ANALYSIS OF TUNNELLING EFFECTS ON LATERAL BEHAVIOR OF UNDERGROUND BUILDING

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ABSTRACT

In recent eras, the demand for underground space, to use as underground parking, railway tunnels/stations, road tunnels, redevelopment of buildings, etc., has increased in several congested areas. Deep excavations are required for underground construction. In most cases, excavation sites are very close to existing structures/facilities and problems related to deep excavations and their effects on surrounding structure are increasing. In practical scenario, to manage heavy loads of multi storied building the provision of pile foundation becomes necessary. But in future, this pile foundation, being at large depths, may get affected by newly built tunnel passing close to it, so to predict effect of such tunnel on pile foundation becomes necessary. This project mainly deals with analysis of such pile foundation under the influence of tunnel with the use of finite element analysis software PLAXIS 3D.

Keyword: - *Underground Space1, Pile Foundation2, Tunnels 3, and Minerals4.*

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1. BACKGROUND

In spite of numerous benefits that can be achieved from the use of underground space, there are issues that have to be seriously taken into 45 considerations and rectified. Goddard (2004) in the ITA (International Tunnelling Association) conference describes that, enhanced benefits in underground space use can be achieved, if the safety (fire, flood, earthquake, terrorism), psychological and health aspects are vigilantly designed. Further, a harmonious relationship has to be created between underground space and the surface fabric for which designers should take utmost care while drafting the plan.
In many countries, underground space use plans' execution gets delayed or restricted due to local guidelines in city development. Legality based on ownership, easements for both public and private is a big concern while planning to go underground.
When extractions of natural resources like oil, gas, minerals, groundwater or any other natural resources would be for public benefit. While regulation for extraction of these resources does exist, rights of access beneath private property are seriously debated. Until 2014, it has been a situation that underground development made without the consent of the owner is considered as trespassing. The second scenario is that many countries have limits of ground to below ground ownership to a certain depth and this approach varies between countries and on regional basis also.
The socio-economic survey can assist in understanding the mindset of the people about their negativity in using underground space. This can be understood in various contexts such as physiological, psychological and innovative architectural designs, which enable us to identify the problem so an attempt can be made to alleviate the problems in using underground space.
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One of the major reasons for the people's receptivity to use underground space is the uncertainties in the safety aspects. Earthquakes, hurricanes, tornados, tsunamis, floods, and terrorist attacks are the key events in the analysis of resiliency. At the same time, this overburden applies to the changes that may occur over the coming years due to global warming and its effects. Prediction, prevention, protection and resiliency are the most important components of safety measures. The safety aspect for underground space use or its development includes protection from fire, floods, earthquake and surveillance.

1.2 Total displacement with change in diameter of tunnel

The change in displacement of the pile because of presence of tunnel '30-BT-10' is shown in figure 4.8.

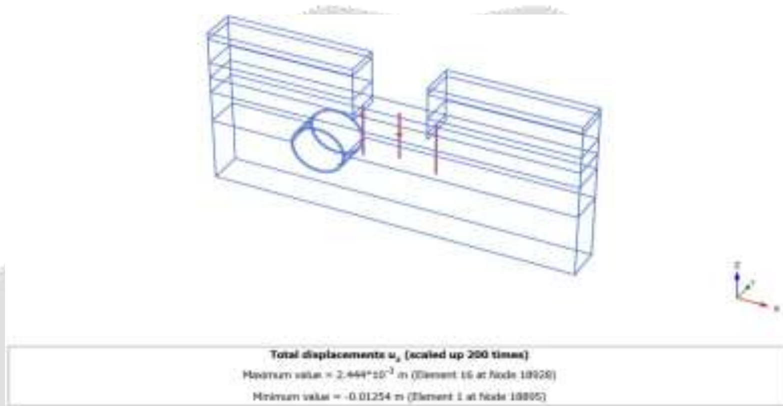

Figure 1: Displacement of pile, because of tunnel '30-BT-10'

With respect to group action, the spacing in the direction of the load is of primary importance. At a spacing center to center of 8d or more (dis the pile diameter), there is essentially no influence of one pile on another providing the spacing normal to the direction of loading is at least 2.5d. When the spacing parallel to loading is less than 8d, the effective value of k (keff) is less than that for an isolated pile. At a spacing of 3d, keff is approximately 0.25k. For other spacing's, k eff can be determined by interpolation between 3d and 8d. This information is based on a model study on piles in sand. Repeated loading causes some deterioration of the soil resistance, effectively reducing the modulus k. Moments are also increased and occur over an increased depth of embedment.

