ISSN 2229-5518

Seismic Performance of Buildings with Lateral Load Resisting Systems

Aswini A R, Jayalekshmi R

Abstract—Attenuating the effects of severe ground motions on the buildings and their contents is always one of the most popular topics in the area of civil and structural engineering and attracts the attention of many researchers and engineers around the world. To minimize the damage due to earthquake on the structures active and passive vibration control methods are there. This paper investigates the seismic performance of buildings with lateral load resisting systems i.e., buildings with shear walls and tunnel form type buildings. by Nonlinear time history Analysis ue tofor ground motions d Elcentro, Loma prieta and Northridge earthquakes. The main parameters studied are the time period, base shear, storey displacement and storey drift. Base shear in case of tunnel form type building is higher than building with shear wall and which possess much smaller displacement compared to building with fixed base and building with shear wall. Tunnel form type building was found to be more effective in reducing storey displacement and storey drift compared to other models. Buildings are modelled and analysed using standard package SAP 2000 V 17.

Index Terms—Seismic performance, Passive vibration control, Shear wall, Nonlinear time history analysis, Tunnel form type buildings.

1 Introduction

EXPERIENCE in past earthquakes has demonstrated that typical methods of construction and many buildings lack basic resistance to seismic forces. In most cases this resistance can be achieved by following simple, inexpensive principles of good building construction practice. Multi-storeyed buildings, if not designed properly for lateral forces, may lead to complete collapse and hence loss of property and life. When an earthquake strikes, the structure moves laterally and vertically caused by the surface ground motion induced by the seismic waves. Typically, the lateral motion is much greater than the vertical motion. The mass, size and configuration of a building or a structure indicate how the structure will respond to an earthquake event. Any structure is to be designed to hold out against the lateral forces induced on to it by the earthquake ground motion. To achieve this, the lateral load resisting systems need to resist all these lateral forces coming on to the structure during an earthquake event. Buildings with uniform distribution of mass and stiffness in both plan and elevation and simple-regular geometry will suffer lesser damage compared to the buildings with irregular geometry and configurations. The regular design approach to the earthquake resistant design of buildings is to provide the building with high strength, stiffness and inelastic deformation capacity which are good enough to hold out against the given level of earthquake generated force. This generally is done by the selection of perfect structural configurations and a very careful structural detailing of all the structural elements, such as beams, columns, and their connections.

- *Aswini A R is currently pursuing masters degree program in structural engineering in Kalam Technological University, India,*
  E-mail: aswiniar12@gmail.com
- *Jayalekshmi R, Professor in Civil Engineering in Kalam Technological University, India*
  E-jayalekshmisankar@gmail.com

The recent technologies used in the earthquake resistance design are not for the strengthening of the building, but for the reduction of the earthquake forces acting on it. Shear walls are incorporated in building to support the gravity loads and resist lateral forces. RC shearwall has high in plane stiffness. Positioning of shear wall has influence on the overall behaviour of the building. For effective and efficient performance of building it is essential to position shear wall in an ideal location Reinforced concrete (RC) buildings often have vertical plate-like RC walls along with slab, beam and column called Shear Walls in addition to slabs, beams and columns. Shear walls provide strength and stiffness to buildings in the direction of their orientation, which significantly reduces lateral sway of the building and thereby reduces damage to structure and its contents. Buildings with shear wall provided at corners found to be more effective from various literatures.

In the recent past tunnel form type building construction technology has developed and widely used all around the world and even in India this technology has been adopted in many major cities. The buildings built with this technology consist of RC wall with slab resting on them. This technology is widely adopted because of the speedy construction. Tunnel form buildings diverge from other conventional RC (reinforced concrete) structures due to lack of beams and columns in their structural components. In these buildings, all of the vertical load carrying members are made of shear walls and floor system.

2 OBJECTIVES

The main objective of the study is to compare the seismic response of conventional moment resistant framed structure and structures with lateral load resisting systems i.e., shear walled and tunnel form construction

ISSN 2229-5518

3 DESCRIPTION OF MODEL

In the present study three models of regular buildings were analysed using the software SAP 2000. The modelling details of considered building configurations are given in Tables 1,2 and 3. The building is kept symmetric in both mutually perpendicular directions in plan to avoid torsional effects. The orientation and size of column is kept same throughout the height of the structure. Storey heights of buildings are assumed to be constant including the ground storey.

TABLE 1 MODELLING DETAILS OF BUILDING

Plan dimension	25x12m
Number of storeys	G+13
Storey height	3m
Parapet height	1.2m
Building use	Hospital
Seismic zone	Zone V

TABLE 2 MATERIAL PROPERTIES

Grade of steel	Fe 415
Grade of concrete	M40
Density of concrete	25kN/m3
Poisson's ratio of concrete	0.20
Compressive strength	1.9kN/m2

TABLE 3 STRUCTURAL MEMBERS

Thickness of slab	150mm
Thickness of external wall	230mm
Thickness of internal wall	150mm
Column size	450x450mm
Beam size	300x500mm
Live load on all floors	3 kN/m2
Floor finish	1 kN/m2

4 MODELS CONSIDERED FOR ANALYSIS

Following three models are considered and are analysed using SAP2000 software. Nonlinear time history analysis is used for the analysis of the models.

