iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 10 **Issue:** VII **Month of publication:** July 2022

DOI: https://doi.org/10.22214/ijraset.2022.45970

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 10 Issue VII July 2022- Available at www.ijraset.com

Effectiveness of Lateral Load Resisting Systems for Open Ground+20 Storied RC Framed Structure

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Abstract: In a highly populated country like India, problem of parking of the vehicles arises, this problem leaves no option for design of open ground storey buildings. Since there are no infill walls in ground storey, stiffness in the upper storey is much more than the ground storey. The columns in the ground storey are heavily stressed, therefore it is required that the ground storey columns must have sufficient strength and adequate ductility, the increased base shear is resisted entirely by the columns of ground storey only. These buildings are vulnerable due to the sudden lowering of stiffness and strength in the ground storey. This results in the attraction of more earthquake forces for the lower time periods, which also results in snapping of lateral ties in column, crushing of core concrete, buckling of longitudinal bars and finally shear failure in open ground storey columns due to lateral earthquake forces. Solution for this problem is to prevent the failure of open ground storey columns due to lateral earthquake forces by providing the lateral load resisting system. Many times, stiffness of walls is not considered while designing, this results in inaccurate designing of elements. An Open Ground +20 storied RC frame subjected to strong motion earthquakes viz. Duzce in Turkey (12/11/1999), Erzincan in Turkey (13/03/1992), Imperial valley at El-centro (19/05/1940), Landers (28/06/1992) and Nahanni in Canada (23/12/1985) creating soft storey effect at ground storey so it should be provided with lateral load resisting systems viz, Shear wall, steel bracing, lead rubber bearing base isolator with different configurations. Performance of equivalent diagonal strut provided to structure is compared with brick work modelled as actual brick work, equivalent diagonal struts, and considering only the mass of brick work. Time History Analysis is used in a RC framed building using ETABS Version18 and SAP2000 Version20 software in comparison with Response quantities Roof displacement, soft storey check, Base shear, overturning moment and storey drift. In this research, equivalent diagonal struts are provided as brick masonary, which shows accurate behavior of structure under strong ground motions as mass and stiffness both are considered during analysis. When Open ground storied structure is subjected to strong ground motions, stiffness at ground storey is drastically reduced. When structure is assigned with Lateral Load Resisting Systems, shear wall with configuration shear wall at ground storey and 1st storey, stiffness at ground storey is increased to 81% and 82% in X and Y direction respectively within permissible limits. Hence it can be concluded that when there is soft storey effect at open ground, structure becomes hazardous in presence of strong ground motions. When structure is subjected to strong ground motions, the vulnerability condition is high. Since we have performed non-linear dynamic time history analysis, more accurate results can be obtained as non-linear analysis considers vertical irregularities.

Keywords: ETABS, SAP2000, Time History, Equivalent Diagonal Strut, Roof Displacement, Base Shear, Overturning Moment, Storey Drift.

I. INTRODUCTION

Open ground storey (OGS) buildings are quite popular in India due to availability of parking space and high commercial value of the land. However, these OGS buildings become first victims during earthquake ground shaking. The same is evident from the collapse and huge damage in ground story columns during past earthquake events. This led to a huge loss of life and property. Hence, there is an urgent need to take up retrofit activities of OGS buildings. There were some instances where retrofit activities were taken up on open ground story buildings. However, the performance of the building was not tested after ground storey retrofit. To build confidence among the general public, there is a need to demonstrate that the retrofitted buildings not only save lives but also resist earthquake with minimum damage. This paper is an attempt to demonstrate the same. The building damage or collapse may be occurred during minor, moderate and major earthquakes. The structure has to survive such level of earthquake ground motion without collapse of structural framework, but possibly some structural as well as non-structural damage. In India open ground construction is quite prevalent from last 25 years and its adverse effect was observed for open ground storey building failed during Bhuj earthquake.

II. AIMS AND OBJECTIVES

To investigate the response of an Open Ground (OG) + 20 Storied RC Framed structure with lateral load resisting systems using Time History Analysis

1) To evaluate the performance of OG + 20 Storied RCC Framed structure with brick work modelled as actual brick work, equivalent diagonal struts, and considering only mass of brick work.
2) To investigate the seismic response of an OG + 20 Storied RCC Framed structure under strong earthquake motions using Time History analysis method.
3) To investigate the performance of various lateral load resisting systems viz. shear wall, lead rubber bearing base isolation and steel bracings under three different configurations.

