CONVINCEMENT BASED SEISMIC DESIGN OF OPEN GROUND STOREY FRAMED BUILDING

A Thesis Submitted
in Partial Fulfillment of the Requirements
for the Degree of

MASTER OF TECHNOLOGY

In

Structural Engineering

By

Chitransha Chandra
(University roll No. 1170444003)

Under the Guidance of

Ms. Neeti Mishra
(Assistant Professor)

BABU BANARASI DAS UNIVERSITY
LUCKNOW

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CERTIFICATE

This is to certify that the thesis entitled titled "**Convincement Based Seismic Design of Open Ground Storey Framed Building**" by **Chitransha Chandra** Under the guidance of Assistant Professor **Ms**. **Neeti Mishra** to the Babu Banarasi Das University, Lucknow for the award of the degree of Master of Technology from Structural Engineering is a bonafide record of research work carried out by him under our supervision. The contents of this thesis, in full or in parts, have not been submitted to any other Institute or University for the award of any degree or diploma.

Thesis Supervisor
Neeti Mishra
Assistant Professor
Department of Civil Engineering
BBDU Lucknow

Dated:-

DECLARATION

I, **Chitransha Chandra** hereby to certify that the work which is being, presented in the M.Tech project report entitled "**Convincement Based Seismic Design of Open Ground Storey Framed Building** " in the fulfillment of the requirement for the award of Master of Technology in Structural Engineering and Submitted to the Department of Civil Engineering of BABU BANARASI DAS UNIVERSITY, Lucknow (U.P) is the authentic record of my own work carried out under the guidance of Assistant Professor **Ms. Neeti Mishra**, Civil Engineering Department.

The matter presented in this thesis has not been submitted by us for the award of any other degree elsewhere.

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ABSTRACT

In this paper we study about the seismic analysis of the open ground storey with three different model and that models are done with help of Etabs software which is product of the CSI company. In first model provided with 250mm thin wall at every position except at ground storey without opening in wall. In second model provided 250mm thin wall at only outer side and 125mm at inner side of the building which is partition wall and also provided opening in second model at outer side. In thirds model provided 250mm thin wall at every position with opening in the wall. In this paper we did comparative study of three model with respect to base shear, storey drift, storey displacement and as well as time periods. Using IS Code 1893 part 1: 2016 and all model exists in the zone IV and 2nd type of soil is taken. Considering the special moment resisting frame (SMRF) and importance factor is taken 1.2. After comparative study we gave the conclusion that which model is giving the better performance as compared as other two structures.

AKNOWLEDGEMENT

I would like to express my special appreciation and thanks to my researcher guide Assistant Professor **Ms. Neeti Mishra**, you have been a tremendous mentor for me. I would like to thank you for encouraging my research. Your advice on both research as well as on my career have been valuable. I would also like to thank my all faculty member of the Civil Engineering of BABU BANARASI DAS UNIVERSITY, Lucknow **Mr. Mohammad Afaque Khan**, **Mr. Faheem Ahmed Khan**, **Mr. Bilal Siddiqui**, **Mr Shubhranshu Jaiswal** and also to the head of department (HOD) **Mr. Anupam Mehrotra**. I also want to thank you for letting my defense be an enjoyable moment, and for your brilliant comments and suggestions, thanks to all faculty member. A special thanks to my family member and also to my all friends. Words cannot express how grateful I am to my all faculty member of BBDU, Lucknow. Thank you for supporting me for everything, and especially I can't thank all of you enough for encouraging me throughout this experience. Finally I thank my God, my best Father, for letting me through all the difficulties

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NOTATIONS

A_{st}	Area of steel
d	effective depth
d’	effective cover
D	overall depth of the beam
ρ	reinforcing ratio
ρmax	maximum reinforcing ratio
φ	diameter of the reinforcement
fy	yield stress of the reinforcement bar
L	span length of the beam
Pu	ultimate load
λ	load enhancement ratio
Δ	deflection
Δmax	maximum deflection
μ	ductility factor

CHAPTER 1

INTRODUCTION

1.1. General

Open ground storey is a type of structure in which the ground storey is fully kept open means there is no wall is build at the ground storey and this structure is increasingly used day by day in the urban area. The main purpose of providing the open ground storey to use to providing the parking area in the ground storey. An open ground storey structure, having only vertical member of the structure (column) in the ground storey of the structure and both partition walls(wall without load bearing) and columns in the upper storey, have two distinct characteristics, namely:-

- It is relatively flexible in the ground storey, i.e., the relative horizontal displacement it undergoes in the ground storey is much larger than what each of the storey above it does. This flexible ground storey is also known as soft storey.
- It is relatively weak in ground storey, i.e., the total horizontal earthquake force it can carry in the ground storey is significantly smaller than what each of the storey above it can carry. Thus, the open ground storey may also be a weak storey. Often, open ground storey buildings are called soft storey buildings, even though their ground storey may be soft and weak. Generally, the soft or weak storey usually exists at the ground storey level, but it could be at any other storey level too. When seismic force acting on the structure then structure acts as the Inverted pendulum which showing in the given below figure.

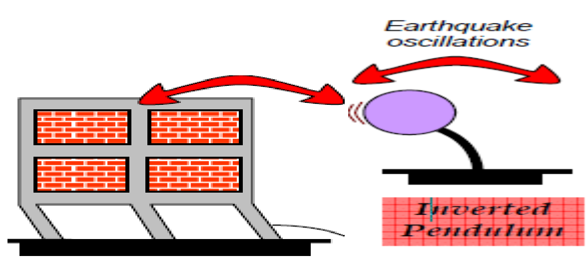

Figure1.1: Open Ground Storey Building

Open ground storey (also known as soft storey) buildings are commonly used in the urban environment nowadays since they provide parking area which is most required. This type of building shows comparatively a higher tendency to fall down (collapse) during earthquake because of the soft storey effect. Large lateral displacements get induced at the first storey level of such buildings yielding large curvatures in the ground storey columns. The bending moments (M) and shear forces (V) in these columns are also magnified accordingly as compared to a bare frame building (without a soft storey). The energy developed during earthquake loading is dissipated by the vertical resisting elements of the ground storey resulting the occurrence of plastic deformations which transforms the ground storey into a mechanism, in which the collapse is unavoidable. The construction of open ground storey is very dangerous if not designed suitably and with proper care. This paper is an attempt towards the study of the comparative performance evaluation of three Open Ground Storey buildings case studies. According to IS CODE, the shear forces and bending moments in the ground storey columns, obtained from the bare frame analysis are to be multiplied by magnification factor. The factor is to take care for the increase in the forces in the ground floor columns due to the presence of soft-storey. There are many such open ground storey buildings existing in the India which have been designed with earlier codes. Such buildings are designed only for gravity load condition. But as per the present code, both seismic lateral loads and the importance factor shall be considered while designing any building. But the surveys of some existing buildings in India comments that there are existing Open Ground Storey buildings that are designed for seismic lateral loads as per design code but not by considering the importance n factor. It was recognized subsequently that the Magnification Factor (MF) of value 1.5 should not be applied to the beams (horizontal member of structure) as because this is likely to result in the formation of 'strong beam-weak column' situation (with the plastic hinge (only two reactions) forming at the column end, rather than the beam end). When the maximum seismic force acts at the structure then it is going to collapse (fall down).

The behavior of OGS framed building is totally differently as compared to a bare framed building (without any infill) or a fully infilled framed building under lateral loads. The bare frame is much less stiffer than a fully infilled frame; it resists the applied lateral load through frame action and shows well-distributed plastic hinges at failure condition. But when this frame is fully infilled, truss action is introduced. A fully infilled frame shows lesser inter-storey drift, though it attracts higher base shear (due to increased stiffness). A fully infilled frame yields lesser force in the frame elements and hence dissipates greater amount of energy through infill walls. The strength and stiffness of infill walls in infilled frame buildings are ignored during the structural modelling in conventional design practice. The design in such cases will generally be conservative in the case of fully infilled framed building than others. But things will be somewhat different for an OGS framed building. OGS building being slightly stiffer than the bare frame, has larger storey drift (especially in the ground storey), and fails due to soft storey-mechanism at the ground floor. Therefore, it may not be conservative to ignore strength and stiffness of infill wall while designing OGS buildings.

The failure pattern observed in the buildings during the Jabalpur earthquake in 1997 showed higher vulnerability of Open Ground Storey buildings. Some reinforced concrete framed building which collapsed partially (some percent of buildings), had open ground storey on one side, and brick infill walls on the other side.

1.2 Typical Masonry Infilled Buildings

Typical masonry infilled frames contain infill walls throughout the building in all storey uniformly. Although infill walls are known to provide the stiffness and strength to the building globally, these are considered as 'non-structural' by design codes and are commonly ignored in the design practice for more convenience. The presence of infill walls in a framed building not only enhance the lateral stiffness in the building, but also alters the transmission of forces in beams and columns, as compared to the bare frame. In a bare frame, the resistance to lateral force occurs by the development of bending moments and shear forces in the beams and columns through the rigid jointed action of the beam-column joints. In the case of infilled frame, a substantial truss action can be observed, contributing to reduced bending moments but increased axial forces in beams and columns, (Riddington and Smith, 1977; Holmes, 1961).The infill in each panel behaves somewhat like a diagonal strut as shown in Fig. below.

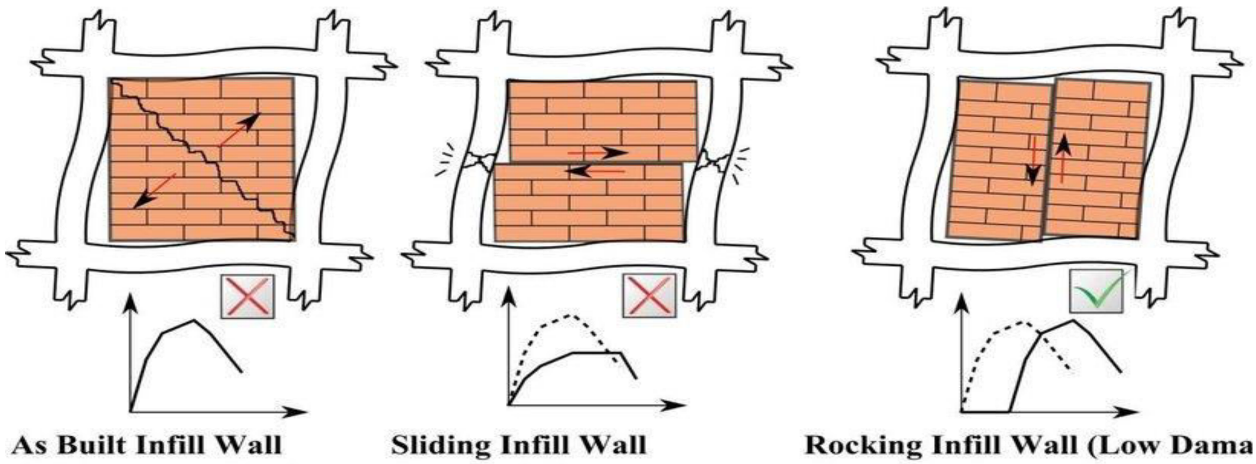

Figure 1.2: Masonry Infilled Buildings

1.3 Open Ground Storey Buildings

The presence of infill walls in the upper storey of the OGS building increases the stiffness of the building, as seen in a typical infilled framed building. Due to increase in the stiffness, the base shear demand on the building increases while in the case of typical infilled frame building, the increased base shear is shared by both the frames and infill walls in all the storeys. In OGS buildings, where the infill walls are not present in the ground storey, the increased base shear is resisted entirely by the columns of the ground storey, without the possibility of any load sharing by the adjoining infill walls. The increased shear forces in the ground storey columns will induce increase in the bending moments and curvatures, causing relatively larger drifts at the first floor level. The large lateral deflections further results in the bending moments due to the P-Δ effect. Plastic hinges gets developed at the top and bottom ends of the ground storey columns. The upper storeys remain undamaged and move almost like a rigid body. The damage mostly occurs in the ground storey columns which is termed as typical ‘soft-storey collapse’. This is also called a ‘storey-mechanism’ or ‘column mechanism’ in the ground storey as shown in the figures below. These buildings are vulnerable due to the sudden lowering of stiffness or strength (vertical irregularity) in the ground storey as compared to a typical infilled frame building.

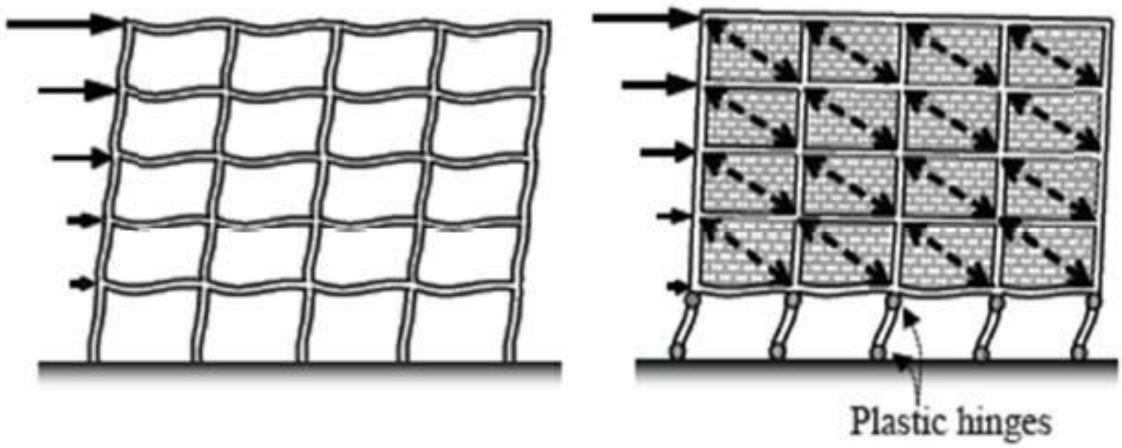

Fig-1.3: Bare Frame Open Ground Storey Frame.

The open ground storey buildings are generally analyzed as bare frame structures i.e. without considering structural contribution of masonry infill walls in the upper stories, this calls for assessment. Because the presence of infill walls in all upper stories except in the ground storey makes the upper stories much stiffer as compared to the open ground storey hence the upper stories move almost together as a single block and most of the horizontal displacement of the buildings occurs in the open ground storey itself. Thus the salient objective of the present study is to study the effect of earthquake with increase in height of medium rise RC framed buildings as well as the effect of infill strength and stiffness on the seismic analysis of open ground storey (OGS) buildings. In the case of horizontal loading due to seismic action, it is usual to assume that an equivalent compression strut can replace the action of the masonry infill panels.

