BORPIPE

A Borouge magazine for the infrastructure industry

بروج Borouge

SECMC AND UTICO SUCCESSFULLY COMPLETE LARGE PE100 PIPELINE PROJECTS

Borouge celebrates 20 years of successful operations in India

KOC project utilises 5 inch RTP pipes & fittings for the construction of flow lines in West Kuwait

The effect of carbon black distribution on polyethylene pipes

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INSPIRING TOMORROW

EDITOR STATEMENT

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Borouge is a member of the PE100+ Association

The editor says…

The cover of this edition features the critical welding step in the installation of the UTICO project in UAE – one of the largest projects of its kind featuring 1200mm diameter PE100. After more than 2 years in the construction phase, it has finally been commissioned late last year. The utility owning this pipeline is planning for the next expansion stage at the time of writing.

The year 2018 marks the 20th Anniversary for Borouge. Over three stages, our plants have expanded its total manufacturing capacity to 4.5 million tonnes of PE & PP from Ruwais, making it the largest integrated manufacturing site for polymers in the world. Similarly, we review two decades of successful market development activities in India.

In the Utilities section, we highlight a landmark new study originating from the Borouge Innovation Center Abu Dhabi that compares, for the first time, the difference when extruding PE100 pipes using black precompounded resin versus the alternative practice of mixing natural (unpigmented) PE100 resin and carbon black masterbatch (CBMB). Tensile and CBMB dispersion results are detailed and discussed. In a related development, we also highlight how the China national standards for PE100 water pipes have finally switched to specifying that only precompounded resin be used in the country in its latest revision. This significant change is a recognition of the efforts by Borouge and also PE100+ Association members over the last decade.

In Industrials, we showcase a Reinforced Thermoplastics Pipe (RTP) project in Kuwait for the Kuwait Oil Company (KOC). RTPs are increasingly popular especially in the Middle East but also gaining traction in Asia Pacific because it offers clear benefits in oil & gas operations and suppliers are coming up with newer manufacturing techniques to take advantage of the current available polymers and reinforcement materials to construct a composite pipe that best fits the needs and budget of the oil & gas industry.

We wrap up this edition with a story of another large diameter PE100 project in Egypt for a desalination plant and also the upcoming trend of using high modulus PP for large diameter utility tunnels in China.

We hope you enjoy reading this issue and look forward to meeting some of you at our upcoming events and exhibitions this year!

Your Editor,

KH Lou

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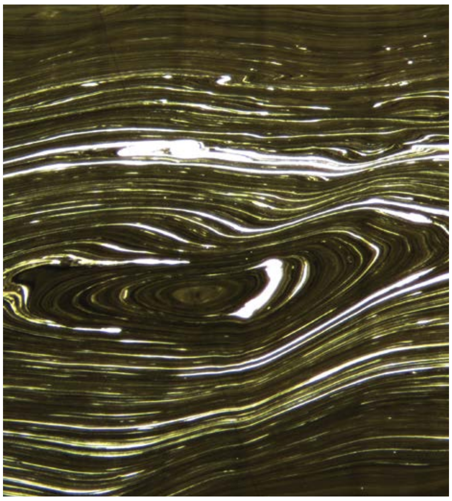

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Large diameter PE100 pipes being produced at Gulf Manufacturing Company.

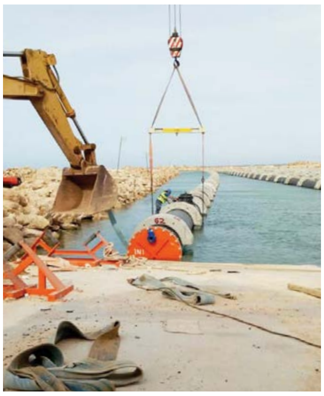
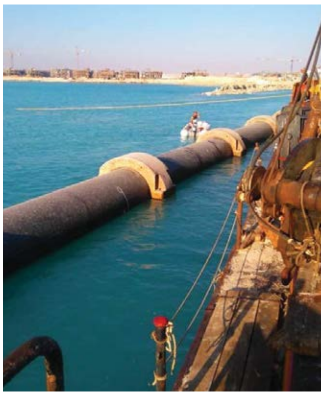
El-Alamein City desalination project uses BorSafe™ PE100 for its large diameter pipeline

by Sultan Alkendi

Egypt is a water scarce country with a fast growing population. Its main source of fresh water, the Nile River, which supplies 97% of its annual renewable water resource[1] is no longer able to support a population that has doubled[2] in the past 25 years to 83 million[3]. The country is therefore turning towards desalination to supplement its water supply needs. A recent desalination project[4], located in the city of El-Alamein was awarded to the Metito-Orascom joint venture. This EGP1.8 billion (USD100 million) project consisting of a wastewater treatment plant and sewage network is scheduled to be fully completed by 2021 and is currently in the construction phase[4].

El-Alamein city is located on the Mediterranean coast and is planned as one of a new generation of millennium cities by the government[4]. The city will eventually occupy an area covering 202 million square metres[4]. The new desalination plant was designed with a PE100 seawater intake and outfall pipeline. The benefits of using a corrosion resistant material in the coastal environment and the ability of quick installation by using PE100 meant that the complete installation, testing and commissioning of the seawater intake and outfall system could be completed relatively quickly. Future operational and maintenance costs would also be minimal since corrosion will not affect the pipeline.

Gulf Manufacturing Company (GM), Egypt's largest supplier of PE100 pipes with almost 50 years[5] of experience in the plastic manufacturing industry supplied the 5.8km of 1600mm OD SDR21 PN8 PE100 pipeline for the desalination plant. Made entirely using BorSafe™ HE3490LS, these were among the largest pipes ever manufactured in Egypt and came with unique challenges for the pipe manufacturer. As this was the first time for Gulf Manufacturing to produce such large pipes, they turned to the BorSafe™ range of PE100 as it had the longest track record of all the PE100 materials used in the Middle East for such sizes. Close support from the Borouge technical service team ensured that the pipes could be manufactured quickly to meet the contract specifications and tight construction deadline.

The PE100 pipe string was easily floated offshore.

The 12m sections of pipe were transported by trailers to the project site approximately 230kms from the pipe factory located on the outskirts of Cairo. PE100 is an excellent material for offshore seawater intake and outfall pipelines as demonstrated in multiple regional projects including the Borouge 2 & 3 expansion projects. The benefits of PE100 for such an application are:

- Low installation cost – Because PE100 is flexible and lighter in weight compared to steel systems, it is easier to position the pipeline offshore. PE100 is also tougher when compared to GRP pipelines. Compared to both these materials, installation time using PE100 is significantly shorter which directly reduces costs

- Easy installation – As PE100 is less dense than seawater, the pipeline string can be easily floated and towed into position with a barge or small vessel

- Low maintenance cost – Due to the absence of corrosion during the operational life of the pipeline, maintenance cost will be minimal. Because PE100 can tolerate ground movements better than rigid pipeline, it is less likely to crack during its operational lifetime during occasional coastal ground movements

After the successful completion of this project, Mr Ali Hashim, chairman of GM remarked, “As the pioneer producer of large HDPE pipes in Egypt, Gulf Manufacturing is proud to have successfully delivered one of the largest and most prestigious PE100 supply contracts in the country. We are glad to have partnered with Borouge in this aspect.”

Gulf Manufacturing Company
Chairman Ali Hashim.

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1 Integrated Water Resources Management Plan, Ministry of Water Resources and Irrigation, Arab Republic of Egypt, June 2005 Report. Link: http://documents.worldbank org/curated/en/561611468234311417/pdf/341800EGY0whit11public10Action0Plan.pdf

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5 Gulf Manufacturing Company. Weblink: http://www.gmpipe.com/

KOC Project utilises 5 inch RTP pipes & fittings for the construction of flow lines in West Kuwait

by Mohamed Ali Jaber

The KOC West Kuwait RTP project completed by MTC.

Master Tech Company (MTC), based in Hamriyah Free Zone, Sharjah, U.A.E. is one of only two Reinforced Thermoplastic Pipe (RTP) manufacturers in the Middle East. They specialise in oil, gas, water and injection flow lines operating under high pressure. It was established in 2007 to address the growing needs of the regional oil & gas sector in terms of plastic composite piping. The company has a production capacity of 6000 tonnes[1] of pipes per annum.

MTC recently completed two projects of 5 inch RTP pipe & fittings for the construction of flow lines for the Kuwait Oil Company (KOC) in the West Kuwait area. The first project was 12km and the second project was 24km long. Both projects have the pipe specification shown in Table 1.

KOC has been one of the earlier adopters of RTP in the Middle East region together with PDO in Oman and Aramco in Saudi Arabia. KOC started using RTP in the early 2000's and their success in eliminating failures due to internal corrosion has encouraged them to adopt this material more widely. The cost of corrosion has been extremely high with one report estimating that the GCC suffered almost USD58 billion[2] in losses from corrosion in 2011 alone. The legacy steel pipes used for the production flowlines suffered from very high rates of internal corrosion especially when the oil fields in Kuwait are increasingly producing more water (high water cut) as they age. In addition, some fields also suffer from high concentrations of hydrogen sulphide (H_2S) and carbon dioxide (CO_2) that will accelerate the rate of corrosion even more.

Outer diameter	162mm (6.38")
Inner diameter	127mm (5")
Liner material	HDPE, PE100 (BorSafe™ HE3490-LS)
Cover material	PE-RT Material (Borstar® HE3466-RT), Added with white masterbatch, UV Stabilised

Table 1. KOC West Kuwait RTP pipeline specification

The project was delivered by low-bed trailers that could fit up to 1.2km of RTP pipes per trailer.

RTP pipelines have therefore become an increasingly attractive option for oil & gas operators to proactively control corrosion and reduce cost by replacing traditional steel pipelines. RTPs offer the following benefits:

- Easy transportation – resulting in quicker and more cost effective installation. A total length of 1.2km of RTP pipes can be loaded onto a low-bed trailer at one time
- Easy installation – RTP is available in spools and jointing is easily completed with the swaging mechanism. In general, 1-4km/day can be installed[1] in this way. A recent Aramco case study[3] showed a significant drop of 80% in project completion times when using RTP compared to standard carbon steel (CS). The typical 1km CS flowline took 70 days to be built while it took only 2 days to be completed with RTP
- Low installation cost – Installation can be completed by 2 experienced technicians
- Low maintenance – RTP is designed to be operated for the entire pipeline's lifetime because it does not corrode
- Long life – RTP can easily last for a minimum 20 years when installed on the surface and 50 years buried
- High pressure rating – 150 to 200 bar design pressure
- High reliability – Robust corrosion free design allows for a wide operation window
- Versatile – Possible reinstallation of RTP in another location if the need arise

Investing in RTP allows operators such as KOC to drive production and operating costs down and achieve lower whole life costs over the entire lifetime of the pipelines. In this project, the combination of BorSafe™ PE100 and Borstar® PE-RT has allowed MTC to provide a viable cost effective solution to KOC. Composite piping such as RTPs will spearhead the entry of polymers into the fiercely conservative oil & gas segment and this successful installation serves as a strong validation of this trend.

Sources:

1 MTC. Website: www.mtcpipes.com

2 Corrosion in the Gulf Cooperation Council (GCC) States: Statistics and Figures – A. Al Hashem, Corrosion UAE 2011

3 Saudi Aramco details nonmetallic products in deployment in oil, gas – Oil & Gas Journal, January 2018; M.A. Parvez, A.Y. Asiri, A. Badghaish, A. K. Al-Dossary, A. Al-Mehlisi

SECMC and UTICO successfully complete large PE100 pipeline projects

Introduction

This article is extracted from the paper, PE100 Large Diameter Water Transmission Pipelines Take Off in Asia (A. Wedgner, M. Qasim and A. Sembrano) which was first delivered at PPXIX 2018.

Many design engineers are dissuaded from specifying PE for large diameter pipe projects due to the high cost of the thick walled PE pipes. However the application of good design practices and modern installation methods can significantly reduce the total cost of the project as shown in the following two examples.

