient for fluid flow (highly polished the inner surface)
- Fittings suitable for high execution speed and sealing.
- Very light weight of GRP pipe compared to steel, concrete and polyethylene pipes
- Very long service life (service life of Faratec pipes is about 50 years)

- Very low operating costs
- High mechanical resistance in the axial and hoo direction (in the circular direction even more than steel)
- Ability to run on a steep slope
- Ability to run in mountainous areas, earthquake-prone areas, loose soils and ...
- High corrosion resistance due to fluid and soil around the pipe
- Aboveground installation capability

In Fig. 1.1, different applications of GRP Pipes are presented. Also, in tables 1.1 and 1.2, technical specifications and advantages of GRP Pipes are presented.

Fig. 1.1. different applications of GRP Pipes

Table: 1.1: GRP Pipes Technical Specifications

Pipe Material	GRP
Maximum axial tensile strength (Mpa)	56 - 125
Maximum Hoop tensile strength (Mpa)	342 - 394
Poisson's ratio	0.22 – 0.3
Axial modulus of elasticity (GPa)	9.4 – 11.7
Hoop modulus of elasticity (GPa)	9.2 – 32.9
Hazen-Williams friction coefficient	150-165
Specific Weight	1.7 - 2

Table 1.2.: GRP Pipes Aspects and Advantages

Aspects	Advantages
Resistant against corrosion	- Long service life - No need for internal and external coatings, cathodic protection or any other common methods - Hydraulic specifications remain constant over time
Service life 50 years	- Maximum economical effectiveness
Low weight (lower than ½ of polyethylene pipes)	- Reduce the cost of loading and unloading - No need for heavy equipment and finally lower installation and operation costs
12 m branches	- Reduce the number of connections and installation time - Ability to carry more pipes in one trailer and reduce shipping costs
Very smooth inner side	- Low coefficient of friction reduces pumping costs and operating costs - Reducing the accumulation of sediments on the inner surface of the pipe
Two-washer reka couplings	- Secure and effective connection of pipes in order to seal as best as possible - Ease of connection and thus reduce installation time - The possibility of partial angular deviations along the line of connection and thus the possibility of removing the elbows at a low angle direction changes.
Flexibility in production	- Ability to supply pipes along the length and diameter required by the customer. - Ability to produce any fittings based on customer order
Leading technology	- Possibility of using pipes with lower working pressure than other pipes due to lower wave velocity in the pipe wall
Manufactured based on advanced international standard	- High quality and stable products in the world that ensure customer confidence and trust in product performance

1.3. Experiments performed on GRP pipes in Farassan company

Given that GRP pipes specifications are based on the Manufacturer Standard, their ultimate efficiency depends on compliance with the requirements of international standards regarding the required performance characteristics. These performance characteristics are in the form of production quality control tests, qualification tests and competency control, which should be considered in the production and supply of GRP pipes.

Generally, Quality control tests are applied at the time of production to the raw materials, the final product and production process and include chemical and mechanical tests. The first step in quality control of GRP pipes is to control the quality of raw materials. Certainly, the quality of raw materials (including matrix and reinforcement) will have a major impact on the long-term behavior and longevity of GRP pipes.

Qualification tests are long-term tests that aim to study the long-term behavior of GRP pipes. It is worth mentioning based on International and national standards for GRP pipe only long-term test results can be used for pipeline system design data and related calculations, and short-term test results have only a quality control aspect. Unlike metal pipes, these pipes do not corrode and react chemically with the surrounding environment, but they are affected over time by phenomena such as creep and Aging

On the other hand, the useful life of pipes that do not fail due to these phenomena is generally considered to be 50 years. As a result, a series of experiments are performed to investigate long-term mechanical and chemical behavior (useful life of 50 years) is necessary. Due to the cases in which GRP pipes may fail, tests have been proposed in international standards, most of which are as follows:

A: Hydrostatic Design Basis (HDB) test: Using this test (Figure 1-2), the samples are subjected to hydrostatic pressure by using different strain gauges in the samples under test

and obtaining failure time and strain-time regression diagram. The tests are performed for up to 10,000 hours (more than 1.5 years), then the logarithmic diagram is extrapolated to 438,000 hours (50 years of useful life). In this experiment, the goal is to study the long-term behavior of GRP pipes in order to determine their pressure class.

Fig.1.2. HDB Test performed in Farassan Co.

B: Long-Term Ring Bending Strain (sb): In this test, the goal is to study the long-term behavior of the pipes due to bending and ovality of the pipe. It should be noted that when the pipe is subjected to external loading (in underground pipes due to the weight of the topsoil and traffic load), the cross section of the pipe changes. Over time, this increase in deflection because of creep will eventually cause the pipe to fail. In this experiment, the goal is to find a strain that the pipe fails over a period of 50 years due to oval creep.

