

PERFORMANCE ANALYSIS OF NONWOVEN POLYESTER GEOTEXTILES USED FOR SLOPE STABILIZATION ON LANDSCAPE RECLAMATION APPLICATIONS

PEYZAJ ONARIM UYGULAMALARINDA ŞEV STABİLİZASYONU AMACIYLA KULLANILAN DOKUSUZ POLYESTER JEOTEKSTİLLERİN PERFORMANS ANALİZİ

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ABSTRACT

Technical textiles, being the fastest growing area of textiles sector, are nowadays applied to several areas. Geotextiles, which is one of the application areas of technical textiles, are defined as any permeable textile material that are used with foundation, soil, rock, earth, etc. to increase stability and decrease wind and water erosion. Because of their technical advantages and low cost solutions, geotextiles have an important place in civil engineering. In this study, the performance analysis of nonwoven polyester geotextiles used for slope stabilization in landscape reclamation applications is examined in Aegean region, İzmir city rainfall conditions. For this aim, five stations having different degrees of slope, in order to determine the soil retention capacity of nonwoven polyester geotextiles having different weights, were built. These stations were slated to the system proposed by IUFRO (International Union of Forest Organizations). To carry out this research, climatic data of the Aegean region, in the city of İzmir, were used.

Key Words: Technical textiles, Geotextiles, Slope stabilization, Soil flow.

ÖZET

Tekstil sektörünün en hızlı büyüyen alanı olan teknik tekstiller günümüzde birçok alanda karşımıza çıkmaktadır. Teknik tekstillerin bir uygulama alanı olan jeotekstiller, toprak ve zemin stabilitesini artırmak su ve toprak erozyonunu önlemek amacıyla kullanılan yüzeylerdir. Sahip olduğu teknik avantajlar ve düşük maliyetleri nedeniyle inşaat mühendisliğinde önemli bir yere sahiptir. Bu çalışmada peyzaj onarım uygulamalarında şev stabilizasyonu amacıyla kullanılan dokusuz polyester jeotekstillerin Ege Bölgesi, İzmir ili yağış koşullarında performans analizi gerçekleştirilmiştir. Bu amaçla beş farklı eğime sahip deneme istasyonu kurulmuş ve çeşitli ağırlıklara sahip polyester jeotekstillerin toprak tutma kapasiteleri incelenmiştir. Deneme istasyonları IUFRO tarafından önerilen sisteme göre eğimlendirilmiştir. Araştırmada İzmir ilinin meteorolojik verileri kullanılmıştır.

Anahtar Kelimeler: Teknik tekstiller, Jeotekstiller, Şev stabilizasyonu, Toprak akışı.

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1. INTRODUCTION

The developments in technology in recent years have enabled the production of textile products with different functions such as healing scars for medicinal purpose, water-proof respiration, anti-bacterial, protection against a possible chemical and biological war, earthquake resistant buildings, prevention of erosion and

providing communication apart from textile's basic function of covering and protecting from external effects (1).

Different usages of textile products besides the conventional usage of textile are stated to be a new field of textile coined as technical textile.

Technical textiles which have a wide variation of products are the most

rapidly growing field in the textile sector. Especially in the last twenty years, the studies carried out in this area have gained great importance. In the contemporary world, textile materials with their variety of fibre and the variation of constructions formed whenever its necessary are not only used in classical textile application fields but also find wide usage in fields

such as medicine, construction, transportation, agriculture and industry. New fibre materials, textile surfaces and textile production technologies have promoted this tendency. Another triggering factor for this sector to rapidly improve is also the new application fields opened for technical textile productions and an increase in the marketing demands (2).

Technical textiles are primarily defined as textile materials and products produced for technical performance and functional qualities rather than their aesthetic and decorative characteristics.

Nowadays, technical textiles are used in landscape architecture for their aesthetic qualities; while they are also used widely in landscape restoration and constructional works within the scope of landscape engineering with their structural functions.

