WHY REPLACE EXISTING PIPELINES WHEN THEY CAN BE REHABILITATED USING POLYETHYLENE PIPES AND FITTINGS

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ABSTRACT

During the lifetime of a pipeline the point is reached where the cost of water loss, leakage management, maintenance and repair works, together with the poor service to the customer justifies its replacement or rehabilitation. Trenchless rehabilitation techniques can have a lower cost and cause substantially less disruption to existing assets and the general population than conventional 'open cut' techniques.

As trenchless technology has developed and increased in use, so has the use of polyethylene pipes in applications such as slip lining, close fit lining and pipe bursting. The majority of pipeline renovation and replacement techniques now use polyethylene as their principal pipe material and the techniques have been developed to the point where they have been used to rehabilitate pipelines of up to 1,400mm internal diameter.

This presentation will give an introduction to the different methods by which water pipelines can be rehabilitated using polyethylene pipes and liners through the use of a variety of trenchless technology techniques. It shall also explain how Engineers and other technical staff working for water utilities can use the standard ISO 11295 to help identify and specify the most appropriate technique for their particular situation.

The original polyethylene pipe materials were not intended for such applications and so the greater use of polyethylene in trenchless technology has been a key driver in the development of tougher materials. One development has been PE100 materials that have a high resistance to slow crack growth through the wall of the pipes. Such materials are referred to as HSCR PE100 and PE100-RC. The presentation will explain how slow crack growth can be initiated by the use of trenchless technology applications and how the new generation of PE100 materials resist the growth of cracks through the pipe wall.

1 INTRODUCTION

Underground pipelines are the arteries which enable modern cities to function, providing water for drinking, cooking and washing, gas for cooking and heating and taking away the wastewater to the treatment plants. Like all structures these pipes deteriorate with time and ultimately require rehabilitation or replacement. Since most cites grow outwards from the centre the oldest pipes are likely to be in the congested central area making replacement extremely costly and disruptive.

For example, in 2000 a survey of the water pipes in the centre of the city of London showed that over half these pipes were over 100 years old and a third over 150 years old(1). Many of these old cast iron pipes were heavily corroded and Thames Water were repairing up to 200 leaks every day. They therefore decided that a major system overhaul was necessary especially as the population is expected to grow to 8.1 million by 2016.

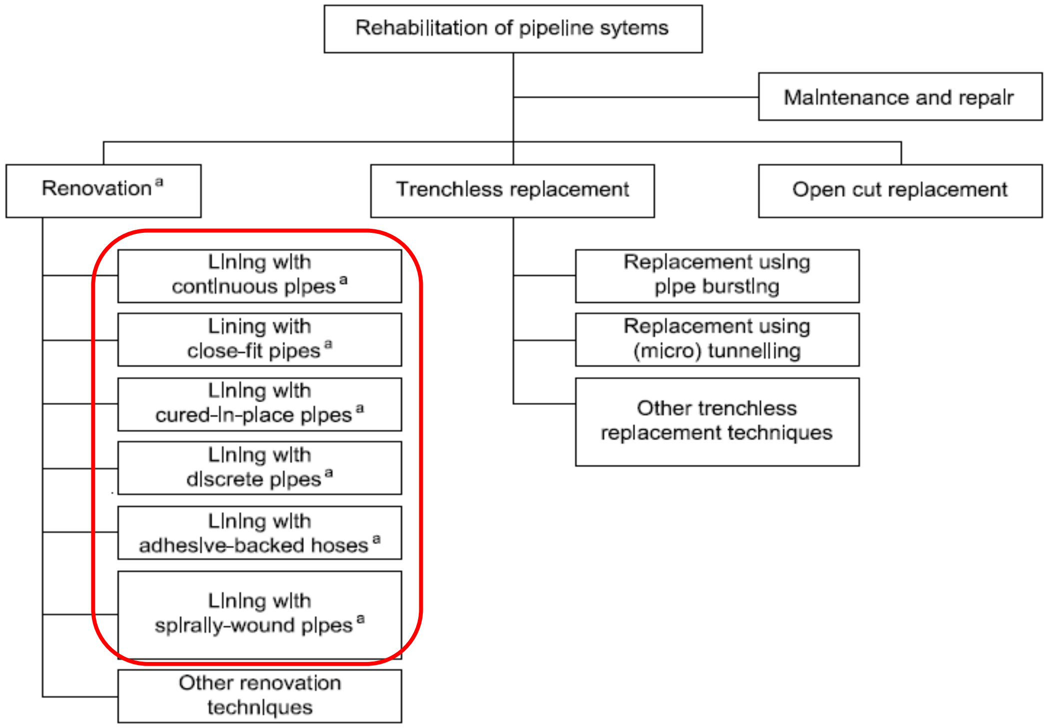
Therefore in 2005 they started a major replacement programme using PE100 pipes for the mains and PE80 pipes for the service connections. To reduce costs and disruption to city life the engineers were asked to consider using trenchless technology wherever possible and ultimately 54% of the work was carried out in this way (using mainly insertion and pipe bursting). In 2010 the programme was extended and overall over 17,000 km of water mains have so far been renovated or replaced, reducing operational costs and water losses by one third.

