

“Study on Seismic Effects in Irregularly Shaped Structures”

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Abstract: - Earthquake engineering primarily aims to analyse, design, and construct structures in a manner that minimizes damage to both the structure and its components during seismic events. Numerous studies have investigated the impact of structural irregularities on seismic performance. Inspired by previous research on the behaviour of irregularly shaped buildings under earthquake loading, the present study examines the influence of plan and shape configurations on structural response. Structures with irregular geometries exhibit significantly different behaviour compared to regular ones when subjected to seismic forces. Among various factors, plan geometry plays a crucial role in determining structural performance under such dynamic loading conditions. This study focuses on evaluating the effects of plan and shape irregularities on buildings under seismic action. To assess structural performance, both equivalent static analysis and response spectrum analysis were carried out using ETABS 19 software. Key response parameters, including lateral displacement, storey drift, and base shear, were analysed and compared across different structural models. The results are presented through graphs and bar charts for better interpretation. The findings indicate that structures with simple and regular plan configurations perform better under seismic loading. Therefore, adopting regular geometries at the planning and design stage is essential for minimizing earthquake-induced damage.

Keywords: Equivalent static analysis, Response spectrum analysis, ETABS, Irregular shape.

1. INTRODUCTION

In the present scenario, many buildings are constructed with irregular configurations in both plan and elevation, which may be highly vulnerable to severe earthquakes in the future. Since such irregularities are often unavoidable in modern construction, it becomes essential to evaluate the performance of these structures under seismic conditions. Understanding their behaviour during earthquakes is crucial so that appropriate design precautions can be implemented. A detailed study of the structural response of irregular buildings is necessary to ensure safety and reliability. While several studies have focused on the seismic performance of regular structures, there remains a limited understanding of how irregular structures respond to earthquake forces. Therefore, a comprehensive assessment of both vertical and horizontal irregularities and their impact on seismic demand is required. A significant portion of India lies in seismic-prone zones, making it imperative to consider earthquake loads during structural design. Earthquake-induced lateral forces are a major concern, as they can generate critical stresses, cause excessive vibrations, and lead to significant lateral displacement or drift. Storey drift, defined as the relative lateral displacement between the top and base of a building, must be controlled to prevent structural and non-structural damage. Ideally, structures should be capable of withstanding moderate earthquakes without structural failure, although minor damage may occur. Recent earthquakes have demonstrated considerable damage to reinforced concrete structures, highlighting the importance of evaluating seismic behaviour accurately. Ensuring an adequate level of safety in structural design is therefore essential. This study focuses on assessing the seismic performance of reinforced concrete (RC) frame buildings using both static and dynamic analysis methods in accordance with IS codes. A multi-storey residential building model is analysed, and key response parameters such as storey displacement, base shear, and storey drift are compared using the response spectrum method. ETABS, one of the most widely used structural analysis and design software tools in the industry, is utilized in this study. The research primarily involves a comparative analysis of results obtained from the seismic evaluation of multi-storey building structures modelled and analysed using ETABS.

SUMMARY:- Past earthquake events have shown that buildings with structural irregularities are more susceptible to damage. The choice of building shape and configuration plays a crucial role in determining its performance during strong seismic activity. For this reason, symmetry and regularity are generally recommended in the design of earthquake-resistant structures. Considering the influence of plan and shape configurations, the present study aims to evaluate the seismic performance of different structural layouts. The objective is to identify which configurations perform more effectively under earthquake loading and should therefore be preferred in design practice.

2. SYSTEM DEVELOPMENT

The actual behaviour of structures observed in the physical world cannot be replicated with complete accuracy in analytical models. Therefore, it is necessary to develop a systematic approach that bridges the gap between real-world behaviour and simulated analysis. In engineering practice, certain assumptions are inevitably made to simplify complex physical problems, which leads to approximate solutions. In this context, six structural models were developed and analysed using ETABS 19 software to study the behaviour of irregular structures under seismic conditions.

Specification for all above mentioned structural models are same and are given as follows.

Table 1 Load Data

Live Load	3 kN/m ² as per IS 875
Floor Finish Load	1 kN/m ² as per IS 875

Table 2 Seismic Definition Specifications

Earthquake Zone	III
Damping Ratio	5%
Importance Factor	1.2
Type of Soil	Medium Soil
Type of Structure	All General RC Frame
Response Reduction Factor	5 [SMRF]
Time Period	Program Calculated
Foundation Depth	2.1m
Poisson's Ratio	0.2

Table 3 Geometric Data

Density of RCC considered	25 kN/m ³
Thickness of slab	120mm
Depth of beam	450mm
Width of beam	300mm
Dimension of column	300 mm x 450mm
Density of infill	20 kN/m ³
Thickness of out wall	230mm
Height of second floor	3.5 m

Height of each floor	3.2m
Poisson's Ratio	0.2
Conc. Cube Comp. Strength, fck	25000 N/mm ²
Bending Reinforcement yield strength, fy	415000 N/mm ²
Shear Reinforcement yield strength, fys	415000 N/mm ²
Beam Rebar Cover	35mm
Column Bar Size	16 ϕ

These 6 models are shaped by considering Plan irregularities i.e. the plan area for each structure is same only there is difference of geometry i.e. horizontal (plan and shape). For all types of structure total number of storey are 15.