III. PROBLEM STATEMENT AND METHODOLOGY

An Open Ground +20 storied RC frame subjected to strong motion earthquakes viz. Duzce in Turkey (12/11/1999), Erzincan in Turkey (13/03/1992), Imperial valley at El-centro (19/05/1940), Landers (28/06/1992) and Nahanni in Canada (23/12/1985) creating soft storey effect at ground storey so it should be provided with lateral load resisting systems viz, Shear wall, steel bracing, lead rubber bearing base isolator with different configurations. Performance of equivalent diagonal strut provided to structure is compared with brick work modelled as actual brick work, equivalent diagonal struts, and considering only the mass of brick work. Time History Analysis is used in a RC framed building using ETABS Version18 and SAP2000 Version20 software in comparison with Response quantities Roof displacement, soft storey check, Base shear, overturning moment and storey drift

1) Non-linear dynamic analysis is carried on the structure to study response of each structure. Non- linear dynamic analysis is carried on the structure with the help of Time History Analysis. For reaching to the conclusion Base shear, roof displacement, overturning moment and storey stiffness on ground storey will be studied.
2) Time history analysis is used to determine the seismic response of a structure under dynamic loading of representative earthquake. Time- history analysis provides for linear or nonlinear evaluation of dynamic structural response under loading which may vary according to the specified time function.

A. Methodology

Non-linear dynamic analysis is carried out on an Open ground + 20 storey RC Structure. Each model is analyzed with Fixed base, Shear wall, Bracing, with assigning at 1st storey, 1st and 2nd storey and throughout configurations. These systems are analyzed with ETABS V18 Software. Base isolation system with isolators designed differently for external and internal columns. Base isolation system is analyzed with SAP2000 V20 software. The objectives of this research work will be completed with the use of ETABS and SAP2000.

1) Model initialization is the first step in which units, steel section database, IS codes for steel and concrete are selected.
2) Equivalent Diagonal Strut is defined in ETABS.
3) Masonary section is designed in section designer
4) Time history functions are defined in ETABS.
5) Beam, column, slab, equivalent diagonal strut sections are drawn.
6) Frame loads are assigned over beam section to apply wall loads.
7) Modelling of Infill wall as EDS (Equivalent Diagonal Struts).
8) Design of shear wall as per IS13920-2016.
9) Modelling of boundary element in shear wall.
10) Modelling and design of internal and external base isolators is done in SAP2000.
11) Sections in ETABS were selected and iteration was done for failed members of bracings.

The performance of open ground storey RC structure having three different configurations with shear wall and bracing is checked using ETABS and for base isolation, it is checked using SAP2000. For this proposed work Non-linear dynamic analysis is performed which is also known as time history analysis. The parameters studied for the seismic performance of all the three types of configurations with fixed base and with lateral load resisting systems are base shear, top storey displacement, stiffness at ground storey, overturning moment, and storey drift.

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 10 Issue VII July 2022- Available at www.ijraset.com

Table 3.4: Description of models

Sr. No.	Model Number	Application of LLRS
1	Model 1	Fixed base
2	Model 2	Shear wall at Ground storey
3	Model 3	Shear wall at ground and 1st storey
4	Model 4	Shear wall throughout building height
5	Model 5	X Bracing at Ground storey
6	Model 6	X bracing at ground and 1st storey
7	Model 7	X bracing throughout building height
8	Model 8	V bracing at Ground storey
9	Model 9	V bracing at ground and 1st storey
10	Model 10	V bracing throughout building height
11	Model 11	Inverted V bracing at Ground storey
12	Model 12	Inverted V at ground and 1st storey
13	Model 13	Inverted V throughout building height
14	Model 14	K bracing at Ground storey
15	Model 15	K bracing at ground and 1st storey
16	Model 16	K bracing throughout building height
17	Model 17	LRB Base isolation