The usage of geotextiles, a type of technical textiles, in order to provide a mass stabilization, for the stabilization of the unstable soil material on surfaces and soil surfaces, is a common application especially in slope areas. These types of applications are used in the preparation of the surface which will provide for the regeneration of the botanic tissue while preventing the slide of the soil surface and in the (in)direct prevention of the soil erosion caused by several reasons (water, wind etc.). Considering the erosion amount every year due to different reasons, the importance of these types of applications proves to be vital in providing a healthy and sustainable environment. In this study, nonwoven polyester geotextiles in slope stabilization studies in landscape reclamation applications and the appropriate material choice for right slopes are provided in order to minimize environmental and economic loss. Furthermore, several suggestions have been posed by carrying out performance analysis towards the success rates of materials with different density and basis weight in different slopes.

Measuring the efficiency of a process provides information concerning the status of the process and enables decisions to be made concerning the adjustment of settings or actions to improve performance (3).

2. THE DEFINITION OF GEOTEXTILES AND APPLICATION AREAS

Geotextile is a synthetic material which has a thin, elastic, resistant and percolating tissue with an appearance of mesh, fabric, and wadding or felt obtained by weaving natural and artificial fibres, metal mesh and twisting yarns together in a vertical direction or knitting them with appropriate techniques (4).

Geotextiles are textile materials used in underground applications of civil and geotechnical engineering fields. Textile structures produced by both natural and synthetic fibres can be used in this field. Geotextiles are materials which have an ability of filtering, retaining, reinforcing and separating used for the combinations of all these functions.

Geotextiles must have at least one of the five functions of separation, reinforcement, filtration, drainage or barrier. The product used as geotextile has an utter advantage in soil retaining for it has strain, traction and tearing resistance, a certain firmness, a resistance to stretch underneath weight, and air and water permeability (2).

The commonly used fields of geotextiles can be listed as; road constructions, park areas, railways, foundations, base concretes, ground applications, underground pipes and canals, storages, airports, harbours, underground systems of sports fields, drainage and filtration systems, drainage pipes, drainage canals, surface drainage, building drainages, hydraulic constructions, coastal protection constructions, dams, the protection of river beds and canals, artificial ponds, water reservoirs and garbage and waste storage areas. Geotextiles can generally be produced with woven, knit and nonwoven technology. Woven geotextiles have a wide application field. Woven fabrics do not show excessive mechanical stretch due to the warp and weft yarns within their structure and for this reason (especially warp knitting) fabrics and fibre/soil mixtures are also used (2).

The value of a geotextile for a certain application is determined by that geotextile's physical characteristics. For example, some geotextiles decompose and rot in time and this is

a desired feature in short termed erosion cases. Some other geotextiles on the other hand do not decompose easily which is a required feature in drainage applications and in the protection of soil from water (separation) (5).

While Figure 1 illustrates a woven geotextile surface, Figure 2 illustrates the structure of a surface produced by nonwoven technology (6).

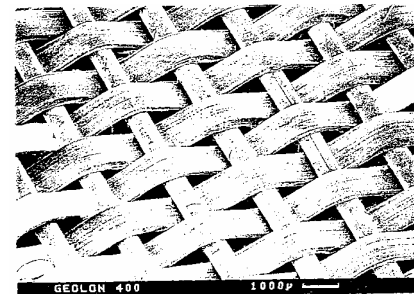


Figure 1. Woven geotextile surface (6)

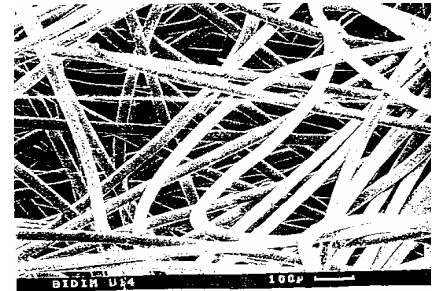


Figure 2. Nonwoven geotextile surface (6)

