Innovative Polyethylene solutions for water transportation and corrosion protection.

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1. Introduction

When selecting the optimum pipe material for your water distribution systems it is not enough just to consider the cost of purchasing the pipes and fittings but also the installation and operational costs. This "Whole Life Cost" approach often shows that the cheapest system to purchase can be more expensive in the long term than what appears to be more expensive systems. The approach should also take account of the environmental footprint of the products employed and the means of construction.

In major projects in large cities with water companies, such as Thames Water in the UK and the Shanghai Waterworks Fengxian in China, Borouge and Borealis have shown that PE systems have the lowest Whole Life Cost for pipe diameters up to 500mm in diameter. This is due to the lower installation costs, the reduced costs of ongoing maintenance and pumping and the longer service life for corrosion free PE systems. Even greater savings can be achieved if "No Dig" PE installation techniques can also be applied. These techniques also reduce the environmental footprint of the project and the disruption to city life.

For large diameter, higher pressure water transportation steel pipelines will undoubtedly be required, but corrosion protection is essential for these pipelines and here again PE provides a solution in the form of external 3 Layer PE (3LPE) coatings. These specialised pipeline coating materials have been developed by Borealis and Borouge and have a successful track record going back over 30 years in the oil and gas industry. As water scarcity increases and the true value of these pipelines is recognised these 3LPE coatings are replacing the lower performing coal tar and cement protective coatings used in the past. Once again the lower Whole Life Cost benefits of the PE coatings are being appreciated by the owners and operators of these systems.

This paper describes in detail the benefits of using PE materials for water distribution systems and for coating large diameter steel transportation pipelines. Many examples are provided from different parts of the world which clearly demonstrate that these solutions will also be of great value to the Indian Water Industry.

2. The 'Thames Water' Whole Life Costing Model

a. Introduction

This model was jointly developed by a team which represented several organisations in the UK including Thames Water, Borealis, TRL (formerly the Transport Research Laboratory) and GPS (Aliaxis) the leading fittings manufacturer. The model considered the cost of supplying, installing and repairing medium and large diameter pipelines manufactured from Polyethylene (PE), Glass Reinforced Polyester (GRP) and Ductile Iron (DI) materials.

b. The Theory behind the Model

The principle of whole-life cost (WLC) analysis is to calculate all costs associated with a project throughout its life on a common basis in order that true comparisons can be made between options. Thus the WLC represents the sum of money to be set aside today to meet all the eventual costs, both present and future, after allowing for the accumulation of interest on that part of it intended for future commitments.

The Cost of Components

The costs of PE pipes and fittings are usually lower than those of other materials for small diameter systems, but in larger diameters they can be more expensive. Despite this, PE systems are still the preferred solution in Europe because other factors such as:-

- Network designers can make use of the smoother walls and superior flow characteristics of PE.
- No corrosion in the pipe bore means that water quality is maintained at a high level through the operational life.

The Cost of Installation
The installation costs for PE pipe systems can be lower than other materials:-

PE pipes can be supplied in longer lengths reducing the installation time reducing labour and traffic management costs.

- PE pipes can be butt welded above the trench enabling the trench width to be reduced.
- PE pipes are light weight requiring little mechanical lifting equipment.
- PE pipes will flex around bends or obstacles reducing the number of fittings
- Welded PE systems will resist axial forces therefore no anchor blocks are required.

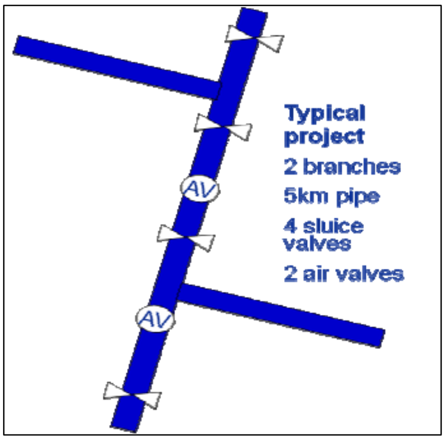
If trenchless techniques such as slip-lining, directional drilling (HDD) or pipe bursting are used even greater savings can be realised using PE pipe systems.

The Cost of Ownership
The cost of ownership covers the cost of maintenance and repair of the system throughout its operational life and in independent surveys PE systems have shown the lowest failure rate of all pipeline materials. PE pipes have a lower ownership costs:-

- Welded PE systems resist axial loads without failure and can better resist the ground movement experienced in modern cities.
- PE systems do not corrode and therefore need no expensive protection or monitoring systems
- No corrosion means no build up in the pipe bore which means lower cleaning and pumping costs.
- Longer operational lifetime means lower replacement costs for PE systems.

Costing the options

Fig 1. Simple project model



In 2004 Thames Water decided to replace a substantial part of their pipe network in central London which was over 100 years old and in need of replacement. In considering their options they needed to compare the different costs but realized that it was essential to consider all the elements and not just the initial cost of the products themselves. They therefore decided to use the Whole Life Cost (WLC) which is the summation of the cost of the components, the cost of installation and the cost of ownership of the system over the full life of the system. The costs will vary considerably depending upon the location of the project and local conditions and therefore it is necessary to look at a specific project. The simple scheme shown in fig. 1 was used for this purpose and was evaluated for 5 km of DN 400mm ductile iron (DI) and glass reinforced plastic

(GRP) pipes and 450mm diameter PE100 being installed in an open trench in a city centre environment.

