A Comparative Study Of Torsional Effect Of Earthquake On 'L' And 'S' Shaped High Rise Buildings

S. A. Powale, N. J. Pathak

Abstract— Damage reports on recent earthquakes have indicated that torsional motions often cause significant damage to buildings, at times leading to their collapse. Asymmetric structures have irregular distribution of mass and stiffness and its centre of mass and centre of rigidity do not coincide and hence causes the torsional effect on the structures which is one of the most important factor influencing the seismic damage of the structure. In this paper, seismic performance of two buildings irregular in plan are analyzed and compared. Two 33 storey buildings with 'S' and 'L' plan shapes are modelled in ETABS 2016 using Time History Analysis..

Index Terms— *Asymmetrical Building, Plan Irregularity, Earthquake, Torsional Irregularity, Time History Analysis*.

1 Introduction

Earthquake Engineering is the most important field in the structural engineering research field. Traditionally structures were analyzed for gravity loading and designed accordingly. The destruction caused by earthquakes to such structures gave rise to a thought of designing such a structure that would safely withstand and resist earthquakes which can occur throughout the structure's designed lifespan. Earthquake analysis utilizes the basics of structural dynamics. There are several streamlined techniques for evaluating the building's seismic performance.
Based on weight allocation and rigidity throughout the building's height. However, a precise assessment of the irregular building's seismic conduct is quite hard and a complex issue. Because of the parameter diversity and the selection of possible models for unbalanced torsion induced constructions, there isn't a common consent and precise practice recommended by common exercise practitioners to evaluate torsional effects. Seismic harm studies and analysis of structural failure modes in previous serious earthquakes have found that the most susceptible construction systems are asymmetric in nature.
In contemporary construction, asymmetric construction systems are almost inevitable owing toward different kinds of practical and architectural demands. Twisting in structures throughout the seismic activity can be produced by a range of details, the utmost mutual of which are unbalanced mass distributions and rigidity. Present codes cope with twisting by limiting the scheme of structures with uneven outlines and likewise by introducing an unintentional eccentricity that need to be taken into account in the design. The horizontal twist coupling owing to eccentricity among the center of mass (CM) and the center of rigidity (CR) in the unbalanced structure produces twisting shaking even in decently translational earth shivering throughout the seismic trembling of the structures, inertia forces operate over the center of mass as resistive force acts over the center of stiffness
A building is said to be torsionally irregular when the maximum horizontal displacement of any floor in the direction of the lateral force at one end of the floor is more than 1.5 times its minimum horizontal displacement at the far end of the same floor in that direction. Thus the ratio of Δmax and Δmin governs the torsional irregularity. [8]

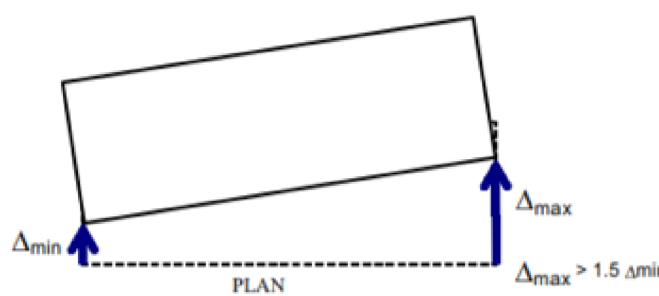

Fig. 1. Torsional Irregularity in Plan

There is an effective understanding of how different parameters may influence torsion. So we can see these parameters by comparison of Torsional Effect 'L' and 'S' shaped plan buildings.

2 Literature Review

2.1 Hamdy H.A.Abd-El-Rahim (2010) [1]

This study was limited to buildings with uneven rectangular plan shapes in concrete reinforced frame structures. Buildings with abnormalities in plan floors appear to be more prone to big deformations and harm when exposed to a powerful ground movement than those with regular plan floors owing to extra torsional forces arising from the current eccentricity amongst the center of mass and the center of the stiffness of resistant components. To determine the seismic degree of

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protection provided to these structures by new design regulations introduced in the Egyptian code, analysis of the seismic response of irregular structures is necessary. Therefore, in this research, it was planned to assess the efficiency of uneven structures loaded with gravity in the system under excitation from the earthquake. Ten irregular configurations represented the structural irregularities in the plan to cover the twisting effects and model them. For these ten models, time history analysis was performed using finite element program SAP2000 with a peak ground acceleration of 0.25 g. Numerical studies for various irregularity impact models were visible in the form of the T- plan compared to others. In the direction of movement, the base shear produced at right angles ranged from 40 % to 80 % of the shear at base. In order to minimize the induced perpendicular base shear, the findings proclaimed the need for structural separation in these uneven structures.

