Evaluating the Seismic Response of an L-Shaped Building with and without X-bracings

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Abstract—This dissertation presents a seismic performance evaluation of a G+11 L-shaped reinforced concrete (RC) building, modeled and analyzed using ETABS software. The structure is assessed as per the latest Indian Standards—IS 1893 (Part 1): 2016 for seismic loading and IS 875 (Part 1 & 2): 2015 for dead and live loads. The building is assumed to be located in Seismic Zone II and founded on medium soil, representing a common low-to-moderate seismic condition in India.

The study is carried out in two phases. The first phase involves a comparative analysis between an Un-braced model and X-braced model to evaluate the overall influence of bracing on seismic performance. Given that fully bracing an entire structure may not be cost-effective in real-world scenarios, the second phase focuses on a configurational assessment aimed at achieving optimal structural performance with economic efficiency. Three X-bracing configurations are examined: bracing at the edges, at the centre, and a combined edge-centre layout.

To evaluate and compare the seismic behaviour of the models, key structural parameters are considered: storey drift, storey displacement, storey shear, bending moments, overturning moment, and base shear. All models are analyzed using Response Spectrum Analysis in accordance with IS 1893:2016. The inclusion of X-bracing is found to significantly enhance seismic performance by increasing lateral stiffness and reducing critical response values. Among the configurations studied, the edge-centre bracing layout offers the best overall performance, effectively controlling torsional irregularities, minimizing displacement and drift, and improving force distribution—making it the most structurally efficient and economically justified option. The results revealed that the model with Edge-Centre bracing exhibited significantly reduced storey displacement and drift compared to the other model where bracings are added at centre and edges, indicating enhanced lateral stiffness and stability. These findings underscore the importance of incorporating bracing systems in L-shaped buildings to mitigate lateral movements while considering the implications on internal force distribution.

This study contributes to the understanding of seismic behaviour in irregularly shaped structures and emphasizes the need for tailored design approaches to optimize performance under seismic loading. The insights gained are valuable for engineers and architects involved in the design and retrofitting of buildings in seismic Zone II regions, ensuring safety and resilience in earthquake-prone areas.

Model V, with edge and central bracing, is more stable due to reduced displacement, drift, and overturning moment. Though slightly costlier, it offers better structural performance and load distribution under lateral forces. The improved safety and resilience make Model V a more efficient and reliable design than Model I, II, III and IV.

In conclusion, the study reinforces the importance of both incorporating and optimally positioning bracing systems in irregular RC buildings. The findings offer practical insights for engineers to enhance seismic resilience while maintaining cost-effectiveness, ensuring safer designs in compliance with Indian seismic codes.

Index Terms—L-shaped building, X-bracing, seismic effect control, seismic analysis, bending moment, IS 1893-2016 (Part-1), shear force, ETABS.

INTODUCTION

The thesis investigates the effectiveness of X-bracing in improving a structure's seismic resistance. It does this by integrating X-bracing into the structural design of two buildings and evaluating its impact on performance under seismic loads. The primary focus is on how X-bracing can reduce the overall deflection and sway of the building by increasing lateral stiffness. The diagonal bracing system known as X-bracing provides additional support against lateral forces such as those generated during earthquakes. This greater lateral rigidity is crucial to preventing the structure from collapsing and deforming excessively.

DIFFERENT WAYS TO CONTROL SEISMIC EFFECT

- **SEISMIC RETROFITTING**

Seismic retrofitting is crucial to the safety and resilience of existing structures in seismically active areas. By strengthening and warning structures to handle seismic pressures, retrofitting can gradually reduce the risk of damage collapse and fertilities during earthquakes.

- **SEISMIC ISOLATION**

Seismic isolation is one of the most crucial techniques for protecting buildings from the destructive force of earthquakes. By utilizing flexibility isolators to isolate the structure from ground motion, seismic isolation reduces the amount of seismic energy that reaches the superstructure.

- **TUNED MASS DAMPERS**

A tuned mass damper (TMD) is one type of seismic control device that can significantly reduce building vibration during earthquakes. A TMD is composed of a mass, a spring, and a damper that are tuned to resonate at the specific frequency.