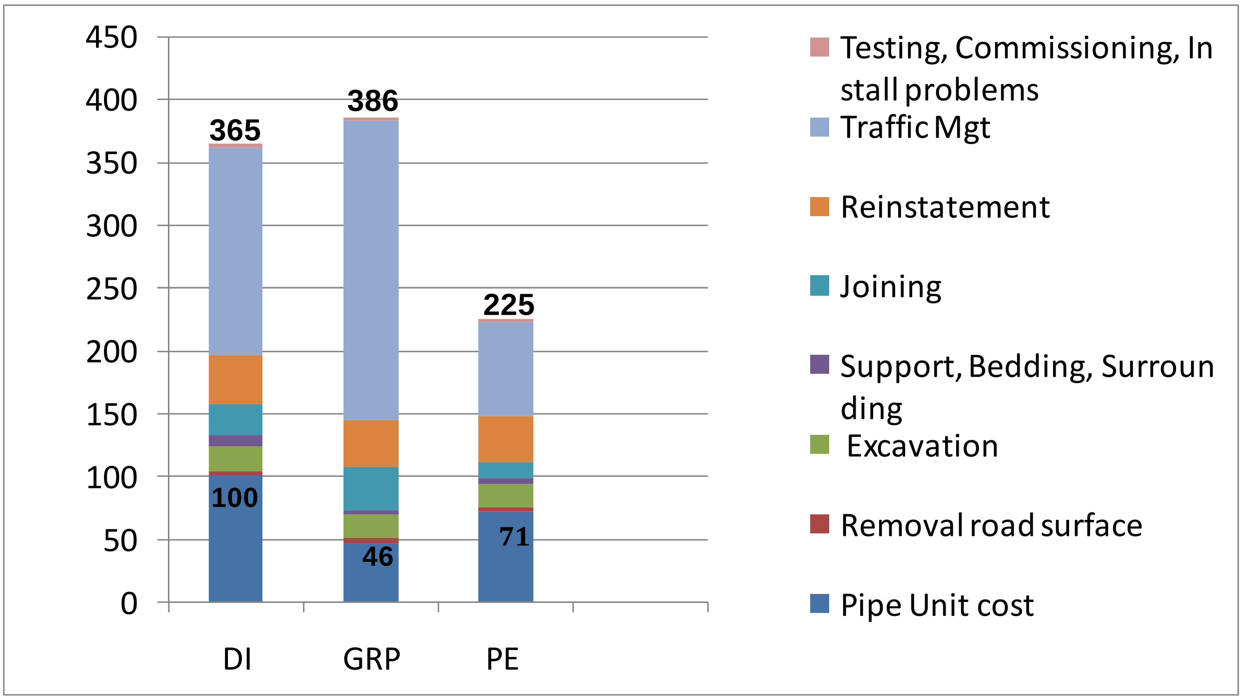


Fig 2. Cost analysis for 5 km project

The graph in fig 2 show the results of the costing exercise carried out in collaboration with Thames Water to assess the Whole Life Cost of different pipe options in Central London. The coloured bands in the vertical bars show the different cost elements. The largest elements are associated with installing the pipes and managing the traffic while this construction work is carried out. Because the PE100 pipe can be supplied in longer lengths and butt welded above the trench the installation time was shorter and these costs were therefore significantly lower. The estimated repair costs of the PE100 system were also the lowest because the statistics collected by the UK water industry shows that PE was the most reliable system.
Based on these calculations PE100 pipes were selected which also meant that Thames Water were able to make use of trenchless technology and save even more on the cost of installation.

In subsequent years Thames Water renewed and replaced around 2,000 km of their old cast iron mains in central London and 40% of that pipe was installed using trenchless technology. The same can be true for cities such as Mumbai or Beijing.

At 900mm the DI pipe was significantly cheaper than the PE pipe and despite the lower laying costs this difference could not be overcome. Hence the whole life cost difference between the different materials, at this large diameter, was much less marked.

3. The Shanghai Waterworks Fengxian Co. Whole Life Costing Model

a. Introduction

The Shanghai Waterworks Fengxian Company (SWFC) was originally established in 1988 and covers a district of 705 km^2, supplying a population of 800,000 with 3.5 Mm^3 per day through a network having a length of 1330 km.

As an operator, SWFC realised that the capital cost of constructing a pipeline, whilst significant, only constitutes part of the life cycle cost and determined to eventually make greater use of the life cycle costing in their planning. In order to do so they collected information from their own records and from neighbouring companies serving Shanghai city.

In order to help compare their findings against those derived from similar studies they adopted the Thames Water model described in section 2.2 of this paper ie. a 5 km long transmission pipeline with two branches and typical fittings.

b. Review of the SWFC Model

The Thames Water study focussed on the installation cost of the model pipeline, together with taking in to account the typical burst rates and the cost of repairing each burst. In addition to these factors the SWFC were also able to collect and incorporate data on the following factors:

1. Cost of leakage
2. Delivery and distribution costs (pumping)
3. Routine maintenance costs - pipeline flushing
4. Pipe bursts – repair costs
5. Pipe bursts – insurance and compensation costs

The SWFC study found the level of leakage from PE pipes to be the lowest of the materials they considered, with leakage rates being 40% lower than for equivalent ductile iron (DI) pipelines in the rural areas. Surprisingly, they found the level of leakage in urban areas to be higher than equivalent DI pipelines, but this was traced down to a design fault at the joint between PE and metallic pipelines. Whilst welded PE pipelines are effectively a continuous pipe, it was discovered that the joints to metallic pipelines were not restrained and that during a period of very cold weather the shrinkage in the PE pipeline length caused the adjacent spigot and socket pipeline joints to open up. Borouge are now working with SWFC in trying to get the local codes of practice and specifications updated to include a requirement for such joints to be anchored or restrained and hence eliminate this problem.

