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Stabilization of 15 Meter Deep Excavation by 22 Meter In Situ Dug Piles

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ABSTRACT: The 24 central office complex of the National Iranian Gas Company was to be extended. This required a 15 meters deep excavation to be performed adjacent to an existing old hospital building complex. The brick masonry structure of the hospital was founded on lime stabilized strip footing and even slight cracks in the building would have disrupted the highly demanded services to the patients.

The National Iranian Gas Company decided to use extreme care in this excavation, especially having experienced previous slides in the neighboring excavations.

To stabilize the excavation and at the same time laterally support the masonry walls of the hospital, a pile wall consisting of twenty five 90 centimeter diameter, 22 meter deep side by side concrete pile was designed. The piles were to run 2 meters above the ground zero for hospital wall lateral support and 5 meters below the finished excavation level to have enough passive resistance for stability. The piles were laterally supported at depth of 3.5 meters below the ground zero by beams anchored to existing basement of the high rise tower which was under construction.

The pile wall was constructed in two stages. In the firs one, excavation for every other pile was carried out; supported by pre cast concrete rings where instability occurred. Then caged reinforcement was lowered and in situ concrete was poured. The remaining piles were built similarly in the second stage. This resulted in a continuous wall of concrete piles. Then the excavation was carried out to -3.5 meter level and lateral support beams were installed and further excavation was continued while monitoring the behavior of the adjacent hospital building.

Except for inflow of sewerage from the hospital at two locations which were blocked, no complications were encountered. The excavation is completed and pile wall is also used as structural element by the structural engineer. Details of analysis, design and construction will be presented in this paper.

1. INTRODUCTION

The National Iranian Gas Company decided to make extension to a 24 story central office complex. The extension needed 15 meter deep excavation adjacent to an existing hospital building. The hospital building was of brick masonry and was founded on wall footings on lime stabilized soil. It was heavily used by the patients and even small cracks in the building would have hampered the normal work of the hospital. The National Iranian Gas Company decided to use extreme care and instructed the authors to design the excavation in such a way to prevent even small lateral displacement by the hospital building. The principles of design of reinforcement and excavations next to an existing building have been summarized by Bowles (1). In this case it was decided to use side by side dug and poured in place concrete piles as the main wall reinforcement and to use extra wall length of two meters above ground zero to support the walls of the hospital. Lateral steel hallow piles were also used as anchors at –3.5 meters to tie the wall to the existing tower. The piles were extended 5 meters below the excavation level, thus total length of the piles were 22 meters.

2.ANALYSIS

The analysis was carried out by the conventional and by the finite element method. The soil had a density of 2 ton/m3 and elastic modulus of 1000 kg/cm2 and had a friction angle of 40 degrees and a cohesion which was neglected for probable rainfall effect during the construction. The soil is the gravelly clay which is also overlain by up to two meters of fill in some places. The piles had a diameter of 90 centimeters and were to be dug by hand and then filled with reinforcement cage and poured in place concrete.

2.1 Conventional Analysis

The cross section of excavation is shown on figure 1.

