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Seismic Response of Structure Equipped with Lead Rubber Bearing Considering SSI

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Abstract: *This study investigated the effect of soil structure interaction on the response of base isolated building. Seismic isolation can significantly reduce the induced seismic loads on a relatively stiff building by introducing flexibility at its base and avoiding resonance with the predominant frequencies of common earthquakes. To provide a better understanding of the movement behavior of structure during earthquake , this study analyzed the response of multi-story reinforced concrete (RC) building which is base isolated by lead rubber bearings (LRBs) is compared with the seismic response of the same structure by considering the effect of soil-structure interaction.Nonlinear dynamic analyses are performed for base isolated multi-story RC structures.The desire is to determine whether the effects of soil–structure interaction increase or decrease the response of the isolator and of the structure.Numerical results suggest that the seismic response of a structure resting on an inelastic base isolation system may be larger when the flexibility of the soil is considered than the 8corresponding response obtained by ignoring the effects of soil structure interaction.*

I. Introduction

For seismic design of structures, the traditional method i.e., increasing stiffness, strength, and ductility of the structures has been in common use. Therefore the dimensions of structural members and the consumption of material are expected to be increased which leads to higher cost of the building as well as larger seismic responses due to larger stiffness of the structures. To overcome these disadvantages, a new concept has introduced in structural engineering, for seismic design i.e., base isolation. Seismic base isolation is a method in which the structure is separated from from its foundation by introducing a suspension system between them.

Inertial forces causes due to earthquake are directly proportional to the mass of the structure and the ground acceleration. So increasing ductility or elastic strength of building is conventional method. But in base isolation, it reduces the seismic demand instead of increasing the capacity. Seismic base isolation of structures such as multi-story buildings, nuclear reactors, bridges and liquid storage tanks are designed to preserve structural integrity and to prevent injury to the occupants and damage to the contents by reducing the earthquake induced forces and deformations in super structure. This is a type of passive vibration control. The performance of these systems depends on two main characteristics:

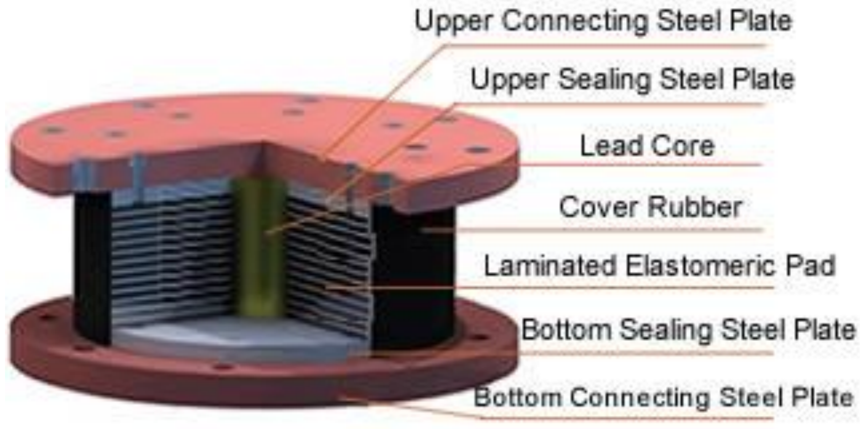
1. The capacity of shifting the system fundamental frequency to a lower value, which is well remote from the frequency band of most common earthquake ground motions.
2. The energy dissipation if the isolator.

The common practice usually ignores effects of SSI on seismic behavior of base isolated structures, accounting on the flexibility of base isolated buildings, despite, the recent studies on the base isolated bridges and structures have shown the effectiveness of SSI on seismic responses of the systems. Hence not only for the seismic design but also from economical aspects, SSI might be necessary to be considered in the design of base isolated building. The coupled effect of SSI and the base isolation on structure has gained the interest of a number of researchers during the recent years .