1: Building with fixed base.

2: Building with shear wall provided at the corners.

3: Tunnel form type building with a structural system composed of reinforced concrete shear walls and slabs as load bearing and transferring elements without accommodating columns and beams.

Nonlinear time history analysis is performed in SAP 2000 v 17. Three different recorded time histories of past EQ are used for the analysis. One is the Imperial valley earthquake occurred in the year 1940. Second one is the Loma prieta earthquake occurred in the year and third one is the Northridge earthquake occurred in the year 1994.Parameters like base shear, storey displacement, storey drift, fundamental period of vibration is studied. These values are then compared to obtain the conclusion that which is more effective in controlling seismic vibration.

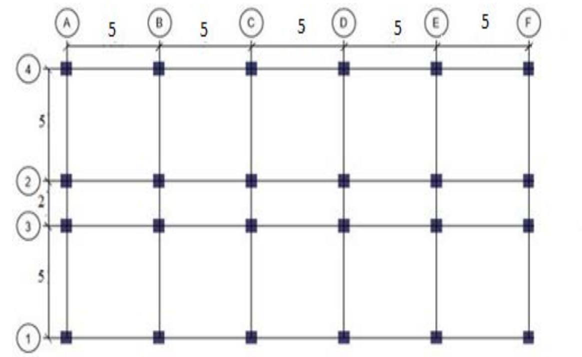

Fig 1 Plan of model 1

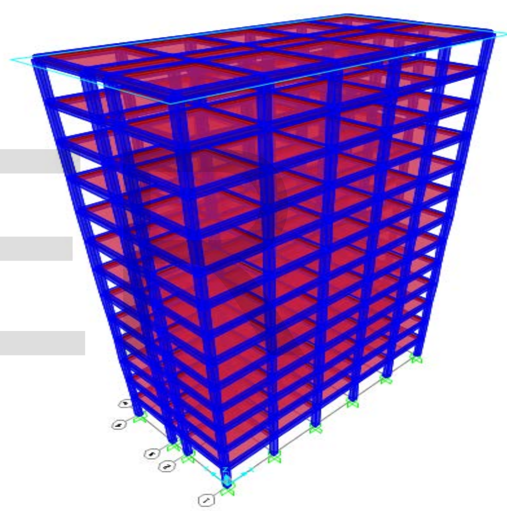

Fig 2 3D view of model 1

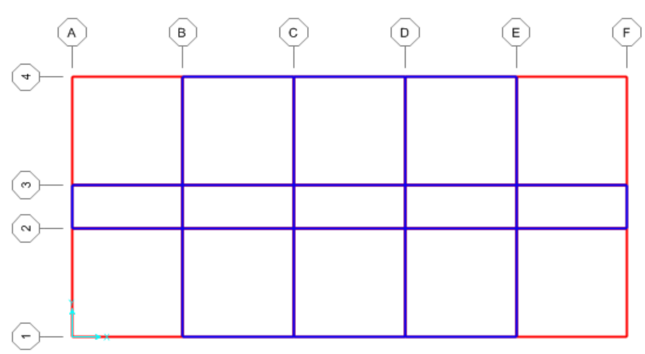

Fig 3 Plan of model 2

ISSN 2229-5518

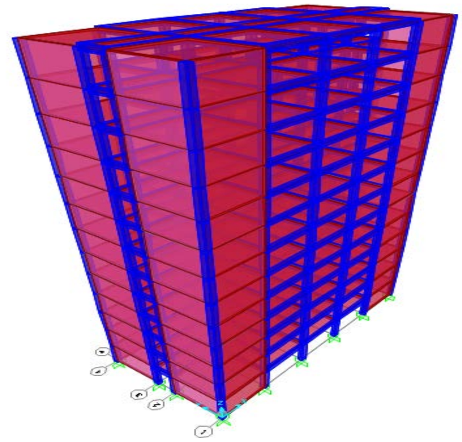

Fig 4 3D view of model 2

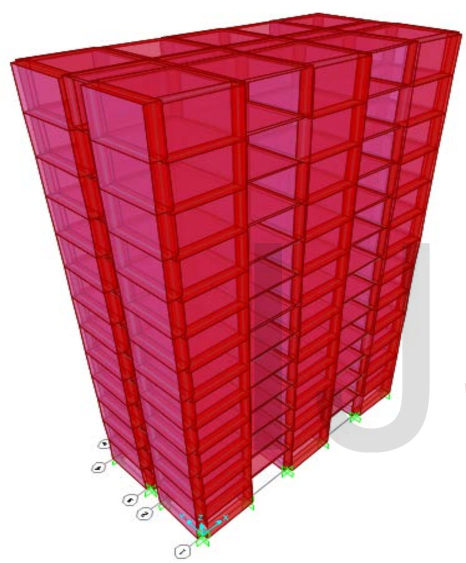

Fig 5 3D view of model 3

5 RESULTS AND DISCUSSION

The modelling and seismic analysis of different buildings was carried out using the software SAP 2000. The results obtained are tabulated below. The parameters which are to be studied are time period, maximum storey displacement, maximum storey drift, base shear.

