Comparative Study of Seismic Analysis of Vertically Irregular R.C. Frame using INDIAN and EURO Code

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Abstract - This research article carried out on comparison of codes (Indian and Euro) for seismic behaviour of R.C building frame. The main cause for the earthquake occurred in the R.C. building, if there is any irregularity in the structure and, if the structure is not constructed with proper strength, and not appropriately designed, which causes the structures to completely collapse. It is critical to understand seismic analysis and construct earthquake resistance structures for the safety of a multi-story building against seismic forces. It has been observed that the Gulf countries' construction requirements are primarily based on EURO standards. So that we analyse an R.C building frame of G+22 with vertical geometry irregularity using comparison with EURO standards and INDIAN standards. The response of the building is being calculated by the Response Spectrum approach with the help of ETABS software. The calculated results of an irregular building are then characterized graphically and in tabular form. This research paper concentrated on the variations in outcomes found by using these codes i.e., Indian & Euro code. This comparative result is performed in the form of Storey Drifts, overturning moment, storey shear, and storey displacement in the X, and Y direction.

Keywords- R.C. buildings, INDIAN standards, EURO standards, lateral forces, ETABS, Response spectrum analysis, Base Shear, Displacement, Seismic Analysis, vertical geometry irregularity.

1. INTRODUCTION
Frames are the major structural component of R.C. structures, and they effectively resist moment, torsion, and shear. These frames are deal out to different types of loads, where horizontal loads are always prevalent. Seismic forces are the most distressing and unpredictable of any natural disasters, and saving lives and engineering properties is extremely challenging. During an earthquake, structural failure begins at weak places. These weak places are generated by a discontinuity in the structure's mass, geometry, and stiffness. These discontinuities are termed Irregular structures. One of the most common causes of structure failure during earthquakes is vertical irregularities in the structure. The dynamic properties of 'irregular' buildings are different from those of 'regular' buildings, as shown by height-wise variations in stiffness, geometry, and mass. Vertically Irregular Structures are defined according to IS 1893:2016. The irregularity in building structures could be related to irregular stiffness, mass, and strength distributions, along with the building's elevation. The analysis and design become more challenging when buildings are developed in high seismic zones [1–3].

2. Types of Irregularities
The structure's irregularities can be divided into two categories i.e., plan and vertical irregularity, these irregularities can be categorized into five different types such as out-of-plane offsets; torsional, re-entrant corners, non-parallel system, diaphragm discontinuity for plan irregularity as well as...
discontinuity in capacity, stiffness, mass, vertical geometry, in-plane discontinuity for vertical irregularity [4–6].

2.1 Vertical Irregularity: The irregular distribution of mass, strength, or stiffness along the elevation of a building structure causes vertical irregularity. An abrupt variation in mass between adjacent floors, such as mechanical plant on a structure's roof, causes mass irregularity. Unexpected variations in stiffness between adjacent levels, such as setbacks in a building's elevation, cause stiffness irregularity [7–9].

2.2 Plan Irregularity: The seismic reaction of plan irregular structures is not only torsional but also translational, and is a result of the structure's stiffness and mass eccentricity. A regular structure may appear irregular if one side of the structure has brick infill walls or rigid lateral resisting systems that have not been taken into account in the study. Because of inaccuracy in the computation of the centre of stiffness and mass, and inaccurate measurement of the size of structural elements, irregularity may exist in a nominally symmetric construction [10–12].

3. RESEARCH AND SIGNIFICANCE
Especially for a high-rise building, codal provision is an important part of a structural design. Different codal standards influence design factors, which has an impact on the building's needs and cost. Standard specifications for developing countries like India are always different from established countries like the America and Europe, etc. The developed standard requirements are suitable for use in construction procedures across the country. On the other hand, standards comprise few criterions that are different or are additionally integrate in relation to one another when situations/conditions demand [13–15].

Gulf countries' infrastructures are always wonderful, and it's been observed that they usually follow EUROPEAN codes for a certain structure type. As a result, evaluating such codes is essential for allowing excellent construction practices in developing countries like India.

