APPLICATION OF GEOSYNTHETICS AND EVALUATION OF WATER QUALITY IN AN ARTIFICIAL LAKE IN HARRAN UNIVERSITY, TURKEY

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ABSTRACT

Geosynthetic materials are mainly used to form an impervious medium against water infiltration and leakage during filling and concrete works in constructions. Besides, they are also used to protect the water quality in artificial lake constructions and, thus, selecting the best available geosynthetic material against leakage is important. This study investigates the effects of water, soil and materials used in design and construction of Osmanbey Campus Artificial Lake in Harran University, Şanlıurfa, Turkey. It also provides some suggestions for the possible problems. Application of a geosynthetic material is analyzed in detail by considering the climatic conditions, workmanship, applicability and water quality assessment in this artificial lake.

KEYWORDS:
Artificial Lake; geosynthetics; water quality; Osmanbey Campus Lake.

INTRODUCTION

A geosynthetic material is a synthetic one composed of soil, and is widely used due its high resistance to various environmental conditions. Geosynthetic materials can be produced enriched with different properties. Nowadays, they are getting cheaper because of their widespread usage.

Geotextiles have been widely used in various civil engineering applications, where they fulfill various functions, such as filtration, separation, drainage, reinforcement, and protection [1]. Geomembrane contains a high density polyethylene to control fluid flows regarding impermeability. As defined in ASTM D4439-00 [2], a geomembrane is an essentially impermeable membrane used in foundation, soil, rock earth, or any other geotechnical engineering-related material as an integral part of a man-made project, structure or system. A smooth high density polyethylene (HDPE) and a flexible polypropylene (f-PP) geomembrane with respective thicknesses of 2 mm and 1.5 mm are used, and three different soil types with hydraulic conductivities of around 10^{-10} ms^{-1} are compacted in the cell [3, 4].

The short history of geomembranes used in civil engineering applications renders difficult estimation of their service lives, predicted by the accelerated laboratory tests using a time and temperature prediction model known as Arrhenius modeling [5]. Gray [6] compared the accelerated ageing methods, which used elevated temperatures to simulate long-term HDPE exposures. The service life prediction of a HDPE insulation on the cables (at a temperature of 40 °C) used in the wire and cable industries is about several hundred years. HDPE geomembrane shows high resistance to leakages due to its strong and high resistance against chemicals, high tensions, low permeability, punching, and cracks. Besides, absolute impermeability gets from connection points with a double-fusion welding system [3].

The combination of several materials to create hybrid geosystems is often advantageous in the geotechnical designs. The combination of two or more geosynthetics has been used, in practice, in various applications for decades [1, 7]. Specific geomembrane–geotextiles are used in drainage, resisting puncturing, and controlling the tear propagation. Geomembranes used in combination with geotextiles are often textured for better compliance and interaction between the synthetic materials. Practical applications of geo-textile–geomembrane systems include landfill liners, highway subgrades, leachate and gas collection systems, and retaining structures [8, 9].

The significant question to be answered is "whether the presence of such a geotextile increases or decreases the leakage flow rate?" Previous experimental studies indicate the difficulty of deriving a conclusion due to the multiplicity of experimental conditions [4, 10, 11].

Various materials and construction types are especially used in various foundation types for the prevention of leakage in the wastewater treatment plants and solid waste landfills in Mid-latitude Western Europe, and also in USA. In the last decade, they have been used in Turkey for the same purposes, i.e. in Gaziantep solid waste landfill and Ceylanpınar wastewater treatment plant [12]. The geomembrane-geotextile material and concrete coverage in compressed foundations are preferred in Şanlıurfa Plain Irrigation Project Phase II constructions, and in the Upper Harran Main Irrigation Canal [13].

Although no serious problems have been encountered during the preparation steps of the above-mentioned works, some problems had to be solved during construction stage. The most important one was the elongation of the geomembranes resulting in deformation and undulation.

In this study, the application of a geosynthetic material at Harran University, Osmanbey Campus Artificial Lake, Şanlıurfa, Turkey is investigated in detail by considering the climatic conditions of the area, workmanship, applicability, and water quality assessment.

MATERIALS AND METHODS

The study area

Osmanbey Campus (Fig. 1) is one of the largest university campuses in Turkey with an area of 27×10^6 m^2 on an undulation topographical area [14]. The area is suitable to establish recreational areas with natural and landscape elements around a radius of 600 m. This will also aid to supply the necessary irrigation water for the green areas, and to form high density pedestrian motions. For these purposes, about 60 $\times 10^3$ m^2 of water level is laid down in an optimum manner to fulfill the designed landscape work [15]. This study investigates the implementation problems, such as the soil characteristics in the area, leakage problems from the water reservoirs, properties and behavior of the materials, the construction method and expected climatic troubles, and water quality problems.

The study area has various geological formations from young to old, such as Gaziantep formation Paleo and Quaternary alluviums. The geological units are white, cream color, soft, chalky and tiny marl layers at the bottom; cream, grey, pink color, wide cracked, chert-like layers hard round and heavy limestone ($CaCO_3$) layers at the top. At the top layers, marl sections are separated and have lithological character for convenient transport. The top alluvium layers consist of separated limestone, cherts and gravel blocks, reddish clay and longitudinal silts [16]. Geological structure of the study area is given in Fig. 2.

Lake modeling

Table 1 states the general characteristics of the lake system. It indicates that a total water volume of 79,069,820 m^3 will be supplied to 5 collection storage lakes, which will increase the attractiveness of pedestrians. Water will be supplied by pumps from the main irrigation canal [15]. The lakes are also fed by water jets in order to visually demonstrate the water surface movement.

