Geosynthetics, J. Kuwano & J. Koseki (eds)
© 2006 Millpress, Rotterdam, ISBN 90 5966 044 7

Implementation of HDPE geomembrane and geotextile liner: A case history from Baku-Tbilisi-Ceyhan (BTC) crude oil pipeline project storage tank farm, Ceyhan marine terminal

Kaya, E.
Japan-Turkey Metro Joint venture P.O. Box 182845 Dubai, UAE - ekrem@jtmjv.ae
(Former Graduate Student at Bogazici University)

Guler, E.
Bogazici University, Civil Engineering Department, Istanbul, Turkey - eguler@boun.edu.tr

Keywords: HDPE Liner, membrane, geotextile, storage tanks

ABSTRACT: BTC Project will provide the additional crude oil transportation capacity required for oil export development of hydrocarbons in the Caspian Sea. The marine terminal at Ceyhan contains seven oil storage tanks each having a storage capacity of 150,800 m^3. As there is a serious risk of pollution hazard due to a potential oil leakage or spill, use of HDPE liner in tank farm is considered especially under the tank bottoms, tank dykes and yard. A case history of the implementation of HDPE geomembrane liner and geotextile underneath the large scale crude oil storage tanks of Baku-Tbilisi-Ceyhan Crude Oil Pipeline (BTC) Project is described from design stage to installation and testing stages.

1 INTRODUCTION

Baku-Tbilisi-Ceyhan Crude Oil Pipeline Ceyhan Terminal Tank Farm is composed of 7 crude oil storage tanks each having a storage capacity of 150,800 m^3, diameter of 100 m and height of 19.2 m. A general plan of the tank farm and a sample tank can be seen in Figure 1 and Figure 2 respectively.

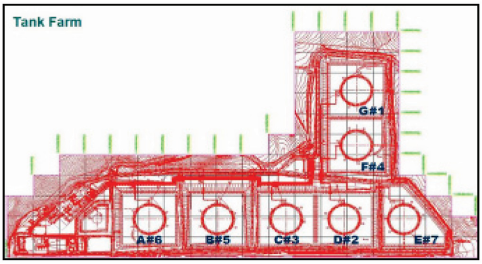

Figure 1. General plan of Ceyhan Marine terminal tank farm.

During the design stage, a large investigation was performed regarding the geo-hazards. One of the most important geo-hazards is the pollution due to potential oil spill. For environmental reasons, in case of an oil spill, no oil shall get in contact with ground. From the local geological maps it was known that the foundation soil is a volcanic rock mass with varying permeability. The permeability is controlled by the observed cracks, which are filled with loose material. The distances between the cracks are sometimes very large.

Figure 2. A view from BTC crude oil storage tanks.

Therefore in the detailed engineering stage, a tank lining system is foreseen by ILF (2002) to cover the tank yard (also underneath the tanks) and the dykes. The lining had to prevent soil pollution in case of an oil spill. It was decided that the preventive liner shall consist of an HDPE liner and a protective layer of geotextile on top. This protective layer shall protect the membrane from the earth cover which has a thickness of minimum 19 cm. With this construction, the geo-hazard due to future pollution is expected to be negligible.

2 SYSTEM DESCRIPTION

Tank Yard Liner and Foundation Sealing have been installed according to ÖNORM S 2073, S2076 and described in a detailed manner in project specification TKF-SPC-EMC-TRG-002-0. Tank yard lining system, from bottom to top consisted of a total of 4 layers as seen in Figure 3. These are as follows:

(1) Sub-grade: average thickness is 5 cm, maximum grain size is 22 mm, grain size distribution is as follows:
Gravel (2–22 mm): 60–84%
Sand (0.06–2 mm): 15–30%
Silt and clay (<0.006 mm): 5–10%
(2) HDPE-liner: structured on both sides with a thickness of 2.5 mm
(3) Geotextile protection layer
(4) Protective layer: min. thickness of this layer is 19 cm, maximum grain size: 63 mm and grain size distribution is as follows:
Gravel (2–63 mm): 64–84%
Sand (0.06–2 mm): 6–26%
Silt and clay (<0.006 mm): 0–10%

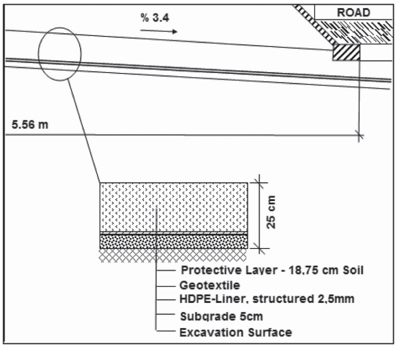

Figure 3. Profile of a typical tank bottom.

A similar system was applied for the slopes of the bunds but additionally a drainage layer with min. thickness 20 cm was implemented.

3 MATERIAL INFORMATION

HDPE Liner and geotextile material requirements were described in project specification "ILF-SPC-EMG-TRG-001 Rev. 2. *Specification Civil/Structural Terminal Onshore*". Materials were supplied according to these specifications which are summarized below.

