International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-9 Issue-2, December 2019

Dynamic Response of Tall Building with Base Isolation Subjected to Earthquake Forces

Budhi Ram Chaudhary, Gurpreet Singh

Abstract: ***In the fast-paced contemporary world, new inventions with rapid construction techniques came across usually built to resist the lateral forces. Among them, the demand for tall buildings has put a revolutionary impact on society. In this study, base isolation as an earthquake resisting design technique was utilized which substantially dissociate a superstructure from its substructure and increase flexibility resisting on the ground vibration areas by providing the different types of base isolators. Lead rubber bearing (LRB) isolator is a passive structural vibration control technique. In this research study, seismic behaviour of tube in tube system steel tall building in square, circular, hexagonal, and octagonal plan configurations with varying frame sections with and without LRB base isolation was analyzed for the comparative analysis on the basis of base shear, overturning moment, time period, storey displacement, storey drift and storey acceleration according to IS 1893 (part 1):2016 and UBC 1997 Earthquake code in E-TABS software by non-linear time history analysis. From the results, Octagonal shape was found to be the best option for tall buildings whereas the hexagonal shaped building showed poor performance during an earthquake.***

Keywords**:** ***Lead rubber bearing (LRB) isolator, time history analysis, base shear, overturning moment, lateral displacement, storey drifts, model period, storey acceleration.***

I. INTRODUCTION

The tall building is the high-rise building, against low rise building and delineated by its height differently otherwise in numerous jurisdictions. Generally, the tall building is constructed for residential, office, hotels, retail, business or combination of these purposes. The residential high-rise building is also called tower blocks (40 or more stories) and very tall structure (taller than 150m) referred to a skyscraper. This type of buildings become possible with the design of elevators (lift) and less expensive, more copious building materials like reinforced concrete and steel. This type of structure poses a specific style challenge for structural and geotechnical engineers at seismically active regions, high compressibility or bad mud. They also pose challenges to firefighters during an emergency. Apartment buildings have each technical and economic blessings in areas of high population density and turn out to be a particular feature of housing accommodation in just about all densely inhabited town areas around the world.

The tall building is the supreme structure that requires constancy because it consists of a lot of frame structure with diverse width and height.

Buildings and structures are considered steady with oblique strengthen by utilizing either bracing frameworks or shear framework or both such as shear wall to guarantee the stability of the building. Besides, the imperative thing to consider is the program to be utilized for the analysis of tall building structure, and wind speed at the construction area to avoid any problems in the future.

The seismic method of analysis method can be classified based on three factors - the type of externally applied loads, the behaviour of building/or structural materials, and the type of structural model (3D, 2D, 1D). “The type of external action and behaviour of the structure can further categorize as linear static analysis, linear dynamic analysis, non-linear static analysis, or non-linear dynamic analysis” [Agarwal & Shrikhande, 2019]. A non-linear dynamic analysis or inelastic time history analysis method is only one method to describe the actual behaviour of the structure during an earthquake.

1.1 Base Isolation System

Base isolation system suggests that of protecting the structure against earthquake forces by decoupling the structure from its substructure resisting on the shaking ground, therefore, protective a building or non-building structure’s integrity but does not make the building earthquake-proof. It is the passive structural vibration resistor techniques like rubber bearings, friction bearings, ball bearings, spring systems and other means. This technique can be used for both new construction and seismic retrofit. The base-isolated system reduces the cost of the structure by 5-6% than conventional code design and base shear for superstructure is around 15% of the structure weight. The passive system is considered as the best method at present with continuing improvements of hardware, applications, design codes, and retrofit guides, and has significant application to buildings, bridges, and industrial plants. The basic theory of seismic isolation is to decrease the response to earthquake motion by (i) decreasing the stiffness, (ii) increasing the modal period of the system, and (iii) providing of improved damping to increase the energy dissipation in the system. “The advanced research work on devices for passive control of buildings seismic loads was done in the New Zealand Physics and Engineering Laboratory starting in the 1970s,” [Dowrick, 2013, p. 292].

Revised Manuscript Received on December 30, 2019.

***** Correspondence Author
Budhi Ram Chaudhary*, M.E. Student, Department of Civil Engineering, Chandigarh University, Mohali, Punjab, India.
Gurpreet Singh, Assistant Professor, Department of Civil Engineering, Chandigarh University, Mohali, Punjab, India.

The codes used for the design of base isolation is Uniform Building Code (UBC 1997) published by the International Conference of Building Officials (55), or Title 24, Part 2 of the California Code of Regulations, Division III [OSHPD – 96].

Base isolated structures experience deformation mostly at the base of the structure (i.e. within the isolated system) and the accelerations are quite uniform over the height. The major outcome of seismic isolation is to escalation the natural time period which reduces the acceleration and therefore force demand on the structure. In terms of energy, base isolation system changes the natural period of a structure away from the strongest elements in an earthquake ground motion, therefore reducing the amount of energy transfer into the structure. The base isolation system is the most effective system on the structures built on stiff soil and structure with the low fundamental period (low rise building); and not on soft soil and structure with the high fundamental period (high rise building). This technology can be used in high rise buildings by providing large isolators.

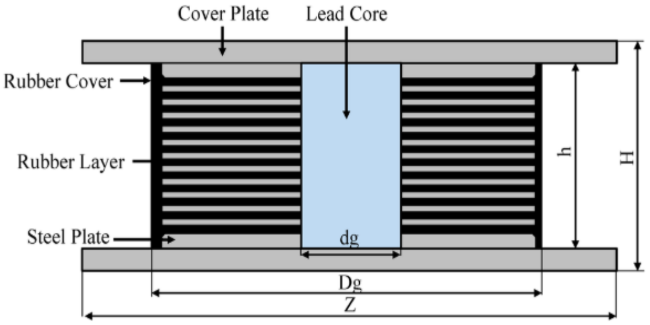

Fig. 1. Section of Lead Rubber Bearing (Hu J. W.[1])

1.1 Objective of the Study

This work includes 25 storey steel building in the square, circular, hexagonal, and octagonal plan configuration with the tube in the tube system by providing lead rubber bearing at the base of each model. Based on the maximum reaction on the column of each model, LRBs were designed manually to isolate the foundation from the substructure. Time history analysis was carried out by taking El-Centro earthquake ground shaking records. The objectives of this work include:

1. To model and investigate the various forms of 25 storey steel framed tube in tube system tall building with and without base isolation.
2. To carry out the dynamic non-linear time history analysis on various shapes (square, circular, hexagonal, and octagonal) of modelled buildings according to IS 1893 (Part 1): 2016, UBC 1997, and IS 800:2007 in ETABS v17.0.0 software.
3. To observe and recognize the dynamic behaviour of analyzed buildings.
4. To compare the seismic parameters such as base shear, overturning moment, fundamental period, story drift, lateral displacement, and storey acceleration.
5. To obtain the most effective structural system to resist the earthquake forces among the different shapes.