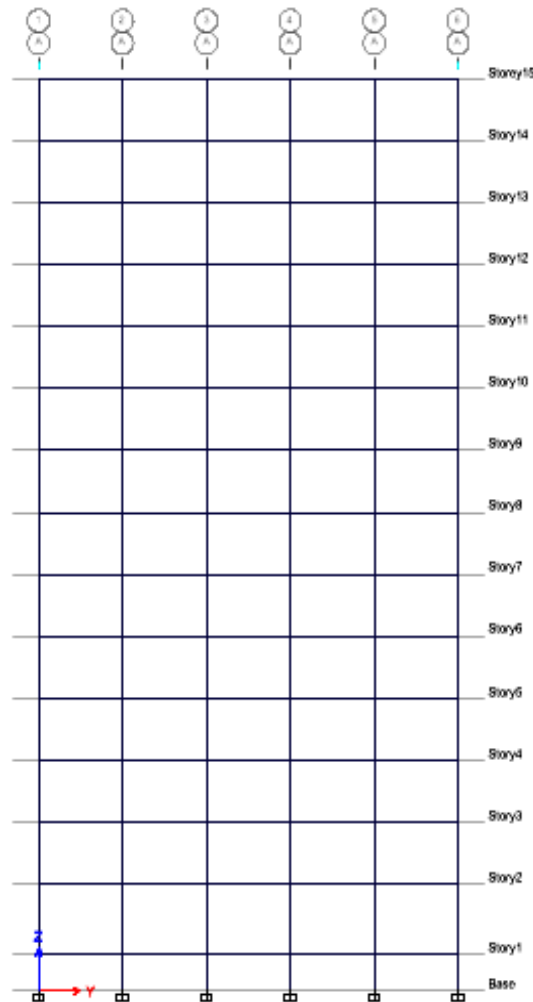


Fig.1 Elevation

Plan of each building models consider are shown below:-

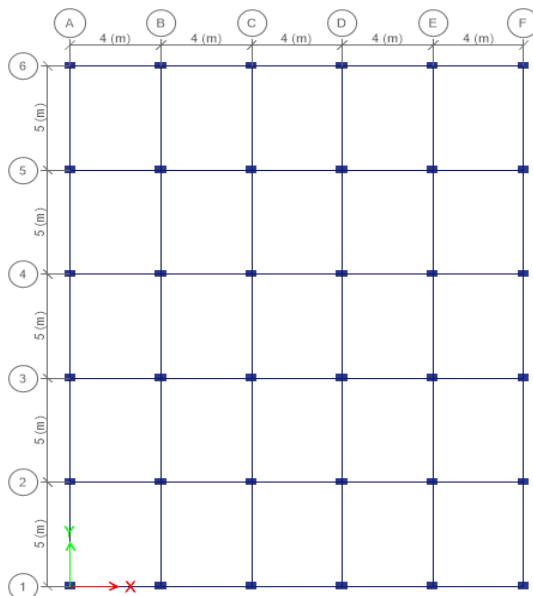


Fig.2 Regular Square Shape (S1)

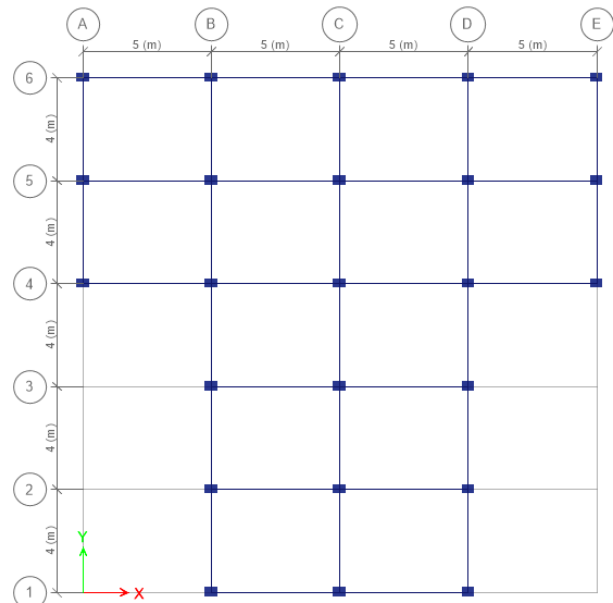


Fig.3 T-Shape (S2)

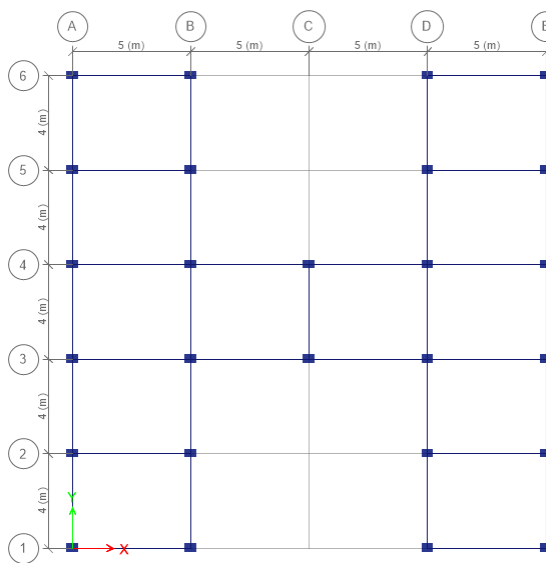


Fig.4 H-Shape (S1)

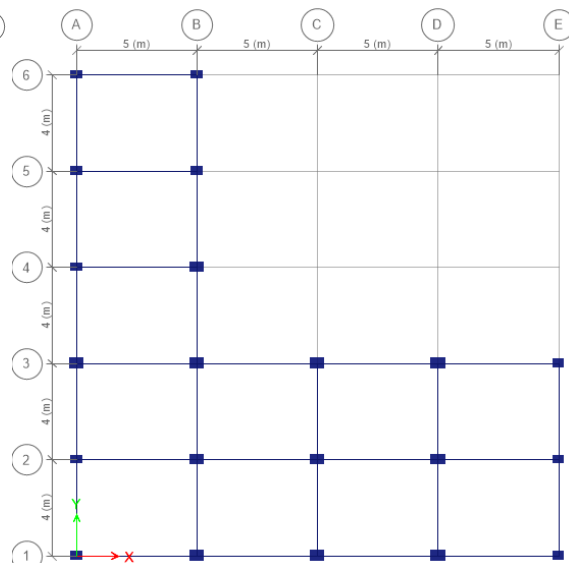


Fig.5 L-Shape (S4)