Many other cities around the world are now following the same philosophy and looking at using their existing pipelines, together with trenchless technology wherever practical to renovate their old gas, water and sewage networks. Also in industrial pipework the insertion of a PE liner is also used to reduce the internal corrosion of steel pipes or increase the resistance to abrasion from mining slurries.

2 REHABILITATION STANDARDS USING PE PIPES

Several different trenchless techniques have been developed over the last 30 years to solve different situations. Many of the systems are patented by the installation companies using a wide range of terminology. This has created some confusion and complicated the process of selecting and specifying the most appropriate method. Fortunately most of these techniques have now been catalogued in ISO 11295[(2)], which also classifies each of them and provides a simple description of each method.

Figure 1. The highlighted box identifies the trenchless techniques that are covered in ISO 11295.



The different techniques are classified in families as shown in figure 1. The family is a group of renovation techniques that are considered to have common characteristics for standardisation purposes. For example, lining with close fit pipes includes pipes that are reduced in diameter by passing them through a die or rollers prior to insertion and pipes that are formed into a U or C shape.

For pressure pipe lining a new classification concept with structural classes A-D has also been adopted as shown in figure 2. A loose or a close fit lining can either be fully structural or semi structural depending upon the SDR chosen for the PE lining pipe and the future operational pressure for the system.

An independent pressure pipe liner as shown in figure 2 is defined as a liner capable on its own of resisting without failure all applicable internal loads throughout its design life, whilst an interactive pressure pipe liner relies on the existing pipeline for some measure of radial support in order to resist without failure all applicable internal loads throughout its design life.

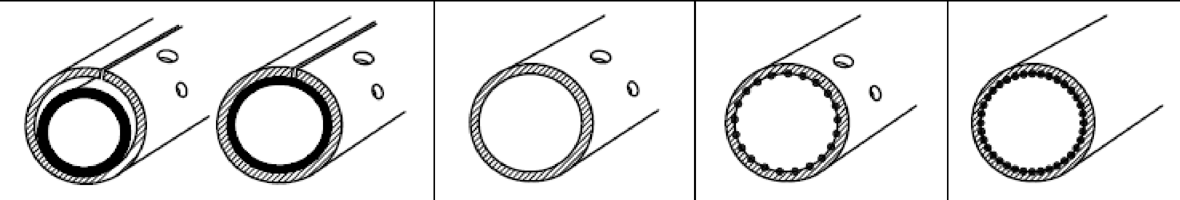
<table>
<tr><th colspan="2">Class A</th><th>Class B</th><th>Class C</th><th>Class D</th></tr>
<tr><td colspan="5"></td></tr>
<tr><td colspan="2">loose-fit close-fit</td><td>inherent ring stiffness</td><td>relies on adhesion</td><td>relies on adhesion</td></tr>
<tr><td colspan="2">Independent</td><td colspan="3">Interactive</td></tr>
<tr><td colspan="2">Fully structural</td><td colspan="2">Semi-structural</td><td>Non-structural</td></tr>
<tr><td>Lining with continuous pipes</td><td colspan="3"></td><td rowspan="4">This International Standard is not applicable</td></tr>
<tr><td rowspan="3"></td><td colspan="2">Lining with close-fit pipes</td><td></td></tr>
<tr><td colspan="3">Lining with cured-in-place pipes</td></tr>
<tr><td colspan="2"></td><td>Lining with adhesive-backed hoses</td></tr>
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Figure 2. Schematic representations of structural classes of pressure pipe liners.