3.1 *HDPE Liner*

The HDPE material (High-density polyethylene) was selected to meet the requirements of ÖNORM B 3700 and S 2073 with a thickness of 2.5 mm, structured on both sides and grading of DB1. Characteristics, Physical Properties, Biological Resistance of the material are summarized below.

3.1.1 *General Characteristics of HDPE Liner*
- General properties: Surface is closed and material is free of flaws (pores, bubbles, inclusions)
- Straightness (g) and Flatness (p): g ≤ 50 mm from the secant measured over a roll length of 10 m and p ≤ 10 cm across the plane measured over a roll length of 10 m
- Nominal thickness: ≥ 2.5 mm
- Liner width (seamless) ≥ 2.0 m

3.1.2 *Physical Properties of HDPE Liner*
- Melt mass-flow rate (MFR): 0.4 g/10 min to 3.0 g/10 min (190/5)
- Relative change of the melt mass-flow rate after processing: Change as compared to the value measured in the incoming inspection of the raw material ≤ 20%
- Carbon black content: 2.0% to 2.5%
- Carbon black dispersion: A1, A2
- Resistance to tear strength: Tear strength ≥ 300 N
- Puncture resistance: 6 tight in case of a falling height of ≥ 2000 mm
- Resistance to punctual, quasi-static, individual loads: Perforation force ≥ 6000 N
- Low temperature brittleness: No cracks at –20°C
- Uniaxial tensile strain:
  (1) Yield strength ≥ 15 N/mm^2
  (2) Elongation at break ≥ 600%
- Multi-axial tensile strain: Elongation at rupture or break ≥ 25%
- Change in dimensions (heat reversion test): ≤ 1% at 100°C

3.2 *Geotextile*

Geotextile material shall meet the requirements of ÖNORM S 2076-2. It must be a mechanically bonded continuous filament nonwoven which is made of UV stabilized Polypropylene as raw material. Main characteristics of the geotextile are as:

- CBR puncture resistance: 7.800 to 10.000 N
- Tensile Strength: 45 to 60 kN/m
- Pyramid Puncture Test together with HDPE-liner of 2 mm thickness (ÖNORM S 2076-2): 3.200 to 4.500 N
- Mass (mechanically bonded continuous filament nonwovens): 800 to 1,200 g/m^2

4 INSTALLATION METHODOLOGY

Installation requirements were all described in document "TKN-PRO-EMC-TRG-029-1 Ceyhan Marine Terminal Construction, Method of Construction for HDPE Geomembrane Applications".

Risk Assessments associated with installation of HDPE liner and geotextile were all addressed in project specific document TKF-REP-HSM-TRG-022 and all necessary health and safety measures were taken accordigly. In order not to damage the geomembrane surface personnel working on the geomembrane were not allowed to wear shoes that can damage the geomembrane or engage in actions which could result in damage to the geomembrane.

Adequate temporary loading and/or anchoring, (i.e. sandbags, tires), which will not damage the geomembrane, was placed to prevent uplift of the geomembrane by wind. The geomembrane was deployed in a manner to minimize wrinkles.

In general, seams were oriented parallel to the slope, i.e., oriented along, not across the slope. Whenever possible, horizontal seams are located on the base of the cell, around 1-1.5 m. from the toe of the slope.

All personnel performing seaming operations were trained in the operation of the specific seaming equipment being used and were qualified by successfully welding a test seam. The project foreman provided direct supervision of the seaming operations.

Regarding the Quality requirements of HDPE liner, external supervision and internal testing (quality control) were carried out according to ÖNORM S 2073 and 2074. Welding activities were performed according to ÖNORM S 2076-1.

Lining sheets were arranged with an overlap and connected by double weld seams thus producing a test-channel between the welds. Welds were made automatically by using Fusion Welder (heated wedge welding machine a picture of which is presented in Figure 4) with continuous recording of welding parameters. Fusion Welder consists of a heated wedge, mounted on a self propelled vehicular unit, between two overlapped sheets such that the surface of both sheets are heated above the polyethylene's point. After being heated by the wedge, the overlapped panels pass through a set of pre-set pressure wheels which compress the two panels together to form the weld. The fusion welder is equipped with device which continuously monitors the temperature of the wedge.

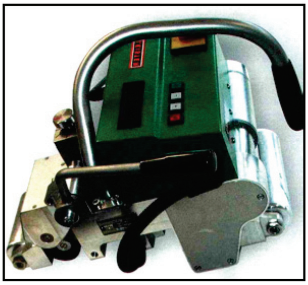

Figure 4. Fusion welder.

Trial welds for definition of welding parameters were made daily before commencement of works. Hand made welds (extrusion welding) were only made at special locations (repairing work, special connections e.g. to pipes) with an extrusion welding gun. Welds haven't been made at temperatures below 5°C. Welds have been made by certified welders. Extrusion fillet welding is applied for repairing of geomembrane panels.