A: Strain Corrosion test: This test (Figure 1-3) is to determine the chemical resistance of pipes in a section of deflected pipe. In GRP pipes that are subject to bending, due to the presence of a strain in the deflected pipe wall, strain-induced corrosion occurs, which can cause the pipe to fail in the long term. The severity of this phenomenon is directly related to the severity of the corrosion of the environment and the amount of deflection and, of course, the strain in the pipe wall.

Fig.1.3. Strain Corrosion Test performed in Farassan Co.

D: Long Term Specific ring Stiffness: In this test, the goal is to estimate the pipe stiffness reduction over time and under the effect of loading and finally to calculate the factor of pipe creep factor. The creep factor, which is one of the important parameters of structral analysis in GRP pipes, is calculated as the result of dividing the 50-year stiffness of the pipe by its initial stiffness.

1.4. GRP pipe connection system

GRP pipes can be connected in two ways: rigid (often for aboveground pipes) or flexible (often for burial pipes). In the flexible connection of pipes, a joint connection piece called Reka coupling is used. Inside the coupling there are three grooves inside which the rubber washers are placed (Figure 1-4), which is why the pipes in this type of connection can allow some longitudinal and lateral movement inside the coupling without coming out of the seal. These features, if the pipe is installed in loose soils with a subsidence potential, can easily match the pipeline with substrate deposits.

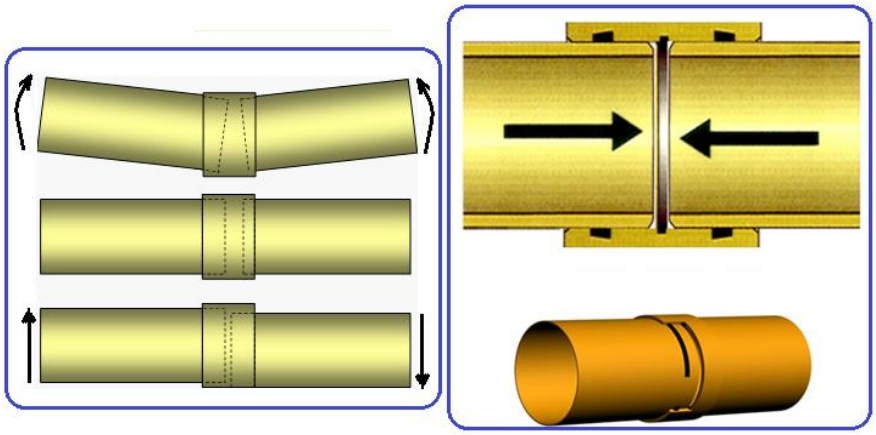


Fig.1.4: location of the pipe inside the coupling of the Reka (right)
and Angle change, horizontal movement and axis change at Reka coupling location (left)

Chapter 2: Technical Comparison of Faratec GRP Pipes & Polyethylene and Steel pipes

Considering the variety of pipes with different materials (steel, ductile iron, concrete, asbestos, polyethylene and fiberglass) in the market for water and sewage as well as industrial applications, and the resulting intense competition in this field, owners should choose the best option based on technical and economic aspects. The increasing use of GRP pipes forces managers to carry out large-scale research on the advantages and disadvantages of this type of pipe. Therefore, in this chapter of the report, the technical comparison of Faratec GRP pipes with polyethylene and steel pipes is presented.

2.1. Comparison of Faratec GRP pipes & Steel Pipes

- ✓ *Technical comparison of steel and GRP pipes - Engineering point of view*

Table 2-1 presents the mechanical specifications of GRP and steel pipes with explanations for each parameter. It is noteworthy that the low quality of the soils in the design area (due to high salinity and the presence of high corrosive chemical compounds) can lead to severe corrosion of metal pipes, which shows the importance of using corrosion-resistant pipes. For this purpose, a sample of high corrosion rate in steel pipes used in a project in Khuzestan province, Iran is shown in Fig.2.1.

Another important note is that the overloading of steel pipes may results in deformation to ellipse form due to low elastic coefficient.

