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Geosynthetics application at landfills in arid climate regions

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1 INTRODUCTION

The State of Kuwait lies at the northeast edge of the Arabian Peninsula at the head of the Arabian Gulf. It is an arid region country with no “fresh” surface water and very limited resources of useable groundwater. The rapid urban and industrial development of Kuwait in recent years has created complex environmental problems and posed serious health hazards. Kuwait has a population of more than 2.1 million people and producing more than 2500 tones of Municipal Solid Waste (MSW) per day. Kuwait is one of the largest producers of per capita solid waste (1.37kg/d) in the world.

Landfilling is still the most preferred method of disposal of municipal solid waste (MSW) in Kuwait. Kuwait has three different sites that receive MSW (Sulaibiyah, Mina Abdulla, and South 7th Ring Road) and two sites that receive construction and demolition material (Jahra, and North 7th Ring Road). All sites in Kuwait act as dumping grounds rather than safe landfill areas, lacking safe engineering practices operation at the landfill sites. Also, all the sites were not designed for sanitary landfilling. Most of the landfill sites were old group of sand quarries that had resulted from excavation jobs and used for the construction of roads, buildings…etc. The average depths of these abandoned quarries are between 5-18 meters. Acknowledging the problems in landfill sites in Kuwait, geosynthetics will be one of the major components in the new sanitary landfilling technology in the country. This paper will presents a survey on the uses of these materials in Kuwait and its major markets. Also, it will evaluate the tensile properties and tear resistance of selected HDPE samples that are used or proposed for waste facilities in Kuwait.

2 CONDITIONS OF LANDFILLS IN KUWAIT

In Kuwait, MSW landfills receive all kind of wastes such as household waste, industrial waste, oil products, agricultural wastes, chemical materials, and all sort of liquid waste. The Liquid waste includes wastewater from areas not connected to the main sewerage system, sludge produced from treatment plants, dairy and food factory products, and brick factory waste (white sludge). Hazardous wastes from oil industry and factories, contaminated soil, harmless medicine, non-gastric hospital waste, and embellishment products are also dumped in MSW landfill. The different kinds of waste are commingled without any guidelines or separation methods. Most of the waste are placed in high, steep slopes and usually exposed to the environment for long period. Large quantities of leachate and landfill gas are expected from all the landfills in Kuwait. Highly toxic and organic leachate have been reported from local landfills (Hamoda and Al Yaqout, 2001). Liner and cover systems that serve as barriers and protective layers are not defined in Kuwait landfill sites. The occurrence of fires is increased in the summer due to the high temperature (exceeding 50°C several times). The health and safety of the workers at the landfills is in critical situation. Both Kuwait Municipality, the agency responsible for supervising landfill sites, and the operators (private companies) have not established health and safety programs for the workers at the landfill sites. Monitoring systems in the landfill operation at landfill sites are missing tool for waste management in Kuwait. Water quality, leachate and gas control, landfill volume survey, ongoing maintenance, and appropriate records and data for waste stream are key issues that are causing current and future disasters for the country (Al-Yaqout and Hamoda, 2001).

3 APPLICATION OF GEOSYNTHETICS IN KUWAIT

The pattern of use of geosynthetics and its demand in Kuwait has been found out by a well-designed and structured questionnaire with a sample size of 30 in June 2001. The major construction companies, consultant and relevant Ministries have been contacted.

Table 1. Pattern of use of geotextile in Kuwait

Year of Installation	Project Name, Location	Quantity (square meter)	Purpose of Use
1990 till date	Public Housing projects	More than 1Million	Roof Drain
1994	Mishrif Neighborhood Center, Mishrif	30,000	Roof Drain
1995	Al-Safat Market, Kuwait City	12,000	Filter and Protection Layer
1996	Solid Waste Disposal, Shuaiba*	12,000	Hazardous Waste Protection
1998	Al-Qurain School	8000	Filter and Protection Layer
1998	Waterfront Project, Sharq	72,000	Sea Front Protection
1999	Coast Guard Complex	65,000	Soil Stabilizer
1999	South Doha Public Housing	65,000	Soil Stabilizer
1999	Al-Fanar Complex	4000	Filter and Protection Layer
1999	Al-Zoor Port	2000	Erosion Control for Shore line
1999	Jahra Infra structure	15,000	Pipeline Protection
1999	Mustafa Sultan Showroom, Shuwaikh	1500	Roof Drain
2000	Al Munther Commercial Building, Benid Al Ghar	8000	Roof Drain
2000	Mazda/ Peuget Showroom, Shuwaikh	2000	Roof Drain
2000	GMS, Showroom, Shuwaikh	3000	Roof Drain
2000	CRC, Building, Benid Al Ghar	7500	Roof Drain
2000	Umm Al Hyman STP, Umm Al Hyman	17,750	Drainage Work
2000	Al Bahar Head Quarters, Kuwait City	700	Roof Drain
2000	Al-Farwania Hospital	4000	Filter and Protection Layer
2000	Kuwait University, Shuwaikh Campus, Shuwaikh	17,000	Roof Drain
2001	Volkswagon Showroom, Shuwaikh	1000	Roof Drain
2001	Bukhamseen Res. Tower	6000	Roof Drain
2001	Yasmin Tower, Shaab	1500	Roof Drain
2001	Al Awadi Tower, Sharq	6000	Roof Drain
2001	Kharafi Apartment and Offices, Kuwait City	1000	Roof Drain

