Retrofit Residential Building by Steel X Bracing According to BNBC 2020

A Project and Thesis submitted in partial fulfillment of the requirements for the award of Degree of Bachelor of Science in Civil Engineering

by

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Certification

This is to certify that this project and thesis entitled "Retrofit Residential Building by Steel X Bracing According To BNBC 2020" is done by the following students under my direct supervision and this work has been carried out by them in the laboratories of the department of Civil engineering under the faculty of engineering of daffodil international university in partial fulfillment of the requirements for the degree of bachelor of science in civil engineering. The presentation of the work was held on 3rd April 2021.

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List of Abbreviations

Wx	Horizontal wind force at X direction
Wy	Horizontal wind force at Y direction
Ex	Horizontal Earthquake force at X direction
Ey	Horizontal Earthquake force at Y direction
RSx	Response spectrum force at X direction
RSy	Response spectrum force at Y direction

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ABSTRACT

Earthquake is a curse of a developing country like Bangladesh, so developing country needs to be ready to resist this kind of hazardous. For this reason we need to study how to increase stiffness of the structure. So we choose Finite Element package ETABS to conduct this study. We also select updated national building code and follow the guideline to simulate analysis. Arbitrary a residential building was selected for this study, which is situated in savar, Dhaka. This building standing on zone-2 according to BNBC 2020, but same structure also simulate remaining 3 difference zone also. Retrofitting is one of the methods to strengthening the structure against earthquake force. In this study we use steel bracing retrofitting method and try to estimate 16 different bracing conditions against earthquake force. Finally we use 300 mm x 300 mm cross sectional size bracing with 13 mm, 16 mm, 18 mm and 25 mm thickness. But the use maximum size of bracing we are able to bring the displacement ratio of the response spectrum to 1.24 from 1.39 at no bracing condition. Although this was not good enough, but finally we were able to mostly reduce the displacement ratio for the response spectrum force.

CHAPTER 1

INTRODUCTION

1.1 General

Earthquakes are one of the biggest challenges for civil engineers in regions with seismic activities. The seismologists believe that Bangladesh will face a serious crisis, so the cities of Dhaka- Sylhet - Chittagong are considered to be in the first stage of danger, which are zone 2 and zone 4 according to BNBC 2020. Dhaka city, the soul of Bangladesh is highly vulnerable to the earthquake disaster due to high density of population, unplanned infrastructure and close proximity with India and Myanmar's active seismic area, poor economic condition, poor emergency preparation and recovery capability. For this reason, it has become imperative for us to strengthen buildings to withstand earthquakes. For example, the magnitude of several earthquakes in different countries of the world is mentioned. Such as: The Great Kanto Earthquake, the worst in Japanese history, hit the Kanto plain around Tokyo in 1923 and resulted in the deaths of over 100,000 people. Nearly 230,000 people died in the 2004 Indian Ocean earthquake.

Some images of the devastation for earthquakes (Fig1.1-1.2) are shown in below.

Fig 1.1 The great kanto earthquake in japan 1923.

Fig 1.2 Indian Ocean earthquake 2004.

Great disasters in cities, with collapsed structures and human losses as an impact, have been caused due to earthquakes. The impact in the economy is great too, considering the collapsed buildings and the seriously damaged structures that are in need of recovery, in order to be functional again. Although the structure of the building is not sufficient for earthquakes, a structure is constructed to complete the building so that it performs comparatively well during earthquakes. There are many strategies for structural improvement. But retrofitting is an appropriate technique for many types of structure.

1.2 Background state of the problem

For this study we have selected a building included in Nobinagar, Dhaka. Which was a 10 story residential building. The construction work of that building has been done according to the old BNBC code. So we will try to strengthening the building according to the updated code BNBC 2020.

1.3 Scope of the study

The main focus of retrofitting is to increase the strength of the structure. The strength of the structure can be increased in many ways; the bracing method is one of them. There are many types of bracing like X-type, V-type, inverted V-type and ZX-type. In this analysis we used only X type bracing.

1.4 Objective of this study

To access the structure behavior of a retrofitted existing RCC building with different Steel bracing system arrangement in different seismic zone.

1.5 Summary on every chapter

In chapter 1.Basic idea of work that has been done under this research.

In chapter 2.The next section mentions what has been done before and what kind of work has been used in the structure.

In chapter 3.Discusses what we analyzed and how we accomplished.

In chapter 4.In the brief description of the fourth chapter we have shown here the images used in bracing of different sizes after detailed analysis.

In chapter 5.We discussed the results of what we analyzed and the displacement ratio in practice. It also recommends ways in which this analysis can be completed in the future.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

At the point when designs fizzle, quakes unleash devastation on lives, cash and an extraordinary arrangement. A significant point or field for considering tremor relief at present is the finished development of quakes in an assortment of seismic designing moderation. It is quite possibly the main seismic tremor inclined territories throughout the entire existence of the country and is critical for tall or costly designs. Before the presentation of 19 current seismic codes for created nations like China, Japan, Turkey, China, and so on among different nations on the world in 1960, earthquake protection was figured without expanding the strength of numerous designs.

2.2 Seismic Retrofitting

Seismic retrofitting[1] is the change of existing structures to make them more impervious to seismic action, ground movement, or soil disappointment because of quakes. The retrofit techniques are also applicable for other natural hazards like hurricanes, cyclones, and extreme breezes from rainstorms. In the past seismic retrofitting was applied basically to public security and monetary movement of structures and political limitations. Performance targets in different locations gradually became recognized as follows depending on the performance of seismic engineering.

- Protecting human existence is a vital factor in open security to guarantee that it doesn't collide with people on foot and that they can securely leave the structure in case of a mishap or unanticipated circumstance.

- While the construction is in a protected leave, it is viable and may should be thought of (not for substitution) before it is viewed as safe for the calling.

- Structure unaffected this degree of retrofit is liked for notable constructions of high social importance.

While building assessments demonstrate that the structure ought to be modified, otherwise the structure's energy potential won't increment and future quake recuperation won't be adequate.

2.3 Classification of Retrofitting Techniques

Structural reinforcement or retrofitting is usually done in the following ways (i) Structure level or global retrofit methods (ii) Member level or local retrofit methods.

Common retrofitting techniques can be summarized as shown.

Table 2.1 Techniques of retrofitting.

Global techniques	**Local techniques**
Adding Shear Wall.	Jacketing of Beams
Adding Bracing.	Jacketing of Columns
Adding Infill Wall	Jacketing of Beam
Adding Wing Wall	Strengthening of Individual Footing

2.3.1 Concrete Jacketing

By placing reinforcing steel rebar around its periphery and then concreting is widely adopted which is called concrete jacketing[2] and this is for enlargement on existing structural members like column and beam. This method increases the member stiffness and its size.

Fig 2.1 Process of concrete jacketing.

Fig 2.2 Concrete jacketing of beam and column joint.

2.3.2 Adding new Shear Wall

For retrofitting of non-ductile reinforced concrete frame buildings and added elements can be precast concrete element and at the exterior of the building new structures are placed. Adding new shear wall[3] is not perfect in the interior of the structure.

Fig 2.3 Retrofitting by adding shear wall.

2.3.3 Install Infill wall

Infill wall[4] is one of the most effective methods of retrofitting. It plays an important role for strengthening the structure.