II. REVIEW OF LITERATURE

Dalal and Desai (2013) studied the wind and seismic time history analysis on lattice shell tube RCC framed buildings by providing three types of bracing (X, Chevron V & V) and shear core considering the IS 1893:2002 for zone III & IS 875:1984(Part 3) at Surat using E-TABS. G + 40 to G+100 storey with 10 storey height interval high rise buildings of square, octagonal, and circular shapes with bracings in centre bay and exterior bay are analyzed. The researcher showed the inverted V bracing system, octagonal shape, and triple-layer bracing was the most efficient structure among them. Multiple bays bracing lateral load resisting system was the most efficient high rise building. Triple-layer mega bracing was more efficient than double-layer bracing.

Shruti and Vijay (2014) studied the seismic load analysis in latticed shell tube RC frame tall building (30, 50, and 60 stories) providing the bare frame, signal diagonal, X bracings. The analysis was done by equivalent static and response spectrum analysis method in SAP2000 according to IS 1893:2002 for comparing the seismic parameter like storey displacement, model period, base shear and storey drift. They showed that the X type of bracing system was the most effective system as it resists displacements and inter storey drift.

Somwanshi and Pantawane (2015) studied the seismic analysis of fixed based and base-isolated building structures. They modelled the two cases of 13 storeys rigid jointed plane frame in symmetric and asymmetric RC buildings with and without base isolation in E-TABS software for Bhuj earthquake ground motion records. Lead rubber bearing was designed considering maximum vertical reactions after analysis by non-linear time history analysis method. After analysis, they found that symmetric and asymmetric base-isolated building decreased the shear force by 17.8% and 3% than fixed-base building respectively. Similarly, base-isolated symmetric and asymmetric building reduced bending moment by 16.11% and 2%, maximum base shear by 35.63% and 19.5% in X-direction, and 34.77% and 13.5% in Y-direction respectively. They also found that storey acceleration decreased by 33% and 6% in the symmetric and asymmetric base-isolated building whereas in case of the fixed base building there was a large difference in storey acceleration from bottom to top. The storey drifts reduced significantly in comparison with a fixed base and increased the lateral displacement in base-isolated buildings.

Hosseini and Rao (2015) evaluated the earthquake behaviour of high rise buildings with shear walls at the centre core and centre of each side of the external perimeter with an opening. They prepared the 40 storey building model and analysis was done according to IS codes by equivalent static lateral force method, response spectrum method and time history analysis methods using E-TABS. It was concluded that that the shear wall at centre core and centre of external perimeters with openings gives better performance in terms of maximum storey displacement, storey drifts, highest base shear, and exhibit high stiffness. They also found that the maximum stress induced due to opening in the shear wall, it was deviated by 5% in the result than shear walls without opening.

Hence, concluded that shear walls with openings help to achieve economy.

Patil et al. (2016) researched for the dynamic analysis of tall tubular steel structures for different geometric configurations. Models were prepared for the 88 storeys (316.8 m) tall steel structure in square, rectangular, triangular and hexagonal configuration and analysis was done according to IS 1893:2002, IS 875:(Part 3) 1987 by equivalent and time history analysis in E-TABS for conducting the optimum geometric configuration of tubular structures. They found that the hexagonal tube structure has the highest model period, less frequency, maximum displacement and storey drifts, and also it was observed that dynamic analysis gives good result than static analysis. Therefore, they concluded that the hexagonal shaped tube frame building is more stable than other shaped tall buildings and the dynamic analysis is much more appropriate for the exact behaviour of high rise structural system.

Ghorpande et al. (2016) calculated the seismic excitation of low to high rise RCC structure with lead rubber bearing base isolation. The models were prepared for 5, 10, 15, and 20 stories RC MRF buildings with LRB base isolation for gravity and seismic loads and analysis was done according to IS 1893:2002 for seismic zone IV using time history analysis of Bhuj Earthquake recorded data in E-TABS. The researchers concluded that base-isolated structures have the least lateral deflection and less moment value than the fixed base structure. The use of base isolators reduced inters storey drift (98% in 5 stories, 31% in 10 stories, 71.3 % in 15 stories, and 33.3% in 20 stories); increased time by 28.9% and structural damage during earthquake. The base shear and base moment were reduced by 11% and 19.4% in base-isolated buildings. It was an excellent seismic control device for both low rise and high rise buildings.

Reddy et al. (2017) studied the effect of base isolation in multistoried reinforced concrete building by making the model of G+5 and G+17 storey regular RC building with LRB and Friction Pendulum System (FPS) designed as per UBC 97 & ASCE07 code by using response spectrum and time history analysis method in E-TABS software for seismic zone III according to Chamoli earthquake data in Uttar Pradesh of magnitude 4.8. They concluded that response of LRB and FPS isolator reduced time, base shear, & storey drift, and increases storey displacement than the fixed-base system. The storey acceleration reduced by using isolation devices over the conventional structure.

Mohan et al. (2017) analyzed different forms of the tube in tube structures subjected to lateral loads. The researchers prepared the 60 storey RC building model with square, rectangular, triangular and hexagonal shapes of the tube in tube system for analysis of wind and earthquake load according to IS 1893:2002 code by response spectrum analysis method in SAP2000. After the analysis, the found that the displacements and the storey drift were reduced in the square tube in tube structure which was less compared to other shaped buildings and showed the best performance in both seismic zones II and IV. Square framed tube in tube structure decreased model period by 75% more than square frame tube, and 71.72%, 54.56%, 70.83% more than rectangular, triangular and hexagonal structure respectively. Base shear was increased by 73.40% in square frame tube in tube structure than square-framed tube structures, also decreased than rectangular, triangular and hexagonal structures. The triangular configuration of a tube in tube structure was most vulnerable structure among all types.

Dar and Singh (2019) performed the dynamic analysis of the base-isolated tubular tall building system (Lead Rubber Bearing) in E-TABS. They prepared the models of G+29 Storey rigid jointed RCC frame buildings in different forms such as simple frame, simple tube, tube in tube, and bundle tube with and without base isolation (LRB). The comparative results made in a simple frame and tube system for each model according to IS 1893:2002 (part 1). They found that model period decreased by 24%, 13%, 10%, and 26% by providing base isolation in simple RCC frame, simple tube, bundled tube, and tube in tube models respectively. The base shear decreased from 10% to 30% in each model by providing base isolation. Base isolation system also reduced overturning moment in the building.

III. METHODOLOGY

Following are the sequence of steps for analyzing the model in the present:

1. Modelling of the 25 storey buildings of square, circular, hexagonal and octagonal configurations with composite steel frame columns and tube systems at exterior & interior frames to form a tube in tube system in E-TABS v 17.2 software.
2. All the four shaped buildings (square, circular, hexagonal, and octagonal) were modelled then loads were considered as per code IS 875 (part 1 & 2) with a fixed base.
3. Non-linear time history analysis was carried out as per IS 1893 (Part 1): 2016 considering El-Centro earthquake ground motion records.
4. Lead rubber bearing (LRB) were designed manually considering maximum support reaction of each model as per code UBC 1997.
5. Then the properties of LRB assigned in each model separately and reanalyzed the models.
6. Results of both fixed base and LRB isolated models were tabulated and discussed.

