Seismic Analysis of Multi-Storied RCC irregular buildings with various bracing system

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Abstract: **Many buildings in the present situation have irregular configurations both in plan and elevation due to aesthetic consideration and city regulation, which in future may be subjected to devastating earthquakes. Irregularities are not avoidable in construction of buildings. However, the behavior of structures with these irregularities during earthquake needs to be studied. Structural irregularities have a significant effect on reinforced concrete buildings during an earthquake. In order to prevent a collapse mechanism caused because of structural irregularities, seismic demand must be determined accurately. The present work aims to investigate the seismic evaluation of multi-storied RCC irregular buildings (L, T, Y, C & E) shapes with combination of irregularities as mass, stiffness and geometric considering concrete bracing, Steel bracing, BRB bracing and SMAs bracing. The performance of a 20-story RCC moment resisting frame is evaluated following seismic code IS-1893:2016. The Non-Linear Time History Analysis of models being considered in the study, the ground motion data of the most severe earthquake in India, the Bhuj earthquake 2001, is used. In Non-Linear Time History Analysis, Fast Non-Linear Analysis (FNA) is used with the help of the ETABS 2021.**

I.INTRODUCTION

The seismic performance of multi-storied reinforced concrete (RCC) buildings has been a critical area of research in civil and structural engineering, particularly for structures with irregular configurations. Urban demands and aesthetic considerations often result in irregular building shapes, both in plan and elevation, such as L, T, Y, C, and E-shaped configurations. These irregularities introduce unique challenges in seismic design, as they alter mass distribution, stiffness, and overall dynamic behavior, increasing vulnerability during earthquakes. To ensure structural safety and minimize damage, it is essential to investigate the effects of such irregularities and develop robust design solutions.

Bracing systems have proven to be an effective technique for improving the seismic resilience of buildings. They provide additional lateral stiffness and strength, mitigating displacements and drifts induced by seismic forces. Among the various types of bracing systems, traditional concrete and steel bracings, buckling-restrained braces (BRB), and innovative shape memory alloy (SMA) bracings are gaining attention due to their distinct performance characteristics. For instance, BRBs offer enhanced energy dissipation capabilities, while SMAs provide a unique combination of shape recovery and damping, making them a promising choice for modern seismic design.

This research focuses on evaluating the seismic performance of irregular multi-storied RCC buildings equipped with different bracing systems. By employing advanced analytical techniques such as Non-Linear Time History Analysis (NLTHA), the study aims to compare the effectiveness of these bracing systems under dynamic seismic loading. The analysis incorporates real earthquake data, specifically from the Bhuj Earthquake (2001), and adheres to the seismic guidelines outlined in IS 1893:2016.

The findings of this study are expected to provide valuable insights into the selection of optimal bracing systems for irregular buildings, ensuring enhanced structural safety and performance. Furthermore, this research contributes to the ongoing efforts to improve the resilience of urban infrastructure in earthquake-prone regions, addressing both practical and theoretical challenges in seismic design.

II. OBJECTIVE OF THE STUDY

To evaluate the seismic performance of multi-storied reinforced concrete (RCC) buildings with various irregular shapes (L, T, Y, C, and E) by using non-linear time history analysis.

To compare the effectiveness of different bracing types made of concrete, steel, buckling-restrained braces (BRB), and shape memory alloys (SMA) on various irregular building models in terms of lateral displacement, storey drift, time period and base shear.

To identify the most prominent bracing system among Shape memory alloys, BRB, steel and concrete brace.

III. NEED OF STUDY

Structures with incorrect design and defective constructions collapse during earthquakes because people are more drawn to a structure's aesthetic look than building methods. Using Shape memory alloy braces and BRB braces have been one effort at such an improvement.

Many scientists have investigated concrete and steel bracing in RC frames when combined with other bracing or shear walls. Some of them discussed the best places for bracing to be placed and various bracing kinds. They discovered that adding bracing to the structures can lessen lateral displacements.

Using ETABS 2021, the current study examines the combination of irregularity considering in irregular structure (L, T, Y, C & E) and their impact of Shape Memory Alloy Bracings, BRB, steel and concrete bracing in RC Structures.

IV. SCOPE OF THE STUDY

The current study looks at different types of bracing and their effects on irregular buildings of shape L,T,E,C and Y with the combination of mass and stiffness irregularity. For analysis, twenty-five models of twenty stories were considered.