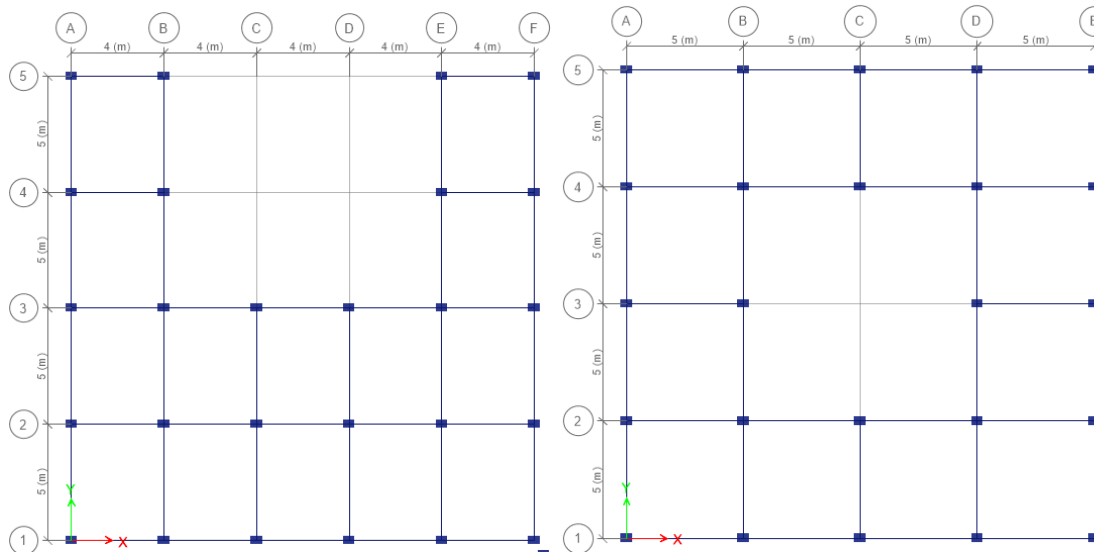


Fig.6 C- Shape (S5)

Fig.7 Square Shape with Core (S6)

3. PERFORMANCE ANALYSIS

Several factors influence the behaviour of a building under seismic loading; among these, storey drift and lateral displacement are considered in this study. For the analysis, a building model located in Seismic Zone III is taken into account. Both Equivalent Static Analysis and Response Spectrum Analysis are performed on the model using ETABS software. The analysis results are presented in the form of tables and charts. Key response parameters such as lateral displacement and storey drift are carefully evaluated after the analysis. These values must comply with the provisions of IS 1893 (2016), which specify that the storey drift in any storey should not exceed 0.004 times the storey height. If the calculated drift exceeds the permissible limits, appropriate design modifications, such as increasing the column section size, are implemented to control excessive drift and ensure structural safety.

