World Journal of Environmental Biosciences

Available Online at: **www.environmentaljournals.org**

Volume 9, Supplementary: 96-105

ISSN 2277- 8047

Geotextiles in Filtration and Drainage Applications in Embankment Dams: Technical Examination and Analysis of Effects

Mohsen Raayati Touran Poshti

MSc, Department of Civil Engineering, Faculty of Engineering, Central Tehran Branch, Islamic Azad University, Tehran, Iran.

ABSTRACT

One of the most important factors in the degradation and eventually destruction of embankment dams is leakage from different parts therein. In embankment dams under normal conditions, employing grain filters is often proposed as the first option. In case access to granular materials is challenging or economically unfeasible, using a plethora of geosynthetics, especially geotextiles, which alleviates almost all the disadvantages of the traditional method, is highly recommended. In this research, the effect of geotextile on drainage and filtration at varying discharge rates was examined by modeling a real-life embankment dam (Ahuiyeh Baft dam). The authors hope that this research will determine the optimal filtration condition, which is a combination of grain filters and geotextile layers, to be used in designing dams. After constructing 61 models (1 real-life and 60 software-simulated models using geotextiles), the results from real-life dam model with grain drainage and filtration and a thickness of 50 cm, and models with geotextile filtration and drainage were compared and analyzed. The grain-filter model with a thickness of 10 cm, 5 layers of type 2 geotextiles, and the same technical specifications of the real-life dam, increased the total stress in the x and y directions by 1.14 and 1.21 times, respectively, and its safety factor in permanent seepage conditions was determined to be 1.616 using static analysis, and, thus, was selected as an optimal alternative to the 50-cm thick grain-filter.

Keywords: *Geotextile, Embankment dam, Technical performance, Drainage, Filtration*

Corresponding author: Mohsen Raayati Touran Poshti
e-mail ✉ mohsen.raayati @ gmail.com
Received: 20 September 2020
Accepted: 04 December 2020

1. INTRODUCTION

Embankment dam, even if made with high-quality materials, good density, and proper construction practices, always seeps some water from the body, which is normal after reaching a stable state. Therefore, methods for reducing and controlling seepage are of utmost importance, in which employing suitable drainage and filtration as a transition layer between soil layers using different granulations to maintain the stability of the dam body, prevent increased pore pressure, and prevent the piping effect is one of the most effective ways to control seepage and prevent dam failure due to seepage force (Mlynarek et al., 1990).
Among the negative effects of water seepage in the body and foundations of embankment dams, is the possibility of displacement and ultimately leaching of soil particles forming the foundation and body of the dam by water, such that failing to control the leakage and consequently improper water flow may eventually lead to instability and failure of the dam. Irrigation and drainage networks with poor protection are more prone to leakage and river banks are eroded sooner without fortification. Geotextiles are among the materials that are extensively used today in construction projects. One of the main applications of these materials is their function infiltration and drainage systems (Bhatia et al., 1995).
The filtration process in conventional grain filters is a complex process that is further complicated by the compactness and woven nature of the geotextile. To achieve proper filtration performance, some ranges have been obtained over the years and through numerous experiments. Different sources have sometimes suggested slightly different ranges for filtration. To select the best materials for geotextile filtration, regardless of the type of environment, there are two general conflicting design criteria, each of which needs to be addressed optimally (Caquel, 2004).
Geotextiles have been used for infiltration and drainage for several decades. The emergence of these materials has led the conditions for addressing filtration and drainage in two different, at times contrasting, methods. Geotextiles are typically studied using laboratory experiments under non-confined conditions with low stresses. Another issue that should be contemplated in designing filters is the possible presence of soil particles in the geotextile, which is owing to the distribution of soil and its varying density on the geotextile layer, given the properties of these materials. This leads to clogging, which, in turn, affects the physical and hydraulic properties of the geotextile. The compactness of geotextiles clogged by soil particles is lower than that of clean geotextiles. This leads to a decrease in the permeability of the geotextile in the direction perpendicular to the plate and inside the plate; and to prevent the occurrence of this effect, close connection and contact between the soil and the geotextile must be ensured during construction (Patanaik and Anandjiwala, 2008).
The main characteristics of geotextiles that affect its performance in these applications include structural characteristics (such as pore size, porosity, mass per width & thickness), mechanical parameters (tensile strength in longitudinal & transverse directions, etc.), hydraulic parameters

(equivalent hole diameter, water permeability, etc.), the capability to permit water to move without causing hydrostatic pressure along with the ability to thwart the movement of soil particles by water, sufficient strength for withstanding construction processed, and high performance during project life and sufficient strength against microorganisms and chemicals exposed to them during the life of the geotextile project (Chen et al., 1982). Caquel (2003) studied geotextile samples taken from protective constructs of river shoreline under riprap that had been in use for between 7 and 10 years (Mlynarek et al., 1998). The purpose of this study was to examine the extent of damage to geotextiles due to initial installation and possible loss properties after several years of use. Visual inspection indicated different failure modes and that the installation conditions and rules affect the behavior of the structure, especially regarding UV protection, in cases where the geotextile is exposed to atmospheric conditions owing to water level fluctuations. After this stage, the samples were subjected to hydraulic and mechanical tests to evaluate the possible blockage and degradation of their properties (Mlynarek et al., 1998).

Patanaik et al. (2008) examined the effects of production parameters in the needle-punching process on the permeability behavior of geotextiles by studying the flow perpendicular to the plane of needle-punched nonwoven geotextiles produced from polypropylene fibers. Their findings revealed that the permeability behavior was under the influence of pore arrangement in nonwoven geotextiles (Patanaik and Anandjiwala, 2008).

