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IMPACT OF NUMBER OF SELECTED RECORDS ON PROBABILISTIC SEISMIC PERFORMANCE OF OFFSHORE JACKET PLATFORMS

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Intensive seismic excitations might be considered as one of the most important loading cases imposed on offshore jacket platforms, especially for the ones located in regions of high seismic hazard. For evaluating probabilistic seismic performance of such intricate structures, Incremental Dynamic Analysis (IDA) could be employed as an efficient and applicable procedure. In order to conduct IDA, appropriate suites of ground motions are required that can be selected by different scenarios and methodologies. Furthermore, due to 3-dimensional numerical models of jacket platforms with a lot of nonlinear structural elements time history analyses of these infrastructures are truly time consuming. Hence, number of selected records can substantially change the computational costs of such assessments. This paper aims to study the effects of sample size of ground motions on probabilistic seismic performance of offshore jacket platforms. In this process, IDA has been performed considering a suite of 40 far field records (selected as explained in (Abyani *et al.*, 2017; Baker *et al.* 2011)) to model the aleatoric variability of the records. To this end, a numerical model of the investigated jacket platform is created in OpenSEES software.

The considered sample platform is located in the Persian Gulf in water depth of about 75 m. The platform comprises a 4-Ieg jacket supporting a wellhead deck, which was designed and analyzed in accordance with the requirements of the American Petroleum Institute. The jacket is approximately 84 m high from mud line up to top of the jacket. The lateral resisting systems of the jacket are the V-bracing and inverted V-bracing systems, which constitute a multistory X-bracing system at the second and fourth horizontal plan. The jacket is fixed to the ground by four through leg piles and the gap between pile and leg is filled with grout to provide a composite section named grouted section. All top side and jacket masses including structural and hydrodynamic masses have been considered as concentrated masses at the element joints. Accordingly, all top side and jacket loads are applied at joints as equivalent point loads.

Regarding the numerical model in OpenSEES software, a very well formulated nonlinear distributed plasticity beam-column element model (De Souza, 2000) based on the force formulation has been used in this paper to model the jacket and pile elements, which has profound advantages over the very common displacement beam-column element formulation. Two force-based elements are applied to model the brace elements and an initial camber equal to 1/1000 of brace length is assigned to the mid node of the brace. Utilizing this technique along with co-rotational formulation for coordinate transformation, makes it possible to accurately model the buckling and post-buckling behavior of braces. The soil-pile-structure interaction is simulated using beam on nonlinear Winkler foundation method. The p-y elements (Boulanger et al., 1999), the t-z elements and q-z elements are implemented to consider soil lateral behavior, skin friction behavior and end bearing reaction of near field soil response, respectively. To obtain the seismic responses of the structure, the aforementioned ground motion set recorded on rock site has been selected as the target record set. The changes in intensity and frequency content of the earthquake motions due to propagation of seismic waves in soil layers, known as site effects, have significant effects on structural responses during seismic excitations. One-dimensional site response analysis methods are frequently employed to estimate the effects of soil deposits on propagated ground motion records, which have less computational expenses than the soil continuum models. These effects can result in some amplification in responses which should be accurately calculated. The site-response analysis includes the following steps:

1) Selecting a set of ground motions which are recorded on rock sites. 2) Applying the rock-outcrop motions and computing soil layers deposit responses. 3) Imposing the responses of various soil layers to the fixed nodes of p-y near field elements. It is emphasized that the dynamic analysis should be conducted in two stages: firstly, the gravity analysis step applying the constant gravity and varying live loads. Secondly, after completion of the gravity step, the dynamic transient analysis should be carried out. The dynamic analyses seem to run more smoothly using the Krylov-Newton algorithm (implemented in this study) instead of the standard Newton algorithm.

Design and safe operation of offshore structures require a clear understanding of the Fluid-Structure Interactions (FSI) as it might have notable impact on seismic performance of the jacket platform, if the seismic excitation coincides with design wave and current load condition. However, most codes of practice like API, do not require or recommend simultaneous consideration of the above said extreme load conditions and instead, require separate consideration of the mentioned design wave and seismic loads (API RP2A-WSD). However, the effect of hydro dynamic forces and the hydro dynamic damping have been considered in the numerical model created in OpenSEES software, using Rayleigh proportional damping method. As mentioned earlier, in this investigation, a standardized ground motion set recorded on rock site is considered as the target suite and several sample sets of records with different sample sizes (7, 10, 15, 20, 25, 30, and 35) are selected from this target suite using Genetic Algorithm (GA). In fact, the purpose is to minimize the Root Mean Squared Error (RMSE) between the statistical properties (sample mean and sample standard deviation in logarithmic scales) of the response spectra of the target (denoted by the index T) and selected (denoted by the index S) record suites in the period range of interest that starts from 0.1 to 5 by an increment of 0.1s ($N = \frac{5-0.1}{0.1} + 1 = 50$) by GA with aggregation functions based on the following equation:

$$RMSE = \sqrt{\frac{1}{N}\left(w_\mu \sum_{i=1}^{N} (\mu_{T_i} - \mu_{S_i})^2 + w_\sigma \sum_{i=1}^{N} (\sigma_{T_i} - \sigma_{S_i})^2 \right)} \quad (1)$$

where μ_T and μ_S represent the logarithm mean of the spectral acceleration of the target population (SS=40) and the selected record suite, σ_T and σ_S are the logarithm standard deviation of the spectral acceleration of the target population and the selected record suite, respectively. Since the variation range of μ and σ are not the same, their influence on numerical value of RMSE can be substantially different. Consequently, w_μ and w_σ are defined as the constant weights of μ and σ to balance the effects of either one on RMSE. It should be noted that the constant values of w_μ and w_σ can be found and updated by try and error and their initial values equal unity. The results of the paper is supposed to quantitatively compare the probabilistic seismic performance of the sample platform based on each selected record suite with the ones based on the target suite. More specifically, it is intended to investigate the effect of number of selected records on IDA and summarized IDA curves, the lognormal hypothesis for the Intensity Measure (IM) values associated with onset of collapse by Anderson-Darling (AD) goodness of fit test (Anderson and Darling, 1954), collapse fragility curves and the RMSE values between the collapse fragilities based on the selected record suites and the target one.

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