Suitability of Different Base Isolation Systems According to Length to Width Ratio of High-Rise Buildings

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Abstract -*Base isolation is not about complete isolation of the structure from the ground, as with magnetic levitation, which may be very rarely practical. Most of the base isolation systems that have been developed over the years provide only 'partial' isolation. 'Partial' in the sense that much of the force transmitted, and the consequent responsive motions are only reduced by providing flexibility and energy dissipation mechanisms with the addition of base isolation devices to the structure. Base isolation, as a strategy to protect structure from earthquake, revolves around a few basic elements of understanding, Period-shifting of structure: Base isolator is a more flexible device compared to the flexibility of the structure. Thus, coupling both an isolator and the superstructure together increases the flexibility of the total isolated structural system. In this way, this technique lengthens the structures natural time period away from the predominant frequency of the ground motions, thus evading disastrous responses caused due to resonance. Mode of vibration: The fundamental mode of vibration (first mode shape) is altered from continuous cantilever type structure to an almost rigid superstructure with deformations concentrated at the isolation level. Damping and cutting of load transmission path: A damper or energy dissipater is used to absorb the energy of the force to reduce the relative deflection of the structure with respect to the ground. Minimum rigidity: It provides minimum rigidity to low level service loads such as wind or minor earthquake loads. We have also considered effect of aspect ratio of building and effect of base isolation along with different aspect ratio is compared.*

***Key Words*: base isolation, aspect ratio, response spectrum analysis, energy dissipation.**

1. INTRODUCTION

The method of base isolation was developed in an attempt to mitigate the effects of earthquakes on buildings during earthquakes and has been practically proven to be the one of the very effective methods in the past several decades. Base isolation consists of the installation of support mechanism which decouples the structure from earthquake induced ground motions. Base isolation allows to filter the input forcing functions and to avoid acceleration seismic forces on the structure. If the structure is separated from the ground during an earthquake, the ground is moving but the structure experienced little movement. The structures constructed with good techniques and machines in the recent past have fallen prey to earthquakes leading to enormous loss of life and property and untold sufferings to the survivors of the earthquake hit area, which has compelled the engineers and scientists to think of innovative techniques and methods to save the buildings and structures from the destructive forces of earthquake. The earthquakes in the recent past had provided enough evidence of performance of different type of structures under different earthquake conditions and at different foundation conditions as a food for thought to the engineers and scientists. This has given birth to different type of techniques to save the structures from the earthquakes.

Base isolation concept was coined by engineers and scientists as early as in the year 1923 and thereafter different methods of isolating the buildings and structures from earthquake forces have been developed world over. Countries like US, New Zealand, Japan, China and European countries have adopted these techniques as their normal routine for many public buildings and residential buildings as well. Hundreds of buildings are being built every year with base isolation technique in these countries.

As of now, in India, the use of base isolation techniques in public or residential buildings and structures is in its inception and except few buildings like hospital building at Bhuj, experimental building at IIT, Guwahati, the general structures are built without base isolation techniques. National level guidelines and codes are not available presently for the reference of engineers and builders. Engineers and scientists have to accelerate the pace of their research work in the direction of developing and constructing base isolated structures and come out with solutions which are simple in design, easy to construct and cost effective as well. Many significant advantages can be drawn from buildings provided with seismic isolation. The isolated buildings will be safe even in strong earthquakes. The response of an isolated structure can be ½ to 1/8 of the traditional structure. Since the super structure will be subjected to lesser earthquake forces, the cost of isolated structure compared with the cost of traditional structure for the same earthquake conditions will be cheaper. The seismic isolation can be provided to new as well as existing structures. The buildings with provision of isolators can be planned as regular or irregular in their plan or elevations. Researchers are also working on techniques like tuned mass dampers, dampers using shape memory alloys etc. Tuned mass dampers are additional mass on the structure provided in such way that the oscillations of the structure are reduced to the considerable extent. The mass may be a mass of a solid or a mass of a liquid. Dampers using shape memory alloys are being tried as remedy to earthquake forces. In this system, super elastic properties of the alloy is utilized and there by consuming the energy in deformation at the same time the structure is put back to its original shape after the earthquake.

Pranesh Mrunal and Ravi Sinha In this paper, behaviour of structures isolated using VFPI subjected to near source ground motions has been numerically examined. Response of typical structural systems isolated with VFPI and other isolation systems under near-sourc e ground motions have been investigated. The traditional isolation systems are found to be of limited effectiveness in reducing the response of structures while VFPI show significant reduction in response.

