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Time Domain FE Seismic Analysis of Mat-Supported Jack-Up Structure on Soft Clay

J. S. Templeton, III, SAGE USA, Inc.

Abstract

This paper presents the methods and results of nonlinear of 3-D finite element analysis of the response of the Maleo Producer Mobile Offshore Production Unit to earthquake loading conditions. The analysis performed combined the determination local site response, the soil –structure interaction and the structural dynamic response to earthquake loading all in a single analysis. This advanced approach was motivated by the need to eliminate unwanted excess conservatism from the determination of response to severe earthquake loading conditions on a soft clay site.

The product of the analyses reported in this paper produced fundamentally based predictions of dynamic response of the subject structure to substantial earthquake loading conditions. The results obtained included sufficient response details to enable acceptable assessments of foundation and structural performance for the design earthquake conditions. The nonlinear dynamic analyses of this study produced results for the platform performance which were more realistic than those previously produced via more conventional analysis techniques. This resulted in the elimination of substantial amounts of unacceptable excess conservatism, and paved the way for certification of the structure.

To the author's knowledge, this is the first complete, combined, finite element analysis of site response, soil-structure interaction and structural dynamic response to earthquake loading yet published, not only for a mobile offshore production unit but indeed for an offshore structure of any kind. The demonstrated capability to perform this kind of analysis has the potential to revolutionize practices for the analysis of offshore structure response to earthquake loading.

Introduction

The Maleo Producer is a Bethlehem 250 mat supported jack-up unit that has been located offshore of Madura Island and converted to serve as a gas production facilities platform. (See Figure 1.) The site has generally soft clay soils and it is in region of significant earthquake activity. Previous studies had indicated that nonlinear, time domain analyses would be required in order to assess properly the dynamic performance of the platform under earthquake loading. This paper presents the results of 3-D nonlinear finite element analyses of the response of the structure, its foundation and surrounding soils, which analyses were performed to determine, in combined analyses, the detailed foundation dynamics, overall structural dynamics, dynamic response of the site soils and the soil-structure interaction.

The work documented in this paper includes: 1.) Application of finite element methods for 3-D nonlinear dynamic analysis of soil-structure interaction to incorporate a dynamic model of the structure including multidirectional earthquake loading capability, 2.) Performance of 3-D nonlinear dynamic analysis of soil-structure interaction for the response of the Maleo Producer platform structure and foundation to multidirectional earthquake loading for Strength Level Events (SLE) and Ductility Level Events (DLE), 3.) determination of multi-directional platform base motions for use as input motions in structural dynamics 4.) assessment of the platform foundation's ability to meet performance requirements for SLE and DLE earthquakes events.

Work Performed

Using the ABAQUS finite element program, SAGE USA developed 3-D models for the analysis of soil-structure interaction of the Maleo Producer platform under multi-directional earthquake loading. A full-space (360-degree) model was