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

Suruchi Vadatile[1] Jawalkar G C[2]
[1]Student, Department of Civil Engineering, N B N Sinhgad college of Engineering, Solapur.
[2]Professor, Department of Civil Engineering, N B N Sinhgad college of Engineering, Solapur.
vadatilesuruchi@gmail.com[1] gcjawalkar.nbnscoe@gmail.com[2]

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— Elastic Methods of Analysis, Qualitative method, Analytical method, Seismic zone ETABS, SAP Software.

I. INTRODUCTION

1.1 General

High-rise buildings can be classified as residential or commercial. Now days, more and more complex high-rise buildings with various architectural feature and style are appearing. The degree of high-rise buildings indicates the economics and technological strength of a country. Most of the cities are dominated by high-rise building because of the growth of economy and population density. The influence of its tallness creates different conditions and difficulties in design, construction and operation. Therefore, a proper understanding of methods and techniques is required of the planning, design, construction and operation.

High-rise buildings should be designed to have a capacity to carry combined actions include permanent actions, variable actions and seismic actions at certain safety level and at certain degree of reliability. Therefore, proper account of actions, material properties, structural systems and method of analysis should be considered while designing the high-rise buildings. Nonlinear static analysis, or pushover analysis, has been developed over the past twenty years and has become the preferred analysis procedure for design and seismic performance evaluation purposes as the procedure is relatively simple and considers post elastic behavior. However, the procedure involves certain approximations and simplifications that some amount of variation is always expected to exist in seismic demand prediction of pushover analysis.

1.2 Push over Analysis

As the name states "Push - over", push the building until you reach its maximum capacity to deform. It helps in understanding the deformation and cracking of a structure in case of earthquake and gives you a kind of fair understanding of the deformation of building and formation of plastic hinges in the structure. It is a sort of approximate tool to understand your building performance.

The pushover analysis of a structure is a static non-linear analysis under permanent vertical loads and gradually increasing lateral loads. A plot of the total base shear verses top displacement in a structure is obtained by this analysis that would indicate any premature failure or weakness. The analysis is carried out up to failure, thus it enables determination of collapse load and ductility capacity.

1.3 Soil Structure Interaction

Most previous studies assume a fixed support between the structure and the soil and that neither the structure nor the soils affect one another. However, in reality, the soil and structure move independently of each other. An analysis should consider SSI, particularly in the construction of heavy and rigid structures. Soil environments may have undesired behavioral effects on structures, depending on the properties of the seismic waves. Therefore, the properties of the soil on which the structure is built are of great importance.

In a system exposed to a dynamic load, damping ratio (C) and stiffness (K) are the two main parameters that affect the displacement of the system. Thus, in the SSI analysis, modeling should take into account not only the elasticity module, Poisson ratio, density and shear wave velocity of the soil but also the damping ratio and stiffness values. Including these parameters is important when selecting the mathematical model to be used for the analysis. The studies conducted to date have attempted to simplify the properties of the soil, which is regarded as an unlimited environment, by idealized methods. Determining the dynamic properties of the soil-structure for a common system by analytical methods is not easy. Such properties can be analyzed using numerical methods (Kramer 2003).

Analysis and modeling of the dynamic SSI is started by using FEM. The direct method and substructure method are the two main solution methods for SSI. In the direct method, the structure and the soil beneath it are modeled together. In the substructure method, the soil-structure system is divided into two substructures, unlimited soil and nonlinear soil around the structure (Wegner 2005, Zhao 2009). In the direct method, the use of a well-established structure dynamic algorithm can solve SSI problems with the time history method (However, the radiation effect is not considered at each step in this method. Instead, these effects are considered in the frequency history in a multi-step method.). The direct method models and analyzes the soil-base-structure system in one step. As shown in Fig. 3, open field input motions are defined at the base and sides of the model. The response of the system affected by this motion can be formulated.

where u**ff (t) is the open field accelerations defined at the limit nodal points. The use of the direct method in SSI problems is only possible using a computer program that gives equal importance to both the soil and structure behavior simultaneously.

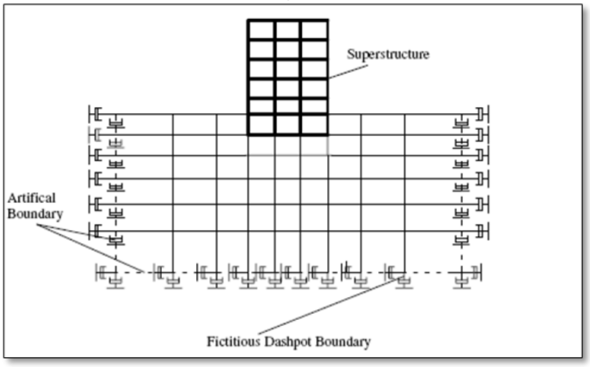


Figure 1.1 Direct method for SSI analysis

1.4 Modeling

The superstructure model used in the scope of the present study is a plane, three-spacing, 15-story, reinforced concrete frame that is 12 m in width and 45 m in height (Fig. 4). All of the beams are 30 × 50 cm and all of the columns are 40 × 40 cm in size. By changing the lateral stiffness characteristics of the HDRBs, three different base-isolated structure models are developed. The behaviors of these models are compared with the behaviors of the “without isolator” model. Characteristics of the HDRB used in this study are given in Table 1. The soft soil computer program models the two-dimensional shell as an element (Fig. 4).

