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STUDY ON SOIL STRUCTURE INTERACTION AND BASE ISOLATED SYSTEM FOR SEISMIC PERFORMANCE OF STRUCTURES RESTING ON DIFFERENT TYPES OF SOILS

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ABSTRACT

The conventional approach to seismic resistant design is to incorporate adequate strength, stiffness and inelastic deformation capacity into the building structure so that it can withstand induced inertia forces. This was with the presumption that during strong ground motion, whenever inertia forces exceed their design earthquake levels, the structure will dissipate this excess energy through deformations at predefined locations scattered over the structural framework. It was observed that, even with members designed for ductility, the structures did not always perform as desired. It was realized that a design based only on the principle of incorporating ductility as a safeguard against seismic effects needs a critical review. Engineers came up with the innovative idea of introducing a flexible medium between supporting ground and the building, thereby decoupling the structure from the energy rich components of seismic ground motion. This strategy came to be known as the Base Isolation method.

This thesis aims to determine the significance of using Base Isolation as a technique to withstand the seismic forces. This thesis also aims to show the importance to consider soil structure interaction rather than analyzing the structure as fixed base. The comparison is mainly done between structures with soil structure interaction effects and base isolated structures. The analysis is done using computer program SAP2000 v18. The method of analysis is Fast Nonlinear Analysis (FNA). There are 18 models which are analyzed in which there are symmetric and asymmetric in plan models, which are analyzed as fixed base models, models with the consideration of soil structure interaction, and models with base isolation (lead rubber bearing). These models are assumed to be resting on three soil types namely limestone, stiff clay, and loose sand. All the models are G+13 storey.

The results show that considering soil structure interaction effects for structures resting on medium and soft soils is more significant when compared to structures resting on hard soil because there is not much difference noticed in the response of structures with and without soil structure interaction effects resting on hard. Also base isolation system is best suited for structures resting on hard soil. The base shear, storey displacements, and torsion are reduced to a great extent..

Keywords:- *Base Isolation, Soil Structure Interaction, Fast Nonlinear Analysis.*

I. INTRODUCTION

An earthquake is the perceptible shaking of the surface of the earth due to underground movement along a fault plane or from volcanic activity. The severity of the shaking can range from barely felt to violent enough to toss people around.

An earthquake is the result of sudden release of energy in the earth's crust which creates seismic waves, and causes vibrations on the ground and structures resting on it. Depending on the characteristics of these vibrations, the ground may develop cracks, fissures and settlements. Shaking and ground rupture are the main effects, principally resulting in more or less severe damage to buildings and other rigid structures. The possible risk of loss of life adds a very serious dimension to seismic design, putting a moral responsibility on structural engineers. Objective of earthquake resistant design is to make such buildings that can resist effect of ground motion and would not collapse during the strong earthquake.

II. SOIL STRUCTURE INTERACTION

Normally, in the conventional method of the dynamic analysis of a building under seismic conditions, base of the structure is considered to be fixed and subjected to the free field ground motion. Such ground motion is that which is not influenced by the presence of the structure. This is applicable to rock formations because due to extremely high stiffness of rock, seismic wave motions is not constrained by the structure supported on it. Hence, it can be termed as free field motion.

However, if the structure is supported on soft soil of considerable thickness overlying the rock, then the structure and soil will interact with one another to influence the behaviour of both. This is termed as soil structure interaction. The motion of the soil influencing the response of the structure and the motion of the structure influencing the response of the soil is termed as soil structure interaction.

III. BASE ISOLATION

In recent times, many new systems have been developed, either to reduce the earthquake forces acting on the structure or to absorb a part of seismic energy. One of the most widely researched, implemented and accepted seismic protection systems is the base isolation system.

It is a system that may be defined as a flexible or sliding interface positioned between a structure and its foundation, for the purpose of decoupling the horizontal motions of the ground from the horizontal motions of the structure, thereby reducing earthquake damage to the structure and its contents. Base isolation is a passive control system, meaning, that it does not require any external force or energy for its activation.

An isolation system should be able to support gravity loads (including those due to vertical seismic acceleration), be sufficiently stiff to minimize displacements under repeated small magnitude lateral loads such as those due to wind, be highly flexible to absorb the energy during strong motion earthquakes and possess capability to self-centre after an earthquake event.

IV. OBJECTIVE OF THE STUDY

- •To study the response of structures for soil structure interaction effects resting on different types of soils subjected to seismic effects.
- •To study the response of structures for base isolated system resting on different soils subjected to seismic effects.
- •To compare the response of structures for soil structure interaction effects & base isolated system resting on different types of soils.