Despite the widespread development and use of geosynthetic materials worldwide, they remain highly neglected in Iran, which can be in part owing to a lack of experience and history of using such materials in this country. Regardless of the aforementioned issues, designers should, nonetheless, consider employing geotextiles that can be designed as filters in embankment dams like other structures and facilities (especially, in situations where high-quality rock materials are not available on the site or can only be transferred from long distances). Since limited research has been performed on the effects of using geotextile filtrations in embankment dams thus far, further studies are needed to examine the effect of this system on controlling leakage flow and to compare it with other existing materials, the results of which could prove to be beneficial in utilizing them with higher confidence in earthen structures.

2. MATERIALS AND METHODS

Case Study

Morphology of the Watershed

The main waterway of the Ahuiyeh embankment dam, which is a seasonal river, runs along the northwest of the basin to its southeast. The basin is located in an area of 29°16' - 29°20' N and 56°43' - 56°46' E.

The Floods in the Region

The estimation of the flood is the most important parameter in choosing the type of spillway, spillway capacity, and full height of the dam. For this purpose, the method of The Soil and Water Conservation Society (SWCS) was used according to the maximum 24-hour rainfall of the watershed with different recurring periods.

Carrying Sediment

To accurately design the construction of reservoirs and to determine the effective life of a dam, it is necessary to evaluate and estimate the total volume of annual sediment production in the watershed. According to calculations, the amount of annual sediment yield in the project area is 1871 cubic meters. Besides, the 25-year and 50-year sediment volumes have been respectively calculated as 46774.6 and 93549.2 cubic meters.

Geological Features of the Case Study

Geological studies for every dam project must include general geological features of the study area, engineering geology and geotechnics, quarry resources, and seismic studies of the area. The purpose of the general geological studies is to introduce the geological case and its evolution and to analyze the geomorphology and drainage pattern of the region, the lithology of the watershed, the tectonics of the study area, and the hydrogeology of the case study. In geotechnical studies, the geological morphology of the site and dam reservoir, the engineering characteristics of the geological structure of the study area, the stability of soil and rock slopes in the axis, and the permeability and sealing of the pathway and reservoir are examined. Quarry resources are also primarily examined to assess the accessibility of the materials needed to build the dam in the study area. The main tectonic faults in the area and the history of seismic events in the region are also examined under seismic studies of the region.

Seismotectonics and Seismicity

Accurate knowledge of the faults around the study area, especially active faults, is significantly involved in examining their seismic potential and finally estimating the maximum possible acceleration at the study site. From the north to the south, the faults in the area of the Ahuiyeh embankment dam project in a radius of 100 km are Baghin fault, Rain fault, Alishahi fault, Sardouieh fault, Lalehzar fault, Bardesir fault, and Rafsanjan fault. For the probabilistic analysis of the Ahuiyeh embankment dam site, a list of earthquakes of the 20th and 21st centuries with a radius of 100 km has been used. To this end, different return periods for the effective life of the structure were determined using the frequency-magnitude relationships, while, the preliminary stages of probabilistic analysis were also prepared by considering the seismic parameters. To determine the design basis acceleration from the calculated magnitude with a 64% probability of an event, the effective life of 50 years and a 6.7 Richter magnitude earthquake were considered. The application of this magnitude in the reduction relationship and the acceleration results of the design basis in both horizontal and vertical components were obtained. According to the calculations performed to determine the acceleration of the design basis, the horizontal acceleration is estimated to be 0.31 g and the vertical acceleration is estimated to be 0.35 g.

Filter and Drainage

Materials in the downstream part of the dam body, if the dam is homogeneous, or in the downstream and upstream part of the clay core and its vicinity, if the dam is inhomogeneous, are used to prevent the migration of fine particles downstream and to develop water drainage in the body of the dam. These materials can be obtained by sieving alluvial materials in the bed of the Ahuiyeh river.

Water

Since the construction of different components of the embankment dam body requires spraying the clay and mixed fine-grained materials of the embankment layers, or the coarse-grained materials of the shell during threshing, and also to prepare the required concrete in the construction of the overflow structure of the basin, water is utmost important. Therefore, the required water supply should be as close as possible to the dam site. Based on the performed field studies, the required water can be provided by constructing a pool in the area of the basin and next to the main waterway, which is about 200-150 meters away from the project site. The used water must have the necessary standards, chemically-speaking, which was proved to be the case according to the field visit and the geological characteristics of the area.

The Site Intended for Construction of Ahuiyeh Dam

The purpose of constructing the Ahuiyeh dam was to collect and store water of all existing waterways and flood water located in the area to support the irrigation of lands and gardens of Ahuiyeh village. The site intended for the construction of Ahuiyeh Dam was placed on a waterway of the same name, which is formed from the confluence of several other secondary waterways upstream of this site, located 29°17’35” N 56°45’14” E, 2487 meters above the sea level.

Based on the results of the field visits, considering the volume required for the dam reservoir and taking into consideration all the constraint and characteristics of the area, different options were considered for the dam axis, and for each of these axes the volume and surface of the reservoir at different heights were calculated and the final option was selected so that its reservoir would have an acceptable volume. As shown in Figure (1), there is a minor waterway on the left side of the site that by constructing an overflow on this side, the floods of the Ahuiyeh seasonal waterways can be directed to a waterway downstream of the site with a high safety factor. Additionally, with the construction of the overflow on this side of the dam, the work volume of the overflow construction is minimized and its operational cost is significantly reduced compared to that of the right-side.