* Geomembrane

The processed results of data obtained from the survey have been presented in Table 1. The results show that geosynthetics have been used in roof drainage, marine works, soil stabilizer and a liner at the Hazardous Solid Waste Treatment and Reception Station (HSWTRS) in Kuwait. Geotextile fabrics were found used among the all range of Geosynthetics products. The popular brands were Fibertex Brands (F150, F 45, F 381, F 110), and Synthetic Industries Pyramat. It was clear from the data obtained during the survey that the use of geosynthtics has started since 1990s. The growth in its demand was very slow till year 2000. It has started its extensive applicability in all major and expensive structures as special building materials. During the survey, most of the consultant and construction companies were found promoting the use the geosynthtics in this country for their ongoing and future civil engineering projects. The major finding of this survey was that no performance test for geosynthtics materials has been conducted in Kuwait before or after its use in any of the previous projects in which geosynthetics has been used. Furthermore, the survey indicates that there is no techno-economic feasibility study has been conducted in the state of Kuwait to evaluate the technical problems of geosynthetics use for long-term exposure of abnormally high temperature in summer and a very low temperature in winter with arid/dry climate in any kind of works/projects. Geomembrane are not used in the construction of base liners and cover systems for any municipal waste containment facilities in Kuwait. Nevertheless, geomembrane was used as base liner at only Hazardous Waste Treatment and Reception Station (HSWTRS) for Shuiba Industrial Area (SIA) and in certain applications such as basement and roof insulators for expansive structures.

4 EVALUATION OF HDPE IN LANDFILLS IN ARID CLIMATE

A number of materials are being considered for lining the landfill in Kuwait. These includes Gatch (local sand), bentonite mixed with amended soils, asphaltic concrete, shortcrete (on the steep slopes) and geosynthetics. Different polymers types are used for landfilling linning materials, including ployvinyl chloride (PVC) and reinforced chlorosulphonated polyethylene (CSPE), but in the light of economics and leachate compatibility tests, the now common choice of high density polyethylene (HDPE) was selected to carry out test for its applicability (Overmann etal.,1993).

In Kuwait, the environment is an important factor when applying any material exposed in the field. The unusual high temperatures in the summer and the change in weather during the winter may cause critical alterations in geomembrane properties. The state of Kuwait falls climatically within the desert zone. The climate of Kuwait is described as very hot, dry summers with an average daily temperature of 45°C (113.1°F) and mild to cool winters in which temperatures fall to as low as 6°C (42.8°F). The temperature is highest in July and August and lowest in January and February. Therefore, the mechanical integrity of the geomembrane must be maintained for the design life of the landfill. Merry and Bray (1997) stated that geomembranes, unlike geotextiles, are rarely designed as structural members that carry loads, but the expected response from geomembranes is to deform due to settlement of the underlyingmaterial,describedaselongation,withoutfailure. Moreover, it was reported that HDPE tends to accumulate moisture due to high temperature, which eventually increased the permeability of the gatch pad after six months of construction (Al-Yaqout, 1999).

The purpose of the lab tests was to help in designating the extent of the effect on geomembrane properties when exposed to an arid climate. The testing program consisted of first evaluating the tensile properties of the geomembrane using ASTM D638-91. Then using ASTM D1004-90, the tear resistance of the geomembrane was evaluated. Two samples were collected from two different locations. The first location was HSWTRS for the Shuaiba Industrial Area (Liner 1). The high-density polyethylene membrane sample was collected from the liner system of HSWTRF. The synthetic membrane liner system was exposed to the environment for a period of one year with no waste being disposed during that period. Although the liner was covered by a protective sand layer, few areas were not protected such as the slopes and around the leachate collection sump. The sample was retrieved from the unprotected areas. The second location was the Shuwaik testing site (Liner 2) where a high-density polyethylene membrane (HDPE) was placed for a period of six months without any protective layer on a compacted three cemented sand liner system.

All tests were conducted at a sample rate of 10.00 (pts/sec) and crosshead speed of 51 (mm/min). Three liner-1 specimens and four liner-2 specimens were tested following the ASTM D1004-90 test method. Furthermore, three liner-1 specimens and six liner-2 specimens were tested following the ASTM D638-91 test method. The humidity and temperature at testing time were 50% and 25°C respectively. For samples prepared according to ASTM D638-91, the width of liner -1 and liner-2 specimens was 6-mm (0.23-in), but the average thicknesses for liner 1 and liner 2 were 2.56-mm (0.1-in) and 1.5-mm (0.06-in) respectively. For both liner specimens the gauge length was 25.0-mm (1-in) and the grip distance was 64-mm (2.52-in). The overall length of the specimens was 115-mm (4.5-in.). For ASTM D1004-90 specimens, the width of the specimens of liner-1 and liner-2 was 12.7-mm (0.5-in) and the thickness was 2.56-mm (0.1-in) for liner-1 and 1.5-mm (0.06-in) for liner-2. Similarly, the grip distances and the specimen gauge lengths for both liner-1 and liner-2 were 50.0-mm (2-in) each. The overall length of the specimens was 101.6-mm (4.0-in.). Test results of tensile properties (ASTM D638-91) and tear resistance (ASTM D1004-90) for liner-1 and liner-2 are shown in Table 2 and 3 respectively.

