A Thesis on

Seismic Behaviour of Re-entrant Corner with Opening in Diaphragm on RC Building

Submitted in Partial Fulfilment of The Requirements for The Degree

Of

Master of Technology

In

Civil Engineering

With Specialization In

Structural Engineering

By

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2020

DECLARATION

I declare that the research thesis entitled "**Seismic Behaviour of Re-entrant Corner with Opening in Diaphragm on RC Building**" is the bonafide research work carried out by me, under the guidance of **Mr. Rajiv Banerjee Associate Professor, Department of Civil Engineering, Integral University, Lucknow.**

Further I declare that this is not previously formed the basis of the award of any degree, diploma, associate-ship or other similar degrees or diplomas, and has not been submitted anywhere else.

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CERTIFICATE

*Certified that the thesis entitled "**Seismic Behaviour of Re-entrant Corner with Opening in Diaphragm on RC Building**" is being submitted by **Mr. MD FAISAL ZIA (Roll No 1800102644)** in partial fulfillment of the requirement for the award of degree of Master of Technology (Structures) of Integral University, Lucknow, is a record of candidate's own work carried out by him under my supervision and guidance.*

The result presented in this thesis have not been submitted to any other university or institute for the award of any other degree or diploma.

Banerjee 14/09/2020

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ABSTRACT

"Seismic Behaviour of Re-entrant Corner with Opening in Diaphragm on RC Building"

The most important cause of damage of RC buildings during earthquake is the irregular building configuration. An RC building which are unsymmetrical and has lack of continuity in geometry, mass or load resisting elements is called as irregular buildings. This obstructs the flow of inertia forces and cause lots of damage to buildings. There are many studies carried out irregular buildings in seismic zones, but still more research is needed in this field. Therefore, this study is about the seismic response of reinforced concrete structures having combination of two plan irregularities, re-entrant corner and diaphragm discontinuity buildings. Study is performed combining this two plan irregularity criteria and analyzing the results in seismic zone 4 and 5. For this 1 is regular building, 3 re-entrant corner buildings with three variations in A/L ratio, three buildings with opening in diaphragm with three varying percentage of opening. 9 structures are made combining these buildings with the combination of two irregularities. Structures are analyzed in etas software by response spectrum analysis. Parameters such as story displacement, story drift, base shear, overturning moments are determined and compared with regular buildings.

CHAPTER-1

INTRODUCTION

1.1 GENERAL

When horizontal forces act at the base of the structure an inertia force are generated. These inertia forces are directly proportional to mass of the building. These inertia forces develop at the floor level as most of the building mass is present at the floor level. These inertia forces are transferred to the walls or the columns by slabs and then to the foundation which disperses them safely to ground. The flow of inertia force should be smooth and continuous through the building. As inertia forces accumulate downwards from the top of the building, the lower story experience higher forces than upper story. Therefore, the lower story should be designed stronger than the upper. The buildings having unsymmetrical geometrical configuration and discontinuity in diaphragm are more unstable in seismic affect than regular one.

1.2 TYPES OF IREGULARITIES

As per IS 1893-part 1 irregularity in a building can be classified as: -

- Plan irregularity
- Vertical irregularity

1.3 PLAN IRREGULARITY

can be further classified as: -

- Torsional Irregularity:- a building is said to be torsional irregular, when floor in the direction of lateral force at one end of the floor is more than 1.5 times its minimum horizontal displacement at the far end of the same floor in that direction and the natural period corresponding to the fundamental torsion mode of oscillation is more than those of the first two translational modes of oscillation along each principle plan direction.

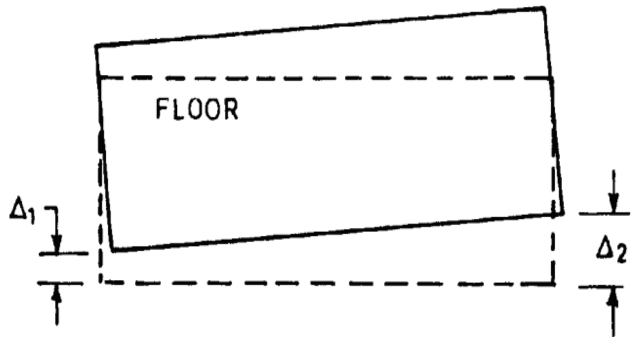


Fig. 1 Torsional Irregularity

- Re-entrant corners: - A building is said to have a re-entrant corner in any plan direction, when its structural configuration in plan has projection of size greater than 15 percent of its overall plan dimension in that direction.in buildings with re-entrant corners, three-dimensional dynamic analysis method shall be adopted.

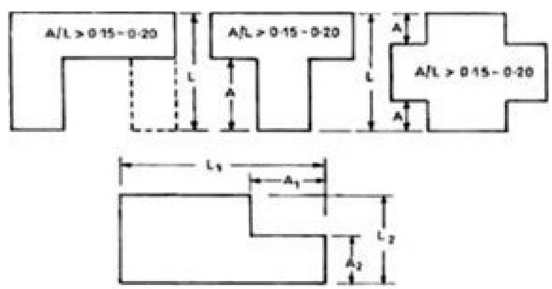


Fig. 2 Re-entrant corner

- Floor slabs having excessive cut-outs or openings: - A building is said to have discontinuity in their in-plane stiffness, when floor slabs have cut-outs or openings of area more than 50 percent of the full area of the floor slab.

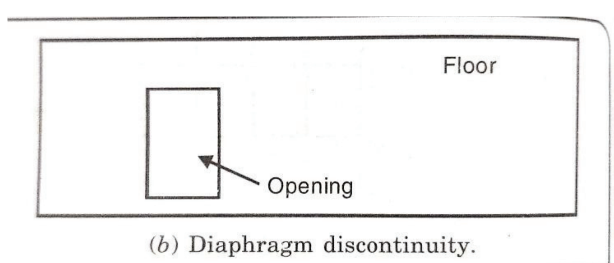


Fig. 3 Diaphragm discontinuity

- Out-of-plane offsets in vertical elements resisting lateral loads cause discontinuity and detours in the load path, which is known to be detrimental to the earthquake safety of the building. A building is said to have out of plane offset in vertical elements, when structural walls or frames are moved out of plane in any story along the height of the building.

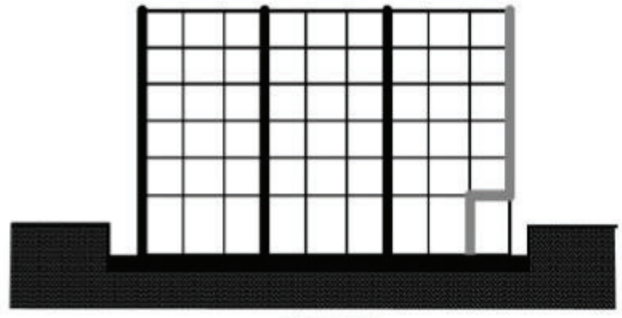


Fig. 4 Out-of-plane offsets in vertical elements

- Non parallel lateral force system: - building undergo complex earthquake behaviour and hence damage, when they do not have lateral force resisting system oriented along two plane directions that are orthogonal to each other. A building is said to have non-parallel system when the vertically oriented structural system resisting lateral forces are not oriented along the two principle orthogonal axes in plan.

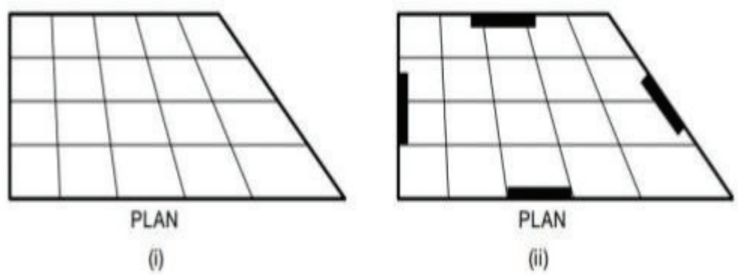


Fig. 5 Non parallel lateral force system

1.4 VERTICAL IRREGULARITY

Can be classified as: -

- Stiffness irregularity (soft story): a soft story is that story whose lateral stiffness is less than that of story above.

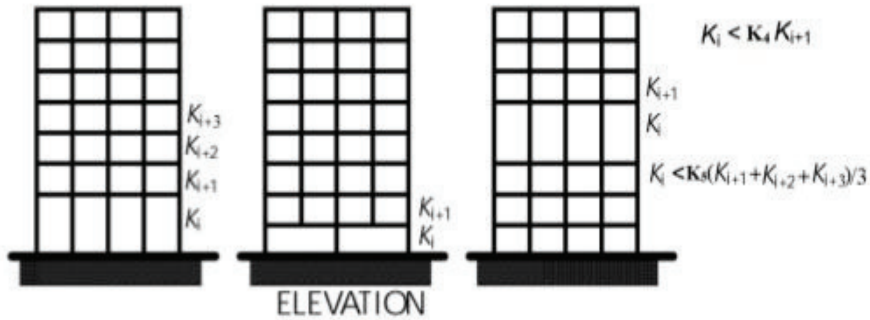


Fig. 6 Stiffness Irregularity

- Mass irregularity: mass irregularity shall be considered to exist, when the seismic weight of any floor is more than 150% of that of the floor below. In a building with mass irregularity and located in seismic zone III, IV and V, the earthquake shall be estimated by dynamic analysis.

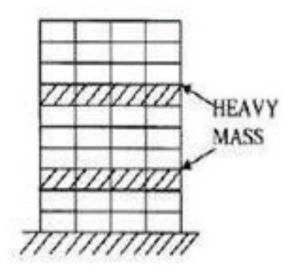


Fig. 7 Mass Irregularity

- Vertical geometric irregularity: vertical geometric irregularity shall be considered to exist, when the horizontal dimension of the lateral force resisting system in any story is more than 125% of story below.

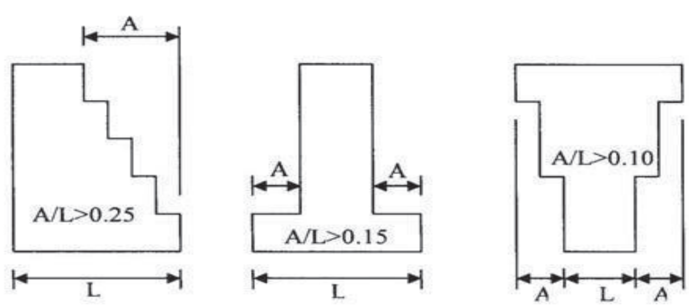


Fig. 8 Vertical Geometric Irregularity

- Floating columns: such columns are likely to concentrated damage to structure. This feature is undesirable and hence should be prohibited, if it is the part of or supporting the primary lateral load resisting system.

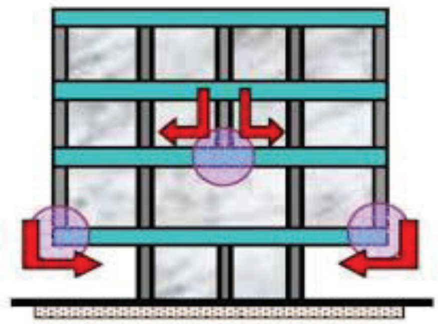


Fig. 9 Floating Columns

1.5 SEISMIC TERMINOLOGY

- Base Shear: It is an estimate of the max. expected lateral force that will occur due to seismic ground motion at the base of structure. It is represented by V

  $V_B = A_h * W$ (refer IS 1893 PART 1 2016)

  Where**,** $A_h = \{(Z/2) * (S_a/g)\}/(R/I)$

- Story Displacement: It is the total displacement of ith story with respect to ground. Displacement estimates can be obtained by dynamic analysis method.
- Story Drift: The word "Drift" can be defined as the lateral displacement of the structure; Storey drift is the slower and small movement of one level of a multilevel building relative to the level below. Inner storey drift is the difference between the floor and roof displacements of any given story as the building sways during the earthquake, marked by the story height, more is the storey drift will cause more damages to the structures, its value should not be beyond the limit 0.004h, where (h) is height of the building.
- Overturning Moment: An overturning moment is quit literally the force that is attempting to overturn an object. These are the applied moments, shears, and uplift forces that seek to cause the footing to become unstable and turn over.

1.6 TYPES OF ANALYSIS

1.6.1 DYNAMIC ANALYSIS

- Response spectrum analysis
- Time history analysis

1.6.2 STATIC ANALYSIS

- Static linear analysis.
- Static nonlinear analysis.

1.7 DYNAMIC ANALYSIS

Dynamic analysis is an analysis of the structure subjected to dynamic loads. Loads such as wind load earthquake load, traffic, blasts, comes under dynamic loading. Inertia forces are developed in a structure when the dynamic loading is subjected to it. Response of a structure can be analyzed by dynamic analysis if load varies rapidly with respect to time.

1.7.1 RESPONSE SPECTRUM ANALYSIS

It is a linear but dynamic analysis in which peak response of a structure subjected to earthquake loading is analyzed or in other word response spectrum analysis (RSA) is a linear-dynamic statistical analysis way which measures the contribution from each natural mode of vibration to indicate the expected maximum seismic response of a necessary elastic structure.

1.7.3 TIME HISTORY ANALYSIS

Is step wise analysis of the dynamic response of a RC structure to a particular loading that may changes with changes of time And the time history analysis is used to determine the seismic response of a building under dynamic loading of representative earthquake is a nonlinear dynamic analysis which is used to analyze structure when the response is nonlinear. From the Time history analysis, we can know the dynamic response of structure for a specific loading that may changes with time.

1.8 STATIC ANALYSIS

A static structural analysis determines the stresses, displacements, strains, and forces in structures or components caused by loads that do not induce significant inertia and damping effects, static analysis is are those analysis which are on rest. I have did only seismic analysis for grid and flat slab, further work will be done latter.

1.9 OBJECTIVE OF STUDY

To study the seismic behaviour of combination of intermittent diaphragm and Re-entrant corners in RC building under seismic zones IV and V considering the parameters like displacement, drift, base shear, overturning moment.

CHAPTER-2

LITERATURE REVIEW

2.1 GENERAL

As per the increasing demand of modern architecture irregularity in buildings have also increased rapidly. This resulted more instability of the structure. Many research works have been carried out on irregular structure of buildings. Static analysis method and dynamic analysis method both plays a key role in the analysis of structure however research shows that dynamic analysis of structure in seismic zone gives more acute results.

2.2 REVIEW OF PREVIOUS WORK

Dr. S.K. Dubey, P.D. Sangamnerkar (2011) [1]: this paper is concerned with the study of torsional response due to plan a vertical irregularity of building. For this he analysed T-shape building with seismic force acting and additional shear due to torsion in column. He concluded that three-dimensional analysis of building by using general analysis computer programme can only take care of eccentricity 'e', but can't give magnitude of eccentricity. This is because there is no any direct method to obtain centre of rigidity or shear centre for each story in a building.

Anantwad Shiris, Rohit Nikam (2012) [2]: This paper aims at studying description of different plan irregularities by analytical method during seismic events. Analyses have been done to estimate the seismic performance of high-rise buildings and the effects of structural irregularities in stiffness, strength, mass and combination of these factors are to be going to be considered. T-section and Oval Shape plan geometry. These irregular plans were modelled in ETABS 9.7v considering 35 and 39 storied buildings, to determine the effect of the plan geometric form on the seismic behavior of structures with elastic analyses. Also, effects of the gust factor are considering in T-shape and Oval Shape plans. In structural configuration shear wall positions located are located in the form of core and columns are considered as gravity as well as lateral columns. He concluded that the dual system offered more economic construction along with the iconic architectural image.

Rakesh Sakale, R K Arora and Jitendra Chouhan (2014) [3]: this paper is the study of seismic behaviour of horizontally irregular buildings with regular building. L-shape, T-shape, C-shape and regular shape buildings of equal height are taken and lateral displacement and story drift are derived after analysis. Results were compared and studied. Analysis is performed in staad pro. For seismic zone II, III, IV, and V. Results were such that from drift point of view for zone II TO IV all frames are within permissible limit and there is no need to provide shear wall. Only with the building with plan C exceeds the permissible limit and may require shear wall. For displacement point of view, all buildings are withing permissible limit only for zone II. In zone III and above regular plan building slightly exceeds the permissible limit but other requires shear wall to control the limit.

Komal R. Bele1, S. B. Borghate (2015) [4]: This paper is focused on buildings with large projections of Re-entrant corners results in torsion. He took four models one regular and other 3 with varying projections. The conclusion of this paper was base shear decreases from Model R to` L5 (decreases with increase in projection). He also concluded that as projection of increases there are more coupling of modes. Result obtained shows that forces in column (common in all building) shows that the variation of P much higher with increase in projection.

Babita Elizabath baby and shreeja s (2015) [5]: this paper is on the study of slab discontinuity at different position that is at the centre, at corners, and at periphery. Pushover analysis are performed in etabs software. Results were that the axial forces, bending moment and story drift are more effectively resisted by the model having slab opening in periphery. So, the opening is more effective to be located at periphery.

Md. Mahmud sazzad, Md. Samdani azad (2015) [6]: he conducted numerical study on the response of different shapes of building on various wind and earthquake zones. So for this he took three different shapes of the building subjected to lateral forces wind load and earthquake load and comparison of the results are presented in the paper. Computer aided analysis are performed for all structures. He concluded that L-shape building shows max. displacement due to earthquake along y direction. This is due to the distribution of seismic force depends upon stiffness. Story drift is max. along y- direction for earthquake and in x-direction for wind load.

Atul Patane, Sachin Kadam (2015) [7]: he studied the seismic behaviour of plan irregular building configuration plan with regular model. He analysed G+9 story building in sap 2000 by response spectrum method. He concluded that a regular general configuration building is more stable in seismic effect than an unsymmetrical irregular building.

Milind V. Mohod (2015) [8]: this paper presents effects of plan and shape configuration on irregular shaped structures. For he took regular building plan, H shape plan, L shape plan, plus shape, E shape building shape, C shape and two of varying percentage of diaphragm plan for analysis. Buildings were designed in Staad pro software having G+ 11 floors. His results were in the form of drift and displacement. He concluded that re- entrant corner buildings show more displacement than diaphragm discontinuity irregular buildings. Drift is within permissible limit but L and C shows maximum drift.

Shiva kumar hallale and H sharada bai (2016) [9]: this study is one three building, one regular and another two with re-entrant corner building plan. Response spectrum method is used for analyzing in etabs. Parameters such as eccentricity, maximum displacement and drift, base shear, max. story acceleration, time period, member force in beam and column. Results obtained were eccentricity, max displacements, max story, drift increases in both direction x and y with the increase in plan irregularities.

Kazi Muhammed mustaqeem and md mansoor ahmad (2016) [10]: this paper consists two types of configuration, one with opening in slabs and other re-entrant corner structure having varying percentage of irregularities. Analysis was performed for static analysis, dynamic analysis and push over analysis and parameters were displacement, drift, base shear and time period. The results were such that the magnitude of displacement is more in static method. Response spectrum showed more accurate results and can be better considered for seismic activity. Pushover analysis gives higher value as it is analyzed for extreme. More percentage of re-entrant corner max drift. Base shear is max. for regular model less for re-entrant models. As base shear of the building increases, more seismic forces will be attracted by the member.

Subodh.S.Patil, Shrinivas.R.Survanshi (2016) [11]: seismic response of regular multi-storey building with asymmetrical plan is checked and compared with regular multi-storey building. A building with g+20 and g+22 building having plan asymmetry is modelled and analysed in finite element analysis stadd pro v8i. shear wall is provided at re-entrant corner in the buildings. Results of this paper as increase in height of L-shape building directly increase in relative displacement & stress at re-entrant corners. Increase in height of T-shape building directly increase in relative displacement and stress will be developed at re-entrant corner. T-shape building with shear wall and without shear wall after analysis shows uniform stress developed at re-entrant corners. In T- shape building re-entrant corners did not fail because of stresses carried by the shear wall. But without shear wall it will fail.

P.S. Anil Kumar and Vinayak Vijapur (2016) [12]: he studied about seismic response of re-entrant corners buildings in different soil strata. He took C, H, L and T shape building with equal plan area and analysed them in different soil at seismic zone IV using dynamic analysis. The results were obtained in terms of base shear, story displacement, story drift and compared with the results of regular model having equal area of plan. He observed that building with re-entrant corner are more prone to seismic damage and are responsive to earthquake corresponding to time period of lower order. Therefore, a regular building is more stable than re-entrant corner building configuration.

Vishwajit. V. Karkhanis & Dr. Y. M. Ghugal (2016) [13]: this paper is concerned with performance of a building with plan irregularity in seismic effect by two method of analysis, standard pushover analysis and modal pushover analysis. A G+6 story building with configuration in plan as L- shaped, C-shaped, T-shaped and regular model are generated n etabs software. Plan of area and loads are kept constant for all models. Parameters such as pushover curves and performance curve are obtained. He concluded that modal pushover analysis of seismic demand for an intense ground motion are accurate for irregular buildings to similar degree for regular building.

Momen M. M. Ahmed, Shehata E. Abdel Raheem, Mohamed M. Ahmed and Aly G. A. Abdel-Shafy (2016) [14]: The objective of this study is to study the seismic behavior of the buildings with irregular plan of L-shape floor plan through the evaluation of the configuration irregularity of re-entrant corners effects on measured seismic response demands. The measured responses include inter-story drift; story shear force; overturning moment; torsion moment at the base and along the building height; top floor displacement;

and torsional Irregularity Ratio. Three-dimensional finite element model of nine stories moment resisting frame buildings as reference model is developed; six L-shaped models are formulated with gradual reduction in the plan of the reference model. The models are analyzed with ETABS using Equivalent Static Load (ESL) and Response Spectrum (RS) Methods. The results prove that buildings with severe irregularity are more vulnerable than those with regular configuration resulting from torsion behavior, and the additional shear force produced in the perpendicular direction to the earthquake input. Also, in the Codal empirical equation for the calculation of fundamental period of vibration could not grasp significant higher vibration modes such as torsional vibration of irregular buildings that could significantly affect seismic demands.