- **FLEXIBLE FOUNDATION**

Flexible foundations are crucial for enhancing a structure's earthquake resistance. By allowing the foundation to form more freely during an earthquake, flexible foundations can absorb and distribute the whole energy generated by ground motion, reducing the pressures transmitted to the superstructure.

- **STEEL BRACINGS**

One structural element that can significantly improve a building's earthquake resilience is steel bracing. By increasing lateral stiffness and strength, steel bracing can withstand the horizontal forces created by an earthquake.

DIFFERENT TYPES OF BRACINGS

1. **X-bracings**

A common structural element used in buildings to increase their lateral stability and seismic load resistance is X-bracing. These buildings' X-shaped diagonal resistance layout gives the structure greater stiffness and strength.

2. **V-bracings**

V-bracing is another type of structural element used to increase a building's lateral stability. Our bracing is positioned diagonally, as stated, but instead of using an X shape, they made a V shape combination, which offers the building additional strength and rigidity, particularly when it comes to withstanding lateral loads caused during an earthquake.

3. **K-bracings**

K-bracing is another type of structural element used to increase a building's lateral stability. These bracings are arranged diagonally to form a k-shaped pattern. This arrangement increases the structure's strength and stiffness, particularly in terms of its ability to sustain standing lateral stresses that may be generated during an earthquake.

4. **Diagonal bracings**

As was previously noted, a diagonal bracing is any type of dressing element arranged in a diagonal pattern, such as K, V, or X bracing. Diagonally bracing is a common structural element used to increase the lateral stability of our buildings, particularly in earthquake-prone areas.

5. **Inverted bracings**

Inverted bracing is one type of structural element that is positioned in an inverted be or why shape. They are typically used in conjunction with other bracing types, such as x, v, and k bracing, to increase the lateral stability of buildings.

ADVANTAGES OF BRACING

- An existing structure can be strengthened and retrofitted with the aid of bracing.
- The bracing system has a major impact on the limiting of the relative floor-to-floor lateral movement.
- The embracing system considerably lessens inter-storey drift.
- It can be designed to obtain the desired strength and stiffness.
- The reduction of lateral displacement is a major benefit of bracings.
- It uses less room, is affordable, and is simple to install.

OBJECTIVES OF THE RESEARCH

The main objectives of this study are as followed-

- To assess the performance of high-rise buildings in various seismic zones.
- To assess how well X-bracing protects high-rise buildings from earthquakes.
- To compare and analyze different models under various loading conditions based on parameters like bending moment and base shear, among others using ETABS software.
- To compare different configurations of X-bracings and find the most economical configuration.

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METHODOLOGY

Steps Involved In Methodology and Design

STEP 1: The G+11 storey structure, which has 12 stories and a typical storey height of 3.05 meters and a bottom storey height of 3.05 meters, was modeled as a regular construction.