Vasant A. Matsagar and R. S. Jangid Analytical seismic responses of structures retrofitted using base isolation devices are investigated and the retrofit schemes are illustrated. The retrofitting of various important structures using seismic isolation technique by incorporation of the layers of isolators at suitable locations is studied. Three specific structures such as historical buildings, bridges, and liquid storage tanks are selected to investigate the effectiveness of the base isolation in seismic retrofitting. Different types of isolation devices, such as elastomeric bearings and sliding systems are evaluated for their performance in the retrofitting works. The response of the retrofitted structural system is obtained numerically by solving the governing equations of motion under different earthquakes and compared with the corresponding conventional structure without any retrofit measures, in order to investigate the effectiveness of base isolation in retrofitting of structures. It is observed that the seismic response of the retrofitted structures reduces significantly in comparison with the conventional structures depicting effectiveness of the retrofitting done through the base isolation technique. This paper also distinctively elaborates on the methods of construction in retrofitting works involving base isolation.

Bruno Briseghella et.al. The L'Aquila earthquake occurred in Italy has highlighted the particular vulnerability of old buildings built in the 70's and 80's. The base isolation system (BIS) has been suggested as an innovative retrofit strategy and adopted for the seismic upgrading of some major buildings. In this paper, a six-storey R.C. building was studied. Different kinds of analysis (spectral, pushover and nonlinear dynamic analysis) were performed by Midas/Gen according to EC8. Results had been compared among the original building and buildings retrofitted by different interventions. Although both retrofitting strategies can reduce the seismic vulnerability of existing building, the comparison pointed out building retrofitted with a "Lift up" technique patented by SOLES Ltd., executed by CONSTA SpA., and presented in the following, exhibited better performance than "column cut" technique. The technique has been successfully applied to the mentioned building under the consultancy of BOLINA Engineering Ltd. and the works are just finished.

By Lin Su et.al. In this paper a comparative study of effectiveness of various base isolators is carried out. These include the laminated rubber bearing with and without lead plug and several frictional base isolation systems. The structure is modeled as a rigid mass and the accelerograms of the NOOW component of the El Centro 1940 earthquake and the N90W component of the Mexico City 1985 earthquake are used. The performances of different base isolation devices under a variety of conditions are evaluated and compared. Combining the desirable features of various systems, a new design for a friction base isolator is also developed and its performance is studied. It is shown that, under design conditions, all base isolators can significantly reduce the acceleration transmitted to the superstructure.

B. M. Saiful Islam et.al. This paper covers the design of base isolators for a building located in Dhaka, Bangladesh, along with its structural and economic feasibility. A time history is generated for Dhaka, adjusting peak ground acceleration as per seismic region from a nearby recorded earthquake. The response spectrum curve based on the site geology of Dhaka is also generated from this time history. Linear static as well as dynamic (time history and response spectrum) analyses have been carried out for both isolated and non-isolated buildings. Similar analyses have also been repeated for buildings with different heights but similar plan areas. The study reveals that for low-to medium-rise buildings, isolation can reduce seismic force along with some savings in structural cost of the building, though incorporating base isolators increase the overall price and installation cost. A meticulous review indicates that savings may be in the order of 5–10% of the total structural cost of the respective building.

J. C. Ramallo et.al. A ''smart'' base isolation strategy is proposed and shown to effectively protect structures against extreme earthquakes without sacrificing performance during the more frequent, moderate seismic events. The proposed smart base isolation system is composed of conventional low-damping elastomeric bearings and ''smart'' controllable semi active! Dampers, such as magnetorheological fluid dampers. To demonstrate the advantages of this approach, the smart isolation system is compared to lead-rubber bearing isolation systems. The effectiveness of the isolation approaches are judged based on computed responses to several historical earthquakes scaled to various magnitudes. The limited performance of passive systems is revealed and the potential advantages of smart dampers are demonstrated. Two- and six-degree-of-freedom models of a base-isolated building are used as a test bed in this study. Smart isolation is shown to achieve notable decreases in base drifts over comparable passive systems with no accompanying increase in base shears or in accelerations imparted to the superstructure. In contrast to passive lead-rubber bearing systems, the adaptable nature of the smart damper isolation system provides good protection to both the structure and its contents over a wide range of ground motions and magnitudes.

1.1 Base Isolation Techniques

In traditional seismic design approach, strength of the structure is suitably adjusted to resist the earthquake forces. In base isolation technique approach, the structure is essentially decoupled from earthquake ground motions by providing separate isolation devices between the base of the structure and its foundation. The main purpose of the base isolation device is to attenuate the horizontal acceleration transmitted to the superstructure. All the base isolation systems have certain features in common. They have flexibility and energy absorbing capacity. The main concept of base isolation is to shift the fundamental period of the structure out of the range of dominant earthquake energy frequencies and increasing the energy absorbing capability. Presently base isolation techniques are mainly categorized into three types viz.