The total width of the base model is determined as 144 m and the total depth as 50 m. The shell mesh size is dense in the structure base and its close surrounding; however, this mesh is sparse in the area away from the structure. The used mesh where the network range for 26 m, 74 m and 144 m are about 1 m, 2.5 m and 5 m, were chosen, respectively. Also in model fictitious dashpots were used as artificial boundary conditions. The connection between the soil and superstructure is established with the help of the base, specified as 1 m in thickness. The ground of the base model is fixed by the fixed supports. The horizontal limits of the soil are modeled as link elements. Link elements with the properties of the soil are placed on these points to prevent the seismic waves that

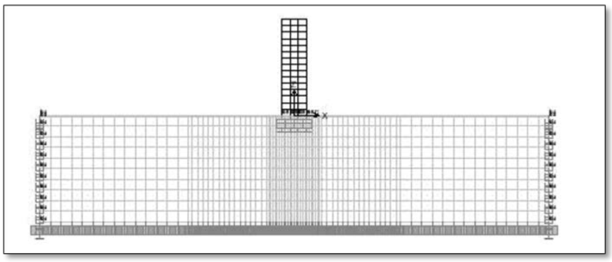


Figure 1.2 Base isolation model developed when considering SSI

1.5 Base Isolation

A system attached at base of a structure that controls the longitudinal and lateral movements of the structure is called Base Isolation.

1.5.1 Base Isolation Devices

Bearings are designed to transmit the vertical load and to dissipate energy through friction, viscous damping or hysteretic damping. Usually they are also intended to reduce or control the horizontal force and displacement demand.

A. Low and High Damping Laminated Rubber Bearings

In laminated rubber bearings, steel plates are inserted in a vulcanized piece of rubber to confine the rubber laterally and reduce its tendency to bulge, as shown in Figure . Hence, shims increase the vertical stiffness and improve stability under horizontal forces. This type of bearing shows a substantially linear response and the rubber properties control essentially the dissipation. Low dissipation rubber provides a linear force-displacement relation, capacities for medium seismicity areas range in the order of 200mm with ultimate capacities up to 300mm (as reported in Priestley et al. [2007]).

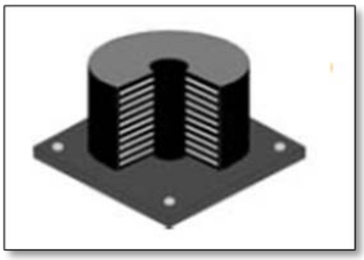


Figure 1.3 Laminated rubber bearing structure

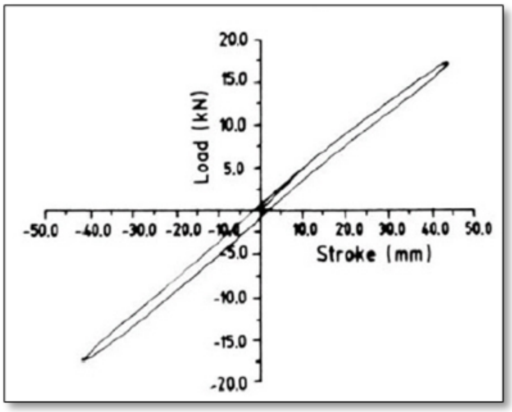


Figure 1.4 Laminated low damping rubber bearing (LDRB) force-displacement relation

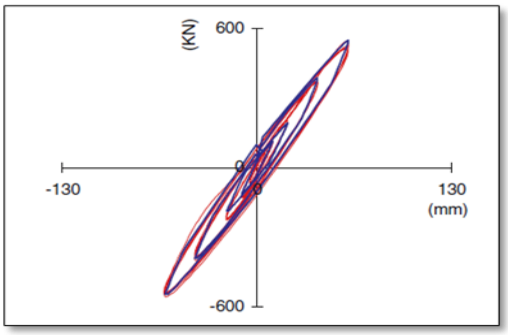


Figure 1.5 Laminated high damping rubber bearing (HDRB) force-displacement relation

viscous damping is of the order of 5% for normal rubber and in the order of 15%-20% for high dissipating rubber (Priestley et al. [2007]). Given the constitutive force displacement relation being quasi-elastic, the devices are usually characterized by recentering capacity and almost constant stiffness. The failure is usually related to instability due to large displacements, either in the form of Euler instability or as roll-out instability (as noticed in Priestley et al. [2007]).

1.6 Objective

1. To study the structure without considering SSI.
2. To study the structure with considering SSI.

II. THEORETICAL FORMULATIONS

2.1 Preliminary Remark

As India is developing country, the population has increasing rapidly. As population increases the rise for building the structures also increases. Nowadays, the heavy and tall structures are developed in small areas due to unavailability of space. Therefore, to overcome such situations, structures of more height than previous one are taken for further study. Accordingly, different types of bracings are provided to this structure to know the behavior of building.

The projects aim at comparative study on analysis of High rise structure using Pushover analysis. Analysis is done for high rise buildings as G+2, G+6, G+10 structures. All the three structures are provided with different soil conditions:

Hard Strata
Medium Strata
Soft Strata

2.2 Methods of Analysis

For seismic performance evaluation, a structural analysis of the mathematical model of the structure is required to determine force and displacement demands in various components of the structure. Several analysis methods, both elastic and inelastic, are available to predict the seismic performance of the structures.

2.2.1 Elastic Methods of Analysis

Seismic engineering is a sub discipline of the broader category of structural engineering. Its main objectives therefore are:

To understand interaction of structures with the shaky ground.

