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# Seismic Analysis of Square and U-Shaped Buildings with Re-Entrant Corners with and without Base Isolator

**Akshatha N[1], Lakshmi P S[2]**

PG Student, Department of Civil Engineering, P.E.S College of Engineering, Mandya, India[1]

Associate Professor, Department of Civil Engineering, P.E.S College of Engineering, Mandya, India[2]

**Abstract:** This study presents a seismic analysis of square and U-shaped buildings with re-entrant corners, evaluating their performance under earthquake loading using two distinct base conditions rubber base isolation and fixed base. The presence of re-entrant corners introduces complex static behavior, which can significantly impact the building's seismic response. The analysis compares the effectiveness of rubber base isolation in mitigating earthquake-induced forces and vibrations in contrast to the fixed base condition, which represents traditional structural support. A three-dimensional model of both building shapes was developed in ETABS 2022 to simulate earthquake excitations, and various seismic parameters such as displacement, acceleration, and structural stresses were assessed. The results highlight the potential benefits of rubber base isolation in reducing seismic responses, especially in structures with irregular geometries like those with re-entrant corners.

**Keywords**: Seismic Analysis, Re-entrant Corner, Pushover Analysis, Base Isolator

## I. INTRODUCTION

Modern building construction frequently incorporates irregularities to meet aesthetic and architectural requirements. Contemporary architecture prioritizes visual appeal and distinctive design features leading architects to create buildings with complex geometries, re-entrant corners, setbacks, and asymmetrical configurations. Buildings with irregularities are more affected to earthquake forces than buildings with regular configuration[11]. That irregularities on buildings increase the lateral seismic forces and inter-storey drifts thus increasing seismic demands in the structural elements[6]. Re-entrant corners are a common horizontal irregularity found in various building shapes like L, C, T, H, U, + shapes. Their presence leads to two significant problems during an earthquake first one is Local Stress Concentration between different wings of the building that result in local stress concentrations at the re-entrant corner, this lack of tensile capacity and force concentration at these corners makes them highly vulnerable to cracking and damage[11]. Second one is torsion which is caused because the center of mass and the center of rigidity.

The severity of these issues depends on the characteristics of the ground motion, mass of the building, type of structural systems, length of the wings and their aspect ratios length to width proportion, and the height of the wings and their height to depth ratios[9]. Base isolation systems are an innovative seismic protection strategy designed to mitigate the effects of earthquakes on structures[13]. Instead of making a building stiff and strong enough to resist lateral seismic forces base isolation decouples the superstructure from its foundation or the ground[10]. The fundamental goal of base isolation is to substantially reduce the absorption of earthquake-induced forces and energy by the structure. This is achieved by strategically placing flexible and energy-dissipating elements, known as isolators or seismic base bearings, between the building's foundation and its superstructure. These isolators allow the superstructure to move relative to the substructure during an earthquake, reducing the acceleration and forces transmitted within the structural system. However, irregular shapes can still cause uneven deformation even with isolation. Combined analysis ensures structural safety and effective seismic performance.

## II. METHIDOLOGY

### A. *Modeling of Building Configurations*

The study involves modeling multi-story RC frame buildings with and without plan irregularities Two types of structural configurations will be considered, Regular square building 25m × 25m in plan and U-shaped building with re-entrant corners. Each building will have the same plan area, number of storeys is 8 storeys, and storey height of 3m to maintain consistency. The buildings will be modelled using structural analysis software such as ETABS 2022.

  

B. *Application of Material and Section Properties*
Define consistent material properties. Assigning appropriate cross-sections to beams, columns, and slabs based on typical reinforced concrete design standards. Consider the effect of gravity loads and seismic mass based on IS 875 and IS 1893:2016.

C. *Defining Load*
Dead Load (DL): Includes the self-weight of structural components such as beams, slabs, columns, and walls, calculated automatically by the modelling software based on the assigned material and section properties.

Live Load (LL): Imposed loads due to occupancy will be applied as per IS 875 (Part 2). Appropriate load combinations and reduction factors will be used depending on usage type.

Wind Load (WL): Wind loads will be applied as per IS 875 (Part 3), considering building height, location, terrain category, and exposure conditions. Windward and leeward pressures, along with suction effects on roofs and walls, will be accounted for.

Seismic Load (EQ): Seismic forces will be defined as per IS 1893:2016, with the following parameters zone factor, soil type, importance factor, and response reduction factor. Lateral loads will be applied in incremental steps for pushover analysis.

D. *Implementation of Supports*
Introduce Natural Rubber Bearings at the base of both building types. Define isolation properties in accordance with design standards. Develop separate models:

Regular building with and without Natural Rubber Bearings.

U-shaped building with and without Natural Rubber Bearings.

E. *Nonlinear Static Analysis*
Perform pushover analysis by applying lateral loads in a stepwise manner until the target displacement is reached. Use nonlinear hinge properties for beams and columns based on FEMA 440. Generate pushover curves for, Regular building with and without Natural Rubber Bearings. U-shaped building with and without Natural Rubber Bearings.

F. *Comparative Evaluation and Interpretation*
Compare and interpret results in terms of Base shear capacity, Maximum roof displacement, Performance point coordinates and Plastic hinge development and failure patterns. Assess the influence of base isolation and plan irregularity on structural performance. Evaluate the effectiveness of rubber base isolators in mitigating seismic response in irregular structures.

## III. MODELLING AND ANALYSIS

Modelling of the buildings was carried out using the software ETABS 2022. Two building configurations were considered one without re-entrant corners i.e., a regular square-shaped building and one with re-entrant corners i.e., a U-shaped building. Both models have the same plan area and were analysed for the study. Additionally, the performance of these buildings under base isolation using Natural Rubber Bearing (NRB) isolators was examined.

