Seismic Performance Of High Rise Buildings With Floating Columns And Shear Wall

Kedar Dattatray Bachal[1], Prof. Y. R. Suryawanshi[2]

[1-2-3] *Department of Civil Engineering, JSPM's Imperial College of Engineering and Research, Wagholi (Savitribai Phule Pune University), Pune- 412207.*

Abstract: *In regions prone to seismic activity, the structural integrity of high-rise buildings is of paramount importance. This study investigates the seismic performance of high-rise buildings equipped with innovative structural elements, namely floating columns and shear walls. Floating columns, also known as base-isolated columns, are designed to decouple the building's superstructure from its foundation, thus reducing seismic forces transmitted to the structure. Shear walls are widely utilized to enhance lateral stiffness and provide resistance against seismic loads. Through advanced computational simulations and analytical models, this research evaluates the seismic response of high-rise buildings under various earthquake scenarios. The focus lies on assessing structural behavior, including deformation patterns, stress distribution, and displacement characteristics. Comparative analyses are conducted between conventional building designs and those incorporating floating columns and shear walls to determine the effectiveness of these innovative techniques in mitigating seismic risks. The principal objective of this project is "Seismic Performance Of High Rise Buildings With Floating Columns And Shear Wall". To Evaluate seismic response of high rise buildings with floating column. To Evaluate seismic response of high rise buildings with shear wall In this project, to develop the economic design of building through response spectrum analysis ETABS software is used. ETABS is the leading design software used by many structural designers. According to the design of IS 1893-2016 seismic design is used to perform the analysis of this structure.*

Keywords: Shear Wall, RCC, Software, Analysis.

1. Introduction

The first floor opening of many urban multi-story structures in our nation is an inevitable future development. This is being used to accommodate parking for cars, reception lobbies, or halls, among other things, on the first[1] floor. The distribution of stiffness and mass along the height affects the seismic force distribution and the total seismic base shear of the building during an earthquake. In addition to how the earthquake forces are transmitted to the ground, a building's overall design, size, and geometry have a significant impact on how it responds to earthquakes. The architect will probably use a variety of techniques to increase the amount of space available for one or more storeys inside the multi-story building. One of these techniques is the use of floating columns, which means that the ends of any vertical elements rest on a beam and cause a discontinuity in the columns in such multi-story buildings. Shear walls have therefore been utilised in their direction of orientation to provide the buildings more strength and stiffness. Recent increases in seismic activity make it necessary to take their impact into consideration of the structural study of the buildings and the effects of seismic loading. Therefore, our focus is on analysing how a multistory building with floating columns that is situated in an earthquake force zone will be affected by a shear wall. when obtaining floating columns, shear walls, and structures for both shear walls and floating columns while comparing them to the standard structure. Additionally, compare the time period, storey displacements, storey drift, and storey shear. Models of multi-story buildings are under consideration. The normal building will be taken into account in the first model, followed by floating columns in the second, and shear walls with floating columns in the third. The seismic analysis of multi storey structure is analyzing by response spectrum method. Using Indian Standard code IS 1893(Part-1) 2002 and relevant software.

2. VARIOUS CODES USED IN DESIGN

- **IS-456:2000:** This design code is used for Plain and Reinforced concrete code
- **IS 1893-2016:** This design code is used for Earthquake Resistant Design of Structures.
- **FEMA 356:** This design code is used for Prestandard and Commentary for the Seismic Rehabilitation Of Building.
- **ATC 40** : This design code is used for Seismic Evaluation, and Retrofit of Building.
- **EUROCODE 8:** This code provides Seismic Design of Building.

3. LITERATURE REVIEW

Yan Shing Lina, Ricky W. K. Chana & Hiroshi Tagawab (2020)–

In this research paper, a new seismic risk mitigation technique by connecting a base isolation system with the EEW is suggested. Proposes a smart system which changes the property of a base isolation system over EEW signal. When there is no risk of earthquake, the base isolation system is locked by shear keys. As the earthquake is signalled by the EEW system, mechanical system releases the base isolation system. Whenever the earthquake ceases, the system resets & base isolation is locked again. Vibration sensors are added to activate the system when EEW fails to detect incoming waves. In the results it maximizes the vibration isolation effectiveness. Described and demonstrated a conceptual framework of proposed system by laboratory scaled experiments. A 6-storey test frame is tested on a shake table subjected to historical earthquakes. Results shows that the proposed system is effective in reducing earthquake responses on the building.