1.4. Infilled Frame

Infilled frames are composite structure made by the combination of infill wall and moment resisting plan frame. The infill walls are used as interior partition walls ad external walls. And also infills are protecting from outside environment to the building to our requirements. Infill walls are tending to contact with the beam and column when the structure is subjected to seismic load, and also exhibit-dissipation characteristics under lateral loads. The presence of masonry infill walls has a affect on the lateral load of a reinforced concrete frame building, increasing the structural stiffness and structural strength. Clearly designed infills can increase the lateral resistance, overall strength and energy dissipation of structure. An infill wall reduces the bending moment (M) in the frame members of the structure and lateral deflections therefore decreasing the probability of collapse and also reduce the displacement.

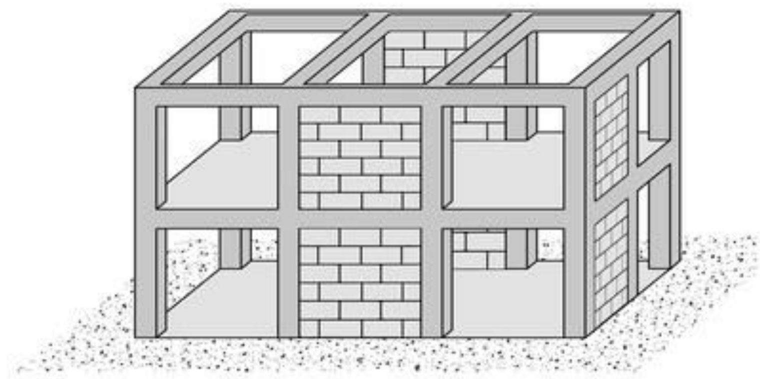

Figure 1.4: Infilled Frame

1.5. Seismic Behavior of Construction Open Floor

Lateral loading of the frame and the filling wall remain intact initially. As the side load increases the filling wall separates the frame surrounding the (voltage) corner unloaded, but in the compression wedge filler walls are still intact. The length over which the fill wall and the frame are intact is called the length of contact. The load transfer occurs through a perfectly diagonal which acts as a compression strut. Because of this behavior of the filling wall, they can be modeled as an equivalent diagonal brace connecting the two compression diagonal corners. Property rigidity must be such that the strut is only active when subjected to compression. Thus, under the lateral load single diagonal will be operational at a time. This concept was first put forward by Holmes (1961).

CHAPTER 2

LITERATURE SURVEY

In this chapter we study following paper related to seismic analysis of the open ground storey and write the conclusion of various paper related to this topic. It starts with a review of relevant international codes of practice followed by a review of published literature on Open Ground Storey buildings. Computational modeling of masonry infill is an integral part of this research. The later part of this chapter presents a detailed review on nonlinear structural models of masonry infill available in literature. A review on probability-based assessment of building response and reliability based seismic design is presented at the end of this chapter.

IS code 1893-2002 recommendations [1]

This Indian Standard Code is published in the 2003. The OGS buildings is considered to be as extreme soft-storey type of buildings in most of the practical situations, and shall be designed considering special provisions so as to increase the stiffness in lateral direction or strength of the soft/open ground storey. A dynamic analysis is suggested which includes the strength and stiffness effects of infill walls and also the inelastic deformations of members, particularly suggested in those soft-storey of such buildings. The members in the soft/open storey shall be designed as per suggested by the codes considered in this project. However, IS 1893 part-1:2016, does not give any explicit recommendations on the modeling of the infills for the open ground storey building frame.

In the absence of infill wall, more accurate analysis such as dynamic analysis, an equivalent static lateral load analysis neglecting the infill walls, that is, a bare frame analysis, can be employed provided the bending moments and the shear forces in the critical members (columns in the ground storey) shall be enhanced by the factor as recommended by the code. The code recommendation to magnify the above forces for the equivalent static analysis (bare frame) for the columns in the soft/open storey is by a factor of 2.5. This multiplication factor will be responsible for compensating the vertical irregularity of the building frame.

Seismic analysis of bare frame, infilled frame, soft storey RC framed buildings [2]

This paper is published by "Charan chikka javaregowda k s[1], Mahadev prasad[2]" in 2008 which conclusions are given below. This analysis is done for the soft story like open one story, open two story, infilled frame and bare frame structure. We concluded that seismic analysis on reinforced concrete frame structure has been done that includes soft story, infilled frame and bare frame following conclusion are obtained:-

- Equivalent diagonal strut method is used for the modeling of the infill wall, effectively this method is used for the this seismic analysis of reinforced concrete frame structure.
- From the obtained studied Fig we concluded that some important points.
- For the earthquake force infilled frame is more effective compare to the bare frame.
- For earthquake force infilled frame structures are more resist than bare frame.
- For the large extent infill structures are more stiffness and strength compare to other type of structures.
- Story drift in infills frame structure is less compare to the bare frame therefore bare frame structure leads to collapse during earthquake force.
- Compare to the bare frame and open one story frame structure, bare frame structure gives more effective than open one story. Bare frame gives more stiffness and strength compare to the open one story. Because in open one story there is no infill at ground floor.
- Story drift in bare frame is less compare to the open one story. Therefore structure leads to collapse during earthquake force.
- Compare to the open one story frame structure and open two story frame structure, open one story frame gives more effective than open two story, open one story is more stiffness and strength compare to the open two story Therefore compare to all frame structure infilled frame structure is strength and stiffness.

Considering dynamic characteristics parameters are:-

Time period: time period is more in the bare frame compare to the other frame like infilled and soft story frames.

Natural frequency: natural frequency is less in the bare frame compares to the infilled and soft story frames.

Base shear: base shear is more in the infilled frame compare to the bare and other structure. Studying the above all parameters we concluded that infilled frames are stiffer and strength compares to other frame structure.

Earthquake Resistant Design of Open Ground Storey Building [3]

This paper is published by " Piyush Tiwari[1], P.J.Salunke[2], N.G.Gore[3]" in 2008 which conclusion are given below:-

- Linear (Static/Dynamic) analysis shows that column forces at the ground storey increase for the presence of infill wall in upper storey. But design force Multiplication factor found to be much less than 2.5.
- Seismic analysis of bare frame structure leads to under estimation of base shear. Under estimation of base shear leads to collapse of structure during earthquake shaking. Therefore its important to consider the infill walls in the seismic analysis of structure. 3) ESA and RSA results shows that, Multiplication factor for (G+4) varies 41.2 %(Column) and 42.8 %(Beam) less than what is prescribed by IS Code of 2.5 Value. Similarly For (G+7) its 36% and 40% and for (G+10) its 32.4 and 40% less value than which is given by IS Code of 2.5.
- From Pushover analysis, its conclude that there is even no need for a MF of 2.5 for Low rise (G+4) structure. And for (G+7) its 52.4% (Beam) & 51.2%(Column) less than value which is given by IS Code 1893:2002 of 2.5,while for (G+10) it comes out to be 40% less than value given by IS Code.
- Pushover curve shows that global stiffness and elastic base shear demand of OGS building changes considerably when infill wall is ignored.

Seismic Analysis of Open Ground Storey Building [4]

This paper is published by "Akshay S. Paidalwar[1] and G.D. Awchat[2]" in 2009 which conclusion is given below:-

- Stiffness of the structure is an important factor in case of OGS type building, in the present study infill can improve stiffness of structure but in to some extent, that is not enough to save structure against seismic effect.
- Problem of OGS buildings cannot be identified properly through elastic analysis as the stiffness of OGS building and Bare-frame building are almost same. RC frame building with open first storey are known to perform poorly during in strong earthquake shaking (little time with maximum frequency). In this study, the vulnerability of building with soft storey is shown an example building.

Seismic Analysis of Medium Rise Open Ground Storey Framed Building by Response Spectrum Analysis Method [5]

This paper is published by the "R. Suresh[1] Dr.K. Narasimhulu[2]" in 2010 which conclusions are given below:-

- The multiplication factor obtained for BASE SHEAR in x- direction under Response spectrum loads is 1.81.
- The multiplication factor obtained for BASE SHEAR in Y- direction under Response spectrum loads is 1.73.
- The multiplication factor obtained for BENDING MOMENT in x- direction under Response spectrum loads is 1.63.
- The multiplication factor obtained for BENDING MOMENT in Y- direction under Response spectrum loads is 1.75.
- Finally The Multiplication factor need for the design columns and beams of Medium Rise (10 storey) open ground story under seismic loads lies between 1.63 to 1.81.

Multiplication factor for open ground storey buildings – a reliability based evaluation [6]

This paper published by "Haran Pragalath D.C[1], Avadhoot Bhosale[2], Robin Davis P[3] and Pradip Sarkar[4]" in 2010 which conclusions are given below:-

There is disparity in the value of MF and its scheme of application for design of open ground storey (OGS) buildings proposed by various International codes. The present effort attempts to study, in a probabilistic framework, the performance of typical two, four and six storey OGS frames designed with MFs suggested by various international codes. Open ground storey frames are "designed" with MF values suggested by IS 1893 (2002), Bulgarian Seismic Design Code (1987), SI 413 (1995) and EC 8 (2003). The probabilistic seismic demand models, fragility curves, reliability indices (for a selected seismic hazard) and cost indices for all the selected open ground storey frames are developed including bare frame and fully infilled frame.

The following major conclusions are drawn on the basis of the present study: The open ground storey building designed with:-

- Multiplication factor of 1.0 (OGS) is found to be more vulnerable than Bare Frame (BF) and Fully Infilled Frame (FF). Performance of FF is found to be superior due to the presence of infilled walls in the entire storey including the ground storey. The scheme of applying MF only to the ground storey proposed by Indian, Bulgarian and Euro codes is found to lead to satisfactory performance only for two storey frames.
- This scheme is found to be not effective for four and six storey frames as these frames cannot match the reliability of a corresponding fully infilled frame.
- For four and six storey frames, the scheme of applying MF to both the open ground storey and the adjacent first storey, as suggested by SI 413 (1995), is found to be a better solution for both the reliability and cost aspects.

Seismic Analysis of G+ 7 Storeys Building With and Without Infill [7]

This paper is published by "Sathya Prakash Gaddam[1], Archanaa Dongre[2]" in 2011 which conclusions are given below:-

- Study of soft storey building is essential in current scenario. Most of the buildings in Indian metro city are found soft Storey.
- Soft storey buildings are considered vulnerable in earthquake prone areas.
- It is important to safeguard building, avoiding soft storey and following building bye laws and using design codes.
- From above result, it can be seen that displacement of soft storey buildings is more than that of RC framed in-filled building. Soft storey effect contributes to reduction of

stiffness in building due to which overall response of the building at particular joint is increasing.

- Corner walls can be provided to the building for the better performance and increase the lifetime of the building.
- Since the behavior of the soft storey is very different during earthquake. For this reason, in regions where the risk of earthquakes is high, soft storey should be avoided, if necessary, earthquake resistant design should be done starting from the design stage through the stage of occupancy.
- Present soft storey should be examined and if necessary, should be strengthen with brick infill walls.
- In constructions where it is necessary to build a soft storey, lateral rigidity of this particular storey should be brought to the rigidity level of the other storey. To be able to do this, the number of columns and shear walls should be increased. Because of this increase, longitudinal and lateral reinforcement should also be increased. These raise the cost of the construction. Soft storey is an irregularity, which affects the behavior of a construction during a quake and also increases the construction costs. For this reason, soft storey should be avoided as much as possible. In case it is necessary, by the controls to be performed as a result of calculation made, irregularities can be eliminated as follows:-
- Building additional walls.
- Increasing the rigidity of the columns and the Shear walls on the soft storey.

Seismic Analysis of High-Rise Open Ground Storey Framed Building [8]

This paper is published by "Deepak[1], Mr. Vaibhav Gupta[2]" in 2011 which conclusions are given below:-

- Shear capacity base of a bare chassis 10 S6B designed with MF 3.0 and 2.5 is about 28% more than the one designed with MF 1.0 while turning varies by a score of more than 15 mm between them
- Based Shear capacity of a strict framework 10S6B designed with MF 3.0 and 2.5 is about 28% more than the one designed with MF 1,0 while turning varies by rating more than 10 mm between them.

- Strong Frame filling 10s with fixed support 3 may take longer charge times than that with a low filling while the steering is nearly identical to about 66 mm for both cases.

A New Earthquake Resistant Design of Open Ground Storey Framed Building [9]

This paper is published by the "Gurram Supriya[1], Mr. Syed Rizwan[2] and A.B.S.Dadapeer[3]" in 2012 which conclusion are given below:-

- IS Code gives a value of 2.5 to increase the beam floors ground forces and column when a building must be designed as building walk-in open ground or a building on stilts. The ratio of IR values for columns and beams of DCR values for the two support conditions and model building were found using ESA and RSA and the two analyzes argues that factor of 2, 5 is too high to be multiplied to the beam and column forces of the ground floor. This is especially true for low-rise buildings CGO.
- Buildings OGS problem cannot be properly identified by the elastic analysis that the rigidity of OGS building and Bare frame building are almost identical.
- The nonlinear analysis reveals that the OGS building fails through a walk-in mechanism on the ground at a relatively low base shear and displacement. And the failure mode is proving fragile.
- Analyzes both elastic and inelastic show that beams forces ground storey to significantly reduce the presence of the filling of rigidity to the adjacent stage. And strength design amplification factor should not be applied to the mass of the beams of stages.
- The linear (static / dynamic) analysis shows that the forces of the column to the floor increases from one floor to the presence of the filler wall on the upper floors. But the design force amplification factor found to be much less than 6. From the literature, it was found that the support provided for the buildings has not given much importance. Linear and nonlinear analyzes show that support condition greatly influences the response and can be an important parameter to determine the factor of amplification force.

Effect of Position of Infill Wall for Seismic Analysis of Low Rise Open Ground Storey Building [10]

This paper is published by "Anchal V.Sharma[1], Laxmikant C.Tibude[2]" in 2013 which conclusions are given below:-

The present study makes an effort to evaluate the effect of OGS building with respect to linear and non-linear dynamic analysis to regular building. The study as a whole identifies the influencing parameters, which can regulate the effect of open ground on displacement of building frames. A large number of curves exhibiting such variation for typical examples presented in this paper can help the designer to get a primary idea about effect of open ground storey in Low rise buildings.