Mohaiminul Haque, Sourav Ray (2016) [15]: The objective of his study is to carry out static and dynamic analysis i.e. equivalent static analysis, response spectrum analysis and time history analysis over different regular and irregular shaped RCC building frame considering the equal span of each frame as per Bangladesh National Building Code- 2006. In this study, four different shaped (W-shape, L-shape, Rectangle, Square) ten storied RCC building frames are analyzed using ETABS v9.7.1 and SAP 2000 v14.0.0 for seismic zone 3. Comparative study on the maximum displacement of different shaped buildings due to static loading and dynamic response spectrum has been explored. From the analyzed results it has been found that, for static load analysis, effects of earthquake force approximately same to all models except model-1(W-shape). W-shape has been found most vulnerable for earthquake load case. It is also found from the response spectrum analysis that the displacements for irregular shaped building frames are more than that of regular shaped building. The overall performance of regular structures is found better than irregular structures.

Reena sahu and Ravi dwivedi (2017) [16]: this paper is the study of diaphragm discontinuity taking 5 structures. One as regular and other 4 as the increasing percentage in slab opening 0%, 4%, 16%, 24%, 36%. Response spectrum analysis using staad pro. is done. Parameters like base shear, bending moment, story drift, shear force are obtained. Results shows that the increase in opening percentages, increases the story drift. 24% opening have less value of maximum shear force as compared to 16% opening.

Lohith kumar B C and Babu abera areda (2017) [17]: this paper focuses on the study of plan configurations of structure having re-entrant corner and torsional irregularities for 10,15, 20 story as per I.S 1893 part 1 2002. Analysis was performed on etabs software and results were formed in terms of torsional moment, fundamental time period and base shear and compared. Results for re-entrant corner structures were such that parameters increase with the height of the building. Fundamental time period is high in lower story and less in higher. Results for torsion irregularity: - as the height of the building increases fundamental parameters such as torsional moments, fundamental period and base shear increases. He also found that there is a linear variation of base shear from 10 to 20 story for all seismic zones and soil types.

Akash Panchal (2017) [18]: in this paper, a multi-storey building with 6 story RCC framed structure has been designed and analysed using software STAAD. PRO. The building is designed as per IS 1893 (part 1) 2002 in different seismic zones. Variation in percentage of steel, maximum shear force, maximum bending moment, and maximum deflection are studied. All the parameters show increase as from zone II to V

Arya V Manmathan, Aiswarya S, Aiswarya S (2017) [19]: this paper focus on seismic response of different position of slab openings such as in centre, corner, and periphery of the building. Response spectrum analysis were performed in etabs software for all structures. He observed that story drift of slab opening in centre is reduced to 53.02% when compared to corner and 64.13% to periphery position. Similarly, base shear of the building with slab opening at centre is 46.44% compared to corner and 57.3% compared to periphery position. Therefore, slab opening at centre is more effective in resisting lateral forces, hence more stable. As the slab opening increases base shear also increases.

Dona Meriya Chacko, Akhil Eliyas (2017) [20]: this paper is a study of various shapes or varying percentage of diaphragm opening at the positions such as centre, corner, and at the periphery of the building. Along with it building taken are with base isolation technique and one with fixed based having G+4 story. Response spectrum analysis is carried out and parameters for seismic design such base shear, story displacement, time period, and story drift are calculated and results are interpolated in tables and graphs. Results obtained for base isolation building show increase in story displacement and time period and decrease of base shear and story drift as compared with fixed base building.

Oman Sayyed, Suresh Singh Kushwah, Aruna Rawat (2017) [21]: In this paper, the focus is made on the performance & behavior of regular & vertical irregular G+10 reinforced concrete (RC) buildings under seismic loading. Total nine building models having irregularity due to partial infill and mass irregularity are modeled & analyzed. Response spectrum analysis (RSA) is carried out for these building models for seismic zone V and medium soil strata as per IS 1893:2002 (part I). Seismic responses like Storey displacement, Storey drift, overturning moment, Storey shear force, Storey stiffness are obtained. By using these responses comparison is made between the regular and irregular building models. This study focuses on the effect of infill and mass irregularity on different floor in RC buildings. The results conclude that the brick infill enhances the seismic performance of the RC buildings and poor seismic responses are shown by the mass irregular building, therefore it should be avoided in the seismic vulnerable regions.

Reshma K Bagawan and M Q Patel (2018) [22]: this paper focus on the study of seismic effect of the building with diaphragm discontinuity- stiffeness irregularity and mass irregularity are considered in slab. Analysis of building were performed by response spectrum method and time history method. Parametrs such as modal period, story shear, story displacement and forces in columns were found. The results were plotted and compared with regular building.he concluded that discontinuity in diaphragm shows more deflection, more story drift and story displacement as compared to regular model. Shear force and time period shows greater results than irregular building. Hence irregular building are more vulnerable to lateral forces.

Akshay Nagpure, S. S. Sanghai (2018) [23]: In this paper, RCC framed building structures have been analyzed using ETABS software by linear time history analysis by changing flexibility of the floors and simultaneously when plan irregularities are provided. He took four plans- opening at the center, opening at the corners, opening at the horizontal faces, opening at the vertical faces. Time history record of El Centro Earthquake has been provided to the software. Responses of all those structures has been plotted and discussed. An attempt is made in this paper to compare the responses of the structures when floor diaphragm flexibility is changed and simultaneously plan irregularities are provided. He concluded that floor Diaphragm Flexibility affects Base Shear of the Building, Column Forces, Beam Forces but doesn’t show considerable difference in Time Period and Storey Drift.

Shaik Muneer Hussain, Dr. Sunil Kumar Tengli (2018) [24]: this project focuses on torsional effects of irregular building under seismic loads. He worked for understanding the torsional behavior of asymmetric building by modelling and analyzing a 14-story building using response spectrum method in etabs. For this a regular building model and irregular building models have been analyzed. Parameters such as max. story drift, displacement, time period and modes of frequencies are determined. Results showed that there is an increase in shear force in columns especially in irregular structures due to torsion. Irregular building shows increase in story drift and displacement.

Siva Naveen E, Nimmi mariam abraham, Anitha kumari (2019) [25]: this includes the study of seismic response of series of irregular structures. There are 34 building with single irregularity and 20 building plans with the combination of more than one irregularity as per IS1893. Buildings having mass irregularity, stiffness irregularity, re-entrant corner, torsional irregularity, vertical irregularity were taken. All structures are modelled and designed in etabs. Results showed that it is not always necessary that irregularity will make structure more stable than regular building in response to lateral force. For single irregularity its shows an increase in response to lateral force. Vertical irregular building has max. displacement whereas the combination of plane irregularity and vertical irregularity shows less max. displacement.

Sanjay Naik, Thushar S Shetty (2019) [26]: The research paper involves the modeling and analysis of G+10 storied building of Regular shape plan, L- shape plan and C shape plan structure using ETABS 2016 software. The parameters such as displacement, drift, shear and overturning moment are compared and it was found that Rectangular shape is the best suited and L shape structure is the least desired shape for construction in seismic zone.

Aradhya B M S, Dr. B Shivakumara Swamy (2019) [27]: This project aims for the study of performance of a Reinforced concrete frame building (G+13) with soft Storey and with bare frame and also with masonry wall infill. Linear dynamic analysis (response spectrum analysis) is done using the software SAP2000 as per IS 1893-2002 (part 1). She concluded that Models having bare frame shows the maximum value of displacement in Both X and Y direction and under both Earthquake zones II and V compare to all other models because of less lateral stiffness of the Storey. The displacement value is considerably reduced in the models with masonry wall infill in both X and Y direction under seismic forces at both Earthquake zones II and V. from this we can conclude that we should prefer masonry wall infill instead of bare frame structures under higher seismic zones.

S K Shanawaz, S. Amaresh Babu (2019) [28]: He studied the effect of combined plan, vertical and mass irregularity on torsional performance of high raised buildings. For this he took asymmetrical buildings of 12 storeys, 15 storeys and 18 storeys with same columns sizes subjected to gravity loads and seismic loads are analyzed using non-linear dynamic analysis. The structure is evaluated in accordance with IS 456-2000 and seismic code IS: 1893-2002 using non-linear time history method with the help of ETABS. He concluded that Torsion percentage in asymmetrical buildings is significantly decreased by minimizing the stiffness eccentricity. Thereby a maximum decrease in torsion is 90% for 18 Storey building with openings. And maximum decrease in joint rotation is 86% for 18 Storey building with openings.

2.3 CONCLUSION

INFLUENCE OF LITERATURE REVIEW AND RESEARCH GAP

Research works has been done for various plan irregularities and vertical irregularities. Conclusion can be made after review of above literatures that unsymmetrical building shows more instability than regular one. The various parameters such as displacements, story drift, overturning moment shows large variations from regular building to plan irregular building and then to vertical irregular building. Shear wall provided is of great help in order to maintain the structural stability of the structure. Base isolation and seismic dampers can also be applied in or to reduce base shear, lateral displacement, story drift. But still much work on the combination of more than one irregularity in a structure has not been done. Studies are performed for single irregularity and very less work for combination of more than one irregularity.

CHAPTER-3

METHODOLOGY

3.1 BASIC PROCEDURE

We have to find the effect of re-entrant corner and opening slab on a building's response to seismic forces. So, in order to do these 10 building models are taken. 1 regular building, 3 re-entrant corner building with varying percentage of re-entrant corner, 3 building with varying percentage of opening in diaphragm, and 3 building models with combination of re-entrant corner and opening in slab with varying percentage. All these structures are planned and designed in etabs for zone IV and V. Analysis are performed based on response spectrum method and results such as base shear, max. story displacement, max, drift, overturning moments are plotted in form of tables. These values in table are further briefed in the form of graphs. These graphs are studied and conclusion based on these experimental results conclusions are made.

3.2 CODAL PROVISION

In design and analysis of the models the codes which has been used in experimental work can be listed below: -

1. IS 1893 PART 1 2016: - This is a general provision building code for earthquake design of the structure. Altogether it has five parts, part 2 is for liquid retaining tanks, part 3 bridge, part 4 industrial structures including stacks and part 5 for dams and embankments.
2. IS 875 part 1: 1987: - This code is a code of practice for design loads (other than earthquake) for buildings and structures. This is only for dead loads on the structures with includes unit weight of building materials and stored materials.

3. IS 875 part 2: 1987: - This code is also for design loads other than earthquake loads. This includes only live load acting on the structure.
4. IS 456: This code is used for the general design of RC building structures.
5. IS 13920 2016: Ductile detailing and design code.

3.3 LOAD COMBINATION

3.3.1 DEAD LOAD

First load which comes under dead load is self-weight of the structure. Etabs automatically assigns the self-weight and we need not apply any extra self-weight. For extra dead load acting on the floor we can refer to page 31 table 2 of IS 875 part 1. Dead loads on floor includes mortar screeding and clay floor tiles load. Here dead load in addition is taken as 0.52 KN/m^2 .

3.3.2 LIVE LOAD

For live load on floor of the structure we can refer to IS 875-part 2 table 1. Here we can see that code specifies various loads value for different types of accommodation or rooms. Live loads are uniformly distributed loads and are applied on floor. Here on an average live load on floor is taken as 2.5 KN/m^2.

3.3.3 MASONARY LOAD

For multistoried building, to reduce the weight of building we can replace clay bricks with autoclaved aerated concrete (AAC)blocks. Unit weight of AAC block is 6 KN/m^3. So for outer walls masonry load is calculated to be 4.59 KN/m and for inner wall it is 3.519 KN/m.

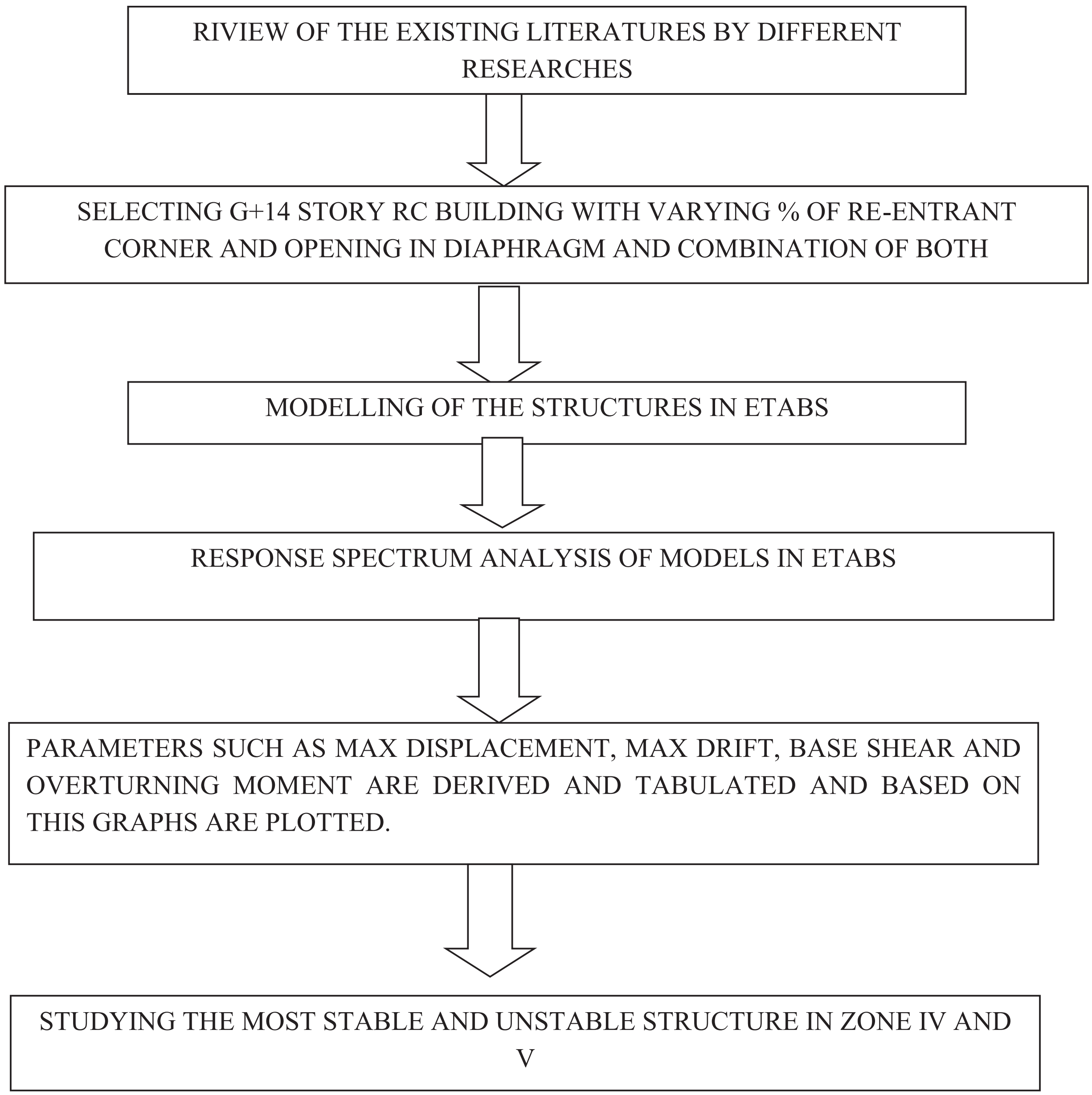
3.3.3 EARTHQUAKE LOAD

The earthquake load case is defined using etabs program and response spectrum in accordance to IS 1893:2002 codes.

3.4 SOFTWARE USED

For planning and analysis of the models etabs software is used. Etabs is an engineering software product that caters to multi-story building analysis and design. Modeling tools and templates, code-based load prescription, analysis methods and solution techniques, all coordinate with the grid-like geometry unique to this class of structure. For the analysis of models etabs 2016 is used

3.5 METHODOLOGY FLOW CHART



CHAPTER-4

EXPERIMENTAL PROGRAM

4.1 BUILDING DESCRIPTION

Aim of this study is to study the seismic behaviour of re-entrant corner RC building with opening in diaphragm. Total of 10 RC building models are taken. Each building has a common property as stated below –

For study purpose, the layout of the plan has 5 X 5 bays of equal length of 6m.

Building parameters are as follows –

- Type of building: SMRF
- Numbers of story: G+14
- Seismic zone: IV and V
- Floor height: 3m
- Grade of concrete: M35
- Grade of steel: Fe500
- Beam dimension: 400 x 600mm
- Column dimension: 400 x 750mm
- Slab depth: 150mm
- Floor finish load: 0.52 KN/m^2
  Mortar screeding – 0.21 x 2 (IS 875 PART 1 table 2 page 31)
  Clay floor tiles – 0.10 (IS 875 PART 1 table 2 page 30)
- Live load on floor: 2.5 KN/m^2 (IS 875 PART 2 table 1)
- Masonry load: 4.59 KN/m (outer wall) [(0.30 (t) x 2.55 (h) x 6 (unit wt.))]
  3.519 KN/m (inner wall) [(0.30 (t) x 2.55 (h) x 6 (unit wt.)]

[AAC (Autoclaved Aerated Concrete Block) is used.]
(unit weight of AAC blocks – 6 KN/m^3)

- Importance factor: 1
- Response reduction factor: 5
- Soil type: II (medium)
- % imposed load: 25% of Live Load
- Time period: 0.7s {0.09h / Sq. root. d} IS 1893 part 1 2016

4.2 DISCRIPTION OF MODELS

Model R –This is a regular RC frame building model with 5 x 5 bay having G+14 story. This is of equal height of story.

Model D1 – This model consists of 16% of diaphragm opening throughout the story with 5 x 5 bay and or equal height.

Model D2 – This RC framed building has 28% of opening in diaphragm throughout the story with 5 x 5 bay and of equal height.

Model D3 – This RC framed building has 36% of opening in diaphragm throughout the story with 5 x 5 bay and of equal height.

Model R1 – This model consists re-entrant irregular building plan with re-entrant 40% in x direction and 40% in y direction throughout the story.

Model R2 – This model consists re-entrant irregular building plan with re-entrant 60% in x direction and 40% in y direction throughout the story.

Model R3 – This model consists re-entrant irregular building plan with re-entrant 80% in x direction and 40% in y direction throughout the story.

Model DR1 – This model consists re-entrant irregular building plan with re-entrant 60% in x direction and 40% in y direction throughout the story and 15% opening in diaphragm

Model DR2 – This model consists re-entrant irregular building plan with re-entrant 80% in x direction and 40% in y direction throughout the story and 17% diaphragm opening

Model DR3 – This model consists re-entrant irregular building plan with re-entrant 40% in x direction and 40% in y direction throughout the story and 23% diaphragm opening.

4.3 STEP BY STEP EXPERIMENTAL PROCEDURE

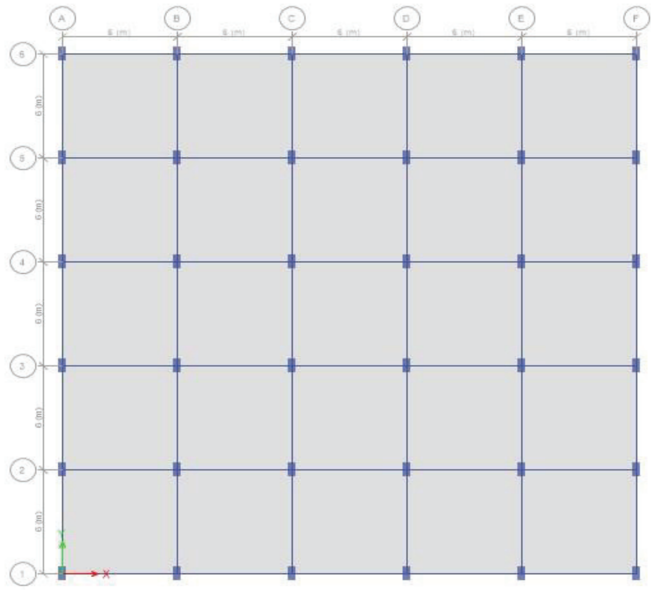


Fig. 10 Model R (plan)

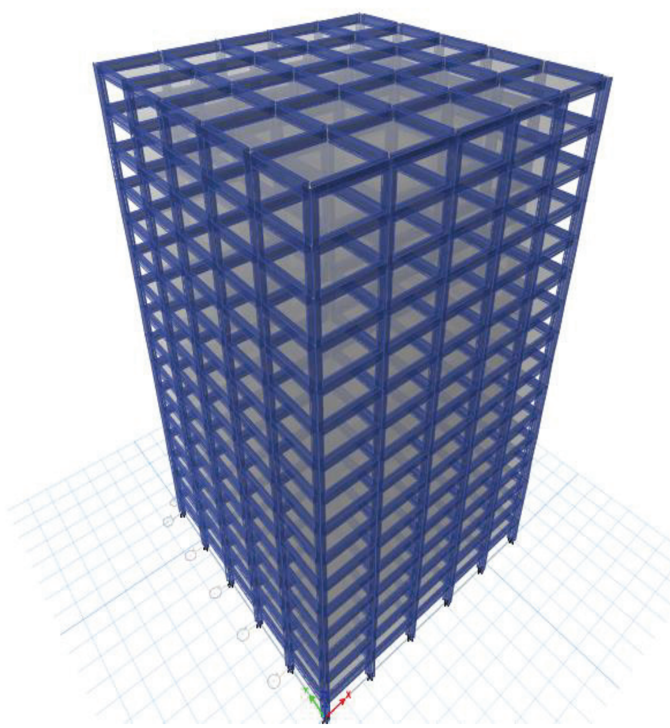


Fig. 11 Model R (3D)