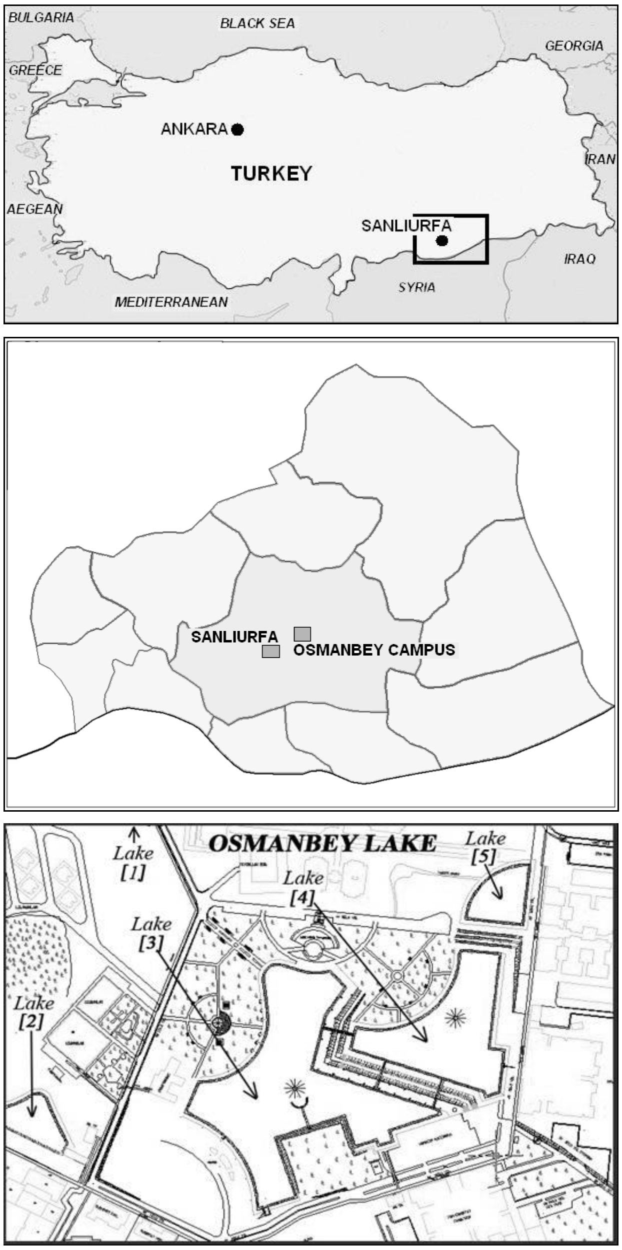


FIGURE 1 - Şanlıurfa Osmanbey Campus Location.

The lake will be supplied with water pumped from the Upper Harran Main Canal, where water comes from Atatürk Dam Lake by the help of Şanlıurfa Irrigation Tunnels. Eighty L/sec of potable water flow-rate will be supplied by electro-pumping from the main canal to the first reservoir by means of a pipeline with a diameter of 225 mm.

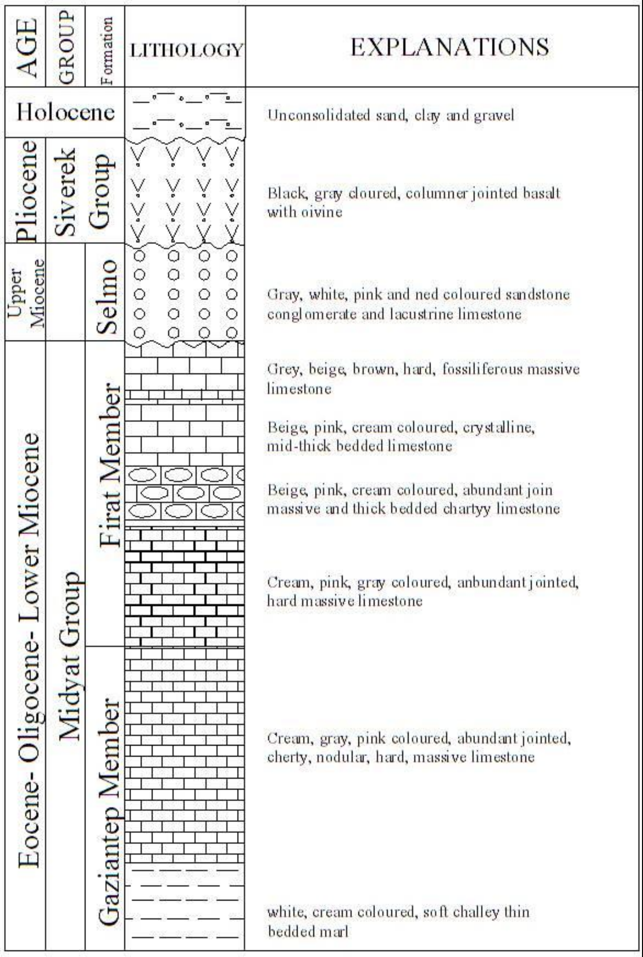


FIGURE 2 - Geology of the study area.

Within the lake system, there are many engineering structures, such as transmission canals between lake areas, drainage, water intake structure, spillways, waterfall structures, safety spillway and discharge structure. Spillways are located just beside the third lake. The connection to the second lake is on the same line. The length B of the spillway is calculated as 5 m according to the following weir discharge formulation:

$$Q = CBH^{3/2} \quad (1)$$

where C is a constant equal to 0.65 and H is the water height (m).

For Q = 0.070 m^3/s and H = 7.5 cm, the upper level code of the spillway is 516.10 m for attaining flow at the system [17]. At the spillways, the side walls of the lakes are raised up to 516.70 m. Water coming from the spillway to the lake area has a 7.5 cm thickness for audio-visual inspections. The spillway discharge is arranged by a valve room next to the pond, with a discharge manhole to connect to the discharge pipeline and to get a connection to stormwater discharge network.