2.2 S.Varadharajan, V.K.Sehgal and B.Saini (2012) [2]

This study summarizes the preceding research work on various kinds of structural abnormalities, i.e. plan and vertical irregularities. The summary of prior study work on distinct kinds of horizontal irregularities explained the choice of multistorey structure models over single storey structure models and the concept of balancing CV (Center of Strength)–CR (Center of Rigidity) position in regulating seismic reaction parameters. With respect to vertical irregularities, strength irregularity was observed to have very higher effect and mass irregularity had a very lesser effect on seismic response. With regard to the method of analysis, the method of MPA (Modal Pushover Analysis) was found to be less precise compared to the dynamic analysis even after much improvement.

2.3 S.G.Maske and P.S.Pajgade (2013) [3]

The research on the impact of torsion effects on structure behavior is performed in this paper. With the help of ETABS software, the structural investigation and design of the 4 storey reinforced concrete asymmetrical framed building was carried out. Static linear analysis was performed. The building includes various irregularities such as irregularity of the plan and irregularity of the re-entrant corner. There are two scenarios: Scenario 1 is without consideration of design eccentricity and Scenario 2 is considering torsion. Results are a comparison of Area of Steel in Tension for different columns. It has been noted that the forces in the columns on the stiffer side of the plan are much lower than those acquired in the flexible side components of the plan. While designing it, the columns that are farthest from the center of rigidity considering design eccentricity failed.

2.4 S.N.Suryawanshi, S.B.Kadam and S.N.Tande (2014) [4]

In this paper, the use of response spectrum technique is used to study the significance of twisting moment impacts on the behavior of the structure. For structural descriptors, nonlinear pushover analysis was used. In this research, gravity loading evaluation and lateral load evaluation are performed for 3 structures as per IS 1893:2002.

a) Symmetric 4 and 7 storey building.

b) Asymmetric 4 and 7 storey building (L plan shape).

c) Asymmetric 4 and 7 storey building (T plan shape).

Response spectrum technique is used to calculate twisting moments, shear at base, dislocations and time period and their ability and demand is measured using pushover analysis.
It is concluded that, for asymmetric building, twisting moment is more than symmetrical building. For asymmetrical building, shear at base and roof dislocation is more than a symmetrical building. Symmetrical building performance in a seismic event is better than asymmetrical building.

2.5 R.Thaskeen and S.Shajee (2016) [5]

Both symmetric and asymmetric buildings are compared with horizontal irregularity in this study. Symmetric buildings have a center of mass that overlaps with the center of rigidity and the impact of torsion in these buildings is due to accidental eccentricity whereas mass and stiffness are irregularly distributed in asymmetric buildings and their center of mass and center of stiffness doesn't overlap and therefore creates torsional/twisting effects on buildings which are one of the most significant factors affecting seismic harm to the structure. In this study, four types of structures with the unchanged outside perimeter area are considered and reinforced by the application of shear cores to evaluate the twisting impact on the buildings. A straightforward linear comparison is also performed for G+12 and G+17 buildings based on eccentricity. During the earthquake, structures with asymmetric distribution of mass and rigidity undergo twisting movements. The efficiency of the buildings is evaluated according to the method prescribed in IS: 1893: 2002 and ASCE 7-05. Structural model assessment is performed using ETABS software.

2.6 S.S.Patil and S.R.Suryavanshi (2016) [6]

Multistory building seismic performance is verified with asymmetrical plan in this paper. It is noticed that significant harm occurs at the re-entrant corner during the earthquake. The finite-element analysis STAAD Pro V8i models a G+20 and G+22 structure with a plan asymmetry. Referring to 1893(Part-1)2002, an accidental torsional/twisting load is applied.

2.7 M.Tripathi, M.Williams.P. And Dr.R.K.Tripathi (2016) [7]

In this article, for research with asymmetric loading, a geometrically symmetrical tall building structure was considered. Software was used to study static linear, linear dynamic and nonlinear static behaviour, and a G+14 RCC frame was used. Three sets of models were analyzed, one with an eccentric mass of magnitude twice the mass on the remaining part, one with four-fold mass and one with six-fold mass magnitude. It was found that shear wall provision decreases the building's torsion. Shear wall structures have less displacement on the top floor than those without shear wall. When shear walls are given, base shear increases, resulting in the reduced time period as well.

3 OBJECTIVES

- The chief objective of this study is to verify the torsional/twisting effect of a 'S' shaped plan building in comparison with a 'L' shaped plan building.
- The main objectives for undertaking the present study are as follows:
    1. To analyse a 33 storey R. C. framed 'S' and 'L' shaped plan building using time history analysis for torsional effect due to irregular plan.
    2. To examine whether 'S' shaped plan resists torsion due to earthquake effectively than 'L' shaped plan.