The methodologies available so for the evaluation of existing buildings can be divided into two categories-

(1) Qualitative method
(2) Analytical method

Structural analysis methods can be divided into the following categories as below:

Equivalent Static Analysis
Response Spectrum Analysis
Time-History Method
Linear Dynamic Method

2.2.1.1 Static Analysis of Buildings Using Is 1893 (Part 1)-2002

As per IS 1893 (part1)-2002, Seismic Coefficient analysis Procedure is summarized in following steps

2.2.1.1.1 Design Base Shear

Design Seismic Base Shear- The total design lateral force or design seismic base shear (Vb) along any principal direction of the building shall be determined by the following expression

VB= Ah W, Whereas= design horizontal seismic coefficient for the structure, and may be calculated using, (Z⁄2)*(I/R)*(Sa/g)

2.2.1.1.2 Seismic Weight of Building

2.2.1.1.3 Zone Factor

Here, Z is the “Zone Factor”. This is a factor used to obtain a design spectrum depending on the perceived maximum risk characterized by maximum considered earthquake (MCE) in the zone in which structure is located. Zone factors as per IS 1893: 2002 (Part 1) are given in table 1.Z can also be determined from the seismic zone map of India, which is shown in figure 1 of IS 1893 (Part 1):2002[1]

Seismic zone	II	III	IV	V
Seismic intensity	Low	Moderate	severe	Very severe
Zone factor	0.10	0.16	0.24	0.36

Table 2.1 Zone factor

2.2.1.1.4 Importance Factor

I is the “Importance Factor”. The importance factors shown in Table are the factors used to obtain the design seismic force depending upon the functional use of the structure

The minimum values of I are given in Table 6 of IS 1893 (Part 1):2002.[1]

Structure	Importance Factor
Important service and community buildings, which as hospitals, schools; monumental structure; emergency building like telephone exchange, television stations, radio stations, railway stations, fire stations, buildings; large community halls like cinemas, assembly halls; and subway stations, power stations.	1.5
All other buildings	1.0

Table 2.2 Importance factor

2.2.1.1.5 Response Reduction Factor

The term R is “Reduction Factor”. This is the factor by which actual base shear force, which is generated if the structure were to remain elastic during its response to the design basis earthquake shaking, shall be reduced to obtain the designed lateral force. Response reduction factor for building system are given below in table as per IS 1893: 2002 (Part 1).. The value of R is given in Table 7 of IS 1893 (Part 1):2002. [1]

Lateral load resisting system	Response reduction factor(R)
Ordinary RCC moment resisting frame (OMRF)	3.0
Special moment resisting frame (SMRF)	5.0

Table 2.3 Response reduction factor

The fundamental natural period is the first (Longest) model time period of vibration of the structure. Because the design loading depends on the building period, and the building period cannot be calculated until a design has been prepared, IS 1893 (Part 1): 2002 provides formulas from which T may be calculated for a moment resisting building without brick infill panels, Ta may be estimated by the empirical expression.

T = 0.075hˆ0.75 for RC frame building, For all other buildings including moment resisting frame building with brick infill panels, Ta may be estimated by the empirical expression ,T =0.09h/√d, Where h is height of building in meters and d is the base dimension of the building at the plinth level in meter, along the considered direction of the lateral force.

2.2.1.1.7 Response Acceleration Coefficient

Sa/g = Average response acceleration coefficient (Dimensionless Value). It is a factor denoting the acceleration response spectrum of the structure subjected to earthquake ground vibrations, and depends on natural period of vibration and damping of the structure. For R.C.C. structures, 5% damping three different curves are recommended in IS 1893: 2002 for different stiffness of supporting media – rock, medium soil and soft soil. The classification of soil is based on average shear wave velocity for top 30 m of rock/soil layers or based on average Standard Penetration Test (SPT) values for top 30m (Table 1, IS 1893: 2002)

Class I – Rock or Hard soil : Well graded gravel and sand gravel mixture with or without clay binder having corrected Standard Penetration Value N > 30

Class II – Medium soil : All soils with N between 10 and 30 or gravelly sand with little or no fines (classified SP) with N > 15

Class III – Soft soil: All soils other than SP with N< 10.

2.2.1.1.6 Design Force

Distribution of Design Force- The design base shear, VB computed above shall be distributed along the height of the building as per the following expression:

$$Q_i = V_B \frac{W_i h_i^2}{\sum_{j=1}^{n} W_j h_j^2}$$

Qpi = Lateral loads as per IS: 1893 – 2002 and ATC – 40 at each floor level

W = Total seismic weight the structure

Wi = Seismic weight floor of i hi = High of floor measured from base

n = is the number of leaves at which the masses are lumped

2.3 Inelastic Methods of Analysis

Structures suffer significant inelastic deformation under a strong earthquake and dynamic characteristics of the structure change with time so investigating the performance of a structure requires inelastic analytical procedures accounting for these features. Inelastic analytical procedures help to understand the actual behaviour of structures by identifying failure modes and the potential for progressive collapse.

2.4 Non-Linear Static Pushover Analysis

The model frame used in the static nonlinear pushover analysis is based on the procedures of the material, defining force – deformation criteria for the hinges used in the pushover analysis. Fig.1 describes the typical force-deformation relation proposed by those documents. Five points labeled A, B, C, D and E are used to define the force deflection behavior of the hinge and these points labeled A to B – Elastic state, B to IO- below immediate occupancy, IO to LS – between immediate occupancy and life safety, LS to CP between life safety to collapse prevention, CP to C – between collapse prevention and ultimate capacity, C to

D- between C and residual strength, D to E- between D and collapse >E – collapse.