On the other hand, the function of waterfall structures is to regulate the water flow, to aerate water, and to supply water resources to the 4th lake. For these purposes, three of them are located at the 3rd lake, and one of them is constructed at the 5th lake connecting the water flow to the 4th lake. Each of these waterfall structures has a discharge rate of 20 L/sec, and a height of 3 cm over threshold flows, in addition to 1/1 threshold slope through safety spillway with an upper elevation code of 516 m. The manhole size is selected as 120/250 for inspection with a slope of 0.005° and friction factor of η = 0.016. Water flow has a velocity of 0.339 m/sec with a depth of 2.9 cm at the manhole. The water exit structure is arranged with an energy reduction threshold to reduce water energy at the inclined plane and to abide to the waterfall conditions. For the calculation of waterfall discharge, Q = 0.020 m^3/sec and B = 2.50 m are adopted. Hence, the entrance cross-section of spillway can be calculated by Eq. 2:

$$Q = C \times B \times \sqrt{2g} \times h^{3/2} \quad (2)$$

TABLE 1 - General information about the lake.

Number of reservoir	Base area (m²)	Circumstance of sphere (m)	Soil area (m²)	Walking area (m²)	Length of walking way (m)	Scarp area (m²)	Total surface area (m²)	Total water volume (m³)	Elevation of excavation	Base elevation	Water elevation	Crest elevation
1	691.49	107.76						968.09	515.34	515.64	517.04	517.34
2	3545.87	286.39		924.95	364.17	908.24	4454.11	4964.22	515.00	515.30	516.70	517.00
3	32437.64	1191.58	827.12	6940.83	2185.33	3683.43	36121.07	47049.80	514.50	514.80	516.20	516.50
4	16092.05	652.46	1140.54	3033.26	930.09	2027.66	18119.71	23430.09	508.00	508.30	509.70	510.00
5	3954.16	255.95		1475.45	605.15	813.52	4767.68	5535.82	514.00	514.30	515.70	516.00
TOTAL	**56721.21**	**2494.14**	**1967.66**	**12374.49**	**4084.74**	**7432.85**	**63462.57**	**81948.02**				
Discharge												
1–2	527.31	264.12										
2–3	1146.08	417.59										
3–5	1007.81	546.34										
TOTAL	**2681.20**	**1228.05**										

By considering the spillway cross-section constant as 0.352, this expression becomes as 0.020 = 0.352 x 2.5 x $\sqrt{2g}$ x $h^{3/2}$, which yields h=3 cm. Moreover, lake water fall calculation for culvert spillway entrance cross-section is given in Fig. 3. At the beginning of the inclined plane, water height can be calculated as follows:

$$h_{cr} = (q^2/g)^{1/3}, \qquad q = Q/B \qquad (3)$$

where $h_{cr} \approx 1.9$ cm; q = 0.008 m^3/sec/m; E_{cr} = 0.029 m; $h_{culvert}$ = 1.2 m < E_{cr} = 0.029 m.

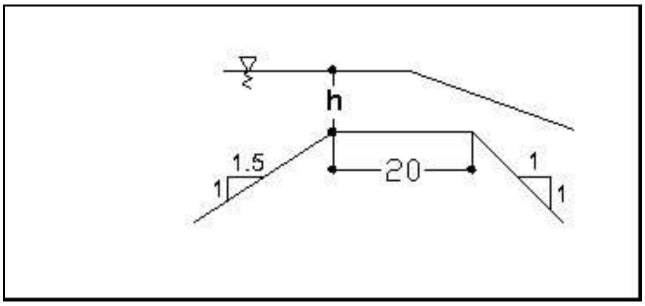
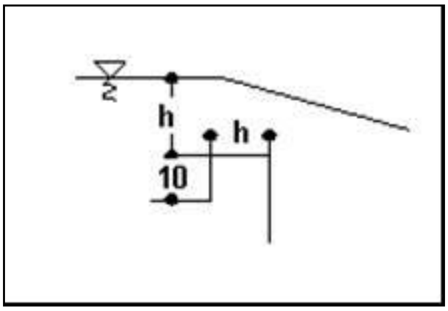


FIGURE 3 - Spillway entrance section at calculation of lake's waterfall

Water height at the end of the waterfall pond is calculated as h =3 cm, h_{water} =23 cm, h_{wall} =55cm < 23 cm. The inclined plane cross-section of the spillway is shown in Fig. 4, where Q = C x B x $h^{3/2}$. According to the spillway cross-section, C = 1.546 is adopted.



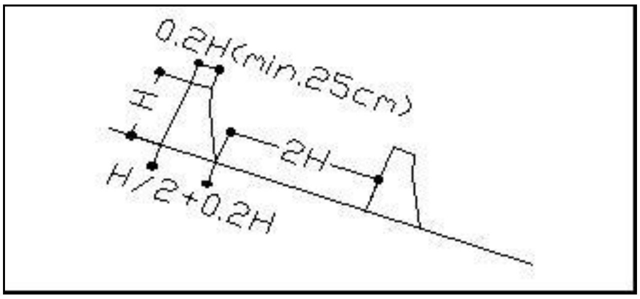


FIGURE 4 - Inclined plane waterfall spillway section and inclined plane energy reduction detail

For the discharge of 80 L/sec, where 10 L/sec is considered as evaporation, the spillway is constructed at the level code of 509.50 m at the 4th lake which has the maximum water level. Water circulations will be obtained by Eq. 1 for C = 0.80 and H = 9.5cm, which yields B = 300 cm for spillway width. The pond base level of discharge spillway is arranged as 507.90 m and water discharge from 160 cm is connected with a ϕ200 mm pipeline to stormwater manhole.

