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THE EN ISO11295 FAMILY OF STANDARDS AND PE100+ NO-DIG GUIDE CONCERNING PIPELINE REHABILITATION USING POLYETHYLENE PIPES AND LINERS

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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. A large number 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.

The presentation will give an introduction to the different methods by which pipelines can be rehabilitated using polyethylene (PE) pipes and liners, discuss the benefits of using a PE100-RC material and explain how Engineers and other technical staff can use the standard EN ISO 11295 to help identify and specify the most appropriate technique for their particular situation. It will also introduce the recent update to the PE100+ Association's website which now includes a No-Dig Technical Guide.

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 renovation 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 a day. They therefore decided that a major system overhaul was necessary as the population was expected to grow to 8.1 million by 2016.

Therefore in 2005 Thames commenced a replacement programme using polyethylene (PE) PE100 pipes for mains and PE80 pipes for service connections. To reduce costs and disruption the engineers were asked to use 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 cities around the world are following the same philosophy and looking at trenchless technology wherever practical to renovate their old utility networks. Also in industrial pipework the insertion of PE liners is used to reduce the internal corrosion of steel pipes and increase abrasion resistance.

A key obstacle to greater use of trenchless technology is a lack of knowledge among designers and asset owners about how the techniques can be applied to their projects in order to achieve the maximum benefit. Hence the PE100+ Association, working with TEPPFA, Exova, Radius Systems and Downley Consultants have developed an online No-Dig Guide. The guide is designed to help decision makers learn about and select from a wide range of trenchless technologies that can be used to install new PE100 pipelines or rehabilitate existing pipelines using PE100 pipes and liners. It is freely available online through the PE100+ Association website.

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 EN ISO 11295[(2)], which also classifies each of them and provides a simple description of each method.

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.

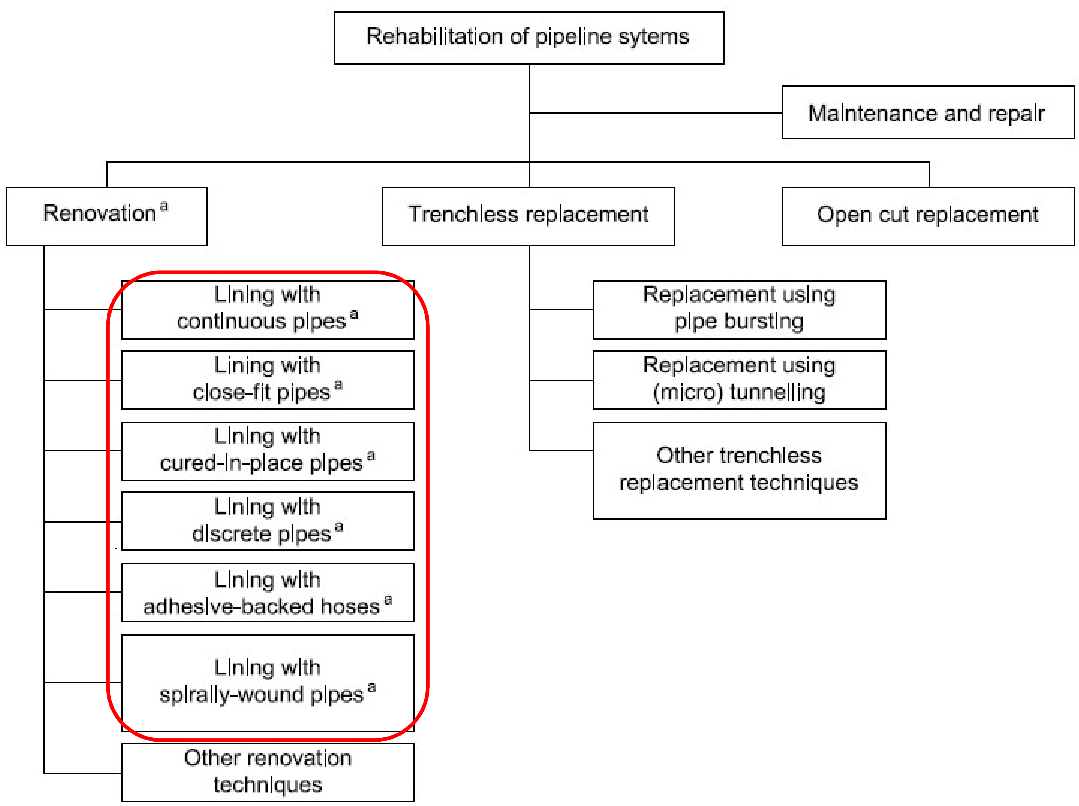
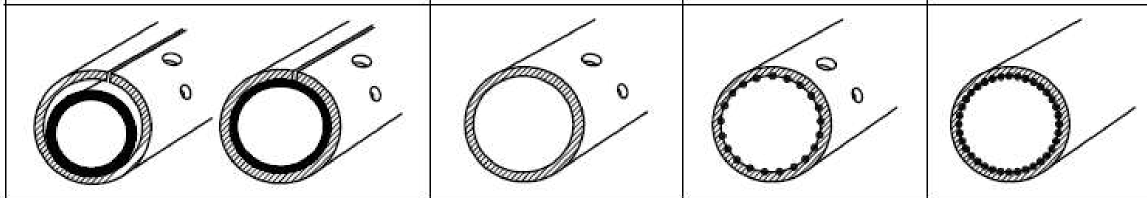