To solve these issues, we need to use analytical approaches to determine the seismic performance of buildings and to ensure that the designed structure must be able to withstand against seismic forces without any failure [16–18].

4. OBJECTIVE
To study and understand several International standard codes (European and Indian), as well as to perform static and dynamic analyses on a 23-storey vertical irregular building using Indian and Euro standards. To prepare various model with Vertical Geometric irregularities in ETABS 2016 software and to analyse the structure with the Response Spectrum Analysis (RSA) or Dynamic Analysis. To investigate the performance of buildings using various codes and standards and determine which ones perform better. In this study focus on the behaviour of structures during earthquake having irregularities with same area. To compare parameters such as displacement, base shear, storey displacement, and storey drift.

5. PROBLEM FORMULATION
Professional software was used to analyse multi-storey reinforced concrete moment-resisting space frames. Equivalent Static Method and Response Spectrum Method are used to analyse a vertically irregular RC building of G+22 stories with five bays in the horizontal direction and five bays in the lateral direction.

6. Analysis Method
Linear static, linear dynamic, nonlinear static, and nonlinear dynamic methods are the four types of analysis methodologies. The first two approaches are acceptable when the structural loads are minimal and there is no point at which the load would approach the collapse load, and they differ in terms of getting the level of forces and their distribution throughout the structure's height. On the other hand, Non-linear static and non-linear dynamic analysis are superior to the linear methods. The structural loading will exceed collapse load under earthquake loads, and the material stresses will be above yield stresses. To acquire better findings, material nonlinearity and geometric nonlinearity should be added into the study. These approaches also give information on the structure's strength, deformation, and ductility, as well as demand distribution.
6.1 Equivalent Static Method
The Equivalent Static Method is a linear static approach in which the structure's reaction is supposed to be linearly elastic. This analysis is performed in accordance with IS 1893:2016.

6.2 Response Spectrum Method
ETABS is used to perform a linear dynamic analysis of a structure. ETABS generates lateral stresses that correspond to seismic zone IV and a 5% damped response spectrum as defined in IS 1893:2016. ETABS programme calculates the fundamental natural period values. The base shear forces, storey drift, and storey displacement were calculated, and graphs were produced in both the X and Y directions.

7. Structural Data of Building
The building plan dimensions are listed in the table 1 below. The building's plan view is depicted, see table 1 to 9 and figure 1 to 9.

Table 1: Building Details Plan of Structures

| Parameters               | Values                                |
|--------------------------|---------------------------------------|
| Material                 | M35 & FE500                           |
| Dimension of Plan        | 30mx30m                               |
| Storey Height            | 3mtr.                                 |
| Bottom storey Height     | 3.2mtr.                               |
| Concrete Density         | 25 KN/m3                              |
| Foundation soil          | Medium                                |
| Slab thickness           | 150mm                                 |
| Live load                | 3KN/m2                                |
| Dead load                | 0.52 KN/m2                            |
| Code of Practice adopted | IS456:2000, IS1893:2016, EC:2, EC:8   |
| Earthquake load          | As per IS 1893-2002 & EURO CODE 8     |
| Seismic zone for IS 1893: 2002 | IV                                   |
| Beam size                | 300X450mm                             |
| Column size              | 450X450mm, 550X550mm, 600X750mm       |
| Analyze the model        | Vertically irregular RC building of (G+22) stories |

Typical floor diagram of vertically irregular building.
Fig. 1: 3D line diagram of the structure

Fig. 2: 3D Rendered View of the structure
8. Results & Graphical Interpretation

The analysis of the results obtained for Storey shear along both the X and Y directions are as below show in the table 2 & 3 and figure 3 & 4.

