TESTING PIPELINE COATINGS FOR SEVERE CONSTRUCTION CONDITIONS

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ABSTRACT

Pipeline construction methods have been developed in the direction of non-digging techniques, such as horizontal directional drilling (HDD). These methods demand different properties of the pipeline coating material. The background for the tests and development work described in this paper are the experiences faced by Gasum in pipeline construction work where especially HDD has been utilized.

The objective of the work was to compare different coating materials and weld seem tapes in as realistic conditions as possible and to evaluate their resistance against abrasive load. The main purpose of the testing equipment was to simulate actual field conditions during pulling a pipeline through soil expected to contain rock or similar harmful elements. A test jig was constructed through which a 16" - 20" pipe could be pulled. During pulling different abrasive loads were applied on the surface. As abrasive element were used natural stone with rounded edges, sharp edged stone (blasted rock) and a V-shaped steel knife. Tests were performed on two different High Density Polypropylene coatings, a Low Density PE-coating, a Polypropylene coating, two different types of fibre concrete coatings and a PP coating, still under development. In addition the tests were performed to six different weld seem coatings.

The test results indicated that the performance of high density polyethylene is sufficient in most applications. The 10 mm HDPE coating could not be penetrated with a natural, round edged stone. A sharp edged stone penetrated the coating with the maximum load the test equipment could perform. The LDPE coating has poor ability to withstand abrasive forces. The performance of PP coating was better than LDPE but all tests considered it did not perform as well as HDPE. Two different types of fibre concrete were tested, 6 and 12 mm. The 6 mm coating was attached to the pipe with grooves in order to improve the bonding. The 12 mm fibre concrete was applied on a smooth surface. The performance of the 6 mm coating was comparable to that of HDPE. The poor bonding between the coating and the surface of the 12 mm fibre concrete caused the coating to peel off as a result of even a minor mechanical damage.

Most weld seem coatings performed rather poorly. One coating, which has been developed for similar applications performed well.

Considering the physical properties of the coatings and also the overall costs of gas pipeline construction the main conclusion is that normal 3 mm HDPE coating is sufficient for most applications. In extreme conditions where the risk for coating damage is high a thicker layer of HDPE, up to 10 mm can be justified. The use of fibre concrete does not provide any particular advantage.
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1. BACKGROUND

The natural gas pipeline in Finland was originally taken into operation 1974. Since then the gas grid has been steadily extended. The environmental demands on pipeline construction have increased all over the world and consequently new methods have been developed in the direction of non-digging techniques, such as horizontal directional drilling (HDD). These methods have some considerable advantages in conditions like those in Finland with several crossings of roads and rivers.

There are, however, some risks connected to HDD. The coating of the pipe may be damaged when pulling the pipe through the drilled hole. Especially the coating of weld seems with sleeves or tape, are very vulnerable to damages.

The background for the tests and development work described in this paper are the experiences faced by Gasum in pipeline construction work where especially HDD was utilized. Figure 1 shows the coating damage which occurred during a crossing of a road. The pipe had obviously been pulled against a sharp piece of rock or a similar object.

![Figure 1. Damages occurred during pulling of the pipe](image)

2. AIMS

The objective of the work was to evaluate the suitability of different types of coatings in conditions, where the coating is subject to extreme abrasive loads. Such conditions may occur when pulling the pipe through a drilled hole, especially in soils containing rock or stones. Damages to the coating are impossible to detect and hence the ability to withstand abrasive loads is necessary. The aim of the tests was to compare the performance of different coating materials and welds seem coatings in as realistic conditions.
as possible. The test was also intended to provide the pipeline designer with a tool to evaluate the possibility and feasibility of using different construction methods and backfill materials.

3. METHODS.

3.1 Test equipment

The main purpose of the testing equipment was to simulate actual field conditions during pulling a pipeline through soil expected to contain rock or similar harmful elements. A test jig (Figure 2) was constructed through which a DN300 - DN700 pipe could be pulled.

During pulling different abrasive loads were applied on the surface. As abrasive element were used natural stone (1) with rounded edges (Figure 2), sharp edged stone (2) (blasted rock, figure 2) and a V-shaped steel knife. For the weld coatings only the sharp edged stone was used.

The test was repeated with increased load until the coating was penetrated and the pipe was exposed. This was tested with an electrical coating tester. The load was applied with a winch on the pipes and with weights on the welds seem coatings.