Lead Rubber Bearing

Lead rubber bearing or LRB is a type of base isolation employing a heavy damping. It was invented by William Robinson, a New Zealander. Heavy damping mechanism incorporated in vibration control technologies and particularly in base isolation devices, is often considered a valuable source of suppressing vibrations thus enhancing seismic performance. It consists of a laminated rubber and a steel flange plates for mounting to the structure. The rubber in the isolator act as a spring. It is very soft laterally but very stiff vertically. The high vertical stiffness is achieved by having thin layers of rubber reinforced by steel shims. These two characteristics allow the isolator to move laterally with relatively low stiffness yet carry significant axial load due to their high vertical stiffness.

Lead rubber bearing, applied to building and bridge constructions, is a practical and cost-effective choice for seismic isolation. It is composed of laminatedelastomericbearing pad, top and bottom sealing & connecting plates and lead plug inserted in the middle of the bearing as shown in the following picture.



During the earthquake, the un-isolated building will vibrate back and forth in varying directions due to the inertial forces and result in deformation and damages of the building. In contrast, the base isolated building will also displace but remains its original shapes and avoid damages - that is because the lead rubber bearing effectively dissipates the inertial force upon the building, extends the building's period of vibration and decrease the acceleration of the building.

The lead plug will slid with laminated rubber during earthquake but convert this energy of movement to heat so that it efficiently reduces the inertial force upon the building, which slow the vibration of the building. Meanwhile, the rubber part will preserve its original shape due to high elasticity.

LRB is modelled as non- linear element by some parameters.

Post yield stiffness – Kp

Initial stiffness – Ku

Yield strength – Q

Post yield stiffness ratio - $\propto$

The post elastic stiffness is obtained by Naeim and Kelly

$$Kp=\frac{GAb}{T}$$

Where, A_b - Area of rubber

T - Rubber thickness

G - Shear modulus of rubber

The effective stiffness K_{eff} of LRB in terms of Kp, Ku and Q is given by

$$K_{eff} = K_p + \frac{Q}{D}$$

Where, D - Design displacement

Effective stiffness of isolation is mostly designed in such a way that to give considered value of isolator period , T is given by

$$T = 2\pi\sqrt{\frac{M}{K_p}}$$

Where, M - Total mass

$$Q = \frac{\pi\beta_{eff} K_p D^2}{(2-\pi\beta_{eff})D - 2Dy}$$

Where ,Dy - Yield displacement

Soil Structure Interaction

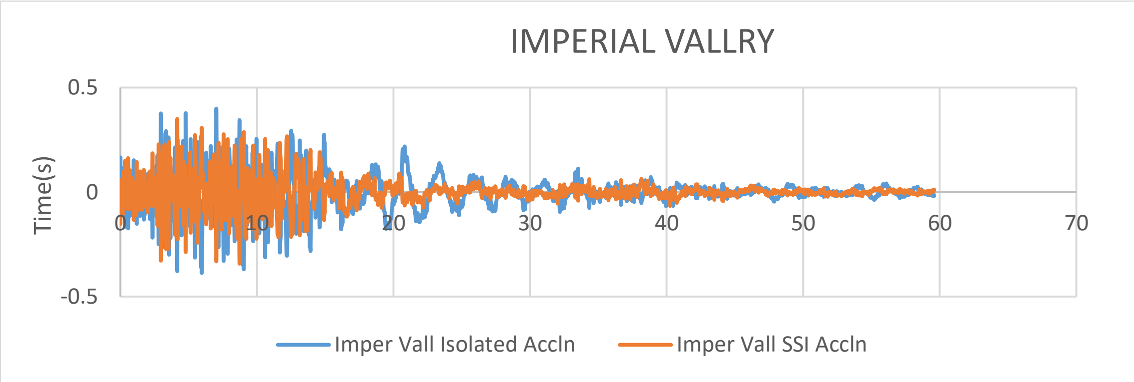
The process in which the response of the soil influences the motion of the structure and the motion of the structure influences the response of the soil is termed as **soil-structure interaction (SSI)**.