IV. MODELLING AND ANALYSIS

For this research work, eight models are prepared (four having a fixed base and four having lead rubber bearing base isolation at the foundation) to perform the non-linear dynamic time history analysis. The building had 2.5 m centre to centre spacing encased columns forming a tube in tube system in four shapes i.e. square, circular, hexagonal, and octagonal plan configuration. The type of building considered is office building and frames are steel moment-resisting frame system. The assumed preliminary data required for the analysis of buildings is as shown in the tables below:

A. Material Properties

Table- I: Material Properties

Material Properties	**Values**
Grade of Concrete (Slab)	M30 (1:0.75:1)
Grade of Rebar	HYSD415
Grade of Structural Steel	Fe345
Young's Modulus of Steel	200000 MPa
Young;s Modulus of Concrete	27386 MPa
Unit Mass of Steel, ρ	7850 kg/m^3

B. Section Properties

Table- II: Section Properties

Section Properties	**Values**
Columns (upto 15 Stories)	600mm x 900mm with ISMB600 encased
Columns (above 15 Stories)	500mm x 800mm with ISMB500 encased
Beams (upto 15 Stories)	ISMB 600
Beams (Above 15 Stories)	ISMB 500
Slab Section (M30)	150 mm
Modeling Type	Non-Linear Shell Element

C. Loads on the Structure

Table- III: Gravity and Lateral Load

Gravity Load	**Value**
Live Load - Floor	4 kN/m^2
Live Load - Roof	1.5 kN/m^2
Floor Finish	1.5 kN/m^2
Earthquake Load	**Value**
Location of Building	Moderate Intensity Zone – IV
Soil Type	Medium Soil (Type – II)
Importance Factor, I	1
Response Reduction Factor, R	5
Fundamental Period = 0.085*h$^{0.75}$	2.166 sec

D. Load Combinations

Table- IV: Load Combination according to IS1893 (part 1)

Load Case	**Combination**
Gravity Analysis	1.5 (Dead Load + Live Load)
Earthquake Analysis	1.2 (Dead Load + Live Load ± EQL) 1.5 (Dead Load ± EQL) 0.9 Dead Load ± 1.5 EQL

3.1 Design of Lead Rubber Bearing

For this research, Lead Rubber Bearing (LRB) type isolator is used for the isolation system at the base of the columns. The design of LRB is carried out according to the textbook of "DESIGN OF SEISMIC ISOLATED STRUCTURE" from theory of practice by JAMES M. KELLY and FARZAD NAEIM and the Research Article "Seismic Analysis of Fixed Based and Base Isolated Building Structures" by Ms Minal Ashok Somwanshi and Mrs Rina N. Pantawane (2015) by using IS 1893:2016 and UBC 1997 Earthquake Codes described as follows:

Table- V: Design Constants

Parameters	**Values (UBC 97)**
Seismic Zone Factor (Z)	Zone 3
Soil Profile Type	S$_d$
Seismic Coefficient (C$_a$)	0.36
Seismic Coefficient (C$_v$) or C$_{vd}$)	0.54
Importance Factor, I	1.25
Reponse Reduction Factor, R	8.5 (For SMRF)
Seismic Source Type	B
Near Source Factor (N$_a$)	1
Near Source Factor (N$_v$)	1
Damping Coefficient (B$_D$ or B$_M$)	1
Effective Damping (β$_{eff}$)	5%

The Procedure of LRB Design:

1) The first step is to find the maximum shear force (W_i) on the columns for a particular building model with the fixed base system and minimum rubber diameter of LRBs is calculated based on this vertical force.
2) By setting target period T_{eff} (2 seconds appear to be the desired one) and effective damping 5% according to IS 1893:2016.
3) The spectral acceleration S_a is calculated from the response spectrum graph of IS 1893:2016 which is found to be 0.728.
4) The design displacement is calculated by the formula:

$$d_{bd} = \left(\frac{t_{eff}}{2\pi}\right) S_a \text{ in mm} \qquad (1)$$

5) The effective stiffness (K_{eff}) for U1 value is calculated by the formula:

$$K_{eff} = \left(\frac{2\pi}{T_{eff}}\right)^2 \frac{W_i}{g} \text{ in kN/m} \qquad (2)$$

Where,

T_{eff} = Effective fundamental period of the superstructure.

W_i = Maximum vertical reaction on the column of fixed base analyzed the model.

K_{eff} = Effective stiffness of the isolation system in the principal horizontal direction at designed displacement (d_{bd}).

6) The dissipated energy at the designed displacement (d_{bd}) is obtained by the formula:

$$E_D = 2K_{eff} d_{bd}^2 \beta \quad \text{in kN-m} \qquad (3)$$

7) The force at design displacement or Characteristics strength is calculated by the formula:

$$F_o = \frac{E_D}{4d_{bd}} \text{ in kN} \qquad (4)$$

8) The Stiffness of the lead core of LRBs is calculated by the formula:

$$K_{pb} = \frac{F_o}{d_{bd}} \quad \text{in kN/m} \qquad (5)$$

9) The stiffness of rubbers of LRBs is calculated by the formula:

$$K_r = K_{eff} - K_{pb} \quad \text{in kN/m} \qquad (6)$$

10) The total thickness of LRBs is calculated by the formula:

$$t_r = \frac{d_{bd}}{\gamma} \quad \text{in m} \qquad (7)$$

11) The diameter of lead rubber bearings is calculated by the formula:

$$D_{bearing} = \sqrt{\frac{K_r t_r}{400\pi}} \quad \text{in m} \qquad (8)$$

12) Calculation of total loaded area (A_L):

- The Diameter of the lead core of LRB is calculated by the formula:

$$D_{pb} = \sqrt{\frac{4f_o}{\pi\, \sigma_{pb}}} \text{ in m} \qquad (9)$$

Where,

σ_{pb} = Total yield stress in lead,
(Assume 11 MPa)

Area of lead core in LRB in m^2,

$$A_{pb} = \frac{\pi}{4} * (D_{pb})^2 \quad (10)$$

- The Diameter of the force-free section,

$$D_{eff} = D_{bearing} - 2t_r \text{ in m} \quad (11)$$

- Force-free area,

$$A_{ff} = \frac{\pi}{4}(D_{ff})^2 \text{ in m}^2 \quad (12)$$

Total Loaded Area, $A_L = A_{ff} - A_{pb}$ in m^2 (13)

13) The Circumference of the force-free section is calculated by the formula:

$$C_f = \pi * t * D_{ff} \quad (14)$$

14) Shape Factor,

$$C_i = \frac{\text{Loaded Area } (A_L)}{\text{Circumference of force free section } (C_f)} \quad (15)$$

