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IMPACT OF SEISMIC PERFORMANCE OF AN RCC BUILDING WITH AND WITHOUT BRACING

Abhijeet Kumar Das[1], Afra Anam Provasha[2]

[1] *Graduate Student, Dept. of Civil Engineering, World University of Bangladesh, Dhaka, Bangladesh*
[2]*Lecturer, Dept. of Civil Engineering, World University of Bangladesh, Dhaka, Bangladesh*

Abstract - *Seismic events pose significant threats to the structural integrity of buildings, necessitating effective solutions to mitigate potential damages. This research paper investigates the seismic performance of a G+7 storey reinforced concrete (RCC) building with and without bracing by using ETABS software and response spectrum analysis to evaluate the dynamic response of the structure. This study employs a comparative approach to evaluate the effectiveness of X-bracing and V-bracing systems in enhancing the structural resilience of buildings subjected to seismic loads. Through comprehensive analysis, this research aims to provide insights into the seismic behavior of the RCC building with and without bracing. To measure how a structure reacts to seismic loads, engineers look at a number of performance metrics, including base shear, inter-story drift, lateral displacements, and story shear.*

Key Words: **Steel Bracing, Seismic Performance, Displacement, Reinforcement, Base Shear, Storey Drift, Response Spectrum, Steel Sections, ETABS.**

1. INTRODUCTION

Buildings with reinforced concrete frames are widely used in construction due to their durability and strength. They may still be susceptible, nevertheless, to lateral forces brought on by earthquakes. Adding steel bracing systems is one way to lessen these stresses and enhance the seismic performance of such buildings. Steel bracing is made up of steel elements that are positioned carefully inside the structure to provide it more rigidity and strength. By absorbing and redistributing the energy produced during seismic events, these bracing can lessen lateral displacements and enhance the structural response as a whole.

Two pivotal factors of how to resist a frame structure under the conditions of cross-stresses which occurs horizontally is with the live load method and bracing with steel is cost efficient. The most iconic structures on Earth have all made use of bracing, the primary retrofit method, to lateral stabilize their structures. The diagonals experience axial stress, which causes bracing to be effective. In order to maintain stiffness and strength against horizontal shear, minimum member sizes are required. Several methods are employed, such as cladding walls with slates, constructing shear walls, covering floor columns with an extra layer of mesh, and utilizing steel bracing. Enhance the ductility or strength of preexisting structures. Bracing increases the capacity and lateral stiffness of the frame, which improves its seismic performance. By means of integrating the bracing system into the frame, a load from the frame would be redirected to the braces, which will be supported by micro trusses capable of carrying high forces, which will also result in the stiffening of the frame. When constructing buildings that will be subjected to lateral loads from earthquakes or wind, one effective design option is the structural steel framed system. Therefore, reinforced concrete frames with low lateral resistance might benefit from steel bracing systems that can be installed during retrofitting.

A soft storey is defined by BNBC-2020 as one whose lateral stiffness is less than either 70% of the storey above it or 80% of the average stiffness of the three storeys above it. The most typical type of vertical discontinuity results from an unanticipated consequence of infill materials in the upper floors. Typically, only the bare frame effect is taken into account when analyzing buildings, ignoring the effects of infill walls.

Today, designers and engineers are increasingly focused on earthquake resistance when analyzing and constructing buildings to mitigate seismic impact. They must handle a range of structures, from simple elements like poles to complex multi-story buildings and bridges, all of which face various loads, including seismic and dynamic forces. The design process involves selecting an appropriate structural system, calculating loads based on the building's purpose, and conducting structural analysis to predict behavior under specific conditions. This includes designing structural components to withstand different forces throughout the building's lifespan, particularly lateral seismic loads. The study adheres to the National Building Code of Bangladesh (BNBC 2020) for seismic design and analysis.