In addition a suite of twelve ISO product standards have been published for the different technique families and the different application areas: non-pressure sewer, pressurised sewer, water supply and gas supply under pressure. In these product standards, tools are provided to demonstrate and assure the long term quality of the liners. In order to review performance in the installed state two distinct stages are recognised: stage M – as manufactured and stage I – as installed. System manufacturers should carry out tests to ensure that products conform to all requirements for the characteristic given in the respective standard.

For example, ISO 11298[3] covers plastic pipe systems for renovation of underground water supply networks. The standard is in several parts, with ISO 11298 Part 1 defining the general requirements common to all relevant renovation techniques and Part 3 the specific requirements for lining with close fit pipes. Therefore by selecting the appropriate parts of the standard the Engineer will be able to clearly define the requirements for his PE lining pipe for the chosen trenchless technique.

3 A NEW GENERATION PE100 MATERIALS OPTIMISES PIPE LIFETIME

Polyethylene (PE) pipes have a long and successful history of being used to rehabilitate old pipeline networks through the use of trenchless technology, in order to reduce gas and water leakage levels and to install new underground systems. However whilst attractive from an economic and environmental viewpoint trenchless installation can be demanding on the pipe by introducing gouges and scores into the outside surface of the pipe which can later develop into cracks. In response polymer suppliers have developed High Stress Crack Resistant (HSCR) PE100 materials which have the ability to cope with this surface damage by dramatically reducing the rate at which any cracks can initiate and grow through the pipe wall, so giving engineers the necessary confidence to specify trenchless technology with PE pipes in the most challenging circumstances.

Whilst most standard PE100 materials use butane as a co-monomer, the majority of HSCR PE100 materials, including those produced by Borouge, use hexene as the co-monomer. Under the correct polymerisation conditions this leads to a PE molecular structure that has a greater number of longer side branches. This results in tie molecules that have a much greater resistance to the propagation of the crack through the pipe wall, so slowing down both the initiation and growth of the crack.

In international standards (ISO 4427 and ISO 4437) PE100 pipes are required to have a minimum time before failure of 500 hours in the notched pipe test (NPT). Whilst there is not yet an international standard for HSCR PE100 polyethylene material producers generally aim to achieve failure times in excess of 8,760 hours (1 year), as is explained in the following section of this paper).

Whilst PE resin producers can claim that the SCG resistance of HSCR PE100 materials is dramatically better than that of regular PE100, such claims need to be backed up by independent test results. There are several types of test in use with more accelerated tests under development. Accelerated tests are required as the time to failure of HSCR PE100 pipe due to SCG is frequently in the order of 10 times longer than that of regular PE100 pipes.