Figure 1. The red box identifies the trenchless techniques that are covered in EN ISO 11295

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 (Standard Dimension Ratio) chosen for the PE lining pipe and the future operational pressure for the system.

Figure 2. Schematic representations of structural classes of pressure pipe liners.

<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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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

In addition a suite of twelve EN 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, EN ISO 11298(3) covers plastic pipe systems for renovation of underground water supply networks. The standard is in several parts with EN 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 of the PE lining pipe for the chosen trenchless technique.

3. THE PE100+ NO-DIG TECHNICAL GUIDE

PE100 and trenchless technology make a perfect match; a combination of method and material that complement each other resulting in economic, cost-effective and non-disruptive installation and rehabilitation works. The range of trenchless methods in which PE100 is used is shown in Table 3. The Guide includes mole ploughing which, although not strictly a trenchless method uses PE100 in the same way. In total the guide covers 11 different trenchless techniques, if the three close-fit lining methods are considered separately, in addition to mole ploughing. The benefit of the combination is clear: the pipe material that water and gas utilities in most regions of the world want in their distribution networks can be installed using the state-of-the-art trenchless installation and rehabilitation techniques.

Table 1. Applications and Trenchless Methods included in the No-Dig Guide

Water Mains	Gas Mains	Sewerage		Cables
		Gravity	Pressure (Rising Mains)	
PE New Installation HDD Impact Moling Mole Ploughing	PE New Installation HDD Impact Moling Mole Ploughing	PE New Installation Pilot tube microtunnelling	PE New Installation HDD Impact Moling Mole Ploughing	PE New Installation HDD Impact Moling Mole Ploughing
PE Rehabilitation Close-fit lining Sliplining Pipe bursting Pipe splitting Pipe extraction	PE Rehabilitation Close-fit lining Sliplining Pipe bursting Pipe splitting Pipe extraction	PE Rehabilitation Pipe bursting Pipe splitting Pipe reaming	PE Rehabilitation Close-fit lining Sliplining Pipe bursting Pipe splitting Pipe extraction	

The core of the Guide is a decision process in which users can enter the parameters of a specific project: project type (new, rehabilitation, gas, water, etc.), diameter and pressure needs, soil types, alignment, length, and for rehabilitation projects, existing pipe material and diameter. The Guide calculates the standard PE diameter and SDR that is suitable and shows this to the user along with a list of trenchless methods that are feasible to achieve what is required. Clicking on any of the methods listed takes the user to the page describing that method.

For each method the Guide provides clear information on the key aspects of the method:

- Technique – general description
- Applications of PE100 (gas/water mains, services, sewer force mains)
- Installation Procedure
- Equipment
- Practicalities – range of soil types, diameter, pressure and length ranges
- Excavations, space and access requirements
- Design, Specification and Planning
- Health, Safety and Environment
- Standards and Codes of Practice

The Guide also includes several common modules to provide information about related works before, during and after the trenchless works themselves. These are:

- Pipe Assembly & Handling
- Installation Manual
- Host pipe cleaning & inspection (for the rehabilitation methods)
- Isolation
- End Fittings
- Inspection & Testing

4. A NEW GENERATION PE100 MATERIALS OPTIMISES PIPE LIFETIME

PE pipes have had 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 PE100-RC 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. It should be noted that these materials are also referred to as HSCR (High Stress Crack Resistant) PE100 resin by some producers

Whilst most standard PE100 materials use butane as a co-monomer, the majority of PE100-RC materials 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 initiation and growth of the crack through the pipe wall, a process commonly referred to as Slow Crack Growth (SCG).