Potential problems

Since the area of the reservoir is composed of limestone at the bottom layers and the filling materials at the top layers, the permeability of the soil is not at a preferred level. Around the lake areas, some of the buildings are located below the lake bottom level depending on the topography of the location. The abundance of the fillings, slope and the side walls are all around the lake. Hence, the compression of the fillings becomes an important issue. Moreover, corrosion of the steel-plating in lake area is a major issue that needs to be solved. The limestone at the base of the lake areas may not keep the water which results in water movements in the foundation.

There is always a need for a better water distribution system in the first lake due to water leakages from the lake. To improve this situation, additional water pumping is necessary from the main irrigation canal. Because of the additional water demand, the systems operational cost increase due to increased electricity consumption.

In the lake area, seasonal temperature variations and high temperature affect the geomembrane and the protective concrete coverage. Therefore, it is necessary to find an optimum solution taking into account various criteria, such as the probable environmental problems, the abundance of alternative materials, and the anticipated construction time and cost.

The main rock unit around Şanlıurfa is composed of Eocene-lower Miocene old Midyat group, which is represented by Eocene-Oligocene old Gaziantep formation at the base and overlying lower Miocene old Euphrates formation. Gaziantep formation in the South Anatolian Project (GAP) region consists of marls at the base with the overlying dispersed limestone. Fragile white and cream marls and stratum with thin-medium thickness are present at the lower level formations. Dispersed limestone is located over the marls which have dirty white colors, chalky and crispy, tough constructed, regularly broken with high density melting gapes. Dispersed limestone with a wide and shallow topography has the medium thickness stratum [16]. Basin area of the lake is spoilt generally with the occasional old Eocene limestone overlain with a 1-m filling material, which cannot keep the water. In terms of bearing capacity, soil safety factor is 5–10 kg/cm^2. There are tectonic events, such as twisty, faulty, and joint landslides. Hence, it will not present any problem during construction [15]. Limestone is permeable because of the porosities and the cracks in its structure, and its hardness is about 3 according to Mohr scale with a density of around 2.6–2.7 g/cm^3 [18]. Reservoirs on this natural foundation may experience water leakages and losses, which may affect the nearby buildings and lead to additional water demand. Homogeneous and suitable materials are not found to eliminate negative effects of the soil. The soils have high swelling degrees. There are rock materials which can be used for recreation and stabilized materials suitable for zonal usage.

Examination of clay coverage alternative for lake forming and slopes indicates that impermeable material has an excessive plasticity, which may cause shrinkage under high seasonal temperatures and sudden humidity changes. Moreover, this alternative is abandoned as a result of additional transportation costs and possibility of plant growth at the lake bottom with time. On the other hand, covering of the lake's bottom with concrete or adulterated concrete is considered, but it is also abandoned because of the possible crack formations with time due to the different settlements and water leakage problems. At the end, it is decided that filling the excavation at lake's bottom with compressed sand and stabilized gravel (0.5-8 mm) material, and its coverage with an impermeable artificial material is the most convenient way. Hence, the first constructed layer has a thickness of 0.15 m, and the second layer has the 0.10 m concrete asphalt overlain by geotextile and geomembrane cover. Such a composition can be called as geocomposite, and as a final cover, concrete or asphalt alternatives are evaluated. After the evaluation of various alternatives, an impermeable lake base could be constructed by leveling the lower soil layer, after spreading and compressing a layer of 0.20 m thickness sand (0.5 mm) with overlying of geomembrane (HDPE with a 1.5 mm thickness) again overlying spread of geotextile (200 g/m^2) and, finally, there is a concrete layer with 8 cm thickness.

There are a lot of soil movements related to excavation and filling material because of the topography in the lake area. The construction technique should be suitable considering impermeability that is the most important issue regarding the foundation and condition of the buildings. After examining the initial project in 1995, partial narrowing and green areas are added to the project to avoid probable water leakages.

For better slope stabilization between the 3rd and 4th lake, these areas are reconsidered with a smaller slope, leading to a wider bottom. This is considered because of the perpendicular shoulder slope, construction difficulties, lack of time, and probable water leakages. Generally, fillings are composed of limestones. Moreover, settlement problems are out of question. Slopes are constructed as 2 (horizontal)/1 (vertical), and safety of static fillings slope stabilization is $F_{OSS} \geq 2.2$, and also slope stability safety factor is found to be $F_{OSD} \geq 1.1$ in case of earthquake [17]. These figures are safe enough in terms of geotechnical standard design criteria. Swelling and rising of the soil are not expected for excavations because of the limestone formation at the bottom. There might be piping due to high permeability of the filling materials and water losses, and this may affect the behavior of filling. Expected potential problems are solved by using synthetic materials such as geomembrane elements to obtain the desired impermeability.

Expected water leakage may come from slope and the concrete at the bottom in the lake area. Under normal conditions, the expected amount can be calculated by Darcy law as follows:

$$V = KI \tag{4}$$

where V is the leakage velocity (m/sec); K is the permeability coefficient (m/sec), and I is the dimensionless hydraulic gradient.

Moreover, slope leakage discharge (Q_{slope}) can be calculated with the relevant data of $K_{concrete} = 2x10^{-8}$ m/sec; time t = 0.08 min; the maximum water level $h_0 = 1.40$ m, and, hence, I = 8.75 m/m; the cross-sectional area A = 2.52 m^2/m; V = 17.5x 10^{-8} m/sec, and, finally, $Q_{slope} = 44.1x\ 10^{-8}$ m^3/sec/min. On the other hand, the leakage discharge from the bottom can be calculated as I = 17.5 m/min; A = 233.5 m^2/m (3rd lake as a sample); V = 35x10^{-8} m/s; and, hence, $Q_{bottom} = 8.17x10^{-5}$ m^3/s/min**.** Finally, the total leakage discharge (Q_T) from the 3rd lake becomes Q_T = 0.09052 L/s/min.