Yutaka Nakamura & Keiichi Okada (2019) –

In their review seismic isolation & response control methods of buildings to make buildings resilient against earthquakes is shown, also three types of laminated rubber bearings and three kinds of damping devices is shown. Seismic isolation provides structural safety as well as safety and security for people with properties in the building. The paper describes three foremost response control dampers which are steel hysteretic damper, the viscoelastic damper & the viscous fluid damper. Effects of seismic isolation & response control methods were verified using shaking table tests, structural health monitoring and earthquake response analyses.

Donato Cancellara & Fabio De Angelis (2019) –

In this review analysis of the dynamic behavior of base isolated multistorey structures characterized by high irregularity in plan is completed. High Damping Rubber Bearings isolators were adopted & then placed in parallel with Friction Sliders isolators. Two different types of dynamic analysis are investigated which are dynamic analysis with response spectrum and nonlinear dynamic analysis. With regard to the recent Italian seismic code the comparative evaluation of the results are obtained. The results of the current study are illustrated within the terms of calculations of the deformations and the stresses of the base isolated structure. For the deformations interest is given to the inter storey drifts at the various levels of the multi storey structure. For the stresses associated to the seismic loadings the interest given on bending moment, axial force and shear within the columns & bending moment & shear within the beams.

M. Suneel Kumara, R. Senthilkumarb & L. Sourabhaa (2019) –

In their review seismic performance of regular 6, 9, 12 and 15 storey special concentric X-braced frames in which tension bracings are designed for the lateral loads of 100%, 70% & 60% of base shear is shown. DCR is varied in beam and columns in range of (0.4–0.7) and bracing in range of (0.6–0.9) under designed lateral loads. Pushover curves are designed to determine the strength & ductility of the frame for all the DCR values. If the terms of strength and ductility are considered then column DCR of 0.4 and 0.5 is proven to be more effective with bracing DCR of 0.8 and 0.9 also it shows that the displacement demand for the frames designed for 60% of the total base shear under maximum considered earthquake is within acceptable limit.

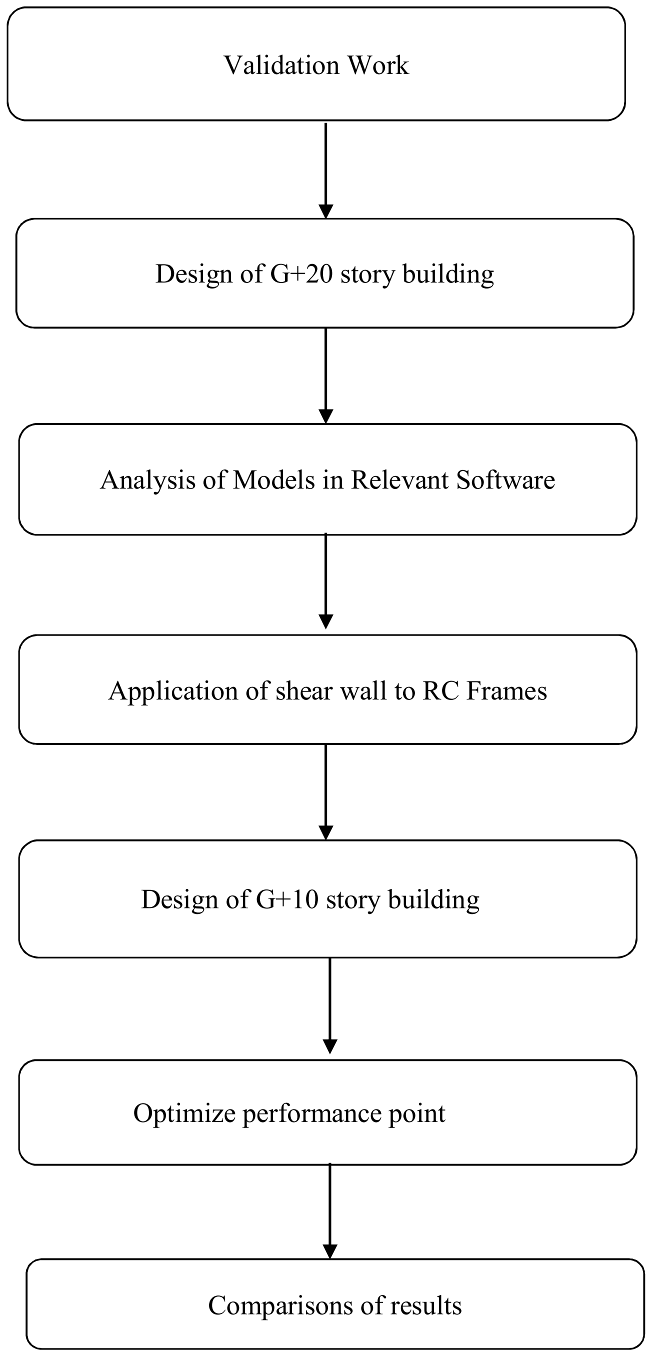
Peyman Narjabadifam, Patrick L. Y. Tiong & Ramin Mousavi Alanjagh (2019) –