Performance Evaluation of Open Ground Storey Building with Soil-Structure Interaction by Pushover Analysis [11]

This paper is published by "Sayali S Takale[1], Dr. V. D. Gundakalle[2] and Hemant Sonawadekar[3]" in the 2013. In present study, different structural forms are modelled and analyzed with different methods considering the effect of soil- structure interaction. Based on parametric results and comparison, the following conclusions are made:-

2.11.1:Linear Analysis

- Base shear of bare frame is minimum and fully infill frame is maximum.
- Top storey displacement of OGS frame is 58% more than top storey displacement in fully infill frame.
- Storey drift is approximately doubled for OGS frame compared to infill frame. It is because ductility demand is largest in open first storey column.
- Modal time period of OGS frame is increased by 38% as compared with fully infill frame due to decrease in stiffness at soft storey.

2.11.2.Pushover Analysis

- Frames are analyzed by pushover analysis in X and Y directions. The base shear value is 10% higher for the pushover analysis as compared to equivalent static method
- Performance point for FI-F and OGS-SC is almost same. Due to the provision of stiffer column, OGS-SC frame behaves same like infilled frame. Hence damage get reduced.

2.11.3.Soil-structure interaction

- Base shear values are marginally decrease for all models in linear analysis as well as non-linear analysis when soil-structure interaction is considered.
- Top storey displacement is 32.25% increased when soil flexibility is added to models.
- Soil-flexibility increases the force and drift demands in columns by 14%.
- Monitored displacement is increases while base shear is decreases in pushover analysis by adding the soil-flexibility.

On basis of structural parameters studied, the general conclusions are:-

- Provision of stiffer columns provides the adequate strength to open ground storey columns hence it improves the behavior of structure.
- Soil flexibility need to examine before finalizing the design of structure.

Comparative Study of Seismic Behavior of Open Ground Storey Buildings, After Replacing Rectangular Columns with Circular Columns [12]

This paper is published by "Kapil Verma" in 2015 which conclusions are given below:-

- The effect of the column shape on the stability of the structure is studied. The efficiency of circular and rectangular columns can be compared since the cross-sectional area of the two columns is kept constant. The % reinforcement is also to be maintained in both columns.
- Story drift is found to be more in the rectangular columns than the frames having circular columns.
- The behavior of circular column is a little better than rectangular column when the comparison is in terms of storey drift, base shear and roof displacement.
- The performance of circular column RC frame is also found to be better than the rectangular column RC frame.
- The pushover curves prove that the roof displacement is maximum for a rectangular column when compared to circular columns. For the same loading, the displacement is found to be more in the square for all the similar loading patterns.
- The performance points of the capacity curves show that circular columns perform better than rectangular columns with regards to the values given.

- The story displacement curves indicate that the story displacements are a just a bit more for rectangular columns. Not much significant variation was found

Seismic Performance of Open Ground Storey RC Buildings for Major International Codes [13]

This paper is published by "D. J. Chaudhari[1], Prajakta T. Raipure[2]" 2017 which conclusions are given below:-

- Performances of the OGS frame in the term of ground storey drift increasing in the increasing order of MFs used by all codes for all the performance levels.
- In case of Indian code first storey is more vulnerable than ground storey whereas for Israel code it is not so. Relative vulnerability of first storey increases due to strengthening of the ground storey.
- Application of magnification factor only in the ground storey may not provide the required performance in all the other stories. It is seen that the OGS buildings designed using Israel code, which considered the MF in the adjacent storey, performed better compared to Indian which indicates that the application of multiplication factor in the adjacent storey may be required to improve the performance of OGS buildings.

CHAPTER 3

METHODOLOGY

3.1. Software

- The innovative and revolutionary new ETABS is the ultimate integrated software package for the structural analysis and design of buildings. Incorporating 40 years of continuous research and development, this latest ETABS offers unmatched 3D object based modeling and visualization tools, blazingly fast linear and nonlinear analytical power, sophisticated and comprehensive design capabilities for a wide-range of materials, and insightful Figic displays, reports, and schematic drawings that allow users to quickly and easily decipher and understand analysis and design results.
- From the start of design conception through the production of schematic drawings, ETABS integrates every aspect of the engineering design process. Creation of models has never been easier - intuitive drawing commands allow for the rapid generation of floor and elevation framing. CAD drawings can be converted directly into ETABS models or used as templates onto which ETABS objects may be overlaid. The state-of-the-art SAP File 64-bit solver allows extremely large and complex models to be rapidly analyzed, and supports nonlinear modeling techniques such as construction sequencing and time effects (e.g., creep and shrinkage).
- Design of steel and concrete frames (with automated optimization), composite beams, composite columns, steel joists, and concrete and masonry shear walls is included, as is the capacity check for steel connections and base plates. Models may be realistically rendered, and all results can be shown directly on the structure. Comprehensive and customizable reports are available for all analysis and design output, and schematic construction drawings of framing plans, schedules, details, and cross-sections may be generated for concrete and steel structures.
- ETABS provides an unequaled suite of tools for structural engineers designing buildings, whether they are working on one-story industrial structures or the tallest commercial high-rises. Immensely capable, yet easy-to-use has been the hallmark of ETABS since its introduction decades ago, and this latest release continues that

tradition by providing engineers with the technologically-advanced, yet intuitive, software they require to be their most productive.

3.2. IS CODE 1893 part1:2016

This code is used for the Earthquake Resistant Design of Structure, where in this code provide the parameter and condition of the type of the seismic analysis.

3.3. Time History Analysis

Time history analysis is dynamic analysis of structure. In time history analysis we study the behavior of structure for load which is in time vs. acceleration format. It's very difficult to do it manually. It is applicable for the multi degree of freedom system, when the dynamic force is active on the structure in the form of seismic wave. It is applicable for both linear and non-linear analysis, and it is used to determine the dynamic structural response when structure subjected to the force which varies with time (force should not be constant). The model which analyze is Linear Time History. The data of the time history is taken from the time history function which name is "ALTADENA-1"Defining the time history function and fill the required value which is given below:-

Time history Analysis maybe in two forms which is given below:-

3.3.1. Linear Time History Analysis

Linear time history analysis calculates the solution to the dynamic equilibrium equation for the structural behavior (displacement, member force etc.) at an arbitrary time using the dynamic properties of the structure and applied loading when a dynamic load is applied. The Modal superposition method and direct method are used for linear time history analysis. Because of linear analysis characteristics, nonlinearity is not considered. When using a nonlinear material, the material is converted to an equivalent linear elastic material for analysis.

The water level can be defined for the linear time history analysis and the effective stress results can be viewed. Also the drained/untrained effects of the material can be included in the analysis

3.3.1.1. Direct method

The direct method is a time history analysis that uses the DOF of the total analysis area as a variable. The dynamic equilibrium equation for the total DOF can be integrated gradually with time to find the solution. The solution is found for each time stage without any form change to the equilibrium equation and various integration methods can be used. The direct integration method conducts the analysis for all time stages and the number or time stages are proportional to the analysis time.

3.3.2. Nonlinear Time History Analysis

Nonlinear time history analysis is known for simulating a structure behavior under severe earthquake more proper than other methods. However for simplicity, most of the bridges in the category of Ordinary Standard Bridge (OSB) are being analyzed by a combined procedure which consists of a linear ARS analysis for earthquake response (demand) and a static nonlinear pushover for ultimate displacement (capacity) per the guidelines of many transportation agencies worldwide. The demand and capacity are then compared to determine the safety of the bridge. For the single degree of freedom (SDF) system, this procedure has been proven to be an effective method with satisfactory accuracy. For bridges in the category of OSB but with noticeable characteristics of multi-degree of freedom (MDF) system, large discrepancies between deformation patterns from linear analysis and nonlinear pushover are often observed by engineers. So, the accuracy of conclusion from this procedure is questioned. To explore nonlinear dynamic behavior of these bridges and investigate the adequacy of the popular combined linear with nonlinear analysis procedure, a series of bridges within the category of OSB ranging from slight to severe mass and stiffness unbalance was analyzed. The analysis methods used for each bridge include linear and nonlinear time history analysis, linear ARS analysis and nonlinear static pushover.

3.4. Response Spectrum Analysis

Response-spectrum analysis (RSA) is a linear-dynamic statistical analysis method which measures the contribution from each natural mode of vibration to indicate the likely maximum seismic response of an essentially elastic structure. Response-spectrum analysis provides insight into dynamic behavior by measuring pseudo-spectral acceleration, velocity, or displacement as a function of structural period for a given time history and level of damping.

It is practical to envelope response spectra such that a smooth curve represents the peak response for each realization of structural period.

Response-spectrum analysis is useful for design decision-making because it relates structural type-selection to dynamic performance. Structures of shorter period experience greater acceleration, whereas those of longer period experience greater displacement. Structural performance objectives should be taken into account during preliminary design and response-spectrum analysis.

3.5. Different View of Model

3.5.1. Open Ground Storey Building with Load Bearing Wall at Every Position (Model-1)

In the Model-1, the outer and inner wall is load bearing wall without any opening in the building which plan, elevation and 3D view is given below:-

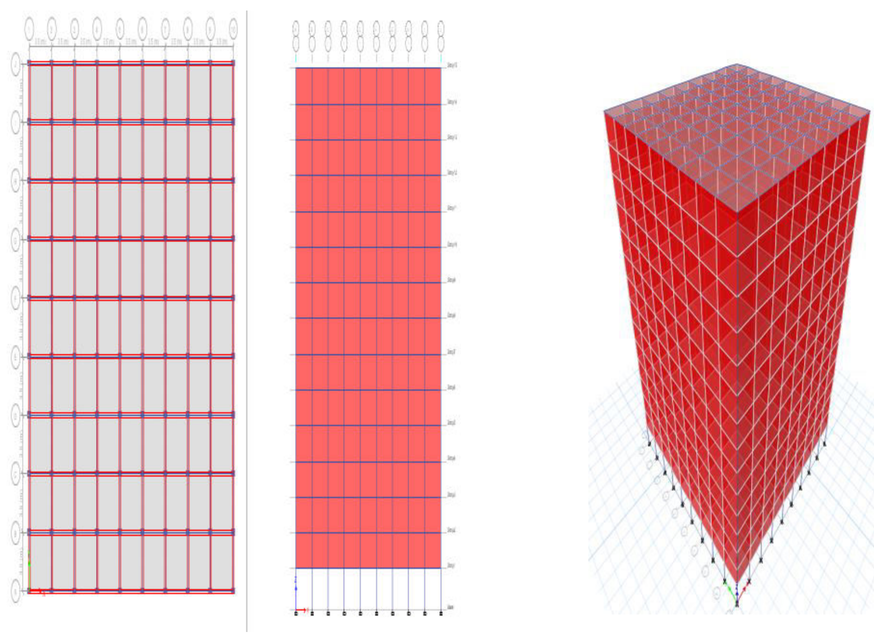

Figure-3.1: Plan, Elevation and 3D View of model-1.

Table-3.1: Load at Model 1.

S.No	Load Name	Values
1.	Dead Load	Auto defined
2.	Live load at slab	$3KN/m^2$
3.	Roof load	$1.5KN/m^2$
4.	Floor finishing load	$1KN/m^2$
5.	Parapet wall	7.5KN/m
6.	EX	IS 1893 Part 1 2016
7.	EY	IS 1893 Part 1 2016
8.	Wall load	15KN/m (Auto)

Table-3.2: Parameter of model-1.

S.No	Parameter	Detailed Value
1.	Concrete	M25
2.	Rebar	HYSD500, Fe250
3.	Slab thickness	150 mm
4.	Thickness of load bearing wall	250 mm
5.	Thickness of partition wall	No
6.	Opening in wall	No
7.	Beam size	300x400 mm
8.	Column size	400x600 mm
9.	Zone	IV
10.	Type of frame	Special Moment Resisting Frame
11	Soil type	II
12	Importance factor	1.2

3.5.2. Open Ground Storey Building with Load bearing Wall at Every Position with Opening At only Outer side of Wall (Model-2)

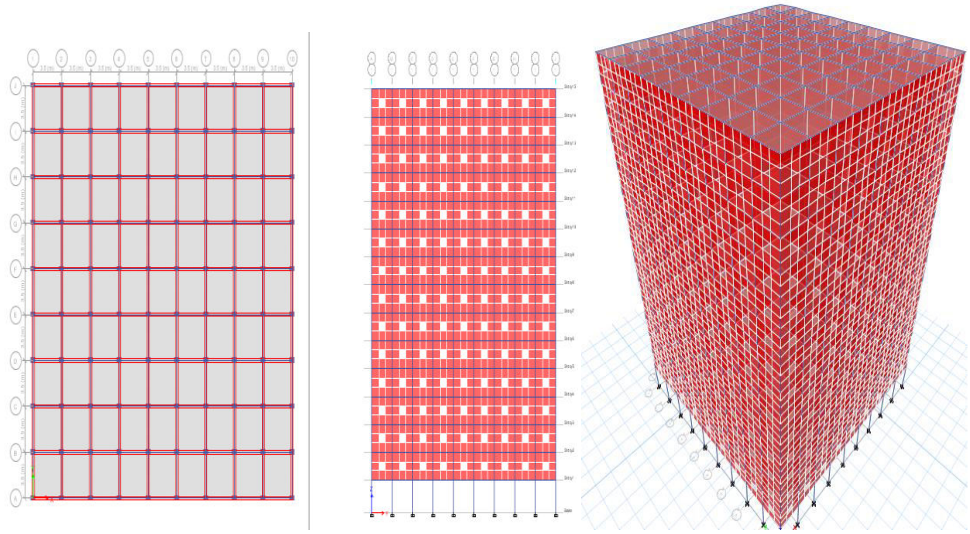

Figure-3.2: Plan, Elevation and 3D View of model-2.

Table-3.3: Load Parameter of Model-2

S.No	Load Name	Values
1.	Dead Load	Auto defined
2.	Live load at slab	3KN/m^2
3.	Roof load	1.5KN/m^2
4.	Floor finishing load	1KN/m^2
5.	Parapet wall	7.5KN/m
6.	EX	IS 1893 Part 1 2016
7.	EY	IS 1893 Part 1 2016
8.	Wall load	15KN/m (Auto)

Table-3.4: Parameter of model-2.

