DIRECT DISPLACEMENT-BASED SEISMIC DESIGN OF RC FRAMES WITH SOIL-STRUCTURE INTERACTION EFFECT

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During recent years, it has been determined by studies that the effect of the displacement on the performance of structure during earthquake is much more than the resistance of the structure. New seismic design concepts based on displacement have been proposed over the past two decades. Among them, Direct Displacement-Based Design (DDBD) is a performance-based seismic design method that has been proposed and well developed (Priestley et al., 2007). In this method, the behavior of a multi-degree-of-freedom (MDOF) system is approximated by an equivalent single-degree-of-freedom (SDOF) substitute structure. The SDOF structure has equivalent secant stiffness at maximum displacement response with an equivalent viscous damping. Assuming the target design displacement and evaluating the corresponding ductility, it is possible to determine the effective stiffness of the equivalent SDOF substitute structure. Then, the base shear force of the system is estimated and distributed along the primary MDOF frame (Mohebkhah and Farahani, 2016). Effect of soil-structure interaction (SSI) and the basic flexibility in changing structural responses, especially displacement response, is undeniable (Nazarimofrad et al., 2019). In general, considering the effect of soil-structure interaction changes the pattern of the displacement profile over the height of the structure. Changing of displacement profile causes the change of the demand displacement. Because this parameter is the main parameter in the DDBD method, the development and modification of this parameter can effect on performance controlling of the final designed structure. With this regard, one of the main challenges that have been present in the development of a DDBD method has been adding the soil-structure interaction effect. Despite attempts to add the effect of soil-structure interaction in the process of DDBD algorithm by (Lu et al., 2019), the sensitivity of this method to the variable parameter on the one hand and the change in the characteristics of responses due to the SSI effect on the other are the reasons that development of this method needs further study.

The shear beam model as shown in Figure 1 was proposed for modeling a multilayer soil behavior by (Idriss and Seed, 1968). In this model, the multilayer soil is characterized by lumping mass representing the mass of soil layer. Besides, the springs modeled as proportional to shear modulus for stiffness of soil layer. With this regards, shear beam model is modeled as a MDOF system.

Therefore, it can be said that despite the development of DDBD method for the differences of concrete frame structures, the development of this method for considering the effects of soil-structure interaction in which the soil and structure system, as an equivalent MDOF model, is more precisely shaped by the use of models such as the shear beam model, is still a study challenge. In fact, consideration of the SSI effect on the algorithm of the DDBD method by changing the final displacement of the structure will significantly affect the base shear design of the structure.

Therefore, the aim of present study is to evaluate the ability of DDBD method for designing RC frame with multilayer soil. To this end, four RC frames with a number of 3, 6, 9 and 12 stories with two layers of soils were designed using the DDBD method. Figure 1 shows the three-story RC frame structures selected for examination in this paper.

To survey the designed frames seismic behavior and also model their nonlinear behavior in structural analyses, it is necessary to model the nonlinear cyclic behavior of plastic hinges properly. In this regard, the model of RC model developed by using OpenSees software. The analyses showed a good correlation between the numerical and experimental results and hence validated the use of numerical' model to simulate the nonlinear behavior of RC frame in a finite-element model.

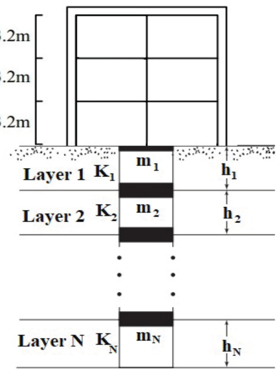

Figure 1. Numerical model of soil-structure interaction developed by shear beam theory.

In the following, the seismic behavior of four frames examined in this study is evaluated by nonlinear time history analysis. To this end, seismic behavior of the four RC frames with two different layers of soils was studied using nonlinear time-history dynamic analyses. Frames were modeled using OpenSees software as two-dimensional systems and layers of soil modeled by shear beam theory. Distributed plasticity fiber based model is used to describe material nonlinearity of the framing members. Seven suitable horizontal earthquake records were selected from the PEER NGA Database. Dynamic analyses were performed for the mentioned frames using the selected earthquake records.

The displacement history results at Figure 2 indicate that the DDBD can provide accurate control of deformations and therefore damage of structures.

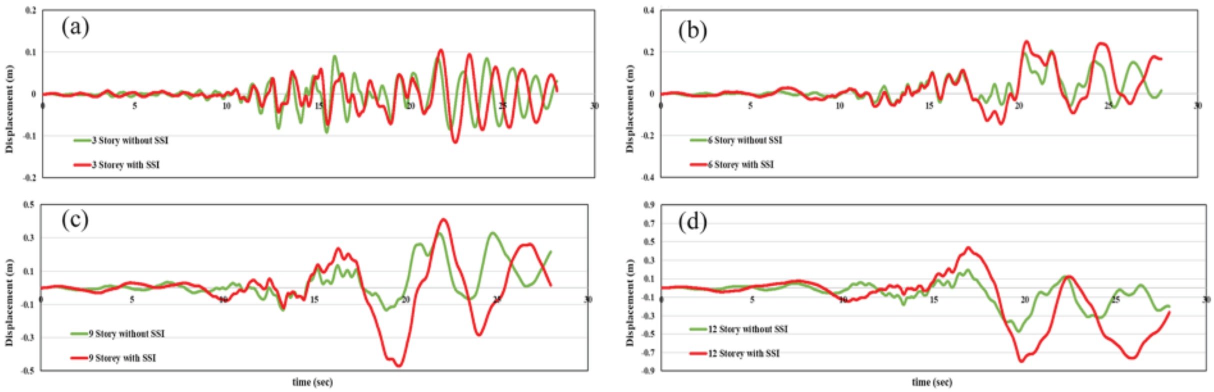

Figure 2. Displacement time history of the roof under the Landers Earthquake excitation with and without the SSI Effect: (a) 3-storey Frame, (b) 6-storey Frame, (c) 9-storey Frame, (d) 12-storey Frame.

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