When a structure is subjected to an earthquake excitation, it interacts with the foundation and the soil, and thus changes the motion of the ground. Soil-structure interaction broadly can be divided into two phenomena: a) kinematic interaction and b) inertial interaction. Earthquake ground motion causes soil displacement known as free-field motion. However, the foundation embedded into the soil will not follow the free field motion. This inability of the foundation to match the free field motion causes the kinematic interaction. On the other hand, the mass of the superstructure transmits the inertial force to the soil, causing further deformation in the soil, which is termed as inertialinteraction.

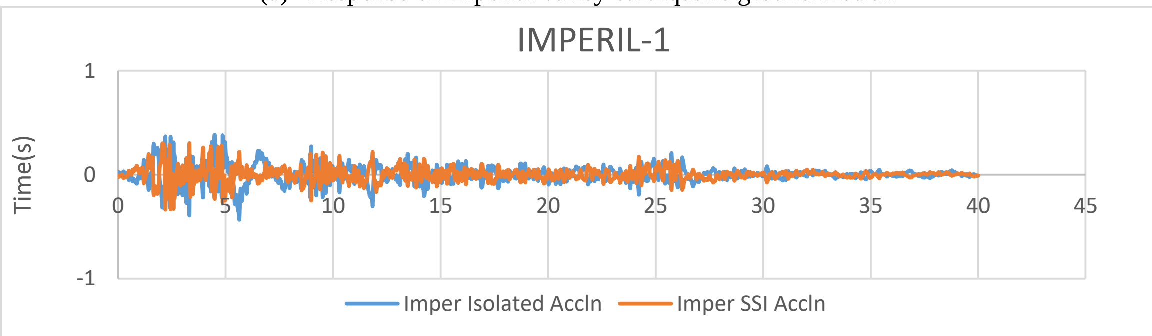
Structural Properties Of Model

FLOOR	FLOOR MASS (Kg)	STORY STIFFNESS (KN/m)	DAMPING EFFECT (Kg/s)
Base	m_0 = 61200	K_0 = 2129.8	C_0 = 69938
1	m_1 = 53073	K_1 = 101196	C_1 = 348140
2	m_2 = 53073	K_2 = 87279	C_2 = 301380
3	m_3 = 53073	K_3 = 85863	C_3 = 296180
4	m_4 = 53073	K_4 = 74862	C_4 = 259810
5	m_5 = 53073	K_5 = 57177	C_5 = 197450