5.1 Fundamental Time period:

Time period for all the model are shown in table below:

TABLE 4 COMPARISON OF FUNDAMENTAL TIME PERIOD

Building Type	X-direction (s)	Y-direction(s)
Building with fixed base	1.83	1.78
Building with shear wall	0.85	0.20
Tunnel form type building	0.26	0.18

Tunnel form type building has the least fundamental period of vibration among all the models. Compared to fixed base, building with shear wall also have smaller time period. The reduction in fundamental period of TFB when compared with framed building is nearly 86%.

5.2 Base Shear

The base shears of all building models are compared in this section. The results show that the base shear in case of tunnel form type building is higher than building with fixed base and building with shear wall. Stiffer shear walls in tunnel form building attract more force at the base which causes higher base shear in them and it attracts more force at the base which may demand strong and heavy foundations and identical behavior is observed for all the earthquakes.

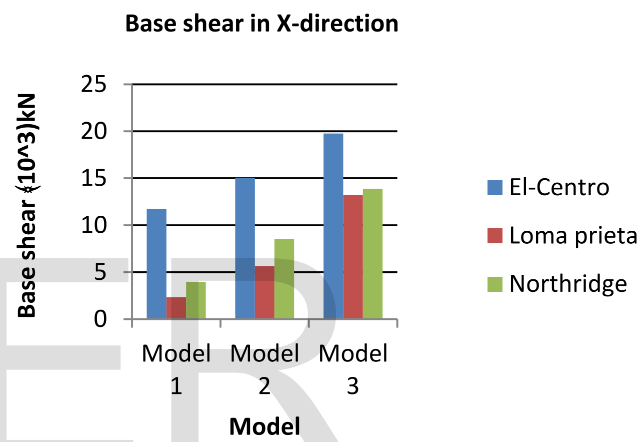

Fig 6 Base shear in X direction

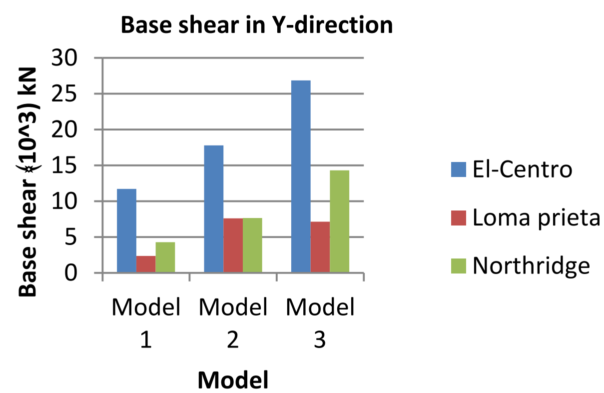

Fig 7 Base shear in Y direction

5.3 Top storey displacement

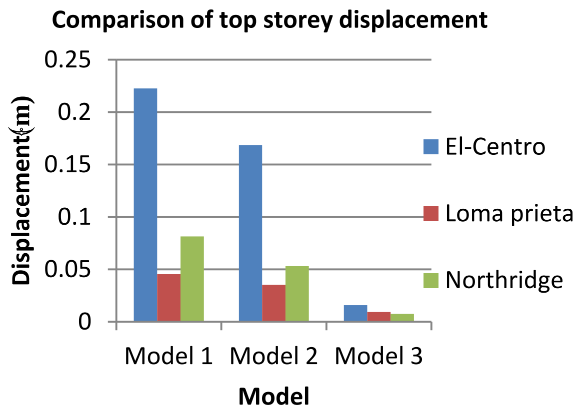

Fig 8 Comparison of top storey displacement for various earthquakes for different models

