



UNION PIPES INDUSTRIES: TWO DECADES OF SUCCESSFUL PARTNERSHIP IN UAE AND BEYOND

Borcoat 3LPE used
for water pipelines
supplying Neom city

Providing fire safety
and security with
PE100 piping systems

Successful completion of
drainage rehabilitation projects
with Krah pipes in the Philippines

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The editor says...



The cover features a world's first: a 1600mm OD SDR21 orange HSCR PE100 pipeline produced in Union Pipes Industries (UPI) for a North American project. PE100 HSCR was specified because the owners prefer the critical pipeline to have a higher slow crack growth resistance. The year 2019 marks two decades of close cooperation with UPI in building the Middle East and regional PE100 market and we look back at the journey with an interview with the chairman Mr Qassim Al Sharafi.

Staying in the Middle East, we showcase how the Borcoat 3-layer PE (3LPE) system helped the Saline Water Conversion Company protect over 100km of DN1200mm steel pipeline supplying water to the prestigious Neom city in Saudi Arabia. We also feature NAFFCO, in the UAE who are using PE100 in the design of their firefighting systems. At NAFFCO, the well publicised benefits of PE100 come into play resulting in a highly reliable, leak free and cost effective solution for a critical application.

In September, Borouge worked with the Singapore Water Association to conduct a seminar for the engineers of the Singapore Public Utilities Board on how to protect the steel

pipelines used for water transmission and distribution in the country.

In China, we highlight how the PE100+ members have come together to stress the importance of using compounds at the Urban & Building Water Trade Fair.

Also on PE100 compounds, we feature the second part of a landmark study from our Innovation Center showing how butt fusion welds are affected when carbon black dispersion is not homogenous, something that often happens when mixing natural PE100 with black masterbatch offline.

We wrap up this edition with a story from the Philippines of the rapid success of large diameter structured wall PE pipes from Krah that have been used in some of the major stormwater / sewage rehabilitation projects in key locations like Boracay and Manila.

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

Your Editor,

A handwritten signature in black ink, appearing to be "KH Lou", written over a light blue grid background.

KH Lou

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Borcoat 3LPE used for water pipelines supplying Neom city

by Chanchal Dasgupta



Steel pipes coated with the Borcoat 3LPE system being loaded for the Neom project.

Neom is a cross-border city in the Tabuk Province in northwestern Saudi Arabia. It is planned as a smart city and also a tourist destination. It is near the Red Sea and the borders that Saudi Arabia shares with Egypt and Jordan. Neom will cover a total area of 26,500km² and will extend 460km along the coast of the Red Sea.

Saudi Arabia aims to complete the first section of Neom by 2025. The project has an estimated total cost of \$500 billion, \$300 billion of which is expected to come from the IPO of state-owned oil company Saudi Aramco. Neom is planned to be totally powered by renewable energy sources. Plans for the city was announced by Saudi Crown Prince Mohammad bin Salman at the Future Investment Initiative conference in Riyadh recently and the city will operate independently from the “existing governmental framework” with its own tax and labour laws and an autonomous judicial system.

The initiative emerged from Saudi Vision 2030, a plan that seeks to reduce Saudi Arabia's dependence on oil, diversify its economy, and develop public service sectors. Klaus Kleinfeld, former chairman and CEO of Alcoa Inc., and former president and CEO of Siemens AG, will lead the development of the city. Current plans call for robots to perform functions such as security, logistics, home delivery, medical care and for the city to be powered solely by wind and solar power. Because the city will be designed and constructed from scratch, other innovations in infrastructure and mobility have been suggested. The development works of Neom Bay, part of the project's first phase, started in the first quarter of 2019 and expected to be completed by 2020. The developments include construction of the current airport at Sharma which will operate regular commercial flights between Riyadh and Neom. Neom Bay's development also involves building of the first residential areas.

As a part of this project the Saline Water Conversion Company (SWCC) is developing a water supply system for Neom, which will take the form of a DN1200mm pipeline of 101.5km in length. For the past few years, SWCC 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 high pressure steel pipelines will be externally coated with 3-layer polyethylene (3LPE system) for lifelong corrosion protection. Welspun, Saudi Arabia has been awarded the supply of steel pipes with 3LPE coating. They will use Borcoat™ 3LPE system for this project and will require 1250MT of PE top coat and 100MT of adhesive.

The three layer polyethylene (3LPE) coating system from Borouge was selected by the project consultants in order to provide the protection for these critical SWCC assets. These coating systems have a very successful track record with SWCC in many of their other projects like the different phases of Shoaiba, Shuqaiq and Eastern Province, protecting steel pipelines from external corrosion and mechanical impact damage during storage, handling, transport and operation. In addition, Borcoat™ 3LPE system has a distinguished track record stretching back more than 15 years in the oil and gas industry in the Middle East and worldwide.

The Borcoat™ bimodal high density 3LPE system is ideal for the task as it provides complete protection against the many factors likely to be encountered along the pipeline route such as corrosive soil, high water table and exposure to severe weather in Saudi Arabia. The Borcoat™ 3LPE system is based on bimodal high density polyethylene (HDPE) together with a grafted copolymer medium density polyethylene (MDPE) adhesive. The top coat Borcoat™ HE3450 ensures that the coating system provides the highest impact, indentation and abrasion resistance over a wide range of operating temperatures from -45°C to +85°C and over a long service life. At the heart of Borcoat™ bimodal HDPE top coat is the Borstar™ process which provides tailor-made high molecular weight polymers with a broad molecular weight distribution (MWD). This ensures excellent melt strength for easy processing, enhanced mechanical and heat deformation properties, and a very high resistance to environmental stress cracking (ESCR).

The Borcoat™ grafted MDPE adhesive ME0420 provides an improved adhesion between the PE and epoxy layers at both ambient and elevated temperatures compared to the older generation low density polyethylene (LDPE) copolymer adhesives. Also, they can be applied over a wider processing window with consistent results, which ensures a high coating integrity and bond strength, even after many years of service. These properties will protect the pipelines in Neom from any damage during handling, transportation and installation and continue to protect the pipes from corrosion over a long service life as demonstrated by the 15 years successful track record with major oil and gas pipelines in the Middle East and longer in the rest of the world.

Providing fire safety and security with PE100 piping systems

by Karam Badawi (NAFFCO) & Mohamed Ali Jaber

The following summarises a discussion between Karam Badawi of NAFFCO and Mohammed Ali Jaber.

Overview

National Fire Fighting Manufacturing FZCO (NAFFCO) based in Dubai, UAE supplies equipment that ensures the safety and security of buildings to protect life and property across industries such as oil and gas refineries, aviation, residential, commercial & government real estate. NAFFCO offers a wide range of firefighting equipment, vehicles, fire pumps, controllers, fire protection systems, passive fire protection, extra-low voltage solutions and safety training.

NAFFCO has over 15,000 employees, including 2,000 engineers and their sales network covers more than 100 countries. The company is ISO 9001, 14001 and 45001 certified and was awarded the prestigious Mohammed Bin Rashid Al Maktoum business excellence award in the last four years for their manufacturing and export excellence. The manufacturing facilities covers over 550,000 square metres and products manufactured are certified by UL, FM, BSI, LPCB & Global Mark.

What kind of products does NAFFCO supply for this segment and how are they different from what was supplied in the past?

Many industrial companies use underground piping systems for the supply of firefighting water in buildings. In this application, Factory Mutual (FM) approved systems are often specified as it is recognised that the products meet the highest standards in terms of fire safety and quality. As a result the costs generally associated with property insurance can be reduced dramatically wherever such products are deployed. In the past, many suppliers have used metallic pipe systems for the underground piping for such systems. At NAFFCO, we have decided that given the outstanding properties of PE100, a HDPE-based piping systems is a perfect choice for the supply of fire extinguishing water and are capable of outperforming piping systems made of other materials. Among the key benefits of HDPE pipes used in underground firefighting systems are high corrosion resistance, long service life and cost-effective operation. NAFFCO products are FM approved with the highest quality standards and guaranteed performance.

Main benefits of PE100 for firefighting systems:

- Design life of 50 years
- Safety – guaranteed with FM approvals
- Simplicity – easy connection to hydrants and sprinklers
- Efficiency – easy maintenance without interrupting the water supply
- Environment friendly – Long product lifecycle with minimal carbon footprint
- Compatibility – pipes & moulded fittings are made from the same material ensuring proper and reliable joints



What are the attributes of a firefighting system and what are the key considerations in the selection of appropriate pipe materials?

Fire protection usually consists of a water distribution system that secures the water supply to sprinklers with appropriate pressure and flow rates. In case of fire, a secure and reliable supply of water for underground distribution and above ground sprinkler systems is crucial for emergency management. The complete system relies on a consistent supply of water with adequate pressure and the right flow rate. Firefighting networks suffer from water hammer due to the sudden opening and closing of valves. Therefore, HDPE pipes are suitable for these networks with their high resistance to water hammer. The water hammer phenomenon has already been taken into consideration in the regression curve validating the operating life of HDPE pipes as 50 years. It is absolutely crucial for the connecting mains, supply pipes and hydrants to provide reliable water distribution in a safe manner. Distribution lines in the potable water grid are typically in the range from DN50 (63mm outer diameter) up to DN300 (355mm outer diameter).

Different uses of HDPE pipes in water networks:

1. Water Network

HDPE pipes are used for potable water networks because it does not affect the water due to its inert property. In addition, a properly installed HDPE network will not leak due to ground movement or water hammer effects due to its ability of being butt fused. Its flexibility is another significant benefit. The smooth internal surface prevents any kind of bacteria to accumulate thus making HDPE pipes the most suitable choice for potable water.

2. Sanitary and industrial drainage

HDPE pipes are used for both sanitary and industrial drainage due to their excellent chemical resistance (acids, alkalis, salts, etc.) and the assurance of a leak free network.

What made NAFFCO consider PE100 in the first place?

The PE100 compound approach has been successfully applied in Europe that led to high penetration of PE in both gas and water distribution. In gas, penetration levels are close to 100% and 85% of all new water pipes installed in Europe are produced from PE compounds. European specifications are set at a high level and include all the necessary properties to ensure PE provide a long leak free operating life. These requirements have now been adopted by the International Standards Organisation in ISO 4437 (2007) and ISO 4427 (2007) for HDPE gas and water pipes respectively. The level of dispersion of carbon black is one essential part of the standards; because these requirements are high it means that the minimum design factors can be set low at 2.00 for gas and 1.25 for water. This ensures the pipes are of a high quality. Published failure data from the UK and Danish water industries confirms that this quality approach is correct – PE demonstrates the lowest failure rate for all materials used for water mains.



How does the fact that PE is a flammable material affect its use in a firefighting network?

PE100 is only used for the buried portion of a firewater piping network, where it will not be exposed to fires or elevated temperatures during any emergency. Because the PE100 pipe will be buried, there is little risk due to the flammability of PE.

Can you summarise the properties required in pipelines used in a typical firefighting system?

Material properties required by industrial pipelines:

Property	Why is it required
Tensile strength	Hoop stress for continuous pressure operation & water hammer
Abrasion resistance	Resist abrasion on the inner surface caused by particles carried in the flow
Chemical resistance	Resist attack by fluid being carried by the pipe
Corrosion resistance	Corrosion caused by fluid being carried by the pipe and/or the surrounding environment
Elastic modulus	Resist deformation and/or buckling of the pipe due to external loads
High integrity joints	Structural integrity + prevent leakage or infiltration
High durability	Minimise maintenance, repair and replacement
Flexibility	Reduce risk of failure and allow easier installation

Piping materials must have appropriate FM approvals to at least meet or exceed the test requirements in the applicable standards.