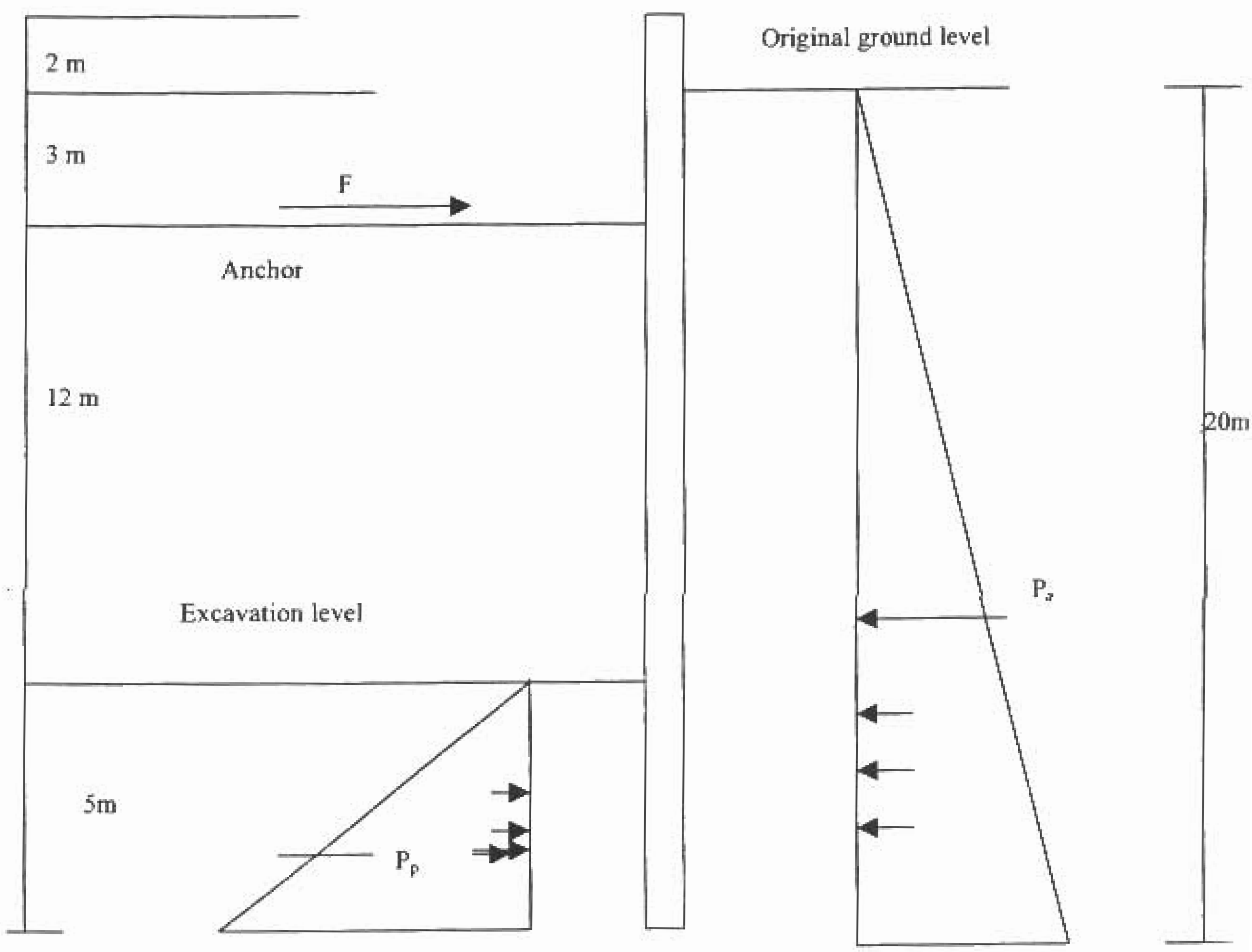

Figure 1. The Cross section for Analysis

The passive and active earth pressure coefficients are

$$k_a = 0.25$$

$$k_p = 4.0$$

The active and passive force is found

$$P = k_a \gamma H = 0.25 * 2 * 20 = 10 \quad kg/cm2$$

$$p_a = .5H * P = .5 * 20 * 10 = 100 \quad T/m$$

$$p_p = .5\gamma \quad H_p^{\,2} k_p = .5 * 2 * 4 * 5^2 = 100 \quad T/m$$

The force in the anchor is found

$$F = p_a - p_p / 1.5 = 100 - 100/1.5 = 17 \quad T/m$$

Therefore the anchor will be designed for 17 ton per meter and the maximum moment in the wall will be found by first finding the point of zero shear from figure 2.