Scope Of The Study

This dissertation deals with analysis of 18, G+13 storey models which are symmetric and asymmetric in plan. Out of these 18 models, 6 are fixed base models, 6 are models with the consideration of soil structure interaction, and 6 are base isolated models. Lead rubber bearing is used as base isolator for the models. Three soil types are used for analysis namely limestone, stiff clay, and loose sand. Three parameters used for the comparison in the response of models are base shear, storey displacements, and torsion. The analysis is performed using the computer program SAP2000 v18.0.1 and the method of analysis is fast nonlinear analysis

V. LITREATURE REVIEW

Subramani et al.(2014) studied the “Earthquake Analysis Of Structure By Base Isolation Technique In SAP”. The objectives were to study the effectiveness of isolated base structures over fixed base structure in terms of immediate occupancy and life safety by pushover analysis and to compare the storey drifts of both the structures. Their case study description is as follows:

The analysis was done using computer program SAP2000. Two G+8 structures were analysed, one fixed base and another isolated base on soft soil.

Dia Eddin Nassani and Mustafa Wassef Abdulmajeed (2015) studied the effectiveness of "Seismic Base Isolation In Reinforced Concrete Structures". Their Objective was to study the effectiveness of isolated base(hdr) structures over fixed base structures. The analysis was performed in SAP2000 following time history analysis using el-centro earthquake data. 4 structures were analysed in which two are symmetrical and two are asymmetrical in plan. The case study description is as follows:

VI. METHODOLOGY

Fast nonlinear analysis (FNA) is a modal analysis method useful for the static or dynamic evaluation of linear or nonlinear structural systems. Because of its computationally efficient formulation, FNA is well-suited for time-history analysis. The accuracy of FNA depends upon the sufficiency of suitable mode shapes, similar to how direct integration requires small enough time steps to accurately characterize dynamic behaviour. In FNA method, damping is handled by limiting the proportional damping at the frequency extremes to 0.99995 to that of critical.

Since FNA is an accurate and efficient analysis method, it may be worthwhile to apply this technique to a series of models which simulate variable computational scenario. For example, foundation springs (when considering soil structure interaction, the stiffness of foundation is calculated and assigned in the form of springs in the software and substructure may be included, then omitted, to provide a comparison study. Fast nonlinear analysis (FNA) may be implemented within SAP2000.

VII. LEAD RUBBER BARING ISOLATION

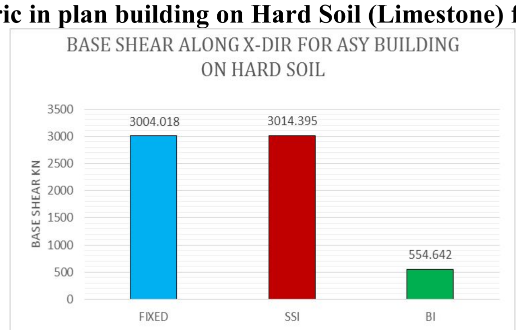
Lead rubber bearing base isolators are those which consists of layers of natural rubber vulcanized and bonded to thin stainless steel plates under heat and pressure. Steel plates prevent bulging of rubber under vertical load and also provide large vertical stiffness to support heavy gravity loads.

Central lead plug is force fitted into a preformed hole at the centre. Rubber provides adequate horizontal flexibility to sustain large strains during a major earthquake coupled with the ability to generate the much desired restoring force.

On the other hand, the lead plug provides higher initial stiffness and hysteresis damping to deal with low strains caused by wind force.

VIII.RESULT & DUSCUSSION

- **Base Shear for Asymmetric in plan building on Hard Soil (Limestone) for X-direction**



- **Base Shear for Asymmetric in plan building on Soft Soil (Loose Sand) for X – direction**