2 LITERATURE REVIEW

Various researches have been performed to review the seismic performances of the RC frames with different bracing systems, such as X-type and V-type bracing, or without bracing. Structural bracing enhances the displacement capacity of a building, and in high-rise RC structures, it is designed to resist lateral forces by increasing stiffness, strength, and energy dissipation. It also investigates different bracing configurations, such as diagonal, V, inverted and K-

type. Suitable bracing system between columns resists lateral loading with sufficient strength to make the structure seismic-resistant. It is space-effective, economical, and not too complicated to install. In this regard, steel bracing has been found to be quite effective and efficient in counteracting the lateral loads in RC structures and thus is considered an optimum solution for seismic stability improvement in reinforced concrete frames. Using a variety of bracing systems helps structures with storey drift and displacement to a lesser extent. The lateral load capacity of a structure can be increased most effectively using X-bracing systems, among other bracing arrangements. The bracing system is designed to decrease the column's bending moment and shear force. By virtue of its axial action, steel bracing transfers the lateral load. Steel cross bracing outperforms all other types of bracing. The current building can be reinforced using steel bracing. [1]

A concrete core or diagonal steel components can act as effective bracing elements, providing stability and resisting lateral loads. In braced structures, beams and columns are typically designed to handle vertical loads, while the bracing system is expected to absorb all lateral forces. Braced systems exhibit notable lateral stiffness and strength, particularly during moderate to strong earthquakes. When comparing bending moments in different bracing configurations, sway behavior differs between diagonal and single-brace systems. Single diagonal bracing generally shows higher deflection, causing noticeable jerks, compared to double diagonal bracing. In single-braced systems, base shear is significant at the top floors and generally distributes evenly from floor to floor.[2]

In multi-story buildings, reinforced concrete frames often utilize either concrete or steel bracing as structural methods to resist earthquake forces. Retrofitting is essential for many existing reinforced concrete buildings that fall short of adequate seismic resistance. By incorporating a steel or concrete bracing system, non-compliant RC frames can achieve greater earthquake resilience. Concrete and steel bracing offer numerous advantages, such as affordability, ease of installation, space efficiency, and adaptability to meet specific stiffness and strength demands. This seismic analysis of RC buildings explores various bracing configurations, including diagonal, V, inverted V, combined V, and X types. The study finds that X-type concrete bracing significantly enhances structural rigidity and minimizes maximum story drift in RC frames. [3]

Recent investigations into RC structures for seismic performance highlight that, over the past few decades, bracing systems and shear walls have emerged as the most suitable structural solutions. Shear walls are highly effective against lateral forces, which often lead to extensive structural damage during earthquakes. For additional horizontal force resistance in frame structures, bracing serves as a cost-effective and efficient alternative. [4]

Prioritizing structural safety against lateral load was of utmost importance for high-rise buildings constructed with RCC frames. The wind, earthquakes, and other natural disasters caused these burdens. Various steel or RCC bracing systems were installed to withstand the lateral loads that the structure was subjected to. Potential benefits of RCC bracing over conventional bracing methods include increased stability and stiffness. The purpose of this research was to examine the seismic behavior of high-rise buildings and compare various RCC bracing systems. Moment Resisting Frames (MRFs), X-Braced Frames, and two other structural configurations are also utilized in this paper.[5]

Over the years, lateral loads have been identified as a primary factor in the failure of reinforced concrete (RCC) buildings. To counteract these forces, bracing systems have proven to be an effective lateral load-resisting solution, particularly in RCC structures. Various bracing methods have successfully mitigated seismic responses, providing both economic and practical advantages. Steel bracing systems, for example, are quick to implement and are commonly installed between existing vertical structural elements. The objective of analyzing a building's seismic response is to design it to minimize damage during an earthquake, enhancing its overall resilience. The purpose of this work was to summarize previous research on unraced and braced multistory RCC buildings. [6]

Research Objective:

1. To assess the seismic performance of RCC buildings equipped with X-bracing and V-bracing systems.
2. To compare the efficacy of X-bracing and V-bracing configurations in improving structural resilience against seismic loads.
3. To analyze the dynamic response of RCC buildings with X-bracing and V-bracing using ETABS software and response spectrum analysis.

2.1 BRACING

Braces are important elements in building that are not only responsible for the structural integrity but also are systems to protect the building from the hazard of falling. Bracing systems are the structural elements that ensure the building's lateral force resistance to wind, seismic, and other load activities that become the trigger for the building's sway or collapse. However, a well-planned philosophy of lateral load resisting system not only allows a building to be more effortlessly resistant to these forces but also minimizes the harm to the structure and occupants.