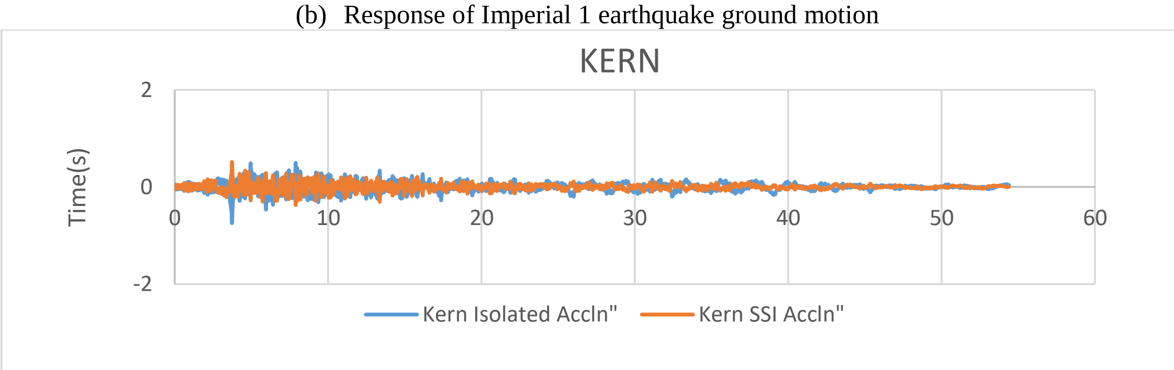
II. Results And Discussion



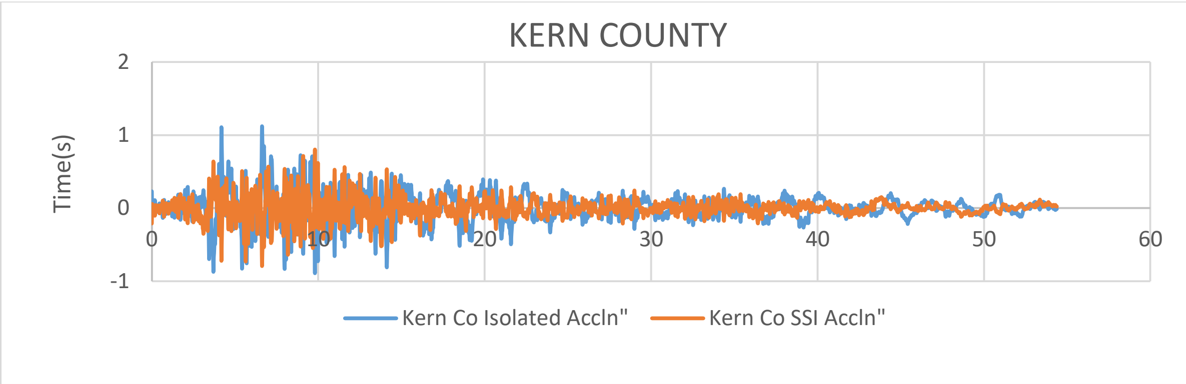
(a) Response of Imperial valley earthquake ground motion



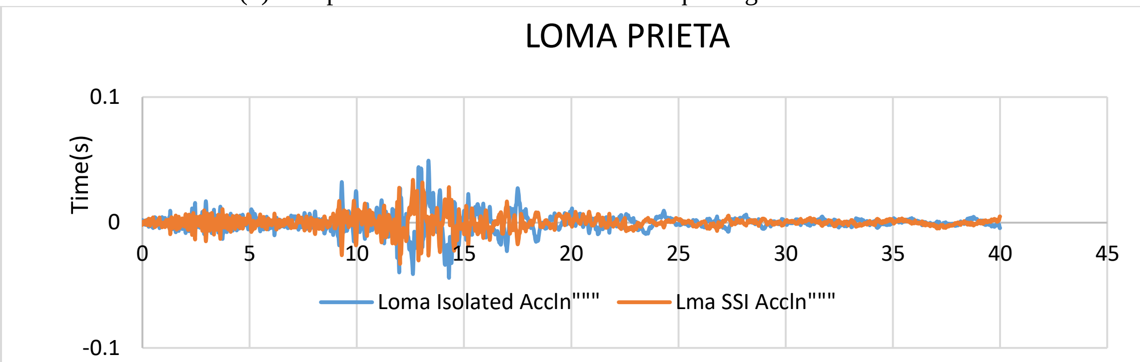
(b) Response of Imperial 1 earthquake ground motion



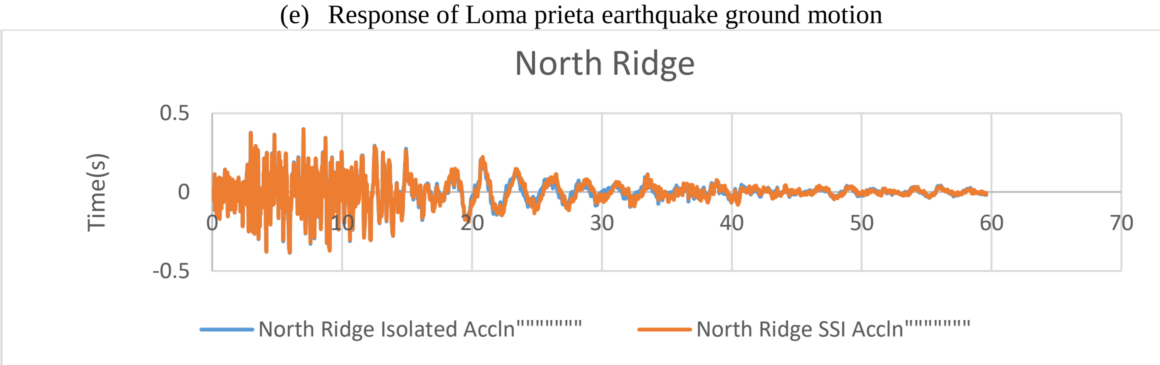
(c) Response of KERN 2 earthquake ground motion



