Damage to coated plastics pipes from trenchless laying techniques
Damage to coated plastics pipes from trenchless laying techniques
Abstract

This project aims at evaluating an external coating on plastics pipes; and its protective function against scratches and scoring damage from trenchless laying techniques. PE100 pressure pipes with four different coatings were tested in horizontal drilling and pipe bursting field trials. During the tests, the lengthwise and cross-sectional deformations of the pipe were measured along with the traction force. The pipes’ surfaces were examined with respect to scratches, and the depth of the most prominent ones were determined.

Of the two laying techniques, pipe bursting was the one that caused the deepest scratches. Horizontal drilling was not significantly worse than ordinary handling during transport and preparation with respect to scratch depth. Dragging of the pipe above ground on asphalt surfaces caused severe damage to the pipe wall.

The deepest scratches were seen on two pipe selections with soft coatings. Due to their thickness, however, these coatings were not penetrated and thus successfully protected the main pipe wall. The hardest coating tested, made of polypropylene, was also the thinnest one, and it was penetrated at one location during the pipe bursting test.

The traction force on the pipe was significantly higher during horizontal drilling than during pipe bursting. On the other hand, ovalisation of the pipe’s cross-section was greater during pipe bursting.

Keywords: Horizontal drilling, pipe bursting, polyethylene, coated pipes, scratches
# Table of contents

Abstract 2

Table of contents 3

Preface 4

1 Background 5

2 Field trials 6

2.1 Testing conditions 6

2.1.1 Test and reference pipes 6

2.1.2 Measuring devices 7

2.1.3 Test sites 7

2.1.4 Analysis before and after pulling 7

2.2 Horizontal drilling in Ballingslöv 7

2.3 Pipe bursting in Bromma 8

2.4 Measurements 10

2.4.1 Traction force 10

2.4.2 Pipe deformation 10

2.4.3 Scratches and scoring 11

3 Results and review 12

3.1 Scratches and scoring at delivery 12

3.2 Scratches and scoring after field trials 12

3.3 Protective coating adhesion 14

3.4 Traction forces and pipe deformation 14

3.4.1 Horizontal drilling 14

3.4.2 Pipe bursting 15

4 Conclusions 17

5 References 18

Appendix A: Scoring, horizontal drilling 19

Appendix B: Deepest scoring, pipe bursting 23
**Preface**

This project aims at evaluating the extent to which an external coating protects plastics pipes against scratches and scoring during laying processes that involve horizontal drilling or pipe bursting.

Funding was provided by Hallingplast, Pipelife, Uponor, Wavin, Styrud and SP, the Swedish National Testing and Research Institute. Skånska Plastsvets and Quickpipe were extremely helpful during the field trials.
1 Background

Coated plastics pipes – where a protective external coating is applied directly to the regular main pipes – have been introduced on the market by several major pipe manufacturers in recent years. One of the anticipated advantages of such a coating was that the surface of the main pipe wall would be protected from damage by the surroundings directly in conjunction with the manufacturing process, thus rendering it unnecessary to scrape off the surface of the pipe prior to welding. The affect of these coatings on butt weldability was studied by Bergström et al (2004), but no significant differences could be determined as to the strength of “non-scraped” welds on coated and non-coated pipes.

However, a more obvious function of the coating is that it protects the main pipe against mechanical abrasion and/or damage during the handling process and during trenchless laying techniques. Trenchless laying techniques are generating more and more interest. In principle, the method involves pulling pipes through existing pipes or a pre-drilled tunnel. Compared to conventional open trench techniques, it is fairly easy to bypass obstructions such as bodies of water or railway embankments. Several different trenchless laying techniques exist. See Bjurström & Wingqvist (2004) for a survey.

Since pipes are pulled through tunnels or burst pipes, they are subjected to harsh treatment, and there is an obvious risk of substantial scratching and scoring. Stokes et al (2001) conducted statistic evaluations of the score depth on PE80 pipes following horizontal drilling and pipe bursting. The conclusion was that pipe bursting resulted in more critical damage with regard to score depth than horizontal drilling. In conjunction with pipe bursting, 0.9 mm deep scores were measured for ∅ 90 mm and ∅ 180 mm SDR 11. In conjunction with horizontal drilling in clay soil, the measurements indicated maximum score depths of approx. 0.1 – 0.2 mm for ∅ 90 mm SDR 11; approx. 0.3 mm for ∅ 180 SDR 17; and approx. 0.7 mm for ∅ 225 SDR 17. Supplementary tests were also conducted, involving the horizontal drilling of a pipe (∅ 90 mm SDR 17) equipped with a polypropylene coating1, and the resulting maximum score depth was approx. 0.4 mm.

