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# Fluid-structure interaction for a jacket model structure with imposed displacement

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ABSTRACT

In this paper we describe a series of experimental tests performed with a $1:45$ scale jacket structure in a water basin. The model structure is assembled on a seismic table that performs a controlled motion, with amplitudes and frequencies that could correspond to actual earthquake conditions translated to the scale of the model. The structural response to the imposed displacement is analyzed in terms of the accelerations and reaction forces at the base of the structure, first in air and afterwards in water. The experimental measurements are equally correlated with the computer predictions of dynamic loading that have been obtained with a FEM commercial software - the ADINA.

KEY WORDS: Offshore jacket structure, earthquakes, fluid-structure interaction, displacement based design.

## INTRODUCTION

The analysis of the response of superficial structures to seismic activity has been the object of a large number of publications so far. Due to the scientific background of structural engineers, the effects of earthquakes on structures were initially analysed on the basis of quasi-static force models. Moreover, most of these works were limited to consider plane frame structures. Earlier research in this area, which includes the effect of soil-structure interaction with gravity platforms, has been conducted by Penzien (1976).

In the study of offshore structures under seismic action a special attention must be given to the interaction of the structure with the surrounding water. Indeed, intense ground shaking due to seismic activity may cause fixed offshore structures to undergo large deformations. As a result significant hydrodynamic forces will appear, directly associated with structural displacement and deformation. Hydrodynamic interaction with the environment, namely with waves, current and wind, gives rise to additional environmental loading on the structure. Non-linear effects play a very important role with this respect. Venkataramana & Kawano (1995) have studied the non-linear response of offshore structures in random seas, to inputs of earthquake ground motions. They take into account the hydrodynamic damping effects in the earthquake response. Their study shows that the hydrodynamic damping force is higher in waves and, furthermore, sea waves generally reduce the seismic response of offshore structures. Wave-current loadings on a jacket model structure have been thoroughly investigated elsewhere - Mendes et al. (2000).

To understand the behaviour of these structures under extreme environmental conditions we are, therefore, confronted with the analysis of problems of fluid structure interaction. Such problems involve a certain degree of complexity, since they demand the simultaneous use of adequate structural and fluid-flow models. Moreover, the choice of the mathematical representation of the fluid motion is crucial in terms of the selection of the most effective solution procedure - Rugonyi & Bathe (2001).

The design of jacket structures to sustain seismic loading has been traditionally worked out on a dual approach basis (see Barltrop & Adams, 1991). In the first approach the structure is designed for strength level earthquakes and should resist without significant damage. The second approach considers ductility level earthquakes and the platform is designed to survive seismic action without collapse, although local damage may occur. Bai & Pedersen (1991) developed an efficient time domain model, suitable to examine plastic deformations in earthquake response analysis of offshore jacket structures. The authors apply a FEM technique and the plastic mode method to earthquake response analysis of three-dimensional frame structures, including geometrical and material non-linearities.

However, earthquake design is ruled by displacements and deformations, rather than forces. Therefore, a more rational approach points to displacement based design methodologies, which require a precise knowledge of ground motion and soil-structure interaction. Displacement based design is an efficient tool in seismic analysis and design of structures. It focuses on displacement demand and damage, instead of force reduction. Although not yet incorporated in the state of practice in earthquake engineering, motion based design of structures has been the object of an intense research - Priestley et al. (2007).

Significant improvements in the design of seismic resistant structures have already been made in the last decades. Advances in numerical analysis of structures and carefully planned model tests have made an important contribution in this direction. This paper describes a series of experimental tests performed with a 1:45 scale model structure in a $10{,}3 \times 6{,}3 \times 2{,}9\ m$ water basin. The model is a $1{,}97\ m$ high tubular structure with 158 structural members, from which $1{,}47\ m$ are submerged underwater. The structure is assembled on a seismic table