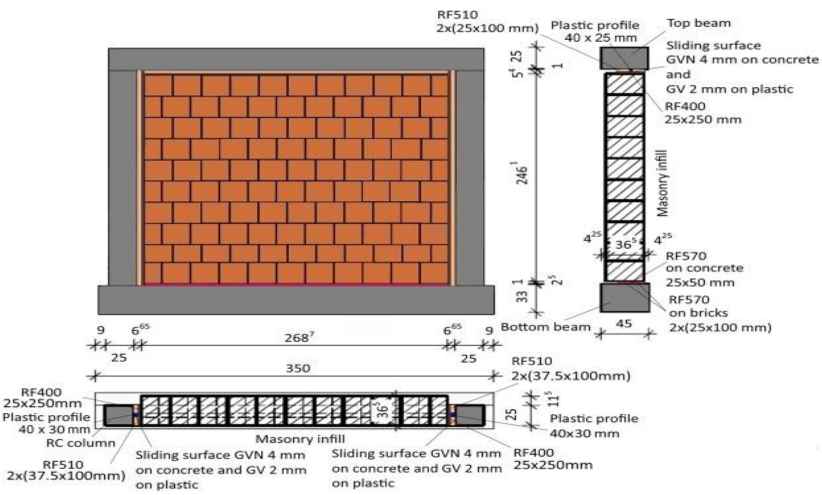


Fig 2. 4 Retrofitting process by adding infill wall.

2.3.4 Mass Reduction

By removal of one or more stories this may be achieved and removal of mass[5] will lead to a decrease in the period which will increase the required strength.

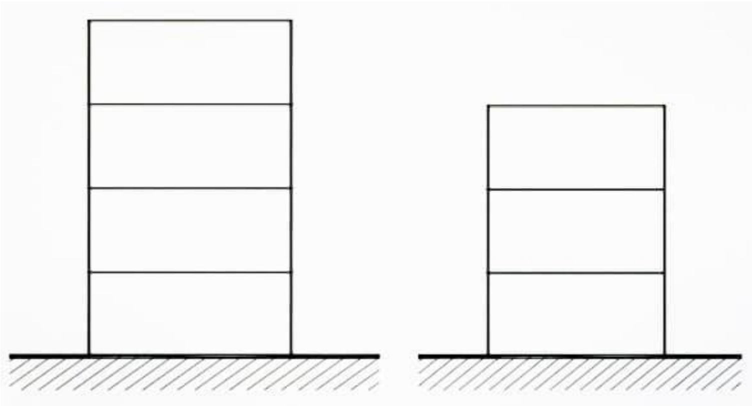


Fig 2.5 Reduction of mass by removing one storey.

2.3.5 Dampers

A Damper[6] is any material or device that absorbs vibrations. Seismic dampers dissipate the energy of seismic waves moving through a building structure.

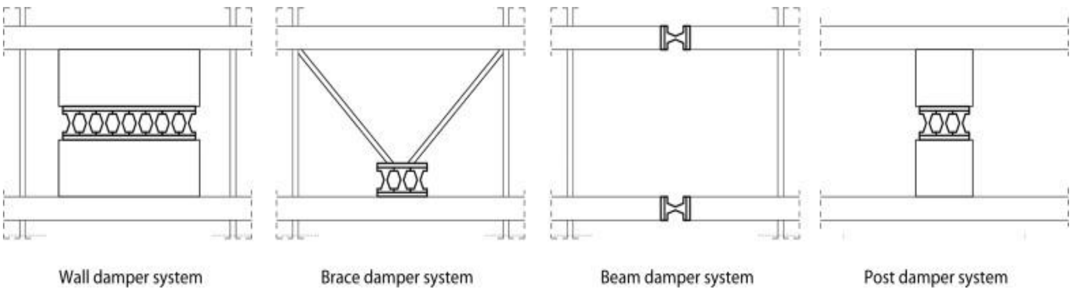


Fig 2. 6 Different kinds of damper.

2.3.6 Bracing

When large openings are required it is an effective solution and potential advantages due to higher strength and stiffness and the amount of work is less. Bracing[7] is also readily available.

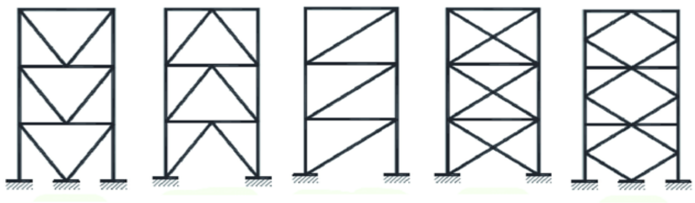


Fig 2. 7 Different kinds of bracing.

2.4 Previous Studies Regarding Retrofitting with Bracing Arrangements

In RCC building shear wall are generally used to oppose parallel quake load, however more often than not steel propping is utilized in steel structure. In Reinforcement Concrete (RC) Frame steel propping is effectively utilized which distributed various reports in most recent twenty years. For improving tremor opposition limit in steel supporting Reinforced cement (RC) building retrofitting measure began on quake harmed structures or existing structure.

To know more insights regarding supporting example framework Kamal M concentrated in 2017. In six celebrated structure was examining with supporting example framework by Kamal, which was risky for Earthquake load however ok for gravity load. There are various sorts of supporting X propping, V supporting speak and there was consider two kinds of propping readiness was thinking about for his examination and correlation was made about the supporting sort and Pattern. In his exploration paper it is obviously seen that more conservative steel is X kind of empty steel like in medium Earthquake zone steel segment is diminished with guaranteeing the underlying security.

Groan Amino A., Majid M. furthermore, Hosseini M. examined conduct in 2012 by non-direct unique examination with various cubic slowing down. Among the investigations they led were a bunch of multi-story steel structures related with three sorts of X, V and Chevron slowing down, two adjoining beach front areas and two perpendiculars to the structure and thought about the conduct of two incongruous cove seismic tremors.

Structures were planned dependent on code. Structures were contrasted with Standard Performance Level PL. Results show that altogether cases, supporting course of action in non-contiguous sounds prompts lower firmness yet higher strength than in nearby narrows, and that for Immediate Occupancy PL, plastic zones show up generally in lower stories, while for Life Safety and Collapse Prevention PLs they show up in scarcely any lower stories.

Chaddar SK, Sharma A has contemplated transformed and V view strategy on RC building (2015). Here the creator utilizes five strategies for slowing down among Robi and Ultano V to think about their adaptability and unbending nature. Seismic coefficient technique (straight static investigation) has been led to assess the impact of various plans of propping part in the structure casing and impact of the steel cross-area.

2.5 Research Methodology

At first we create model of a residential building and then we gave it a run. After the run we saw that the structure had failed. After averaging Ex, Ey, Rsx and Rsy, we were at long last ready to decide how far our structure had advanced when we utilized a technique to pass it. The name of that method is retrofit. We installed X type bracing with different sizes. After increase the size of bracing, then we saw that our building has ok by according to BNBC 2020.

2.6 Summary

This analysis found down that various authors alluded to various evaluation techniques. Some exploration techniques were utilized. Most outsiders have utilized X-supporting or no particular bracing in the structure and researched building frames for bracing. All the analysis work was done essentially to expand the strength of structures by bracing method. The entire construction has understood the adequacy of various supporting examples so the building reconstruction project requires different bracing patterns of the building.

The aftereffect of this analysis will give a comprehension of the conduct of retrofitted framework with steel bracing in reinforcement concrete (RC) building which isn't recognizable in straightforward direct examination.

CHAPTER 3

MODELING AND ANALYSIS

3.1 INTRODUCTION

The previous chapter deal with the different progressed and traditional techniques for seismic retrofitting applied at present time in better places of the world. In our nation due inaccessibility of cutting-edge material and ability work, traditional techniques for seismic retrofitting are adopted. Presumption of the contextual investigation for examination in ETABS, input information for gravity configuration just as seismic retrofitting, examination and plan for gravity loads, assessment of seismic insufficiencies of the structure intended for gravity burden and plan of seismic. Retrofitting by used steel bracing has been discussed in this chapter.