In this review effects of characteristics of both isolation system and superstructure on seismic performances of a seismically base isolated buildings subjected to near and far field ground motions through the extensive numerical analyses is investgated. Considered superstructures of 3, 7, and 11 story buildings with steel and reinforced concrete moment resisting and braced frames. By using the isolation systems seven isolation strategies are practically designed, using three target displacements and two coefficients of friction. Created 84 structural models. Carried out nonlinear time history analysis on the two dimensional model of the isolated buildings subjected to seven near field and seven far field ground motions. Studied base shears, story displacements, and story accelerations. Shown that the effectiveness of aseismic base isolation depends significantly on inherent mass, stiffness, and damping of the structure, also effect of isolation damping is more than mass and stiffness of the superstructure. The effectiveness of aseismic base isolation with the design strategies increases as there is increase in the inherent mass and stiffness of the superstructure. In this study, it is found that FPS performs better than HRB, specifically in near field excitations.

Dhanaraj M. Patil, Keshav K. Sangle (2015)-

In their reviews they aimed to compare the seismic behaviour of different bracing systems in high rise 2-D steel buildings. Nonlinear static pushover analysis were carried out to assess the structural performance on different bracing systems in high rise steel buildings of 15, 20, 25, 30 and 35 storeys. Five structural configurations were used moment resisting frames (MRFs), chevron braced frames (CBFs), V-braced frames (VBFs), X-braced frames (XBFs) and zipper braced frames (ZBFs). Investigated the effects of some parameters influencing the seismic performance, including type of the bracing system, the height of the building and lateral load patterns. The results show that the different braced frames performed well in terms of storey displacement, inter storey drift ratio, base shear and performance point when compared with the moment resisting frame in high rise steel buildings. It can be concluded that on a comparative account of the obtained results, that use of CBF, VBF and ZBF enhances structural performances.

4. METHODOLOGY



5. RESULTS AND DISCUSSION

5.1 Result:

In this 3 types of building models are selected for the analysis method. Also its modelling parameter are discussed in detail. RCC buildings of with and without shear wall and floating column is taken for analysis. After modelling response spectrum analysis method applied and results for that is compared. Also obtain the push over curve to determine the performance point of models.

5.2 Model data

The model used for validation is described below.