The ground motion data from the most destructive earthquake to strike India, the Bhuj earthquake of 2001, is used in the Non-Linear Time History Analysis (NLTHA) for models considered in the study.

The structure is assessed using NLTHA and the ETABS 2021 Non-Linear version software (CSI Ltd) analysis engine following seismic code IS-1893:2016.

V. METHODOLOGY

This study evaluates the seismic performance of multi-storied RCC buildings with irregular shapes (L, T, Y, C, and E) using different bracing systems: concrete, steel, buckling-restrained braces (BRB), and shape memory alloy (SMA) braces.

Building Models

- Twenty-story RCC buildings with irregular shapes are designed.
- Material properties include M30-grade concrete and Fe550-grade steel.

Seismic Analysis

- The Non-Linear Time History Analysis (NLTHA) method is used to study the buildings' response under earthquake loads.
- Ground motion data from the Bhuj Earthquake (2001) is used.
- Models are analyzed as per IS 1893:2016 for Zone V seismic conditions.

Bracing Systems

- Each building is first analyzed without bracing to establish a baseline.
- Then, the four bracing types are applied to study their effect on building performance.

Analysis Tools

- ETABS 2021 software is used for modeling and seismic analysis.

Performance Metrics

- Story Displacement: Measures lateral movement of stories.
- Story Drift: Checks the relative movement between adjacent floors.
- Base Shear: Calculates total seismic force at the base.
- Time Period: Studies the impact of bracing on building vibration.

Comparison and Results

- Results are compared to find the best bracing system for each irregular shape.

- SMA bracing is specifically assessed for its innovative energy dissipation properties.
- This methodology provides insights into improving the safety and stability of irregular buildings during earthquakes.

VI. MODEL INFORMATION

For analysis, the following twenty-five models of twenty stories were considered in this study.

Model 1: L –Type model without bracing

Model 2: L –Type model with concrete bracing

Model 3: L –Type model with steel bracing

Model 4: L –Type model with BRB bracing

Model 5: L –Type model with SMA bracing

Model 6: T –Type model without bracing

Model 7: T –Type model with concrete bracing

Model 8: T –Type model with steel bracing

Model 9: T –Type model with BRB bracing

Model 10: L –Type model with SMA bracing

Model 11: E –Type model without bracing

Model 12: E –Type model with concrete bracing

Model 13: E –Type model with steel bracing

Model 14: E –Type model with BRB bracing

Model 15: E –Type model with SMA bracing

Model 16: C –Type model without bracing

Model 17: C –Type model with concrete bracing

Model 18: C –Type model with steel bracing

Model 19: C –Type model with BRB bracing

Model 20: C –Type model with SMA bracing

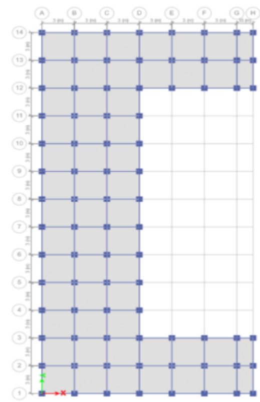
Model 21: Y –Type model without bracing

Model 22: Y –Type model with concrete bracing

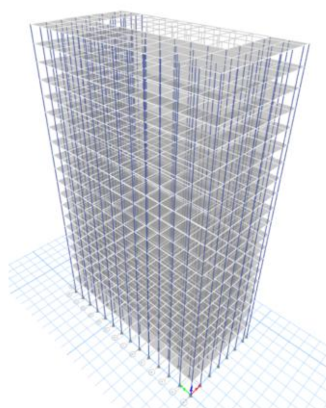
Model 23: Y –Type model with steel bracing

Model 24: Y –Type model with BRB bracing

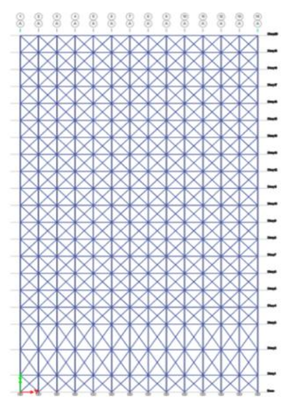
Model 25: Y –Type model with SMA bracing



Plan view of C-Type model.



Isometric view of C-Type model.