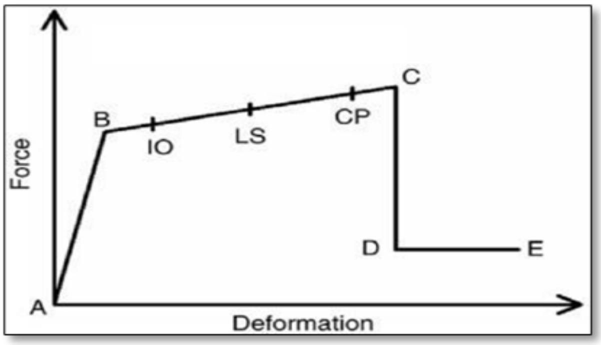


Figure 2.1 Deformation vs Force graph

Several types of output can be obtained from the nonlinear static pushover analysis:

Base shear versus displacement at a specified control joint can be plotted in the format where the vertical axis is spectral acceleration and the horizontal axis is spectral displacement. The demand spectra can be superimposed on that plot.

Base shear versus displacement at a specified control joint can be plotted.

2.5 Pushover Load Case

A pushover analysis can consist of more than one pushover load case. Each pushover load case can have a different distribution of load on the structure. For example, a typical pushover analysis might consist of three pushover load cases. The first would apply gravity load to the structure, the second would apply one distribution of lateral load over the height of the structure, and the third would apply another distribution of lateral load over the height of the structure.

2.6 Analysis of Frame Using ETab Software

Frame has been analyzed using ETABS software referring IS: 456-2000, IS 1893(Part-I) 2002.

Following are the advantages of ETABS software:

Easy to use interface.
Conformation with the Indian Standard Codes.
Versatile nature of solving any type of problem.
Accuracy of the solution.
Require less time than other software’s.

ETABS features a state-of-the art user interface, visualization tools, powerful analysis and design engines with advanced finite element and dynamic analysis.

III. PARAMETRIC INVESTIGATION

3.1 Preliminary Remark

So as to control the effect of earthquake on building the base isolation technique is one of the best solutions. Seismic isolation consists of essentially the installation of mechanisms such as isolators which decouple the structure from base. The seismic isolation system is mounted beneath the structure and is referred as ‘Base Isolation’. The idea of separating the superstructure from the substructure has dependably been an elegant thought in principle, yet just as of late has it turn into a suitable solution. The objective is to have flexible material in the horizontal plane that is equipped for anticipating vitality stream into the superstructure. This flexibility expands the superstructure's period, which, thus, lessens the induced acceleration.

In case of RCC multistoried buildings are more suspect able to dynamic vibrations. By providing base isolation in multistoried building (3 storey, 7 storey and 11 storey) the following parameters are analyzed in both directions.

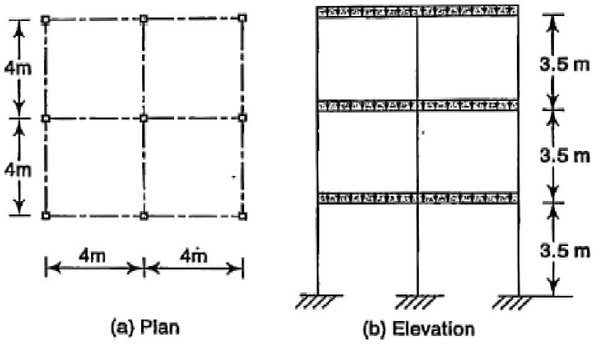
Base Shear
Displacement
Peak Storey value
Storey Drift

3.2 Problem Validation

Problem Statement: -Earthquake resistance design of structure adopted from a book by S. K. Duggal.

A plan elevation of three storey RCC school building is shown in fig.4.1 The building is located in seismic zone V. the type of soil encountered is medium stiff and it is proposed to design the building with special moment resisting frame. The intensity of dead load is 10 KN/m2 and the floor is to cater to imposed load of 3 KN/m2. Determine the design seismic loads on the structure by static analysis.

The following results were obtained for analysis on ETABS software.



(a) Plan (b) Elevation

Figure 3.1: Validation Problem Plan and Elevation

Solution:-

Design Parameter:-

For seismic zone V, zone factor, Z=0.36

Importance factor, I=1.5

Response reduction factor R=5

Floor area = 8x8=64m2

For live load up to and including 3KN/ m2

Percentage of live load to be considered=25%

Seismic weight contribution from one floor = 64x(10+ 0.25 x 3) = 688KN

Load from roof = 64 x 10 = 640 KN

Hence, the total seismic weight of the structure = 2 x 688 + 640 = 2016 KN

Result:- As per Earthquake resistance design of structure (S. K. Duggal)

Figure 4.2: Problem Validation Lateral Forces

Storey	Elevation (m)	Location	Base Shear (Theoretically)	Base Shear (Software)
S3	9.9	Top	175.37	175.3958
S2	6.6	Second	86.38	86.4113
S1	3.3	First	25.41	25.3528
S0 (Base)	0	Base	277.16	277.1599