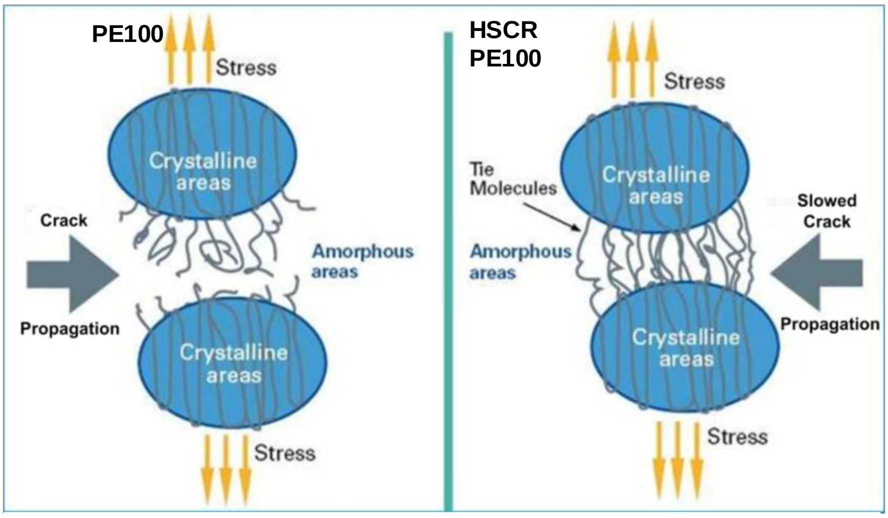
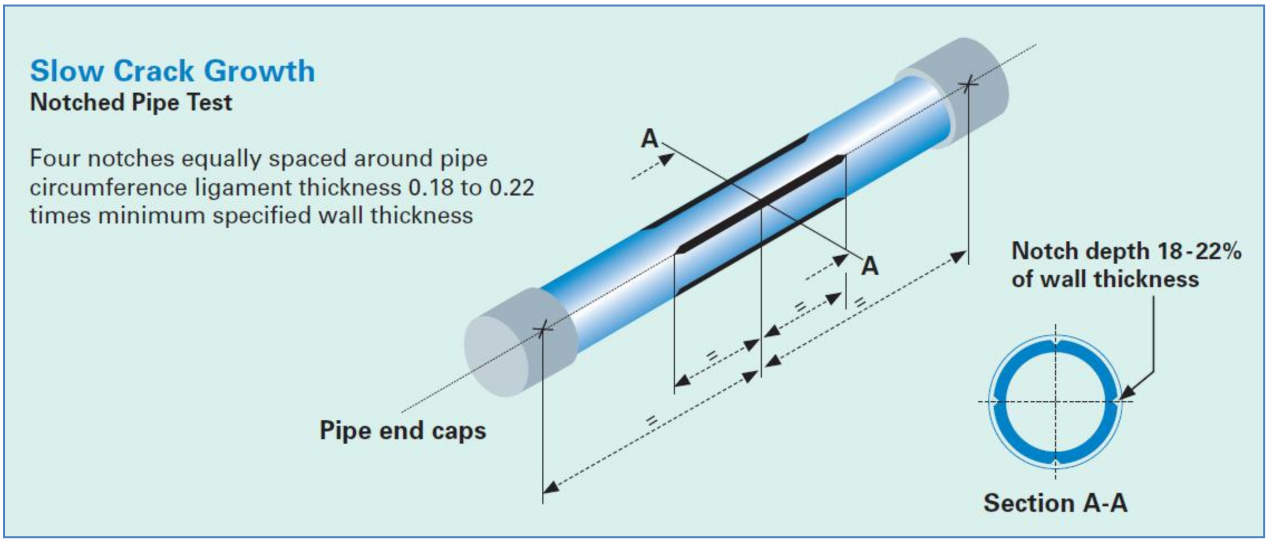


Figure 3. The greater number and longer side branches of HSCR PE100 resist the initiation and growth of the crack through the pipe wall

The NPT is the only test related to the measurement of SCG that is referred to in PE pressure pipe standards such as ISO 4427. In the case of PE100 pipes the standard calls for notches to be cut in the SDR 11 pipe as described in Figure 4 and for the pipe to be filled with water and submerged in a water bath at a temperature of 80^{o}C whist maintaining an internal pressure of 9.2 bars. Under such conditions cracks will be initiated at the root of the notches cut in to the pipe and these will propagate through the pipe wall until a failure occurs.