Four different models were developed for the study:

Model I: Square-shaped building with fixed base
Model II: U-shaped building with fixed base
Model II: Square-shaped building with NRB isolator
Model IV: U-shaped building with NRB isolator

A. *Building Description*
1. *Building Geometry and Structural Layout*
- Number of Stories: G+8
- Storey Height: 3m
- Type of analysis: Non-Linear Static analysis (pushover analysis)

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- Thickness of wall: 230mm
- Beam: 300mmX450mm
- Column: 450mmX450mm
- Slab thickness: 150mm
- Plan: 25m x 25m
- Parapet Height: 1.2m

2. *Material Properties*
- Concrete Grade: M-40 grade for concrete
- Steel Grade: Fe-500 grade steel
- Poisson’s Ratio: For concrete (typically 0.2).
- Density of Concrete: Approx. 25 kN/m³ for reinforced concrete.

3. *Load considered*
- Dead load
- Live load: 3kN/$m^2$
- Floor finish: 1.2kN/$m^2$
- External wall load: 13kN/$m^2$
- Parapet wall load: 6kN/$m^2$

4. *Seismic Parameters*
- Seismic Zone: Zone IV
- Soil Type: II
- Importance Factor (I): 1.5
- Reduction factor(R): 5

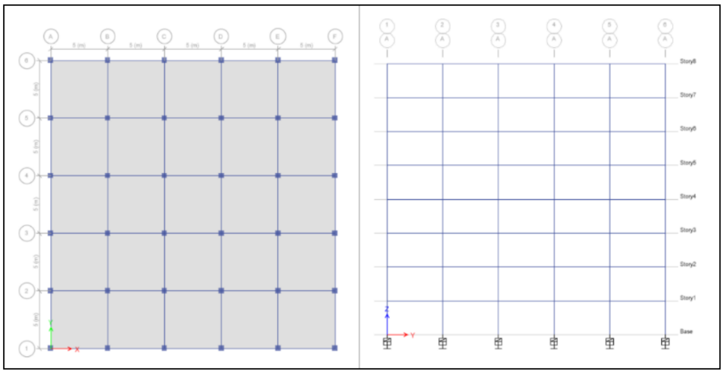

Fig 3.1: Plan and Elevation of Square-shaped Building

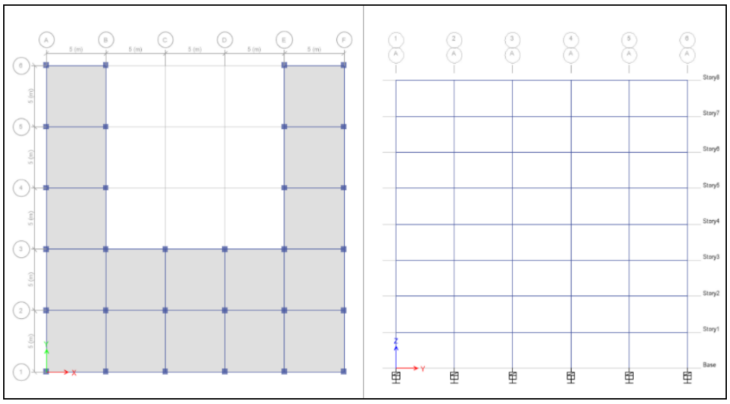

Fig 3.2: Plan and Elevation of U-shaped Building

  

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B. *Design Philosophy for Nonlinear Static Analysis for Earthquake Loading.*

Unlike traditional elastic analysis, which considers linear behavior under seismic forces, the nonlinear static approach acknowledges that structures may undergo significant inelastic deformations during strong earthquakes. The design philosophy behind this method is centered around two fundamental objectives:

- Ensuring elastic performance under moderate earthquake.
- Preventing collapse under severe earthquakes.

This philosophy aligns with capacity design principles, where the structure is designed to ensure that ductile failure mechanisms govern the response, and brittle failures are avoided. In nonlinear static analysis, lateral forces are incrementally applied in a specific. The structure is pushed until a target displacement is reached or a mechanism forms. The analysis provides insight into strength degradation, hinge formation, inter-storey drifts, and overall collapse potential. This method is particularly useful for identifying weak points in the structure, Estimating global and local performance levels such as Immediate Occupancy, Life Safety, and Collapse Prevention. Comparing the actual capacity of the structure to the demand imposed by design-level ground motions. The design philosophy of pushover analysis thus ensures that structures are not only code-compliant but also resilient and reliable during real earthquake events. It provides a more accurate understanding of structural behavior, especially for irregular, retrofitted, or base-isolated buildings, where conventional elastic analysis may be insufficient.

## IV. BASE ISOLATION SYSTEM DESIGN

Seismic isolators are specially designed devices implemented at the base of a structure to protect it from earthquake-induced damage by decoupling the superstructure from the ground motion[16]. This decoupling is achieved by introducing a flexible isolation layer that shifts the structure's natural period of vibration to a longer duration, moving its response out of the high-energy range of typical earthquake ground motions[16]. This significantly reduces the forces and accelerations transmitted to the building, concentrating the deformation within the isolation layer itself[16]. Isolators are designed to sustain large deformations without significant damage and to re-center the structure after an earthquake, while also providing rigidity under low service loads like wind[16].

A. Types of Base Isolators

1. *Elastomeric Bearings*

These are one of the most widespread solutions and consist of multiple bonded layers of rubber and steel shims[16]. The rubber provides horizontal flexibility and large deformation capacity, while the steel shims provide vertical stiffness and restrain the rubber's bulging under vertical load[17]. Elastomeric bearings carry gravity loads and help dissipate earthquake energy[17].

a. Low-Damping Rubber Bearings (LDRBs) / Natural Rubber Bearings:

A natural rubber base isolator is a key component within base isolation systems, primarily falling under the category of elastomeric bearings[14]. These isolators are designed to enhance a structure's seismic resilience by decoupling it from ground motion during an earthquake, thereby reducing the forces transmitted to the building[14]. These use natural rubber with inherent energy-absorbing capacities, typically providing 2% to 4% damping at 100% shear strain. They often require external supplemental damping devices to control or limit displacements[17].

b. High-Damping Rubber Bearings (HDRBs):

Made from specially compounded rubber (e.g., with added carbon black or other fillers) that exhibits significant inherent damping properties[17]. These bearings offer a high level of energy dissipation 10-20% equivalent viscous damping ratio at 100% shear strain, often eliminating the need for auxiliary dampers. HDRBs provide a combination of low horizontal stiffness and high vertical stiffness. Their mechanical properties can be influenced by shear deformation and loading frequency. Base isolation systems are widely used to mitigate seismic energy in buildings and other structures, enhancing their resilience[14].

c. Lead Rubber Bearings (LRBs):

These are a type of elastomeric bearing that incorporate a central lead core[16]. The lead core enhances the bearing's energy dissipation capacity through its inelastic deformation and increases the initial stiffness[16]. LRBs are widely implemented in bridges and buildings[17].