It is not completely clear exactly what consequences scratches and scores have on the service life of a pressure pipe. A scratch or score will produce a concentration of stress, since the pipe’s wall thickness is reduced, and it may also, depending on its geometric configuration, cause a notch effect. In their technical specifications, pipe manufacturers recommend (Pipelife Sverige, 2000; Nordisk Wavin, 2000; Wavin Plastics 2001; Rix, 2005) that score depth should not exceed 10 % of the wall thickness, and that scores should not be too steeply inclined. This has been adopted as a rule of thumb in the field.

1 The same type as test pipe 2 in the present project.
2 Field trials

At the first project meeting, on November 14, 2003, it was decided that two separate field trials would be conducted:

1. Horizontal drilling through “worst case scenario” material.
2. Pipe bursting through existing iron pipes.

2.1 Testing conditions

The field trials were performed at appropriate sites where lengths of at least 100 metres were pulled. The pipes used in this study, along with the reference pipes, were joined to the front of the regular pipes being pulled.

2.1.1 Test and reference pipes

Each field trial comprised a test pipe with a length of 8 m, consisting of a 2 m long coated PE100 pipe (test pipe), with the dimension Ø160 mm SDR 11, from each manufacturer represented. These test lengths were welded in a progressive order, reflecting increased external diameter, where the pipe with the smallest diameter came first. In order to avoid reductions in force on the front test pipe due to the larger diameter of the reamer and the bursting cones, non-coated pipes with a length of 12 m were positioned before and after the 8 m long test section. These un-coated pipes also acted as reference pipes, and were tested as to score depth. Since the test pipe sections are likely to be long enough that weld beads will not bring about a reduction in traction force, it was decided that the beads should be allowed to remain in place during the laying process. SP was responsible for the welding of the test pipes and the fitting of the measurement equipment to the front test pipe in each field trial. Welding parameters, etc were determined in consultation with the manufacturers.

List of test and reference pipes:

<table>
<thead>
<tr>
<th>Test pipe</th>
<th>Marking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test pipe 1</td>
<td>Wavin TS, PE 100, PN 16, SDR 11, Ø 160 mm, yellow polyethylene</td>
</tr>
<tr>
<td></td>
<td>0000 WAVIN/W RAL KO DVGW DG-8111 BN 0614 PE100 003 SDR11 160×14.6 =251003= 23 DIN8074 GRAD B WAVIN TS Gasrohr mit Schutz eigenschaften</td>
</tr>
<tr>
<td>Test pipe 2</td>
<td>Uponor Profuse, PE 100, PN 16, SDR 11, Ø 160 mm, white polyethylene, brick-coloured polypropylene coating, approx. 0.5 – 0.9 mm</td>
</tr>
<tr>
<td></td>
<td>UPONOR A/S PROFUSE EDSE SBC 218-KP72 PE/0 160×14.6 SDR11 PE100 PN16 PE80 PN10 29.03.2001 01209 m --COATED ROR--</td>
</tr>
<tr>
<td>Test pipe 3</td>
<td>Hallingplast, PE 100, PN 16, SDR 11, Ø 160 mm, black polyethylene, blue polythene coating, approx. 3 mm thick</td>
</tr>
<tr>
<td></td>
<td>160×14.6 PE100 SDR11 HALLINGPLAST 28/08/02 (0084, 0000) PP-HM BESKYTTELSEKAPPE 3.0 mm</td>
</tr>
<tr>
<td>Test pipe 4</td>
<td>PipeLife Robust, PE 100, PN 10, SDR 17, Ø 160 mm, black polyethylene, blue polyethylene coating, approx. 3 mm thick</td>
</tr>
<tr>
<td></td>
<td>PIPELIFE PE100 ROBUST PIPE ANDRAN. POVLAK PEHD 160×9.5 SDR17 PN10 CSN EN 12201</td>
</tr>
<tr>
<td>Reference pipe</td>
<td>PipeLife, PE 100, PN 10, SDR 17, Ø 160 mm</td>
</tr>
<tr>
<td></td>
<td>= PIPELIFE = 160×9.5 PN10 PE100 $$ 67</td>
</tr>
</tbody>
</table>
2.1.2 Measuring devices