1) Passive base isolation techniques
2) Hybrid isolation with semi-active devices
3) Hybrid base isolation with passive energy dissipaters.

1.3 Objectivesof investigation

The main purpose of analysis is to compare the response of the RCC building with varying aspect ratio with fixed base with R.C. building with varying aspect ratio with base isolation. Lead rubber bearing is used for analysis purpose. Following are the objectives of the present study:-

1. To study the suitability of different base isolation systems for different length to width ratios of building.
2. Seismic analysis of symmetrical R.C.C. building with base isolation and without base isolation using ETABS software.
3. Optimization of base isolation technique (which base isolation is most effective for different length to width ratios).

2. METHODOLOGY

In the current study, buildings are modelled using the finite element software ETABS. The analytical models of the building include all components that influence the mass, strength, stiffness and deformability of structure. The building structural system consists of beams, columns, and slab. The non-structural elements that do not significantly influence the building behavior are not modelled. Modal analysis and Response spectrum analysis are performed on models. In present work, 3D RC 9 storied buildings of 7 different dimension according to aspect ratio differ by 0.5 is taken which has area of 400 m^2 situated in zone III, is taken for the study in which two cases has been considered one with fixed base and second with base isolation using Lead rubber bearing. Details of models are shown in table 1.

Table -1: Description of models

Model	Aspect Ratio	Sizes in Plan
Model-1	1	20mX20m
Model-2	1.5	16.3mX24.5m
Model-3	2	14.1mX28.2m
Model-4	2.5	12.6 mX31.6m
Model-5	3	11.5mX34.6m
Model-6	3.5	10.7mX37.5m
Model-7	4	10mX40m

Table -2: Properties of materials

Concrete grade	M30
Rebar grade	Fe500
embedded steel section	Fe250
Unit weight of concrete	25 kN/m^3
Unit weight of steel	78.5 kN/m^3
Density of brick masonry	18.83 kN/m^3

Table -3: Loads considered in analysis

Self-Weight of the Frame elements & slabs	It is calculated & used automatically during analysis by the ETABS software
Super-imposed Dead Load	1- Floor finish = 1.5kN/m^2 2- Wall load = 7.5 kN/m for internal and 13 kN/m for external walls
Live load	2 kN/m^2
Seismic load	According to IS 1893