Nonwoven products compose the 80% of all geotextile applications. In the field of geotextiles, nonwoven structures are generally used below roads, on underground drainage surfaces, in river beds, airports and under athletic fields. At the same time they also have a function under the surface of canalizations, in separation of earth stratum, in control of persistent erosions and as a geomembrane coating material in landfill. The main reason for the synthetic fibres to be preferred in permanent applications is their ability to resist biodegradation. Mostly polypropylene, polyethylene, polyester, polyamide and polyvinylchloride are used as synthetic fibres in the production of geotextiles. The two most used synthetic fibres in the production of geotextiles are polypropylene and polyethylene, especially for their chemical endurance. Polypropylene fibres are at the same time the most important raw materials because of low costs, low weight

densities and durability qualities. In demand of high strength, polyester is used. Other polymers with high strength can also be used in the field of geotextiles. However, since the costs are high and they cannot be obtained in large amounts, they are not commonly preferred. Natural fibres such as linen, cotton, jute, sisal, abaca and kenaf can also be used in the production of geotextiles where they are expected to fulfil the functions of geotextile for a limited amount of time in applications (6).

To exemplify previous studies regarding performances of geotextile materials; studies of Cartaud and his friends (7); The experimental analysis of leakages in the usage of geotextile materials applied underneath geomembrane, Tolooiyan and his friends (8); A comprehensive method research for the analysis of geotextile layer effects in the stabilization of filled areas, Faure and his friends (9); The analysis of the filtration capacity of geotextile material in Valcros Damp after 21 years, Reis and his friends (10); The study of determining the soil amount lost with erosion by geotextile used in the rainfall catchment of Keklik Creek in the city of Kahramanmaraş, Shin and Oh (11); a study titled "Coastal erosion prevention by geotextile tube technology", Haeri and his friends (12) and their study on the effect of geotextile reinforcement on the mechanical behaviour of sand can be given.

3. MATERIAL AND METHOD

In the study carried out between March 2010 and July 2012, with the aim of determining the soil hold capacity of polyester nonwoven geotextile materials with different weights (50, 150, 300 and 500 gr/m²) in different slopes, 5 test stations which were constructed on an ironwork with a surface measure of 1m² (100 cm x 100 cm) and depth of 20 cm with aerated concrete, have been set. These stations have been sloped in order to simulate field types with different slopes according to the system accepted by IUFRO (International Union of Forest Research Organizations) (13). Some of the features of the geotextile material used in the study are given in Table 1.

Table 1. Some features of the geotextile material

Mass (gr/m ²)	50	150	300	500
Type of fiber	PES			
Fiber Linear density (dtex)	5.3			
Length (mm)	5			

According to the system accepted by IUFRO, the slope classifications used in field research and field classifications are determined as; lowland (0 - 10%), slight land slope (11 - 20%), average land slope (21 - 33%), steep land (34 - 50%), very steep land (51 < ... %) (14). These stations, constructed in plain (9°), slight (14°), average (22°), steep (31°) and very steep (45°) slopes, determined according to IUFRO, were

each divided into 20 cm divisions and separated by resistant glass material (Figure 3). 90° pulsating, fogging and low particle pulsating micro springs were placed within the four corners of each station forming an irrigation system which provided the whole surface to be irrigated without outpouring. Micro springs were integrated into the main line with thin pipes and connected to the water meter to control the water amount running. The whole system was placed under a coating, in a greenhouse, with the aim of excluding all external conditions (rain, wind etc.) (Figure 4).

All divisions separated by glass, measuring 100 cm x 20 cm x 20cm, in each experiment station were filled with sandy-alluvial region soil (14) to 10 cm height, based on the principles of geotextile material usage (5). Later on, four different geotextile materials weighing 50gr/m², 150gr/m², 300gr/m² and 500gr/m², in the direction of a coincidental test pattern were placed within the prepared parcels. In order to control the accuracy of the test, one of the five parcels in each station was not applied with geotextile. These parcels which were under the same conditions throughout the research have made it possible to interpret the efficiency of the study. Underneath each parcel, a green plastic net coating was placed in order to prevent the slide of the base soil. The reason for this operation was to enable the landslide after the irrigation to be only from the upper part so that the surface flow could be determined.