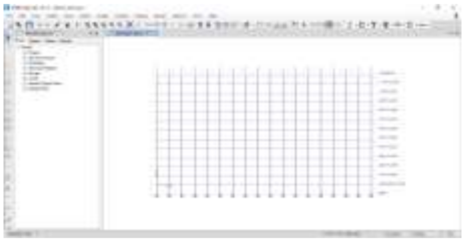

Fig. 1 Model I

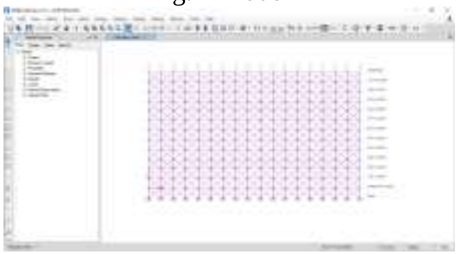

Fig. 2 Model II

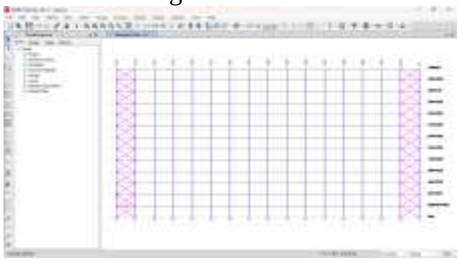

Fig. 3 Model III

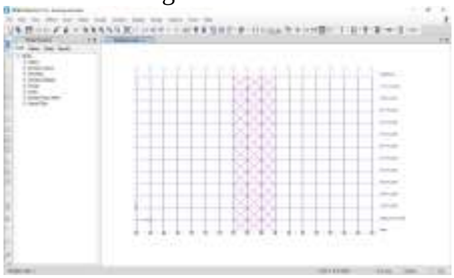

Fig. 4 Model IV

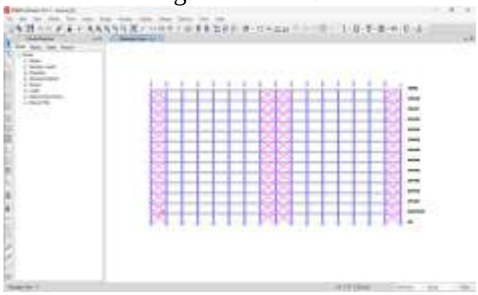

Fig. 5 Model V

STEP 2: Assigning Fixed Support at the bottom of the structure in X, Y and Z direction**.**

STEP 3: Defining section properties of beam and column. Here, we have considered 300x500mm beam size and 500X500 column size.

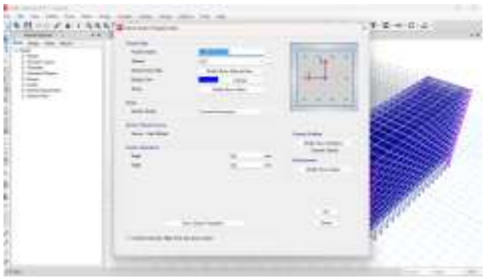

Fig . 6

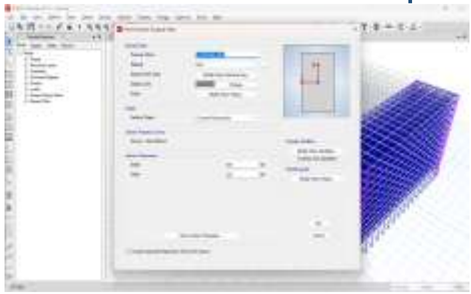

Fig. 7

STEP 4: Assigning the properties of X-type steel bracing to the structure.

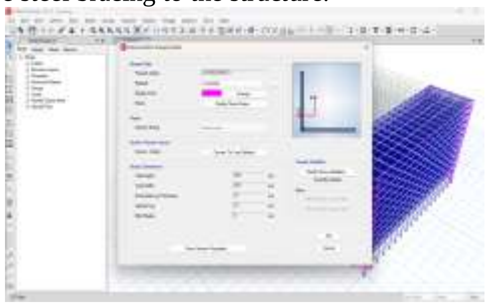

Fig. 8

STEP 5: Defining Loading conditions for dead load, live load.

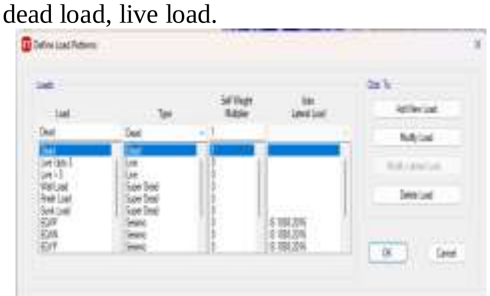

Fig. 9

STEP 6: Defining Seismic load data for the considered structure, here Zone II and medium soil condition is taken.

Fig. 10

STEP 7: Analyzing the structure for dead load.

