JIMMA UNIVERSITY

JIMMA INSTITUTE OF TECHNOLOGY

FACULTY OF CIVIL AND ENVIROMENTAL ENGINEERING

STRUCTURAL ENGINEERING STREAM

Effect of Diaphragm Discontinuity in Seismic Response of G+4 Reinforced Concrete U-Shape Building

A Thesis Submitted to School of Graduate Studies of Jimma University in Partial Fulfillment of the Requirements for the Degree of Masters of Science in Structural Engineering

BY

SELAMAWIT ADDISE

NOVEMBER, 2022 JIMMA, ETHIOPIA

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ADVISOR: Eng. Elmer C. Agon (ASSO. PROF)

CO-ADVISER: Eng. Solomon Biratu(MSC)

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CERTIFICATION

As a member of the examining board of the final MSc open defense. We certify that we have read and evaluated the thesis prepared by Selamawit Addise Entitled "Effect of Diaphragm Discontinuity in Seismic Response of G+4 Reinforced Concrete U-Shape Building"; and recommended that it be accepted as fulfilling the thesis requirement for the degree of Master of Science in Structural Engineering.

Approved By Board of Examiners

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DECLARATIONS

I, the undersigned, declare that this thesis entitled "**Effect of Diaphragm Discontinuity in Seismic Response of G+4 Reinforced Concrete U-Shape Building**" is my original work, and has not been presented by any other person for an award of a degree in this or any other University, and all sources of material used for theses have been dually acknowledged.

Candidate:- Selamawit Addise

Signature________________

As Master research Advisors, we hereby certify that we have read and evaluate this MSc research prepared under our guidance, by Selamawit Addise entitled: **"Effect of Diaphragm Discontinuity in Seismic Response of G+4 Reinforced Concrete U-Shape Building**" We recommend that it can be submitted as fulfilling the MSc Thesis requirements.

Engr. Elmer C. Agon, Asso. Prof

______________________________ _______________ 06/12/2022

Main Advisor Signature Date

Eng.Solomon Biratu (MSc)

______________________________ _______________ Nov. 29/2022

Co- Advisor Signature Date

ABSTRACT

The major cause for structures failure during earthquakes is irregular configuration of buildings. Earthquake damages initiates due locations of structural weaknesses present in multi-storied framed buildings.

Now a days opening in the floors is common for different reasons like stair cases, lighting, architectural aesthetics and other. The main objective of this research is to analyze the effect of the openings in slabs at different location, at different size of opening and different opening shape of U –shaped building. To see the effect of this regular in elevation and irregular in plane U-shape buildings are modeled with diaphragm discontinuity and without diaphragm discontinuity building is analyzed by finite method analysis that is ETABS V.19 software. The design has been done based on the rules specified in the ESEN 1998:2016 which has been the reference standard. Responses quantities like; storey displacement, storey drift, storey force, and base shear are carried out for different shape, size and location of opening of diaphragm through response spectrum analysis. In this research parametric study has been conducted using same parameters including seismic location, ground type, and ductility class, loading condition, behavior factor same ductility class (DCM), and material type for all models. A G+4 total of 13 different models were analyzed and compared carried out and the findings results are concluded as follows:

For same cross sectional area and shape on different opened down positions of slab opening at Y-shorter front edge frames showed the maximum reduction storey displacement as compared to other frames it reduce top storey displacement by 6.50% and 2.80% in the X and Y direction respectively and the base shears of opening at y-longer corner (M4) have decreased 8.09% to the x-direction and 8.92% y-direction than without diaphragm discontinuity.

*For the same opening position with different cross sectional area of slab that is 4*4 open down area shows better performance in reduction of displacement than diaphragm without discontinuity frame. Percent reduction of top storey displacement for 4*4 open down slab size area frame shows 4.2% X direction and 2.8% and Y.. For this specific model 4*4 area opened frame decrease the base shear by 7.87% in the X direction and 8.75% in the Y direction. But for the same opening position with the same cross sectional area of opening and different shape of opening there is no effect on displacement , drift and base shear both in x and y directions.*

Keywords*: base shear, stiffness, storey displacement, storey drift, response spectrum analysis*

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ABBREVIATIONS

MMC	A method of modal combinations
IBC	International Building Code
POA	Static pushover analysis
MDOF	Multi degree of freedom
EC8	Euro code eight
FEMA	Finite element analysis
IS	Indian standard
ESEN	Ethiopian standard European norm
LLRS	Lateral load resist system
SNNPR	South Nation Nationality and Peoples regions
ELF	Equivalent Lateral Force
VLLR	Vertical Lateral Load resisting element

SYMBOLS

dr	design interstorey drift
L_{max}, L_{min}	larger and smaller in plan dimension of the building measured in orthogonal directions
F	Storey shear force
Fb	base shear
Q	Behavior factor
I	Importance factor assigned on important structures
α	Ratio of the smaller design bending moment $M_{Ed,A}$ at one end of a seismic link to the greater bending moments $M_{Ed,B}$ at the end where plastic hinge forms, both moments taken in absolute value
$\alpha 1$	multiplier of horizontal design seismic action at formation of first plastic hinge in the system
αu	multiplier of horizontal seismic design action at formation of global plastic mechanism

ACKNOWLEDGMENT

Thanks to God for each and every success in my life and satisfactory accomplishment of this research. My deepest gratitude goes to my feeder advisor Eng. Elmer C.Agon (Ass.Prof) for his professional, genuine guidance and valuable advice to accomplish this thesis. Without his guidance, encouragement, advice and persistent help, this thesis would not have been possible. Next, my deepest gratitude goes to my feeder co-advisor Eng. Solomon Biratu for his valuable guidance and persistent help to accomplish this thesis on time. Also, my deepest gratitude goes to Ministry of Science and Higher Education (MOSHE) and Jimma University (JU) to create this beautiful environment for me and have got the chance of this lovely education. I would like to extend my special appreciation to my husband and my family for their being with me in all ups and downs. At last, but not least, I would like to express my profound heartfelt thanks to those people who have collaborated with me, especially my friend

CHAPTER ONE

INTRODUCTION

1.1Background

Damages of earthquake in multi-storied framed building, generally initiate at locations of structural weaknesses present to resist the lateral load resisting structures. During strong earthquake motions the distribution of mass, stiffness, strength in both the horizontal and vertical planes of buildings affect the behavior of multi-story framed buildings. Such discontinuities of diaphragms are often associated with sudden variations in the frame geometry along the length of the building. Floor and roof systems act as horizontal diaphragms in building structures. They collect and transmit inertia forces to the vertical elements of lateral load resistant systems, such as columns and structural walls. They also ensure that vertical components act together under vertical and earthquake loads. Floor and roof systems act as horizontal diaphragms to transfer lateral load to vertical load resisting system of building. Diaphragm is the structural element that transmits lateral loads to the vertical resisting elements of structure like moment – resisting frames, braced frames, structural hybrid Systems walls and tube Systems. In flexible diaphragm, excessive openings can leads to load path deficiencies at boundaries of the openings. In irregular plan, openings of diaphragms may considerably weaken slab capacities**.** Discontinuities of diaphragm in the lateral stiffness are due to openings, cut-outs, adjacent floors at different levels or change in the thickness of diaphragm. The diaphragm of a structure often does different duty as the floor system or roof system in a building, or the deck of a bridge, which simultaneously supports vertical loads and transfer horizontal loads. Floor diaphragm openings are constructed for the aesthetic purpose of stairways, shafts or other architectural features**.** Earthquake loads and gravity load flow in a continuous path through the horizontal and vertical elements of structures and transferred to the ground. Sidestepping and offsetting are elevation discontinuities, leads to high stress concentrations. Discontinuities are present in plan irregularity and elevation irregularity. In this research, the effect of diaphragm discontinuity in seismic response of G+4 U-shaped irregular buildings is done which is used to find the appropriate size shape and location of diaphragm discontinuity in U-shaped buildings.

Irregularity of building structure is major problem which leads to disaster during severe earthquake. Irregularities are not avoidable in construction of buildings; however, the behavior of structures with these irregularities during earthquake needs to be studied. In order to prevent damages due to irregularity problem, seismic demands must be determined accurately. Several Studies have focused on evaluating the response of regular structures.

In the present thesis, the effect of diaphragm discontinuity on the seismic response and performance of a selected common peripherally irregular plan (U) shape G+4building is studied. Multistory building having discontinuity floor diaphragms that considerably weaken slab capacity and affect even distribution of seismic loads to the vertical lateral load resisting elements.
This study focuses on determining the effect of diaphragm discontinuity on seismic response of RC buildings which are designed using Euro Code8 2004 mostly similar to ES EN 1998 – 2016 Code using response spectrum analysis.

1.2 Statements of the Problems

In the past and present time impact of earthquake load is a serious case in developed and developing countries. Earthquakes occurred in the past are devastated buildings, loss of human life and properties. Know a day this serious problem occurred in Ethiopia specifically in seismic Zone 4&3 regions.

Most of the time buildings or structures with floor plan have open down throughout the floor or in some section of the floor like low story floors in a building. When there is a large opening, effect of the size of opening or diaphragm discontinuity which affects seismic response and performance of a selected irregular plan U-shape G+4 building is studied. The existence of these openings has different architectural function or aesthetic value. Slab opening down (diaphragm discontinuity) which affects rigidity of a diaphragm and distribution of lateral load to the lateral load resisting element. Though we know opening down has adverse effect in building in load transferring mechanism, no rules have been set in all country building codes to prefer place (position), size and shape where opening down has less effect.

1.3 Research Question

Under these topics we will see the following major effect of discontinuity of diaphragm for irregular U-shaped plan.

- Which opening size and opening shape will affect seismic response of U shaped building?

- What is the effect of diaphragm discontinuity on seismic response of RC buildings such as base shear, storey drift and storey displacement?
- Which location, size and shape is preferable to increase seismic performance of the diaphragm?

1.4 Objectives of the Study

1.4.1 General objective: **-** The general objective of this study will be to investigate the effect of diaphragm discontinuity in seismic response of G+4 reinforced concrete U-shape building using finite element analysis.

1.4.2 Specific objectives

- To investigate the different openings of a G+4 U-shaped building using response spectrum analysis.
- To determine the effect of diaphragm discontinuity on seismic response like base shear, storey drift and storey displacements.
- To compare and select suitable and practical location, size and shape of U-shape building.

1.5 Significances of the study: The importance of this thesis deals how could to use response spectrum method analysis of seismic response of irregular building. For construction industry to select appropriate size, shape, and location of U-shaped building for different purposes like staircases, architectural aesthetics, and lighting purposes. And for other researcher as the reference.

1.6 Scope and Limitation of the Study

This study paper considers the effect of diaphragm discontinuity in seismic response of U-shape building due to open down analyzed using software ETABS.v19. To compare the result, response spectrum analysis is selected to evaluate the linearly elastic structures are considered. This study is done for RC framed G+4 building with 6 stories and fixed support conditions.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

2.1 Floor diaphragm and structural function

2.1.1 General feature of diaphragm

The main function of floor and roof systems is to support gravity loads and to transfer these Loads to other structural members such as brace system, tubal system and load resisting walls. Furthermore, they play a main role in the distribution of lateral force to the vertical elements of the lateral load resisting system. Diaphragm is horizontal-resistance members that transfer lateral forces between vertical resistance elements like shear walls or frames. By the floor and roof elements of the building diaphragms are generally provided; but, horizontal bracing systems independent of the roof or floor structure serves as diaphragms. Most of time floors and roofs have to be penetrated by staircases, elevator and duct shafts, skylights and atria. The penetrations are critical to the effectiveness of the diaphragm size and location of these.

2.1.2 Concept of diaphragm discontinuity According to IS-1893:2002: Diaphragms with abrupt discontinuities or variations in stiffness, which include those having cut-out or open areas greater than 50 percent of the gross enclosed diaphragm area, or changes more than 50 percent from one story to the next in effective diaphragm of stiffness. In structural engineering, transfer lateral loads to shear walls or frames primarily through in-plane shear stress by a diaphragm is a structural system. Horizontal loads are usually wind and earthquake loads. There are different studies conducted in the field of essential to good seismic performance of buildings. The important aspects which affecting seismic configuration of buildings are overall geometry, structural systems, and load paths. ((Taranath, (2004).)Although these studies proved to be contributing diaphragm discontinuity by different authors are described below.

2.1.2 Effects of opening (diaphragm discontinuity) Horizontal and vertical elements of structures transfer ground Gravity and earthquake loads to the supporting should flow in a continuous and smooth path. Sidestepping and offsetting discontinuities which are common vertical discontinuities are frequently present in elevation. High stress concentrations which happened by openings in diaphragms may considerably weaken slab capacities. In plan, this reduction of resistance depends on the location and size of the openings. The diaphragm behaves like a continuous beam under uniform seismic forces at a floor level small openings do not fail the load transfer. High stress concentrations may exist at the connection between structural walls and slabs, and between columns and flat slabs (Brussels. Code, P. s.l. : , 2005)))

P.P. Vinod Kumar and Dr. V.D. Gundakalle (2015) study on a G+15 RC building subjected to seismic force for the effort of diaphragm openings in multi-storeyed R C framed buildings using Pushover analysis by ETABS software and the various analyses are performed for different opening size. The results of this study indicate that the effect of diaphragm openings on the seismic response of multi-storeyed buildings played a major role in reducing the base shear, hence attracting lesser earthquake forces (Vinod Kumar, n.d.)

Mohamed Mahmoud Ahmed, Aly Gamal Abdel Al-Shafy, Alaa Abd Rb Al-Nabi Mohamed (2017) study on the effect of creating symmetrical openings in the slabs of high buildings on their structural properties through a numerical study using ETABS software. It is found that openings can affect internal and edges than corner, or it was located at the middle stories of the building was larger when they were located (Mohamed Mahmoud Ahmed, 2017)

Wai-Fah Chen, said that, the creating of a large opening in the slab decreases in plane stiffness. Additionally, Lateral forces induced by the earthquake motion increases when the structure stiffness can be increase (Wai-Fah Chen:, 2003.)

Miss. Reshma K Bagawan1 and Prof. M Q Patel2(2017) study on Seismic Performance Study of RC Framed building with Diaphragm Discontinuity In this project two types of diaphragm discontinuities are considered as stiffness and mass irregularity in the slab portion. Method of analysis are Responses spectrum analysis and Time history. The Response quantities and Time history quantities like; modal period, storey shear, story displacement ,storey drift base force, joint displacement and column forces are estimated and are compared for regular building and building with diaphragm discontinuity. From this study it is concluded regular building has the less displacement and drift compared to that building with diaphragm discontinuity and has greater time period and shear force than irregular building. Hence regular building is less vulnerable to earthquakes (Patel2:, (2017))

K sanjay 1*, p mallikharjuna rao 2*(2018.) Study on effect of diaphragm discontinuity in the seismic response of multi-storeyed building. The behavior of multi-storey building G+11 of regular and irregular configuration under earth quake is difficult and it varies of wind loads are assumed to act at the same time with earth quake loads. In this paper a residential of multi-story building is studied for earth quake and wind loads using response spectrum method and STADD PRO. By assuming that material property is linear static and dynamic analysis are done. These analysis are performed by considering different seismic zones and for each zone the soil type is assessed by taking the Soft soil .Different response like story drift, displacements base shear are plotted for different zones for different types of soils (K Sanjay 1*, 2018)

Gaurav Kumar et al. (2018) analyzed the behavior of different irregular plan buildings during seismic excitation. The building plans, have considered as eccentricity between center of mass and center of rigidity are subjected to higher damages in compare to building plan which have no eccentricity between center of mass and center of rigidity. The buildings which have zero eccentricity perform well during earthquake. Most common shape of building plans are Square shape, 'L' shape, 'C' shape, and 'T' shape, which are mostly used in urban areas nowadays, which carried out as per clause 7.1 of IS Code 1893 (part 1)2002, are modelled by using ETABS software. Story drift, Story displacement and Torsion (Ratio of max story drift to average story drift) parameters that considered for the study and four models are considered. After analysis using Linear Time history method, comparison of seismic performance of different models was performed and most vulnerable building shape against earthquake forces was located in this study. (G. Kumar, (2018).])

Akhilesh Rathi et al. (2018) analyzed the reinforced concrete framed structure designed for setback and regular building of loads (DL, LL & EL). The behavior of 20-Storied buildings with and without setbacks was studied. The buildings were analyzed using Time History Analysis and Response Spectrum Method and Novelty: The effect of Setback is studied performed the parameters such as Time Period, storey drifts, Displacements, Storey Shears, Bending Moments and Shear Forces and related with the building without a setback. (A. Rathi, A. Raut, , 2018) B.

Srikanth and V. Ramesh (2013) comparative study of seismic response for seismic coefficient and response spectrum methods. In this thesis, the earthquake response of symmetric multi-storied building by two methods are studied. The methods include seismic coefficient method as recommend

ded by IS Code and modal analysis using response spectrum method of IS Code in which the stiffness matrix of the building corresponding to the dynamic degrees of freedom is generated by idealizing the building as shear building. The responses obtained by above methods in two extreme zones as mentioned in IS code i.e. zone II and V are then compared. Test results Base Shears, Lateral Forces and Storey Moments are compared. (Devesh P. Soni and Bharath B. Mistry."y, 2006,).

Reena Sahu et al. (2017) investigate the Seismic analysis is a subset of structural analysis which involves the calculation of the response of a structure subjected to earthquake vulnerability. An attempt is carried out to know the difference between a with diaphragm discontinuity and without diaphragm discontinuity of building. To achieve this objective various models with varying percentages of diaphragm openings were modeled, analyzed and compared for seismic parameters like base shear, maximum storey drifts, shear force, bending moment and axial force. It can be seen from the results that bases shear in the buildings calculated from the earthquake static analysis is higher than the response spectrum analysis. Provision of the diaphragm opening alters the seismic behavior of the buildings. Models with a symmetrical opening in both directions expressed similar response for all the parameters while models with change in the symmetry behaved differently. The increase in the opening percentage, increase the storey drift in all the models. It can be seen from the results that storey drift in the buildings calculated from the earthquake static analysis is higher than the response spectrum analysis. Shear force, bending moment and axial force obtained from the earthquake static analysis is higher as compared to response spectrum analysis. (R. Sahu and R. Dwivedi), (2017))

Akhilesh Rathi et al. (2018) analyzed the reinforced concrete framed structure designed for setback and regular building of loads (DL, LL & EL). The behavior of 20-Storied buildings with and without setbacks was studied. The buildings were analyzed using Time History Analysis and Response Spectrum Method and concluded that the effect of Setback is studied considering the parameters such as Time Period, storey drifts, Displacements, Storey Shears, Bending Moments and Shear Forces and correlated with the building without a setbackA. ([Rathi, A. Raut, , (2018).])

1vinod V, 2pramod Kumar H E V (E 2017) study on influence of stiffness discontinuous diaphragm characteristics on the seismic behavior of Rc structure. In this present study, an attempt to carry out study the effect of various parameters associated with diaphragm on the seismic behavior of RC framed structure. Spectrum Analysis as per IS 1893 is used to assess the seismic behavior made to study the effect of discontinuities in the diaphragm namely different openings with comparing the seismic behavior of four and eight story RC building. For this purpose, ETABS 2015, FE analysis software with Response. Parameters such as Natural Time Period, Base Shear, Mode shape, Drift and Displacements and internal forces in members are used to compare the seismic performance. Maximum displacement and drift for four and eight story building shown lesser displacement value in stiffness diaphragm compared to no diaphragm. (1vinod V, 2017)

Md Shehzad Choudhary et al. (2018) addressed the difference between a building without diaphragm discontinuity and a building with diaphragm discontinuity. In this project a regular 15 and 20 storey RC buildings having shear wall are modelled with and without diaphragm discontinuity and are analysed by ETABS (2013). The models having slab openings has lower storey displacement, storey drift, storey shear, modal period than the regular building model. For 15 storey building, when there is increase in percentage area of slab openings it is found that there is decrease in the storey displacement, storey drift, storey shear and modal period in both x & y direction. Also for 20 storey building, when there is increase in percentage area of slab openings it is found that there is decrease in the storey displacement, storey drift, storey shear and modal period in both x & y directions. The study shows that variation in the slab thickness reduces the performance of the buildings during earthquakes. It is found that the slab openings in a building having shear wall gives better performance during earthquakes (S. Choudhary, S. Arfath, M. Ahmed, N. Pasha,, (2018).])

Rajesh Kadiyala1 and Tejaswi Kota2(2016), study on Effect of Diaphragm Discontinuity of the Building The present paper attempts to for investigate the proportional distribution of forces each story due to seismic force. It has been observed that depend on the lateral storey stiffness distribution the story drift, displacement and other response entities . A regular G+5 reinforced concrete (RC) buildings are modeled and analyzed with diaphragm discontinuity and without diaphragm discontinuity and are analyzed by computer software SAP2000 (V14). It is observed that in irregular buildings, there is greater contribution of Responses quantities from higher modes even though there is no significant variation in time periods. A study an idea on the attack of the buildings subjected to earthquake given on story drift and displacement entities. ((Rajesh Kadiyala1 and Tejaswi Kota2"", 2016)

J.Sreenathet. al on their paper studied for the investigation of the effect of diaphragm discontinuity in the seismic response of multi-story building. Many buildings in the nowaday have irregular configurations both in elevation and plan. It is necessary to identify the performance of the structures to resist disaster for both new and existing buildings. In this study buildings with diaphragm Discontinuity and a building without diaphragm discontinuity an attempt is made to compare the difference. This present paper makes a Humble effort to portrait the behavior of the five different multi storied buildings models was carried out with diaphragm openings by using the analysis method of response spectrum analysis using ETABS v 9.7.4 software. To achieve this objective, various models with different diaphragm openings were modeled analyzed and compared for seismic parameters like base shear, maximum story drifts, and response spectrum results. ((Sreenath, n.d.)

