Rehabilitation of an existing RC retaining wall using geogrid reinforced granular fill

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ABSTRACT: Geogrids are widely used as reinforcement in soils behind retaining structures. Beside construction of a new wall, existing conventional RC retaining wall systems can also be rehabilitated without the need of demolishing it. This is a time and cost saving method and can be applied easily in a short time. The system is combined with permeation grouting and used for the rehabilitation of an existing deformed RC wall in front of an oil filling platform in Kocaeli, Turkey with success. New tanks have been built on the platform and no further displacement has been reported since July, 2011.

Keywords: Geogrid, retaining wall, reinforcement, rehabilitation

1 INTRODUCTION

A major application area of geosynthetics is reinforcement of soil body behind retaining walls in order to reduce lateral forces acting on the wall. Among several types of geosynthetic materials geogrids are most widely used for this purpose. Beside constructing a new reinforced soil wall, existing conventional RC retaining walls may also be rehabilitated making use of this system. In this study the investigation, design and construction phases of the rehabilitation of an existing RC retaining wall, which had undergone some lateral displacement, using geogrid reinforced granular fill are explained. The area behind the retaining wall was used as a fuel oil filling platform and 6 new tanks should be built on the platform. The platform had to be put out of service during the rehabilitation process. Geogrid reinforced granular fill has been successfully applied in a very short time, without demolishing the existing RC wall, and so considerable amount of time and cost savings could be made.

2 PROJECT LOCATION

The project site is located in Dilovasi region of Kocaeli city in Turkey (Figure 1). The deformed retaining wall behind which the oil filling platform is placed is in the northern part of the plant, owned by an oil storage company. The total plan area of the plant is 46.033 m2. The sattelite view of the site is given in Figure 2 below.

Figure 1: Location of Kocaeli city (Source: www.turkiyeharitasi.com)

Figure 2: Satellite view of the project site (Source: www.google.com/maps)

3 SITUATION BEFORE THE REHABILITATION WORKS

The construction year of the existing conventional RC retaining wall is unknown, but from the photos taken 15 years before the date of the work it is obvious that it is at least older than 15 years. The wall has a “L” shape in plan. The length of the shorter and longer sides are 25m and 40m, respectively. Clean height of the wall changes from round 200cm up to 520cm. The section dimensions and reinforcement detail of the wall are given in Figure 3 below.

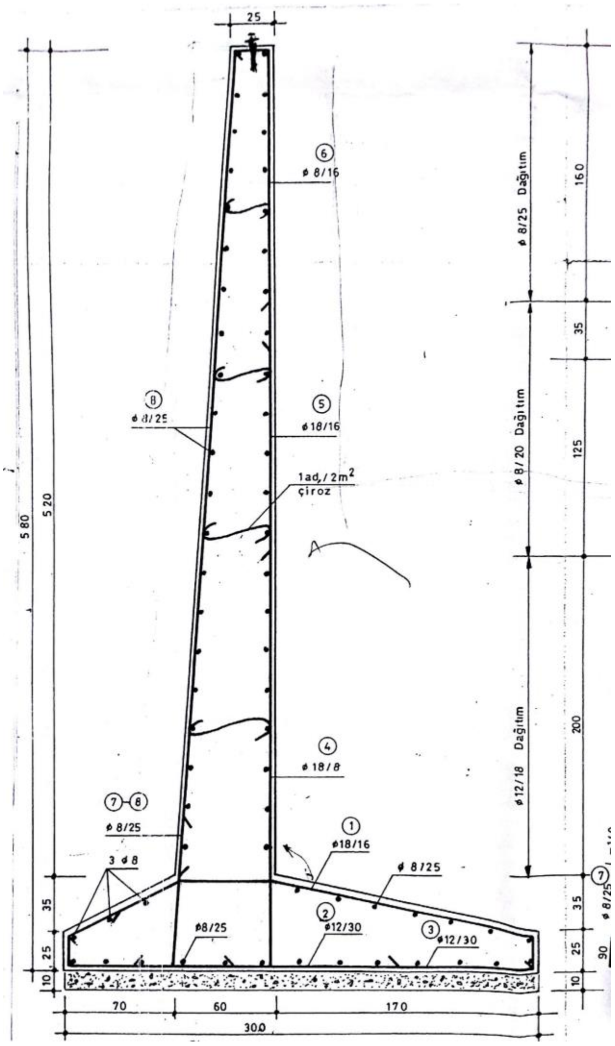

Figure 3: Typical cross-section and reinforcement detail of the existin RC wall.