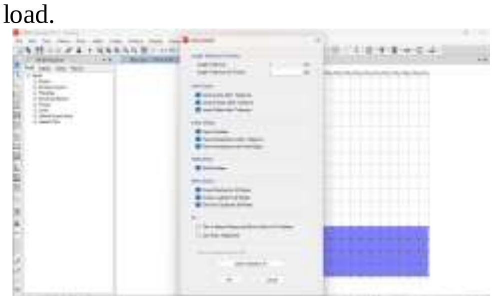

Fig. 11

GEOMETRICAL DATA

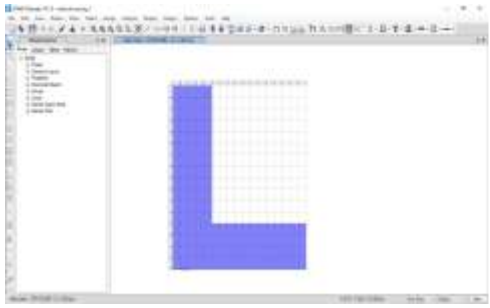

Fig. 12

Table 1 Geometrical specifications

PARTICULARS	DATA
Type of structure	L-Shaped RCC building (X-bracing)
Number of stories	12
Floor to Floor height	3.05m
Depth of the foundation	3m
Total height of the building	39.55 m
Length & Width of the building	80 m x 68m
Shape & Size of column	Rectangular 500X500
Shape & Size of beams	Rectangular 300X500
Steel used for bracing	ISA 200X200X12

MATERIAL PROPERTY

Table 2 Property of Concrete

PARTICULARS	DATA
Grade of concrete	M25
Directional symmetry type	Isotropic
Weight per unit volume	24.9926 kN/m3
Mass per unit volume	2548.538kg/m3
Modulus of elasticity	25000MPa
Poisson’s ratio	0.2
Coefficient of thermal expansion	.000013 l/C
Shear modulus, G	11410.89Mpa

Table 3 Property of Steel

PARTICULARS	DATA
Grade of steel	Fe500
Directional symmetry type	Isotropic
Weight per unit volume	76.9729 kN/m3
Mass per unit volume	7849.047kg/m3
Modulus of elasticity, E	210000Mpa
Poisson's ratio	0.3
Coefficient of thermal expansion, A	.0000117 l/C
Shear modulus, G	83769.23 Mpa

Table 4 Property of Rebar

PARTICULARS	DATA
Grade of Rebar steel	HYSD415
Directional symmetry type	Uni-axial
Weight per unit volume	76.9729 kN/m3
Mass per unit volume	7849.047kg/m3
Modulus of elasticity, E	200000Mpa
Coefficient of thermal expansion, A	.0000117 l/C
Yield strength of distribution & main bars (Fy_{sec})	Fe415

LOADING CONDITIONS

- **Dead load (DL)**

In accordance with IS 875-1987 (Part I: Dead loads), "Code of Practice for Design Loads (Other than Earthquake) for Buildings and Structures," the dead load is taken into account.
Unit weight of Reinforced Concrete = 25 kN/m3, Self-weight = 1kN, Slab load= 4.95kN/m2, Terrace slab load= 5.95kN/m2, Full wall load (200mm)=10.4kN/m and Parapet load=2.4kN/m

- **Imposed load (LL)**

Live load is another name for imposed load. According to IS 875-1987 (Part II-Imposed loads), "Code of Practice for Design Loads (Other than Earthquake) for Buildings and Structures," the imposed load is taken into account.
Live load Slab load= 3/m2 Load on terrace=1.5kN

- **Earthquake load (EL)**

The IS 1893-2002 (Part I) is used to determine the earthquake load. The elements taken into account are:
Zone factor = .10 (II), Importance factor = 1, Response reduction factor = 5, Soil condition = Medium soil
Damping = 5 %