What is the current trend in the fire safety and security segment in UAE and the wider region?

Regional contractors and end users increasingly prefer a system which can guarantee its performance even under extreme climatic conditions but is yet simple to install. Clients and building owners also demand systems with the highest safety ratings. All NAFFCO products meet these requirements.

What are the new developments the company is looking into?

NAFFCO is currently focusing on augmenting Smart firefighting systems used inside buildings to provide maximum efficiency.

When did NAFFCO begin working with Borouge?

NAFFCO chose BorSafe™ HE3490-LS and HE3490-LS-H grades for the production of their pipes and moulded fittings since the start of its production in 2009. Being located close to Borouge allowed NAFFCO to have easy access to the high quality and innovative solutions that is readily available at Borouge's facilities in the UAE. It was well known even back in 2009 that Borouge produces the most advanced materials for use in PE pipes and fittings with world-class production facilities that brings together the very best of Europe and the Middle East.

Has the cooperation with Borouge helped NAFFCO to promote PE100 for their projects?

NAFFCO'S association with Borouge PE100 material have increased the chances of approval for project especially in the UAE and GCC in general with minimum efforts and qualification process as the end user will now be more aware of the importance of the material, its ease of working and the assurance that the product will meet and even exceed all the requirements of the specifications.

Union Pipes Industries: Two decades of successful partnership in UAE and beyond

by Sultan Al Kendi



A SDR21 1600mm OD PE100 being produced in UPI for a North American project.

Union Pipes Industry (UPI) has been established in Abu Dhabi since 1999 to cater for the needs of the UAE and Middle East regional market for high quality polyethylene (PE) pipes. UPI supplies pipes and fittings up to 2,000mm in diameter for potable water, sewage, irrigation, oil and gas and many other special applications. In many projects, UPI also provides an installation service using its own team of trained welders equipped with the latest welding equipment and the experienced engineering staff offer an advisory service covering the needs of the client from quality assurance to design and specifications. In fact UPI is able to supply a complete Engineering, Procurement and Construction (EPC) package for major projects.

In the following Q&A, we met up with the Chairman of UPI, Mr. Qassim Al Sharafi who shared his insights on the state of the HDPE and plastic pipe market, the local and regional infrastructure and construction market, a relook at UPI's history and current market position and an outlook for plastic pipes for the near future.

Looking back 20 years since UPI started up, what are you most proud of?

We saw the future in plastic pipes as it was rapidly replacing GRP and other conventional materials.

The distinctive benefit of PE pipes (corrosion free, flexibility, high durability, cost effectiveness, etc.) gave us the confidence that in the future, polyolefin pipes would prevail in the market. Moreover, at that time, there was no other plastic pipe manufacturer in Abu Dhabi. Currently, UPI is one of the world's leading suppliers of PO pipe systems. UPI plants in UAE, KSA and India have unique expertise in manufacturing and delivering large HDPE pipes and related fittings. The range of pipe size goes all the way up to 2000mm OD for pressure application and ID 4000mm for gravity application. UPI also produces injection molded products, corrugated pipes, T-liner, sheets, manholes and tanks.

What were the first challenges faced when introducing plastic pipes to the local and regional market?

When we introduced plastic pipes to the local market, this material was new to the Front End Engineering Design (FEED) consultants who were working on major projects and therefore a major effort had to be made by our technical team, material supplier and technology providers to highlight and demonstrate the advantages of using polyolefin pipes in the different projects. It was a challenge to give confidence to the client's engineers about plastic pipes as they were accustomed to using conventional pipe materials such as carbon steel, DI, GRP, AC and RC pipes.

How did UPI overcome such challenges and what learning did the company take from such experiences?

Fortunately, Borouge and UPI started production of PE products together in 2001 and that was great support for UPI to introduce the advantages of using PE pipes to potential clients and consultants through numerous workshops and seminars and participation at local exhibitions. Furthermore the support of the local UAE authorities for water, sewage, electricity and oil and gas was also a great assistance to our efforts.

What were the early accomplishments that set UPI up for success?

We proved to the main client / consultant in the sewage segment the efficiency and suitability of the PE pipes for major projects where they had only used GRP pipes before. The Abu Dhabi Municipality thoroughly studied the technical submissions made by us and agreed to use PE pipes in their project for treated sewage pumping mains to Al Mafraq treatment plant in 2003. The work included installation of 72,000m of HDPE pipes and fittings and 4800m section by horizontal directional drilling (HDD). The successful completion of WDP Effluent Disposal Pipeline for Occidental Petroleum (OXY) was also one of the major accomplishments in the early stage with 4500m of 630mm OD PE pipes with working pressure of 22 bars.

What has been UPI's crowning achievement?

Our crowning achievement would be the Borouge 2 Sea Water Supply & Outfall project that was supplied, installed and tested with our 1600mm HDPE pipes covering 26,000m total length in 2008. Then there is the Barakah Nuclear Power Plant Project that we supplied and welded 6,480m of 914mm OD PE pipes and fittings. By supplying our products in UAE's first nuclear power plant project, UPI proved our superior quality. Finally, there is the ADNOC - Takreer RRE Project where we supplied, installed and tested 3000mm ID pipes of 16,600m length and 2000mm OD pipes with a length of 22,500m.

What differentiates UPI and contributed to it being known as a world class plastic pipe manufacturer?

First and foremost, we did not go the most common way to make short term profit with commodity products. We chose to follow the hard way that involves ensuring the customer's true satisfaction even for difficult to extrude pipes sizes / remote & challenging project sites / difficult & new specifications that often required the supply of special HDPE fittings while ensuring superior quality at reasonable prices. Secondly, we will not stop despite challenges and difficulties. In the ADNOC – Takreer RRE project, the world's largest intake line, we succeeded after addressing all the risks and difficulties of a "submerged method" never used before! These are the reasons behind our success and achievements so far.

What role has innovation played in UPI's success?

A good example is the RRE project. Here, innovation and the characteristics of the plastic pipes used played a major role in its success. In this project, we had to install a 3m diameter pipe under the sea at more than 1600m length using a method never used before. We had some unexpected difficulties at the initial stage but we overcame them quickly, successfully and completed the project "on-time" with the highest quality.

What role has partnerships played in UPI's success?

Our partnership with Borouge played a critical role in our success. Borouge supplied advanced quality raw materials as well as assisted UPI to secure many interesting opportunities. We started marketing our PE products together and have since grown together.

How has UPI contributed to the plastic pipe industry?

From the beginning of our pipe business, we worked very closely with Borouge to develop unique plastic pipes using both our lab and production facilities. This was the major factor of HDPE's success in Abu Dhabi's infrastructure and oil and gas sectors. We also worked very closely with GPPA by participating in their workshops and seminars. We received numerous acknowledgements from GPPA and PPI for our achievements in plastic pipes conversion - especially more than 3 awards by GPCA for excellence in plastics conversion using pioneering and innovative process to manufacture products for first time in the world.

How can the PE100 industry work better together to promote the benefits of this material over conventional piping systems?

We have to keep improving the PE100 material which is already very reliable and superior to alternative piping systems but there are still engineers who do not specify the use of PE100 today. But we are confident that this will change because the consultants and contractors will slowly see the benefits to the end users just by comparing the advantages that PE100 can offer today.

How can a material supplier like Borouge help market leaders like UPI grow the PE100 market more effectively?

Even though Borouge material shows superior quality, we are still waiting for Borouge to develop materials that can be used in even higher temperatures and achieve higher operating pressure conditions, so we can meet the new expectations in oil and gas and expand the our product's application range and use.



UPI Chairman Mr. Qassim Al Sharafi.

Recently UPI has produced the largest ever PE100 orange pipe, can you give us some background on this?

The application was really a big challenge for us and Borouge. We have been asked by an authority in Alaska (USA) and an American contractor to provide a polyethylene pipe with 1600mm diameter to be able to take internal stress and not to be vulnerable to slow crack growth. They want to install a polyethylene pipeline to connect a dam with a hydroelectric turbine. Moreover they requested that the pipeline be easy to be inspected in the future internally using a robotic-camera. For all the above reasons UPI chose the PE100 orange material made from BorSafe™ HE3492-LSH to produce for the first time an SDR 21 1600mm OD pipeline that meets all the specifications and unique client requirements. This is another challenge that UPI has met successfully!

Where do you see UPI in the future?

UPI will remain one of the key players in the global pipe market with superior quality and unique innovative products. UPI is also planning to extend production facilities to produce larger sizes of pressure pipes up to 3000mm and fluoropolymer such as PVDF and ECTFE pipes to be used in oil and gas applications that will replace metallic steel pipes currently suffering from corrosion and other failures, after some years of operation.

How do you see the regional plastic pipe industry in the future?

The demand of plastic pipes is likely to grow further owing to the expected growth of residential and commercial real estate in the Middle East. PE pipes should witness the highest growth rate owing to the increasing application in various industries and gradual replacement of conventional pipes like concrete, GRP, carbon steel, ductile iron etc. In the areas of water supply, storm water and sewage applications, HDPE will continue to be the dominant material for large diameter infrastructure pipelines. For plumbing, chemical, oil and gas, irrigation and desalination applications, HDPE has proved to be a reliable and long lasting solution with many competitive advantages.

What will be UPI's key driver for success in the future?

Continue our hard work, innovate and never give up. We must meet all challenges and always offer advanced plastic products.

Borouge announces future growth plans at Chinaplas 2019

- Major increase in black PE compound capacity
- Plans to double polyolefin production by 2030

Guangzhou, China – 21 May 2019: Borouge, a leading petrochemicals company that provides innovative, value creating plastics solutions, has announced that it will significantly increase production of pre-compounded black polyethylene for pressure pipe applications by investing in a production unit which is expected to be completed within 2020.

Borouge has an established global track record in providing its customers with advanced plastic pipe solutions with superior processability, performance and quality. The company's decision to expand capacity of PE black product follows soon after China's Water Standards Committee revised the PE water pipe standards, to promote the use of pre-compounded materials for piping applications for greater quality assurance.

The investment will address the rising demand for the materials as many cities in China and other emerging economies continue to expand and modernise their utilities infrastructure.

This latest announcement comes shortly after Borouge confirmed the next expansion phase of its Ruwais petrochemicals complex, which will see the construction of the world's largest mixed-feed cracker with an ethylene output of 1.8 million tonnes.

The new cracker will be the fourth in Borouge's Ruwais complex and will have an overall capacity to produce 3.3 million tonnes of olefins and aromatics from a variety of feedstocks including ethane, butane and naphtha. It will also enable the production of many petrochemicals building blocks, enhancing both the company's growth ambitions and long-term supply security for its customers.



Ruwais plant.

Use of disinfectants in drinking water networks in the Middle East

by Farraj Tashman

Background

Water utilities around the world have been using chlorine-based products since the early 1900s to disinfect potable water. These disinfectants are effective in killing water-borne germs that can pose a serious threat to human life if not removed.

