Green terramesh retaining wall as embankment fill at V27 viaduct in north marmara highway project

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ABSTRACT: The use of geosynthetics for weak soil, embankment and slope stability problems has been increased since 1960s because they can easily act as an engineering tool by means of flexible design methods and they provide great economic advantages. Today, geosynthetics are being frequently utilized as the solution to soil improvement and retaining wall problems. Additionally, geosynthetics with modular system can create innovator, sustainable and alternative formula in building sector. This paper includes design and construction method of green terramesh retaining wall, which is a geosynthetic retaining wall type with flexible front surface, applied as embankment fill at V27 viaduct in North Marmara Highway Project.

Keywords: Geosynthetics, terramesh, embankment, viaduct

1 INTRODUCTION

Before the name of "geosynthetics" was proposed, the discipline of it began many years ago. Since the earliest periods of human history, people made basic structures using adobe bricks and mud by reinforcing them tree branches. The French engineers strengthened the reservoirs with sticks in 16th and 17th centuries. In the early 1960s, the Ducth integrated geotextiles into extraordinary Delta Work flood protection scheme.

From the date, 1977, Dr. Giroud first used the terms "geosynthetics" and "geotextile" in a presentation in Paris to today, geosynthetics have had extended functions in every major sector of civil engineering such as railways, highways, retaining walls, coastal protection…

If this discipline is limited to retaining wall and slope design, it is noticed that geosynthetic reinforced retaining walls are the best cost effective and durable solution over traditional concrete and masonary gravtiy walls or cantilever retaining walls.

This paper deals with the design and application of green terramesh system, which is a kind of geosynthetic retaining wall, as V27 viaduct approach fill in KM: 105+553, North Marmara Highway Project.

1.1 *Materials used in geosynthetic walls*

Trade mark and type are the main criteria in the choice of geosynthetics while design of them was been making by trial and error in the early times of geosynthetics. However, today, solution method of geosynthetic are not different from any other geotechnical problems'.

Before the decision on the use of geosynthetics, whether it is necessary or not must be determined. After the evaluation of geosynthetic's economic and practical advantage over conventional methods, design calculations are made with respect to the characteristics of the selected geosynthetic. Specification is created according to the chosen product and its performance features. In addition to the fill tests, geosynthetic must be tested and verified the design. Before the construction is completed, it cannot be said that the design of geosynthetics is over.

1.1.1 *Geogrids*

The main bearing material in the geosynthetic reinforced retaining walls is the geogrid. They are manufactured by using several polymer raw materials such as polypropylene, polyester, polyethylene etc. They are generally used in retaining walls and soil reinforcement applications.

Depending on the type of polymer and density, ultimate tensile strength of the geogrids change. They can be strip-shaped or mesh-shaped. The ones whose shape is strip work with the basis of friction while the working principle of mesh-shaped geogrids is the interlocking of fill material between the apertures.