Figure 1: The Minor Waterway for Overflow Construction, Placed on the Left Side of the Selected Site

GeoStudio

GeoStudio is one of the geotechnical programs based on finite elements, through which it can perform analyses such as stress-strain, seepage, slope stability, and dynamic analysis. It includes plug-ins SIGMA/W for stress-strain analysis, SEEP/W for flow and seepage analysis, SLOPE/W for slope stability analysis, and QUAKE/W for dynamic analysis among others (Johari and Pak-Niat, 2009).

Modeling in SEEP/W Plug-in

This sub-program of GeoStudio is devised to examine the seepage conditions and water flow in the soil. Among the capabilities of this sub-program is calculating the flow rate for a certain section of soil and calculating the flow rate (leakage rate) of a whole embankment. SEEP/W can analyze steady-state conditions (Johari and Pak-Niat, 2009).

Upstream and downstream water heads are configured using the Draw Boundary Condition menu. Through this menu, the location and extent of the head or flow rate can be assigned to each node. For instance, ahead with 100 meters above the water level must be assigned to the upstream, while ahead of 35 meters should be allocated for the downstream.

The flow rate of the nodes is determined using the Draw Flux Section menu, through which, the intended sections are first drawn, and following the analysis, the amount of flow rate is presented through the Draw Flux Label command.

After modeling the problem and assigning the specifications of the materials therein as well as the aforementioned features, the model will be ready for analysis (Johari and Pak-Niat, 2009).

Modeling in SLOPE/W

This subprogram of the GeoStudio software suite can check the stability of ramps and determine the safety factor of slope design. One of the most important features of this plug-in is the capability of modeling reinforcements such as restraints, nail, and geosynthetics to enhance the safety of slopes. Various factors affect the stability of slopes, including soil adhesion, soil friction coefficient, water level, and presence or absence of reinforcers among others. Files from SIGMA/W or SEEP/W cannot be imported to SLOPE/W for project modeling. The Material Properties option in the KeyIn menu is used to assign material properties. In this window, the basic parameters related to each of the materials used such as specific gravity, adhesion, internal friction angle, and the desired resistance model should be first specified. In this project, the Mohr-Coulomb resistance model is employed (Johari and Pak-Niat, 2009).

The most prevalent method for expressing the shear strength of geotechnical materials is associated with the Mohr-Coulomb equation, which is expressed as follows:

$$\tau = c + \sigma_n \tan \emptyset \qquad (1)$$

Equation (1) is the equation of a straight line that represents the relationship between shear strength and normal stress. The intersection of the line with the shear strength axis yields the adhesion (C) of the soil, while the slope of the line represents the internal friction angle (ϕ).

Parameters C and ϕ can be total resistance or effective resistance parameters. As for the analysis of slope stability, effective resistance parameters provide a more realistic solution, especially for the critical slip surface.

Modeling in SIGMA/W

The product from the GeoStudio suite can analyze the stress-strain (Load / Deformation), in-situ stress (Insitu), and consolidation through which total and interparticle stresses and pore water pressure can be obtained, and thus observe the resulting deformations in the soil.

After performing the analysis operation, using the Contours option located in the Draw menu, a window is opened as shown in Figure 1. In the Contour Parameter section, the parameter is required to extract the maximum and minimum values and to display the color contour in the cross-section model.

3. RESULTS

Technical Specifications of Geotextiles

To assess the performance of geotextile filtration as an alternative or combination of grain filter, geotextiles with technical specifications as per the description in Table 1 were employed.

Table 1: Technical Specifications of Different Types of Geotextiles (Roof Iran Company)

Specification	ASTM Test Method	Result			Unit
Category	--	1	2	3	--
Unit Weight	D5261	200	300	500	g/m^2
Thickness	D5199	2.1	3.7	4.6	Mm
Tensile Strength Test Using Clamps	D4632	700	950	1690	N
Excess Rupture in Length	D4632	60	59	55	%
Excess Rupture in Width	D4533	62	62	58	%
Required Force for Porosity	D4833	405	720	1100	N
Ultraviolet (UV) Resistance	D4355	>90	>90	>90	%
Transverse Tension	D4595	6.2	8.2	13.2	KN/M
Melting Point	D276	>240	>240	>240	C^o
Apparent Size of Porosity	D4751	0.25	0.21	0.15	Mm
Electrical Permeability	D4491	2.30	1.80	1.20	Sec^{-1}
Permeability	D4491	0.21	0.22	0.25	cm/sec
Headward Erosion Rate	D4491	115	90	75	L/m^2/sec

Considering the thickness of 50 cm for the grain filter downstream of the Ahuiyeh dam, after constructing and analyzing a model with real-life performance specifications, 60 different models were simulated as follows and were thus employed as a basis for comparison.