Table 2.1: Quantitative Comparison of GRP & Steel Pipes Specifications
(LeBlanc and Palsson, 2013)

Material/ Technical Specifications	Steel Pipes	GRP Pipes	Notes
Maximum Axial Tensile Strength (Mpa)	207	56 - 125	The hoop mechanical resistance of GRP pipes is higher than that of steel. The axial strength of GRP pipes is sufficient and about 60% of steel pipes, which can be provided if necessary .
Maximum Radial Tensile Strength (Mpa)	207	342 - 394	
Manning Roughness Coefficients	0.012	0.009	Lower roughness of GRP pipes and their greater resistance to corrosion cause more durability, lower energy loss and thus reduces the cost of coating and protection, pumping and operation in the project compared to steel pipes.
Hazen-Williams Roughness Coefficients	110	150-165	
Service Life	About 20 Years	At Least 50 Years	The longer service life of GRP pipes is the lower the cost of operation and maintenance costs than steel pipes.
Relative Specific Weight	7.8	1.7 - 2	The weight of GRP pipes is a quarter of steel, which, in addition to the variety of pipe connection methods, in addition to facilitating transportation and loading, makes it easier to implement GRP pipes and thus reduces project cost.
Poisson's Coefficient	0.3	0.22 – 0.3	The lateral strain of the GRP pipe against the applied loads is equal to Steel pipes.

Fig.2.1. Sample of Steel Pipes High Corrosion (Khuzestan Province)

As also shown in Table 2-1, lower roughness of GRP pipes and their high resistance and durability against corrosion (stability of roughness during useful life) will require less primary energy and less energy loss over time. For steel pipes, not only is the initial roughness higher than that of GRP pipes (the coefficient of friction of Hazen-Williams is 110 while for GRP pipes it is 150), but also over time the amount of pipe roughness increases due to sedimentation and corrosion of the passing fluid. Considering the relationship between Hazen-William (eq.1) and considering the same length, diameter and flow rate for both steel and GRP lines, it can be said that the use of GRP pipes reduces energy loss by 77%, which in turn reduces total pump head and reducing the pumping cost.

Eq.1:

$$h_f = \frac{10.65 Q^{1.852} L}{C^{1.852} D^{4.87}} \xrightarrow[\text{C.GRP=150}]{\text{C.Steel=110}} \frac{h_{f.\text{Steel}}}{h_{f.\text{GRP}}} = 1.77$$

Figure 2-2 shows an estimate of the amount of energy consumed during the operation of GRP and steel pipes in a given water transmission line project. In this figure, the energy stability required for pumping in GRP pipes compared to steel pipes is determined.

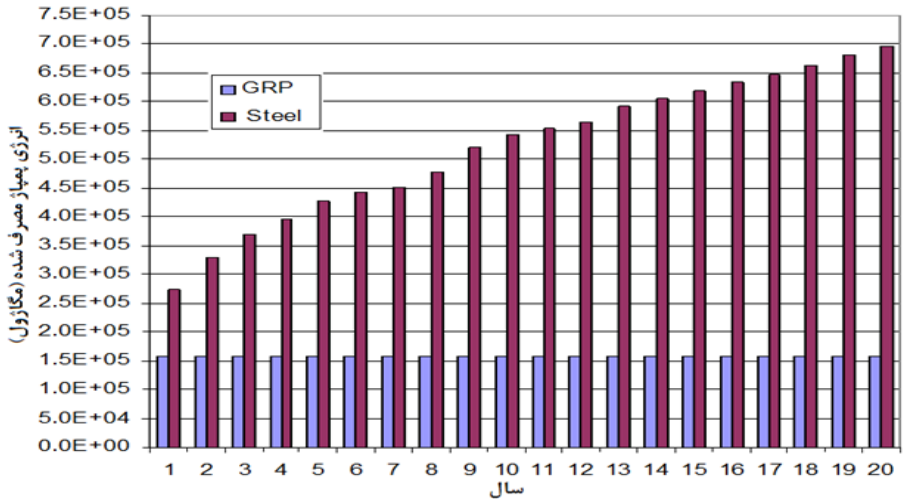
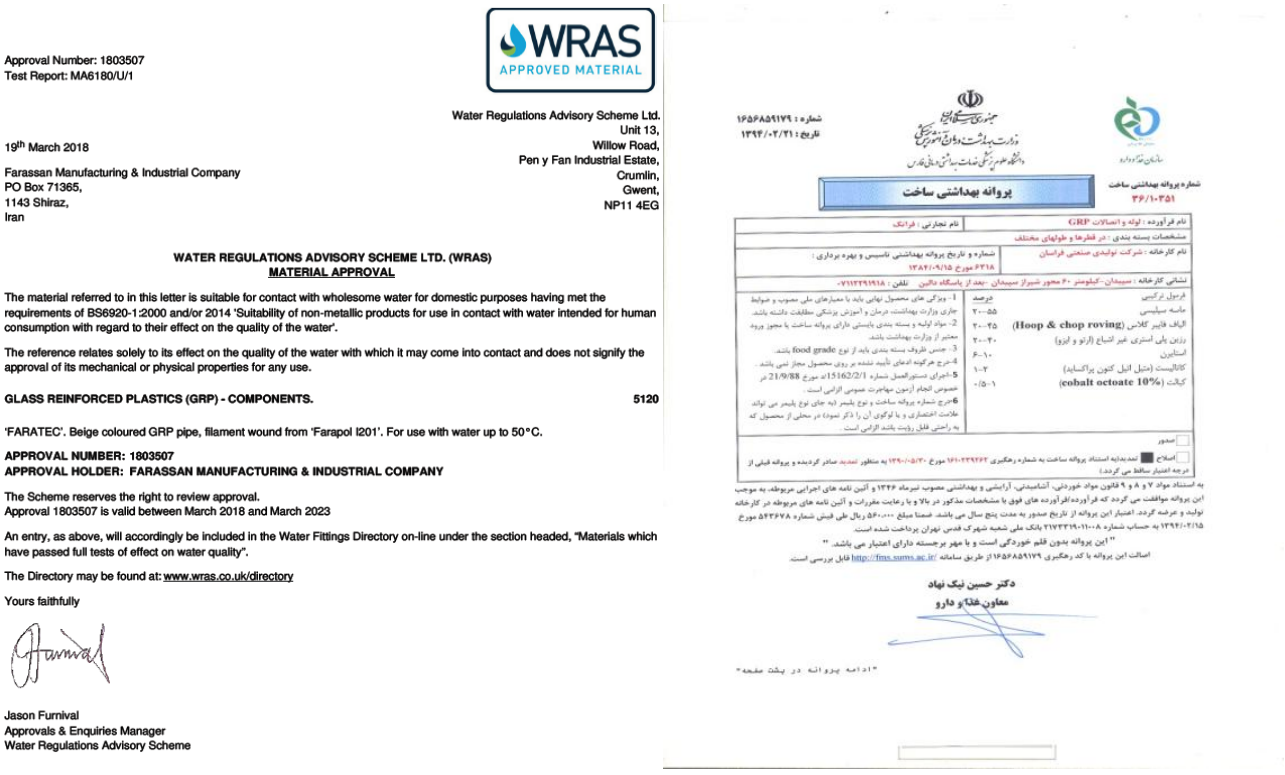