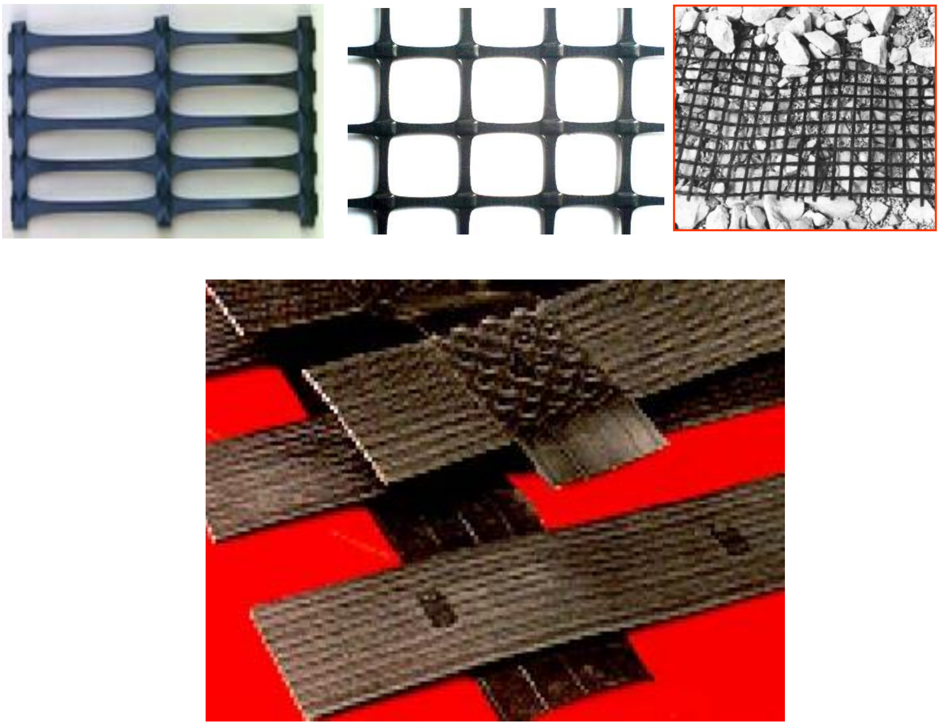

Figure 1. Type of geogrids having different properties

The geogrid type used in V27 viaduct approach fill is consist of biaxial array of strips including a high tenasity polyester tendon core and a polyethylene sheath, which is named as Paragrid. The working principle of it depends on the friction force developed between geogrid and the fill material.

1.2 *Green terramesh*

One of the components forming the wall is front face member and the wall is called accordingly. Mostly the dominant parameter in the decision on the facing element is architecutal needs. Geogrids are placed between these facing elements or connected these facing elements with some connection apparatus.

In this project, green terramesh system was utilized as facing unit, which can be classfied as flexible system. After the wall construction, this system enable to grow grass at the face by hydroseeding thanks to its 70^0 inclined face. Therefore, green terramesh retaining wall is also a environmentally friendly modular system.

Green terramesh moduls manufactıred in accordance with EN 10223-3 standard, is obtained by assembling units made of hexagonal double twisted wire mesh 8x10 cm, a geosynthetic erosion control blanket, a welded mesh panel and two pre-formed steel brackets. Steel wire is heavily galvanized with 5% of Zn-Al alloy and coated with polymer (PVC). To preform required slope angle, two steel brackets with 8 mm in diameter are used. Figure 2 shows the components of green terramesh retaining wall.

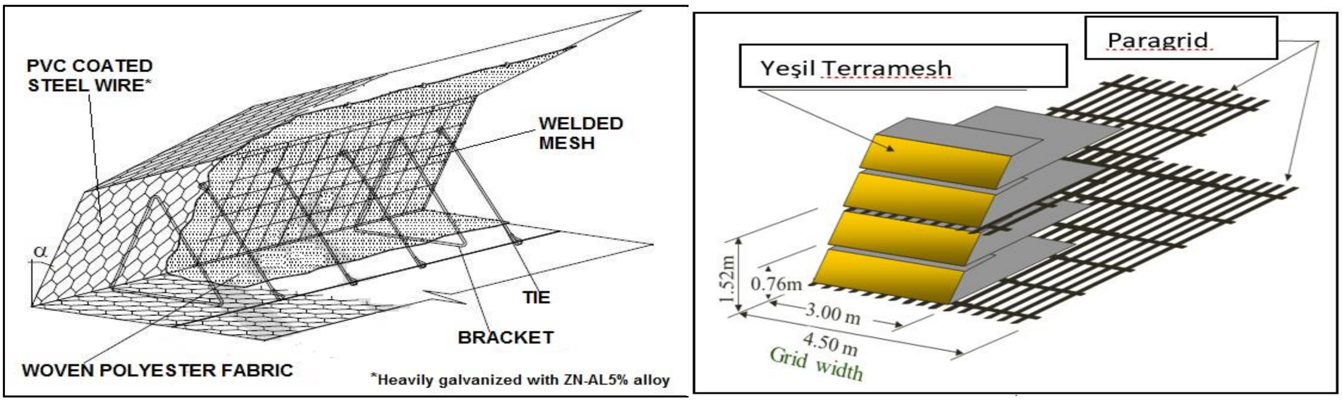

Figure 2. Green terramesh retaining wall components

2 DESIGN CRITERIA

Design criteria for green terramesh retaining wall is same as for conventional slopes' such that in both cases, essential factor of safety should be obtained against short and long-term stability:
1) Internal stability: Slide surface is in the geogrids
2) External stability: Slide surface is under and behind the reinforced soil mass
3) Both of them: Slide surface is in the reinforced soil mass as well as behind it

Stability controls for geosynthetic reinforced retaining walls are made with modified conventional limit equilibrium slope stability methods. For circular or wedge sliding, relationship between sliding and resisting forces or moments determines the factor of safety. In terms of the location and tensile strength of geogrids, which are used for reinforcement, they rise the resisting effect of forces or moments for the critical potential slip surface. Tensile capacity of the geogrid is the smaller of the allowable pullout resistance in the front of or behind the potential slip surface or long-term design tensile force. Optimum grid design is made by changing the location and space of them. In practice, various software provides the opportunity to find distinct slip surfaces and to calculate necessary pullout and tensile capacity of the geogrids respectively.