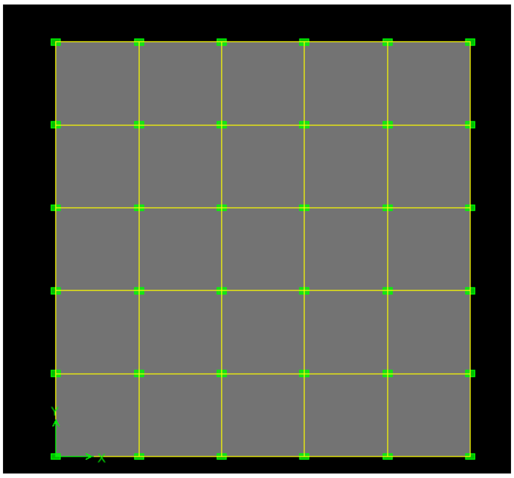

Fig -1: Plan of Model 1

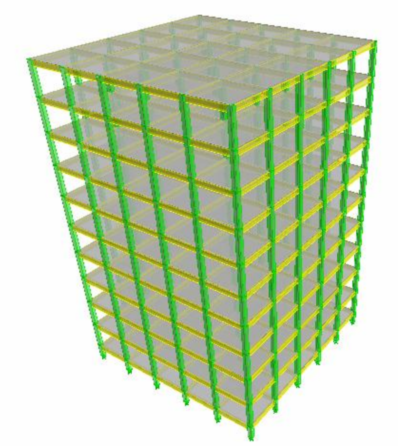

Fig -2: 3D rendered view of Model 1

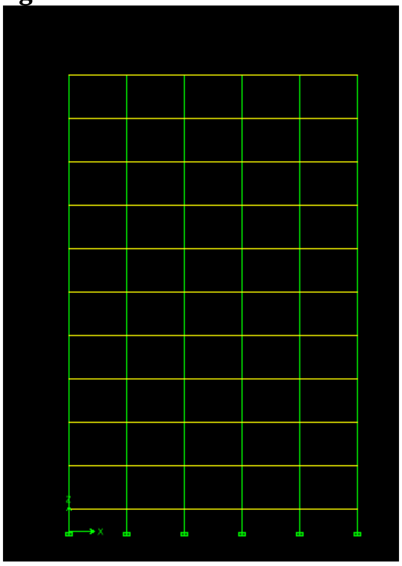

Fig -3: Elevation of Model 1 with fixed base

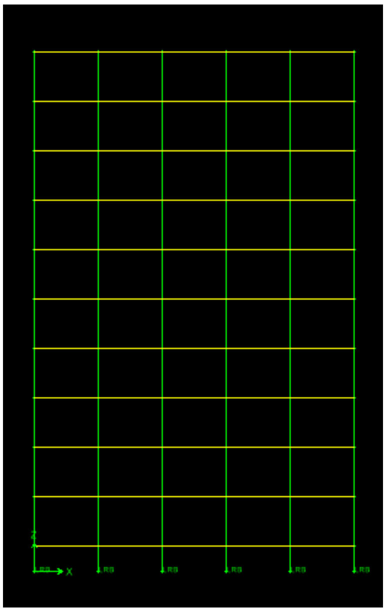

Fig -4: Elevation of Model 1 with isolated base (LRB)

3. RESULTS AND DISCUSSIONS

After performing Analysis on 14 building models, it is observed that values of lateral displacement (mm) with floor level in X direction increased around 20-30 % with base isolation as compared to fixed base. Values of lateral displacement (mm) with floor level in Y direction increased slightly around 18-22 % with base isolation as compared to fixed base. Values of Story over-turning moment of building decreased in X direction around 19-29 % with isolation as compared to fixed base. Values of Story over-turning moment of building decreased in Y direction around 15-25 % with base isolation as compared to fixed base case. Value of Base shear in X direction decreased by around 14-24 % with base isolation as compared to fixed base. Value of Base shear in Y direction decreased by around 12-20 % with base isolation as compared to fixed base. Value of Time period increased by around 25-30% with base isolation as compared to fixed base. Maximum Story drift in X direction of model 1 is increased by 7% with base isolation as compared to fixed base, but on higher stories drift decreases considerably. Maximum Story drift in X direction of model 2 increased by 1% with base isolation as compared to fixed base, but on higher stories drift decreases considerably. Maximum Story drift in X direction of model 3 increased by 6.5% with base isolation as compared to fixed base, but on higher stories drift decreases considerably. Maximum Story drift in X direction of model 4 increased by 6.8 % with base isolation as compared to fixed base, but on higher stories drift decreases considerably. Maximum Story drift in X direction of model 5 increased by 1.7% with base isolation as compared to fixed base, but on higher stories drift decreases considerably. Maximum Story drift in X direction of model 6 increased by 1.71% with base isolation as compared to fixed base, but on higher stories drift decreases considerably. Maximum Story drift in X direction of model 7 increased by 6.4% with base isolation as compared to fixed base. Maximum Story drift in Y direction of model 1 increased by 13.4% with base isolation as compared to fixed base. Maximum Story drift in Y direction of model 2 for increased by 13.1% with base isolation as compared to fixed base. Maximum Story drift in Y direction of model 3 for increased by 8.6% with base isolation as compared to fixed base. Maximum Story drift in Y direction of model 4 increased by 15.7% with base isolation as compared to fixed base. Maximum Story drift in Y direction of model 5 increased by 13.6% with base isolation as compared to fixed base. Maximum Story drift in Y direction of model 6 increased by 14.5% with base isolation as compared to fixed base. Maximum Story drift in Y direction of model 7 increased by 15.07% with base isolation as compared to fixed base.