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 PE100-RC 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.

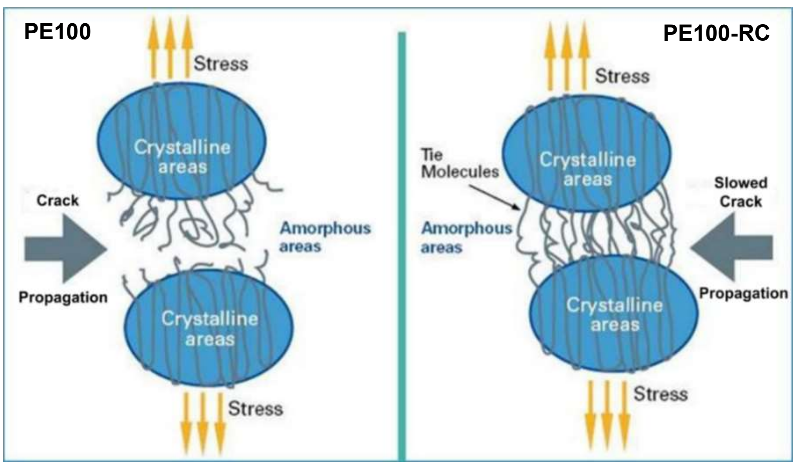

Figure 3. The greater number and longer side branches of PE100-RC resist the initiation and growth of the crack through the pipe wall

Whilst PE resin producers can claim that the SCG resistance of PE100-RC 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 PE100-RC pipe due to SCG is frequently in the order of 10 times longer than that of regular PE100 pipes.

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 80ºC 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. PE100-RC materials 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 PE100-RC pipes to be used in trenchless technology applications, calls for a minimum failure time of 8,760 hours, which equates to one year.

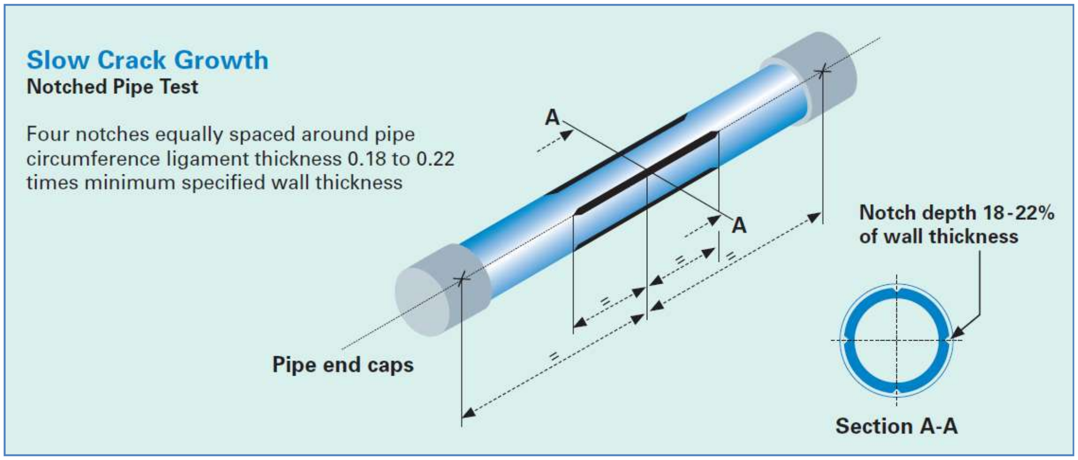

Figure 4. The Notched Pipe Test undertaken in accordance with ISO 13479

5. SOME EXAMPLES OF REHABILITATION USING PE PIPES AND LINERS

a) 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 pipe 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.

b) 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. 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 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 a PE100-RC material was recommended to ensure that the pipe would provide the expected life.