Repeated loading has the effect of reducing k to approximately 30 percent of the applicable to initial loading. The net effect is that the deflection observed under first application of a load is essentially doubled if the load is cycled 50 times or more.

If both group effects and repeated load effects must be considered, keff can be as low as 10 percent of that applicable to initial loading of an isolated pile. It is the writer's experience that for most problems an analytical investigation based on reasonable values for k, determined with the aid of routine soil tests and judgment based on data given in Table 3.1, will lead to the decision that an adequate design can be developed without further information. For the remaining problems, it is relatively easy to make in situ tests to get more accurate design information if the potential benefits outweigh significantly the additional cost of an acceptable design based on available data. A simple lateral load test on a pile will provide accurate design information. For simplicity the loads should be applied and the deformations measured at the ground surface; however, this is not essential. Further, the test pile need not be a prototype. It is only necessary that the pile be of sufficient depth to be considered infinitely long for theoretical evaluation. It is necessary to make an assumption regarding the nature of the variation of k with respect to depth; for example, constant, stepped, or triangular.

The displacement of the tunnel at same depth and same distance from the pile, but with the less diameter (4.25 m) is 12.47mm. It clearly indicates that the displacement increases when diameter of the tunnel increases, though the variation in displacement is very less. However, the reduction degree varies. When the pile diameter increases from 0.8 m to 1.0 m, the lateral displacements of the pile body and the pile top change slightly. The lateral displacements of the pile body and the pile top decrease from 6.62 mm to 6.14 mm only. However, the maximum lateral displacement at the pile top dropped sharply to 3.41 mm when the pile diameter increased to 1.2m, thus apparently showing a nonlinear relationship. The linear relationship is developed gradually at different types of soil interface (Figure 4.8), which could be interpreted from two aspects. On the one hand, the dead load of the pile body increases nonlinearly with the increase in pile diameter, which is beneficial to the increase in the lateral resistance of the pile body. On the other hand, increased pile diameter expands the pile-soil contact area (linear relationship between pile-soil contact area and pile diameter). As a result of the frictional force between pile body and soil mass, the lateral displacement of soil mass will cause lateral stress on the pile body and thereby cause lateral displacement of the pile body. The final variation law of lateral displacement of pile body is used to determine which between the dead load or lateral friction of piles takes the dominant role.

2. THICKNESS OF SOFT SOIL

The presence of a soft soil layer can influence the propagation of incoming wave from the bedrock, undoubtedly modifying the ground motions and soil dynamic behavior. To discuss the effects of relative thickness of soft soil, the deformation modulus of surface soil in the model is determined to be twice the deformation modulus of soft soil. The lateral displacement of the pile body increases with the increase in the relative thickness of soft soil. The lateral displacement of the pile body increases from 3.92 mm to 6.63 mm as the soft soil thickness increases from 5 m to 10 m (two soil layers).

In elastic homogeneous medium, the upward movement of the soil is due to relief effect of the excavated soil above the tunnel but this movement decreases as x/D increases as shown in figure 4.9. This is because the soil is remote from concentration of loading. • The results show that there is a good agreement between the complex variable analysis for z/D=1.5, While using z/D = 2 and 3, the curve diverges in the region far away from the center of the tunnel. The finite element method over predicted the settlement trough width i compared with the results of Peck for soft and stiff clay but there is an excellent agreement with Rankin's estimation.