S.No	Parameter	Detailed Value
1.	Concrete	M25
2.	Rebar	HYSD500, Fe250
3.	Slab thickness	150 mm
4.	Thickness of load bearing wall	250 mm
5.	Thickness of partition wall	No
6.	Opening in wall	1000mmX950mm
7.	Beam size	300x400 mm
8.	Column size	400x600 mm

9.	Zone	IV
10.	Type of frame	Special Moment Resisting Frame
11	Soil type	II
12	Importance factor	1.2

3.5.3. Open Ground Storey Building with Load Bearing Wall At Outer Side With Opening, with Partition Wall Inside (Model-3)

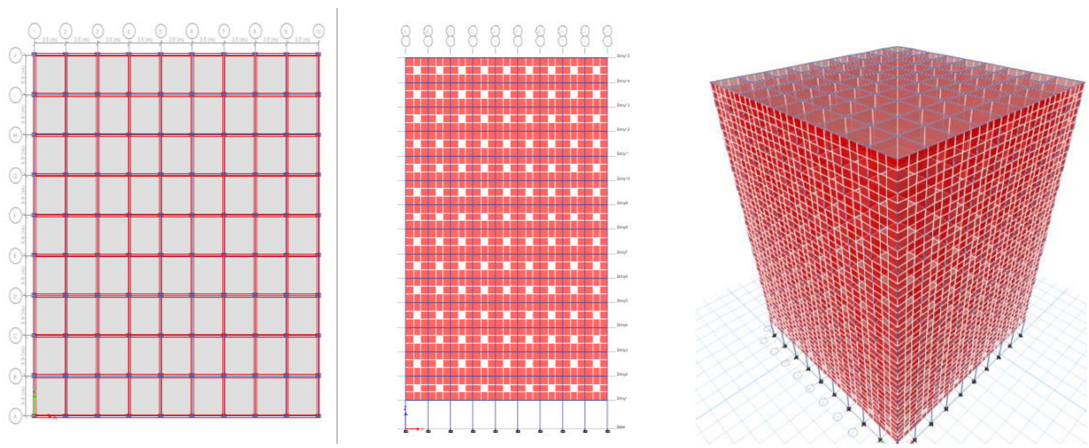

Figure-3.3: Plan, Elevation and 3D View of model 3.

Table-3.5: Parameter for Model-3

S.No	Parameter	Detailed Value
1.	Concrete	M25
2.	Rebar	HYSD500, Fe250
3.	Slab thickness	150 mm
4.	Thickness of load bearing wall	250 mm
5.	Thickness of partition (inner) wall	115mm
6.	Opening in wall	1000mmX950mm
7.	Beam size	300x400 mm
8.	Column size	400x600 mm
9.	Zone	IV
10.	Type of frame	Special Moment Resisting

		Frame
11	Soil type	II
12	Importance factor	1.2

3.6. Load Combination

According to Indian Standard Code 1893 part1:2016 following load combination is given below:-

Table-3.6: Load Combination

A.1.5(DL+LL)	B.1.2(DL+LL+EX)	C.1.2(DL+LL-EX)
D.1.2(DL+LL+EY)	E.1.2(DL+LL-EY)	F.1.5(DL+EX)
G.1.5(DL-EX)	H.1.5(DL+EY)	I.1.5(DL-EY)
J.0.9DL+1.5EX	K.0.9DL-1.5EX	L.0.9DL+1.5EY
M.0.9DL-1.5EY		

CHAPTER 4

RESULT AND DISCUSSION

In this chapter we will study all the analysis of the models which we analyzed in the Etabs software. This chapter mainly includes the base shear, maximum storey displacement, maximum storey overturning moment, modal period and frequency with graph, response spectrum curve of the every model.

4.1. Modal Periods and Frequency

According to IS CODE 1893 part1:2016, the modal time period is defined as The modal natural period of mode k is the time period of vibration in mode k. where k= 1,2,….defined mode.

4.1.1. Modal Periods and Frequency of Model-1

The table of the modal period and frequency of open ground storey building with load bearing wall at every position is given below:-

Table-4.1: Modal Period of Model-1

Mode	Period (sec)	Frequency (cyc/sec)	Circular Frequency (rad/sec)	Eigenvalue (rad2/sec2)
Mode1	0.715	1.399	8.7879	77.2268
Mode2	0.524	1.91	11.9989	143.9725
Mode3	0.505	1.979	12.4321	154.5559
Mode4	0.118	8.469	53.2154	2831.8825
Mode5	0.114	8.782	55.1762	3044.4077
Mode6	0.078	12.797	80.403	6464.6499
Mode7	0.034	29.357	184.4541	34023.3042
Mode8	0.033	30.167	189.5442	35926.9943
Mode9	0.022	44.83	281.6771	79342.0008
Mode10	0.022	44.867	281.9053	79470.6257
Mode11	0.019	51.541	323.8397	104872.1435
Mode12	0.019	51.541	323.8397	104872.1456

The graph of the time period of the Model-1 is given below:-

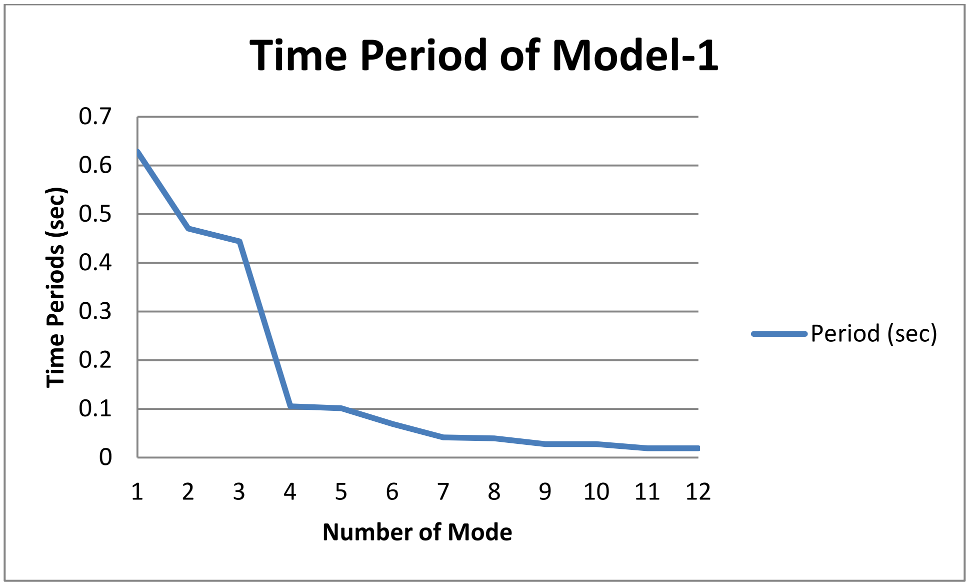

Fig-4.1: Time Period of Model-1.

4.1.2. Modal Periods and Frequency of Model-2

The table of the modal period and frequency of open ground storey building with load bearing wall at every position and providing opening at the only outer side of wall in the building is given below:-

Table-4.2: Modal Period of Model-2

Mode	Period (sec)	Frequency (cyc/sec)	Circular Frequency (rad/sec)	Eigenvalue (rad^2/sec^2)
Mode1	0.712	1.405	8.8309	77.9847
Mode2	0.519	1.927	12.1097	146.6458
Mode3	0.503	1.988	12.492	156.05
Mode4	0.117	8.521	53.5405	2866.589
Mode5	0.113	8.835	55.5117	3081.5479
Mode6	0.078	12.857	80.7822	6525.7641
Mode7	0.034	29.527	185.5258	34419.8186
Mode8	0.033	30.328	190.5566	36311.8295
Mode9	0.022	45.133	283.5759	80415.3183
Mode10	0.022	45.169	283.807	80546.423
Mode11	0.019	51.52	323.7086	104787.263
Mode12	0.019	51.519	323.7009	104782.2711

The graph of the time period of the Model-2 is given below:-

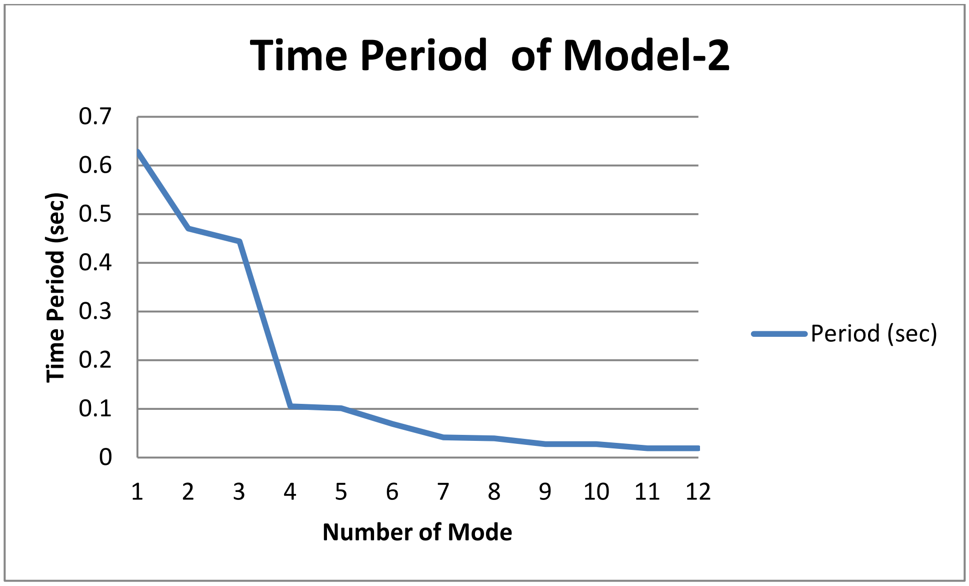

Fig-4.2: Time Period of Model-2

4.1.3. Modal Periods and Frequency of Model-3

The table of the modal period and frequency of open ground storey building with load bearing wall at only outer position and providing opening at the only outer side of wall in the building and using partition wall inside building is given below:-

Table-4.3: Modal Period of Model-3

Mode	Period (sec)	Frequency (cyc/sec)	Circular Frequency (rad/sec)	Eigenvalue (rad^2/sec^2)
Mode1	0.628	1.592	10.001	100.0206
Mode2	0.47	2.129	13.3767	178.9374
Mode3	0.444	2.251	14.1448	200.0752
Mode4	0.105	9.505	59.7233	3566.8741
Mode5	0.101	9.855	61.9229	3834.4517
Mode6	0.069	14.506	91.1411	8306.7011
Mode7	0.041	24.21	152.1155	23139.1308
Mode8	0.039	25.679	161.3482	26033.2483
Mode9	0.027	36.622	230.1044	52948.0413
Mode10	0.027	36.674	230.4285	53097.2729
Mode11	0.019	51.484	323.4836	104641.6291
Mode12	0.019	51.483	323.4778	104637.8888

The graph of the time period of the Model-3 is given below:-

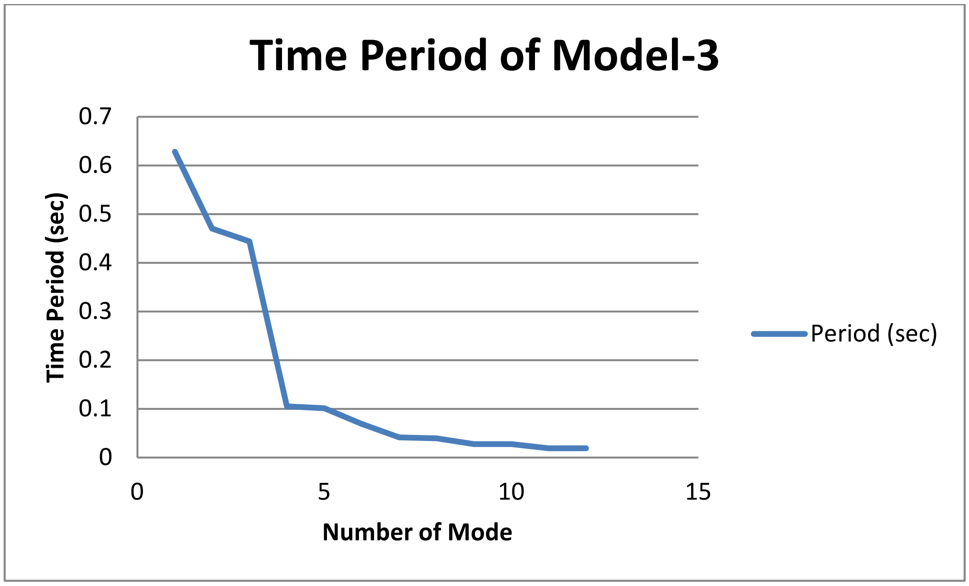

Fig-4.3: Time Period of Model-3

The Fig of the modal time period of the model-1, model-2, and model-3 is given below for the comparative study:-

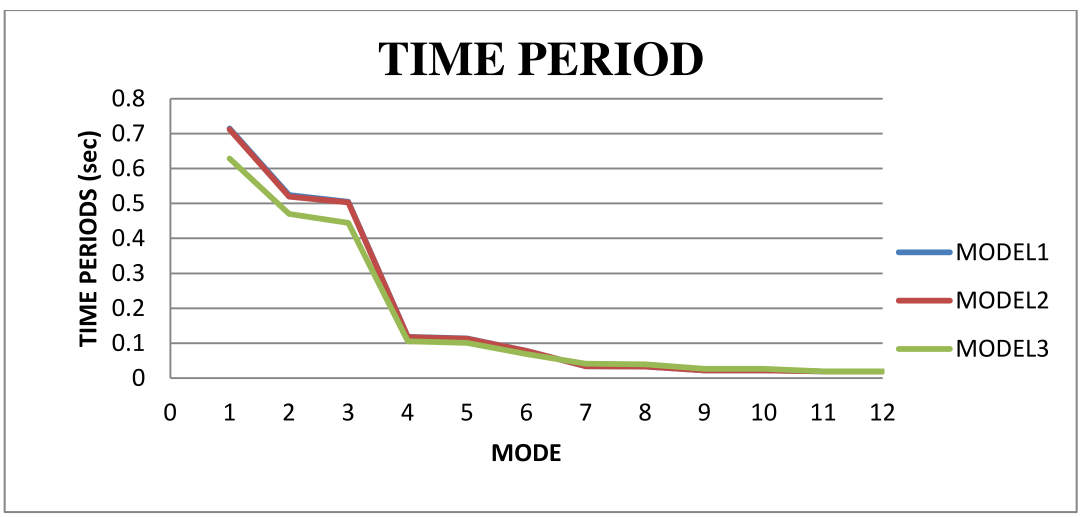

Fig-4.4: Modal time period of M1, M2 and M3

4.2. Base Shear

Base shear is an estimate of the maximum expected lateral forces on the base of the structure due to seismic activity

