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A State-of-the-Art report on soil reinforcement in Turkey

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ABSTRACT: The use of reinforced soil retaining structures in Turkey is quite recent. The technology has been introduced to Turkey mainly during the boom of the motorway constructions, that started in the early 1980's. The first technique used in Turkey was the Web-Soil technology. Some years later, the Reinforced Earth Company established itself in Turkey and started using its own technology. Most walls were constructed mainly for the Highway Administration of Turkey. In the mean time, some geosynthetic-reinforced slopes have been used mostly in private projects. An experimental geotextile reinforced retaining wall was built in İstanbul during the winter of 1993 using a lime-stabilized backfill cohesive soil. In the year 1997 the first commercial geosynthetic reinforced Segmental Retaining Wall has been constructed. The second geosynthetic reinforced Segmental Retaining Wall is being constructed now also for the Highway Administration. In this paper, some of the research findings of reinforced soil and a brief summary of the applications of reinforced soil technology in Turkey are provided.

1 INTRODUCTION

The concept of reinforced soil has been fist applied in Turkey with the Web-Soil and Reinforced Earth technologies. These type of modern technologies were mainly introduced to Turkish engineers with the construction of motorways which started as early as 1970's, but got extensive during the 1980's. The technology approved by the Highway Administration and observed by other engineers as being successful and economical, found itself application opportunities on other construction sites. Geosynthetic reinforcements were introduced in the construction of reinforced slopes with the overwrap technique. Both geotextiles and geogrids were used as reinforcing elements for the reinforced slope projects. Most of these applications were used on projects where public visibility was not possible, however a few exceptions exist. The Kilyos Wall built in 1993, was the first experimental geosynthetic reinforced wall where the backfill consists of lime treated clay. The objective of this wall was to investigate the replacement of granular material with an improved cohesive backfill with emphasis on real measurements and observation of field behavior. The first geosynthetic reinforced Segmental Retaining Wall was constructed during the Summer of 1997. It was a project realized for the Highway Administration. It was used to elevate an existing road to pass over a tunnel portal. Generally, this wall was the stepping stone for further progress in Turkey with such technology. A second wall using the same geotextile reinforced Segmental Retaining wall technique is being currently constructed in Antalya as a support for an bridge approach embankment, A brief summary for every technique used and improvement made in the area is given below under proper headings.

2 WEB-SOIL TECHNOLOGY

This technology uses front panels that are similar to the front panels of Reinforced Earth technique. On the backside of the panels, there are special attachments, which allow the connection of band shaped reinforcement. This band shaped reinforcement is made of polymer and comes in rolls. So reinforcement is practically woven between the attachments behind the panels and a steel rod located at a certain distance behind the facing. The depth of the reinforced zone may change according to the design parameters. These types of walls have been extensively used during the construction of Kınalı-Sakarya Highway. The total surface area of the Web-Soil features constructed in this project was approximately 35,000 m^2. The walls were mainly used to support the side wings of approach embankments and as retaining structures. The maximum height to which the Web-Soil wall was constructed was 18 m. However the majority of the walls were much lower. 10% of the Web-Soil walls constructed within the projects had heights less than 5 m. 50% of the walls were between 5 to 10 m high, constituting the majority. The remaining 40% were higher than 10 m.

3 REINFORCED EARTH WALLS

The Reinforced Earth technology was used most extensively in Turkey in the late 1980' s. A list of the projects is summarized in Table 1. Most of the projects were retaining walls built for the Turkish Highway Administration. However, two municipalities started using this technology. The largest city in Turkey, İstanbul, and the second largest city and the capital of the country Ankara, have both ordered several Reinforced Earth walls. The majority of these wall are also between 5 to 10 m high. The maximum wall height constructed is 23 m and consists of levels with a small berm in-between. Again the majority of the walls are constructed as retaining structures or side wings of approach embankments. Where they are used to support side wings of embankments, usually the bridge itself sits on a reinforced concrete structure (Figure 1 and 2). However more recently for some of the cases the reinforced wall was also used as the bridge abutment. Figure 3 shows such an overpass bridge with two spans. As can be seen in Figures 4 and 5 the prefabricated reinforced concrete beams are directly supported by the Reinforced Earth bridge abutment.

4 WRAPPED FACED GEOSYNTHETIC REINFORCED FEATURES

Several features where the facing was established by over-wrapping the geotextile reinforcement were constructed. Many of these features have facing inclinations smaller than 70° and consequently are reinforced slopes. A great majority of them were constructed for private owners. The most widely used application for these geosynthetic-reinforced slopes is rehabilitation of landslides or provision of flat areas for structures constructed on potential landslide areas. The applications include mostly housing projects and creation of large storage areas.