The delivery and distribution costs, which essentially relate to the cost of pumping the water in to supply were found to be significantly lower for PE pipelines than for DI or steel pipelines, presumably due to the smoother internal pipe surface and lack of tuberculation or corrosion deposits. Whilst the figures varied, the saving were found to be between 40 and 70%, presumably depending on the diameter and condition of the pipelines.

Based on a study of pipeline flushing operations over 2 years, SWFC determined that the water consumed in flushing PE pipelines was far less than that required for other pipelines. Whilst the figures are open to some interpretation, the quantity of water required for flushing PE pipelines came to less than 10% per unit length of that required for asbestos cement and DI pipelines of equivalent diameter.

SWFC analysis of their pipe repair costs, per unit length of pipeline, which also took in to account the burst frequency, found PE pipelines to have the lowest cost in rural areas, but be more expensive that DI in urban areas. As highlighted above, the high frequency of bursts in urban areas was traced down to a lack of anchored or restrained joints at connections to metallic pipelines with push fit joints.

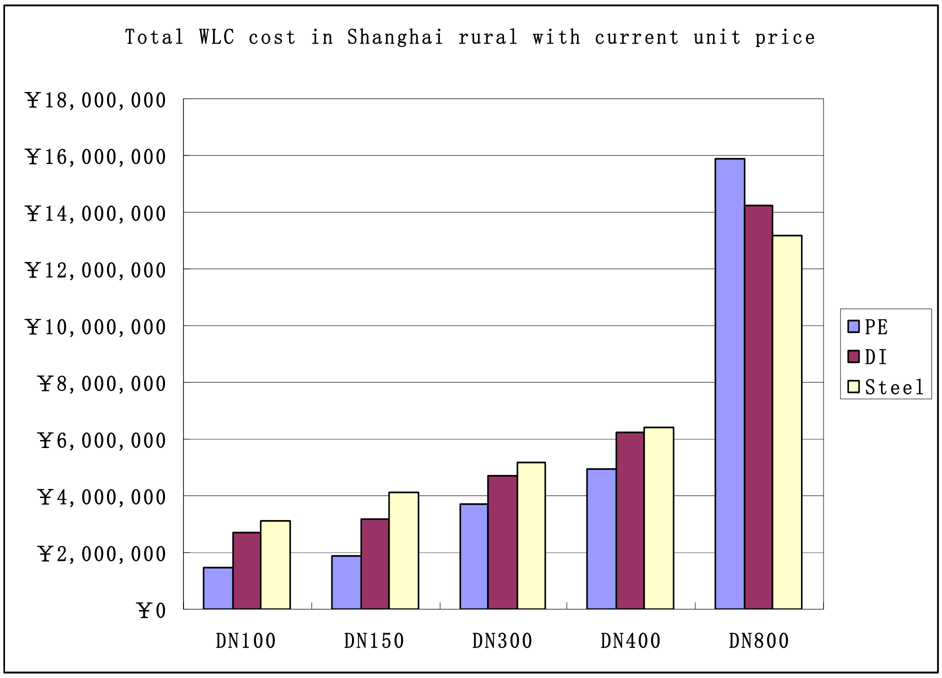
With regard to the payment of compensation and insurance claims related to pipe bursts it was found that the cost per incident for all the different pipeline materials was very similar.

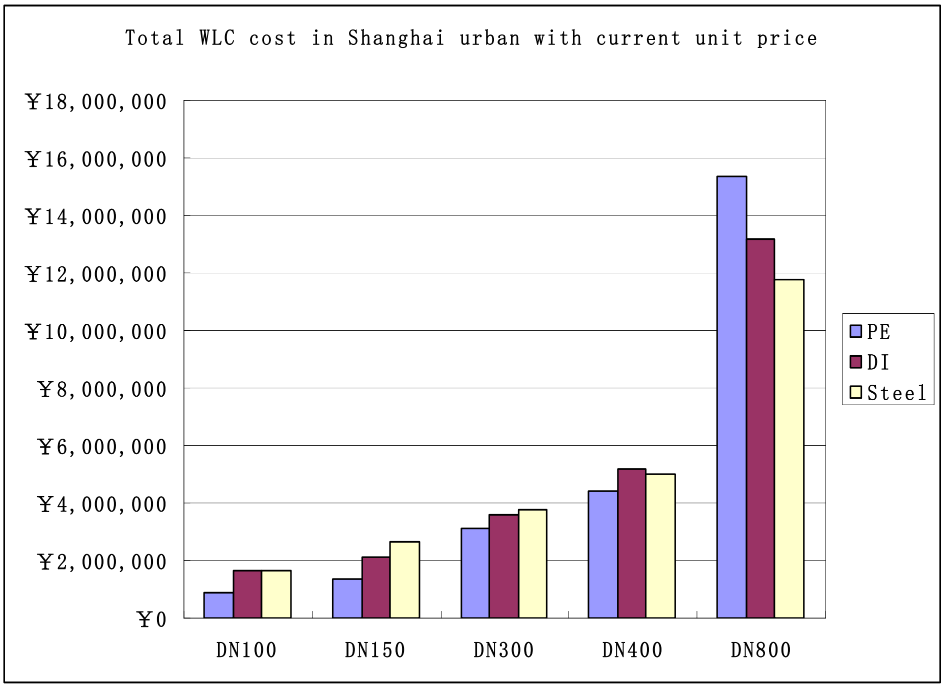
A major difference between the Thames and SWFC financial calculations is the cost associated with the full or partial closure of roads and traffic management during construction. In the UK the utility undertaking works in the highway is responsible for these costs, whilst in Shanghai they are borne by the municipality. When SWFC undertook their analysis these costs were ignored as they did not directly impact on the utility's budget. Hence, whilst one of the main advantages of PE pipelines is their ability to minimise installation times and road closures by being installed using trenchless technology or by being welded together prior to excavation of the trench etc. these benefits were not reflected in the SWFC whole life cost calculations.