Table 1*Model Data*

Height of building	64m
Plan Area	1050m^2
Plan Dimension	30X35m
Column size	600X600mm
Beam size	300X450mm
Thickness of Slab	150mm
Unit weight of Concrete	25kN/m3
Grade of Concrete	M25
Grade of Steel	Fe415
Seismic zone	4
Importance factor	1
Response reduction factor	5
Type of soil	II

5.3 Analysis of 20 Storey RC Building

The following are the details of the model used for validation

1. G+20 story building
2. Height of building -64m
3. Plan Area – 1050m2
4. Plan Dimension – 35X30m
5. Column size - 600 X 600mm
6. Thickness of slab - 150mm
7. Beam size – 300X450mm
8. Grade of Concrete - M25
9. Grade of Steel - Fe415

10. Seismic zone - 5
11. Importance factor - 1
12. Response reduction factor - 5
13. Type of soil – II
14. Unit weight of Concrete - 25kN/m3
15. Model 1(M1) - General G+20
16. Model 2(M2) - G+20 Floating column¬- At first floors
17. Model 3(M3) - Shear wall- At corners

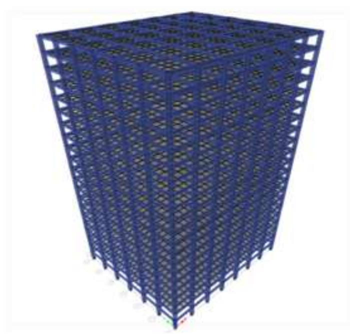


Figure G+20 Building 3D View (M1)

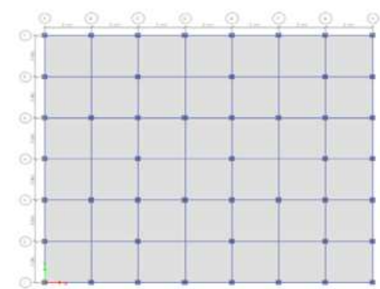


Figure G+20 plan view (M1)

5.4.1 Deformed Shapes:

G+20 Story

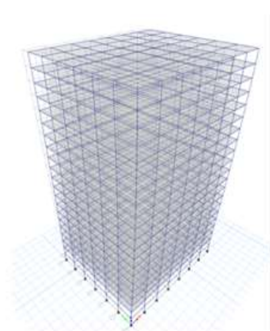


Figure Deformed Shape (Mode1) (M1)

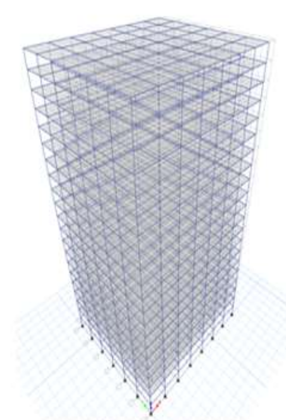


Figure Deformed Shape (Mode2) (M2)

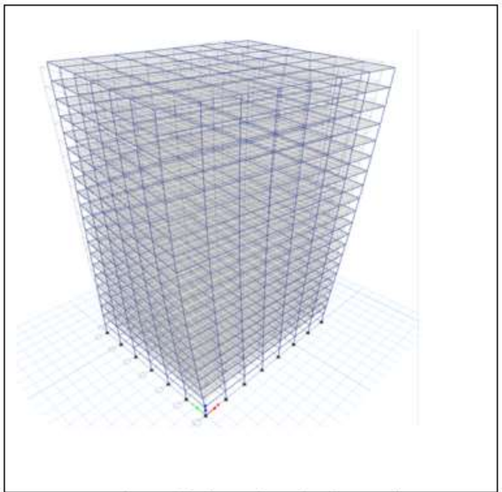


Figure Deformed Shape (Mode3) Torsion

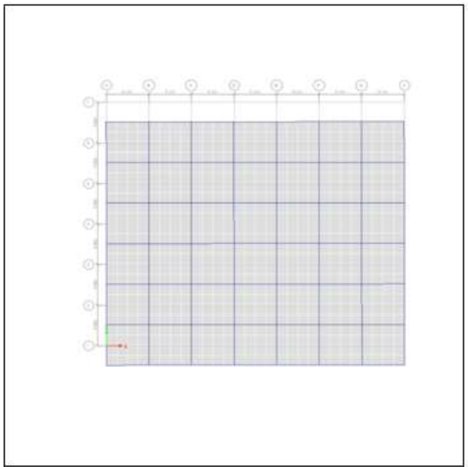


Figure Deformed Shape mode1 (M2)