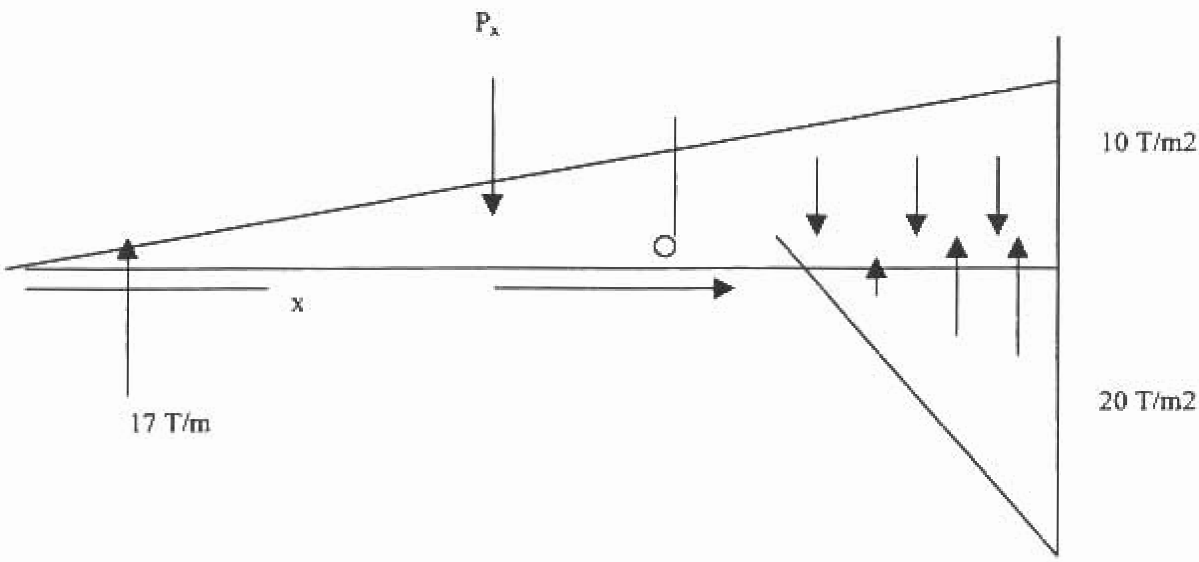

Figure 2. The Point of Maximum Shear

$$0.25x^2 = 17$$

$$x = \sqrt{\frac{17}{.25}} = 8.24 \quad m$$

He maximum moment is then

$$M = .25x^2 . \frac{x}{3} - 17(x-3) = 43 \quad Tm/m$$

Therefor the anchor will be designed for 17 ton per meter and the wall is designed for about 50 ton meter per meter.

2.2 Finite Element Method

The finite element code Plaxis (2) will be used to model the finite element model. This program uses 15 node triangular elements and is used for soil and rock plastic problems. It has the capability of modeling the Mohr Coulomb soil and also the wall beam and the anchor.

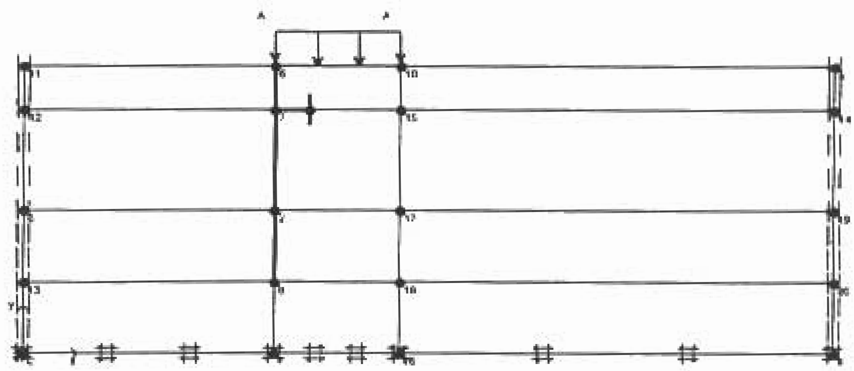

Figure 3 The Finite Element Model by Plaxis

Figure 3 shows the finite element model by Plaxis. The soil, wall and the anchor are modeled.

Figure 4 shows the deformed mesh after the excavation. The maximum displacement is the heave of the soil about 1.7 centimeters and the lateral displacement of the wall is below 5 millimeters. This analysis shows that the assumed configuration for pile system for the wall and the anchor layout is acceptable for design.