The SECMC pipeline from Nabisar to Vejhair in Pakistan

Pakistan suffers from a critical shortage of electricity generation capacity. Therefore the Sindh state government entered in to a joint venture with the Engro Corporation to establish SECMC, the Sindh Engro Coal Mining Company. SECMC is to exploit the large coal reserves located beneath the Thar Desert, close to the Indian border. The project is being undertaken in three phases, with the initial phase comprising an open cast coal mine producing 7.6 million tonnes of coal per year and a power station housing two 330MW generation plants. Together these will need 85 million litres per day (MLD) of water, which, as shown in Figure 4, will be drawn from a canal at Nabisar in the irrigated region and then pumped across the sand dunes to a reservoir at Vejhair.

After being drawn from the canal at Nabisar the water will reside in a reservoir having 15 days capacity. Due to its high salt content the water will then pass through a Reverse Osmosis (RO) plant, before being pumping at a rate of 1m^3/sec along a 60.6km pipeline.

To minimise the pipeline cost (imported pipes face high duties) it was decided to produce the pipes in Pakistan. Whilst large transmission pipelines had previously being produced using carbon steel, the government irrigation department had experienced many corrosion related problems such as frequent repairs and high levels of leakage. Hence, when they were approached by Hi-Tech Pipe and Engineering Industries, the department were willing to consider a PE100 option, as the pumping head would be less than 16 bar.

Figure 4. Route of the SECMC pipeline across the Thar Desert.

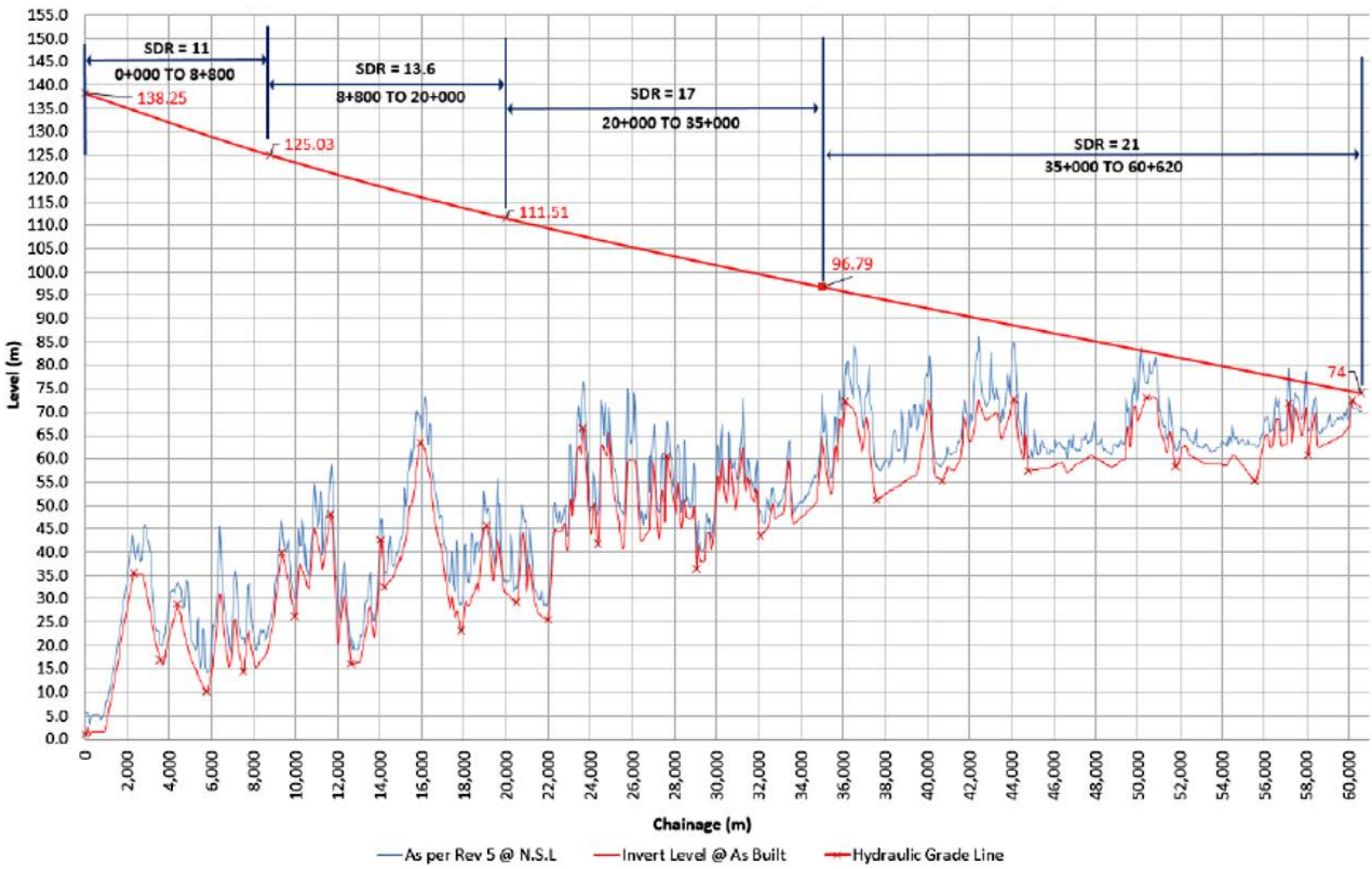

Figure 5. PE100 1200mm OD Final Design Profile and Pipeline SDR.

Unfortunately the project engineering consultant was not familiar with the design of PE100 pipelines and initially designed the whole 60.6km length as a SDR11 1200mm OD pipeline which, due to the high weight of PE100 material, was too expensive. Hi-Tech therefore asked Borouge and the Gulf Plastic Pipe Academy to assist in optimising the design. After several iterations, Borouge were able to come to a final optimised design, which is shown in Figure 5, that reduced the total weight of PE100 material from 22,990MT to 15,220MT, a saving of 7,770MT or 34%. This equated to a material cost saving of USD12.8 million and a total production saving in excess of USD15 million.

The potential savings were even higher, as much of the last section could have been SDR26 pipes, but SECMC decided to adopt a robust design and remain with SDR21.

As there is no facility to fabricate large diameter fittings in Pakistan it was envisaged that all of the air valve and washout branches spaced at regular intervals along the pipeline route would have to be imported at a significant cost. Therefore Borouge suggested to SECMC and Hi-Tech that they consider the use of electrofusion branch saddles which can be joined to the side of the pipe using an electrofusion system. After jointing, a hollow core drill is used to make the opening for the branch in the side of the pipe. Such systems generally have a water pressure limitation of 10 bar.

After reviewing options, Hi-Tech adopted the Georg Fischer ELGEF Plus top loading branch saddles system and over 100 pieces of 315mm OD branches were installed on the SDR17 and SDR21 pipeline sections as shown in Figure 6. The electrofusion branch saddles were installed on site following the laying of the 1200mm OD pipeline. Whilst this was a time consuming process that had to be carried out by trained personnel, it facilitated the rapid laying of the pipeline and had the added advantage that the location of the washout or air valve could be adjusted if the pipeline was not laid as per the design profile.

At the time of writing, the SDR 13.6, 17 and 21 sections of the pipeline have been installed on site. Despite using an extra low sag PE100 Hi-Tech have been unable to consistently produce the 1200mm SDR11 pipes with an acceptable wall thickness. Because of this, the project designers only kept only 3km out of the original 14km pipeline as PN16 SDR11 while the rest was changed to PN12.5.

Current status of the project and lessons learnt

After the completion of the project, Borouge, together with the other stakeholders, held a workshop in Karachi to identify the main lessons learnt in the project:

- When designing a PE100 transmission pipeline, make full use of the different SDRs to minimise the amount of material used in pipe production and hence the pipe cost.
- Make sure that the designer does not mix ISO and ASTM standards as this can lead to confusion during the design process and drafting of the technical specification.
- When laying through sand dunes and other very undulating terrain make maximum use of the flexibility of PE100 pipelines to “smooth out” the profile.
- When producing low SDR (high wall thickness) pipes, converters must be willing to invest in a die head specifically designed for that purpose. Going for a low cost alternative can lead to inefficient pipe production and large scale waste of material.
- The project involved the first large scale use of electrofusion branch saddles in Pakistan and these appear to have been a great success, significantly reducing costs and allowing the installation of branches after the pipes have been laid.

The UTICO pipeline from Ras Al Khaimah to Sharjah in the UAE

UTICO are the largest private water and power utility in the UAE and are involved in the operation of power generation, desalination and wastewater treatment plants along with water transmission and distribution networks having a total length of over 400km. In 2016 UTICO entered in to a landmark ‘demand only’ contract with SEWA, the Sharjah Water and Electricity Authority. All previous similar water supply projects had been undertaken on a ‘take or pay’ agreement. The project will eventually supply SEWA together with the Emirates of Umm Al Quwain and Ajman with up to 45 MIGD (Million Imperial Gallons/Day) of potable water, which equates to 205.6 MLD.

The first phase of the project involved water being produced at UTICO’s reverse osmosis plant in Ras Al Khaimah and delivered to the SEWA network and other Emirates through a 50km long pipeline. Nearly 90% of the 50km route comprises a 1200mm OD SDR17 PE100 pipeline with four branches to supply consumers along the route, whilst the first 5.7km from the reverse osmosis plant is a 1400mm OD SDR13.6 pipeline. The higher pressure rating was selected for the first section as it includes the majority of the static lift (rise in level) along the route. The total weight of PE100 material for the first phase was 13,500MT.

Figure 6. Electrofusion branch tees being installed for a washout and an air valve.

The 1200mm OD pipeline being produced at the UTICO manufacturing facility.

Installation of the pipeline.

The 1200mm OD pipes and fittings were produced by the Cosmoplast Industrial Co. of Sharjah, whilst the 1400mm OD elements came from Union Pipes Industry of Abu Dhabi. Regarding the selection of PE100 for a large diameter transmission pipeline, the UTICO design team explained that as a private utility, they were very aware of the cost of water produced at and pumped from their desalination plant and hence the impact of this water being lost through leakage. Having previously used PE100 for both their onsite pipework and offsite pipelines, UTICO were able to take in to account the cost of leakage, maintenance and lower pumping costs during the life of the pipeline and determined that, as operational pressures would not exceed 10 bar, PE100 was the preferred material.

Current status of the project and lessons learnt

The last sections of the 1400mm pipeline and the connections to the SEWA network are under implementation and the first phase of the USD57 million pipeline were operational by September 2018. It is the largest trans-emirate pipeline in the UAE and the largest PE100 pipeline in the Middle East. A plan of the project first phase is shown in Figure 8. UTICO are designing the 2nd phase of the project so that it can meet its full potential. This will comprise an intermediate pumping station and 2nd RO plant together with laying an additional 8.3km of 1400mm OD pipeline and a to-be-confirmed length of 1600mm OD. In addition to some of the points raised in the SECMC project, UTICO highlighted the following lessons that they had learnt from implementing the project:

- The ability to weld together long lengths of pipeline beside the trench allows jointing to take place during trench excavation, saving time and allows the trench width and preparation to be minimised. Proper pipe rollers and supports should be used.
- Being able to avoid the use of thrust blocks due to the pipe being continuously welded is a major time and cost saving with large diameter pipelines.
- Problems were encountered with locally produced fabricated (segmented) fittings that failed during a pressure test. Consider using machined fittings and ensure that the manufacture and derating of fabricated fittings is in accordance with ISO4427.
- The importance of trained and certified staff in the correct jointing of PE pipes and fittings is essential, as is the protection of the welding process in a dusty desert environment. Both points should be highlighted in the technical specification.
- Pressure testing is relatively simple for a large diameter pipeline as large supports and or concrete anchors are not required to support test flanges at pipe ends.

