OTC 19495

Model Tests for Steel Catenary Riser in Marine Clay

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This paper was prepared for presentation at the 2008 Offshore Technology Conference held in Houston, Texas, U.S.A., 5–8 May 2008.

Abstract

The issue of fatigue damage caused by cyclic interaction of the steel catenary risers with the seabed has gained prominence with the widespread use and lengthening of the spans for this type of system. This paper presents the findings from a series of large-scale model tests of soil-riser interaction in re-constituted high plasticity marine clay from the Gulf of Guinea. Data are presented on soil stiffness during virgin penetration, unload-reload stiffness as a function of displacement amplitude, the effects of soil-riser separation during robust load cycles, force-controlled versus displacement controlled load conditions, stiffness degradation under cyclic loading, and stiffness regain due to consolidation and thixotropy.

Introduction

Steel Catenary Risers (SCRs) are utilized to connect floating platforms with seabed systems and feature prominently in deepwater projects. Figure 1 gives the general arrangement of such a riser, where the 'Touchdown Zone' (TDZ) refers to the area where the riser is in 'dynamic' contact with the seabed. The interaction between SCR and seabed in the TDZ is of great importance when evaluating the structural fatigue life of the riser (Hatton, 2006); a stiffer seabed will result in greater localized stresses in the riser and vice versa. Recent work has investigated seabed-SCR interaction to improve interaction models that better capture the geotechnical behaviour within the structural analysis (e.g. Aubeny et al., 2006 and Clukey et al., 2005).

Physical model testing has been an important tool to investigate seabed-SCR interaction in the TDZ, as reported by several authors including Dunlap et al. (1990), Bridge et al. (2004) and Giertsen et al. (2004). However, this work was based on test data for kaolin or low plasticity soils. The majority of deepwater projects are located in areas with clays of much higher plasticity, such as the Gulf of Guinea, Gulf of Mexico and South China Sea. Andersen (2004) has demonstrated that the cyclic behaviour of clays is dependent on both plasticity index and overconsolidation ratio. The authors therefore decided to perform seabed-riser interaction tests on a high plasticity soil taken from the Gulf of Guinea.

Figure 2 illustrates several facets of soil-riser interaction behavior that were investigated. The first involves the mobilization of soil resistance during initial monotonic penetration of the riser into the seafloor. Upon completion of the initial penetration phase, two limiting conditions of cyclic loading of the riser were investigated. The first involved force-controlled loading conditions in which the riser was unloaded and reloaded to a uniform level of compression resistance in each load cycle. The second involved displacement controlled loading in which the riser is reloaded to a uniform penetration depth. It is readily apparent from Figure 2 that fundamentally different soil-riser interaction will occur under displacement-controlled conditions, as soil resistance will decline with each successive load cycle. With regard to the relevance of loading mode to actual field conditions, either can be relevant depending on the condition being considered. During the trench formation phase (which may occur repeatedly during the life of a riser), the riser successively embeds itself deeper with each load cycle, so a force-controlled mode would likely be a closer approximation to field conditions. In contrast, as the trench approaches a steady-state configuration, a soil-riser interaction behavior in a displacement-controlled mode is likely to be most relevant. Accordingly, soil-riser interaction behavior in both loading modes merit investigation.