8.1. Storey Shear

Table 2: Storey Shear value as per Indian code:

| Load pattern | Z  | Soil Type | I   | R | Base Shear |
|--------------|----|-----------|-----|---|------------|
| EQ X         | 0.24 | II        | 1.2 | 3 | 379.33     |
| EQ Y         | 0.24 | II        | 1.2 | 3 | 379.33     |

Table 3: Storey Shear value as per euro code:

| Load Pattern | ag/g | Spectrum Type | Soil Factor | Tb | Tc | Td | B   | q  | λ  | Base Shear |
|--------------|------|---------------|-------------|----|----|----|-----|----|---|-----------|
| EQ X         | 0.4  | 2             | 1.5         | 0.1| 0.25| 1.2| 0.2 | 3.12| 1 | 1138.06   |
| EQ Y         | 0.4  | 2             | 1.5         | 0.1| 0.25| 1.2| 0.2 | 3.12| 1 | 1136.92   |

Figure 3: Storey Shear Comparison along X – Direction
6.2. Overturning Moment

Table 4: Overturning Moment Comparison along X – Direction

| Case Combo, SPEC X | Max. Overturning Moment (KN-m) |
|--------------------|-------------------------------|
| IS 1893:2016       | 13642.96                      |
| Eurocode 8         | 42821.58                      |

Figure 5: Overturning Moment Comparison along X – Direction

Table 5: Overturning Moment Comparison along Y – Direction

| Case Combo, SPEC Y | Max. Overturning Moment (KN-m) |
|--------------------|-------------------------------|
| IS 1893:2016       | 13642.96                      |
| Eurocode 8         | 42721.64                      |
8.3. Storey Displacement

Table 6: Storey Displacement Comparison along X – Direction

| Case Combo, SPEC X | Max. Storey Displacement (mm) |
|--------------------|-------------------------------|
| IS 1893:2016       | 12.362                        |
| Eurocode 8         | 38.808                        |

Figure 6: Storey Displacement Comparison along X – Direction

Table 7: Storey Displacement Comparison along Y – Direction

| Case Combo, SPEC Y | Max. Storey Displacement (mm) |
|--------------------|-------------------------------|
|                    |                               |

Figure 5: Overturning Moment Comparison along Y – Direction

Max. Overturning Moment in Y

Overturning Moment (KNm)

EUROCODE 8

IS 1893:2016

Figure 6: Storey Displacement Comparison along X – Direction

Table 7: Storey Displacement Comparison along Y – Direction

| Case Combo, SPEC Y | Max. Storey Displacement (mm) |
|--------------------|-------------------------------|
|                    |                               |
8.4. Storey Drift

Table 8: Storey Drift Comparison along X – Direction

| Case Combo, SPEC X | Max. Storey Drift |
|--------------------|-------------------|
| IS 1893:2016       | 0.000416          |
| Eurocode 8         | 0.001217          |

Figure 7: Storey Displacement Comparison along Y – Direction

Figure 8: Storey Drift Comparison along X – Direction
9. CONCLUSION

In this study, the dynamic analysis for structural parameters which govern the durability, stability, and safety of the building for various International Standard Codes. The following conclusions may be derived based on the results of the dynamic study of structure.

1. Because of the high values of response reduction factors defined by EURO code, the computed design base shear according to Eurocode 8 is up to 67 percent greater than IS 1893, and the values for storey shear along the X-direction and Y-direction are practically identical.

2. Because of higher base shear design, the storey displacement at top is high for Eurocode-based design and the displacements are varying on higher side as height of structure is increases.

3. The calculated storey drift according to Eurocode 8 is up to 65 percent higher than IS 1893 due to increased design base shear.

4. The structure analysed for IS 1893:2016 has shown better values for the structural parameters considered, when compared to the Eurocode 8. Hence Indian Code is better in terms of structural parameters and structural safety.

In this study we analyse vertical irregular R.C building frame using different International codes (Indian and Euro), in which Indian Standard code has low values and perform well within the permissible limit for the structural parameters when compared with Euro Standards. Equivalent Static Analysis and Response Spectrum Analysis are used to analyse this structure. Pushover Analysis and Time History Analysis can be used to continue this study. This structure can be studied by considering both the plan and vertical irregularities at the same time. This structure may also be analysed by providing bracings and shear walls.

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