In general, excavations may cause slope stability problems, whereas fillings may be attached with stability and settlement problems. An important issue is the determination of the surrounding water quantity during the design stage. Stability and settlement are negatively affected by the existence of water [17]. The potential negative effects of water leakages through concrete body, cracks and lines can be stated as follows.

1 - Downward water leakage towards concrete body:

a. It leads to a softened soil foundation and results in strength losses.

b. If the soil has a swelling property, there will be expansion and cracks on the concrete body. Clay formations have swelling percentage of 1.03 % and swelling pressure of p = 0.50 kg/cm^2.

2 - If there are leakages through the covering concrete to the filling system, there will be trouble in the stability, and this may cause to sliding in the main structure.

3 - In the case of filling settlement or any small sliding, there may be cracks present at the covering concrete body and water leakages may then increase, and

4 - In the case of the whole canal body over fillings, the effect of water leakages from sides and base may cause the settlement to become denser. Even though the filling material is rock, it may have negative effects.

The aforementioned effects may be at a serious level at plyo-quarternaire old covered stratum (~24.3 km), which is composed of clay, sand and weak-cemented aglomerate, small to medium level at old olygomiocene marl-leveled limestone (~7.8 km), and negligible level at plyo-quarternaire old basaltic formation (~4.0 km) [16].

If no precaution is taken for side surface fillings and lake base excavations for prevention of water leakages, there may be distortion at filling and excavation properties after a while throughout the sliding surface, starting from top to bottom footings of the side slopes. These situations may result in significant destruction at the lake body. Moreover, the same stability problems may occur at the excavation sides in the long term. In addition to all these negative effects, it is clear that there may be distortion of soil and unwanted settlements at the lake base.

To overcome the negative water effects without any structural maintenance at the lake body in the long term, and to supply the expected service facilities, maximum impermeability is obtained by a geomembrane with a thickness of 1.5 mm and overlying the lining of geotextile as a protecting element under concrete cover. In order to prevent the geomembrane from being punctured and to obtain a well-arranged surface for geomembrane, there is a stratum layer with a thickness of 20 cm under geomembrane that is formed by washed and sieved sand. This stratum protects the geomembrane.

Existing filling with washed and sieved sand without significant distorting has a thickness of 20 cm, overlayed by HDPE-type geomembrane with a thickness of 1.5 mm, using protective geotextile of 200 g/m^2 together with 8 cm concrete, respectively. Leakage is not expected at dilatations. With time, there will be leakages at the lake base if there is a distortion at the geomembrane. To observe the water leakage and interference from this situation, there are ϕ200 mm drainage pipes at the lake's base, and these pipes are connected to ϕ300 mm, and ϕ400 mm drainage pipes, located at the natural soil stratum. Hence, collected water may be released to dry stream beds. These drainages can be followed by observation manholes. Lake drainage plan is given in Fig. 5.

Discharge of the 3rd and 4th lakes can be considered in two stages as stated:

a) Constructing the base discharge unit above 25 cm from the lake bottom with an absorbent entrance grid will ensure that the unwanted materials do not give any harm to the discharge and storm water drainage system. The discharge systems of both lakes are separately connected to the storm water network.

b) The area under 25 cm of absorbent entrance as a safety section will connect, after clearing the 3rd lake bottom, to the lake base discharge system with a valve controlled by a ϕ200 mm HDPE-type pipe from a place, which is between the 3rd and the 4th lake head box. The same procedure is also done for the 4th lake to the bottom discharge system.

Since Şanlıurfa is located in a warm region, there may be shrinkage cracks present at the protective concrete bodies in the bottom of the lake and the side slopes. To minimize the presence of these cracks, the concrete area sizes are designed to be 4 m x 4 m. To reduce the cracks formed by shrinkage, chemicals and over concrete, protective textile materials are used during the concrete works. In spite of all these precautions, there are still shrinkage cracks at the lining and connection places, slopes and the concrete base. These cracks are repaired by the repair mortar. Moreover, the productivity can be observed in progressive periods. Concrete lining plan is given in Fig. 6.

If there is a delay in covering after spread-out of geomembrane, there is a shape deformation in geomembrane due to the elongations based on weather conditions, especially due to the high temperature in the area. Temperature is around 45 ^{0}C at noon time during summer [19].

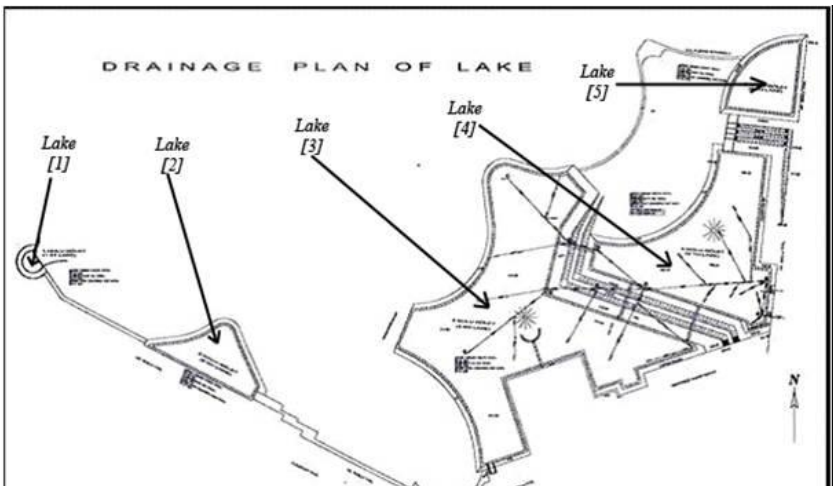


FIGURE 5 - Drainage plan of the lake.

