Sealing foundations of existing buildings by grouting: A case study from Turkey

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***Abstract*— Groundwater can cause destructive effects both on concrete and reinforcement material. A reinforced concrete building Foundation of examined building located in southwest of Turkey. Foundation was below the groundwater level and there was massive water seepage into basement storey during winter seasons. Four water pumps were not enough to drain the seepage water and building was prepared to sacrifice.**

Quaternary aged soil which consists of 66% gravel and 34% sand was very permeable. Compaction grouting was employed to minimise soil permeability. 1:3 ratio cement-water mixture was injected into soil. The grouting was enforced from bottom to up and 25 kPa pressures were applied. Evenly distributed twenty grouting holes were drilled 6 meters in depth. It was sealed successfully and there was no seepage during last three winter seasons. The method can be employable to all existing buildings with groundwater isolation problems.

***Index Terms*—foundation, groundwater, waterproofing, grouting**

I. Introduction

Weakness of buildings might be originated from structural deficiencies and/or soil conditions. Uncontrolled urban growth has increased to meet challenging ground conditions in many countries. These phenomena have promoted growth of problematic buildings in Turkey. An extensive literature is available to improve conditions of existing buildings [1, 2, 3, 4].

Foundation sealing was getting popular after enforcement of new building codes in 1998. Groundwater affects not only physic-mechanical properties of soils but also foundations. Corrosion can cause destructive effects on concrete and reinforcement. The examined foundation of a reinforced concrete building was below the groundwater level and there was an enormous water seepage into basement storey during winter seasons. Four water pumps were not enough to drain the seepage water.

In order to provide an impermeable curtain surface grouting was frequently employed especially in dam constructions. In this study however mass grouting was employed to minimise soil permeability. Foundation was sealed successfully and there was no seepage during last three winter seasons. The process caused heaving up to ten centimetres on floor of basement storey. Additionally sewage system of the building and a shallow water pumping hole close to building was congested.

II. Location Attributes

The study has been carried out in Ortaca town of Turkey as shown in Figure 1. Figure 2 illustrates a simplified geological map of Ortaca and its surrounding area. Quaternary aged sediments cover a large area and overly rock units. These sediments are related to watercourses and in gravel size.

Figure 3 illustrates a borehole 10 m in length. Soil profile consists of gravel and includes some sand bands at several depths. Sieve analysis of a sample, taken just beneath the foundation level, is given in Figure 4 and it contains 66% gravel and 34% sand. Groundwater level was variable between 4.5 and 1.3 meters in summer and winter seasons respectively. Chemical contents of groundwater were another issue because it would speed up corrosion and they are listed in Table 1 [5]. These values were not high enough to accelerate spoil of concrete. However, water fluctuation was more harmful because of oxidation of steel.

TABLE I
CHEMICAL CONTENTS OF GROUNDATER

Parameters	AverageValue
$ECx10^6$ (nmhos/cm)	759.9
pH	7.75
calcium (me/l)	2.38
magnesium (me/l)	6.77
sodium (me/l)	1.67
potassium (me/l)	0.14
carbonate (me/l)	1.34
bicarbonate (me/l)	4.35
chloride (me/l)	34.08
%Na	5.24
SAR (%)	0.22
RSC	-2.99
total salt (ppm)	483.5
sulphate (mg/l)	76

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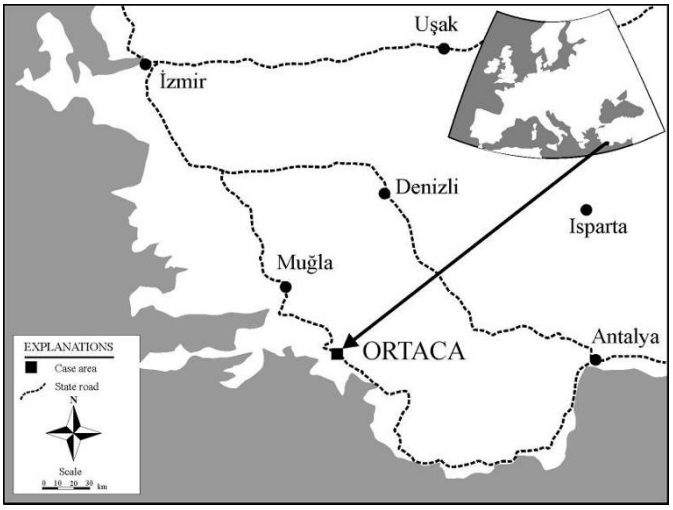