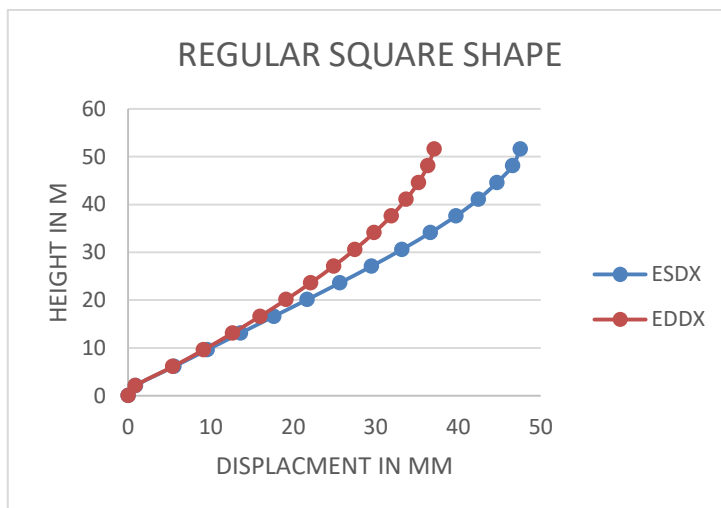


Fig.8 Displacement Graph X-Direction

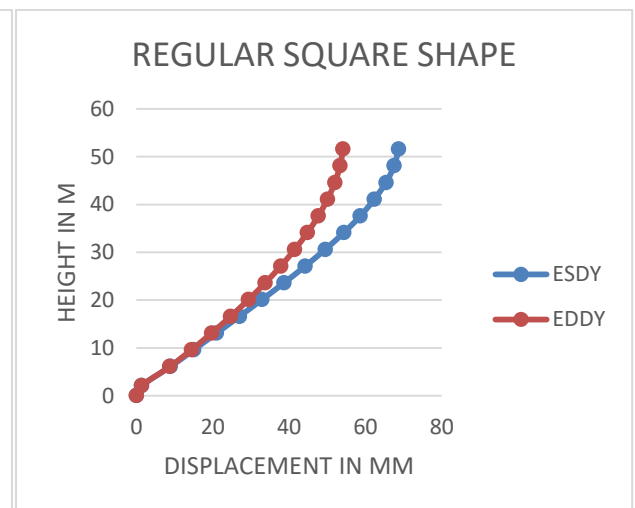


Fig.9 Displacement Graph Y-Direction

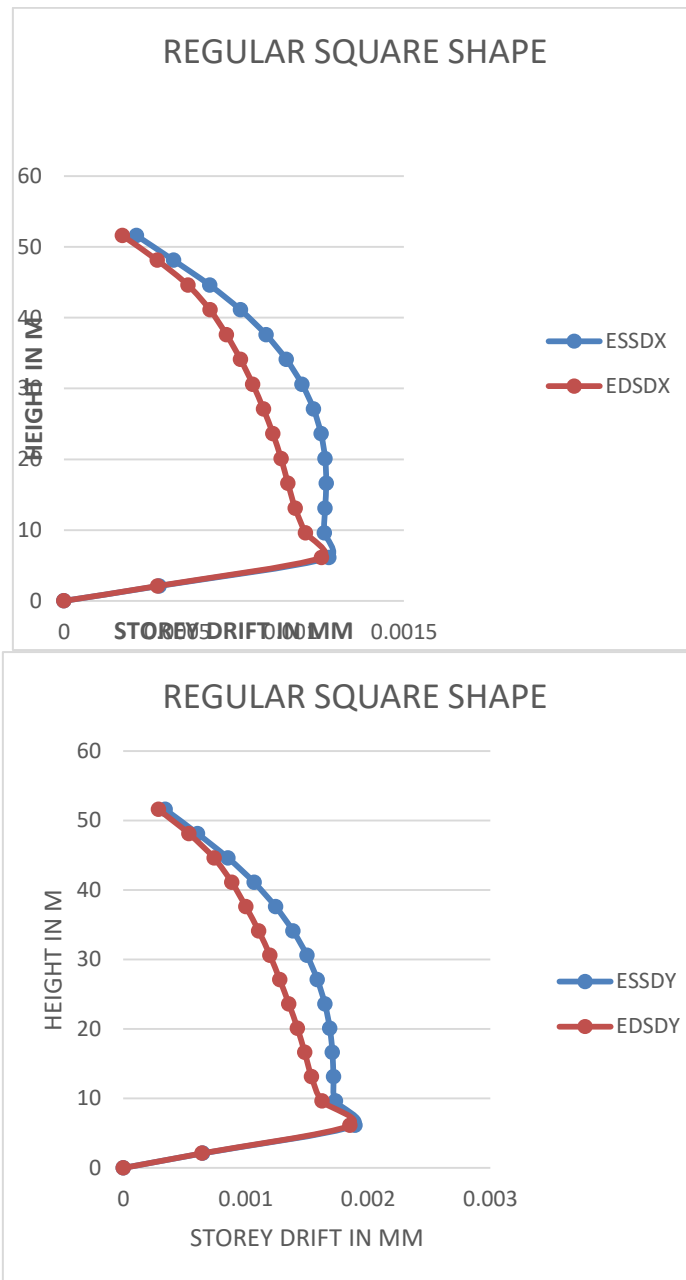


Fig.10 Storey Drift X-Direction

Fig.11 Storey Drift Y-Direction

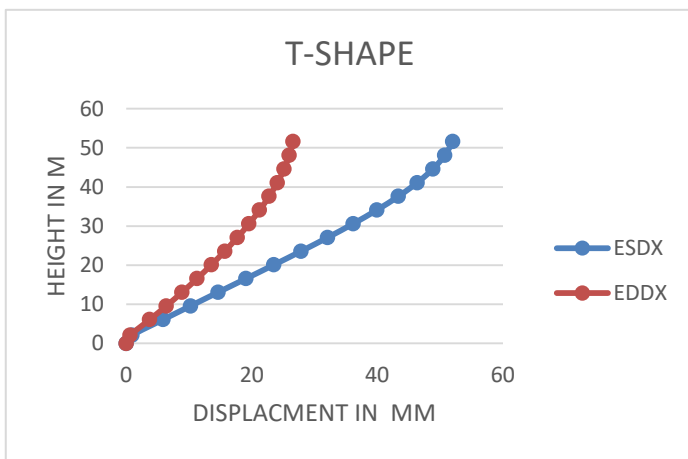


Fig.12 Displacement Graph X-Direction

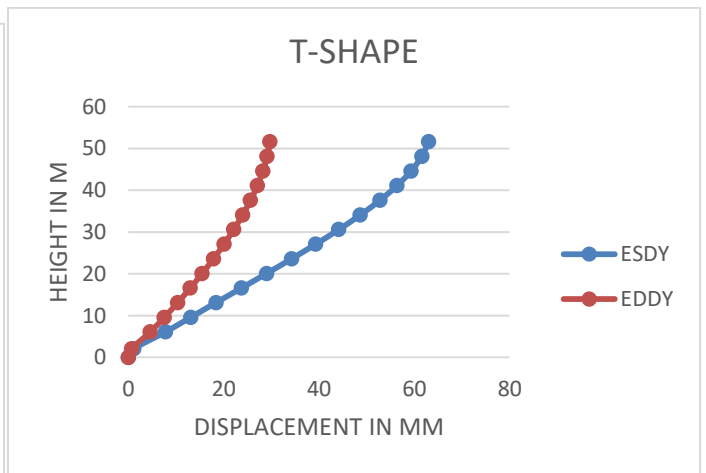


Fig.13 Displacement Graph Y-Direction

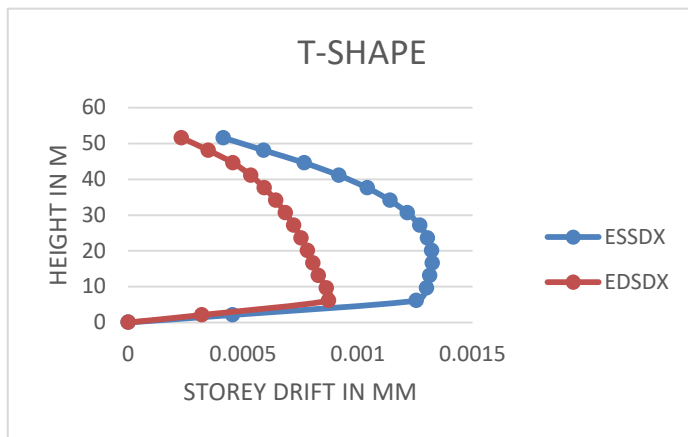


Fig.14 Storey Drift X-Direction

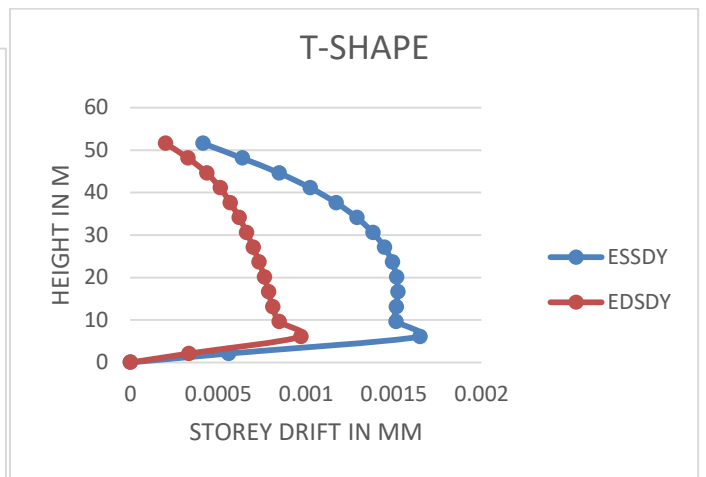


Fig.15 Storey Drift Y-Direction

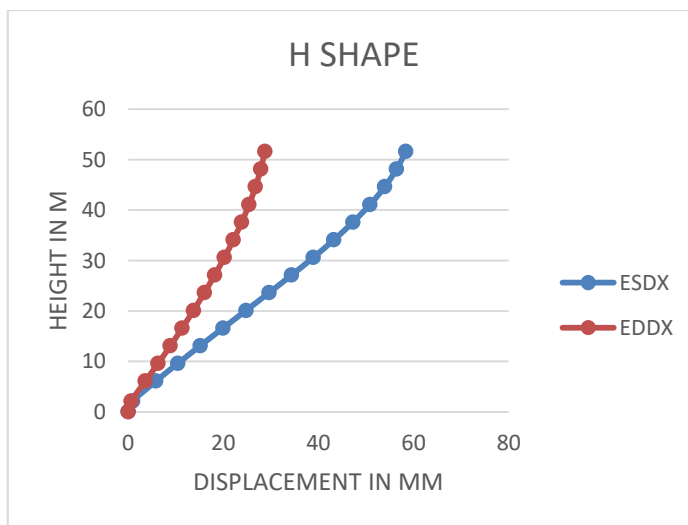


Fig.16 Displacement Graph X-Direction

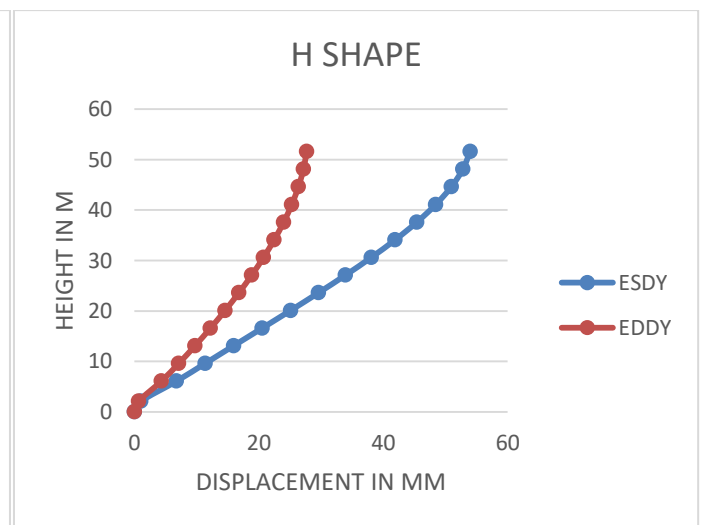