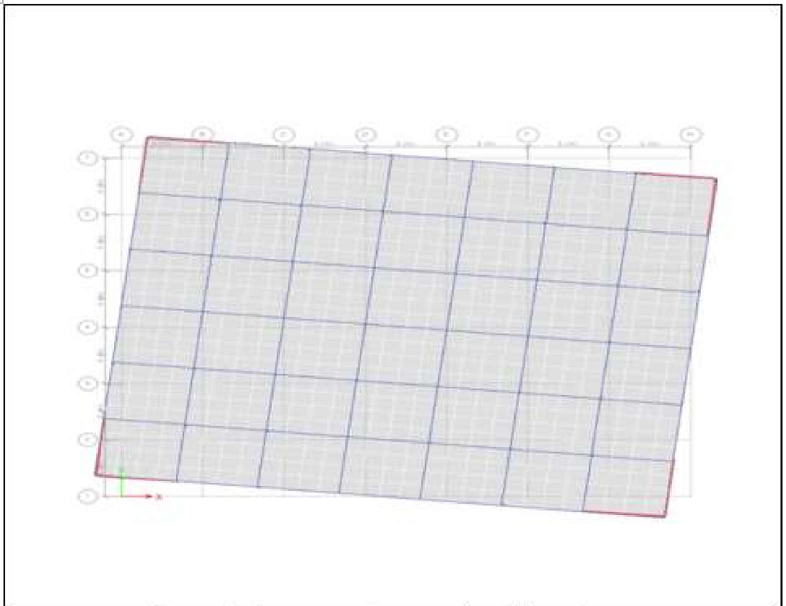


Figure Deformed Shape Mode3Tortional (M2)

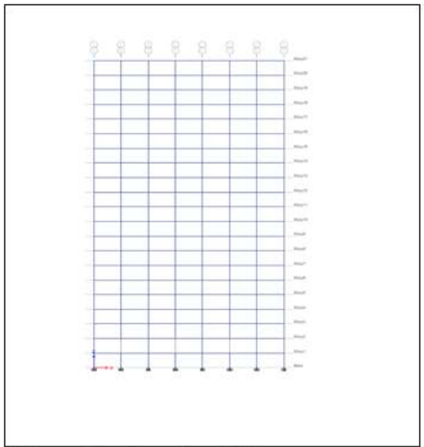


Figure Elevation view (M2)

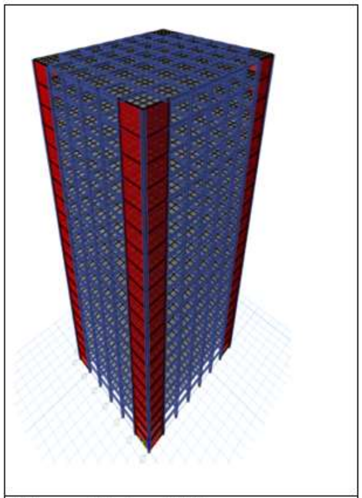


Figure 3D view(M3)

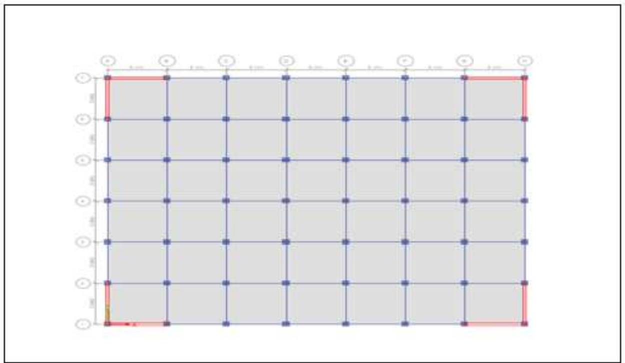


Figure Plan view (M3)

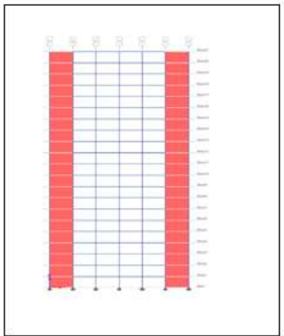


Figure Elevation(M3)

Time Period of Buildings:

Table 5 *Values of Time Period in seconds*

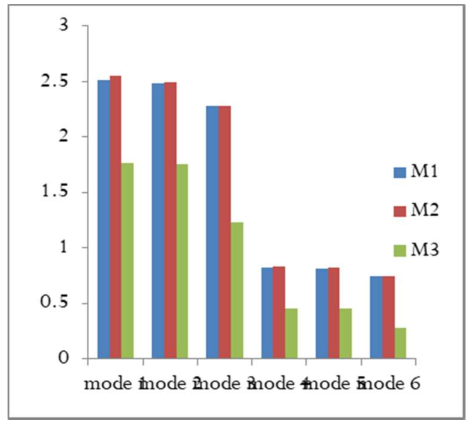
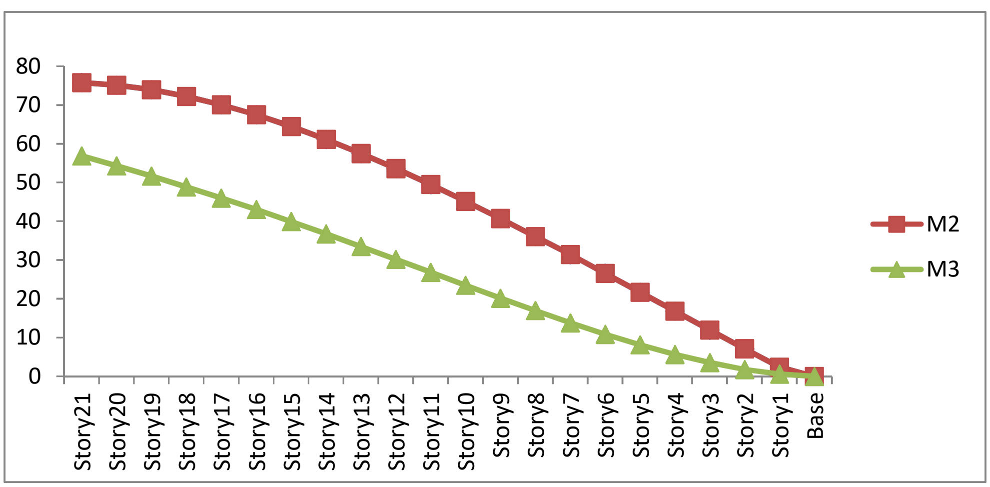


Figure 28 Story vs displacement (mm)

Mode Number	M1	M2	M3
1	2.509	2.55	1.768
2	2.482	2.495	1.754
3	2.279	2.28	1.229
4	0.821	0.829	0.456
5	0.813	0.818	0.454
6	0.748	0.748	0.277
7	0.473	0.473	0.206
8	0.469	0.469	0.206
9	0.435	0.435	0.123
10	0.325	0.325	0.122
11	0.323	0.323	0.119
12	0.3	0.31	0.085

Table 6 Story shear values

Story shear (KN)



O/p case	M1	M2	M3
EQX	3353.9	3353.94	4261.3007
1.2(DL+LL+FL+EQX)	4024.7315	4024.7315	5113.5609

5.4.3 Comparison of Results:

Table 8 *Results of RC Buildings*

Parameter Studied	**M2 model**			**M3 model**		
Time Period (Sec)	Modes			Modes		
	1^{st}	2^{nd}	3^{rd}	1^{st}	2^{nd}	3^{rd}
	2.509	2.482	2.279	1.768	1.754	1.229
Story Shear (KN)	EQ X	1.2(DL+LL+FF+EQX)		EQ X	1.2(DL+LL+FF+EQX)	
	3353.93	4024.73		4261.3007	5113.56	
Top Story displacement(mm)	75			66		
Mass Participation Ratio (%)	91.93			86.96		