As bracing is a very strong structural system, it is frequently used in buildings that are susceptible to lateral stresses, such as wind and seismic pressure. The action of bracing carries

the lateral loads, whereas the frame's beams and columns are the ones carrying the vertical loads.

Various types of bracing utilized in building are determined by their share. Several of them are:

2.1.1 Diagonal Bracing

On most building sites, you will see diagonal bracing. Installing diagonal members is the method to use. It runs along the perimeter of a building and is often constructed of steel. These diagonal elements do a great job of distributing lateral stresses, like earthquake or wind, throughout the building.

Figure 2.1: Diagonal- Bracing

2.1.2 X Bracing or Cross Bracing

"X bracing" or "Cross bracing" is a structure of a building where the exterior walls are reinforced with diagonal members in an X pattern. Diagonal components provide substantial resistance to lateral forces, intersecting at the midpoint of the wall's height. Cross bracing not only strengthens the structure but can also be used to create visually appealing patterns, adding both functional and architectural value to a building's design.

Figure 2.2: X- Bracing or Cross Bracing

2.1.3 V Bracing:

V-bracing is highly effective for numerous structural systems, providing strong resistance to both tension and compression forces. The angle and arrangement of the diagonal members, usually positioned at defined intervals along the building's height, are determined by the specific structural needs and the expected lateral forces at the location.

Figure 2.3: V Bracing

2.1.4 K Bracing:

Similar to V-Bracing, K-Bracing provides lateral stability to buildings and other structures through structural bracing.

Figure 2.4: K Bracing

2.1.5 Inverted V Bracing:

One type of diagonal bracing utilized in multi-story structures is inverted V bracing. Diagonal members coming from the columns on each floor and going to a common node near the top of the construction, it forming creating an inverted V. Stability has increased by this system which could well redistribute lateral stresses from the top stories to the bottom.

Figure 2.5: Inverted V Bracing

3. MODELING AND ANALYSIS:

Table -1: Building Information

Type of building	Residential
No. of Stories	GF + 7
Story height	90 ft
Ground floor length	77 ft
Ground floor width	55 ft

Table -2: Material Properties

Yield strength of steel, fy	60 ksi
Compressive strength of concrete, f_c'	4 ksi
Unit weight of concrete	150 psf
Unit weight of brick	121.34 psf

Table -3: Member Properties

Slab Thickness	5 inch
Size of Beam	12 inch x 20 inch (ground floor) 16 inch x 18 inch (remaining stories) 12 inch x 24 inch (remaining stories)
Size of column	12 inch x 26 inch 12 inch x 36 inch 16 inch x 16 inch
Steel Section Properties	
Steel Angel Section	ISA 200X200X25

Table -4: Building Code

Building Code	ACI 318-99 BNBC 2020

Table -5: Seismic Data

Seismic Zone	3
Seismic Zone Factor, Z (Table no 6.2.14 of BNBC 2020)	0.28
Impact Factor, I (Table no 6.2.17 of BNBC 2020)	1
Response Reduction Factor, R (Table no 6.2.19 of BNBC 2020)	5
Soil type	2