4.2.1. Base Shear of Model-1 due to EX

The value of the base shear of the model-1 is given below in the table due to defined seismic force EX

Table-4.4: Base Shear of Model-1 due EX

Storey	Elevation (m)	X Direction (KN)
Story15	45.5	2798.9721
Story14	42.5	3886.5419
Story13	39.5	3357.2191
Story12	36.5	2866.6272
Story11	33.5	2414.7663
Story10	30.5	2001.6363
Story9	27.5	1627.2373
Story8	24.5	1291.5691
Story7	21.5	994.632
Story6	18.5	736.4257
Story5	15.5	516.9504
Story4	12.5	336.206
Story3	9.5	194.1926
Story2	6.5	90.9101
Story1	3.5	19.2031

The column Fig is given below due to EX in the Model-1

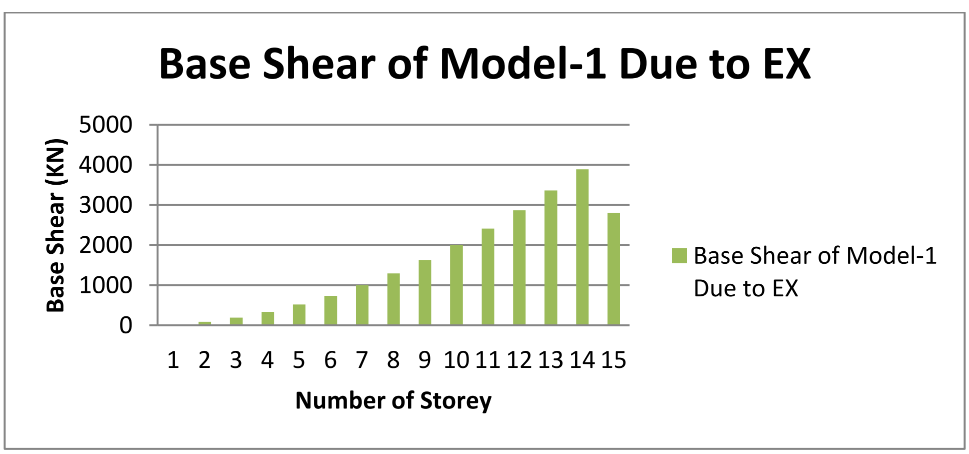

Fig-4.5: Base Shear of Model-1 due to EX

4.2.2. Base Shear of Model-1 due to EY

The value of the base shear of the model-1 is given below in the table due to defined seismic force E

Table-4.5: Base Shear of Model-1due to EY

Storey	Elevation (m)	Y Direction (KN)
Story15	45.5	2129.6177
Story14	42.5	2957.1029
Story13	39.5	2554.3639
Story12	36.5	2181.0936
Story11	33.5	1837.292
Story10	30.5	1522.9592
Story9	27.5	1238.095
Story8	24.5	982.6995
Story7	21.5	756.7728
Story6	18.5	560.3147
Story5	15.5	393.3254
Story4	12.5	255.8047
Story3	9.5	147.7528
Story2	6.5	69.1696
Story1	3.5	14.6108

The column Fig is given below due to EY in the Model-1

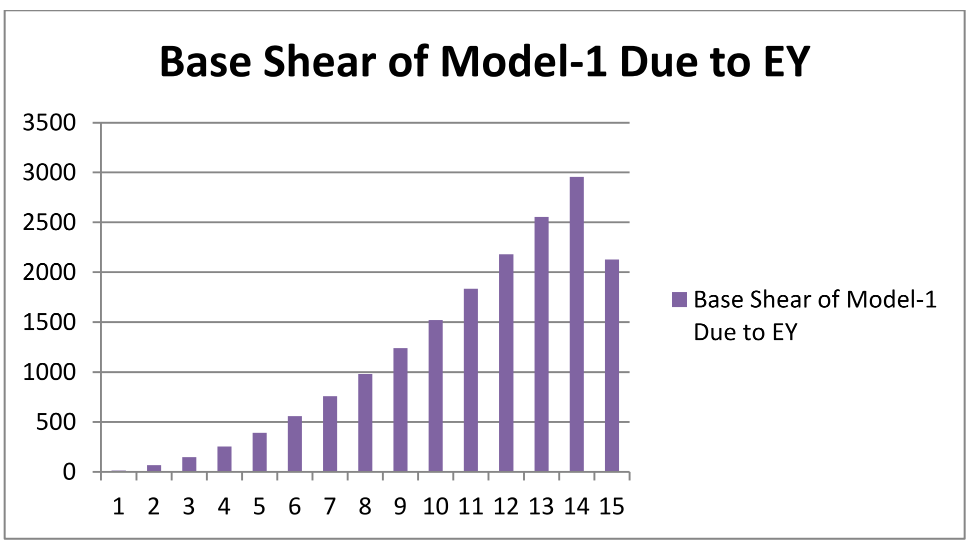

Fig-4.6: Base Shear of Model-1 due to EY

4.2.3. Base Shear of Model-2 due to EX

The value of the base shear of the model-2 is given below in the table due to defined seismic force EX

Table-4.6: Base Shear of Model-2 due to EX

Storey	Elevation (m)	X Direction (KN)
Story15	45.5	2776.0808
Story14	42.5	3847.2384
Story13	39.5	3323.2685
Story12	36.5	2837.6379
Story11	33.5	2390.3465
Story10	30.5	1981.3943
Story9	27.5	1610.7815
Story8	24.5	1278.5079
Story7	21.5	984.5735
Story6	18.5	728.9785
Story5	15.5	511.7226
Story4	12.5	332.8061
Story3	9.5	192.2288
Story2	6.5	89.9908
Story1	3.5	19.0721

The column Fig is given below due to EX in the Model-2

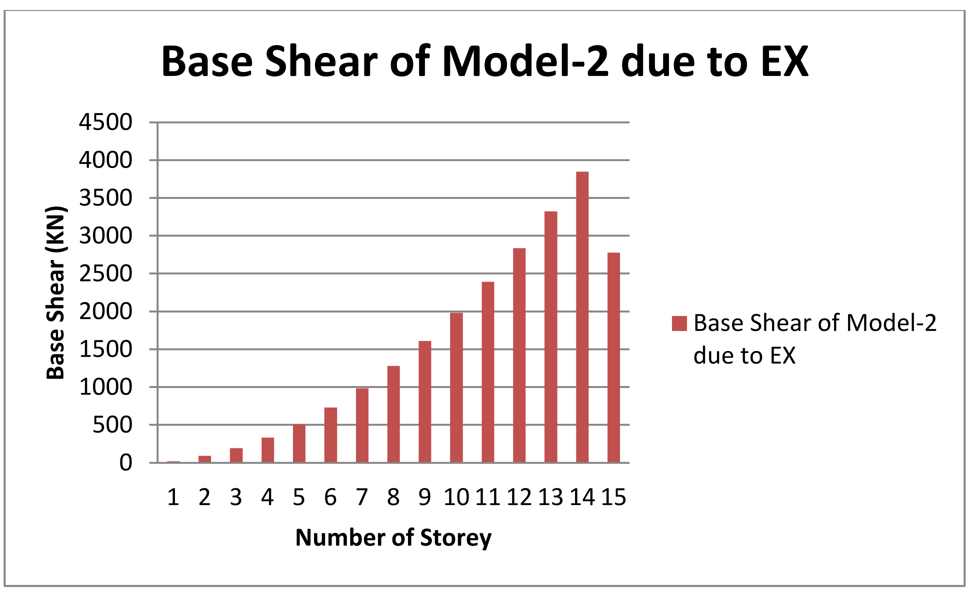

Fig-4.7: Base Shear of Model-2 due to EX

4.2.4. Base Shear of Model-2 due to EY

The value of the base shear of the model-2 is given below in the table due to defined seismic force EY

Table-4.7: Base Shear of Model-2 due to EY

Storey	Elevation (m)	Y Direction (KN)
Story15	45.5	2122.5402
Story14	42.5	2941.5276
Story13	39.5	2540.9098
Story12	36.5	2169.6056
Story11	33.5	1827.6148
Story10	30.5	1514.9376
Story9	27.5	1231.5738
Story8	24.5	977.5236
Story7	21.5	752.7868
Story6	18.5	557.3635
Story5	15.5	391.2537
Story4	12.5	254.4574
Story3	9.5	146.9746
Story2	6.5	68.8053
Story1	3.5	14.5822

The column Fig is given below due to EY in the Model-2

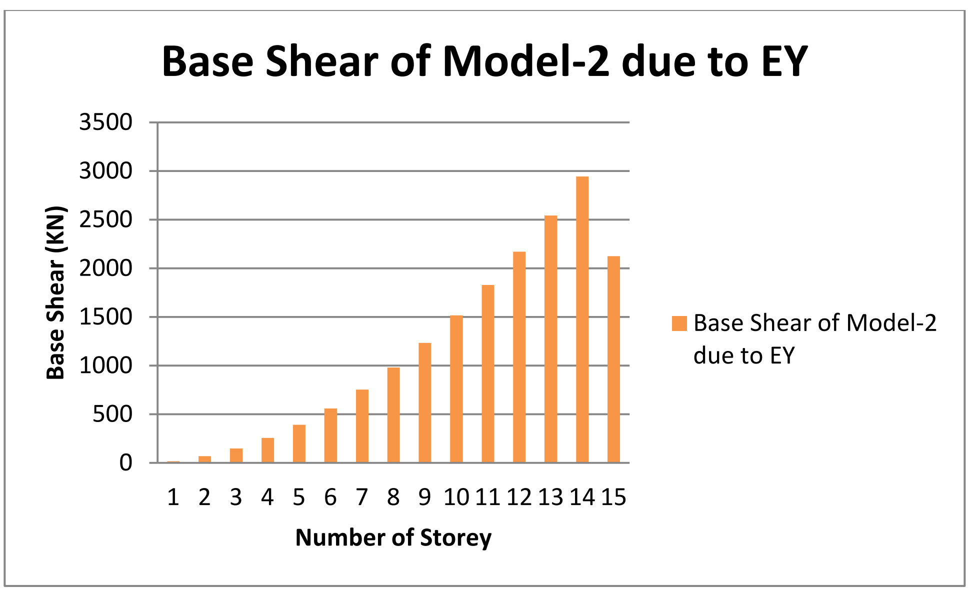

Fig-4.8: Base Shear of Model-2 due to EY

4.2.5. Base Shear of Model-3 due to EX

The value of the base shear of the model-3 is given below in the table due to defined seismic force EX

Table-4.8: Base Shear of Model-3 due to EX

Storey	Elevation (m)	X Direction (KN)
Story15	45.5	2277.37
Story14	42.5	2977.0381
Story13	39.5	2571.5841
Story12	36.5	2195.7974
Story11	33.5	1849.6781
Story10	30.5	1533.2262
Story9	27.5	1246.4416
Story8	24.5	989.3244
Story7	21.5	761.8745
Story6	18.5	564.0921
Story5	15.5	395.977
Story4	12.5	257.5293
Story3	9.5	148.7489
Story2	6.5	69.6359
Story1	3.5	16.1211

The column Fig is given below due to EX in the Model-3

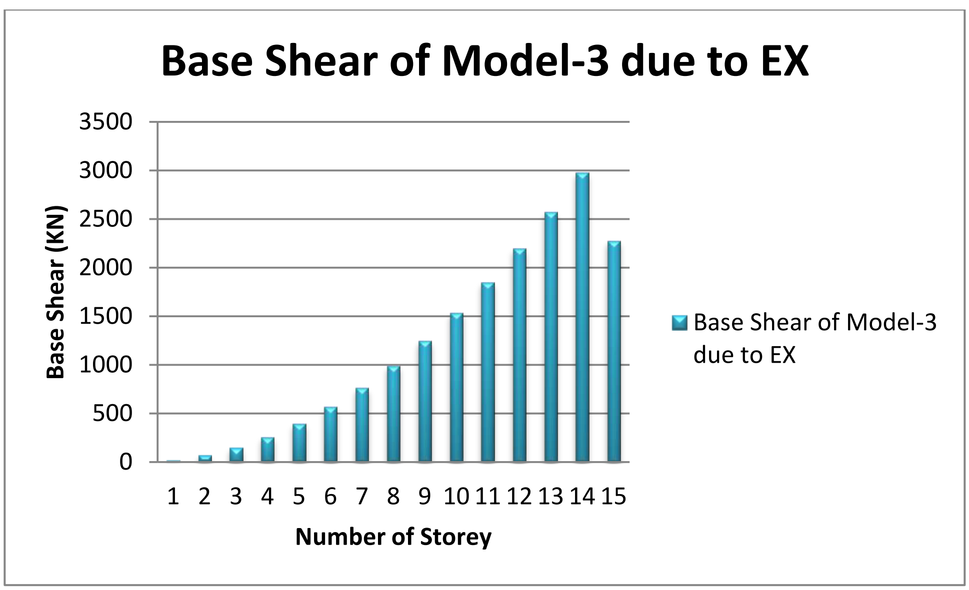

Fig-4.9: Base Shear of Model-3 due to EX

4.2.6. Base Shear of Model-3 due to EY

The value of the base shear of the model-3 is given below in the table due to defined seismic force EY

Table-4.9: Base Shear of Model-3 due to EY

Storey	Elevation (m)	Y Direction (KN)
Story15	45.5	1971.9561
Story14	42.5	2577.7931
Story13	39.5	2226.7137
Story12	36.5	1901.3231
Story11	33.5	1601.6212
Story10	30.5	1327.608
Story9	27.5	1079.2836
Story8	24.5	856.6479
Story7	21.5	659.701
Story6	18.5	488.4427
Story5	15.5	342.8732
Story4	12.5	222.9925
Story3	9.5	128.8005
Story2	6.5	60.2972
Story1	3.5	13.9591