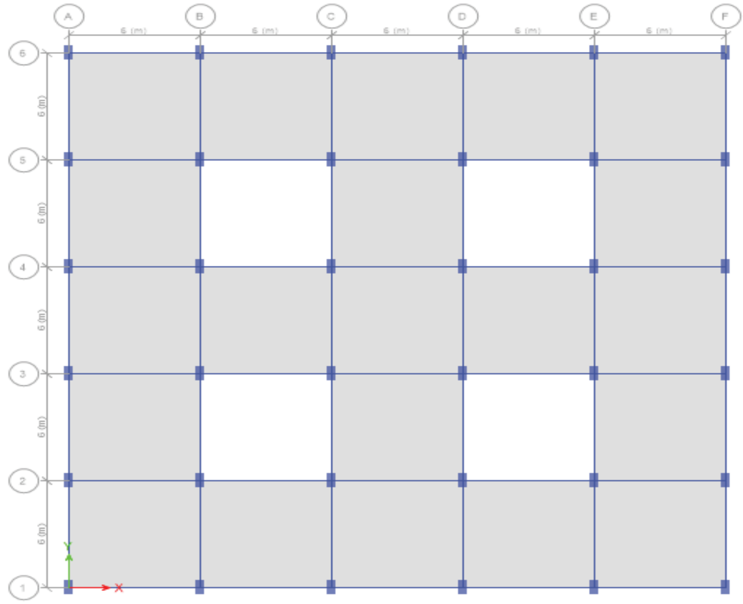


Fig. 12 Model D1 (PLAN)

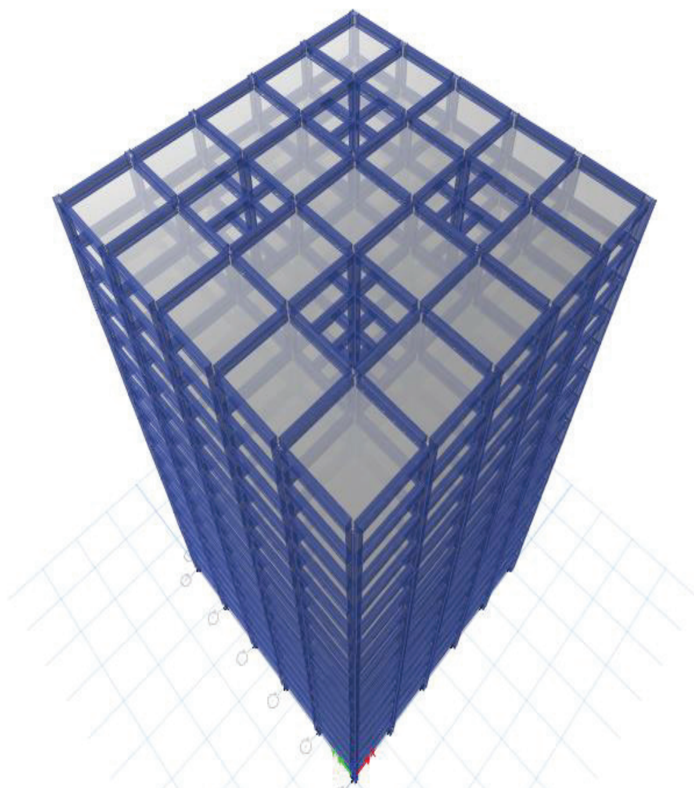


Fig. 13 Model D1 (3D)

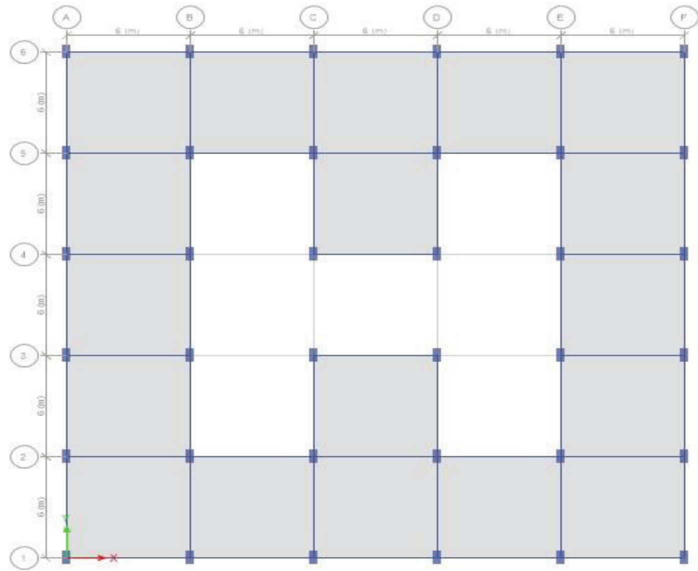


Fig 14 Model D2

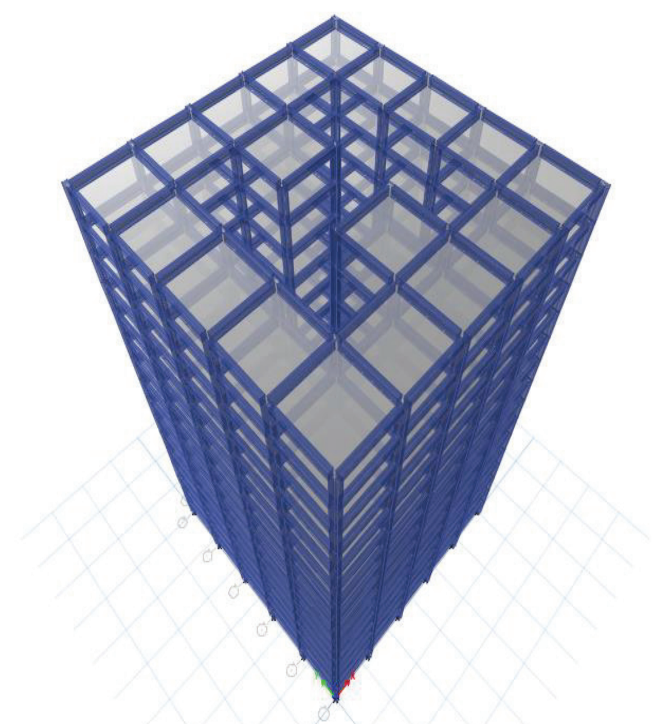


Fig 15 Model D2 (3D)

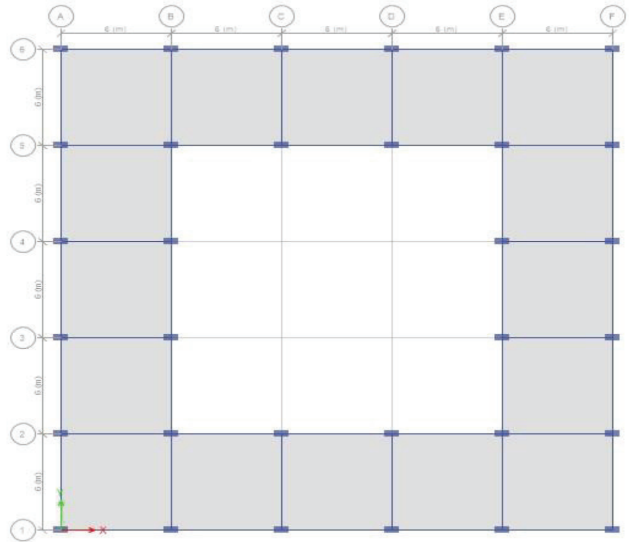


Fig. 16 Model D3

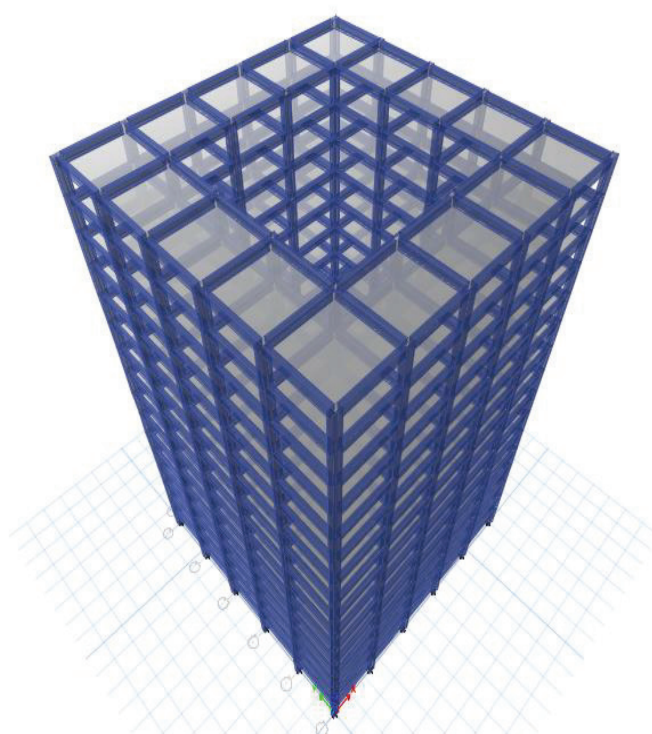


Fig. 17 Model D3 (3D)

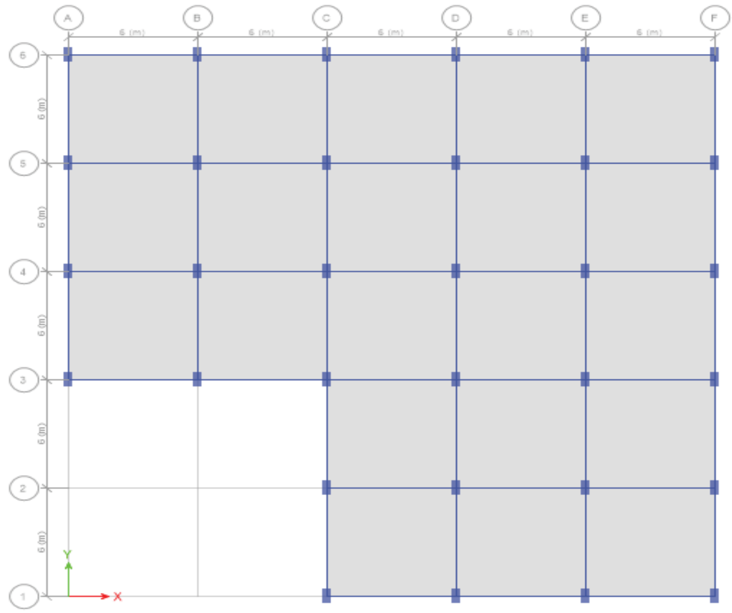


Fig. 18 Model R1

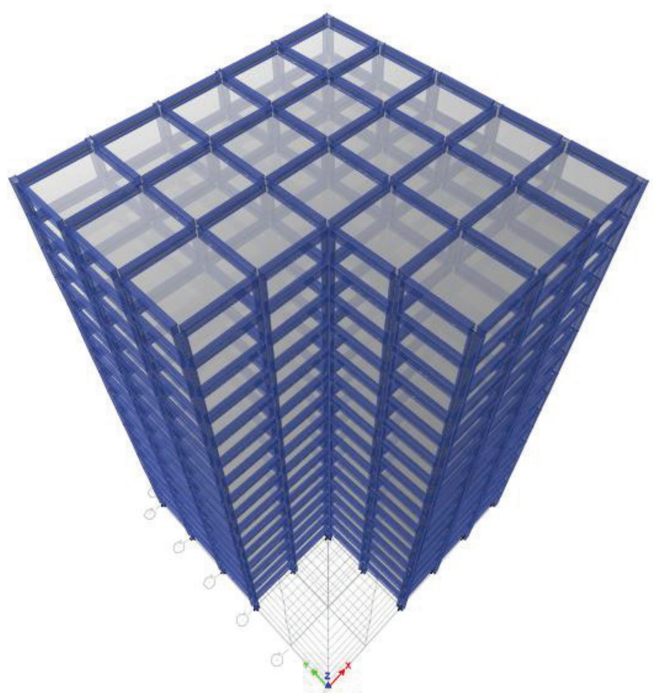


Fig. 19 Model R1 (3D)

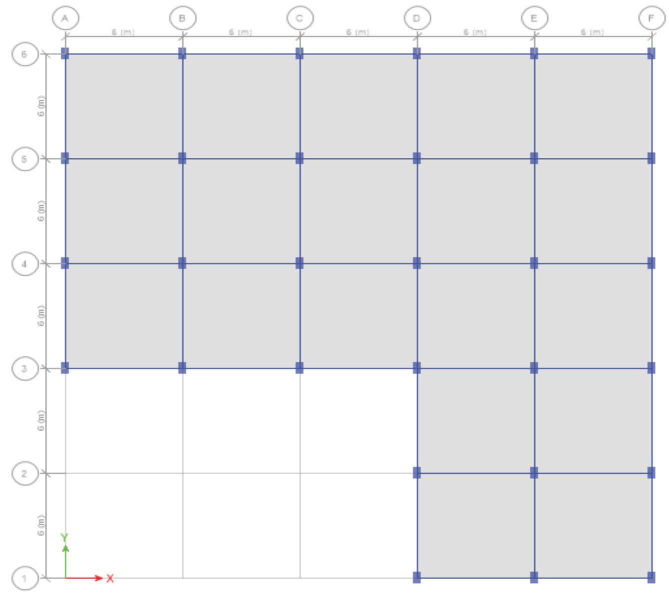


Fig. 20 Model R2

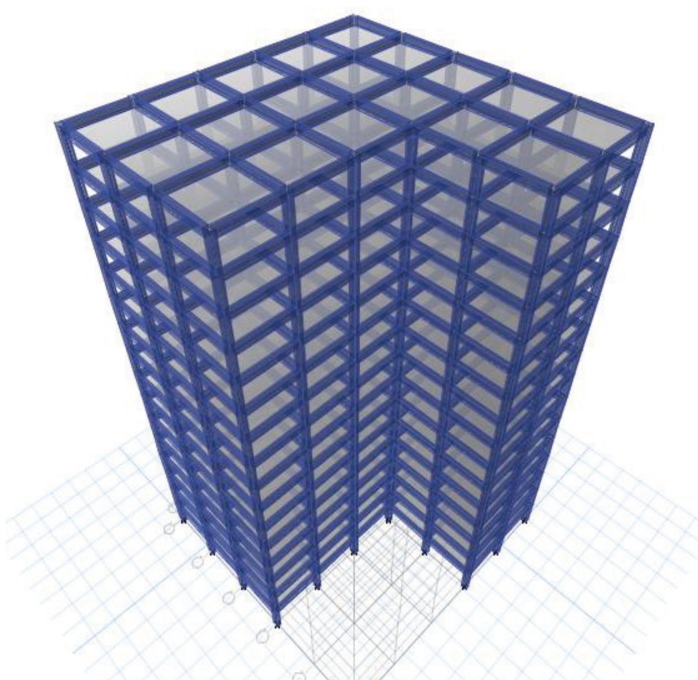


Fig. 21 Model R2 (3D)

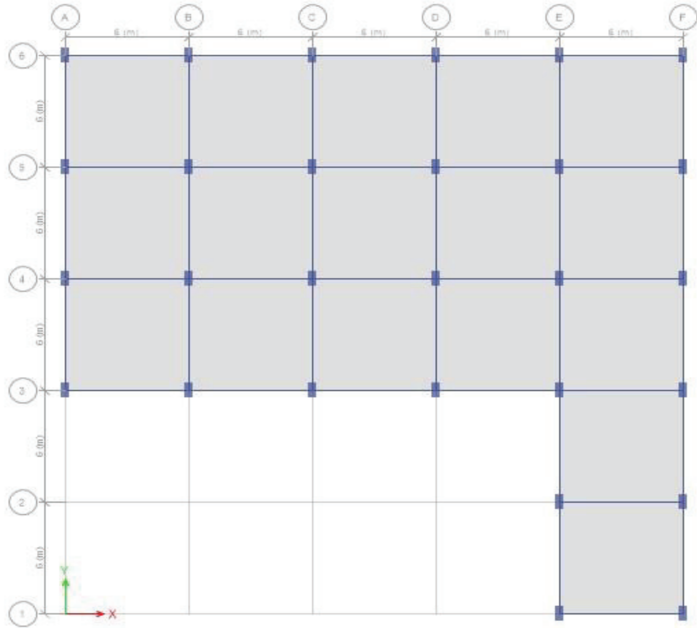


Fig. 22 Model R3

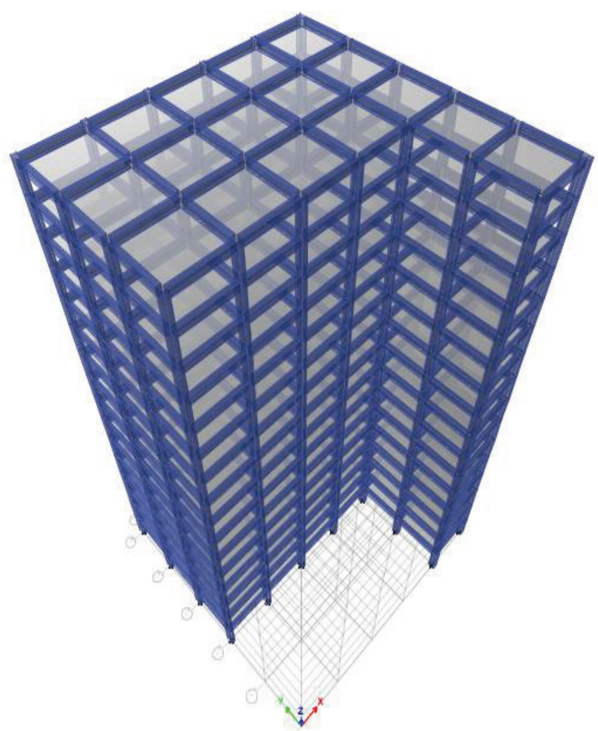


Fig. 23 Model R3 (3D)

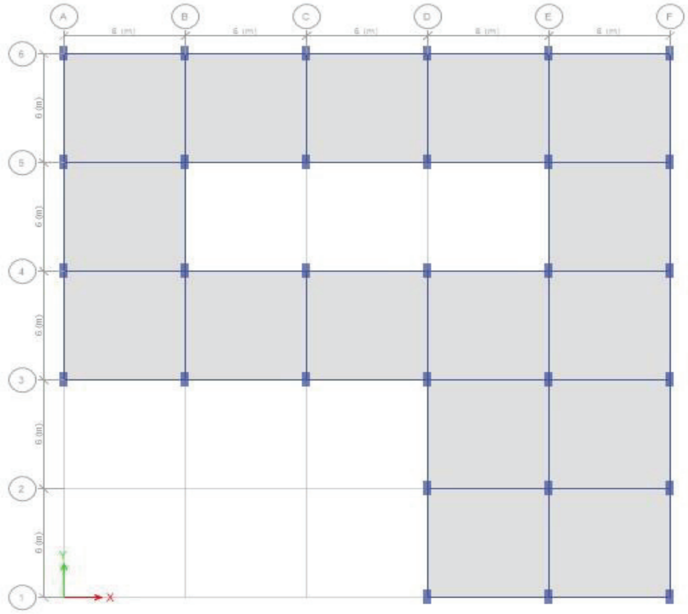


Fig. 24 Model DR1

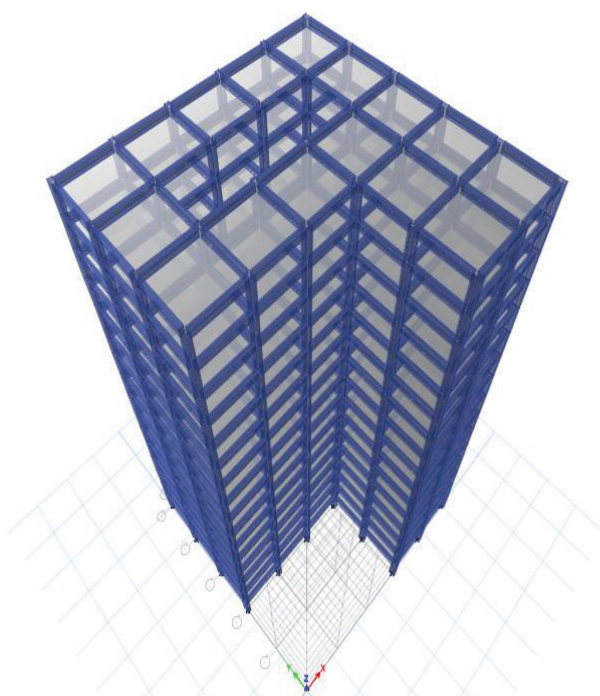


Fig. 25 Model DR1 (3D)

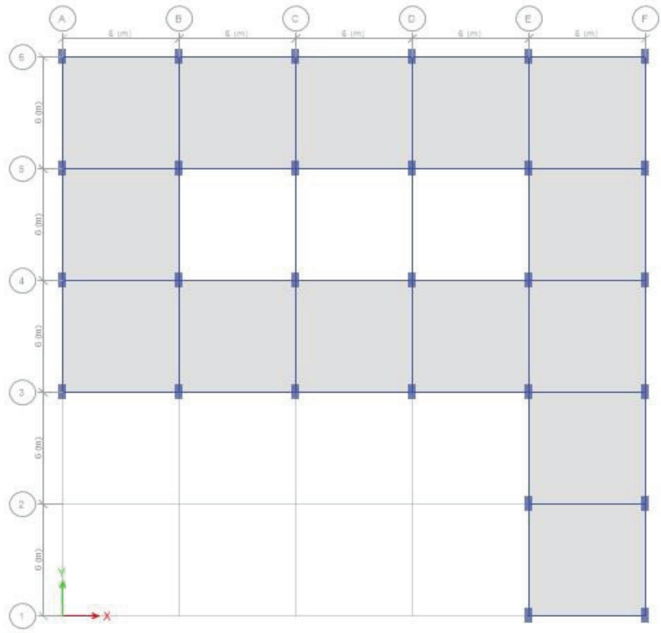


Fig. 26 Model DR2

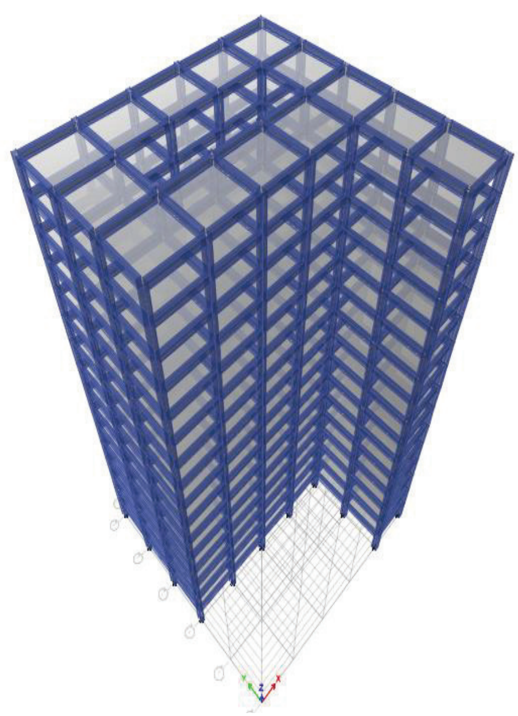


Fig. 27 Model DR2 (3D)