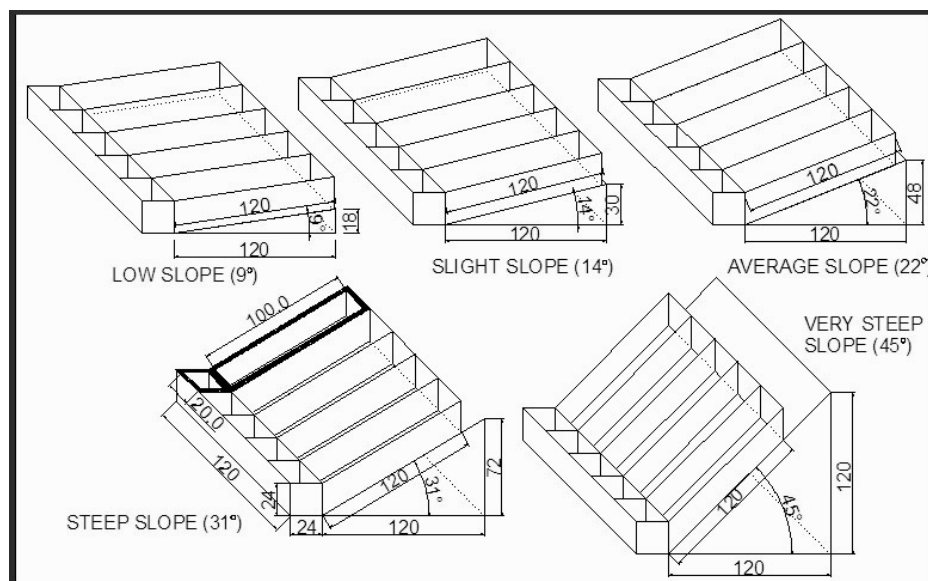


Figure 3. The structure of experiment stations and slopes



Figure 4. The front and side view of experiment stations

After the geotextile materials were placed, 10 cm thick sandy-alluvial region soil sifted from rocks was spread over to be compressed. Densely porous permeable filtration materials were framed with wires and placed underneath each parcel, in the gathering sections, which were enumerated with different letters and numbers for the sake of an ease in measurement and accuracy. The measurements were taken by weighing the soil after it was dehydrated and dried thanks to the porous material.

To form the possible natural conditions, regional soil and data regarding the annual rainfall status in the research area was used to determine the irrigation amount in the study. To be able to measure the amount of precipitation used in the study, according to the General Directorate of Meteorology standards of grading meteorological cases, 6-20 mm/m² amount of rainfall was appointed in between a precipitation range of medium intensity (16). Since the Aegean region is placed within the anticipated rainfall intensity in the climatic data of the city of Izmir, the rainfall data of the city of Izmir was taken as a model for the application. Once again, the data obtained from the General Directorate of Meteorology was used to form this rainfall model.

According to the data of 1970-2009, it was determined that December was the month which had the most amount of rainfall in the city of Izmir. According to meteorological data from the province of Izmir, 145.3mm/m² with the highest amount of rainfall was realized on 29.09.2006 (18). In the study, the maximum amount of rainfall

for the month which is the highest values occurred between 1970-2009 was deemed appropriate to use the data.

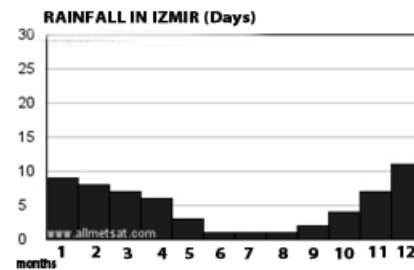


Figure 5. The number of rainy days throughout months (16)

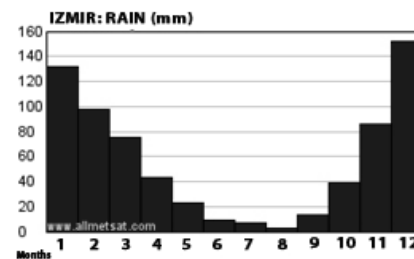


Figure 6. The average amount of rainfall throughout months (16)

Within the same time span in the city of Izmir, the data of 1970-2009 indicated that the maximum rainfall realised at 12,2 day with a total amount of 130 mm/m² (19). Thus, these amounts were taken as basis for irrigation (Figure 5 and 6).

