Evaluating Seismic Efficiency with Combination of Bracings in Steel Building using ETABS Software

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Abstract - In earthquake-prone areas, structures face high risks of severe damage. When it comes to designing for seismic resistance, steel is a key factor due to its physical properties of strength and ductility. This study focuses specifically on the evaluation of steel-framed buildings with various bracing systems. Bracing elements play a critical role in how a structure responds during an earthquake. Steel bracing offers a cost-effective and efficient solution for withstanding lateral forces in a framed building. It is widely considered as one of the most effective methods for resisting lateral loads. The ETABS software is used to analyze the behavior of steel-framed structures. This paper presents a comparison of models with different bracing types, including X-braces, diagonal braces, and eccentric braces

***Key Words*: Bracings, ETABS software, Autocad, Beams, Coumns, Deck Slab, Storey Drift, Storey Displacement, Base Shear, Response Spectrum Method**

1. INTRODUCTION

It is commonly accepted that the powerful force of earthquakes is caused by the shifting of tectonic plates beneath the Earth's surface, as well as the activity of volcanoes. These destructive events create intense vibrations that can greatly damage man-made structures. To combat this, engineers have developed bracing systems that can withstand the high-frequency movements. One such system, called a braced frame, has proven to be particularly effective in retrofitting buildings for seismic resilience. This is due to its impressive stiffness, which minimizes sideways displacement and the bending forces on support columns. By incorporating diagonal braces between floors, axial loads are transferred to the columns, resulting in a natural and efficient structural system. In the realm of construction, steel bracing has emerged as a top choice for earthquake-resistant design. It offers both cost-effectiveness and ease of installation, and its compact design allows for greater flexibility in meeting strength and stiffness requirements. Notably, it has proven successful in reinforcing existing structures with inadequate lateral stiffness

2. METHODOLOGY

The project includes the study of mainly 2 software's AutoCAD and E-TABS. Column, beam junction from each floor and slab design will be done as per IS code. Various types of load calculations including dead load, live load, wind load, earthquake load and their combinations are calculated and applied to the structure. Planning is done by using AutoCAD. The structure is analysed, and load calculations are done by using E-TABS. The 3D view is developed using E-TABS.

2.1 Study Area

The location of Multi storeyed steel building is assumed to be modelled in Eastern part of India (WestBengal) having more seismic effects.For this study, a G+5 building with lift room, it has storey height of 3.5 meters each. Different types of steel bracing are provided on various positions of the building. The structural models of the structure are modeled using ETABS software. The dead load and live load are considered as per IS 875, and earthquake analysis is done as per IS 1893 for zone-V.

2.2 Autocad

AutoCAD is an essential tool for architects, engineers, and construction professionals, providing them with precise 2D and 3D drawing capabilities through its computer-aided design (CAD) and drafting software. This powerful software offers features such as drafting, annotation, and design for 2D and 3D geometry, including solids, surfaces, and meshes. Not only that, but it also enables users to automate tedious tasks like comparing drawings, counting, adding blocks, and creating schedules, among others. With its limitless potential, AutoCAD makes it possible to effortlessly create and modify geometric models for a wide range of structures and objects. AutoCAD is an essential tool for architects, engineers, and construction professionals, providing them with precise 2D and 3D drawing capabilities through its computer-aided design (CAD) and drafting software. This powerful software offers features such as drafting, annotation, and design for 2D and 3D geometry, including

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2.3 ETABS

ETABS, a powerful Civil Engineering software, is essential for analyzing and designing multistory buildings. This versatile software is crucial for calculating seismic forces on structural models under both static and dynamic load conditions. Additionally, ETABS offers a seamless integration of all aspects of the engineering design process. CAD drawings can easily be exported to ETABS, allowing for a thorough understanding of building geometry. With ETABS, creating models and presenting results is effortless at the object level, making it a valuable tool for any engineer. A plan of G+5 storey building is planned in Autocad software. Layout of Beams and Columns has been taken . This model is transferred to ETABS software and modelled. Loads Have been applied on the basis various IS codes. The structure is analysed by Response Spectrum Method.