15) Total Height of LRB,

$$H = (N * t) + (N - 1)t_s + 2t_{ap} \text{ in m} \quad (16)$$

Where,
N = 0.2/t = 0.2/0.01 = 20; N = No. of rubber
t = Single rubber layer thickness (0.01)
t_s = Thickness of steel lamination (0.003) and
t_{ap} = Laminated anchor plate thickness (0.04) m

16) The bearing horizontal stiffness for U2 & U3 (Linear Stiffness) is calculated by the formula:

$$K_b = \frac{G * A_r}{H} \text{ in kN/m} \quad (17)$$

Where,
G =Shear modulus (varying from 0.4 to 1.1 MPa) Adopt 1 MPa
A_r = Rubber layer area

17) The total bearing vertical stiffness for U2 and U3 (Non-linear Stiffness) is calculated by the formula:

$$K_v = \frac{6 * G * S_i^2 * A_r * k}{(6 * G * S_i^2 + k)H} \text{ in kN/m} \quad (18)$$

Where,
S_i = Shape Factor, and
k = Rubber compression modulus = 2000 MPa

Table VI: Summary of LRB Design Specifications

Properties of LRB	Model Value			
	Square	Circular	Hexagonal	Octagonal
Rotational Inertia, I	0.048 kg-m^2	0.0479 kg-m^2	0.1685 kg-m^2	0.0711 kg-m^2
Linear Stiffness, For U2 & U3	9630.346 kN/m	9618.116 kN/m	17580.334 kN/m	11616.609 kN/m
Horizontal Stiffness, For U2 & U3 (Non-linear)	2398.851 kN/m	2395.744 kN/m	4424.558 kN/m	2903.934 kN/m
Vertical Stiffness (k_v), for U1	3139144.05 kN/m	3133672.47 kN/m	6879000.82 kN/m	4043290.22 kN/m
Distance from End - J	0.0257 m	0.0257 m	0.0257 m	0.0257 m
Yield Strength, F (For U2 & U3)	175.27 kN	175.05 kN	319.96 kN	211.42 kN
Effective Damping, β_{eff}	0.05	0.05	0.05	0.05
Stiffness Ratio (Post Yield)	0.10	0.10	0.10	0.10

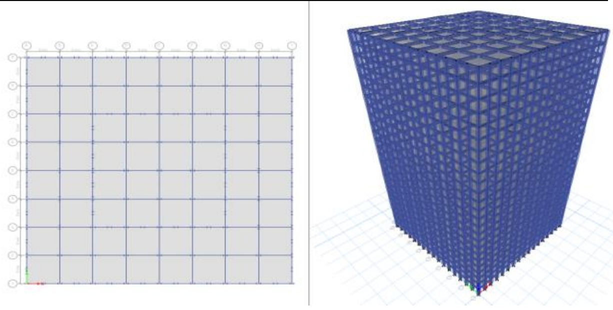

Fig. 2. Plan & 3D View of Square Building

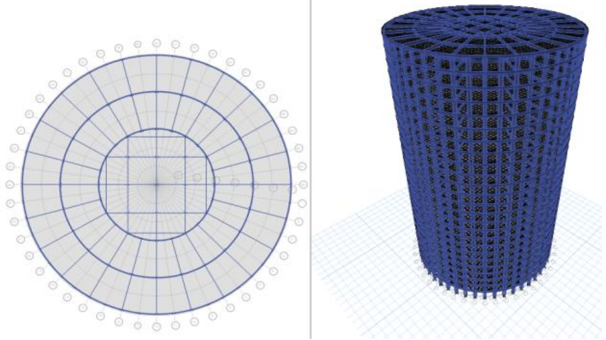

Fig. 3. Plan & 3D View of Circular Building

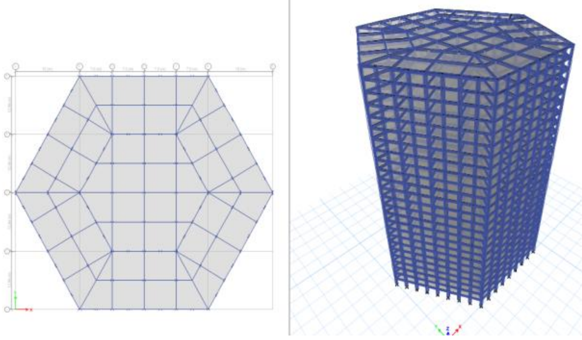

Fig. 4. Plan & 3D View of Hexagonal Building

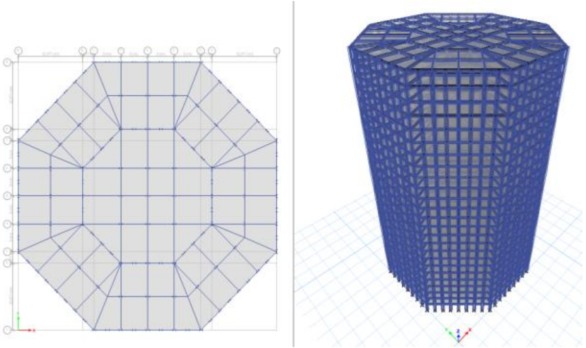

Fig. 5. Plan & 3D View of Octagonal Building

V. RESULTS AND DISCUSSION

The models are analyzed by the non-linear time history method for the zone IV as per IS 1893:2016(part1) and UBC 1997 earthquake code. The effect of the base isolation system of the tall buildings is evaluated.

The significant variation in earthquake parameters like base shear, overturning moment, model periods, inter-storey drifts, lateral displacement and storey acceleration concerning fixed base and base isolation is noticed and discussed in this section.

Table VII: Analysis Results of Fixed Base Buildings

S.N.	Parameter	Results			
		Square	Circular	Hexagonal	Octagonal
1.	Maximum Shear Force (kN)	9572.75	9560.594	17475.1939	11547.1355
2.	Base Moment (kNm)	-108.24	-71.91	-65.57	98.759
3.	Maximum Base Shear (kN)	113.982 (X-direction) 123.7377 (Y-direction)	124.8024 (X-direction) 133.1167 (Yidirection)	188.8038 (X-direction) 178.6743 (Y-direction)	141.7338 (X-direction) 146.7227 (Y-direction)
4.	Maximum Storey Drift (mm)	0.000643 (X-direction) 0.000662 (Y-direction)	0.001022 (X-direction) 0.001039 (Y-direction)	0.001221 (X-direction) 0.001237 (Y-direction)	0.00076(X-direction) 0.000769(Y-direction)
5.	Maximum Acceleration (m/s^2)	410.76 (X-direction) 409.47 (Y-direction)	416.75 (X-direction) 415.92 (Y-direction)	412.36 (X-direction) 411.96 (Y-direction)	104.82 (X-direction) 411.39 (Y-direction)
6.	Maximum Displacement (mm)	37.482 (X-direction) 38.371 (Y-direction)	56.729 (X-direction) 57.49 (Y-direction)	70.494 (X-direction) 70.942 (Y-direction)	44.843 (X-direction) 44.438 (Y-direction)
7.	Maximum Storey Stiffness (kN/m)	1697783.15(X-direction) 1699425.60 (Y-direction)	1030262.61(X-direction) 1037690.96 (Y-direction)	1247286.16 (X-direction) 1283040.44 (Y-direction)	1812845.969(X-direction) 1824849.38 (Y-direction)