Common types of disinfectant

To keep the potable water safe while it is being distributed to consumers, chlorine, in different forms, can be added in a process called chlorination. Chlorine can be administered into the potable water at different points along the network. Depending on the bio-load expected downstream, mini booster stations can be installed. Chlorine that is administered this way are commonly in the form of elemental gas (Cl_2), liquid solution (Sodium Hypochlorite – NaOCl or Monochloramine - NH_2Cl), and salt (Calcium Hypochlorite - $\text{Ca}(\text{OCl})_2$).

Effectiveness Parameters

The first main parameter affecting the process of disinfection is the water quality. Contaminants such as organic material, dirt, soil, etc. decreases the effectiveness of the disinfection

mechanism. Because of this, water utilities typically inject chlorine disinfectant after a series of different treatment stations. The second parameter is the acidity (pH) of the water. Chlorine disinfectant gets less sensitive when pH is above 7.5. The third parameter is the temperature; as the temperature increases, some chlorine disinfectants break down and becomes less effective.

Disinfection Process

As shown in figure 1 & 2 below, disinfectant is added to the treated water just before it is being pumped to the domestic network or intermediate storage tanks. While the dosage of chlorine can be as high as 4ppm at the initial administration point of the main transmission line, it gets diluted along the way after being mixed and dispersed to 1ppm as it reaches the consumer which is considered safe and does not impose harmful health effects on human beings. The majority of the water utilities in MEA use hypochlorite to disinfect potable water piping networks but recently, a few utilities started to use Cl_2 gas in their networks.

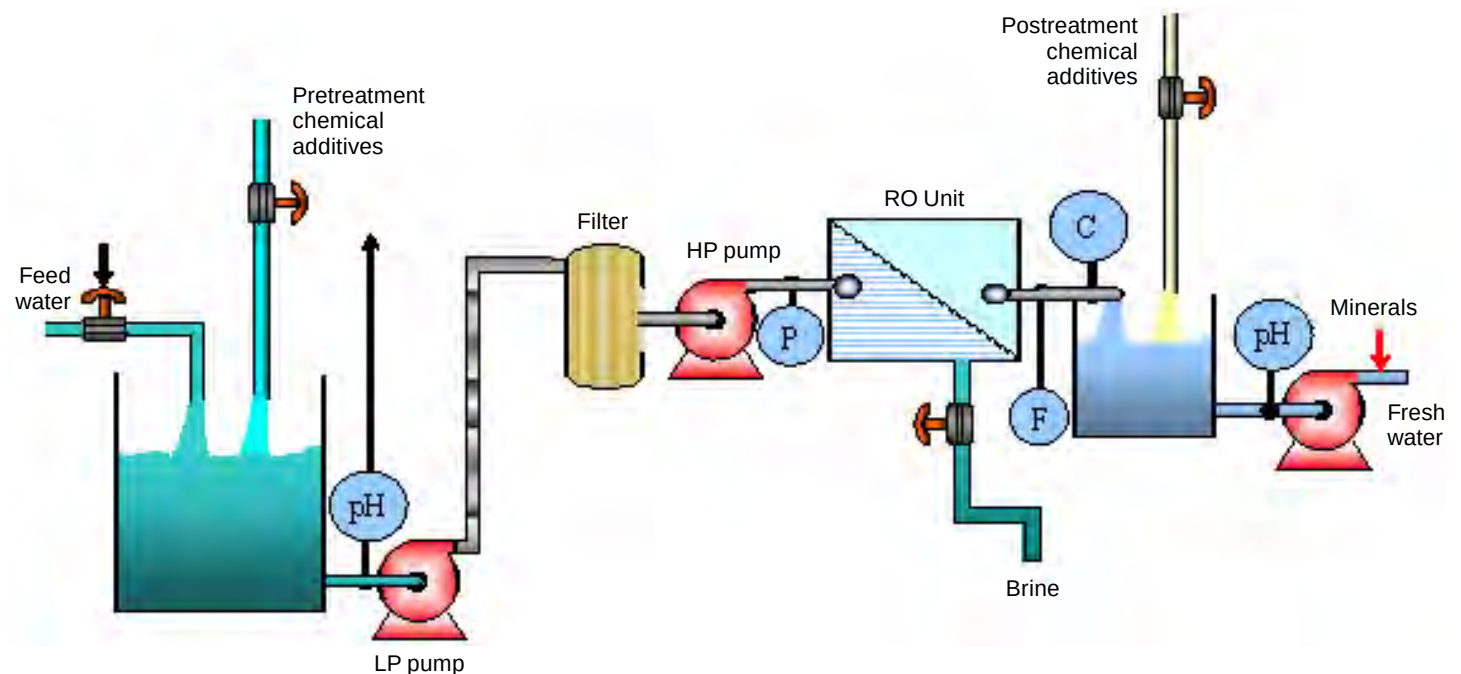


Figure 1. Typical reverse osmosis (RO) or raw water treatment plant.

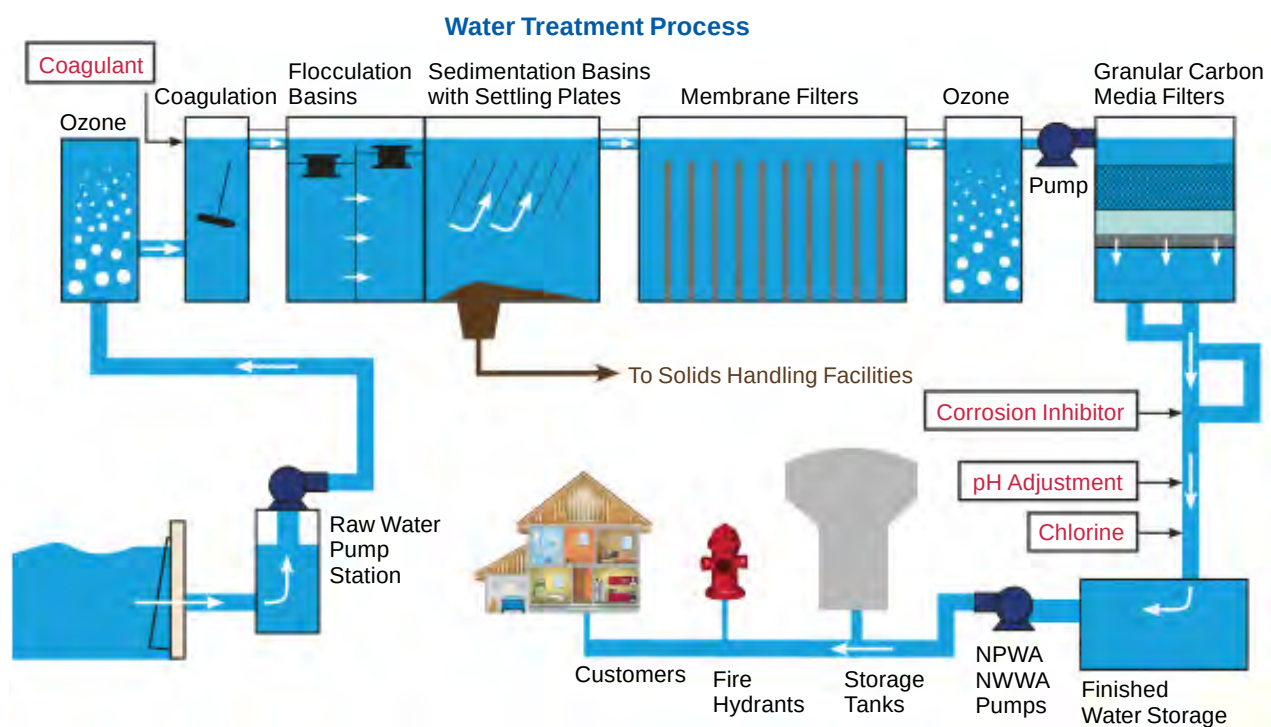


Figure 2. Typical reverse osmosis (RO) or raw water treatment plant.

Piping Material

Chlorine is a very aggressive oxidising agent which can, if not controlled, affect lead and copper pipes which are strictly regulated in drinking water. Realising this negative effect on lead and copper pipes, engineers started to specify non-metallic piping systems – such as PE100 for domestic networks and house connections and PPR and PE-RT inside the house. Nevertheless, these non-metallic pipes will eventually deteriorate if the residual chlorine contents and network operational conditions are not properly controlled.

Material Classification

While the most commonly referred standard for PE100 for water applications - ISO 4427 “Plastics piping systems - Polyethylene (PE) pipes and fittings for water supply” does not specify any type of chlorine requirements for PE100 in water networks, engineers and end users may refer to ASTM D3350 “Standard Specification for Polyethylene Plastics Pipe and Fittings Materials” – 2014 edition for more information if there is a need to evaluate the oxidative resistance of PE materials against chlorinated water. In this standard, the resistance of PE is tested to ASTM F2263.

Pipe Disinfectant Index (PDI)

To help specifiers and end-users judge the suitability of PE pipe to convey chlorinated water or to predict the expected lifetime of the pipe, the Plastic Pipe Institute (PPI) and Jana Laboratories have developed and normalised a Pipe Disinfectant Index (PDI) based on test results to ASTM F2263 and ASTM D3350 classification and other parameters to reflect the resistance of PE pipe material against disinfectants during the expected lifetime of the pipe in service. It was found that if $PDI \geq 1$, the expected service lifetime of the PE pipe can reach 50 years, and at least 100 years for a $PDI \geq 2$. (Reference: PPI – TN44/2015)

PDI Equation and Parameters

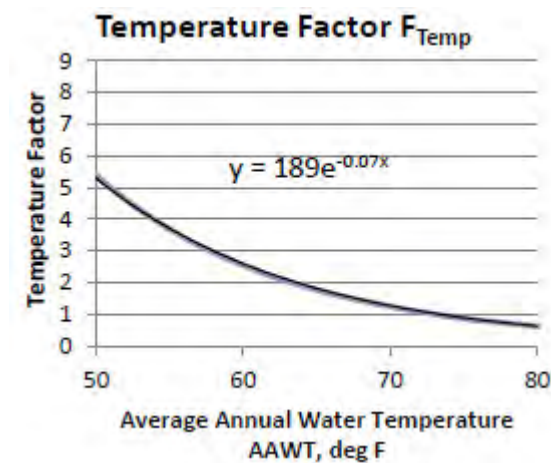
The equation to calculate PDI takes into consideration several factors affecting the resistance of PE material against chlorinated water. The product of all of these factors will give the PDI:

$$PDI = F_{Temp} \times F_{Pres} \times F_{WQ} \times F_{MAT} \times F_{Size}$$

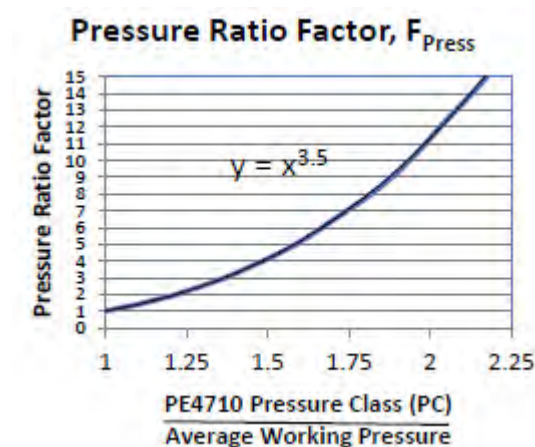
Categorisation	90°C (194°F) Test Temperature		
	Test Stress 2.48 MPa (360 psi) Time (h)	Test Stress 2.76 MPa (400 psi) Time (h)	Test Stress 3.10 MPa (450 psi) Time (h)
CC0	Unspecified	Unspecified	Unspecified
CC1	2700	1900	1200
CC2	7400	5100	3400
CC3	16 200	11100	7400

Table 1. Minimum Log Average Test Times for Oxidative Resistance Classification.