Table 3.1 Storey Response Values Total Base Shear

3.3.1 Structural Modelling

Live Load	4KN/m2
Density of RCC considered:	25KN/ m3
Steel	HYSD 500
Thickness of slab	125mm
Depth of beam	450mm
Width of beam	230mm
Dimension of column	400x500mm
Density of infill	20 kN/ m3
Thickness of outside wall	230mm
Thickness of inner partition wall	150mm
Height of each floor	3m
Height of soft storey (Stiffness irregularity)	4.5m
Unit Weight of wall	15 KN/ m2
Height of swimming pool	1.8 m
Weight of swimming tank (Mass irregularity)	18 KN/ m2
Earthquake Zone	IV
Damping Ratio	5%
Importance factor	1.5
Type of Soil	Rocky
Type of structure	Special Moment Resisting Frame
Response reduction Factor	5
No of floor	18 floor
No of modes	54 – Each floor 3 no of modes
Type of diaphragms	Rigid
Modal combination	SRSS
Type of irregularity	Stiffness, mass & vertical geometry irregularity
Location of soft storey	1st storey
Location of swimming tank	1st storey
Vertical geometry building	Cantilever type building from Is 1893- 2016
P-Delta effect	Non –iterative-Based on mass

Direction of lateral force	Both X and Y direction
Load combination	All load combination are taken from IS 1893-2016
Type of support at base	Roller (Isolated)

3.3.2 Modeling

3.4 Parametric Formulation

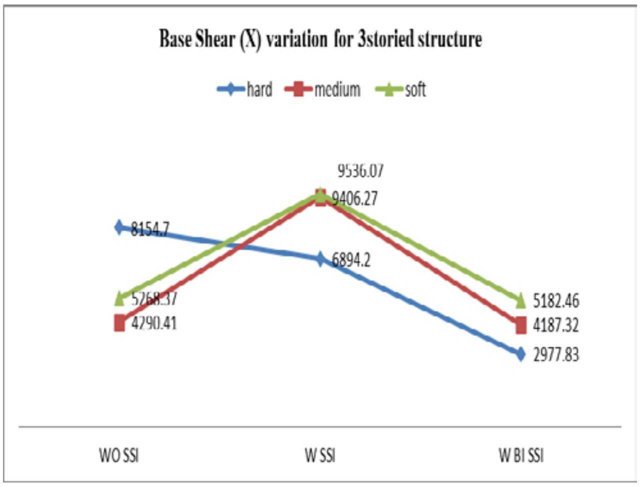
In the following case the (G+3), (G+7) & (G+11) regular buildings are considered with Base Isolation (BI) and Soil Structure Interaction (SSI). All cases are analyzed for hard, medium and soft soil strata. Isolators in structure are provided at base of footing for both longitudinal and lateral displacement. The parameters of base shear, displacement, peak storey and storey drift are obtained for all cases and compared by providing base isolators considering SSI of strata.

Analysis of Base Shear

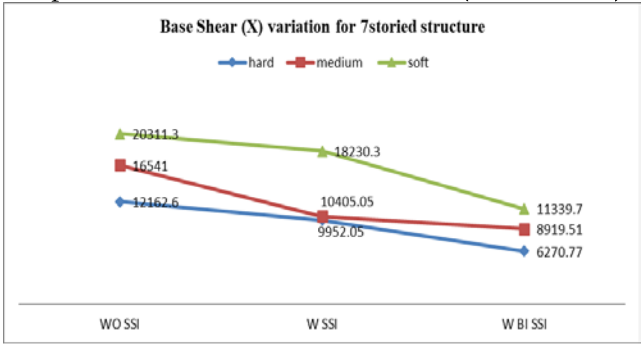
Structural behavior of 3, 7 and 11 storied building provided with base isolators on hard, medium and soft soil strata is analyzed. Observations obtained for base shear in X direction are as follows:

No	Type of Structure	Base Shear in kN					
		3 Storey		7 Storey		11 Storey	
		X	Y	X	Y	X	Y
1	WO SSI(hard soil)	8154.7	6649.01	12162.6	9560.4	17312.9	13831.8
2	WO SSI(medium soil)	4290.41	3602.66	16541	12999.4	23545.7	18811.54
3	WO SSI(soft soil)	5268.37	4423.86	20311.3	15962.5	28912.5	23100.14
4	W SSI(hard soil)	6894.2	5170.55	9952.05	8098.6	15147.4	12437.91
5	W SSI(medium soil)	9406.27	7058.36	10405.0	11389	21343.2	17272.37
6	W SSI(soft soil)	9536.07	8684.18	18230.3	14347.9	26855.5	21386.54

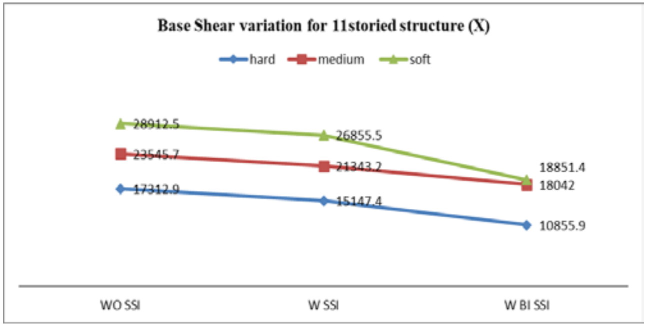
Table 3.2 Variation of Base Shear



Graph 3.1: Variation of Base Shear (X direction)

