EFFECTIVENESS OF BASE ISOLATOR IN HIGH RISE BUILDING FOR DIFFERENT SOIL CONDITIONS USING FEM

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***Abstract*: The estimation of earthquake motions at the site of a structure is the most important phase of seismic design as well as retrofit of a structure. In classical methods used in structural analysis, it is assumed that, the motion in the foundation level of structure is equal to ground free field motion. This assumption is correct only for the structures resting on rock or very stiff soils. For the structures constructed on soft soils, foundation motion is usually different from the free field motion and a rocking component caused by the support flexibility on horizontal motion of foundation has been added. The phrase 'soil-structure interaction' may be defined as influence of the behavior of soil immediately beneath and around the foundation on the response of soil-structure subjected to either static or dynamic loads". A foundation is a means by which superstructure interfaces with underlying soil or rock. Under static conditions, generally only vertical loads of structure need to be transfer to supporting rock. In seismic environment, the loads imposed on a foundation from a structure under seismic excitation can greatly exceed the static vertical loads as even produce uplift; in addition, there will be horizontal forces and possibly movement at foundation level. The soil and rock at site have specific characteristics that can significantly amplify the incoming earthquake motions travelling from the earthquake source.**

***Index Terms*— Base Isolator, High Rise Building, Soil Interaction, Soft Soil Structure, Time History Analysis**

I. INTRODUCTION

In classical methods used in structural analysis, it is assumed that, the motion in the foundation level of structure is equal to ground free field motion. The estimation of earthquake motions at the site of a structure is the most important phase of seismic design as well as retrofit of a structure. This assumption is correct only for the structures resting on rock or very stiff soils. For the structures constructed on soft soils, foundation motion is usually different from the free field motion and a rocking component caused by the support flexibility on horizontal motion of foundation has been added.

Passive control systems have significant application to buildings, bridges and industrial plants. Seismic base isolation is the most developed system at the present time. The basic concept of seismic isolation is to reduce the response to earthquake motion by,

(i) Reducing stiffness,

(ii) Increasing the natural time period of system

(iii) Provision of increased damping to increase the energy dissipation in the system. The principal of seismic base isolation is based on decoupling of structure by introducing low horizontal stiffness bearing between the structure and foundation. The isolation decreases the frequency of overall building-isolation system. This low frequency system does not permits transmission of high frequency of earthquake motion to structure.

Consideration of earthquake ground motions, the way they propagate through the earth, their characteristics description at a certain location and methods for incorporating this information into engineering designs have been the subject of considerable research and interest so far. The energy released from a source mechanism will travel in the form of seismic waves through the rock formation where some energy absorption takes place. Some amount of energy is absorbed by isolators. Numerous studies on different earthquakes where site amplification caused substantial damage and collapse of many buildings are available. Observations made after the destructive earthquakes have shown a correlation between damage and local geology, for base isolated structures also.

The natural complexity in behavior of in-situ soils has led to development of many idealized models of soil behavior based on classical theories of elasticity and plasticity for analysis of Soil-foundation interaction problem.

In the present work, two different storey structures are modeled with and without base isolation for different soils. Both Response Spectrum and time history method are use for earthquake response. Koyna earthquake time history is used to find the response of structure. Stadd-Pro-2007 software is use for analysis of structure.

In normal dynamic analysis of building, the usual method of dynamic analysis is to determine the free field ground motion at the building assuming that the base is fixed. This may be true for building is founded on rock. However, if a base isolated building is founded on soft soil, the earthquake motion at base of building is not likely to be identical to the free field ground motions and structure will interact to create a dynamic system quite different from just free field ground motion.

The use of fix base model may not be able to take into account all of the possible modes of response such as deformation of the base of structure or rocking of structure.

Additionally, the period of vibration of structure may be very long because of interaction. If structure is base-isolated the change in the period may also affect the response of overall structure or its sub structure or components.

The influence of soil–structure interaction (SSI) and possible effects of building and foundation rocking can be examined by investigating the modal properties of the isolated technology beyond conventional solutions. Seismic isolation is a suitable technology for protection of a variety of buildings that have the requisite dynamic characteristics. Isolation technology has matured in recent years to highly dependable and reliable level.