1. Grain filter with a thickness of 40 cm, and with (1) 5 layers of geotextile, (2) 10 layers of geotextile, (3) 15 layers of geotextile, and (4) 20 layers of geotextile (each with type 1, type 2, and type 3 geotextiles)
2. Grain filter with a thickness of 30 cm, and with (1) 5 layers of geotextile, (2) 10 layers of geotextile, (3) 15 layers of geotextile, and (4) 20 layers of geotextile (each with type 1, type 2, and type 3 geotextiles)
3. Grain filter with a thickness of 20 cm, and with (1) 5 layers of geotextile, (2) 10 layers of geotextile, (3) 15 layers of geotextile, and (4) 20 layers of geotextile (each with type 1, type 2, and type 3 geotextiles),
4. Grain filter with a thickness of 10 cm, and with (1) 5 layers of geotextile, (2) 10 layers of geotextile, (3) 15 layers of geotextile, and (4) 20 layers of geotextile (each with type 1, type 2, and type 3 geotextiles)
5. No grain filter, and with (1) 5 layers of geotextile, (2) 10 layers of geotextile, (3) 15 layers of geotextile, and (4) 20 layers of geotextile (each with type 1, type 2, and type 3 geotextiles)

Typically, in the two-dimensional analysis of embankment dams, the process is performed in the critical and maximum cross-section of the dam and according to the prevailing conditions in the form of plane strain. For this purpose, the middle section of the Ahuiyeh dam was selected, in which the height of the dam from the core floor was 23 meters. Moreover, the maximum width of this section was 141 meters. The water level behind the dam at this point is considered to be maximum (i.e. 20 meters). In this section, the results for stable seepage analysis are provided.

Overall, seepage control in dams is an integral part of the basic analysis in their design and study, in that it is of utmost significance to control the seepage and to examine the methods used for this aim with the ultimate purpose of preventing uneconomical and excessive permeation, leading to instability in the face of the piping effect. The purpose of using a filtration and drainage system is to facilitate seepage flow and hydrostatic pressure depreciation so that the escape of fine particles will not lead to instability. In this regard, first, the effect of the grain filter layer with a thickness of 50 cm was studied, followed by evaluating the performance of the grain filter with different thicknesses using different layers and types of geotextiles in the downstream filter of the dam.

As it was previously said, first the real-life dam model was generated with a grain filter thickness of 50 cm, which, according to the analysis of seepage rate, leaked 3.2412 x 10^{-2} cm^2/s, which by multiplying this number by the length of the dam (i.e. 284 meters), the dam leaked a total of 920.50 cm^3/s (figure 2). This amount was considered the basis for comparison with models with grain filters of different thicknesses using different layers and types of geotextiles in the filter downstream of the embankment dam.

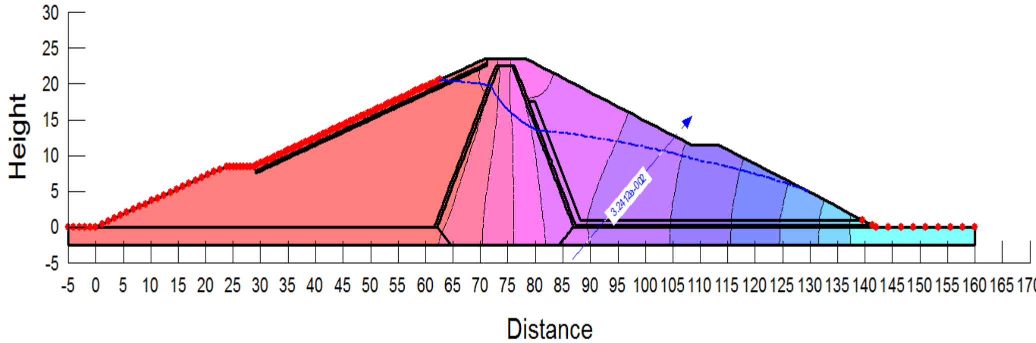
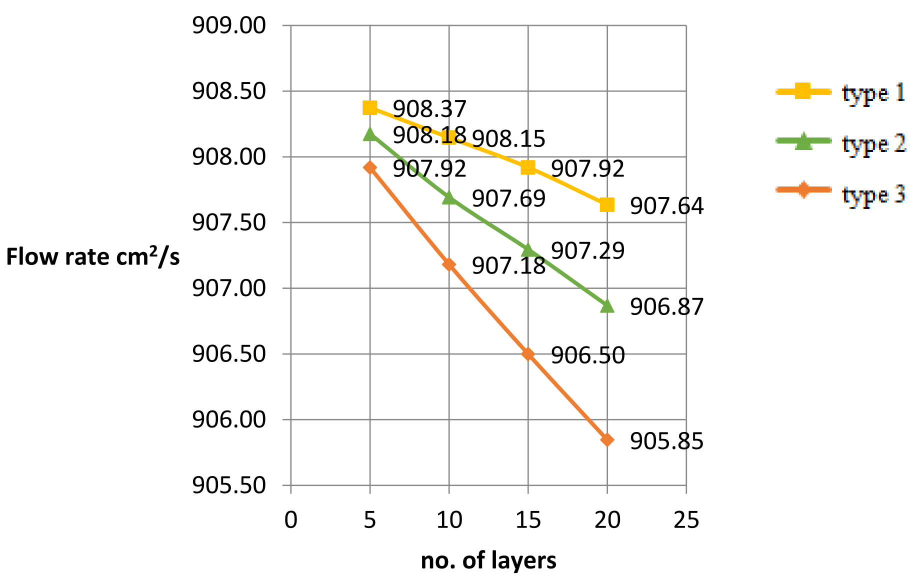