c. Summary of the SWFC Model Findings

The following charts present a comparison of the whole life costs for the same model as in the Thames Water study, but taking in to consideration different pipeline diameters. Please note that one Chinese Yuan is equivalent to US$ 0.15 or £ 0.096.

Fig 3. Cost analysis for 5 km project in Urban and Rural shanghai





The charts show that in both urban and rural situations PE pipelines have a lower whole life cost on pipelines having nominal diameters of up to 400 mm, but are more expensive at the largest diameter on DN 800.

This is in line with the findings of the Thames Water study, though it should be noted that the cost differences are not as marked as in the Thames study as the costs associated with traffic management and those costs incurred by the municipality were not taken in to account. As with the Thames Water study, the use of PVC pipelines was not considered as their use by both utilities has largely been discontinued.

d. Summary of the SWFC Conclusions

The SWFC have continued their study and came to the following conclusions:

1. **Design Factor** – The SWFC network has a target operational pressure of 4.5 bar hence the HDPE pipe SDR could be reduced to 21, which has a pressure rating of 8 bar. This step would lower the material cost of the pipes and raise the cross over point ie. the size at which HDPE pipelines are more economical than other materials.
2. **Pipe Length** – Water projects in Shanghai typically use 6 m long pipes. Increasing the use of 12 m long pipes, where there are no access and handling problems, such as in rural areas would reduce the installed cost of the pipelines.
3. **Trench Widths** – SWFC did not take advantage of the narrower trench widths that can be adopted when using HDPE pipes that are welded together outside the trench. Narrow trenching can reduce the installed cost by reducing the quantities of excavation and backfilling, together with the time required for these operations.
4. **Backfill Materials** – SWFC identified that by using highly stress crack resistant HDPE pipelines they would be able to avoid the use of imported pipeline bed and surround material in some areas and instead use lower quality selected excavated material. Such an approach has the potential to make significant savings on the installed cost of the pipeline.
5. **PE Pipe Failures** – The failures mainly occurred at flanged joints between pipes and fittings or at joints to pipelines of other materials. Some also occurred at incorrectly made joints between PE pipes. Such problems can be tackled by improved codes of practice and specifications, together with improved site supervision.
6. **Use of Trenchless Technology** – SWFC determined that there was great scope for employing trenchless technology in the replacement and renovation of existing pipelines. This is especially true of urban areas if the costs associated with traffic management and road closures are taken in to account when assessing project costs.

4. PE Materials -Significance of Quality and Standardisation.

The development of polyethylene (PE) piping materials has been continuous since their inception in the early 1950's (refer figure 2). Whilst small diameter LDPE water service pipes were used in the 1960's widespread usage of PE started in the gas in the 1970's with the introduction of complete MDPE systems of pipes and fittings which could be welded together completely eliminating corrosion and potential leakage. A further major step came with the realisation that PE pipes could be inserted into old corroded and leaking iron pipes without digging up the roads.

The introduction of PE100 materials in the late early 1990's provided another surge in the market penetration of PE pipes for gas and water systems because it meant that higher pressure could be achieved (up to 10 bar gas and 16 bar water) and larger diameter pipes could be produced more competitively. Because PE100 materials are bimodal (i.e. the structure is made up of two molecular weight components in two reactors) it is possible to develop a higher strength material that is also very tough and can still be processed relatively easily.