In the design of V27 viaduct approach fill, software named as "Macstars" is used for limit equilibrium analysis. Calculations are made according to Eurocode 7 standard with the load combinations A1+M1+R2 and A2+M2+R1 for static case; M2+R1+kh±kv for seismic case.

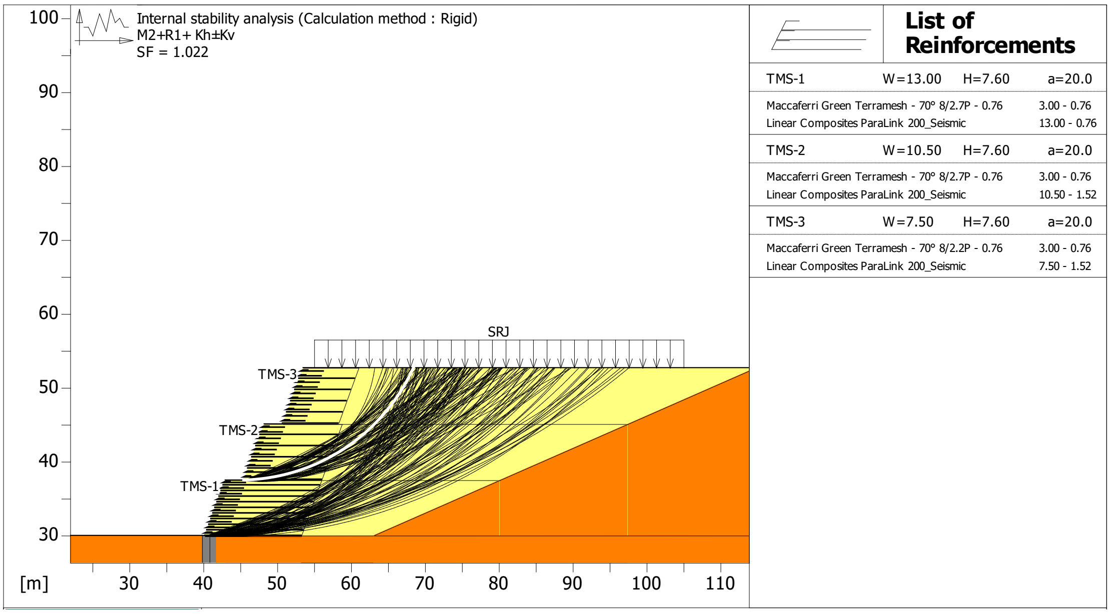

Figure 3. Tasarım Analiz Çıktısı

2.1 *Design parameters*

The project location is İstanbul, Turkey defined as 1st degree seismic zone according to seismicity map released by Earthquake Research Center so peak ground acceleration:A_0 was selected as 0.4 g. In the computations, traffic load was takes as 15 kPa.
The parameters belong to foundation soil, back fill and structural fill are listed in Table 1. :Besides Table 2 shows the gradation of the fill.

Table 1. Properties of the fill and foundation soil

Layer Name	**Unit Weight (kN/m^3)**	**Elastic Modulus (kPa)**	**Cohesion (kPa)**	**Internal Friction Angle (^{0})**	**Model Type**
Alluvion	17~18	10,000	40	1	Mohr-Coulomb
Rock (Siltstone~sandstone)	25~26	600,000	300	10	Mohr-Coulomb
Road fill	20~20.5	50,000	10	35	Mohr-Coulomb

Table 2. Grain size distribution of fill material

Grain Size (% Passing) / Sieve Analysis															
4"	3"	2"	1 1/2"	1"	3/4"	3/8"	No 4	No 10	No 40	No200	**Atterberg Limits**	**Max. Dry Density (g/cm^3)**	**Optimum Water Content** (%)	**CBR** (%)	**Swell** (%)
100	78.5	70.4	64.1	46.0	40.2	28.4	19.8	13.7	6.5	3.5	N.P.	2.08	9.4	31.0	0.00

The geogrid, Paragrid 200, used as reinforcement and green terramesh facing unit characteristics are given in Table 3.

Table 3. Paragrid 200 used geogrid type in the project

	Unit	PARAGRID 200	GREEN TERRAMESH 3X3X0,76 (mesh 8x10; wire diameter 2.2/3.2mm)
Ultimate tensile strength	kN/m	200	50.11
Factor of safety - $\mathbf{f_m}$	-	1.10	1.30
Design Tensile Capacity	kN/m	**131.56**	**38.50**

V27 viaduct approaach column is reinforced concrete and due to the piles, the load coming from the viaduct is transferred directly to the hard stratum. The aim of the green terramesh retaining wall design is to hold the approach fill. Therefore, the assumption that the loads coming from the viaduct has no influence on the green terramesh retaining wall was made. The phonemenon is shown in Figure 4 and the design assumption is given in Figure 5.