II. Literature Review

Hamid Reza Tabatabaiefar, Ali Massumi (2010) As the Iranian seismic code does not address the soil–structure interaction (SSI) explicitly; the effects of SSI on RC-MRFs are studied using the direct method in this paper. Four types of structures on three types of soils, with and without the soil interaction, are modeled and subjected to different earthquake records. The results led to a criterion indicating that considering SSI in seismic design, for buildings higher than three and seven stories on soil with (shear wave velocity) Vs<175m/s and175<Vs<375 m/s, respectively, is essential. A simplified procedure has been presented, on the basis that lateral displacement increments could be applied to the fixed-base models using simple factors.

Eduardo Kausel (2010) Soil–structure interaction is an interdisciplinary field of endeavor which lies at the intersection of soil and structural mechanics, soil and structural dynamics, earthquake engineering, geophysics and geo-mechanics, material science, computational and numerical methods, and diverse other technical disciplines. Its origins trace back to the late 19th century, evolved and matured gradually in the ensuing decades and during the first half of the 20th century, and progressed rapidly in the second half stimulated mainly by the needs of the nuclear power and offshore industries, by the debut of powerful computers and simulation tools such as finite elements, and by the needs for improvements in seismic safety. The pages that follow provide a concise review of some of the leading developments that paved the way for the state of the art as it is known today. Inasmuch as static foundation stiffness is also widely used in engineering analyses and code formulas for SSI effects, this work includes a brief survey of such static solutions.

J. Yang, J.B. Li, G. Lin (2006) indicate that direct integration of the ground acceleration data provided for seismic soil–structure interaction analysis often causes unrealistic drifts in the derived displacement. The drifts may have a significant effect on large-scale interaction analysis in which the displacement excitation is required as an input. This paper proposes a simple approach to integration of the acceleration to acquire a realistic displacement–time series. In this approach, the acceleration data is firstly baseline-corrected in the time domain using the least-square curve fitting technique, and then processed in the frequency domain using a windowed filter to further remove the components that cause long-period oscillations in the derived displacement. The feasibility of the proposed approach is assessed using several examples and comparisons are made between the results obtained using the proposed scheme and those using other complicated procedures.

H.Yoshioka; J.C. Ramallo; and B.F.Spencer Jr (2002) states in this paper that one of the most successful means of protecting structures against severe seismic events is base isolation. However, optimal design of base isolation systems depends on the magnitude of the design level earthquake that is considered. The features of isolation system designed for an El Centro-type earthquake typically will not be optimal for a Northridge-type earthquake and vice versa. To be effective during a wide range of seismic events, an isolation system must be adaptable. To demonstrate the efficacy of recently proposed ‘‘smart’’ base isolation paradigms, this paper presents the results of an experimental study of a particular adaptable, or smart, base isolation system that employs magnetorheological ~MR! dampers. The experimental structure, constructed and tested at the Structural Dynamics and Control/Earthquake Engineering Laboratory at the Univ. of Notre Dame, is a base-isolated two-degree-of-freedom building model subjected to simulated ground motion. A sponge-type MR damper is installed between the base and the ground to provide controllable damping for the system. The effectiveness of the proposed smart base isolation system is demonstrated for both far-field and near-field earthquake excitations.

A. B. M. Saiful Islam1*, M. Jameel1, M. A. Uddin1 and Syed Ishtiaq Ahmad (2011) observes in this work that seismic base isolation is now a days moving towards a very efficient tool in seismic design of structure. Increasing flexibility of structure is well achieved by the insertion of these additional elements between upper structure and foundation as they absorb larger part of seismic energy. However in Bangladesh, this research is still young for building structures. Therefore, this is a burning question to design isolation device in context of Bangladesh. Effort has been made in this study to establish an innovative simplified design procedure for isolators incorporated in multi-storey building structures. Isolation systems namely lead rubber bearing (LRB) and high damping rubber bearing (HDRB) have been selected for the present schoolwork. Numerical formulation and limiting criteria for design of each element have been engendered. The suitability to incorporate isolation device for seismic control has been sight seen in details. The study reveals simplified design procedures for LRB and HDRB for multi-storey buildings in Bangladesh. The detail design progression has been proposed to be included in Bangladesh National Building Code (BNBC).