Both ISO 4427 and EN 12201 call for the pipes to have a minimum time before failure of 500 hours and good quality regular PE100 should be able to achieve 1000 hours. HSCR PE100 materials such as BorSafe™ HE3490-LS-H from Borouge will however typically achieve failure times in the region of 10,000 hours or higher. The German specification PAS 1075 “Pipes made from polyethylene for alternative installation techniques” which is aimed at HSCR pipes to be used in trenchless technology applications, calls for a minimum failure time of 8760 hours, which equates to one year.

Figure 4: The Notched Pipe Test undertaken in accordance with ISO 13479



4 SOME EXAMPLES OF REHABILITATION USING PE PIPES

3.1 SLIP LINING GAS PIPES IN CENTRAL MILAN

Slip lining or loose fit lining is the simplest lining technique but results in a reduction in carrying capacity of the main unless the internal pressure can be raised to compensate. This was the case for a medium pressure gas distribution system in Via Stresa in the centre of Milan[4]. The existing pipe was a 500mm bitumen coated steel pipe laid in the 1950's which was leaking due to through wall corrosion and had subsequently been de-rated to low pressure operation.

Figure 5. Plastic spacers centralise the PE80 liner in the gas main.

It was proposed that a 160m section of the main would be renovated using 400mm SDR11 PE pipe using slip lining. The local gas company AEM specified that the liner pipe should be produced from BorSafe™ ME3441 MDPE PE80 material in order to ensure that the pipe met their performance requirements yet was flexible enough to minimise disruption in the centre of the city. This material is a bimodal MDPE with an exceptionally high stress crack resistance and a high resistance to rapid crack propagation which would enable the mains pressure to be raised once all the renovation was completed.

The 400mm SDR11 was produced in 6m lengths by Idrotherm 2000 s.r.l. On site the pipe lengths were butt welded and attached to a pulling head to enable them to be drawn through the 160m of steel main. Plastic spacers were used to centralize the PE pipe in the host main. The lining pipe was introduced through a 12m long launching pit but due to the flexibility of the MDPE pipe only two small, 4m long, receiving pits were required thereby reducing the disruption to a minimum. The project was completed in just four days convincing AEM that they indeed had a solution to their medium pressure mains renovation programme.

3.2 CLOSE FIT LINING OF SLURRY PIPES IN WESTERN AUSTRALIA

Of all the commonly used pipeline materials polyethylene has the highest abrasion resistance which makes it ideal for transporting ore slurries and other materials. Where higher pressures are required steel pipes are used but these are often lined with polyethylene pipe to extend their operational life. This was the case at the Sinosteel mine near Karratha in Western Australia which was being developed to yield 22 million tonnes of iron ore each year.

Figure 6. Reducing the diameter of the HSCR PE100 liner pipe prior to insertion.

Borouge customer Kingston Bridge Engineering in Perth received the order from United Pipelines, a US based specialist pipe lining company, for 2 x 30km special sized PE100 pipelines for close fit lining of a 30 and 32 inch steel slurry transportation and return water pipelines[5]. Since close fit lining techniques can cause damage to the external surface during installation, a pipe produced using HSCR BorSafe HE3490-LS-H PE100 material was recommended to ensure that the pipe would provide the expected life.

The pipes were extruded by Kingston Bridge and delivered to site where they were butt welded together and then inserted into the steel pipes by United Pipelines of the USA using their “Tite Liner” technology. Before insertion the PE pipes are drawn through a hydraulically powered roller reduction box which reduces the outside diameter of the pipe as shown in figure 6. This smaller diameter PE pipe can then be easily pulled through the steel pipe and once in position the load is released so the pipe can recover and form a tight compression fit with the bore of the host pipe where it will protect this pipe from abrasion and corrosion.

4.3 CLOSE FIT LINING OF A WATER MAIN IN CHINA

The Changzhou Water Company in southern China is responsible for providing fresh water to 2 million of the local inhabitants but like many other water companies they have many problems with their existing network of iron pipes. One particular concern for the water company was a leaking 1000mm diameter cast iron main which was installed in 1998 under the Wanfu Road. Where the road drops 3.5 metres to pass under a railway bridge the misaligned pipe joints were leaking and the concern was that this could ultimately damage the foundations of the bridge which carries the high speed Beijing to Shanghai rail link. The high level of internal corrosion in the pipe was also contaminating the water and therefore it was decided to replace or renovate a 400 metre section of the main.