5 TESTING

All necessary inspections and tests were identified and described in project specific document "TKF-PLN-QAC-TRG-803, Inspection and Test Plan for HDPE Geomembrane Liner". All welds were physically tested by a set of Nondestructive Testing Methods (NDT) along the process.
Leak tests of weld seams are:

- Air Pressure Test
- Vacuum Chamber Test (hand made welds)
- Spark Test

Strength tests for weld seams are:

- Peeling test on construction site
- Peeling test in a laboratory

In order to examine the test welds by peeling test, as demonstrated in Figure 5, sample strip cut with the weld centrally located are tested by stressing the top sheet in relation to the overlapped edge of the lower sheet in an effort to peel the weld away. A pass result occurs when the specimen meets the minimum peak load requirements stated below. The speed of testing machine clamp should not exceed 5 m/min.

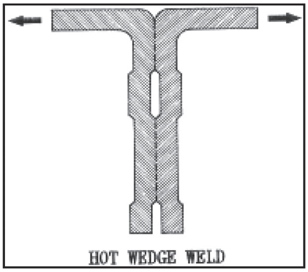

Figure 5. Peeling test procedure.

6 TEST RESULTS

Test results for the trial welds performed at Tank F, one of the seven storage tanks located in Ceyhan Tank Farm, are presented in the Tables 1-3.

Test results showed that all necessary material and installation requirements satisfied and tests have been passed.

Table 1. Air pressure test results.

Description	Value
Number of welds tested	23
Range of applied pressure	2.3–2.7 bar
Duration	5 min
Criteria for pressure difference	<0.15 bar
Obtained pressure difference	"0" for all tested welds
Result	Passed

Table 2. Peel test results (for Fusion Welds).

Description	Value
Wedge Temperature	420 °C
Speed setting	3 m/min
Peel Value obtained	35.1 N/mm
Criteria	>26.25 N/mm
Result	Passed

Table 3. Spark test results (for Extrusion Welds).

Description	Value
Seam tested	W27
Voltage	40W
Speed	10 m/min
Criteria	No defect
Obtained	No defect
Result	Passed

Table 4. Properties measured on virgin geomembranes and samples left in crude oil for a week.

Test	Tensile strength DIN 16726 (MPa)	Elongation at rupture DIN 16726 (%)	Water absorption DIN 53495 (%)
Virgin Sample	24.7	848	0.04
Sample left in crude oil	25.6	849	0.12

One of the most important issues was the durability of the membrane. Since the geomembrane was covered by earth fill the UV stability was not that much critical. However in case of a spill, the HDPE membrane will contact the crude oil. Since polymers are quite sensitive against oil and oil products, special durability test were conducted at the DSI laboratory in Ankara, Turkey. Two sets of tests were conducted. First set of tests were conducted on original geomembrane samples. The second sets of tests were conducted on samples which were left immersed in crude oil for seven days. The results of the tests are summarized in Table 4.

As can be seen from Table 4, leaving the geomembrane in crude oil does not affect the tensile strength and the elongation at rupture significantly. However there was a marked increase in water absorption which may indicate that longer exposure to crude oil may have a negative effect also on the strength properties.

In addition tests were conducted to check the behavior of the geomembrane in cold weather becomes brittle. Therefore DIN 16726 rolling test was conducted at a temperature of –30°C and no failure was observed.

7 CONCLUSION

As a conclusion it can be stated that the tank farm was underlined successfully with a geomembrane liner and Quality Control/Assurance and Health, Safety procedures were strictly followed. Compared with the other leakage prevention measures, HDPE implementation provides the most cost effective solution for similar large scale projects.

This project also sets a good example for other environmental problems where geosynthetics can be used.

REFERENCES

DIN 16726 Plastic roofing felt and waterproofing sheet testing.

DIN 53495 Testing of textiles; determination of water absorption of textile fabrics.

DSI (State Waterworks Authority) Ankara Laboratories, 2004, "05.FR.O6 Rev. 001, HDPE Liner Test Report".

ILF Consulting Engineers, 2002. "ILF-SPC-EMG-TRG-001 Rev. 2 Specification Civil/Structural Terminal Onshore".

Ö-Norm S 2074 Part 2 "Geotechnical investigations for waste disposal facilities, earthwork".

Ö-Norm S 2073 "Waste disposal facilities, Polymer membrane liners; requirements and test methods; marking of conformity".

Ö -Norm S 2076 "Waste disposal facilities, Polymer membrane liners; installation".

Ö-Norm B 3700 "Plastic-sheets for waterproofing; classification, general requirements and tests".

Tekfen Construction, 2003. "TKF-SPC-EMC-TRG-002-0 Ceyhan Marine Terminal Construction Works Specification for Concrete Protective Liner".

Tekfen Construction, 2003. TKN-PRO-EMC-TRG-029-1 Ceyhan Marine Terminal Construction, Method Of Construction for HDPE Geomembrane Applications.

Tekfen Construction, 2003. TKF-PLN-QAC-TRG-803 Inspection and Test Plan for HDPE Geomembrane Liner.

Tekfen Construction, 2003. TKF-REP-HSM-TRG-022 Risk Assessment for Installation of HDPE Pipes, Geotextile and Laying of HDPE Liner Geomembrane.