3.1 MODEL OF BUILDING:

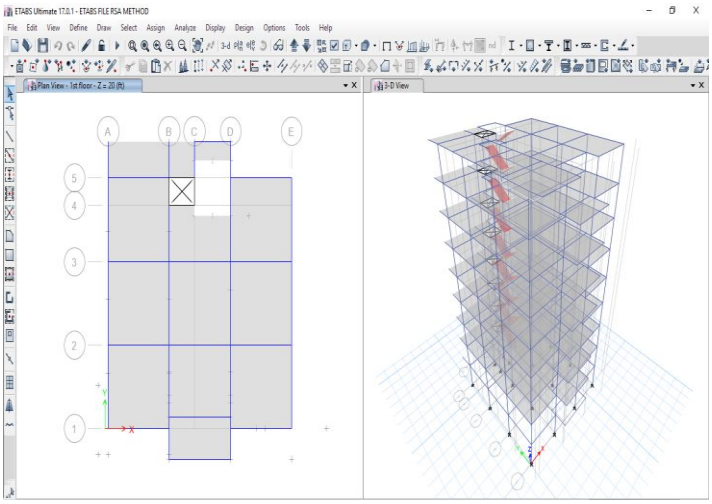


Figure 3.1: Plan and 3D view of building without bracing

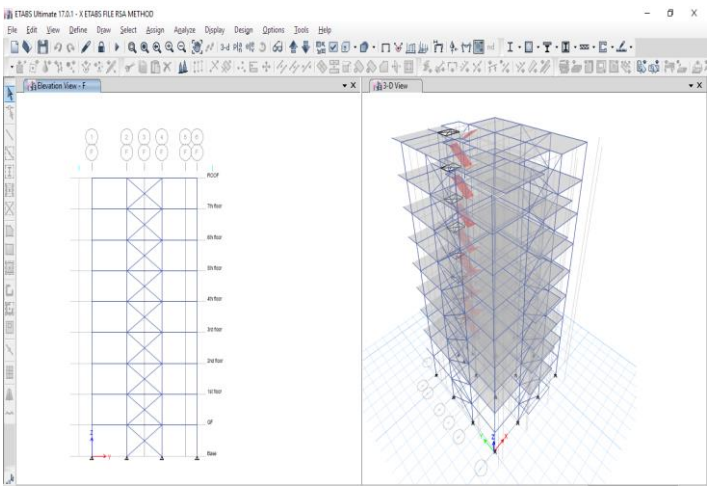


Figure 3.2: Elevation and 3d view of building with X bracing

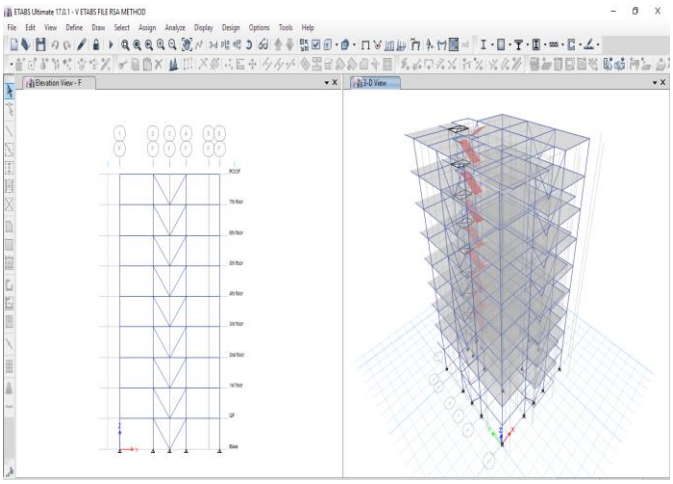


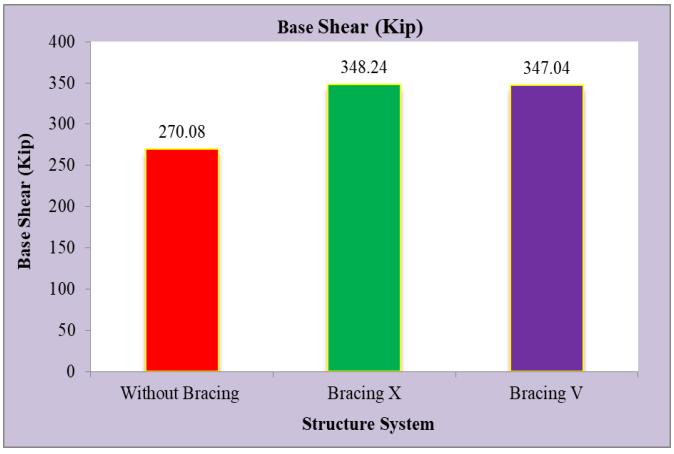
Figure 3.3: Elevation and 3d view of building with v bracing

4. RESULT AND DISCUSSION:

4.1 Base Shear: Base shear refers to the total lateral force or shear that is transferred to the foundation of a building or structure during an earthquake or other dynamic loading conditions. It is an important parameter used in the design of structures to ensure their stability and resistance to seismic forces. Base shear is determined by analyzing the seismic forces acting on the structure and calculating the total lateral force that needs to be resisted by the foundation.