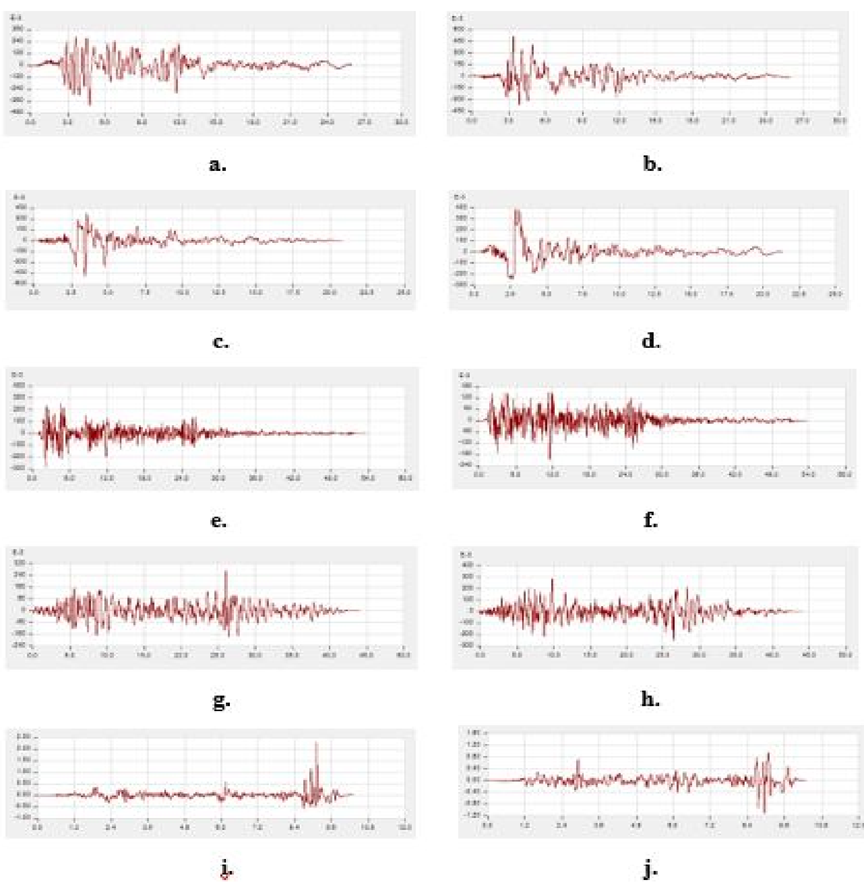

Fig. Time Histories for Earthquake a. Duzce in X-direction, b. Duzce in Y-direction, c. Erzincan in x-direction, d. Erzincan in Y-direction, e. Imperial Valley in X-direction, f. Imperial Valley in Y-direction, g. Landers in X-direction, h. Landers in Y-direction, i. Nahanni in X-direction, j. Nahanni in Y-direction respectively.

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IV. RESULTS AND DISCUSSION

A. Results

The performance of open ground storey RC structure having three different configurations with shear wall and bracing is checked using ETABS and for base isolation, it is checked using SAP2000. For this proposed work Non-linear dynamic analysis is performed which is also known as time history analysis. The parameters studied for the seismic performance of all the three types of configurations with fixed base and with lateral load resisting systems are base shear, top storey displacement, stiffness at ground storey, overturning moment, and storey drift.

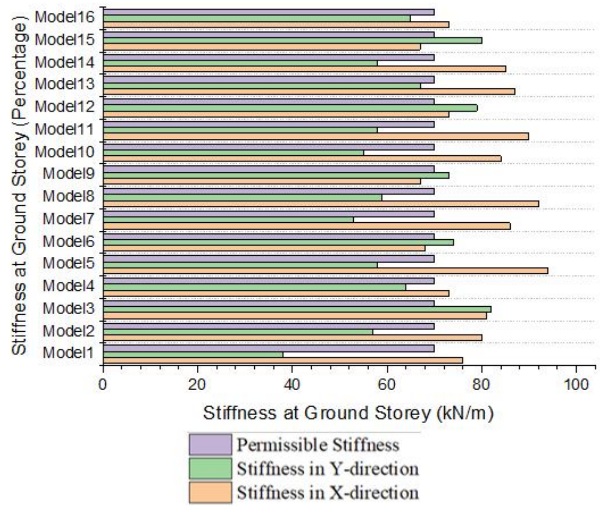

Fig. Stiffness at ground storey(percentage)