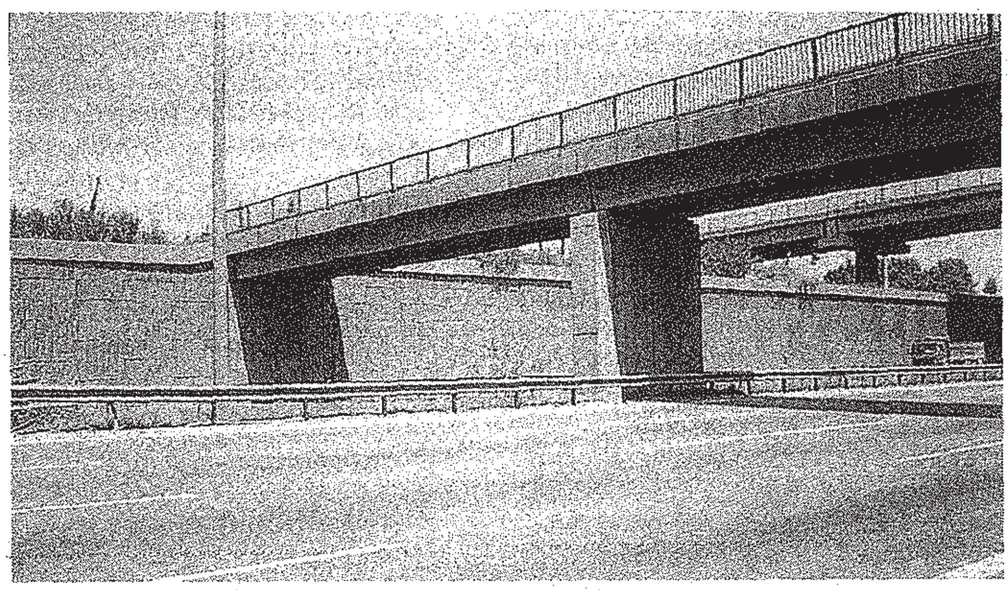

Figure 1. Side wing walls of bridge abutments

Table 1. A list of reinforced earth walls in Turkey

Project	Contractor	Construction Year	Surface Area (m^2)	Height (m)	Description of the Project
Havza Bridge	Bal İş	1990	3253	8	8 bridge side wings for highway and railroad passes
Gümüşova Highway	Bayındır/ Astaldi	1990	900	8	28 side wing walls
İzmir Çeşme Highway	Bayındır	1993	26000	23	10 retaining structures and 6 side wing walls
Tarsus Adana Gaziantep Highway	Tekfen	1996	43000	23	Retaining structures and side wing walls
Pozantı Tarsus Highway	Doğuş	1993	1680	9	Retaining walls
Ankara Söğütözü Asot Overpass	Metis	1993	3415	13	Retaining walls
Ankara Kazım Karabekir Overpass	Metis	1993	4140	8	Retaining structures and side wing walls
Mamak Çankaya Avenue	Ceylan	1995	43500	18	Many retaining walls
Bursa Karacabey Avenue	Treko	1995	900	9	Bridge abutments and side wing walls
İstanbul Okmeydanı Overpass	Polat	1996	2800	8	8 bridge abutments and retaining structures
İstanbul Kasımpaşa İplikçi Overpass	Kiska	1996	2500	7	Bridge abutment and retaining structure
İstanbul Sefaköy Bridge Overpass	Güngen	1996	1611	7	Bridge abutment and retaining structure
İstanbul Pendik Kurtköy Avenue	Yapısal	1996	2222	14	Retaining walls
İstanbul Çubuklu Overpass	Kurular	1996	1000	8	Retaining walls and bridge abutments
Toprakkale İskenderun Highway	Nurol	1997	40000	23	Retaining walls
		TOTAL:	180000		