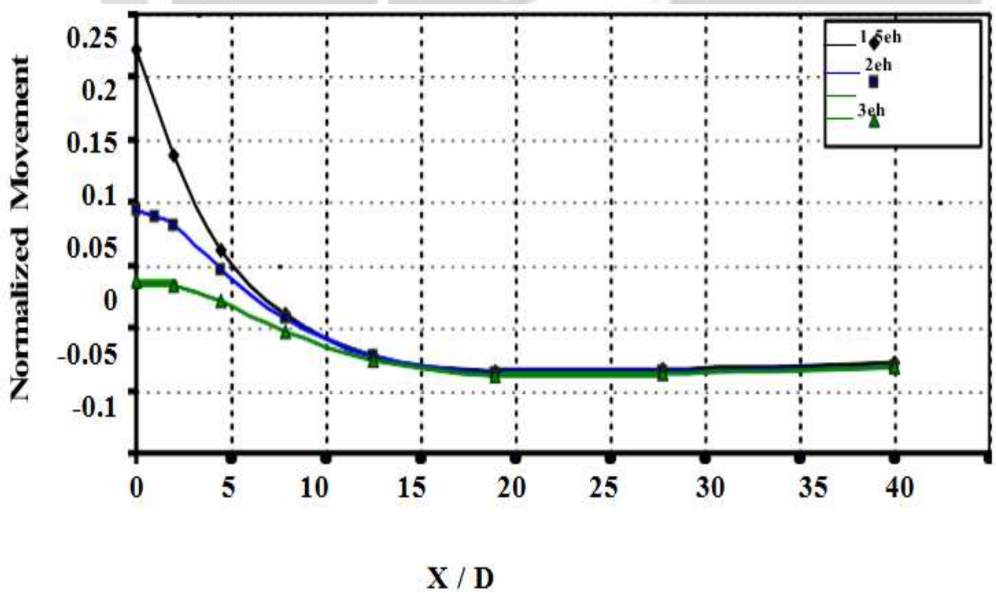

Figure. 3: Surface displacement for elastic-homogeneous soil model predicted by the finite element method for different z/D ratios.

3. CONCLUSIONS

Pile foundation of building is influenced by tunnel only when tunnel is in very close vicinity of pile and its influence is negligible if located far away from the structure. The distribution of the tunnel induced internal forces strongly depends on the position of the pile tip with regard to the tunnel horizontal axis. The critical configuration corresponds to piles with a tip just below of the tunnel. When tunnel is located at various depths, the variation of total displacement with depth of pile depends upon position of tunnel and the tip of pile. The diameter of tunnel also has small influence on displacement of pile. As the diameter increases the displacement of pile also increases.

One of the major reasons for the people's receptivity to use underground space is the uncertainties in the safety aspects. Earthquakes, hurricanes, tornados, tsunamis, floods, and terrorist attacks are the key events in the analysis of resiliency. At the same time, this overburden applies to the changes that may occur over the coming years due to global warming and its effects.

Prediction, prevention, protection and resiliency are the most important components of safety measures. The safety aspect for underground space use or its development includes protection from fire, floods, earthquake and surveillance.

4. REFERENCES

[1]T. Engin and V. Ari, "Energy auditing and recovery for dry type cement rotary kiln systems—A case study," Energy Convers. Manage., vol. 46, no. 4, pp. 551–562, Mar. 2005.

[2] F. Liu, M. Ross, and S. Wang, "Energy efficiency of China's cement industry," Energy, vol. 20, no. 7, pp. 669–681, Jul. 1995.

[3] S. Khurana, R. Banerjee, and U. Gaitonde, "Energy balance and cogeneration for a cement plant," Appl. Therm. Eng., vol. 22, no. 5, pp. 485–494, Apr. 2002.

[4] M. Vaseghi, A. Amiri, and A. Pesaran, "A review of energy efficiency and CO2 emissions in the US cement industry," in Proc. 23rd IEEE-IAS/PCA Cement Ind. Tech. Conf., 2012, pp. 1–9.

[5] A. Pahuja, "Energy auditing and monitoring in the cement industry," Cement Ind., vol. 81, pp. 670–694, 1996.

[6] K. Kamal, "Energy efficiency improvement in the cement industry," presented at the Seminar Energy Efficiency, Geneva, Switzerland, 1997, organized by ASSOCHAM-India and RMA-USA.

[7] T. Engin, "Thermal analysis of rotary kilns used in cement plants," in Proc. 1st MAMKON Mech. Eng. Congr., Istanbul, Turkey, 1997, pp. 4–6.

[8] "Unlock energy savings with waste heat recovery," Washington, DC, USA, DOE/EE-0577, 2012, Anonymous.

[9] "Waste heat recovery: Technology and opportunities in U.S. industry," Ind. Technol. Program Energy Efficiency Renew. Energy, Washington, DC, USA, 2008.

[10] "Waste heat reduction and recovery for improving furnace efficiency, productivity and emissions performance," Ind. Technol. Program Energy Efficiency Renew. Energy, Washington, DC, USA, DOE/GO-102004, 2004.