Figure 2. Test equipment.
Left: Test rig with pipe and winch
Right: Abrasive stones.
3.2 Tested materials

Testing was performed on the following coating materials

- DN700 High density polyethylene (HDPE), 3 mm
- DN500 High density polyethylene (HDPE), 10 mm
- DN300 Low density polyethylene (LDPE), 3 mm
- DN500 Polypropylene (PP), 3 mm
- DN400 HDPE 2.5 mm + Fibre concrete, 6 mm
- DN300 HDPE 3 mm + Fiber concrete, 12 mm
- DN300 FBE + PP tape “Curv”, 2 mm

Weld seem coatings (Tapes and sleeves)

- Denso, Densolid TLC
- Denso, Densolen Tape AS40 Plus
- Raychem HTLP 60
- Raychem Dirax
- Canusa GTS 65
- Canusa TBK

3.3 Test conditions

The tests were performed indoors in an industrial hall. The surface temperature of the coating was 15 - 17 degrees Celsius.

4. RESULTS

4.1 General

The test results are indicated for each product below in tables 1 and 2. The maximum load without penetration and the penetration load are given for each product. Due to practical reasons the tests could not be repeated several times and the load figures shall be considered more as relative than absolute figures. The load was added stepwise and the actual penetration load for each product lies somewhere between the measured loads.

The test results are separately given for each test, respectively product, in tables 1 and 2 below. Photographs showing the impact on the pipe are shown in appendices A - D.

<table>
<thead>
<tr>
<th></th>
<th>Stone 1 No penetration Load (kg)</th>
<th>Stone 1 Penetration Load (kg)</th>
<th>Stone 2 No penetration Load (kg)</th>
<th>Stone 2 Penetration Load (kg)</th>
<th>Steel knife No penetration Load (kg)</th>
<th>Steel knife Penetration Load (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HDPE 3 mm</td>
<td>1920</td>
<td>2400</td>
<td>2000</td>
<td>2400</td>
<td>1050</td>
<td>1500</td>
</tr>
<tr>
<td>HDPE 10 mm</td>
<td>2000</td>
<td>-</td>
<td>2000</td>
<td>2300</td>
<td>1000</td>
<td>1500</td>
</tr>
<tr>
<td>LDPE 3 mm</td>
<td>510</td>
<td>1050</td>
<td>540</td>
<td>700</td>
<td>510</td>
<td>700</td>
</tr>
<tr>
<td>PP 3 mm</td>
<td>1050</td>
<td>1500</td>
<td>700</td>
<td>1000</td>
<td>230</td>
<td>700</td>
</tr>
<tr>
<td>FC 6 mm</td>
<td>2000</td>
<td>2300</td>
<td>2000</td>
<td>2300</td>
<td>500</td>
<td>700</td>
</tr>
<tr>
<td>FC 12 mm</td>
<td>1000</td>
<td>1500</td>
<td>500</td>
<td>700</td>
<td>500</td>
<td>700</td>
</tr>
<tr>
<td>Curv</td>
<td>1000</td>
<td>1500</td>
<td>1000</td>
<td>1500</td>
<td>500</td>
<td>700</td>
</tr>
</tbody>
</table>
4.2 Pipe coatings

The 3 mm HDPE coating, which was tested, is the normal coating used by several gas companies. It has good resistance against transport and handling. The 10 mm HDPE coating has been developed for applications where the pipe may be subject to mechanical damage. It could not be penetrated as the test equipment could not produce the necessary load without being damaged. The HDPE pipes are shown in appendix A.

The LDPE is extremely vulnerable to all kind of damages. PP coating has certain advantages under some conditions. Due to its hardness it has good protective properties under static loads. It is, however, vulnerable to dynamically caused damages by sharp objects (appendix B). This test was performed under relatively mild weather conditions. PP turns more brittle in cold conditions.

Fibre concrete coatings have generally been considered as very suitable for pipelines in severe conditions. A relatively thick layer of fibre reinforced concrete has good protective properties against external damages under most conditions. Sharp objects may, however, cause damages under relatively low loads. The test results show that the adhesion between the pipe and the coating is more important than the properties of the coating itself. The pipe with a 6 mm coating was equipped with a profiled HDPE coating, providing a strong adhesion between the different coating layers. The other pipe, with a 12 mm coating peeled off almost completely from the smooth surface below (appendix C).

The FBE+PP Curv tape is a product yet under development and not available commercially. The test pipe was coated in laboratory conditions and the bonding between the FBE and the tape as well as between the tape layers was insufficient. The coating material has performed well compared to other coatings in static tests. The tape consist of polypropylene fibres in several layers at 90 degrees angels against each other. The composition seems to be vulnerable against cutting forces.

