Ductility demands in high-rise structures of special moment resistance frame (SMRF) due to soil-structure-pile interaction (SSPI)

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Studies to date have shown that the assumption of a rigid base for the analysis of low-rise structures with a rock bed is mostly acceptable. But for high-rise structures with flexible bases, the response structure can experience different conditions. Due to the simultaneous importance of the P-Δ secondary effect and the base foundation motion of high-rise structures with flexible soil and less attention of researchers to this issue, this study investigated the effect of soil-structure-pile interaction on response high-rise structure. 3D models of 15, 20, 25, and 30 Story building structures on group piles are used. The foundation soils are assumed to be 25 m layered sand. The site classification for the soil is type D (corresponding to the American Code of Minimum Design Loads and Associated Criteria for Buildings and Other Structures). For structural modeling, beam element is used for frames and piles. Shell elements are used for the rigid diaphragm and pile caps. A solid 3D element with 8 nodes is selected for direct finite element modeling of soils. Structural elements are assumed to behave linearly in general and nonlinearly in critical cases. Results show that the effects of soil-structure-pile interaction on response depend on the structure heigh, soil type, length pile, the distance between the piles, site distance from the fault, and frequency content of earthquake record. In general, two criteria for measuring the response of the structure, including the relative displacement of the stories and ductility demand of the structure have been considered. In the lower stories of the tallest building of this study, the results show that ductility demands of the structure and story drift under dynamic soil-structure-pile interaction due to the simultaneous increasing effect of the secondary P-Δ effect and the rotational movement of the piles, increased more than 40% and 20%. Target displacement of the tallest building roof under soil-structure-pile interaction also increased by more than 20%. All these cases show the importance of the soil-structure-pile interaction on structure response. The importance of pile behavior under the effect of seismic loads has also been investigated in this study. The results show that if the pushover curve of the piles under load remains in the elastic range, the relative displacement of lower stories of the structure will increase by more than 15%. In this study, to reduce the time of the results analysis process in high-rise structures, the polynomial regression equation is presented. This relationship is obtained according to the ductility demands curve of the structure. With this relationship, soil-structure-pile interaction is simulated and without Time-consuming non-linear analysis, the requirement to use soil-structure-pile is specified.

Keywords:

Ductility demand of high-rise structures, dynamic soil-structure-pile interaction, foundation rotation effect, secondary effect P-Δ.