6. CONCLUSION

- The reinforced concrete In the present study, linear dynamic analysis is carried for analyzing RCC building frames by using ETAB2019 software. The Response Spectrum analysis is performed on building frames of different models and their results are compared. Push over analysis carried out to check performance point. The results are shown in form of mode shapes, graphs and tables.
- Structure which having floating column will reduce dead load of structure.
- Story drift is decreasing with increasing height of structure in every model.
- Maximum story drift and displacement values are increasing for floating column.
- As the transfer of load of floating columns to conventional columns because of that axial forces are increasing in conventional columns.
- In comparison to buildings without floating columns, it has been discovered that displacement is higher in buildings with floating columns.
- Providing shear wall will give up to 70 % more strength and stability to the structure. Displacement in shear wall model will be lesser as compare to other structure.
- Installation of shear wall in having lesser height won't be as of economic note.
- Base shear is increased with increase in number of story and also in shear wall case.
- The analysis provides us with information about the displacement, shear force, and bending moment at each story of the structure.

References

1. *Abdolrahim Jalali and Peyman Narjabadifam "Optimum Modal Characteristics for Multi-Story Buildings Isolated With LRBS" 4th International Conference on Earthquake Engineering Taipei, Taiwan October 12-13, (2006)*

2. B. Samali, K. C. S. Kwok "Use of Viscoelastic Dampers in Reducing Wind and Earthquake Induced Motion of Building Structures" @ Elsevier Engineering Structures, Vol. 17, No. 9, (1995).

3. Bilal L. Khana, Muhammad Azeem a, Muhammad Usman, Syed H. Farooq, Asad Hanif, Muhammad Fawad "Effect of near and far Field Earthquakes on performance of various base isolation systems" @ Elsevier (2019).

4. Book of James M. Kelly "Earthquake Resistant Design with Rubber" @ Springer Verlag London Limited (1993).

5. C.P. Providakis "Effect of LRB Isolators and Supplemental Viscous Dampers on Seismic Isolated Buildings Under Near-Fault Excitations" @ Elsevier (2008).

6. Dhanaraj M. Patil, Keshav K. Sangle "Seismic Behaviour of Different Bracing Systems in High Rise 2-D Steel Buildings" @ Elsevier (2015).

7. *Dhara Panchal, Sharad Purohit "Dynamic Response Control of a Building Model using Bracings" @ Elsevier (2013)*

8. *Dimos C. Charmpis, Petros Komodromos and Marios C. Phocas "Optimized Earthquake Response of Multi-Storey Buildings with Seismic Isolation at Various Elevations" @ John Wiley and Sons Earthquake Engg Struct. Dyn. (2012).*

9. *Donato Cancellara & Fabio De Angelis), "Dynamic assessment of base isolation systems for irregular in plan structures: Response spectrum analysis vs nonlinear analysis" @ Elsevier (2019).*

10. *Donato Cancellara, Fabio De Angelis "Dynamic assessment of base isolation systems for irregular in plan structures, Response spectrum analysis vs nonlinear analysis" @ Elsevier (2019).*

11. *Ehsan Kazeminezhada, Mohammad Taghi Kazemib, S. Mohammad Mirhosseinia "Modified procedure of lead rubber isolator design used in the reinforced concrete building" Institution of Structural Engineers @ Elsevier (2020).*

12. *Emrah Erduran, Nhan D. Dao and Keri L. Ryan "Comparative response assessment of minimally compliant low-rise conventional and base-isolated steel frames" John Wiley & Sons, Ltd. Earthquake Engineering Struct. Dynamics (2010).*

13. *Esra Mete Guneyisi & Ahmet Hilmi Deringol "Seismic response of friction damped and base-isolated frames considering serviceability limit state" Journal of Constructional Steel Structure @ Elsevier Jun (2018).*

14. *Esra Mete Guneyisi & Ahmet Hilmi Deringol "Seismic response of friction damped and base-isolated frames considering serviceability limit state" @ Elsevier (2018)*

15. *Franco Braga, Michelangelo Laterza "Field testing of low-rise base isolated building" @Elsevier Engineering Structures 26 (2004).*

16. *H. W. Shenton, A. N. Lin "Relative Performance of Fixed-Base and Base-Isolated Concrete Frames" J. Struct. Eng. (1993).*

17. *Hendramawat A Safarizkia, S.A. Kristiawan , & A. Basukib "Evaluation of the Use of Steel Bracing to Improve Seismic Performance of Reinforced Concrete Building" @ Elsevier (2013)*