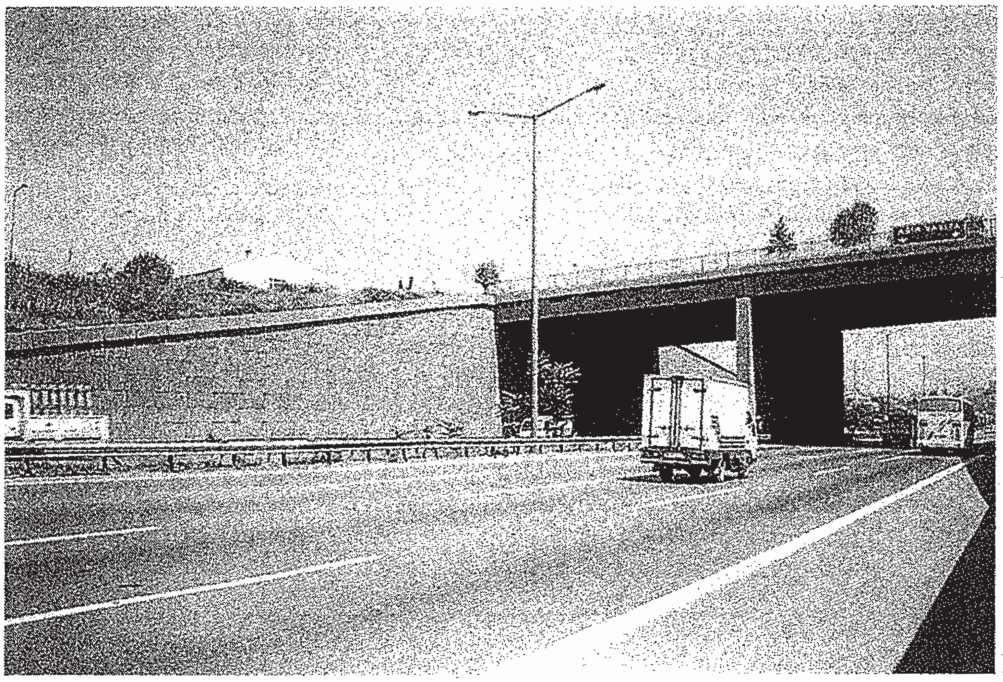

Figure 2. Side wing walls of bridge abutments

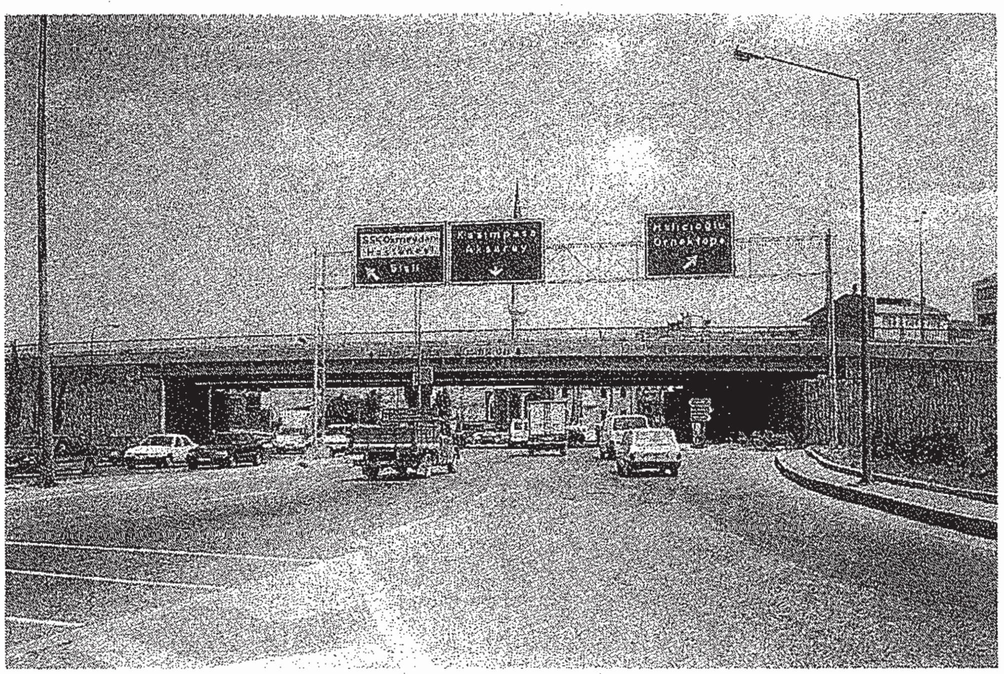

Figure 3. General view of over pass bridge

5 KİLYOS WALL

In 1992, a three-year research project was developed as to construct a full-scale geotextile reinforced retaining wall in İstanbul. The Kilyos Wall project funded by National Science Foundation of USA, the Scientific and Technical Research Council of Turkey, and Boğaziçi University Research Fund was unique in its focus in field measurements, and was the first known reinforced wall where the backfill consists of lime treated clay. The wall had a trapezoidal face section with upper and lower bases of 8.8 m and 18.2 m respectively. The wall consisted of 6 layer with a total height of 5.25 m. Natural clay available at the site was mixed with 4% lime. The selection of this percentage was based on laboratory tests, which indicated that 4% was the optimum mix percentage in terms of strength and permeability characteristics.

The geosynthetic used as reinforcement was a nonwoven needle punched geotextile with a strip tensile strength of 5.9 kN/m and an equivalent opening size of 0.13 mm. No safety factor was applied to this strength. The Federal Highway Administration method (Christopher et al. 1990) was followed for the design of the wall. The wall was designed to fail by rupture under its own weight with a safety factor of slightly less than one. Throughout the project life, six Glötzl pressure cells were used to measure the vertical pressure within the wall and five Glötzl pressure cells were used to measure the horizontal stresses. Deformations were measured with a new developed technique, utilizing electronic coils. Further details are reported by Ismeik (1996).

A maximum surcharge load of 41 kPa was exerted at the top surface of the wall, which did not bring the wall to failure. Based of the idea that saturation of clay could result in both a significant loss of strength and cause a reduction in cohesion, was the basis for another attempt at bringing the wall to failure. Two large holes were dug into the top surface of the wall and continuously filled with water. During the filling process the water leaked through the first layer of geotextile material and drained horizontally away from the wall. It was clear that the geosynthetic layer worked as a lateral drain, therefore no pore water pressure was developed and reduction in the shear strength was really not achieved since no saturation occurred at lower layers. Attempts at bringing the wall to failure ended at this point and the project was terminated.