III. Objectives

1. To study the literature available regarding soil-structure interaction (SSI), base isolation and understanding the effects of both on structural performance.
2. To study the structure without considering soil-structure interaction.
3. To study the structure considering soil-structure interaction.
4. To study the performance of base-isolated structure considering soil-structure interaction.

5. To highlight the effect of SSI on base isolated structure.

IV. SYSTEM DEVLOPMENT

Material modeling

Soil – structure interaction plays an important role in the behavior of foundations. For structures like beams, piles, mat foundation and box cells it is very essential for consider the deformation characteristics of soil and flexural properties of foundations. It can be seen that when interaction is taken into account, the true design values arrived-at may be quite different from those worked out without considering interaction. In general in most of the case interaction causes reduction in critical design values of the shear and moments etc. However, there may be quite a few locations where the values show an increase. Because of these possibilities have their own roles to play in economy and safety of structure.

Several studies have indicated that the maximum bending moment in a foundation raft or beam could be substantially affected by interaction with superstructure. Reduction of 80% is reported in certain cases. The rigidity of foundation raft relative to soil is of extremely high values of bending moments in relative rigid rafts as compared to those in flexible rafts. An elasto-plastic analysis also indicates similar trend, although to a much lesser degree. An equal settlement is the severest cause for cracking and even failure of superstructures. On the other hand, rigidity of superstructure helps in reducing differential settlements. Of course to realize this, only interactive analysis has to be carried out.

V. PROBLEM STATEMENT

A G+10 model without using base isolator and with using base isolator is studied for soil structure interaction.

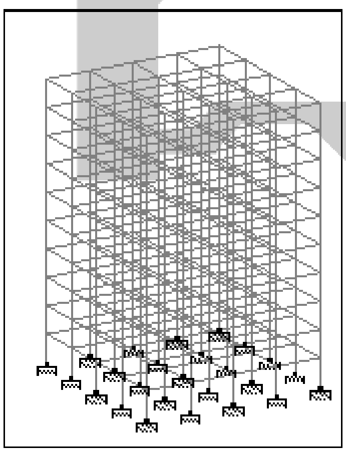


Fig. 1 Ten storey fix base building Structure

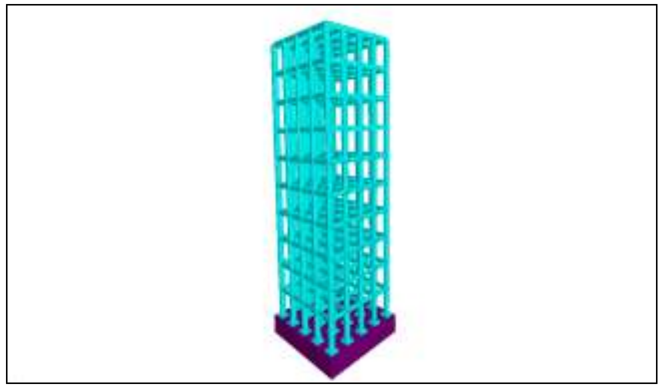


Fig. 2 G+10 Structure with base isolation founded on soil

Above figure shows the schematic representation of G+10 storey building.

The below table shows the data required for G+10 structure, also data assumed for the same structure.

Table 1 Data assumed for the analysis

Sr. No.	Properties	(G+10) Storey
1	Height of floor	3m
2	Slab thickness	120mm
3	Column size	300mm x 900mm
4	Beam size	230mm x 450mm
5	Material	M25 concrete and Fe415 steel
6	Dead Load	(a) Self weight of structure (Density = 25KN/sqm.) (b) Weight of infill (Density = 20KN/sqm.) (c) Floor Finish – 1KN/Sqm
7	Live Load	2KN/Sq.m
8	Earthquake data	IS 1893-2002. For time history analysis the Koyna earthquake data
9	Earthquake data	Zone: II Response Reduction factor: 5 Importance factor: 1.5 Damping Ratio: 0.05
10	Software for analysis	STADD-Pro-2007

A realistic dynamic model of soil requires the representation of soil stiffness, material damping, allowing for

strain dependence (non-linearity) and vibration of soil properties in three dimensions.
The soil may be modeled in following ways
(i) Equivalent static spring model
(ii) Elastic or viscous-elastic half space
(iii) Finite element modeling

It is convenient to model soil as finite element discrimination. Hence this model is utilized in the study.