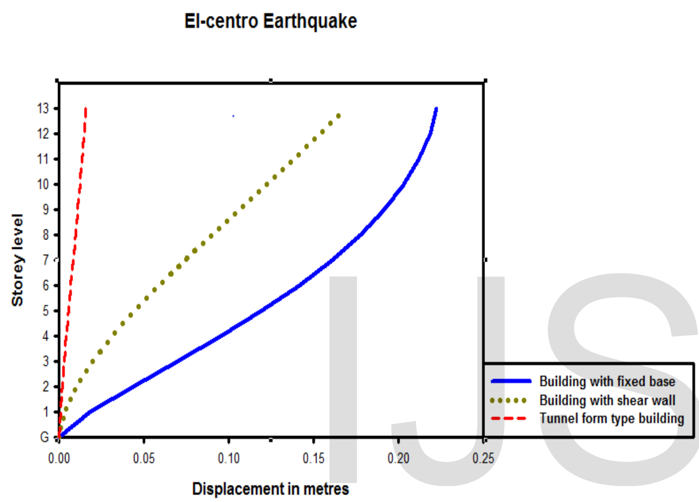

Fig 9 Story displacement of various models for El-Centro earthquake

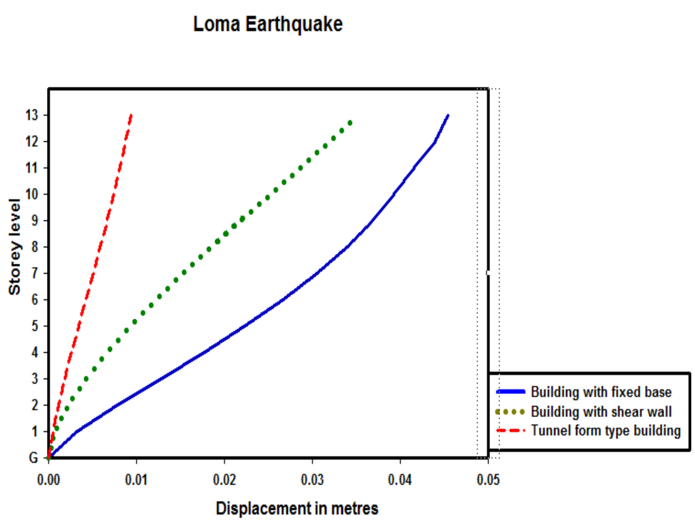

Fig 10 Story displacement of various models for Loma Prieta earthquake

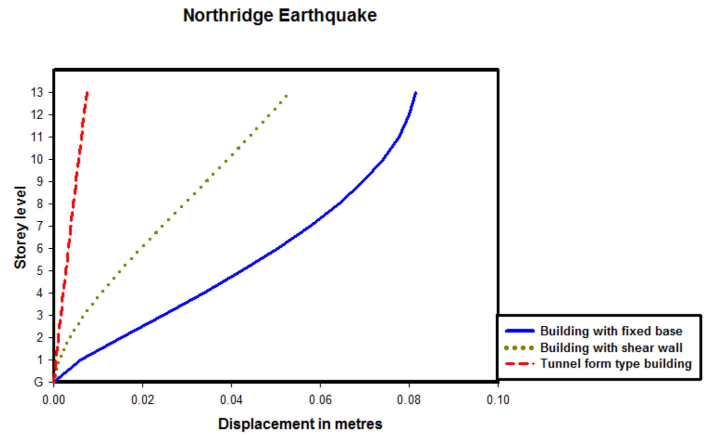

Fig 11 Story displacement of various models for Northridge earthquake

The maximum displacements of all models are individually compared for the three earthquakes. The tunnel form type building performs better than the conventional building and building with shear wall. This shows that the tunnel form type building offers more resistance to the lateral forces such as seismic forces than the conventional building. Shear walls in tunnel form buildings offer stiffness and hence the displacement experienced is lesser when compared to framed buildings. Similar variation is observed for all the earthquakes.

5.4 Maximum Storey Drift

Interstory drift is the difference of adjacent story displacements. In tunnel form type building, maximum interstory drift is observed in the upper floors and this remains constant for few upper floors. The lower floors experience lesser drift. In framed models, the lower floors experience the highest drift and it reduces for the upper floors in general. Also, the pattern of drift followed in tunnel form type is gradual and of uniform nature unlike framed type. Framed building models are experiencing higher drifts than tunnel form building models. Maximum interstory drift is also higher in the framed models when compared to tunnel form type models. In the case of building with shear wall maximum drift is observed in top storeys.