Table VIII: Analysis Results of LRB Base Isolated Buildings

S.N.	Parameter	Results			
		Square	Circular	Hexagonal	Octagonal
1.	Maximum Shear Force (kN)	9404.4121	9336.1724	17354.031	11186.4475
2.	Base Moment (kNm)	-69.303	-48.9654	-48.9604	58.684
3.	Maximum Base Shear (kN)	81.7629 (X-direction) 83.0567 (Y-direction)	94.0515 (X-direction) 95.5445 (Y-direction)	140.2367 (X-direction) 136.7827 (Y-direction)	95.2759 (X-direction) 95.9945 (Y-direction
4.	Maximum Storey Drift (mm)	0.000651 (X-direction) 0.000671 (Y-direction)	0.001033 (X-direction) 0.001051 (Y-direction)	0.001256 (X-direction) 0.00129 (Y-direction)	0.000971 (X-direction) 0.000977 (Y-direction)
5.	Maximum Acceleration (m/s^2)	572.57 (X-direction) 583.21 (Y-direction)	675.50 (X-direction) 681.72 (Y-direction)	878.18 (X-direction) 897.84 (Y-direction)	185.14 (X-direction) 654.75 (Y-direction)
6.	Maximum Displacement (mm)	66.258 (X-direction) 68.101 (Y-direction)	96.58 (X-direction) 97.988 (Y-direction)	118.408 (X-direction) 120.936 (Y-direction)	91.955 (X-direction) 91.955 (Y-direction)
7.	Maximum Storey Stiffness (kN/m)	1607460.078 (X-direction) 1608717.247 (Y-direction)	984582.283 (X-direction) 991905.292 (Y-direction)	1247286.16 (X-direction) 1223482.00 (Y-direction)	1371315.175 (X-direction) 1378504.239 (Y-direction)

A. Base Shear Force

The base shear of the fixed base and base-isolated buildings is as shown in figure 6 and 7 below. By comparing from the bar diagrams of the fixed base and LRB base-isolated models, it shows that the base shear in square, circular, hexagonal, and octagonal models are decreased by 28.267%, 24.639%, 25.723%, and 32.778% in X-direction and 32.876%, 28.225%, 23.445%, and 34.574% in Y-direction respectively. Reduction of base shear reduced the seismic effect on the building and make the structure stable during an earthquake.

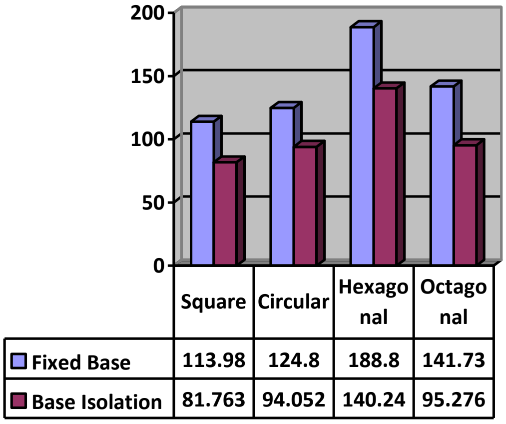

Fig. 6. Comparison of Base Shear in X-direction

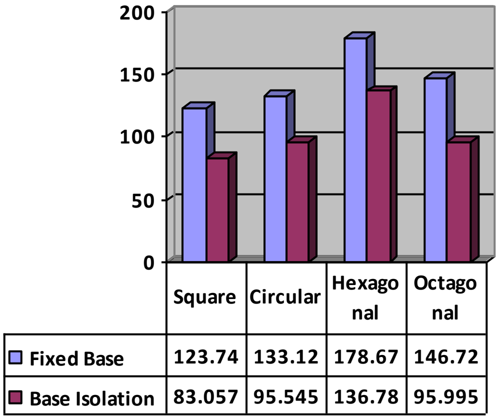

Fig. 7. Comparison of Base Shear in Y-direction

B. Overturning Moment

The maximum overturning moment in a column of a fixed base and base-isolated buildings are as shown in figure 8. It is observed that the maximum bending moment in base-isolated buildings decreased by 35.976%, 31.914%, 25.339%, and 40.578% in square, circular, hexagonal, and octagonal shapes models in comparison to fixed base building models respectively.

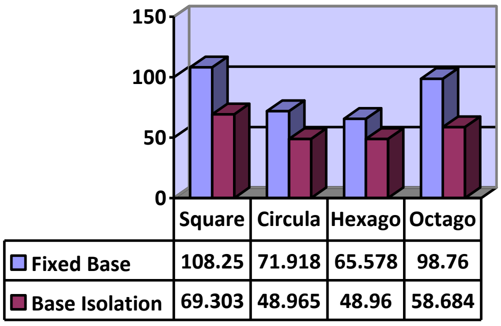

Fig. 8. Comparison of Maximum Overturning Moment

C. Time Period

The model period of the structure is the time taken to complete one oscillation. Increased the model period increases the reaction time of structure during an earthquake and improves the seismic performance by reducing the seismic response of the structure. The maximum and minimum model period of all four models of the fixed base are compared with base-isolated models both in X and Y direction as shown in figure 9 and 10. From the diagram 9, it is observed that the maximum model period is increased by 23.688%, 20.545%, 15.02%, and 28.84% and the minimum period from diagram 10, by 13.615%, 13.49%, 10.91%, and 22.43% in square, circular, hexagonal, and octagonal configurations model respectively.