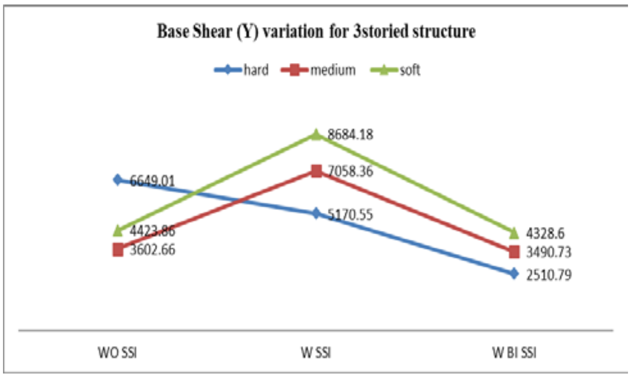


Graph 3.2: Variation of Base Shear (X direction)

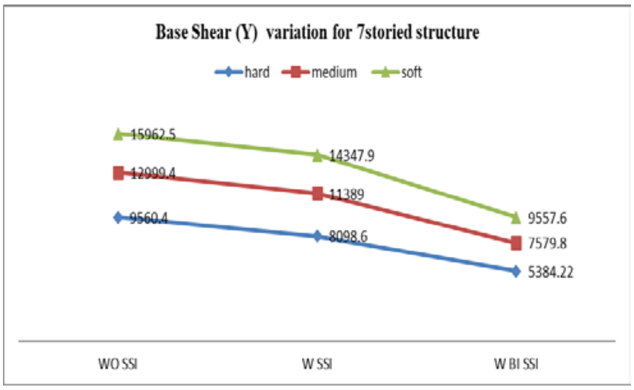


Graph 3.3: Variation of Base Shear (X direction)

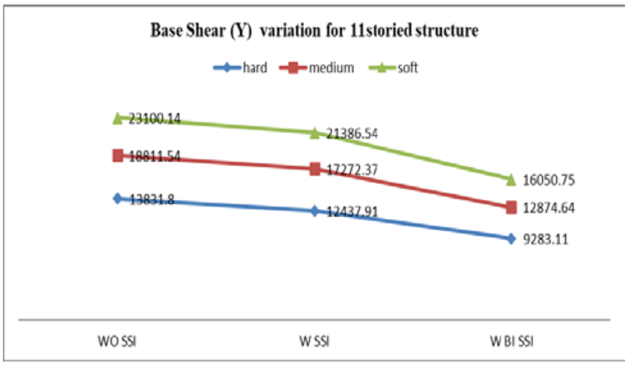
	Observations
	For Soil Strata (Hard, Medium & Soft) & Condition (WO SSI, W SSI & W BI SSI)
1	Base shear intensity is linear except for 3 storied structure
2	Magnitude of base shear is comparatively more in WO BI
3	Variations of base shear decrease linearly.



Graph 3.4: Variation of Base Shear (Y direction)

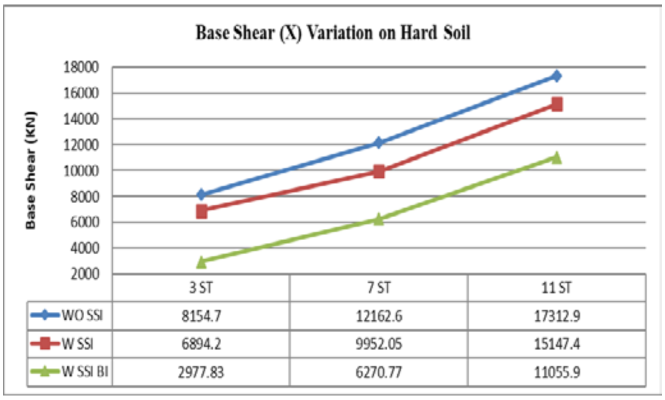


Graph 3.5: Variation of Base Shear (Y direction)

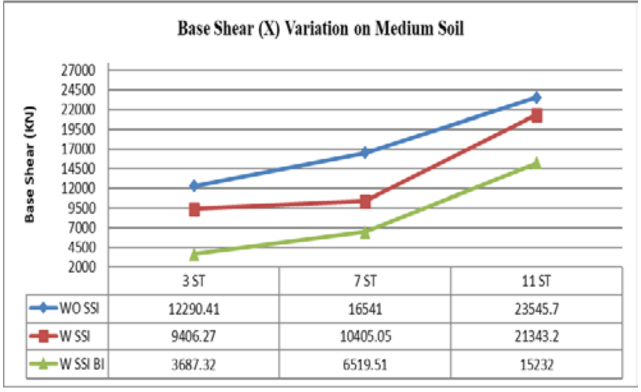


Graph 3.6: Variation of Base Shear (Y direction)

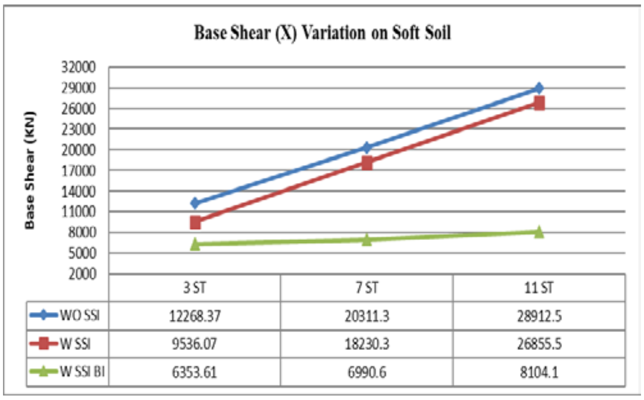
Observations	
For Soil Strata (Hard, Medium & Soft) & Condition (WO SSI, W SSI & W BI SSI)	
1	Base shear intensity is linear except for 3 storied structure
2	Magnitude of base shear is comparatively more in WO BI
3	Variations of base shear decrease linearly.