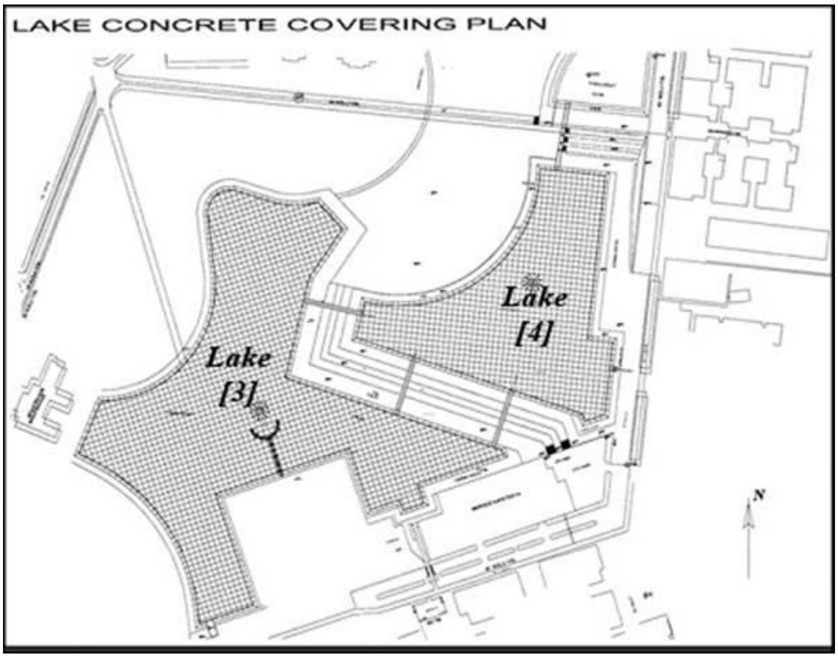


FIGURE 6 - Concrete covering plan of the lake.

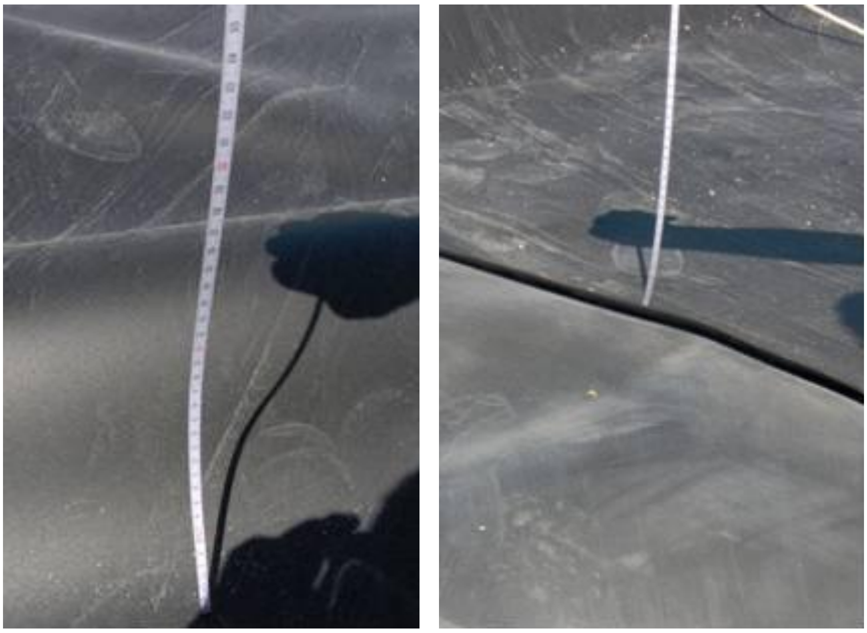


FIGURE 7 - Measurement of shape deformation of geomembrane due to delay of concrete covering.

Geomembranes have technical stretching properties of 80% vertically and horizontally, elongation and shrinkage, due to the temperature differences between day and night. If the concrete structures are not placed at the same time together with geomembrane, it may take time to get weak concrete, and due to the temperature changes, there may be skids and cracks at concretes based on geomembrane shape deformation.

If there is a delay in cover concrete productions over the geomembrane due to the elongation, there is a deformation of 20 cm, and at some extreme cases, this deformation even reaches 30 cm, especially during summer when the temperature is at its maximum level. Measurement of this change is shown in Fig. 7.

Concrete movements may increase and also the side slope concrete may have stability problems. During the cutting of dilatations, there is a probability of cutting geomembrane. In such a situation, there may be a conflict in the prevention of water leakage. Consequently, geomembrane and concrete covers can be produced simultaneously, and high temperature conditions could be avoided. It may be suitable to precede construction in spring or autumn, where seasonal or daily temperature differences are at the minimum level.

In the case of uncovered geomembranes, the leakages accelerate if welding and joints are not well applied. Hence, there may be high level shape deformation in the geomembrane. These defects and spectra sometimes may resemble a mushroom on water, and generally act as circular air bubbles depending on the situation and the amount of leakages, soil properties, climate changes, and underground water levels. Besides, when there is a leakage between the geomembrane and clay soil, some microorganisms appear. Moreover, these organisms result mostly in holes and damage of the geomembrane. These situations are especially encountered on wastewater treatment plants and where the underground water level is high and also base is covered by impermeable clay soil. After the completion of construction, such defects can be hardly repaired at high costs. Therefore, in the case of uncovered and unprotected geomembrane production, welding and connection works should be carried out carefully.

Due to the abundance of alternatives, various types are considered, such as the materials and their properties, production and construction conditions and their production times, necessary technical rigging, provision of these rigging, workmanship quality, capacity and capability of the contractor, climatic conditions are taken into consideration. Besides, factors such as the expectations of employer, budget and appropriation of circumstances anticipated the time, expected utility and aesthetics. Productions type is selected for the construction after the evaluation of all these technical components.