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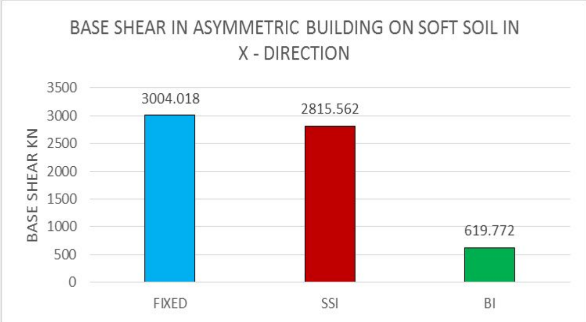
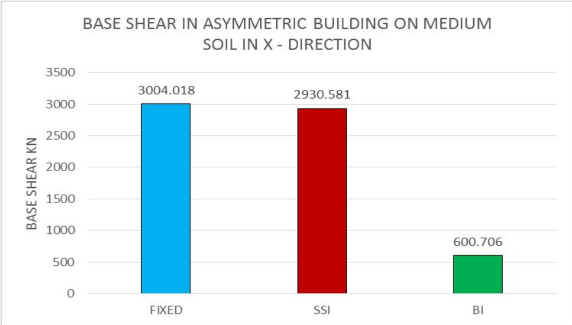
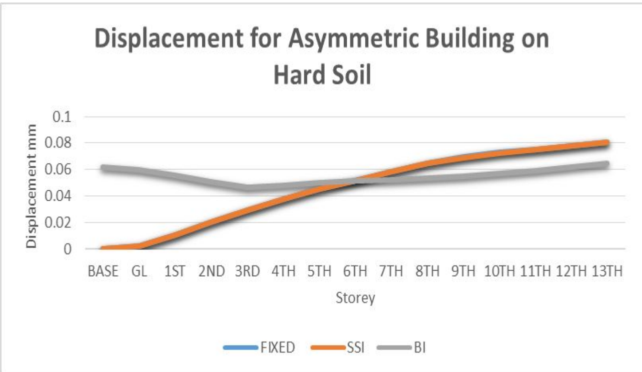


- **Base Shear for Asymmetric in plan building on Medium Soil (Stiff Clay) for X – direction**



Storey Displacements

- **Storey displacements for Asymmetric and symmetric in plan buildings resting on limestone in x – direction**



Storey	Fixed	SSI	BI
Base	0	8.19E-07	0.061579
G.L.	0.002167	0.002171	0.059715
1st	0.010616	0.010622	0.055539
2nd	0.020292	0.020299	0.050517
3rd	0.029478	0.029484	0.046537
4th	0.037707	0.037712	0.048256
5th	0.044915	0.044917	0.049779
6th	0.051322	0.051284	0.051153
7th	0.058555	0.058513	0.052436
8th	0.064515	0.06447	0.053681
9th	0.069164	0.069116	0.055101
10th	0.072613	0.072564	0.056769
11th	0.075038	0.074987	0.058923
12th	0.077678	0.077727	0.061504
13th	0.080623	0.080674	0.064302

- **Storey displacements for asymmetric in plan buildings resting on stiff clay in x-direction**

Storey	Fixed	SSI	BI
Base	0	0.000817	0.061298
GL	0.002167	0.003332	0.059325
1st	0.010616	0.011123	0.055094
2nd	0.020292	0.020407	0.050121
3rd	0.029478	0.030139	0.044537

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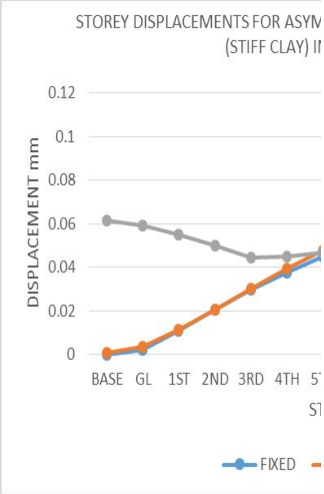
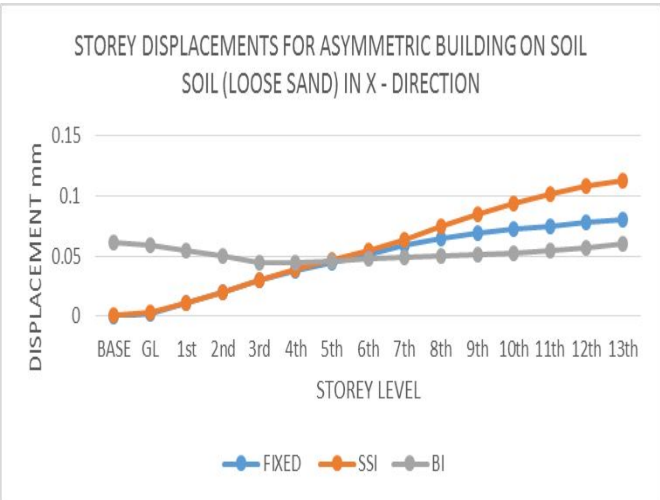


4th	0.037707	0.039314	0.044915
5th	0.044915	0.047468	0.046528
6th	0.051322	0.054675	0.047971
7th	0.058555	0.062038	0.049289
8th	0.064515	0.071772	0.050543
9th	0.069164	0.081626	0.051926
10th	0.072613	0.090561	0.053484
11th	0.075038	0.098147	0.0554
12th	0.077678	0.104067	0.057768
13th	0.080623	0.108302	0.060334