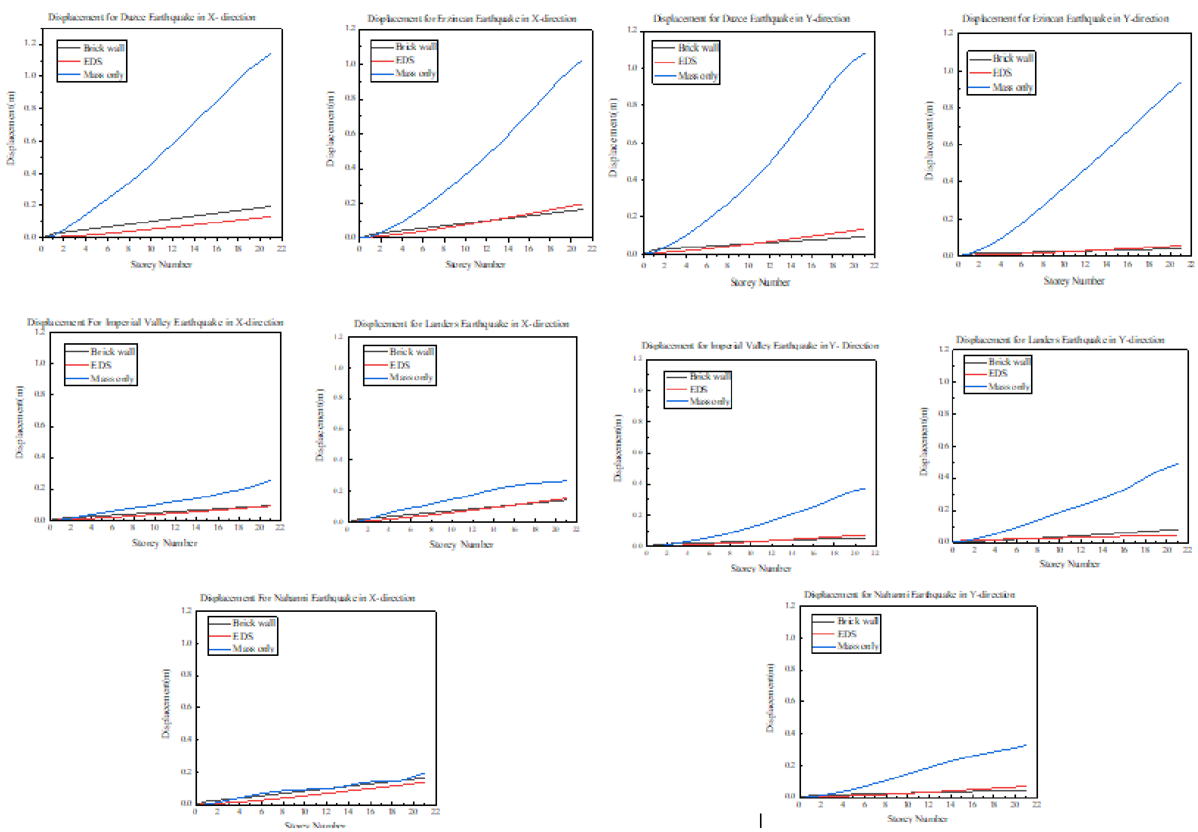

Fig. Displacement in X and Y direction for fixed base with wall modelled as Brick wall, EDS and mass only