Conclusion

This paper has demonstrated how developments in material and pipe extrusion technology, along with developments in standards, specifications and structural analysis have driven the use of PE100 pipe systems in ever larger applications. Whilst some people within the plastics pipe industry are familiar with the use of large diameter PE100 pipes for industrial applications, this paper has demonstrated that the use of PE100 for large diameter water transmission applications can be justified when the whole life cost (construction and operation) of such a pipeline is taken into account. The lessons learnt section of the paper has shown that undertaking such projects, which require thousands of tonnes of material, is not without its challenges, but that the use of intelligent design and high quality extrusion lines can minimise material costs. Equally important is the establishment of good jointing and installation practices on site, along with being willing to adopt new ideas such as electrofusion branch fittings. The authors hope that this paper will encourage others to consider PE100 pipe systems for similar projects.

Figure 8. Map of the UTICO Ras Al Khaimah to Sharjah 1200 and 1400mm OD Water Pipeline.

Borouge celebrates 20 years of successful operations in India

by Chanchal Dasgupta

The Borouge India 20th Anniversary celebration at the Taj Santacruz Hotel, Mumbai.

The team in the Borouge Mumbai office recently marked 20 years of successful operation in the Indian plastics market with a celebratory event at the Taj Santacruz Hotel.

Over this period, the country's economy has thrived and the population has grown rapidly. Investments in major industrial, commercial and infrastructure projects have created demand for substantial quantities of pipes. At this time for reflection, Borouge's Infrastructure Marketing Manager, Chanchal Dasgupta, looked back at some highlights in the development of the PE100 pipes market in India and presents some valuable insights into the success of the business.

Early years of HDPE pipe market development

HDPE pipes were first introduced into India in the late 1960's and whilst many of the early projects using these materials were undoubtedly carried out to a good standard, as the market expanded and there was shortage of domestic production, some unscrupulous pipe manufacturers started mixing in poor quality materials. The resulting inclusions introduced into the pipe walls initiated brittle crack failures in many projects which resulted in some states banning the use of HDPE pipes in their infrastructure projects during early 80's. While starting their operations in 2001, it required Borouge to work with few high quality pipe producers to explain the importance of high quality compounded PE piping materials to ensure a long maintenance free service life to convince engineers and utility owners. Borouge also had to work towards aligning Indian PE pipe standard to international specifications which is still on.

One of the earliest large diameter PE100 pipe projects in India where Borouge participated was a large sewerage system for the Gujarat Industrial Development Corporation in Ahmedabad. In total 10km of 1000mm diameter pipe and 30km of 710mm PE100 pipe was produced for the scheme. Pioneer Polyfab produced the 1000mm diameter pipe, a first for India, using BorSafe™ HE3490-LS PE100 material. As well as meeting the highest performance standards, this "low sag" material significantly helped the manufacturing process of large diameter pipe by reducing the tendency for the material to flow to the bottom of the pipe during extrusion.

PE100 pipes providing a safe and secure water supply

Access to clean water for domestic, agricultural and industrial purposes is essential for continuous development particularly in a country where large areas are prone to prolonged periods of drought whilst others regularly suffer severe flooding following the monsoon rains. Unfortunately, many of the main waterways have become highly polluted and require significant further investment in domestic and industrial wastewater systems and water treatment plants. Also, many of the water networks within India's towns and cities are old and leaking and there is a great need for renovation and replacement to reduce the loss of treated water. These are all applications where PE100 pipe systems have provided successful solutions around the world.

In 2003 PE100 pipes were used in a water distribution network in the coastal state of Karnataka in the south west of India. This was part of large Asian Development Bank funded project and the international project consultants, Dalal Mott-MacDonald & CES specified that PE100 should be used for all water distribution pipes up to 355mm in diameter as they were well aware of the practical benefits which included corrosion resistance, flexibility and a smooth bore which would reduce pumping costs.

Installation of a 1000mm diameter PE pipeline for the GIDC project in Ahmedabad.

Pipeline installation in progress at Mangalore, Karnataka.

The flexibility of the material certainly provided benefits in the lanes of Mangalore, where narrow trenches could be dug and the welded strings of pipe lowered into the trench. Another part of the project was twin 350mm diameter PE100 pipelines to cross the Netravati River, where welded PE100 was the only practical solution. In total some 1400km of pipe was required for the project which was manufactured by Manikya Plastichem from Mysore, using BorSafe™ HE3490-LS.

The Kerala Water Authority were also faced with long underwater sections within the Cherathala raw water supply pipeline. Again PE100 pipes were selected for the project for their excellent corrosion resistance and ease of installation and a total of 9km of 900mm diameter PE100 pipes were purchased from Union Pipes in Abu Dhabi for the project. The pipes were butt welded into long strings floated into position and then sunk into a pre-dug trench in the bed of Muvattupuzha river and Vemanad lake.

In recent years many large urban projects have been initiated to renovate or replace old leaking water distribution systems. One of the largest was in Nagpur where Veolia Water India were awarded the water supply and maintenance contract by the city for 25 years. To accomplish this Veolia set up a separate company, Orange City Water (OCW), in a joint venture with Vishvaraj Environment Ltd., one of India's leading civil engineering and services companies. The technical challenge was considerable, as it involved connecting around

One of the many Borouge training workshops for Veolia engineers in Nagpur in progress.

450,000 homes to the distribution network whilst reducing leakage from 60% to international standards. OCW invested USD22 million in the project to renovate the city's six water production plants and repair and extend the 2,500km of pipe network.

In the project, Veolia wished to use the latest installation practices but in the past they had experienced problems of PE pipe failures during horizontal drilling operations. To overcome these problems, Borouge set up a training programme for their engineers to ensure that good quality pipes and fittings were selected and the optimum welding and installation procedures were used. Following their experience on this project Veolia specified Borouge PE100 materials in their contracts in Gulbarga, Hubli-Dharwad, Ilkal, Puthur in the state of Karnataka and in the Nangloi project in Delhi.

One of the largest urban water distribution project in India has been the Telangana State Water Grid set up by the Telangana state government to provide clean and safe drinking water to every household in India's newest state. This project comprised of 5,000km of water trunk mains plus a 50,000km secondary network and a further 75,000km of pipes to deliver drinking water to individual households. Hyderabad based Megha Engineering & Infrastructures Limited (MEIL) was appointed as the main contractor and operator for the project for a ten year period. Work commenced in November 2015 with construction of the 1,200km Gajwel water grid completed in under 10 months.

Over the past twenty years, Borouge has worked with many different customers to supply charitable organisations with PE100 pipe and fittings for water supply systems to poor communities in India. One of the earliest was in 2006 when the Sri Sathya Sai Central Trust developed a scheme to supply drinking water to nearly 800,000 people in 450 villages in the East and West Godavari districts of Andhra Pradesh. The project was carried out over a 16 month period and comprised a total of 765km of BorSafe™ HE3490-LS PE100 pipes.

In 2007 Borouge and Borealis formalised their CSR programme under the name “Water for the World” (www.waterfortheworld.net) and since then they have supported many water supply projects around the world. Some of the main beneficiaries in India have been Malkapur, the Jadan Ashram in Rajasthan, three rural water supply and sanitation projects for schools and villagers in Hatticore, Bhaktapur and Panchkhal region of Nepal and water supply for slum areas in Nagpur and Bangalore.

Of these, the Malkapur project in 2009 warrants a special mention as it was India’s first rural 24x7 water supply scheme and won a Prime Minister’s award for Excellence in Public Service and was featured on CNBC’s “Beyond Business”. Prior to the project the 30,000 inhabitants of Malkapur only received water for a few hours a day through a 20-year old pipeline, which lost up to 35% of the water supplied. The new system was designed to supply a projected population of 67,000 with a continuous water supply with a water loss of less than 5%. Each of the 3,000 homes in the village would have an individual metered supply. The PE100 raw material was provided by Borouge and the pipe and electrofusion fittings manufactured by Kimplas and EPC Industries.

Pipeline installation for the Water for the World project in Malkapur.

PE100 pipes supporting India’s agricultural industry

Although agriculture is a smaller proportion of the economy it remains an important sector and the major employer in India. Increasing production becomes more difficult as the climate becomes more erratic and efficient irrigation schemes become increasingly important.

An example was the Narmada Valley Development Authority (NVDA) irrigation project at Punasa in the Khandwa district of Madhya Pradesh in central India. The scheme was designed to transport water from the Indira Sagar reservoir at Punasa on the Narmada River to provide irrigation for 110 farming communities spread over an area of over 300km^2.

The project was undertaken by IVRCL of Hyderabad who used 750km of 225 to 280mm diameter PE100 pipes to transport water to the communities. One of the main benefits offered by the welded PE100 pipe system was the higher speed of installation possible using mechanical narrow trenching equipment which minimised disruption to the farmers and greatly reduced installation costs. The project was completed well within the scheduled targets and the Narmada Valley Development Authority were so impressed that they have specified PE100 pipes in subsequent irrigation projects.

Installation of PE100 pipes by narrow trenching in the Punasa Project.

Tea is one of the most important crops to the Indian economy and the picturesque tea plantations are visited by many tourists. However, as weather conditions become more erratic, plantation owners installed semi-permanent sprinkler irrigation systems. In the past these pipe systems were manufactured from aluminium but more recently the benefits of polyethylene systems have been recognised.

An example was the Zurrantee tea estate in the Dooars foothills close to Darjeeling in which a new irrigation system was installed covering 159 hectares of the estate. The system was designed by leading consultant Mr RN Chatterjee and produced by Hallmark Aquaequipments Pvt. from Borouge PE100 materials. The water was drawn from the nearby Neora River and carried through a network of mains, sub-main and lateral lines to the sprinkler heads which irrigate the tea crop. The 200mm diameter main was installed through very tough terrain and would be subjected to water hammer due to the changes in elevation. Dual feeder pipes were then installed above ground, one above the other using specially designed mechanical supporting clamps fixed into the steeply sloping terrain. The portable sub-mains and laterals of 160 and 110mm diameter PE100 pipes 6 metres in length were fitted with quick release couplings to connect to each other or to one of the many other components in the system.

Using this system on a rotational basis to cover each part of the 159 hectares every 17 days during the dry periods increased the yield significantly compared to previous years. In addition, they were able to obtain two additional pickings, which considerably increased income as leaf produced during the normally lean periods fetches higher prices. Using the higher performance of PE100 pipes enabled the designer to minimise the cost of the system whilst meeting all the pressure and flow requirements of the system and reducing pumping costs.

PE100 pipes supporting India's industrial development

With industrial development, many new large diameter pipelines were required to transport water or chemicals or dispose of wastewater. The high corrosion resistance and ease of installation make PE100 pipes ideal for these applications and Borouge has worked with a number of pipe manufacturers to provide high quality pipes for many industrial projects.

In 2010, Tamil Nadu's first desalination plant, was commissioned at Minjur, 35km north of the state capital, Chennai. The plant draws water from the Bay of Bengal and using reverse osmosis technology supplies 100 million litres of purified water each day. The design team selected PE100 pipes for the large diameter intake and outfall pipes as they would be able to transport the saline rich solutions without any risk of corrosion.

In total over 1.6km of 1600mm diameter SDR 28 PE100 pipes were required to construct the intake and outlet pipes for the Chennai plant, which were produced by Pipelife in Norway from BorSafe™ HE3490-LS PE100 material and transported to Chennai by towing them across the sea. The pipelines were assembled into 750 metre strings some distance from the plant in the protected harbour at Ennore Port. During bad weather the pipe strings were further protected by sinking the assemblies to the seabed. The pipelines were then re-floated and then towed to the installation site where they were fitted with 7 tonne concrete anchor blocks at 4 metre intervals to hold the pipeline in position at the bottom of the ocean.

PE100 Sprinkler system in Zurrantee Tea plantation in North Bengal.

Sinking of 1600mm HDPE intake and outfall line for Minjur Desalination plant in Tamil Nadu state.

Installation of PE100 pipes for mini Hydel Power Plants in the mountains of Himachal Pradesh.