ASHVIN G. SONI et. al on their paper studied effect of irregularities in buildings and their consequences. Many buildings in the present scenario have irregular configurations both in plan and elevation. So it is necessary to identify the performance of the structures to withstand against disaster for both new and existing one. Structures experience lateral deflections under earthquake loads. Magnitude of these lateral deflections is related to many variables such as structural system, mass of the structure and mechanical properties of the structural materials. This is due to the irregularities in plan or elevation or in both, all multistoried buildings be analyzed as three dimensional system using IS standard. The paper discusses the performance evaluation of reinforced concrete buildings with irregularity. Structural irregularities are important factors which decrease the seismic performance of the structures. The study as a whole makes an effort to evaluate the effect of vertical irregularity on reinforced concrete buildings, in terms of dynamic characteristics and the influencing parameters which can regulate the effect on Story Displacement, Drifts of adjacent stories, Excessive Torsion, Base Shear, etc. obtained result, the base frame (regular) develops least storey drifts while the building with heavy loading on 4th and 7th stores shows maximum storey drifts on the storey levels. Hence, this is the most vulnerable to damages under this kind of loading. The buildings with irregularities also showed unsatisfactory results to some extent. The result proves that irregularities in buildings are harmful for the structures and it is important to have simpler and regular shapes of frames as well as uniform load distribution of load around the building. (SONI, A. G., Agrawal, D. G., &Pande, A. M. ., 2015)

M.T. Al Harashet. al on their paper studied inelastic seismic response of reinforced concrete buildings with floor diaphragm discontiniuty. As they stated floor has great role in carrying, and transferring of vertical load and also it distributes seismic load induced to load column and frame by diaphragm action. In reinforced concrete buildings, the in-plane flexibility of the floor diaphragms is often neglected for simplicity in practical design (i.e., the floor systems are frequently treated as perfectly rigid diaphragms). Past research, which is acknowledged in recent building standards, has shown that this assumption can result in considerable error when predicting seismic response of reinforced concrete buildings when diaphragm plan aspect ratio is greater than 3:1.Two 3-story reinforced concrete buildings are designed as a building Frame System in order to investigate the effect of diaphragm openings on the seismic response of reinforced concrete buildings;. Each building is modeled and analyzed with and without floor diaphragm discontinuity and considered -4 cases. The inelastic behavior of the buildings is investigated under both static lateral loads (push-over) and dynamic ground motions (time-history), where a suite of three well-known earthquakes is scaled to model moderate ground motions. The parametric study conducted involves two opening size/locations and two lateral load resisting frames stiffness/locations, where three types of diaphragm models (rigid, elastic, and inelastic) are assumed. It was concluded that it is necessary to use an inelastic diaphragm model in order to capture the seismic response of reinforced concrete buildings with floor diaphragm openings accurately. (. Al Harash, 2011)

2.2 Stiffness and strength requirement

2.2.1 Configuration

Typical building configuration deficiencies include an irregular geometry, a weakness in a story, a concentration of mass, or a discontinuity in the lateral-force-resisting system. Vertical irregularities are defined in terms of strength, stiffness, geometry, and mass. Although these are evaluated separately, they are related and may occur simultaneously. For example, a building that has a tall first story can be irregular because of a soft story, a weak story, or both, depending on the stiffness and strength of this story relative to those above. ((Taranath, (2004).)

2.2.2 Regularity

Structures with regular plan configurations are compact, i.e. described by polygonal convex lines. Square, rectangular and circular shapes are compact. Square or rectangular configurations with minor re - entrant corners can still be considered regular.

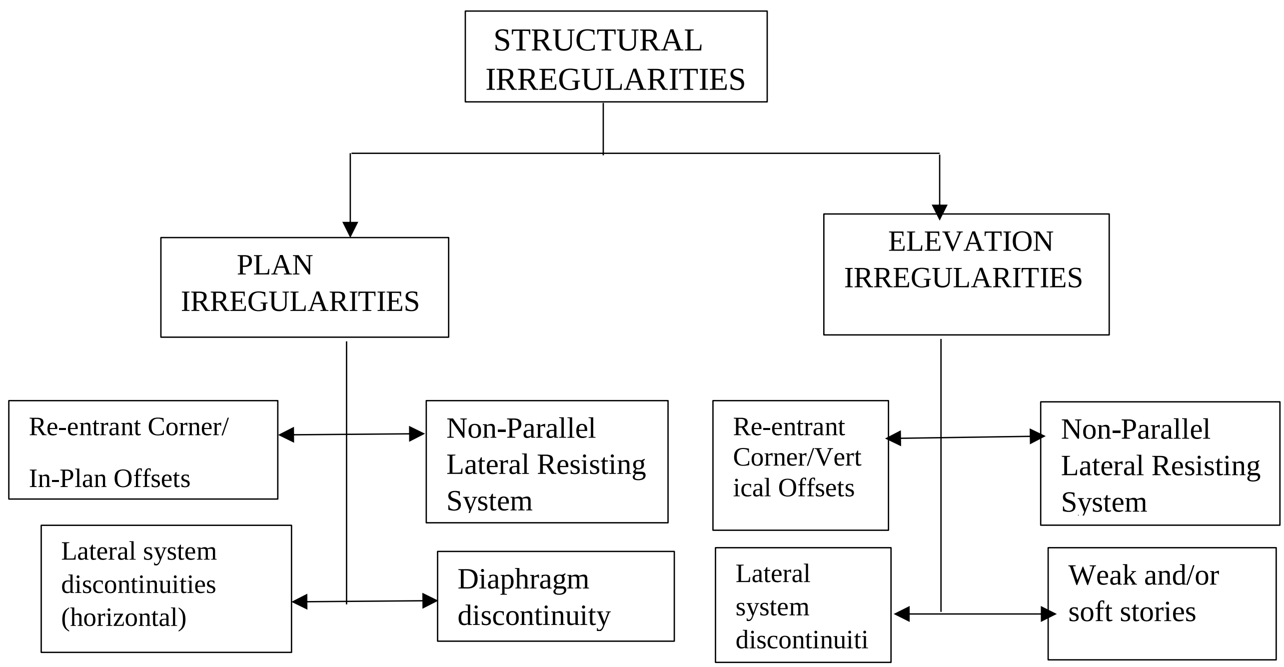


Figure 2:1 typical structural irregularities

Criteria for structural regularity in plan A building can be characterized as regular in plan if it meets all of the following numbered conditions, at all storey levels:

1. For two orthogonal horizontal axes the distribution in plan of the lateral stiffness and the mass is approximately symmetrical with respect. Along these two axes normally, the horizontal components of the seismic action are consequently applied. As absolute symmetry is not required, it depends on the designer to judge whether this criteria is met or not.

2. The outline of the structure in plan should have a closed configuration, delimited by convex polygonal line. What counts in this respect is the structure, as defined in plan by its vertical elements, and not the floor (including balconies and any other cantilevering parts). Any single reentrant corner or edge recess of the outline of the structure in plan should not leave an area between it and the convex polygonal line enveloping it which is more than 5% of the area inside the outline. For a rectangular plan with a single re-entrant corner or edge recess, this is equivalent to, for example, a recess of 20% of the parallel floor

dimension in one direction and of 25% in the other; or, if there are four such re-entrant corners or edge recesses, to, for example, a recess of 25% of the parallel floor dimension in both directions. L-, C-, H-, I- or X-shaped plans should respect this condition, in order for the structure to be considered as regular in plan.

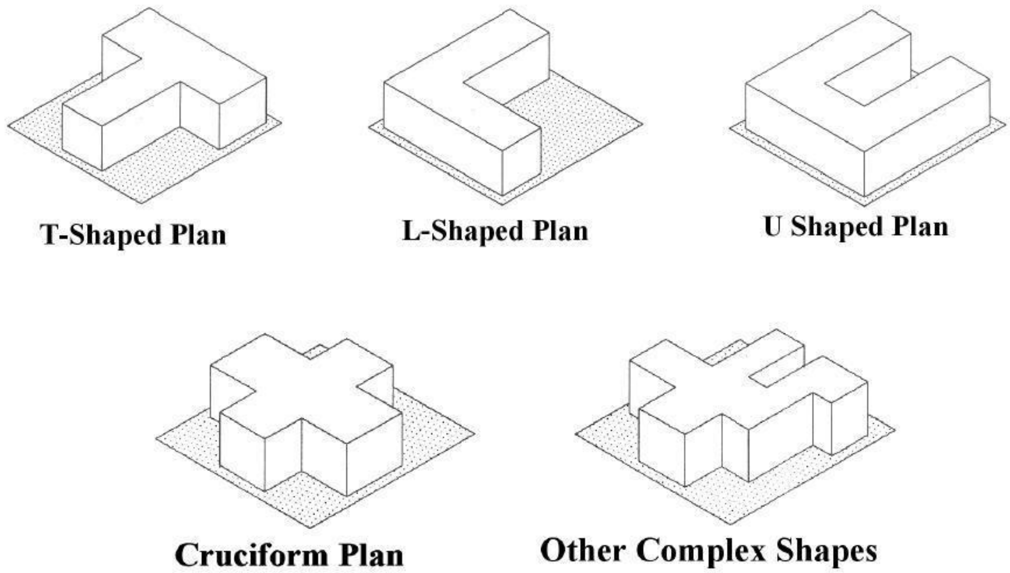


Figure 2:2Typical plan irregularities

3. It should be possible to consider the floors as rigid diaphragms, in the sense that there in plane stiffness is sufficiently large, so that the floor in-plan deformation due to the seismic action is negligible compared with the interstorey drifts and has a minor effect on the distribution of seismic shears among the vertical structural elements. Conventionally, a rigid diaphragm is defined as one in which, when it is modelled with its actual in-plane flexibility, its horizontal displacements due to the seismic action nowhere exceed those resulting from the rigid diaphragm assumption by more than 10% of the corresponding absolute horizontal displacements. However, it is neither required nor expected that fulfilment of this latter definition is computationally checked. For instance, a solid reinforced concrete slab (or cast-in-place topping connected to a precast floor or roof through a clean, rough interface or shear connectors) may be considered as a rigid diaphragm, if its thickness and reinforcement (in both horizontal directions) are well above the minimum thickness of 70 mm and the minimum slab reinforcement of Eurocode 2 (which is a Nationally Determined Parameter (NDP) to be specified in the National Annex to Eurocode 2) required in of EN 1998-1 for concrete diaphragms (rigid or not). For a

diaphragm to be considered rigid, it should also be free of large openings, especially in the vicinity of the main vertical structural elements. If the designer does not feel confident that the rigid diaphragm assumption will be met due to the large size of such openings and/or 0‘+/] the small thickness of the concrete slab, then he or she may want to apply the above conventional definition to check the rigidity of the diaphragm.

4. The aspect ratio of the floor plan, $\lambda = L_{max}/L_{min}$, where L_{max} and L_{min} are respectively the larger and smaller in-plan dimensions of the floor measured in any two orthogonal directions, should be not more than 4. This limit is to avoid situations in which, despite the in-plane rigidity of the diaphragm, its deformation due to the seismic action as a deep beam on elastic supports affects the distribution of seismic shears among the vertical structural elements.

5. In each of the two orthogonal horizontal directions, x and y, of near-symmetry according to condition 1 above, the ‘static’ eccentricity, e, between the floor centre of mass and the storey centre of lateral stiffness is not greater than 30% of the corresponding storey torsional radius, r: $e_x < 0.3r_x$ $e_y < 0.3r_y$

The torsional radius r_x in equation is defined as the square root of the ratio of (a) the torsional stiffness of the storey with respect to the centre of lateral stiffness to (b) the storey lateral stiffness in the (orthogonal to x) y direction; for r_y, the storey lateral stiffness in the (orthogonal to y) x direction is used in the denominator.

6. The torsional radius of the storey in each of the two orthogonal horizontal directions, x and y, of near-symmetry according to condition 1 above is not greater than the radius of gyration of the floor mass: $r_x \geq l_s$ $r_y \geq l_s$

2.2.3Structural Systems

The dynamic behavior of structures under earthquake actions is dependent upon the lateral resisting system employed. Construction materials and structural configurations differ widely in stiffness, strength and ductility; thus, different systems deform, resist actions and dissipate energy in various ways. To achieve satisfactory seismic performance, structural systems should possess: Adequate stiffness; Adequate strength; High ductility; High damping; high stability; high redundancy

2.2.4 Vertical load path: Vertical load and lateral seismic force resisting systems capable of transmitting inertial forces from the location of masses throughout the structure to the foundations.

Structures should be provided with Structures designed for vertical loads have very limited capacity to withstand horizontal loads. Weak lateral resisting systems and connections interrupt the load path. In framed structures, gravity and inertial loads generated at each storey are transmitted first to the beams by floor diaphragms (or slabs), then to columns and foundations. Load transfer properties of beam - to – column and column - to – foundation connections may alter the load path. Continuity between structural components is important for the safe transfer of the seismic forces to the. Failure of buildings during earthquakes is often due to the inability of their parts to work together in resisting lateral forces. (Amr S. Elnashai, (2008).)

2.3 Classification of diaphragm behavior The distribution of horizontal forces by the horizontal diaphragm to the various vertical lateral load resisting (VLLR) elements depend on the relative rigidity of the horizontal diaphragm and the VLLR elements. According to FEMA 273, floor diaphragms shall be classified as rigid, stiff and flexible. (Amr S. Elnashai, (2008).; Farzad Naeim, (2001)) (Anon, (1997))

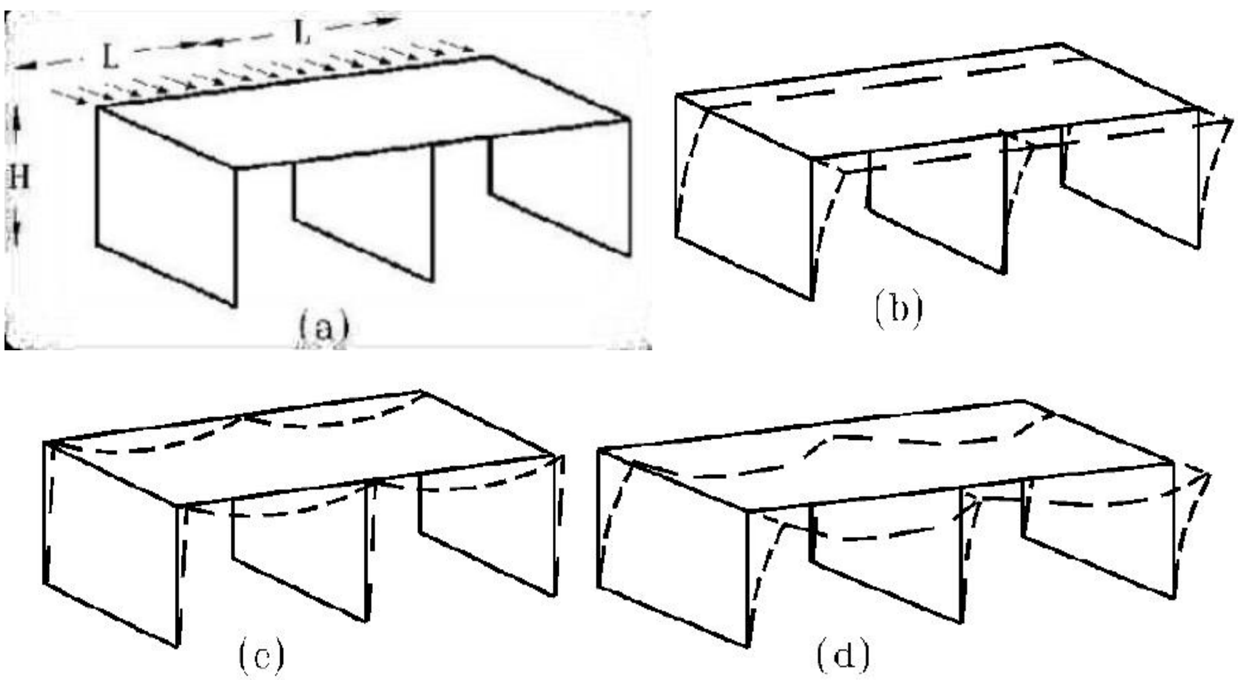


Figure 2.3: Diaphragm behavior

(a) Loading and building proportions. (b) Rigid diaphragm behavior. (c) Flexible diaphragm behavior, (d) Semi rigid diaphragm behavior

2.3.1. Rigid diaphragm Diaphragms shall be considered as rigid when the maximum lateral deformation of the diaphragm is less than half the average inter-story drift of the associated story.

Rigid diaphragm distributes the horizontal forces to the VLLR elements in proportion to their relative stiffness. It is based on the assumption that the diaphragm does not deform itself and will cause each vertical element to deflect the same amount. Rigid diaphragms capable of transferring torsional and shear deflections and forces are also based on the assumption that the diaphragm and shear walls undergo rigid body rotation and this produces additional shear forces in the shear wall. In rigid diaphragms, the diaphragm deflection when compared to that of the VLLR elements will be insignificant. Rigid diaphragms consist of reinforced concrete diaphragms, precast concrete diaphragms, and composite steel deck. (Amr S. Elnashai, (2008).)

2.3.2. Flexible diaphragm Diaphragms shall be considered as flexible when the maximum lateral deformation of the diaphragm along its length is more than twice the average inter-story drift of the story immediately below the diaphragm. For diaphragms supported by basement walls, the average inter-story drift of the story above the diaphragm may be used in lieu of the basement story. Flexible diaphragm distributes horizontal forces to the vertical lateral load resisting elements independent of relative stiffness of the VLLR element, and the lateral load distribution is according to the tributary area. In the case of a flexible diaphragm, the diaphragm deflection as compared to that of the VLLR elements will be significantly large. Flexible diaphragm distributes lateral loads to the VLLR elements as a series of simple beams spanning between these elements. Flexible diaphragm is not considered to be capable of distributing torsional and rotational forces. . Flexible diaphragms are - roofs or floors, including but not necessarily limited to, those sheathed with plywood, wood decking, or metal decks without structural concrete topping slabs. (Amr S. Elnashai, (2008).)

2.3.3. Stiff diaphragm No diaphragm is perfectly rigid or perfectly flexible. Reasonable assumptions, however, can be made as to a diaphragm's rigidity or flexibility in order to simplify the analysis. If the diaphragm deflection and the deflection of the VLLR elements are of the same order of magnitude, then the diaphragm cannot reasonably be assumed as either rigid or flexible. Diaphragms that are neither flexible nor rigid shall be classified as stiff. (Amr S. Elnashai, (2008).)

2.4 Structural response to a seismic action

2.4.1 Building drift

Drift is generally defined as the lateral displacement of one floor relative to the floor below. Drift control is necessary to limit damage to interior partitions, elevator and stair enclosures, glass, and cladding systems. Stress or strength limitations in ductile materials do not always provide adequate drift control, especially for tall buildings with relatively flexible moment-resisting frames or narrow shear walls. Total building drift is the absolute displacement of any point relative to the base. Adjoining buildings or adjoining sections of the same building may not have identical modes of response, and therefore may have a tendency to pound against one another. Building separations or joints must be provided to permit adjoining buildings to respond independently to earthquake ground motion. (Sreenath, J., Rao, H. S., &Ghorpade, V. G., n.d.)

Story drift is expressed as the difference of the deflections at the top and bottom of the story under consideration: this is also often expressed as a ratio between the deflection and the story, or floor-to floor height.

Drift limits serve to prevent possible damage to interior or exterior walls that are attached to the structure and which might be cracked or distorted if the structure deflects too much laterally, creating racking forces in the member.

Thus the IBC requires that drift be limited in typical buildings to between 0.02 and 0.01 times the building height, depending on the occupancy of the building. For a building that is 30 feet high, drift would be limited to between 3.6 inches and 7.2 inches depending on the building type. When the earthquake-induced drift is excessive, vertical members may become permanently deformed; excessive deformation can lead to structural and nonstructural damage and, ultimately, collapse. (vanVreden, 2006))

2.4.2 Natural period of vibration

The ground shaking during an earthquake contains a mixture of many sinusoidal waves of different frequencies, ranging from short to long periods. The time taken by the wave to complete one cycle of motion is called period of the earthquake wave. In general, earthquake shaking of the ground has waves whose periods vary in the range 0.03 - 33sec. Even within this range, some earthquake waves are stronger than the others. Intensity of earthquake waves at a particular building location depends on a number of factors, including the magnitude of the earthquake, the epicentral distance, the type of ground that the earthquake waves traveled through before reaching the location of interest and rigidity of the structure, flexible building undergoes larger relative horizontal displacements than rigid building. (Murty, (2004))

2.4.3 Lateral force distribution Floor diaphragms in reinforced concrete buildings are typically modeled as rigid during the design phase and so the effect of in-plane diaphragm flexibility on the structure is often not considered. For the rigid diaphragm model, the diaphragm has equal in-plane displacements along its entire length under lateral load such that horizontal forces are transferred to the vertical LLRS proportional to the relative stiffness of each frame. A flexible diaphragm, however, exhibits in-plane bending due to lateral load, resulting in additional horizontal displacements along its length. This can lead to damage of the diaphragm due to high flexural stresses along its boundaries. This flexibility also increases the lateral load transfer to frames that were not designed to carry these additional lateral loads based on a rigid diaphragm model. If this effect is sizeable, it can lead to overloading of structural elements (Biskinis, D. E., Roupakias, G. K., &Fardis, M. N. s.l. :,, (2004))

2.4.4 Base shear force Base shear is an estimate of maximum expected lateral force that will occur due to ground seismic motion at base of the structure. It depends on:-

- Soil condition at the site
- Potential source of seismic activity
- Level of building ductility nature
- Fundamental period of vibration
- Mass of building that expose to seismic The seismic base shear force Fb, for each horizontal direction in which the building is analyzed, shall be determined using the following expression:

$$F_b = S_d(T_1) \cdot m \cdot \lambda \quad \text{……………………………………………..(2.1)}$$

Where Sd (T1) is the ordinate of the design spectrum at period T1; T1 is the fundamental period of vibration of the building for lateral motion in the direction; m is the total mass of the building, above the foundation or above the top of a rigid basement λ is the correction factor, the value of which is equal to: $\lambda = 0{,}85$ if $T1 < 2$ TC and the building has more than two stories, or $\lambda = 1{,}0$ otherwise. (Piazza, (2008, October))

2.4.5 Story displacement Due to lateral load structure displace to horizontal direction but the magnitude of displacement depends on structure type, magnitude of lateral and nature of material which the structure made. The displacement of frame obtained from linear static pushover analysis used to understand the displacement capacity and stiffness capacity of building. At every deformation step, the plastic hinge location can determine and hinge state also shows.