The column Fig is given below due to EY in the Model-3

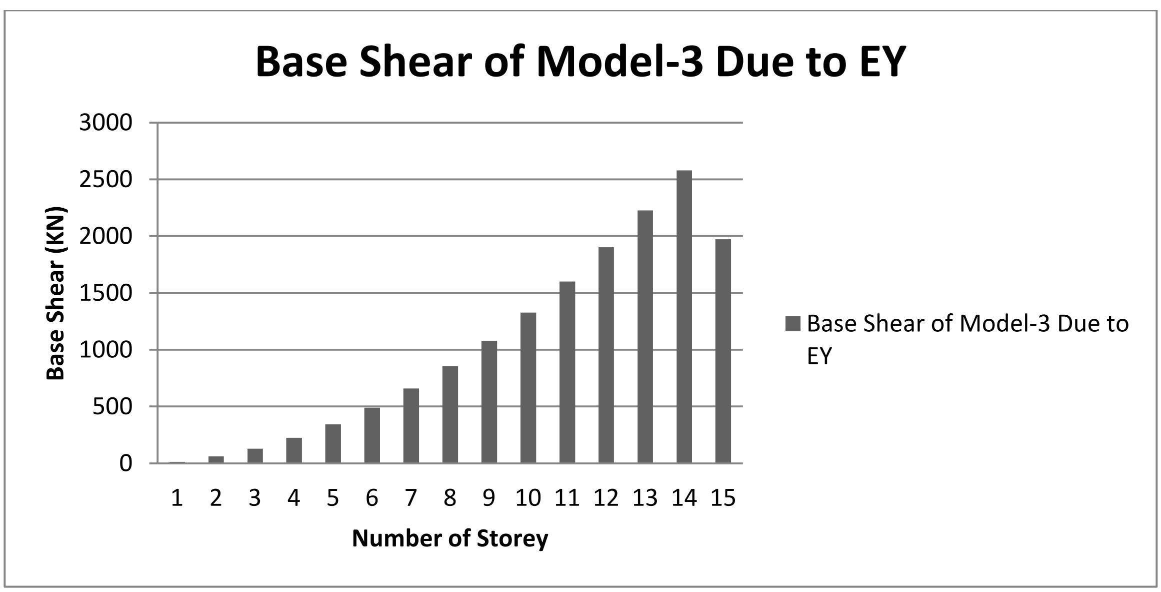

Fig-4.10: Base Shear of Model-3 due to EY

After study the base shear in the every model we draw the variation of the base shear of all models by using column Fig:-

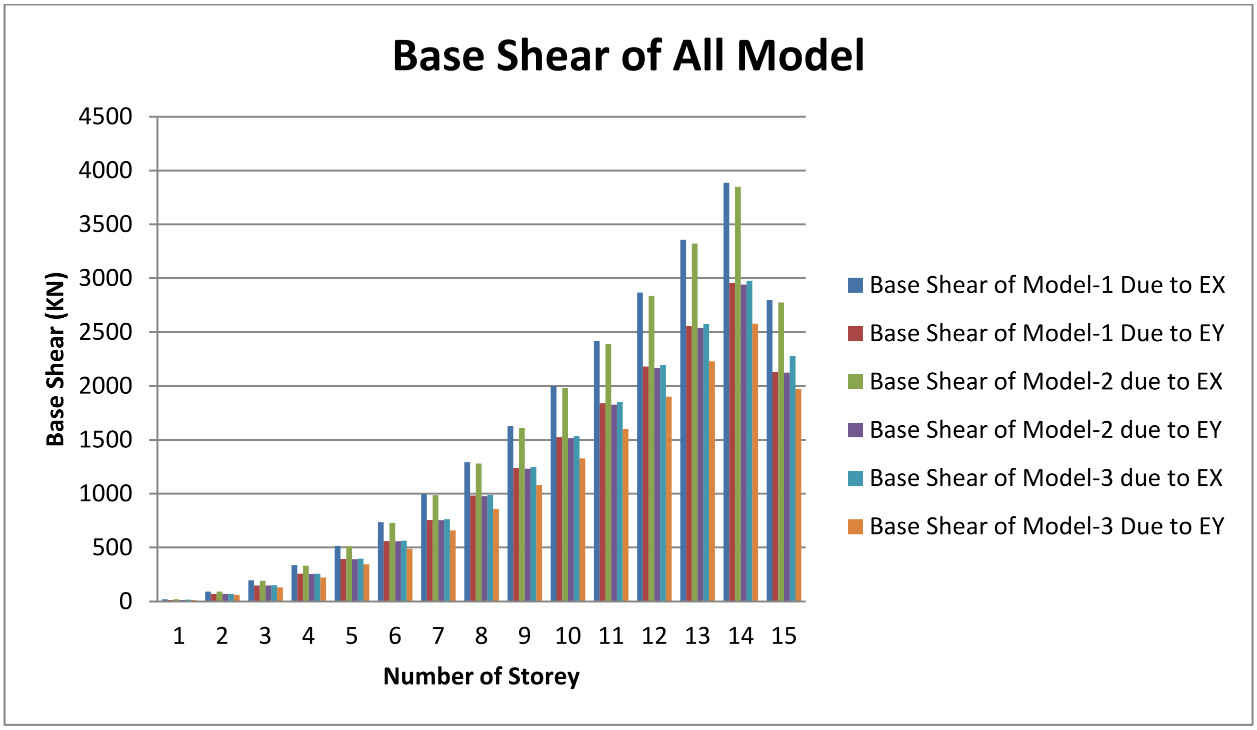

Fig-4.11: Base Shear

4.3. Maximum Storey Displacement

4.3.1. Maximum Storey Displacement of Model-1 due to Load Case 1.5(DL-EY)

Table-4.10: Maximum Storey Displacement of Model-1

Storey	Elevation	X- Direction (mm)	Y-Direction(mm)
Story15	45.5	0.0002033	14.436
Story14	42.5	0.0001576	14.285
Story13	39.5	0.0003358	14.135
Story12	36.5	0.001	13.984
Story11	33.5	0.001	13.833
Story10	30.5	0.001	13.683
Story9	27.5	0.001	13.532
Story8	24.5	0.001	13.381
Story7	21.5	0.001	13.23
Story6	18.5	0.002	13.079
Story5	15.5	0.002	12.929
Story4	12.5	0.002	12.778

Story3	9.5	0.003	12.628
Story2	6.5	0.004	12.478
Story1	3.5	0.006	12.327
Base	0	0	0

The column Fig is given below which represent the variation of the storey displacement of Model-1 in the Y-direction

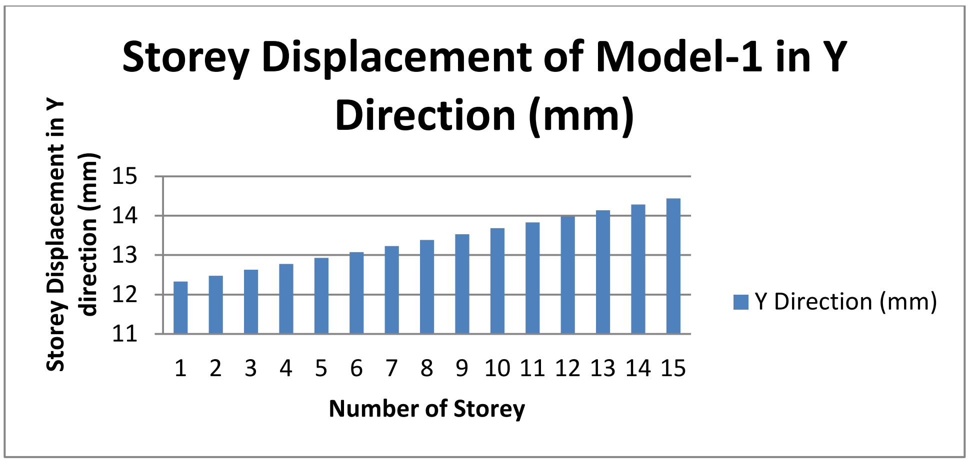

Fig-4.12: Storey Displacement of Model-1

4.3.2. Maximum Storey Displacement of Model-2 due to Load Case 1.5(DL-EY)

Table-4.11: Maximum Storey Displacement of Model-2

Storey	Elevation	X- Direction (mm)	Y-Direction(mm)
Story15	45.5	0.0002864	14.367
Story14	42.5	0.0003094	14.217
Story13	39.5	0.0004696	14.067
Story12	36.5	0.001	13.917
Story11	33.5	0.001	13.767
Story10	30.5	0.001	13.617
Story9	27.5	0.001	13.466
Story8	24.5	0.001	13.316
Story7	21.5	0.001	13.166
Story6	18.5	0.002	13.016
Story5	15.5	0.002	12.866
Story4	12.5	0.002	12.716
Story3	9.5	0.003	12.566
Story2	6.5	0.005	12.417
Story1	3.5	0.009	12.268

The column Fig is given below which represent the variation of the storey displacement of Model-2 in the Y-direction

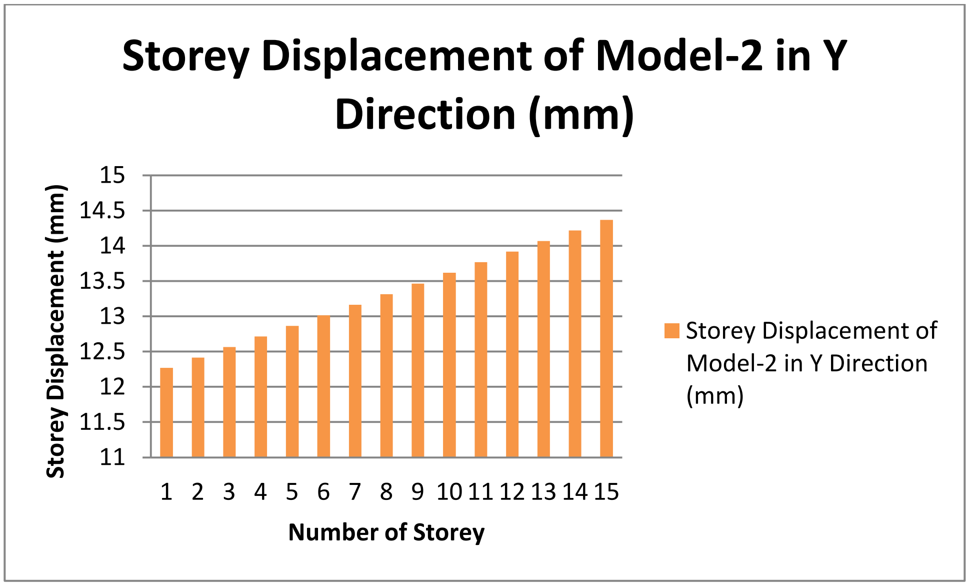

Fig-4.13: Storey Displacement of Model-2

4.3.3. Maximum Storey Displacement of Model-3 due to Load Case 1.5(DL-EY)

Table-4.12: Maximum Storey Displacement of Model-3

Storey	Elevation	X- Direction (mm)	Y-Direction(mm)
Story15	45.5	0.001	12.7
Story14	42.5	0.000454	12.566
Story13	39.5	0.001	12.432
Story12	36.5	0.001	12.299
Story11	33.5	0.001	12.166
Story10	30.5	0.001	12.032
Story9	27.5	0.002	11.899
Story8	24.5	0.002	11.765
Story7	21.5	0.002	11.631
Story6	18.5	0.002	11.498
Story5	15.5	0.003	11.364
Story4	12.5	0.003	11.231
Story3	9.5	0.003	11.098
Story2	6.5	0.004	10.964
Story1	3.5	0.007	10.832
Base	0	0	0

The column Fig is given below which represent the variation of the storey displacement of Model-3 in the Y-direction

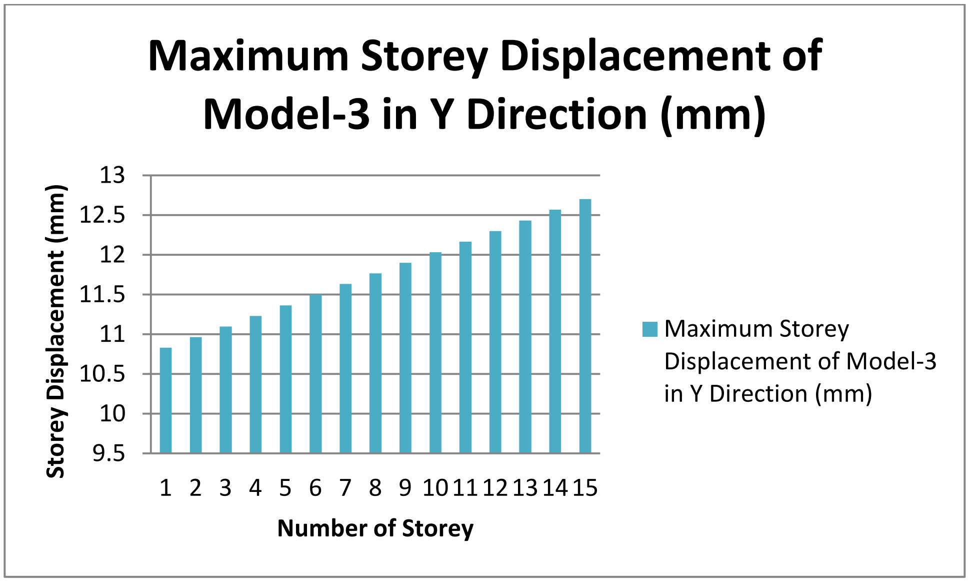

Fig-4.14: Storey Displacement of Model-3

After study the storey displacement of the all model, we draw the column Fig which represents the variation of the storey displacement of all models.