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2. *Sliding Bearings*

Sliding bearings are a category of base isolators, also known as seismic base bearings, which are advanced engineering technologies designed to mitigate the effects of seismic forces on buildings and other structures[14]. By decoupling a structure from ground motion during seismic activities, these bearings enhance structural resilience and safety[14]. They also support the building's weight and provide horizontal flexibility to absorb earthquake forces, thereby enhancing structural responses and preventing or minimizing collapse[14].

a. Friction Pendulum Bearings (FPBs):

These devices work on the principle of a pendulum, utilizing an articulated slider on a concave spherical dish[16]. They lengthen the period of vibration and dissipate energy through friction. The radius of curvature of the dish provides a restoring force[14]. FPBs are self-centering due to their curved surface.

b. Triple Pendulum Bearings:

These are multi-spherical sliding bearings featuring four spherical sliding surfaces and three independent pendulum mechanisms [14]. They provide different response characteristics depending on the intensity of the seismic event[14].

## V. SELECTION OF BASE ISOLATOR

Among various types of base isolators mentioned above, the Natural Rubber Bearing is one of the most commonly used devices due to its simplicity, cost-effectiveness, and reliable performance in moderate to high seismic zones. Natural Rubber Bearings consist of alternating layers of natural rubber and steel plates, which provide flexibility in the horizontal direction while maintaining vertical load-carrying capacity. This flexibility allows the structure to decouple from ground motion, significantly reducing acceleration and inter-storey drift during an earthquake. NRBs are particularly suited for regular, symmetric buildings with moderate to heavy mass and are widely used in both new constructions and retrofitting of existing structures. Thus, natural rubber base isolator is incorporated as part of the nonlinear static analysis.

Target Displacement, Base Shear, T secant, T effective, Modification & Ductility Ratios considered from pushover analysis. Shear Modulus, Diameter, Thickness, No. of Bearings, Load per Bearing, Stiffness, Damping Ratio considered from IS 1893 (Part 6).

Table I: Parameter Designed for Natural Rubber Bearing as per IS 1893 (Part 6)

| Parameter | Value |
|---|---|
| Plan Dimension | 25m × 25m |
| Column Spacing | 5m |
| No. of Columns | 36 |
| No. of Storeys | 8 |
| Storey Height | 3m |
| Total Building Height | 24m |
| Seismic Base Shear | 7296.4kN |
| Spectral Acceleration | 2.51063 $m/s^2$ |
| Effective Weight | 2906.2 kN |
| Mass | $2.962 \times 10^5$ kg |
| Target Displacement | 166.26 mm |
| T secant | 1.487 sec |
| T effective | 1.256 sec |
| Isolation System Stiffness | 7413.74 kN/m |
| No. of Bearings | 36 |
| Stiffness per NR Bearing | 897.22 kN/m |
| Shear Modulus | 0.7 MPa |
| Diameter of Bearing | 600 mm |
| Rubber Thickness | 213 mm |
| Loaded Area | 282743.34 $mm^2$ |
| Lateral Stiffness | 0.93 kN/m |
| Max Shear Strain | 78.1% |
| Vertical Load per Bearing | 80.73 kN |
| Damping Ratio | 10% |
| Modification Factor | 0.712 |
| Ductility Ratio | 2.208 |

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## VI. ANALYSIS RESULTS AND DISCUSSIONS

### A. *Pushover Analysis of Regular vs. Irregular Structures*

Table II: Pushover Analysis of Regular and Irregular Structures

| Parameter | Regular Building (Square) | Irregular Building (U-Shaped) | Difference |
|---|---|---|---|
| Maximum Base Shear in kN | 7330.48 | 5313.70 | 37.94% |
| Maximum Roof Displacement in mm | 181.95 | 167.91 | 8.36% |

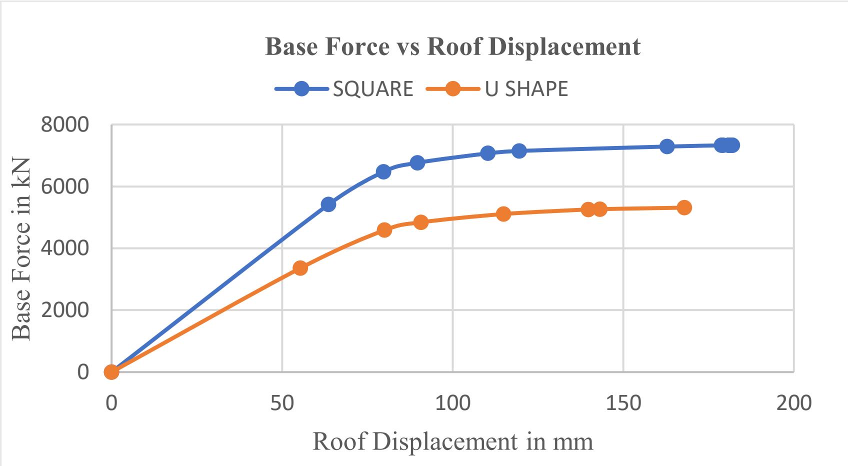


Fig 1: Pushover curve of Regular and irregular structures

Regular and irregular structures subjected to Pushover analysis as per the recommendations of FEMA 440 Target displacement using ETABS 2022 software. The Fig 1 depict a pushover curve, showing the relationship between base force and roof displacement. It compares two data sets regular and irregular building. The regular building curve generally shows 37.94% higher base force values compared to the irregular building curve, indicating that regular structures might handle more load before displacement. A higher base shear indicates better load resistance against lateral forces.