3. WORK DONE IN AUTOCAD

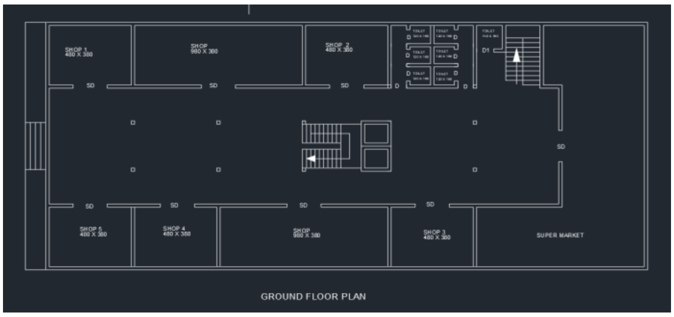
The project is delt with mainly 2 software's specifically AutoCAD; for drafting and designing of floor and site plans, Etabs; for the analysis of various loads acting on the structure ; The result thus developed in Autocad is provided below.

3.1 PLANS IN AUTOCAD

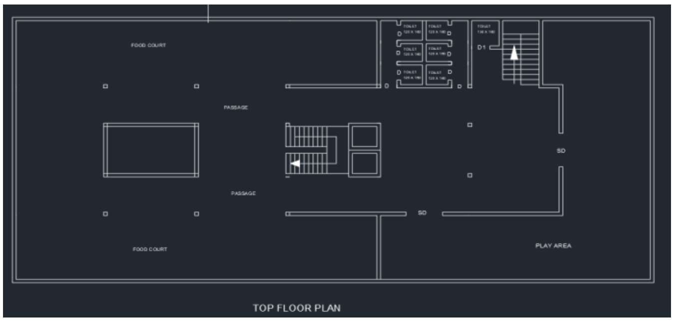
The ground floor plan consists of entry to the shopping mall accompanied with a reception at the entrance. It consists of 7 units of shops and a Super Market has been provided. Washroom and toilet facilities are provided at the ground floor separately. The total mall area of ground floor alone is around 6900 sq. ft. access to the next floors are provided in the form of lift and stairs. Fire lift and stairs is also provided till top floor. Five shops with 480x380 cm and Two shop with 980x380cm.The same floor plan is anabled up to 4 floors.The fifth floor, which is the last floor of the mall, consist of Food Court and Play Area. This floor also includes the entertainment zone, gym etc Access to this floor is also provided in the form of lift, stairs. Two lifts and two staircase are provided. It also includes toilet and washroom facilities . Fire stair and lift is also provided for the purpose of safety. The total area of the fifth floor is around 6900sq.ft.

Story displacement is when a story within a structure is shifted from its base or foundation level. This displacement is known as storey drift, which measures the lateral movement of a story compared to the story below it. The storey drift ratio, which is calculated by dividing the storey drift by the story height, is used to further assess the severity of this displacement.

3.1.1 First Floor Plan

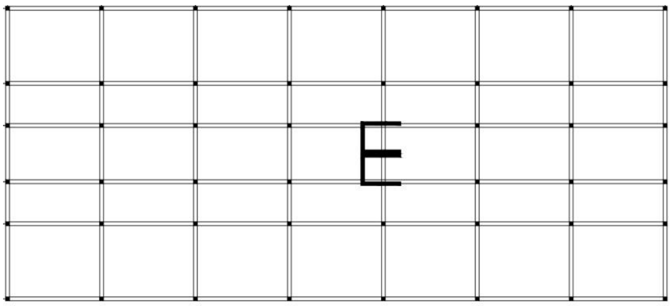


3.1.2 Top Floor Plan



3.2 Layout of Beams and Columns

The positions of beams and columns are pointed out in Autocad. The layout consist of only beams and columns. The positioned columns from specified coordinates are taken into consideration in Etabs to model the Structure.