In order to monitor the loads exerted on the pipes during the pulling process, the extension of the pipe and its ovalisation were measured using small battery-operated position indicators and data loggers placed inside the test pipe. Traction forces were measured with a load cell fitted in the pipe puller.

2.1.3 Test sites

Soil conditions, the pipe’s depth and length, the type and dimensions of the reamer and the bursting cone, etc were documented in both field trials. In addition to this, any specific events or difficulties that arose during the pulling process were duly noted.

2.1.4 Analysis before and after pulling

All test pipes were measured with regard to geometric configuration before and after testing. Existing transportation and handling damage, along with any scratching and scoring arising during the pulling process were measured as to number, length and depth and photographed. In addition to this, the adhesion properties between the coating and the pipe were inspected before and after the pulling process.

2.2 Horizontal drilling in Ballingslöv

The first field trial was conducted on September 1, 2004, and it consisted of a horizontal drilling operation under a railway embankment in Ballingslöv, on the outskirts of Hässleholm. The length drilled was 123 m, and this drilling operation was performed by Styrud AB. The fused test and reference pipes were placed in front of the regular pipe material used at this site, which in this case consisted of cable conduits: PN6 PE80 SDR17 Ø 160 mm, with a length of 126 m. The client was the municipality of Ballingslöv, and the main contractor was NCC.

The fusing of these test, reference and regular pipes was performed by Skånska Plastsvets AB. According to plan, a test pipe length of 4 × 2 m coated PE pipes (P1 – P4), and a reference pipe length of 6 × 2 m were positioned in front of (R1 – R6) and after (R7 – R12), see Fig. 1. The total length was 32 m. These pipes were fused together in situ, alongside the road, and they were dragged along a terrain consisting of grass-covered soil during the pulling process before being transferred underground, see Fig. 2.

The maximum drilling depth was measured to be 4.01 m under the railway embankment. Due to the faulty dimensions of the traction force measuring device delivered, no direct measurement of the traction force was possible, but the meter of the hydraulics system employed by Styrud registered values ranging from 300-1500 PSI. A Kodiak reamer, with the dimension Ø250 mm, was used.

The pulling process was initiated at 8:12 pm and concluded at 11.17 pm. The soil conditions were fairly benign; sand and clay. There were, however, a few stretches of rocky terrain, which meant that the total process was fairly rough going. The rougher portions, after pulling approx. 50 m, show up clearly in the results detailed in item 3.4.1. After approx. 80 m, the maximum traction force was measured. This part of the track was so rocky that the bentonite slurry flow ceased entirely, and it was assumed at first that the pipe had broken.

Once the pulling process was concluded, the test and reference pipes were disconnected from the regular pipe material using a chain saw, and then cut into smaller samples, approx 2m in length, for analysis by SP.
2.3 **Pipe bursting in Bromma**

The second field trial was conducted using vibration-free pipe bursting, and it took place on September 14, 2004, on Solviksvägen, in Stockholm. The regular pipes in this project were intended for the relining of existing potable water mains made of cast iron, Ø150 mm, with butt welded PE80 pipes, Ø160 mm PN10, and the client was SVEAB. The total length was 240 m, divided into three stretches measuring 60, 80, and 100 m respectively. The actual pipe bursting procedure and the welding process were performed by Quickpipe AB.

The test and reference pipes were attached in front of the regular pipes on the intermediate stretch that measured 80 m. The reason this particular stretch was chosen, was the opportunity available to dig an extra long trench – a prerequisite for the removal of the test and reference pipes after pulling.