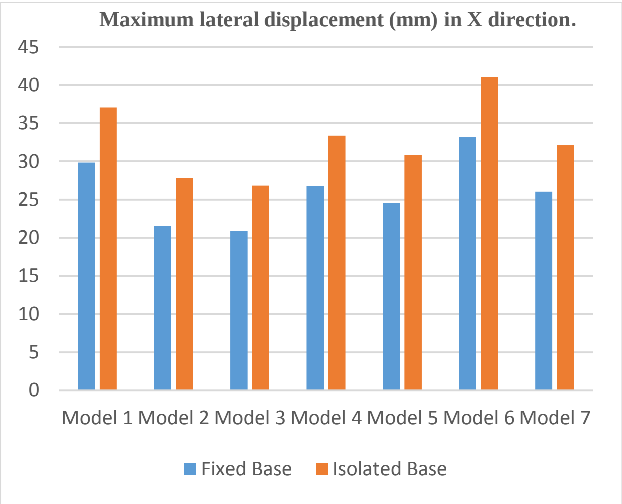

Chart-1: Values of Maximum lateral displacement (mm) in X direction

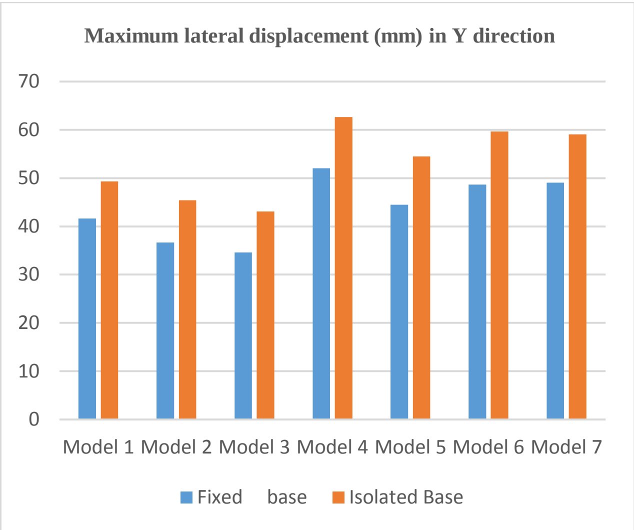

Chart-2: Values of Maximum lateral displacement (mm) in Y direction

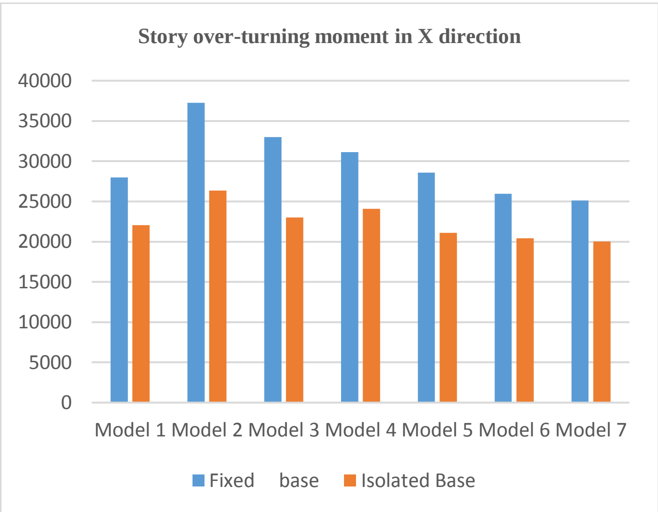

Chart-3: Values of Story over-turning moment in X direction

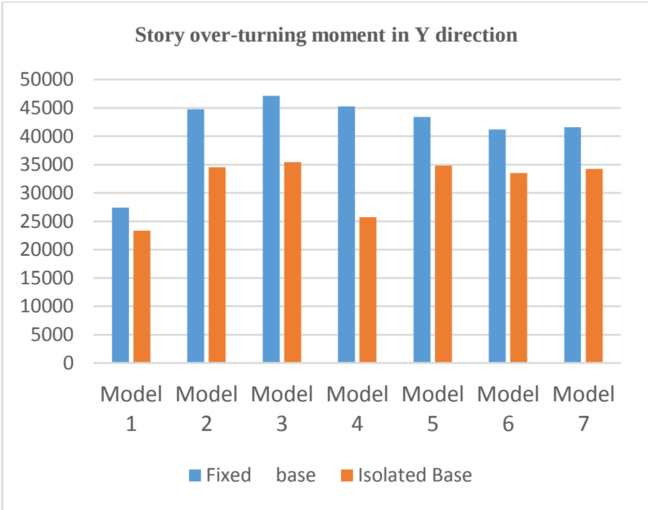

Chart-4: Values of Story over-turning moment in Y direction

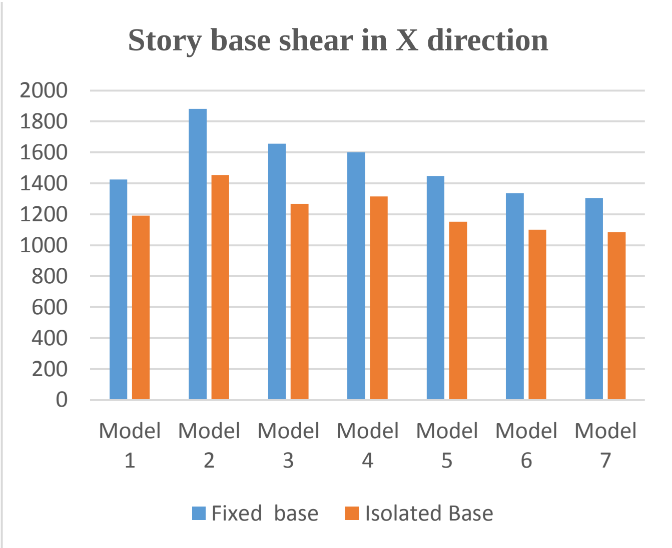