Fig.17 Displacement Graph Y-Direction

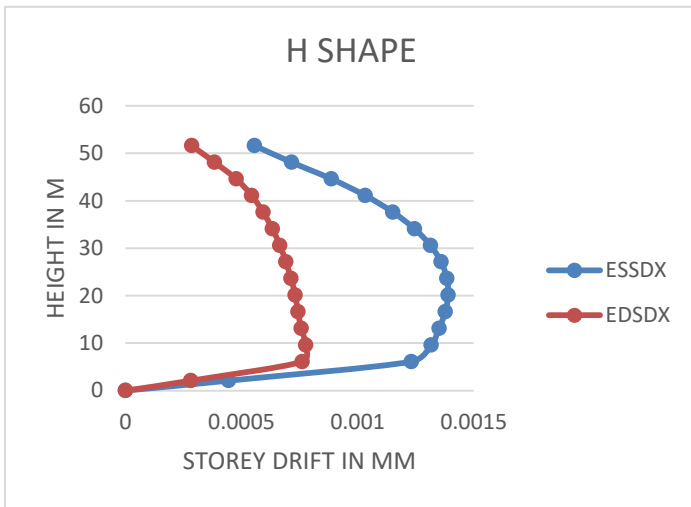


Fig.18 Storey Drift X-Direction

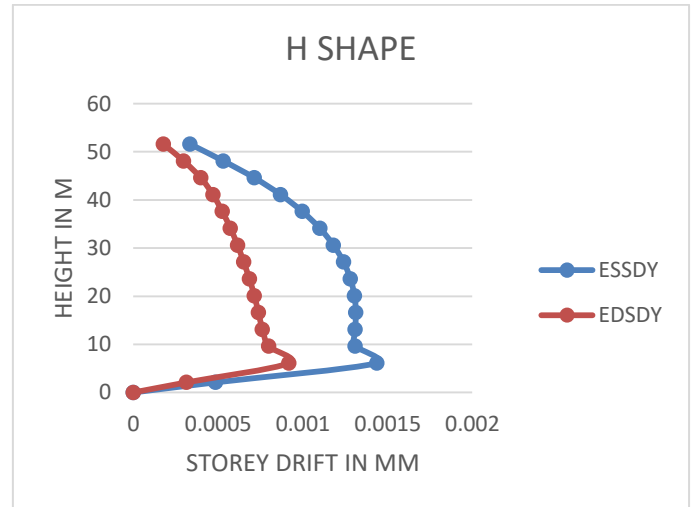


Fig.19 Storey Drift Y-Direction

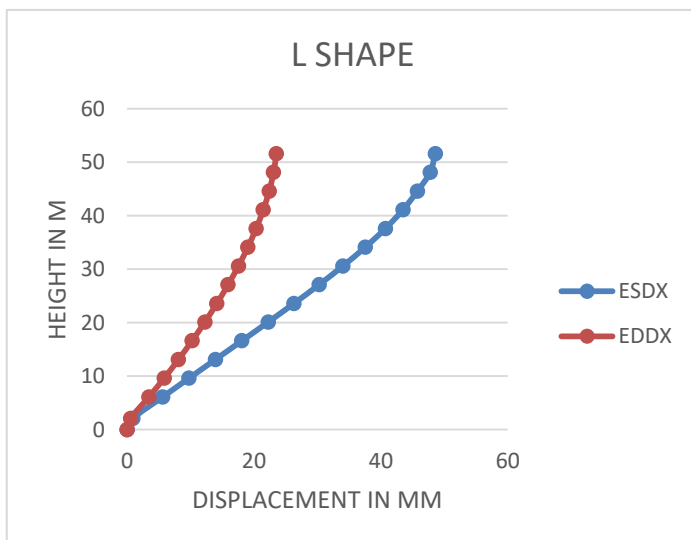


Fig.20 Displacement Graph X-Direction

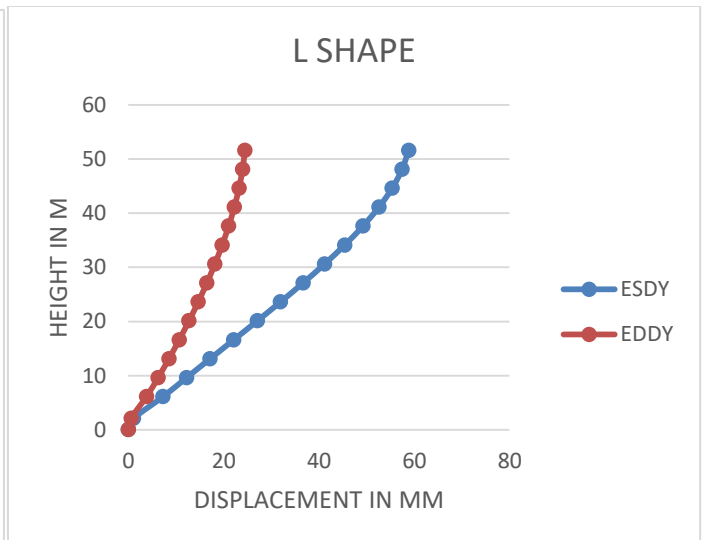


Fig.21 Displacement Graph Y-Direction

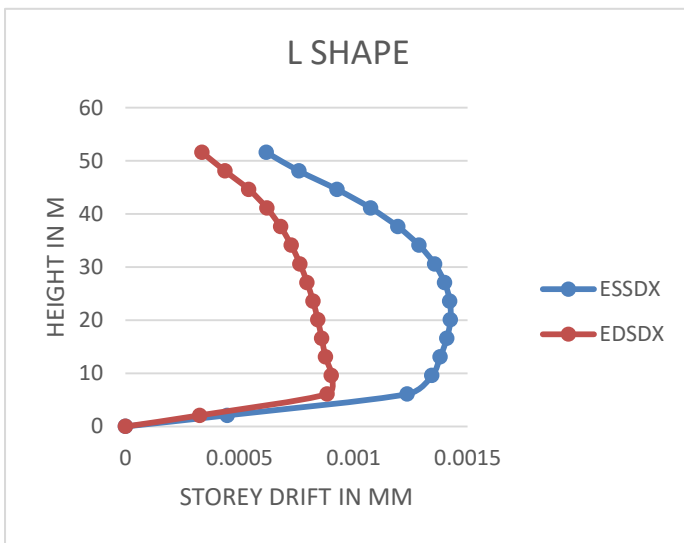


Fig.22 Storey Drift X-Direction

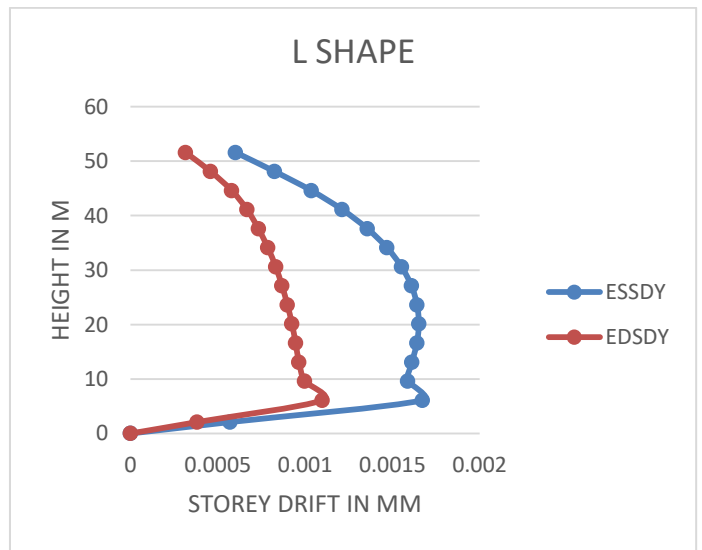


Fig.23 Storey Drift Y-Direction

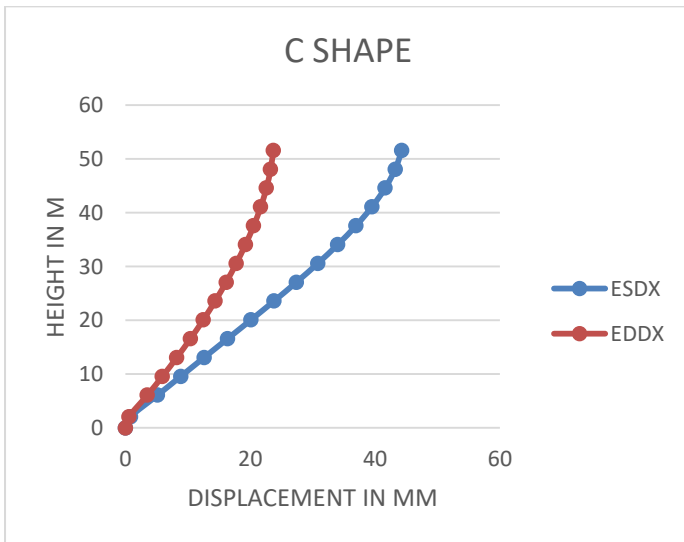


Fig.24 Displacement Graph X-Direction

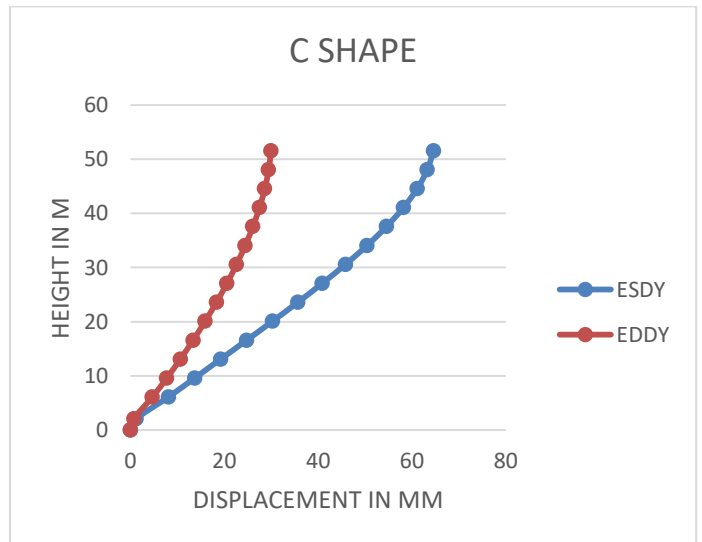


Fig.25 Displacement Graph Y-Direction

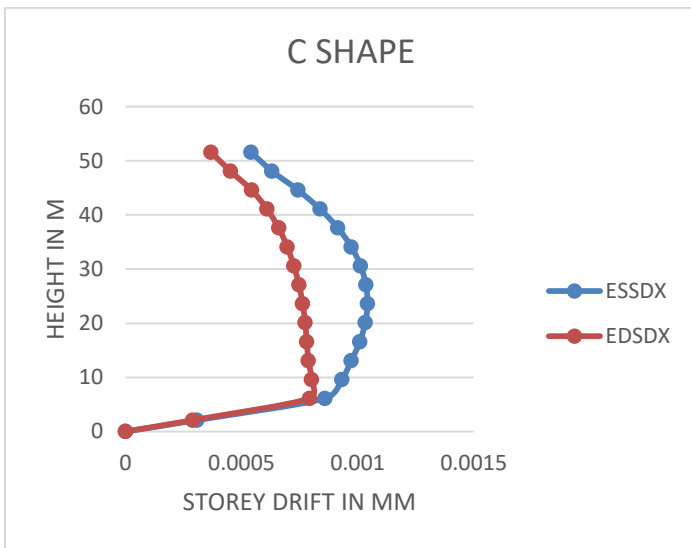


Fig.26 Storey Drift X-Direction