### B. *Story Drift Analysis: Regular vs. Irregular Structures*

Table III: Story Drift Analysis in Regular and Irregular Structures

| Story | Square | U Shape | % Reduction |
|---|---|---|---|
| Story1 | 0.002522 | 0.002129 | 15.59% |
| Story2 | 0.003986 | 0.003597 | 9.77% |
| Story3 | 0.003950 | 0.003676 | 6.94% |
| Story4 | 0.003519 | 0.003337 | 5.17% |
| Story5 | 0.002921 | 0.002818 | 3.52% |
| Story6 | 0.002236 | 0.002208 | 1.25% |
| Story7 | 0.001518 | 0.001562 | 2.90% |
| Story8 | 0.000848 | 0.000968 | 14.15% |

  

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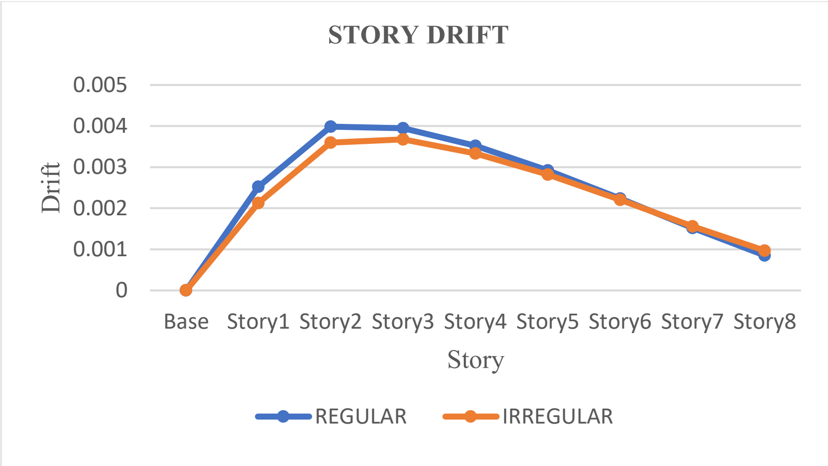


Fig 2: Story drift

Fig 2 depicts the story drift across different stories, comparing irregular building and regular building conditions. The regular building line shown in blue, consistently shows higher story drift values than the irregular building line shown in orange. Both lines show an increase in story drift from story2 to story3, peaking at story2, and then sharply declining towards the base. U-shape shows reduction in drift for stories 1 to 6, with max reduction of 15.61% at story1.However, drift slightly increases in stories 7 and 8. The regular building shows higher story drifts, which suggests it might be less stiff overall or responding with more uniform deformation, whereas the irregular building's configuration may localize deformation more efficiently. i.e its unique shape is helping concentrate or limit movement to certain areas, reducing drift at other floors.

C. *Story Displacement: Regular vs. Irregular Structure*

Table IV: Story Displacement in Regular and Irregular Structure

| Story | Square in mm | U-shape in mm | % Reduction |
|---|---|---|---|
| Story1 | 7.565 | 6.387 | 15.59% |
| Story2 | 19.523 | 17.177 | 12.02% |
| Story3 | 31.372 | 28.206 | 10.09% |
| Story4 | 41.929 | 38.216 | 8.85% |
| Story5 | 50.692 | 46.671 | 7.93% |
| Story6 | 57.400 | 53.294 | 7.15% |
| Story7 | 61.955 | 57.979 | 6.42% |
| Story8 | 64.499 | 60.881 | 5.62% |

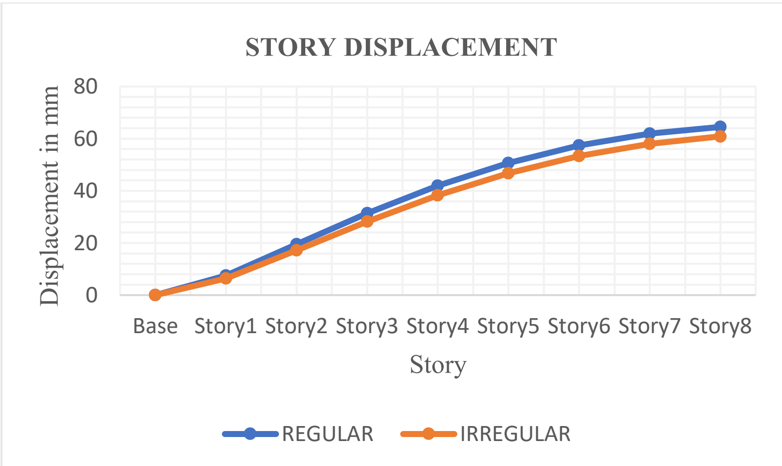


Fig 3: Story displacement

  

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Fig.3 displays the story displacement across different stories from story8 to the Base, comparing regular and irregular conditions. Both regular and irregular lines show a decrease in displacement as they approach the Base. The regular condition generally shows slightly high displacement compared to the irregular condition. Story Displacement for U Shaped building is 60.8mm and for regular square shaped building is 64.5mm. U-shape reduces displacement across all stories, most significantly in lower floors up to 15.6% at story 1.The U-shape resist twisting due to the spread of mass and stiffness across its arms. U-shaped building resisting motion slightly better leading to lower total displacement, even though it's irregular.