Chart-5: Values of Story base shear in X direction

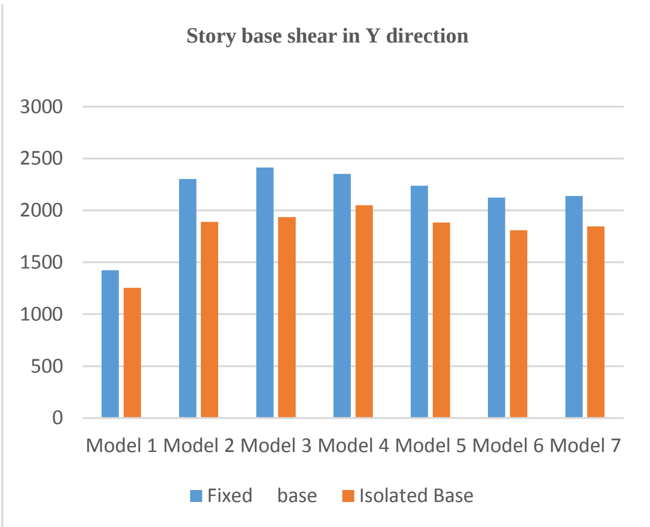

Chart-6: Values of Story base shear in Y direction

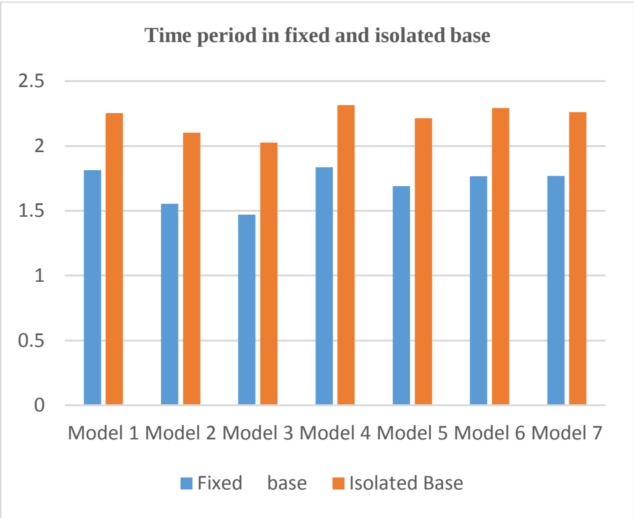

Chart -7: Values of Time period in fixed and isolated base

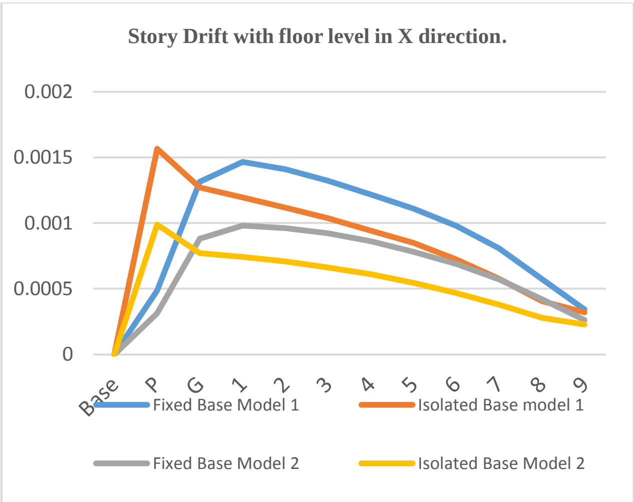

Chart -8: Values of Story Drift with floor level in X direction for model 1 & model 2

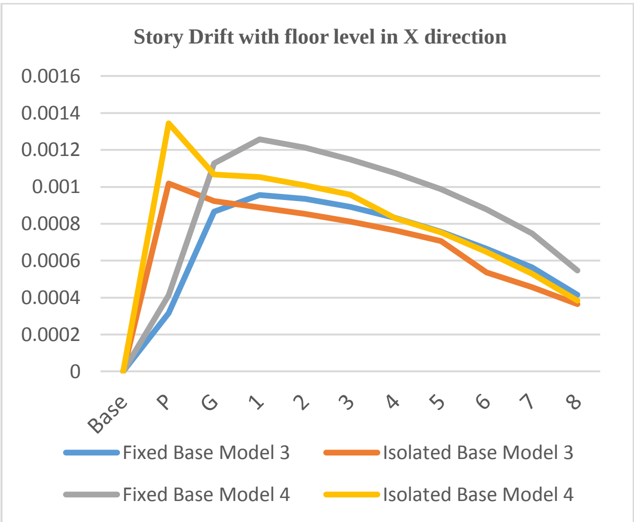

Chart -9: Values of Story Drift with floor level in X direction for model 3& model 4