One effective way to overcome leakage and contamination from a corroded iron water main is to insert a close fitting PE100 liner pipe into the bore, which will effectively provide a new pipeline at a considerably lower cost and without the disruption caused by installing a replacement pipe. Whilst this is an attractive option from an overall economic and environmental viewpoint, trenchless installation techniques can introduce scratching and scoring on the outer pipe surface.

Figure 7. The pipe folded and strapped being inserted into the old leaking water main

This damage can develop into cracks which gradually make their way through the pipe wall, eventually leading to a brittle failure of the pipe. To overcome this concern it was decided to use a High Stress Crack Resistant (HSCR) PE100 material to produce the liner pipe. This provides a much higher resistance to crack initiation and growth, thereby giving engineers greater confidence to use the lining technique.

For the project a non standard 983mm diameter pipe with a 15mm wall thickness was manufactured by Shanghai Chinaust using BorSafe HE3490-LS-H HSCR PE100 material from Borouge. On site the team from the Shanghai Water Special Engineering Co. butt welded the pipe sticks together and removed the external bead prior to passing the pipe through a folding machine that formed it into a “U” shaped section. Strapped in this form the effective diameter of the liner pipe is greatly reduced and it could be easily inserted into the bore of the old pipe. Once in position the PE100 pipe was pressurised to break the strapping and to form a close fit liner, which will eliminate leakage and prevent further contamination of the drinking water, thereby providing the water company with a very cost effective solution to their problem.

4.4 RENOVATING A LEAKING IRON WATER MAIN IN NORWAY

Although the ductile iron water mains in Trondheim, Norway had only been installed in the early 1970's they were in a poor condition and a number of major leaks had occurred. In order to overcome this problem and improve the water quality it was decided to renovate a 900m length of the 600mm diameter main. Because the ground was heavily congested with many other services and the full capacity of the main was required it was decided to use the pipe bursting technique to replace the pipe using a 710mm diameter PE100 pipe.

Because the new PE main would have to pass through ground containing many shards of broken iron pipe it was decided to use a High Stress Crack Resistant (HSCR) PE100 material for the new water main and protect it further with a outer coating of polypropylene. The new pipe was produced by local specialist pipe producer Hallingplast using BorSafe HE3490-LS-H PE100 material for the core and a 5mm layer of BorECO™ BA212E PP-B for the protective outer coating.

Local specialist contractor Sandum carried out the installation. The 18m pipe lengths from the factory were butt welded into 150m pipe strings, which were coupled to the pulling head behind the hydraulic bursting head. The bursting head was pulled through the old main at around 50cm/min, which meant each 150m pipe string was installed in around 3 hours. Once in place the pulling head could be cut off and the end of the pipe cleaned up and joined to the adjacent section using electrofusion couplers.

Figure 8. The new main installed after the pulling head had been removed.

The whole process was very efficiently and quickly carried out with a minimum disturbance to the local environment and with cost savings of around 30% compared to open trench installation.

5 CONCLUSIONS

Extending the life of underground water, gas and sewage pipelines using plastic pipes and modern rehabilitation techniques provide utilities with major benefits compared to conventional replacement using open trench installation. Excavation and reinstatement costs can be significantly reduced and major disruption of city life can be avoided.

In the oil and gas and mining industries similar techniques can be used to reduce the internal corrosion and abrasion of steel pipelines significantly extending their operational life.

Using the new High Stress Crack Resistant (HSCR) PE100 materials to produce the liner pipe gives the engineers greater confidence to use of these lining techniques. These specially designed polymers provide a much greater resistance to the growth of cracks from any scores or damage on the outside of the pipe during installation ensuring a long operational life.

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