3.2 Criteria for Selection of Buildings

There are numerous ten storied RC structures in Dhaka city having plinth area going from 1500 to 2500sft. A couple of quantities of these structures were planned and built appropriately that can withstand seismic forces. Some of them were planned appropriately yet having a great deal of development shortcoming because of absence of expert man force, for example, rebar detailing, concrete quality, clear cover of reinforcement etc.   A significant percent of these buildings are vulnerable even for a moderate earthquake because of faulty design and defective construction or practically there were no design and instruction during construction work. Another major issue is not follow Building code which is provided by government.

3.3 Input Data for Analysis

Following input value has been utilized for examining the structures. ETABS additionally computes a few important information which are pertinent to the information by utilizing code related formula.

3.3.1 Material specifications

The material property of this Residential building tabulated in table 3.1

Table 3.1 Material property of residential building.

Material Name	Strength (ksi)	Elastic modulus (ksi)
concrete	4	3605
Steel	60	29000

3.3.2 Building layout & Cross sectional properties

Residential building plan view shown in Fig.3.1.

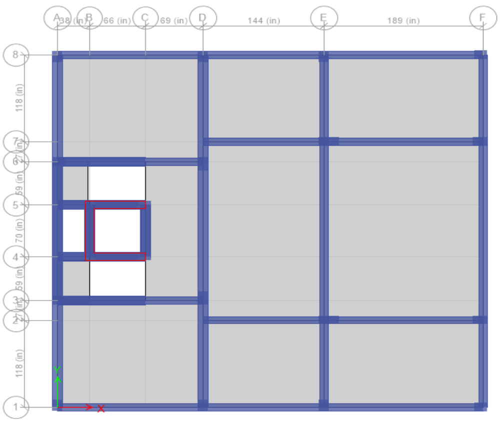
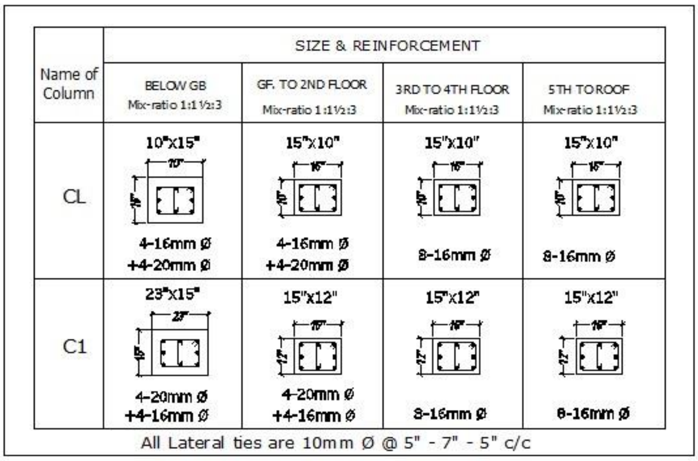


Fig 3.1 Plan view of residential building.

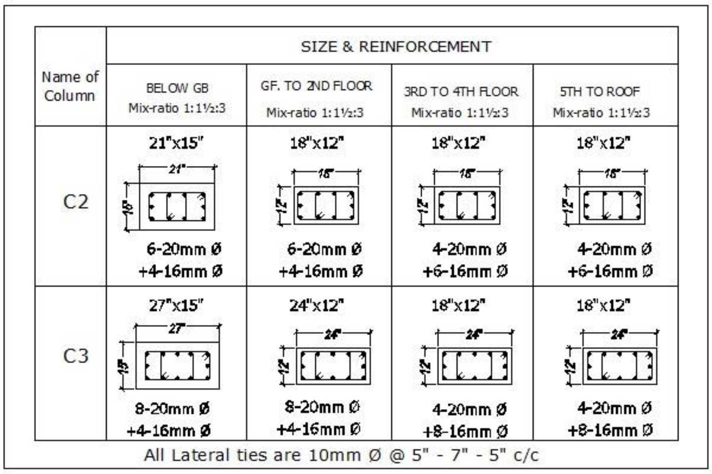
Column Minimum size of column arrangement was wiped out by ACI code (ACI 318-02 R10.8) if the structure isn't unique second opposing edge. Cross sectional properties of column depend on combined flexure and axial loads. Minimum column size 100 square inch and least lateral dimension 10 inch is considered for analysis. Beam As per ACI code (ACI 318-02 9.5.2.1) minimum depth of beam stipulated unless computation of deflection indicates a lesser thickness. To calculate the uniform depth of a beam having more than one span with various span lengths, larger span is considered. Besides the general practice of non-engineered buildings in Dhaka city has been taken in to account. Hence, the depth of beam 15 inch and width 10 inch is considered in this analysis.



Name of Column	SIZE & REINFORCEMENT			
	BELOW GB Mix-ratio 1:1½:3	GF. TO 2ND FLOOR Mix-ratio 1:1½:3	3RD TO 4TH FLOOR Mix-ratio 1:1½:3	5TH TO ROOF Mix-ratio 1:1½:3
CL	10"x15" 4-16mm Ø +4-20mm Ø	15"x10" 4-16mm Ø +4-20mm Ø	15"x10" 8-16mm Ø	15"x10" 8-16mm Ø
C1	23"x15" 4-20mm Ø +4-16mm Ø	15"x12" 4-20mm Ø +4-16mm Ø	15"x12" 8-16mm Ø	15"x12" 8-16mm Ø

All Lateral ties are 10mm Ø @ 5" - 7" - 5" c/c

Fig 3.2 Column schedule of residential building (CL and C1).



Name of Column	SIZE & REINFORCEMENT			
	BELOW GB Mix-ratio 1:1½:3	GF. TO 2ND FLOOR Mix-ratio 1:1½:3	3RD TO 4TH FLOOR Mix-ratio 1:1½:3	5TH TO ROOF Mix-ratio 1:1½:3
C2	21"x15" 6-20mm Ø +4-16mm Ø	18"x12" 6-20mm Ø +4-16mm Ø	18"x12" 4-20mm Ø +6-16mm Ø	18"x12" 4-20mm Ø +6-16mm Ø
C3	27"x15" 8-20mm Ø +4-16mm Ø	24"x12" 8-20mm Ø +4-16mm Ø	18"x12" 4-20mm Ø +8-16mm Ø	18"x12" 4-20mm Ø +8-16mm Ø

All Lateral ties are 10mm Ø @ 5" - 7" - 5" c/c

Fig 3.3 Column schedule of residential building (C2 and C3).

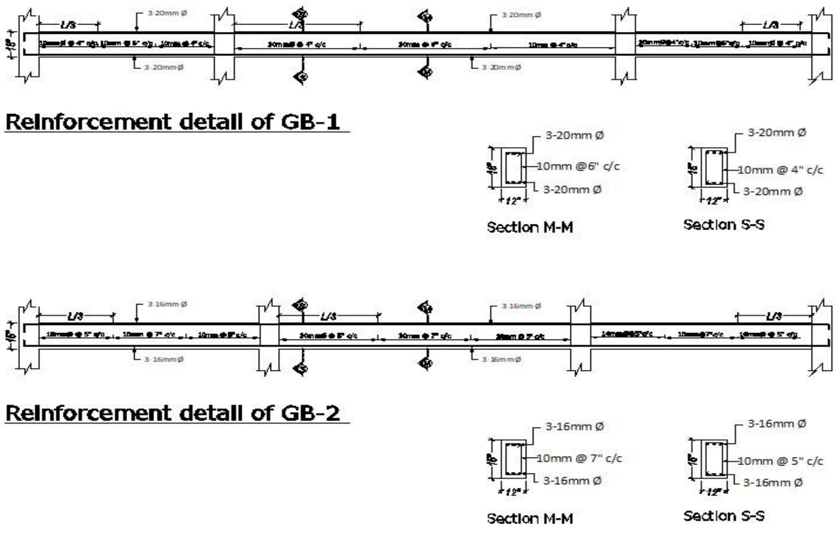


Fig 3.4 Beam schedule of residential building (Beam 1).