According to plan, a test pipe length of $4 \times 2$ m coated PE pipes (P1-P4) was used. Due to the crowded conditions of this built-up residential area, a shorter length of reference pipes was used, $5 \times 2$m in front (R1-R5) and $1 \times 2$m behind (R6) the test pipe, equalling a total pipe length of 20 m, see Fig. 3. These pipes were welded together in situ, alongside the road Alviksvägen, on a terrain consisting of grass and gravel. After the test lengths and the regular pipes were welded together, they were hooked up to a digger that transported them to the site. This transport phase meant that the pipes were dragged some 800 m
along an asphalt-covered road, see Fig. 4. This procedure resulted in significant scratching and scoring prior to testing, see Fig. 5.

The water mains were located approx. 2 m underground. The traction force during the pipe bursting procedure was noted by Quickpipe to be approx. 100 – 250 kN. During this trial, another device for traction force measurement, a Grundolog, was used by Vretmaskin, see Fig. 6, p. 10. This device was attached to the bursting cone at the front of the first reference pipe (R1), positioning the data logger of the device inside R1. The Grundolog registered a maximum traction force of approx. 30 kN. The actual pipe bursting was performed with a bursting cone with a diameter of 200 mm.

The pipe bursting procedure was initiated at 09:17 am, and concluded at 10:40 am, when the test material appeared in the receiving shaft and was separated from the regular piping.

Soil conditions were classified as normal; soil containing sand and rocks.

**Fig. 3** Overview of test and reference pipes during the pipe bursting procedure in Bromma. Pulling direction indicated at left in the figure.

**Fig. 4** Pipe handling during pipe bursting.

**Fig. 5** Examples of scoring caused by dragging pipes along an asphalt road.
2.4 Measurements

During the trials, continuous measurements were performed as to traction force and the axial and radial deformation of the test pipe. Before and after each trial, the test pipe was inspected for scratches and scoring. The depth of the most prominent scratches was determined on all test pipes and a selection of the reference pipes.

2.4.1 Traction force

For the horizontal drilling trials in Ballingslöv, the objective was to measure traction force during the pulling process with a load cell supplied by Perforator. However, the equipment available at the test site was not suitable for this purpose. The main reason for this was that the front hood of the device had a diameter that was substantially larger than that of the test pipe, increasing the likelihood that any results obtained would be misleading with regard to scratches and score depth. In spite of this, a quantitative inspection of the traction force process could be conducted by recording the hydraulic pressure of the machinery used Styrud at regular intervals.

During the pipe bursting tests in Bromma, traction force was measured with a device called the Grundolog (Fig. 6) supplied by Vretmaskin AB.

![Grundolog – Traction force measuring device.](image)

2.4.2 Pipe deformation

Deformation occurring during the pulling process was measured axially and radially with a positional indicator fitted in the first test pipe, see Fig. 7. The Duncan indicators were of a resistive type; with a stroke length of 12.5 mm. Data was collected every 30 seconds and logged in a TinyLogger. The logger and the DC batteries for running the indicators were attached to the pipe, and in this way “accompanied” the pulling process.
2.4.3 Scratches and scoring

The test pipes 1 (Wavin), 2 (Uponor) and 3 (Hallingplast) were inspected with regard to scratches and scoring prior to the field trial\(^2\). This was done to obtain a picture of how pipes were handled prior to delivery and to differentiate between the scratches arising during the trials from those already present.

After completing field trials, the depth of the most prominent scratches on all test pipes, and on a selection of reference pipes, was measured. This was performed in the following manner: The pipes were sliced open to expose a cross-section of each scratch. These cross-sections were then photographed. The score depth was then measured on the photograph.

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\(^2\) Test pipe 4 (PipeLife) arrived at SP immediately prior to field testing, so no delivery inspection as to score depth was possible.
3 Results and review

3.1 Scratches and scoring at delivery

The test pipe(s) 1 – 3 were inspected with regard to scratches and scoring upon delivery to SP, i.e. before the trial took place. Several minor scratches were present, mainly shallow scratches and nicks, most probably the result of handling and transportation.

The deepest scratches in test pipes 1 – 3 were approx. 0.28 mm, 0.25 mm, and 0.48 mm respectively, see Fig. 9 below. The score depth arising from normal handling procedures is comparable, with regard to size, to the scoring caused by horizontal drilling.