Fig.2.2. Estimation of consumed energy rate for GRP and Steel pipes

✓ *Technical comparison of steel and GRP pipes - environmental point of view*

Due to the high durability of GRP pipes and their non-corrosion property, it is clear that there is no change in physical quality of the passing fluid. Also, the existence of the health certificate of the Ministry of Health and WRAS of Frassan GRP pipes (Figure 2-3) indicates that there is no change in the chemical quality of the passing fluid (even for drinking purposes). In addition, unlike steel, GRP pipes can be recovered and used in other fields after their service life.



Approval Number: 1803507
Test Report: MA6180/U/1

WRAS APPROVED MATERIAL

Water Regulations Advisory Scheme Ltd.
Unit 13,
Willow Road,
Pen y Fan Industrial Estate,
Crumlin,
Gwent,
NP11 4EG

19th March 2018

Farassan Manufacturing & Industrial Company
PO Box 71365,
1143 Shiraz,
Iran

WATER REGULATIONS ADVISORY SCHEME LTD. (WRAS)
MATERIAL APPROVAL

The material referred to in this letter is suitable for contact with wholesome water for domestic purposes having met the requirements of BS6920-1:2000 and/or 2014 'Suitability of non-metallic products for use in contact with water intended for human consumption with regard to their effect on the quality of the water'.

The reference relates solely to its effect on the quality of the water with which it may come into contact and does not signify the approval of its mechanical or physical properties for any use.

GLASS REINFORCED PLASTICS (GRP) - COMPONENTS. 5120

'FARATEC'. Beige coloured GRP pipe, filament wound from 'Farapol I201'. For use with water up to 50°C.

APPROVAL NUMBER: 1803507
APPROVAL HOLDER: FARASSAN MANUFACTURING & INDUSTRIAL COMPANY

The Scheme reserves the right to review approval.
Approval 1803507 is valid between March 2018 and March 2023

An entry, as above, will accordingly be included in the Water Fittings Directory on-line under the section headed, "Materials which have passed full tests of effect on water quality".

