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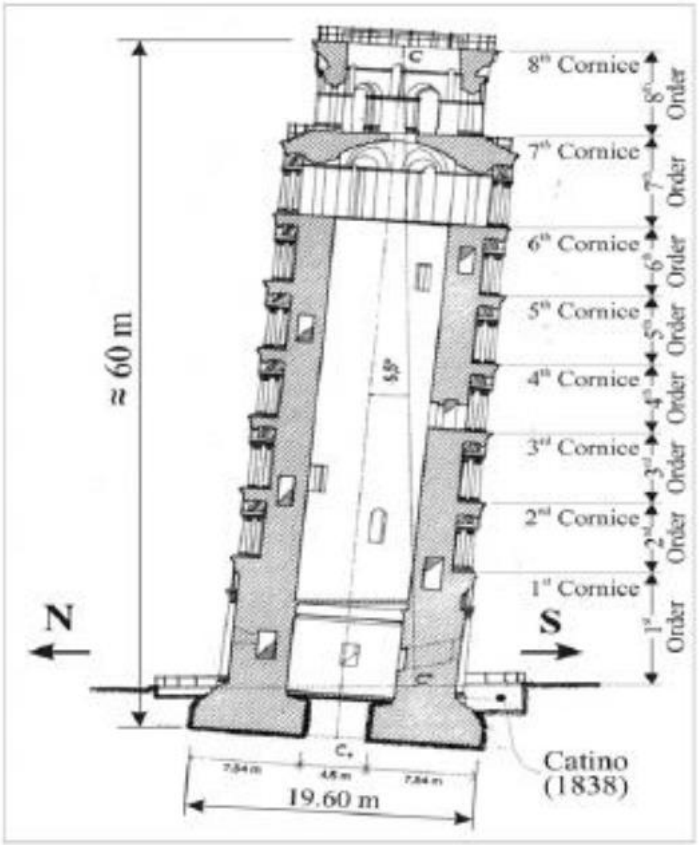
UNIVERSITY OF CONNECTICUT

Soil Mechanics
Department of Civil and Environmental Engineering

Term Project - Fall 2021
The Leaning Tower of Pisa: Settlement calculations

Background information:

The construction of the Leaning Tower of Pisa began in 1173 and due to two long breaks, it went on for 176 years. Those breaks were most likely caused by political events. The first break came in 1178, and by that time, the construction work had only reached the 4th order of the final Tower, which is illustrated in Figure 1.



Weight	142 MN
Height of the centre of gravity	22.6 m
Overturning moment	327MNm
Average foundation pressure:	≈ 500 kPa

Figure 1: Cross-section of the Tower (Burland, Jamiolkowski, & Viggiani, 2009)

The second break came in 1278 after the tower had reached the 7th order of the finished Tower. Completion with the rise of the bell Tower was first achieved in 1360 and although completion would have taken almost 15% of the time had it not been for the two shutdowns, these have actually proven to be crucial for the Tower Existence. Had they built the Tower giving it no time to consolidate, the weight of the Tower would have caused an undrained bearing capacity failure in the underlying soil and the Tower would have been history already after the first construction phase.

By the time of the final stage of construction, the tower had already leaned significantly, as evidenced by the changed centerline direction of the 8th order, that was added last.

The dimensions of the Tower are shown in Figure 1. The diameter of the foundation is 19.6 m and the total weight of the tower at the end of construction is 141,640 kN (~142MN) resulting in an average foundation pressure of $q = \frac{141640kN}{\pi(\frac{19.6}{2})^2 m^2} = 469kPa$ (rounded up as 500 kPa in Figure 1).