RESULTS AND DISCUSSION

1. STOREY DISPLACEMENT (mm)

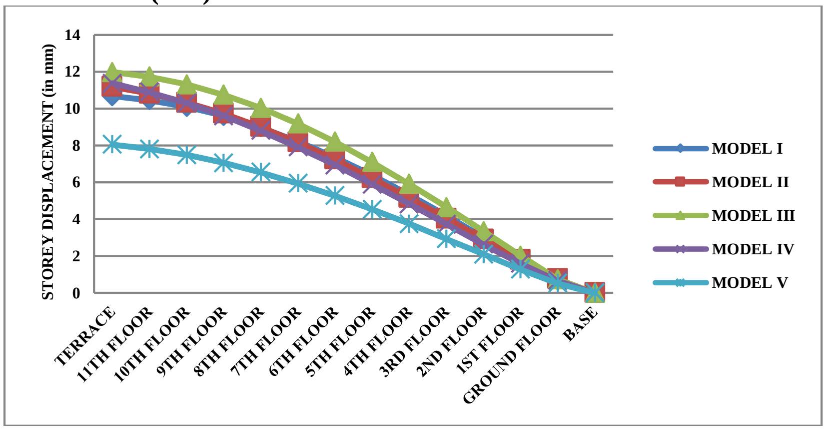

Fig. 12

Inference: Full bracing (Model II) increases displacement slightly due to increased weight of bracings, making it unsuitable. The best reduction is seen in Model V, where Edge-Center bracing lowers displacement by over 30%, ensuring superior efficiency and stability throughout the structure.

2. STOREY DRIFT (mm)

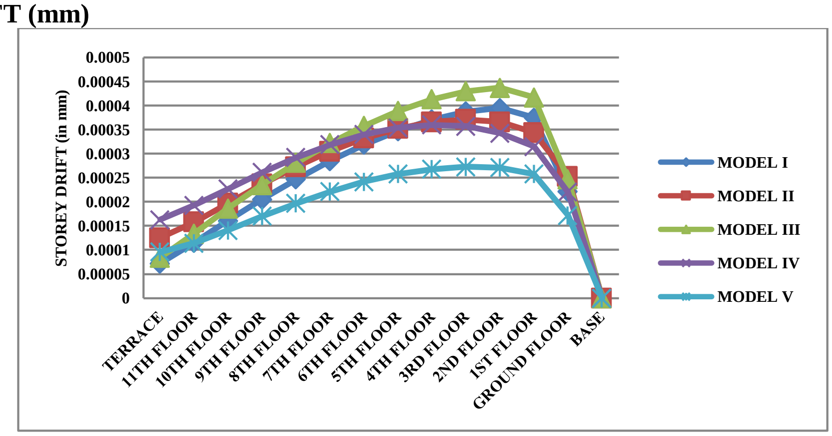

Fig. 13

Inference: Model II again shows higher drift than the un-braced case, proving ineffective. Model V consistently minimizes drift, with reductions up to 42%, making it the most stable and efficient solution among all bracing configurations.

3. STOREY SHEAR (Tonf)

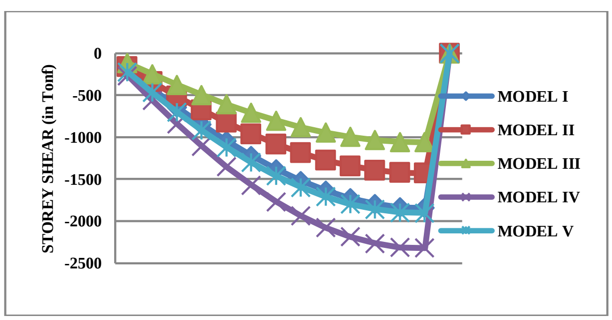

Fig. 14

Inference: Although full bracing lowers shear compared to un-braced, it remains uneconomical due to poor displacement and drift performance. Model V provides balanced shear reduction while avoiding instability seen in corner bracing, emerging as the most efficient configuration.

4. STOREY OVERTURNING MOMENT (kN-m)

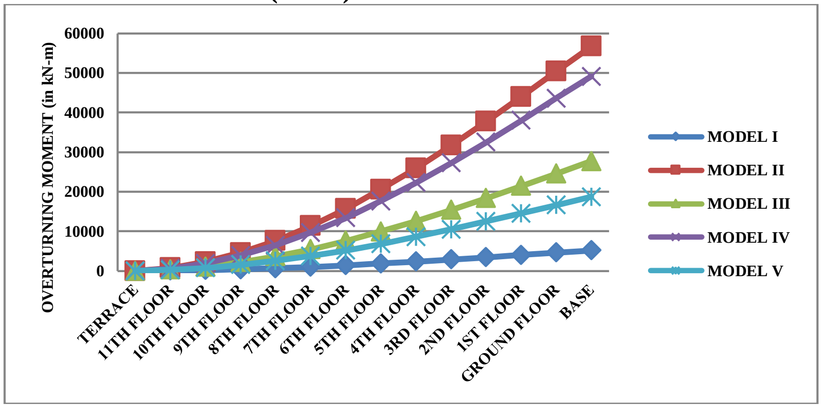

Fig. 15

Inference: Full bracing drastically increases overturning moment, nearly tenfold, making it highly uneconomical. In contrast, Model V reduces overturning by up to 62% compared to corner bracing, proving to be the most practical and economical arrangement.