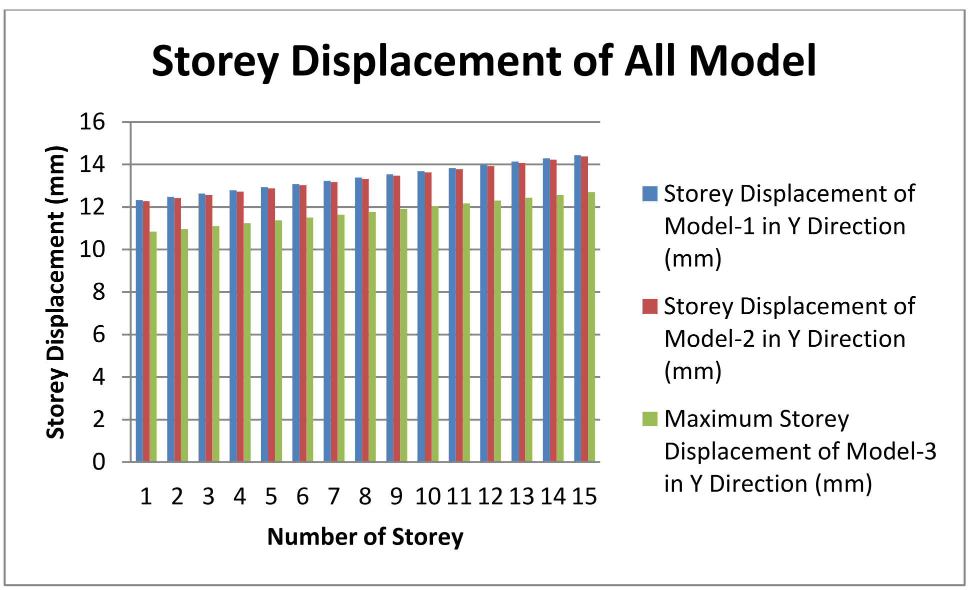

Fig-4.14: Storey Displacement.

4.4. Maximum Storey Overturning Moment

4.4.1. Maximum Storey Overturning Moment of Model-1

Table-4.13: Maximum Storey Overturning Moment of Model-1

Storey	Elevation (m)	X-Direction (KN-m)
Story15	45.5	0.1347
Story14	42.5	2.0864
Story13	39.5	6.7778
Story12	36.5	14.1877
Story11	33.5	24.2944
Story10	30.5	37.0768
Story9	27.5	52.5131
Story8	24.5	70.5822
Story7	21.5	91.2623
Story6	18.5	114.5322
Story5	15.5	140.3704
Story4	12.5	168.7552
Story3	9.5	199.6654
Story2	6.5	233.0794
Story1	3.5	268.9162
Base	0	312.6353

4.4.2. Maximum Storey Overturning Moment of Model-2

Table-4.14: Maximum Storey Overturning Moment of Model-2

Storey	Elevation (m)	X-Direction (KN-m)
Story15	45.5	-0.1217
Story14	42.5	-2.0837
Story13	39.5	-6.798
Story12	36.5	-14.2432
Story11	33.5	-24.3976
Story10	30.5	-37.2398
Story9	27.5	-52.7482
Story8	24.5	-70.9012
Story7	21.5	-91.6774
Story6	18.5	-115.055
Story5	15.5	-141.0127
Story4	12.5	-169.5287
Story3	9.5	-200.5815
Story2	6.5	-234.1495
Story1	3.5	-270.1657
Base	0	-314.0954

4.4.3. Maximum Storey Overturning Moment of Model-3

Table-4.15: Maximum Storey Overturning Moment of Model-3

Storey	Elevation	X-Direction (KN-m)
Story15	45.5	-0.1478
Story14	42.5	-2.4846
Story13	39.5	-7.9162
Story12	36.5	-16.4182
Story11	33.5	-27.9665
Story10	30.5	-42.5366
Story9	27.5	-60.1043
Story8	24.5	-80.6454
Story7	21.5	-104.1354
Story6	18.5	-130.5501
Story5	15.5	-159.8649
Story4	12.5	-192.0557
Story3	9.5	-227.098
Story2	6.5	-264.9673
Story1	3.5	-305.6026
Base	0	-355.3461

4.5. Response Spectrum Curve

A response spectrum is a plot of the peak or steady-state response (displacement, velocity or acceleration) of a series of oscillators of varying natural frequency that are forced into motion by the same base vibration or shock. ... For transient input (such as seismic ground motion), the peak response is reported.

4.5.1. Response Spectrum Curve for Pseudo Spectral Acceleration vs. Time for Model-1 at Storey15 due to Time History

The Fig of the response spectrum curve of the model-1 due to applied time history data is given below:-

Table-4.16: Response Spectrum Curve Data for Model-1

Period (sec)	Damping 0 (mm/sec^2)	Damping 0.02 (mm/sec^2)	Damping 0.03 (mm/sec^2)	Damping 0.05 (mm/sec^2)
0.019	230759.36	240377.71	242376.79	243699.95
0.022	239281.58	239262.19	239588.14	240024.49
0.022	238635	239264.66	239591.7	240014.38
0.03	241495.52	241535.99	241553.17	241568.02

0.033	242795.5	242611.52	242593.63	242547.5
0.034	243114.86	242886.27	242856.49	242802.62
0.036	243579.03	243319.53	243292.54	243232.37
0.04	244373.82	244322.99	244293.58	244226.82
0.045	245385.36	245605.37	245574.69	245501.27
0.05	247078.98	246854.54	246793.46	246689.94
0.056	248686.43	248540.86	248483.8	248369.65
0.061	250561.22	250455.72	250372.91	250179.22
0.067	251180.61	252619.98	252618.48	252409.33
0.071	253049.81	254813.92	254489.59	254041.1
0.077	252755.27	255275.95	255779.34	256120.39
0.078	257943.93	257637.69	257477.39	257199.29
0.083	258078.37	261555.21	261296.4	260719.96
0.091	268031.01	269323.36	268331.63	266445.99
0.1	287223.33	271727.92	271656.21	272897.66
0.111	442241.81	338021.51	314829.01	286411.49
0.114	300408.28	313684.1	305077.28	286206.9
0.118	331082.39	298815.47	291047.24	277065.75
0.118	322916.12	296637.94	289419.38	276623.9
0.125	345470.45	300648.03	292033.37	286304.47
0.133	382587.74	336995.93	328527.02	315575.67
0.143	442785.14	380606.43	363810.74	338990.68
0.154	409760.98	362798.26	350724.36	333010.71
0.167	336061.21	335860.37	335305.37	331423.08
0.182	418766.02	374621.95	360500.76	339647.35
0.2	346358.48	313736.66	311907.47	310441.87
0.213	338220.64	314603.37	316410.03	318012.98
0.227	420526.34	374640.69	356948.97	343314.75
0.25	413612.14	369056.11	359368.58	346637.55
0.278	454702.1	437175.37	428007.05	409154.17
0.303	633670.75	588021.89	567047.92	527702.36
0.333	907090.58	811291.15	769593.09	695887.98
0.357	1107912.98	983226.73	928459.64	831574.35
0.385	1403350.29	1208328.23	1123622.61	976679.7
0.417	1945698.64	1532363.65	1386455.75	1179136.82
0.455	2554474.92	1876066.64	1650115.98	1338726.76
0.5	3895862.71	2025483.19	1690593.35	1266683.59
0.505	3723592.03	1961879.74	1636646.08	1235852.41
0.524	2507660.35	1608919.82	1378111.12	1081349.63
0.556	1209067.59	987930.22	913964.91	782774.67
0.625	425146.62	421371.83	415374.92	398926.5
0.667	342041.48	330774.64	324483.72	311179.82
0.714	297844.32	285940.49	280242.64	269146.41
0.715	297678.45	285604.21	279842.73	268655.27

0.769	276850.35	255528.29	246121.66	229314.22
0.833	233014.38	218100.41	211440.06	199423.04
0.909	206674.94	190337.62	183072.6	170425.18
1	150625.29	142073.21	138220.16	131239.12
1.111	131366.04	124022.85	120617.11	114292.73
1.25	96670.73	91936.46	89696.34	85874.08
1.429	56247.49	54734.89	54054.69	52697.38
1.667	46066.16	42946.2	41882.19	40252.58
2	29154.4	28396.32	28039.22	27341.23
2.5	14864.88	14782.08	14733.28	14622.85
3.333	6714.91	6638.2	6600.65	6523.95
5	2461.56	2479.2	2487.68	2503.96

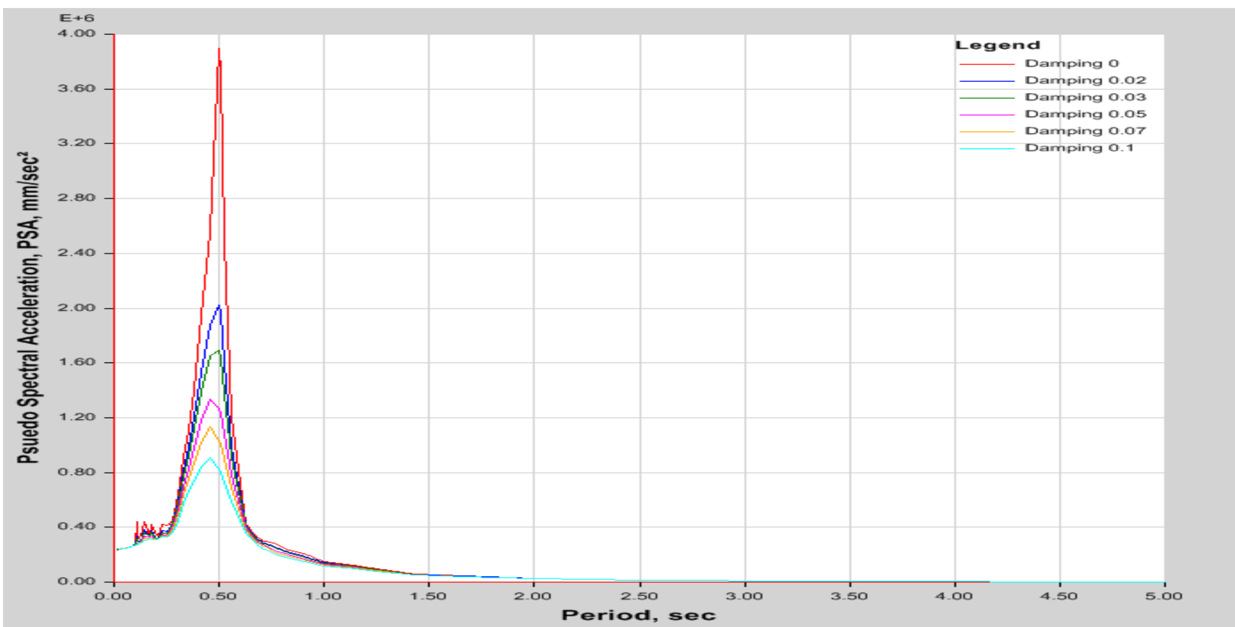

Fig-4.1: Response Spectrum Curve for Model-1

4.5.2. Response Spectrum Curve for Pseudo Spectral Acceleration vs Time for Model-2 at Storey15 due to Time History

The Fig of the response spectrum curve of the model-2 due to applied time history data is given below:-

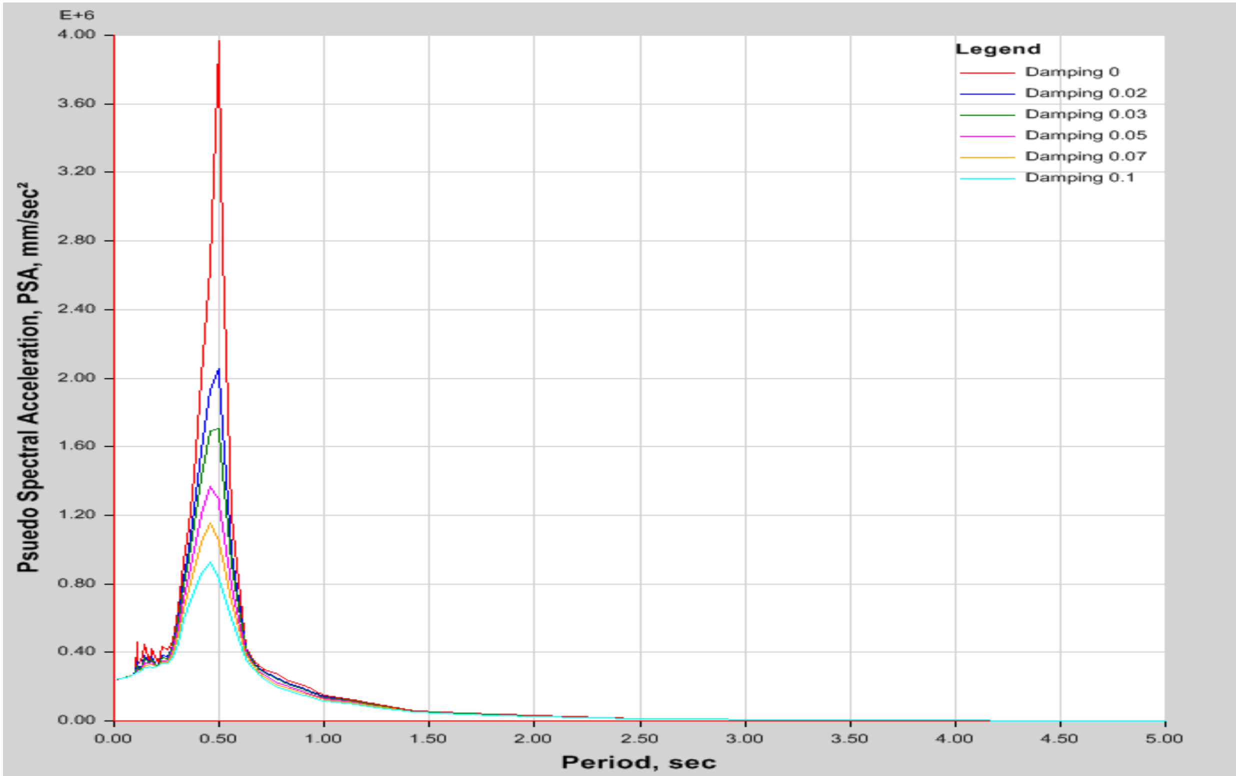

Fig-4.2: Response Spectrum Curve for Model-2.

