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Investigation of Ground Disturbance Caused by Pile Driving: Case Study

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Abstract : Piling is the most widely used foundation method for heavy structures in poor soil conditions. The geotechnical engineer can choose among a variety of piling methods, but in most cases, driving piles by impact hammer is the most cost-effective alternative. Under unfavourable conditions, driving piles can cause environmental problems, such as noise, ground movements and vibrations, with the risk of ground disturbance leading to potential damage to proposed structures. In one of the project sites in which the authors were involved, three offshore container terminals, namely CT1, CT2 and CT3, were constructed over thick compressible marine mud. The seabed was around 6m deep and the soft clay thickness within the project site varied between 9m and 20m. CT2 and CT3 were connected together and rectangular in shape and were 2600mx800m in size. CT1 was 400m x 800m in size and was located on south opposite of CT2 towards its eastern end. CT1 was constructed first and due to time and environmental limitations, it was supported on a “forest” of large diameter driven piles. CT2 and CT3 are now under construction and are being carried out using a traditional dredging and reclamation approach with ground improvement by surcharging with vertical drains. A few months after the installation of the CT1 piles, a 2600m long sand bund to 2m above mean sea level was constructed along the southern perimeter of CT2 and CT3 to contain the dredged mud that was expected to be pumped. The sand bund was constructed by sand spraying and pumping using a dredging vessel. About 2000m length of the sand bund in the west section was constructed without any major stability issues or any noticeable distress. However, as the sand bund approached the section parallel to CT1, it underwent a series of deep seated failures leading the displaced soft clay materials to heave above the standing water level. The crest of the sand bund was about 100m away from the last row of piles. There were no plausible geological reasons to conclude that the marine mud only across the CT1 region was weaker than over the rest of the site. Hence it was suspected that the pile driving by impact hammer may have caused ground movements and vibrations, leading to generation of excess pore pressures and cyclic softening of the marine mud. This paper investigates the probable cause of failure by reviewing: (1) All ground investigation data within the region; (2) Soil displacement caused by pile driving, using theories similar to spherical cavity expansion; (3) Transfer of stresses and vibrations through the entire system, including vibrations transmitted from the hammer to the pile, and the dynamic properties of the soil; and (4) Generation of excess pore pressure due to ground vibration and resulting cyclic softening. The evidence suggests that the problems encountered at the site were primarily caused by the “side effects” of the pile driving operations.

Keywords : pile driving, ground vibration, excess pore pressure, cyclic softening
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