4. MODELLING IN ETABS

Through the use of the optimization procedure in ETABS software, we were able to design a resilient G+5 building that can withstand earthquakes. Our goal was to strike a balance between earthquake performance and structural efficiency, keeping the structural members at their minimum feasible sizes. Our recommended plan was created in AUTOCAD and then transferred to ETABS for implementation. The spacing between columns has been assigned in the X and Y directions. The distance from (0,0) coordinate in the X direction are 5m,10m,15m,20m,25m. In the Y direction, the spacing of the columns is 4m,6.3m,9.3m,11.6m,15.6m. the plan and elevation of the model will appear in ETABS software.

4.1 Beams and Columns

The materials properties of beams and columns have been defined. The section properties chosen are different ISMB 200, ISMB 250, ISMB 300, ISMB 500 are provided.

Beams are horizontal structural elements responsible for transferring loads from the slab (dead and live loads) to the columns. They take Transverse Loads. The columns are one of the most important structural elements in structural engineering design, responsible for transferring loads from the slab (dead and live loads) to the foundations and then to the soil beneath

4.2 Deck Slabs

A deck slab is considered a plate when analyzing its structural properties. When the slab's stiffness differs in two perpendicular directions, it is classified and evaluated as an orthotropic deck. Typically utilized in smaller steel constructions, deck structural slabs boast exceptional resistance. This is due to the use of steel decking, which provides significantly greater strength compared to conventional concrete slabs. As a result, there is a notable increase in the strength-to-weight ratio, allowing for a considerable reduction in overall weight. A deck slab is considered a plate when analyzing its structural properties. When the slab's stiffness differs in two perpendicular directions, it is classified and evaluated as an orthotropic deck. Typically utilized in smaller steel constructions, deck structural slabs boast exceptional resistance. This is due to the use of steel decking, which provides significantly greater strength compared to conventional concrete slabs. As a result, there is a notable increase in the strength-to-weight ratio, allowing for a considerable reduction in overall weight.

4.3 Stairs

Stairs serve as the primary means of accessing different floors within a building, and the specific area where stairs are housed is commonly referred to as a staircase. Typically, stairs are composed of a series of steps that are arranged in a single flight or multiple flights. The design of a staircase is crucial and should meet certain requirements for optimal functionality. These requirements include a suitable width, with 0.9 meters deemed appropriate for residential buildings and 1.5 to 2.5 meters for public buildings. Additionally, the number of steps in a flight should not exceed a maximum of 12 to 14 steps, while a minimum of 3 steps is recommended. The distance between each step, known as the rise, should also be consistent and is typically between 150 to 175 mm in residential buildings and 120 to 150 mm in public buildings. However, in commercial buildings, the rise may be increased to account for economic space. Stairs serve as the primary means of accessing different floors within a building, and the specific area where stairs are housed is commonly referred to as a staircase. Typically, stairs are composed of a series of steps that are arranged in a single flight or multiple flights. The design of a staircase is crucial and should meet certain requirements for optimal functionality. These requirements include a suitable width, with 0.9 meters deemed appropriate for residential buildings and 1.5 to 2.5 meters for public buildings. Additionally, the number of steps in a flight should not exceed a maximum of 12 to 14 steps, while a minimum of 3 steps is recommended. The distance between each step, known as the rise, should also be consistent and is typically between 150 to 175 mm in residential buildings and 120 to 150 mm in public buildings. However, in commercial buildings, the rise may be increased to account for economic floor space.

4.3 3D MODEL OF G+5 Building

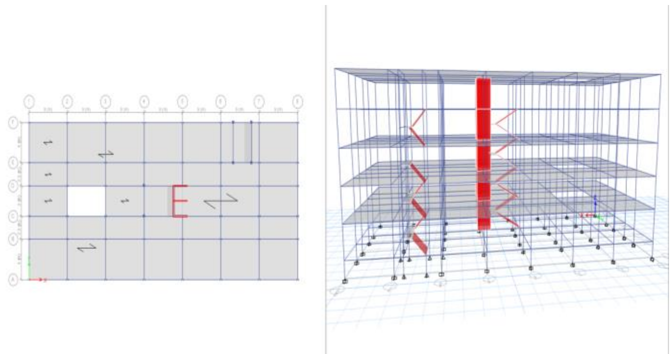


Chart -1: **Model**

5. LOAD CALCULATIONS

The types of loads acting on structures for buildings and other structures can be broadly classified as vertical loads, horizontal loads and longitudinal loads. The vertical loads consist of dead load, live load and impact load. The horizontal loads comprises of wind load and earthquake load. The longitudinal loads i.e. tractive and braking forces are considered in special case of design of bridges, girders etc