Soil Type	G(kN/m^2)	E(kN/m^2)
Soft Soil	11500	32000
Medium Soil	21500	60000
Hard Soil	28500	80000

Table 2 Dynamic Properties of Soil

Soil is modeled as solid element in STADD. Solid block elements are eight node solid elements. All elements are connected to each other at nodes to act as soil mass. The reasons for taking solid block element is (i) it is easy to model (ii) properties remain same in all directions.

This paper is intended to show a summary of STAAD Pro07 capabilities to obtain results of finite element analyses as accurate as possible.

VI. RESULT

Base isolated structures resting on soil are significantly shown below figures. It can be further concluded from these figures that the displacement at the base isolation level being more results in reduction in the building deformation. In base isolated buildings with soft soil model, the deformation is less.

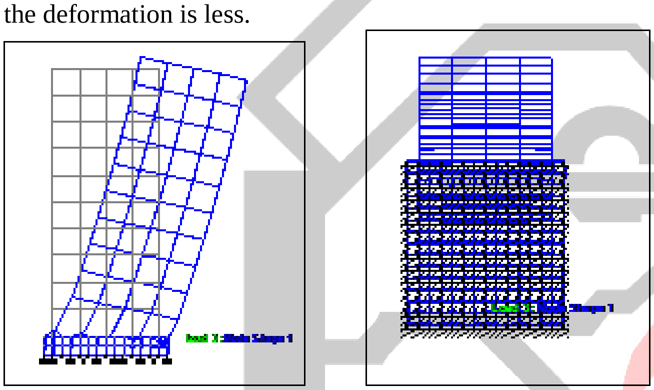


Fig.3 (G+10) on soft soil base with Isolated Building – Mode 1

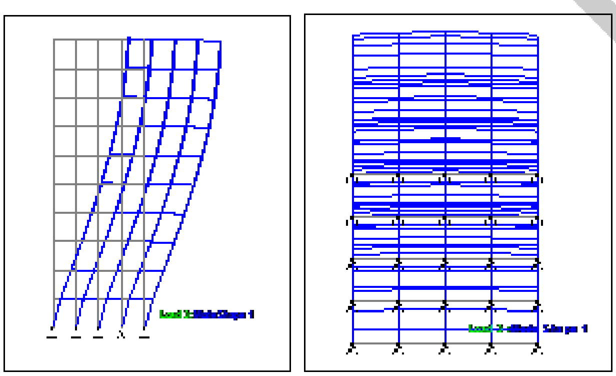
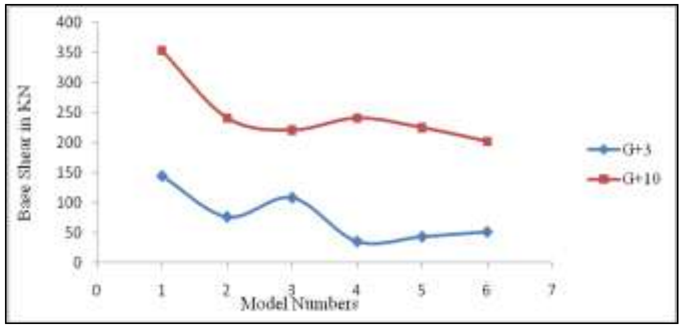
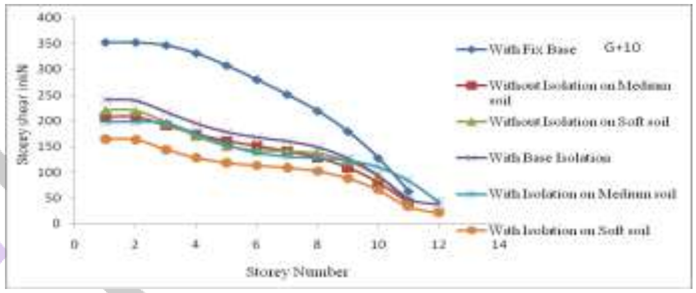