Fig. 1. Location map of the study area

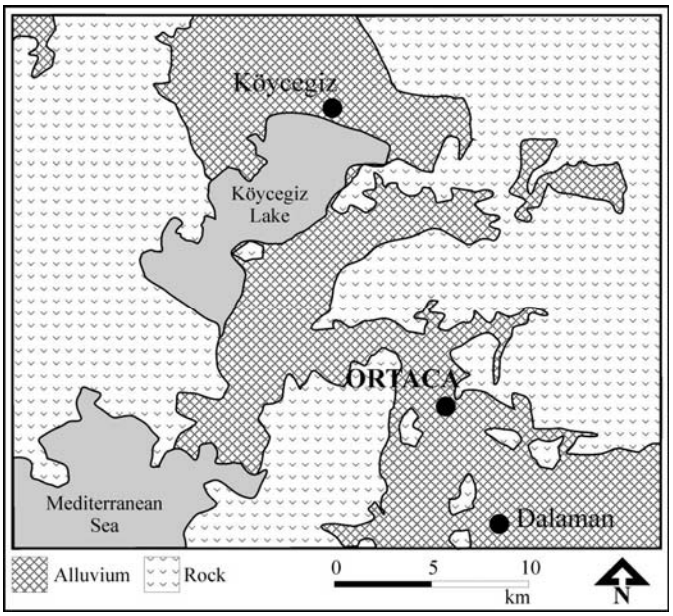

Fig. 2. Geological map of the study area (from MTA 2010)

III. Material and method

Grouting is used to express injection of liquid material(s) into a geological formation [6]. In practice, proper grout material is injected into loose soils [7, 8] to improve geotechnical properties of problematic soils. It is a cost competitive method [9] and easy to apply [10].

In this study, 1/3 cement-water mixture is injected into soils. The grouting was enforced from bottom to up and 25 kPa pressures were applied for every meter (Table 2). Evenly distributed borehole pattern was employed as illustrated in Figure 5. Twenty grouting holes were drilled 6 meters in depth. Schematic view of the building before and after injection is illustrated in Figure 6.