Graph 3.7: Variation of Base Shear on hard soil strata (X direction)

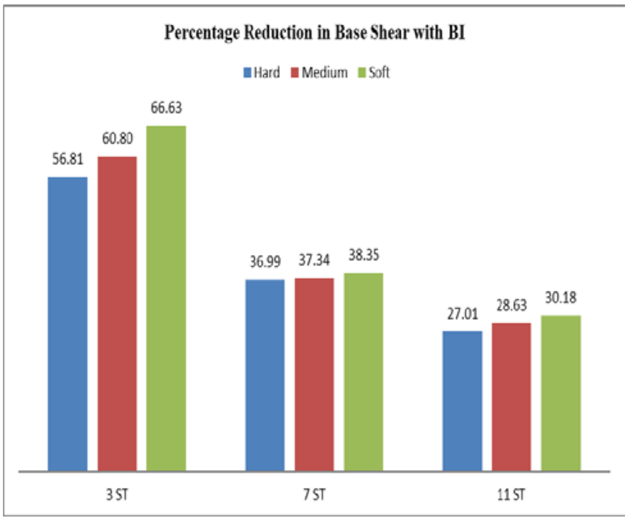


Graph 3.8: Variation of Base Shear on medium soil strata (X direction)



Graph 3.9: Variation of Base Shear on soft soil strata (X direction)

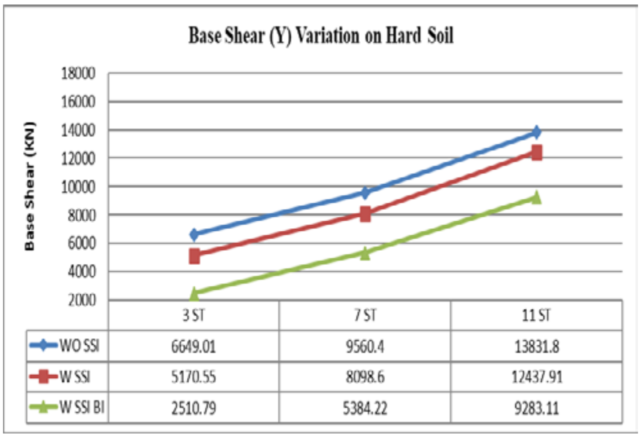
Observations	
For Soil Strata (Hard, Medium & Soft) & No. of Storey (3, 7 & 11)	
1	Base shear intensity is directly proportional to no. of storey
2	Magnitude of base shear is comparatively more is SSI and BI is not considered.
3	Variation of increase in base shear is almost linear in nature.



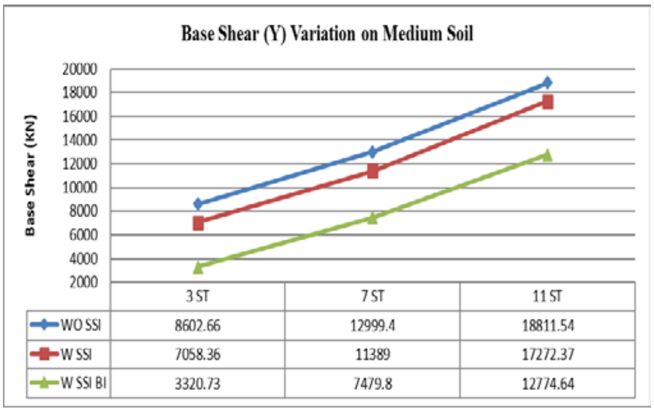
Graph 3.10: Percentage Variation of Base Shear for different soil strata (X direction)

Observations	
For	Soil Strata (Hard, Medium & Soft) & No. of Storey (3, 7 & 11)
1	The reduction in Base shear is maximum on soft strata i.e. almost 66.63 % and 60.80%, 56.81% for medium and hard strata respectively.
2	% reduction in base shear occurs as height of structure increases from 66.63% to 30.18%.
3	On hard soil strata % of base shear varies from 56.81% to 27.01%
4	In 3 storied building % variation in base shear is from 66.63% to 56.81%, 38.35% to 36.99% , 30.18% to 27.01% in 7 and 11 storied structure respectively.

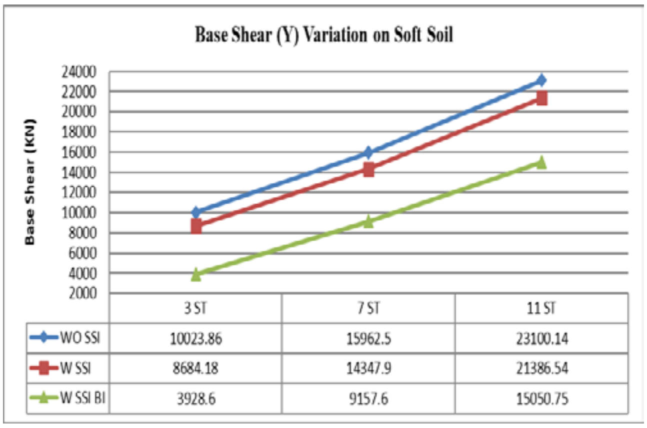
Structural behavior of 3, 7 and 11 storied building provided with base isolators on hard, medium and soft soil strata is analyzed. Observations obtained for base shear in Y direction are as follows:



Graph 3.11: Variation of Base Shear on hard strata (Y direction)