![Fig. 8 Examples of scratches and scoring on test pipes 1 (Wavin), 2 (Uponor), and 3 (Hallingplast).](image)

The number of scratches found varied substantially between the different makes, see Table 1. The criteria as to what constituted a scratch was not strictly defined, but any damage clearly visible to the eye was noted. Areas displaying continuous or linked damage were recorded as a single instance of scoring. Examples of scoring are shown in Fig. 8. The largest number of scratches was found on test pipe 1. Test pipe 2, which had the hardest coating, polypropylene, displayed the least amount of scoring. On condition that the pipes are handled in a similar manner, the number of scratches should decrease in relation to the hardness of the coating and increase as the pipe ages.

<table>
<thead>
<tr>
<th></th>
<th>Test pipe 1</th>
<th>Test pipe 2</th>
<th>Test pipe 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Wavin</td>
<td>Uponor</td>
<td>Hallingplast</td>
</tr>
<tr>
<td>A</td>
<td>15</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>B</td>
<td>18</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>C</td>
<td>16</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>Mean</td>
<td>16.3</td>
<td>3.7</td>
<td>6</td>
</tr>
</tbody>
</table>

*Table 1 Number of scratches, test pipes 1 – 3. Three pipes, 2 m in length (A, B and C), from each manufacturer were tested.*

3.2 Scratches and scoring after field trials

When the pipes were removed after the trial sessions, they were so severely scratched that it was not possible to count the number of scratches. Photographs of the most prominent scratches in cross-section are included in Appendices A and B.

Score depth is shown in Fig. 9. Horizontal drilling does not cause significantly deeper scoring than what is caused by normal handling prior to pulling. Pipe bursting, however, causes much more extensive damage.
The various types of protective coatings yield clearly different results. The thick polythene coating on test pipe 4 appears to be the softest, and it most easily retains deep scratches. In terms of score depth, the hard polypropylene coating found on test pipe 2, appears to be the most durable. However, due to the thinness of this coating, the only pipe to display coating penetration was test pipe 2.

Table 2 Values for the deepest scoring when applying horizontal drilling and pipe bursting.

<table>
<thead>
<tr>
<th>Pipe</th>
<th>Score depth, horizontal drilling</th>
<th>Score depth, pipe bursting</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mm</td>
<td>% wall thickness</td>
</tr>
<tr>
<td>First reference pipe</td>
<td>0.29</td>
<td>2.9</td>
</tr>
<tr>
<td>Last reference pipe before test pipe</td>
<td>0.28</td>
<td>2.8</td>
</tr>
<tr>
<td>Test pipe 1 (Wavin)</td>
<td>0.25</td>
<td>1.7</td>
</tr>
<tr>
<td>Test pipe 2 (Uponor)</td>
<td>0.26</td>
<td>1.7</td>
</tr>
<tr>
<td>Test pipe 3 (Hallingplast)</td>
<td>0.31</td>
<td>1.7</td>
</tr>
<tr>
<td>Test pipe 4 (PipeLife)</td>
<td>0.71</td>
<td>5.5</td>
</tr>
<tr>
<td>First reference pipe after test pipe</td>
<td>0.49</td>
<td>4.8</td>
</tr>
</tbody>
</table>

In horizontal drilling, the score depth values for the non-coated pipes corresponded to the measurements found in the study by Stokes et al (2001), see page 5. The Stokes study was conducted on clay soil, but during the pulling process, the pipes mainly came into contact with the bentonite slurry pumped out through the reamer, so the properties of the
soil material should not have any significant impact. With regard to pipe bursting procedures, the score depth values were considerable higher, some 30 – 50 %, than in the Stokes study.

No real purpose was served by analysing the number of scratches produced during the pulling operation, since the outer walls of the pipes were practically covered with lengthwise scratches and scoring.

### 3.3 Protective coating adhesion

The protective coating was not peeled away or detached in any other manner from the pipe itself during horizontal drilling or pipe bursting in our trials. When the pipes were cut into sections after testing, the coating still adhered well to test pipes 2 (Uponor) and 4 (PipeLife). The coating on test pipe 3 (Hallingplast) had become loose, but this is in line with the intentions of the manufacturer.

### 3.4 Traction forces and pipe deformation

#### 3.4.1 Horizontal drilling

During the trial using horizontal drilling, no direct registration of the traction force in the pipe the took place, but an assessment of the reamer pressure is made possible using the hydraulic pressure reading from the machinery used by Styrud, see Fig. 10.