The Directory may be found at: www.wras.co.uk/directory

Yours faithfully

Jason Furnival
Approvals & Enquiries Manager
Water Regulations Advisory Scheme

پروانه بهداشتی ساخت

دکتر حسین نیک نهاد
معاون غذا و دارو

Fig.2.3. Health ministry (Iran) and WRAS (UK) Certificate of Faratec GRP Pipes

In general, the positive environmental effects of GRP pipes compared to steel pipes can be expressed as follows:

- Sealing of GRP pipe connections
- Non-emission of industrial and sanitary effluents into the environment
- Ability to perform pipe repair operations on site in the shortest time and minimum cost and prevent the spread of fluid in the environment.
- Impossibility of contamination to enter the flow inside the pipe
- Possibility of easy washing of the pipeline and abrasion resistance in sewage networks
- Productivity of the pipeline after its useful life
- Possibility to sell pipes after the expiration date and reuse with change of use
- Possibility of using pipes as a powder as a concrete additive (filler)
- Resistance of GRP pipes to various types of erosion such as corrosion due to fluid and surrounding environment
- Lack of chemical reaction between the pipe and the fluid passing through it
- No change in the characteristics of the pipe due to decreasing and increasing the ambient temperature
- Resistance to sunlight (UV) and no change in the mechanical properties of the pipe
- No change in the characteristics of the fluid passing through the pipe
- No effect on the quality of drinking water

✓ *Technical comparison of steel and GRP pipes - in terms of labor*

Construction and installation of pipes is one of the most important parts related to labor in a water transmission line project. Due to the high speed of installation of GRP pipes using coupling connections and low weight of pipes, it can be clearly stated that the use of GRP pipes causes less time and manpower in the implementation of the project.

In this regard, research shows that the average construction and installation time ratio of one meter of GRP to steel pipe with the same manpower in different projects is 28/58, which accelerates the implementation of the project with GRP pipes in less than half a time. (Shah Khan and Jordaan, 2004).

✓ *Technical comparison of steel and GRP pipes - in terms of installation and operation*

If installed underground, steel pipes are less durable than GRP pipes. Also, as a result of steel pipe protection methods (protection by coating and cathodic protection), it increases the costs of using it.

The welding of steel pipe (especially in diameters less than 800 mm) eliminates the epoxy paint coating on the inside surface of the pipes, which cannot be repaired due to the low diameter. This causes the pipes to corrode and damage more than the weld points.

The wave propagation speed of steel pipes (C = 1150-1300 m / s) is much higher than GRP pipes (C = 300-500 m / s), which in turn increases the risks of water hammer. Therefore, in order to control the water hammer, we have to use protective equipment in the project line, and as a result, we incur high costs in the project.

The low number of repairs as well as the higher speed of repairs in GRP pipes can lead to lower operating costs (in addition to lower energy costs) than steel pipes. For example, comparing the number of repairs performed on steel and GRP lines between the Ghadir (Khuzestan) water supply project (Table 2-2) between 1989 and 1993 shows that the percentage of elbow repairs and joints in GRP pipes was much lower than steel pipes.

Table 2-2: Repair of steel and GRP pipe fittings in Ghadir water supply project from 1989 to 1993

Description	Total	Repairs	Repairs (%)
GRP Coupling	9207	11	0.12
Steel Mechanical joints	873	13	1.5
GRP elbow	70	1	1.4
Steel elbow	72	2	2.8

Comparing the report of repairs of old and new GRP and steel pipelines related to Southeast Khuzestan water supply project provided by Southeast Water Operation Company shows that the old GRP pipes (with 115 km and 29 years of operation) From 2012 to 2014, they had only 15 repairs (0.013% of the total length of the GRP pipe), which is only 4.21% of the total steel and GRP repairs in these three years. Meanwhile, steel pipes (with 325 km and 29 years of operation) during the years 2012 to 2014 had 340 repairs (0.104% of the total length of steel pipes), which is 95.51% of the total repairs in three years.

Also, the hours spent for repairing the GRP line in these three years are equal to 66.5 hours, which is on average equal to 4.43 hours for each repair, while the hours spent for repairing the steel line in these three years are equal to 2280 hours. It averages 6.71 hours per repair, which is approximately 1.5 times the average time spent on each GRP repair.

Finally, it is enough to mention the following two examples in the implementation of the project with GRP pipe as a replacement for steel pipe:

According to a report from a Canadian hydroelectric power plant project, comparing the cost of implementing and operating a 1400-foot water intake using GRP and steel pipes reduces the cost of building and installing a transmission line by 34 and 30 percent, respectively, when using GRP pipes. (LeBlanc and Palsson, 2013).

Also on a 32-kilometer water transfer route in southern Australia, after comparing all the costs of preparing, executing, operating and maintaining the options for using GRP and steel pipes, it was suggested that the use of GRP pipes would reduce up to 2.8 million dollar (Lawson and Hobart, 2012).