Table -6: Base Shear

Without Bracing	Bracing X	Bracing V
270 kip	248.24 kip	347.04 kip



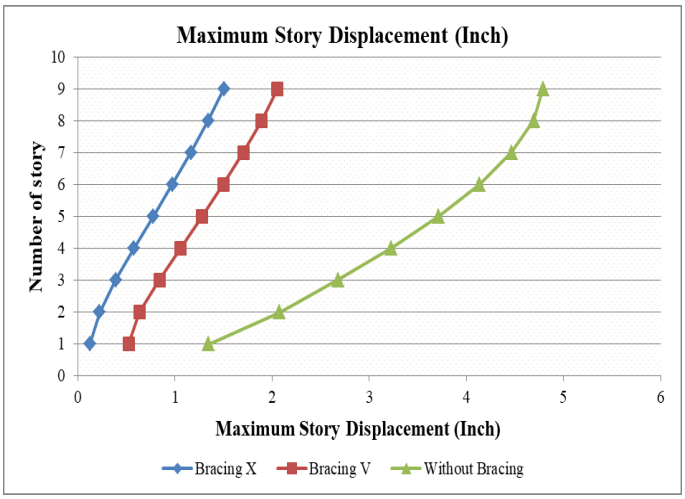
Graph 1: Base Shear

Result: Among three models, the largest base shear has been generated of the Bracing X due to seismic forces whilst the least amount has been appeared at the Without Bracing structure and model V has experienced much lateral force at the base than the Without Bracing structure resistance against seismic ground acceleration.

4.2 Story Displacement: Usually, story displacement is understood as the extent to which each story is horizontally displaced from the ground level. It is often measured in terms of inter-story drift, which is the relative horizontal displacement between adjacent floors or stories. Inter-story drift is typically expressed as a ratio or a percentage of the height of the story.

Table -7: Maximum Story Displacement (inch)

Story	Elevation ft.	Bracing X	Bracing V	Without Bracing
ROOF	90	1.50	2.05	4.79
7th floor	80	1.34	1.89	4.69
6th floor	70	1.16	1.70	4.46
5th floor	60	0.97	1.49	4.13
4th floor	50	0.77	1.28	3.71
3rd floor	40	0.57	1.05	3.22
2nd floor	30	0.39	0.84	2.68
1st floor	20	0.22	0.63	2.07



Graph 2: Lateral Story Displacement (Inch)

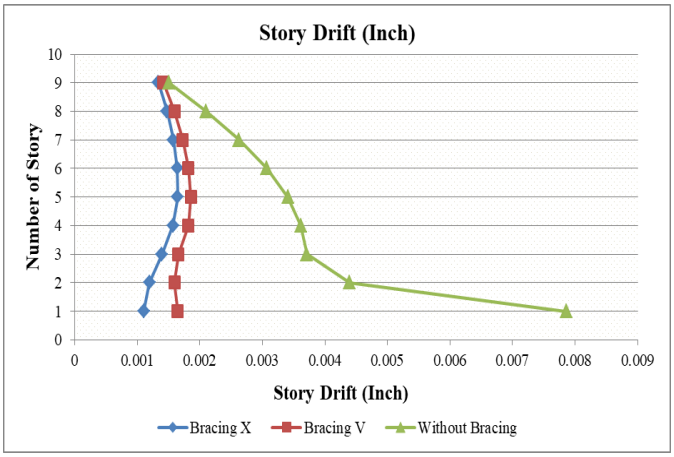
Result: From the graph, it is observed that the Without Bracing has experienced the highest amount of lateral displacement whereas the Bracing X frame has faced the least. This is also very close to the displacement of bracing V. In addition, lateral story displacement is higher in top stories for all frames as the lower ones are more rigidity connected with the support at base.

4.3 Story Drift: Story drift is typically expressed as the ratio or percentage of the horizontal displacement between two consecutive floors to the height of the story. It represents the relative amount of deformation or drift experienced by

each story compared to its height. For example, a story drift of 0.005 indicates that the horizontal displacement between two floors is 0.005 times the story height.