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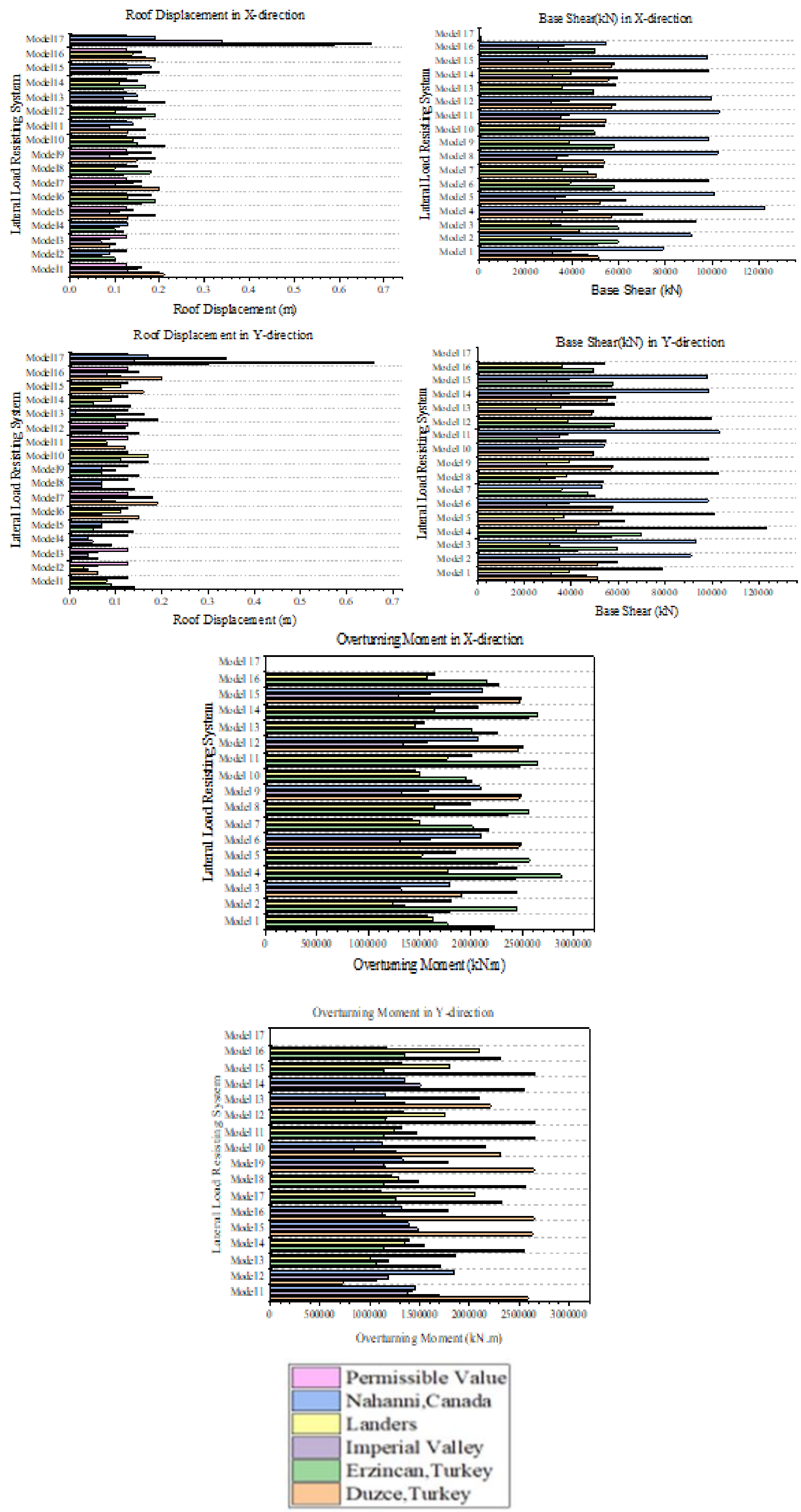