Table-4.17: Response Spectrum Curve Data for Model-2

Period (sec)	Damping 0 (mm/sec^2)	Damping 0.02 (mm/sec^2)	Damping 0.03 (mm/sec^2)	Damping 0.05 (mm/sec^2)
0.019	236876.82	246013.04	248016.22	249341.82
0.019	236922.68	246013.31	248015.4	249341.11
0.022	248140.59	244633.09	244984.32	245556.73
0.022	249370.93	244638.6	244984.9	245544.64
0.03	247048.38	247101.85	247125.41	247152.8
0.033	248100.17	248155.16	248138.61	248104.14
0.034	248553.95	248412.52	248397.03	248361.51
0.036	249167.04	248919.51	248900.53	248856.26
0.04	249973.21	249941.35	249921.36	249873.31
0.045	250999.24	251247.21	251227.79	251176.67
0.05	252723.73	252519.66	252470.8	252392.26
0.056	254354.77	254236.66	254194.4	254109.89
0.061	256262.98	256190.2	256123.75	255962.39
0.067	256865.04	258397.01	258417.92	258247.74
0.071	258801.69	260644.66	260334.82	259922.8
0.077	258413.09	261082.33	261634.97	262051.54
0.078	261012.94	262728.49	262832.93	262818.63

0.083	263847.55	267536.56	267308.43	266792.24
0.091	274223.73	275567.69	274588.71	272741.25
0.1	292002.61	275834.62	277942.48	279596.45
0.111	458657.62	347264.88	322928.86	293595.97
0.113	332432.75	330413.51	317905.61	295414.92
0.117	343845.74	309877.89	301633.17	286956.05
0.118	341286.52	308543.2	300546.63	286127.85
0.125	347339.35	303615.51	297363.61	292177.64
0.133	385637.78	341229.83	332987.96	320413.84
0.143	447991.63	383949.86	367437.29	343063.17
0.154	414360.29	366945.45	353402.83	335940.93
0.167	338890.61	339129.3	338646.2	334904.52
0.182	419953.85	378457.91	364360.13	343580.03
0.2	354851.61	318016.46	316243.89	316884.17
0.213	343590.32	321093.3	322977.25	324711.15
0.227	431137.27	385137.97	367416.85	350449.97
0.25	415969.09	374570.16	364898.36	352259.53
0.278	464785.05	443383.28	434241.94	414634.8
0.303	645969.22	598387.54	577298.54	537706.87
0.333	924678.62	828140.77	786093.12	711718.32
0.357	1131837.56	1002418.16	947083.88	849147.76
0.385	1432477.63	1235383.71	1149694.76	1000924.58
0.417	1999536.12	1578551.27	1422175.4	1203805.8
0.455	2648566.31	1931963.87	1692127.45	1367479.16
0.5	3970312.8	2057787.21	1706300.62	1287186.28
0.503	3853938.02	2016095.81	1684730.34	1263558.64
0.519	2751114.62	1711600.29	1453851.97	1136177.21
0.556	1199294.22	987136.45	912749.98	781273.37
0.625	428517.4	422931.51	416120.68	402913.43
0.667	344780.49	332647.56	325926.73	313928.48
0.712	301626.42	290041.89	284405.05	273273.84
0.714	300930.76	288665.27	282776.43	271288.06
0.769	277451.05	255932.02	246419.33	229390.16
0.833	234269.06	219279.36	212772.75	201214.33
0.909	206785.8	190391.52	183221.42	171346.28
1	151758.61	143193.7	139332.26	132330.91
1.111	131892.69	124531.52	121116.3	115053.68
1.25	96782.13	92029.14	90026.47	86288.51
1.429	56228.26	54854.61	54166.42	52793.54
1.667	46394.78	43388.54	42224.9	40592.57
2	29369.27	28637.65	28279.45	27579.28
2.5	14976.49	14892.06	14842.45	14730.44
3.333	6805.18	6731.18	6693.05	6615.21
5	2495.2	2507.16	2515.55	2532.06

4.5.3. Response Spectrum Curve for Pseudo Spectral Acceleration vs Time for Model-3 at Storey15 due to Time History

The Fig of the response spectrum curve of the model-2 due to applied time history data is given below:-

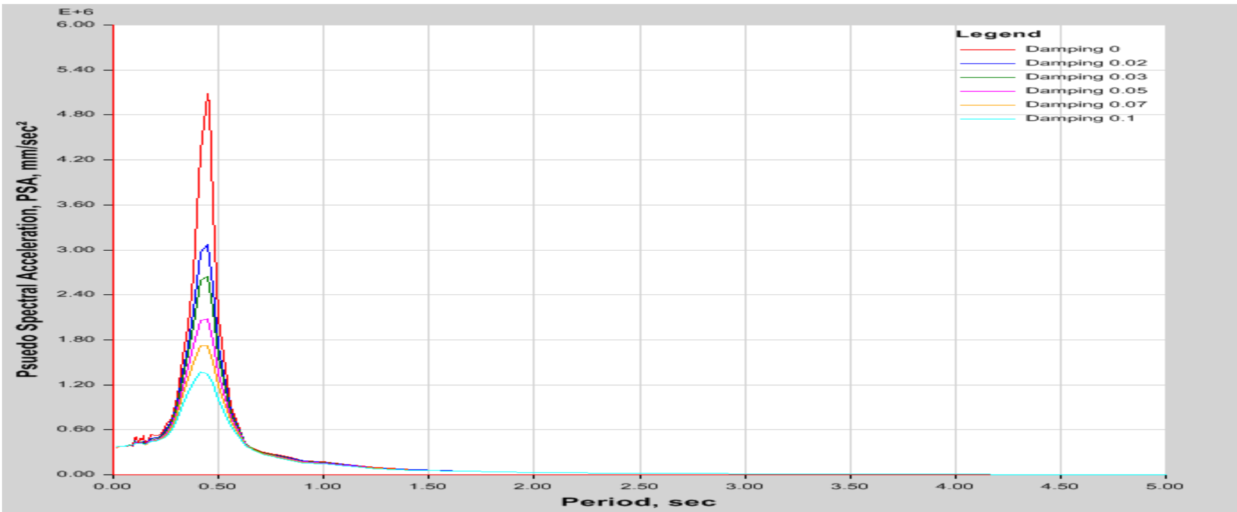

Fig-4.3: Response Spectrum Curve for Model-3

Table-4.18: Response Spectrum Curve Data for Model-3

Period (sec)	Damping 0 (mm/sec^2)	Damping 0.02 (mm/sec^2)	Damping 0.03 (mm/sec^2)	Damping 0.05 (mm/sec^2)
0.019	361358.89	374605.81	377130.24	378500.18
0.019	361392.21	374604.37	377128.26	378498.84
0.022	374352.66	373797.79	373893.77	374112.5
0.022	374296.21	373880.31	373940.43	374138.51
0.03	375079.89	375175.33	375254.62	375413.55
0.033	376631.75	376995.12	377064.34	377197.72
0.034	377784.86	377985.11	378056.68	378188.13
0.036	378172.95	378321.92	378390.85	378517.47
0.04	378708.54	378737.89	378803.53	378923.8
0.045	380134.48	380005.29	380072.77	380191.35
0.05	380642.7	381357.39	381470.75	381615.71
0.056	382962.75	383448.09	383499.7	383542.58
0.061	384366.22	384866.28	384961.06	385073.58
0.067	391676.68	387356.94	387180.59	387124.82
0.071	387114.87	387767.92	387680.38	387737.03
0.077	382411.4	386644.84	387406.36	388318.38
0.078	399145.58	395624.55	394515.81	393221.8
0.083	398219.58	394078.56	394393.82	394845.5

0.091	381807.81	393498.66	394786.82	394917.65
0.1	496566.55	426063.87	417535.04	405371.32
0.111	476770.22	439742.05	427091.32	410796.09
0.113	499160.25	457898.8	446044.34	430912.21
0.117	501181.39	435153.21	432734.42	427642.14
0.118	422831.99	416390.56	416990.25	418218.89
0.125	481381.29	442283.29	434666.76	425667.93
0.133	465404.16	440707.32	434950.51	425705.14
0.143	521833.53	452039.62	429253.58	404094.06
0.154	412389.2	394165.14	394579.45	396310.66
0.167	464819.58	455639.86	451311.88	443651.59
0.182	538212.71	481854.98	463598.82	453336.38
0.2	522376.64	495860.38	486202.13	468229.97
0.213	522635.61	497268.36	488546.4	475689.96
0.227	542365.08	523460.47	514100.82	495733.99
0.25	685569.68	618141.04	595273.27	562083.35
0.278	763144.44	730882.34	713282.53	677293.05
0.303	1036980.59	956724.73	918805.75	854332.59
0.333	1567110.08	1368280.47	1282831.99	1163190.14
0.357	1979126.18	1718532.51	1615944.65	1436598.39
0.385	2665741.16	2191418.65	1993935.32	1718501.43
0.417	4305245.62	2965614.46	2596585.56	2065271.6
0.455	5090232.44	3073790.32	2646441.47	2084847.23
0.5	4933683.71	2870500.72	2499531.73	1988463.68
0.503	3578236.1	2499557.09	2202960.14	1789610.88
0.519	2093844.9	1719763.93	1579352.97	1354580.86
0.556	910077.74	844760.19	813281.69	765576.84
0.625	421354.49	426707.07	426368.02	420938.62
0.667	412493.83	417515.76	417210.27	412118.26
0.712	347990.68	343764.97	341040.53	334368.44
0.714	303166.01	288717.85	287338.24	283924.49
0.769	275496.91	264762.05	259724.26	250177.07
0.833	246938.32	232808.66	226503.94	215135.09
0.909	189123.38	181713.38	178363.93	172245.41
1	173719.72	165631.26	161935.08	155148.92
1.111	138889.75	132803.13	129938.54	124544.3
1.25	94642.33	91526.02	90188.8	87601.04
1.429	66659.98	64270.94	63150.36	61109.57
1.667	52722.59	51038.31	50239.19	48720.86
2	33627.61	33028.64	32731.91	32145.56
2.5	17423.87	17388.78	17386.47	17366.18
3.333	7965.91	7942.59	7980.57	8049.96
5	3190.4	3210.94	3220.92	3240.3

4.6. Storey Stiffness

4.6.1. Storey Stiffness of Model-1 due to earthquake force EX

Table-4.19: Storey Stiffness of Model-1 due to EX

Storey	Shear X (KN)	Drift X(mm)	Drift Y(mm)	Stiffness X (KN/m)
Story15	2798.9721	0.132	0.000008472	21219585.72
Story14	6685.5139	0.132	0.000009144	50654989.91
Story13	10042.733	0.132	0.00001112	76049177.64
Story12	12909.3602	0.132	0.00001366	97714357.33
Story11	15324.1265	0.132	0.0000161	115953319
Story10	17325.7628	0.132	0.00001808	131072152
Story9	18953.0001	0.132	0.00001956	143372135
Story8	20244.5692	0.132	0.00002077	153151969
Story7	21239.2012	0.132	0.00002227	160708091
Story6	21975.6269	0.132	0.00002514	166334854
Story5	22492.5773	0.132	0.00003143	170319500
Story4	22828.7833	0.132	0.00004539	172958988
Story3	23022.9759	0.132	0.00007971	174546381
Story2	23113.8861	0.132	0.0002241	174948053
Story1	23133.0891	5.058	0.001	4573775.238

4.6.2. Storey Stiffness of Model-2 due to earthquake force EX

Table-4.20: Storey Stiffness of Model-1 due to EX

Storey	Shear X (KN)	Drift X(mm)	Drift Y(mm)	Stiffness X (KN/m)
Story15	2776.0808	0.131	0.00001115	21232356.63
Story14	6623.3192	0.131	0.00001309	50637321.72
Story13	9946.5877	0.131	0.00001468	75997158.58
Story12	12784.2255	0.131	0.0000167	97632407.34
Story11	15174.572	0.131	0.00001809	115849764
Story10	17155.9664	0.131	0.00001894	130952769
Story9	18766.7478	0.131	0.00001933	143245374
Story8	20045.2557	0.131	0.0000198	153023314
Story7	21029.8293	0.131	0.00002113	160580276
Story6	21758.8077	0.131	0.00002579	166212597
Story5	22270.5304	0.131	0.00003719	170196298
Story4	22603.3365	0.131	0.00006094	172881231
Story3	22795.5653	0.131	0.0002195	174285723
Story2	22885.5561	0.131	0.001	174634769
Story1	22904.6281	5.009	0.001	4572892.392

4.6.3. Storey Stiffness of Model-3 due to earthquake force EX

Table-4.21: Storey Stiffness of Model-1 due to EX

Storey	Shear X (KN)	Drift X(mm)	Drift Y(mm)	Stiffness X (KN/m)
Story15	2277.37	0.103	0.00002001	22212424.67
Story14	5254.4081	0.103	0.00002601	51207814.84
Story13	7825.9922	0.103	0.00002828	76199081.45
Story12	10021.7896	0.103	0.0000313	97515707.15
Story11	11871.4677	0.103	0.0000339	115462199
Story10	13404.6939	0.103	0.00003604	130342417
Story9	14651.1355	0.103	0.00003757	142451239
Story8	15640.4598	0.103	0.00003858	152091387
Story7	16402.3344	0.103	0.00003941	159554337
Story6	16966.4264	0.103	0.00004079	165128232
Story5	17362.4034	0.103	0.00004465	169130855
Story4	17619.9327	0.103	0.00004522	171807298
Story3	17768.6816	0.102	0.0001509	173396833
Story2	17838.3175	0.103	0.0003685	173342801
Story1	17854.4385	3.906	0.001	4571308.677

CHAPTER 5

CONCLUSION

The seismic analysis of the open ground storey building in three different conditions. In which first model is with load bearing wall at every position. In the second model providing the opening at the outer wall which is load bearing wall. In the third model outer wall is load bearing wall and inner wall is without opening. After analysis above three models we find some conclusion which is given below:-

I. The mode of the time period for the models3 is better as compared to the other models. In Model-3, mode of time period decrease about 11% as compared to Model-2 and about 9.95% decrease as compared to Model-1. We found that to reduce the mode of time period is depend upon the type of wall and opening.

II. After analysis we found that in Model-1 has large storey stiffness as compared Model-2 and Model-3 from storey12 to storey1. But at storey13 and above we found the Model-3 have more storey stiffness as compared to the Model-1 and Model-2.

III. In the storey overturning moment we found the Model-3 have more storey overturning moment at the base of the building in negative direction which is more about 12% as compared to Model-1. From this result we found that if we increasing the dimension of the opening then it will increase the storey overturning moment at the base so we try to keeping dimension as much as we can reduce.

IV. The value the base shear of the model-1 is more than model-2 and model-3 which represent that the self weight of the model-1 is high as compared to the other model.

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