2.5 Method of Structural Analysis

For seismic performance evaluation, a structural analysis of the mathematical model of the structure is required to determine force and displacement demands in various components of the structure. Several analysis methods are available to predict the seismic performance of the structures. These are:

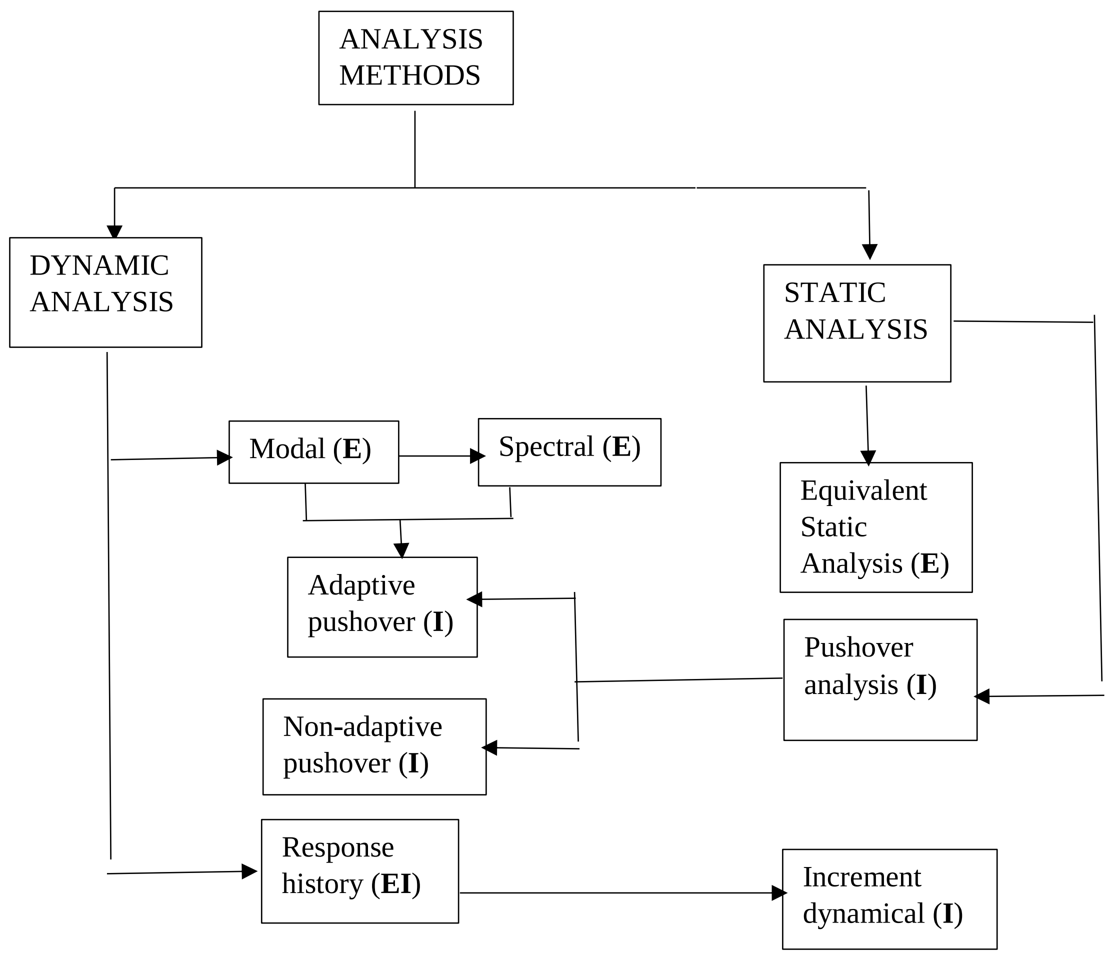


Figure2. 4 Common methods of structural analysis used in earthquake engineering

2.5.1 Equivalent static analysis

Equivalent static analysis (also referred to as equivalent lateral force, ELF method) is the simplest type of analysis that is used to assess the seismic response of structures. It is assumed that the behavior is linear elastic (which corresponds to material linearity), while geometrical non - linearity, i.e. second - order (P-Δ) effects, can be accounted for implicitly. The horizontal loads considered equivalent to the earthquake forces are applied along the height of the structure and are combined with vertical (gravity) loads. (Amr S. Elnashai, (2008).)

2.5.2Time history analysis

The inelastic time history analysis is the most accurate method to predict the force and deformation demands at various components of the structure. But the applicability of inelastic time history analysis is limited because the dynamic response is very sensitive to modeling and ground motion characteristics. It requires proper modeling of cyclic load-deformation characteristics considering the deterioration properties of all important components. Also, it requires the availability of a set of representative ground motion records that accounts for uncertainties and differences in severity, frequency and duration characteristics. Moreover, computation time, the time required for input preparation and interpreting voluminous output make the use of inelastic time history analysis impractical for seismic performance evaluation. Inelastic static analysis, or pushover analysis, has been the preferred method for seismic performance evaluation due to its simplicity. It is a static analysis that directly incorporates nonlinear material characteristics and geometric nonlinearity.

2.5.3 Pushover Analysis

Pushover analysis is a static nonlinear procedure using a simplified nonlinear technique to estimate seismic structural deformations. It is an incremental static analysis in case of force or displacement to determine the capacity curve of a structure. The analysis conducted through applying of horizontal loads in a well-defined pattern to the structure incrementally. Then plot the result in terms of base shear to displacement at each increment, until collapse condition (Oguz, 2011).

Most of the simplified nonlinear analysis procedures utilized for seismic performance evaluation make use of pushover analysis and/or equivalent SDOF representation of actual structure. However, pushover analysis involves certain approximations that the reliability and the accuracy of the procedure should be identified. For this purpose, researchers investigated various aspects of pushover analysis to identify the limitations and weaknesses of the procedure and proposed improved pushover procedures that consider the effects of lateral load patterns, higher modes and failure mechanisms

2.5.4 Response spectrum analysis

In this method linear dynamic analysis of the frame models are performed, the maximum response of the building is estimated directly from elastic or inelastic design spectrum characterizing the design earthquake for the site and considering the performance criteria of the building. Responses quantities like; storey displacement, storey drift, storey shear and modal period are carried out by checking their performance through response spectrum analysis

2.6 Gaps in Research Areas

Many types of research are done on effect of diaphragm discontinuity of reinforced concrete building with opening at the different floors level by using regular building. But there is no researches done on effect of diaphragm discontinuity on location, size and shape of different diaphragm discontinuity on the effect of seismic response of the U-shaped building. To see the effect seismic response two types of building are considered that is diaphragm with discontinuity and diaphragm without discontinuity of RC buildings. By considering this gap this research is done to determine the effect of diaphragm discontinuity due to location, shape and size on seismic load performance of RC building. In this research RC building with diaphragm discontinuity at a different location, shape and size is designed using ES-EN-2016 and Euro code8: 2004 by using ETABS 2019 software. Then Response spectrum analysis is done to evaluate the performance of buildings with the diaphragm discontinuity at different location, shape and size and comparison is drawn.

CHAPTER THREE

STRUCTURAL MODELLING AND ANALYSIS METHOD

3.1 Study area

Hosaina is one of the town of Ethiopia which is located at the SNNPR of Ethiopia and with an average altitude of 2177 ASL, (source from Google). Within the city there are different kinds of huge activities are done in addition to this a well-known Wachamo University. Hosaina town is located at latitude of 7.5083N and longitude of 37. 8562E.The seismic zone of the town is zone 3. The soil type of the area is deposits of very dense sand, gravel, or very stiff and classified as soil class B. The research conducted area classified seismic zone III and the ground type and other properties of the area will depend on the code (ES EN 2016).

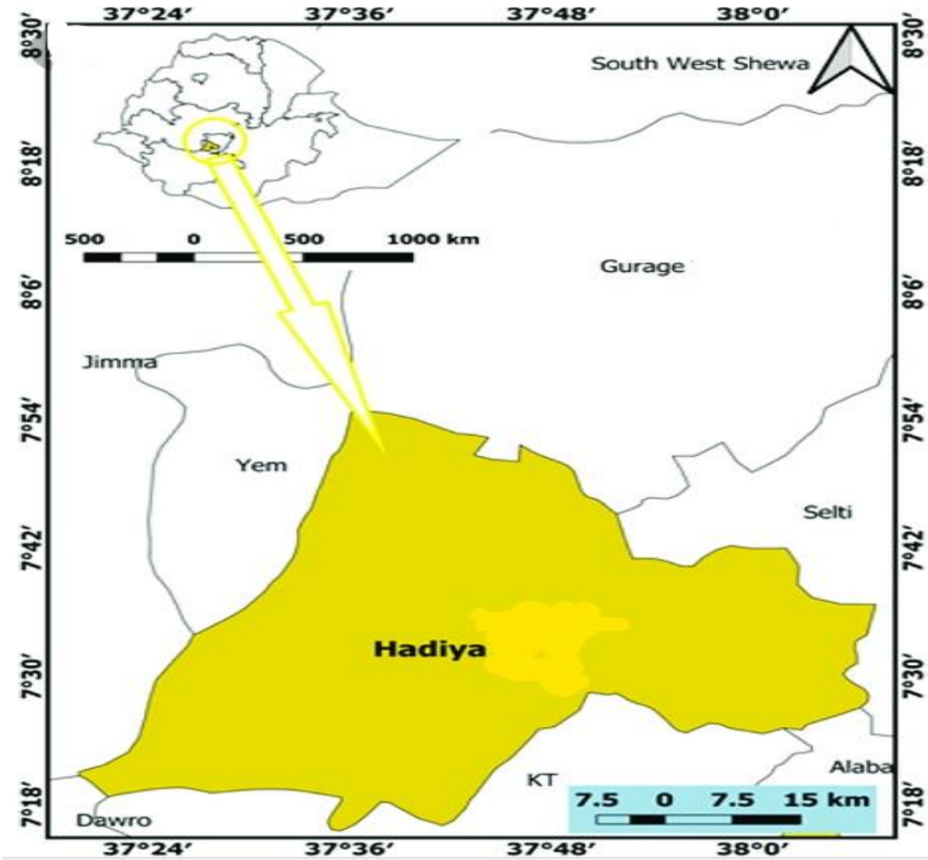


Figure 3. 1Map of Hossana town

3.2 Research design

There are various methods that can be used to conduct research and these can be either quantitative, qualitative or combination of both. Based on this, the paper has a quantitative nature (comparative). In order to achieve the objectives of this research linear dynamic (response spectrum) analysis for earthquake load has done on G+4 RC framed building with diaphragm discontinuity at different locations, size and shape on each building is designed and analyzed. The theoretical framework of effect of diaphragm discontinuity due to location, size and shape in RC building for evaluation seismic response of the building has done using Finite element software ETABS 2019 using response spectrum analysis. The following things are the basic research design producers have been used to achieve the objectives of the study.

- Review of existing literature by different researchers related to subject area of the study.
- Collecting of secondary data (allowed loads, material properties) available for modeling and design of the openings with the diaphragm discontinuity from written documents code books such as ES EN -2016 and Euro codes.
- Modeling and design of G+4 plan irregular building with diaphragm discontinuity and without diaphragm discontinuity RC moment-resisting frame with opening at different locations, size and shape was done according to ES EN-2016 and Euro Code 2004 using ETABS 2019 commercial software.
- Beams and columns are modeled as rigid joint frame elements.
- Modeling of openings is done by removing same size of slab area at a different location and shape case .But to compare the result of size of opening effect different area size is considered.
- After modeling and designing of G+4 building models Response spectrum analysis is demonstrated using the computer software ETABS 2019.

3.3 Study variables

3.3.1 Dependent variable

- Storey drift
- Storey displacement
- Base shear
- Storey force

3.3.2 Independent variable

- Shape of the diaphragm opening
- Opening Size of the diaphragm
- Location of the opening

3.4 Data Collection Processes

In this research G+4 RC framed building were analyzed for the effect of diaphragm discontinuity in seismic response of reinforced concrete u-shape building. Comparison is carried out between diaphragm with discontinuity and diaphragm without discontinuity is selected as for irregular with one side long and other side short (U) shaped plan that is selected to remove the symmetry of building without opening and with opening on different location, shape and size to investigate the effect of diaphragm discontinuity of building. All stories of each building have 3m height. Modeling will be done on the interface of ETABS 2019 building design and analysis software. In these models, the diaphragm discontinuity is located at different locations of the models to evaluate the effect of diaphragm discontinuity location on seismic performance. The research data have been collected from secondary source and code books which are briefly discussed below**.** Models and modeling producers also discussed.

Justification for the selection of the samples

The samples selected for this study are based on their numerously constructed in the world and specifically in Ethiopia. Also, the model selected should be simple to minimize the manipulation time for response spectrum in ETABS. When the modeling is complex the analysis complex and the output is unattainable.

3.5 Population and sampling method

The sampling size of this research take framed RC building G+4 buildings.

3.6 Sources of data

3.6.1 Primary data

This data obtained from analytical analysis by using ETABSv19.0 software.

3.6.2 Secondary data

This data also obtained from the literature review which related to this thesis, that is; Journals referred at literature review, Books like Taranath (2004), Arm S .Elnashia,L.D.S.(2008), Standard codes like Euro codes 2004 and ESEN-2016 and thesis paper to study area.

3.7 Data collection procedure

Data collection depend on the output required from the software and it required good interpretation of the outputs. Its procedure depend on the data required for data presentation and analysis.

3.8 Data presentation and analysis Data presented by in the form of table and for further it also presented using Microsoft excel options like graph, chart, figures etc.

Due attention and care is taken when extracting results from ETABS and plotting them in excel.

3.9 Data Quality Assurance

In order to assure data quality of this study the following measures are taken:

- The ETABS software is checked for the known simple structural systems to check whether it is working well or not.
- The structural modeling, the loading and the different connections of the frame system was checked
- In case of any unreliable results due to some unobserved errors, the structure is re-modeled and reanalyzed.
- A due attention and care is taken when extracting results from ETABS and plotting them in Excel.

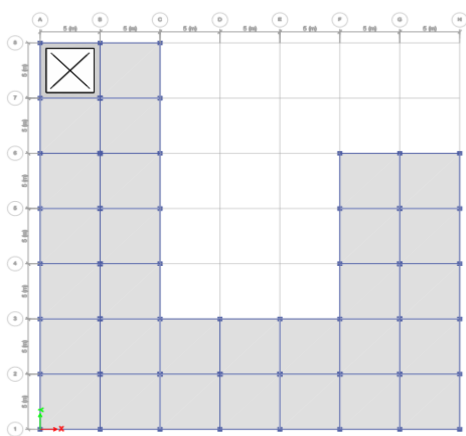
3.10. Modelling

A brief description of software's used in training ETABSv19.0: ETABS is an engineering software product that cater to multi-story building analysis and design. Modeling tools and templates, code-based load prescriptions, analysis methods and solution techniques, all coordinate with the grid-like geometry unique to this class of structure. Basic or advanced systems under static or dynamic conditions may be evaluated using ETABS. Intuitive and integrated features make applications of any complexity practical to implement. Interoperability with a series of design and documentation platforms makes ETABS a coordinated and productive tool for designs which range from simple 2D frames to elaborate modern high-rises. 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 graphic 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.

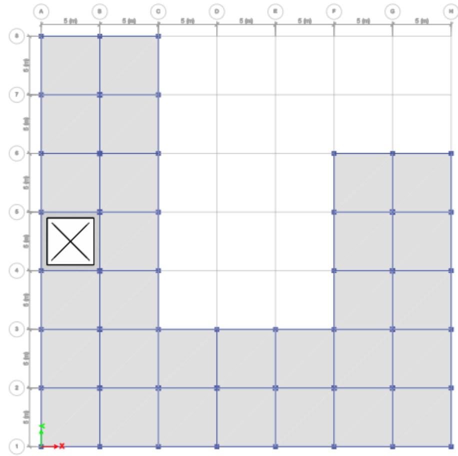
3.10.1Modelling description

It is very important to develop a mathematical model on which performance-based analysis is performed to determine the effect of diaphragm discontinuity location on RC buildings which is constructed in the seismic zone III region. The first part of this chapter presents a summary of various parameters defining the computational models, the basic assumptions and the geometry of the selected building considered for this study.

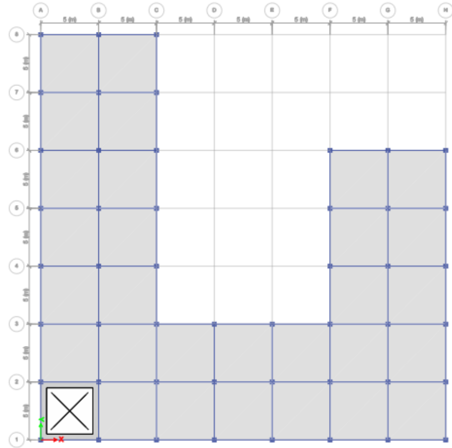
This thesis is based on linear response spectrum analysis of RC frames with diaphragm discontinuity and without diaphragm discontinuity. Different openings location size and shape were considered. The model were analyzed using six storey buildings with diaphragm discontinuity and without diaphragm discontinuity. The model plan dimension is 35m×35m. It is 7 bay of 5m in both x and y direction respectively. This chapter presents a summary of various parameters defining the computational models, the basic assumptions and the RC frame geometry considered for this study.



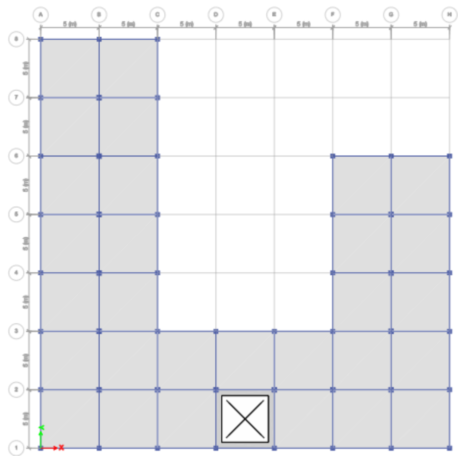
Model 2(M2)



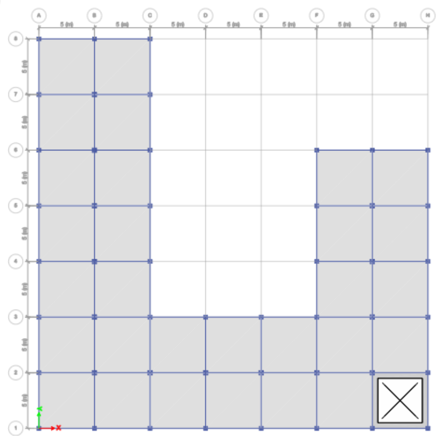
Model 3 (M3)



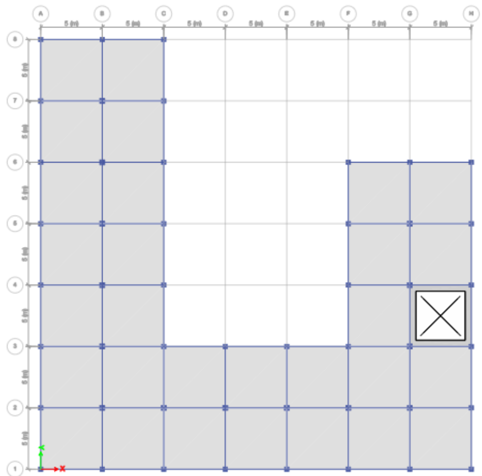
Model 4 (M4)

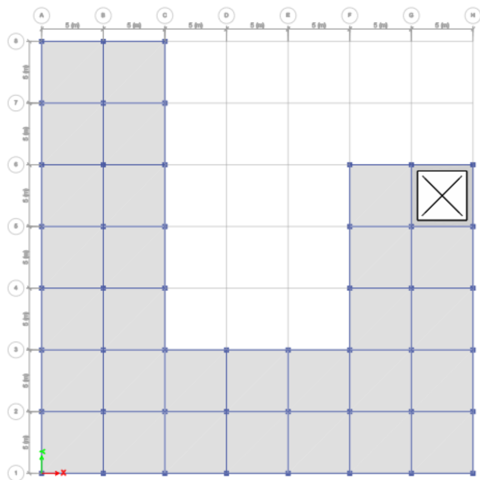


Model 5 (M5)