[11] C. K. Hyde, Technological Change and the British Iron Industry 1700–1870. Princeton, NJ, USA: Princeton Univ. Press, 1977.

[12] W. C. Turner, Energy Management Handbook. New York, NY, USA: Marcel Dekker, 2004.

[13] R. J. Goldstick and A. Thumann, Principles Of Waste Heat Recovery. Atlanta, GA, USA: Fairmont, 1985.

[14] R. E. Sonntag, C. Borgnakke, G. J. Van Wylen, and S. Van Wyk, Fundamentals of Thermodynamics. New York, NY, USA: Wiley, 1998.

[15] M. S. Peters, K. D. Timmerhaus, R. E. West, K. Timmerhaus, and R. West, Plant Design and Economics for Chemical Engineers. New York, NY, USA: McGraw-Hill, 1968.

[16] Use Feedwater Economizers for Waste Heat Recovery, U.S. Dept. Energy, Washington, DC, USA, Tech. Fact Sheet, 2006.

[17] Introduction of Low-Temperature Waste Heat Recovery Power Generation (WHRPG) Technology in Cement Kiln, RES, China National Technical IMP & EXP Corp., Tehran, Iran, Tech. Rep., 2010.

[18] S. Karellas, A. Leontaritis, G. Panousis, E. Bellos, and E. Kakaras, "Energetic and exergetic analysis of waste heat recovery systems in the cement industry," Energy, vol. 58, pp. 147–156, Sep. 2013.
[19] K. Silvo, M. Melanen, A. Honkasalo, S. Ruonala, and M. Lindström, "Integrated pollution prevention and control—The Finnish approach," Resour. Conserv. Recycling, vol. 35, no. 1/2, pp. 45–60, Apr. 2002.
[20] D. C. Erickson, G. Anand, and I. Kyung, "Absorption/Sorption heat pumps and refrigeration systems-heat-activated dual-function absorption cycle," in Proc. ASHRAE Trans., 2004, vol. 110, pp. 515–524, Symp. Papers-AN-04-07.
[21] F. Heberle and D. Brüggemann, "Exergy based fluid selection for a geothermal organic Rankine cycle for combined heat and power generation," Appl. Therm. Eng., vol. 30, no. 11/12, pp. 1326–1332, Aug. 2010.
[22] A. Schuster, S. Karellas, E. Kakaras, and H. Spliethoff, "Energetic and economic investigation of organic Rankine cycle applications," Appl. Therm. Eng., vol. 29, no. 8/9, pp. 1809–1817, Jun. 2009.
[23] D. P. Duffy, "Better cogeneration through chemistry: The organic Rankine cycle," Business Energy, Nov./Dec. 2005, [Online]. Available: http:// www.distributedenergy.com.
[24] S. Lu and D. Yogi Goswami, "Optimization of a novel combined power/refrigeration thermodynamic cycle," Trans. ASME, J. Sol. Energy Eng., vol. 125, no. 2, pp. 212–217, May 2003.
[25] P. Nag and A. Gupta, "Exergy analysis of the Kalina cycle," Appl. Therm. Energy, vol. 18, no. 6, pp. 427–439, Mar. 1998.
[26] X. Zhang, M. He, and Y. Zhang, "A review of research on the Kalina cycle," Renew. Sustain. Energy Rev., vol. 16, no. 7, pp. 5309–5318, Sep. 2012.
[27] C. Dejfors, E. Thorin, and G. Svedberg, "Ammonia-water power cycles for direct-fired cogeneration applications," Energy Convers. Manage., vol. 39, no. 16–18, pp. 1675–1681, Nov./Dec. 1998.
[28] P. Lolos and E. Rogdakis, "A Kalina power cycle driven by renewable energy sources," Energy, vol. 34, no. 4, pp. 457–464, Apr. 2009.
[29] M. B. Ibrahim and R. M. Kovach, "A Kalina cycle application for power generation," Energy, vol. 18, no. 9, pp. 961–969, Sep. 1993.
[30] D. Kouremenos, K. Antonopoulos, and E. Rogdakis, "Performance of a solar driven compound NH3/H2O H2O/LiBr absorption refrigeration system in Athens," Sol. Wind Technol., vol. 7, no. 6, pp. 685–697, 1990.
[31] V. Dostal, "A supercritical carbon dioxide cycle for next generation nuclear reactors," Massachusetts Inst. Technol., Cambridge, MA, USA, 2004.