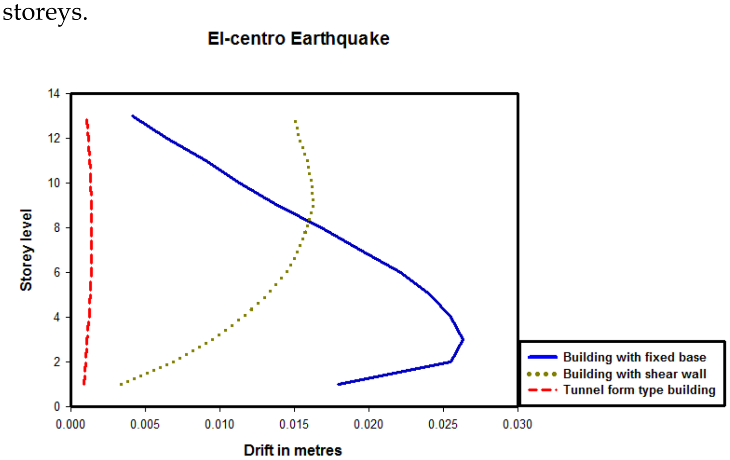

Fig 12 Story drift of various models for El-centro earthquake

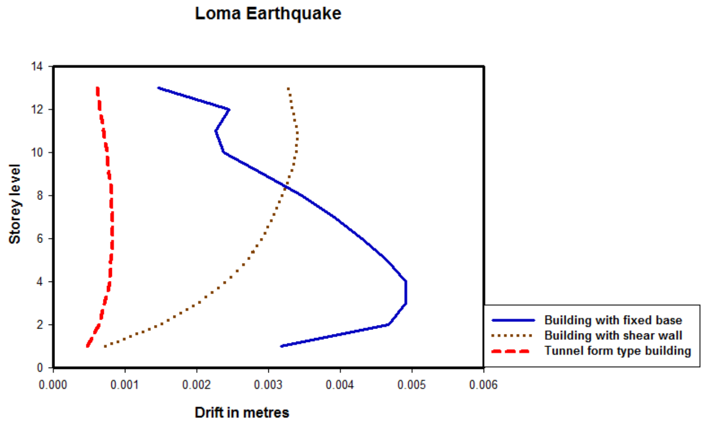

Fig 13 Story drift of various models for Loma prieta earthquake

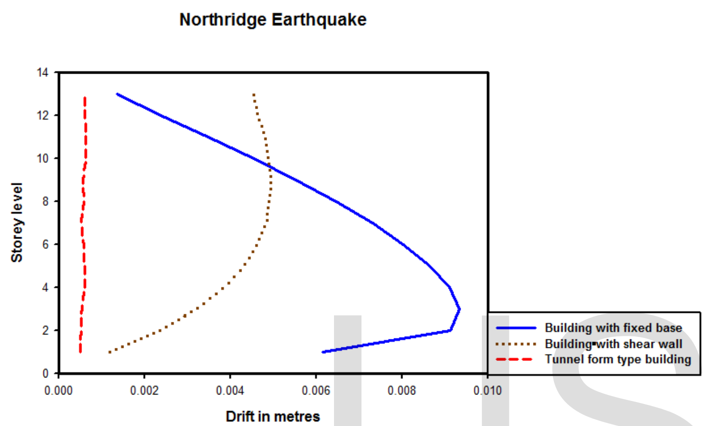

Fig 14 Story drift of various models for Northridge earthquake

Since the tunnel form type models exhibit comparatively lesser interstory drift, damage to non-structural components will be less. This result shows that the RC Wall building is safer against drift caused by the seismic forces as it produces less storey drift compared to that of the conventional building in the same seismic zone.

5.5 PARAMETRIC STUDY

For getting more insight into the seismic behavior of different models, the effect of storey height is investigated. The variation of time period, base shear, storey displacement and storey drift are determined for the different models and compared. For that G+10, G+15, G+20 storied buildings are considered.

5.5.1 Comparison of Fundamental Time period

Tunnel form type building has the least fundamental period of vibration among all the models. Similar behavior is observed for all the buildings with different heights. Similar variation of time period is observed for all the buildings under all the earthquakes.