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

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 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 was then easily pulled through the steel pipe and once in position the load was released so allowing the pipe to try and revert to its original diameter, so forming a tight compression fit with the bore of the host pipe where it protected the pipe from abrasion and corrosion.

c) Close fit lining of a ductile iron water main in ChangZhou, 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. At this point, 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 hence was decided to replace or renovate a 400m 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.

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

Whilst for the Engineer 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. 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 PE100-RC material to produce the liner pipe. As described earlier, this provides a much higher resistance to crack initiation and growth, thereby giving engineers greater confidence in the use of a lining technique.

For the project a non-standard 983mm diameter pipe with a 15mm wall thickness was manufactured by Shanghai Chinaust using a PE100-RC material. 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 was greatly reduced and it could be easily inserted into the bore of the old pipe.

Once in position the PE100-RC pipe was pressurised to break the strapping and to form a close fit liner, which eliminated leakage and prevented further drinking water contamination, thereby providing the water company with a very cost effective solution.

d) Installing new pipelines and replacing old water mains in Kunming, China

Kunming is the capital city of Yunnan Province in the south west of China. Located at a height of almost 2,000 metres on the shores of Lake Dian, it has a mild climate, which has enabled it to become the largest exporter of flowers in Asia and a major centre for horticulture in China. Kunming is well served by water and gas utilities, whose networks need to be constantly expanded to keep up with the city’s growth. Borouge have supported the SADE General Construction & Engineering Co. in undertaking several trenchless to replace existing asbestos cement water mains with pipes produced using PE100-RC material through techniques such as horizontal directional drilling and pipe bursting.

One example was a major expansion project in January 2015 that involved installing a new 305 m long, 630 mm OD, SDR11, 16 bar pressure water main across a major highway and through an adjoining area marshy ground. The pipeline was installed using Horizontal Directional Drilling (HDD) to reduce excavation in the difficult conditions and to limit the disruption to the traffic on the highway. The pipes were produced by Cangzhou Mingzhu Plastic Co. again using a PE100-RC material and for the section under the major highway, a steel ducting pipe was installed first to provide further protection to the PE water main.

A second example, which took place in Oct. 2015 involved the replacement of existing water mains using pipe bursting technology. The existing water mains comprised a DN 200 mm cast iron pipeline and a DN 280 mm asbestos cement pipeline that were replaced by a 225 mm OD, SDR11 and a 315 mm OD SDR11 PE100 pipelines respectively. Whilst pipe bursting is an effective trenchless way of replacing existing pipelines with the same or slightly larger diameter PE pipelines, the installation process can lead to the new pipeline being badly scratched or scored. Hence SADE again decided to use polyethylene pipes produced using a PE100-RC pipe resin in order to minimise the risk of failure due to SCG in the long term.

After being delivered to site in 6m ‘sticks’ the pipes were butt welded together by SADE using a semi-automatic welding machine to help ensure good quality welding of the pipes strings that were then pressure tested prior to installation. The new pipeline lengths installed by pipe bursting were 950 m in the case of the 225 mm OD pipeline and 800 m in the case of the 315 mm OD pipeline.

Old pipe after pipe bursting **New butt welded PE pipes**

Figure 8. Replacing old asbestos water main in the Southwest of China through pipe bursting

6. CONCLUSIONS

Installing new pipe systems and extending the life of existing water, gas and sewage pipelines using plastic pipes and modern trenchless techniques provides 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, gas and mining industries similar techniques can be used to reduce the internal corrosion and abrasion of steel pipelines, significantly extending their operational life.

It is hoped that the PE100+ Association’s online No-Dig Guide will help bridge the gap between the PE pipe and trenchless technology communities and their respective areas knowledge. It will assist users in selecting and then implementing different trenchless methods to install suitable PE100 pipes both for new installations and rehabilitation. The aim is to support the increased use of both trenchless technology and PE100 pipe especially in newer markets where experience is limited. The Guide can be found at: www.pe100plus.com

Making use of specially designed PE100-RC materials dramatically reduces the risk of premature failure due to slow crack growth, which can be initiated by installation damage when the pipes and liners are installed using trenchless techniques. Hence, by helping to ensure a long operational life, the use of such materials provides engineers with greater confidence in the use of trenchless techniques and supports the growth of the no-dig industry across the world.

7. REFERENCES

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