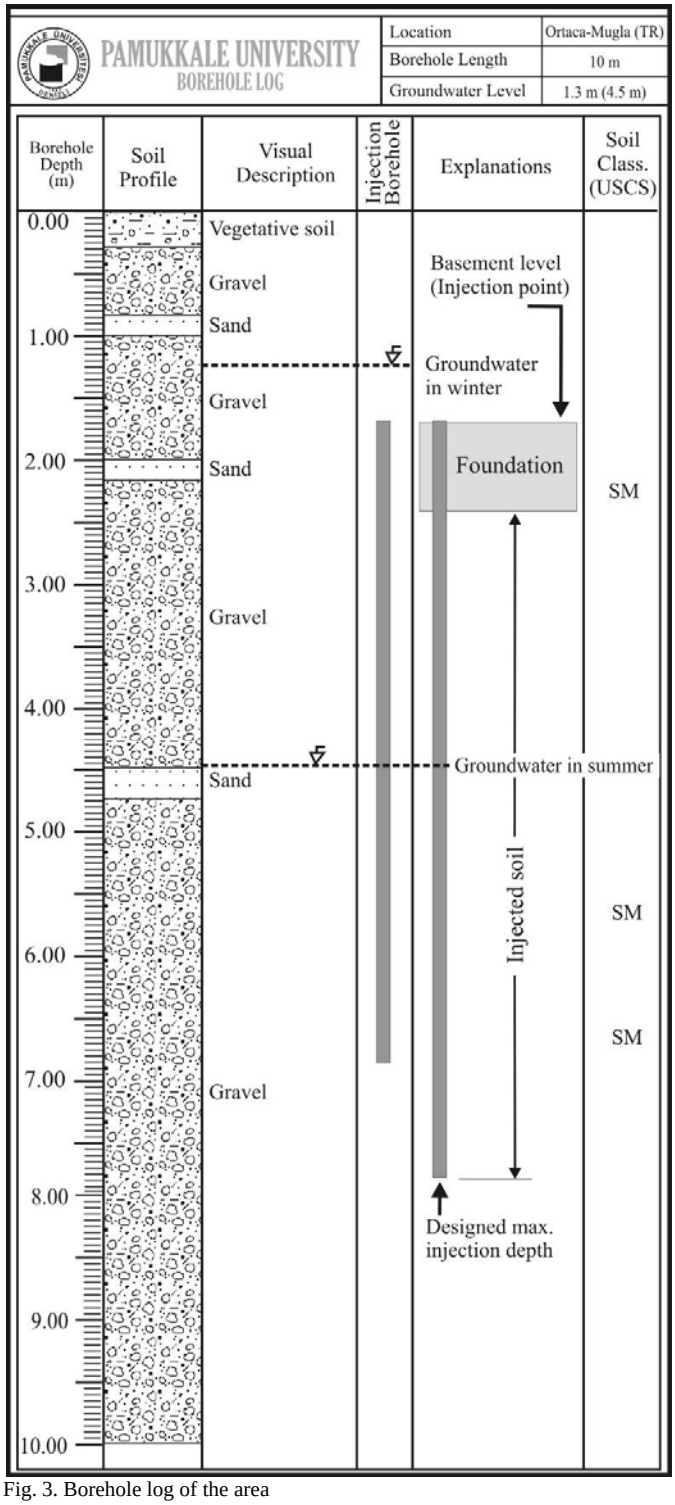

Fig. 3. Borehole log of the area

TABLE II
INJECTION PRESSURES IN BOREHOLES

Injection Level (m)	Grouting Pressure (kPa)
0.00 – 1.00	25
1.00 – 2.00	50
2.00 – 3.00	75
3.00 – 4.00	100
4.00 – 5.00	125
5.00 – 6.00	150

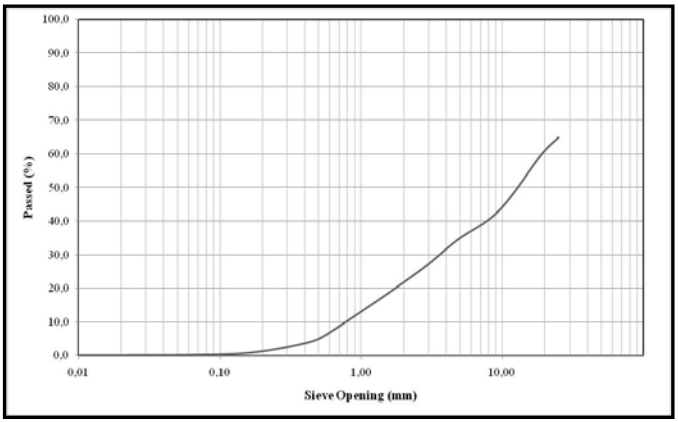

Fig. 4. Sieve analysis of soil (depth 3.0 meter)

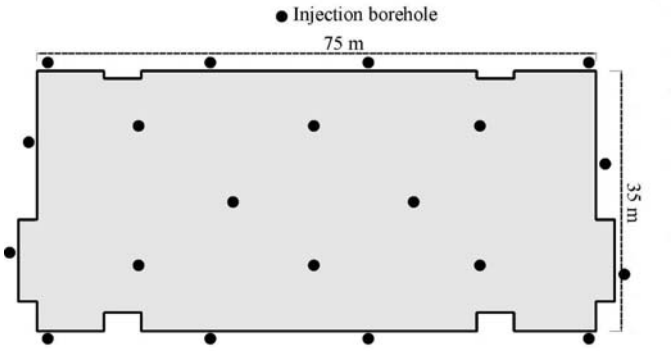

Fig. 5. Injection pattern of sealed building

IV. Conclusion

Groundwater can cause destructive effects on concrete and reinforcement. The examined foundation of a reinforced concrete building was below the groundwater level and there was an enormous water seepage into basement storey during winter seasons. Four water pumps were not enough to drain the water seepage and building was prepared to sacrifice.

Quaternary aged soil was including 66% gravel and 34% sand and it was very permeable. Compaction grouting was employed to minimise soil permeability. 1:3 ratio cement-water mixture is injected into soils. The grouting was enforced from bottom to up and 25 kPa pressures were applied for every meter. Evenly distributed twenty grouting holes were drilled 6 meters in length. Injection material was designed to wrap whole foundation. The applied pressures caused heaving up to ten centimetres on floor of basement storey. Additionally sewage system of the building and a shallow water pumping hole congested.

It was sealed successfully and there was no seepage during the last three winter seasons. The method can be employable to all existing buildings with seepage problems.