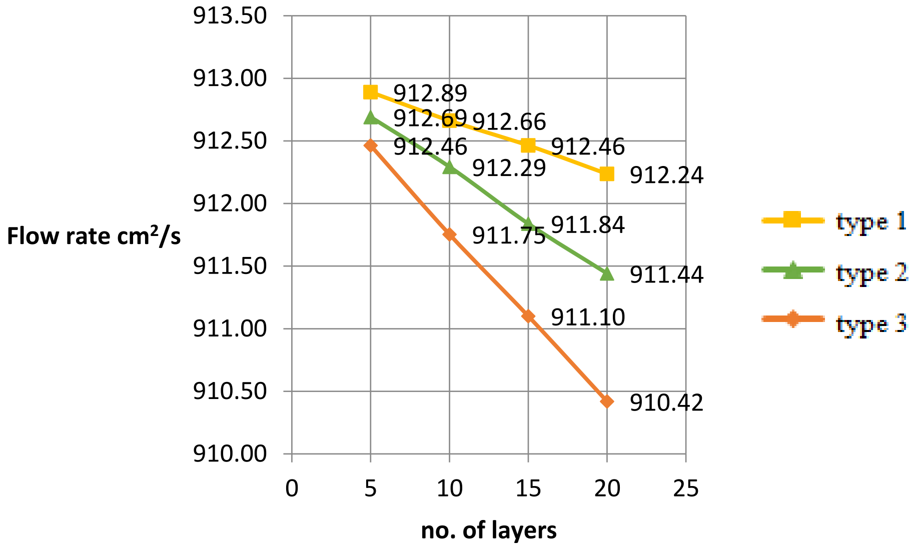
Figure 2 - Analysis of the Output Flow of the Real-life Dam

Grain Filtration Performance with Varying Number of Layers and Different Types of Geotextiles

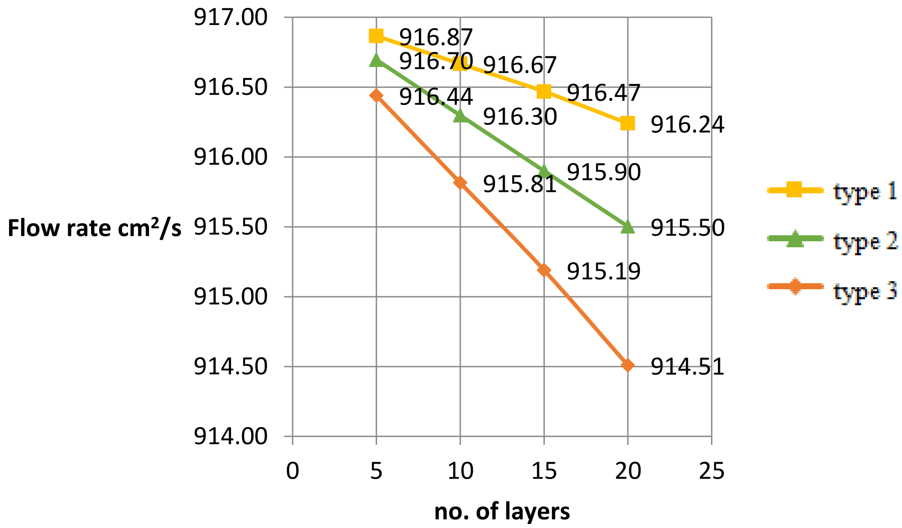
In this section, the effect of varying the number of layers and employing different types of geotextiles in a downstream grain filter on the filtration performance of the geotextile-soil system with a constant amount for each iteration was examined. Accordingly, the aforementioned model variations were generated using GeoStudio software, the results of which were compared with each other.



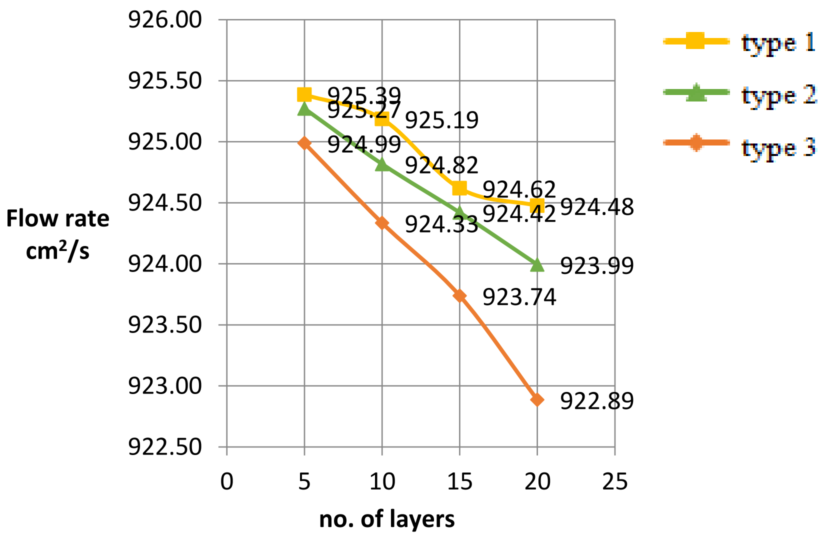
(a)


913.50
913.00
912.50
912.00
911.50
911.00
910.50
910.00
Flow rate cm²/s
912.89
912.69
912.66
912.46
912.46
912.29
912.24
911.84
911.75
911.44
911.10
910.42
0
5
10
15
20
25
no. of layers
type 1
type 2
type 3