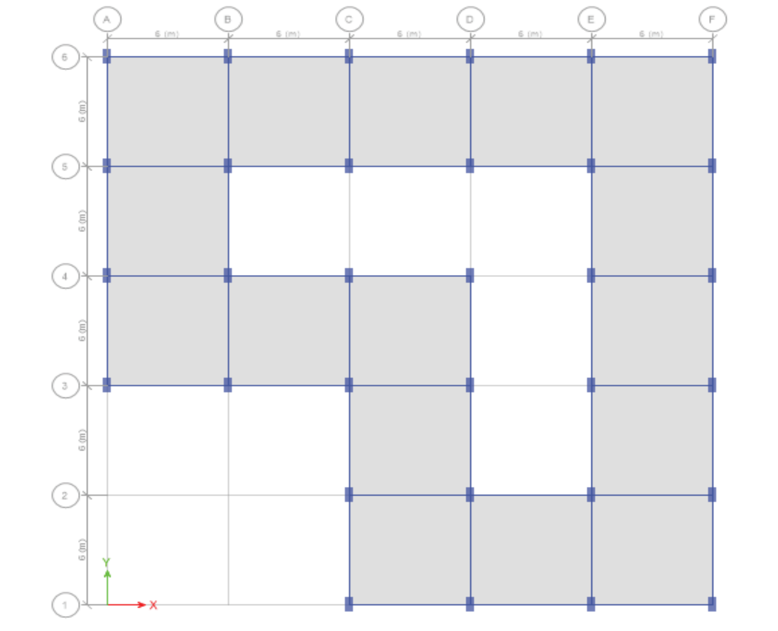


Fig. 27 Model DR3

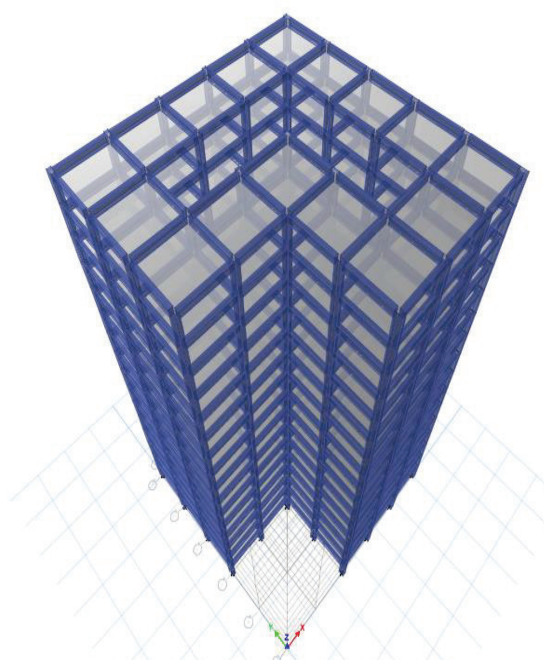


Fig. 28 Model DR3 (3D)