Minimum properties of geomembrane and the protective geotextile placed in Osmanbey Lake are given in Table 2. Geomembrane elements are connected with a special welding system named double-fusion. Geotextile is used for protection and separation purposes. Geotextile element connections are obtained by 15 cm-overlapped layers.

TABLE 2 - Minimum properties of protective geotextile.

Property	Unit	Minimum value	Standard of experiment
Thickness	(mm)	1,5-2	DIN 53353
Unit weight	(g/m^2)	200	
Limit strength	(N/mm^2)	35	
Elongation at rupture	(%)	80	
Tearing-tensile strength	(N)	200	DIN 53515
Perforation strength	(N)	400	

Due to hot weather during daytime, concrete production is performed during the night time with a low slump to reduce the shrinkage cracks on the concrete. To reduce the effect of hot temperatures during daytime, cotton materials are used for protection purposes, but shrinkage cracks are still a problem. Addition of synthetic fiber material to concrete is used to reduce the cracks and improve the strength of the concrete. It is observed that shrinkage cracks are reduced by 60 %. Increase of strength is tested during the operation.

RESULTS AND DISCUSSION

The lake area lies in dry stream beds and consists of five different spheres depending on the topographical conditions. They are leveled according to the topography, water supply points, green area and service purposes. The water distribution reservoir depending on the natural conditions and fits with the road planning is presented in Fig. 1. The first reservoir area is the exit of the pumping line and will serve for water circulation between water surfaces [15]. The water supplied by the Upper Harran Main Canal was pumped to the first lake and then distributed to the others. Water is only available in the canal system between the months of March and October because of the GAP irrigation program. In this period, water from the main canal is supplied to the lake areas and at the end of the irrigation season (winter); water in the lakes is discharged for maintenance. Water movements between the lakes are achieved by pipes, open canals and spillways. The basins and slopes of the lakes are examined according to the geological structure of the area. The water collection areas generally consist of limestone and accumulation materials [20].

Geomembrane and geotextiles are produced during daytime due to testing of welding and sewing productions as there is a need for lighting during night-time in the large production area, Harran University Campus, Şanlıurfa, Turkey. Thus, the main problem faced during the construction in the lake area is the elongation of geomembrane because of hot weather conditions (Fig. 8). Concrete construction is done starting from late evening until the morning because of shape deformation of geomembrane, especially due to hot weather during daytime. Constructions of both geomembrane and concrete bodies are done at different times because of the reasons mentioned above. This results in additional workmanship costs, low productivity and delays in the planned finishing time of the construction.

Problems during operation and performance evaluation

One of the most important problems that may arise during the operation is evaporation. While the average precipitation of Şanlıurfa is 450 mm/year, evaporation is 1850 mm/year [19]. In other words, evaporation is 4.11 times higher than precipitation. Water reaches the lake by means of electro-pumping from the Upper Harran Main Canal, supplied by Şanlıurfa irrigation tunnels and Atatürk Dam Lake. There is a 355 g/ml/L of salt (NaCl) in the water at Atatürk Dam Lake. Therefore, there will be salt residuals in the lake area as a result of evaporation. It is expected that there will be 21500 kg of salt accumulation in the artificial lake area. It is necessary to remove these salts during the operation and maintenance periods.

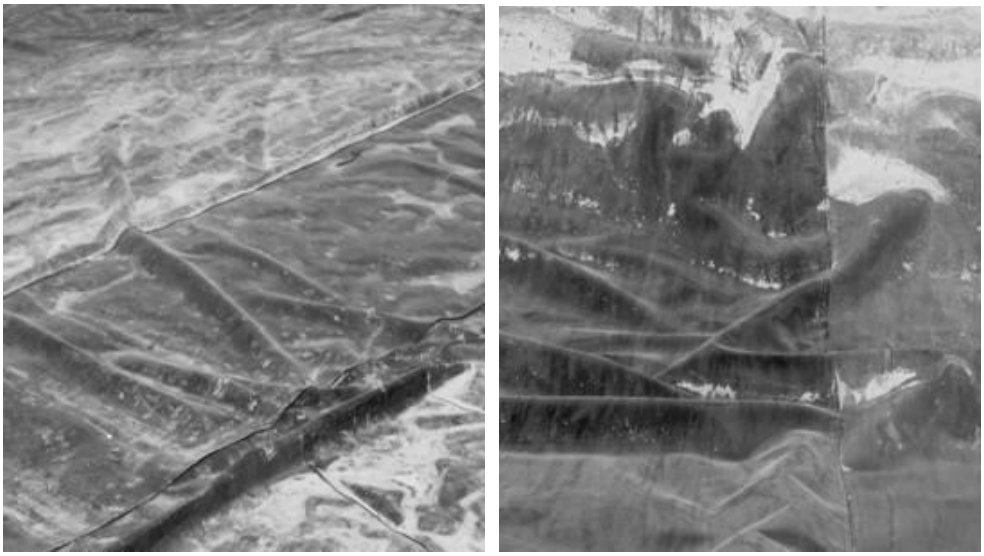


FIGURE 8 - Elongation of geomembrane due to shape deformations based on climatic conditions.

TABLE 3 - Observed changes at lake's water during operation period by analysis.