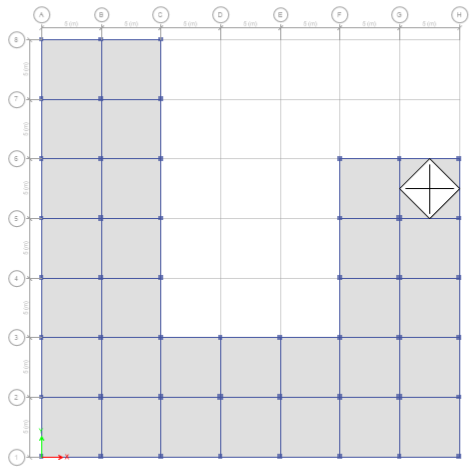
Model (M6)

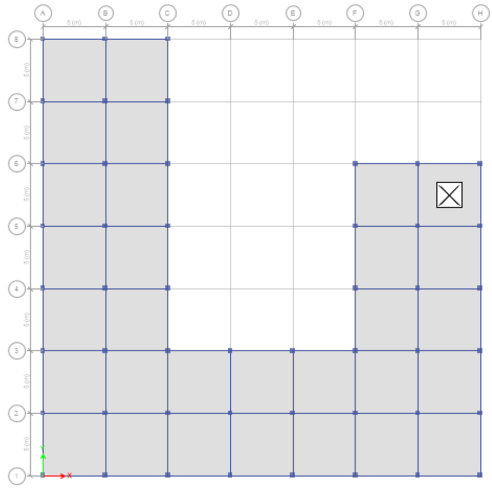




Model (M7)

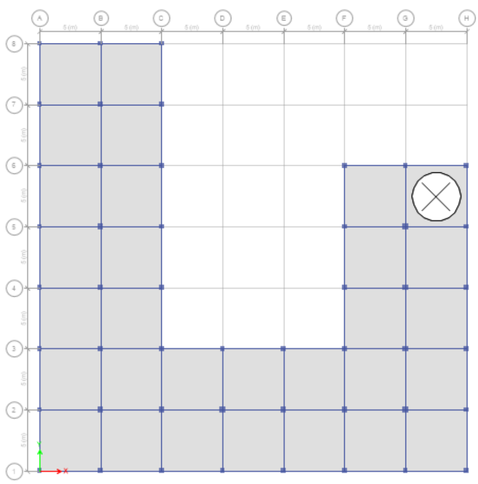
Model (M8)

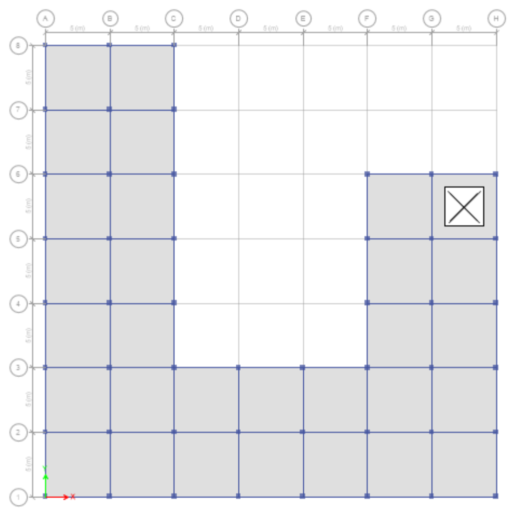




Model M2**

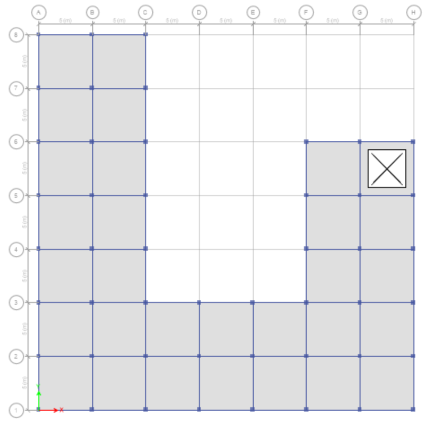
Model M3*





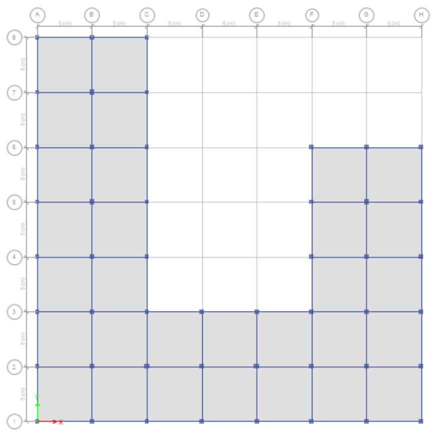
Model M2*

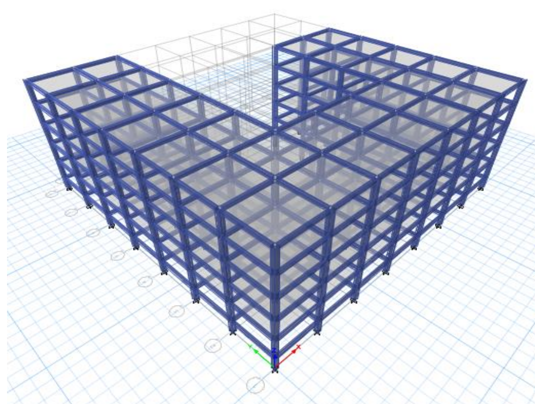
Model M1**



Model M1*

Figure 3. 2Different model of the plan view building with diaphragm discontinuity





Model 1 (M1) 3-D view of G+4 building

Figure3. 3 Building without diaphragm discontinuity

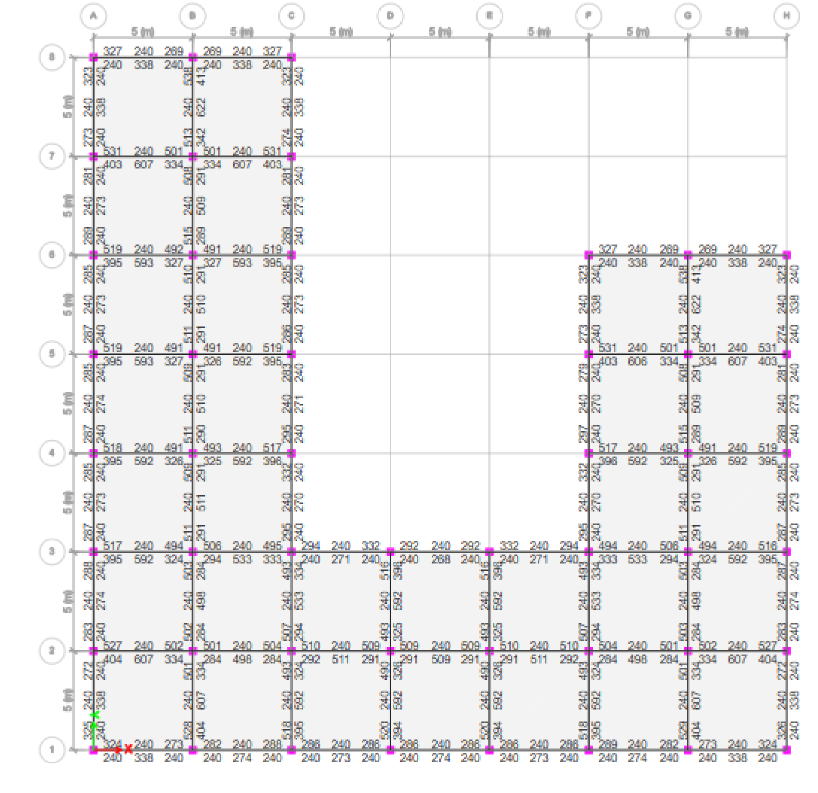


Figure3. 4 Sample designs of buildings in the plan view for regular plan model

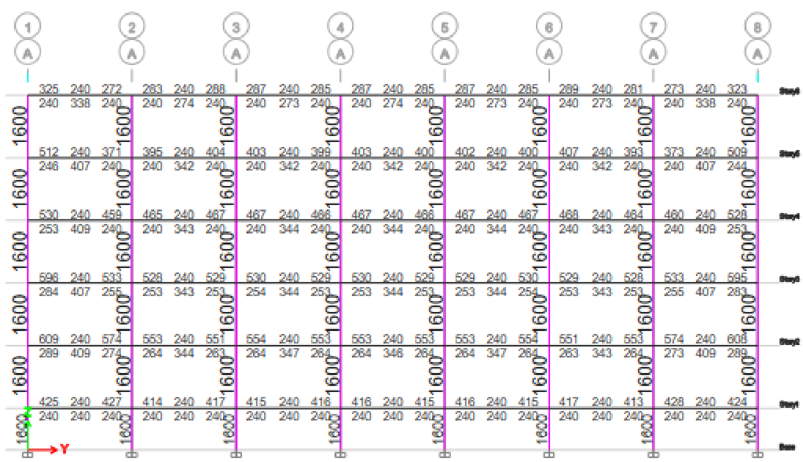


Figure3. 5Sample design of buildings in the elevation view of axis A

3.10.2 Building Description

G+4 rigid jointed frame of shopping use buildings irregular in plan (U- shape) with the provision of diaphragm discontinuity at different location ware selected in seismic Zone III region of Ethiopia. These Buildings designed based on Ethiopian Building Code Standard ESEN: 2016 has similarity to the European Code-2004 (as used by the software). ETABS 2019 was used for the analysis and design of the building by modeling as a 3-D frame system. Seismic performance is predicted by using performance-based analysis of simulation models of buildings with the provision of diaphragm discontinuity at different locations, shape and size.

Parametric studies of cases

Analysis result and set discussion on selected 13 representative structures that are categorized in three parametric studies are present hereafter.

Table 3. 1 List of parameters in each three case

Cases	Parametric study
Case-1	Opening position
Case-2	Opening size
Case-3	Opening shape

Detail structural and material description of building structures for this research are summarized in Table 3.2 below, which consists building code, opening location, Opening cross section(m), Opening shape and Building description. To verify the effect of diaphragm discontinuity 13 structures are chosen and analyzed as discussed in the Table below.

Table 3. 2 Structures for parametric study-number of story as parametric study.

Code	Opening location	Opening area(m)	Opening shape	Building description
M1	No	No	No	Without diaphragm discontinuity
M2	At y-axis to longer front edge	4*4	Square	With diaphragm discontinuity

M3	At y-axis to the center of longer side	4*4	Square	With diaphragm discontinuity
M4	At y-axis to the corner of longer side	4*4	Square	With diaphragm discontinuity
M5	At the center of x-axis	4*4	Square	With diaphragm discontinuity
M6	At the center of y-axis to the shorter side	4*4	Square	With diaphragm discontinuity
M7	At the corner of y-axis to the shorter side	4*4	Square	With diaphragm discontinuity
M8	At the front edge of y-axis to the shorter side	4*4	Square	With diaphragm discontinuity
M1*	At the front edge of y-axis to the shorter side	3.54*3.54	Rectangular	With diaphragm discontinuity
M2*	At the front edge of y-axis to the shorter side	Radius(R)=2	Circular	With diaphragm discontinuity
M3*	At the front edge of y-axis to the shorter side	Length(L)=3.54	Parallelogram	With diaphragm discontinuity
M1**	At the front edge of y-axis to the shorter side	3*3	Square	With diaphragm discontinuity
M2**	At the front edge of y-axis to the shorter side	2*2	Square	With diaphragm discontinuity

3.10.3 Structural Modeling Data

Modeling of buildings involves the modeling and assemblage of its various load-carrying elements. The model must ideally represent the mass distribution, strength and stiffness. Data required for modeling of buildings and loads applied for the study are discussed below.

Building Data

- Type of structure = G+4 RC frame
- Number of stories = 6 storey
- Floor to floor height = 3 m
- External wall thickness = 20cm
- Depth of the slab =15cm

Vertical and horizontal element system

Vertical and horizontal structural elements used for the parametric study is reinforced concrete frame system without any shear wall and bracing, which consists of reinforced concrete column as vertical element and beam as horizontal elements. In this research rectangular shape of structural elements (column and beam) are used.

Beam and Column sizes for all models

- Size of all floor columns = 40x40cm
- Size of all beams = 25×40cm

The following assumptions considered in this research.

- Modal damping 5% is considered.
- Beams and columns are modeled as frame elements and joined node to nodes.
- The effect of soil-structure interaction is ignored in the analysis. The columns are assumed to be fixed at the ground level.
- Plan dimension and beam size is kept similar to all Storey
- Beam column joints are taken as rigid joints
- Only the primary structural components and walls are assumed to participate in the overall seismic behavior.
- Ductility class medium only considered
- Geometric non –linearity (P- Δ) considered

To evaluate the response of selected building structure lots of design parameters are considered in ETABS software. In any software providing wrong data or missing single parameter gives wrong response. In this regard, careful considerations made in the input information where the basic design parameters are given in Table 3.3. Also sample drawing of 2D and floor plan view of each building structure are shown Figure 3.2-3.4.

Table 3. 3 Details of selected building structure

Building parameters	Details
Location where building construct	Hossaina
Usage	Shopping
Concrete	C25/30Mpa for column and C20/25Mpa for beam and slab structural members
Reinforcement bar	S400Mpa for longitudinal and S300 for confinement Rebar
Seismic zone	III
Slab thickness	150mm
Plinth level	0.6m
Wall load(line load in all beam)	14kN/m
Floor finish and part ion load	1.6kN/m2
Density of concrete	24kN/m3
Damping of structure	5 percent
Poisson ratio	0.2
Structural system of building	Moment resisting reinforced concrete frame fixed at

	Base
Size of diaphragm discontinuity	Constant size for all model but different for size effect
Geometry of building	Plan irregular
Ductility class	Medium(DCM)
Importance class of building	Class (II) and value of 1
Soil class	B

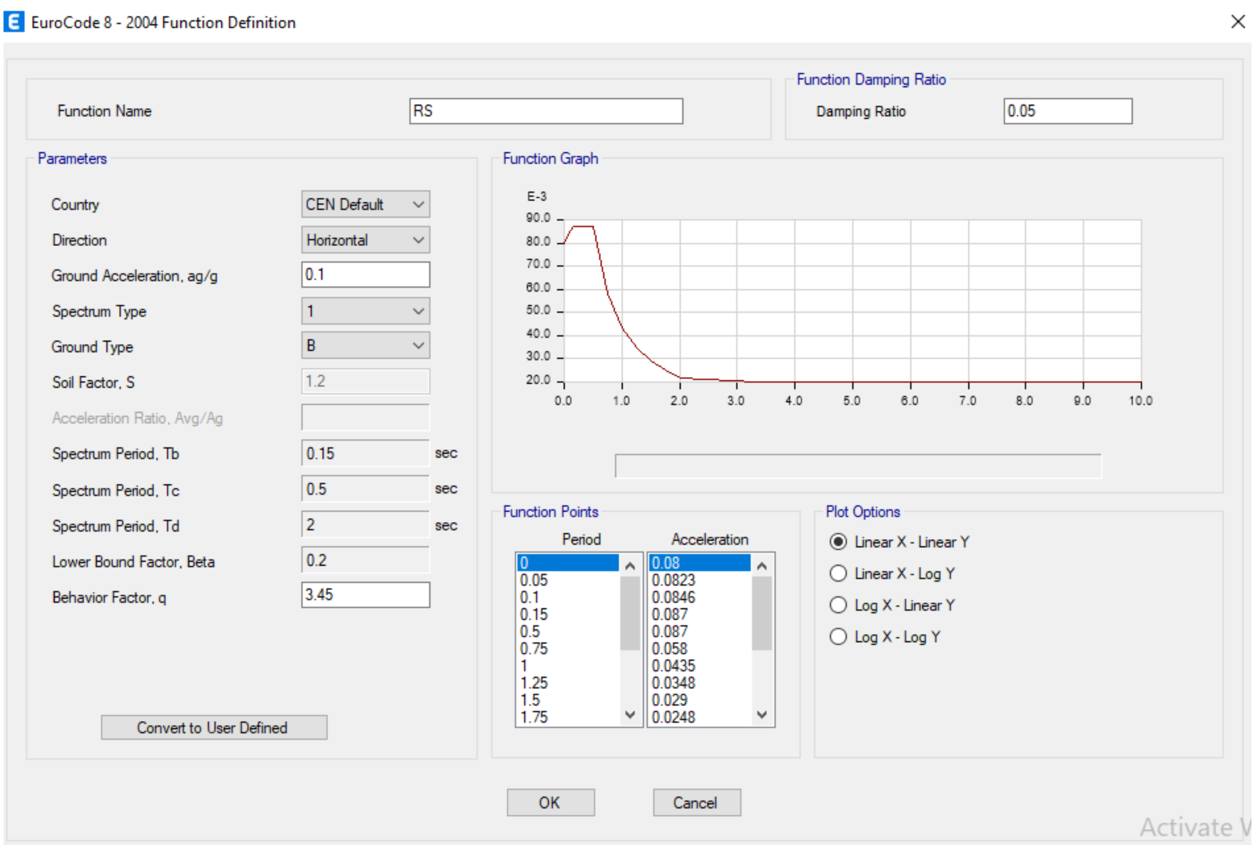


Figure3. 6 Input parameters for horizontal response spectrum Etabs

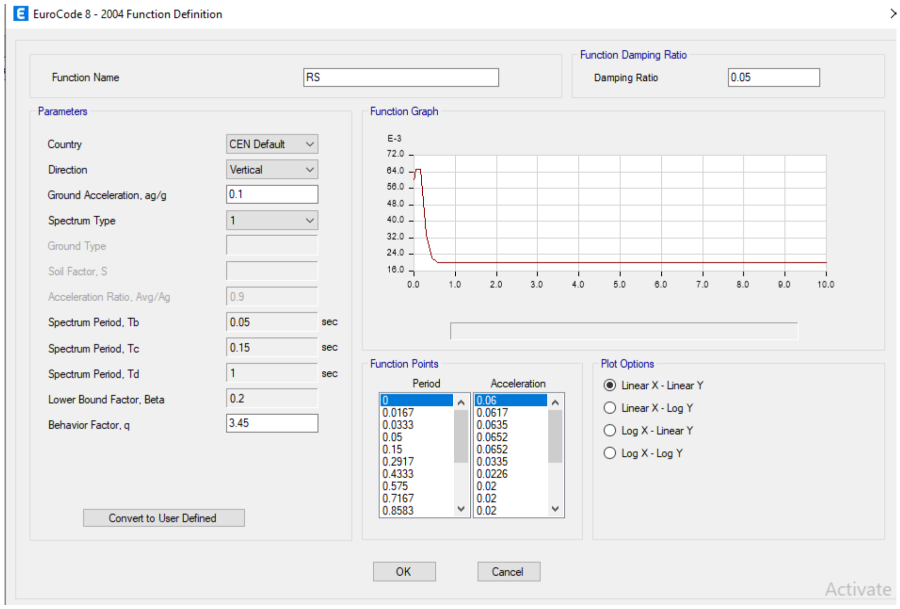


Figure3. 7Input parameters for vertical response spectrum Etabs

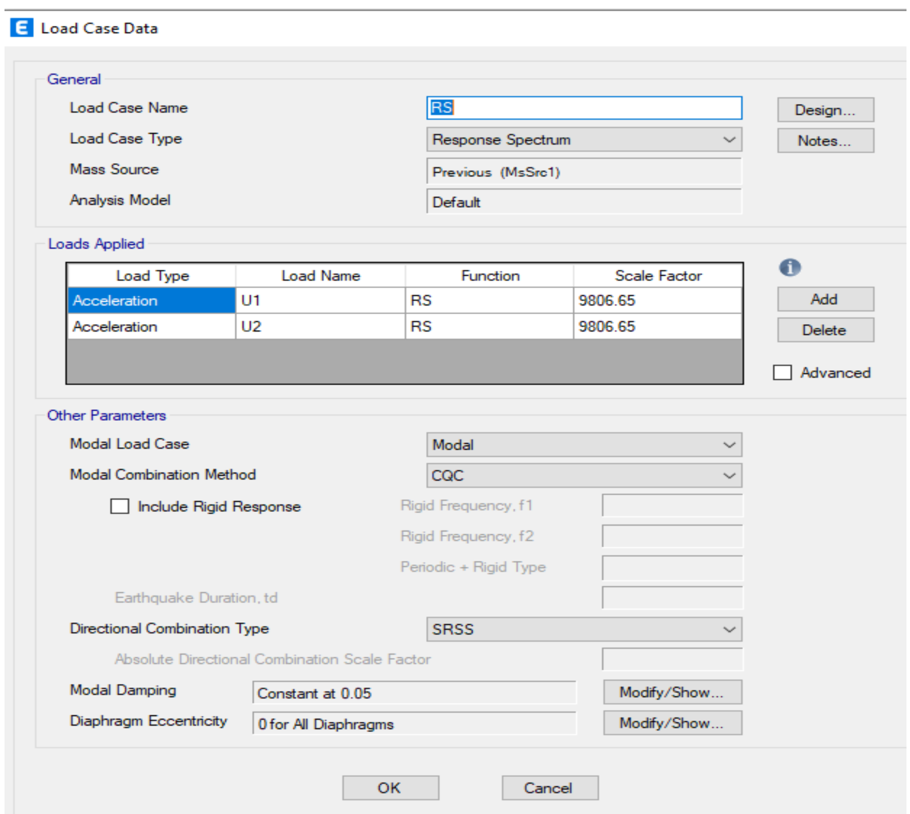


Figure3. 8 Input parameters for Modal load case in Etabs

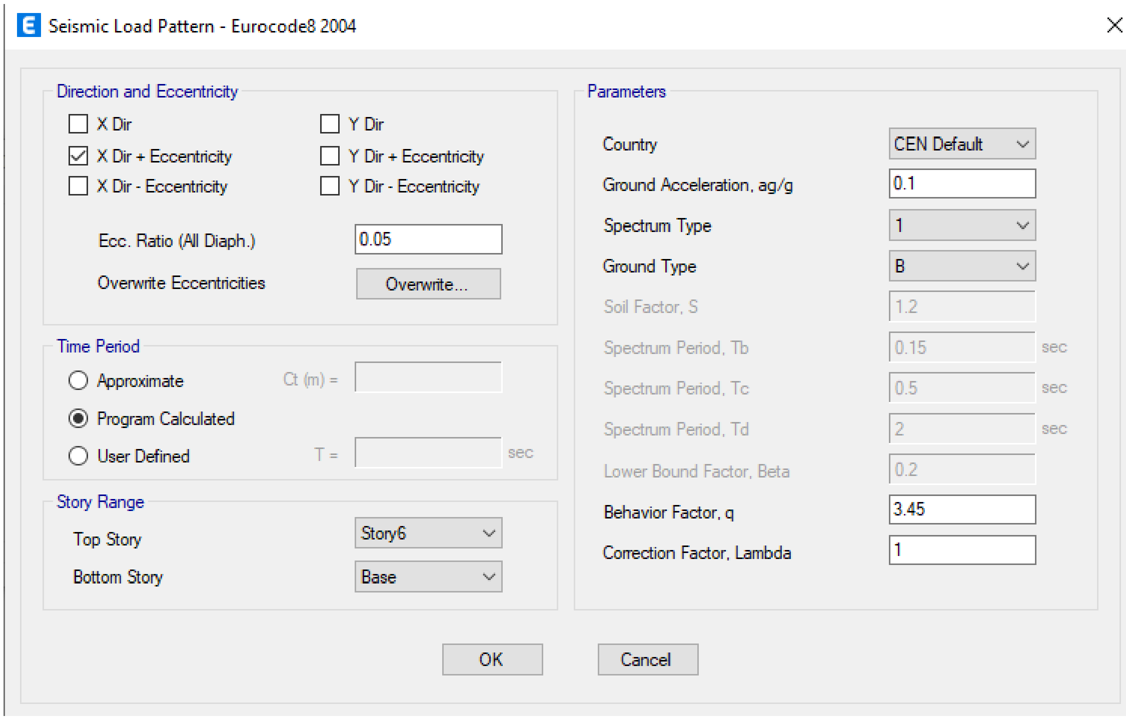


Figure3. 9 Sample Input seismic load pattern in etabs

3.10.4 Material properties

Normal-weight concrete (24kN/m3) with a characteristic cube compressive strength of 30MPa and cylindrical strength of 25Mpa for column and a characteristic cube compressive strength of 25MPa and cylindrical strength of 20Mpa for beam and slab yield strength of 400MPa for longitudinal reinforcement and300MPa for shear reinforcement are used.