4.3.2 Define Material Property

Grade of concrete – M35

Grade of steel - Fe 500

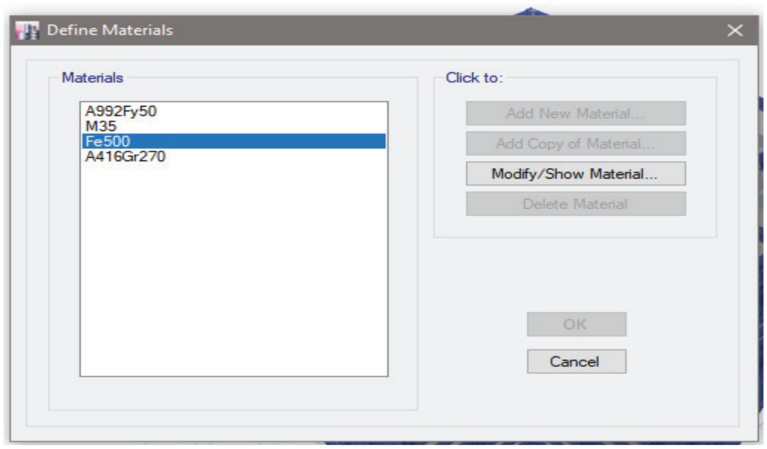


Fig. 30 Defining material properties

4.3.3 Define Section Property

Size of beams – 400 x 600m

Size of columns – 400 x 750m

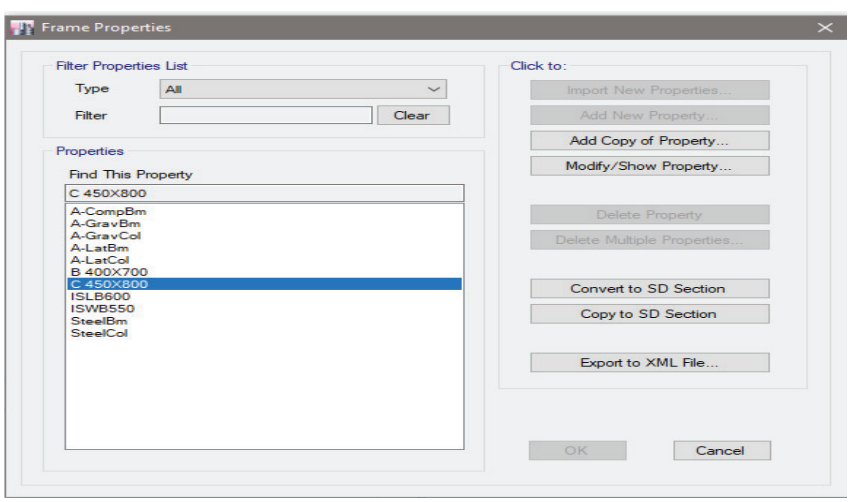


Fig. 31 Defining section properties

4.3.4 Assign loads

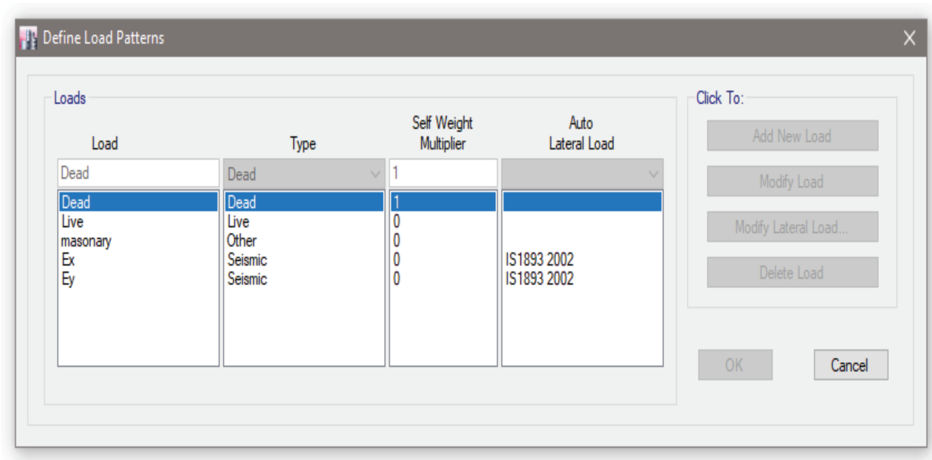


Fig. 32 assigning loads

4.3.5 Define Load Combination

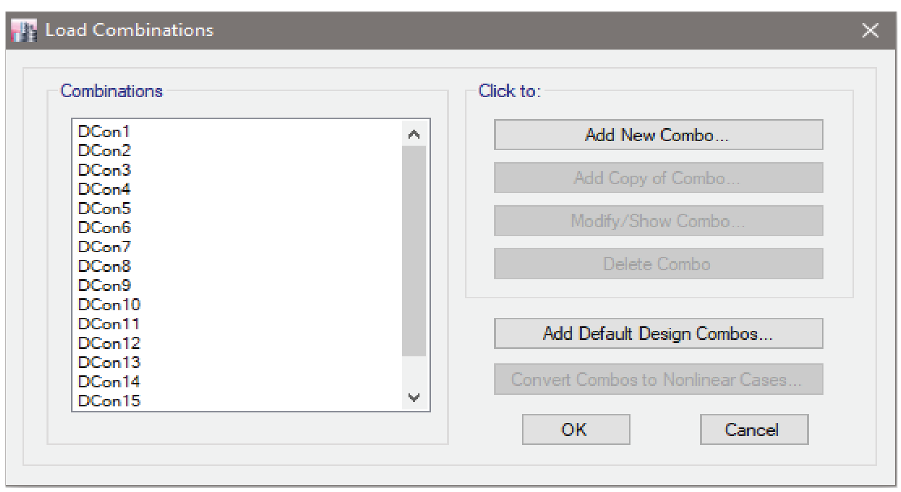


Fig. 33 Defining load combination

4.3.6 Define function (Response Spectrum)

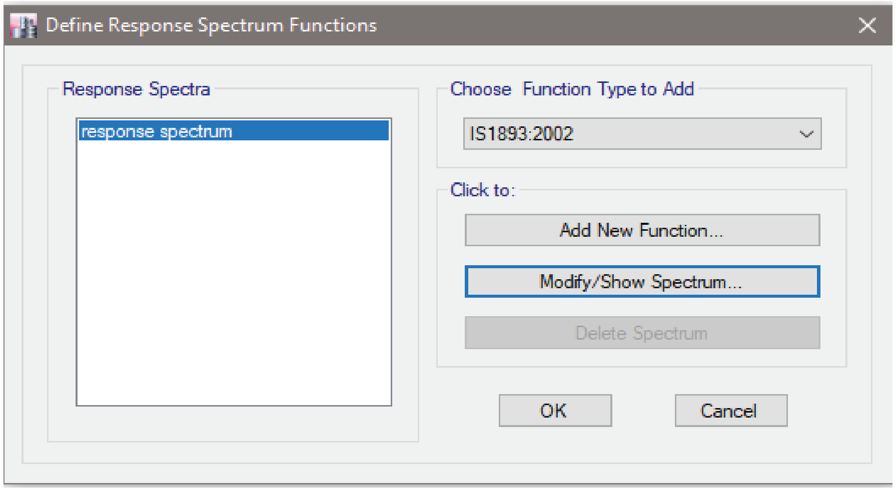


Fig. 34 Defining function

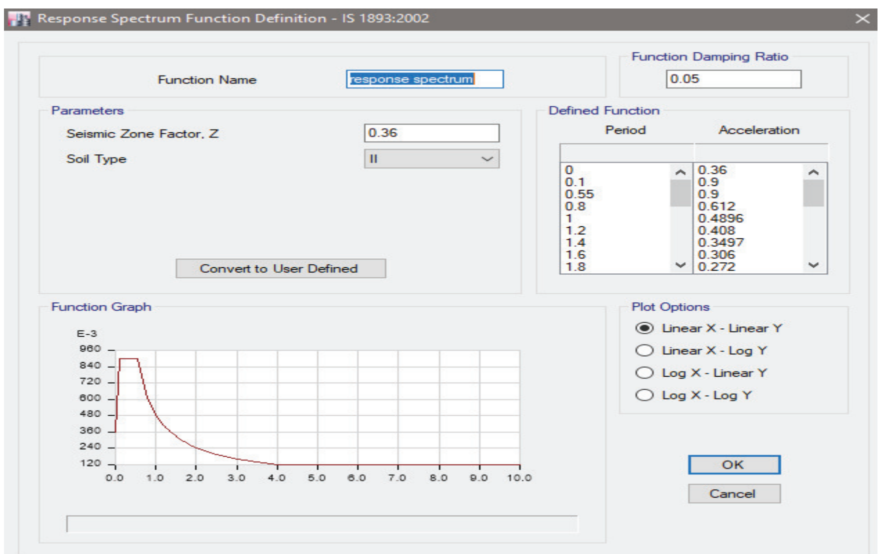


Fig. 35 Defining response spectrum

4.3.7 Define load cases

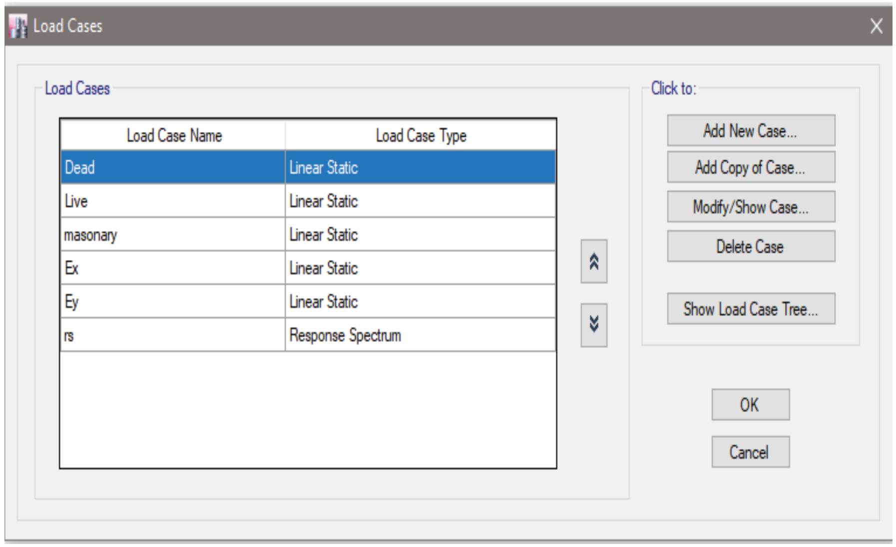


Fig. 36 Defining load cases

4.3.8 Define modal case

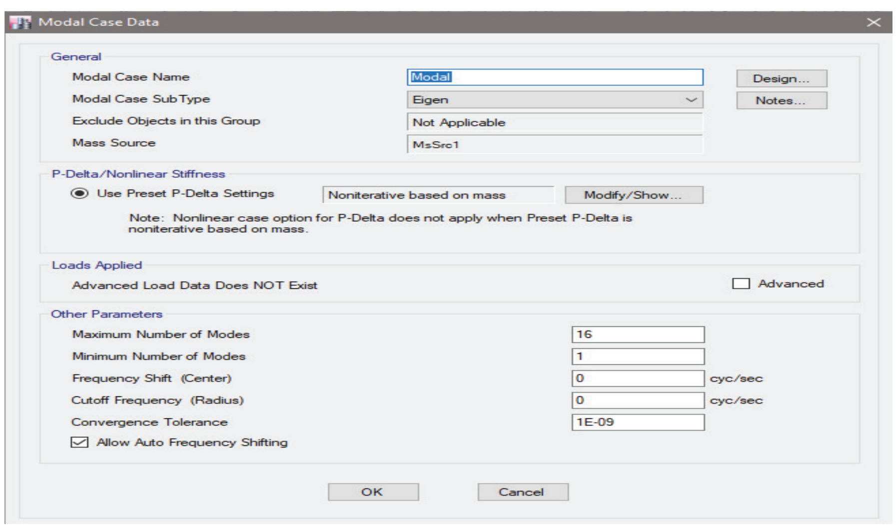


Fig. 37 Defining modal case

4.3.9 Define mass source

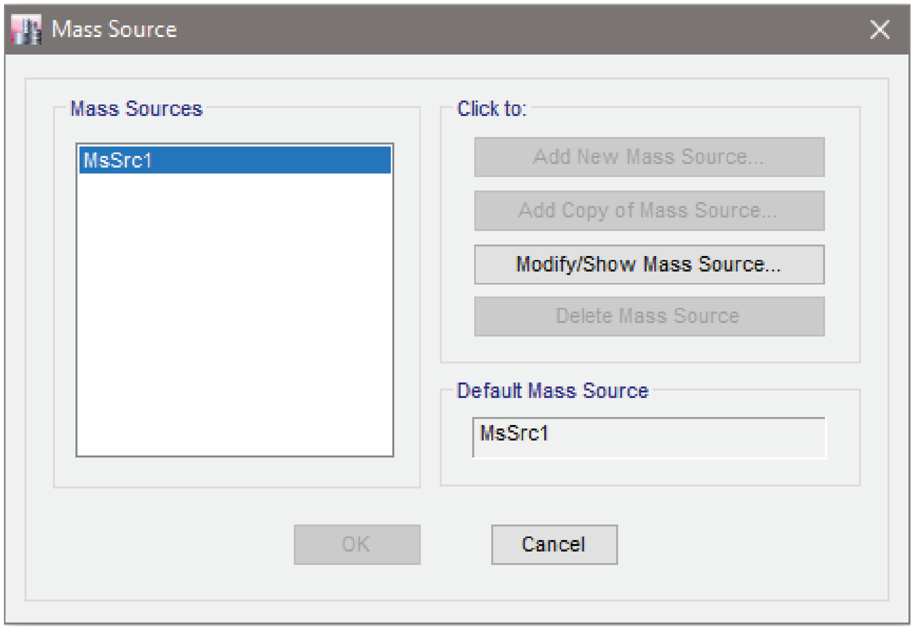


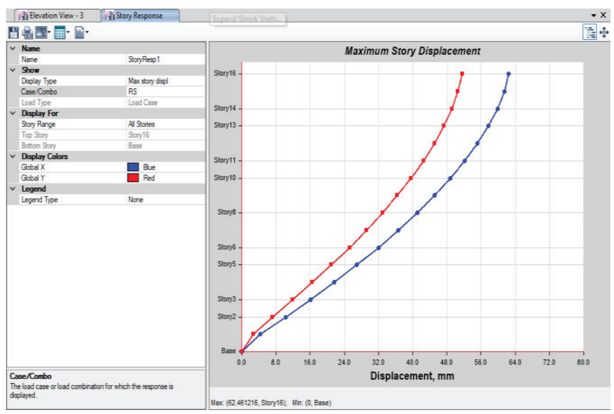
Fig. 38 Defining mass source

CHAPTER-5

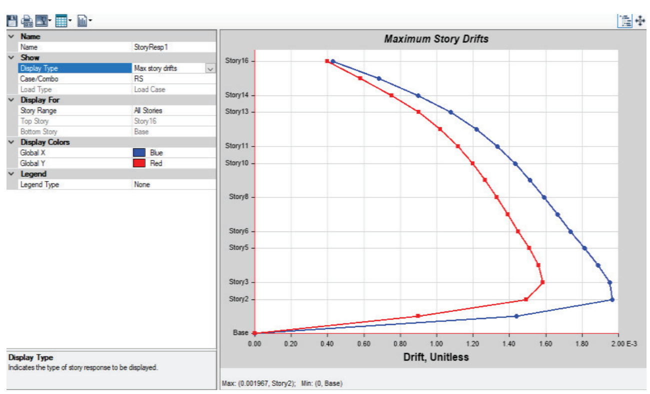
RESULTS AND DISCUSSION

5.1 ANALYSIS RESULTS IN ETABS

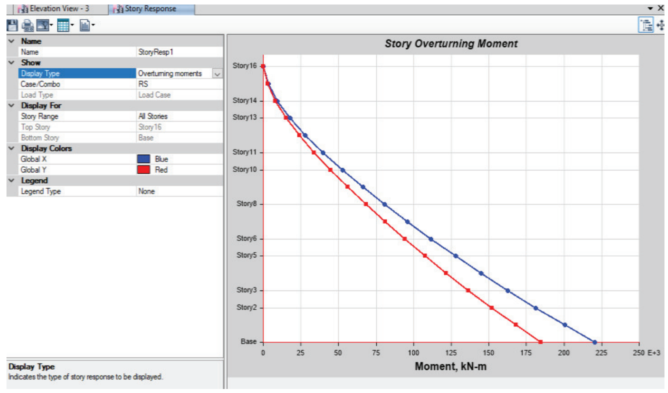
5.1.1 Model R



max. story displacement

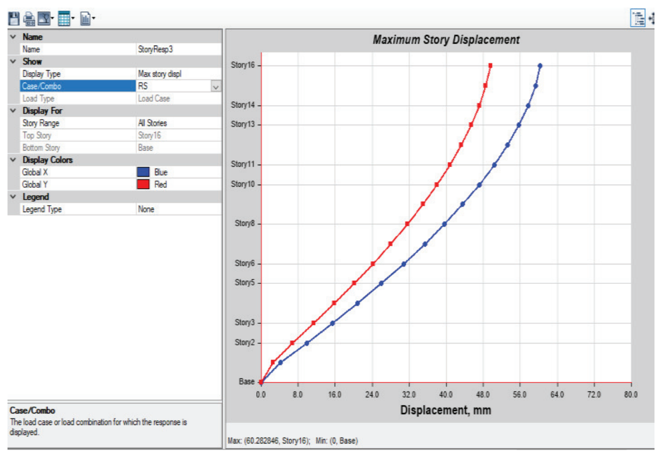


max. story drift

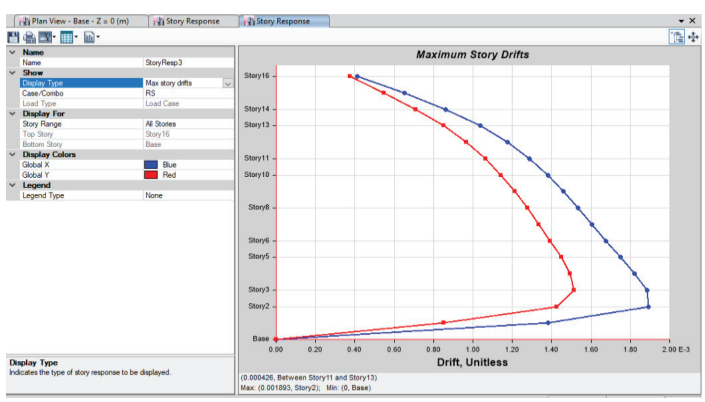


overturning moment

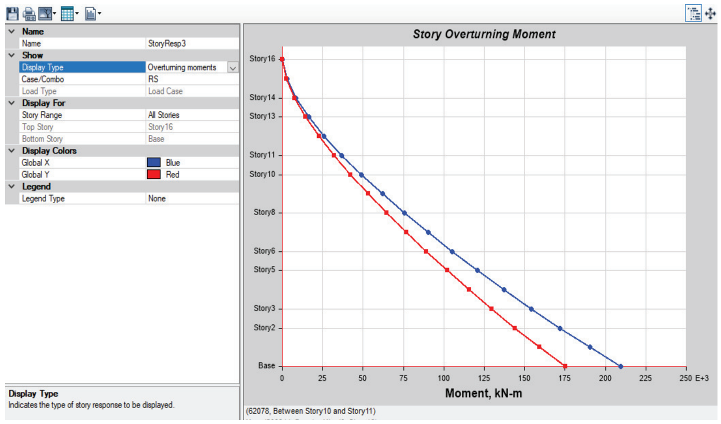
5.1.2 Model D1



max. story displacement

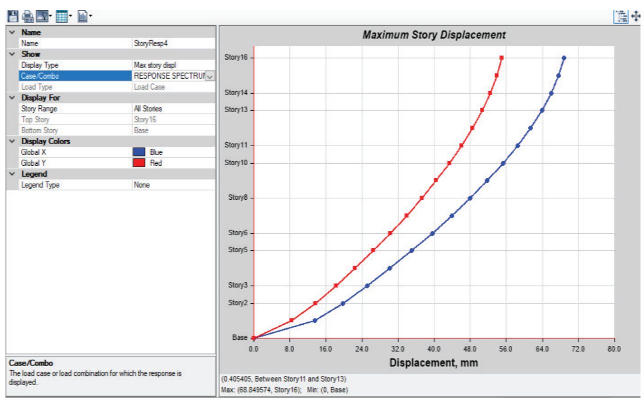


max. story drift

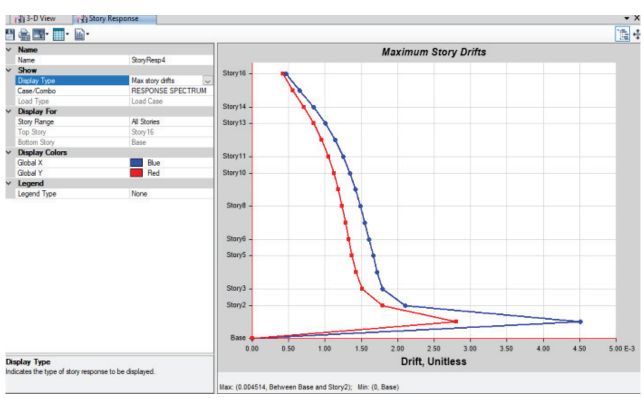


overturning moment

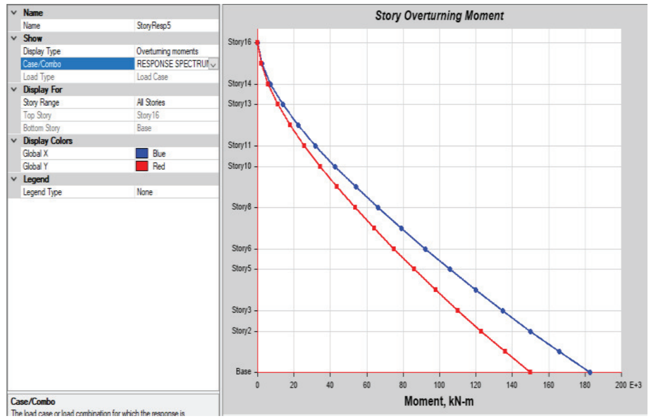
5.1.3 Model D2



max. story displacement

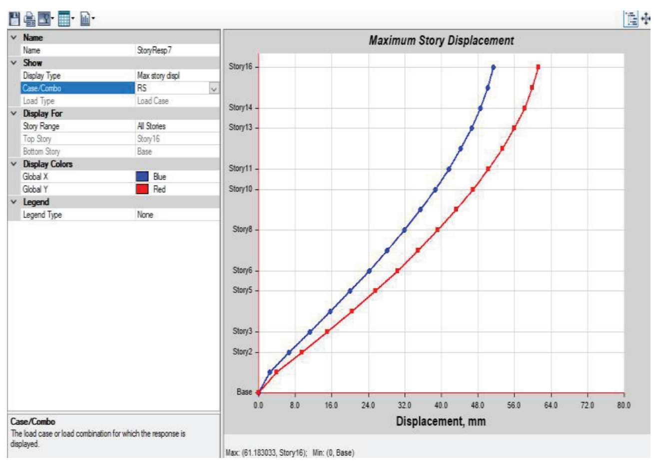


max. story drift

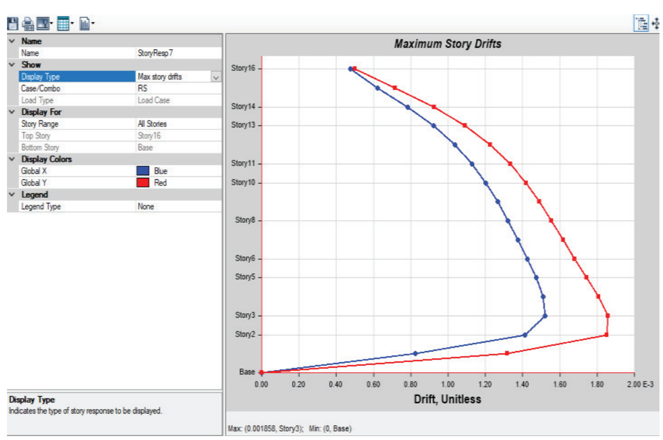


overturning moment

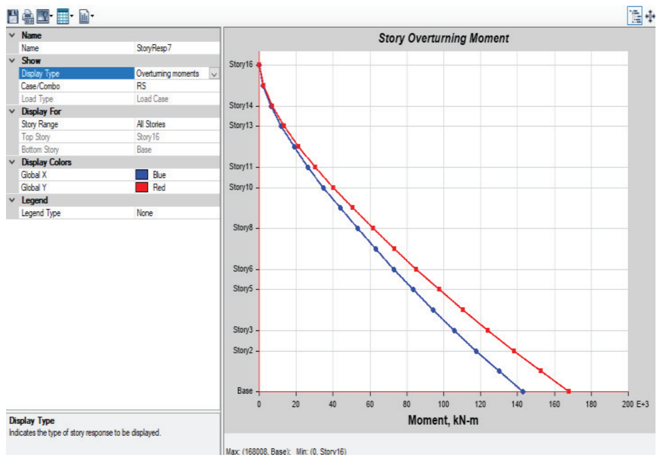
5.1.4 Model D3



max. story displacement

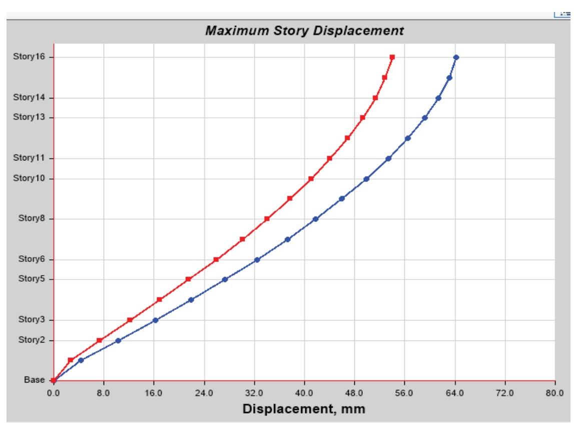


max. story drift

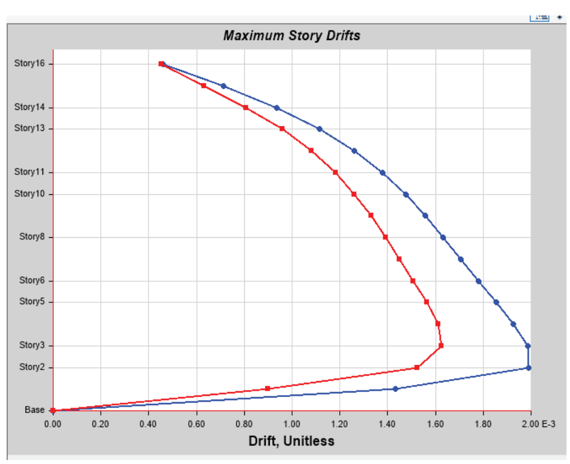


overturning moment

5.1.5 Model R1



max. story displacement



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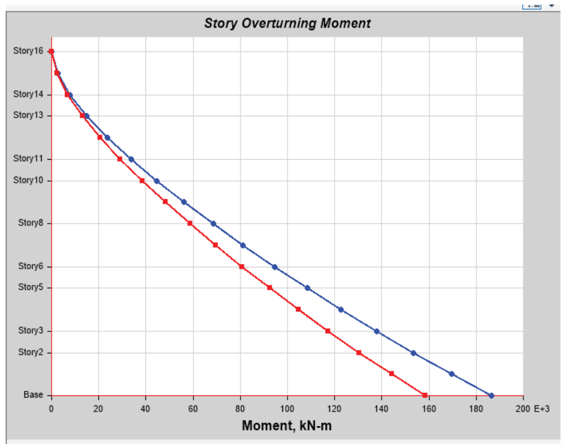
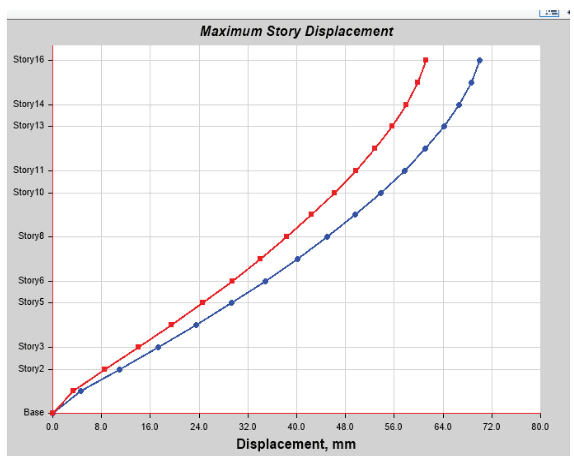
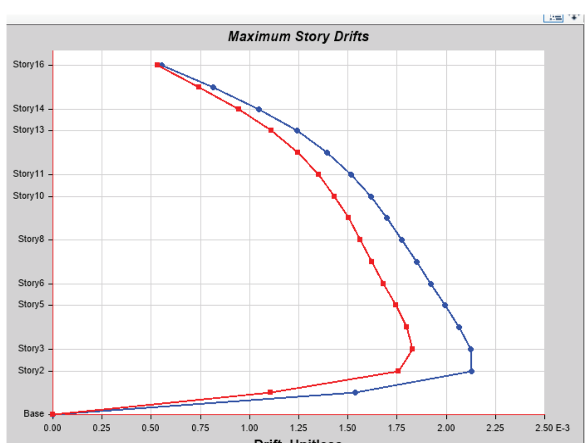


overturning moment

5.1.6 Model R2



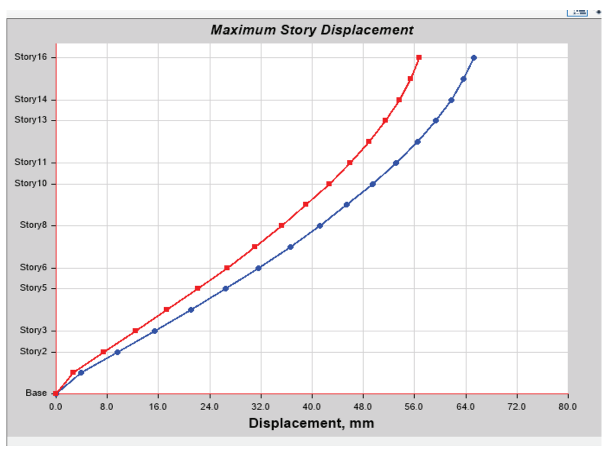
max. story displacement



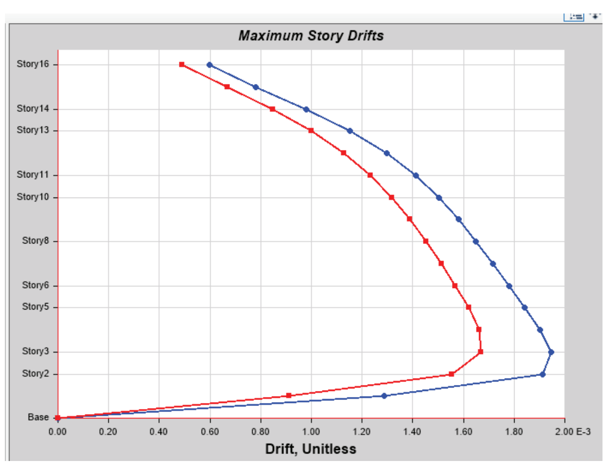
max. story drift

overturning moment

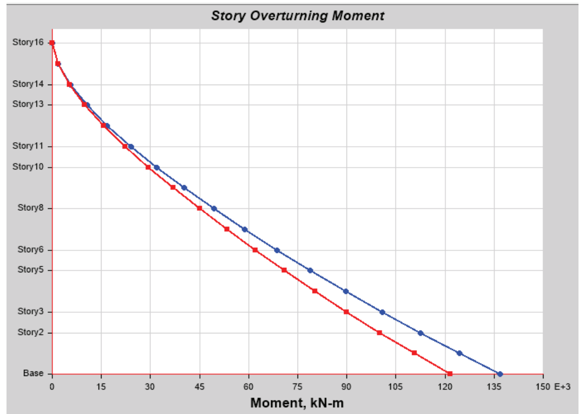
5.1.7 Model R3



max. story displacement

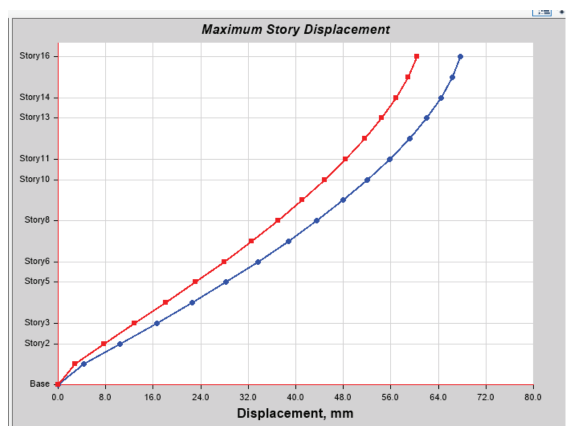


max. story drift

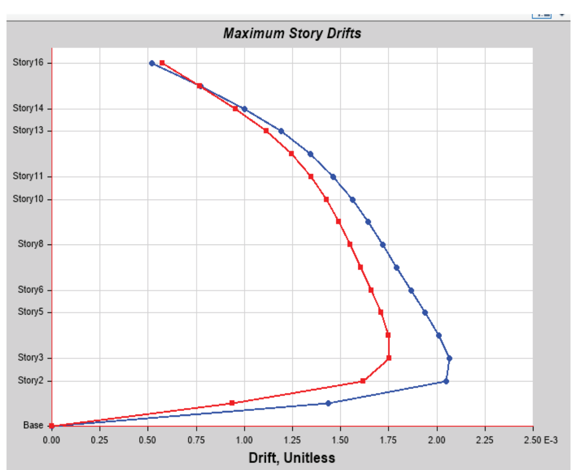


overturning moment

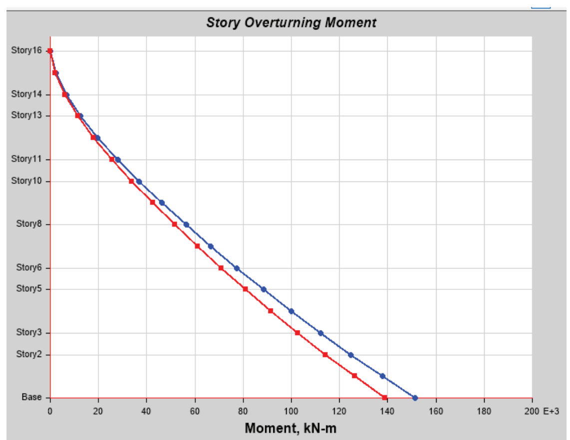
5.1.8 Model DR1



max. story displacement

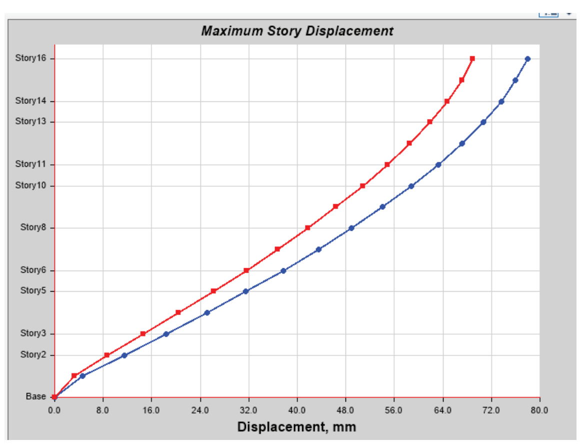


max. story drift

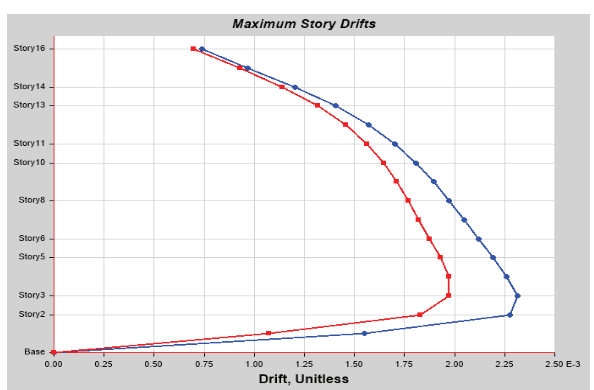


overturning moment

5.1.9 Model DR2



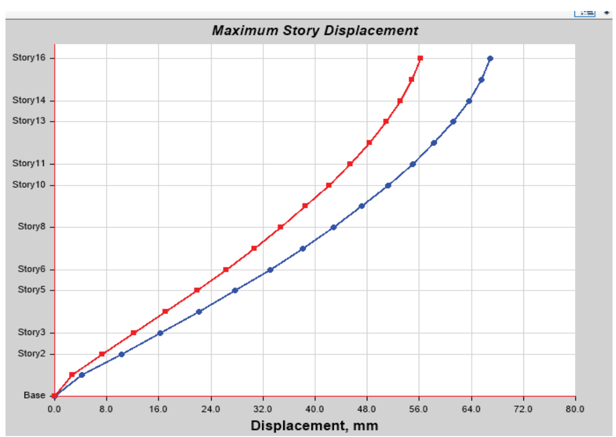
max. story displacement



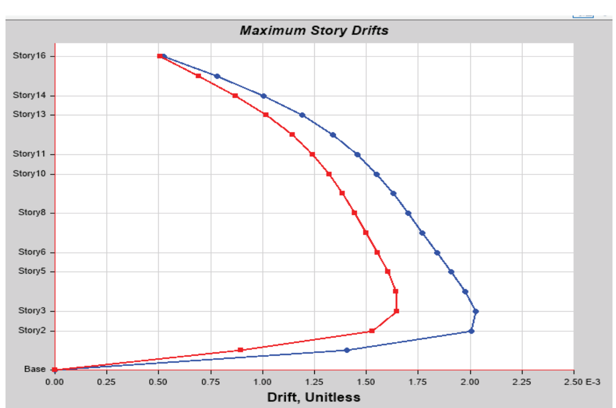
max. story drift

overturning moment

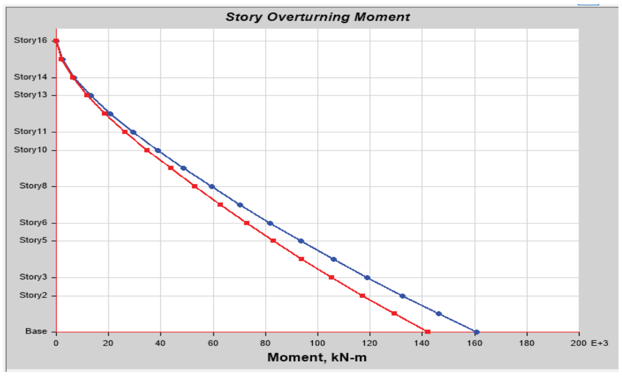
5.1.10 Model DR3



max. story displacement



max. story drift



overturning moment

5.2 RESULTS IN TABULAR FORM

ZONE IV

STOREY	R	D1	D2	D3	R1	R2	R3	DR1	DR2	DR3
1	6.80	6.53	13.17	4.45	6.84	7.31	6.39	6.95	7.65	6.81
2	10.69	10.29	16.72	7.47	10.79	11.55	10.27	11.06	12.26	10.85
3	14.42	13.89	20.09	10.47	14.60	15.63	14.04	15.04	16.73	14.76
4	17.97	17.32	23.31	13.37	18.23	19.53	17.66	18.84	21.02	18.50
5	21.31	20.54	26.37	16.14	21.65	23.23	21.10	22.44	25.11	22.05
6	24.44	23.57	29.26	18.77	24.87	26.71	24.37	25.83	28.98	25.39
7	27.36	26.39	31.99	21.25	27.88	29.98	27.44	29.01	32.63	28.53
8	30.06	29.01	34.53	23.57	30.67	33.04	30.31	31.97	36.05	31.46
9	32.54	31.40	36.88	25.72	33.23	35.86	32.97	34.71	39.22	34.17
10	34.79	33.98	39.02	27.70	35.57	38.43	35.41	37.20	42.14	36.64
11	36.78	35.50	40.94	29.48	37.64	40.75	37.61	39.43	44.77	38.86
12	38.50	37.16	42.61	31.03	39.43	42.76	39.53	41.37	47.09	40.80
13	39.90	38.51	43.99	32.34	40.91	44.45	41.15	42.98	49.06	42.42
14	40.95	39.52	45.08	33.39	42.03	45.76	42.46	44.23	50.66	43.67

Table No. 1: Max. Story displacement (mm)