Fig. Roof Displacement, Base Shear and Overturning Moment in X and Y direction

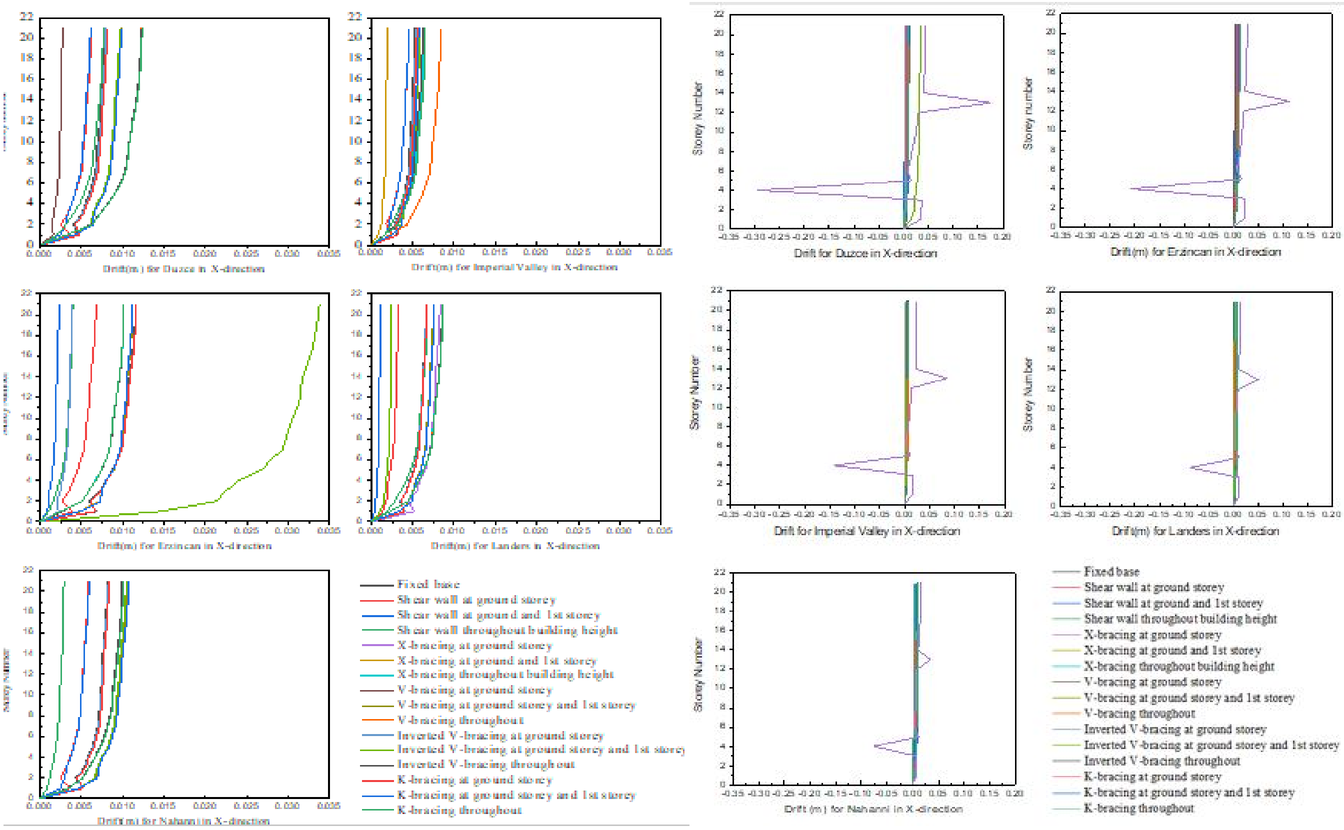
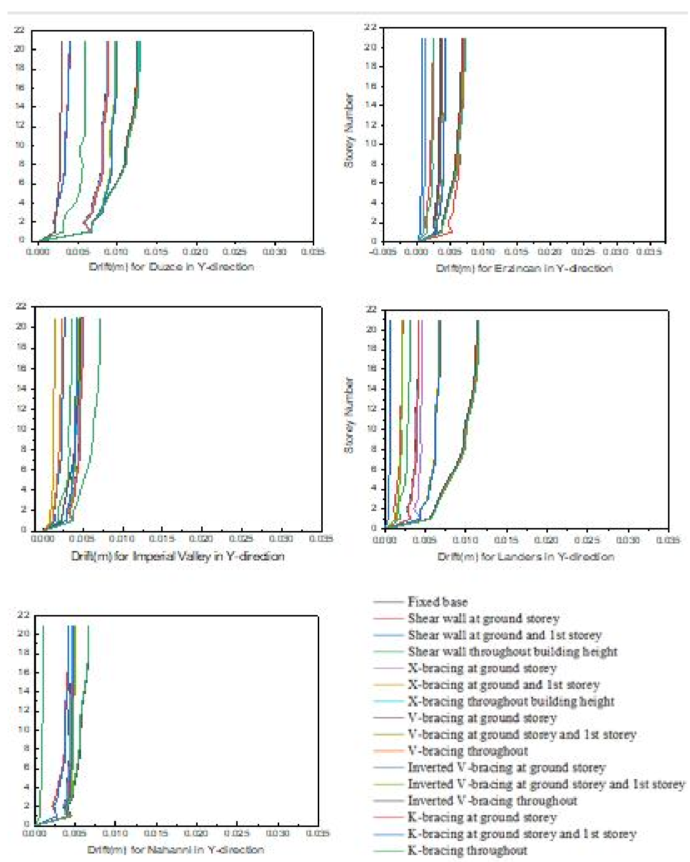