The excellent performance of the wall, when overloaded showed that the use of lime treated clay in this case study allowed the efficient construction of the wall. This will substantially reduce the cost of similar projects due to the possibility of using available on site soils instead of having granular material transported to the site. Increased permeability and good structural perfomnace was also observed. Both the instrumentation data, obtained from all sensors, and observations of the actual wall performance indicated that the wall performed its intended function with negligible settlement. This case study proved to be cost effective and illustrated the importance of drainage (Güler and Ismeik 1997).

6 BLOCK FACED GEOSYNTHETIC REINFORCED WALL

The first Segmental Retaining Wall in Turkey where concrete blocks are used as the facing and the reinforcement is a geotextile, has been constructed during the Summer of 1997. This wall was constructed under the design and supervision of the author. Mr. Robert Barrett from USA was the consultant during design and construction. The project was constructed as part of the Altunizade-Ümraniye Highway construction. The highway had interrupted the Nurbaba Street and it had to be elevated to pass over the tunnel portal.

The facing elements were simple building blocks and as the backfill a greywacke has been used. The reinforcement was a woven geotextile with an ultimate tensile strength of 40 kN/m. Though it was the first wall of its kind in Turkey, it included tremendous amounts of complexities. These can be summarized as follows:

1. The existing road had a mixed cross-section and the retaining structures supporting the fill had deteriorated severely. So they had to be removed from the side. Due to this fact and that the original ground is sloped, the two sides of the road had to be formed on two different elevations can be seen in the cross section in Figure 6;

2. The foundation of the soil was a heavily weathered rock. Its consistency was similar to that of overconsolidated clay. The foundations of the two walls, each on one side of the road, had to be constructed on different elevations. This fact brought up the concern that there can be a stability problem on the slope that is created between the two foundation levels. Special concern and analysis was devoted to the foundation of the wall constructed on the crest of the slope created by excavation;

3. Provisions were needed for the utility lines. There were four utilities that had to pass from underneath the road, namely water, telephone, natural gas and high voltage electrical power. Since