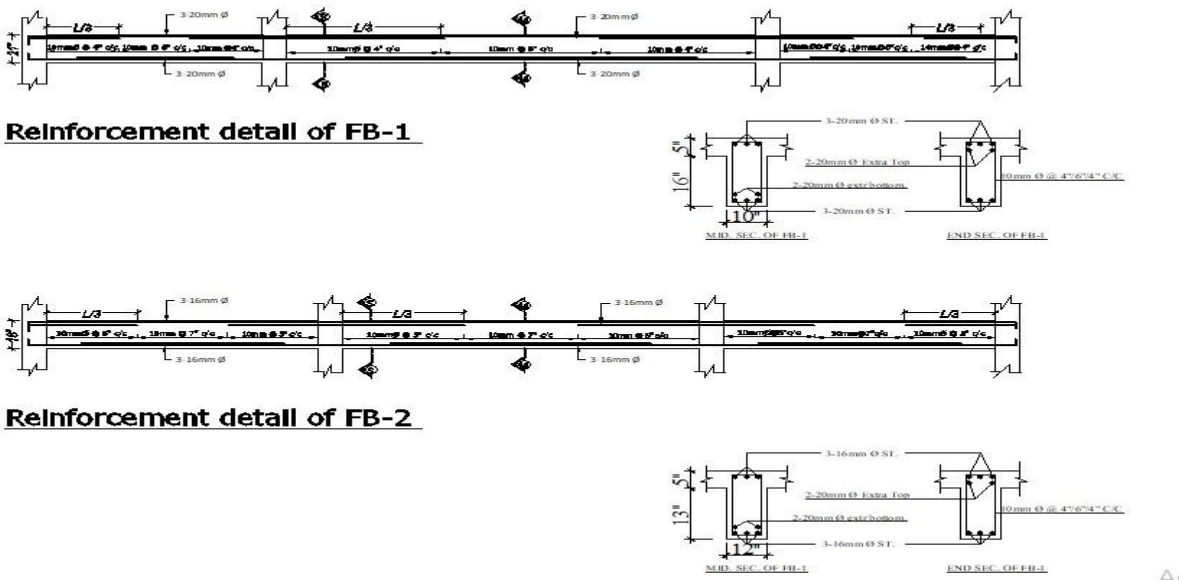


Fig 3.5 Beam schedule of residential building (Beam 2).

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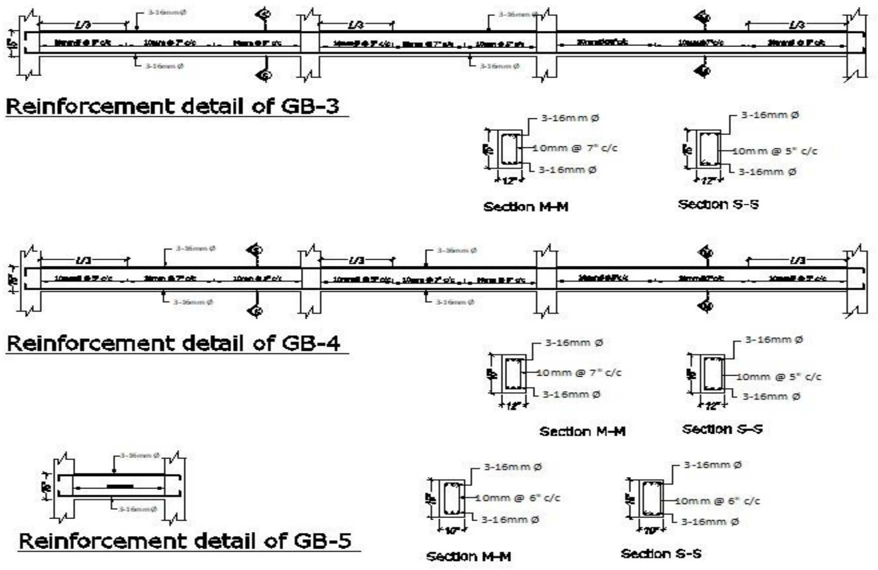

Fig 3.6 Beam schedule of residential building (Beam 3).

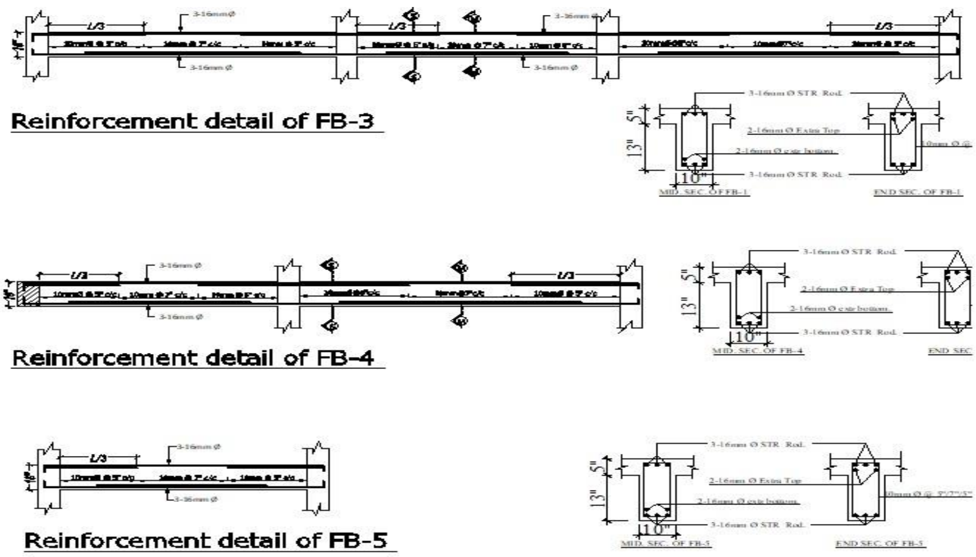

Fig 3. 7 Beam schedule of residential building (Beam 4).

Beam Layout are designed according to BNBC 2006 and beam profile section are given in (Fig. 3.4-3.7).

3.3.3 Concrete protection for reinforcement

In common, concrete, the structure up steel is guaranteed by the ordinarily high alkalinity (pH more than 12) of the strong around the help. A protective oxide layer is adjusted to the structure up steel that helps with preventing the supporting steel from burning-through inside seeing high alkalinity. Also provide Clear cover to protect reinforcement from corrosion.

3.3.4 Gravity loads

Gravity loads are shown below according to BNBC 2020:

Table 3. 2 Gravity loads.

Load	Value
Floor finish	20 psf
Partition wall	25 psf
Stair Roof Beam	0.2 kip/ft.
Boundary Wall	0.1 Kip/ft.
Live	42 Psf

3.3.5 Seismic loads as per equivalent Static load method

In our analysis, 4 different zone according to BNBC 2020 are analyzed. We create 4 different model in FE packages in ETABS, zone coefficient values are zone-1 (Z=0.12), zone-2 (Z=0.2), zone-3 (Z=0.28) and zone-4 (Z=0.36). Earthquake forces are applied in terms of Ex and Ey which are worked in X and Y both direction, its affected base to roof of the structure. In all condition soil type selected “A” and time period of response spectrum is 0.15sec, 0.4 sec and 2 sec applied. After implementation of this in FE packages, we try to correct acceleration factor of response spectrum forces according to **section 2.5.9.4** in BNBC 2020. Finally extract displacement ratio of structure from ETABS.