F_{Temp} : is the **temperature** factor based on average annual temperature. It is noticed that as the temperature increases, this factor decreases. For example, in UAE's desert environment, the average annual temperature at 1 meter buried depth is around 28°C to 29°C.



F_{Pres} : is the **pressure** factor normalised to the ratio of the pipe nominal pressure to average annual pressure. As the average working pressure goes below the nominal pressure of the pipe, this factor will boost the PDI. (Example: 12 bar working pressure in a PN16 pipe)



F_{wQ} : is the **water quality** factor which correlates to the average residual chlorine concentration and the average water pH.
Note: This table is based on hypochlorite as disinfectant, it does not address chlorine dioxide as a disinfectant.

		Average Water pH										
		6.5	6.75	7	7.25	7.5	7.75	8	8.25	8.5	8.75	9
Average Disinfection with Chlorine Residual (ppm)	0.5	2	2.1	2.3	3	3.9	6.1	10	10	10	10	10
	0.7	1.5	1.7	2	2.4	2.9	3.8	5	6.9	9.8	10	10
	1	1.2	1.3	1.5	1.7	2.1	2.6	3.4	4.6	6.1	8.9	10
	1.5	1	1.1	1.2	1.4	1.6	2	2.6	3.4	4.4	6.4	9.1
	2	0.8	1	1.1	1.2	1.4	1.8	2.3	3	3.9	5.7	8.2
	2.5	0.8	0.8	0.9	1.1	1.3	1.6	2	2.7	3.5	4.9	7.2
	3	0.8	0.8	0.9	1.1	1.3	1.5	1.9	2.5	3.2	4.4	6.4
	4	0.7	0.7	0.8	0.9	1.1	1.3	1.7	2.2	2.7	3.8	5.5

If the pH and residual Chlorine values are in-between the values shown above, select F_{wQ} by rounding the value residual chlorine and/or pH to the nearest tabulated number.

Table 2. Water Quality Factor - F_{wQ} .

F_{Mat} : is the **Material** factor based on ASTM D3350 classification. For CC3 classification, this factor is 1.0

Chlorine Category	Material Factor, F_{Mat}
CC1	0.16
CC2	0.45
CC3	1.0

Table 3. Pipe Material Factor - F_{Mat} .

F_{Size} : is the **pipe size** factor. As the pipe size increases, the internal surface area and hence the chlorine concentration per unit area decreases.

Normal Pipe Size	Size Factor, F_{Size}
4	1.0
>4"	Data Under Development; use 1.0 as a conservative value

Table 4. Pipe Size Factor - F_{Size} .

Conclusion

PE has been used in drinking water networks successfully for almost 5 decades in many parts of the world. The overwhelming results point to the fact that residual chlorine used in water networks today do not pose an issue to the PE pipe material. Where higher expected residual chlorine levels are present in a pipeline due to temporary operational issues, engineers may consider the framework above to evaluate the possible effects to their water networks.

A review of 3-layer PE (3LPE) pipe coating standards

by Chanchal Dasgupta

Introduction

Three layer PE coating is the most popular system for the corrosion protection of oil and gas pipelines in most parts of the world. It has also been adopted by several countries for coating of large diameter steel water pipelines as well.

A three layer PE (3LPE) coating consists of the following:

1. Fusion bonded epoxy (FBE) – applied to the steel pipe surface
2. MDPE grafted adhesive – Bonds FBE and PE layers
3. Black PE top coat (outer layer)

The major advantage of 3LPE coating over the other types of coating is that FBE has high barrier to permeation of gas / oxygen while PE has high barrier to moisture and provides excellent resistance against mechanical damage. Thereby, a combination of FBE and PE coating will have excellent resistance against oxygen & moisture permeation and good resistance to mechanical damage thus preventing the steel pipe from corroding.

Coating standards

Oil and gas pipelines are usually owned by large multinational or state owned companies involved in the exploration, refining, distribution of oil, gas and petrochemicals. The manufacturing and use of steel pipes for transporting oil and gas, as well as coating, welding and installation are well regulated in the industry and there are well established international, national or company standards covering all aspects of 3LPE corrosion coating of these pipelines.

Some of the major standards are:

- International Standard: ISO 21809-1 Covers LDPE (Class A), MDPE/HDPE (Class B)
- Canadian Standard: CAN CSA Z245.21-06 (3LPE)
- DIN 30670 (German), NFA 49-710/711 (French) and EN 10286 have been replaced by ISO 21809-1
- DNV-RP-F106 Factory Applied External Pipeline Coatings For Corrosion Control
- Australian Standards: AS/NZS 1518 extruded 3LPE. AS4321 Fusion Bonded 2LPE
- Shell DEP 31.40.30.31-Gen. 3LPE Coating
- Russian Standards: Gazprom, Transneft for 3LPE
- Total GS EP COR 220 (3LPE)
- China Standard: GB/T 23257-2017 (3LPE)
- UAE: ADCO, GASCO and ADMA standards for 3LPE
- India: EIL, MECON, ONGC, GSPL and Indian Oil 3LPE Standards

Standard ISO 21809-1: 2011

Scope: Petroleum and natural gas industries — External coatings for buried or submerged pipelines used in pipeline transportation systems:

Coating class	A	B	C
Top layer material	LPDE	MDPE/HDPE	PP
Design temperature ranges (°C)	-20 to +60	-40 to +80	-20 to +110

Table 1. Coating classes and design temperature ranges.

Part 1: Polyolefin coatings (3LPE and 3LPP)

The following fields of application are not covered by ISO 21809-1:

- All polyethylene-based coatings for steel pipes and fittings used for the conveyance and distribution of water and wastewater,
- All polyethylene-based coatings for steel pipes and fittings in distribution pipelines for gaseous and liquid media

For the above applications DIN 30670 is usually used.

Coating materials are often selected according to the **Operating temperature** given in the specification. But the ISO21809-1 definition of **Design temperature** includes more:

“Temperature range including maximum and minimum temperature likely to be reached during transport, handling, installation and operation”.

In many cases, the pipe may be coated and transported from a country in the arctic region for installation in a country in a tropical climate. In such cases the ambient environment of the arctic region should be included in the design temperature range. Typically, the **Design temperature** of a pipeline is considered as 10°C higher than the **Operating temperature**, which should be kept in mind. For 3LPE coating mainly class B material (MDPE/HDPE) is considered as class A material (LDPE) has become obsolete due to lower design temperature and operating properties. For higher design temperature greater than 80°C, polypropylene (PP) is often used although some 3LPE systems are capable of operating up to design temperatures of 90°C.

The applied coating requirements according to ISO21809-1 as follows:

Properties		Unit	Test Method	Class A	Class B	Class C
Continuity		–	Annex B	Free of defects and discontinuities, delaminations, separations and holidays		
Impact strength at 23°C ± 3°C		J/mm	Annex E	>5	>7	>10
Indentation	at 23°C ± 3°C	mm	Annex F	≤0,3	≤0,2	≤0,1
	at maximum design temperature			≤0,4	≤0,4	≤0,4
Elongation at break of PE/PP at 23°C ± 3°C		%	ISO 527-3	≥400	≥400	≥400
Peel strength		N/mm	Annex C C.5 (hanging mass)	≥10 at ≥23°C ≥2 at ≥60°C	≥15 at ≥23°C ≥3 at ≥80°C	≥25 at ≥23°C ≥4 at ≥90°C or at maximum operating temperature if above 90°C
Degree of cure of the epoxy (1st layer) ΔT _g		°C	Annex D	According to the manufacturer's specification and ≤5°C		
Product stability during application of the PE/PP top layer process		%	ISO 1133	≤20 ΔMFR for Classes A and B; ≤35 for Class C (virgin compounded granulate before application / coating after application of the same batch)		
Average radius of cathodic disbondment	at 23°C/28 d; -1,5V	mm	Annex H	≤7		
	at 65°C/24 h; -3,5V			≤7		
	Maximum operation temperature/28; -1,5V			≤15		
Flexibility		–	Annex I	No cracking at an angle of 2,0° per pipe diameter length		
Hot water immersion test		mm	Annex M	Average ≤2 and maximum ≤3		

Table 2. Properties of the applied coating.

In the new draft (FDIS ISO21809-1:2018), the following additional requirements / changes have been proposed for 3LPE:

- MFI and density of adhesive
- Compound density for black PE top coat
- Carbon black content and dispersion of black PE top coat
- UV and Thermal ageing for non-black PE top coat with limits of elongation at break
- The peel test requirement for 3LPE has been increased from 15 to 18N/mm at 23°C and from 3 to 5N/mm at 80°C
- Average radius of CD has been relaxed from <7mm to <5mm for 23°C/28 days and from <7mm to <4mm for 65°C/24 hours

DIN 30670 - 2012

This standard specifies the requirements for factory-applied three-layer extruded polyethylene-based coatings, and one or multi-layered sintered polyethylene-based coatings for

the corrosion protection of steel pipes and fittings. DIN EN ISO 21809-1 specifies requirements at international level for three-layer extruded polyethylene and polypropylene-based coatings for steel pipes for petroleum and natural gas pipeline transportation systems. The following fields of application are not covered by DIN EN ISO 21809-1, which are covered by DIN30670:

- All polyethylene-based coatings for steel pipes and fittings used for the conveyance and distribution of water and wastewater,
- All polyethylene-based coatings for steel pipes and fittings in distribution pipelines for gaseous and liquid media,
- Single and multi-layer sintered polyethylene-based coatings for steel pipes and fittings used for transport pipelines and distribution pipelines

CAN-CSA- Z 245.21-06

This standard covers the qualification, application, inspection, testing, handling, and storage of materials required for plant-applied polyethylene coating applied externally to pipe, whereby an adhesive is interposed between a bare or epoxy-primed pipe and the polyethylene. The coated pipe is primarily intended for buried or submerged service for oil or gas pipeline systems. This standard covers the following coating systems:

- (a) System A1: a coating that consists of an adhesive and a polyethylene outer sheath;
- (b) System A2: a coating that consists of an adhesive and a polyethylene outer sheath that has more stringent peel adhesion requirements than those for System A1
- (c) System B1: a coating that consists of a liquid or powdered epoxy primer, a polymeric adhesive, and a polyethylene outer sheath; and
- (d) System B2: a coating that consists of a powdered epoxy primer, a powdered copolymer adhesive, and a powdered polyethylene outer layer.

The Canadian standard allows lower thicknesses for stronger PE materials as shown in Table 3. Care should be taken while selecting PE Top coat for projects following Canadian Standard, as many HDPE grades do not reach Vicat softening point of 120°C as well as shore D hardness of 60. Also it is not explicitly specified for Canadian standard what are the limits of upper and lower design temperature for 3LPE coating as is mentioned in other standards.

