©2016 Published in 4th International Symposium on Innovative Technologies in Engineering and Science 3-5 November 2016 (ISITES2016 Alanya/Antalya - Turkey)

Differential Settlement Problem of Buildings on the Rock and Filling

*[1]Sedat Sert, [1]Ertan Bol and [1]Aşkın Özocak
*[1]Faculty of Engineering, Department of Civil Engineering, Sakarya University, Turkey

Abstract:

Adapazarı region, in Turkey, is hit by moderate magnitude earthquakes of 6.5 - 7.5 every 10 - 30 years. The great loss of life and damage resulted by the massive earthquake that occurred in the region in 1999 was the biggest reason of creating new residents at the north of the city where the bedrock are encountered in shallow depths as in Camili, Karaman and Korucuk. Construction of new buildings in these areas continues rapidly in the current status. These regions seem to have the advantage of having no problem related to soil bearing capacity failure and liquefaction during the earthquakes. However, observations of diagonal cracks at a large number of buildings a few months/years after their construction in these areas have revealed the fact that there are some other problems. Due to the sloping topography in these regions, some portion of the foundations of some buildings was seated over a filling instead of excavating the whole soil under the building and seating the foundation completely on the bedrock. In these cases, the reason of the damage of the buildings is clear to be differential settlement of the building. In this study, the soil properties and the reasons of the damages that happen to a building, which was built by following this method, are examined.

Key words: Shallow Foundation, Excavation, Filling, Differential Settlement

1. Introduction

Civil engineering structures are often constructed on or adjacent to slopes or near the supposed excavation. This may be due to land limitation or for architectural purposes. The investigation of bearing capacity of loaded slopes is very important in this case because they are more susceptible to fail than other type of earth structures. The bearing capacity of the foundations on the slope can be calculated by the methods of Brinch-Hansen (1961) and Vesic (1975) [1,2]. Coduto (2001), revealed the following concerns for the foundation which is built on the slope [3]:

* Because of lateral support reduction, the possibility of exceeding bearing capacity,
* Destruction of the foundations at the event of a landslide,
* The slow downward flow of soil over the bedrock and its forcing the foundation to move down the slope.

The foundations, which were seated partially on filling in sloping ground, get more complex. High cost of constructing foundations on fully excavated rocky media and the lack of need to basement result to excavate soil to a relatively small amount of depth and fill the excavated material from one side to the other side in the foundation area and placing the foundation over it.

*Corresponding author:

Address: Faculty of Engineering, Department of Civil Engineering Sakarya University, 54187, Sakarya TURKEY. E-mail address: sert@sakarya.edu.tr, Phone: +902642955738

If the filling isn`t compacted properly, the foundation probably seats on different soils which have different compressibility and this causes differential settlements. In such a case, even if the structure does not collapse, it can`t satisfy serviceability limits and a large economic loss is also needed for repairment. Types of building damages related to differential settlements can be seen in Figure 1 [3]. Convex type of differential settlements and the direction of the cracks clearly point out the buildings which partially built on the filling. According to Poulos et al. (2001), cracks and building damage may be occurred in framed and shear wall buildings if the value of angular distortion is bigger than 1/500 and 1/150 respectively [4].

Figure 1. Settlement damages on buildings [3]

2. Materials and Method

Adapazarı soils have been blamed for the destruction that appeared after the 1999 earthquakes and new residences have been encouraged to be built at the north of the city which has better soil conditions. A large number of constructions have been built in Camili, Karaman and Korucuk by both the government and private housing sector. After the earthquake, some settlement problems have been appeared although the buildings have been constructed where soil conditions are good. Due to the topographical features of these regions, foundations of some of the houses must be excavated in order to place on a flat surface. In some cases, in order to reduce the amount of excavation on hard soil/soft rock, foundations were observed to have been built by filling the excavated material instead of a whole excavation. This paper presents a case study regarding the damage to the building partially built on filling at slope in Camili region.

A 3-storey building in Camili region was examined in this study. Firstly, existing soil investigation report, architectural and structural design projects were investigated. Next, the cracks and damages on the building were observed by visiting the site. In Figure 2, the crack on the entrance of the building and the filling can be seen.

In the existing soil investigation report, it is indicated that clay stone as bedrock is encountered 1.5 m below the surface and depth of foundation is recommended as 1.5 m. The continuous foundations of the building were designed to have a width of 140 cm. To determine the soil

profile under the building, 4 borings were performed and some disturbed samples were taken. The locations of borings can be seen in Figure 3.