Parameter	Institute of Turkish Standards	World health organization (WHO)	Environmental protection Agency (EPA)	Europan Commis-sion (EC)	Raw Water (Before Filled Water)	Sample Points		
						L1	L2	L3
Turbidity	25	5	1	1	**1.1**	**1.3**	**1.1**	**1.5**
Color	20	15	15	-	**8**	**6**	**6**	**8**
Hardness ($CaCO_3$)	--	500	--	--	**12.4**	**11.74**	**12.77**	**13.88**
Free chlorine	0.5	5	-	-	**0**	**0.1**	**0.1**	**0.1**
pH	6.5 - 9.2	6.5 – 8.5	6.5 - 8.5	6.5 - 9.5	**8.24**	**8.33**	**8.40**	**8.50**
Mn	0.05	0.5	0.05	0.05	**0.001**	**0**	**0**	**0**
Fe	0.2	-	0.3	0.2	**0.01**	**0**	**0**	**0**
Zn	5	-	5	-	**0.01**	**0**	**0**	**0**
Cl	600	250	250	250	**13.8**	**19.8**	**21**	**18.6**
NH_4	0.5	1.5	-	0.5	**0.23**	**0.38**	**0.42**	**0.40**
Al	0.20	0.20	0.20	0.20	**0.005**	**0.003**	**0.001**	**0.003**
Cr (total)	0.05	0.05	0.05	0.05	**0.01**	**0.416**	**0.537**	**0.671**
Fluoride	1.5	1.5	0.7-2.4	1.5	**0.12**	**0.29**	**0.33**	**0.38**
Pb	0.05	0.05	0.05	0.01	**0.001**	**0**	**0**	**0**
Nitrate-NO_3^-	50	50	45	50	**0.22**	**0.03**	**0.01**	**0.03**
Ammoniac (NH_3) (for surface water)	--	--	--	--	**0.18**	**0.29**	**0.33**	**0.31**

Moreover, there may be additional water needs due to evaporation in the lake area. This situation will require additional pumping and an increase in the electricity cost. Landscape and green area works started around the lake area to prevent such a situation. Water in the lake is drinkable and there are changes in the water quality after approximately six months of operation as seen in Table 3. Raw water quality (of water when the lake is firstly filled) and used water quality in the lake (of water staying in the lake for approx. 6 months) are evaluated comparatively in order to take into consideration not only the weather, but also the physical conditions, social conditions, and environmental factors.

Evaluation of lake water quality

Water analyses are carried out according to potable water parameters, such as iron, manganese, zinc, and lead. Table 3 indicates no significant changes in water quality within the period considered in this study. There are no significant changes in the parameters of turbidity, color, toughness, free chlorine, aluminum, pH, manganese, iron, zinc, and nitrate, whereas there are important changes in ammonium, chrome, fluorine and ammonia which are important parameters for the surface water. [21-23].

According to the values, chlorine, chromium, and fluorine are not harmful for the time being, but ammonium and ammonia are especially important pollution parameters and their increase is not desired. The increase in organic pollution causes changes in oxygen content and formation of algae increases as well as some microorganisms. Such causes may be related to the fact that the lake is completed just before the winter months and opened for use immediately. Between the first and the second evaluation of water analysis, only the winter and spring months of the same year have passed. It is expected that the increase in temperature in the coming summer might cause some decrease in oxygen amount in water due to the utilization of oxygen by microorganisms. Other factors that may be considered as reasons for a reduced water quality are the lack of aeration (lack of recycling of water) and the potential increase in the campus population. It is also considered that the decrease of water quality may result in eutrophication. Studies related to water quality of the lake cover between the filling part of the lake and water quality controls for six months. It is expected that the water quality will decrease. To overcome this negative situation, water should be aerated continuously at certain time intervals.

CONCLUSIONS

Osmanbey Lake has a special importance because it is the largest artificial campus lake in Turkey, and because of the properties of materials used. It needs a good planning, management, control and organization of design, selection and production of the materials until the construction end. During the constructions, various problems are encountered such as the project cost. Another important subject is the assurance of the workmanship quality. Important topics are the external factors like the climatic conditions and the construction period that should be planned according to local conditions. If it is not possible to select or postpone the construction period, it is necessary to select the suitable material for seasonal conditions. Since there are great temperature differences between day and night during summer, such a construction should not be carried out in summer. Especially, there is a deformation of geomembrane due to its structure during summer, and the structure of geotextile. It keeps the dust at windy weather and these dusts get out later from the concrete connection places.

Related to the selected materials and their production preferences, evaluations are carried out during the first six months in terms of the expected utility. Observation of the lake behavior will continue in the future for better and adaptive results. Scientific studies are very significant for such a costly structure due to its plan, material and construction. Such an inspection will enhance input data for further constructions.

NOMENCLATURE

ϕ	pipe diameter [L]
A	Cross-sectional area [L^2]
B	Spillway width [L]
C	Coefficient of spillway [dimensionless]
E_{cr}	Level of critical energy [L]
F_{OSD}	Slope stability safety factor [dimensionless]
F_{OSS}	Safety of static fillings slope stabilization [dimensionless]
η	Friction factor [dimensionless]
g	Acceleration due to gravity [LT^{-2}]
H	Water height at the end of waterfall pond [L]
h_0	Maximum water level [L]
h_{cr}	Depth of critical flow [L]
$h_{culvert}$	Water height at beginning of inclined plane [L]
h_{wall}	Height of wall [L]
h_{water}	Height of water [L]
I	Hydraulic gradient [dimensionless]
K	Permeability coefficient [LT^{-1}]
$K_{concrete}$	Permeability coefficient of concrete [LT^{-1}]
p	Swelling pressure [KL^2]
Q	Spillway discharge [L^3T^{-1}]
q	Discharge quantity for unit width [$L^3T^{-1}L^{-1}$]
Q_{bottom}	Leakage discharge of bottom [L^3T^{-1}]
Q_{slope}	Leakage discharge of slope [L^3T^{-1}]
Q_T	Total leakage discharge [L^3T^{-1}]
t	Thickness of concrete [L]
V	Leakage velocity [LT^{-1}]

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