Specified pipe OD, mm	Minimum coating thickness, mm				
	Primer thickness	Adhesive thickness	Polyethylene thickness		
System B1			LD or LLD	MD	HD
<100	0.12	0.10	1.80	1.00	0.85
100 - 250	0.12	0.10	2.00	1.15	1.00
>250 - 500	0.12	0.10	2.20	1.15	1.00
>500 - 800	0.12	0.10	2.50	1.15	1.00
>800	0.12	0.10	3.00	1.15	1.00

Table 3. Coating thickness requirements in CAN-CSA-Z 245.21-06.

SHELL SPECIFICATION, DEP 31.40.30.31 - Gen.

External polyethylene and polypropylene coating for line pipe (amendments / supplements to ISO 21809-1). DEP standard is intended for use by all parties involved in the design, procurement, manufacturing, coating and transport of polyethylene or polypropylene coated line pipe for oil and gas production, oil refineries, chemical plants, gas plants and marketing depots and installations. It is also applied in other similar facilities. DEP standard allows higher design / operating temperature if the material passes the requirements. The categories of temperature are as follows:

Operating temperature, °C
<20
20 to 60
60 to 80
>80

Table 4. Operating Temperature Categories in Shell DEP 31.40.30.31.

These are some of the main international standards that have been discussed in this issue. On a future issue, the company and national standards will be discussed.

The effects of carbon black distribution on the integrity of the butt fusion joints of PE pipes

by Suleyman Deveci

Introduction

Carbon black (CB) is added for UV light stability of PE pipes employed under direct sunlight and its efficiency depends on its concentration and dispersion. We reported on the influence of CB particle distribution on the mechanical properties of polyethylene pipes in BorPipe 45. It was revealed that areas with no CB, called 'windows', severely degraded the post-yield mechanical strength of polyethylene pipes. In this study, different butt-fusion joints were produced using pipes with different degrees of windows, alongside a (reference) pipe without windows, in order to determine the effect of CB inhomogeneity on the integrity of butt-fusion welds.

Tensile tests on waisted tensile specimens were used to assess the mechanical integrity, as it has been demonstrated that waisted specimens generate the best differentiations between different welding conditions. Optical and scanning electron microscopy (SEM) on tensile fracture surfaces of the butt-fusion joints showed that the windows lead to a degradation in mechanical performance and integrity.

Materials and Methods

The same set of pipes produced for the previous study were used in the current study. A description of the pipe samples is given in Table 1. The welding protocol is summarised in Table 2. The specimen shape and dimensions are depicted in Fig. 1. All tensile tests were repeated four times for each sample. All specimens were conditioned at 23°C and 50% relative humidity for at least 24h after specimen preparation. CB dispersion and distribution in the weld zone of pipe samples were studied by light microscopy analysis of 15µm-thick microtomed sections, prepared perpendicularly to the pipe axis (crossflow) at the weld interphase, as well as parallel to the pipe axis (inflow), covering the melt affected zone.

Sample No.	Sample Description	Material	Extrusion throughput
Sample 1	Reference Sample HE3490LS	Pre-compounded	115kg/h
Sample 2	High level of Windows	NPC + CBMB mixture	115kg/h
Sample 3	Medium level of Windows	NPC + CBMB mixture	95kg/h
Sample 4	Low level of Windows	NPC + CBMB mixture	70kg/h

Table 1. Description of pipe samples.

Welding protocol	Value	Unit
Welding temperature	210	°C
Welding pressure	0.15	N/mm ²
Preheating bead width	2.5	mm
Preheating time (zero pressure)	220	s
Changeover time	11	s
Pressure increase time	13	s
Cooling time	1800	s
Average bead width after welding	15	mm

Table 2. Butt fusion welding protocol.

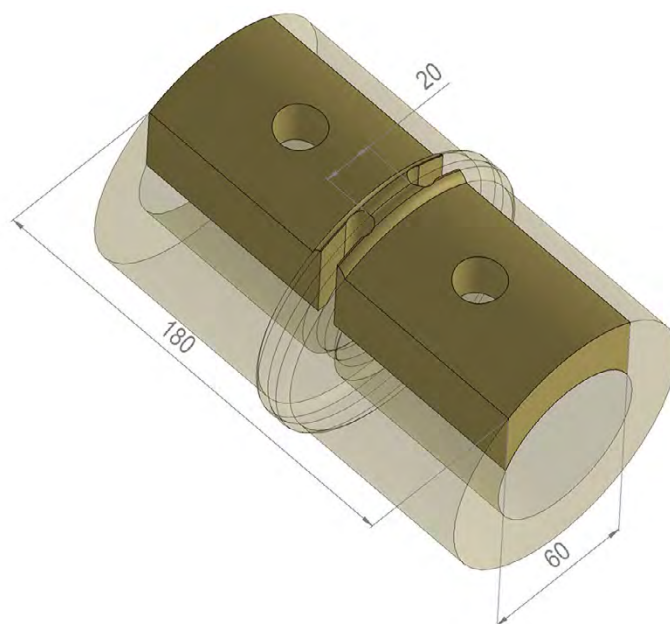


Figure 1. Preparation of tensile specimens from butt fusion welded pipes by CNC milling, measurements are in mm.

RESULTS

Figs. 2 and 3 show the effect of butt-fusion welding on CB distribution in the in-flow and cross-flow direction, respectively. It can be recalled from the previous work that CB dispersion in all four samples was good; that is, no CB agglomerates of size $>30\mu\text{m}$ were seen in any of the samples, and the welding process in no way affected the CB dispersion in the weld zone. However, the CB distribution in the weld zone is seen to be strongly dependent on the CB distribution or amount of windows present in the parent pipes. In Fig. 2, a clear interface cannot be differentiated in the weld zone for Sample 1, indicating homogeneity of material from both pipes during welding, resulting in a continuous morphology. On the other hand, for Samples 2, 3, and 4, a drastic change in morphology is seen at the weld zone, wherein the windows are seen to be flattened out in a region of about 1mm thickness. As a result, the alignment of the flow-fronts changes by 90° , and an interface region with smears perpendicular to that in the pipe can be seen. Apart from the formation of such a morphologically discontinuous interface at the weld zone for these samples, the impact of this flattening can be seen in the images given in Fig. 3.

For Sample 1, no windows are seen, as expected. For Samples 2, 3, and 4 (with windows), the joining and flattening process leads to a drastic increase in the size as well as number of windows. The effective number of windows in the weld zone does not appear to be a mere summation of windows from the two pipes used, but significantly more amplified, due to the contribution from flattening material from several hundreds of micrometers in depth in the weld zone. For Sample 2, the size of the largest window in the weld zone is about 5mm, whereas the most prominent windows in the parent pipe have been reported to be in the range of $200\text{--}300\mu\text{m}$ in our previous study. Similar observations can be seen for Samples 3 and 4 as well. The area fraction of windows was quantified according to the procedure explained in our previous work and is given in Table 3, together with the white area fraction of pipes calculated in the previous work, for comparative purposes.

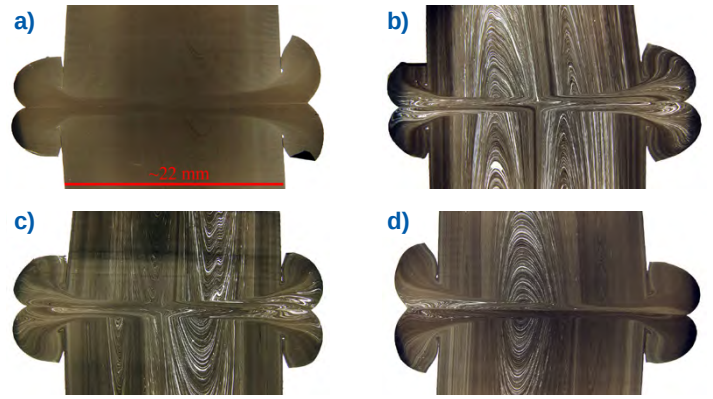


Figure 2: Microscopy images of $15\mu\text{m}$ sections (in-flow direction) taken from the weld zone: (a) Sample 1, (b) Sample 2, (c) Sample 3 and (d) Sample 4.

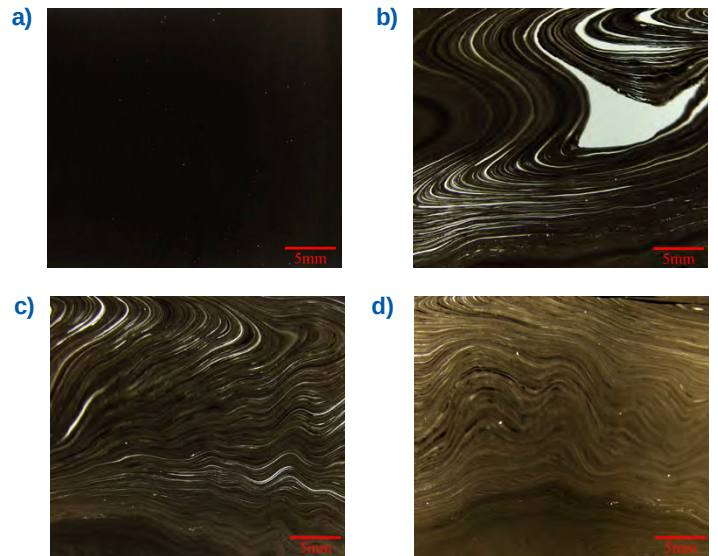


Figure 3: Microscopy images of $15\mu\text{m}$ sections (cross-flow direction) taken from the weld zone: (a) Sample 1, (b) Sample 2, (c) Sample 3 and (d) Sample 4.

It should be noted that welding beads are excluded from this quantification work. It was found that there was a significant difference in the homogeneity of the CB distribution for these samples between the in-flow and cross-flow directions. As expected, the white area fraction at the weld zone of Sample 1 was similar to that obtained for the pipe (close to 0%), for both the in-flow and cross-flow directions. For Sample 2, although the white area fraction at the pipe and weld zone were similar in the in-flow direction, a significant difference was observed between the in-flow and cross-flow directions. This is attributed to flattening of windows at the weld interphase during welding. The difference in white area fraction of Sample 3 in the in-flow and cross-flow directions was not significant, but the windows appeared to be more blurred at the interphase, indicating a certain level of shear mixing perpendicular to the pipe axis during welding. This phenomenon become clearer for Sample 4, where the distinct borders between the windows and matrix become more interfused and co-continuous. The width of the most prominent window increased dramatically for Sample 2, whereas that of Samples 3 and 4 remained the same as their respective parent pipe samples.

Fusion of two similar polymers is obtained by inter-diffusion of chains during intimate contact between the surfaces of the two constituents above their melting points. The strength of such a fusion joint under mechanical load is strongly defined by the inter-diffusion layer thickness. Intimate contact area, temperature, pressure, and time of intimate contact are the main process parameters that alter the inter-diffusion layer thickness and hence fusion weld quality. If the inter-diffusion process is not adequate, the main failure mechanism during tensile loading is simple chain pull-out, resulting in breakage at low strains and brittle-like fracture surfaces. Above the critical inter-diffusion layer thickness, the chains are entangled and form crazes upon tensile loading, increasing the strain at break and fracture energy, and producing ductile-like fracture surfaces. Any condition during the fusion welding process that prevents or reduces intimate contact (foreign particulate contaminations, or inclusions), or decreases the

chain diffusion process by any means, (inadequate fusion temperature, pressure, or contact time), will decrease the strength of the fusion interphase. Fracture energy obtained by tensile tests on waisted tensile specimens demonstrates the best differentiations between adequate and inadequate welding conditions. The tensile test results of waisted specimens from welded pipe samples are summarised in Table 4.