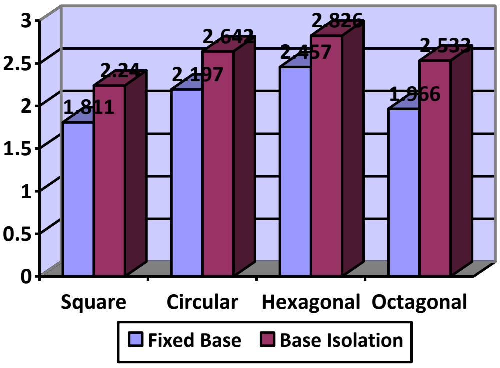

Fig. 9. Comparison of Maximum Time Period

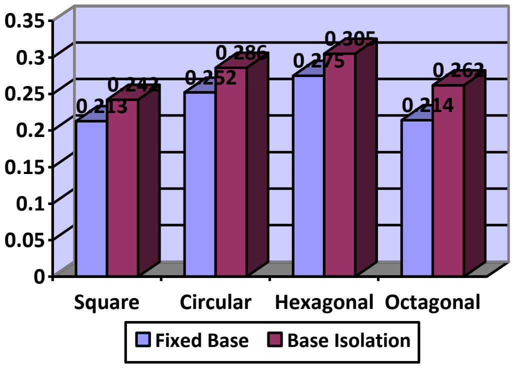

Fig. 10. Comparison of Minimum Time Period

D. Storey Drifts

The floor level vs. storey drifts graph of all models with a fixed base and base-isolated buildings are shown in figure 11 and 12. From the figure, it is observed that the storey drifts significantly reduced by comparing the fixed base models with a base-isolated building. The square and the hexagonal shaped buildings had little variation in storey drifts whereas in case of circular and octagonal building large variation in storey drifts found. It is found that storey drift increased at 17 storeys in each model because of change of frames sizes above 15 storeys. According to IS 875:2016 (Part 3), the maximum storey drift in any storey of the building due to lateral force shall not exceed 0.4% of storey height in mm i.e. for this research maximum drift should not exceed 300mm and hence storey drifts are within a permissible value. Square and hexagonal-shaped building have little variation in storey drifts whereas in case of circular and octagonal building large variation is experienced in storey drifts. For the time-history analysis method, maximum inter storey drifts is 0.02/R, where R is the response reduction factor as per UBC-97.

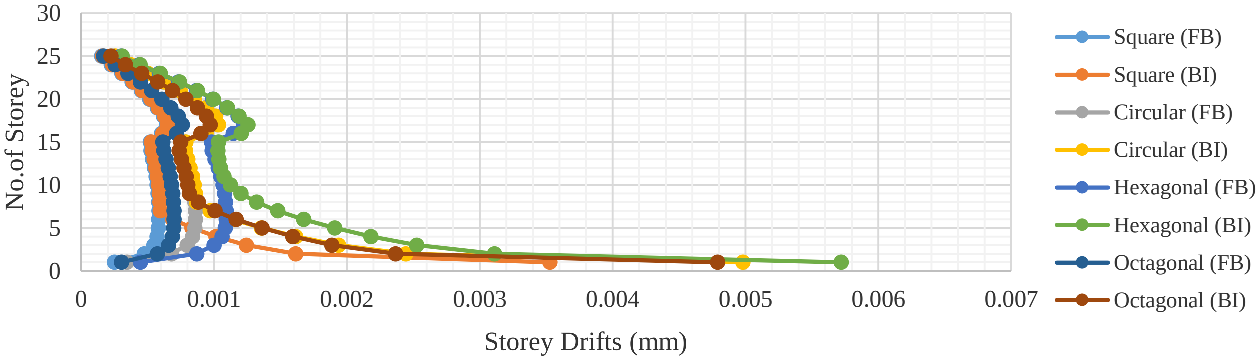

Fig. 11. Comparison of Storey Drifts in X-direction

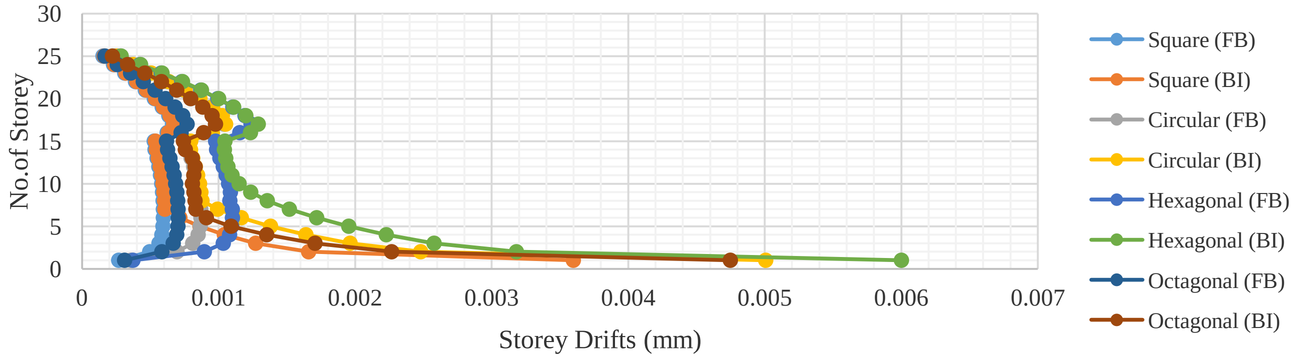

Fig. 12. Comparison of Storey Drifts in Y-direction

E. Storey Displacement

The floor level Vs lateral displacements graph of models of a fixed base and base-isolated building are shown in figure 13 and 14 for both X and Y direction. From the graphs, it is observed that the base-isolated building has more displacement than a fixed base building. However, it is found that displacement increased by 76.77%, 70.25%, 67.97%, and 105.06% in X-direction and 77.48%, 77.44%, 70.47%, and 106.93% in Y-direction in the square, circular, hexagonal, and octagonal buildings respectively in the base-isolated system. The maximum horizontal displacement should not exceed H/500 mm the structure undergoes with the huge moment and shear forces according to code for high rise buildings, where H is the height of the building. The maximum displacement of all the models is found within the permissible value.

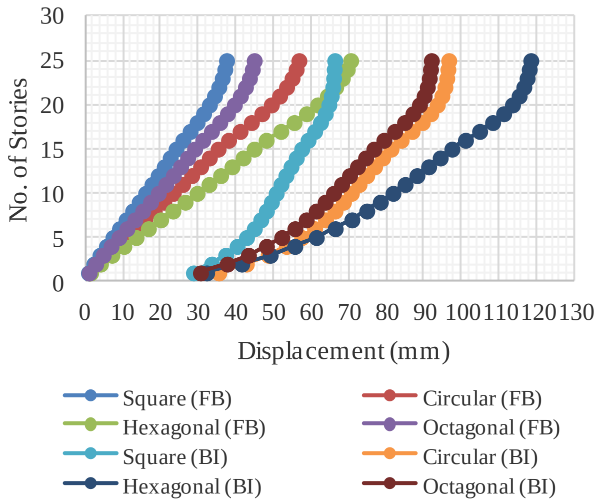

Fig. 13. Comparison of Lateral Displacement in X-direction

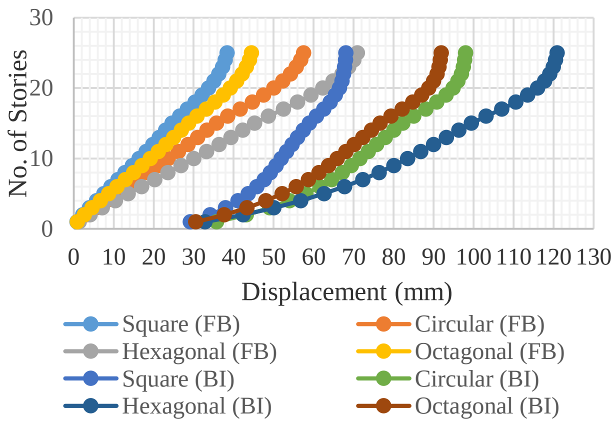

Fig. 14. Comparison of Lateral Displacement in Y-direction

F. Storey Acceleration

The floor level Vs acceleration graph of a fixed base and base-isolated models are shown in figure 15, 16, 17, 18, 19, 20, 21, and 22. From figures, it is found that the acceleration at base of isolated models increased by 39.39%, 62.087%, 112.964%, and 76.626% in X-direction and 42.43%, 63.9%, 117.94%, and 59.155% in Y-direction in square, circular, hexagonal, and octagonal buildings respectively when comparing with fixed base models. It is also observed that the acceleration remains almost the same in the upper storey but varies in bottom stories of all models.