PE100 pipes were also used in mini Hydel Power Plants in the mountainous state of Himachal Pradesh in northern India. The melting snow forms many rivers which can be used to create electrical power. These relatively small-scale plants bring water continuously down the mountain to a header tank before it passes through a turbine. In the past water was conveyed through concrete channels or concrete or steel pipes but on several recent installation projects, PE100 pipes have been used. One of the major disadvantages of open concrete channels is that they quickly get filled up with rocks and boulders, which reduces the flow of water to the generator. Construction is also difficult at these high altitudes and concrete or steel pipes are heavy and difficult to manoeuvre in these areas and many prefabricated bends are required to follow the tortuous path down the mountain. However, PE100 pipes are light and easy to handle and being flexible can follow the contours of the slope.

Jain Irrigation Systems were awarded the pipe supply contract for the Marhi hydroelectric scheme which was installed almost 4,000m above sea level near the town of Manali. This project required 942m of 710mm diameter PE100 pipe to carry the water from the intake to the feeder tank above the turbines. The design was so successful it was also used in the Himurja hydroelectric scheme near the town of Keylong and the Pangi Valley project in the district of Chamba.

Recently the City and Industrial Development Corporation (CIDCO) of Maharashtra commissioned the construction of a large Exhibition and Business Centre in the city of Navi Mumbai. A prestigious building of this type needs a large capacity air conditioning system. In the past, the air conditioning chambers would be constructed in concrete set into the concrete floor of the building with vertical metal risers to deliver the cool air into the building. However, in this project the architect decided to use 1200mm diameter buried PE100 pipes for the main ducts and smaller diameter PE100 pipes as the vertical risers.

This was the first time that PE pipes have been used in such a large air conditioning system in India and some important advantages were apparent compared to concrete. As concrete is porous some of the cool air is lost, whereas PE systems are non-porous thereby reducing energy costs. Energy losses due to heat transfer were also reduced by 50% and the problem of rising moisture from the soil was also eliminated. Finally, the PE system was much easier and quicker to install, one major saving was that the concrete floor could be cast immediately after the PE pipe had been installed and tested.

India has large reserves of coal seam gas which can be used to replace coal or oil for industrial and domestic fuel. To efficiently gather the gas and water from each well and transport it to the main collection points requires the use of many kilometres of PE pipe. Reliance Industries are developing their Sohagpur field in central India where they plan to drill 229 wells and install two gas gathering stations. The first tenders for PE pipes, were based on ASTM rather than ISO specifications and Borouge worked with customers to develop the qualifying technical documentation demonstrating the compliance of pipes produced from BorSafe™ HE3490-LS PE100 compound to the ASTM specifications. Two customers, namely Sangir Plastics and Kriti Industries won the tender for approximately 65km of pipe ranging from 18 inches to 22 inches in diameter.

Future prospects for PE100 pipes in India

Over the last 20 years Borouge has worked with pipe and fitting producers, EPC contractors, standards bodies and end users in India to demonstrate the advantages of using PE100 compared to alternative piping materials. Many workshops have been conducted to create awareness of the best practices in PE100 pipes in providing high quality infrastructure. Through regular interaction with the Bureau of Indian Standards, Borouge continues to contribute to the formulation of new standards as well as updating and upgrading of existing quality standards for PE pipes.

The industry is also becoming aware of the benefits of High Stress Crack Resistant PE100 for HDD and pipeline rehabilitation. Borouge continues to demonstrate the qualitative benefits of using pipes made from pre-compounded PE100 black resin over those made from natural polymer and carbon black masterbatch by publishing papers and sharing the latest testing information to the local pipe industry. From this strong knowledge base and supported by the many practical examples of successful projects, the future market for high quality PE100 pipes will continue to benefit from the high rate of growth in India.

PE100 pipes installed for Central Air Conditioning system in CIDCO Exhibition Building at Vashi.

Latest draft of the Chinese national standard for PE water piping specifies only ready-made PE compounds

by Jinghui Li

The Chinese national standard committee SAC/TC48/SC3 has updated national standard GB/T13663 to require the utility water segment to use only ready-made PE compounds to manufacture PE pipes for drinking water applications. This is the first time that only ready-made black PE compounds are allowed to be used and marks a significant change from the widely accepted local practice of mixing natural PE resin with carbon black masterbatch. The new draft also incorporates new test methods to identify recycled PE in the finished pipe and is set as a parameter that must be checked during the quality control step.

This significant milestone was reached after more than a decade when early proponents for the use of black precompounded resin like Borouge together with our key partner customers and the PE100+ Association first promoted the benefits of using PE compounds to members of the local standards committee. This brings the Chinese national PE water piping standards closer in line to that of the internationally recognised and widely referenced ISO4427 standard and raises the quality level of PE pipes used for water distribution in the country.

To gather wider industry feedback as well as convey the details put forth in the upcoming draft national standard GB/T13663:2018 to all industry players, the China Water Standard Committee recently invited more than 300 participants consisting of experts in the standard setting bodies, resin suppliers, pipe converters, water utility companies, testing service providers and equipment manufacturers to their meeting in Wuhan from 31 March to 2 April. The gathering also serves as a platform for the participants to share information on latest industry developments. Representatives from the PE100+ Association were also invited by the organiser to introduce the benefits of ready-made black PE compound over natural PE and carbon black masterbatch mixing.

In the same meeting, Borouge gave a keynote speech detailing the difference between ready-made PE compounds versus the commonly preferred 'salt+pepper' approach of mixing natural PE with black masterbatch. Particular focus was given to the latest research findings based on the study performed by researchers at the Borouge Abu Dhabi Innovation Center[1]. The details of this study is shared in greater detail in a related article in this current edition of BorPipe. The availability of such information has resulted in a growing awareness by many authorities and standardisation authorities on the benefits and quality implications of using ready-made compounds in the manufacture of PE pipes.

Reference:

1 Effect of carbon black distribution on polyethylene pipes; S. Deveci, N. Preschilla, B. Eryigit; Proceedings of the 19th Plastic Pipe Conference PPXIX September 24-26, 2018.

Air Selangor expands the use of PE100 in its pipeline renovation program

by KH Lou

The water supply for the Malaysian state of Selangor is supplied by Pengurusan Air Selangor Sdn. Bhd. (previously known as SYABAS). In 2017, it provided water services to over 2,223,928 accounts[1] or about 11 million[1] people in Selangor, Putrajaya and the city of Kuala Lumpur. Based on latest available data, in 2017, 34 hotspots – areas with highest frequency of pipe bursts – were identified for pipe replacement. The total cost of pipe replacement was RM161.2 million (USD39.4 million).

The total length of pipes in Selangor, Putrajaya and Kuala Lumpur is 28,447 kilometres. Although instances of pipe burst increased in 2017, the number of pipe leaks dropped in 2017 compared to 2016 as shown in Figures 1 & 2.

The increased instances of burst pipes was mainly attributed to ageing pipes. Non-revenue water (NRW) as shown in Figure 3 has come down but remains elevated. In 2016 the high level of water loss encouraged Air Selangor to start an aggressive pipe replacement programme.

In Selangor, 22.6% of the pipes by length[2] consists of ageing asbestos cement and many instances of burst pipes can be directly attributed to this fact alone. Almost half[2] (49.1%) of the pipes are mild steel while plastic pipes, PVC & PE, make up 13.4% & 6.8% respectively. There is therefore a lot more opportunity for PE100 to contribute to the pipeline network upgrade and expansion program.

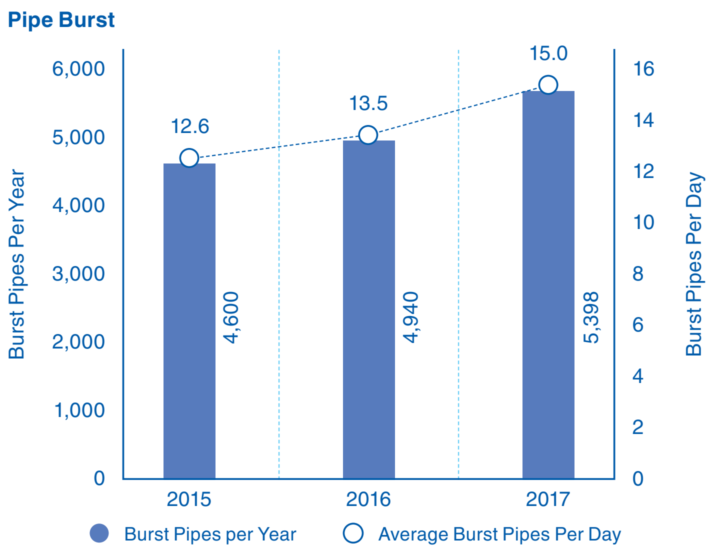

Figure 1. Instances of burst pipes.

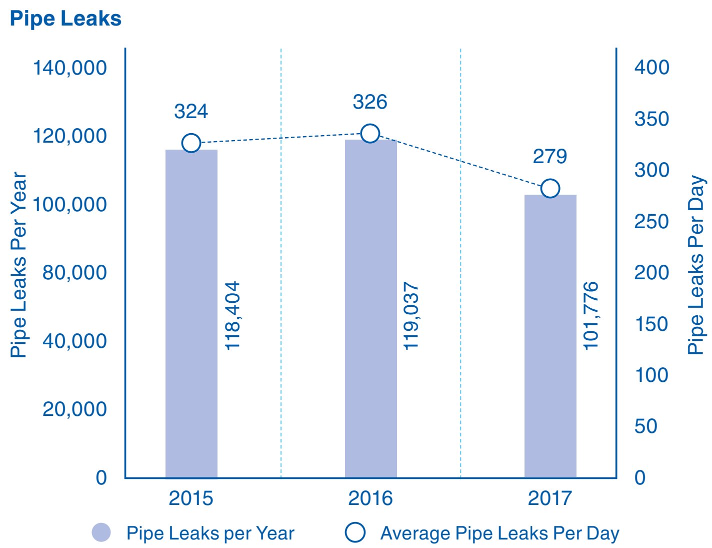

Figure 2. Instances of pipe leaks.

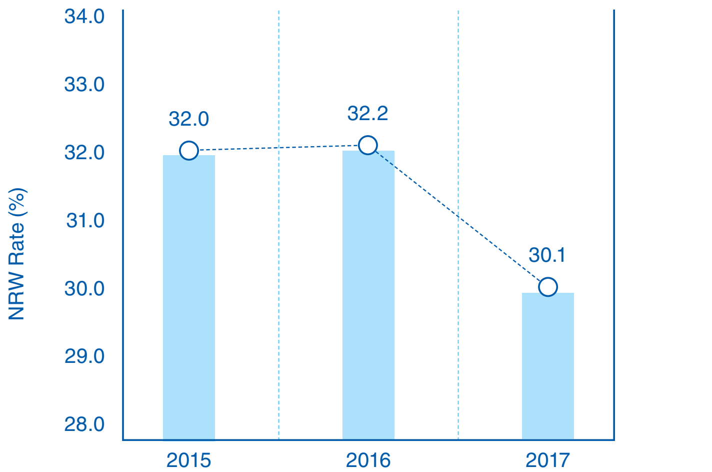

Figure 3. Non-revenue water.

PE100 produced for the Air Selangor pipeline replacement program by Cew Sin.

A continuation of the pipe replacement program was undertaken in 2018 when Air Selangor awarded a new contract in mid-2018 for the supply of PE100 pipes in the Banting, Port Klang and Kuala Selangor areas of the state. These areas all lie along the coast where PE100 is well suited due to its corrosion resistance and high tolerance of ground movement. PE100 being a fully welded system will also help in reducing the leakage rates that can contribute to further lowering the NRW percentage in the state. The contract is being supplied by Cew Sin Plastic Pipe Sdn. Bhd with the help of BorSafe™ HE3490-LS. The total contract called for the supply for up to 3000MT of PN16 PE100 pipes from 32-450mm in diameter. The total pipeline covers a length of 757.5km and is expected to be completed by 2021.

Year	Length
2015	No projects awarded
2016	144.50km (23 hotspots)
2017	178.55km (34 hotspots)

Pipe replacement programs undertaken by Air Selangor.