In the light of this data, the maximum precipitation amount was determined as (130 mm/m² / 12,2 days) daily 10,65 1/m² in the study. This amount was determined as the amount to be used in 1 m² ground. Since the total test surface in the stations with different slopes was determined as 5 m², in order to give the estimated

amount of rainfall per square meter it was calculated that 10,65x5 m² = 53,25 litres must pass through the water meter. The water pressure used in the test was 2, 6 lt/m²/min. Considering that all test surfaces were irrigated under fixed flow, the water amount flowing from the counter was calculated as 12 lt/ 5 m² per minute. In this regard, it took approximately 4,09 minutes to give the field the estimated 53,25 litres of daily water amount via micro springs. By giving the determined amount of water consecutively twelve times, a simulation set of the maximum rainfall conditions of the city of Izmir was performed. During the test, this simulation was repeated in different seasonal conditions (heat and humidity) in 7 sets composed of 12 repeats. The amount of landslide after each application was classified according to the slopes and the basis weight of the geotextile material, weighed on precision balance and the obtained data was studied in order to be evaluated.

4. FINDINGS

The data obtained throughout the test was classified into a table, according to the slopes, the weight of the geotextile material and soil amount passing through surface flow (Table 2).

After each application in the research, material on surface flow was measured and recorded. These measurements were gathered after each 12 repeats, the maximum number of rainy days in Izmir, and calculated in order to determine the daily amount on surface flow after each rainfall.

$$P_x = q_1 + q_2 + q_3 + \dots + q_{12} / 12 \quad (1)$$

Table 2. The data on the average amount of obtained soil flow

		MEASUREMENT VALUES WITHOUT GEOTEXTILES (GRAM)						GEOTEXTİLE APPLICATIONS WITH 50 GRAM/ M ² (GRAM)				
SLOPES		100%	60%	40%	25%	15%		100%	60%	40%	25%	15%
MEASUREMENTS	P ₁	3.34	0.08	0.00	0.00	0.00	P ₁	24.18	0.00	0.00	0.00	0.00
	P ₂	0.40	0.75	0.32	0.00	0.00	P ₂	0.87	0.97	0.31	0.00	0.00
	P ₃	3.03	10.45	1.33	0.00	0.00	P ₃	2.02	3.13	0.92	0.37	0.00
	P ₄	7.05	0.00	0.00	0.00	0.00	P ₄	10.73	0.00	0.00	0.00	0.00
	P ₅	80.75	0.00	0.00	0.00	0.00	P ₅	70.32	0.00	0.00	0.00	0.00
	P ₆	24.70	0.00	0.00	0.00	0.00	P ₆	7.88	0.00	0.00	0.00	0.00
	P ₇	2.78	0.19	0.18	0.00	0.00	P ₇	0.25	0.21	0.17	0.00	0.00
AVERAGE	S1	17.44	1.64	0.26	0.00	0.00	S2	16.60	0.62	0.20	0.05	0.00
		GEOTEXTİLE APPLICATIONS WITH 150 GRAM/ M ² (GRAM)						GEOTEXTİLE APPLICATIONS WITH 300 GRAM/ M ² (GRAM)				
SLOPES		100%	60%	40%	25%	15		100%	60%	40%	25%	15%
MEASUREMENTS	P ₁	0.81	0.00	0.00	0.00	0.00	P ₁	1.82	0.00	0.00	0.00	0.00
	P ₂	0.40	0.46	0.27	0.00	0.00	P ₂	0.47	0.57	0.00	0.00	0.00
	P ₃	5.76	1.28	0.77	0.56	0.00	P ₃	4.72	3.17	0.39	0.00	0.00
	P ₄	45.39	0.00	0.00	0.00	0.00	P ₄	33.11	0.00	0.00	0.00	0.00
	P ₅	55.42	0.54	0.00	0.00	0.00	P ₅	33.05	0.00	0.00	0.00	0.00
	P ₆	0.32	1.55	0.00	0.00	0.00	P ₆	0.00	0.00	0.55	0.00	0.00
	P ₇	0.51	0.18	0.00	0.00	0.00	P ₇	0.36	0.03	0.00	0.00	0.00
AVERAGE	S3	15.51	0.57	0.15	0.08	0.00	S4	10.50	0.54	0.13	0.00	0.00
		GEOTEXTİLE APPLICATIONS WITH 500 GRAM/ M ² (GRAM)										
SLOPES		100%	60%	40%	25%	15%						
MEASUREMENTS	P ₁	0.00	0.00	0.00	0.00	0.00						
	P ₂	0.37	0.80	0.51	0.00	0.00						
	P ₃	2.79	0.82	0.26	0.00	0.00						
	P ₄	12.59	0.53	0.00	0.00	0.00						
	P ₅	32.04	0.00	0.00	0.00	0.00						
	P ₆	0.00	1.50	0.00	0.73	0.00						
P ₇	0.36	0.00	0.00	0.00	0.00							
AVERAGE	S5	6.88	0.52	0.11	0.10	0.00						