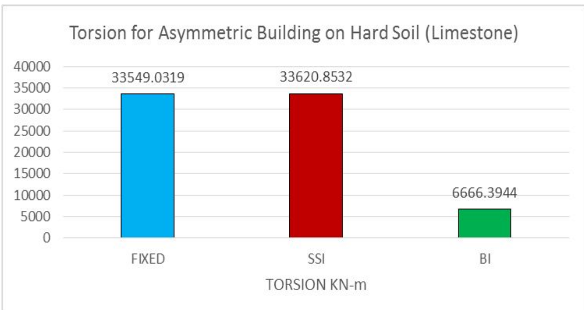
- **Storey displacements for asymmetric in plan structures resting on soft soil (loose sand) in x - direction**



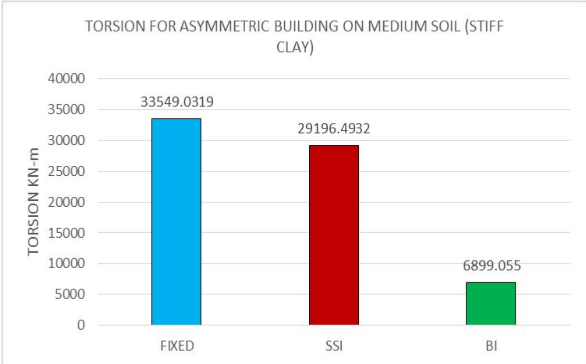
Storey	Fixed	SSI	BI
Base	0	0.000883	0.061111
GL	0.002167	0.003188	0.059139
1st	0.010616	0.010736	0.054895
2nd	0.020292	0.019916	0.049944
3rd	0.029478	0.029686	0.04438
4th	0.037707	0.03885	0.04434
5th	0.044915	0.047049	0.045964
6th	0.051322	0.054578	0.04741
7th	0.058555	0.063815	0.048729
8th	0.064515	0.07451	0.049967
9th	0.069164	0.08468	0.051327
10th	0.072613	0.093917	0.052608
11th	0.075038	0.101799	0.054686
12th	0.077678	0.10803	0.056986
13th	0.080623	0.112554	0.060593

IX. TORSION

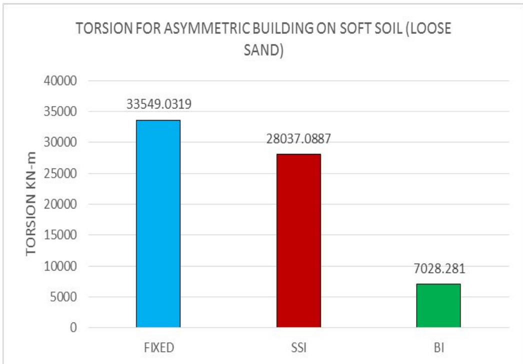
- **TORSION FOR ASYMMETRIC IN PLAN STRUCTURES RESTING ON LIMESTONE**



- **TORSION FOR ASYMMETRIC IN PLAN STRUCTURE RESTING ON STIFF CLAY**



- **TORSION FOR ASYMMETRIC IN PLAN STRUCTURE RESTING ON LOOSE SAND**



X. CONCLUSIONS

General Conclusions

After the analysis was carried out, and the results were compared, it is found that considering soil structure interaction for structures resting on medium (stiff clay) and soft soils (loose sand) is more significant when compared to structures resting on hard soil (limestone) as there is not much difference in the response of structures resting on hard soil with and without the consideration of soil structure interaction.

- Base isolation system is found to be most effective for structures resting on hard soil (limestone) when compared to structures resting on medium soil (stiff clay) and soft soil (loose sand).

Specific Conclusions

- Through the comparison in the response of structures for soil structure interaction effects and base isolation system, it is found that:

- The base shear have reduced for base isolated structures compared to structures with soil structure interaction effects by 82% on limestone, 80% on stiff clay, and 79% on loose sand.

- The storey displacements have reduced for base isolated structures compared to structures with soil structure interaction effects by 22% on limestone, 43% on stiff clay, and 45% on loose sand.

- The torsion for base isolated structures reduced when compared to structures with soil structure interaction effects by 81% on limestone, 76% on stiff clay, and 75% on loose sand.

Scope for further study

• The effectiveness of base isolation technique can be checked on different gradients of sloping ground differing the number of storeys on different soil strata.

• Base isolation along with different bracing systems could be used to further minimise the storey deflections.

• Base isolation could be implemented on vertical irregular and mass irregular buildings on different soil strata.

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