Elevation view of C-Type with bracing

VII. RESULTS AND DISCUSSION

L-Type Building

- Story Displacement:

SMA bracing reduced displacement by 40%, BRB by 35%, steel by 28%, and concrete by 20% compared to the unbraced model.

- Story Drift:
  SMA braces achieved a 35% reduction, BRB reduced by 30%, steel by 25%, and concrete by 18%.
- Base Shear:
  SMA and BRB increased base shear by 50% and 45%, respectively, while steel and concrete increased it by 38% and 30%.
- Time Period:
  SMA reduced the time period by 15%, BRB by 12%, steel by 10%, and concrete by 8%.

T-Type Building

- Story Displacement:
  SMA bracing reduced displacement by 42%, BRB by 37%, steel by 30%, and concrete by 22%.
- Story Drift:
  Drift decreased by 30% with SMA, 28% with BRB, 23% with steel, and 17% with concrete.
- Base Shear:
  SMA and BRB increased base shear by 52% and 48%, while steel and concrete increased it by 40% and 32%.
- Time Period:
  Time period reduction was 16% for SMA, 13% for BRB, 11% for steel, and 9% for concrete.

E-Type Building

- Story Displacement:
  SMA bracing reduced displacement by 42%, BRB by 38%, steel by 31%, and concrete by 24%.
- Story Drift:
  Drift was reduced by 34% with SMA, 30% with BRB, 26% with steel, and 19% with concrete.
- Base Shear:
  SMA and BRB increased base shear by 54% and 49%, while steel and concrete improved it by 44% and 36%.
- Time Period:
  SMA reduced the time period by 17%, BRB by 14%, steel by 12%, and concrete by 10%.

C-Type Building

- Story Displacement:
  Displacement was reduced by 40% with SMA, 38% with BRB, 30% with steel, and 22% with concrete.
- Story Drift:
  SMA braces reduced drift by 35%, BRB by 32%, steel by 26%, and concrete by 20%.
- Base Shear:
  SMA and BRB braces increased base shear by 53% and 48%, while steel and concrete improved it by 42% and 34%.
- Time Period:
  Time period reduction was 16% for SMA, 14% for BRB, 11% for steel, and 9% for concrete.

Y-Type Building

- Story Displacement:
  SMA bracing provided a 45% reduction, BRB 40%, steel 33%, and concrete 25%.
- Story Drift:
  Drift was reduced by 32% with SMA, 29% with BRB, 24% with steel, and 18% with concrete.
- Base Shear:
  SMA and BRB increased base shear by 55% and 50%, while steel and concrete increased it by 43% and 35%.
- Time Period:
  SMA reduced the time period by 17%, BRB by 14%, steel by 12%, and concrete by 10%.

VIII. CONCLUSION

Seismic analysis using nonlinear time history method is performed on L, T, E, C, and Y-shaped models in which C-shape emerges as the most favourable shape, followed by the Y-shape, E-shape, and then the L and T shapes.

The percentage decrease in lateral displacement for C-Type model is 90% and 84% in x and y directions for SMA braces, 85% and 80% for BRB braces, 75% and 74% for steel braces, and 73% and 68% for concrete braces, compared to the unbraced model. In terms of storey drift, the C-Type model experiences reductions of 84% and 81.5% in x and y directions with SMA braces, 82% and 80% with BRB braces, 73% and 69% with steel braces, and 71% and 68% with concrete braces when compared to unbraced model.

The time period for Y-Type model is reduced by 82% with SMA braces, 77% with BRB braces, 71% with steel braces, and 70% with concrete braces compared to the unbraced model. Alternatively, the Y-Type model experiences an increase in base shear of 90% and 88% in x and y directions with SMA braces, 82% and 86% with BRB braces, 78% and 85% with steel braces, and 79% and 80% with concrete braces when compared to unbraced model.

Shape memory alloy bracing consistently demonstrate superior performance, followed by Buckling restrained bracing, steel bracing and concrete bracing from the better results across all bracing systems.

IX. FUTURE SCOPE

1. Investigate the performance of other lateral force resisting systems, such as dampers, in mitigating the seismic response of irregular buildings.
2. It can be studied by considering varying height of structure to get clear idea till which story height the effect of bracing will be significant.
3. Further research can be carried by using the same system with soil interaction properties.

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