Sources:

1 Air Selangor website, annual report 2017

2 Malaysia Water Industry Guide 2016

TECHNICAL INSIGHTS

Challenges in welding large diameter PE100 pipes

Left and right. Welding the 2000mm diameter PE100 pipeline with the Worldpoly2500 in Gaziantep, Turkey. (Courtesy of Worldpoly)

Overview

In this issue's Technical Insights column, Rob Hall, CEO of Worldpoly answers some of your key questions about the jointing for large diameter PE100 pipes. Worldpoly is an Australian-owned and based company that develops and produces international standard PE pipe welding fusion equipment from 40-3600mm that is exported to 120 countries. The company has been in operation for almost 60 years and is actively involved in growth of the international HDPE pipe industry.

Background

Solid wall PE100 pipes are fast gaining acceptance around the world as a competitive piping material in diameters above 1200mm[1,2,3]. The key PE100 characteristics such as flexibility, corrosion resistance and the ability to be fused into a long and continuous pipe string that is end load resistant is increasingly gaining acceptance with designers and project owners who previously preferred steel or glass fibre reinforced pipe (GRP) especially for pipe diameters above 1000mm. The primary consideration favouring steel or GRP over PE100 was that they were available at much more competitive cost especially in larger diameters but consideration of the lower transport and installation costs often reverse this view. Recently, Worldpoly supplied its Worldpoly2500 butt fusion machine for Turkey's largest and most advanced wastewater treatment plant project in Gaziantep, southern Turkey. The project required welding of PE100 pipes up to 2000mm in diameter.

What are the main differences when it comes to welding pipes above 1600mm diameter compared to welding smaller pipes?

Experience handling large diameter pipe is a given. However, when welding larger diameter HDPE and PP pipes, it is equally important to strictly follow all parameters of the specified welding procedure to the letter.

How has the design and functionalities of butt welding machines evolved to cater for increasing pipe sizes?

Engineering design is a significant factor. As the size of the equipment increases, you cannot simply guess what the machine will need to be capable of both producing and withstanding. Another factor is the requirement to stay within the temperature, time and pressure requirements when dealing with such large pipe and equipment. At such large pipe sizes, dealing with these factors become much more complicated than when working with smaller pipe sizes. The implementation of CNC control and data logging now allows excellent quality control, and hydraulic open/close/locking main clamps allow more correct welds to be performed each day. Without these features, welds can be inconsistent and painfully slow.

(Courtesy of Worldpoly)

Are there any special precautions required when jointing large PE100 pipes?
Large diameter thick walled pipes are not light. These often huge weights place a significant amount of strain on machine alignment, and potentially increasing drag to an unreasonable proportion of the welding pressure. Pipe rollers and strings of the correct length will solve this problem, but don't be tempted to push the far end with a loader bucket!

Were there any specific challenges that was encountered when the contractor was welding the large pipes for the recent project in Gaziantep?
The relatively remote location of the worksite in Gaziantep itself didn't bring us many challenges, as Worldpoly is used to assisting our clients in much more remote locations. The client required welds be produced according to ISO standards, with the equipment being able to withstand rough handling and potential vagaries of power supply that the site would deliver. Trained local operators would operate the machine, so of course, quality control was of the utmost importance. All of these factors posed minimal issues for the team at Worldpoly, as our existing equipment adheres to these requests. One point, however, did offer up a challenge for our engineering team. The client required the machine's physical dimensions to be as small as possible so the freight considerations to the site could be kept at a reasonable cost.

How was the challenge above solved?
With over 60 years in the PE pipe industry, we've come up against many odd and often challenging requests when it comes to one-off or new machine builds. But with this amount of experience comes a significant amount of knowledge, and our engineering team can just about complete these sorts of requests in their sleep now. This request was handled with gusto by Worldpoly, and was a great reminder to me about why our engineering team is so successful in delivering on client's requests. The welds performed in Gaziantep were as good, if not better, than those done in cities around the world including Dubai, Houston or Melbourne.

What recommendations do you have for contractors or project owners who are looking to weld large diameter PE100 projects? What should they look out for in order to ensure the smooth completion of their projects?
The correct handling of pipe and fittings is not difficult and must be adhered to. I'm sure it could be tempting to cut corners to save time on site on jobs like this, but it's integral the operators and management respect the requirements and standards in place – they're there for a reason. As with any HDPE pipe project, it is necessary to have pipe and fittings manufactured and certified to the correct specification, welding equipment designed to weld that pipe on-location, and correctly trained and experienced operators. In short, don't take shortcuts.

Sources:

1 Taking PE pipe to new heights…and new diameters!; N. Jansen, A. Lueghamer; PPXIX Conference 2018

2 PE100 large diameter water transmission pipelines take off in Asia; A. Wedgner, M. Qasim, A. Sembrano; PPXIX Conference 2018

3 Performance of large marine HDPE pipes during the submersion as based on laboratory testing; I. Radeljic, I. Bjorklund; PPXIX Conference 2018

The effect of carbon black distribution on polyethylene pipes

by Suleyman Deveci, Nisha Preschilla, Birkan Eryigit

This article is extracted from the paper of the same name presented at the PPXIX 2018 Conference.

Introduction

Carbon black (CB) remains the most economical solution to prevent photo degradation of polyethylene due to UV light exposure. The efficiency of CB with respect to preventing the photo degradation of polyethylene in sunlight depends on the CB type, particle size, concentration and dispersion [1–3]. Insufficient dispersion and distribution of CB in polyethylene pipes are likely to occur if CB and natural polyethylene material are insufficiently mixed. This results in areas with lower CB contents appearing as light and dark swirls in microscopic images; these are commonly known as 'windows'. These windows are mostly a result of poor mixing of CB and natural polyethylene material in a single screw pipe extrusion line without a proper screw design and necessary mixing elements [4].

To prevent this mixing problem, the use of black pre-compounded polyethylene material for plastic pipe production is required by ISO 4427-1 [5]. It was reported that these black and white swirl patterns change direction at the butt fusion interface and camouflage lack of fusion, if present, in this region during non-destructive testing of polyethylene joints [6]. Recently, some brittle failures were observed in polyethylene pipe joints between pipes with insufficient CB distribution [7]. The role of CB dispersion in the initiation and propagation of cracks in polyethylene remains unknown [8]. In this article, we aim to show how the CB distribution affects the mechanical properties of polyethylene pipes by preparing plastic pipes with controlled CB distributions, containing low, medium and high levels of windows, and performing tensile tests on the pipes and analysing the fracture surfaces of these samples by stereo and scanning electron microscopy (SEM).

Materials and methods

High density polyethylene powder was collected from a polymerisation reactor. This was compounded with antioxidants and CB masterbatch (CBMB) containing 40% CB and 60% carrier resin to produce a black pre-compounded (ready-made) material using a counter-rotating continuous mixer. The same powder was also compounded with antioxidants but without CBMB to produce a stabilised, non-pigmented polyethylene compound (NPC). Pipes with an outer diameter of 110mm and a wall thickness of 22mm were produced. The black pre-compound (or ready-made compound) was used to produce reference pipes with no windows (Sample 1). A dry mixture of NPC and CBMB was prepared with a tumbler mixer. The mixture was then used to produce pipes with different CB distributions (Samples 2, 3 and 4) by changing the extruder output and keeping all other parameters constant. Descriptions of the pipe samples are given in Tables 1. The temperature profile of the barrel was kept constant, while the screw speed was changed to obtain different residence times and thus different levels of CB distribution.

Sample	Sample Description	Material	Note
Sample 1	Reference Sample HE3490LS	Pre-compounded	Extrusion speed: 115kg/h, 100%
Sample 2	High level of Windows	NPC + CBMB mixture	Extrusion speed: 115kg/h, 100%
Sample 3	Medium level of Windows	NPC + CBMB mixture	Extrusion speed: 95kg/h, 80%
Sample 4	Low level of Windows	NPC + CBMB mixture	Extrusion speed: 70kg/h, 60%

Description of samples.

Materials	CB Content	MFR5	MFR21	FRR 21/5	Density
	wt%	(g/10 min)	(g/10 min)		(g/cm³)
Pre-compound	2.11	0.27	8.76	32.4	0.96
NPC	Not measured	0.27	8.77	32.5	0.95
Sample 1	2.11	0.25	8.07	32.3	0.9603
Sample 2	2.26	0.27	8.09	30.0	0.9607
Sample 3	2.40	0.26	7.99	30.7	0.9606
Sample 4	2.37	0.28	8.26	29.5	0.9609

CB content, MFR and density of materials and pipe samples.

Results

The CB content, MFR and density of each sample are given in Table 2. All pipes showed very similar values. However, the CB content differed slightly for Samples 2 to 4 due to the dry mixing process.

CB dispersion and distribution

The CB dispersion and distribution in samples prepared from cross-flow directions are given in Figure 1. The CB dispersion in all four samples was found to be good; that is, no CB agglomerates of size >30μm were seen in any of the samples. However, the distributive mixing was seen to be very different. Sample 1 showed no windows that did not contain CB, although it exhibited a few spots that did not contain CB. According to ISO 18553 [11], the visual rating of the appearance of Sample 1 was A1/A2, which is well within the acceptable range. Sample 2 showed the worst level of distributive mixing among the four samples. A high level of windows was seen in this sample. The width of the most prominent windows was in the range 200–300μm. According to ISO 18553, the visual rating of its appearance was between C1 and C2. Sample 3 also showed a high level of windows; however, the concentration of windows per unit area was slightly lower, and the windows were thinner compared to Sample 2. The width of the most prominent windows was in the range 80–140μm. The visual rating of its appearance was closest to C1. Sample 4 showed fewer windows than Samples 2 and 3. The width of the most prominent windows was in the range 50–100μm. The visual rating of its appearance was between B and C1.

Tensile tests on pipe samples

An overlay of engineering stress–strain curves at 25mm/min (strain rate of $13s^{-1}$) for representative specimens selected from each sample is given in Figure 2. Samples 1, 3 and 4 showed the standard behaviour of a tensile curve for a high-density polyethylene material: (a) elastic region (linear increase in stress with strain), (b) a yield point (the first maximum stress in the stress–strain curve), (c) strain softening (an immediate decrease in stress), (d) natural drawing (constant stress versus strain), (e) strain hardening (linear increase in stress by increase in strain) and finally (f) breaking of the specimen. Yield and post-yield properties of all samples are given in Table 3. The yield properties of the samples appear to be similar. Considering the physical properties of the samples given in Table 3, this is expected as the yield properties of polyethylene materials are exclusively related to the density of the material [12]. On the other hand, the post-yield properties of the samples showed significant differences.

a)
b)
c)
d)

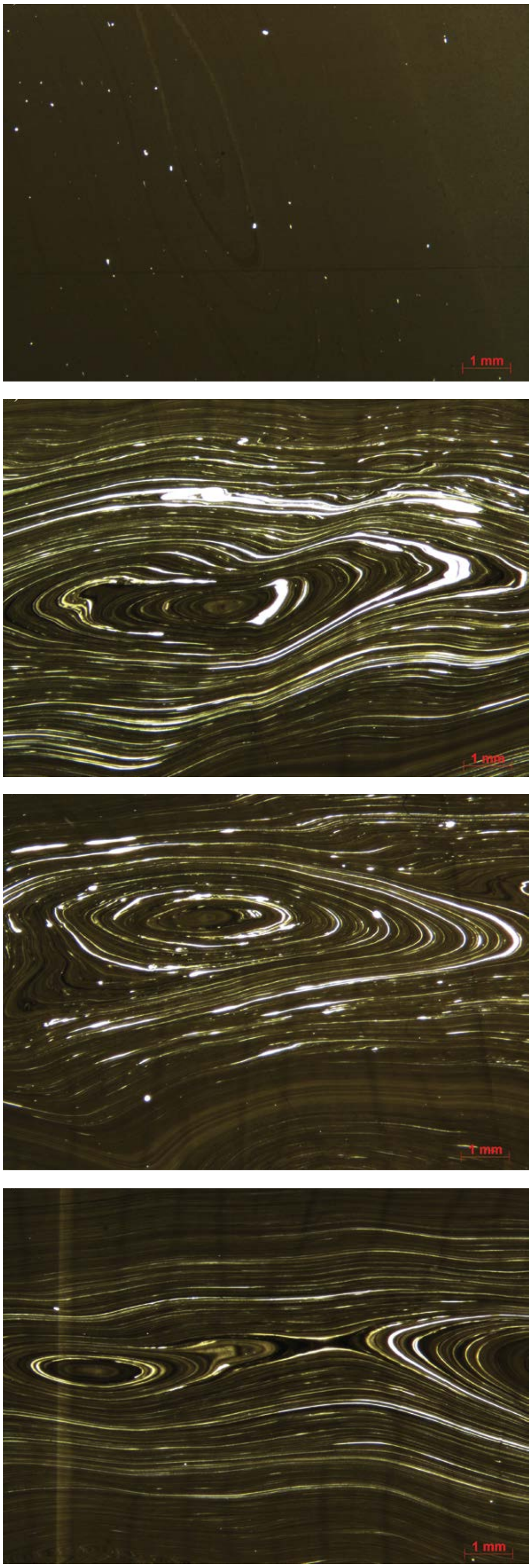

Figure 1. Microscopy images of 15μm slices (cross-flow) taken from pipe specimens: (a) Sample 1, (b) Sample 2, (c) Sample 3 and (d) Sample 4.