Table -8: Story Drift (inch)

Story	Elevation ft.	Bracing X	Bracing V	Without Bracing
ROOF	90	0.0013	0.0014	0.0015
7th floor	80	0.0014	0.0015	0.0020
6th floor	70	0.0015	0.0017	0.0026
5th floor	60	0.0016	0.0018	0.0030
4th floor	50	0.0016	0.0018	0.0034
3rd floor	40	0.0015	0.0018	0.0036
2nd floor	30	0.0013	0.0016	0.0037
1st floor	20	0.0011	0.0015	0.0043



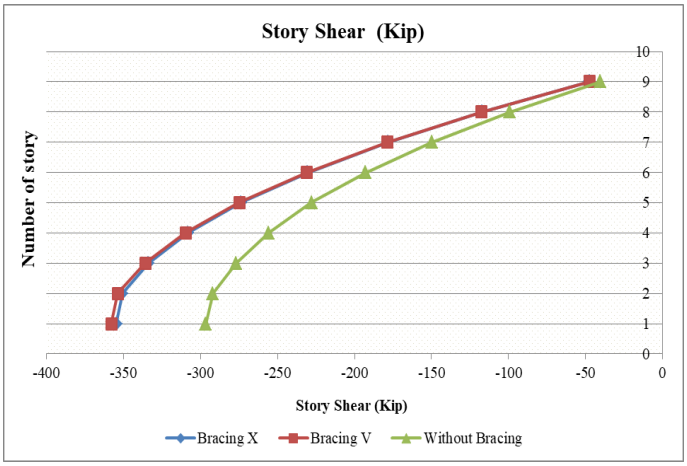
Graph 3: Story Drift (inch)

Result: The graph shows that without bracing structure has higher story drift. Without bracing structure has experienced the largest story drifts per story due to having less stiffness and inadequate lateral load resisting system. On the other hand bracing X has less story drift compare to without bracing structure and V bracing. More story drift indicates less stiffness as well as the necessity of strengthening those stories.

4.4 Story Shear: Story Shears represent the distribution of shear forces across different floors or levels of a building. They indicate the magnitude of lateral forces transferred to each level and are a result of the interaction between the applied loads and the lateral load-resisting system. Comparing the story shear values between the models with and without Bracing enables an assessment of the load transfer mechanisms and the effectiveness of Bracing in redistributing lateral forces and shear concentrations at specific levels.

Table -9: Story Shear (Kip)

Story	Elevation ft.	Bracing X	Bracing V	Without Bracing
ROOF	90	-47.33	-47.38	-40.39
7th floor	80	-117.23	-117.40	-99.20
6th floor	70	-178.30	-178.65	-149.93
5th floor	60	-230.44	-231.06	-192.71
4th floor	50	-273.69	-274.66	-227.84
3rd floor	40	-308.11	-309.54	-255.71
2nd floor	30	-333.78	-335.82	-276.82
1st floor	20	-350.81	-353.69	-292.05



Graph 3: Story Shear (Kip)

Result: The story shear in the ground floor of the model with bracing (X and V) is almost 17% less than the story shear in the ground floor of the model without bracing. At ground floor story shear is high and it decreases gradually in upper floor.

5 CONCLUSIONS

1. X-bracing significantly reduces lateral displacement by 68-89% while V-bracing achieves a reduction 53-76%.

2. The reduction in story drift for X-bracing was almost 80% at the bottom stories but gradually decreasing towards the top, with a slight increase in story drift by 26% at the roof compared to the unbraced frame, hinting at potential challenges in maintaining bracing effectiveness at higher levels.

3. Conversely, V-bracing reduced story drift by 15%-63% from top to bottom stories, however, it increased drift by 28% at the roof.

4. Both X-braced and V-braced frames exhibit approximately 29% higher base shear compared to the unbraced frame. Also, the story shear in both X-braced and V-braced frames is notably higher, ranging from 17-21% greater than the unbraced frame in both x and y directions indicating significant force redistribution within the structure, possibly due to the concentrated load paths created by the bracing systems.

5. Bracing, whether in the form of X-bracing or V-bracing, offers significant potential for seismic retrofitting and strengthening, as evidenced by notable reductions in lateral displacement and story drift compared to unbraced frames.

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BIOGRAPHIES

ABHIJEET KUMAR DAS, B.Sc. in Civil Engineer, World University of Bangladesh, Dhaka, Bangladesh.