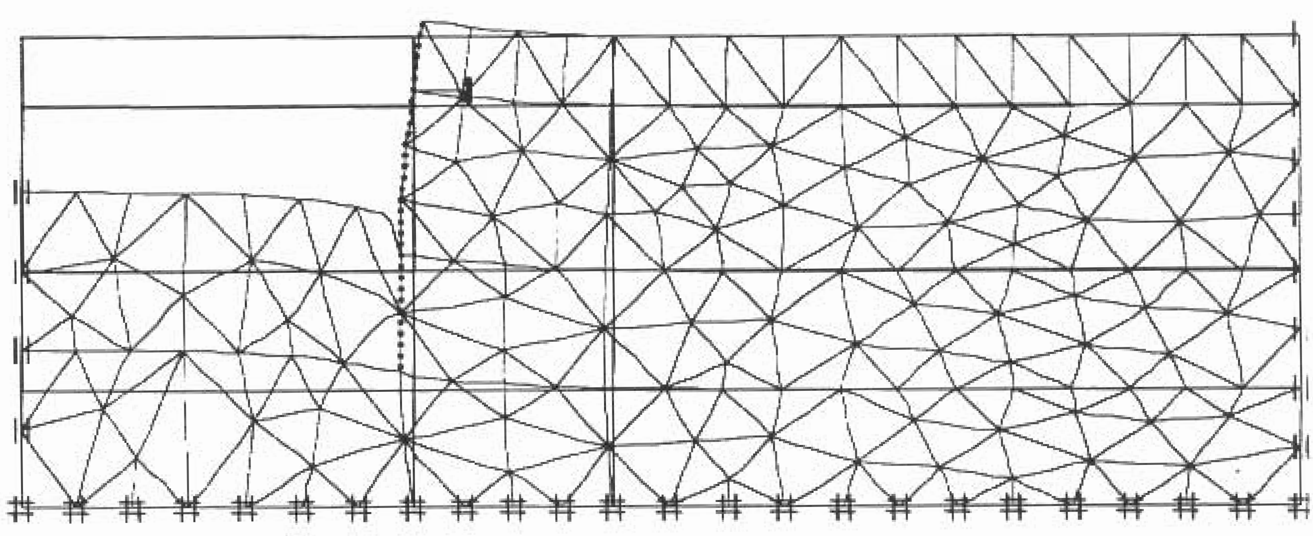

Figure 4 The Deformed Mesh of the Excavation.

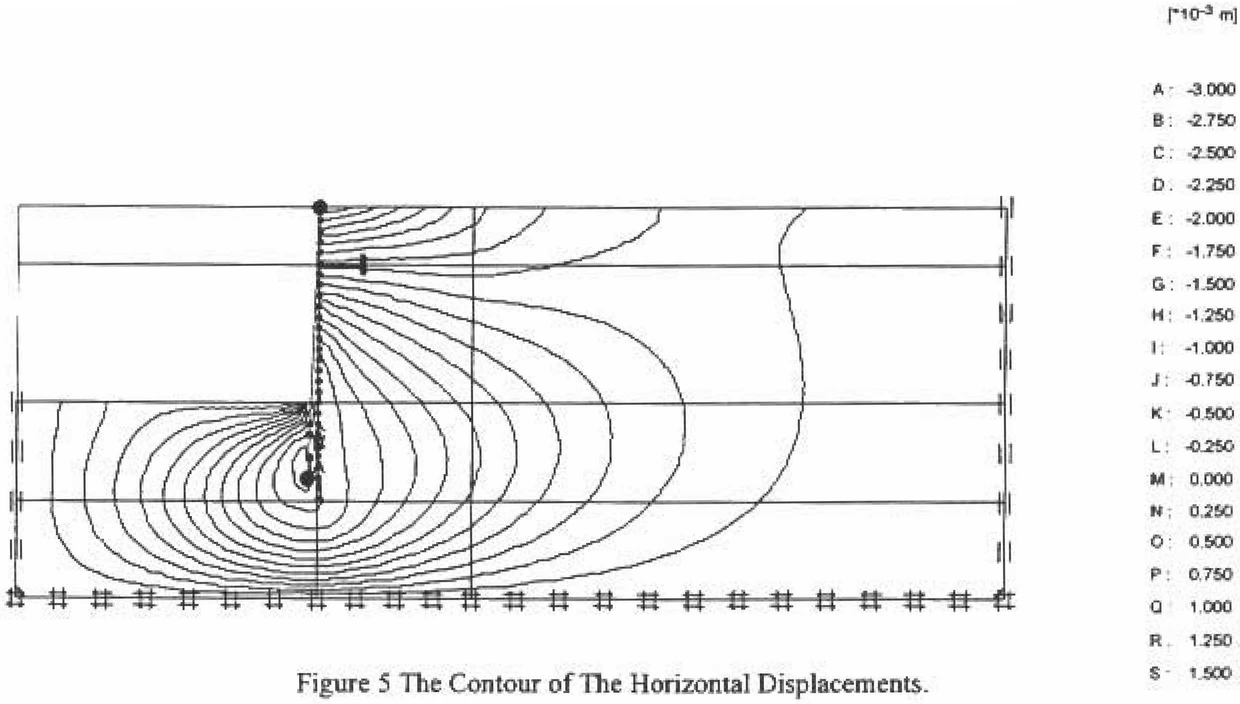

Figure 5 The Contour of The Horizontal Displacements.