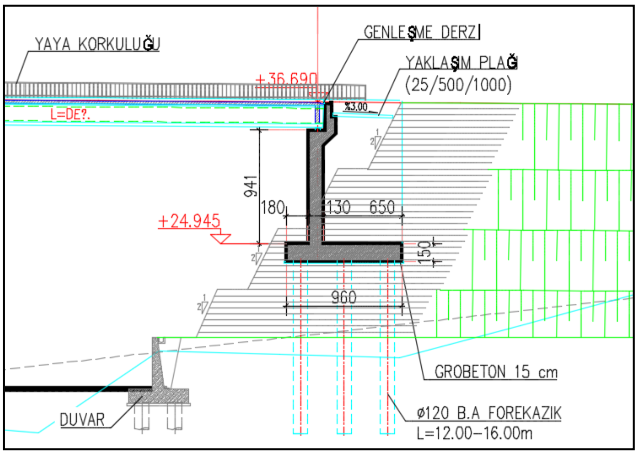

Figure 4. V27 viaduct approach column typical cross section

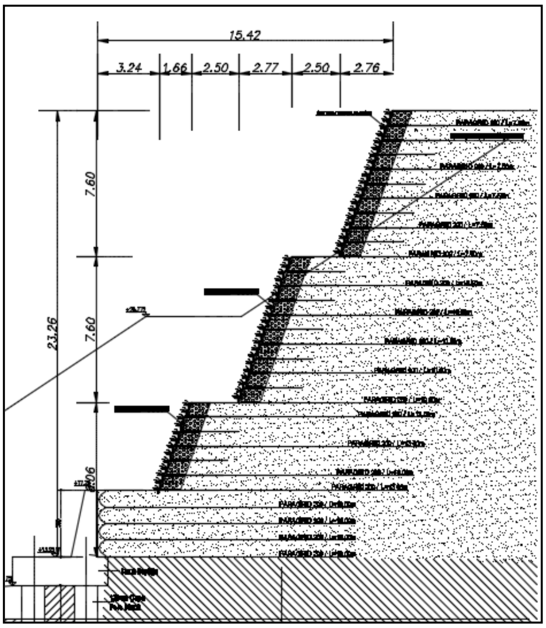

Figure 5. V27 viaduct approach fill green terramesh cross section

In addition, ın green terramesh retaining wall analysis, the existing concrete retaining wall at the lowest level in section was not taken into consideration. Internal and external stability checks as well as global stability control were made for green terreamesh.

Factor of safety values got from the analysis are given in Table 4. When these values are examined, it can be seen that they are bigger than 1, which is enough value according to Eurocode 7.

Table 4. Analysis results

	Seismic	**Static**		
Load Combination	*M2+R1±kh*	*A1+M1+R2*	*A2+M2+R1*	*Min. Factor of Safety*
Global Stability	1.59	2.15	1.89	>1.00
Internal Stability-Lowest Level	1.23	1.54	1.35	>1.00
Internal Stability-Intermadiate Level	1.25	1.63	1.38	>1.00
Internal Stability-Upper Level	1.32	1.99	1.75	>1.00
Sliding	1.47	6.50	3.56	>1.00
Overturning	1.80	8.73	5.75	>1.00
Bearing Capacity	1.02	1.33	1.40	>1.00

2.2 *Construction details*

At the construction phase, firstly jet grout columns were made as foundation preparation. Then, concrete retaining wall at the lowest level was constructed. After leveling the ground, green terramesh retaining wall application began.

To prevent the earth pressure on concrete retaining wall as well as to improve the soil in terms of bearing capacity and to decrease the differential settlements, lapping wall was applied in the first 4 m height from the ground. First of all, Paragrid 200 was laid on the ground. Secondly, geogrid that would be lapped was attached at the behind face of the concrete retaining wall. Thirdly and as the final step of the repeating construction phase, fill in 1 m thickness was compacted at each 25 cm layer and the grid attached to the concrete retaining wall was wrapped up in a bungle in 1.5 m length. This procedure was repeated for 4 times. In 50 cm distance at the lapping face and behind the concrete retaining wall, crushed stone was placed for the precaution of drainage. Lapping wall construction phases can be observed from Figure 6 and 7.