Table 2. Geomembrane Tensile Properties Testing Results

	Specimen	Cross	Peak (1)	Tensile	Ultimate (2)	Stress (3)	Young's (4)
Sample		Area	Load	Strength	Elongation	at 0.2% yield	Modulus
	#	(mm^2)	(KN)	(MPa)	(%)	(MPa)	(MPa)
	1	15.36	0.3172	20.65	-	17.69	154.3
Liner 1	2	14.88	0.3395	22.82	~	19.40	201.3
	3	15.00	0.2997	19.98	-	18.70	144.3
	Mean	15.08	0.3188	21.15	~	18.6	166.1
	St.						
	Dev.	0.25	0.0199	1.48	~	0.86	30.4
	1	9.00	0.2152	23.91	802.00	17.97	143.90
	2	9.00	0.2137	23.74	806.80	17.62	161.30
Liner 2	3	9.00	0.2145	23.83	749.60	17.75	137.90
	4	9.00	0.2136	23.73	788.00	17.42	190.00
	Mean	9.00	0.2143	23.81	786.40	17.69	158.30
	St.						
	Dev.		0.0055	11.00	~	0.23	23.4
Legend:	(Specifications)						
	(1) > 0.336 KN for liner 1, > 0.216 for liner						
	(2) > 600% for liner 1, > 800% for liner 2						
	(3) > 13.4 MPa for liner 1, > 18 MPa for liner 2						
	(4) > 483 MPa for liner 1, > 900 MPa for liner 2						

Results from testing high-density polyethylene specimens indicate that Young's Modulus decreases considerably after long field applications. Furthermore, the strength of the specimens barely met minimum standards provided by manufactures. The mean Young's Modulus for liner-1 was 166.1 MPa, which is 66% less than the minimum 483 MPa. Similarly, the mean Young's Modulus for liner-2 was 158.3 MPa, which is 82.4% less than the minimum 900 MPa. The average peak load for liner

Table 3. Geomembrane Tear Resistance Testing Results

Sample	Specimen	Maximum Load	Maximum Tear Resistance	Minimum Requirement
	#	(KN)	(KN/M)	(KN)
	1	0.3569	139.60	0.27
	2	0.3677	143.90	0.27
Liner 1	3	0.3542	138.60	0.27
	Mean	0.3542	140.7	0.27
	Standard			
	Deviation	0.0071	2.8	-
	1	0.2326	465.20	0.2
	2	0.2243	448.60	0.2
Liner 2	3	0.2369	473.80	0.2
	4	0.2346	469.20	0.2
	Mean	0.2321	464.20	0.2
	Standard			
	Deviation	0.0055	11.00	-

(1) and liner (2) was 0.3188 KN and 0.2143 KN respectively. The minimum requirements of peak load for liner-1 and liner-2 were 0.336 and 0.216 KN respectively. This supports the study conducted by Merry and Bray (1997) on high-density polyethylene (HDPE). The previous study concluded that the secant of modulus and strength decreases considerably at strain rates appropriate for long-term field applications. Furthermore, the average ultimate elongation for liner-2 was 786.40%, which was below the minimum acceptable requirements of manufacturer specification (800 %). For tear resistance, the average maximum loads for liner-1 and liner-2 were 0.3542 and 0.2321 KN respectively. The minimum requirements for liner-1 and liner-2 were 0.27 and 0.2 KN respectively.

5 CONCLUSIONS

Geotextiles have been used extensively in Kuwait for roof drain and marine works since 1990s. Nevertheless, Geomembranes (HDPE) were used scarcely in special expensive projects such as the hazardous waste landfill and its application have been recommended for liner and cover system in all future Municipal Solid Waste Landfills by Kuwait Municipality. The high future demand of this material is predicted in all the sectors especially in solid waste landfills due to positive response by both private and public sectors. Geomembrane is rather designed as structural members that carry loads but the expected response is to deform due to settlement to underlying materials so the reduction in modulus of elasticity may change the geomembrane response. Results from index testing of HDPE specimens indicate that the young modulus decreases considerably for long field applications. Therefore, the ability of HDPE to elongate without failing need to be reevaluated in arid climate. Also, index test result of HDPE average ultimate elongation show slight variation with manufacturer specifications where tear resistance results meet specification standards. Modification in HDPE properties for long term use in landfills may be necessary if it will be used in the future landfills liner and cover systems. Further research should be conducted on quality control of such materials in arid developing country. Also, training courses and seminars may increase the level of appreciation of such valuable material.

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