Sty.	R	D1	D2	D3	R1	R2	R3	DR1	DR2	DR3
1	0.00131	0.00126	0.00140	0.00090	0.00132	0.00141	0.00127	0.00136	0.00151	0.00133
2	0.00130	0.00125	0.00119	0.00101	0.00132	0.00141	0.00129	0.00137	0.00154	0.00135
3	0.00125	0.00121	0.00114	0.00100	0.00128	0.00137	0.00126	0.00134	0.00150	0.00131
4	0.00120	0.00116	0.00110	0.00098	0.00123	0.00132	0.00122	0.00129	0.00146	0.00127
5	0.00115	0.00111	0.00107	0.00095	0.00118	0.00128	0.00118	0.00124	0.00141	0.00122
6	0.00110	0.00107	0.00103	0.00091	0.00113	0.00123	0.00114	0.00119	0.00136	0.00118
7	0.00106	0.00102	0.00099	0.00088	0.00108	0.00118	0.00110	0.00114	0.00131	0.00113
8	0.00101	0.00097	0.00094	0.00084	0.00103	0.00113	0.00105	0.00109	0.00126	0.00108
9	0.00095	0.00092	0.00089	0.00080	0.00098	0.00107	0.00100	0.00104	0.00120	0.00103
10	0.00089	0.00085	0.00083	0.00075	0.00091	0.00101	0.00094	0.00097	0.00113	0.00097
11	0.00081	0.00078	0.00075	0.00069	0.00084	0.00092	0.00086	0.00089	0.00104	0.00089
12	0.00071	0.00069	0.00067	0.00061	0.00074	0.00082	0.00076	0.00079	0.00093	0.00079
13	0.00060	0.00057	0.00056	0.00052	0.00062	0.00070	0.00065	0.00066	0.00080	0.00067
14	0.00045	0.00043	0.00043	0.00041	0.00047	0.00054	0.00051	0.00051	0.00064	0.00052

Table No. 2: Max. Story drift

Sty.	R	D1	D2	D3	R1	R2	R3	DR1	DR2	DR3
0	120840	114672	100007	78406	102224	88303	74918	83088	84111	88269
1	108500	102848	89784	70504	91783	79400	67169	74669	75723	79276
2	96672	91493	79966	62948	81776	70887	59724	66617	67731	70640
3	85336	80604	70519	55710	72187	62734	52585	58909	60094	62416
4	74454	70159	61407	48749	62982	54897	45739	51511	52757	54500
5	63983	60132	52611	42032	54127	47333	39174	44383	45662	46884
6	53909	50520	44139	35543	45608	40020	32887	37505	38777	39550
7	44253	41347	36030	29289	37442	32970	26896	30885	32099	32510
8	35076	32674	28358	23309	29682	26226	21238	24563	25667	25807
9	26492	24604	21233	17680	22422	19876	15981	18616	19561	19523
10	18670	17288	14806	12510	15805	14053	11220	13165	13912	13781
11	11820	10912	9252	7950	10007	8922	7075	8364	8890	8739
12	6196	5702	4778	4183	5246	4688	3692	4399	4705	4588
13	2130	1953	1617	1440	1803	1614	1261	1515	1633	1577
14	0	0	0	0	0	0	0	0	0	0

Table No. 3 Overturning Moment

ZONE V

STOREY	R	D1	D2	D3	R1	R2	R3	DR1	DR2	DR3
1	10.20	9.805	19.75	6.67	10.24	10.97	9.59	10.43	11.48	10.22
2	16.04	15.42	25.08	11.20	16.19	17.33	15.41	16.60	18.39	16.28
3	21.64	20.84	30.13	15.70	21.90	23.45	21.07	22.57	25.10	22.15
4	26.95	25.98	34.96	20.05	27.34	29.30	26.49	28.27	31.54	27.76
5	31.96	30.82	39.55	24.21	32.48	34.84	31.66	33.67	37.67	33.08
6	36.66	35.36	43.90	28.16	37.31	40.07	36.55	38.75	43.47	38.09

7	41.04	39.59	47.98	31.88	41.82	44.98	41.16	43.52	48.95	42.80
8	45.10	43.51	51.80	35.36	46.00	49.56	45.46	47.96	54.07	47.19
9	48.82	47.11	55.32	38.59	49.85	53.79	49.46	52.06	58.84	51.25
10	52.19	50.36	58.54	41.55	53.35	57.65	53.12	55.80	63.21	54.96
11	55.18	53.25	61.41	44.22	56.46	61.12	56.42	59.15	67.16	58.29
12	57.75	55.73	63.91	46.55	19.15	64.15	59.30	62.06	70.64	61.20
13	59.85	57.76	65.99	48.52	61.37	66.67	61.73	64.48	73.59	63.63
14	61.42	59.28	67.62	50.08	63.05	68.64	63.70	66.35	75.99	65.51

Table No. 4: Max. Story displacement (mm)

Sty.	**R**	**D1**	**D2**	**D3**	**R1**	**R2**	**R3**	**DR1**	**DR2**	**DR3**
1	.00196	.00189	.00210	.00141	.00199	.00212	.00191	.00204	.00227	.00200
2	.00195	.00188	.00179	.00152	.00198	.00212	.00194	.00206	.00231	.00202
3	.00188	.00182	.00171	.00151	.00192	.00206	.00190	.00200	.00226	.00197
4	.00181	.00175	.00166	.00147	.00185	.00199	.00184	.00193	.00219	.00191
5	.00173	.00167	.00160	.00142	.00177	.00192	.00177	.00186	.00211	.00184
6	.00166	.00160	.00155	.00137	.00170	.00184	.00171	.00179	.00204	.00177
7	.00159	.00153	.00148	.00132	.00163	.00177	.00165	.00172	.00197	.00170
8	.00151	.00146	.00142	.00126	.00155	.00170	.00152	.00164	.00189	.00163
9	.00143	.00138	.00134	.00120	.00147	.00161	.00150	.00156	.00180	.00155
10	.00133	.00128	.00125	.00128	.00137	.00151	.00141	.00146	.0017	.0014
11	.00122	.00117	.00113	.00103	.00126	.00139	.00129	.00134	.00156	.00133
12	.00107	.00103	.00100	.00092	00111	.00124	.00115	.00119	.00140	.00119
13	.00090	.00086	.00084	.00078	.00093	.00104	.00097	.00100	.00120	.00100
1	.0006	.0006	.0006	.0006	.0007	.0008	.0007	.0007	.0009	.0007

4	8	5	5	2	1	1	9	7	6	

Table No. 5: Max. Story drift

STOREY	R	D1	D2	D3	R1	R2	R3	DR1	DR2	DR3
0	181261	172009	150011	117609	153336	132455	112377	124633	126167	132404
1	162751	154272	134676	105756	137675	119101	100753	112004	113585	118915
2	145009	137240	119949	94423	122665	106331	89587	99925	101596	105996
3	128005	120906	105778	83565	108280	94101	78878	88364	90141	93624
4	111681	105238	92110	73124	94473	82346	68609	77267	79135	81750
5	95975	90199	78917	63049	81190	71000	58761	66575	68494	70326
6	80864	75780	66209	53315	68412	60031	49331	56258	58166	59325
7	66379	62021	54046	43933	56163	49455	40344	46328	48149	48765
8	52614	49012	42537	34964	44523	39339	31857	36844	38500	38710
9	39738	36907	31850	26520	33633	29815	23971	27924	29341	29284
10	28006	25932	22209	18765	23707	21080	16830	19748	20869	20672
11	17730	16368	13878	11925	15011	13383	10612	12546	13336	13109
12	9294	8553	7168	6275	7870	7032	5538	6598	7057	6882
13	3195	2929	2426	2160	2704	2421	1892	2273	2449	2366
14	0	0	0	0	0	0	0	0	0	0

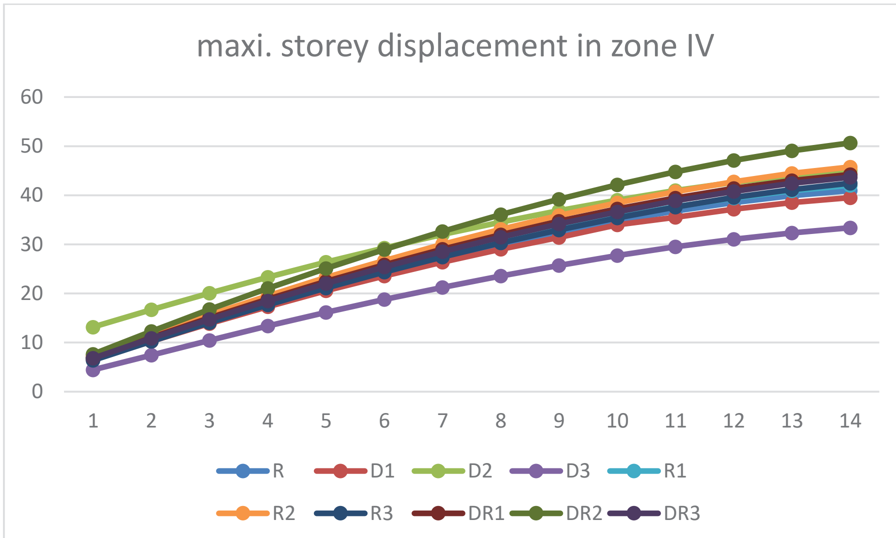
Table No. 6 Overturning Moment

S.No.	MODELS	BASE SHEAR (ZONE IV)	BASE SHEAR (ZONE V)
1	R	4076.3465	6114.519
2	D1	3872.2100	5808.310
3	D2	3312.7800	4969.170
4	D3	3690.9300	5536.400
5	R1	3506.9188	5260.370
6	R2	3122.2062	4683.300
7	R3	2696.8046	4045.200
8	DR1	3074.9743	4612.46
9	DR2	3165.2912	4747.937
10	DR3	3160.2926	4740.438

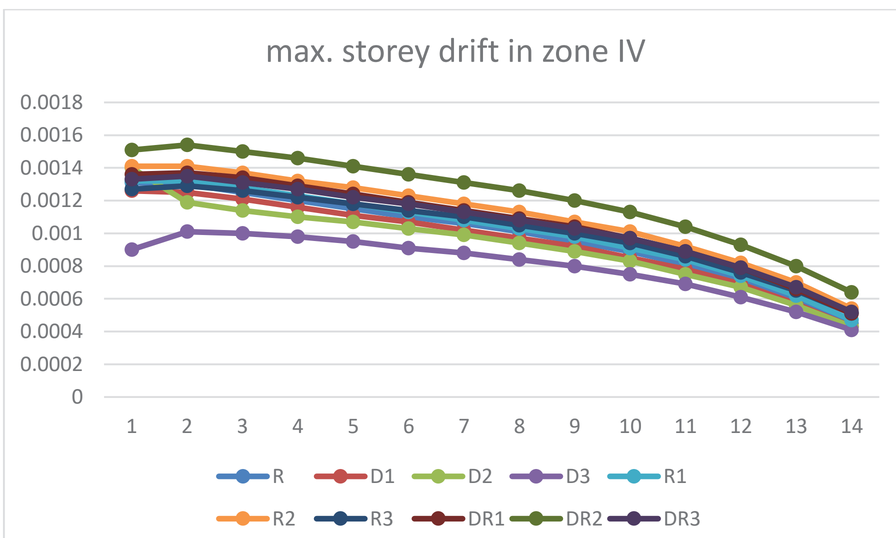
Table No. 7 Base Shear

5.3 RESULTS IN GRAPHS

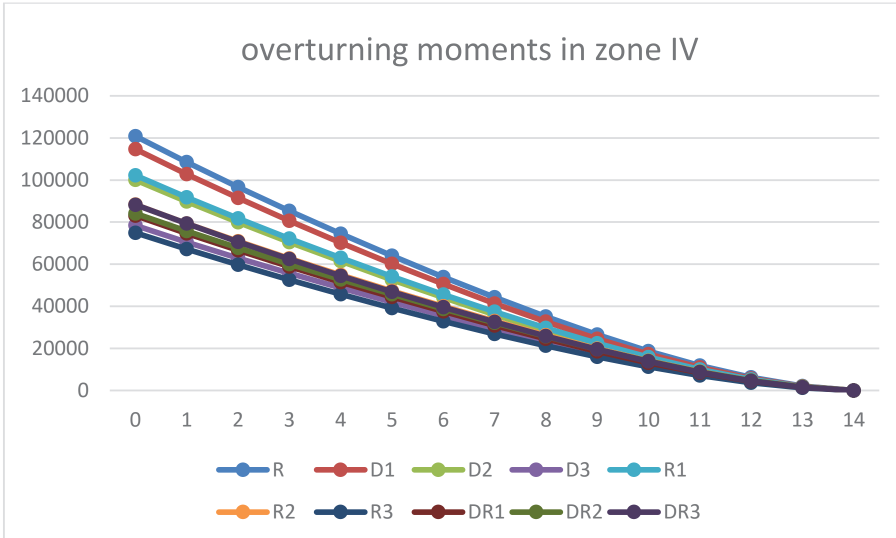
5.3.1 Graphs showing values of all Storey for all structures.



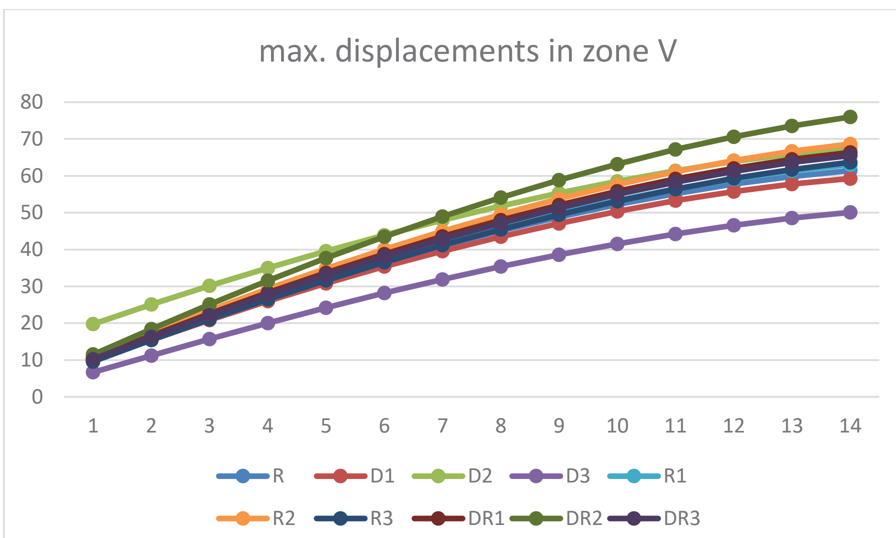
Graph no. 1



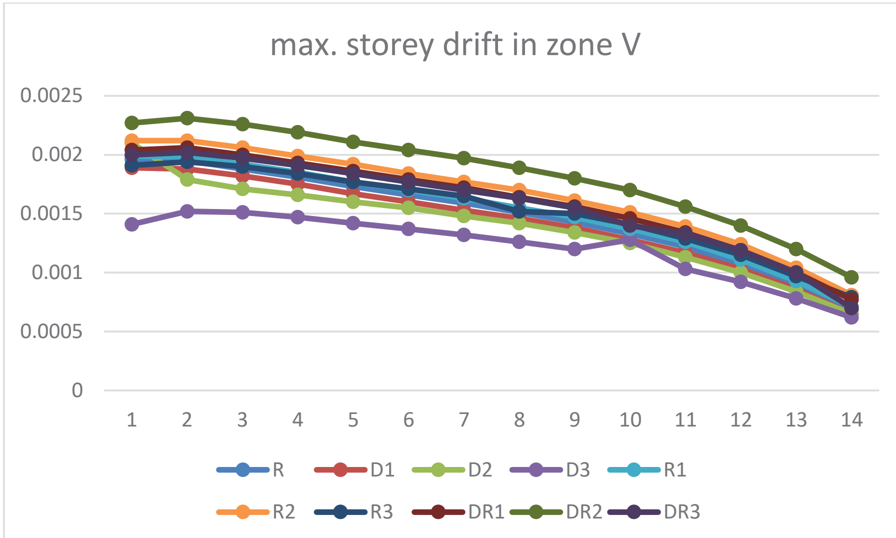
Graph no. 2



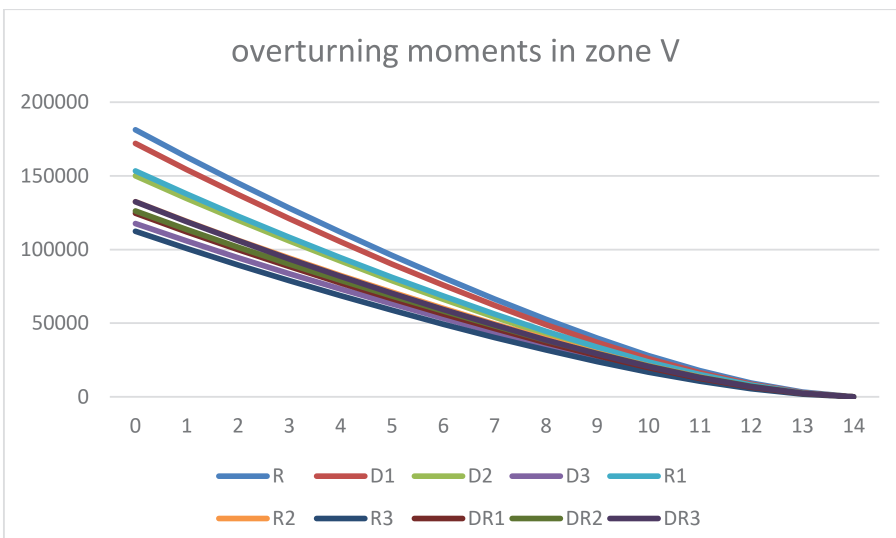
Graph no. 3



Graph no. 4

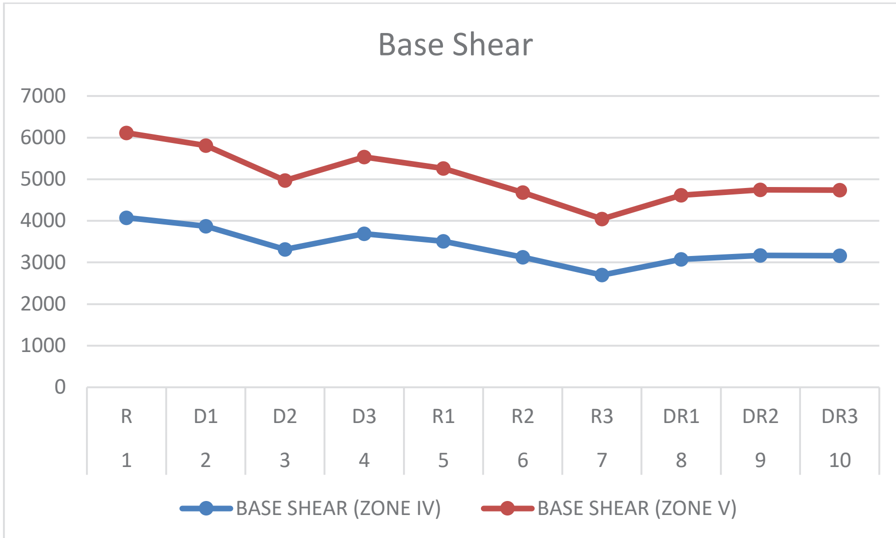


Graph no. 5



Graph no. 6

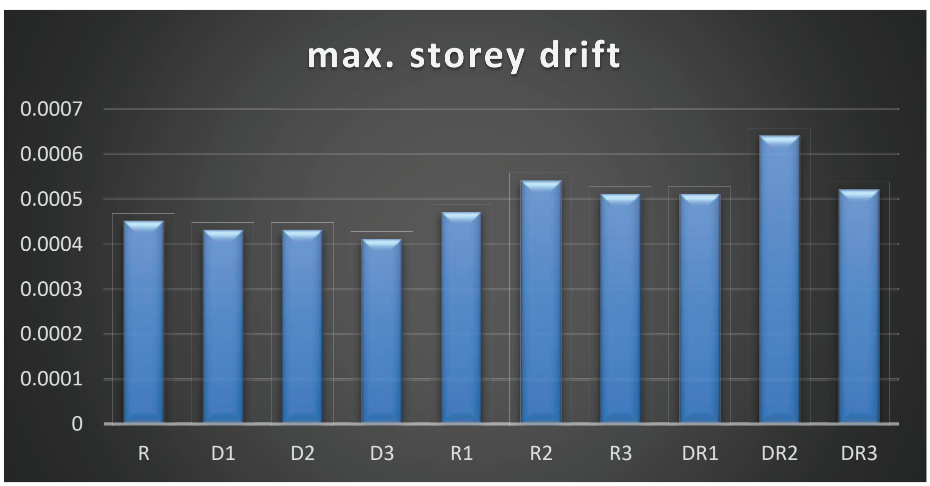
5.3.2 Line graph representing base shear values for all structures.