Samples		Yield Stress	Yield Strain	Stress at Break	Nominal Strain at Break
		MPa	%	MPa	%
S1	Average	25.2	10	30.1	800
	Std. Dev	0.1	0.1	0.3	70
S2	Average	25	10	15.6	270
	Std. Dev	0.5	0.1	2.5	160
S3	Average	24.9	10	19.8	430
	Std. Dev	0.3	0.1	4.2	130
S4	Average	24.9	10	25.7	670
	Std. Dev	0.3	0.1	6.3	220

Table 3. Tensile test (25mm/min) on pipe samples.

Observations during the tensile experiments showed that necking in Sample 1 propagated all the way through the specimen, and material flow into the necking zone through the neck shoulder reached the gripping area. After passing through yielding, strain softening, cold drawing and strain hardening regions, once the thickness of the specimen at the gripping area decreased to a level at which the mechanical grips could no longer hold the specimen, the specimen failed at 740% nominal strain without a real break but due to slippage from the grips. This value is well above the elongation value required by ISO 4427-2 [13], which is a minimum of 350%. However, Sample 2, with the same molecular and physical properties as Sample 1, as given in Table 3, failed at significantly lower strains of 270% on average, after showing significantly reduced cold drawing with no strain hardening behaviour. Samples 3 and 4 showed post-yield properties that were better than of Sample 2 but inferior to those of Sample 1. On average, Samples 3 and 4 met the minimum elongation required by ISO 4427-2, but one can understand from the large standard deviation that some specimens showed elongations below 350%.

This behaviour is attributed to the inhomogeneous mixture of CB and the polymer matrix, especially when large windows are present, which indicate discontinuity in the physical properties of the CB polyethylene composite structure. Clearly, these windows are the source of stress concentrations, especially at their borders. This phenomenon is observed during the tensile tests in the present study. In Figure 3a, a tensile specimen is shown before the test. The white arrows indicate windows that are visible at the surface of the specimen. Figure 3b shows the same specimen at 20% elongation after yielding. At this stage, many other windows became visible to the naked eye due to stress whitening phenomena. The borders of windows that exhibit discontinuity in physical properties become sharper as the material elongates (Figure 3c). At some point, microcracks at the sharp edges of the windows are observed due to poor interface bonding (Figure 3d) and higher stress concentration. These microcracks further developed with increasing strain and finally led to macroscopic failure as shown in Figure 3e.

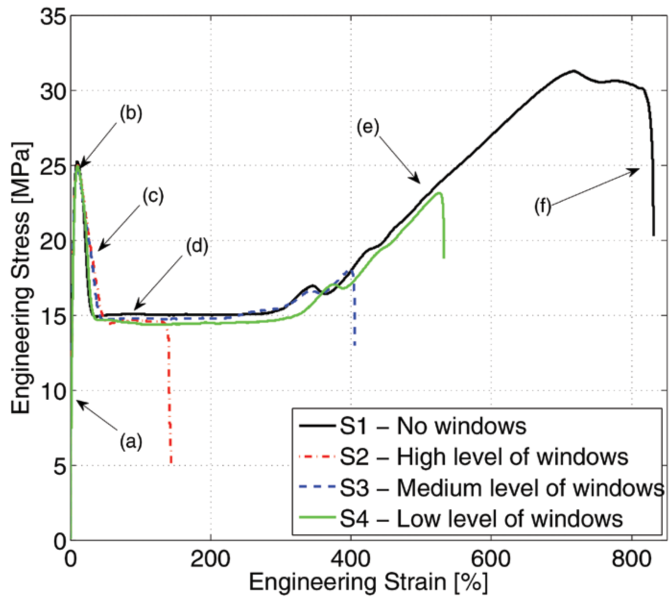

Figure 2. Engineering stress–strain curves of samples elongated to fracture at a test speed of 25mm/min.

Analyses of fracture surfaces

Figure 4 shows light microscopy images of fracture surfaces for all samples at a displacement rate of 250mm/min. A typical fracture surface of polyethylene at high elongation was observed for Sample 1. Sample 3 and Sample 4 also showed similar fracture behaviour to Sample 1, with Sample 3 showing tiny windows visible to the naked eye (Figure 4(c), red arrows). Fracture surfaces of samples indicated that an inherent stress concentration point initiated the fracture at the mid-section of the specimen (Figure 4(a), Zone A), followed by propagation through fibrillated wedges (Figure 4(a), Zone B) to the failure. Sample 2 shows a complete ductile failure at the macroscopic level associated with the inhomogeneous structure of the matrix due to poor mixing of CB, which is clearly visible in Figure 4(b), in which windows are clearly visible to the naked eye (red arrows). SEM images of black areas (Figure 5b) showed similar packed crazes tearing to failure. SEM of the fracture surface of Sample 2 in the windowed area (Figure 5a) shows brittle features associated with a highly fibrillated structure, which are similar to those observed during slow crack growth in polyethylene.

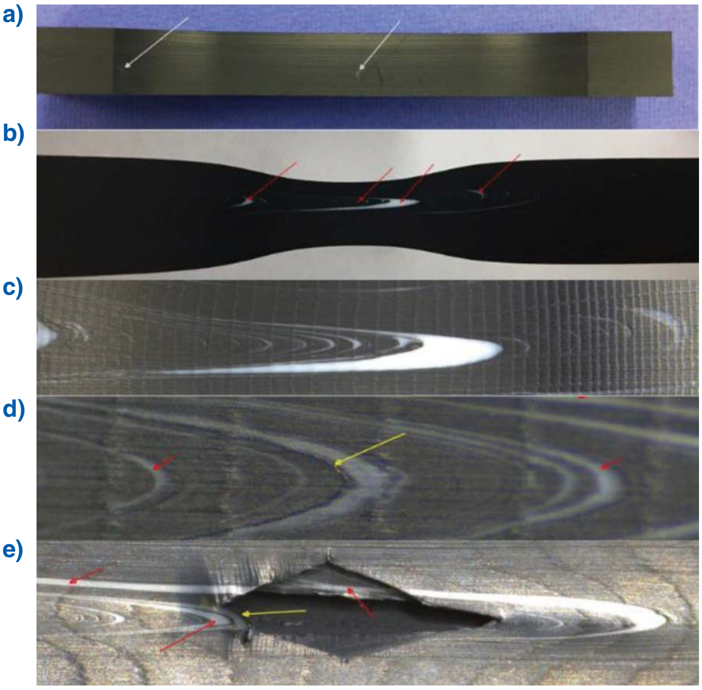

Figure 3. Propagation of windows to fracture: (a) tensile specimen before testing—white arrows indicate 'windows' visible to the naked eye; (b) tensile specimen after yield (20% elongated)—red arrows show windows curled towards the tensile direction; (c) tensile specimen (40% elongated); (d) interface separation at the edge of windows marked with a yellow arrow; (e) fracture occurrence at the interface separation (yellow arrow).

Conclusions

In this study, four plastic pipes made of the same polyethylene material with different CB distributions were produced by single screw extrusion. These pipes were elongated to fracture by means of tensile testing. Fracture surfaces of pipes were investigated with light microscopy and SEM. It is observed that the CB distribution in the NPC+CBMB pipes was inadequate. Increasing the residence time by reducing the production speed helped to improve the CB distribution; however, even with a 40% decrease in throughput, the CB distribution in the NPC+CBMB pipes did not match that in pre-compounded pipes.

A significant decrease was observed in the post-yield properties of polyethylene pipes with an insufficient CB distribution, whereas the yield properties were not affected. NPC+CBMB pipes showed 80% less elongation than pre-compounded pipes. Polymer domains with less or no CB (windows) showed delamination from the polymer matrix as the material elongated, finally leading to fracture much earlier than expected. A highly heterogeneous CB distribution was observed on fractured surfaces of pipes produced with the NPC+CBMB production method. Interestingly, polymer domains with no CB within the polymer matrix showed brittle failure once elongated to fracture, although the corresponding natural material shows completely ductile failure when it is strained as a single component. Finally, we have reported the significance of CB homogeneity with respect to the mechanical properties of plastic pipes.

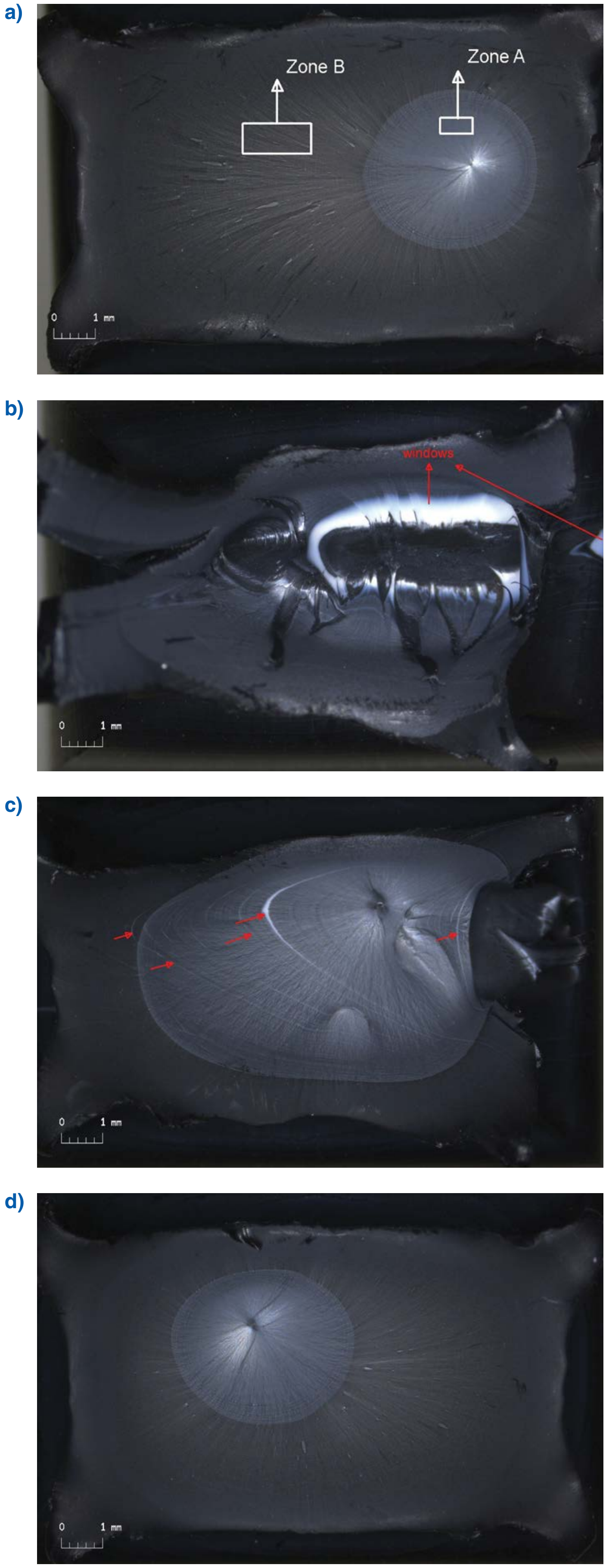

Figure 4. Optical images of fracture surfaces: (a) Sample 1, (b) Sample 2, (c) Sample 3 and (d) Sample 4.