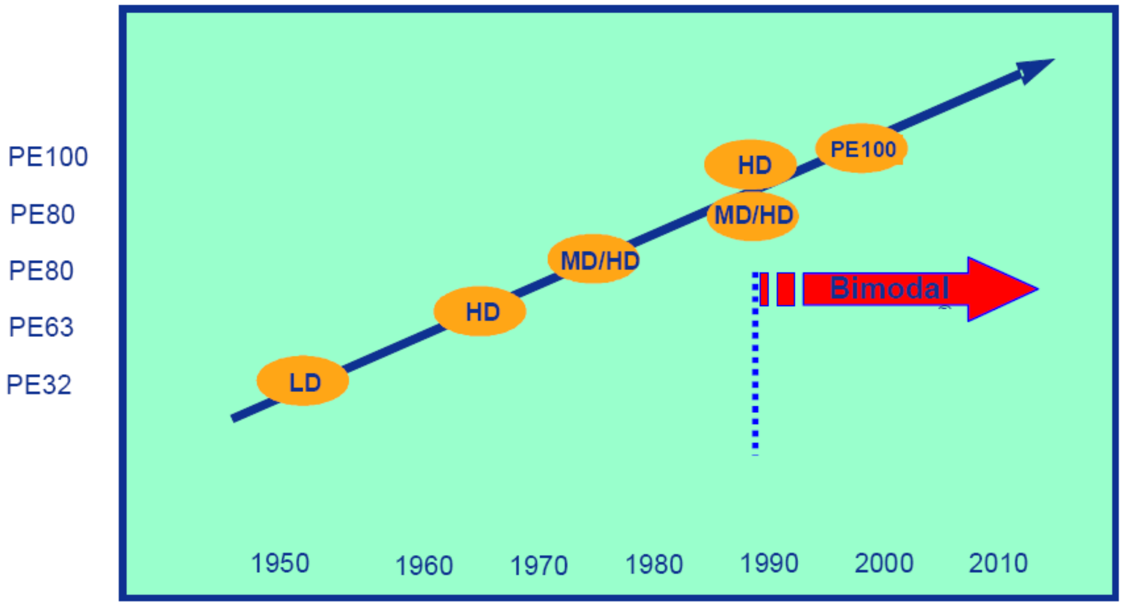


Fig 4. Graph showing the continuous improvement of PE materials

Bimodal processes enabled the polymers to be further engineered and "low sag" PE100 polymers were developed which enabled very large diameter, thick walled pipes to be produced with a very even wall thickness distribution. Today pipes of 2000 mm diameter and 100 mm wall thickness are produced by a number of manufacturers around the world and the first 2500mm solid wall pipes are under production at the moment in Middle East.

4.1 Why is material toughness important?

A particular focus of the development has been the balance between strength and toughness for whilst strength controls the pressure rating of the pipe it is primarily the material's toughness or resistance to brittle cracking that defines the material's potential service life or **durability**. This has been verified in practice as PE pipe systems do not fail by ductile bursting (unless the system is seriously over pressurised) but by cracking from stress concentrations or defects. Therefore raw material producers have put a lot of effort into improving the material's resistance to slow crack growth.

The early high density PE80 materials exhibited a high short term strength but a lower long term strength as brittle failures intervened at an early stage creating a steeper slope to the pressure characteristic (refer figure 2). With bimodal PE100 materials it is possible to address this and maintain ductile failures throughout the complete test period providing greater security against brittle failures in service (refer Figure 3).

The introduction of ISO 9080 brought a new rationale to PE pipe design in that it enabled the long term (50 year) strength to be calculated from shorter term pressure tests at ambient and higher temperatures. The pressure tests at these higher temperatures will accelerate the brittle mode of failure bringing it earlier in the test period (refer fig 2) and these failures can be taken into account in predicting the 50 year strength of the material.

As shown in figure 2 (below) there are PE materials that will meet the MRS10 requirement whilst showing an early transition to brittle failure. But whilst these materials meet the PE100 requirements they are not suitable for pressure pipe production because they are too sensitive to crack growth from the scratches and scores that they are likely to receive during installation. Also larger diameter and thicker walled pipes will be more likely to fail in a brittle mode than the small diameter thin walled pipes that are tested due to the constraints to ductility that occurs in thick sections.

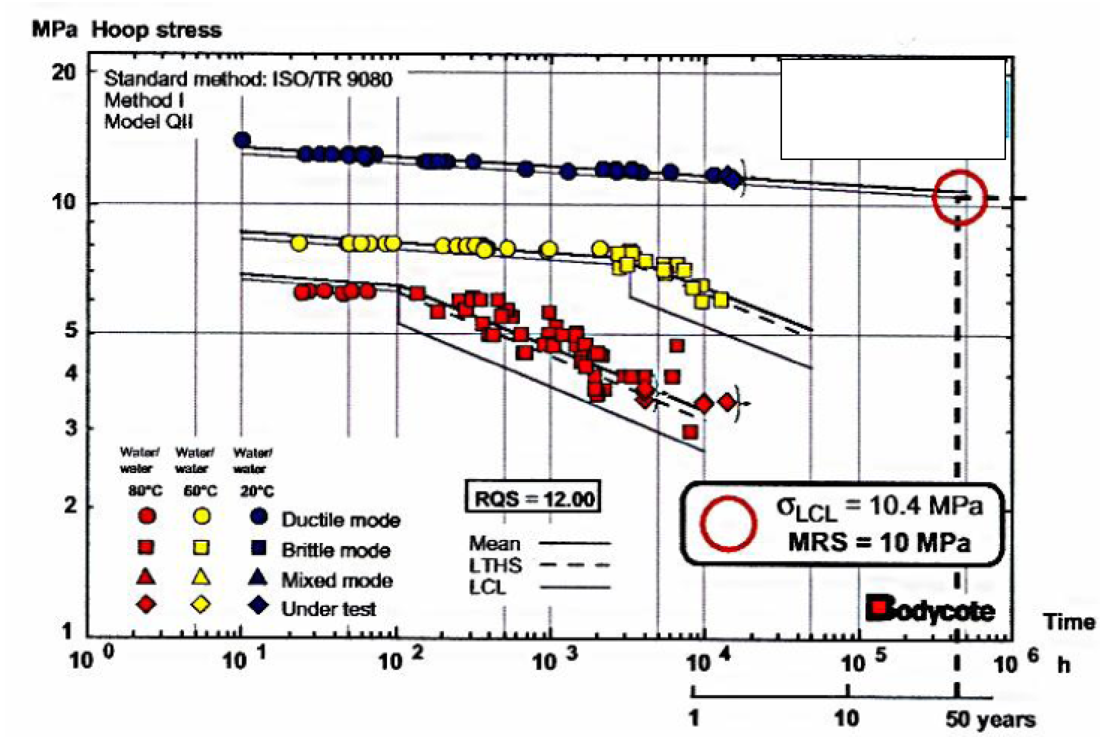


Fig 5. A "brittle" PE100 material that is not suitable for gas and water pipe production