3.10.5 Loading

Uniform live load of 4kN/m^2 (assumed building service for shopping) and partition wall load and floor finishing (marble finishing) dead load of 1.6kN/m^2, wall load on beam (line dead load) 14kN/m, and also permanent dead load of the structure is computed using the software using unit weight of concrete**.**

3.10.6 Seismic load Data

The seismic load parameter at each zones described in ES EN 1998:1-2016.acordingle to this guideline the seismic hazard map is divided in to 5 zones, where the ratio of the design bedrock acceleration to the acceleration of gravity for the respective zone indicated below.

Table 3. 4 Bed rock Acceleration Ratio ao

Zone	5	4	3	2	1	0
ao =ag/g	0.2	0.15	0.1	0.07	0.04	0

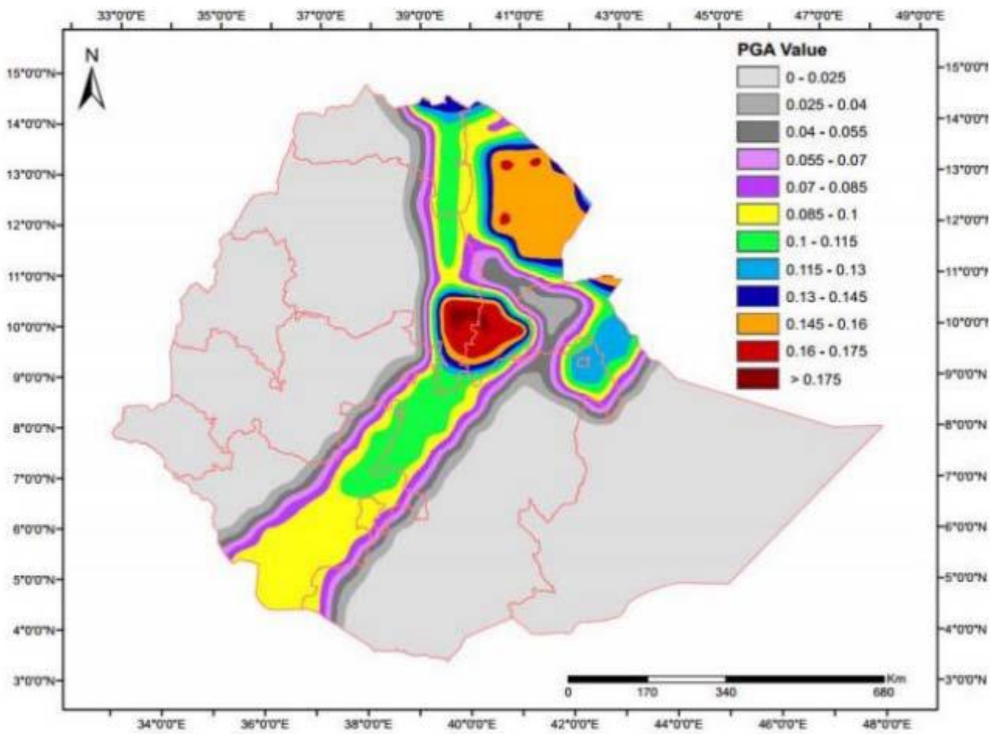


Figure3. 10 Ethiopia's Seismic hazard map in terms of peak ground acceleration

In linear analysis and design of building to find seismic design force for we use, type 1 elastic response spectrum, also the values of parameter are shown below.

The following data are taken to consider earthquake load in the seismic Zone 3 region of Ethiopia recommended by ES EN 1998-2016.

Table 3. 5 Seismic load data and factors

Earthquake Data	
bedrock acceleration ratio (**αo** =ao/g) (ratio of design bedrock acceleration to acceleration of gravity)	0.1g
Design PGA	1*0.1g = 0.1g
Behavior factor, q	3.45
Spectrum type	I

3.11 Basic representation of the seismic action

Within the scope of ES EN 1998:2016 the earthquake motion at a given point on the surface is represented by an elastic ground acceleration response spectrum, henceforth called an "elastic response spectrum". The shape of the elastic response spectrum is taken as being the same for the two levels of seismic action introduced in ES EN 1998-1, 2016 Section 2.1(1) P and 2.2.1(1) P for the no-collapse requirement (ultimate limit state – design seismic action) and for the damage limitation requirement. The horizontal seismic action is described by two orthogonal components assumed as being independent and represented by the same response spectrum. For the three components of the seismic action, one or more alternative shapes of response spectra may be adopted, depending on the seismic sources and the earthquake magnitudes generated from them. When the earthquakes affecting a site are generated by widely differing sources, the possibility of using more than one shape of spectra should be considered to enable the design seismic action to be adequately represented. In such circumstances, different values of ag will normally be required for each type of spectrum and earthquake. For important structures ($\gamma I > 1$) topographic amplification effects should be taken into account

3.11.1 Horizontal elastic response spectrum For the horizontal components of the seismic action, the elastic response spectrum Se(T) is defined by the following expressions (see Figure. 3.1):

$0 \leq T \leq T_B$: $Se(T) = a_g \cdot S \cdot [1+\frac{T}{TB} \cdot (\eta \cdot 2.5 - 1)]$ 3.1

$T_B \leq T \leq T_C$: $Se(T) = a_g \cdot S \cdot \eta \cdot 2.5$ 3.2

$T_C \leq T \leq T_D$: $Se(T) = a_g \cdot S \cdot \eta \cdot 2.5 [\frac{TC}{T}]$ 3.3

$T_C \leq T \leq T_D$: $Se(T) = a_g \cdot S \cdot \eta \cdot 2.5 [\frac{TCTD}{T^2}]$ 3.4

Where

Se (T) is the elastic response spectrum;

T is the vibration period of a linear single-degree-of-freedom system;

ag is the design ground acceleration on type

A ground (ag = γI·agR);

TB is the lower limit of the period of the constant spectral acceleration branch;

TC is the upper limit of the period of the constant spectral acceleration branch;

TD is the value defining the beginning of the constant displacement response range of the spectrum;

S is the soil factor;

η is the damping correction factor with a reference value of η = 1 for 5% viscous damping, see (3) of this subclause.

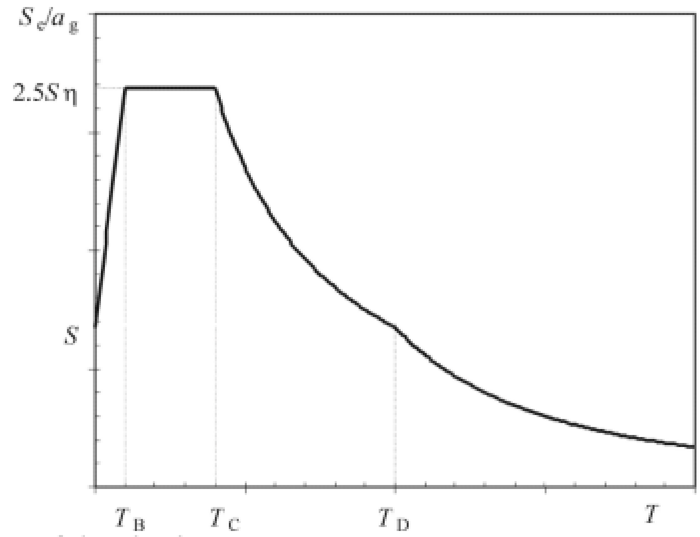


Figure 3. 11: Shape of the elastic response spectrum

Source Figure 3.1 of EBCS EN 1998-1, 2016 The values of the period TB, TC and TD and of the soil factor S describing the shape of the elastic response spectrum depend upon the ground type.

Table 3. 6: Values of the parameters describing the recommended Type 1 elastic response spectra

Ground type	S	$T_{B(S)}$	$T_{C(S)}$	$T_{D(S)}$
A	1	0.05	0.25	1.2
B	1.35	0.05	0.25	1.2
C	1.5	0.1	0.25	1.2
D	1.8	0.1	0.3	1.2
E	1.6	0.05	0.25	1.2

Source Table 3.2 of EBCS EN 1998-1, 2014

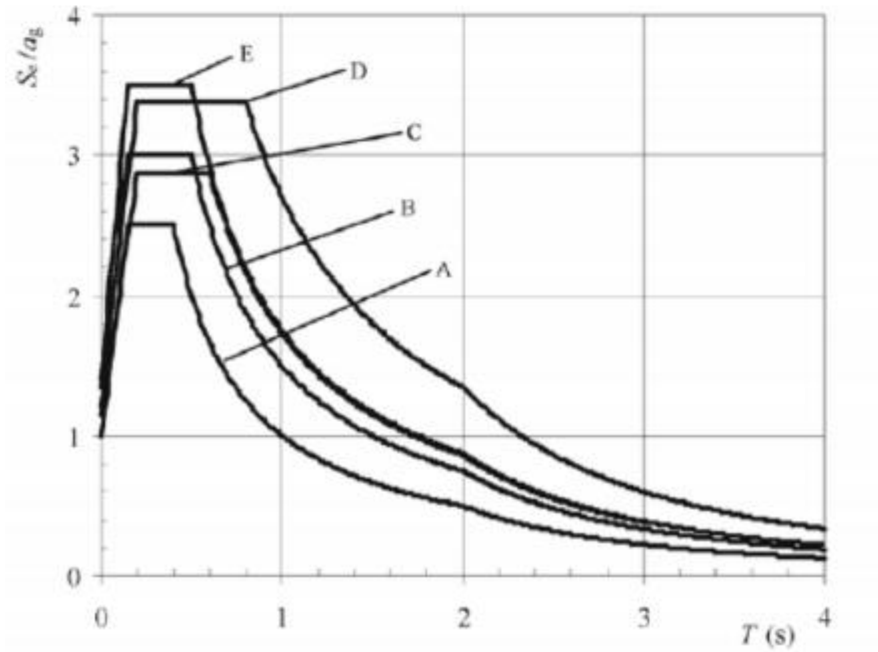


Figure 3. 12: Recommended Type 1 elastic response spectra for ground types A to E (5% damping)

Source Figure 3.2 of EBCS EN 1998-1, 2016

The value of the damping correction factor η may be determined by the expression:

$$\eta = \sqrt{10/(5+\xi)} \geq 0.55 \qquad (3.5)$$

Where ξ Is the viscous damping ratio of the structure, expressed as a percentage. If for special cases a viscous damping ratio different from 5% is to be used, this value is given in the relevant Part of EBCS EN 1998. The elastic displacement response spectrum,

SDe(T), shall be obtained by direct transformation of the elastic acceleration response spectrum, Se(T), using the following.

3.11.2 Vertical elastic response spectrum

The vertical components of the seismic action shall be represented, by an elastic response spectrum $S_{ve}(T)$ is drived by the following expressions (see Figure. 3.1):

$0 \leq T \leq T_B$: $S_{ve}(T) = a_{vg}.\,[1+\frac{T}{TB}.\,(\eta.3.0-1)]$ 3.6

$T_B \leq T \leq T_C$: $S_{ve}(T) = a_{vg}.\eta.3.0$ 3.7

$T_C \leq T \leq T_D$: S_{ve} (T) =$a_{vg}.\eta.$ 3.0 [$\frac{TC}{T}$] 3.8

$T_C \leq T \leq T_D$: S_{ve} (T) =$a_{vg}.\eta.$ 3.0 [$\frac{TCTD}{T^2}$] 3.9

Table 3. 7: Values of the parameters describing the recommended vertical elastic response spectra

Spectrum	$^{avg}/_{ag}$	$T_{B(S)}$	$T_{C(S)}$	$T_{D(S)}$
Type 1	0.90	0.05	0.15	1.0
Type 2	0.45	0.05	0.15	1.0

Source: Table 3.4 of EBCS EN 1998-1, 2016

3.12 Importance Factors Factor and Behavior Factors

3.12.1 Behavior factor for horizontal seismic action

The purpose defining behavior factor, to avoid explicit inelastic structural analysis in design, the capacity of the structure to dissipate energy, through mainly ductile behavior of its elements and/or other mechanisms, is taken into account by performing an elastic analysis based on a response spectrum reduced with respect to the elastic one, henceforth called a "design spectrum". This reduction is accomplished by introducing the behavior factor q. The value of behavior factor define by the following equation

q= qo kw (3.6)

Where;

qo=is the basic value of the behavior factor, dependent on the type of the structural system and on its regularity in elevation

kw= is the factor reflecting the prevailing failure mode in structural systems with walls.

Concrete buildings designed in accordance with are classified in two ductility classes DCM (medium ductility) and DCH (high ductility), depending on their hysteretic dissipation capacity. Both classes correspond to buildings designed, dimensioned and detailed in accordance with specific earthquake resistant provisions, enabling the structure to develop stable mechanisms associated with large dissipation of hysteretic energy under repeated reversed loading, without suffering brittle failures.

Table 3. 8 Basic value of behavior factor, qo, for regular in elevation

Structural type	DCM	DCH
Frame system, dual system, coupled wall system	$3.0\alpha_u/\alpha_1$	$4.5\alpha_u/\alpha_1$
Uncoupled wall system	3.0	$4.0\alpha_u/\alpha_1$
Torsion ally flexible system	2.0	3.0
Inverted pendulum system	1.5	2.0

But in this research studies the lateral force resisting mechanism of models used frame system and plan irregular. For buildings which are not regular in plan the approximate value of α_u/α_1 that may be used when calculations are not performed for its evaluation are equal to the average of 1.0 and 1.3 therefore for ductility class medium $\alpha_u/\alpha_1=1.15$, behavior factor, q=3*1.15=3.45(ES EN 1998:1-2016)

3.12.2 Importance classes and importance factors

Buildings are classified in 4 importance classes, depending on the consequences of collapse for human life, on their importance for public safety and civil protection in the immediate post-earthquake period, and on the social and economic consequences of collapse. The importance factor γ_I = 1.0 is associated with a seismic event having the reference return period indicated in EBCS EN 1998-1, 2016 Section 3.2.1(3). The definitions of the importance classes are given in Table 4.3.

Table 3. 9: Importance classes for buildings

Importance class	Buildings
I	Buildings of minor importance for public safety, e.g. agricultural buildings, etc.
II	Ordinary buildings, not belonging in the other categories.
III	Buildings whose seismic resistance is of importance in view of the consequences associated with a collapse, e.g. schools, assembly halls, cultural institutions etc.

IV	Buildings whose integrity during earthquakes is ofv vital importance for civil protection, e.g. hospitals, fire stations, power plants, etc.

Source Table 4.3 of EBCS EN 1998-1, 2016

The value of γI for importance class II shall be, by definition, equal to 1.0. The recommended values of γI for importance classes I, III and IV are equal to 0.8, 1.2 and 1.4, respectively.

CHAPTER FOUR

ANALYSIS, RESULT AND DISCUSSION

The results of this study are presented and described by tables and plotting the graph for each models considered in the study. The analysis carried out by the response spectrum analysis. The result maximum storey drift, maximum roof displacements and base shear are presented for all models. In this study diaphragm with opening and diaphragm without opening buildings output are compared.

4.1 Discussion on lateral displacement

4.1.1 Discussion on lateral displacement for slab open down position as a parametric case

From the tables and graphs plotted below the lateral displacement results as been discussed as follow. Figure 4.1 to 4.6 shows that the maximum lateral displacement for seismic load for discontinues and continues U-shape floor plan case respectively at different storey level. The lateral displacements of the structures for various opening systems have been compared. The percentage reduction in top story displacement of all diaphragm with discontinuity types with respect to diaphragm without discontinuity frame of all storied shown below in table 4.1 to 4.12 for discontinues and continues U-shape floor plan with different opening cases.

4.1.1.1 Top storey displacement comparison X-direction (mm)

Lateral storey displacement for location of opening case along x-direction

Table 4. 1: Lateral storey displacement for location of opening case along x-direction

Lateral Displacement (mm) X								
Story	M1	M2	M3	M4	M5	M6	M7	M8
Story6	4.05	3.877	3.98	4.162	4.129	4.008	4.136	3.787
Story5	3.69	3.533	3.628	3.794	3.764	3.653	3.77	3.451
Story4	3.08	2.947	3.026	3.165	3.14	3.047	3.145	2.878
Story3	2.24	2.143	2.2	2.302	2.284	2.216	2.288	2.092
Story2	1.24	1.189	1.221	1.278	1.268	1.23	1.27	1.16
Story1	0.29	0.278	0.283	0.293	0.292	0.285	0.292	0.276
Base	0	0	0	0	0	0	0	0

Table 4.2: Percentage reduction comparison of top storey displacement for opening position case X-direction

Discontinuity Type	Storey displacem	% change compared to M1
Diaphragm without discontinuity(M1)	4.05	
Opening at y-longer front edge(M2)	3.877	4.27% (reduction)
Opening at y-longer center(M3)	3.98	1.73% (reduction)
Opening at y-longer corner(M4)	4.162	2.77% (increment)
Opening to x-direction(M5)	4.129	1.95% (increment)
Opening To y-shorter center(M6)	4.008	1.03% (reduction)
Opening To y-shorter corner(M7)	4.136	2.12% (increment)
Opening to y-shorter front edge(M8)	3.787	6.49% (reduction)

Lateral storey displacement for position of opening as parametric case *(X)*

Table 4.3: Lateral storey displacement for position of opening as parametric case (Y)

Lateral Displacement (mm) Y								
Story	MI	M2	M3	M4	M5	M6	M7	M8
Story6	3.708	3.782	3.781	3.822	3.68	3.619	3.638	3.604
Story5	3.39	3.458	3.457	3.494	3.364	3.311	3.329	3.298
Story4	2.835	2.893	2.892	2.923	2.813	2.772	2.787	2.761
Story3	2.07	2.112	2.111	2.133	2.053	2.026	2.036	2.017
Story2	1.154	1.177	1.177	1.189	1.144	1.131	1.136	1.126
Story1	0.274	0.277	0.276	0.278	0.271	0.269	0.27	0.269
Base	0	0	0	0	0	0	0	0

4.1.1.2 Top storey displacement comparison Y-direction (mm)

Table 4. 2 Percentage reduced of opening position case building top storey displacement comparison Y-direction

Discontinuity Type	Diaphragm without discontinuity(M1)	Opening at y-longer front edge(M2)	Opening at y-longer center(M3)	Opening at y-longer corner(M4)	Opening to x-direction(M5)	Opening To y-shorter center(6)	Opening To y-shorter corner(M7)	Opening to y-shorter front edge(M8)
Storey displacem	3.708	3.782	3.781	3.822	3.68	3.619	3.638	3.604
% change compared to M1		2% (increment)	1.97% (increment)	3.07% (increment)	0.76% (reduction)	2.4% (reduction)	1.89% (reduction)	2.8% (reduction)

Maximum lateral displacement direction (X)