D. *Overturning Moment: Regular vs. Irregular Structure*

Table V: Overturning Moment in Regular and Irregular Structure

| Story | Square in kN-m | U-shape in kN-m | % Reduction |
|---|---|---|---|
| Base | 797627.7478 | 453754.2039 | 43.13% |
| Story1 | 788319.7914 | 449884.8611 | 42.93% |
| Story2 | 682612.7339 | 390431.1152 | 42.80% |
| Story3 | 577200.7717 | 330836.7180 | 42.68% |
| Story4 | 472127.2543 | 271087.6618 | 42.58% |
| Story5 | 367405.1403 | 211181.3932 | 42.49% |
| Story6 | 263029.3565 | 151118.5277 | 42.52% |
| Story7 | 158995.6431 | 90900.1930 | 42.82% |
| Story8 | 55300.1115 | 30527.7669 | 44.79% |

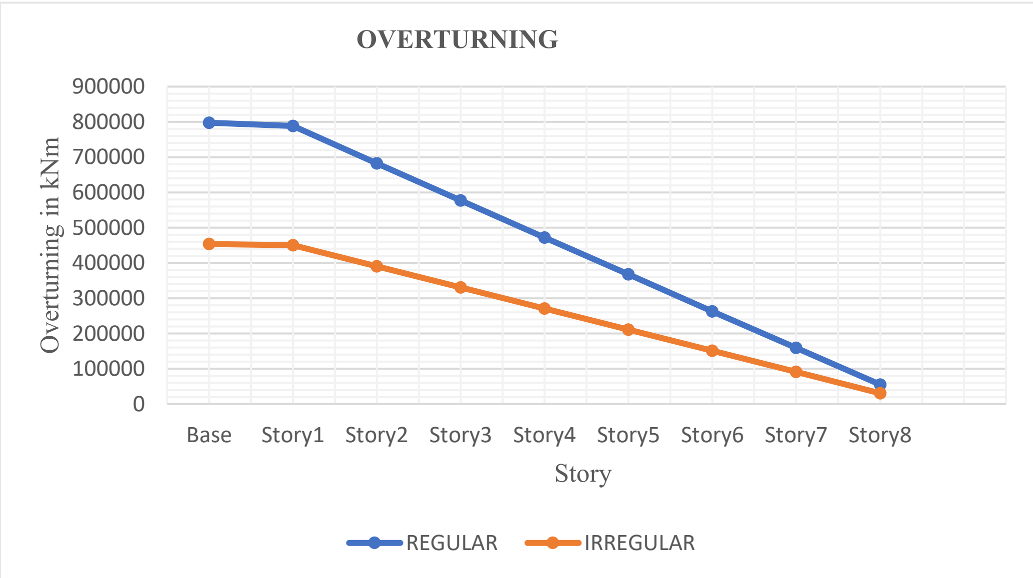


Fig 4: Overturning moment

Fig 4 compares the overturning force for regular and irregular structures across different stories. The blue line represents the regular structure, and the orange line represents the irregular structure. It is highest at the base and reduces as you go up because more load is being resisted below. The regular structure consistently experiences a higher overturning force than the irregular structure at each story level.

Overturning moment reduces consistently by about 42% in all stories with the U-shape. The regular structure has more uniform deformation and greater overall displacement, which leads to higher lateral forces being transferred down the structure. These forces, combined with the story height, produce larger overturning moments at each level.

  

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E. *Pushover Output in ETABS*

Table VI: Comparition of Pushover Output in ETABS for Regular and Irregular Structure

| Parameter | Regular structure | Irregular structure |
|---|---|---|
| Structure Type | Square shape | U shape |
| Site Class | D | D |
| Damping Ratio | 0.05 | 0.05 |
| Performance Point Shear | 7296.41kN | 5312.98kN |
| Performance Point Displacement | 166.26mm | 167.526mm |

There is approximately 27.18% reduction in Performance Point Shear for the irregular structure compared to the regular structure. The performance point displacement for the regular structure is 166.26 mm, while for the irregular structure it is 167.526 mm. This shows a very slight increase of about 0.76%. This shows that the regular geometry leads to better overall strength and load distribution under seismic demand. Although both structures show comparable displacements at their performance points, the square structure exhibits greater base shear resistance, confirming that regular structural geometry contributes to stronger and more stable seismic performance. The U-shaped structure's lower capacity may lead to higher vulnerability under stronger seismic loading despite similar displacements.

F. *Hinge Performance: Regular vs. Irregular Structure*

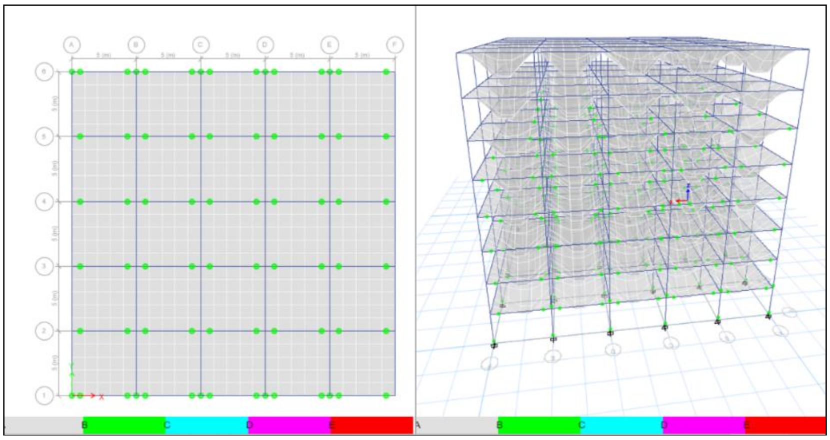

Fig 5: Hinge Performance of regular structure

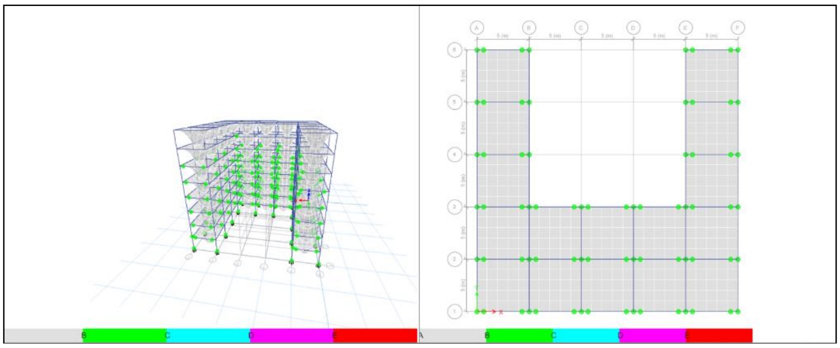

Fig 6: Hinge Performance of irregular structure

Fig 5 and Fig 6 displaying displacements from PUSHX Mode 1 at Step 12/14 . The formation of green hinges throughout both regular and irregular structures indicates that both buildings are behaving well under lateral loads. Despite geometric irregularity, the U-shaped building has been designed effectively, distributing loads without exceeding elastic or immediate occupancy limits. This results in similar hinge performance in both models. U-shape didn't lead to early yielding, possibly due to good reinforcement.