For these reasons in the revision of the international standards in 2007 for PE gas and water pipes (ISO 4437 & ISO 4427) it was agreed that materials showing brittle failures in the pressure characteristic at 80°C will no longer be accepted (4&5). Therefore it is important in selecting PE100 materials for gas and water pipe manufacture that a material with a ductile pressure test characteristic similar to figure 3 is chosen.

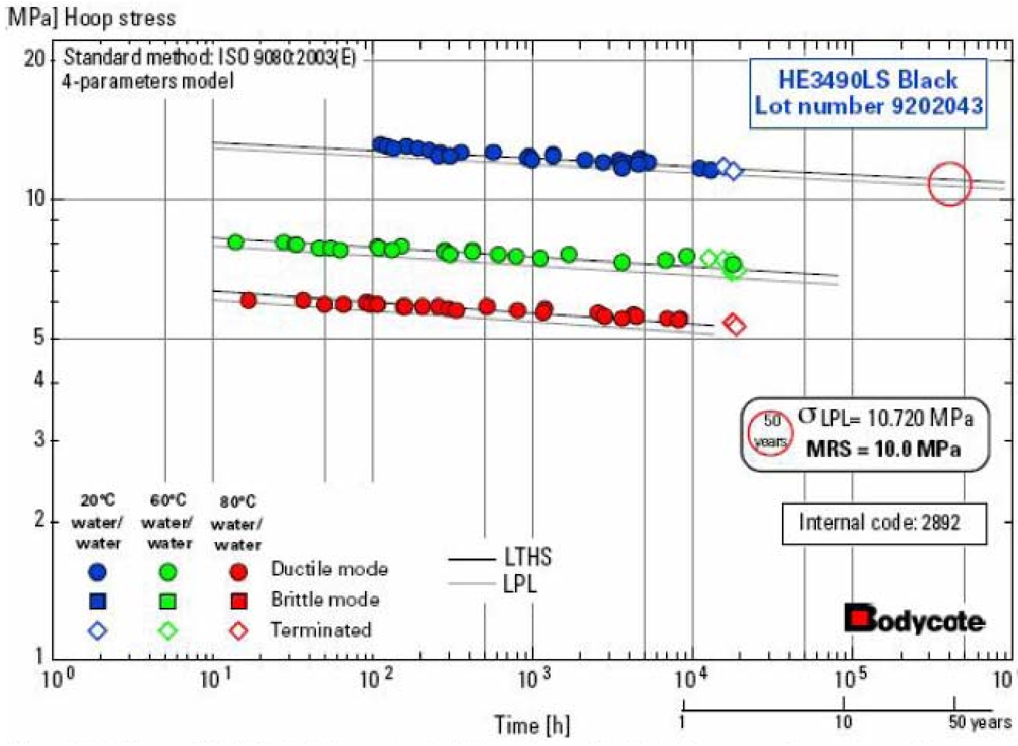


Fig 6. A "tough" PE100 material that is suitable for gas and water pipe production

Along with the strength the importance of other mechanical properties are also very important with respect to operation and installation of PE pipes. All the international standards, ISO (ISO 4427-2007, ISO 4437-2007) EN (12201 & 1555) has clearly specified the requirements for critical properties like Slow Crack Growth (SCG) for water pipes and SCG & Rapid Crack propagation for gas pipes. These are the minimum requirements and a good quality PE-100 must meet these requirements for the minimum guaranteed life of 50 years. Even the new generation materials like BorSafe™ HE3490-LS-H are proved to be much superior in SCG properties when compared with conventional material. These materials can be used for demanding installations like no dig technologies and sand less bedding.

All over the world water is becoming more critical and therefore water leakage from corroding iron pipes and other systems is coming more and more into the spotlight. Nowhere more so than in the African continent is water conservation such an important issue, therefore the durability of the water network is a crucial consideration. Even from a purely financial point of view since the cost of the pipe and fittings is only 10-15% of the cost of installation nobody wants to be digging up pipe networks prematurely and therefore the durability of the network is the most important issue.

Most water companies have used a range of pipe materials throughout the years but only a few has realized the importance of good quality PE materials and especially PE100. Because of its superior properties, there is substantial increase in usage of PE materials and also awareness.

Industry Associations like PE100+ association and GPPA are driving the quality awareness within the industry to have sustainable Plastic Piping Systems.

5. Nagpur City, India 24X7 water supply project by Veolia

5.1 Introduction

Veolia is one of the partners in a JV called Orange City Water (OCW) who has been awarded water rehabilitation project by Nagpur city, India for operation and maintenance on BOOT basis for 25 years. The total project cost is 500 Mn Euros. This is the first full city 24X7 project in India.

Borouge has shared its vast experience on water distribution network with HDPE pipes with Veolia team and introduced its latest generation PE100 material HE3490LS-H for this project.