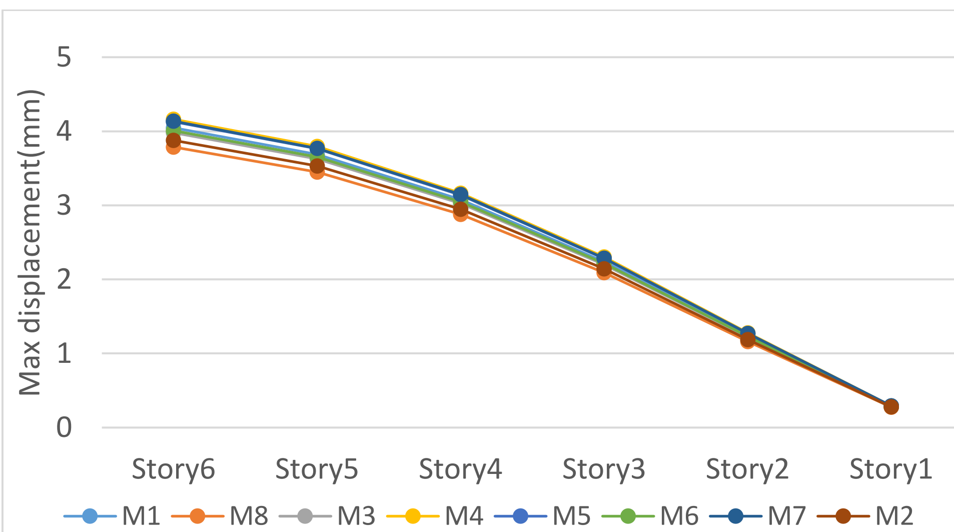


Figure 4. 1: Maximum lateral displacement direction (X)

Maximum lateral displacement direction (y)

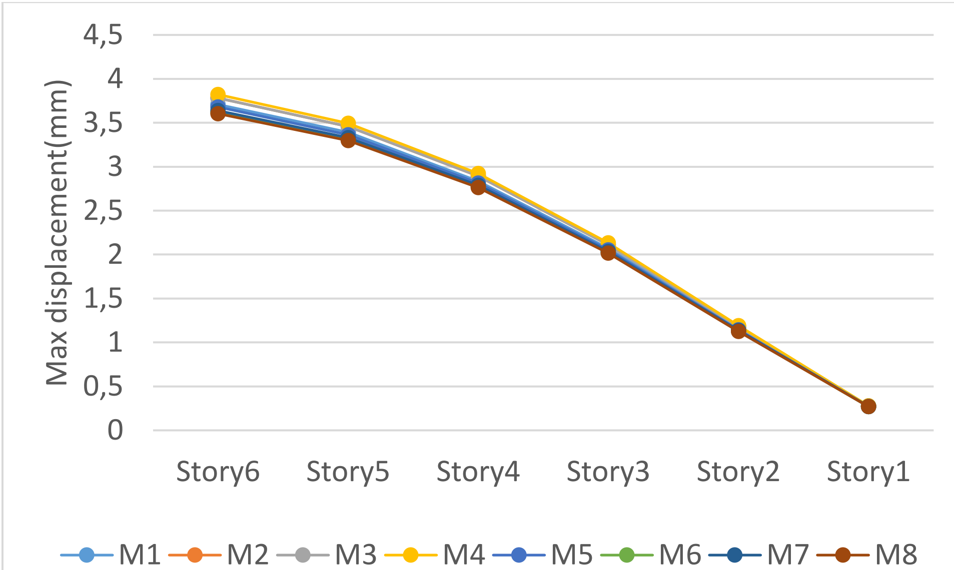


Figure 4. 2: Maximum lateral displacement (Y) direction

From figure 4.1, 4.2 shown that the storey displacement of opening at y-shorter front edge are lower that of no opening building reinforced frame. Opening at Y-shorter front edge frames (M8) showed the maximum reduction storey displacement as compared to other frames shown figure above. Opening at Y-shorter front edge reduce top storey displacement by 6.50% and 2.80% in the X and Y direction respectively. As discussed above the storey displacement for opening to shorter front edge plan model frame are the more efficient location type by reduction of top storey displacement for this specific model.

The lateral displacement drastically reduced after the application of opening systems. Maximum reduction in the lateral displacement is observed for the opening at front edge of y-longer direction of diaphragm discontinuity. Since it is selected position to compare the effect of diaphragm discontinuity seismic response of u-shaped for other cases of models. As the number of storey of building increase the rate of reduction of displacement decrease in a little amount.

4.1.2 Discussion on lateral displacement for slab open down size as a parametric case

Displacement along x-direction

Table 4. 3: Lateral storey displacement along x-direction for opening size case

Lateral Displacement x (mm)				
Story	M1 (no opening)	M2** (2*2)	M1** (3*3)	M8 (4*4)
Story6	4.047	3.989	3.937	3.877
Story5	3.689	3.636	3.588	3.533
Story4	3.077	3.033	2.993	2.947
Story3	2.238	2.206	2.177	2.143
Story2	1.242	1.225	1.208	1.189
Story1	0.288	0.285	0.282	0.278
Base	0	0	0	0

Displacement along y-direction

Table 4. 4: Lateral storey displacement along y-direction for opening size case

Lateral Displacement y(mm)				
Story	M1 (no opening)	M2** (2*2)	M1** (3*3)	M8 (4*4)
Story6	3.708	3.635	3.604	3.573
Story5	3.39	3.324	3.2968	3.269
Story4	2.835	2.78	2.761	2.737
Story3	2.07	2.03	2.017	2
Story2	1.154	1.132	1.126	1.116
Story1	0.274	0.27	0.269	0.268
Base	0	0	0	0

4.1.2.1 Top storey displacement comparison X-direction (mm)

Table 4. 5: Percentage reduced of opening size case building top storey displacement comparison

Discontinuity Type	M1(no opening)	M2** (2*2)	M1** (3*3)	M8 (4*4)
Storey displacement(mm)	4.05	3.989	3.937	3.877
% change compared to M1		1.51%	2.8%	4.27%

4.1.2.2 Top storey displacement comparison Y-direction (mm)

Table 4. 6: Percentage reduced of opening size case building top storey displacement (mm) y-direction comparison

Discontinuity Type	M1(no opening)	M2** (2*2)	M1** (3*3)	M8 (4*4)
Storey displacement(mm)	3.708	3.635	3.604	3.573
% change compared to M1		1.97%	2.8%	3.64%

Slab open down opening size maximum lateral displacement direction (X)

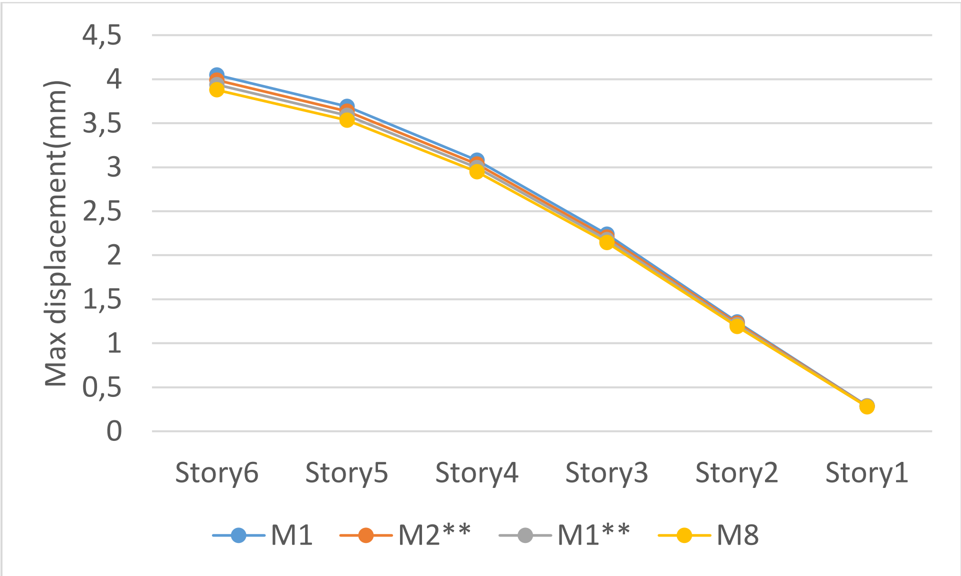


Figure 4. 3: Maximum lateral displacement longer direction (X)

Slab open down opening size maximum lateral displacement direction (Y)

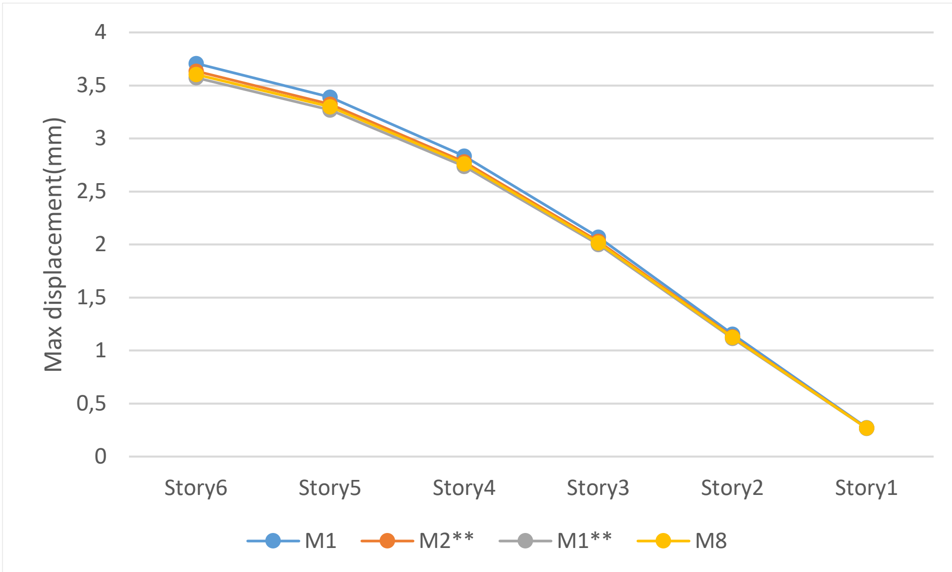


Figure 4. 4: Maximum lateral displacement shorter direction (Y)

From figure 4.3, 4.4 shown that the opening size frames showed different reduction in displacement that of a G+4 building depending on size of opening. That is M8 (4*4) sized opening area shows better performance in reduction of displacement than diaphragm without discontinuity frame. Percent reduction of top storey displacement for 4*4 slab area opened down size frame shows in the X and Y direction are 4.2% and 2.8% respectively. From the analysis of building for opening size case it shows that when the size of opening increase the percentage of reduction of storey displacement increase. It shows that increasing opening size can decrease the performance of the structure.

4.1.3 Discussion on lateral displacement for slab open down shape as a parametric case

Displacement along x-direction

Table 4. 7: Lateral Story Displacement for opening shape as a parametric case along x-direction

Lateral Displacement (mm) X				
Story	M1(no opening)	M1*(rectangular)	M2*(circular)	M3*(parallelogram)
Story6	4.047	3.903	3.903	3.903
Story5	3.689	3.557	3.557	3.557
Story4	3.077	2.967	2.967	2.967
Story3	2.238	2.158	2.158	2.158
Story2	1.242	1.198	1.198	1.198
Story1	0.288	0.28	0.28	0.28
Base	0	0	0	0

Lateral Story Displacement for opening shape as a parametric case along y-direction

Table 4. 8: Lateral Story Displacement for opening shape as a parametric case along y-direction

Lateral Displacement (mm) y				
Story	M1(no opening)	M1*(Rectangular)	M2*(Circular)	M3*(Parallelogram)
Story6	3.708	3.589	3.595	3.592
Story5	3.39	3.285	3.29	3.287
Story4	2.835	2.75	2.754	2.752
Story3	2.07	2.009	2.012	2.011
Story2	1.154	1.122	1.123	1.122
Story1	0.274	0.268	0.268	0.268
Base	0	0	0	0

4.1.3.1 Top storey displacement comparison of opening shape as a parametric case (X)

Table 4. 9: Percentage reduction comparison of top storey displacement opening shape as a parametric case X-direction

Discontinuity Type	M1 (No opening)	M1* (rectangular)	M2* (circular)	M3 (parallelogram)
Storey displacement	4.05	3.903	3.903	3.903
% change compared to M1		3.63%	3.63%	3.63%

4.1.3.2 Top storey displacement comparison Y-direction (mm)

Table 4. 10 Percentage reduction comparison of top storey displacement for opening shape as a parametric case Y-direction

Discontinuity Type	M1(no opening)	M1* (Rectangular)	M2* (Circular)	M3* (Parallelogram)
Storey displacement(mm)	3.708	3.59	3.59	3.59
% change compared to M1		3.18%	3.18%	3.18%

Maximum lateral displacement for shape as parameter along x-direction

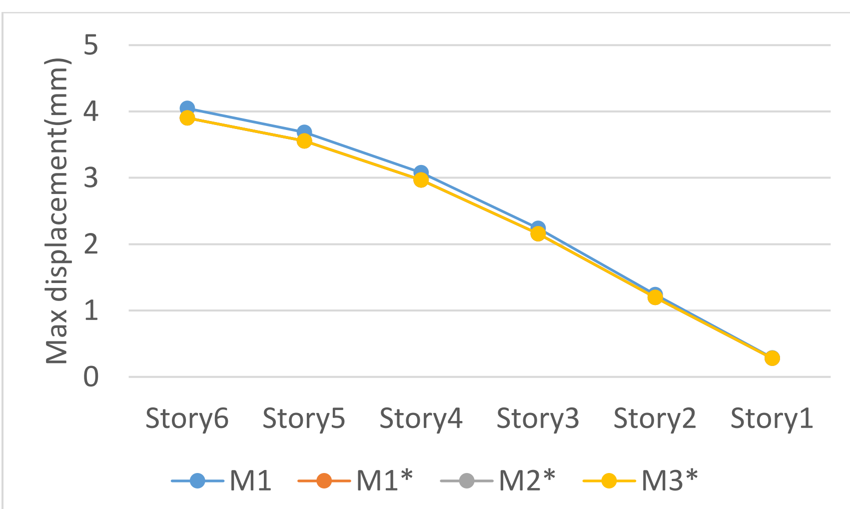


Figure 4. 5: Maximum lateral displacement for shape as parameter (X)

Maximum lateral displacement for shape as a parameter direction (Y)

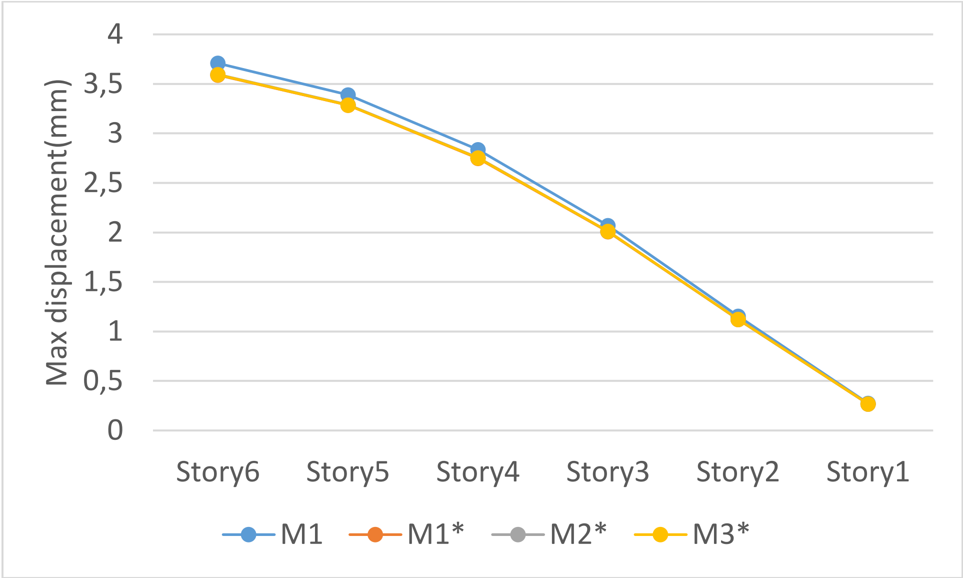


Figure 4. 6: Maximum lateral displacement for shape as a parameter(Y)

From figure 4.5, 4.6 shown that the storey displacement of diaphragm without discontinuity frame are higher that of diaphragm with discontinuous frame. Diaphragm without discontinuity frames showed the maximum reduction in storey displacement. Diaphragm without discontinuity reduce top storey displacement by 3.56% and 3.05% in the X and Y direction respectively. Changing the Shape of diaphragm discontinuity has no effect on lateral storey displacement on u-shaped building

4.2. Discussion on Storey Drift

Suggested maximum drift at the top of buildings vary between H/50 and H/2000 where H is the height of the building. A limiting value for the maximum displacement within the elastic limits was obtained as a function of the height of a story, the stiffness of a story, number of stories, the yield strain of steel εy and the maximum allowable concrete strain εc. Therefore, obtained values are within limits. Below figures are curves maximum displacements vs.story levels for push X and push Y.

Storey drift is defined as the displacement of one storey level relative to the other storey level above or below. The storey drifts have been usually used to calculate expected damage to the structure during earthquake events. As per ESEN 1998-1:2016 interstorey drift is evaluated as the difference of the average lateral displacements ds at the top and bottom of the storey under consideration. For buildings having non-structural elements of brittle materials attached to the structure the code provides the following interstorey drift limit

$d_r \cdot v \leq 0.005h$

Where, dr is the design interstorey drift and h is the storey height v is the reduction factor which takes into account the lower return period of the seismic action associated with the damage limitation requirement. The recommended values of ν are 0.4 for importance classes III and IV and ν = 0.5 for importance classes I and II. Therefore, the drift limitation for the study will be

$d_r \leq 0.005h/0.5=0.01h$

4.2.1 Discussion on storey drift for slab open down position as a parametric case

Storey drift for position opening as parametric study along x-direction

Table 4. 11: Storey drift for position opening as parametric study in x-direction

Story	M1	M2	M3	M4	M5	M6	M7	M8
Story6	0.000131	0.000126	0.000129	0.000135	0.000134	0.00013	0.000134	0.000123
Story5	0.000214	0.000206	0.000211	0.000221	0.000219	0.000213	0.000219	0.000201
Story4	0.000286	0.000274	0.000281	0.000294	0.000292	0.000283	0.000292	0.000268
Story3	0.000334	0.000320	0.000329	0.000343	0.000341	0.000331	0.000341	0.000313
Story2	0.000319	0.000306	0.000314	0,000329	0.000326	0.000316	0.000327	0.000299
Story1	0.000144	0.000139	0.000142	0.000147	0.000146	0.000143	0.000146	0.000138
Base	0	0	0	0	0	0	0	0

Storey drift for position of opening as parametric study in y-direction

Table 4. 12: Storey drift for position of opening as parametric study in y-direction

	Storey Drift Y							
Story	M1	M2	M3	M4	M5	M6	M7	M8
Story6	0.000118	0.00012	0.00012	0.000121	0.000117	0.000114	0,000115	0.000114
Story5	0.000196	0.0002	0.000199	0.000202	0.000194	0.000191	0.000192	0.00019
Story4	0.000262	0.000267	0.000267	0.00027	0.00026	0.000255	0.000257	0.000254
Story3	0.000307	0.000314	0.000314	0.000317	0.000305	0.0003	0.000302	0.000299
Story2	0.000296	0.000302	0.000302	0.000305	0.000293	0.00029	0.000291	0.000289
Story1	0.000137	0.000138	0.000138	0.000139	0.000135	0.000135	0.000135	0.000134
Base	0	0	0	0	0	0	0	0

Drift along for position of opening as a parameter x-direction

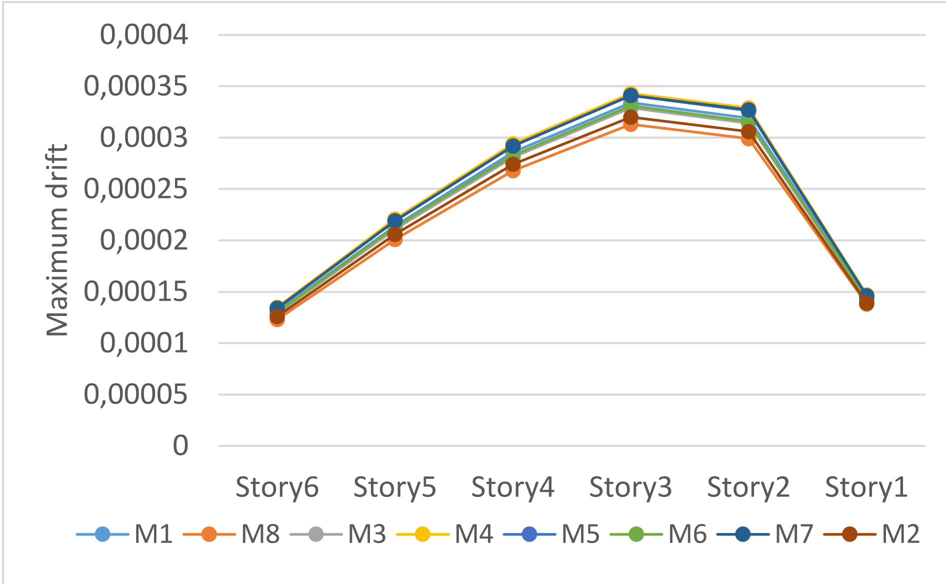


Figure 4. 7: storey drift for position of opening as a parameter (X)

Storey Drift for position of opening as a parameter along y-direction

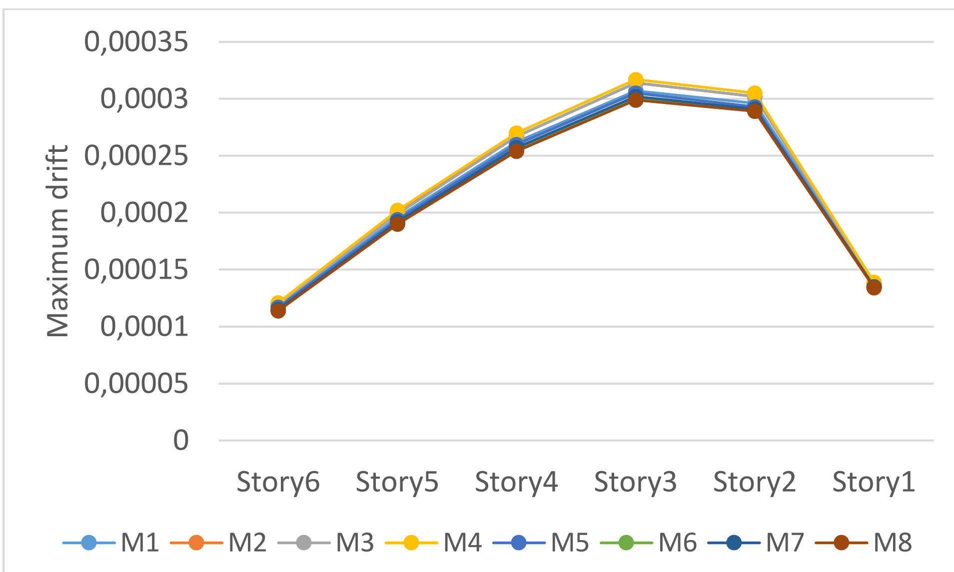


Figure 4. 8: storey drift position of opening as a parameter (Y)

As shown figure 4.7 and 4.8 the story drift is higher when no opening is used. But when opening applied the story drift decreased linearly. The story drift increase linearly for the first 2 storey then it reaches its maximum drift at the middle storeys 3 then fall back to the last storeys. Opening at y-shorter front edge shows better reduction in story drift 6.107% X and 3.39% Y than diaphragm without discontinuity as shown in fig above.