Fig. Storey drift in X-direction



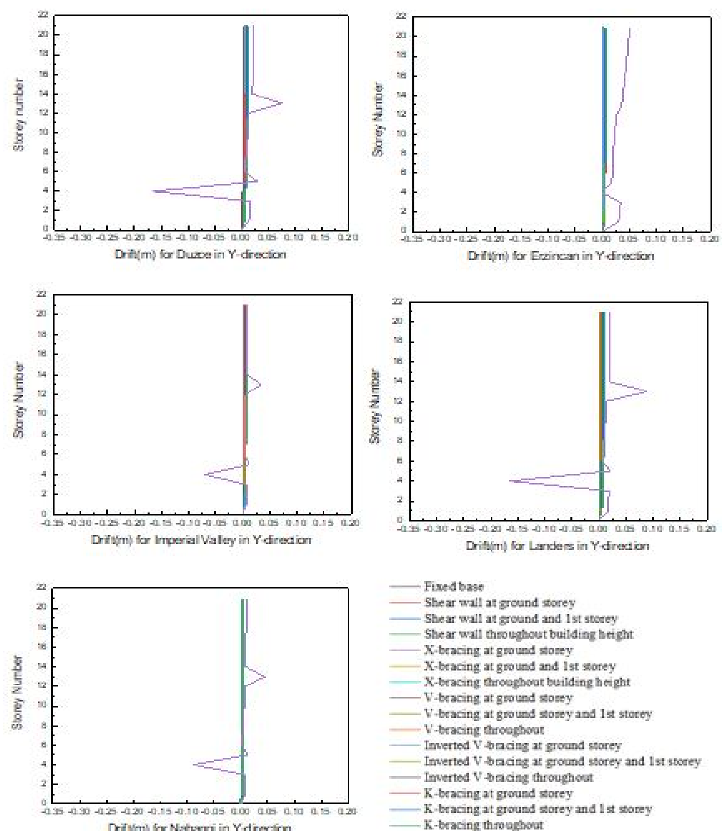


Fig. Storey drift in Y-direction4

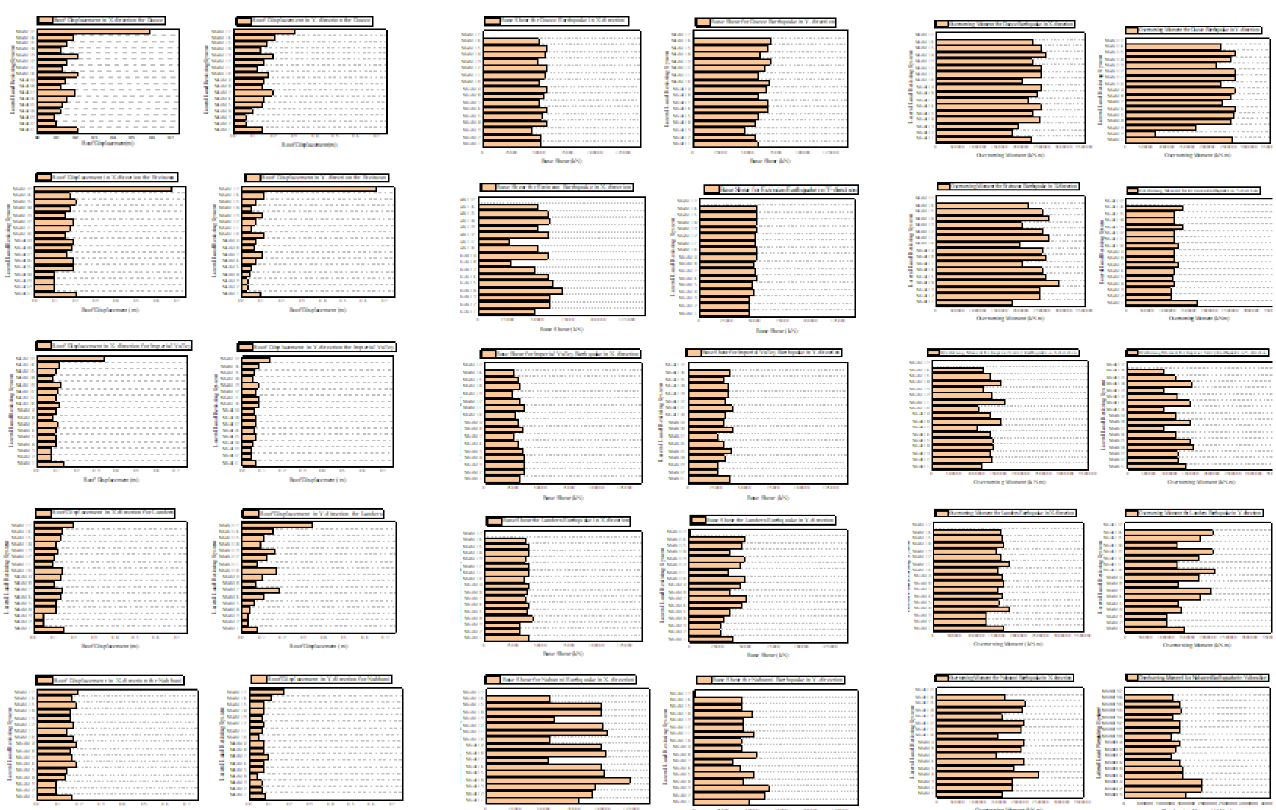


Fig. Roof displacement, Base Shear and Overturning Moment in X and Y direction

B. Discussion

1) Response of structure for Brick Masonary modelled as brick work, EDS and considering only mass of Brick Masonary

Response of Model 1 structure for brick masonary modelled as brick wall, Equivalnet diagonal struts and considering mass only is recorded under 5 strong motion earthquakes. which model performs better in displacement is noted. It is observed that, Displacement of brick wall model considered for brick masonary is found lowest in all eartquakes. Brick wall modelling increases rigidity of struture and shows exaggerated bending moments on adjacent section. Hence it is not preffered in modelling of brick masonary.