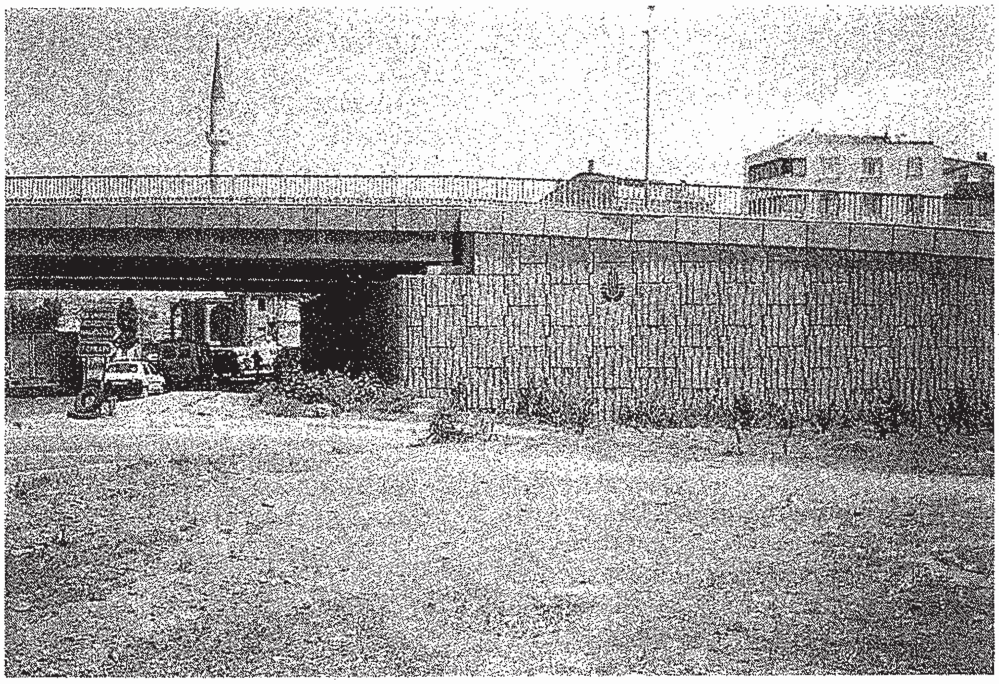

Figure 4. Close up of the bridge abutment

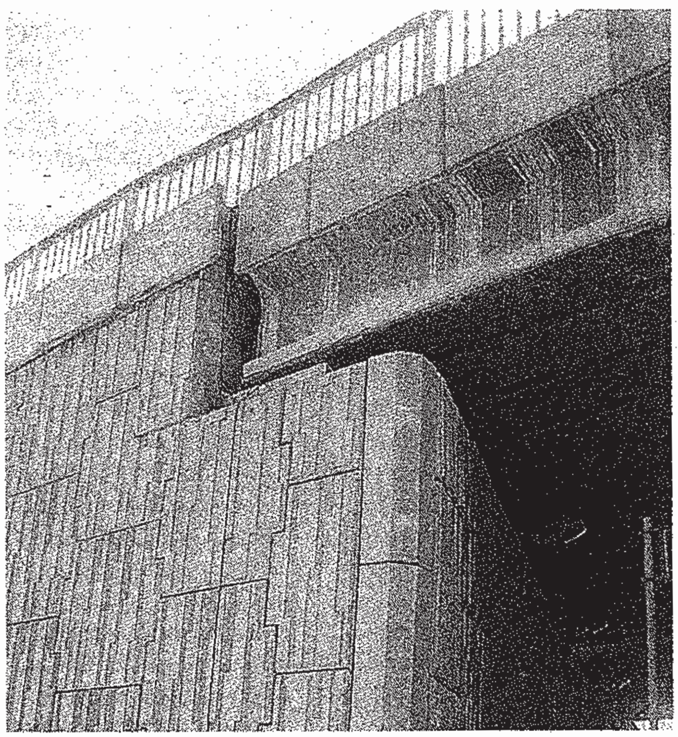

Figure 5. Detail of the bridge beams resting on the Reinforced Earth Wall

these lines could not be placed side by side, it was not possible to locate the utilities at the center of the road. When the utilities were distributed over the road surface, the reinforcement at the top layers had to be kept short. This problem was solved by considering the top portion as a separate short wall itself and its effect on the lower layers was considered as a surcharge load (Figure 7);

4. Ladders were needed to provide access to the houses and they were constructed as part of the reinforced soil wall as illustrated in Figure 8; and

5. At one point the road jumps up onto the tunnel portal. At this point the height of the wall suddenly reduces from 9 m to 1 m as shown in Figure 9 and the foundation becomes a rigid structure. To prevent future problems a joint was provided at this point.

The cost of the whole wall was $172,000 where the reinforced concrete alternative would have cost $263,000. So a saving of 35% was achieved. A second wall using the same technology is under construction right now and is expected to be completed at the end of August. This wall supports the approach embankment of the new Manavgat bridge. The bridge is on a motorway and has a midspan of 80 m with a clearance from the river of 8 m. A cross section of the wall is given in Figure 10. As can be seen from the cross section, the total height supported reaches 6 m. Of these the top one, meter is a slope and the rest consists of two walls with a one m wide berm in between. Since the area is very green, this berm has been specifically designed to allow some green vegetation at mid height of of the wall. (Figures 11 and 12). The design was conducted taking into consideration of the two stage wall. The wall takes the motorway from an elevation of 2 m and reaches a height of 5 m at a distance of approximately 250 m. The total wall facing constructed at this project will be approximately 5500 m^2. On one side of the bridge the motorway approaches the bridge with a curb.

The use of small blocks as the facing element and geotextile reinforcement allowed the wall to adopt itself easily to the curb.

On both sides of the river, steps were required to allow pedestrians to reach the bridge. The steps are constructed using the same technology on all four corners of the bridge as can be seen in Figure 13. The use of different coloured blocks allowed for various designs as well as writing some monograms (Figure 13) like TCK which are the initials for Turkish Highway Authority.

7 SUMMARY

In Turkey, enough confidence was gained with the concept of reinforced soil technology. Many walls have been successfully constructed without any reported failures. Savings in construction time and cost has been demonstrated when compared to reinforced concrete retaining walls. The recently constructed geosynthetic reinforced structure with modular block facing has gone even one step

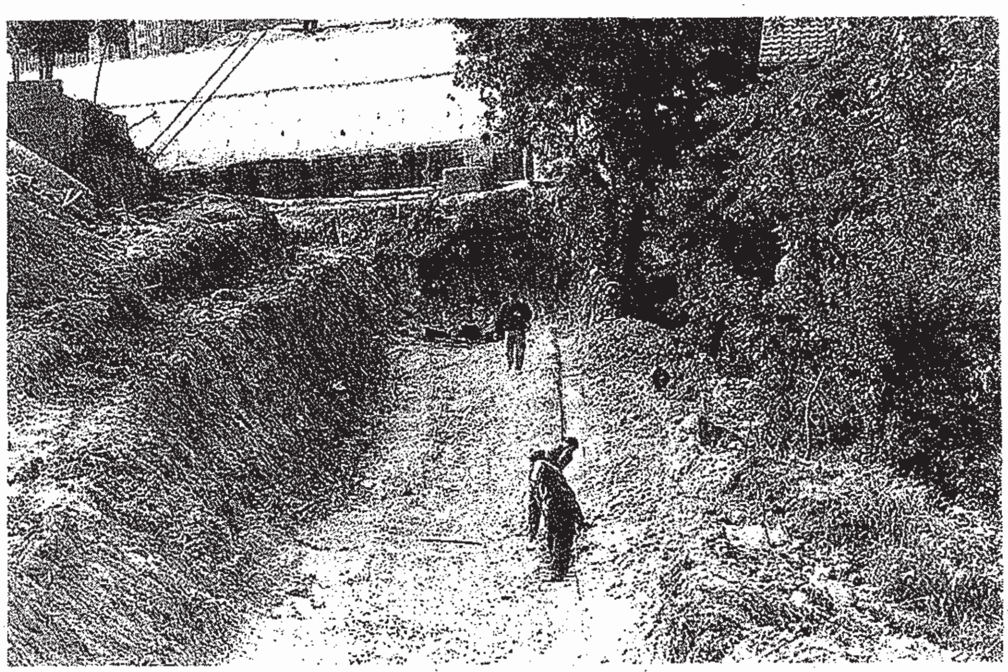

Figure 6. View of the foundation for the Nurbaba Geosynthetic Reinforced Segmental Retaining Structure