4.2.2 Discussion on storey drift for slab open down size as a parametric case

Storey drift along x-direction

Table 4. 13: Storey Drift opening size as parametric study in x-direction

Storey Drift X				
Story	M1(No opening)	M2* (2*2)	M1** (3*3)	M8 (4*4)
Story6	0.000131	0.000129	0.000128	0.000126
Story5	0.000214	0.000211	0.000209	0.000206
Story4	0.000286	0.000282	0.000278	0.000274
Story3	0.000334	0.000329	0.000325	0.00032
Story2	0.000319	0.000315	0.000311	0.000306
Story1	0.000144	0.000143	0.000141	0.000139
Base	0	0	0	0

Storey drift for opening size as parametric study in Y-direction

Table 4. 14: Storey Drift opening size as parametric study in y-direction

Storey Drift Y				
Story	M1(no opening)	M2** (2*2)	M1** (3*3)	M8 (4*4)
Story6	0.000118	0.000115	0.000114	0.000113
Story5	0.000196	0.000192	0.000189	0.00018
Story4	0.000262	0.000257	0.000254	0.000252
Story3	0.000307	0.000301	0.000299	0.000297
Story2	0.000296	0.00029	0.000289	0.000286
Story1	0.000137	0.000135	0.000134	0.000134
Base	0	0	0	0

Drift along x-direction for opening size case

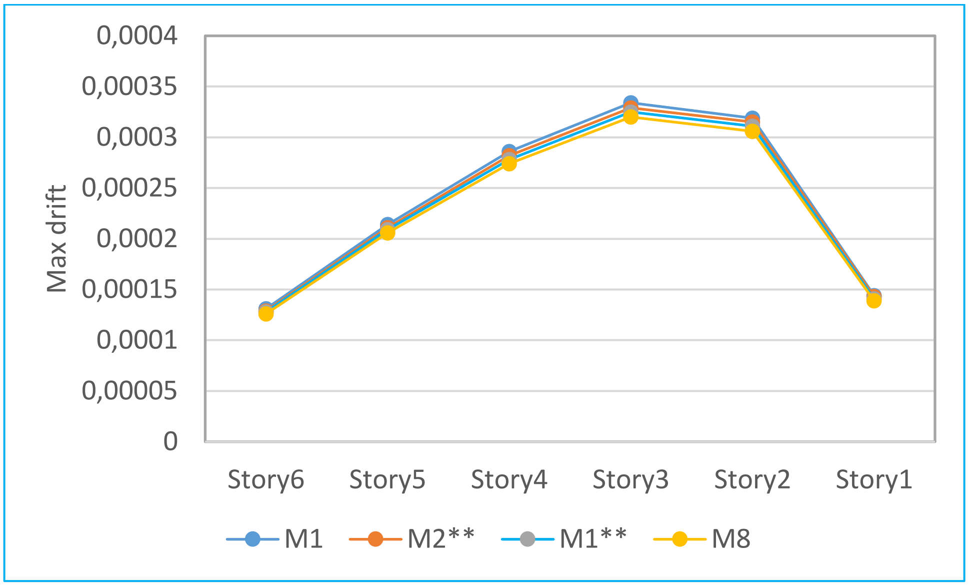


Figure4. 9: storey drift for opening size case (x)

Drift along y-direction for opening size case

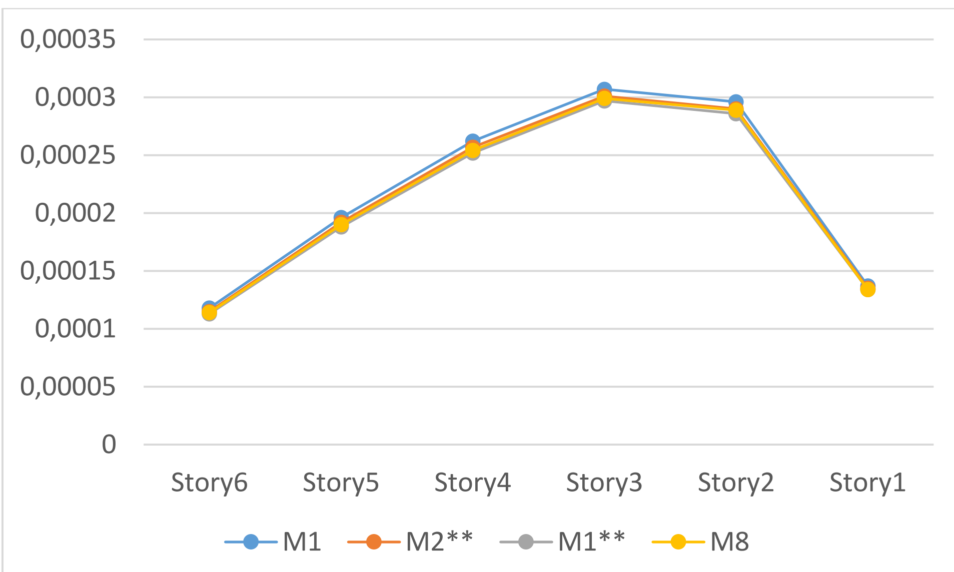


Figure 4.12: storey drift for opening size case (y)

From figure 4.11 and 4.12 shown that the story drift decreased when used opening system. The story drift increase linearly for the first 3 storey then it reaches its maximum drift at storeys 3 then fall back down to the last 2 storeys. Storey drift of frame shows better reduction when cross sectional area models increase. In this model storey drift of diaphragm without opening reduce 3.82%at x and 3.39% at y than diaphragm with discontinuity of opening cross sectional area 4*4.

4.2.3 Discussion Storey drift for opening shape as a parametric case

Storey drift along x-direction

Table 4. 15: Storey drift opening shape as parametric study in x-direction

Storey Drift X				
Storey	M1(no opening)	M1* (Rectangular)	M2* (Circular)	M3* (Parallelogram)
Story6	0.000131	0.000127	0.000127	0.000127
Story5	0.000214	0.000207	0.000207	0.000207
Story4	0.000286	0.000276	0.000276	0.000276
Story3	0.000334	0.000322	0.000322	0.000322
Story2	0.000319	0.000308	0.000308	0.000308
Story1	0.000144	0.00014	0.00014	0.00014
Base	0	0	0	0

Storey drift opening shape as parametric study along Y-direction

Table 4. 16: Storey drift opening shape as parametric study in Y-direction

Storey Drift y				
Story	M1(no opening)	M1* (Rectangular)	M2* (Circular)	M3* (Parallelogram)
Story6	0.000118	0.000114	0.000114	0.000114
Story5	0.000196	0.000189	0.000189	0.000189
Story4	0.000262	0.000253	0.000253	0.000253
Story3	0.000307	0.000298	0.000298	0.000298
Story2	0.000296	0.000288	0.000288	0.000288
Story1	0.000137	0.000134	0.000134	0.000134
Base	0	0	0	0

Drift along x-direction for opening shape case

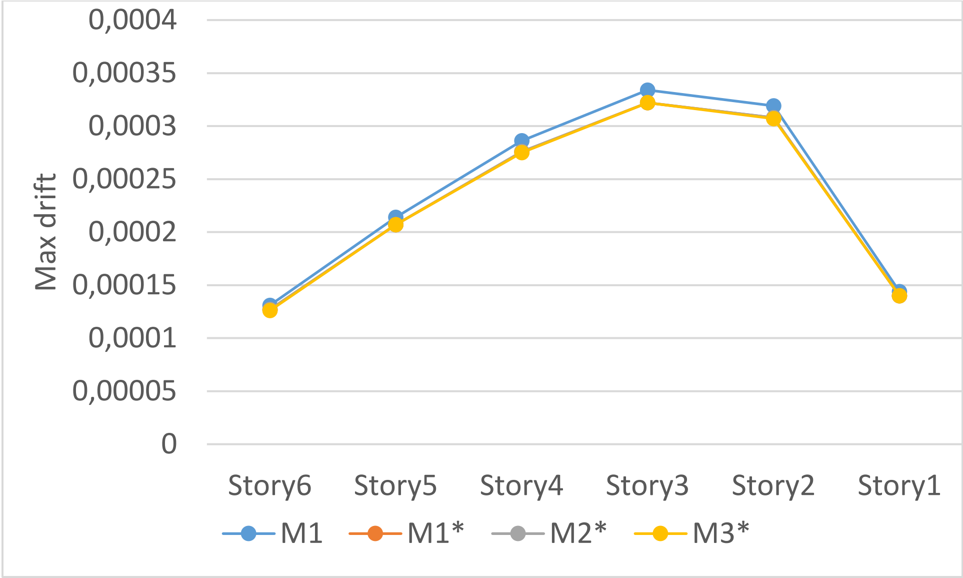


Figure 4. 10: storey drift for opening shape (x)

Drift along y-direction for opening shape case

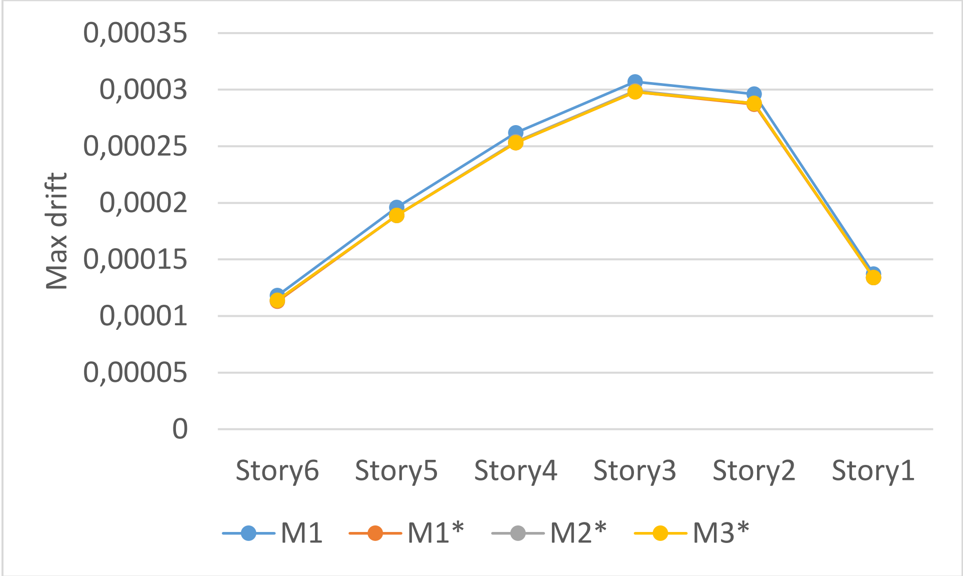


Figure 4. 11: storey drift in for opening shape (Y)

From figure 4.9 and 4.10 shown that the story drift decreased when used opening system. The story drift increase linearly for the first 2 storey then it reaches its maximum drift at the middle storeys 3 then fall back to the last storeys. Diaphragm with opening are the efficient type of system to reduce drift 3.05%at x and 3.39 at y respectively. But the opening shape diaphragm discontinuity has no effect on drift value.

Discussion on story drift

The difference of displacements between two consecutive stories divide by the height of that storey (storey drift) is very important parameter in the analysis and design of buildings. If the storey drift values at each floor level reach their maximum allowable limit, then roof displacement will reach undesirable values. Maximum storey drift for diaphragm without discontinuity frame is in the storey just above second and third storey for all buildings, this result shows the frame structure deflects in shear configuration where the rate of change of deflection goes on reduced with height as seen from the analysis result in figure 4.7 to 4.10. In these models maximum storey drift is found around middle height and above the middle height of the building, as shown from analysis results on figure shown above. For reduction of storey drift opening system is more effective on u-shaped plan than without opening as shown figure above.

4.3Discussion on Base shear

4.3.1 Discussion on Base shear for slab open down position as a parametric case

Base shear is an estimate of the maximum expected lateral force that will occur due to seismic ground motion at the base of a structure. These seismic forces of the upper stories are transmitted to lower stories and finally to the ground through the foundation. From figure 4.13 shows the base shear at the base for all structural systems. There is a change of shear force and base shear in both X and Y directions when opening has applied to the U shaped RC frame building.

Storey force for position of opening as a parameter x-direction

Table 4. 17 Storey force for position of opening as a parameter x-direction

Storey force(KN)								
Storey	M1	M2	M3	M4	M5	M6	M7	M8
Story1	368.0847	365.7139	365.358	364.6925	364.7263	365.1992	364.7749	365.5834
Story2	355.0305	323.2696	322.9549	322.3667	322.3966	322.8146	322.4395	323.1542
Story3	285.3811	253.9975	253.7503	253.2881	253.3116	253.64	253.3453	253.9069
Story4	205.7317	184.7255	184.5457	184.2095	184.2266	184.4655	184.2512	184.6595
Story5	136.5933	115.9688	115.856	115.6449	115.6557	115.8056	115.6711	115.9274
Story6	15.2008	15.3337	15.3188	15.2909	15.2923	15.3122	15.2944	15.3283
Base Shear	**1366.022**	**1259.009**	**1257.784**	**1255.493**	**1255.609**	**1257.237**	**1255.776**	**1258.56**

Storey force for position of opening as a parameter y-direction

Table 4. 18: Storey force for position of opening as a parameter y-direction

Storey force(KN)								
Storey	M1	M2	M3	M4	M5	M6	M7	M8
Story1	394.476	373.5257	373.4708	373.549	374.0823	374.1974	374.1417	374.1296
Story2	337.8579	330.1748	330.1262	330.1953	330.6667	330.7685	330.7192	330.7086
Story3	281.5312	259.423	259.3848	259.4392	259.8096	259.8895	259.8508	259.8425
Story4	250.2045	188.6713	188.6435	188.683	188.9524	189.0106	188.9824	188.9763
Story5	129.4011	118.446	118.4286	118.4534	118.6225	118.659	118.6413	118.6375
Story6	15.5669	15.6613	15.659	15.6623	15.6846	15.6894	15.6871	15.6866
Base Shear(KN)	**1411.511**	**1285.902**	**1285.713**	**1285.582**	**1287.818**	**1288.214**	**1288.023**	**1287.981**

Table 4. 19: Base shear opening location as a parameter

Base shear (KN)								
Direction	M1	M2	M3	M4	M5	M6	M7	M8
X	1366.022	1259.009	1257.784	1255.493	1255.609	1257.237	1255.776	1258.56
Y	1411.511	1285.902	1285.713	1285.582	1287.818	1288.214	1288.023	1287.981

4.3.1.1Base shear comparison for position as a parameter X-direction (KN)

Table 4. 20: Percentage increase comparison of base shear for position as a parameter X-direction (KN)

Discontinuity Type	Diaphragm without discontinuity(M1)	Opening at y-longer front edge(M2)	Opening at y-longer center(M3)	Opening at y-longer corner(M4)	Opening to x-direction(M5)	Opening To y-shorter center(M6)	Opening To y-shorter corner(M7)	Opening to y-shorter front edge(M8)
Base shear(KN)	1366.022	1259.009	1257.784	1255.493	1255.609	1257.237	1255.776	1258.56
% change compared		7.83%	7.92%	8.09%	8.08%	7.96%	8.07%	7.86%

4.3.1.2Base shear comparison for position as a parameter Y-direction (KN)

Table 4. 21: Percentage increase comparison of base shear for position as a parameter Y-direction (KN)

Discontinuity Type	Diaphragm without discontinuity(M1)	Opening at y-longer front edge(M2)	Opening at y-longer center(M3)	Opening at y-longer corner(M4)	Opening to x-direction(M5)	Opening To y-shorter center(M6)	Opening To y-shorter corner(M7)	Opening to y-shorter front edge(M8)

Base Shear(KN)	1411.511	1285.902	1285.713	1285.582	1287.818	1288.214	1288.023	1287.981
% change compared to M1		8.90%	8.91%	8.92 %	8.76%	8.73%	8.75%	8.75%

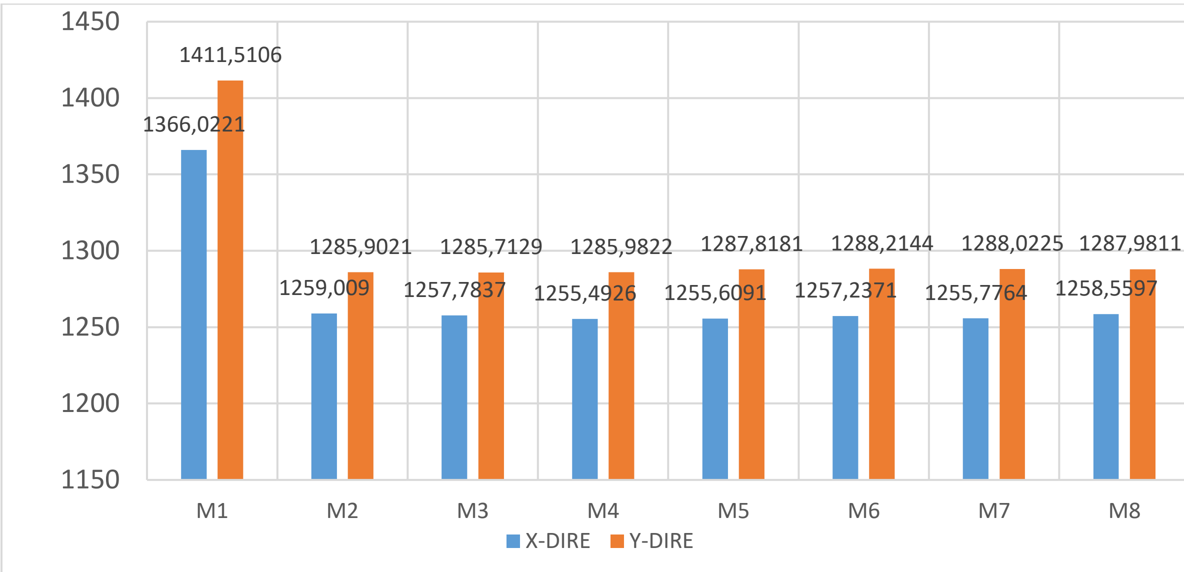


Figure 4. 12: Base shear for location of opening case

Base shear is an estimate of the maximum expected lateral force that will occur due to seismic ground motion at the base of a structure. These seismic forces of the upper stories are transmitted to lower stories and finally to the ground through the foundation. Figure 4.13 to 4.15 shows the base shear at different floor levels for all structural systems in both X and Y directions and for different floor plans (diaphragm with discontinuity and without discontinuity). Table 4.7 to 4.12 shows the comparison of percent increase of base shear of different opening types .The result shows opening at y-longer corner (M4) showed the maximum reduction base shear as compared to diaphragm without discontinuity. M4 model frame reduce its resistance by 8.09% in the X direction and 8.92% in the Y direction.

There is a change of shear force and base shear in both directions when opening has applied to the RC frame. The maximum shear force of all systems are at base level for all RC frame with diaphragm discontinuity are compared to without diaphragm frame.