![Fig. 10](image_url)  The traction force progression for horizontal drilling. The diagram shows the hydraulic pressure values provided by the machinery used by Styrud and these figures correspond to the force exerted on the reamer rather than on the pipes.

The traction force exerted in the pipe can be assessed by way of the axial strain, see Fig. 11. In the pipe bursting trials, see below, the extension of the pipe was found to be proportional to the traction force. The same type of pipe was used on both occasions, and the data from the pipe bursting operation can be used to assess the traction force for the horizontal drilling operation. For most of the duration of the pulling operation, the axial extension maintained an average value of approx. 0.47 %, peaking occasionally at 1 %.
These extensions correspond to traction forces of approx. 21 kN and approx. 45 kN respectively.

It is interesting to note that the radial extension values obtained are identical, and that they are a scaled-down mirror image of the axial extension. The Poisson’s ratio for polyethylene is approx. 0.4, and the radial extension is around 40 – 45 % of the axial extension. This means that the cross-section of the pipe is deformed in a uniform manner, and thus is not ovalised, and that the deformation is a direct consequence of the lateral contraction resulting from the extension of the pipe. The radial force acting on the pipe is, in other words, marginal, and it is reasonable to expect fairly insignificant score depths.

![Graph showing deformation process in test pipe No. 1, horizontal drilling.](image)

**Fig. 11** Deformation process in test pipe No. 1, horizontal drilling.

### 3.4.2 Pipe bursting

Traction force values and pipe deformation values from the pipe bursting trial are shown in Fig. 12. The local peak in traction force, occurring after approx. 10 minutes, takes place before the test pipe is pulled in, and the force is exerted on the first reference pipe. After this, the force is increased continuously until approx. 20 minutes have passed. Then there is a lapse until approx. 50 minutes have passed, due to problems with the equipment, and the force decreases somewhat. When the pulling process continues, the force maintains an average value of slightly over 15 kN.

The axial extension of the pipe corresponds well to the traction force in the sense that they vary in tandem and appear to be proportional. During the latter portion of the pulling process, the average extension is approx. 0.33 %. With a force of 15 kN, this means a modulus of elasticity for the material in test pipe No. 1 (Wavin), amounting to approx. 670 MPa.
Compared to the horizontal drilling process, ovalisation of the pipe’s cross-section is clearly visible. This is shown by the variations in radial deformation, where diameters increase in one direction and decrease in the other, which is at a right angle\(^3\). The fact that deformation differs in size in the two directions shows that the indicators are not fitted parallel to the ovalisation direction, and that the maximum ovalisation exceeds the values obtained by the indicators. The peak in ovalisation after approx. 15 minutes takes place when test pipe No. 1 is inserted into the shaft and begins to penetrate the burst iron pipe. During the major portion of the pulling process, ovalisation is less than 0.5%.

\(^3\) The reason why the red curve showing radial deformation in Fig. 12 is no longer present after 50 minutes is because the indicator failed at that point.
4 Conclusions

Generally speaking, the deepest scoring takes place in pipe bursting operations. In several instances, the depth of the most prominent scratches exceeds or is close to 10 % of the material thickness used as a guideline in the field with regard to acceptable score depth, see Table 2, page 13.

Horizontal drilling does not produce significantly deeper scoring compared to “normal” handling procedures for storage and transportation. However, it is evident that the handling process at work sites, such as dragging pipes along asphalt roads, etc, may cause significant damage to coatings; see Fig. 5, page 9.

The deepest scratches on the coated plastics pipes appeared on the pipes with the softest coatings (test pipes 3 and 4); see Fig. 9, page 13. In both instances, however, these coatings were thick enough to protect the main pipes from scoring. Test pipe 2, with a polypropylene coating, displayed, in absolute terms, a significantly lesser degree of scoring than the other pipes tested in the pipe bursting trials, but this type of coating was also the only one observed to be penetrated, thereby exposing the main pipe to damage. However, the score depth found in the main material is substantially less than for the corresponding test pipes without protective coatings, i.e. test pipe 1 and the reference pipes.

