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Assessment of Soil-Structure Interaction Effects on Seismic Behavior of Isolator and Mass Damper Equipped Buildings

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ABSTRACT

This study examines the impact of Soil-Structure Interaction (SSI) on the response of seismic-isolated buildings. Reinforced concrete office buildings with different heights are studied. The High Damping Rubber Bearing (HDRB), Lead Rubber Bearing (LRB) and Double Sliding Pendulum (DSP) isolators are utilized to isolate the buildings base. Also, Tunned Mass Damper (TMD) is implemented at top of buildings to improve building response. Soft, medium and hard soils are modelled using direct and substructure approaches. On the other hand, the influence of foundation type on buildings response is examined. The results indicate that considering SSI in soft soil reduces base shear of 6-storey building by 30%, but increases top storey displacement from 128 mm to 182 mm. It is found that base isolators are more efficient in reducing base shear (41-66%) than TMD (10-25%). Simple equations are suggested to calculate the fundamental period based on building height. The soil layer near the foundation, around 75% of the building height, primarily determines the building's response. Therefore, soil investigation can be restricted to a maximum depth of 75% of the building height. Finally, it is found that using pile foundation in soft soil alters building response to resemble that in hard soil conditions.

1. INTRODUCTION

The earthquakes occur due to the relative movements of the tectonic plates at their boundaries [1]. During an earthquake, huge amounts of energy are released. The size and severity of an earthquake are estimated by two important parameters: intensity and magnitude [2]. Earthquakes can be devastating to human life and economy as well. It is found that around 10,000 persons die every year due to earthquakes [3]. The earthquakes cannot be expected or avoided. It is essential to develop methods for protecting structures and preserving human life.

A modern method was developed to isolate the structures and their occupancy from earthquake hazard. Flexible materials are used at base of the structures called isolators [4]. Using these isolators increases the period of superstructure and reduces the induced forces and deformation in the structures [5-7].

Many types of isolators are available nowadays such as HDRB, LRB, DSP etc. These isolators showed valuable efficiency in improving the seismic response of structures. On the other hand, a tuned damping can be added to structures using Tuned Mass Damper (TMD).

Many studies on seismic isolated structures often neglect the influence of soil-structure interaction and foundation type. This may lead to inaccurate assessments of base isolation systems, potentially diminishing their efficiency, particularly for structures on deformable soil [8, 9]. Therefore, the SSI should be considered to understand the real behavior of structure [10].

After 1971, SSI was given seriously attention and many research has investigated the importance of SSI for both fixed and isolated base structures [11]. Spyrakos et al. [12] revealed the importance of considering the SSI on the response of base isolated buildings. The study showed that the effect of SSI on system damping is small where the latter is influenced by the isolation system. Al-Jubair and Al-Mosawi [13] showed that considering the supporting soil has a negligible effect on base shear of base isolated structures. Bandyopadhyay et al. [14] studied the effect of SSI on fixed base and base isolated 3-storey reinforced concrete building. A dynamic analysis for fixed base building and building founded on soft soil was conducted by Kabtamu et al. [15]. The study depicted that considering SSI reduces the base shear but the inter storey drift will be increased. The influence of soil condition on multi-storey building with raft foundation was proven by Abdel Raheem et al. [16]. They found an inverse relationship between soil stiffness and the fundamental period of building. Soft soil gave higher storey displacement. Spyrakos et al. [17] showed that considering SSI is significant for light structures founded over low stiffness soil stratum. Bagheri et al. [18] carried out numerical simulation for structure with pile raft foundation to investigate the effect of soil pile interaction. Forcellini [19] showed that beneficial effects of base isolation systems are highly reduced when the structure located over deformable soil and SSI is considered. Edip et al. [20] showed