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G. *Pushover Curve of Fixed Base vs. Base Isolated Structures*

Table VII: Pushover Curve of Fixed Base and Base Isolated Structures

| Parameter | Fixed Base | Base Isolated | Change |
|---|---|---|---|
| Max Base Shear (kN) | 7330.48 | 824.18 | 88.76% |
| Max Displacement (mm) | 181.95 | 960 | 427.41% |

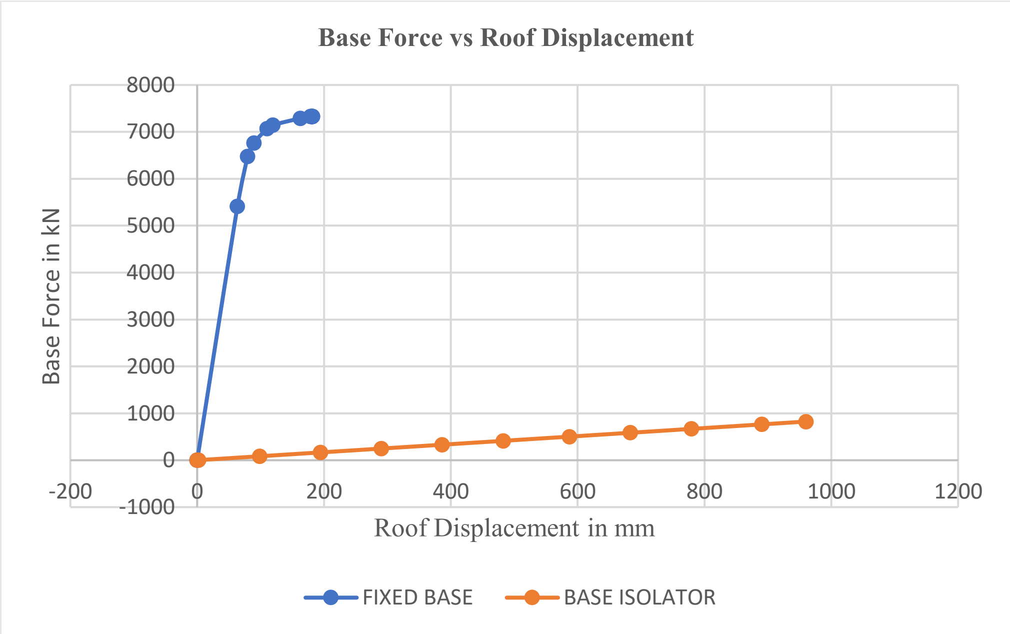


Fig 7: Pushover curve

Fig 7 compares the relationship between base force and roof displacement for two system a fixed base and a base isolator. The fixed base shows a steep increase in base force with minimal displacement, peaking quickly. In contrast, the base isolator demonstrates a gradual increase in base force as displacement increases, indicating better displacement absorption and reduced force. Base Force Reduced by 88.74% and roof displacement Increase by 427.50%, This clearly shows the effectiveness of base isolation in reducing seismic force demands while allowing greater displacements to absorb energy.

H. *Story Drift Analysis: Fixed Base vs. Base Isolated Structures*

Table VIII: Story Drift Analysis in Fixed Base and Base Isolated Structures

| Story | Fixed Base | Base Isolator | % Reduction |
|---|---|---|---|
| Story1 | 0.002522 | 0.001312 | 47.98% |
| Story2 | 0.003986 | 0.000117 | 97.07% |
| Story3 | 0.003950 | 0.000115 | 97.09% |
| Story4 | 0.003519 | 0.000114 | 96.76% |
| Story5 | 0.002921 | 0.000114 | 96.10% |
| Story6 | 0.002236 | 0.000113 | 94.94% |
| Story7 | 0.001518 | 0.000113 | 92.56% |
| Story8 | 0.000848 | 0.000112 | 86.80% |

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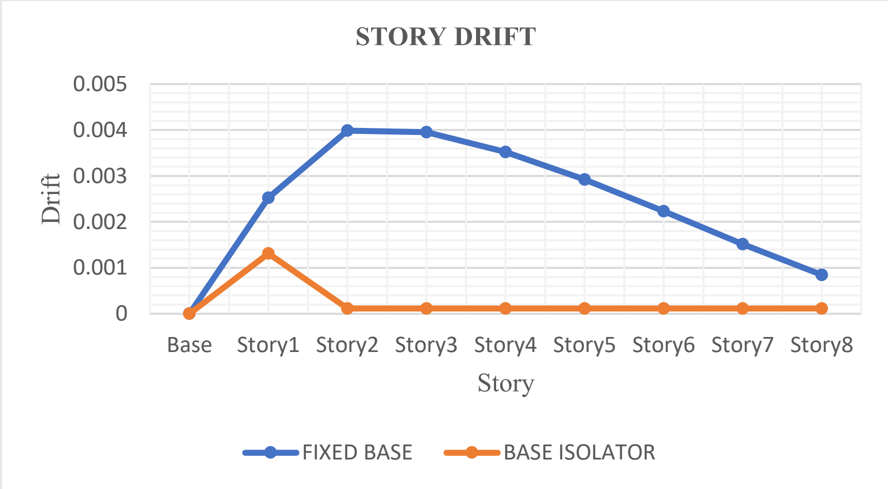


Fig 8: Story Drift in Fixed Base and Base Isolated Structures

Fig 8 compares the drift in stories under two conditions: Fixed Base and Base Isolator. The drift is measured on the vertical axis, with the stories labeled on the horizontal axis. The Fixed Base shows a higher drift, peaking at story2, whereas the Base Isolator has a significantly lower drift, peaking at Story1 and then leveling off. Story drift reduces drastically across all floors due to base isolation, Maximum reduction of 97% in middle stories even in upper stories story 8, reduction is still significant to 87%. This suggests that the Base Isolator is more effective in reducing story drift across the structure.