All specimens of Sample 1 showed ductile failure away from the fusion interphase after reaching a maxima at the yield point, following the typical stress-strain curve of butt-fusion joint tensile specimens. In contrast, all specimens of Sample 2 showed brittle-like failure at the fusion interphase before yielding. Two out of four specimens from Sample 3 and one out of four specimens from Sample 4 also showed brittle failure at the fusion interphase. Accordingly, the average energy required to break the specimens was found to be significantly different for the tested samples. Fig. 4 shows engineering stress-displacement curves for each specimen of Sample 1. A typical stress-displacement curve was obtained, with each specimen reaching a yield point and elongating to a complete break in ductile mode. A representative image of a fracture surface for Sample 1 is given in Fig. 8(a), showing complete ductile failure away from the fusion interphase. Fig. 5 shows engineering stress-displacement curves for each specimen of Sample 2. Each showed brittle failure at the butt-fusion interphase. A representative image of a fracture surface for Sample 2 is given in Fig. 9(a), where windows can be clearly seen at the fracture surfaces (marked with red arrows). A small area of micro ductility was also seen at the fracture surface (marked with red ellipses). Fig. 6 shows engineering stress-displacement curves for each specimen of Sample 3. Two out of four specimens failed in brittle mode at the butt-fusion interphase. Fig. 10(a) shows the failure interface after the brittle fracture of a specimen of Sample 3. The appearance is very similar to the brittle fracture surface of Sample 2, with more micro ductility zones (marked with red ellipse). The fracture surface of a specimen that failed in ductile mode is also given in Fig. 10(b), where a pattern

Parameter	Sample 1	Sample 2	Sample 3	Sample 4
% White area-In-flow direction-pipe	0.04	8.75	5.86	4.80
% White area-Cross-flow direction-pipe	0.04	9.86	5.78	4.29
% White area-In-flow-weld zone	0.04	9.03	5.26	3.31
% White area-Cross-flow-weld zone	0.04	21.90	4.39	0.96
Width of most prominent window-pipe (μm)	~0	200-300	80-140	50-100
Width of most prominent window-cross flow weld zone (μm)	~0	400-500	80-160	50-100
Visual rating according to ISO 18553 (from pipe) (μm)	A1-A2	C1-C2	C1	B-C1
Visual rating according to ISO 18553-cross flow weld zone (μm)	A1-A2	E	C2	B-C1

Table 3. Quantification of white areas in CB distribution images obtained from pipes and weld zones.

Samples		Maximum Stress MPa	Maximum displacement %	Work to break Nm	Brittle Failure %
Sample 1	Average	27.3	35.7	294.3	0%
	Std. Dev	0	4.1	35	
Sample 2	Average	24.7	13.0	93.9	100%
	Std. Dev	1.1	2.6	26.8	
Sample 3	Average	26.7	20.7	156	50%
	Std. Dev	0.9	8.8	70.4	
Sample 4	Average	26.7	31.5	255.4	25%
	Std. Dev	0.3	6.9	48.5	

Table 4: Tensile test results of welded pipe samples.

of macro ductility is observed to cover the whole fracture surface. Fig. 7 shows engineering stress-displacement curves for each specimen of Sample 4. One of the specimens failed in brittle mode at the butt-fusion interphase, while the other three reached a yield point and elongated to a ductile fracture. The brittle fracture surface of Sample 4 is shown in Fig. 11(a), with a large area of micro ductility zones in the middle of the weld surface.

It appears that the amount of micro ductility observed on a brittle fracture surface correlates well with the homogeneity of the material, i.e. the pattern of windows in the cross-flow direction (Fig. 3). A homogenous structure leads to complete ductile failure with macroscopic ductility across the whole fracture surface. In contrast, an inhomogeneous morphology leads to brittle fracture at the weld interphase, with some level of micro ductility depending on how the windows interfuse into the matrix following shear flow during welding. As the level of interfusion increases, the amount of micro ductility also increases. Such micro ductility zones were not observed at the fracture surfaces of tensile elongated samples prepared from parent pipes in our earlier study. Taking this into consideration, one can conclude that the patterns of micro ductility observed at brittle fracture surfaces of welded samples most probably originate from the inhomogeneous but co-continuous morphology of windows that are interfused into the matrix due to the shearing action at the weld interphase. A representative image of a tensile fracture surface of the butt-fusion region for Sample 1 is given in Fig. 8(a), wherein a ductile failure is seen. An enlarged view of the ductile fracture surface is shown in Fig. 8(b). It should be noted that the fracture occurred away from butt-fusion interphase. Multiple points of fracture initiation can be seen, from inherently present stress concentration points (i.e. micro voids, which are introduced due to nature of welding processes). This resulted in the presence of multiple ductile failure domains, with lengths ranging from 0.5mm-22mm (the entire wall thickness) as seen in Fig. 8(a). Two different magnification SEM images of the weld fractured specimen of Sample 1 are shown in Fig. 8(c) and (d). Closely packed crazes with ductile tear to fracture can be seen, even in the regions between the ductile domains, as demonstrated in the lower magnification

image. The overall morphology clearly signifies a ductile failure mode. The morphology at higher magnification is comparable to that of zone B in the high speed tensile fractured surface reported earlier.

Fig. 9(a) shows the full fracture surface of the butt-fusion region for Sample 2, and Fig. 9(b) shows a higher magnification image. Widely varying fracture morphologies can be readily seen on the fracture surface, which occurred exactly at the butt-fusion interphase. The presence of a large number of windows is clear, and the bigger windows are observable to the unaided eye (marked with red arrows). The overall fracture mechanics of this sample are quite complex due to the different fracture behaviours of the various morphologies, unlike typical, very flat brittle fracture behaviour due to lack of fusion, contamination, or cold welds. However, on a macroscopic scale the fracture surface is quite flat, and was located at the butt-fusion interphase. With the support of stress-displacement curves (Fig. 5), it can be concluded that the failure mode is predominantly brittle, with hardly any regions showing macroscopic ductility. The global crack velocity was visually observed to be much faster for specimens of Sample 2, as evidenced by the very sharp decrease of load at load-displacement curves (Fig. 5).

However, crack growth and formation of fracture surface topology in inhomogeneous materials is quite a complex phenomenon. Once the crack is initiated with an intensified stress at the crack tip, crack front grows and changes direction towards where the material yield stress is lower. As the crack front changes its direction based on the material's elasticity, regions with different fracture topologies are generated. The local crack velocity at these separate regions is supposed to be related to material's elasticity. The crack would propagate faster at regions where ductile fibrillations were not observed at all as a result of strain energy released to create flatter surface.

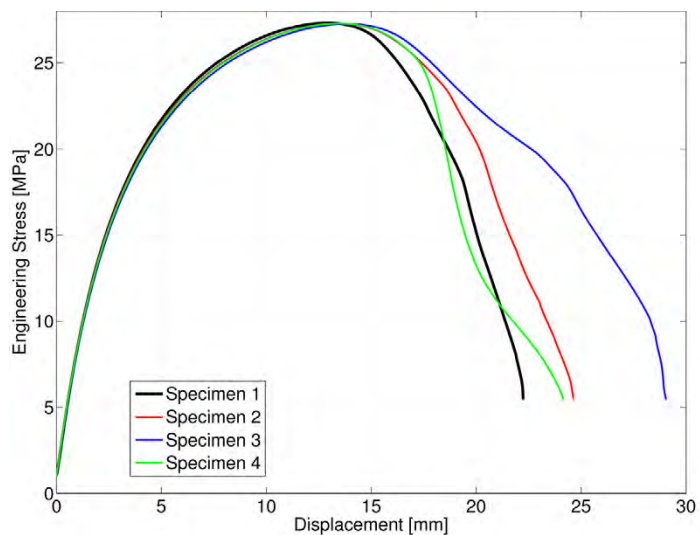


Figure 4. Engineering stress-displacement curves of welded pipe specimens (Sample 1) elongated to fracture at a test speed of 5mm/min.

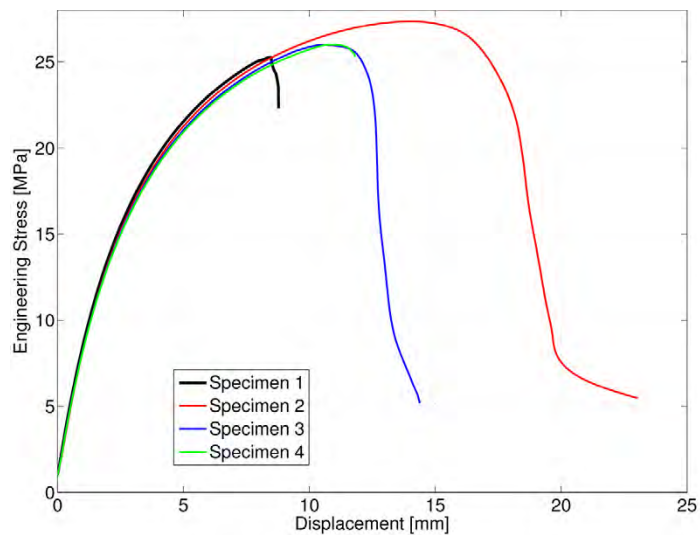


Figure 6: Engineering stress-displacement curves of welded pipe specimens (Sample 3) elongated to fracture at a test speed of 5mm/min.

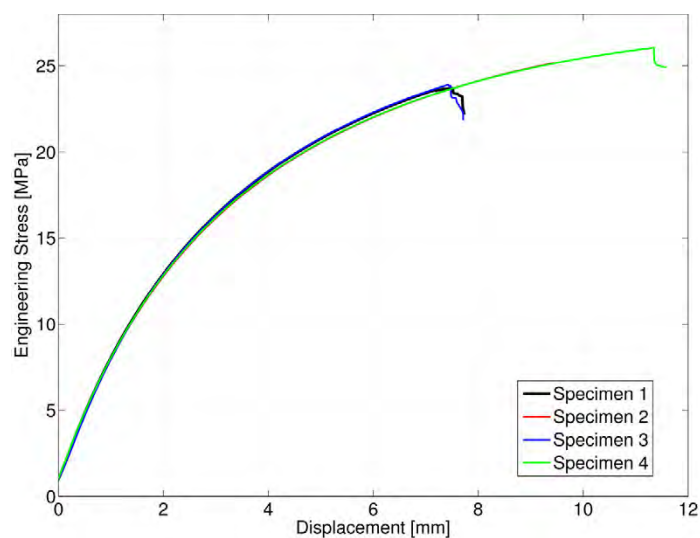


Figure 5. Engineering stress-displacement curves of welded pipe specimens (Sample 2) elongated to fracture at a test speed of 5mm/min.