5.2 High Stress Crack Resistance (HSCR) PE100 material

HE3490LS-H is a PE100 material with excellent resistance to slow crack growth. Most of the pipe failures in a PE water distribution system is due to slow crack growth of notches and scratches inflicted on the pipes during handling and installation. Compared to a good PE100 which has resistance to slow crack growth (notch test) of >2000 hours, a HSCR (high stress crack resistance) PE100 material like HE3490LS-H has resistance to slow crack growth of >18000 hours. Borsafe HE3490-LS-H has been specified by Veolia in Nagpur project specification and is being used very successfully for all the Horizontal Directional Drilling (HDD) pipe sections.

Following the successful Nagpur project Veolia has also used high stress crack PE100 material BorSafe HE3490-LS-H in their Hubli-Dharwad and Ilkal projects also.

6. Large dia Strategic water transportation pipelines

6.1 Due to the high pressures involved most of these pipelines are produced in steel and therefore they need to be protected from external corrosion. Although the protective coating materials are only a very small percentage of the investment in the oil, gas or water pipelines their role in ensuring continued performance is critical to the supply network. The need, therefore, to look ahead and choose the best materials at the time of initial installation is crucial in delivering effective, long-term performance with the lowest lifetime cost.

In the past pipeline protection systems for water have been manufactured using materials such as coal tar tape coating (according to AWWA C203), cement lining (according to AWWA C205) and single layer FBE. But now more and more 3LPE coating solutions (according to DIN30670) are being used to meet the specific needs of the project, design life and location. Three layer PE (3LPE) coating systems have become the most popular choice for onshore oil and gas pipelines and now with water becoming an increasingly precious resource they are also being selected for coating major water pipelines.

6.1.1 The development of 3LPE coatings

6.1.2 Coating systems for pipelines have evolved over the years from simple coal tar enamel, cement coatings to asphalt enamel, FBE, and finally three layer PE (3LPE) coatings. In the oil and gas industry 3LPE coatings now account for over 55% of the market due to the materials superior resistance to handling damage and its good in-service performance. However coating manufacturers continue to develop their products to improve performance and expand the operational envelope.

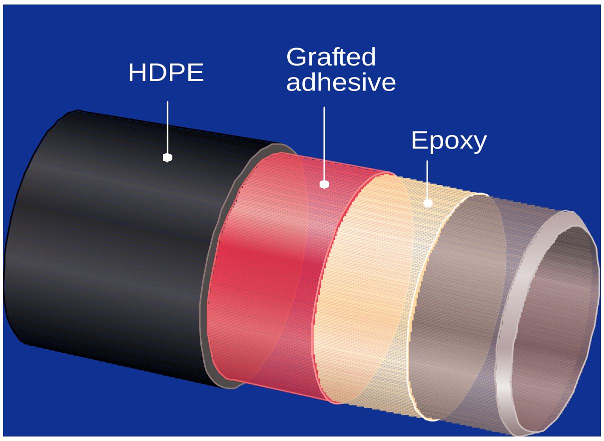


Fig 7. Typical 3LPE coating system

Borealis and Borouge have been supplying 3LPE coatings for more than 25 years and their systems are approved and used by most of the world's major oil and gas companies, where pipeline safety is the highest concern. Their Borcoat™ system is based on a bimodal high density PE (HDPE) top coat together with a grafted copolymer medium density (MDPE) adhesive.

The bimodal HDPE top coat ensures that the coating system provides high impact, indentation and abrasion resistance, resistance to stress cracking and weatherability over a wide range of operating temperatures from -45°C to +90°C and over a long service life.

The most recent development is a top coat Borcoat™HE3450-H which is designed to withstand the higher temperatures in the Middle East and Africa and has higher indentation and abrasion resistance so important during transport and installation. This new generation top coat is a superior bimodal HDPE material produced using the Borstar® process with new catalyst and co-monomer technology.

These improvements can be directly translated to benefits for the pipeline owners, coaters and installers. The higher temperature resistance means the surface of the coating will not soften at the high ambient temperatures experienced in the Middle

East and Africa. The higher resistance to abrasion and slow crack growth means an increased resistance to failure from the scratches and notches that can occur during installation, handling and transportation of the pipeline. The polymer also provides a higher barrier to moisture which means that it is suitable for regions with a high water table. A number of pipe coaters have also been able to run their extruders at a higher output rate due to the higher melt flow rate of the material.

7. Water industry adopts 3LPE coatings

A number of water companies have opted for the higher protection offered by 3LPE coating systems. One of the early adopters (since 2003) is the Saline Water Conversion Company (SWCC), Saudi Arabia who have been building a number of large diameter steel pipelines across the Kingdom of Saudi Arabia for transporting water from the large desalination plants at the coast to major cities throughout the country. The biggest of them, which is almost completed, will carry water from Ras Al Khair to Saudi Arabia's capital city of Riyadh. The population of Riyadh was estimated to be 5 million in 2010 but this is expected to rise to 8 million by 2020 and the current water supplied from Al Jubail cannot meet the needs of this rapidly growing city.

8. The Ras Al Khair Water Project in Saudi

The new twin steel water pipeline will be used to transfer desalinated water from the Ras Al Khair Integrated Water and Power Plant (IWPP), 70 km northeast of Jubail, to Riyadh city. The plant will produce 1,050 MW of power and one million cubic metres of water per day for SWCC to distribute.

Fig 8. The twin water pipelines joining Ras Al Khair on the coast to the capital city of Riyadh.