3.4 Modeling for seismic retrofitting with different bracing system

In the second chapter we have already seen that there are different types of retrofitting. We chose steel bracing technique from a variety of retrofitting[8]. Because steel bracing is very readily available. We have many steel factories in this developing country which is one of the reasons for easy availability. Then we used X bracing with 16 sizes (Table 4.1) in 4 zone, then we find out displacement ratio (Fig 4.3-4.18) and finally we have to do compared displacement ratio in every zone, which are shown in. The braces where we placed them are also given in Figure 4.2.

CHAPTER 4

RESULT AND DISCUSIONS

4.1 INTRODUCTION

A parametric study has been conducted by simulating behavior of residential building with 4 difference zone. A parametric study has been conducted by simulating behavior of residential building with 4 difference zone. In the past sections we have found out about methodology. The residential constructing effectively settled in savar. Yet, in this section we will talk about what we have examination in FEA bundle (ETABS). We have worked for displacement ratio with four zones here: Zone 1, Zone 2, Zone 3, Zone 4 as per BNBC 2020. In our investigation four distinctive size of thickness and four diverse cross sectional x supporting utilized. Supporting thickness are 13mm, 16mm, 18mm and 25mm which are accessible in agricultural nation like Bangladesh. The cross sectional sizes are 150x150, 200x200, 250x250, 300x300 (in mm unit). Our investigation result and charts are talking about in detail in area 4.3.

4.2 Analysis for variant bracing

Here are few 3D Figure of the building that we have analyzed. In This analysis we generally use X steel bracing.

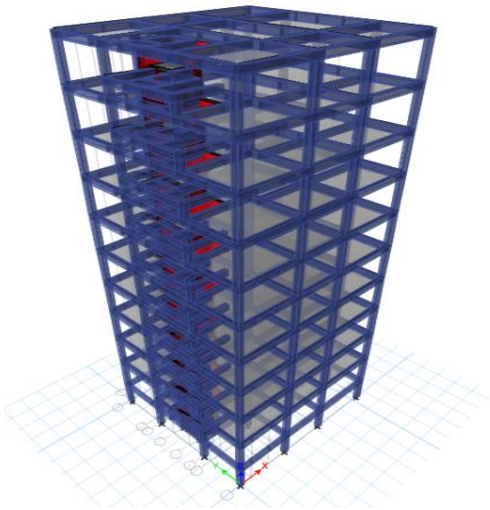

Fig 4.1 Without bracing (3D view).

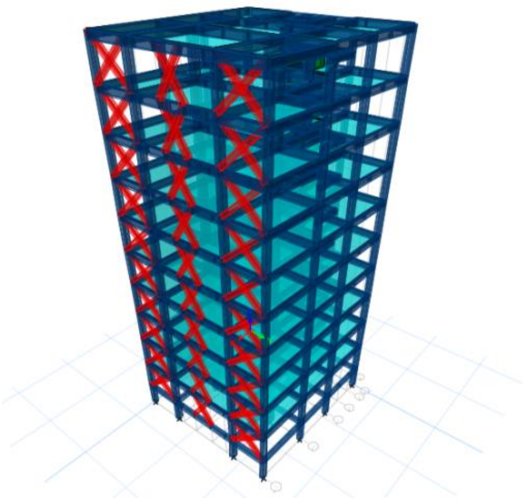

Fig 4.2 With bracing (3D view).

In this FE Analysis we are used gradually 16 types of steel x bracing with 4 different thicknesses, which are shown in Fig 4.1 and 4.2. The sizes of bracing X type are shown in below table.4.1.

Table 4.1 Different sizes steel cross bracing.

bracing profile ID	Cross Section size(mm × mm)	Thickness (mm)
I-150-1	150×150	13
I-150-2		16
I-150-3		18
I-150-4		25
I-200-1	200×200	13
I-200-2		16
I-200-3		18
I-200-4		25
I-250-1	250×250	13
I-250-2		16
I-150-3		18
I-250-4		25
I-300-1	300×300	13
I-300-2		16
I-300-3		18
I-300-4		25

4.3 Zone analysis:

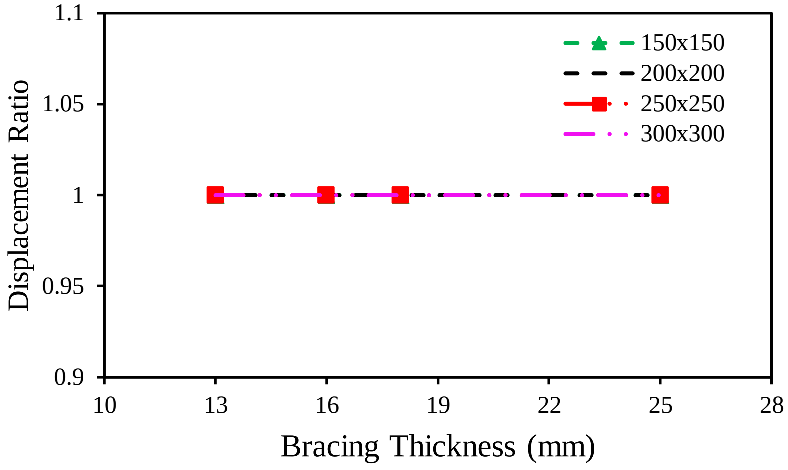

Fig 4.3 Displacement ratio for zone 1 with different size X bracing (X direction Earthquake).

The displacement ratio of x direction of the earthquake force was ok according to BNBC 2020 without bracing with value of 1.002. It is further strengthened after install X bracing, we was seen that displacement ratio remain same in all seismic zone for X directional earthquake force which are shown in (Fig.4.3, 4.7, 4.11 and 4.15). No bracing and bracing condition no significant change occur.

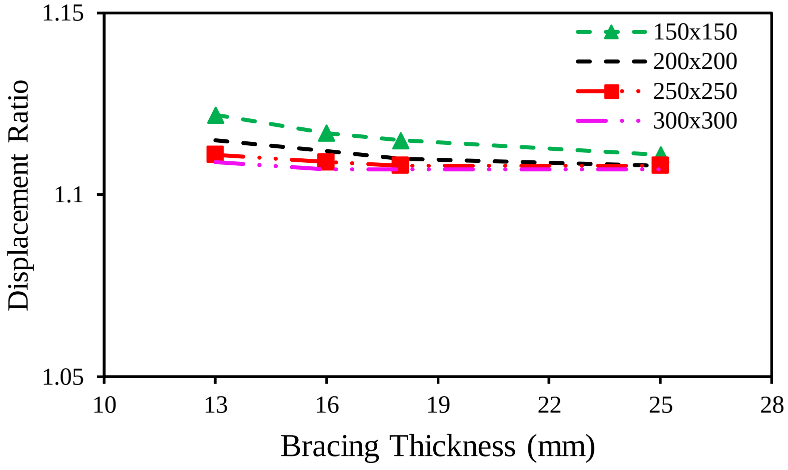

Fig 4.4 Displacement ratio for zone 1 with different size X bracing (Y direction Earthquake).

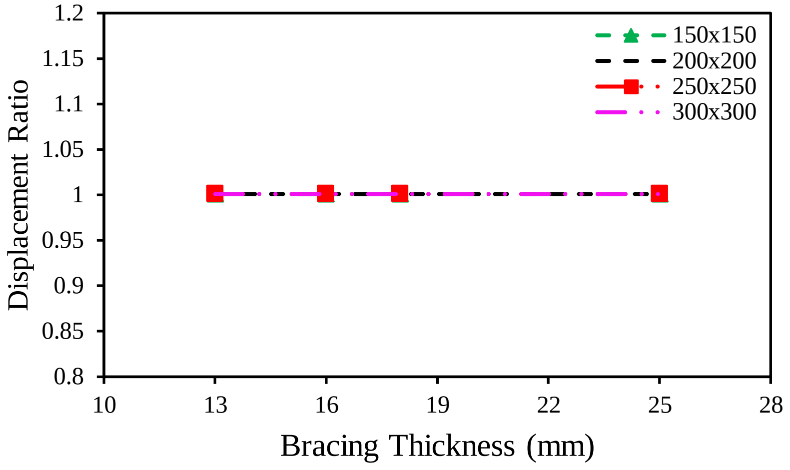

Fig 4.5 Displacement ratio for zone 1 with different size X bracing (X direction response spectrum).