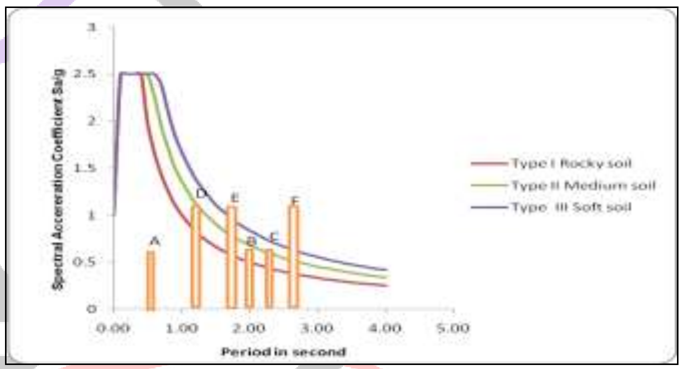
Fig. 4 (G+10) on Fix base without Isolated Building – Mode 1



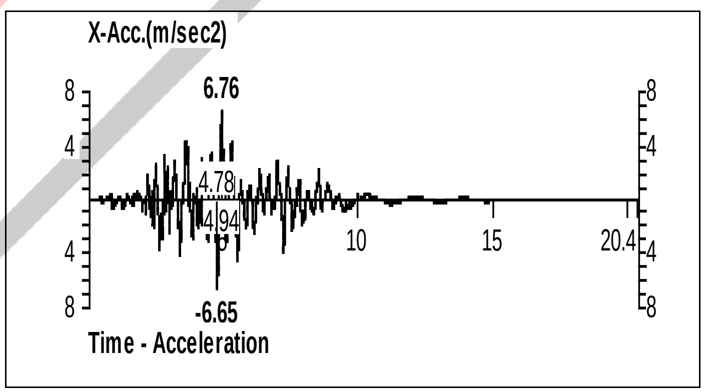
Graph 1- Model Number versus Base shear in kN



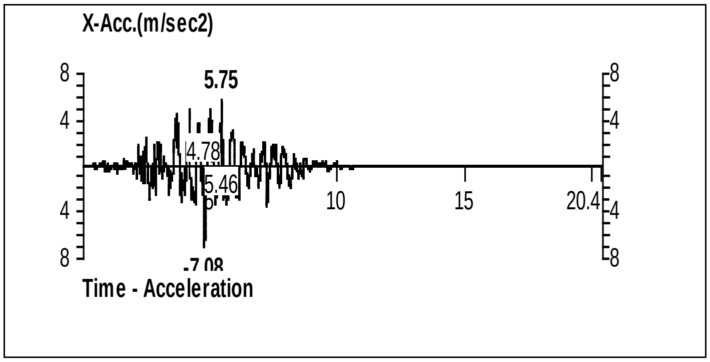
Graph 2- Storey and storey shear in kN (G+10)



Graph3- Response Spectra for Rock and soil sites as per IS 1893-(Part1)-2002



Graph 4- Time history response of acceleration for Koyna 1967 earthquake for (G+10) on soft soil without base isolation



Graph 5- Time history response of acceleration for Koyna 1967earthquake for (G+10) on soft soil with base isolation

VII. CONCLUSION

Analytical investigations have been carried out to study the behavior of base isolated structure founded on different types of soil considering the soil structure interaction. Based on this work following conclusions can be drawn.

- The time period of structure increases when soil structure interaction is considered on base isolated structure.
- The response quantities like displacements, acceleration and base shear are affected due to soil structure interaction. The responses of base isolated structure are amplified when soil behavior is taken into account in the analysis.
- The deformation in soil at isolation level is significantly affected, so soil structure interaction should be considered for base isolated structures, essentially when founded on soft soils.
- Effect of soil structure interaction is prominent in case of soft and medium soil with base isolation.

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