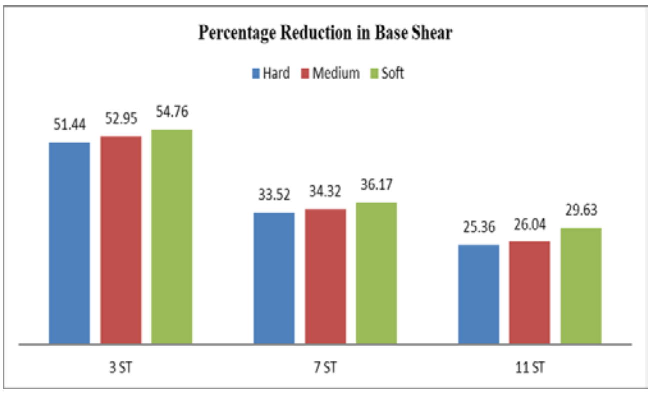


Graph 3.12: Variation of Base Shear on medium soil strata (Y direction)



Graph 3.13: Variation of Base Shear on hard soil strata (Y direction)

Observations	
Soil Strata (Hard, Medium & Soft) & No. of Storey (3, 7 & 11)	
1	Base shear intensity is directly proportional to no. of storey
2	Magnitude of base shear is comparatively more is SSI and BI is not considered.
3	Variation of increase in base shear is almost linear in nature.



Graph 3.14: Percentage Variation of Base Shear for different soil strata (Y direction)

Observations	
For	Soil Strata (Hard, Medium & Soft) & No. of Storey (3, 7 & 11)
1	The reduction in Base shear is maximum on soft strata i.e. almost 54.76 % and 36.13%, 29.63% for medium and hard strata respectively.
2	% reduction in base shear occurs as height of structure increases from 54.76% to 29.63%.
3	On hard soil strata % of base shear varies from 54.76% to 29.63%
4	In 3 storied building % variation in base shear is from 51.44% to 54.76, 33.52% to 36.17%, 25.36% to 29.63% in 7 and 11 storied structure respectively.

IV. CONCLUSIONS

4.1 Introduction

The series of analyses has proven the benefits of base isolation. The stiffness parameters of bearings were designed and analyzed to maximize the seismic performance of the structure. Base isolation has displayed significant positive effects by increasing the structure's natural period and hence reducing inertia forces on the structure. This investigation outlined the major relevant issues concerning the conceptual design of a base isolated structure. The parameters of the building and the site conditions chosen for the study were deliberately chosen in such a way that the earthquake effects were most severe. In reality, the stiffness calibration approach can be integrated together with the base isolation design in early stages of projects in order to develop structures of high seismic performance.

4.2 Conclusions

1. The benefits of implementing an isolation system were investigated by comparing the performance of base isolated multistory buildings with and without SSI. With the inclusion of seismic isolation devices, the base isolated wit SSI have significantly reduced top floor deflections, accelerations, inter storey drifts and base shears when compared without considering SSI on different soil strata (hard, medium, soft).

2. From a strictly strength viewpoint, the base isolated building does not show a great reduction in base shear for 3 storied building.

3. The percentage reduction in base shear is maximum in soft soil strata (66.63%) compared to medium and hard soil with SSI effect. As the height of building increases the % reduction in base shear also decreases.

4.3 Scope for Future Studies

After complete research related to SSI and BI effect on multistoried buildings the following points can be considered for future studies.

1. The effect of SSI and BI can be considered for multistoried buildings on clayey soil strata.
2. Using modified base isolation techniques can also be co related with the considered parameters.
3. The effect of geometries in plan for multistoried buildings can also be considered.
4. Dynamic analysis for multistoried buildings can be performed by using dampers and various BI techniques.

V. REFERENCES

1. Esteban S, Fernando Lopez-Caballero, Arézou Modaressi-Farahmand-Razavi (2011) “Effect of the inelastic dynamic soil–structure interaction on the seismic vulnerability assessment”- Journal of Structural Safety, 51-64.

2. Johnson.E A., Ramallo J C., Spencer B F., Sain Michael K.(1998), “Intelligent Base Isolation Systems”, World Conference on Structural Control, Kyoto, Japan, 1998.

3. Jingbo LIU, Yin GU, WANG Yan and Bin LI, (2006) “Efficient Procedure for Seismic Analysis of Soil-Structure”- Journal of Tsinghua science and technology,ISSN, Vol.11(6) 1007-0214

4. Kausel Eduardo (2010), “Early history of soil–structure interaction”, -Journal of Soil Dynamics and Earthquake Engineering, 822-833

5. Matinmanesh H. Asheghabad M. Saleh,(2011) “Seismic Analysis on Soil-Structure Interaction of Buildings over Sandy Soil”- Journal of The Twelfth East Asia-Pacific Conference on Structural Engineering and Construction, 1737-1740.

6. Naderzadeh Ahmad, (2009) “Applications of seismic Base Isolation Techniques in Iran”, Journal of Structural Safety.

7. Reza Hamid Tabatabaiefar, Massumi Ali, (2010) “A simplified method to determine seismic responses of reinforced concrete moment resisting building frames under

influence of soil–structure interaction", Journal of Soil Dynamics and Earthquake Engineering, 1259-1269.
8. Saze, Kanti Deb,(2011) "Seismic base isolation – An overview",India Special Section: Geotechnical and earthquake, 1-10.
9. Spyrakos C.C, Maniatakis Ch.A., Koutromanos I.A (2009, "Soil structure interaction effects on base-isolated buildings founded on soil stratum"- Journal of Engineering Structures-pages - Engineering Structures, 729-737.