5. BASE SHEAR (Tonf)

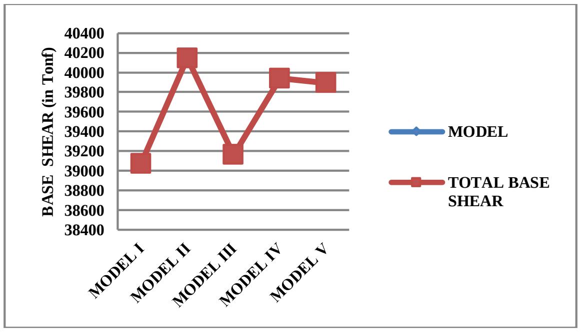

Fig. 16

Inference- Model II slightly increases base shear, adding unnecessary foundation demand. Model III shows the lowest shear, but Model V balances displacement, drift, and overturning while maintaining reasonable base shear, making it the best overall system.

6. BENDING MOMENT (kN)

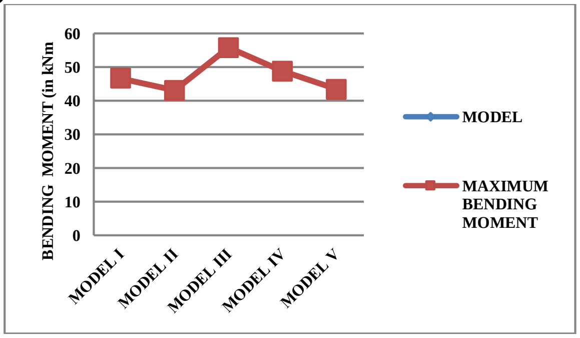

Fig. 17

Inference: Fully bracing reduces bending moment slightly but is still uneconomical overall. Model V provides low bending moment levels while avoiding excessive demand like in centre or corner-only bracing, offering the most stable and cost-effective performance.

CONCLUSION

- Model V, with center and corner bracing, offers the most efficient displacement reduction, outperforming unbraced and partially braced models.
- Model V shows the lowest and most consistent storey drift, outperforming unbraced and partially braced models, making it the most efficient.
- Model V offers the most balanced and efficient storey shear performance, outperforming all other models in reducing instability and excess forces.
- Model V delivers the lowest overturning moments across all floors, making it the most stable and economical solution among all bracing models.
- Centre bracing minimizes base shear most effectively, but Model V offers the best overall balance of stability, efficiency, and performance.

- Model V offers the best balance, achieving low bending moments like full bracing but with greater overall efficiency and structural stability.

SUMMARY

The comparative study reveals that while full bracing (Model II) offers strength, but it is uneconomical and increases displacement, drift, overturning moment, and base shear due to added weight. The un-braced model (Model I) lacks stiffness, and centre-only (Model III) and corner-only bracing (Model IV) show inconsistent performance. Model V, with centre and corner bracing, consistently delivers the best results—reducing displacement (up to 33%), drift (42%), and overturning moment (62%), while maintaining low bending moment and balanced base shear. Though Model V has higher initial cost, it ensures greater stability and strength, making it the most efficient and economical long-term solution.

FUTURE SCOPE OF THE RESEARCH

- It is possible to consider how bracing interacts with other structural elements.
- Look into integrating X-bracing with other retrofit techniques to enhance performance.
- Conduct experimental studies to verify the computational results and investigate how X-braced RC buildings behave under dynamic loading.
- The impacts of different X-bracing configurational setups can be examined. The economical as well as strength is considered.

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