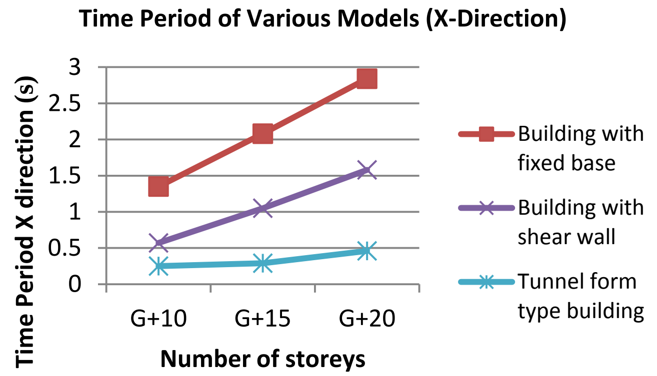

Fig 15 Variation of Fundamental period of various models in X-direction

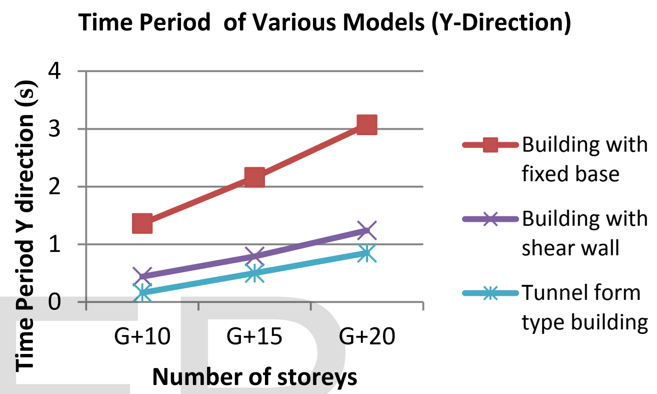

Fig 16 Variation of Fundamental period of various models in Y- direction

5.5.2 Comparison of Base Shear

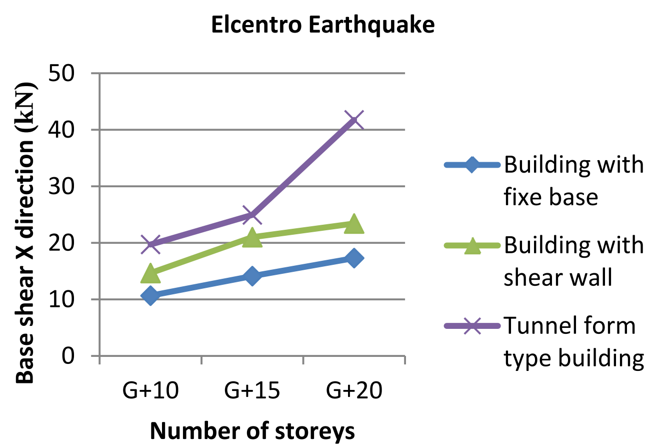

Fig 17 Base shear in X direction for El-centro Earthquake

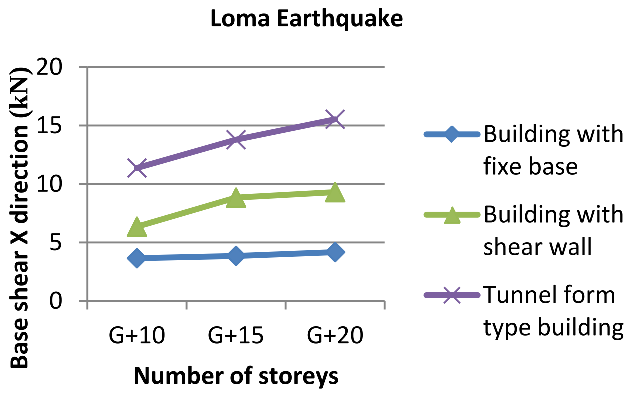

Fig 18 Base shear in X direction for Loma prieta Earthquake

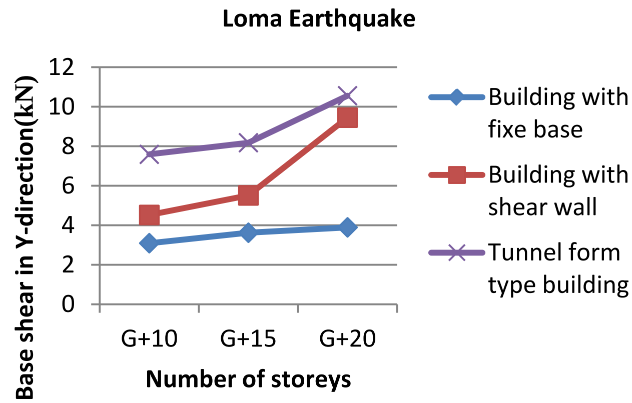

Fig 21 Base shear in Y direction for Loma prieta Earthquake

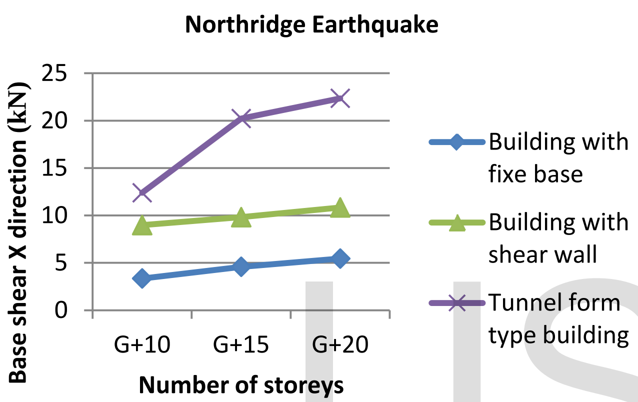

Fig 19 Base shear in X direction for Northridge Earthquake

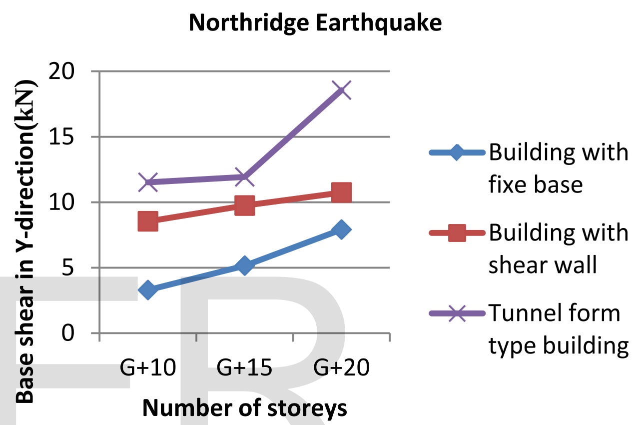

Fig 22 Base shear in Y direction for Northridge Earthquake

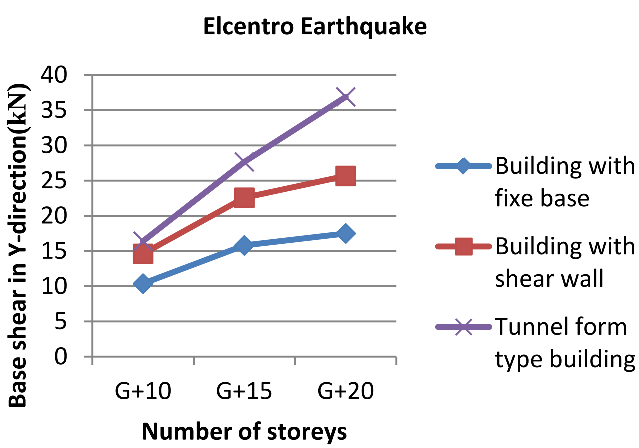

Fig 20 Base shear in Y direction for El-centro Earthquake

The result shows that the base shear in case of tunnel form type building is higher than the building with fixed base, building with shear wall and same behavior is resulted for all the earthquakes. Compared to tunnel form building, building with shear wall has lesser base shear under all the earthquake. Similar variation of base shear is observed in all the models with varying height.

5.5.3 Comparison of top storey displacement

From the above graphs, it can be seen that the top storey displacement is much less in tunnel form type building compared to the conventional building. This shows that the tunnel form type building offers more resistance to the lateral forces such as seismic forces than the conventional building. Similar variation of top storey displacement is observed in all the models with varying height.