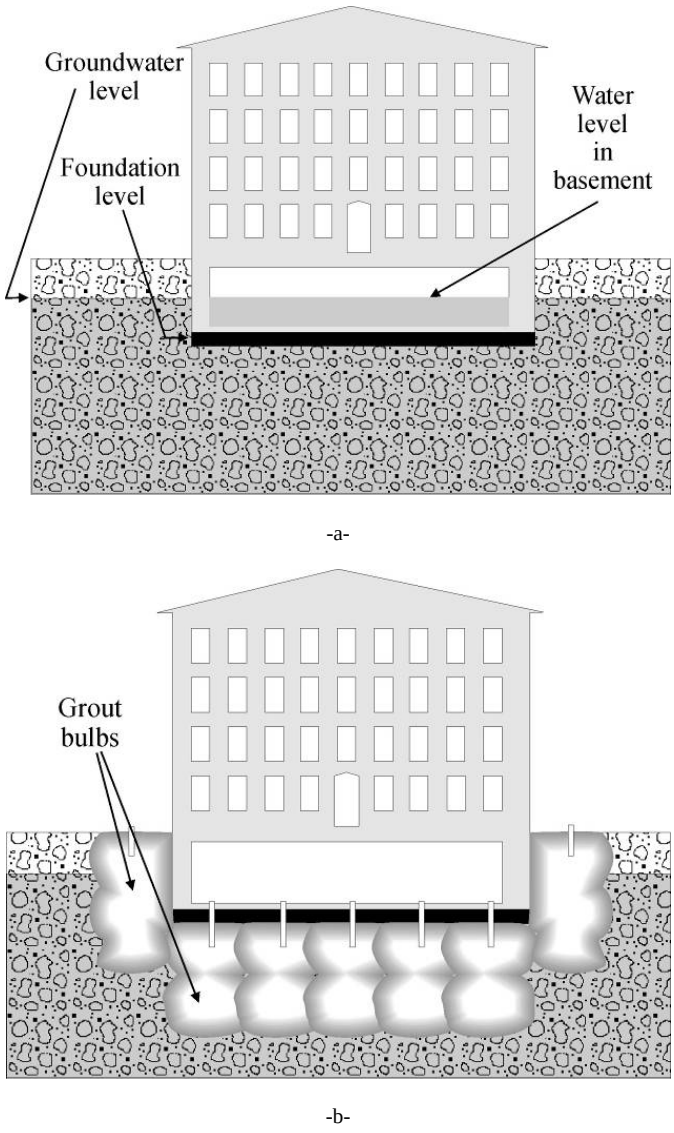

Fig. 6. Schematic view of the building (a) before and (b) after injection

Acknowledgement

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References

[1] UNDP/UNIDO, 1985, Vol. 4 – Post-Earthquake Damage Evaluation and Strength Assessment of Buildings under Seismic Conditions, Volume: 4, Vienna
[2] FEMA, 1997, NEHRP Guidelines for the Seismic Rehabilitation of Buildings, Pub. No: 273, Washington D.C.
[3] CEN, 2003, Eurocode 8: Design of structures for earthquake resistance, Ref. No. prEN 1998-1:2003 E, Brussels
[4] Rai, D. C., 2005, IITK-GSDMA Guidelines on Seismic Evaluation and Strengthening of Existing Buildings: Provisions with Commentary and Explanatory Examples, IIT Kanpur and Gujarat State Disaster Mitigation Authority, Gandhinagar
[5] Ayranci Y., 2006, Determining quality of greenhouse irrigation water in Ortaca-Mugla, Selcuk University, Journal of Agricultural Faculty, 20 (39): (2006) pg.:32-36 (in Turkish)
[6] Byle M. J. and Borden R. H., 1995, Verification of Geotechnical Grouting (A Report from the ASCE Committee on Grouting of the Geotechnical Engineering Division), Geotechnical Special Publication No: 57, American Society of Civil Engineers

[7] El-Kelesh A. M, Mossaad M.E. and Basha I. M., 2001, Model of compaction grouting, Journal of Geotechnical and Geoenvironmental Engineering, Volume: 127/11, pgs: 955-964
[8] Warner J., 2004, Practical Handbook of Grouting: Soil, Rock, and Structures, John Wiley and Sons, 700 pgs.
[9] Gallagher P.M., 2000, Passive Site Remediation for Mitigation of Liquefaction Risk, PhD Thesis, Virginia Polytechnic Institute
[10] Akyol E. and Sen G., 2006, Soil injection and applications, Symp. on Structural Repairing and Strengthening, 7-8 December 2006, Pamukkale, Denizli-Turkey (In Turkish)