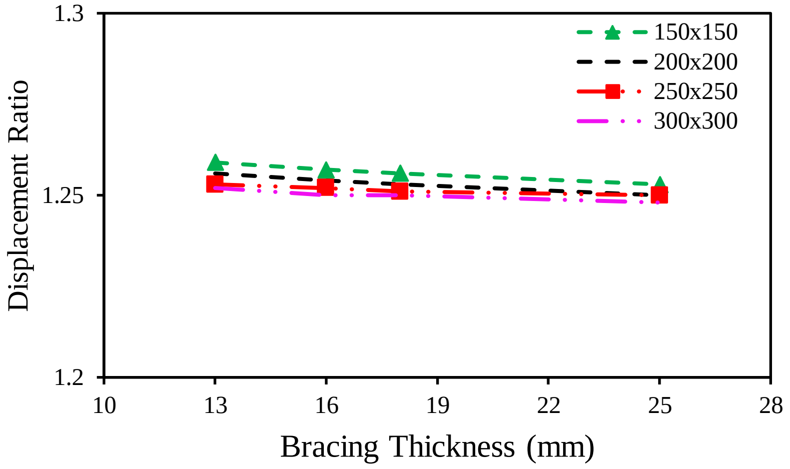

Fig 4.6 Displacement ratio for zone 1 with different size X bracing (Y direction response spectrum).

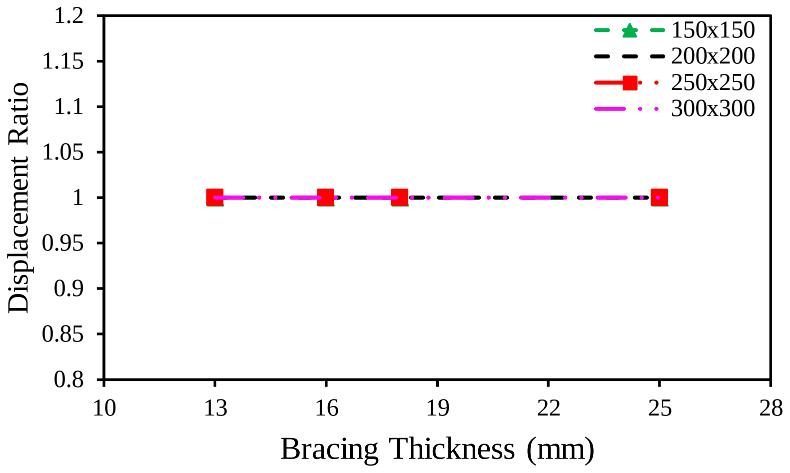

Fig 4.7 Displacement ratio for zone 2 with different size X bracing (X direction Earthquake).

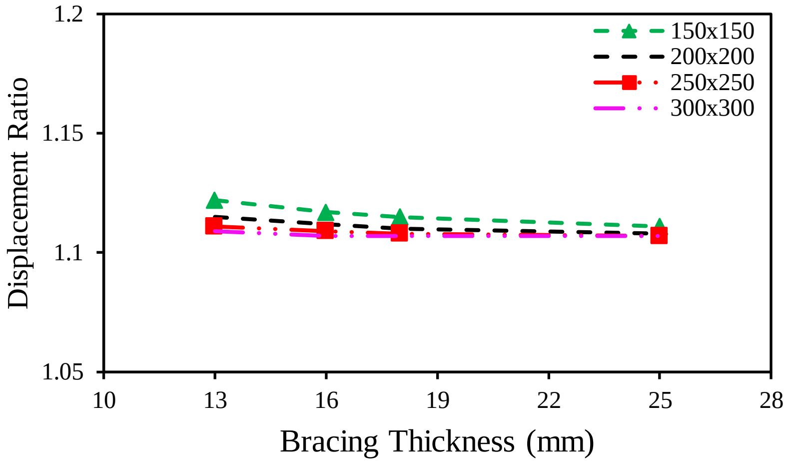

Fig.4.8 Displacement ratio for zone 2 with different size X bracing (Y direction Earthquake).

The value of displacement ratio of the earthquake force y direction was extreme in without bracing with the value of 1.536. After install I-150-1 bracing, it is fixed according to BNBC 2020 with the value of 1.107. We was seen that displacement ratio remain same in all seismic zone and all bracing type (I-150-1 to I-300-4) for Y directional earthquake force which are shown in (Fig.4.4, 4.8, 4.12 and 4.16).

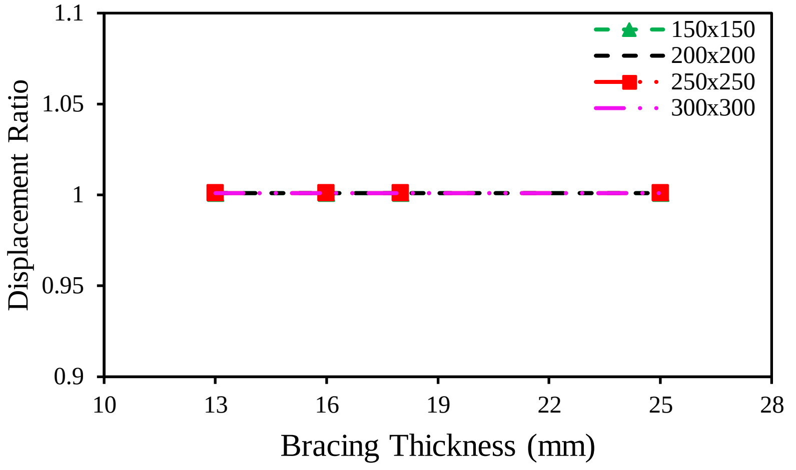

Fig 4.9 Displacement ratio for zone 2 with different size X bracing (X direction response spectrum).

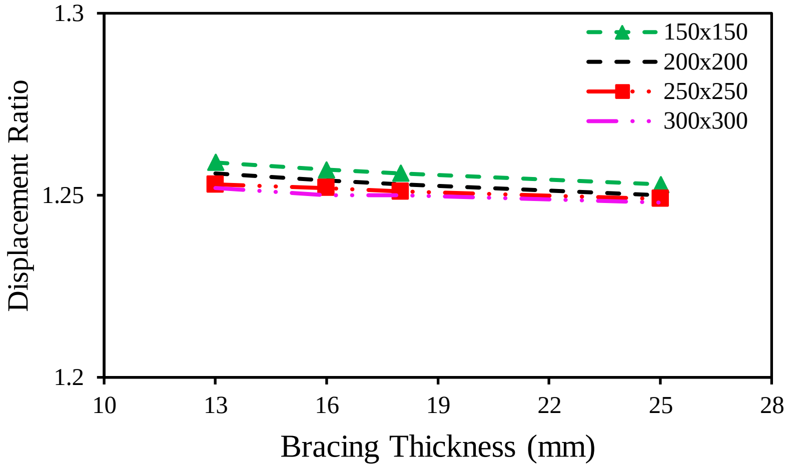

Fig 4.10 Displacement ratio for zone 2 with different size X bracing (Y direction response spectrum).