a)

b)

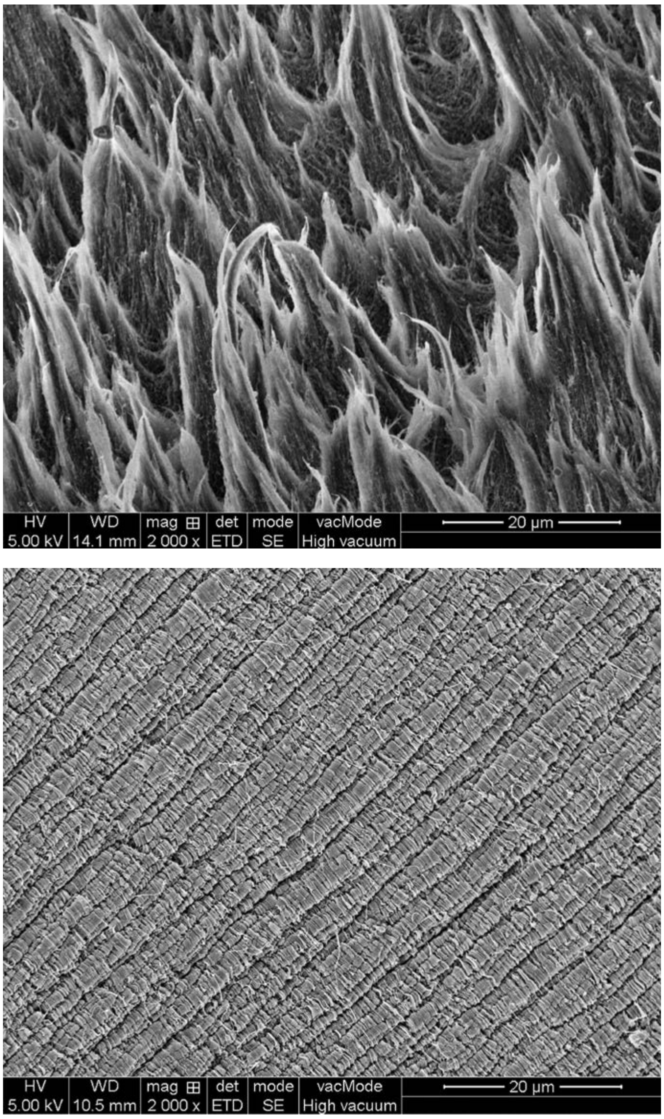

Figure 5. SEM images of fracture surfaces of (a) windowed area of Sample 2 and (b) black area of Sample 2.

Sources:

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CONSTRUCTION

Development of large utility tunnels with high modulus polypropylene

by Dongyu Fang & Mark Yu

Introduction

Plastic pipes are increasingly used to transport liquid and gas in larger diameters. In this article, we show how high-modulus polypropylene (HM-PP) is used in an innovative design for utility tunnels up to 4000mm in diameter.

Utility tunnels were first developed using concrete and was meant to house all service connections – water, gas, sewage, telecoms, district heating and power supply in one corridor for ease of installation, maintenance and upgrades. The idea of having all these services grouped together is increasingly important in major urban centers in China that are growing at a very fast pace. It is with this in mind that China started to look into upgrading the design of the traditional utility tunnel. While concrete is stiff and fire retardant, it performs poorly during extreme ground movements such as earthquakes and suffers from corrosion.

Designers are evaluating HM-PP as an alternative material for constructing a utility tunnel because it has sufficiently high stiffness but still retains reasonable flexibility. This allows the entire HM-PP structure to interact with the soil to deflect and accommodate surrounding load. An added benefit of using HM-PP is its corrosion resistance and ease of installation due to its relatively lighter weight compared to concrete.

Utility tunnels – A background

The utility tunnel concept is not new. A paper published by A. Laistner and H. Laistner in 2012 reviewed the development of utility tunnels for sustainable urban development [1]. The concept of utility tunnel was first introduced in the 19th century.

The utility tunnel was first developed using concrete and it has not changed significantly today despite the fact that different materials are being tested based on various design. Laistner Engineering Developments made a design using corrugated steel, HDPE and fiber reinforced concrete in different projects from 1994 to 2004 [1]. Steel and HDPE were chosen to reinforce concrete to give the structure better flexibility while still relying on the long track record of concrete. The lack of flexibility of concrete had been one of the major contributors to look for alternative materials.

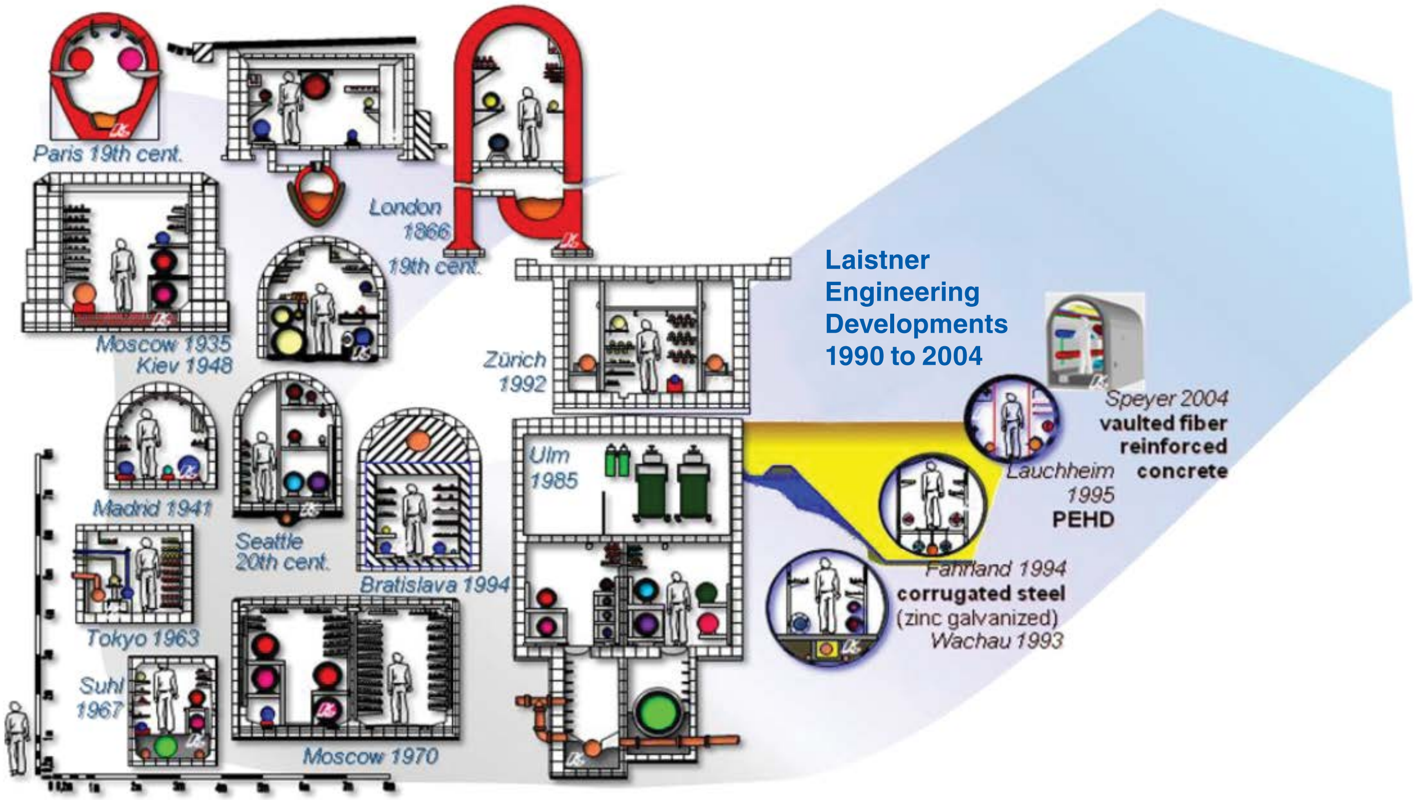

Figure 1. Development of utility tunnel until 2004 with different types of materials[1].

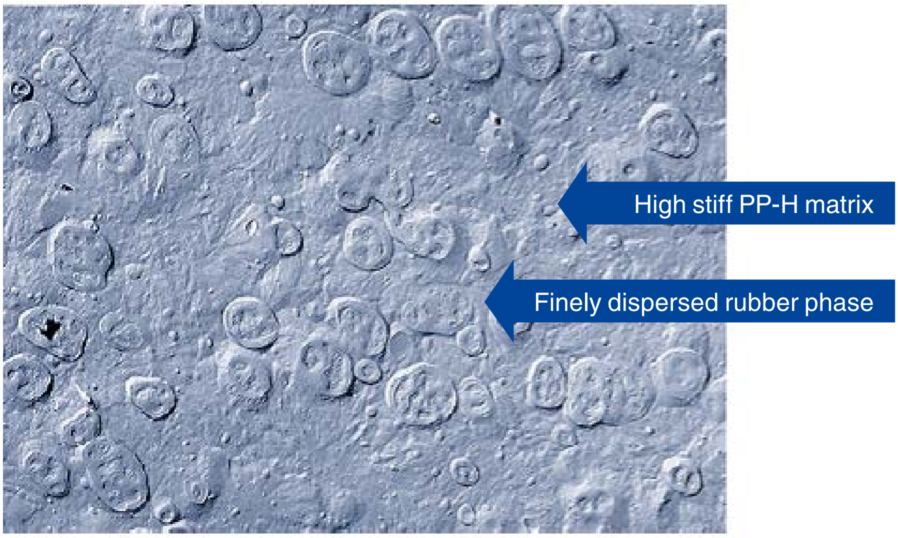

Figure 2. Morphology of HM PP-B copolymer[2].

Properties	Standard PP-B	PP-B HM	Method
$MFR_{2.16}$ (g/10min)	0.3	0.3	ISO 1133
Density (g/cm^3)	0.90	0.90	ISO 1183
E-Modulus (MPa)	1300	1700	ISO 527-2
Stress at yield (MPa)	28	31	ISO 527-2
Notched impact (kJ/m^2) +23°C -20°C	 50 4	 50 5	ISO 179

Comparison between standard PP-B and PP-B HM.

Utility tunnels were not widely used in China before 2013 with the only notable example being one along Zhang Yang Road in Shanghai spanning several kilometers. By 2015, China decided to support this concept and planned its development into the 5-year development plan. A 'national standard of utility tunnel' was issued in 2015 under GB50838-2015 (Technical Code for Urban Utility Tunnel Engineering). Since 2016, the construction of more than 1700km of utility tunnels began in more than 140 cities in China with more than 6500km additional tunnels being planned and designed. Utility tunnels have therefore become a key infrastructure investment in China over the last 3 years.

The GB50838-2015 standard only covered concrete utility tunnel. Due to the well-known limitations of concrete, new materials are also being tested for such tunnels in China. Corrugated steel is a popular choice but suffers from corrosion. Plastic is another material being considered with HDPE being tested as far back as 1995[1]. The introduction of HM-PP allows designers to take advantage of a much stiffer but lighter material compared to HDPE but still meet the stiffness and flexibility criteria.