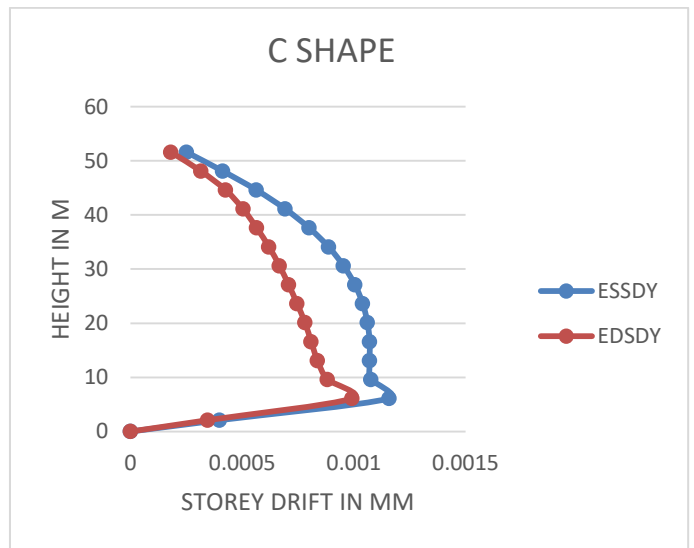


Fig.27 Storey Drift Y-Direction

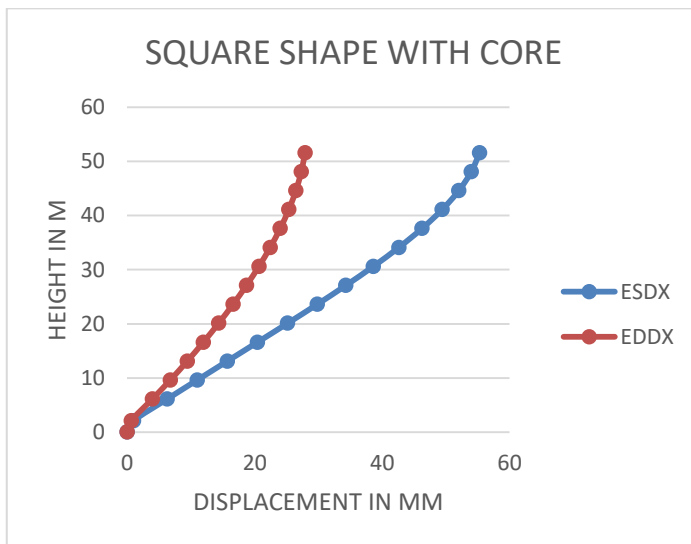


Fig.28 Displacement Graph X-Direction

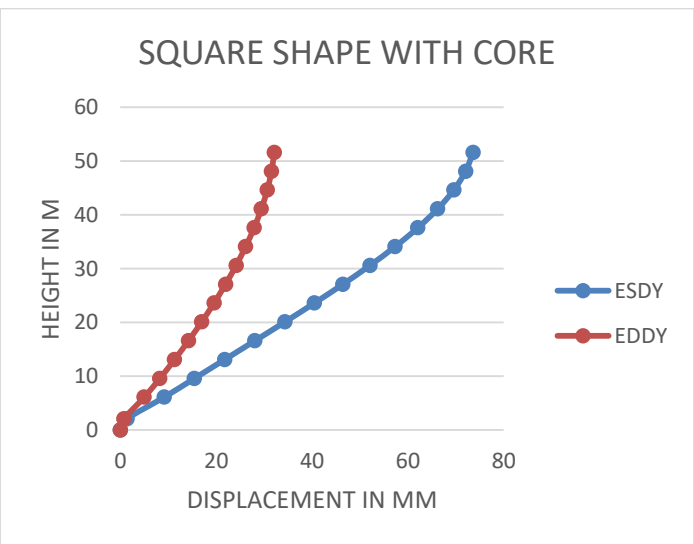
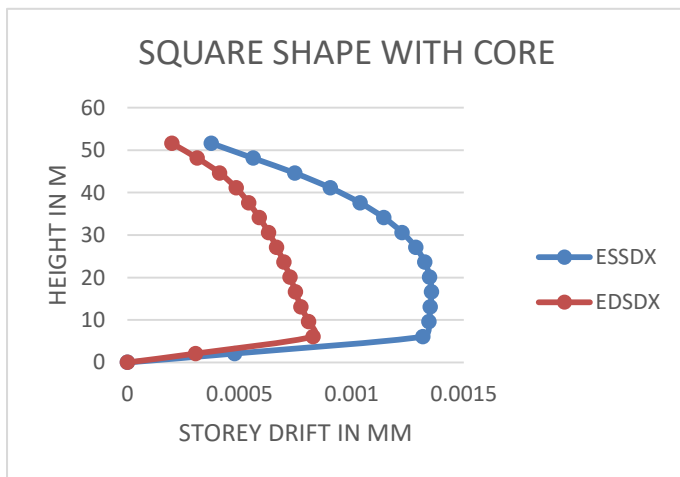
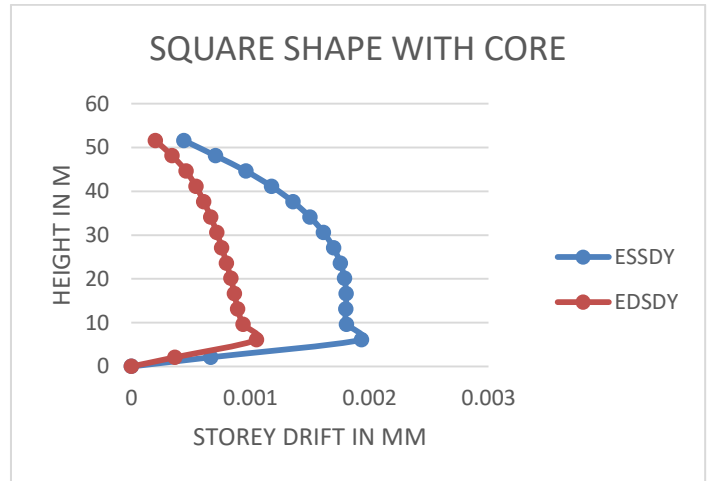


Fig.29 Displacement Graph Y-Direction


Fig.30 Storey Drift X-Direction

Fig.31 Storey Drift Y-Direction

We have plotted graphs of individual structure for storey drift and lateral displacement. These graphs are specifically defined in this chapter. The response of structure against seismic forces changes with plan irregularity. Considering the effect of lateral displacement on different shapes of the building of the structure, it has been observed that static analysis shows more displacement as compared to dynamic analysis method. Limiting value of drift for the given structure as per IS: 1893-2016 is 20.64cm, which is not exceeded in any of the structure.

4. CONCLUSIONS

- 1) Considering the effect of lateral displacement in X direction on regular shape, T shape, H-shape, L-shape, C-shape, square shape with core of the building of structure it has been observed that static displacement gives more displacement in comparison to dynamic displacement.
- 2) Considering the effect of lateral displacement in Y direction on regular shape, T shape, H-shape, L-shape, C-shape, square shape with core of the building of structure it has been observed that static displacement gives more displacement in comparison to dynamic displacement.
- 3) The limiting value of storey drifts as per clause 7.11.1 of IS 1893:2016 is 20.64cm which is more as compared to the value obtained from static and dynamic analysis for regular shape, T shape, H-shape, L-shape, C-shape, square shape with core of the building of structure in X direction.
- 4) The limiting value of storey drifts as per clause 7.11.1 of IS 1893:2016 is 20.64cm which is more as compared to the value obtained from static and dynamic analysis for regular shape, T shape, H-shape, L-shape, C-shape, square shape with core of the building of structure in Y direction.

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