Figure 2. Settlement crack and filling on the slope

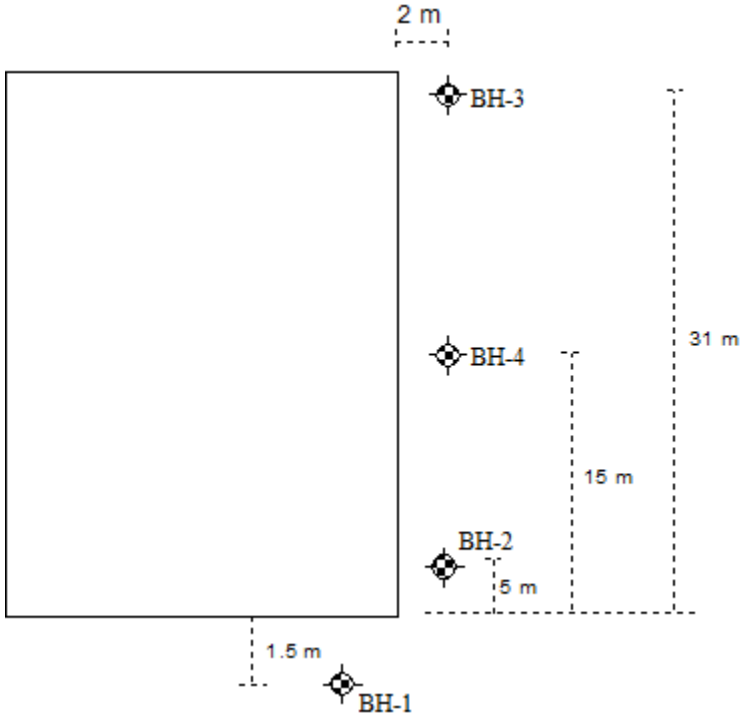

Figure 3. The locations of the borings

According to the borings, It has been understood that some parts of the buildings were directly seated on the bedrock while the other parts on the filling. Starting from the existing ground level, the depth of the filling has been determined to be between 3.50 m – 2.20 m at the front side of the building and around 2 m at the center of the building. It has also been determined that there is no filling at the backside of the building and foundation was directly seated on the bedrock (Figure 4).

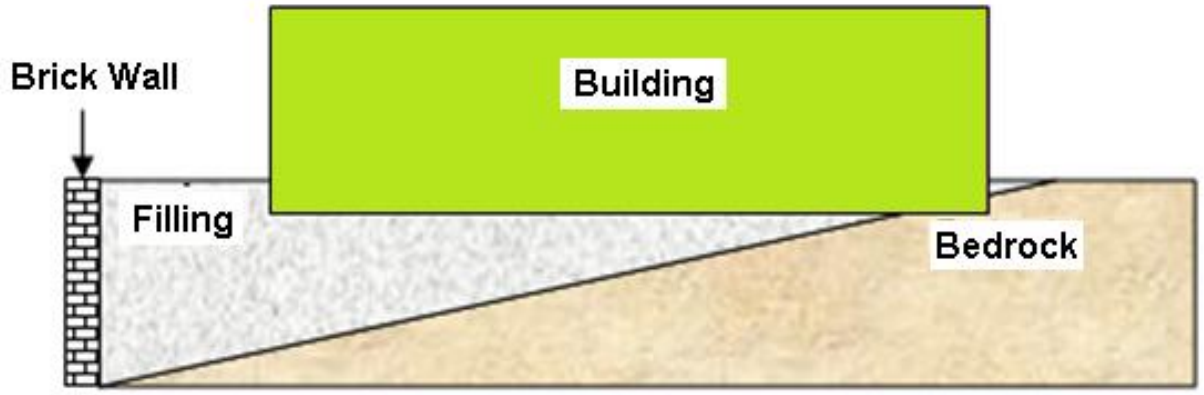

Figure 4. A-A section for the building

The samples were tested according to TS1900-1/2006 at Sakarya University Geotechnical Laboratory and classified with TS1500/2000 and ASTM D2487 [5-7]. Table 1 shows the properties of the samples.

Table 1. Soil Properties in Study Area

Borehole Number	Depth (m)	SPTN	w_n	w_L	w_p	% FC	Class (TS)	Class (ASTM)
BH-1	3.50	R	18	42	19	88	CI	CL
BH-2	2.20	R	19	45	18	91	CI	CL
BH-3	1.00	--	12	43	19	84	CI	CL
BH-4	1.50	14	19	42	17	76	CI	CL

After investigating the samples, it was concluded that the soil was used as backfill material because all of the samples have a CI - intermediate plasticity clay symbol according to TS1500/2000 (CL - according to ASTM). While the samples had contained fractured rock at the beginning, it was observed that they had a tendency to break when they were soaked in water. The results of wet sieving tests confirmed this information (Figure 5). It can be interpreted that the clayey fill material had a tendency to have a differential settlement after becoming saturated with heavy rains. The residents of the building confirmed that the cracks became more visible just after the heavy rain in fall months of 2010.

Figure 5. Breakdown of weathered rock with soaking and remaining part after washing

3. Discussion and Conclusion

Adapazarı is notorious for its inferior top soils. Many people have blamed soil conditions for the destruction that appeared after the August 1999 earthquake and new residences have been encouraged to be built at the north of the city which has better soil conditions. However, after the earthquake, some settlement problems have been appeared in even static conditions although the buildings have been constructed where soil conditions are good. Survey of damage has shown that damage arising from foundation soils is not significant when compared with destruction due to inadequate structural design and building techniques. It is clear that reasonably high structures can be built in soft soils of Adapazarı with proper foundations and design. It is also concluded from this study that it is necessary to have a homogenous soil conditions under foundations on filling to prevent differential settlements.

References

[1] Brinch-Hansen, J. A general formula for bearing capacity Bulletin Danish Geotechnical Institute :11: Kjøbenhavn, 1961.
[2] Vesic, AS. Bearing capacity of shallow foundations, Winterkorn-Fang: Foundation Engineering Handbook (1st ed) Van Nostrand-Reinhold, NewYork, 1975.
[3] Coduto, DP. Foundation Design: Principles and Practices, 2nd ed., Prentice Hall, NJ, 2001.
[4] Poulos, HG, Carter, JP, Small, JC. Foundations and retaining structures – Research and practice, Proc. XV Int. Conf. Soil Mechanics and Foundation Engineering, Istanbul, 4, pp. 2527-2606, 2001.
[5] Turkish Institute of Standardization, TS1900-I, Methods of testing soils for civil engineering purposes in the laboratory – Part 1: Determination of physical properties (in Turkish), TSE, Ankara, Turkey, 2006.
[6] Turkish Institute of Standardization, TS1500, Classification of soils for civil engineering purposes (in Turkish), TSE, Ankara, Turkey, 2000.
[7] ASTM, Standart Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System) (ASTM D2487), 2011.