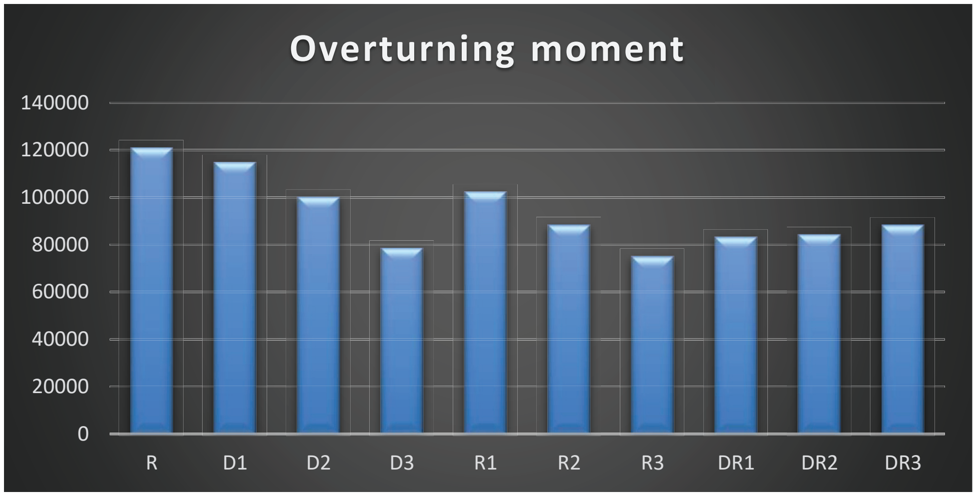
Graph no. 7

5.3.3 Bar graphs representing the maxi. Values of outcomes for different RC buildings in zone IV

Graph No. 8 Max. story displacement



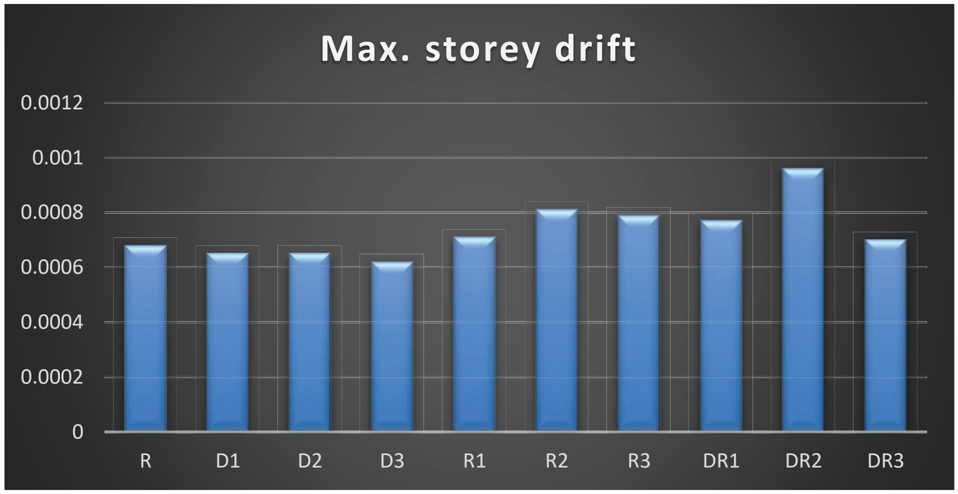
Graph No. 9 Max Story Drift



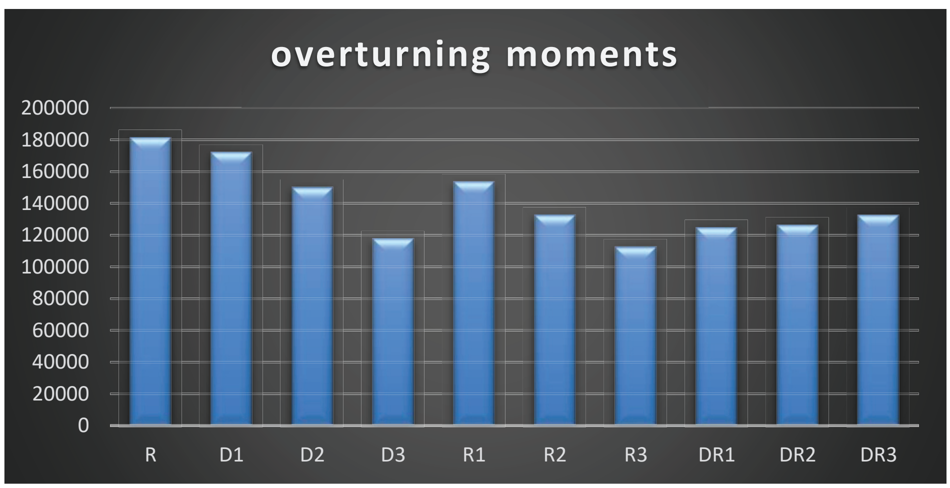
Graph No. 10 Overturning Moment

5.3.4 Bar graphs representation of max. Values for different RC buildings in zone V

Graph No. 11 Max. story displacement

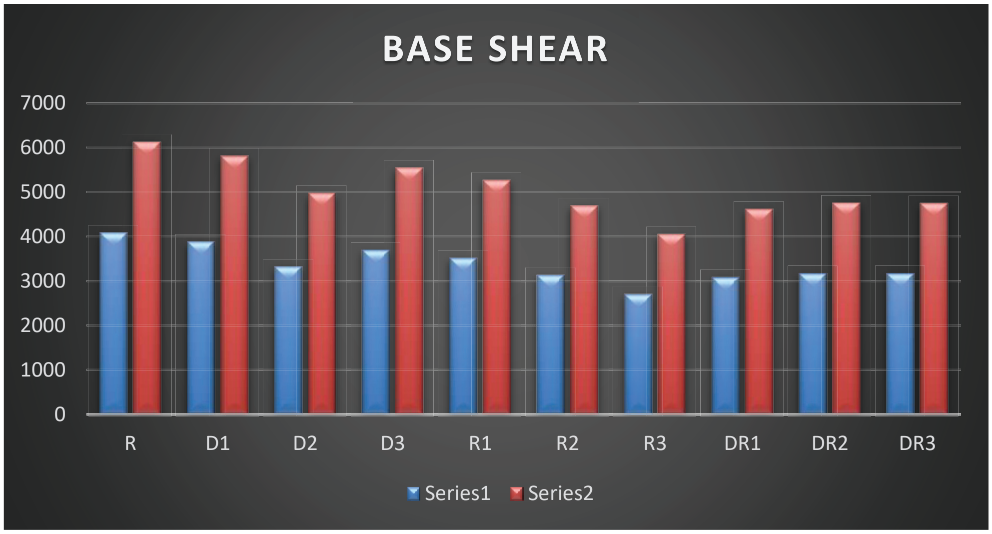


Graph No. 12 Max. Story Drift



Graph No. 13 Overturning Moments

5.3.5 Line graph representing base shear values for all structures.



Graph No. 14 Base Shear. (Series1 – Zone IV, Series 2 – Zone V)

CHAPTER 6

6.1 CONCLUSION

Seismic response of plan irregular building in two different zones IV and V are studied. After study of results obtained from the analysis of structure, following conclusion can be made-

1) For base shear (refer graph no.14), regular building shows max. lateral force at the base. Irregular plan building shows decrease in the value of base shear when percentage of irregularity increases. Among irregular structure model D1 shows more base shear, then R1 and very less variation among buildings having combination of irregulaties. By this we can conclude that more weight of building – high base shear.
2) For max. displacement (graph no. 8 and 11), model DR2 shows maximum for both zones.and model D3 show least displacement. By this we can say that diaphragm opening not much effect the displacement but re-entrants do. And combination of both makes structure more unstable.
3) When it comes to story drift (refer graph no. 9 and 12) from results, we can see that more percentage of opening less drift value and more varying percentage re-entrant more drift. Therefore, when it comes to the combination of two models DR2 shows max. drift for both zones.
4) Models R shows max. overturning moment (graph no. 10 and 13) and as opening in slabs increases it reduces. Similarly, it is for re-entrant corner models. But for the combination of two irregularity there is an increase in overturning moment as varying percentage increases. Hence, we can say that large slab opening results in less overturning moment.

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2. Indian Standard code for Earthquake resistant design structures 1893 Part I: 2016
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PUBLICATIONS

Seismic Impact of Re-entrant Corner with Opening in Diaphragm on RC Building

Md Faisal Zia, Rajiv Banerjee

Abstract*: *The most important cause of damage of RC buildings during earthquake is the irregular building configuration. An RC building which are unsymmetrical and has lack of continuity in geometry, mass or load resisting elements is called as irregular buildings. This obstructs the flow of inertia forces and cause lots of damage to buildings. There are many studies carried out irregular buildings in seismic zones, but still more research is needed in this field. Therefore, this study is about the seismic response of reinforced concrete structures having combination of two plan irregularities, re-entrant corner and diaphragm discontinuity buildings. Study is performed combining this two plan irregularity criteria and analyzing the results in seismic zone 4 and 5. For this 1 is regular building, 3 re-entrant corner buildings with three variations in A/L ratio, three buildings with opening in diaphragm with three varying percentage of opening. 9 structures are made combining these buildings with the combination of two irregularities. Structures are analyzed in etas software. Parameters such as story displacement, story drift, base shear, overturning moments are determined and compared with regular buildings.

Keywords: Re-entrant corner, diaphragm discontinuity response spectrum, displacement, drift, base shear, overturning moment.

I. INTRODUCTION

When horizontal forces act at the base of the structure an inertia force are generated. These inertia forces are directly proportional to mass of the building. These inertia forces develop at the floor level as most of the building mass is present at the floor level. These inertia forces are transferred to the walls or the columns by slabs and then to the foundation which disperses them safely to ground. The flow of inertia force should be smooth and continuous through the building. As inertia forces accumulate downwards from the top of the building, the lower story experience higher forces than upper story. Therefore, the lower story should be designed stronger than the upper. The buildings having unsymmetrical geometrical configuration and discontinuity in diaphragm are more unstable in seismic affect than regular one.

Many researchers carried out research work on irregular building design ins seismic zones. Komal R. Bele1, S. B. Borghate (2015) focused on buildings with large projections of Re-entrant corners results in torsion. He took four models one regular and other 3 with varying projections. The conclusion of this paper was base shear decreases from Model R to` L5 (decreases with increase in projection). He also concluded that as projection of increases there are more coupling of modes. Result obtained shows that forces in column (common in all building) shows that the variation of P much higher with increase in projection. Rakesh Sakale, R K Arora and Jitendra Chouhan (2014) studied seismic behaviour of horizontally irregular buildings with regular building. L-shape, T-shape, C-shape and regular shape buildings of equal height are taken and lateral displacement and story drift are derived after analysis. Results were compared and studied. Analysis is performed in staad pro. For seismic zone II, III, IV, and V. Results were such that from drift point of view for zone II TO IV all frames are within permissible limit and there is no need to provide shear wall. Only with the building with plan C exceeds the permissible limit and may require shear wall. For displacement point of view, all buildings are withing permissible limit only for zone II. In zone III and above regular plan building slightly exceeds the permissible limit but other requires shear wall to control the limit. Babita Elizabath baby and shreeja s (2015) studied slab discontinuity at different position that is at the centre, at corners, and at periphery. Pushover analysis are performed in etabs software. Results were that the axial forces, bending moment and story drift are more effectively resisted by the model having slab opening in periphery. So, the opening is more effective to be located at periphery. Shiva kumar hallale and H sharada bai (2016) took three building, one regular and another two with re-entrant corner building plan. Response spectrum method is used for analysing in etabs. Parameters such as eccentricity, maximum displacement and drift, base shear, max. story acceleration, time period, member force in beam and column. Results obtained were eccentricity, max displacements, max story, drift increases in both direction x and y with the increase in plan irregularities. Kazi Muhammed mustaqeem and md mansoor ahmad (2016) his research paper consists two types of configuration, one with opening in slabs and other re-entrant corner structure having varying percentage of irregularities. Analysis was performed for static analysis, dynamic analysis and push over analysis and parameters were displacement, drift, base shear and time period. The results were such that the magnitude of displacement is more in static method. Response spectrum showed more accurate results and can be better considered for seismic activity. Pushover analysis gives higher value as it is analyzed for extreme. More percentage of re-entrant corner max drift. Base shear is max. for regular model less for re-entrant models. As base shear of the building increases, more seismic forces will be attracted by the member. Subodh. S.Patil, Shrinivas. R.Survanshi (2016) focused on seismic response of regular multi-storey building with asymmetrical plan is checked and compared with regular multi-storey building.

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A building with g+20 and g+22 building having plan asymmetry is modelled and analysed in finite element analysis stadd pro v8i. shear wall is provided at re-entrant corner in the buildings. Results of this paper as increase in height of L-shape building directly increase in relative displacement & stress at re-entrant corners. Increase in height of T-shape building directly increase in relative displacement and stress will be developed at re-entrant corner. T-shape building with shear wall and without shear wall after analysis shows uniform stress developed at re-entrant corners. In T- shape building re-entrant corners did not fail because of stresses carried by the shear wall. But without shear wall it will fail. Reena sahu and Ravi dwivedi (2017) studied about diaphragm discontinuity taking 5 structures. One as regular and other 4 as the increasing percentage in slab opening 0%, 4%, 16%, 24%, 36%. Response spectrum analysis using staad pro. is done. Parameters like base shear, bending moment, story drift, shear force are obtained. Results shows that the increase in opening percentages, increases the story drift. 24% opening have less value of maximum shear force as compared to 16% opening. Akshay Nagpure, S. S. Sanghai (2018) studied RCC framed building structures which have been analyzed using ETABS software by linear time history analysis by changing flexibility of the floors and simultaneously when plan irregularities are provided. He took four plans- opening at the centre, opening at the corners, opening at the horizontal faces, opening at the vertical faces. Time history record of El Centro Earthquake has been provided to the software. Responses of all those structures has been plotted and discussed. An attempt is made in this paper to compare the responses of the structures when floor diaphragm flexibility is changed and simultaneously plan irregularities are provided. He concluded that floor Diaphragm Flexibility affects Base Shear of the Building, Column Forces, Beam Forces but doesn't show considerable difference in Time Period and Storey Drift. Sanjay Naik, Tushar S Shetty (2019) research paper involves the modelling and analysis of G+10 storied building of Regular shape plan, L- shape plan and C shape plan structure using ETABS 2016 software. The parameters such as displacement, drift, shear and overturning moment are compared and it was found that Rectangular shape is the best suited and L shape structure is the least desired shape for construction in seismic zone.

Research works has been done for various plan irregularities and vertical irregularities. Conclusion can be made after review of above literatures that unsymmetrical building shows more instability than regular one. The various parameters such as displacements, story drift, overturning moment shows large variations from regular building to plan irregular building and then to vertical irregular building. Shear wall provided is of great help in order to maintain the structural stability of the structure. Base isolation and seismic dampers can also be applied in or to reduce base shear, lateral displacement, story drift. Still very less work is carried out in the field of combinations of plan irregularity.

II. THEORY

As per IS 1893 Part 1 irregularities of two types:
paper in both email address.

1. Plan irregularities
2. Vertical irregularities

Re-entrant corners: inside corners of an asymmetrical building are subjected to stress concentration during earthquake motion. Thus, these corners are more prone to damage during earthquakes.

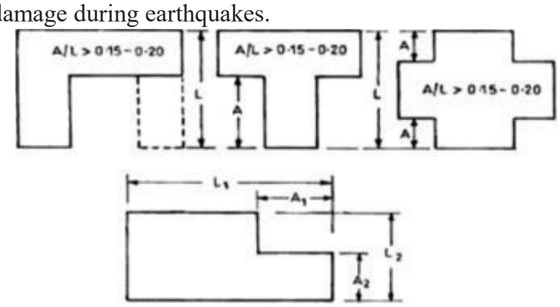

Fig. 1: Re-entrant corner

Diaphragm discontinuity: roof or floor acts as diaphragms (horizontal resisting elements). The diaphragm discontinuity is because of the cut-out or large openings. This causes reduction in the load carrying capacity of diaphragm and may cause damage during earthquake.

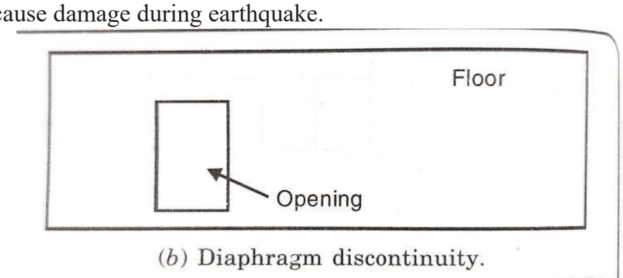

Fig. 2: Diaphragm discontinuity

III. OBJECTIVE OF STUDY

To study the retaliation of plan irregular structures as per IS 1893 part 1 in seismic zones IV and V and collate with reaction of regular building model.

IV. METHODOLOGY

(A). Review of the existing literatures by different researchers.
(B). G+14 story, 10 buildings are taken with 1 regular plan, 3 with varying re-entrant corner plan, 3 with varying opening in diaphragm, 3 with the combination of varying re-entrant corner and opening slab.
(C). Modelling and analysis are done as per IS 1893 part 1 by response spectrum method in etabs software for zone IV and V.
(D). Parameters such as base shear, max. story displacement, max. story drift, overturning moment are plotted in forms of tables and then graphs.
(E)results are collated with regular building models.

V. DETAILS OF THE BUILDING

For study purpose, the layout of the plan has 5 X 5 bays of equal length of 6m.

Building parameters are as follows –

- Type of building: SMRF
- Numbers of Storey: G+14
- Seismic zone: IV and V
- Floor height: 3m
- Grade of concrete: M35
- Grade of steel: Fe500
- Beam dimension: 400 x 700mm
- Column dimension: 450 x 800mm
- Slab depth: 150mm
- Dead load on floor: 0.52 KN/m2

  Mortar screeding – 0.21 x 2 (IS 875 PART 1 table 2 page 31)

  Clay floor tiles – 0.10 (IS 875 PART 1 table 2 page 30)
- Live load on floor: 2.5 KN/m2 (IS 875 PART 2 table 1)
- Masonry load: 4.59 KN/m (outer wall)

  3.519 KN/m (inner wall)

  [AAC (Autoclaved Aerated Concrete Block) is used.]

  (unit weight of AAC blocks – 6 KN/m^3)
- Importance factor: 1
- Response reduction factor®: 5
- Site type: II
- % imposed load: 25%

VI. MODELS.

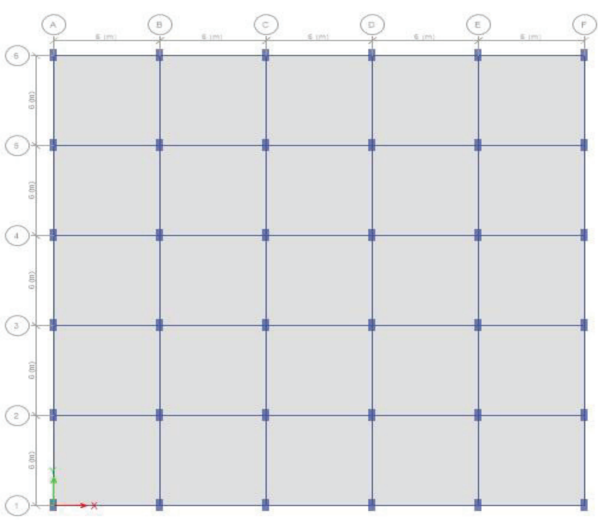

Fig. 3: MODEL R-REGULAR

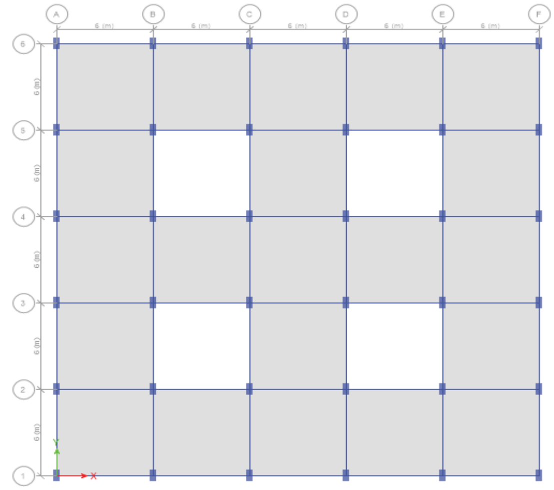

Fig. 4: MODEL D1 (16% OPENING)

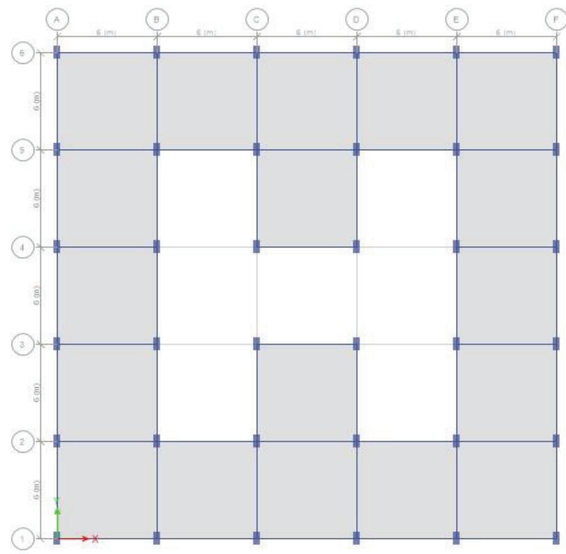

Fig. 5: MODEL D2 (28% OPENING)

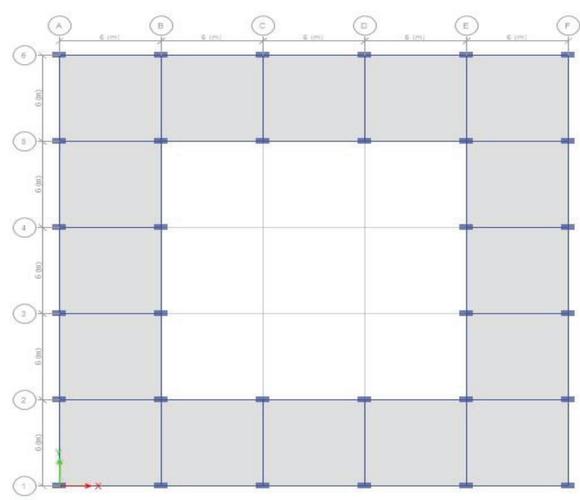

Fig. 6: MODEL D3 (36% OPENING)

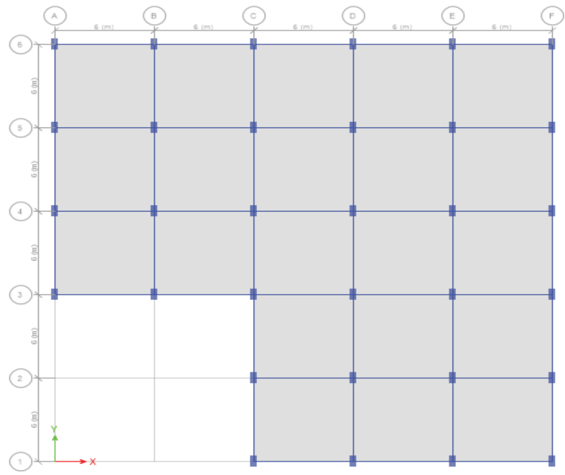

Fig. 7: MODEL R1 (RE ENTRANT CORNERS 40% IN X AND 40% IN Y)