The numerical value represented by the sign “q_x” in the equation stands for the daily values while “P_x” stands for the average daily value which forms a set, obtained after every 12 daily applications. At the end of the test, the daily average obtained from the values of 7 sets composed of 12 days were combined into a table to show the changes which had occurred throughout the study (Eq. 1).

$$S_x = P_1 + P_2 + P_3 + \dots + P_7 / 7 \quad (2)$$

In this equation on the other hand, the average of the “P_x” data obtained after 12 daily applications were taken to calculate the “S_x” average value which was obtained as a result of the 7 sets repeated during the whole test (Eq. 2).

In the discussion and conclusion section, the equation below was used in order to compare the success of performances of the different geotextile materials in different slopes regarding their percentages of soil containment on surface flow.

$$Q_x = S_x - S_{(x-1)} \times 100 / S_x \quad (3)$$

The symbol “Q_x” stands for the success rate of the compared geotextile material to the other geotextile materials in the same slope. “S_x” represents the soil amount on surface flow in the estimated geotextile material in the same slope to be compared in terms of performance while S_(x-1) represents the daily average obtained from the test as a

result of the application of the geotextile material which has lesser weight than the material to be compared to the estimated geotextile material in the same slope (Eq. 3).

5. RESULTS AND DISCUSSION

When the comparative results formed in the light of the studied data were examined, several results emerged regarding the usage of the different geotextile materials in different slopes in estimated precipitation conditions. These results were calculated and turned into percentage data by proportioning the difference in the soil amounts on surface flow in the estimated slopes with each other (Figure 7).