High modulus block polyproplene (HM-PP)

Depending on its molecular structures, PP can be categorised into PP homo polymer (PP-H), PP random copolymer (PP-R) and PP block copolymer (PP-B). Ethylene is normally used as the co-monomer. PP block copolymer can be made at certain ethylene content to achieve a two-phase structure as shown in Figure 2 [2]. The morphology of PP block copolymer looks like ethylene-propylene rubber 'islands' scattered in PP-H 'ocean'. The PP-H matrix gives the polymer superior stiffness, whereas the rubber phase contributes to outstanding impact resistance and flexibility.

PP-B is normally used for non-pressure pipe applications such as sewage and drainage pipes. Whilst standard PP-B grades have a stiffness of around 1100–1300MPa, the newly developed HM PP-B achieves both higher modulus and higher impact resistance. HM PP-B thus enables the manufacture of pipes with larger dimensions with reduced wall thickness. This ensures its durability but at the same time increases the economic competitiveness of the pipe.

Design considerations when using HM PP-B structured wall pipes

HM-PP structured wall pipes can either be made from corrugated or spiral wound pipes. The standard ISO21138 covers corrugated pipes up to 1200mm and spiral wound pipes up to 4000mm in diameters. For the current utility tunnel applications, spiral wound pipe was chosen as the basis for the design of the main structure.

Ring stiffness is the key design consideration if HM PP-B is to be considered for use in a utility tunnel. The definition of ring stiffness, S (defined in MPa or KN/m2) in the ISO standard is shown in Equation (1) [3].

$$S = \frac{EI}{D^3} \qquad (1)$$

Where,

- E: E-modulus of pipe material, MPa
- I: the moment of inertia of the pipe wall, m^3
- D: average pipe diameter, m

For a given profile design the ring stiffness S is proportional to E and $1/D^3$. Therefore the higher the modulus or the smaller the pipe, the higher the pipe ring stiffness. On the other hand, if a material has a higher modulus, the value of I can be smaller for the pipe design. A smaller value of I implies a smaller profile design to achieve the same ring stiffness.

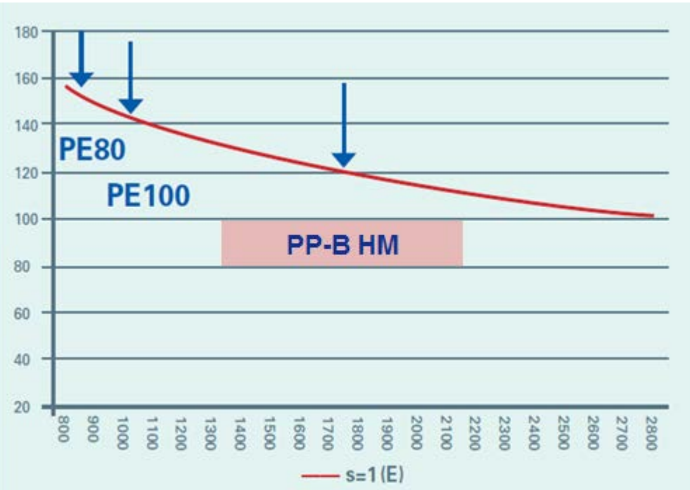

Figure 3. Comparison of 3000mm solid wall thickness (vertical axis) made from a HM PP-B (E=1700MPa), typical PE80 (E=800MPa) and PE100 (E=1000MPa). The horizontal axis represents the modulus.

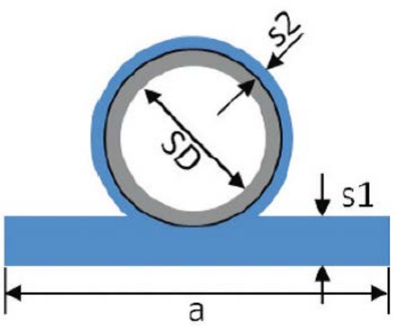

Figure 4. Structural design of typical spiral wound pipe.

Figure 3 compares a 3000mm diameter solid wall pipe made from HM PP-B (E=1700MPa) with the typical PE80 (E=800MPa) and PE100 (E=1000MPa) materials. These PE materials are commonly used to manufacture PE spiral wound pipes. As shown in Figure 3, the wall thickness required by a 3000mm spiral wound solid wall pipe decreases dramatically with an increase in modulus to maintain the same stiffness S. Material savings could reach as high as 23% when selecting a higher modulus material. Using HM PP-B in a corrugated wall design may result in a pipe that is 40-60% lighter [4].

HM PP-B can be used to produce large spiral wound pipe up to 4000mm. If we take the simplest structural design, like a 'Ω' as shown in Figure 4, the main design parameters include pitch (a), main pipe wall thickness (S1), core tube diameter (SD), and outer layer thickness of core tube (S2). The design of these parameters can be optimised to achieve a balance between mechanical properties (e.g. ring stiffness, ring flexibility) and processability in addition to cost (e.g. pipe weight, wall thickness, etc.) and standards.

Ground interaction with HM PP-B utility tunnel

A key concept of how a utility tunnel made from HM PP can function properly while buried is in its interaction with its surrounding. Flexible structures like plastic pipes and even a flexible HM-PP tunnel do not carry the majority of the load from the ground above especially when sufficient soil compaction is achieved around them. Figure 5 shows this in a simplified way. Flexible structures such as PE and PP, which can flex and transfer the load to the surrounding soil, do not need to withstand the entire top load. A flexible structure therefore transfers the load to the surrounding soil which protects the pipe from taking on the full load as compared to a rigid structure as long as there is sufficiently good ground compaction around it.

Another advantage of HM-PP is its excellent durability. In a recent trial project, the HM-PP was aged for 6-12 month before being deformed by 45% and it still returned to its original shape without cracks. This was followed by a pressure test at 95°C and the pipes passed both tests. The cross section of the design of the HM-PP trial project is showed in Figure 6.

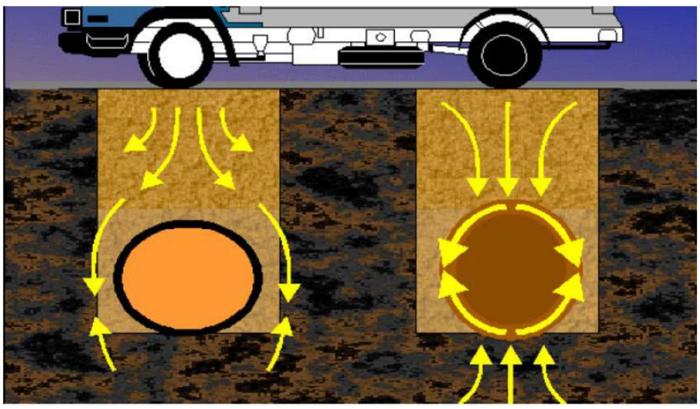

Figure 5. Controlled deformation of a flexible plastic pipe as compared to a rigid pipe and its interaction with surrounding soil.

The main structure of the tunnel was tested for deformation on site as shown in Figure 7. Based on the current design, its deformation was less than 2% with a ring stiffness, SN>12.5. An integrated system can be formed from sections made from HM-PP as shown in Figure 8. It can also be easily integrated with a concrete section.

The recent trial project using HM-PP opens up the possibility for designers to consider this material for a utility tunnel. Tests on the section of the pilot project made from HM-PP are continuing and additional results will be published when they become available.

Figure 6. the design of HM-PP utility tunnel.
(Courtesy of Minsheng Pipe)

Figure 7. On-site deformation testing of the tunnel.
(Courtesy of Minsheng Pipe)

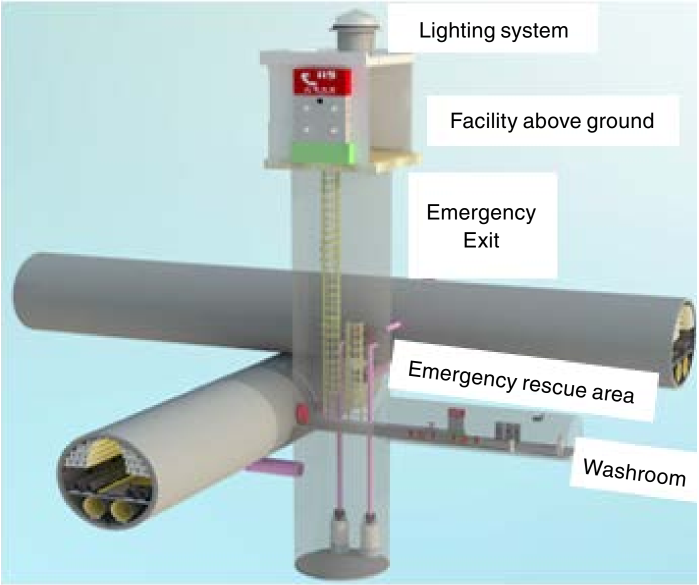

Figure 8. HM-PP utility tunnel system. (Courtesy of Minsheng Pipe)

Properties	Concrete	HM PP-B	Corrugated steel
Stiffness	Very high	>SN12.5 for 3000-4000mm	High
Flexibility	Not flexible	Flexible	Relatively flexible
Corrosion resistance	Low	High	Low
Diameter and shape	Unlimited, round/rectangular shape	Up to 4000mm so far	Semi-circular culvert
Seismic resistance	Poor	Good	Poor
Weight	Very heavy	Light weight	Heavy
Design	Fixed after the design is done	Connections can be added at a later stage	Fixed after the design is done

Comparison between HM PP-B utility tunnels with other materials.

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Acknowledgement
The development detailed above is a joint project with Minsheng Pipe.

EVENTS

Borouge continues engagement with the Nepal Bureau of Standards

by Chanchal Dasgupta

Nepal is a landlocked country high up in the Himalayas surrounded by India and China. Due to its hilly terrain, setting up piped water network has been relatively challenging. In Nepal, only 41% of the rural population[1] have access to piped drinking water while the corresponding urban[1] access is 58%. Since 2000, the Asian Development Bank (ADB) has supported the government in improving water supply and sanitation services in 70 small towns in Nepal[2].

In the hilly countryside of Nepal, HDPE pipes are ideal because they are light and can be easily carried to site and are flexible and follow the undulating terrain. HDPE pipes and welded joints are end load resistant due to its homogenous joints that enables it to withstand soil movement and earthquakes. Being viscoelastic, it can accommodate very high pressure surges as well.

Borouge has had a long relationship with the Nepal Bureau of Standards and Metrology (NBSM) and had conducted several workshops in the past with the aim of trying to improve the local PE pipe standard. The Nepal standard used to specify black pre-compounded PE80 material for HDPE pipes for many years. This has since been replaced with PE100 material. The recent availability of commercially attractive natural PE100 material from neighboring countries have put pressure on the convertors in Nepal to give in to the use of natural PE with black masterbatch.

Borouge has consistently encouraged NBSM not to dilute the high quality standards they have already set for Nepal and a workshop was conducted at NBSM office in Kathmandu recently. Director General, Mr Biswobabu Pudasaini and Deputy Director General of NBSM, Mrs Romi Manandhar together with almost 20 water engineers and several heads of the water boards welcomed the Borouge team.

NBSM was leaning towards keeping the Nepal PE pipe standard of only allowing black precompounded PE100 but was keen to clarify several technical points raised by the local industry. The Borouge team comprising Prashant Nikhade, Chanchal Dasgupta and Srinivas Goud helped clarify some points with the participants. The participants were urged to learn from the long proven success of PE in gas. Examples of PE pipes being banned in many parts of India as the brittle material used during the early 80's that were of poor quality should also serve as a lesson for Nepal to avoid. Another example of good quality practice that was highlighted was of HDPE pipes that are being used for some

The Nepal Bureau of Standards and Metrology office.

Prashant Nikhade addressing the participants at the NBSM office.

of the largest ever water distribution projects in India due to stringent quality enforcement.

Borouge suggested a few modifications to the current NBSM standard so that it is easy for the converters to implement. Mrs Romi Manandhar appreciated the initiative and effort of Borouge in creating awareness on the quality standards in the pipe industry and requested continued cooperation between Borouge and NBSM.

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