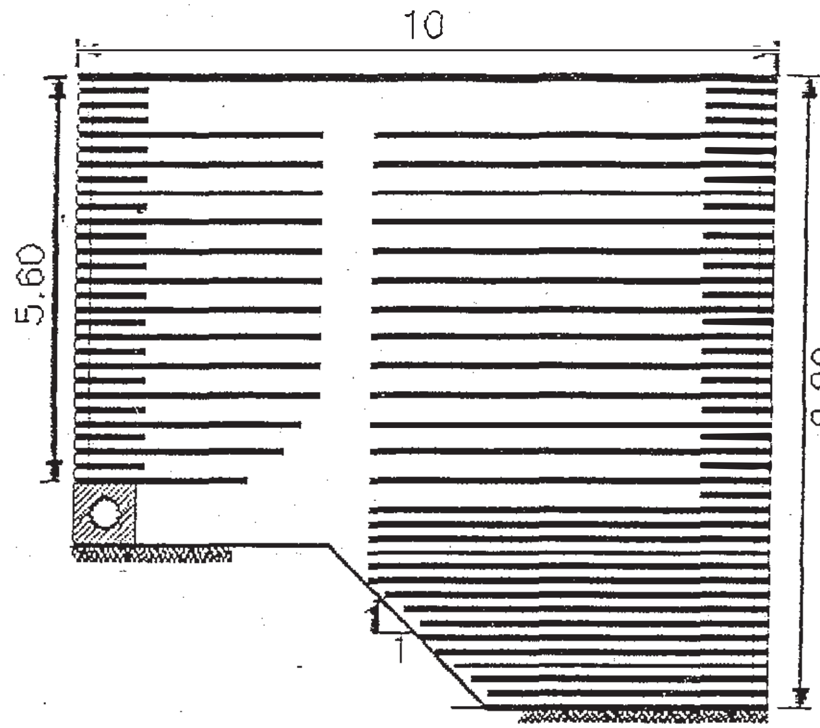

Figure 7. Cross section of the Nurbaba Geosynthetic Reinforced Segmental Retaining Structure

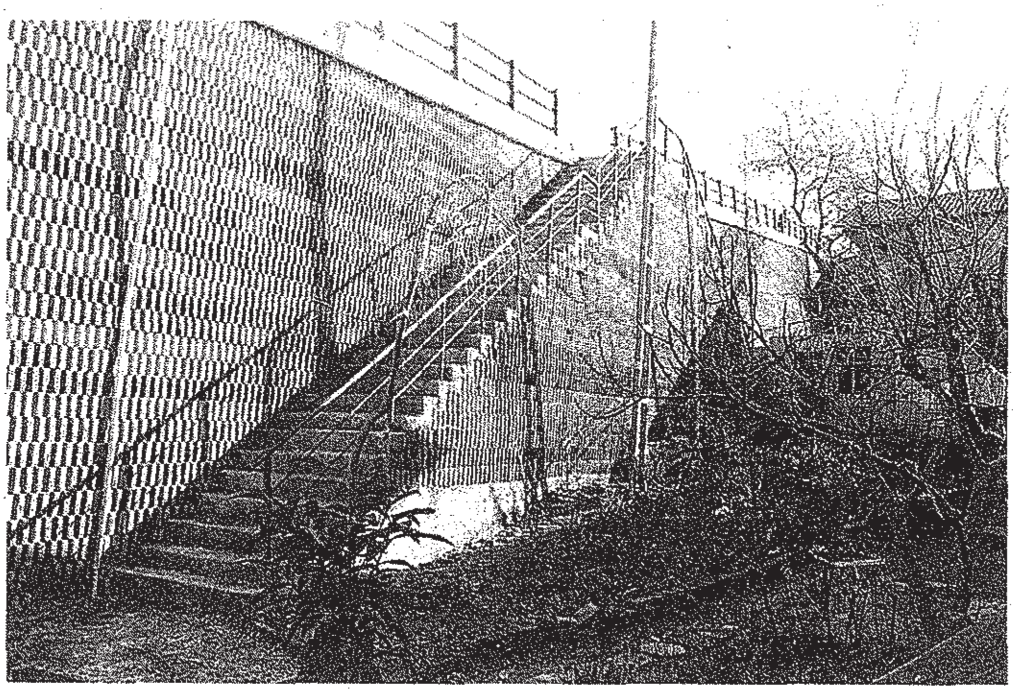

Figure 8. A detail of the ladder structure embedded into Geosynthetic Reinforced Segmental Retaining Structure