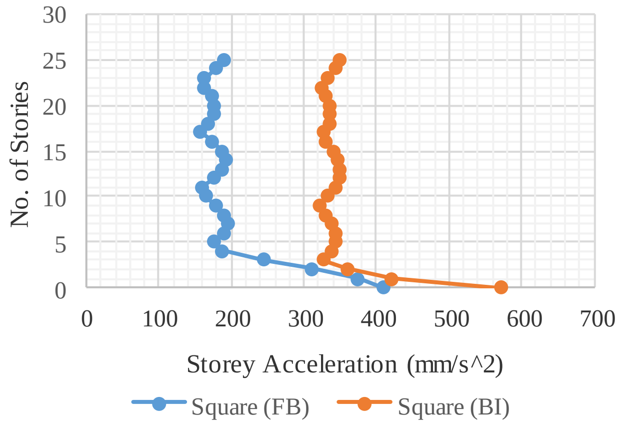

Fig. 15. Storey Acceleration in X-direction

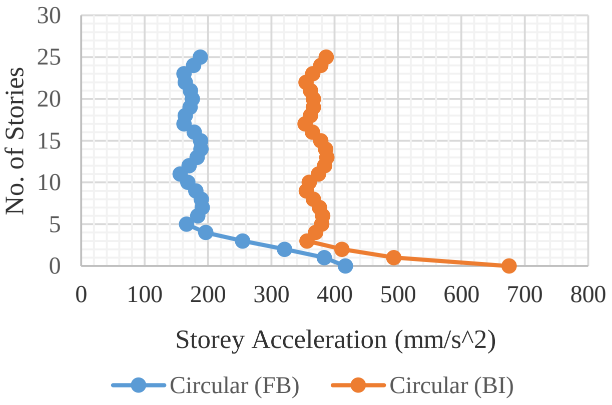

Fig. 16. Storey Acceleration in X-direction

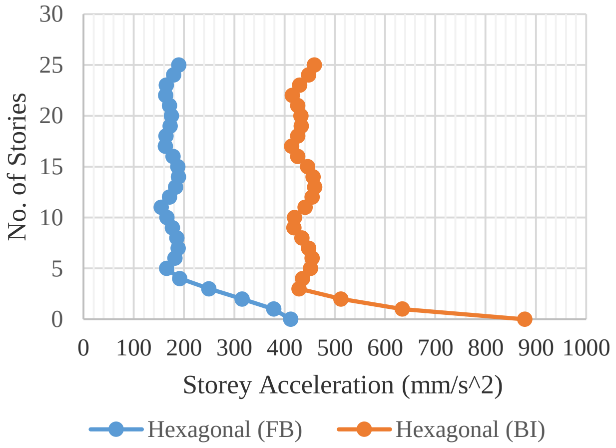

Fig. 17. Storey Acceleration in X-direction

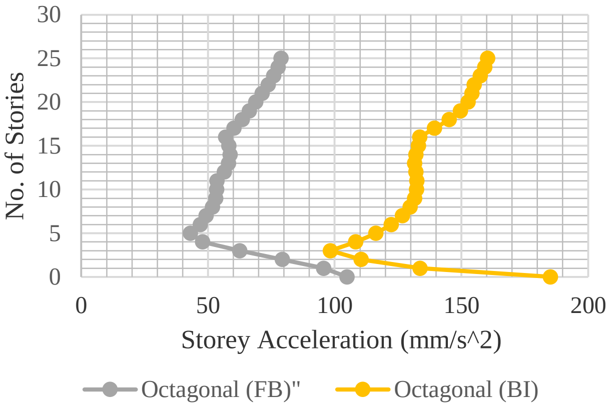

Fig. 18. Storey Acceleration in X-direction

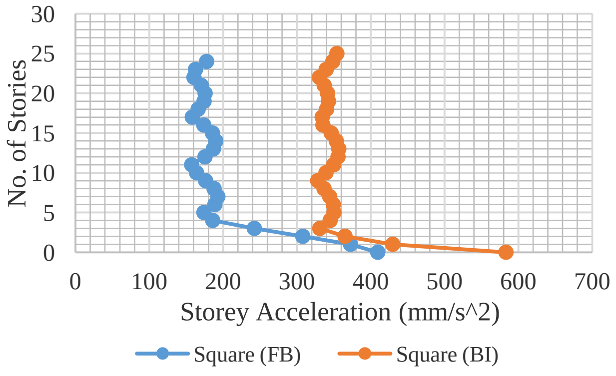

Fig. 19. Storey Acceleration in Y-direction

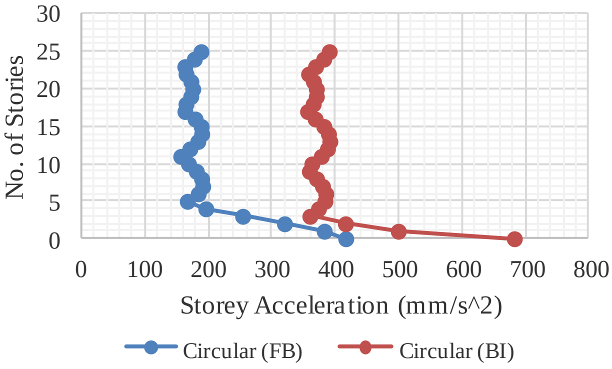

Fig. 20. Storey Acceleration in Y-direction

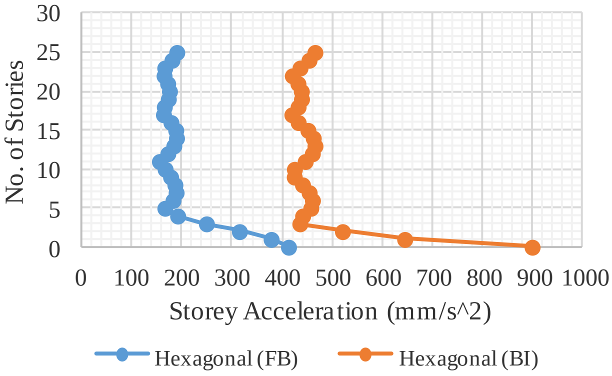

Fig. 21. Storey Acceleration in Y-direction

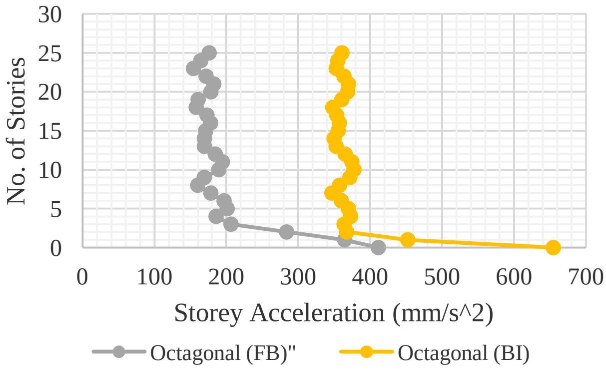

Fig. 22. Storey Acceleration in Y-direction

VI. CONCLUSION AND FUTURE SCOPE

From the above analytical results of four shaped buildings with fixed shape and base isolation system, the following conclusions are summarized as:

1) It has been observed that the base isolation system decreased the base shear of all models in comparison to fixed-base models in both X- and Y-direction. It is experienced that in the circular model, least shear force is decreased by 24.639% in X-direction, whereas in, in the hexagonal model by 23.445% in Y-direction. Similarly, the octagonal model practised decreased in the highest shear by 32.887% and 34.574% in X and Y-direction respectively. It is noticed that the decline in base shear reduced the seismic effect on the building and make structure stable during an earthquake. Hence, it is concluded that the hexagonal-shaped model is the best for reducing the base shear among the four models.

2) Base isolation system decreased the overturning moment at the base of each model. The hexagonal model reduced the least moment by 25.339% and the octagonal model by 40.578% as compared to the fixed base model. Hence, it is found that the octagonal-shaped building performs well for reducing the overturning moment by providing LRB isolation.
3) On comparing the results of hexagonal and octagonal shaped models with their respective fixed-base models based on model period, it is found that hexagonal-shaped buildings presented an increase in the minimum period, whereas, on the other hand, octagonal-shaped buildings showed an increase in the maximum period. An improved model period increases the reaction time of structure during an earthquake, in turn, improves the seismic performance of the model. Hence, the octagonal building proves to be the best model in case of period among other models.
4) Analysis results show the storey drifts within the permissible value (i.e. 0.4% of storey height) and it is significantly reduced in the upper stories. Based on comparative analysis, octagonal-shaped models presented a reduction in storey drifts from base to top. Hence, considered to be the best option in minimizing the structural damages to the structure during the earthquake.
5) The base-isolated structure exhibits the maximum lateral deflection. From the analysis, the hexagonal model shows the more displacements whereas the square model shows the less displacement in both X and Y direction respectively.
6) All the models with base isolation system increased the point displacement in every storey. Increased displacement makes the structure more flexible and minimizes the structural and non-structural damages during earthquake ground motion.
7) The square model shows the least acceleration and hexagonal model shows the highest acceleration in both X and Y-direction by comparing the fixed-base model with the base-isolated model of each shaped buildings.

Finally, it is concluded that the LRB base isolation system increases the stability of the structure against earthquake forces and hence makes the structure economical. Therefore, the octagonal-shaped model was the best and hexagonal shaped the least option for the symmetric tall building.

Future Scope

1) The present research was done only for four shaped models. The research can be done in other various types of building configurations in future.
2) Further researches can be done by providing different types of base isolation system in the same models.
3) Further research can be done with steel, concrete and composite frames by response spectrum analysis method.
4) Further research can be done with different structural systems like shear frame, diagrid, bundled tube, bracing systems with and without base isolation.
5) The models of the present research can proceed out with and without core wall at the centre of the building by varying the beam and column sizes.

REFERENCES

1. Agarwal P. and Shrikhande M., “Earthquake Resistant Design of Structures,” *PHI Learning Pvt. Ltd*., Delhi, India, Eighteen Printing, 2019.
2. Dalal J. A. and Desai A. K., “Wind and Seismic Time History Analysis for Lattice Shell Tube RCC Framed Buildings,” *International Journal of Advances in Engineering and Technology*, Vol. 6, Issue 2, 2013, pp. 826.
3. Dar A. R. and Singh S., “Dynamic Analysis of Base Isolated Tubular Tall Building System (Lead Rubber Bearing) in E-TABS,” *International Journal of Civil Engineering and Technology*, Vol. 10, Issue 3, 2019, pp. 2361-2368.
4. Duggal S. K., “Earthquake Resistant Design of Structures,” Second Edition, *Oxford University Press*, New Delhi, India, 2019.
5. G Iswarya, Ghorpande V. G., and Rao H. S., “Seismic Excitation of Low to High Rise RCC Structure with Lead Rubber Bearing Base Isolation,” *International Journal of Civil Engineering and Technology*, Vol. 7, Issue 6, 2016, pp. 472-481.
6. Hosseini M. and N. V. Ramana, “Earthquake Analysis of High Rise Buildings with Shear Walls at the Center and Center of Each Side of the External Perimeter with Openings,” *International Journal of Science and Research*, Vol. 5, Issue 12, 2015, pp. 59-71.
7. K. T. Mohan, Y. Rahul, and N. Virendra Kumar K., Analysis of Different Forms of Tube in Tube Structures Subjected to Lateral Loads,” *International Journal of Innovative Research in Technology*, Vol. 4, Issue 2, 2017, pp. 56-64.
8. L. Shruthi and Vijaya S., “seismic Analysis of Lattice Shell Tube RC Framed Building,” *International Journal of Engineering Research and Technology*, Vol. 3, Issue 7, 2014, pp. 1201-1205.
9. Patil Basavanagouda A. and S. Kavitha, “Dynamic Analysis of Tall Tubular Steel Structures for Different Geometric Configurations,” *International Journal of Engineering and Research-Online*, Vol. 4, Issue 4, 2016, pp. 878-887.
10. Reddy M. R., Srujana D. N., and Lingeshwaran N., “Effect of Base Isolation in Multistoried Reinforced Concrete Building,” *International Journal of Civil Engineering and Technology*, Vol. 8, Issue 3, 2017, pp. 85-95.
11. Somwanshi, Minal A., and Rina N. P.., “Seismic Analysis of Fixed Based and Base Isolated Building Structures,” *International Journal of Multidisciplinary and Current Research*, Vol. 3, 2015, pp. 2321-3124.
12. Subramanian N., “Design of Steel Structure – Limit States Method,” *Oxford University Press*, New Delhi, India, Fourth Impression, 2018.

AUTHORS PROFILE

Budhi Ram Chaudhary M. E. Student in Structural Engineering, Department of Civil Engineering, Chandigarh University, Gharuan, Mohali, Punjab received B.E. in Civil Engineering from Pokhara University, Pokhara, Nepal. Research interest includes ral Engineering, Steel and Concrete Structures, High Rise Buildings, Structural Analysis and Design, Earthquake Engineering.

Er. Gurpreet Singh Assistant Professor, Department of Civil Engineering, Chandigarh University, Gharuan, Mohali, Punjab was received M.E. (Structure) from Thapar University, Patiala, India in 2014. Research Interest Structural Engineering, Earthquake Engineering, Concrete Composite Structures and Dynamic Analysis of Frames.