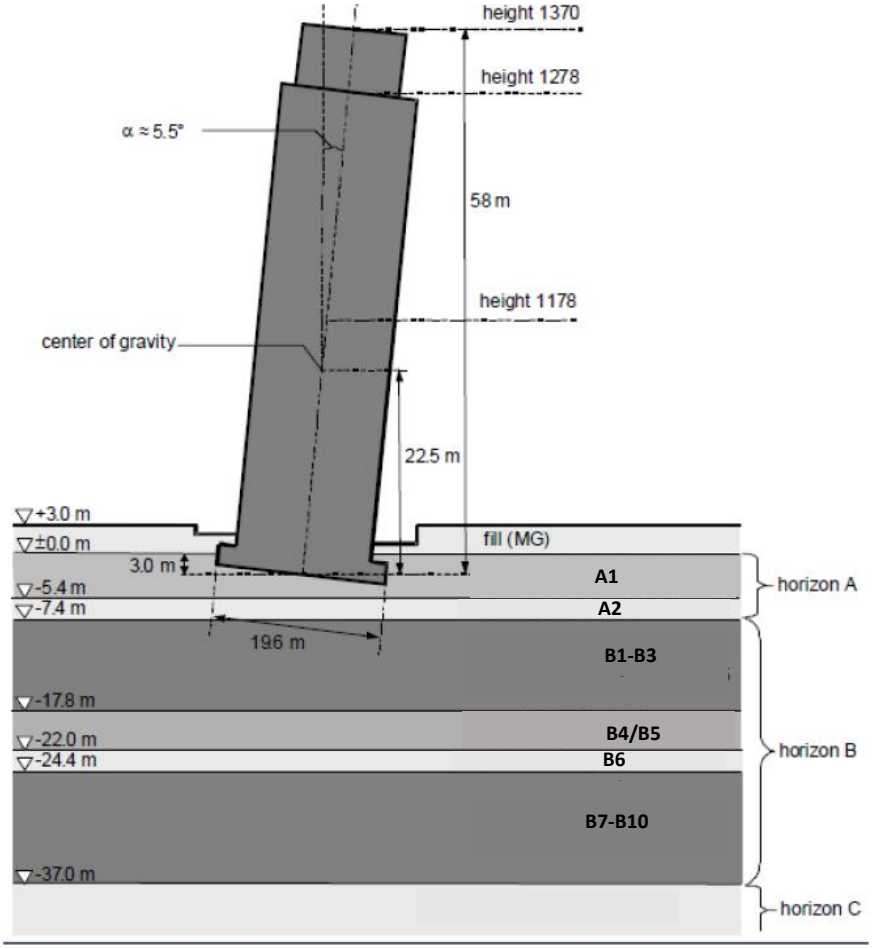


Figure 2: Geology of the subsoil beneath the Tower (Leoni & Vermeer 2002)

Term Project - Phase 3:

Comparison:

In phase 2, you calculated the 1-D primary consolidation settlement of each of the three clay layers, in the north and in the south side of the tower separately, as well as the differential settlements (total settlement on the south side minus the total settlement on the north side) across the tower.

Mitchell et al. (1977) mentioned that the total settlement of the north side in 1977 was 0.8 m, on the south side 2.8 m, and the differential settlement 2 m. Compare these values with your calculated values and if there are differences, provide some possible reasons for those (in the report/presentation).

Assignment:

1. Present your findings (including the problem statement and the methodology) in the form of
    a. A **written report** (A template has been uploaded to HuskyCT along with this instruction file) [Maximum 10 pages]
    OR
    b. An **oral video presentation** (A PowerPoint template has been uploaded to HuskyCT along with this instruction file) [Maximum 10 minutes duration]. (https://confluence.uconn.edu/ikb/teaching-and-learning/recording-technologies/options-for-creating-videos)
2. **The names of all the group members should be clearly mentioned in the deliverable**.
3. Upload your file **(.pdf file for option a. or .mp4 file for option b.**) to HuskyCT by the deadline. **No email submission will be accepted.**
4. **Only one member is required to submit the assignment.**
5. The deadline for this phase of the project is **12:59 PM on December 10th**.

References

Kristiansen, M. 2012 An under-excavation model for The Leaning Tower of Pisa, MS Thesis, Norwegian University of Science and Technology.

Leoni, M., & Vermeer, P. A. (2002). 3D creep analysis of the Leaning Tower of Pisa. Stuttgart: Institute of Geotechnical Engineering Stuttgart.

Mesri, G., Heiden, J.E., Shahien, M., 1997a. Geotechnical characteristics and compression of pisa clay. In: Proceedings of the 14th International Conference on Soil Mechanics and Foundation Engineering, Hamburg, Germany. pp. 373–376.

Mitchell, J.K., Vivatrat, V., and Lambe, W.T. 1977. Foundation performance of the Tower of Pisa. Journal of the Geotechnical Engineering Division, ASCE, 103(GT3): 227–249.

Burland, J. B., Jamiolkowski, M. B., & Viggiani, C. (2009, July 01). Leaning Tower of Pisa: Behaviour after Stabilization Operations . International Journal of Geoengineering Case Histories , ss. 156-169.