Figure 5 shows the lateral contour of the horizontal displacement and it can be seen that the maximum is at the embedded wall section and is below 5 millimeters.

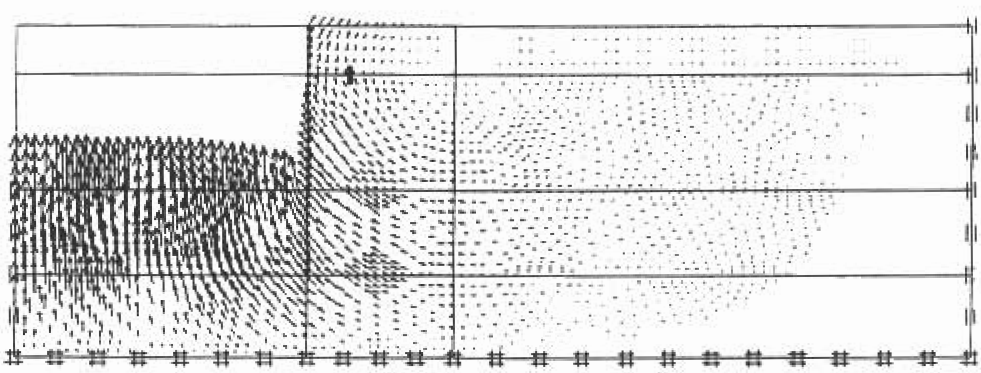

Figure 6 The Arrow Figure for the Total Displacements

The maximum bending moment by Plaxis is 18 Ton meter per meter which is about 1/3 of the Conventional method.

The anchor force is also calculated to be 16 ton per meter which is almost equal to the 17 conventional method. This shows that the conventional method gives reliable result as far as the anchor force is concerned but overestimates the bending moment in the wall.

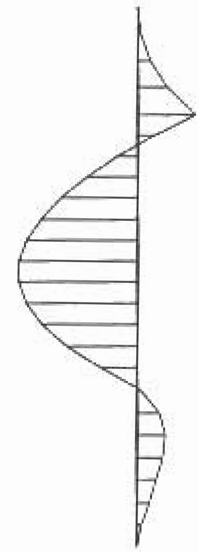

Figure 7 The Beam Bending Moment.

3.DESIGN

As can be seen by the analysis, a wall system capable of resisting 50 ton meter per meter moment and an anchor system capable of resisting 17 ton per meter are sufficient to limit the deformations to within 5 millimeters for the wall

The wall was designed as a series of continuous dug piles each having a diameter of 90 centimeters. The excavation was carried out by hand and in unstable conditions reinforced rings were used to stabilize the excavation. Then the reinforcement cage was installed and the cylinder was filled with concrete. By using casing the concrete was extended to two meters above ground zero to be able to support the walls of the adjacent hospital. Thus the total length of the pile was 22 meters, two meters for the support of the wall, 15 meters for excavation and 5 meters for final embedment. The anchor was designed as pipe piles of the National Iranian Gas Company (Rejected Pipes for normal Gas Operation) and was anchored at –3 meters ground zero to the floor of the adjacent tower. The floors were stiffened so that no harmful effect will happen to the tower building. The digging of piles was not permitted to be side by side and it was every other pile excavation. Also each three piles were poured before further excavation of piles was permitted. The excavation of the soil was carried out to anchor level first and after the installation of the anchors further excavation was carried out while closely monitoring the behavior of the adjacent buildings.

4.RESULTS AND CONCLUSIONS

The excavation was carried out successfully and except for inflow of sewerage from the hospital at two locations, which were blocked , no complications were encountered. The pile wall is to be used as a structural element by the structural engineer. It can be concluded that this large scale soil reinforcement and excavation prevented the adjacent hospital building from any damages.

5.References

1. Bowles, J. E. (1982) "Foundation Analysis and Design", McGraw Hill Book Company

2. Plaxis (1998) "Finite Element Code for Soil and Rock Plasticity", Version 7 for windows, Edited by P.A. Vermeer, Plaxis Orgainization