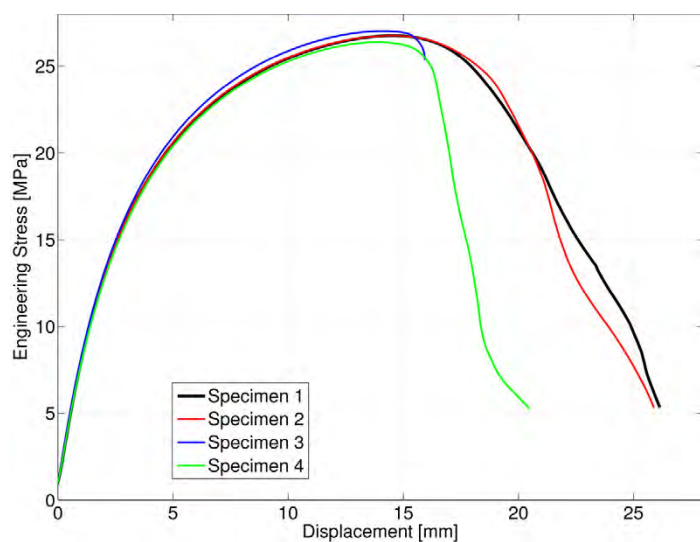


Figure 7: Engineering stress-displacement curves of welded pipe specimens (Sample 4) elongated to fracture at a test speed of 5mm/min.

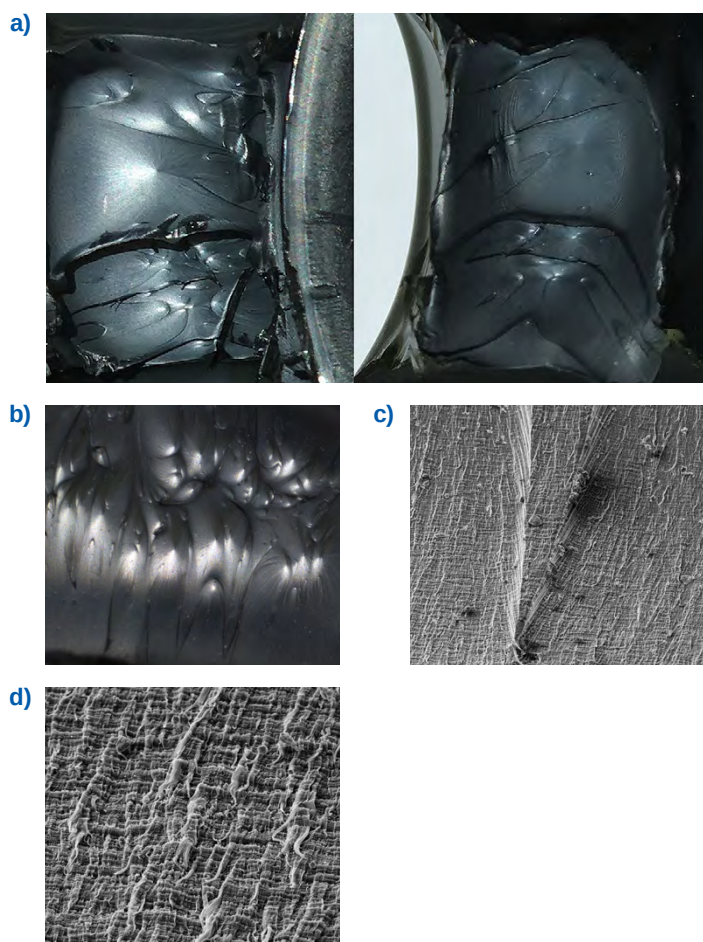


Figure 8: (a) Digital macro-photography image of full fracture surface of butt fused Sample 1 Specimen 1, (b) low magnification microscopy image of fracture surface of butt fused Sample 1, (c)-(d) SEM images of weld fractured Sample 1, taken at two different magnifications.

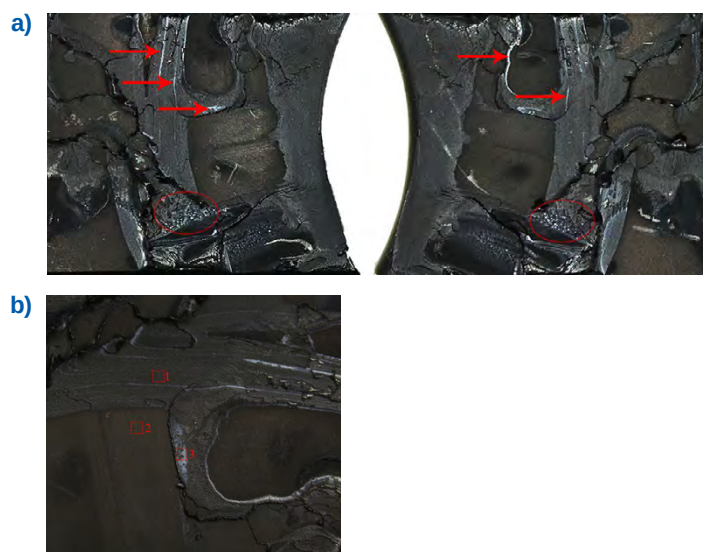


Figure 9: (a) Digital macro-photography image of full fracture surface of butt fused Sample 2 Specimen 1, (b) Low magnification microscopy image of fracture surface of butt fused Sample 2

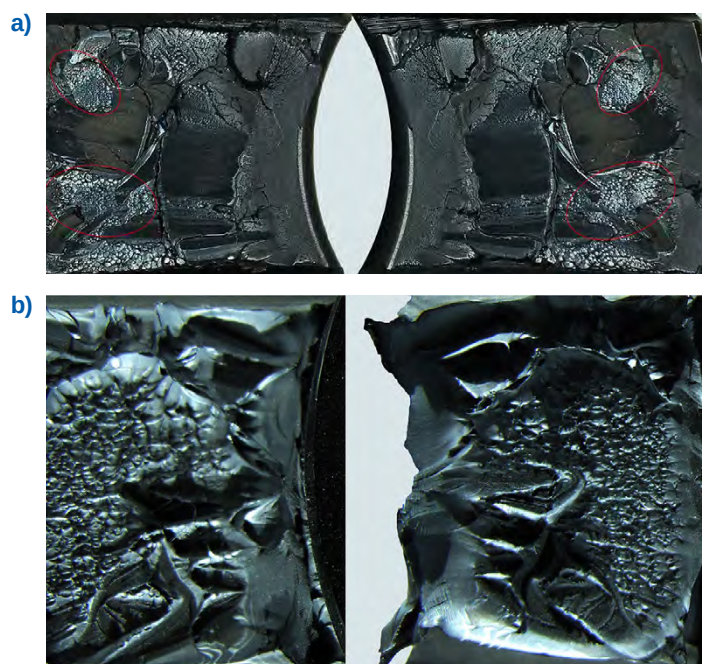


Figure 10: (a) Digital macro-photography image of brittle fracture surface of Sample 3 Specimen 1, (b) Digital macro-photography image of ductile fracture surface of Sample 3 Specimen 3.



Figure 11: (a) Digital macro-photography image of full fracture surface of butt fused Sample 4 Specimen 3.

Conclusions

In this study, four PE pipes made of the same material with different CB distributions were produced by single screw extrusion. These pipes were butt-fused using the same welding parameters. Tensile specimens milled from the joints were elongated to fracture, and the fracture surfaces were investigated with microscopy techniques. In samples with inhomogeneous CB distribution (windows), welding tends to create a morphologically discontinuous interface with re-alignment of the flow-fronts perpendicularly to the flow direction. This re-alignment, along with flattening of the material during joining, leads to a dramatic increase in the size as well as number of windows. In effect, the observed structure has a highly co-continuous morphology of two different phases, and the strength or integrity of the material is highly dependent of the interface adhesion between them.

In our previous study, poor interfacial strength was demonstrated between the black material and the windows, and therefore an increased level of co-continuousness was expected to further weaken the material performance. The effect of these morphological changes as a function of CB distribution correlate well to the failure modes seen in the tensile tested samples after butt-fusion welding. On the other hand, the weld zone of pre-compounded material demonstrated a continuous morphology, without any notable evidence of interface formation at the weld zone, which is accordingly reflected in the tensile test results. SEM analysis of the weld fracture surface showed insight into the fracture behaviour of PE material with windows.

Aside from associated changes in the crystallinity and molecular orientations perpendicular to the load axis, the welding process causes negligible change to the macro

ductility of the precompounded homogenous material itself. For inhomogeneous materials, regions with large windows lead to complete brittle failure, whereas regions with visibly co-continuous distribution lead to predominantly brittle failure, with micro ductility in some areas. Of considerable interest is the brittle failure mode of the black regions in samples without windows observable by light microscopy, wherein a new phenomenon of discontinuous, micron-scale ductility pattern (micro ductility) is achieved, which is far from the mm-scale continuous bulk ductility (macro ductility) exhibited by homogenous material. It can therefore be inferred that fine-scale windows, at size ranges that cannot be detected by light microscopy techniques, may still have a dominant role in the material performance, as is evident from tensile testing results.

Finally, it was experimentally observed that windows of sizes less than 100µm, which do not cause significant mechanical degradation in the parent pipes, can transform to windows of much greater size at the butt-fusion interphase due to melt shearing perpendicular to the pipe axis, and can easily cause severe degradation in mechanical properties and decrease the overall integrity of pipelines. Therefore, it is essential to achieve a very homogenous CB dispersion and distribution in PE to ensure it is free from windows, not only for resistance against photochemical degradation but also to improve the overall mechanical integrity of PE pipelines.

Important Note

The overall conclusion from this two part study shows that using PE100 compounds ensures that the pipe will have the optimum properties and joint strength.

Successful completion of drainage rehabilitation projects with Krah Pipes in the Philippines

by Jeneleen Lansangan (Krah Manila) & KH Lou



Boracay locals demonstrating the Bayanihan spirit (Communal unity & cooperation to achieve a common goal) during the installation of three pre-jointed DN/ID 1500mm segments.

Introduction

The Philippines is a group of over 7,000 islands in the western Pacific Ocean between China and Indonesia and home to over 100 million people. The islands are grouped into three major geographical areas Luzon, Visayas and Mindanao and the capital city Manila is one of the most densely populated areas in the world. The Philippines is located on the “Pacific Ring of Fire” and the island group experiences many earthquakes and typhoons and severe storms. An efficient and robust drainage system is therefore essential and the local branch of plastic drainage specialist Krah has been working hard to establish their products with the local drainage engineers.

Boracay Island Rehabilitation Phase 1

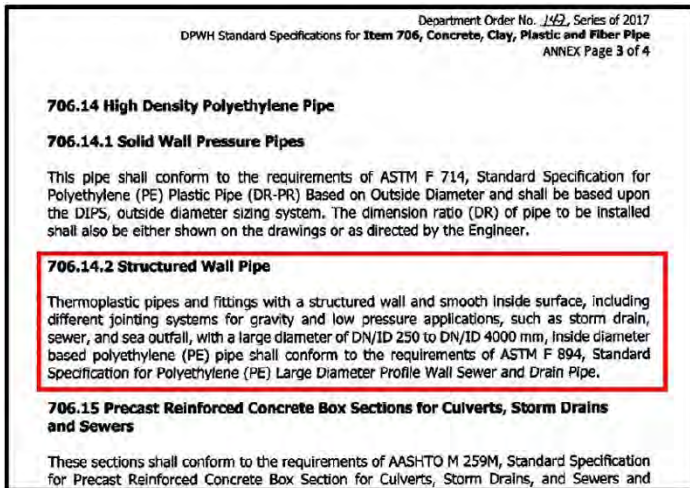
The Krah system was initially approved by the Bureau of Research and Standards (BRS) of the Philippines in December 2017. This enabled the product to be entered in the standards of the Department of Public Works and Highways (DPWH) who are responsible for highway drainage and the development of the country's infrastructure. Once accredited the products can be used in any of the DPWH projects in the Philippines.