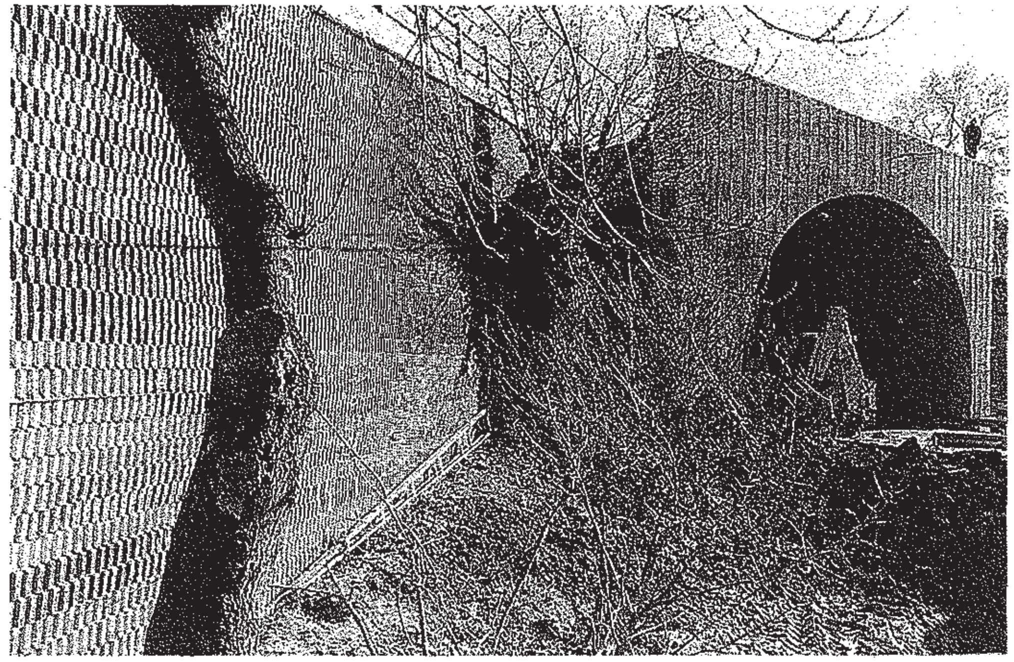

Figure 9. View of the wall passing onto the tunnel portal

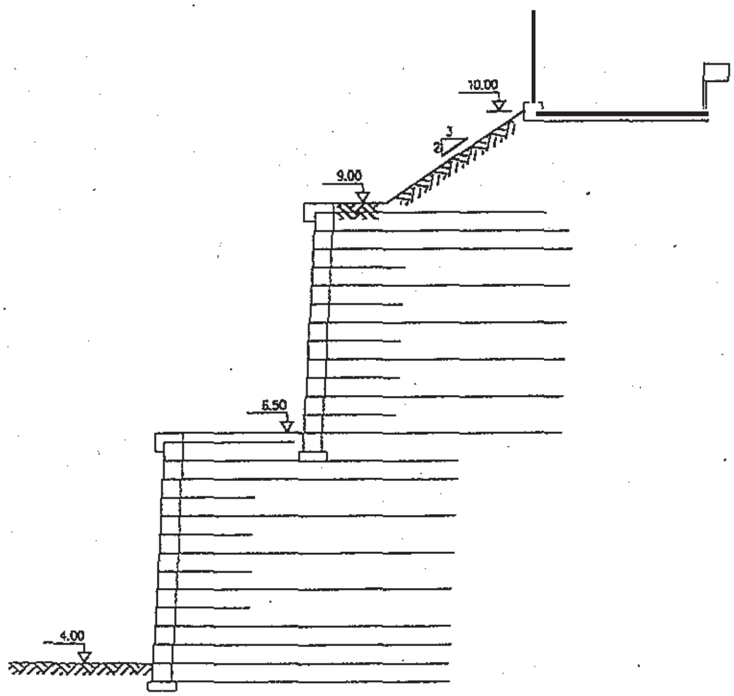

Figure 10. Cross-section of the Manavgat Geosynthetic Reinforced Segmental Retaining Structure

