

Cylindrical Diaphragm Wall Movement During Deep Excavation for In-ground LNG Storage Tank in Coastal Area

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ABSTRACT

The lateral deflection of a cylindrical diaphragm wall and the associated ground movement induced by a deep excavation are analyzed by performing site instrumentations and numerical analyses in a coastal area of Korea. Wall lateral deflection, rebar stress and pore water pressure are measured and analysed in 8 directions. Variations of soil properties with the decrease of confining pressure are compared by performing various in-situ tests before and after the excavation. To calculate the wall's lateral deflection accurately, the effects of small-strain nonlinearity and confining pressure reduction developed during the excavation are considered in the proposed numerical analysis. By comparing the numerical and measured results, the importance of considering small-strain nonlinearity and confining pressure reduction in the nonlinear FEM are emphasized. Also, parametric studies on the performance of cylindrical diaphragm walls are carried out for similar future excavations in coastal areas.

INTRODUCTION

Although a reliable evaluation of ground movement in major offshore construction projects is essential in terms of safety and cost concerns, the current techniques for evaluation of marine soil properties and design procedures show a considerable lack of accuracy when compared with the instrumented results. This can usually be attributed to a misinterpretation of marine soil behavior under working load conditions.

The strain level experienced in a soil medium under working load conditions usually ranges below about 0.5%, and soil behaves nonlinearly from small-strain ranges of about $10^{-3}\%$ (Jardine et al., 1986; Burland, 1989). The stiffness of granular soils and weathered rock is considerably affected by the in-situ confinement, and the modulus values based on the Standard Penetration Test (SPT) obtained by site investigations before major excavation are quite different from those values after excavation. In current design practice, a subgrade reaction method and/or a linear finite element method are often employed for the analysis of the deformational behavior of geotechnical offshore structures using soil properties determined by SPT N-values and/or conventional triaxial tests, which cannot properly consider the effects of confinement, small-strain nonlinearity and hysteresis loading/unloading loops. Thus, it is necessary to develop refined site investigation and numerical analysis methods that can consider the aforementioned effects for a reliable ground movement analysis during deep excavations in coastal areas.

In this paper, a case study of a deep excavation for a 56-m-deep cylindrical in-ground LNG storage tank in a coastal area was investigated. A 1.7-m-thick and 75-m-deep cylindrical diaphragm

wall, 8 m in diameter, was utilized as a retaining structure for the excavation. Detailed site investigations were performed both before and after excavation to determine the variations in deformational characteristics due to the decrease of confinement. The small-strain nonlinearity of the site was evaluated by effectively combining the maximum shear moduli determined by a down-hole test with the modulus reduction curves determined by a resonant column test. Instrumentation equipment was installed at the diaphragm wall and the adjacent ground, and the distributions of wall deflection, pore water pressure and rebar stress were monitored at various locations during the excavation (Samsung Corporation, 1998). The results of a series of numerical analyses were compared with the monitored wall deflection, and the importance of considering the effects of small-strain nonlinearity and confining pressure was assessed. Finally, the effects of wall stiffness on the performance of cylindrical diaphragm walls were evaluated for similar future projects in coastal areas.

OUTLINE OF DIAPHRAGM WALL AND EXCAVATION WORK

In-ground LNG storage tanks were constructed at Incheon on the west coast of Korea. Each storage tank had a capacity of 200,000 kl and a diameter of 80 m; the inner excavation depth was 56 m. A 1.7-m-thick and 75-m-deep cylindrical diaphragm wall was constructed as a retaining structure to withstand the earth and water pressures during excavation without any prop system. The horizontal support was achieved by virtue of hoop-compression stresses on the circular wall. The wall was installed 3 m into the soft rock and cast by 26 panels. The earth-retaining wall was constructed by the slurry wall construction method. Fig. 1 shows a cross-section of the LNG storage tank.

The excavation was carried out in 8 stages to prevent the occurrence of nonuniform lateral pressures. The ground-water table inside the retaining wall was lowered by deep wells and maintained its level about 1 m below the bottom of the excavation

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KEY WORDS: Cylindrical diaphragm wall, lateral deflection, instrumentation, FEM, confining pressure, small-strain nonlinearity, parametric study.