I. *Story Displacement: Fixed Base vs. Base Isolated Structures*

Table IX: Story Displacement in Fixed Base and Base Isolated Structures

| Story | Fixed Base in mm | Base Isolator in mm | % Reduction |
|---|---|---|---|
| Story1 | 7.565 | 0.123 | 98.37% |
| Story2 | 19.523 | 0.472 | 97.58% |
| Story3 | 31.372 | 0.818 | 97.39% |
| Story4 | 41.929 | 1.161 | 97.23% |
| Story5 | 50.692 | 1.503 | 97.04% |
| Story6 | 57.4 | 1.843 | 96.79% |
| Story7 | 61.955 | 2.181 | 96.48% |
| Story8 | 64.499 | 2.518 | 96.09% |

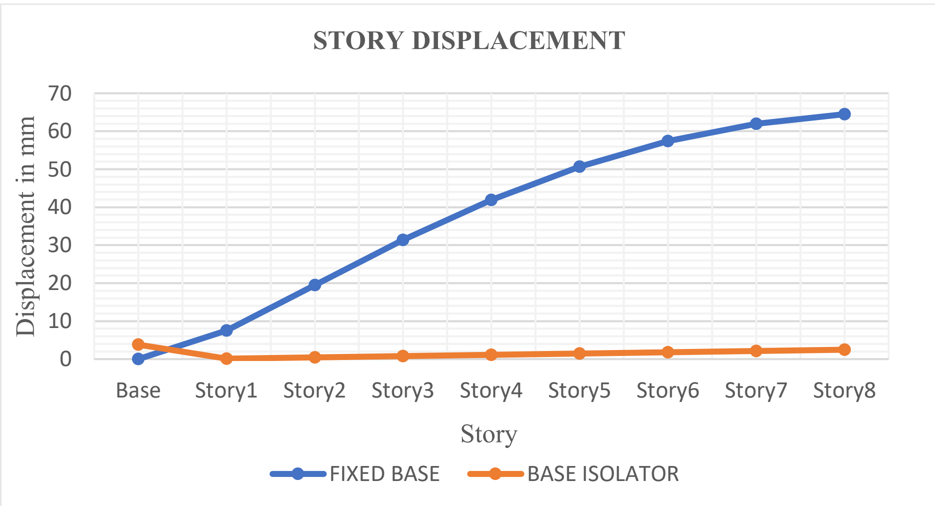


Fig 9: Story Displacement

  

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The Fig 9 compares the story displacement between a fixed base and a base isolator across different building stories. The fixed base shows a significant increase in displacement as the story level increases, peaking at around 64.499 mm by story8. In contrast, the base isolator maintains a much lower and relatively constant displacement throughout, staying below 10 mm. Displacement reduction due to base isolators is very high, ranging from 96% to 98% across all stories. This suggests that the base isolator effectively reduces displacement in structures compared to a fixed base.

J. *Overturning Moment: Fixed Base vs. Base Isolated Structures*

Table X: Overturning Moment in Fixed Base and Base Isolated Structure

| Story | Fixed Base in kN-m | Base Isolator in kN-m | % Reduction |
|---|---|---|---|
| Base | 797627.7478 | 785809.959 | 1.48% |
| Story1 | 788319.7914 | 778977.5437 | 1.19% |
| Story2 | 682612.7339 | 675595.0291 | 1.03% |
| Story3 | 577200.7717 | 572212.524 | 0.86% |
| Story4 | 472127.2543 | 468830.0273 | 0.70% |
| Story5 | 367405.1403 | 365447.5383 | 0.53% |
| Story6 | 263029.3565 | 262065.0565 | 0.37% |
| Story7 | 158995.6431 | 158682.5811 | 0.20% |
| Story8 | 55300.1115 | 55300.1115 | 0.00% |

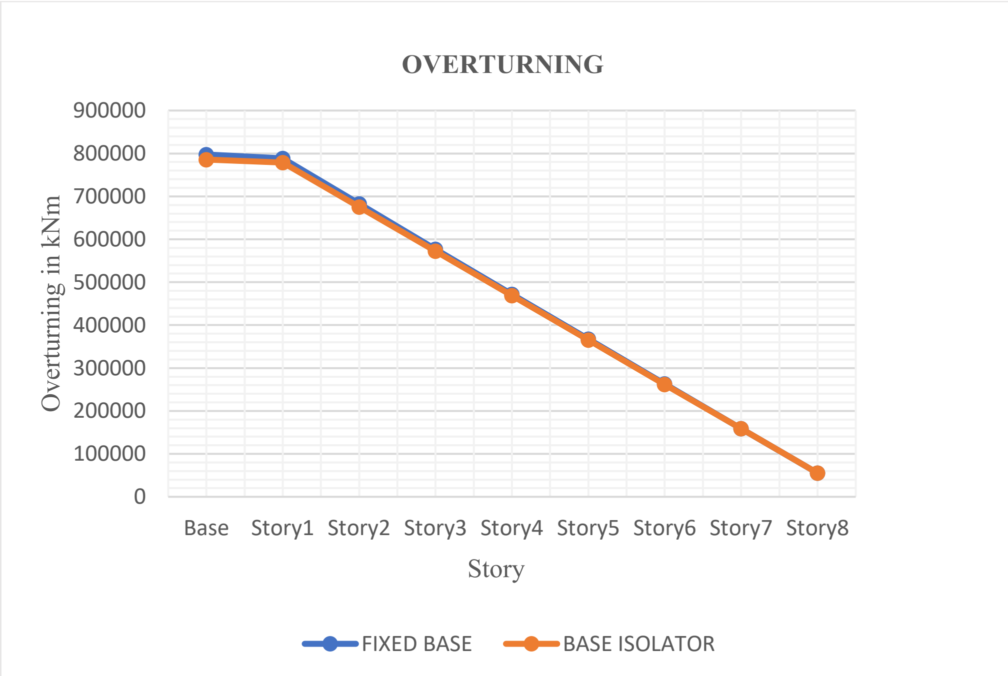


Fig 10: Overturning Moment

Fig 10 illustrates the overturning moment in kNm across different stories of a structure, comparing two types of base conditions fixed base and base isolated. As the story level increases, the overturning moment decreases for both conditions. The data suggests that the base isolated condition generally has a slightly lower overturning moment compared to the fixed base, indicating better performance in reducing overturning forces.