The wall had undergone a maximum deformation of 60mm, at the top of the corner part. Although no measurement records were present, no sign of continuity could be found. Also optical measurements did not show any further displacement in a one month period. The oil storage company wanted to build 6 new tanks onto the filling platform, right behind the deformed retaining wall. The plan dimensions of the new tank area was given as 6,0m x 19,0m. The total maximum weight of the tanks was given as 350 tons. With the foundation itself the total load reaches about 470 tons. So the maximum vertical base pressure is expected to be around 4,1 tons/m2 behind the wall.

In order to evaluate the necessity of a rehabilitation of the retaining wall, a soil investigation has been conducted to determine the soil profile and characteristics of the soil layers.

4 SOIL PROFILE

In order to determine the soil profile at the project site 4 borings have been made, 3 of them located behind the wall and 1 borehole located in front of the wall. The depths of the borings are given below in Table-1.

Table 1. Borehole depths

Borehole Nr.	Depth
SK-1	10,00 m
SK-2	12,00 m
SK-3	14,00 m
SK-4	10,00 m
TOTAL	46,00 m

The layout of the boreholes and the soil profile are given in Figure 4 and Figure 5, respectively. A test pit has also been excavated in front of the wall, in order to determine the soil type right beneath the foundation of the wall.

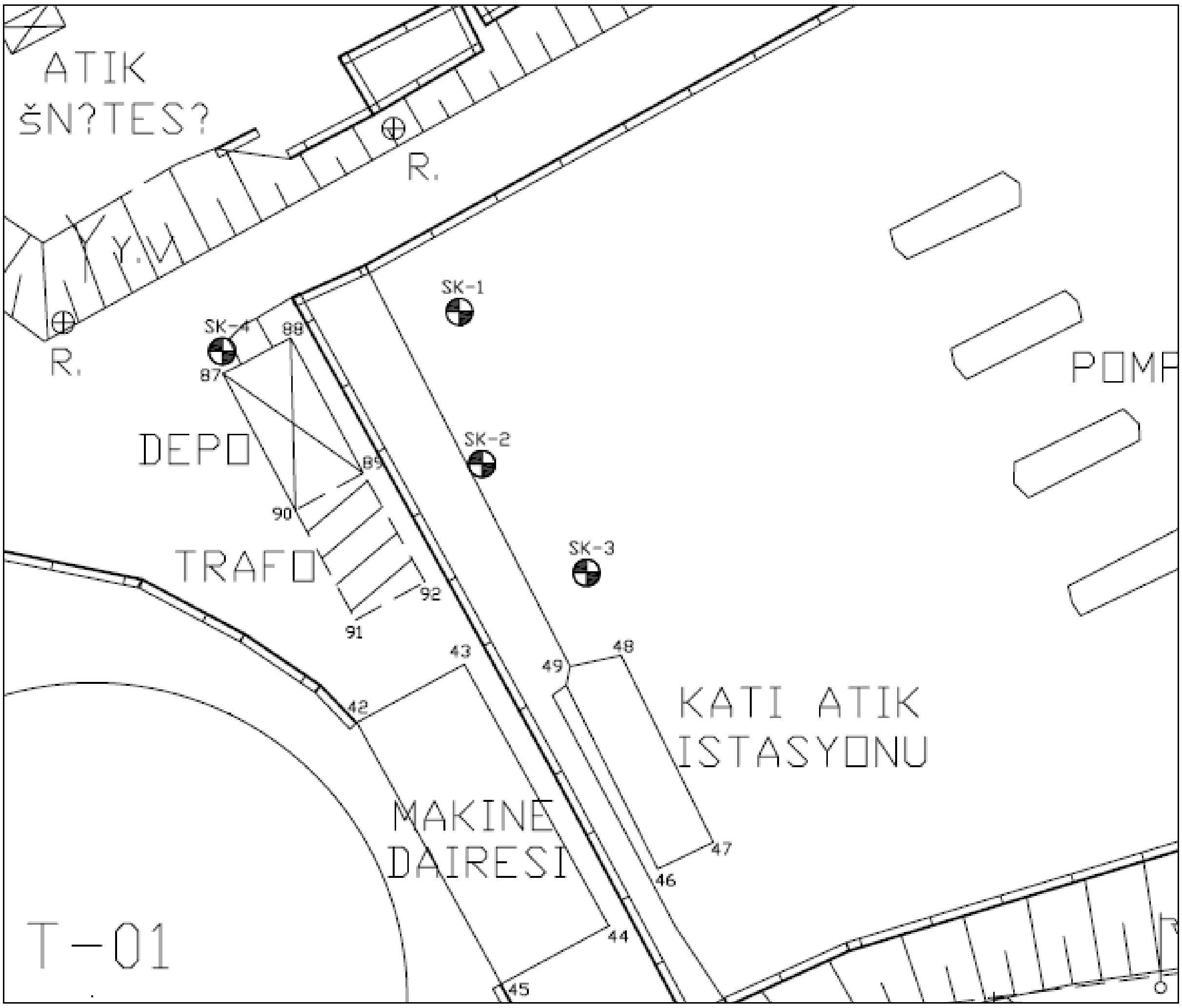

Figure 4: Layout of the soil investigation boreholes

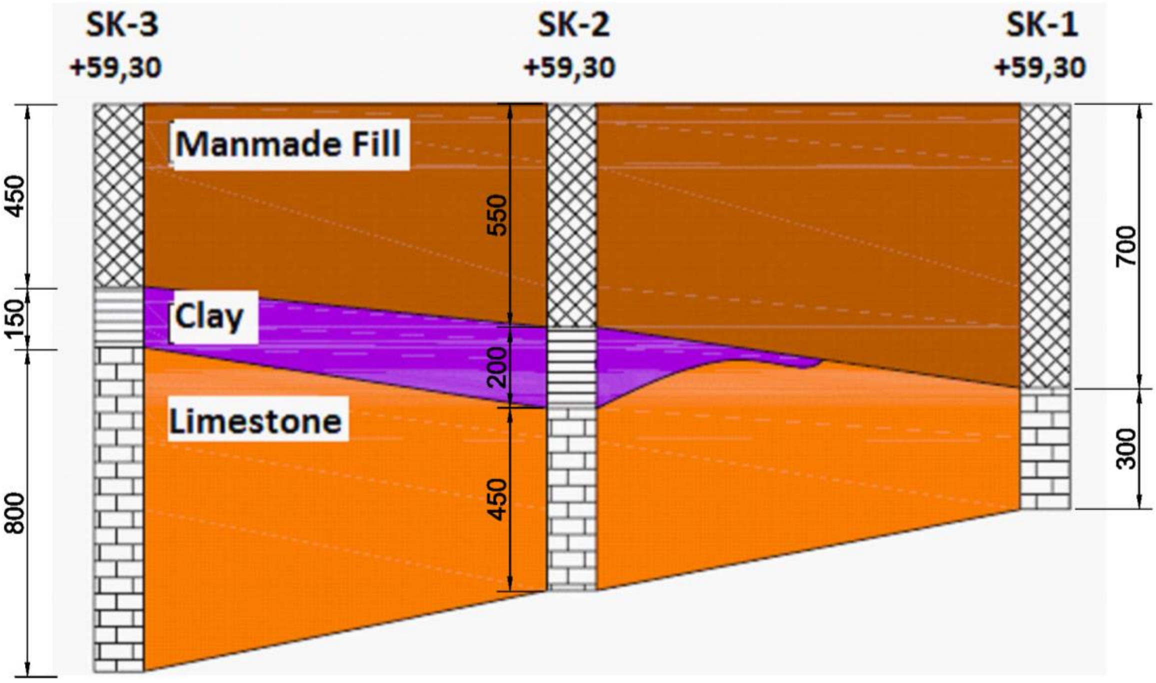

Figure 5: Soil profile at site behind the wall

The soil profile at the site consists of 3 main layers which are given below in Table 2:

Table 2. Soil layers

Layer Definition	Short Description	Thickness	Top Elevation
Uncontrolled Manmade Fill	Clayey soil containing concrete blocks and limestone gravels of loose – middle dense density	1,50 – 7,0 m	0,00 m
Very stiff Clay	Yellowish brown coloured, containing slightly fine gravelly	1,50 – 2,0 m	-1,50 ~ -7,00 m
Slightly weathered Limestone	Gray coloured, medium bedded	> 8,0 m	-1,50 ~ -7,50 m

5 DESIGN OF THE REHABILITATION SYSTEM

Before commencing with the design of the rehabilitation system the stability of the existing retaining wall is analysed. At the end of the analyses the stability safety factors of the wall against overturning, sliding and total collaps have been determined as insufficient, as given below in Table 3.

Table 3. Stability safety factors of the retaining wall

Type of check	Existing Case	New Case *)
Overturning	1,28	0,98
Sliding	0,86	0,7
Total collaps	1,28	1,19

**) New case defines the case when the new tanks are built and completely filled.*

Thus it was obvious, also from the displacement that was observed, that a rehabilitation of the wall was required in order to carry the new loads with an adequate safety factor.

The rehabilitation system, which will also function as a soil improvement for the new tank foundations, is a combination of two different methods:

- Permeation grouting at lower part of the manmade fill,
- Geogrid reinforced granular fill beneath the foundation (upper part of the manmade fill is excavated).

The section drawing of the rehabilitation system is given below in Figure 6.