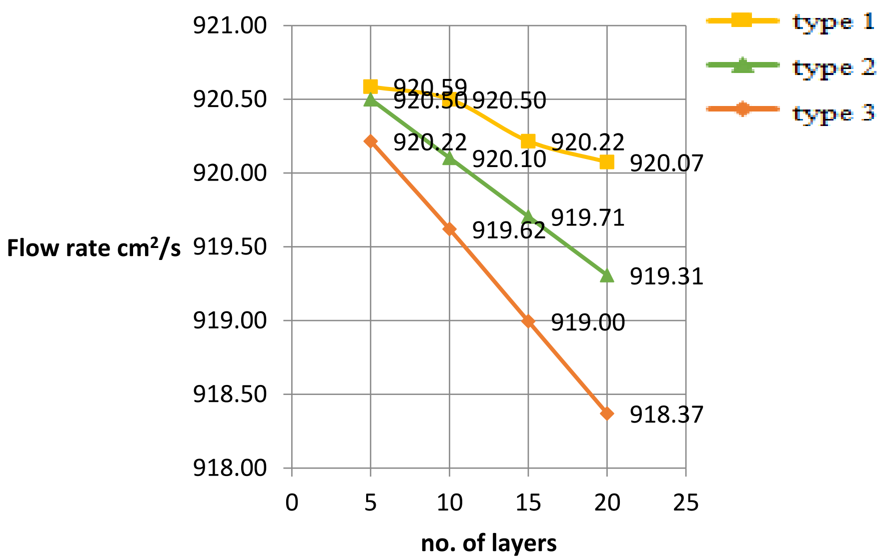
(b)


917.00
916.50
916.00
915.50
915.00
914.50
914.00
Flow rate cm²/s
916.87
916.70
916.67
916.47
916.44
916.30
916.24
915.90
915.81
915.50
915.19
914.51
0
5
10
15
20
25
no. of layers
type 1
type 2
type 3

(c)


926.00
925.50
925.00
924.50
924.00
923.50
923.00
922.50
Flow rate cm²/s
925.39
925.27
925.19
924.99
924.82
924.62
924.42
924.48
924.33
923.99
923.74
922.89
0
5
10
15
20
25
no. of layers
type 1
type 2
type 3

(d)



(e)

Figure 3: (a) Changes in Flow Rate in 40 cm Grain-filter Mode and Varying Numbers of Layers and Different Types of Geotextiles; (b) Changes in Flow Rate in 30 cm Grain-filter Mode and Varying Numbers of Layers and Different Types of Geotextiles; (c) Changes in Flow Rate in 20 cm Grain-filter Mode and Varying Numbers of Layers and Different Types of Geotextiles; (d) Changes in Flow Rate in 10 cm Grain-filter Mode and Varying Numbers of Layers and Different Types of Geotextiles; (e) Changes in Flow Rate in No Grain-filter Mode and Varying Numbers of Layers and Different Types of Geotextiles

Examining Figure 3 indicates that, for grain filter with a thickness of 40 cm and 12 combinations generated by varying number of layers and different types of geotextiles, by increasing the number of layers by 5 in different types, the flow rate is decreased by an average of 3.66% (Figure 3 (a)).
For grain filter with a thickness of 30 cm and 12 combinations generated by varying number of layers and different types of geotextiles, with a linear increase in the number of layers, the flow rate decreases linearly, and the pace of which increases as the weight of the geotextile increases (Figure 3 (b)).
The reduction of flow rate in the transition from 5 layers to 20 layers in type 1, type 2, and type 3 geotextiles is 7%, 13%, and 21%, respectively, which indicates that as the surface weight of the geotextiles employed in downstream filter increases, the leakage flow rate changes with a decreasing trend (Figure 3 (c)).
As the thickness of the grain filter decreases, the flow rate increases, and hence the flow velocity is increased, which is in line with theoretical backgrounds (Figure 3 (d)).
By removing the grain filter, and with the linear increase in the number of geotextile layers, considering that the whole flow is regulated merely by the geotextile, the trend of flow rate reduction becomes irregular and non-linear, indicating the effective presence of the grain filter even with the minimum thickness in flow regulation (Figure 3 (e)).
According to the results of the analysis of graphs obtained from 60 generated models:

1) As the number of geotextile layers increases, the leakage rate decreases.
2) The decreasing trend of leakage flow changes against increasing the number of layers of different geotextile, indicating that in the constant thickness of the grain filter layer, increasing the number of geotextile layers decreases the fluid permeation flow capacity of the filter layer.
3) Overall, using geotextiles reduces the permeability of the whole system of the geotextile-soil downstream filtration, as a result of which the flow velocity is reduced as well.
4) As the surface weight of the geotextiles employed in downstream filter increases, the leakage flow rate changes with a decreasing trend.

By comparing the output flow rates of the models presented in the charts and assuming that the output flow rate of the real-life dam model is constant, the following options with an output flow rate equal to that of the real-life dam with a 50 cm grain filtration were nominated as promising alternatives:

1. Model with a grain filter with a thickness of 10 cm and 5 layers of type 2 geotextile
2. Model with a grain filter with a thickness of 10 cm and 10 layers of type 1 geotextile

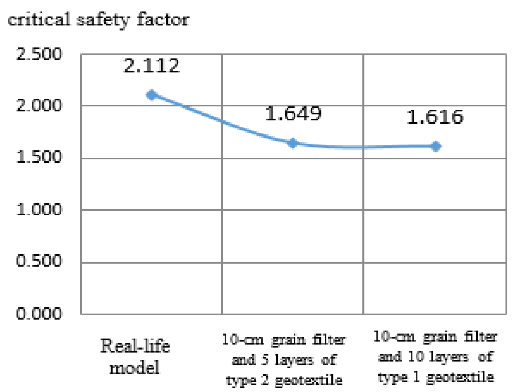
In the following, considering the technical issues, analyses, and studies performed, one of the two proposed options is selected as the replacement for the 50 cm real-life grain filter.