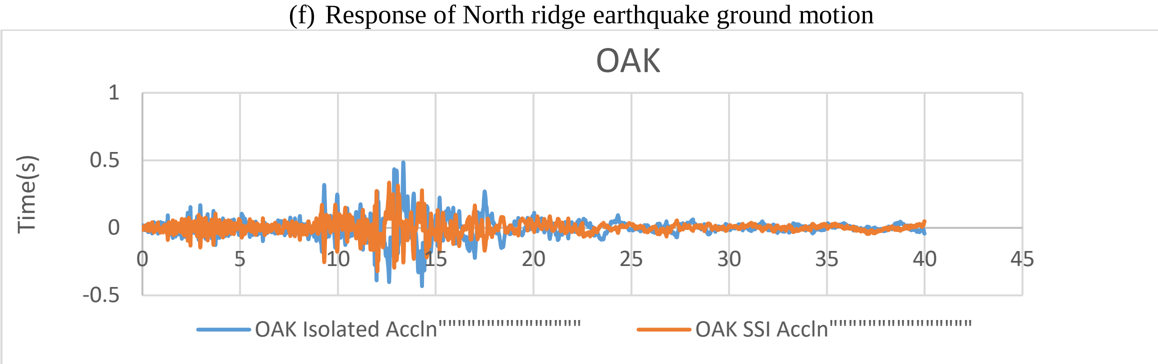
(d) Response of KERN COUNTY earthquake ground motion



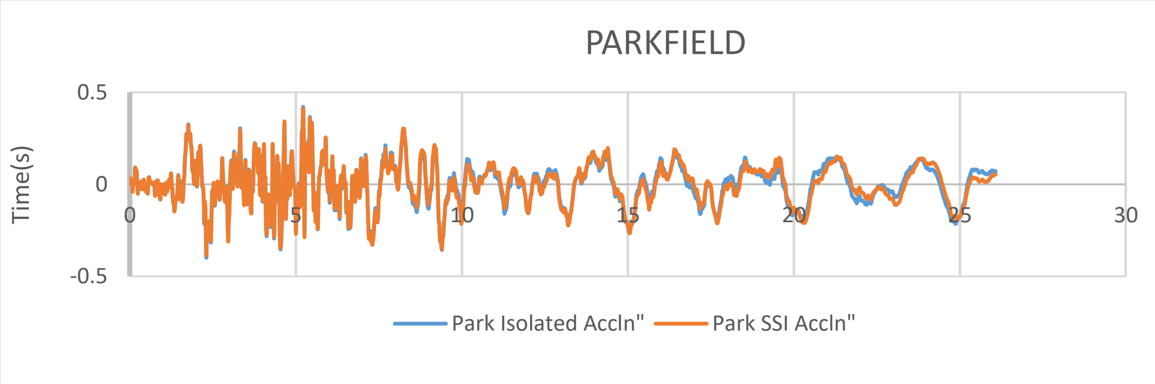
(e) Response of Loma prieta earthquake ground motion



(f) Response of North ridge earthquake ground motion



(g) Response of OAK earthquake ground motion



(h) Response of Parkfield earthquake ground motion

The study of seismic response of base isolated structure with and without SSI is presented in above figures. Various time histories are used to study the effect SSI on base isolated structure. The allplotted figures show the time period on left structure and acceleration on right structure. From this study, it is observed that acceleration of structure has reduced after considering the SSI effect but it is not marginal effect.

III. Conclusion

A comprehensive study to look at the effect of soil structure interaction on seismic isolated structure has been carried out. MDOF structure is modelled in SAP 2000 by using lead rubber bearing and without considering SSI effects nonlinear analysis has done for eight time histories. Again the same model has analyzed considering the SSI effects. It has found that there is considerable reduction in ground acceleration .

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