The traction force exerted on the pipe, and the resulting extension, is significantly higher in horizontal drilling operations compared to pipe bursting operations. During the major portion of the process, the traction force and the lengthwise extension amounted to approx. 21 kN and 0.47 % for horizontal drilling compared to approx. 15 kN and 0.33 % for pipe bursting.

The cross-section deformation values obtained show that horizontal drilling does not produce any ovalisation of the pipe and hardly any radial pressure. This suggests that the traction force during horizontal drilling is mainly generated by cohesion forces between the wall of the pipe and the tunnel. If this is the case, no significant scoring is to be expected.

On the other hand, in the pipe bursting trial, ovalisation of the pipe occurs with a magnitude of 0.5 %. This means that significant radial pressure is exerted on the pipe and it is likely that the pipe is squeezed between the shards of the burst iron pipe which collapses under the pressure exerted by the surrounding soil matter?.

The following conclusions were reached:

- Protective coatings protect the main pipe from scratches, and a thick coating appears to be most beneficial in this respect.
- Pipe bursting operations cause significantly deeper scoring compared to horizontal drilling operations.
- The handling of the pipes at work sites may produce considerable scratching and scoring on coatings.

More research is needed to determine the consequences of the scoring described in Appendices A and B on the service life of pipes. In addition to score depth, the geometric configuration of the score, i.e. how “steeply inclined” it is, should have a great deal of impact on whether a crack leading to failure develops or not.
5 References


Appendix A: Scoring, horizontal drilling

Reference pipe 1

Fig. 13 Deepest scratch, horizontal drilling, reference pipe No. 1 – first pipe pulled. Score depth: 0.29 mm.

Reference pipe 6

Fig. 14 Deepest scratch, horizontal drilling, reference pipe No. 6 – last pipe before the test pipe. Score depth: 0.28 mm.
Test pipe 1 (Wavin TS)

![Image of Test pipe 1]

Fig. 15  Deepest scratch, horizontal drilling, test pipe No. 1, Wavin TS. Score depth: 0.25 mm.

Test pipe 2 (Uponor Profuse)

![Image of Test pipe 2]

Fig. 16  Deepest scratch, horizontal drilling, test pipe No. 2, Uponor Profuse. Score depth: 0.26 mm.
Test pipe 3 (Hallingplast)

Fig. 17 Deepest scratch, horizontal drilling, test pipe No. 3, Hallingplast. Score depth: 0.31 mm.

Test pipe 4 (PipeLife Robust)

Fig. 18 Deepest scratch, horizontal drilling, test pipe No. 4, PipeLife Robust. Score depth: 0.71 mm.
Reference pipe 7

Fig. 19  Deepest scratch, horizontal drilling i reference pipe No. 7 – first pipe after the test pipe. Score depth: 0.49 mm.
Appendix B: Deepest scoring, pipe bursting

Reference pipe 1

Fig. 20  Deepest scratch, pipe bursting, reference pipe No. 1 – first pipe pulled. Score depth: 0.74 mm.

Reference pipe 5

Fig. 21  Deepest scratch, pipe bursting, reference pipe No. 5 – last pipe before the test pipe. Score depth: 1.50 mm.
Test pipe 1 (Wavin TS)

Fig. 22  Deepest scratch, pipe bursting, test pipe No. 1, Wavin TS. Score depth: 1.24 mm.

Test pipe 2 (Uponor Profuse)

Fig. 23  Deepest scratch, pipe bursting, test pipe No. 2, Uponor Profuse. Score depth: 0.76 mm.
Test pipe 3 (Hallingplast)

Fig. 24 Deepest scratch, pipe bursting, test pipe No. 3, Hallingplast. Score depth: 1.40 mm.

Test pipe 4 (PipeLife Robust)

Fig. 25 Deepest scratch, pipe bursting, test pipe No. 4, PipeLife Robust. Score depth: 1.48 mm.
Reference pipe 6

Fig. 26  Deepest scratch, pipe bursting, reference pipe No. 6 – first pipe after the test pipe. Score depth: 1.29 mm.
SP Swedish National Testing and Research Institute develops and transfers technology for improving competitiveness and quality in industry, and for safety, conservation of resources and good environment in society as a whole. With Sweden’s widest and most sophisticated range of equipment and expertise for technical investigation, measurement, testing and certification, we perform research and development in close liaison with universities, institutes of technology and international partners.

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