5.1 Structural Details

Structural Details		
1	No of storey	G+5
2	Dimension of structure	6900sq.ft
3	Seismic zone area	IV as per IS 1893-2002
4	Dimension of beam	ISMB450
5	Dimension of column	ISMB450
6	Dimension of bracings	ISMB200, ISMB450, ISA150X150x150mm, ISMC400
7	Floor to floor height	3 m
8	Length of bay	3 m
9	No of bays	5

Table:1 **Structural Details**

5.2 Earthquake load

Earthquake Zone	V
Seismic zone factor	0.36
Silt type	II(Medium)
Eccentricity Ratio	0.05

Table:2 **Earthquake load**

5.3 LOAD CALCULATIONS

Wall load = density x thickness of wall x height of wall

= 25 x 0.23 x 2.97 = 17.07 KN/m

Parapet Load = 22 x 0.7 x 0.23 = 3.542 KN/m

Sunshade Load = 25 x 0.6 x 0.12 = 1.8KN/m

Staircase Load

As per IS 875 part II Live Load = 3 KN/m2

Dead Load = 25 x 0.12 = 3 KN/m2

Landing

As per IS 875 part II

Live Load = 3 KN/m2

Dead load = 25 x 0.12 = 3KN/m2

Wind Load = 0.6 x v2 = 0.6 x (1 x 1 x 0.99 x 47)2 = 1.3KN/m2

5.4 ANALYSIS

Equivalent Static Analysis Equivalent Static analysis is the simplest method of analysis. This method is as per IS1893-2002. In this method of analysis base shear (VB) is determined by, VB = Ah x W Therefore, Ah = ZISa/2Rg Where, Ah = Design acceleration spectrum value, using the approximate fundamental natural time period 'T'. W = Seismic weight of the building

6. RESPONSE SPECTRUM ANALYSIS

The response spectrum method is based on a special type of mode superposition. The idea is to provide an input that gives a limit to how much an eigenmode having a certain natural frequency and damping can be excited by an event of this type.

6.1 WITHOUT BRACING

6.1.1 Maximum Storey Displacement

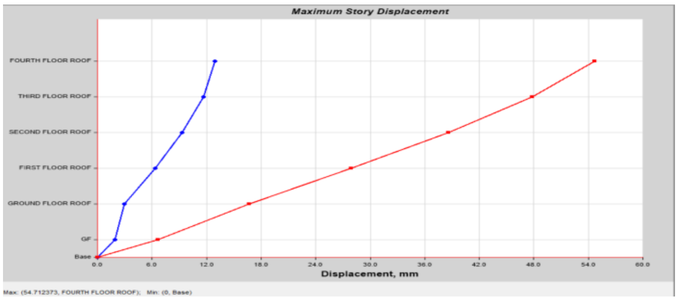


Chart -1: Storey Displacement without Bracing

In this graph, displacement on X-axis and floor on Y-axis. The blue line indicates in variance with X-axis and red line indicates variance with Y-axis. Here maximum displacement occur at fourth floor i.e., 55mm. When it is considered with X-axis maximum displacement is 13mm.