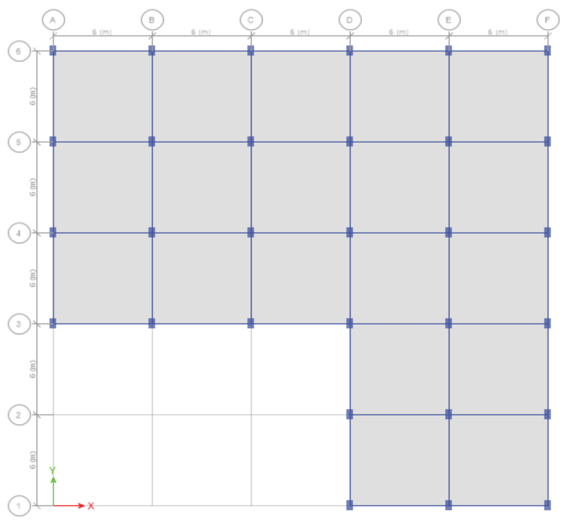

Fig. 8: MODEL R2 (RE ENTRANT CORNERS 60% IN X AND 40% IN Y)

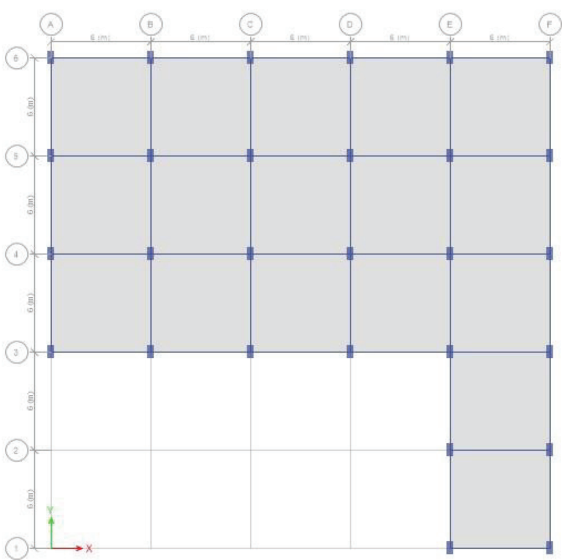

Fig. 9: MODEL R3 (RE ENTRANT CORNERS 80% IN X AND 40% IN Y)

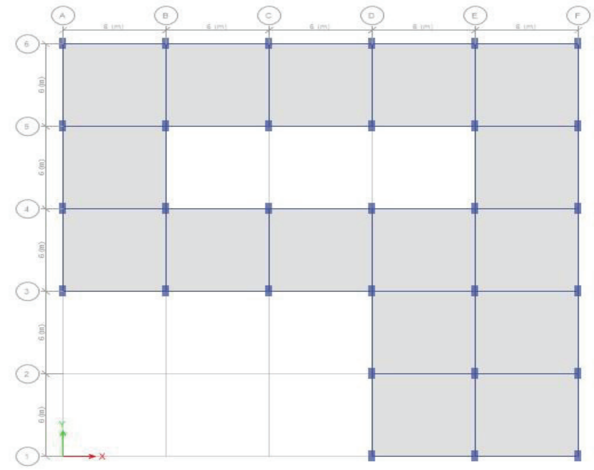

Fig. 10: MODEL DR1 (15% diaphragm opening and 60% re-entrant in x)

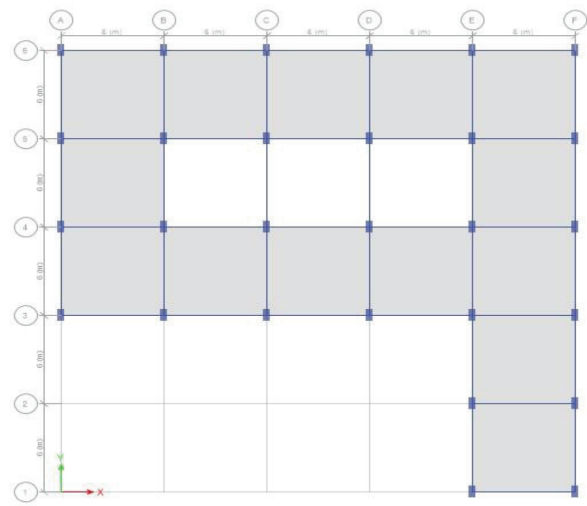

Fig. 11: MODEL DR2 (17% diaphragm opening and 80% re-entrant in x)

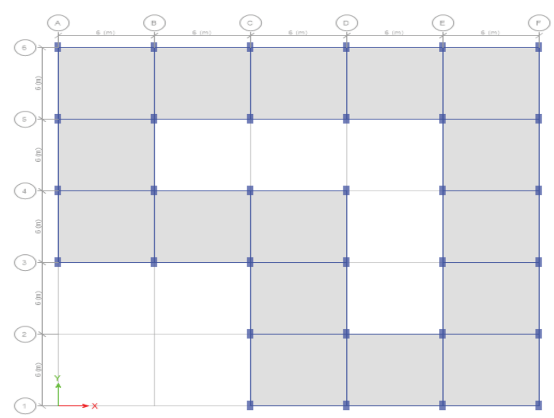

Fig. 12: MODEL DR3 (23% diaphragm opening and 40% re-entrant in x)

VII. RESULTS (Tables and graphs)

TABLE 1: Max. story displacement (mm) (ZONE IV)

STOREY	R	D1	D2	D3	R1	R2	R3	DR1	DR2	DR3
1	6.80	6.53	13.17	4.45	6.84	7.31	6.39	6.95	7.65	6.81
2	10.69	10.29	16.72	7.47	10.79	11.55	10.27	11.06	12.26	10.85
3	14.42	13.89	20.09	10.47	14.60	15.63	14.04	15.04	16.73	14.76
4	17.97	17.32	23.31	13.37	18.23	19.53	17.66	18.84	21.02	18.50
5	21.31	20.54	26.37	16.14	21.65	23.23	21.10	22.44	25.11	22.05
6	24.44	23.57	29.26	18.77	24.87	26.71	24.37	25.83	28.98	25.39
7	27.36	26.39	31.99	21.25	27.88	29.98	27.44	29.01	32.63	28.53
8	30.06	29.01	34.53	23.57	30.67	33.04	30.31	31.97	36.05	31.46
9	32.54	31.40	36.88	25.72	33.23	35.86	32.97	34.71	39.22	34.17
10	34.79	33.98	39.02	27.70	35.57	38.43	35.41	37.20	42.14	36.64
11	36.78	35.50	40.94	29.48	37.64	40.75	37.61	39.43	44.77	38.86
12	38.50	37.16	42.61	31.03	39.43	42.76	39.53	41.37	47.09	40.80
13	39.90	38.51	43.99	32.34	40.91	44.45	41.15	42.98	49.06	42.42
14	40.95	39.52	45.08	33.39	42.03	45.76	42.46	44.23	50.66	43.67

TABLE 2: Max. story drift (ZONE IV)

Sty.	R	D1	D2	D3	R1	R2	R3	DR1	DR2	DR3
1	0.00131	0.00126	0.00140	0.00090	0.00132	0.00141	0.00127	0.00136	0.00151	0.00133
2	0.00130	0.00125	0.00119	0.00101	0.00132	0.00141	0.00129	0.00137	0.00154	0.00135
3	0.00125	0.00121	0.00114	0.00100	0.00128	0.00137	0.00126	0.00134	0.00150	0.00131
4	0.00120	0.00116	0.00110	0.00098	0.00123	0.00132	0.00122	0.00129	0.00146	0.00127
5	0.00115	0.00111	0.00107	0.00095	0.00118	0.00128	0.00118	0.00124	0.00141	0.00122
6	0.00110	0.00107	0.00103	0.00091	0.00113	0.00123	0.00114	0.00119	0.00136	0.00118
7	0.00106	0.00102	0.00099	0.00088	0.00108	0.00118	0.00110	0.00114	0.00131	0.00113
8	0.00101	0.00097	0.00094	0.00084	0.00103	0.00113	0.00105	0.00109	0.00126	0.00108
9	0.00095	0.00092	0.00089	0.00080	0.00098	0.00107	0.00100	0.00104	0.00120	0.00103
10	0.00089	0.00085	0.00083	0.00075	0.00091	0.00101	0.00094	0.00097	0.00113	0.00097
11	0.00081	0.00078	0.00075	0.00069	0.00084	0.00092	0.00086	0.00089	0.00104	0.00089
12	0.00071	0.00069	0.00067	0.00061	0.00074	0.00082	0.00076	0.00079	0.00093	0.00079
13	0.00060	0.00057	0.00056	0.00052	0.00062	0.00070	0.00065	0.00066	0.00080	0.00067
14	0.00045	0.00043	0.00043	0.00041	0.00047	0.00054	0.00051	0.00051	0.00064	0.00052

TABLE 3: Overturning moment (ZONE IV)

Sty.	R	D1	D2	D3	R1	R2	R3	DR1	DR2	DR3
0	120840	114672	100007	78406	102224	88303	74918	83088	84111	88269
1	108500	102848	89784	70504	91783	79400	67169	74669	75723	79276
2	96672	91493	79966	62948	81776	70887	59724	66617	67731	7064
3	85336	80604	70519	55710	72187	62734	52585	58909	60094	62416
4	74454	70159	61407	48749	62982	54897	45739	51511	52757	54500
5	63983	60132	52611	42032	54127	47333	39174	44383	45662	46884
6	53909	50520	44139	35543	45608	40020	32887	37505	38777	39550
7	44253	41347	36030	29289	37442	32970	26896	30885	32099	32510
8	35076	32674	28358	23309	29682	26226	21238	24563	25667	25807
9	26492	24604	21233	17680	22422	19876	15981	18616	19561	19523
10	18670	17288	14806	12510	15805	14053	11220	13165	13912	13781
11	11820	10912	9252	7950	10007	8922	7075	8364	8890	8739
12	6196	5702	4778	4183	5246	4688	3692	4399	4705	4588
13	2130	1953	1617	1440	1803	1614	1261	1515	1633	1577
14	0	0	0	0	0	0	0	0	0	0

TABLE 4: MAX. STORY DISPLACEMENT (MM) (ZONE V)

STOREY	R	D1	D2	D3	R1	R2	R3	DR1	DR2	DR3
1	10.20	9.805	19.75	6.67	10.24	10.97	9.59	10.43	11.48	10.22
2	16.04	15.42	25.08	11.20	16.19	17.33	15.41	16.60	18.39	16.28
3	21.64	20.84	30.13	15.70	21.90	23.45	21.07	22.57	25.10	22.15
4	26.95	25.98	34.96	20.05	27.34	29.30	26.49	28.27	31.54	27.76
5	31.96	30.82	39.55	24.21	32.48	34.84	31.66	33.67	37.67	33.08
6	36.66	35.36	43.90	28.16	37.31	40.07	36.55	38.75	43.47	38.09
7	41.04	39.59	47.98	31.88	41.82	44.98	41.16	43.52	48.95	42.80
8	45.10	43.51	51.80	35.36	46.00	49.56	45.46	47.96	54.07	47.19
9	48.82	47.11	55.32	38.59	49.85	53.79	49.46	52.06	58.84	51.25
10	52.19	50.36	58.54	41.55	53.35	57.65	53.12	55.80	63.21	54.96
11	55.18	53.25	61.41	44.22	56.46	61.12	56.42	59.15	67.16	58.29
12	57.75	55.73	63.91	46.55	19.15	64.15	59.30	62.06	70.64	61.20
13	59.85	57.76	65.99	48.52	61.37	66.67	61.73	64.48	73.59	63.63
14	61.42	59.28	67.62	50.08	63.05	68.64	63.70	66.35	75.99	65.51

Table 5: max. story drift (ZONE V)

Sty.	R	D1	D2	D3	R1	R2	R3	DR1	DR2	DR3
1	.00196	.00189	.00210	.00141	.00199	.00212	.00191	.00204	.00227	.00200
2	.00195	.00188	.00179	.00152	.00198	.00212	.00194	.00206	.00231	.00202
3	.00188	.00182	.00171	.00151	.00192	.00206	.00190	.00200	.00226	.00197
4	.00181	.00175	.00166	.00147	.00185	.00199	.00184	.00193	.00219	.00191
5	.00173	.00167	.00160	.00142	.00177	.00192	.00177	.00186	.00211	.00184
6	.00166	.00160	.00155	.00137	.00170	.00184	.00171	.00179	.00204	.00177
7	.00159	.00153	.00148	.00132	.00163	.00177	.00165	.00172	.00197	.00170
8	.00151	.00146	.00142	.00126	.00155	.00170	.00152	.00164	.00189	.00163
9	.00143	.00138	.00134	.00120	.00147	.00161	.00150	.00156	.00180	.00155
10	.00133	.00128	.00125	.00128	.00137	.00151	.00141	.00146	.0017	.0014
11	.00122	.00117	.00113	.00103	.00126	.00139	.00129	.00134	.00156	.00133
12	.00107	.00103	.00100	.00092	00111	.00124	.00115	.00119	.00140	.00119
13	.00090	.00086	.00084	.00078	.00093	.00104	.00097	.00100	.00120	.00100
14	.00068	.00065	.00065	.00062	.00071	.00081	.00079	.00077	.00096	.0007

TABLE 6: overturning moment (ZONE V)

STORY	R	D1	D2	D3	R1	R2	R3	DR1	DR2	DR3
0	181261	172009	150011	117609	153336	132455	112377	124633	126167	132404
1	162751	154272	134676	105756	137675	119101	100753	112004	113585	118915
2	145009	137240	119949	94423	122665	106331	89587	99925	101596	105996
3	128005	120906	105778	83565	108280	94101	78878	88364	90141	93624
4	111681	105238	92110	73124	94473	82346	68609	77267	79135	81750
5	95975	90199	78917	63049	81190	71000	58761	66575	68494	70326
6	80864	75780	66209	53315	68412	60031	49331	56258	58166	59325
7	66379	62021	54046	43933	56163	49455	40344	46328	48149	48765
8	52614	49012	42537	34964	44523	39339	31857	36844	38500	38710
9	39738	36907	31850	26520	33633	29815	23971	27924	29341	29284
10	28006	25932	22209	18765	23707	21080	16830	19748	20869	20672
11	17730	16368	13878	11925	15011	13383	10612	12546	13336	13109
12	9294	8553	7168	6275	7870	7032	5538	6598	7057	6882
13	3195	2929	2426	2160	2704	2421	1892	2273	2449	2366
14	0	0	0	0	0	0	0	0	0	0

TABLE 7: Base shear

S.No.	MODELS	BASE SHEAR (ZONE IV)	BASE SHEAR (ZONE V)
1	R	4076.3465 KN	6114.519 KN
2	D1	3872.2100 KN	5808.310 KN
3	D2	3312.7800 KN	4969.170 KN
4	D3	3690.9300 KN	5536.400 KN
5	R1	3506.9188 KN	5260.370 KN
6	R2	3122.2062 KN	4683.300 KN
7	R3	2696.8046 KN	4045.200 KN
8	DR1	3074.9743 KN	4612.46 KN
9	DR2	3165.2912 KN	4747.937 KN
10	DR3	3160.2926 KN	4740.438 KN

GRAPHS

ZONE IV

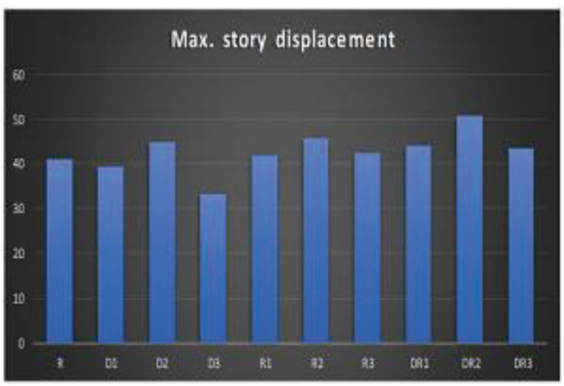

Fig. 13: Max. story displacement

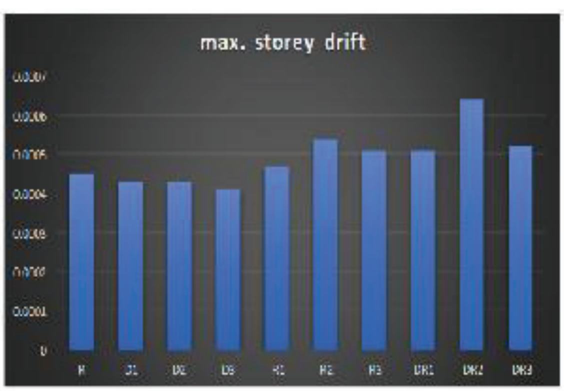

Fig. 14: max. story drift

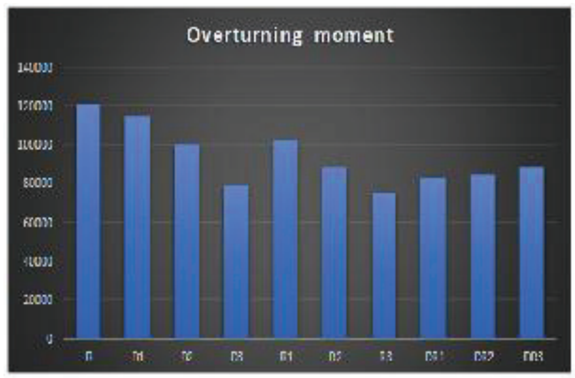

Fig. 15: Overturning moment

ZONE V

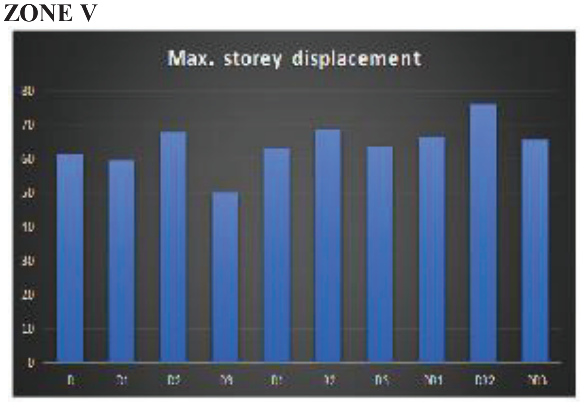

Fig. 16: max. story displacement

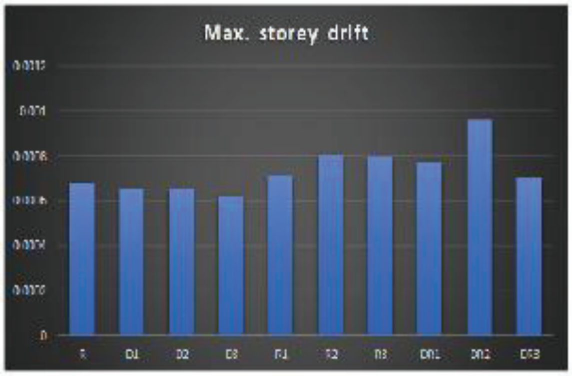

Fig.17: max. story drift

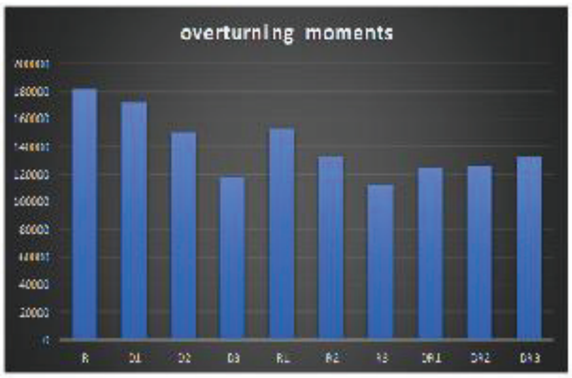

Fig. 18: overturning moments

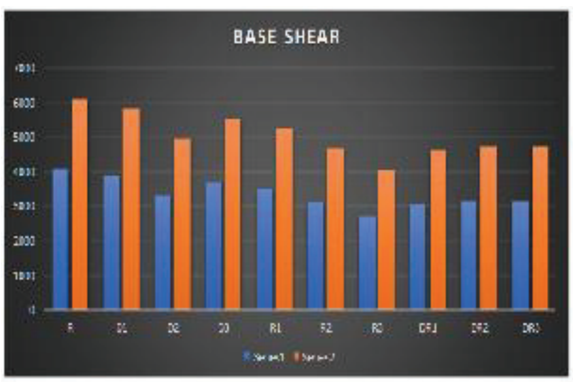

Fig. 19: base shear

VII. CONCLUSION

Seismic response of plan irregular building in two different zones IV and V are studied. After study of results obtained from the analysis of structure, following conclusion can be made-

1) For base shear (refer table 7 and fig. 19), regular building shows max. lateral force at the base. Irregular plan building shows decrease in the value f base shear when percentage of irregularity increases. But when it comes combined irregular building model DR2 shows max. base shear. Hence, we can also say weight of building also effects base shear, more weight more base shear.
2) For max. displacement (fig. 16 and 13), model DR2 shows maximum for both zones.and model D3 show least displacement. By this we can say that diaphragm opening not much effect the displacement but re-entrants do. And combination of both makes structure more unstable.
3) When it comes to story drift (refer Fig. 14 and 17) from results, we can see that more percentage of opening less drift value and more varying percentage re-entrant more drift. Therefore, when it comes to the combination of two models DR2 shows max. drift for both zones.
4) Models R shows max. overturning moment (refer fig. 18 and 15) and as opening in slabs increases it reduces. Similarly, it is for re-entrant corner models. But for the combination of two irregularity there is an increase in overturning moment as varying percentage increases. Hence, we can say that large slab opening results in less overturning moment.

Hence, it can be seen that due to more weight of the building base shear and overturning moment is more and due to unsymmetry of the structure max. displacement and story drift is more.

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