The total length of the pipeline is more than 910 km and it ranges in diameter from 48 inches (1.2m) to 72 inches (1.8 m). The pipelines starts at sea level and finish in the city of Riyadh, which is at 700 metres above sea level and to raise the water to this height two pumping stations have had to be built along the pipeline.

The 3LPE coating system from Borouge was selected by the project consultant, ILF Consulting Engineers, in order to protect these critical SWCC assets. These coating systems have a very successful track record with SWCC in protecting many of their other steel pipelines from external corrosion and mechanical impact damage during storage, handling, transport and operation (prominent projects include Shoaiba Water Transmission, Eastern Province, Shuqaiq and the Taif al Baha projects). The Borcoat™HE3450 HDPE top coat also provides complete protection against other factors such as corrosive soil, high water table and severe weather in Saudi Arabia all of which had to be carefully considered to ensure these critical water pipelines would have along and trouble free lifetime.

9. The Gujarat GWIL water project

The water industry in India has traditionally relied upon cement coating to protect their large diameter steel water transportation pipelines but attitudes are now changing and higher specification systems are being sought. Gujarat in western India suffers from severe water shortages which have undoubtedly constrained its growth in past years. In the past ten years they have faced at least three drought years and in the worst affected areas, such as the Saurashtra and Kutch regions, the Government has been forced to provide drinking water in road tankers which is an inefficient and very expensive process. To combat this problem Gujarat Water Infrastructure Limited has invested in a large water supply project comprising of 432 km of steel pipes from 74 to 96 inches in diameter. Unlike earlier projects, where they also used cement lining of steel pipes, this time they have chosen external 3-layer PE coating and internal liquid epoxy coating to reduce handling damage and to improve the long term protection of these strategic pipes from corrosion.

Fig 9. Some of the first pipe lengths being installed in the Gujarat water project

The coating of the pipes were done between April and December 2012 and were carried out by coating companies who all have plants in Gurarat State, namely PSL Limited, Welspun Corporation and Hazira Pipe Mill. The entire project has used Borcoat™HE3450 for the top coat and a significant portion has used Borcoat™ME0420 adhesive supplied by Borouge. Several leading contractors are involved with different phases of the installation including Larsen and Toubro, SPML Infra, Hindustan Construction Company, Megha Engineering and Infrastructure Ltd and Pratibha Industries.

Similar large diameter pipeline projects with 750 to 3000 mm diameter and over 1100 kms length for Gujarat irrigation department is upcoming, which has specified 3LPE as the coating system.

These are important reference projects for 3-layer PE coatings, which will be closely monitored by many other states and a successful outcome will lead to considerable increase in future demand for 3LPE coatings from the water sector in India.

10. Concluding comments

In the oil and gas industry 3LPE coating systems are recognised as providing the highest protection against external corrosion. As water becomes more scarce water companies are also seeking a higher level of protection for their strategic pipelines. Major water transportation projects in the Middle East, Africa and now India underline this growing trend.

Borealis and Borouge have been supplying 3LPE coatings for more than 25 years and their systems are approved and used by most of the world's major oil and gas and now water companies. Recent developments include a new bimodal HDPE top coat material that can cope even better with the higher ambient temperatures experienced in the Middle East and Africa. This will provide even greater protection against coating damage during transportation and installation and ensure that the pipelines will have a long trouble free operational life.

As far as water distribution pipelines are concerned, the analysis of the Thames Water and Shanghai whole life (life cycle) costing studies, together with exercises undertaken by other bodies, including Borouge and Borealis have demonstrated that: Whilst conditions vary, the capital (construction) and whole life cost of small and medium sized pipelines laid in polyethylene was found to be consistently lower than those laid in ductile iron, steel or GRP.

With larger pipelines the capital cost of HDPE pipe is normally higher than the other materials, whilst the variance in life cycle cost of the different materials is much less than for smaller sizes, with different materials proving to have lower costs in different environments.

With regard to only capital costs, the cross over point at which PE100 polyethylene pipelines become more expensive than DI varies significantly depending on different environments and the pressure rating of the pipelines in question. When considering 10 bar rated pipelines, experience in the UK, Shanghai and the Gulf region suggests that the crossover point will typically be in the region of DN 500 – 600, when considering conventional trenched projects.

When life cycle or whole life costs are taken in to consideration the cross over point when considering conventional projects will typically increase in value and may be in the region of DN 700 – 800. It should be emphasized that these values vary widely due to the wide variance in operational practices and costs.

The environmental impact of different materials further support the use of PE pipes for water distribution networks as a sustainable material.

Particularly in urban areas, the use of trenchless technology such as directional drilling and relining of pipelines should be considered, regardless of the pipeline size. Here development of new generation PE (e.g., HSCR PE100) pushes the operating envelop further up for PE pipes and increases the design life.

Undertaking life cycle cost analysis is very dependent on the capture of good quality data, particularly that related to operational and maintenance areas such as leakage rates, repair costs, pipe burst rates, compensation payments and the cost and frequency of pipe flushing etc. Hence it is very important that data collection programmes should be implemented to start capturing it. Experience with other utilities suggests that operators should first target easily identifiable and collectable data such as details of pipeline bursts, repair costs and estimated levels of leakage.

Last but not least is the quality of the raw material to be used in production of pipes or coatings. A material which confirms to latest ISO standards must be used as a minimum. Many a time the quality of infrastructure remains perpetually weak due to a weak local standard.

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