The initial project was on Boracay Island in November 2018 comprised 7.5km of Krah pipe in diameters DN/ID 1,000-1,500mm, replacing the reinforced concrete box culvert drainage systems usually used. The installation was successfully completed in just 4 months which convinced the DPWH of the benefit of the system and proved to be a breakthrough for various other projects throughout the Philippines.

Boracay Rehabilitation Phase 2

In the first quarter of 2019, under the Tourism and Infrastructure Enterprise Zone Authority (TIEZA) with the support of Department of Environment and Natural Resources (DENR) and DPWH, the continuation of Boracay Island's rehabilitation commenced. Krah Pipes structured wall pipes of diameter DN/ID 1800mm, the largest diameter yet supplied and manufactured in Krah Pipes Manila plant, was installed with a total length of 1.4km along the secondary roads of

the island that was originally designed by the agency as box culverts for drainage outfall. The general contractor's site engineer, Mr. James Dalupang stated that "With the original box culvert design, the installation will be too long". With the use of Krah pipes, they achieved an output of 12 metres per hour which is three times the installation speed compared to concrete box culverts.



Department Order 147, 2017.



Recently repaved roads in Boracay with Krah drainage pipes on both sides.



Electrofusion jointing off-trench of a DN/ID 1800mm along Barangay Balagbag in Boracay Island.

Davao City Pilot Project

Davao City is known as the main trade, commerce and industry hub in Mindanao and the durian capital of the Philippines. It is also the hometown of the country's incumbent president, Honourable Rodrigo Roa Duterte. With the support of Regional Director, Engr. Allan Borromeo of DPWH Region XI together with Director Reynaldo Tagudando of BRS, Krah pipes were first installed in Mindanao for a drainage system pilot project in June 2019 along Damaso Suazo St., Davao City. DN/ID 1000mm pipes were installed with a total length of 200 m that was completed in a span of 8 days. With the successful completion of the pilot project, the DPWH Region XI selected Krah pipes for:

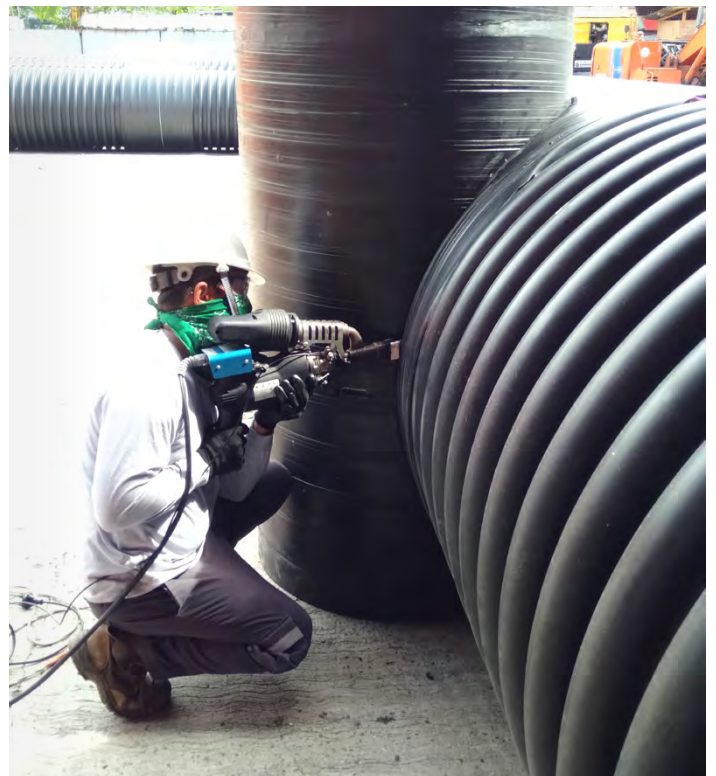
- 4km of DN/ID 800-1600mm pipes for the Davao Coastal Road in Davao City
- 21km DN/ID 2000mm for the Tagum Coastal Road in the province of Davao Del Norte
- 1km of DN/ID 3000mm for the La Verna Flood control project all of which will be implemented in 2019.



Quality control inspection by DPWH Region XI personnel.



Laying of DN/ID 1000mm along Damaso St. Davao City using light equipment.



Welding of a tangential manhole of DN/ID 800mm to Krah pipe DN/ID 1000mm.



Supervision of pipe laying by Krah engineer.

Rehabilitation with Krah pipes in Metro Manila

Alongside Davao City, Manila, the country's capital with an area of about 38km², one of the oldest cities in the world and in 2018 was named the most densely populated city in the world, has also implemented a flood control project using Krah pipes with a diameter of DN/ID 1200mm that were installed along Zapote Road, Las Piñas City in Metro Manila. It was implemented by DPWH District Engineers office of Muntinlupa and Las Piñas City. Zapote Road is a busy highway connecting to Cavite Expressway that leads to Ninoy Aquino International Airport and various major highways like CP Garcia and South Luzon Expressway.

Due to its location, the rehabilitation of the existing pipelines with new concrete pipes was expected to result in severe congestion and thus the local stakeholders raised their concerns. However, these concerns were mitigated by substituting the concrete pipes with Krah HDPE pipes. With Krah pipes, the installation was significantly simplified, enabling the installation to be completed more rapidly whilst providing a long lifespan after installation. The jointing of pipes via electrofusion was done along the trench beside traffic and the project was completed in less than a month.

With the continuous support of DPWH and its regional and district implementing offices, more drainage and flood control projects are being designed with Krah structured wall pipes. Together with the commitment to be a solution provider, Krah aims to render its cooperation to the government's initiatives and support the President's "Build, Build, Build" program for a better Philippines!



Electrofusion of the pipe sections.

Steel pipe coating seminar jointly organised with the Singapore Water Association

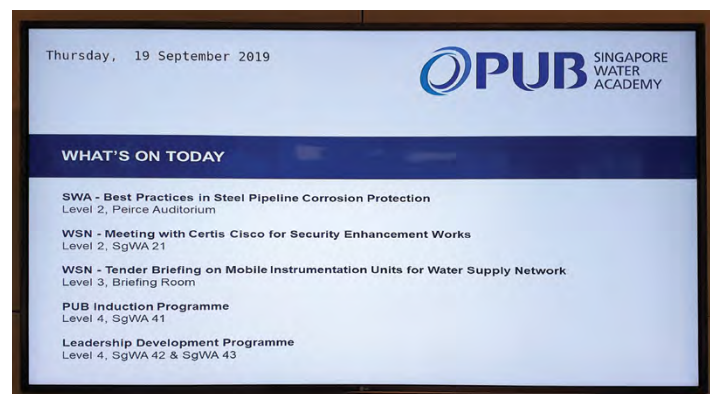


Borouge and the Singapore Water Association (SWA) jointly organised a seminar on steel pipeline coating with 3-layer polyethylene (3LPE) featuring our Borcoat HE3450 and HE3450H materials. It was targeted at the ageing steel water pipelines still used in Singapore that are already leaking due to corrosion.

This seminar was primarily organised to share the latest developments in steel pipeline corrosion protection with engineers from the Singapore Public Utilities Board (PUB). PUB manages the water supply and distribution in the country.

Chanchal Dasgupta delivered two presentations covering:

- An overview of all the typical steel pipe coating materials used in the oil and gas, industrial and water industry with a detailed comparison of their properties and benefits
- Case studies of 3LPE coating for water pipeline projects across MEA, India and Asia using our Borcoat materials and how this can be relevant for Singapore PUB



The event was held at the PUB WaterHub which also houses a water treatment plant and the PUB R&D technical group.



The Borouge and SWA team.

Almost 60 people attended from the water value chain such as consultants, construction contractors and equipment suppliers. Almost 33 engineers & managers from Singapore PUB, SP Group and PSA Corporation also attended. Borouge Malaysian customer WASCO was also present.

“The seminar was a great success because it allowed many engineers in PUB to share the issues they faced with the ageing steel pipelines and evaluate 3LPE as a potential solution”, said Vivien Seong, Executive Director of SWA.



Chanchal Dasgupta gave a detailed overview of the different types of PO pipeline coating and stressed the benefits of the Borcoat system.



The participants had the opportunity to network with the Borouge team during the coffee breaks.

PE100+ Association and Borouge promote PE100 compounds at UWT China 2019

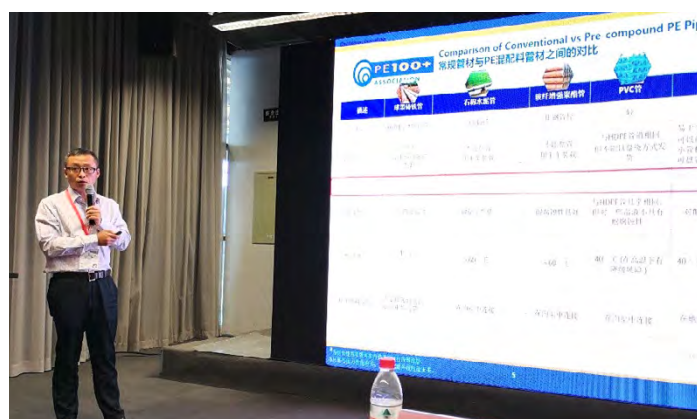
Shanghai International Urban & Building Water Trade Fair and Conference (UWT) China 2019 is an annual water industry event for professionals in the water supply and drainage fields. The key themes this year are “municipal water supply & drainage, building water supply & drainage, municipal pipe network, smart water and township sewage reform”. PE100+ Association representatives from Borouge, PetroChina, Basell and SCG came together at UWT China 2019 to promote PE100 compounds for pressure water pipeline. Dr. Dongyu Fang, Borouge Marketing Manager Infrastructure APAC, said “Representatives from PE100+ Association came together to promote PE100 compounds to show our joint view that these materials offer the best advantage for water pressure pipes. This also showed the PE100+ members' commitment to provide quality PE compounds to improve water security and reduce water leakage.”

Dr. Zhu Jun from PetroChina represented the PE100+ Association and presented the benefits of PE100 compounds for drinking water pipes at a water pipeline network operation and leakage control seminar, which was running in parallel with UWT China 2019. According to Dr. Jun, “Members from PE100+ Association all agreed that it is important to increase awareness of the concept of PE100 compounds in the water pipe market so that GB/T13663.1:2017, GB/T13663.2:2018, and GB/T13663.3:2018 can be successfully implemented.”

Over 150 participants from the water value chain attended the water pipeline network operation and leakage control seminar. In the seminar, Jinghui Li, Borouge AMM Utilities Asia North, presented in-depth technical evidence to demonstrate the advantages of PE100 compounds through case studies of Borouge materials used in projects such as the Shanghai Disney project, Dubai Palm Island project and Beijing Zhongguancun project, etc. This generated strong interests from participants and further cooperation is under discussion.



PE100+ Association representatives promoting PE100 compounds at UWT 2019.



Dr. Zhu Jun from PetroChina represented PE100+ Association and presented the benefits of PE100 compounds.



Mr. Li Jinghui presenting case studies of projects recently implemented.

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