2.2. Comparison of Faratec GRP pipes & polyethylene Pipes

According to research and experiments performed on GRP and polyethylene pipes, some mechanical characteristics of these pipes are presented in Table 2-3 (LeBlanc and Palsson, 2013).

Table 2-3: Comparison of some mechanical characteristics of GRP and polyethylene pipes

(LeBlanc and Palsson, 2013

	GRP Pipes	HDPE Pipes
Maximum nominal pressure (bar)	50	25
Maximum fluid temperature **°c**	160	80
Maximum axial strength Mpa	125	32
Maximum hoop strength Mpa	394	32
Thermal expansion coefficient 10^-6/°C	30	180
Maximum produced diameter mm	4000	2500
Maximum axial elasticity Gpa	13.1	1.03
Maximum radial elasticity Gpa	39.30	1.03
Maximum Hazen-Williams Friction Coefficient	165	150
Maximum long term hoop strength Mpa	144.8	8.274
Maximum long term axial strength Mpa	60.0	8.27

The results presented in this table show that:
The radial and axial tensile modulus of the GRP pipe is more than the polyethylene pipe, which causes less strain due to the loads.
Also short-term and long-term radial and axial resistance of GRP pipes is much higher than polyethylene.
There is a limit to the production of diameter and pressure in polyethylene pipes.
The maximum fluid temperature that can be passed through polyethylene pipes is much lower than GRP and also the coefficient of thermal expansion in polyethylene pipes is much higher than GRP which causes more strains of these pipes than GRP pipes at high temperatures.

- ✓ *Disadvantages of polyethylene pipes*

In this section, the issues that cause problems with the use of polyethylene pipes are briefly mentioned:
1- The method of installing polyethylene pipes is such that it slows down the execution speed. This is especially difficult when using high diameter polyethylene pipes.

2. The hardness of polyethylene pipes is lower than other pipes, which causes a lot of damage during operation and operation.

3. These pipes are vulnerable to vermin such as mice.

4- The resistance of polyethylene pipes with large diameter is low against incoming loads.

5. The inner surface of the polyethylene pipes protrudes during installation and welding, which increases the hydraulic drop.

6. Due to the fact that the structure of polyethylene pipes is in the category of thermoplastic polymer pipes, the mechanical and chemical properties of this pipe are highly dependent on temperature. Researchers have shown that increasing the temperature from -10 to -70C in polyethylene pipes reduces the maximum resistance of the pipes from 32 to 7 MPa (Figure 2-4.

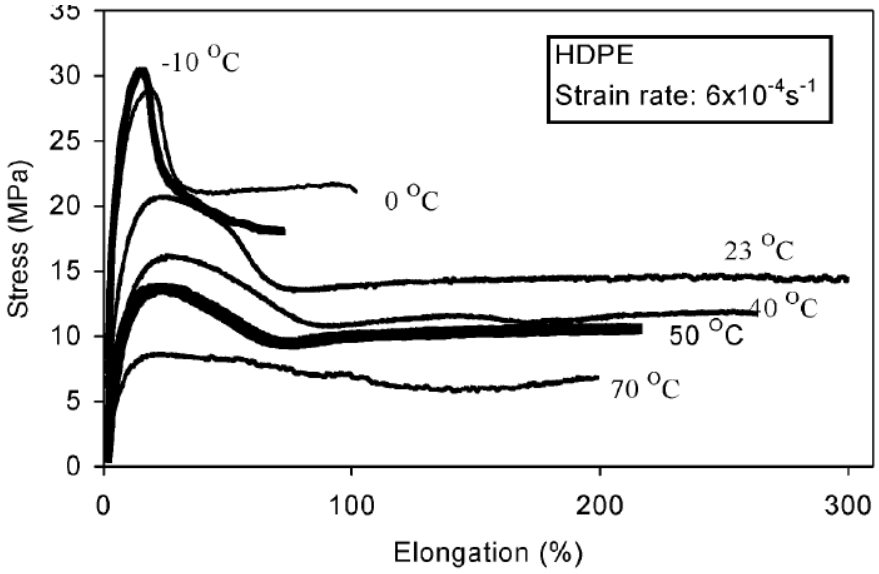


Figure 2-4. stress-strain curves of polyethylene pipes at different temperatures (Merah et.al, 2006)

7. The service life of polyethylene pipes at very low or very high temperatures is lower than GRP pipes.

8- The coefficient of thermal expansion of polyethylene pipes is 6.5 times that of GRP pipes, where causing the pipe to separate at the connection point. It should be noted that this coefficient for GRP pipes has no effect on the connection of GRP pipes due to coupling connection.

9- Polyethylene pipes are limited in the production of different diameters and are produced only in diameters of 16 to 2500 mm.