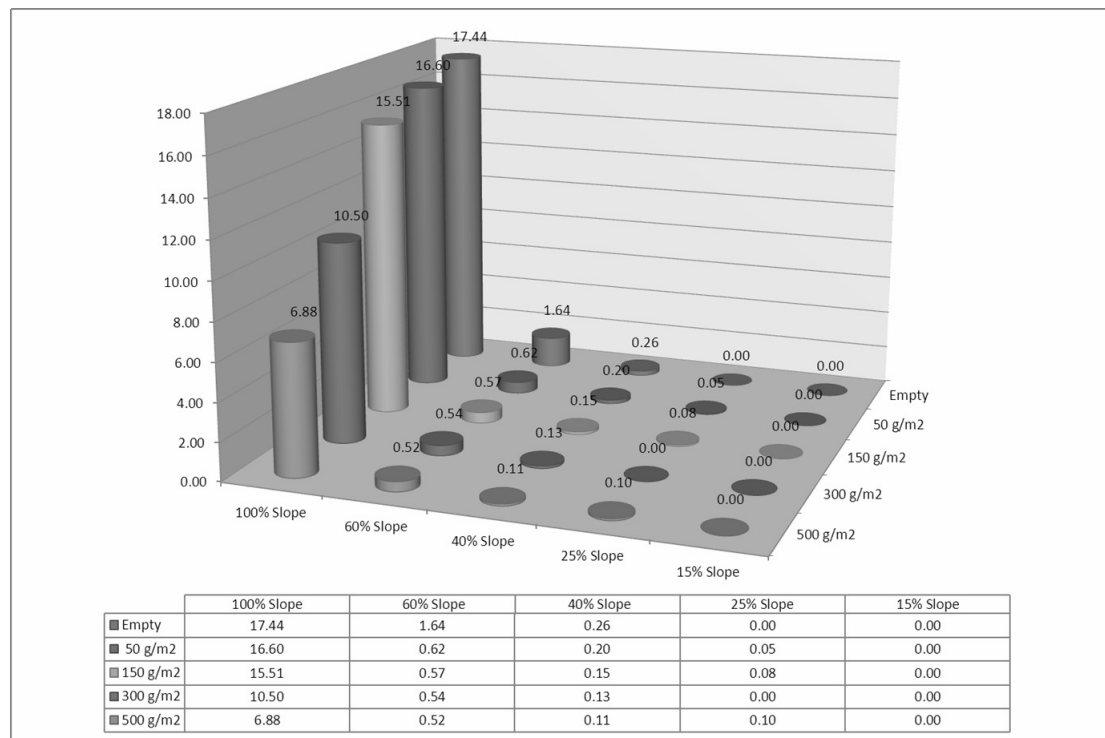


Figure 7. The comparative results for the average soil amount on surface flow according to the applications of geotextile with different weights in specific slopes

As a result of the research findings;

- In low-15% slope and slight-25% slope, there was almost no sign of soil on surface flow with the exception of the rare activities of the particles too small to be evaluated. In these types of slopes it has been concluded that there is no need for the usage of geotextile material.
- In average- 40% slope, a routine landslide started yet this surface flow was not in high amounts and it was observed that the thickest (500g/m²) geotextile material used in the study could decrease
- In steep- 60% slopes, it was observed that the surface flow increased six times compared to the average - 40% slope which was the previous slope group in empty parcels. It was also seen that the geotextile material used in this slope reached success with a rate between 62% and 68% according to the weights per meter square (50 g/m² and 500g/m²). In the light of this data, it was interestingly found that in the areas with steep-60% slope, the geotextile material was successful in holding the soil on surface flow; however, the weight

per square metre of the used material did not create an observable difference.

- In very steep-100% slope with the most surface flow in the study, it was observed that the amount of the soil flow was 10 to 17 times more when compared to other slopes. In this slope, the rate of the performances of geotextiles with that of the surface flow in the parcels which never used, revealed that geotextiles were more successful respectively weighing 50 g/m² in 4,81%, 150 g/m² in 11,06%, 300 g/m² in 39,79% and 500 g/m² in 60,55%. In terms of these results, it can be concluded that in very steep slopes, the usage of geotextiles show positive results ranging in weights and the usage of the geotextile material with a 500 g/m² weight had the most successful performance, decreasing the surface flow in a rate of 60,55%.

In conclusion; in the most appropriate conditions, it takes approximately 100 to 400 years to form only 1 square centimetre of soil which is the basis of the whole ecosystem and the most valuable natural resource. The most fertile part of the soil, the surface, is being carried away and destroyed

because of natural conditions and human activities which make this situation one of the most important environmental problems in our world. Considering that the results in the study were obtained in 0,2 m² and after one day; moreover, in the precipitation conditions of the city of Izmir which can be considered as having a dry climate, it is very important how small amounts in natural conditions, in the direction of present masses and processes can reach high amounts in reality. In the regions where the rainfall and slope are more, these amounts will geometrically and incrementally increase.

The fact that the slopes which were used in the study not only include natural structures of canyons, hillsides and piedmonts but also human constructions such as roads, dams, reservoirs and building constructions, even agricultural activities, it is obvious that problems faced in this field requires security precautions. The threats posed by the possible flow of soils on surface such as landslides, avalanches and erosions to the nature, human life and daily life quality are on an alarming level. Nonetheless, in the light of the obtained data, it can be

derived that in the appropriate slopes, the usage of the nonwoven polyester geotextile material, a technical textile with the appropriate weight, can

prevent most of these threats by decreasing the amount of the soil loss on surface flow and help to preserve the natural structure; thus, contribute

to the path of solving one of the most dangerous environmental problems.

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