Displacement of model, considering mass of brick masonary only found highest in all earthquakes. Due to not considering stiffness of brick masonary, there is no resisting force in brick masonary area which can resist earthquake force, hence it cannot resist force, displacement increases.

Displacement of model considering brick masonary as EDS found to be moderate. Stiffness of brick masonary is considered by providing equivalent diagonal struts which opposes earthquake forces and mass of brick masonary is applied on beam sections for considering mass of brick masonary. Mass and stiffness are considered while modelling brick masonry, which was found to be most appropriate method of modelling.

Hence, EDS is preffered for modelling of brick wall.

Displacement of model, considering mass of brick masonary only found highest in all earthquakes. Due to not considering stiffness of brick masonary, there is no resisting force in brick masonary area which can resist earthquake force, hence it cannot resist force, displacement increases. Displacement of model considering brick masonary as EDS found to be moderate.

2) Response of Structure According to Earthquake Ground Motions

It is observed that,

Roof displacement for all earthquakes for Model 1 found to be lowest among all LLRS. When an Open ground storey structure is provided, not only stiffness of OGS is significantly reduced, but stiffness of adjacent storey is also reduced, by providing shear wall at ground and 1st storey, this problem can be solved.

Roof displacement for Model 13 found out to be highest among all bracing models.

Roof displacement for Model 17 found out to be highest among all models, because when the base is movable, the roof will also move in greater extent.

Base shear for Model 4 found to be highest.

Base shear for Model 3 found to be lowest among shear wall, and bracing.

Base shear for Model 17 found to be lowest.

Overturning moment for Model 6 found to be highest.

Overturning moment for Model 3 found to be lowest.

Overturning moment for Model 17 found to be lowest.

Storey drift is highest for Model 17 for all ground motions.

Roof displacement in Model 17 system is highest in X and Y directions for Erzincan earthquake due to its Peak Ground Acceleration value 0.234g and magnitude 6.69Mw with duration of strong shaking for 10 seconds.

Roof displacement for Model 3 is lowest in X and Y directions for Landers earthquake due to its low Peak Ground Acceleration value 0.180g.

Base shear is highest Model 4 for Nahanni Earthquake because of its Peak Ground Acceleration value 0.228g and magnitude 6.76Mw.

Overturning moment is highest for Model 4 for Nahanni Earthquake because of its Peak Ground Acceleration value 0.228g and magnitude 6.76Mw.

V. CONCLUSION

From the result of software analyses following conclusions are drawn:

1) When equivalent diagonal struts are provided as brick masonary, it shows accurate behavior of structure under strong ground motions as mass and stiffness both are considered during analysis.
2) When Open ground storied structure is subjected to strong ground motions, stiffness at ground storey is drastically reduced. When structure is assigned with LLRS shear wall with configuration shear wall at ground storey and 1st storey, stiffness at ground storey is increased to 81% and 82% in X and Y directions within permissible limits. Hence it is concluded that when there is soft storey at open ground, structure becomes hazardous in presence of strong ground motions.

3) When structure is subjected to strong ground motions, the vulnerability condition can be known for structure in worst case scenario. Since we have performed non-linear dynamic time history analysis, more accurate results can be obtained as non-linear analysis considers vertical irregularities.

VI. ACKNOWLEDGEMENT

I would like to express my gratitude to Dr. M. V. Waghmare who had been instrumental in guiding me through each and every phase of my dissertation. She has been a sense of inspiration enthusiasm without which the successful completion of project would have been an impossible dream.

I offer profound gratitude towards Dr. U. R. Awari (HOD, Department of Civil Engineering) for providing me all the excellent academic facilities required to complete this work. I am deeply indebted to Principal Dr. D. S. Bormane and Faculty of Civil Engineering Department in particular for simulating suggestions and encouragement, which helped me all the time for work and writing of this dissertation. I would also like to appreciate enthusiastic cooperation of our library staff without whose help, knowing the information would have been a tedious work.

Finally, yet importantly, I would like to thank my family members and friends who have tremendously boosted me and who have been my driving force throughout my dissertation. Their support and blessings helped me to reach this stage

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