6.1.2 Maximum Storey Drift

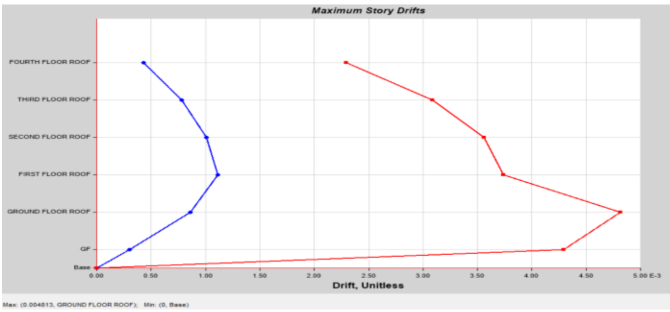


Chart -2: **Storey Drift Without Bracing**

In this graph, displacement on X-axis and floor on Y-axis. The blue line indicates in variance with X-axis and red line indicates variance with Y-axis. Here maximum drift occurs at ground floor i.e., 4.9. When it considered with X-axis maximum displacement is 1.2 mm on first floor. The base shear for response spectrum analysis = -666.2KN

6.2 Minimum Storey Displacement and Storey Drift of Different Bracing Systems

As far the undisputed analysis of different bracing sytem which are X-Bracing, V- Bracing and Inverted V- Bracing, X

Bracing is Considered to be the best and most efficient type and it is provided at outer edge

6.2.1 Storey Displacement of X Bracing at Outer edge

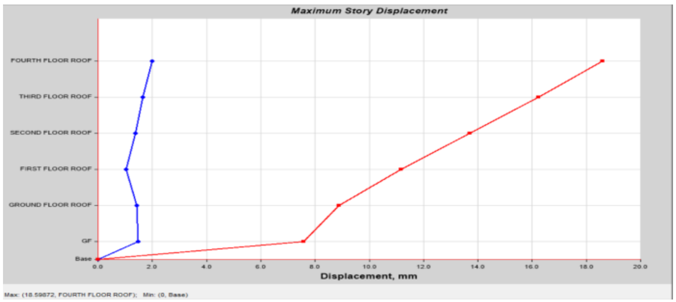


Chart -3: Storey Displacement at outer edge

In this graph, displacement on X-axis and floor on Y-axis. The blue line indicates in variance with X-axis and red line indicates variance with Y-axis. Here maximum displacement occur at top floor i.e., 18.5mm. When it is considered with X-axis maximum displacement is 2mm on top floor

6.2.2 Storey Drift of X Bracing at Outer edge

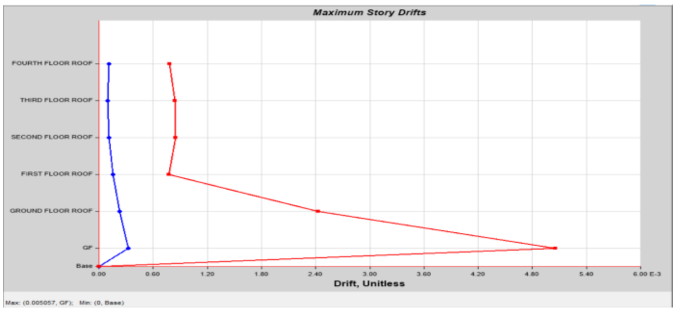


Chart -4: Storey Drift at Outer Edge

In this graph, displacement on X-axis and floor on the Y-axis. The blue line indicates in variance with X-axis and the red line indicates variance with Y-axis. Here maximum drift occurs at ground floor i.e. 5. When it considered with X-axis maximum displacement is 3 mm on ground floor. The base shear for response spectrum analysis = -1008.2KN

7. CONCLUSIONS

Storey displacement for the system with X-bracing in the outer edge is the most efficient of all types of bracings and is reduced by 37.5% of Y-direction as compared to unbraced system. The base shear of the braced frame increases as compared to the unbraced system because of the seismic weight of the structure increases. Section ISMB 450 is providing a good response compared to other sections. X bracing provided at the outer edge of the concrete building reduces 27% compared to the steel building.

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BIOGRAPHIES

"Anooj J is a Civil Engineering Student who is very much interested in Structural Analysis and Forensic Structural Engineering. He is very interested in new technologies, Research and innovation"

"Devipriya B is a civil Engineering student who is very passionate about the career and a rapid learner. She is passionate in Green Technologies and construction materials. "

"Dominic Savio Cleetus is a civil engineering student who can perform well in management and Quantity Surveying

"Lincy Bosco is a civil engineering student who looks forward for more technologies and opportunities in civil engineering. She is interested in Highway Engineering"