10. Polyethylene pipes are limited in production at high working pressures.

11- The weight of polyethylene pipes is about 2 to 2.5 times that of GRP pipes, which includes transportation and execution problems, and as a result, increasing the time and cost of execution for polyethylene pipes.

- ✓ *Technical specifications of Fratech GRP pipes vs PE*

1- Corrosion resistance

GRP pipes are resistant to corrosion caused by a variety of sulfate and destructive soils from the external side as well as internal oxidation and do not require any internal or external coating. This saves a lot of time and money on the project. The service life of GRP pipes is at least 50 years.

2- Roughness coefficient

The roughness coefficient of GRP pipes is superior to polyethylene pipes. Also, this coefficient for GRP pipes remains constant over time. According to the AWWA M45 standard, this coefficient in the Hazwn-Williams pressure loss equation for GRP pipes is between 165-150 but for polyethylene pipes it is about 145 to 140 and this reduces the diameter of the GRP pipe for equal flow rates. As a result, the cost per cubic meter of water transferred decreases.

3- Connections and fittings

Pipe connections are made of GRP pipe and are equipped with a special rubber washer. This type of joint is done with a hand jack and 2 clamps around the pipe. This connection significantly increases the installation speed compared to other types of pipes and greatly reduces installation costs.

Other fittings such as Elbow, Tee, Reducer, etc. are produced in any shape and size of GRP based on ISO, AWWA, ASTM standards. According to the production process of these fittings, it is possible to produce any type of standard or non-standard connection according to the design needs.

4- Weight

GRP pipes weigh up to 45% of the weight of the corresponding polyethylene pipes (especially in high pressure classes and large diameters) and this eliminates the need for heavy cranes for loading, unloading and installation, which will reduce costs. At the same time, the cost of transporting, which accounts for a significant percentage of the total cost of the project, is reduced.

5- Service life

Due to its numerous advantages, especially corrosion resistance and easy maintenance, the service life of GRP pipes is at least 50 years.

6. Installation

GRP pipes are very easy and economical to install. These pipes can be buried in the ground up to a depth of 16 meters or are installed above ground. Also, if buried at a depth of at least 1.5 meters, they can withstand live loads such as traffic load.

7- Mechanical resistance and impact tolerance

Due to the fact that GRP pipes are composite, it is possible to design the pipe based on the required mechanical strength against the incoming loads. Therefore, the pipe is designed based on the type of use with a very high safety factor. The mechanical strength of GRP pipes is greater than that of polyethylene pipes, and polyethylene pipes are highly vulnerable to impact. It is worth noting that it is possible to design semi-steel (GRP) pipes with hoop resistance (up to 800 MPa) even higher than steel pipes.

8. Burial depth

The maximum allowable depth of burial of GRP pipes (2500 stiffness class) is between 7 and 16 meters according to the conditions of native soil and substitute soil. In addition, if the pipes are buried at a depth of more than 1 meter, it is possible to bear any traffic load.

9- Operating costs

Due to its resistance to corrosion and impact, as well as its long service life, GRP pipes have no maintenance costs during operation. Also, the energy required to pump water over time is less than that of polyethylene pipes.
In addition to reducing the direct costs of the project, the use of GRP pipes is a very important factor in economic estimates of project time. This means that the faster the operation of the transmission line, the better the investment will be made and the speed of implementation of this project with GRP pipes will be a maximum of half the time required for polyethylene pipes.

10. Elasticity and flexibility

If loaded into polyethylene pipes more than usual, they deform quickly, which is usually not reversible. In the case of GRP pipes, due to the appropriate elasticity coefficient, they change against transient loads and return to their original state again.

12. High pressure tolerance

Another advantage of GRP pipes is their ability to withstand relatively high pressures, which makes these pipes a good choice for transmission lines and high pressure process lines. It is worth noting that polyethylene pipes can only produce up to 25 bar the working pressure (in small diameters), which is a major limitation for them.

13. Operating temperature

The maximum operating temperature of GRP pipes is up to 160 degrees Celsius, which is completely superior to polyethylene pipes.

14- Proper adaptation to the environment

Due to the high durability of GRP pipes and their non-corrosion, it is quite clear that there is no change in physical quality in the passing fluid. Also, the existence of the health certificate of the Ministry of Health (Iran) and WRAS (UK) of Farassan GRP pipes indicates that there is no change in the chemical quality of the passing fluid (even for drinking purposes). In addition, after their useful life, GRP pipes will be able to be recovered and used in other fields.