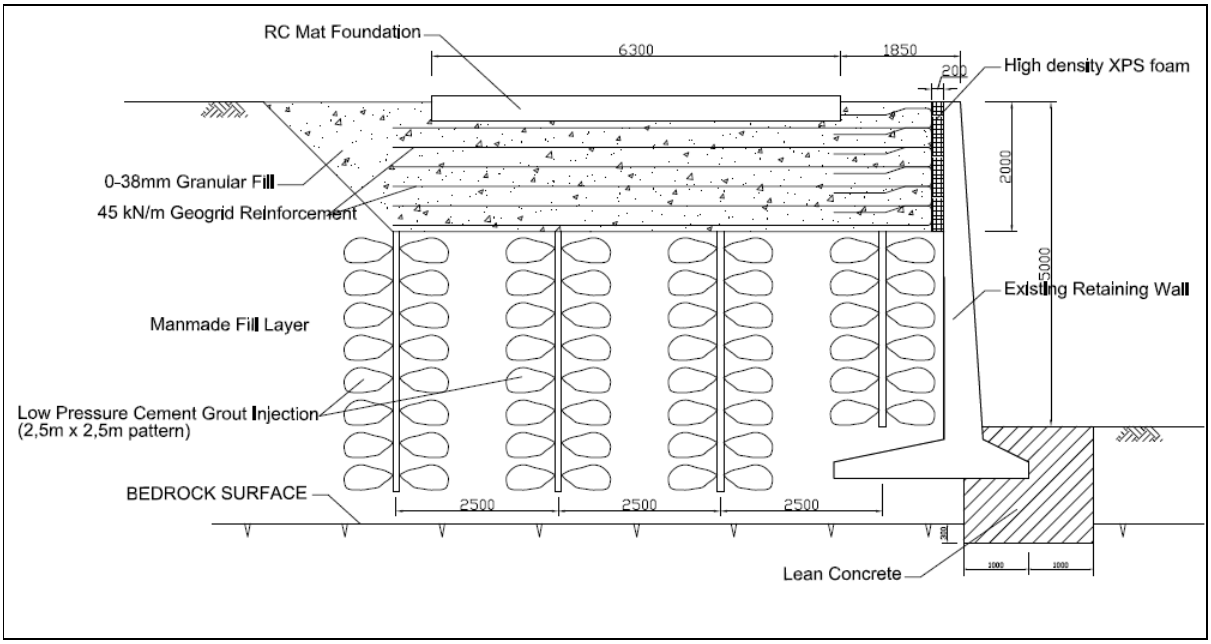

Figure 6: Typical crosssection of the rehabilitation system

As the problematic soil is regarded as the uncontrolled manmade fill layer only, the rehabilitation system design covered only the fill layer. The lower part of the of the fill layer is improved by applying a systematic permeation grouting, in a 2,50 x 2,50m pattern in plan. The vertical spacing between the outflow points on the grouting pipes was 50cm.

The upper 220cm thick layer of manmade fill is excavated and transported outside the plant, as it was not suitable material for the engineering fill. A geogrid reinforced granular fill is placed instead. The granular fill material has been placed as 30cm thick horizontal layers and compacted as to reach minimum and average Proctor Density values of 95% and 98 percent, respectively. 6 layers of uniaxial geogrid reinforcement having an ultimate tensile strength of 45 kN/m have been used. The vertical spacing of the geogrid layers was equal to fill layer thickness which is 30cm.

As an extra measure, underpinning of the retaining wall foundation is made in order to increase the above mentioned stability safety factors.

6 CONSTRUCTION PHASE

The construction phase consists of following steps:

a. Excavation behind the retaining wall until 220 cm depth,
b. Underpinning of the retaining wall foundation,
c. Drilling of boreholes for grouting,
d. First stage of permeation grouting,
e. Second stage of permeation grouting,
f. Placement of lowest layer of granular fill and compaction,
g. Placement of lowest layer of geogrid reinforcement,
h. Repeating of steps f and g for the next 5 layers of granular fill and geogrid reinforcement.
i. Construction of the mat foundation.

Compaction has been made by using light electrical table compactors in order not to cause any further deformation in the wall. Sand cone and Proctor tests of adequate amount have been performed at each layer of granular fill after compaction and the above mentioned criteria is fulfilled. Figures 7 to 10 show the different phases of the construction.

Figure 7: Excavation behind the wall

Figure 8: Drilling of boreholes for grouting

Figure 9: Grout injection

Figure 10: Placement of XPS foam boards after cleaning the site from grout

Figure 11: Placement of lowest geogrid layer (and also 1 layer of geotextile)

Figure 12: Placement of granular fill over the geogrid

Figure 13: Placement of top layer of granular fill

Figure 14: Sand cone test

7 CONCLUSION

An existing conventional RC retaining wall was deformed throughout the years and new fuel oil tanks should be built on the platform right behind the wall. In order to evaluate the stability safety of the wall soil investigations have been made by drilling of 4 boreholes. Analysis both for the existing and for the new case have shown that the stability safety factors are below the required values and the wall should be rehabilitated to gain the necessary safety.

The designed rehabilitation system should have two functions: decreasing the lateral earth pressure acting on the wall and constituting a firm foundation soil for the new tanks to be built. Following methods have been combined for the best result:

- Permeation grouting at lower part of the manmade fill,
- Geogrid reinforced granular fill beneath the foundation (upper part of the manmade fill is excavated).

Both methods have been applied as to satisfy the necessary acceptance criteria. Also the foundation of the retaining wall has been underpinned to transfer the loads directly to the slightly weathered lime stone.

As the existing retining wall has been kept and not demolished, the oil filling platform and the 6 new tanks could be taken into service in a very short time. Also a cost saving of about rough 50% has been made.

The construction works have been finished in July 2011. Since then the terminal and the new tanks have been used without any furhter deformation in the wall.

8 REFERENCES

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