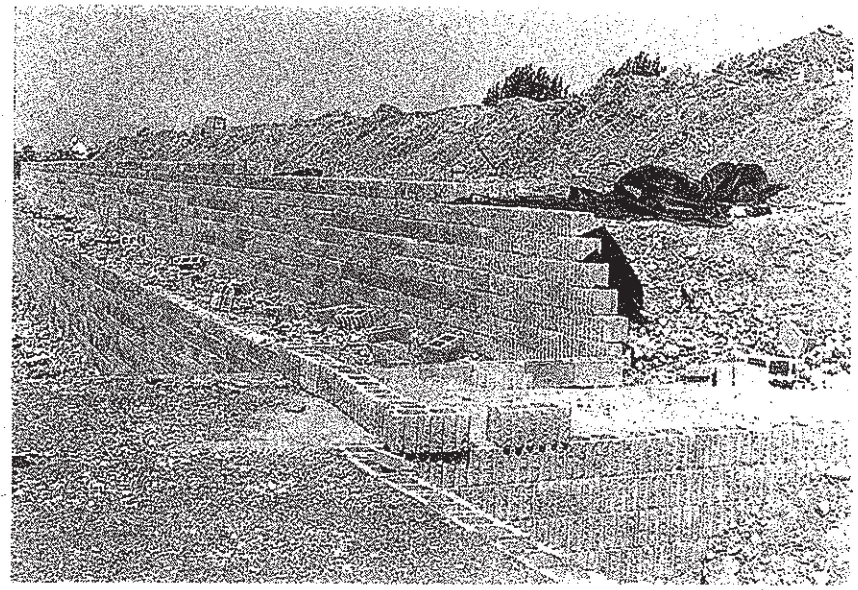

Figure 11. View of the Manavgat Geosynthetic Reinforced Segmental Retaining Structure

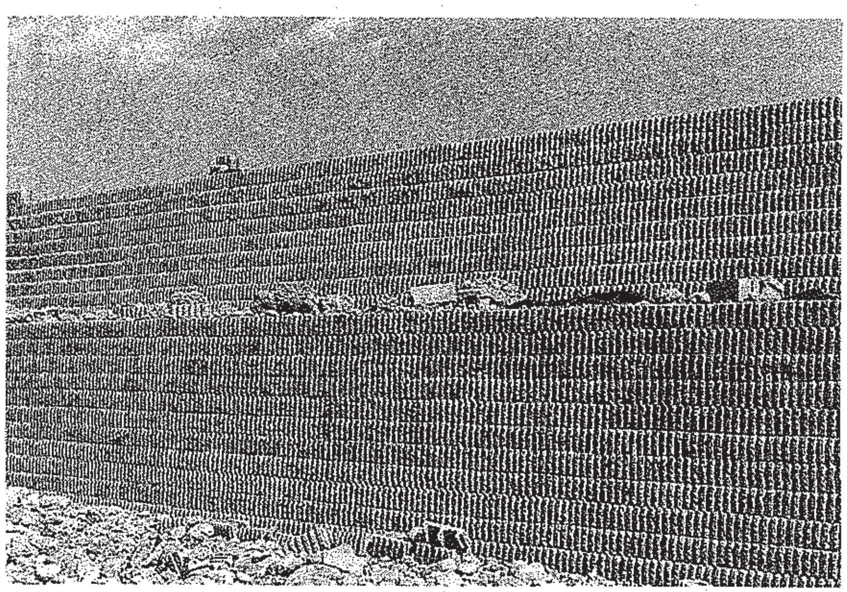

Figure 12. View of the Manavgat Geosynthetic Reinforced Segmental Retaining Structure

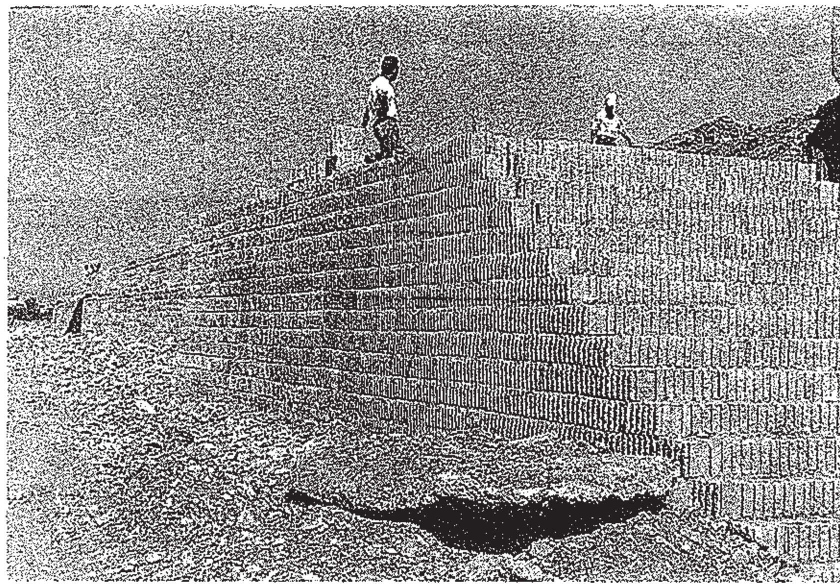

Figure 13. Steps of the Manavgat Geosynthetic Reinforced Segmental Retaining Structure

forward and became very popular. A second wall using the same technologyy is being constructed presently. The engineering community of Turkey has admired the easy construction technique, the tremendous cost saving and the aesthetic advantage of the geosynthetic reinforced modular block faced wall. It is anticipated that similar projects with wider scale will be constructed in the near future for commercial and governmental projects. As a summary it can be stated that the future of the reinforced soil retaining structures in Turkey seems to be promising great success.

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