2.3. Comparison of polyethylene, steel and Faratec GRP pipes

Based on all the above and according to the standards of production and installation of steel, polyethylene and GRP pipes, the technical comparison of these pipes has been done in the form of the following table:

Table 2-4: General comparison of polyethylene, steel and GRP pipes

Row	Effective Factors	GRP Pipes	Steel Pipes	PE Pipes
1	Physical strength of the pipe and external load resistance	Good	Excellent	Medium
2	The roughness of the interior wall and its stability during the design period	Excellent	weak	Excellent
3	Abrasion resistance	Excellent	Medium	Good
4	Maximum working temperature	medium	Excellent	Weak
5	Impact resistance	Good	Excellent	Weak
6	Useful life	Excellent	Medium	Good
7	Production in all required diameters	Excellent	Excellent	Good
8	Production Speed	Excellent	Excellent	Good
9	Speed and ease of installation	Excellent	Medium	Medium
10	Ease of branching	medium	Excellent	Good
11	Ease of operation	Excellent	Excellent	Excellent
12	Ease of maintenance	Good	Excellent	Excellent
13	Transfer and transportation speed	Excellent	Medium	Good
14	Hydraulic pressure drop per 1000 meters	Excellent	Weak	Good
15	Existence of access to raw materials	medium	Excellent	Excellent
16	No need for external insulation	Excellent	Weak	Excellent
17	No need for internal coating and corrosion resistance	Excellent	Weak	Excellent
18	Existence of experience, skills and equipment needed to run	Excellent	Excellent	Excellent
19	Outdoors storable	Good	Good	Weak
20	High pressures application	Good	Excellent	Weak
21	Weight in large diameters	Excellent	Weak	Good
22	Ease of connection	Excellent	Excellent	Excellent

In order to provide a comparison of the above table quantitatively to each of the descriptions provided, a score is given as follows, and finally the score of each pipe type is determined based on this and is presented in the form of Table 2-5.
Excellent (4 points), Good (3 points), Medium (2 points), Poor (1 point)

Table 2-5: Technical score of polyethylene and GRP pipes based on table 2.4 comparison

Material	Score
GRP	77
PE	65
CS	64

Given the advantages shown in Table 2-5, it is clear that GRP pipes are technically better than polyethylene and carbon steel pipes.

Chapter 3: Economic comparison of GRP pipes With polyethylene and steel pipes

3.1. Economic comparison

Comparison of GRP pipes with each of the other pipes is provided below.

✓ *Economic comparison of Faratec GRP pipes with polyethylene*

The difference between the cost of supply and implementation of polyethylene pipes compared to GRP increases with larger diameters, so that the cost of supplying polyethylene pipes from 17% (for diameter 400 mm) to 65% (for diameter 1600 mm) is higher than GRP pipes. Also, the cost of implementing polyethylene pipes is from 1% to 16% more than GRP pipes.

✓ *Economic comparison of Faratec GRP pipes with steel*

The difference between the cost of supply and implementation of steel pipes compared to GRP increases with increasing diameter, so that the cost of supplying steel pipes from 5% to 67% more than GRP pipes. Also, the cost of implementing steel pipes is from 28% to 158% more than GRP pipes.

It should be noted that the above costs are only related to the initial investment costs of pipes and the operating costs as well as the return time of the investment are not taken into account. Involving these values in comparisons will increase the differences

3.2. Conclusion

In general, it can be concluded that the use of GRP pipes as a replacement for steel and polyethylene pipes for each group of employer, contractor and operator will have the following benefits:

✓ *The benefits of using GRP pipes for contractors*

- The low weight of GRP pipes compared to polyethylene pipes (about 45%) and steel pipes (30 to 60%) not only speeds up transportation and implementation, but also reduces the manpower spent on construction and installation. The pipes of a project become a water transmission line. As a result, the return on investment will happen much faster, which will lead to greater satisfaction and peace of mind for investors to enter into such projects for investment.
- Connecting GRP pipes faster than welding steel and polyethylene pipes reduces project execution time, less manpower in GRP pipes and thus much faster project return on investment.

✓ *The benefits of using GRP pipes for employers*

- The longer service life of GRP pipes than polyethylene pipes will not require re-investment and thus save costs.
- Less manpower required for installation and also faster project execution with GRP pipes in less than half the time of steel and polyethylene pipes will cost less for employers.
- Also, the return on investment will happen much faster, which will lead to greater satisfaction and peace of mind for investors to enter into such projects for investment.

- ✓ *The benefits of using GRP pipes for operators.*

- Low number of repairs and also higher speed of repairs in GRP pipes can reduce the operating cost compared to PE and CS pipes.
- The high ease of maintenance of GRP pipes compared to PE and CS pipes will not lead to long-term cut-off in the network.
- Proper flexibility of GRP pipe coupling prevents them from failing during earthquakes and Land subsidence during operation.

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