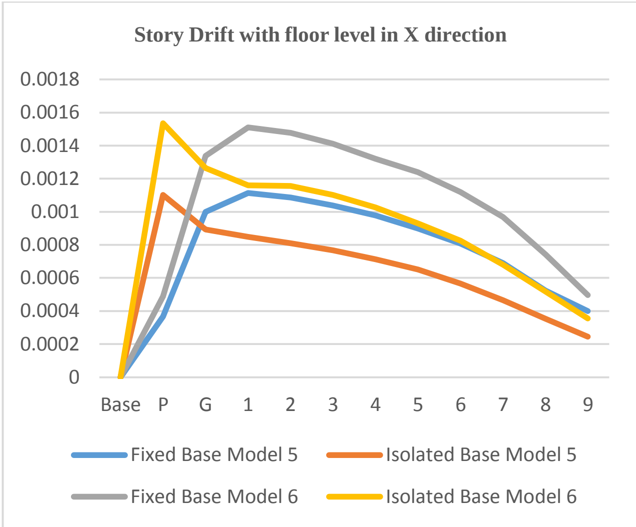

Chart -10: Values of Story Drift with floor level in X direction for model 5& model 6

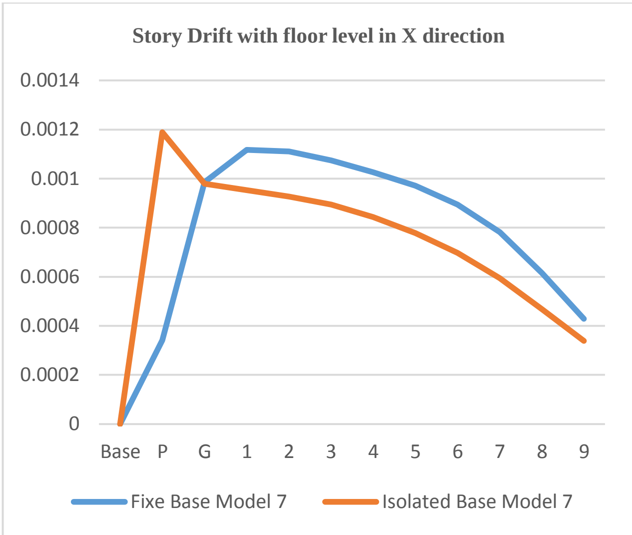

Chart -11: Values of Story Drift with floor level in X direction for model 7

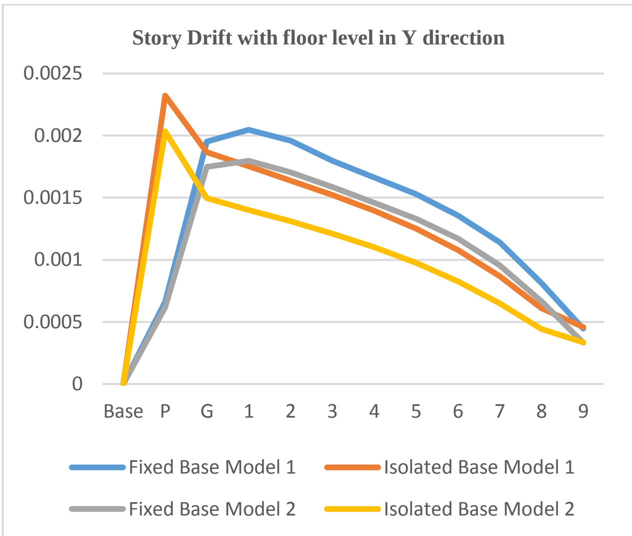

Chart -12: Values of Story Drift with floor level in Y direction for model 1 & model 2