Technical Comparison

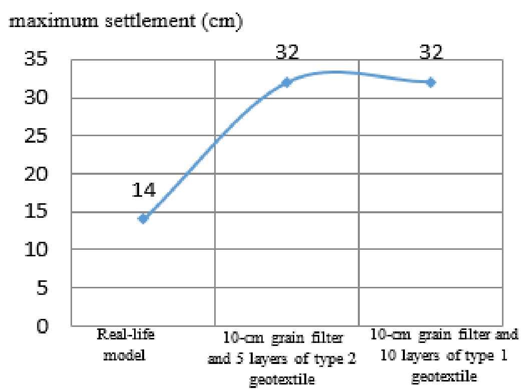
Safety Coefficient: The minimum value of safety coefficient in embankment dams in permanent leakage conditions was calculated to be 1.5 using linear static analysis, which according to the diagram of Figure 4 (a), the values obtained for the safety coefficient in all three models is more than the above-mentioned minimum value.
Maximum Settlement: The results from studying the maximum settlement in the studied section indicate that although employing geotextile in the downstream filter causes the maximum settlement to be 2.3 times that of the 50 cm grain-filter model, the maximum settlement in samples with

geotextiles is 0.6% of the dam height, which is an acceptable value (Figure 4 (b)).

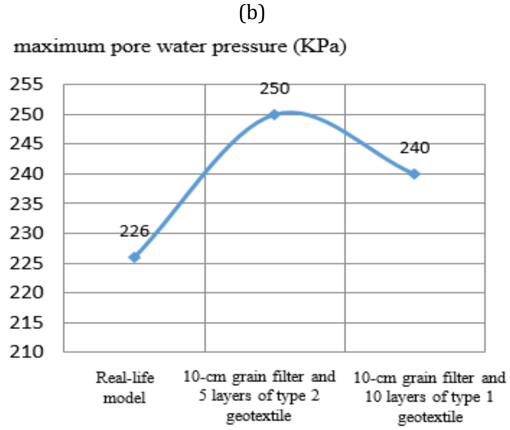
Maximum Pore Water Pressure: From the values obtained on the maximum pore water pressure (Figure 4(c)), it can be concluded that by reducing the grain filter thickness by 80% and replacing it with several layers of geotextiles, the maximum pore water pressure value is increased by only 6-10%, which is a negligible amount.



(a)



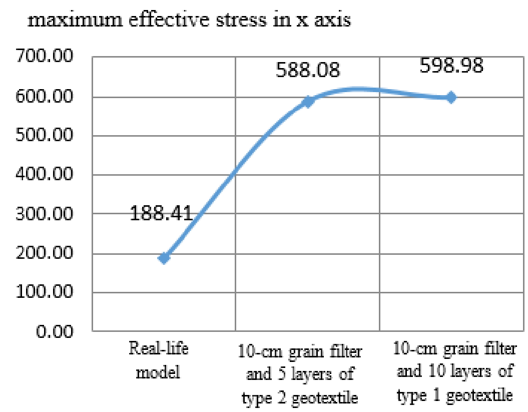
(b)



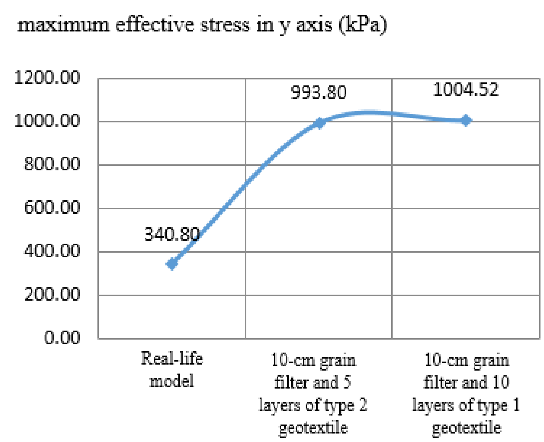
(c)

Figure 4: (a) Critical Safety Coefficient in the Selected Models, (b) Maximum Settlement in the Selected Models (cm), (c) Maximum Pore Water Pressure in the Selected Models (kPa)

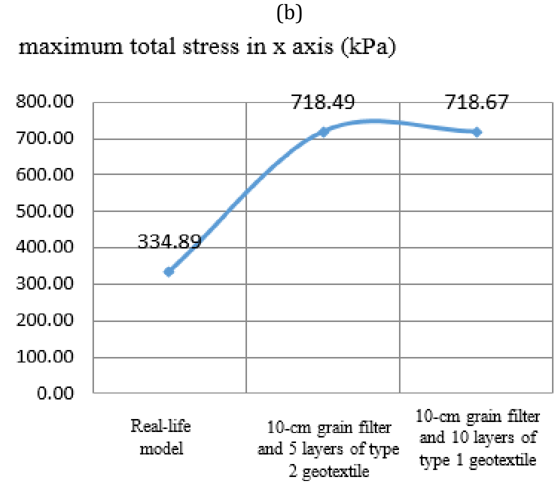
Maximum total stresses and effective stresses: According to the diagrams in Figure 5 for the maximum total stresses and maximum effective stresses, the maximum amount of pore water pressure is not more than any of these values, thus it can be concluded that maximum pore water pressure in models containing geotextiles are acceptable values.