4 METHODOLOGY

The methodology adopted for this study includes analytical work with supplementary software work using software: ETABS.

SOFTWARE WORK

1. Time History Analysis of a 33 storey R. C. framed building, 'S' shaped irregular plan building.
2. Time History Analysis of a 33 storey R. C. framed building, 'L' shaped irregular plan building.
    a. Modelling of 33 storey R. C. framed building.
    b. Testing under various load cases producing torsion as per IS: 1893 (Part I): 2016.
    c. Comparative result generation over different parameters.

5 DATA ADOPTED AND SPECIFICATIONS

- **Building Plan Shapes:** 'L' and 'S' Shapes.
- **Storeys in Model:** 33 Storeys.
- **Master Storeys:** 11th Storey, 22nd Storey and 33rd Storey.
- **Total Height of Building:** 99 metres.
- **Materials:** (Pre-defined in ETABS)
    a. Steel – HYSD500
    b. Concrete – M35 Grade
- **Structural Member Sizes**:
    a. Slab – 150 mm
    b. Beam – 450 mm × 600 mm
    c. Columns up to 11th Storey – 600 mm × 750 mm
    d. Columns up to 22th Storey – 550 mm × 700 mm
    e. Columns up to 33rd Storey – 500 mm × 650 mm
- **Shear Walls:** Provided at Lift Ducts (200 mm thick)
- **Load Considerations:**
    a. Dead Load
        i. Self-Weight of Frame: Predefined in ETABS
        ii. Wall Load: 7.2 kN/m
        iii. Floor Finish: 2 kN/m³
    b. Live Load: 2 kN/m³
- **Earthquake Analysis Data:**
    a. Location: PUNE
    b. Zone: III
    c. Time Period: Program Calculated.
    d. Lateral Load Resisting System: Special Moment Resisting Frame.
- **Time History Data Used**:
    a. El Centro.
    b. Bhuj.
- **Architectural Plan Layouts**:

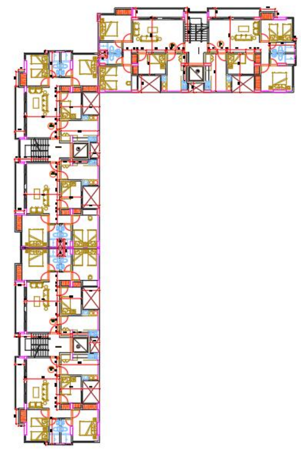

Fig. 2. L Shaped Layout

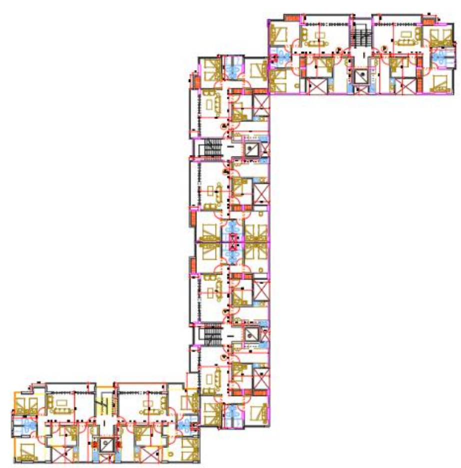

Fig. 3. S Shaped Layout

6 ANALYTICAL WRK

In the present study, analysis of 'S' and 'L' shaped plan buildings of 33 storey were analyzed using ETABS using Time History Analysis.

- Modelling:

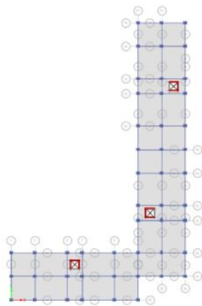

Fig. 3. ‘L’ Shape Structural Plan Model

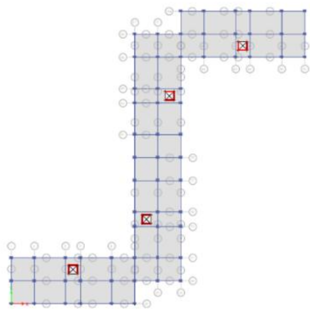

Fig. 3. ‘S’ Shape Structural Plan Model

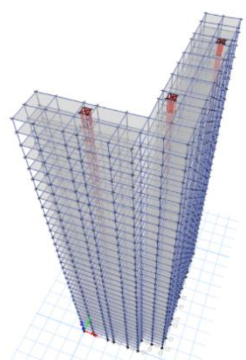

Fig. 3. ‘L’ Shape Structural 3D Model

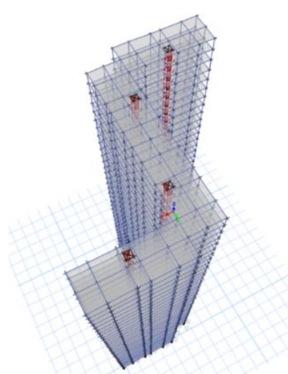

Fig. 3. ‘S’ Shape Structural 3D Model

- Deformed Shapes after analysis:

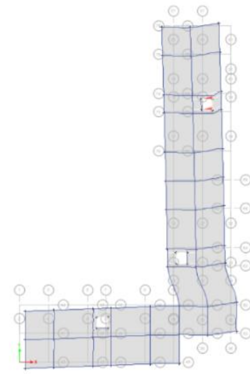

Fig. 3. ‘L’ Shape Deformed Structural Plan Model

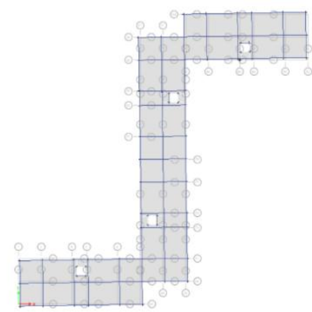

Fig. 3. ‘S’ Shape Deformed Structural Plan Model

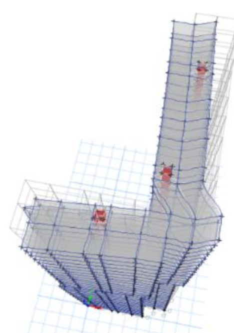

Fig. 3. ‘L’ Shape Deformed Structural Plan Model

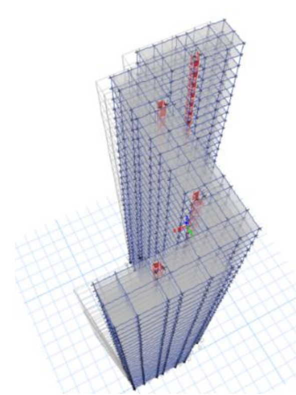

Fig. 3. ‘S’ Shape Deformed Structural Plan Model

7 Results And Discussions

The following are the results obtained after analysis using ETABS.

a. EL CENTRO

Table. 1. Joint Displacements along X Direction

	S Shape	L Shape
Δ_{max} (mm)	51.688	97.25
Δ_{min} (mm)	51.317	59.402
$\Delta_{max}/\Delta_{min}$	1.007	1.637

Table. 2. Joint Displacements along Y Direction

	S Shape	L Shape
Δ_{max} (mm)	52.039	56.066
Δ_{min} (mm)	49.545	42.72
$\Delta_{max}/\Delta_{min}$	1.050	1.312

b. BHUJ

Table. 3. Joint Displacements along X Direction

	S Shape	L Shape
Δ_{max} (mm)	31.011	78.95
Δ_{min} (mm)	30.811	47.589
$\Delta_{max}/\Delta_{min}$	1.006	1.658

Table. 4. Joint Displacements along Y Direction

	S Shape	L Shape
Δ_{max} (mm)	21.842	70.253
Δ_{min} (mm)	20.377	58.066
$\Delta_{max}/\Delta_{min}$	1.071	1.209

Comparing the results obtained for 'S' and 'L' shaped plan 33 storey buildings:

- Seismic Weight of 'S' shaped structure is greater than that of 'L' shaped structure.
- As Seismic Weight is more, shear at base is also greater for 'S' shaped building than 'L' shaped building.
- Joint Displacements of 'S' shaped building are less as compared to 'L' shaped building.
- The $\Delta max/\Delta min$ ratio for 'L' shaped building in X direction is more than 1.5 and hence the building is torsionally irregular.
- The $\Delta max/\Delta min$ ratio for 'S' shaped building in both direction is less than 1.5 and the building therefore is not torsionally irregular.

8 Conclusion

With the results obtained and discussed, 'S' shaped plan buildings show lesser values of joint displacements when compared to 'L' shaped plan buildings. Also the $\Delta max/\Delta min$ ratio for 'L' shaped building in X direction is more than 1.5 and hence the building is torsionally irregular while the $\Delta max/\Delta min$ ratio for 'S' shaped building in both direction is less than 1.5 and hence the building is not torsionally irregular. Hence, 'S' shaped plan building resists torsional/twisting effect better than 'L' shaped plan building during the earthquake.

Thus it can be concluded that 'S' shaped plan buildings show better earthquake resistance than 'L' shaped plan buildings when torsional irregularity is the primary point of consideration.

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