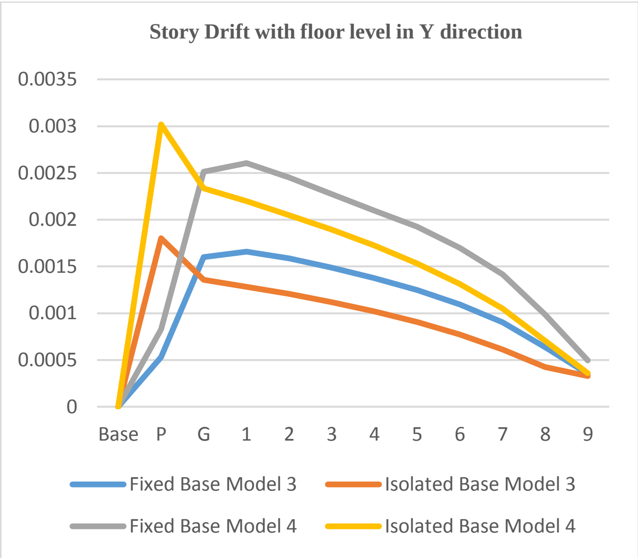

Chart -13: Values of Story Drift with floor level in Y direction for model 3& model 4

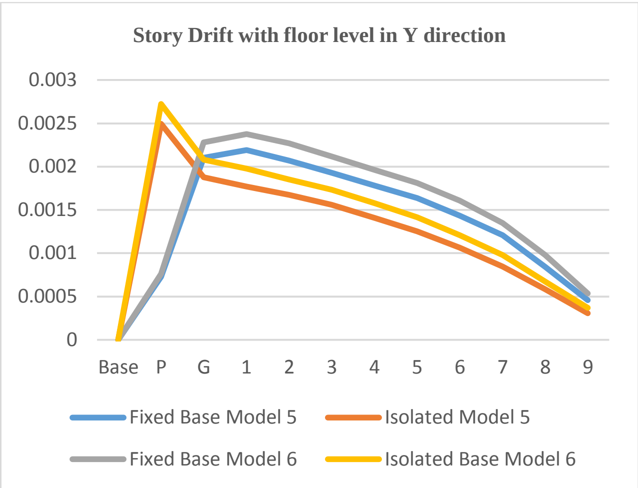

Chart -14: Values of Story Drift with floor level in Y direction for model 5& model 6

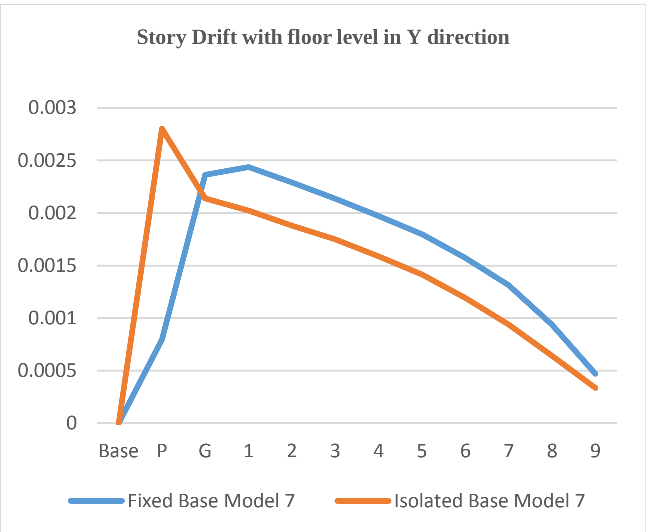

Chart -15: Values of Story Drift with floor level in Y direction for model 7

4. CONCLUSIONS

From the analysis it is found that the lateral displacement in both X and Y direction increases around 20% with LBR base isolation building as compared to fixed base building which makes building more ductile. Also lateral displacement in both directions is minimum for the aspect ratio 1.5 and from analysis, it has been concluded that there is decrease of around 25% in over-turning moment of isolated base as compared to fixed base. Over turning moment is least for model i.e. with aspect ratio 1.From analysis, it has been concluded that there is decrease of around 20% in base shear of isolated base as compared to fixed in both X and Y directions. Model 1 i.e. aspect ratio 1 and model 7 i.e. with aspect ratio 4 has minimum base shear. From analysis results, it has been concluded that there increase in time period of isolated base as compared to fixed base of around 25% which makes structures falls out of earthquake resonance range. Model 2 with aspect ratio 1.5 has minimum time period and model 1 with aspect ratio 1 has maximum time period. From above analysis results it has been concluded that maximum story drift increases for all models with base isolation as compared to fixed base case, but drift decreases considerably in upper stories which makes structures safer during earthquakes. Overall model 2 and 3 with aspect ratio 1.5 and 2 has minimum drift values. Overall LBR bas isolation system increases structure response during earthquakes and with aspect ratio point of view model 2 and 3 are best suitable configuration with aspect ratio of 1.5 and 2.

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