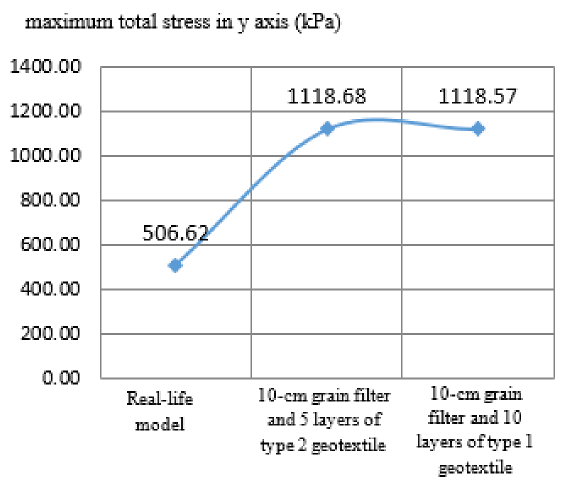
(a)



(b)



(c)



(d)

Figure 5: (a) Maximum Effective Stress in the x Axis in the Selected Models (kPa), (b) Maximum Effective Stress in the y Axis in the Selected Models (kPa),(c) Maximum Total Stress in the x Axis in the Selected Models (kPa), (d) Maximum Total Stress in y Axis in the Selected Models (kPa)

4. CONCLUSION:

Geotextiles are one of the most prevalent types of geosynthetics that have been used in at least 80 applications thus far. Over the past several years, the use of geotextiles in hydraulic and geotechnical engineering has enjoyed steady growth and their use has increased owing to technical and economic benefits compared to commonly used materials. As mentioned earlier, one of the main applications of geotextiles is sought infiltration. But in most cases, geotextiles are employed to simultaneously address several needs. For example, infiltration applications, geotextiles are also involved in reinforcement. Therefore, to select geotextile materials for their filtration capacities, it is essential to satisfy the maintenance and permeability requirements.

In this study, the effect of the geotextile filter on the performance of the downstream filter area of embankment dams was examined. For this study, the Ahuiyeh embankment dam in Kerman province was considered for a case study. To this end, several models were simulated using the GeoStudio computer application. The variables whose effect on the performance of the downstream filter area were studied in this study are the number of geotextile layers and the thickness of the downstream oblique filtration area.

The results of the models simulated to examine the effect of the geotextile layer on the performance of the downstream filtration area are as follows:

In the model simulated with a downstream oblique filter area and a thickness of 50 cm:

- The minimum safety coefficient was 2.11, which was within the acceptable range.
- The results of the calculated height settlement in the studied section show that the maximum settlement was equal to 0.006 (0.6%) of the dam height, which is also within the acceptable range.
- The pore water pressure is always lower than the vertical and horizontal stresses and therefore there is no risk of hydraulic failure.

In the model simulated with the combined filtration area of geotextile - downstream granular materials:

- In case that geotextiles are used in the oblique and horizontal parts of the downstream filter area, as the number of layers increases, the safety factor improves.
- According to the results of numerical models, as the number of geotextile layers increases, the flow rate per unit width decreases.
- This indicates that in the constant thickness of the filter layer, increasing the number of geotextile layers, horizontally and obliquely, weakens the fluid flow capacity of the filter layer.
- Increasing the number of geotextile layers in the downstream filter has a greater effect on layers with smaller thickness, as increasing the thickness of the filter layer decreases its effect.
- As the grain filter thickness increases, the flow decreases, so the flow velocity will decrease, a finding which is in line with theoretical expectations.
- Considering the technical issues, the following option is proposed as an alternative to the 50 cm grain filter:
  - ✓ Sample with a grain filter, a thickness of 10 cm, and 5 layers of type 2 geotextile

Finally, it is safe to argue that owing to the significance of earthquakes and the role of faults in the instability of dams against dynamic loading, it is necessary to perform dynamic analysis by considering geotextiles as the filtration. For future research, the author recommends studying the combined effect of geotextile layers in the downstream and upstream filters of the dam.

REFERENCES

1. Bhatia, S. K., Huang, Q., & Hawkins, W. M. (1995). The soil-geotextile interface stability under sudden change in hydraulic condition. Industerial Fabrics Association International, 345 CEDAR ST., SUITE 800, ST.PAUL, MN55101 (USA), pp.297-315 .
2. Caquel, F., (2004), Behaviour of non-woven geotextiles in river bank protection work, 4th Int. con. On Filters and Drainge in Geotechnical and Environmental Engineering Geofilters.
3. Chen, Y. H., Demery, P. M. & siomns, D. B. (1982), Hydraulic function and performance of various geotextiles in drainage and related applications, Proc. Second Int. conf. On Geotextiles, Las Vagas, IFAI Publishers, St. Paul, Minneapolis 1 155-160 .
4. Johari, A. R., & Pak-Niat, E. (2009). Static and dynamic analysis of embankment dams using Geostudio, First edition, Tehran, Construction Sciences.
5. Mlynarek, J., Lafleur, J., & Lewandowski, J. B. (1990). Field study on long term geotextile filter performance. In *Proceedings of the Fourth International Conference on Geotextiles. Geomembranes and Related Products. The Hague, Netherlands* (pp. 259-262).

6. Mlynarek, J., Palmeira, E.M., & Vaid, Y. P., (1998), Modeling the slurry performance of nonwoven geotextiles systems in filteration test, Can. *Geothech journal, 37*: 792-814.
7. Patanaik, A., & Anandjiwala, R. D. (2008). Water flow through the polypropylene-based geotextiles. Published in Wiley intersience.
8. Roof Iran Company, catalog of technical specifications of different types of geotextiles from the website: http://www.roofiran.com (This company is a manufacturer of geotextiles in Iran and the technical specifications of the company's products have been used for modeling).