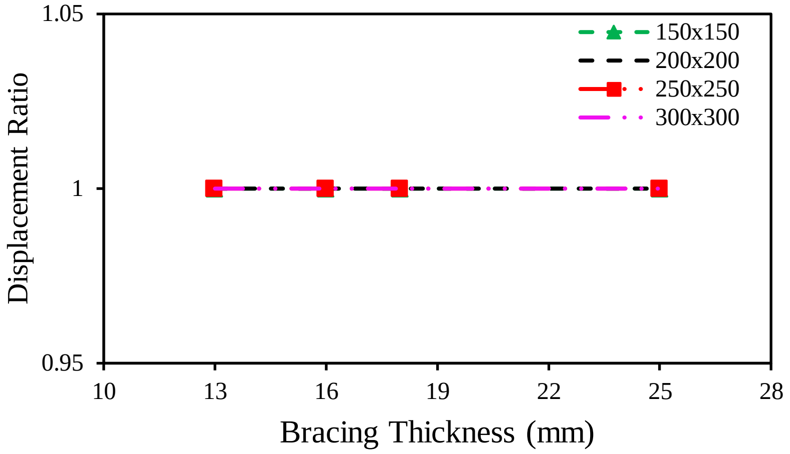

Fig 4.11 Displacement ratio for zone 2 with different size X bracing (X direction Earthquake).

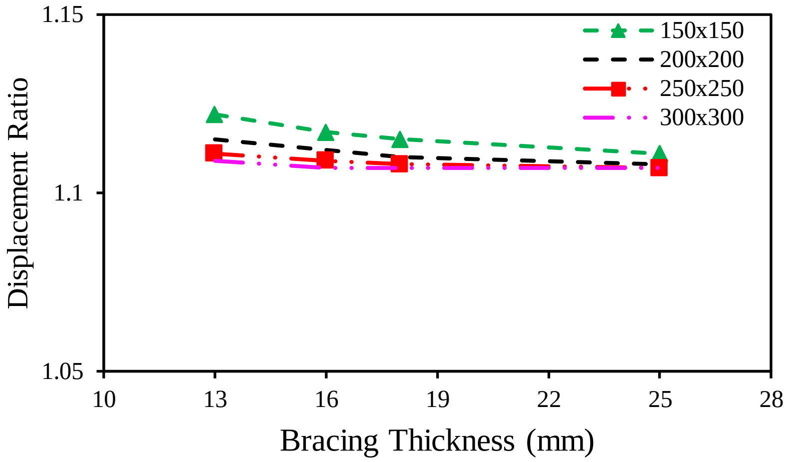

Fig 4.12 Displacement ratio for zone 3 with different size X bracing (Y direction Earthquake).

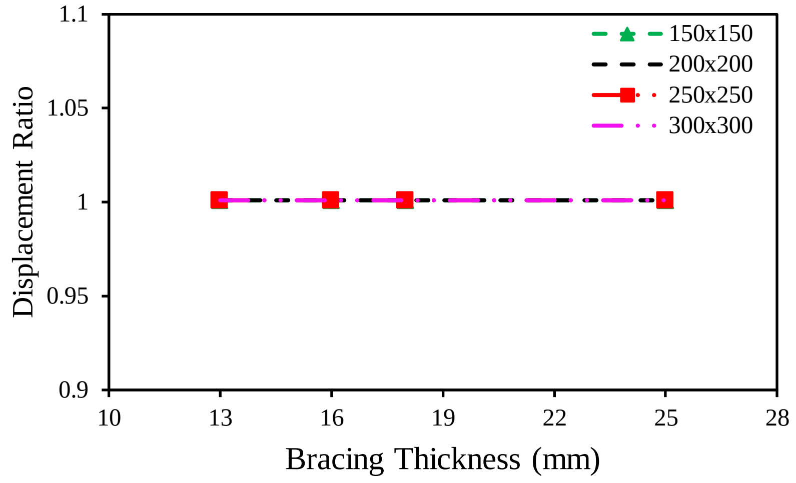

Fig 4.13 Displacement ratio for zone 3 with different size X bracing (X direction response spectrum).

The value of displacement ratio of the response spectrum force X direction was correct according to BNBC 2020 without bracing with the value of 1.004. After increasing the maximum size of bracing, it becomes stronger than before with the value of 1.001. We was seen that displacement ratio remain same in all seismic zone for Y directional earthquake force which are shown in (Fig.4.5, 4.9, 4.13 and 4.17).

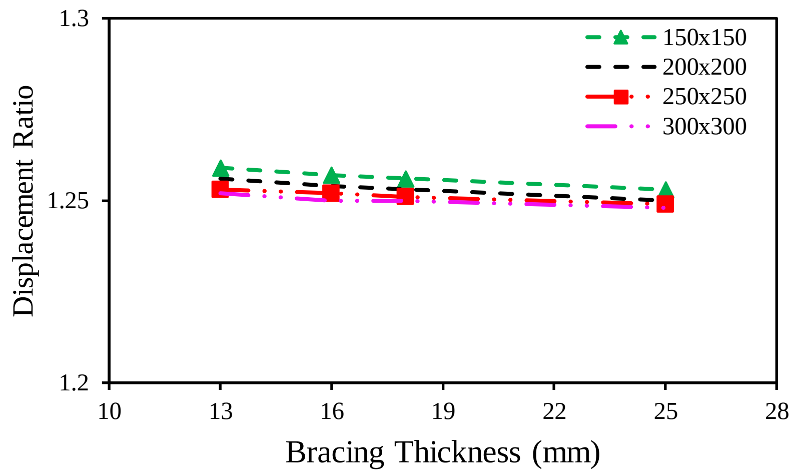

Fig 4.14 Displacement ratio for zone 3 with different size X bracing (Y direction response spectrum).

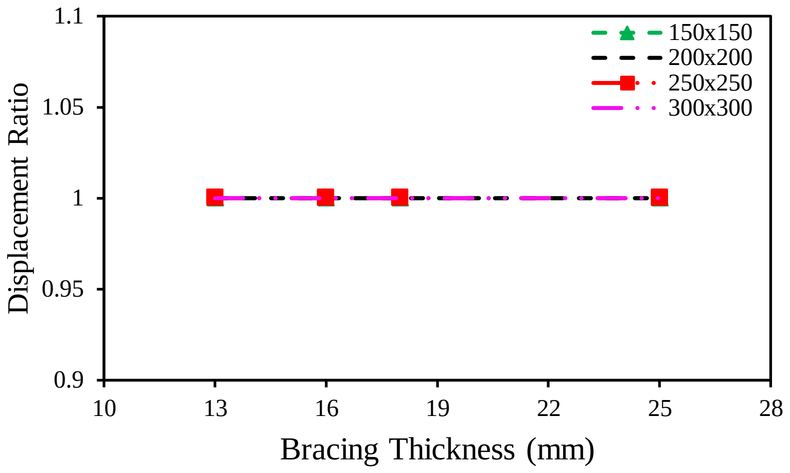

Fig 4.15 Displacement ratio for zone 4 with different size X bracing (X direction Earthquake).

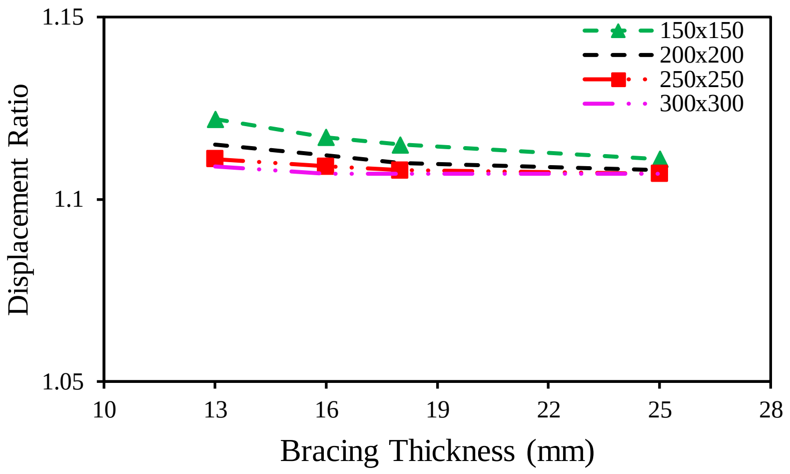

Fig 4.16 Displacement ratio for zone 4 with different size X bracing (Y direction Earthquake).