18. *Henri P. Gavin, and Robert L. Nigbor, "Performance of the Base-Isolated Christchurch Women's Hospital in the Sep. 4 2010 Darfield Earthquake & Feb.22 2011 Christchurch Earthquake" 20th Analysis & Computation Specialty Conference @ ASCE (2012).*

19. *Hyun Choi, Wook-Bae Kim & Sang Jo Lee "A method of calculating the non-linear seismic response of a building braced with viscoelastic dampers" @ John Wiley & Sons (2003).*

20. *J. S. Hwang; Member, & S. W. Ku "Analytical Modeling of High Damping Rubber Bearings" @ ASCE (1997).*

21. *Keri L. Ryan, Kelby York "Vertical Distribution of Seismic Forces for Simplified Design of Base Isolated Buildings" @ ASCE Structures Congress (2007).*

22. Kun Ye, Yan Xiao, Liang Hu "A Direct Displacement-Based Design Procedure for Base-Isolated Building Structures with Lead Rubber Bearings (LRBS)" ©Published by Elsevier (2019).

23. M. R. Maheri, A. Sahebi "Use of steel bracing in reinforced concrete frames" @ Elsevier (1997).

24. M. Suneel Kumara, R. Senthilkumarb, L. Sourabhaa "Seismic Performance of Special Concentric Steel Braced Frames" @ Elsevier Institution of Structural Engineers (2019).

25. M.A. Youssef H. Ghaffarzadeh, M. Nehdi "Seismic performance of RC frames with concentric internal steel bracing" @ Elsevier (2007).

26. O. V. Mkrtycheva, G. A. Dzhinchvelashvilia, A. A. Bunova "Study of Lead Rubber Bearings Operation with Varying Height Buildings at Earthquake" @ Elsevier Procedia Engineering 91 (2014)

27. Peyman Narjabadifam, Patrick L. Y. Tiong, Ramin Mousavi Alanjagh "Effects of Inherent Structural Characteristics on Seismic Performances of Aseismically Base-Isolated Buildings" Iranian Journal of Science and Technology, Transactions of Civil Engineering @ Springer (2019).

28. R.S. Jangid "Optimum Lead Rubber Isolation Bearings for Near-Fault Motions" @ Elsevier Engineering Structures (2007).

29. Robert Tremblay "Inelastic seismic response of steel bracing members" @ Elsevier (2002)

30. S. M. Kalantari, H. Naderpour & S. R. Hoseini Vaez "Investigation Of Base-Isolator Type Selection On Seismic Behavior Of Structures Including Story Drifts And Plastic Hinge Formation" The 14th World Conference on Earthquake Engineering (2008)

31. S.M. Kalantari, H. Naderpour and S.R. Hoseini Vaez "Investigation of Base-Isolator Type Selection on Seismic Behavior of Structures Including Story Drifts and Plastic Hinge Formation" The 14th World Conference on Earthquake Engineering October 12-17, Beijing, China (2008).

32. Shailendra Kumar Damodar Dubey, and Sunil Y Kute "Experimental Investigation on The Ultimate Strength of Partially Infilled and Steel-Braced Reinforced Concrete Frames" @ Springer International Journal of Advanced Structural Engineering (2013).

33. Songye Zhu & Yunfeng Zhang "Seismic Analysis of Concentrically Braced Frame Systems with Self-Centering Friction Damping Braces" Journal of Structural Engineering @ ASCE January (2008).

34. Wenwu Lan, Jiaxing Ma, Bing Li "Seismic performance of steel concrete composite structural walls with internal bracings" @ Elsevier (2015).

35. Yan-Shing Lina, Ricky W.K. Chana, Hiroshi Tagawab "Earthquake early warning- enabled smart base isolation system" @ Elsevier (2020).

36. Yutaka Nakamura & Keiichi Okada "Review on seismic isolation and response control methods of buildings in Japan" @ Springer (2019).

37. Yutaka Nakamura and Keiichi Okada "Review on Seismic Isolation and Response Control Methods of Buildings in Japan" @ Springer Nakamura and Okada Geo environmental Disasters (2019).