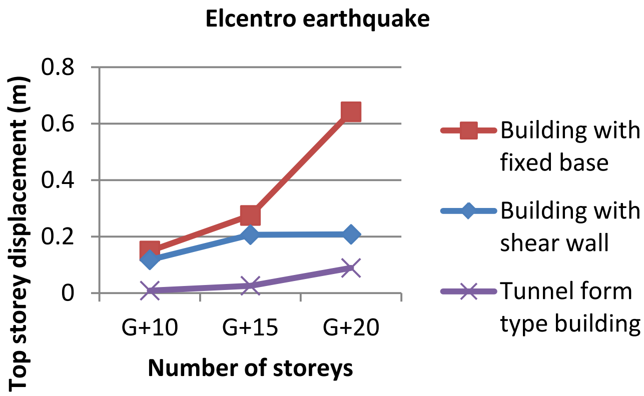

Fig 23 Variation of top storey displacement for El-centro Earthquake

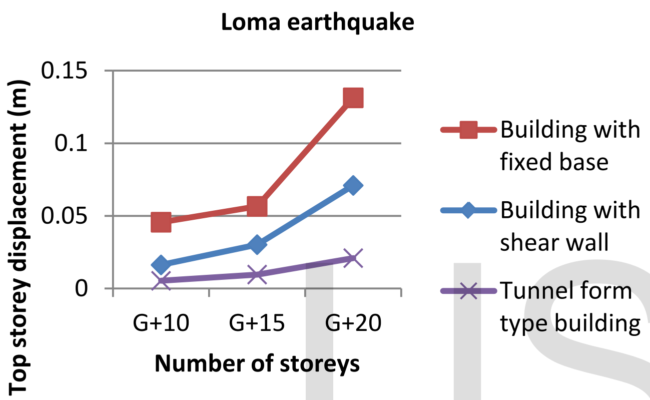

Fig 24 Variation of top storey displacement for Loma prieta Earthquake

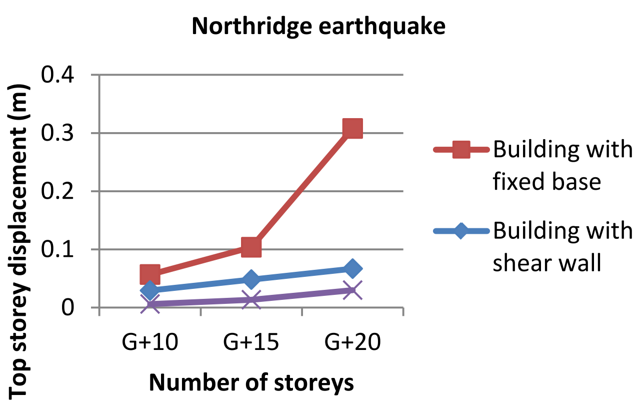

Fig 25 Variation of top storey displacement for Northridge Earthquake

5.5.4 Comparison of drift

In tunnel form models, story displacement exhibits a consistent and identical pattern for 10-, 15- and 20-storey. For low-rise buildings, if a particular story level is considered, the displacement is too high for framed model when compared with that of a TFB model. But this difference reduces as the height of building increases.

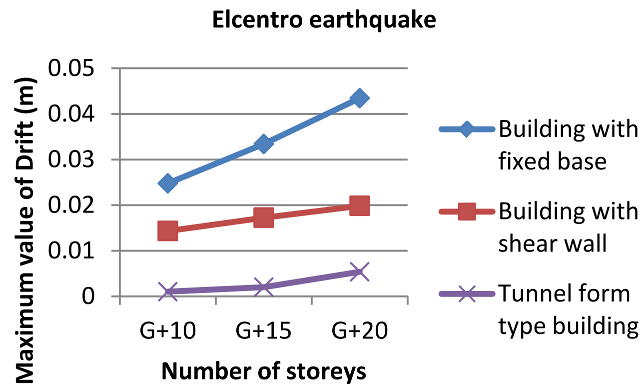

Fig 26 Variation of Story drift for El-centro Earthquake

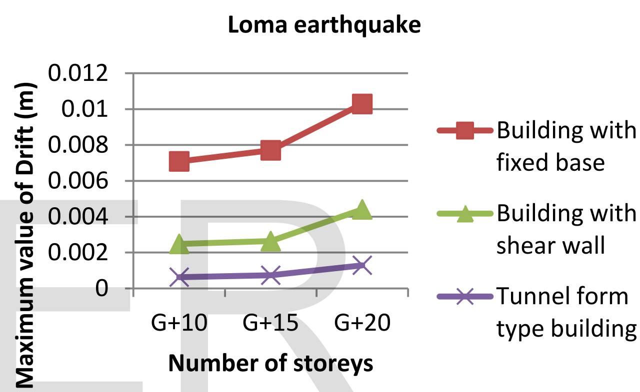

Fig 27 Variation of Story drift for Loma prieta earthquakes

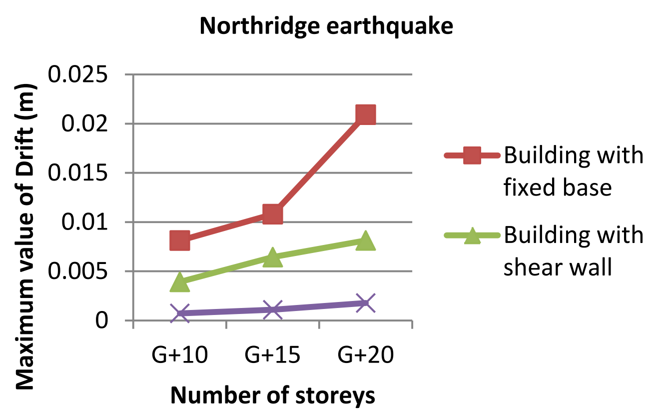

Fig 28 Variation of Story drift for Northridge earthquakes

This indicates the dependence of results on the ground motion characteristics. For all the three earthquakes, generally, the tunnel form buildings exhibit lesser story displacement than framed buildings. Shear walls in tunnel form buildings offer stiffness and hence the displacement experienced is lesser when compared to framed buildings. This result shows that the RC Wall building is safer against drift caused by the seismic forces as it produces less storey drift compared to that of the conventional building in the same seismic zone and identical behavior is resulted for all the earthquakes.

