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Finite Element Analysis of Conductor/Seafloor Interaction

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Abstract

This paper presents results of finite element analysis of the lateral interaction of well conductors with soil. Nonlinear, 3-D finite element analyses were performed for the site conditions at an actual deep water production system location as well as for comparison to results from centrifuge model tests. Both static and cyclic analyses are reported. The analyses incorporated elastic-plastic, work hardening models of soil behavior. The model of soil behavior included in these analyses was an elastic-plastic, work hardening model tied precisely to the site specific stress-strain soil behavior exhibited in high quality advanced soil test data or to model soil properties, as appropriate. The soil behavior modeling replicated both static and dynamic behavior of the site soils including both low level stiffness response and also the damping provided by soil hysteresis.

The product of the analyses reported in this paper produced fundamentally-based p-y curves to represent the equivalent lateral soil reactions on the conductor. These equivalent p-y curves were appropriate for use in nonlinear dynamic analyses of soil-conductor interaction of the entire riser and conductor system.

The results published in this paper achieve a new level for realism and accuracy in the characterization of lateral soil/conductor interaction. This is demonstrated through fundamentally based analysis by achieving simultaneously analyses accurately tied to high quality soil test data, producing and results more consistent with centrifuge test data than have previously been published.

Introduction

The finite element method is experiencing increased use in offshore foundation engineering. The finite element method is a technique for solution of mathematical problems governed by systems of partial differential equations. It can produce close approximate solutions to problems with highly complex geometries, material behaviors and boundaries which would result in highly complex feildwise variations in the solution variables. With respect to the true solution to a properly posed boundary value problem in solid mechanics, taken as an ideal, one can generally obtain a finite element solution that is as close to the ideal as is desired, so long as one can work the problem within program capabilities and pay the required attention to minimizing any unavoidable errors. (See Templeton, 2002.)

The objective of the work reported here was to provide, via finite element analysis, fundamentally-based numerical results for the lateral interaction of well conductors with their surrounding soil. The work is important because the conventional methods for assessment of conductor lateral performance, i.e. the application of "p-y" curves as formulated in API RP2A (2000) for pile performance, may underestimate the stiffness of the soil-conductor interaction. The determination of more realistic p-y relations can enable elimination of undesirable over-conservatism in fatigue analyses of the riser/conductor systems for deep water . Jeanjean (2009) discusses the importance of a realistic and accurate assessment of this interaction. Figure 1 (from Jeanjean, 2009) shows a diagram of the arrangement of vessel, risers, conductors and soil in a deepwater floating production system.

The finite element analysis techniques and results described in this paper have been applied to four deep water offshore development projects. This paper discusses the applications to two offshore sites as well as comparison to experimental results from centrifuge model testing.