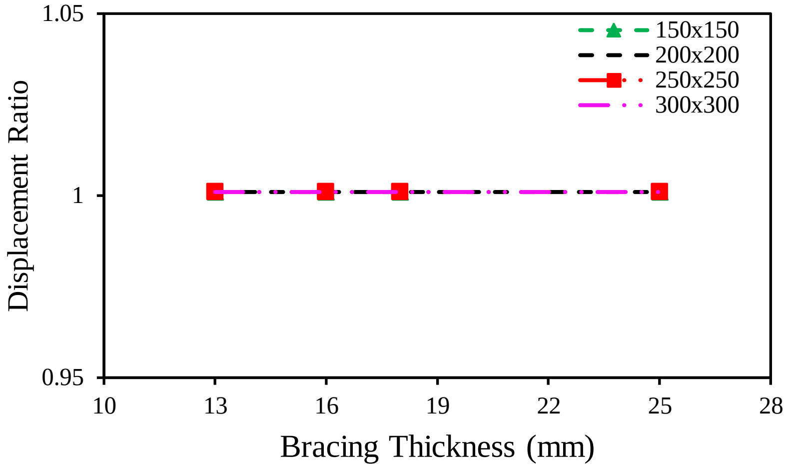

Fig 4.17 Displacement ratio for zone 4 with different size X bracing (X direction response spectrum).

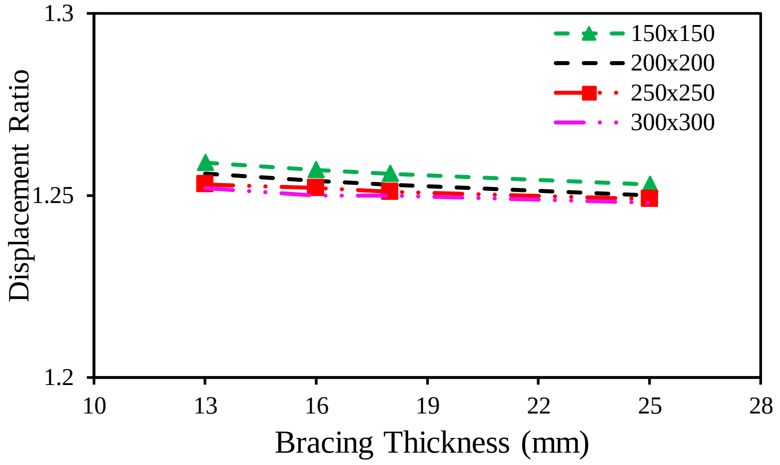

Fig 4.18 Displacement ratio for zone 4 with different size X bracing (Y direction response spectrum).

The value of y direction of the response spectrum force was irregular in without bracing with the value of 1.388. After maximum increasing the size of bracing, it is fixed according to BNBC 2020 with the value of 1.24. But till now it was not good enough. We was seen that displacement ratio remain same in all seismic zone for Y directional earthquake force which are shown in (Fig.4.6, 4.10, 4.14 and 4.18).

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

We have done this analysis using bracing to protect the building from earthquakes. We have also got some displacement ratios by doing this analysis. Some of the findings of this analysis are shown below.

- After analyzing the existing RC building, we collaborate all displacement ratio for earthquake and response spectrum force. Then we saw extreme displacement towards the y of the earthquake and irregular displacement towards the y of the response spectrum. We also found that the value of earthquake and response spectrum in the direction of x is correct according to the code of BNBC 2020.
- Then we started using bracing to reduce the displacement ratio for response spectrum and earthquake force. Also stiffness of this building increases due to installation of bracing.
- First we use 150 mm*150 mm cross sectional size bracing with 13 mm, 16 mm, 18 mm and 25 mm thickness. But we did not success to reduce the displacement ratio for response spectrum force in y axis. But the displacement ratio for earthquake in the direction of y was ok by according to BNBC code 2020 in all 4 seismic zone.
- Then we gradually use 200 mm*200 mm and 250 mm* 250 mm cross sectional size braces with 13 mm, 16 mm, 18 mm and 25 mm thickness. But even then we were not able to get the desired displacement ratio for response spectrum force.
- Finally we use 300 mm*300 mm cross sectional size bracing with 13 mm, 16 mm, 18 mm and 25 mm thickness. But now the use maximum size of bracing we are able to bring the value of the response spectrum to 1.24 from 1.39 no bracing condition. Although this was not good enough, but finally we were able to mostly reduce the displacement ratio for the response spectrum force.

5.2 Future Recommendation

In this survey, work has been done to increase the strength of the building to protect it from earthquakes. Based on the results of the study and the experience gained during the research, some steps can be recommended for the improvement of this study as described below:

- Several types of retrofit methods can be used for better results in such studies. Such as - jacketing of column, jacketing of beam, adding shear wall etc.
- It is better to use BNBC's most recently published code for this survey, then the accuracy rate of the survey will increase a lot.
- We done our analysis with X- type bracing, V and ZX bracing are also need to perform in FEA.
- This analysis will be performing by T bracing instead of I bracing.
- Instead of steel bracing FRP or CFRP raping will be used in beam, slab and column.
- Other soil types can be used to get more accurate results.

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APPENDIX

Table.A. 1 Response spectrum value for zone-1.

T	Sa
0	0.0192
0.2	0.048
0.4	0.048
0.6	0.04
0.8	0.03
1	0.024
1.2	0.02
1.4	0.017143
1.6	0.015
1.8	0.013333
2	0.012
2.2	0.009917
2.4	0.008333
2.6	0.007101
2.8	0.006122
3	0.005333
3.2	0.004688
3.4	0.004152
3.6	0.003704
3.8	0.003324
4	0.003

Table.A. 2 Response spectrum value for zone-2.

T	Sa
0	0.032
0.2	0.08
0.4	0.08
0.6	0.066667
0.8	0.05
1	0.04
1.2	0.033333
1.4	0.028571
1.6	0.025
1.8	0.022222
2	0.02
2.2	0.016529
2.4	0.013889
2.6	0.011834
2.8	0.010204
3	0.008889
3.2	0.007813
3.4	0.00692
3.6	0.006173
3.8	0.00554
4	0.005

Table.A.3 Response spectrum value for zone-3.

T	Sa
0	0.0448
0.2	0.112
0.4	0.112
0.6	0.093333
0.8	0.07
1	0.056
1.2	0.046667
1.4	0.04
1.6	0.035
1.8	0.031111
2	0.028
2.2	0.02314
2.4	0.019444
2.6	0.016568
2.8	0.014286
3	0.012444
3.2	0.010938
3.4	0.009689
3.6	0.008642
3.8	0.007756
4	0.007

Table.A.4 Response spectrum value for zone-4.

T	Sa
0	0.0576
0.2	0.144
0.4	0.144
0.6	0.12
0.8	0.09
1	0.072
1.2	0.06
1.4	0.051429
1.6	0.045
1.8	0.04
2	0.036
2.2	0.029752
2.4	0.025
2.6	0.021302
2.8	0.018367
3	0.016
3.2	0.014063
3.4	0.012457
3.6	0.011111
3.8	0.009972
4	0.009