6 SUMMARY AND CONCLUSION

Earthquakes can create serious damage to structures. Structures already built are vulnerable to future earthquakes. Tunnel form buildings exhibit good performance during seismic ground motions by providing good lateral stability. The basic criteria that a structure should satisfy are stiffness, strength and ductility which can be achieved in tunnel form buildings.

The main parameters studied are the time period, base shear, storey displacement and storey drift. Base shear in case of tunnel form type building is higher than building with shear wall and which possess much smaller displacement compared to building with fixed base and building with shear wall. Tunnel form type building was found to be more effective in reducing storey displacement and storey drift compared to other models when subjected to dynamic loads. Tunnel form buildings are stiffer and massive than framed structures which evidently reduce deformation under earthquake load. Tunnel form buildings have lesser story displacements and storey drift than framed buildings

Acknowledgment

I express my deep and sincere gratitude to my guide, Dr. Jayalekshmi R, for the kind co-operation and guidance for the completion of my project. I also extend my gratitude to Dr. C K Prasad Varma Thampan, for his invaluable directions and advices.

REFERENCES

[1] Abdul Hamid N. H and Masrom.M. A (2012), "Seismic Performance of Wall-Slab Joints in Industrialized Building System (IBS) Under Out-Of-Plane Reversible Cyclic Loading" *IACSIT International Journal of Engineering and Technology, Vol. 4, No. 1.*

[2] AngithaSasidharan, Mohammed Aslam (2015) "Comparative Study of Tunnel Form and Framed Buildings by Dynamic Analysis" *International Journal of Research in Advent Technology, (E-ISSN: 2321-9637).*

[3] Anudai.S. A, Hamid.N.H (2016), "Comparative Study of Seismic Behavior of Tunnel Form Building Between Experiment and Modeling" SpringerScience+Business Media Singapore.

[4] Balkaya C, Kalkan E (2004): "Seismic vulnerability, behavior and design of tunnel form building structures", *Elsevier Ltd.*

[5] BinuSukumar, Hemamathi.A, Kokila.S, Hanish.C.(2016) "A Comparative Study on Non-Linear Analysis of Frame with and without Structural Wall System" SSRG *International Journal of Civil Engineering (SSRG-IJCE) – volume 3 Issue 3ISSN: 2348 – 8352.*

[6] Can Balkaya and ErolKalkan; (2003)" Estimation of fundamental periods of shear-wall dominant building structures"; *Earthquake engineering and structural dynamics Earthquake EngngStruct. Dyn; 32:985–998.*

[7] Chandurkar P. P, Pajgade.P. S. (2013) "Seismic Analysis of RCC Building with and Without Shear Wall" *International Journal of Modern Engineering Research (IJMER) Vol. 3, Issue. 3, pp-1805-1810 ISSN: 2249-6645.*

[8] Eshghi.S, Tavafoghi.A(2008) "Seismic Behaviour of Tunnel Form Building Structures: An Experimental Study" *Int. Inst. of Earthquake Engineering and Seismology (IIEES), Tehran, Iran.*

[9] Haider S. AL-JubairandFareed H. Majeed (2014) The Effect of Shear Walls on Seismically IsolatedBuildings of Variable Geometric Configurations, International Journal of Engineering Research & Technology (IJERT) ISSN: 2278-0181 Vol. 3 Issue 10.

[10] Hamid N. H, Saleh.S. M andAnuar.S. A (2014), Seismic performance of double-unit tunnel form building under in-plane lateral cyclic loading, WIT Transactions on The Built Environment, Vol 141.

[11] JunwonSeo, Jong Wan Hu and BurteDavaajamts (2015) Seismic Performance Evaluation of Multistory Reinforced Concrete Moment Resisting Frame Structure with Shear Walls, sustainability ISSN 2071-1050.

[12] Lan Chung1 and TaewonPark, (2016) Evaluation of Natural Frequency Through Measurement of Ambient Vibration for Wall-type RC Structures, Journal of Asian Architecture and Building Engineering.

[13] Marisa Pecce, Fabio Antonio BibbòandFrancescaCeroni, (2014) Seismic behavior of RC buildings with large lightly reinforced walls, Journal of Asian Architecture and Building Engineering.

[14] Mojtabamansouritalebi "seismic response evaluation of Wall and slab structures" (2015), International Institute of Earthquake Engineering and Seismology (IIEES).

[15] Pradeep B, Shiva Kumar KS and Ambrish G (2016) Study of seismic behavior of conventional and rc wall building, IJRET: International Journal of Research in Engineering and Technology.