Figure 6. Concrete retaining wall and lapping wall foundation preparation

Figure 7. Lapping wall construction behind the concrete retaining wall

After completion of the lapping wall construction, Paragrid was laid to the facing and green terramesh units were placed on this level. For the same level, green terramesh units were assembled by using steel rings with the help of pneumatic pistol. To turn green, vegetative soil is used in the front face in 20-30 cm width. Figure 8 shows some stage of green terramesh construction.

Figure 8. Some stage of green terramesh construction

When the wall construction was completed to 24.945 level, piles for viaduct approach column foundation were bored, which can be seen from Figure 9. Construction of foundation was proceeded with the formation of green terramesh retaining wall at the same time. Green terramesh units suppressed the view of viaduct column (Figure 9). Once the wall construction was finished, hydroseeding was applied to facing of the wall.

Figure 9. Bored piles and completed green terramesh retaining wall

3 RESULTS

a) Geosynthetics are frequently used in improvement of poor bearing capacity, slope and fill problems since 1960s
b) Green terramesh retaining wall with 70^0 facing angle provides saving in area and fill amount for high slope applications.
c) Green terramesh retaining wall is environmentally friendly modular system in case facing get green by hydroseeding.
d) Such a flexible, geosynthetics reinforced retaining wall application comes in fast, economic and safe solution.
e) During 5 months from the moment that the motorway was opened to operation, at every 1 month measurement was taken from the top level of the asphalt and the wall. Accordingly, total 5 mm vertical deflection is measured whereas there is no horizontal deflection. When the vertical deflection value is compared with 23 m fill height it can be thought that it is negligible.
f) This study shows that green terramesh retaining wall is suitable for both the construction and working principle of viaduct column piles.

REFERENCES

ASTM, Annual Books of ASTM Standards, American Society for Testing and Materials, West Conshohocken, Pennsylvania, Volume 4.09 (II), Soil and Rocks; Geosynthetics, 1997

Berg, R. R. (1993), "Guidelines for Design, Specification and Contracting of Geosynthetic Mechanically Stabilized Earth Slopes on Firm Foundations", Federal Highway Administration, Report No. FHWA-SA-93-025

Bowles J.E., (1988), "Foundation Analysis and Design", 4.baskı, McGraw Hill, pg. 530-540

BS8006, (1995). "Code of Practice for Strengthened/Reinforced Soils and Other Fills", British Standard

Christoper. B. R., Gill, s. A., Giroud, J. P., Juran, I., Mitchell, J. K., Schlosser, F., and Dunnicliff, J. (1990), "Reinforced Soil Structures, Vol. I : Design and Construction Guidelines", Federal Highway Administration, Report No. FHWA-RD-89-043.

FHWA HI-95-038, (1998), NHI Course No. 13213, "Geosynthetic Design and Construction Guidelines", Federal Highway Administration, National Highway Institute.

FHWA-SA-96-071, (1997). "Mechanically Stabilized Earth Walls and Reinforced Soil Slopes, Design and Construction Guidelines", Federal Highway Administration

Holtz, R. D., Kramer, S. L., Hsieh, C. W., Huang, A. B. and Lee, W. F. (2001), "Failure Analysis of an 80 m High Geogrid Reinforced Wall in Taiwan", Proceedings of the 15th International Conference on Soil Mechanics and Geotechnical Engineering, Istanbul, Turkey.

Holtz, R.D. (2001), "Geosynthetics for Soil Reinforcement", The Ninth Spencer J. Buchanan Lecture, 9 November 2001, College Station Hilton, 810 University Drive, College Station, TX77840

NF P 94-220-0, 1998. "Soil Reinforcement- Backfilled Structures Reinforced with Quasi-inextensible and Flexible Reinforcing Strips or Sheets-Part 0 : Design", Norme Française

Rankilor, P.R. (1981), Membranes in Ground Engineering, John Wiley & Sons, Inc., Chichester, England, pg 377

Özçelik, H., "Flexible and Rigid Facing Member Geosynthetic Reinforced Retaining Wall Application", Reunion of Prof. İsmet Ordemir and 7th METU Geotechnical Engineering Symposium, 22nd October 2013, METU, Ankara

Özçelik, H. "Polymer Strip Reinforced Earth Wall Application at Mine Breaker Wingwall", Soil Mechanics and Foundation Engineering 11th National Congress, 7-8th September 2006, Karadeniz Technical University, Trabzon

Özçelik H., 2005. "Reinforced Earth Wall Design and Application", Reunion of Prof. İsmet Ordemir and 3rd METU Geotechnical Engineering Symposium, pg 46-52

Özçelik H., 2009. "Polymer Strip Reinforced Earth Wall Application at Bridge Abutment", 3rd National Geotechnical Congress, 3-4th December 2009, Çukurova University, Adana