Overturning moment reductions are relatively small, starting from 1.48% at the base and decreasing to 0% at the top. The base-isolated structure shows lower overturning moment across stories because it reduces lateral forces through increased flexibility and energy dissipation.

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K. *Hinge Performance: Fixed Base vs. Base Isolated Structures*

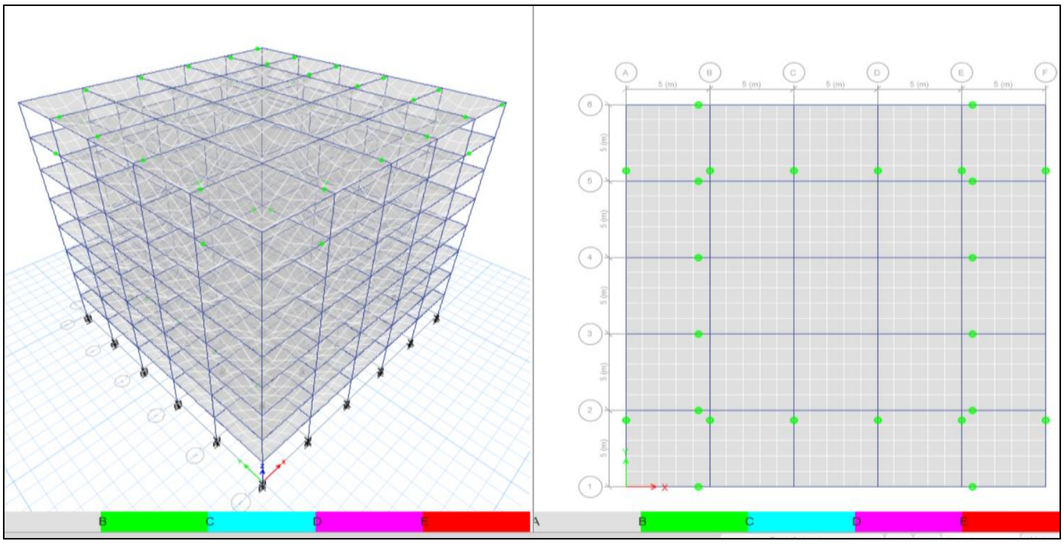

Fig 11: Hinge Performance in regular structure with base isolation

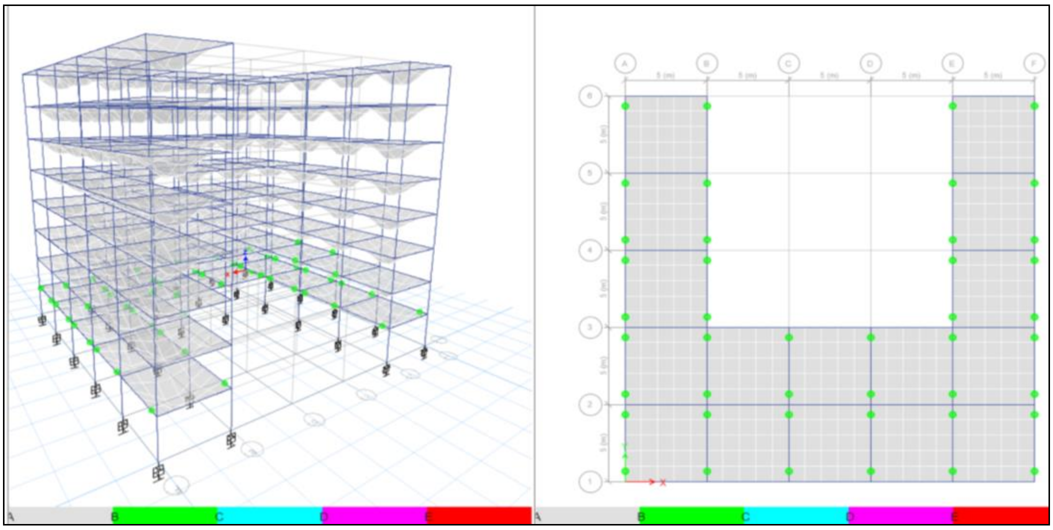

Fig 12: Hinge Performance in irregular structure with base isolation

Fig 11 and Fig 12 displaying displacements from PUSHX Mode 1 at Step 12/14. The formation of green hinges has decreased in both cases shows that much of the structure has entered nonlinear behavior. However, in the regular building, a few green hinges remain at the top, where drift is low. In the base-isolated U-shaped structure base isolation protects the superstructure, but irregular geometry causes limited yielding at the base, where a few green hinges remain.

## VII. CONCLUSION

1. Regular structures with symmetrical geometry perform better in terms of base shear capacity and load distribution.
2. Irregular structures, while having lower overall strength, can still achieve acceptable performance with proper design, though they may exhibit localized stress concentrations.
3. Both structures exhibit adequate deformation capacity, but the regular building's curve suggests a more stable and ductile behavior, which is beneficial for energy dissipation during seismic events. These results confirm that regular geometry contributes to better structural performance, while irregular forms may lead to earlier yielding unless carefully designed.
4. Re-entrant corners in the U-shaped structure cause localized stress concentrations and torsional irregularities, affecting seismic performance. Proper design and detailing can mitigate these effects, ensuring safe structural behavior.

5. Base isolation significantly improves the seismic performance of structures in several ways. It helps in reducing the base shear and overturning moments, thereby lowering the overall force demand on the structure during an earthquake. It also plays a crucial role in minimizing story drift and displacement, which reduces the risk of damage to structural components and ensures better occupant safety. Furthermore, by controlling these forces and deformations, base isolation preserves the structural and non-structural integrity of the superstructure, ensuring the building remains functional and suffers minimal damage during and after seismic events.
6. The combination of base isolation and optimized structural geometry results in better seismic resilience, minimizing damage and improving life safety.

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