4.3.2 Discussion on Base shear for slab open down size as a parametric case

Storey force for opening size as a parameter along x-direction

Table 4. 22: Storey force for opening size as a parameter along x-direction

Storey force(KN)				
storey force	M1(No opening)	M2** (2*2)	M1** (3*3)	M8 (4*4)
Story1	368.0847	367.6606	366.8495	365.5834
Story2	355.0305	324.7386	324.1262	323.1542
Story3	285.3811	255.1517	254.6706	253.9069
Story4	205.7317	185.5649	185.2149	184.6595
Story5	136.5933	116.4904	116.2729	115.9274
Story6	15.2008	15.2407	15.2792	15.3283
Base Shear(KN)	**1366.022**	**1264.847**	**1262.413**	**1258.56**

Storey force for opening size case y-direction

Table 4. 23: Storey force for opening size as a parameter y-direction

Storey force(KN)				
storey	M1(no opening)	M2** (2*2)	M1** (3*3)	M8 (4*4)
Story1	394.476	376.4943	375.5942	374.1296
Story2	337.8579	332.541	331.8525	330.7086
Story3	281.5312	261.2822	260.7412	259.8425
Story4	250.2045	190.0234	189.63	188.9763
Story5	129.4011	119.2892	119.0446	118.6375
Story6	15.5669	15.6069	15.6434	15.6866
Base Shear(KN)	**1411.511**	**1295.237**	**1292.506**	**1287.981**

Table 4. 24: Base shear for size as a parametric case

Base shear (KN)				
Direction	M1(no opening)	M2** (2*2)	M1** (3*3)	M8 (4*4)
X	1366.0221	1264.847	1262.413	1258.56
Y	1411.5106	1295.237	1292.506	1287.981

4.3.2.1 Base shear comparison for size as a parameter X-direction (KN)

Table 4. 25: Percentage increase comparison base shear for size as a parameter X-direction

Discontinuity Type	M1(no opening)	M2**(2*2)	M1**(3*3)	M8(4*4)
Base Shear(KN)	1366.022	1264.847	1262.413	1258.56
% change compared to M1		7.41%	7.58%	7.87%

4.3.2.2 Base shear comparison for size as a parameter Y-direction (KN)

Table 4. 26: Percentage increase comparison of base shear for size as a parameter Y-direction

Discontinuity Type	M1(no opening)	M2**(2*2)	M1**(3*3)	M8(4*4)
Base Shear(KN)	1411.511	1295.237	1292.506	1287.981
% change compared to M1		8.24%	8.43%	8.75%

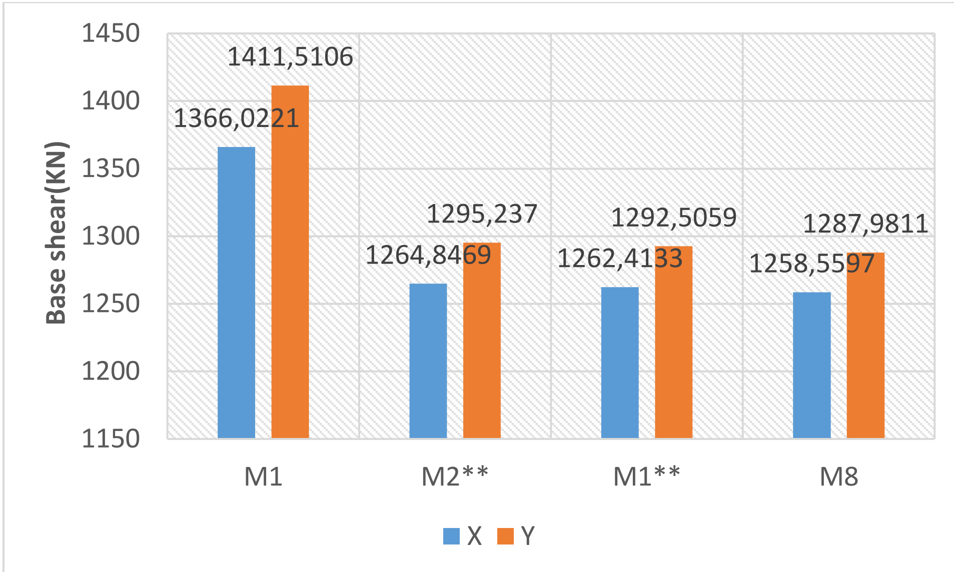


Figure 4. 13: Base shear Opening size case

From figure 4.15 shown diaphragm without discontinuity shows a better performance by increase the base shear both in the X and Y direction. For this specific model M8 opened frame which has diaphragm with has cross sectional area of 4*4 decrease the base shear by 7.87% in the X direction and 8.75% in the Y direction. For the figure describe above M8 opening system shows the better performance of by reducing the base shear than of M1 model which is diaphragm without discontinuity.

4.3.3 Discussion on for Base shear opening shape as a parametric case

Storey force (KN) for opening shape case X-direction

Table 4. 27: Storey force for opening shape case X-direction

Storey force(KN)				
storey	M1(no opening)	M1* (Rectangular)	M2* (circular)	M3* (Parallelogram)
Story1	368.0847	366.2664	366.3558	366.3839
Story2	355.0305	323.6848	323.7593	323.788
Story3	285.3811	254.3238	254.3823	254.4049
Story4	205.7317	184.9628	185.0053	185.0217
Story5	136.5933	116.1162	116.1428	116.1532
Story6	15.2008	15.3062	15.3067	15.3106
Base Shear(KN)	**1366.022**	**1260.66**	**1260.9522**	**1261.062**

Storey force (KN) for opening shape as a parametric case Y-direction

Table 4. 28: Storey force for opening shape as a parametric case

Storey force(KN)				
Storey	M1(no opening)	M1*(Rectangular)	M2*(Circular)	M3*(Parallelogram)
Story1	394.476	374.913	374.1221	374.9991
Story2	337.8579	331.3262	331.5064	331.4016
Story3	281.5312	260.3278	260.4693	260.387
Story4	250.2045	189.3293	189.4322	189.3724
Story5	129.4011	118.8574	118.9219	118.8845
Story6	15.5669	15.6675	15.673	15.6707
Base Shear(KN)	**1411.511**	**1290.421**	**1290.1249**	**1290.7153**

Table 4. 29: Base shear for shape as a parametric case

Base shear (KN)				
Direction	M1(No opening)	M1* (Rectangular)	M2* (circular)	M3* (Parallelogram)
X	1366.0221	1260.66	1260.9522	1261.0623
Y	1411.511	1290.421	1290.1249	1290.7153

4.3.3.1 Base shear comparison for shape as a parameter X-direction (KN)

Table 4. 30: Percentage increase comparison of base shear for shape as a parameter X-direction

Discontinuity Type	M1(no opening)	M1*(rectangular)	M2*(circular)	M3*(Parallelogram)
Base Shear(KN)	1366.022	1260	1260	1260
% change compared to M1		7.76%	7.76%	7.76%

4.3.3.2 Base shear comparison for shape as a parameter Y-direction (KN)

Table 4. 31: Percentage increase comparison of base shear for shape as a parameter Y-direction

Discontinuity Type	M1(No opening)	M1* (rectangular)	M2* (circular)	M3* (Parallelogram)
Base Shear(KN)	1411.511	1290	1290	1290
% change compared to M1		8.61%	8.61%	8.61%

Storey shear for opening shape case

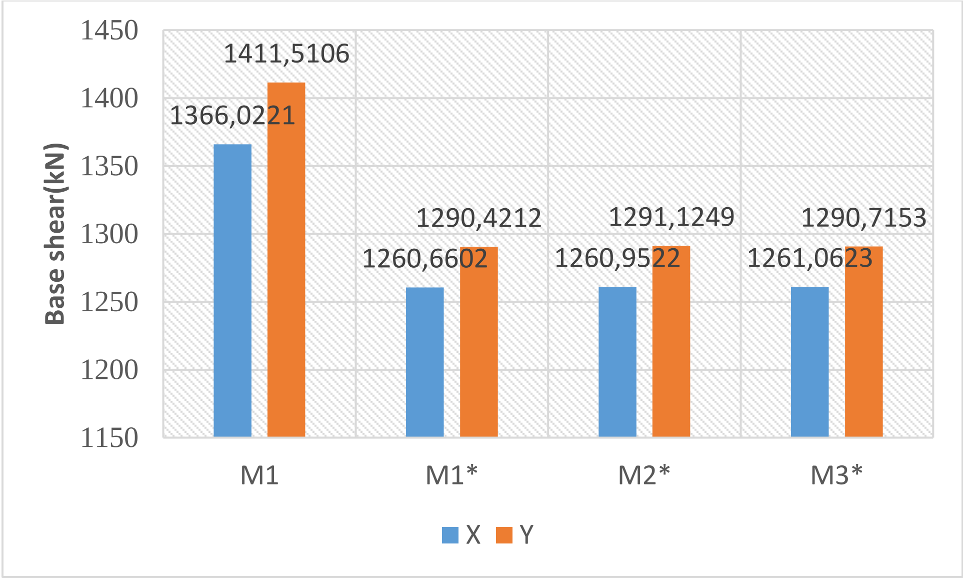


Figure 4. 14: Base shear for opening shape case

From figure 4.14 shown above diaphragm without discontinuity RC frame shows a batter performance by increasing base shear both in the X and Y direction. For this specific model diaphragm without discontinuity RC frame reduce the base shear by7.76% in the X direction and 8.61% in the Y direction. But the figure describe above shows the same cross sectional area opening shape has no effect on base shear of irregular plan U shaped RC framed building.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

From the results obtained in this study the following conclusions have been drawn According to this study:.

In case of position of opening

- Opening to the shorter y-direction at the front edge of the frame (M8) shows higher reduction of displacement and drift. This frame have showed a reduction of top storey displacement by 6.49% in the X and 2.8% in the Y direction.
- Opening at y-longer corner (M4) showed the maximum reduction base shear as compared to diaphragm without discontinuity. M4 model frame reduce its resistance by 8.09% in the X direction and 8.92% in the Y direction. And diaphragm without discontinuity shows a better performance by increase the base shear both in the X and Y direction

In case of size of opening

- In this case, increasing the size of cross sectional area of diaphragm openings reduces the displacement and drift depending on the size cross section of building. In this comparison Model 8 that is diaphragm discontinuity with 4*4 cross sectional area opening model has shown 4.2% in the X and 2.8% Y direction top storey displacement reduction than other frames.
- And storey drift of M8 shows better reduction in in their respective order in this model3.82%at x and 3.39% at y respectively
- Increasing the size of opening system decrease the base shear of reinforced concrete frame structure. Diaphragm discontinuity with 4*4 cross sectional area opening shows better reduction base shear capacity of the structure that is 7.87% and 8.75% in the X and Y direction respectively. It indicates that the stiffness of building has decreased.

In case of shape of opening

- Model 1 diaphragm without discontinuity has higher top storey displacement, drift and base shear than diaphragm with discontinuity in x and y directions. But shape of diaphragm openings either circular, rectangular or parallelogram with similar cross sectional area has no effect both in x and y direction of displacement, drift or base shear

5.2 Recommendation

- This study was carried out using linear dynamic (response spectrum) analysis method for the seismic analysis. This can be validated by an interested body using a nonlinear dynamic (time history) analysis method.
- In ES EN-2016 manual the effect of diaphragm discontinuity on lateral load is not included; so the design and analysis principles for lateral load effect of diaphragm discontinuity should be incorporated by considering performance-based design
- This study considered plan irregular shapes. It is possible to study other plan irregularities with elevation irregularity.

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Appendix

Appendix

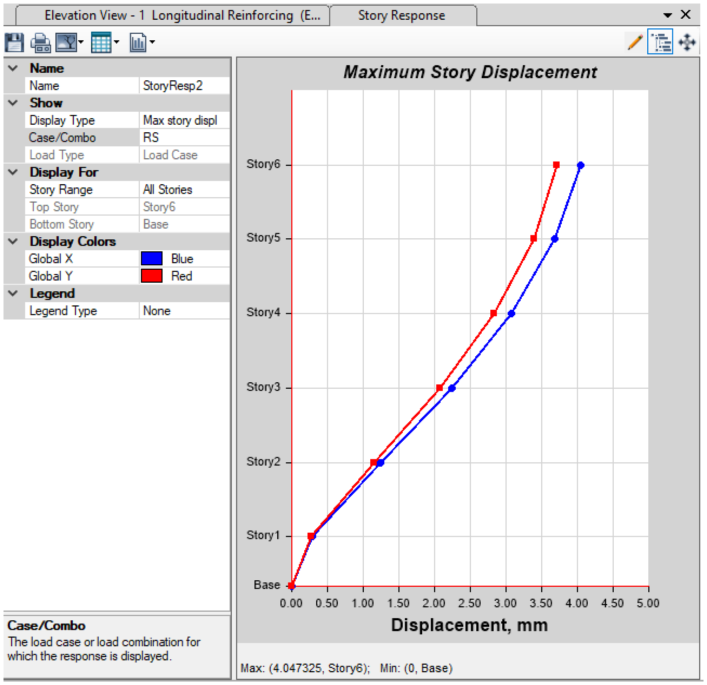

Figure A. 1: Etabs output for lateral displacement of M1

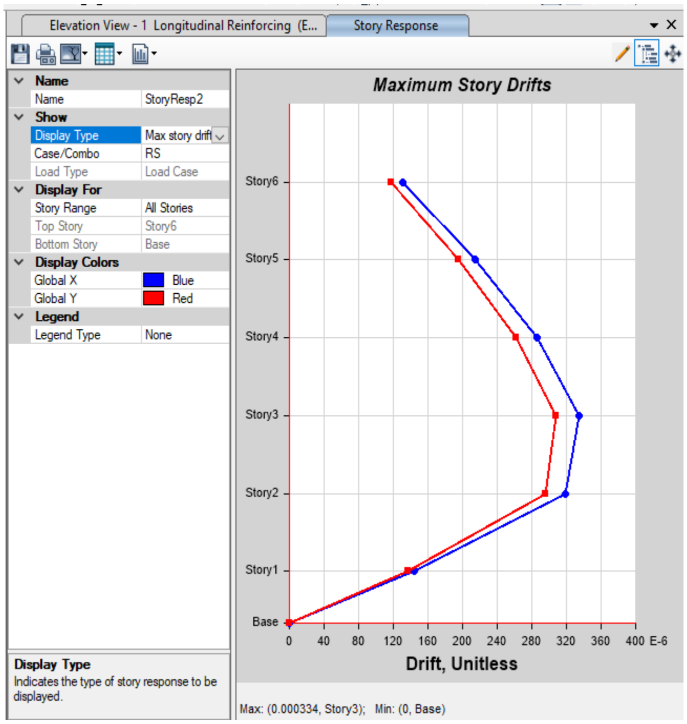

Figure A. 2: Etabs Sample for output of drift of model M1

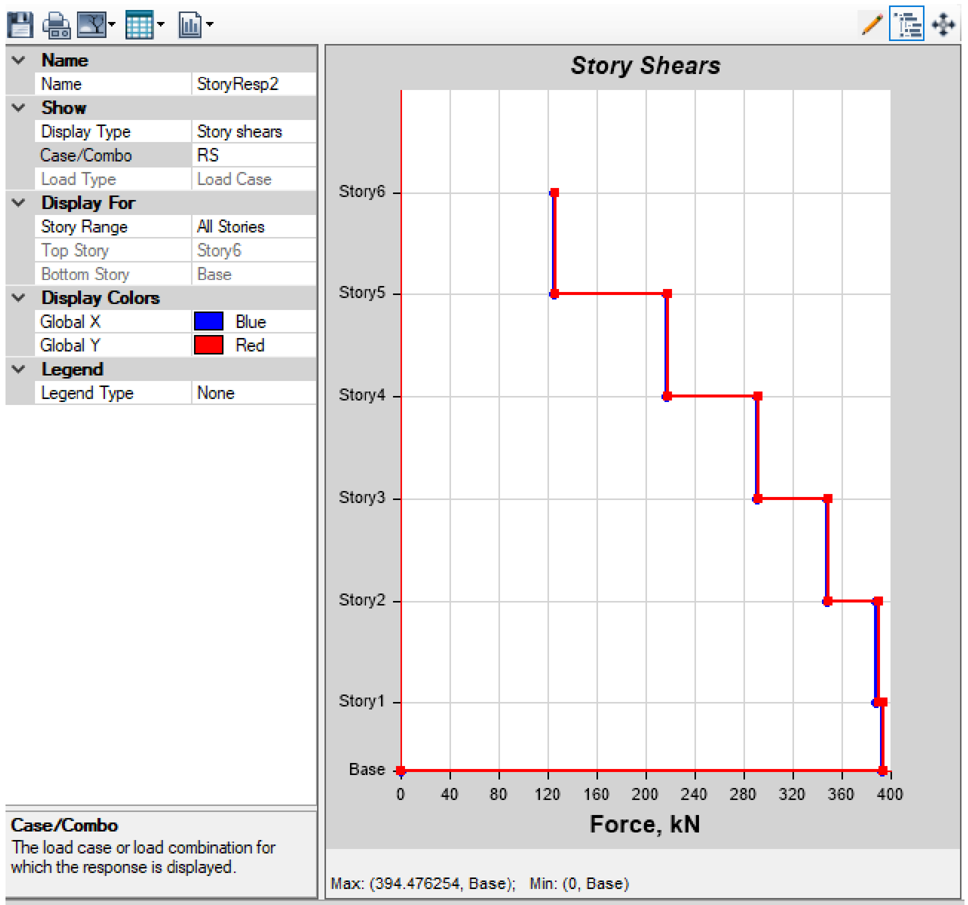

Figure A. 3 Etabs Sample for output of story shear of model M1

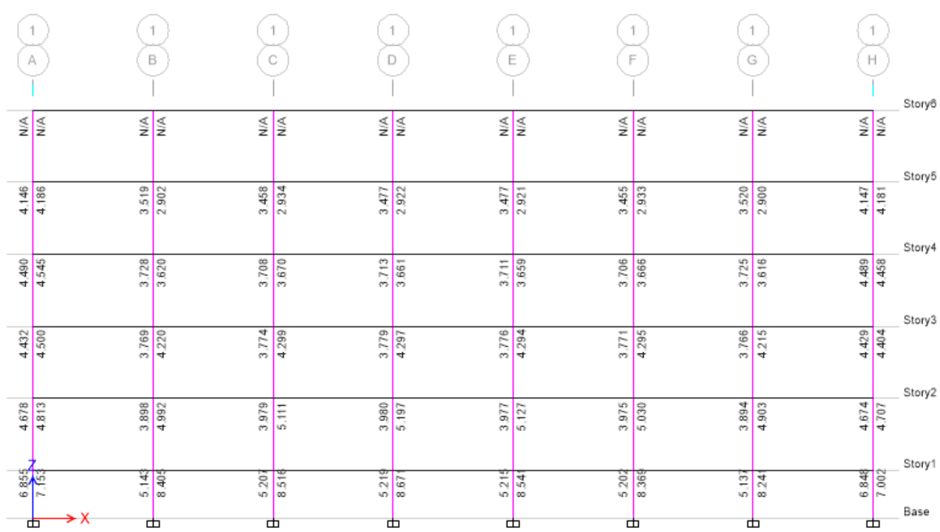

Figure A. 4: Sample column / beam capacity ratios for six story building model along axis 1

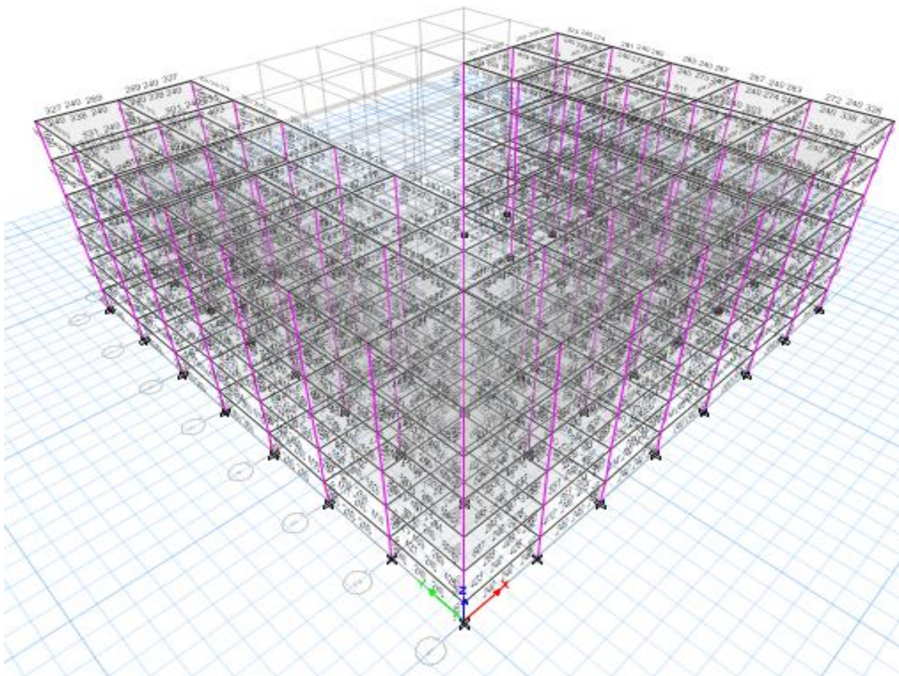

Figure A. 5:3-D design detail of building models

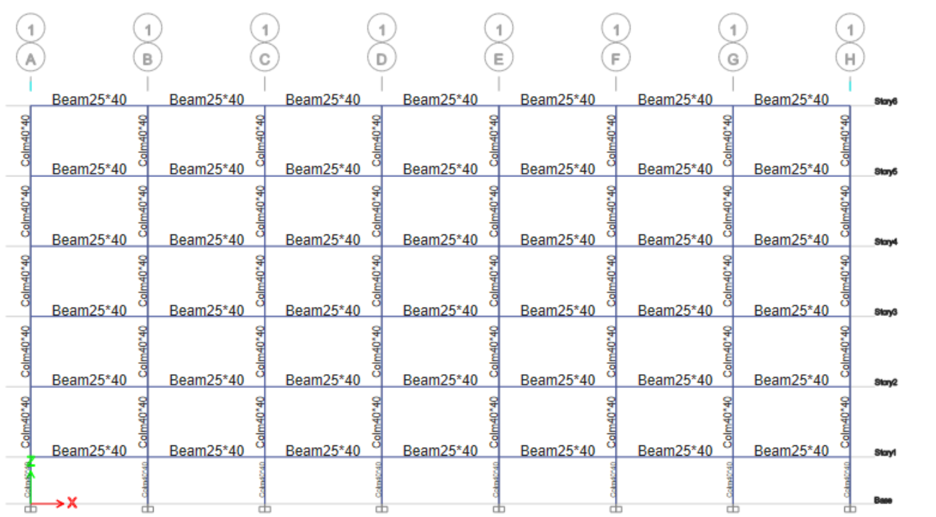

Figure A. 6: Design Sections and Reinforcements for Sample Models