4.3 Weld seems coatings

<table>
<thead>
<tr>
<th>Stone 2</th>
<th>No penetration Load (kg)</th>
<th>Penetration Load (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Densolid TLC</td>
<td>400</td>
<td>730</td>
</tr>
<tr>
<td>Densolen tape</td>
<td>240</td>
<td>400</td>
</tr>
<tr>
<td>Raychem HTLP 60</td>
<td>550</td>
<td>650</td>
</tr>
<tr>
<td>Raychem Dirax</td>
<td>830</td>
<td>930</td>
</tr>
<tr>
<td>Canusa GTS 65</td>
<td>240</td>
<td>400</td>
</tr>
<tr>
<td>Canusa TBK</td>
<td>240</td>
<td>400</td>
</tr>
</tbody>
</table>

Most tapes and sleeves were penetrated at relatively low loads. Raychem Dirax has been developed for HDD drilling and pulling purposes and performed well. The penetration load was double compared to most other coatings. The critical point is the edge between coated and uncoated pipe (appendix D)

Densolid TLC is an easily applicated coating with good properties against abrasion. The coating is hard and it peeled off in large pieces when penetrated.

5. INVESTMENT COSTS

In table 3 below are given relative cost factors for different coatings. The price of gas pipes varies considerable depending on market situation, size of the order etc. The estimated cost factors shall be
considered as indicative only. The prices for coatings are related to the price of 3 mm HDPE, thus having the cost factor 100 and the prices for weld seam coatings are related to Canusa GTS. Prices for Denso product are not available.

### Table 3. Cost factors

<table>
<thead>
<tr>
<th>Cost factor</th>
<th>HDPE = 100</th>
<th>Canusa GTS = 100</th>
</tr>
</thead>
<tbody>
<tr>
<td>HDPE 3 mm</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>HDPE 10 mm</td>
<td>250</td>
<td></td>
</tr>
<tr>
<td>LDPE 3 mm</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>PP 3 mm</td>
<td>125</td>
<td></td>
</tr>
<tr>
<td>FC 6 mm</td>
<td>150</td>
<td></td>
</tr>
<tr>
<td>FC 12 mm</td>
<td>200</td>
<td></td>
</tr>
<tr>
<td>Curv</td>
<td>260</td>
<td></td>
</tr>
<tr>
<td>Raychem HTLP 60</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Raychem Dirax</td>
<td>500</td>
<td></td>
</tr>
<tr>
<td>Canusa GTS 65</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Canusa TBK</td>
<td>215</td>
<td></td>
</tr>
</tbody>
</table>

The PP coating is slightly more expensive than HDPE 3 mm. 10 mm HDPE, 12 mm fibre concrete and Curv are on the same level and the 6 mm fibre concrete is somewhere between.

Canusa and Raychem sleeves are equally priced, Canusa TBK is twice the price. Raychem Dirax is considerably more expensive than all the other coatings.

### 5. CONCLUSIONS

Under normal construction conditions, when the pipeline is laid in a trench, using backfill material without harmful elements such as sharp stones etc. and the pipe is handled with normal care under transportation, most coatings perform well and the main consideration is the capability to protect the pipe from corrosion when in operation. Alternative construction methods or the risk of damage during difficult transport and handling conditions bring forward the advantages of stronger coatings.

A more resistant and expensive coating can be motivated when the pipeline is laid in a rocky terrain and the transportation of sand or other high quality backfill is difficult and expensive. In such cases the rock can be crushed and used as such. As has been earlier mentioned one purpose of the test was to find a suitable coating combination for trenchless construction methods.

The coatings used in this test are oil based plastic products or reinforced fibre concrete. The latter has been considered to be a very resistant coating in difficult conditions. Such conditions may be different types of trenchless construction methods, the use of low quality backfill materials, crossings etc. This test indicates that a commonly used 3 mm HDPE coating fulfills most requirements in various situations. It has very good mechanical properties and it is the most economic alternative. For purposes, where additional durability is required a double or triple layer of HDPE provides sufficient protection against most external mechanical damages.
APPENDICES

A. Figure 3.  HDPE coatings
B. Figure 4.  PP coating and FBE + Curv coating
C. Figure 5.  Fibre concrete coatings
D. Figure 6.  Weld seem coatings
Appendix A

Figure 3.
Above: HDPE 3 mm coating. Test result with stone 1, 2400 kg
Below: HDPE 10 mm coating. Test result with steel knife 650 kg.
Figure 4.
Above: PP coating. Test result with stone 1 and stone 2, 1500 kg
Below: FBE + Curv Test result with stone 2, 2000 kg.
Figure 5.
Above: Fibre concrete 12 mm coating. Test result with stone 1, 1500 kg
Below: Fibre concrete 6 mm coating. Test result with stone 1, 1500 kg
Appendix D

Figure 6.
Above: Raychem HTLP 60. Test result with stone 2, 400 kg
Below: Raychem Dirax. Test result with stone 2, 930 kg