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# Comparative Study on Static and Dynamic Analysis of a G+5 RCC Building as per IS 1893 (Part 1): 2016 on Serviceability Parameters

Rahul Meena
M.E Scholar, Department of Civil Engineering,
Jabalpur Engineering College,
Jabalpur, India

R.K Grover
Professor, Department of Civil Engineering,
Jabalpur Engineering College,
Jabalpur, India

***Abstract:*** **Accurate estimation of seismic forces and structural response is essential for earthquake-resistant design. IS 1893 (Part 1):2016 allows the use of both Equivalent Static Analysis (ESA) and Response Spectrum Analysis (RSA) for regular medium-rise RCC buildings, though the responses obtained from these methods may differ. This study presents a comparative seismic analysis of a G+5 RCC building located in Seismic Zone III with medium soil conditions and 5% damping, modelled and analysed in ETABS as per IS 1893 provisions. Storey displacement and storey drift in both X and Y directions are evaluated under static and dynamic loading. The equivalent static base shear is observed to be higher than the unscaled dynamic base shear; therefore, response spectrum results are scaled to satisfy code requirements. The results indicate that ESA may not adequately represent the actual mass and stiffness distribution, leading to possible over- or underestimation of displacement and drift demands, whereas RSA provides a more realistic variation of seismic response along the height. The study concludes that although both methods are applicable for G+5 buildings, response spectrum analysis offers a more reliable assessment of seismic performance.**

***Keywords— Equivalent Static Method, Response Spectrum Method, Base Shear, Storey Drift, Storey Displacement, ETABS, IS 1893***

## I. INTRODUCTION

Understanding the structural response of buildings is particularly important in regions susceptible to seismic activity. Reinforced cement concrete (RCC) frame structures form a significant share of India's urban building stock, making seismic evaluation a critical aspect of structural design practice. IS 1893 (Part 1):2016 outlines procedures for assessing earthquake effects using both static and dynamic analysis methods.

The Equivalent Static Method represents seismic action through simplified lateral forces derived from seismic weight and vertical distribution, while the Response Spectrum Method accounts for the dynamic behaviour of structures by incorporating natural periods, mode shapes, and modal mass participation. Despite the improved accuracy of dynamic analysis, the static approach remains commonly adopted for low- to medium-rise buildings due to its computational simplicity. Hence, a comparative assessment is required to examine the differences in seismic response predicted by these two methods for medium-rise RCC buildings.

## II. OBJECTIVE OF THE STUDY

- To conduct seismic evaluation of a G+5 reinforced cement concrete (RCC) building using the equivalent static method in accordance with IS 1893 (Part 1):2016.
- To perform response spectrum analysis by incorporating the dynamic and modal characteristics of the structure.
- To examine and compare seismic responses obtained from static and dynamic analyses in terms of storey displacement and storey drift in both X and Y directions.
- To investigate the influence of base shear scaling on the outcomes of dynamic analysis.
- To evaluate the suitability of equivalent static and response spectrum methods for the seismic assessment of medium-rise RCC buildings.

## III. SCOPE OF THE STUDY

The scope of the present study is confined to the following aspects:

- A regular G+5 reinforced cement concrete (RCC) moment-resisting frame structure.
- Linear elastic seismic analysis carried out using ETABS software.
- Seismic action defined in accordance with IS 1893 (Part 1):2016 for Seismic Zone III with medium soil conditions.
- Evaluation limited to serviceability-based structural response parameters, namely storey displacement and storey drift.

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- Nonlinear behaviour, including material cracking, yielding, and plastic hinge development, is beyond the scope of this study.

## IV. METHODOLOGY

A three-dimensional RCC building model was created in ETABS with consistent geometry, material properties, mass distribution, and loading parameters adopted for both static and dynamic analyses. Seismic actions were applied independently along the X and Y directions.

### A. *Equivalent Static Method*

The design base shear was evaluated using codal parameters including zone factor, importance factor, response reduction factor, and the fundamental natural period of the structure. This base shear was then apportioned over the height of the building in accordance with the provisions of IS 1893.

### B. *Response Spectrum Method*

For response spectrum analysis, modal properties were evaluated to obtain natural periods and mode shapes, and the design spectrum for medium soil with 5% damping was applied. Modal responses were combined using the SRSS method, and the dynamic base shear was scaled to match the equivalent static base shear as per IS 1893.

## V.MODELLING

### A. *Building Description*

The building analysed is a G+5 RCC moment-resisting frame with overhead water tank (OHT) and lift machine room (LMR), situated in Seismic Zone III. The structure has an overall height of about 20.3 m with a consistent storey height of 2.9 m. Beams and slabs were modelled using M30 grade concrete, while columns and shear walls were assigned M35 grade concrete. The base of the structure was assumed to be fixed, and semi-rigid diaphragm behaviour was assigned at all floor levels.

Table 1 Building Description

| | |
|---|---|
| Type of Structure | RCC Moment Frame |
| Location | Mumbai |
| Number of floors | G+5+OHT&LMR |
| Height of Project | 20.3m |
| Length of Project | 22.158m |
| Width of Project | 11.353m |
| Typical height of Project | 2.9m |

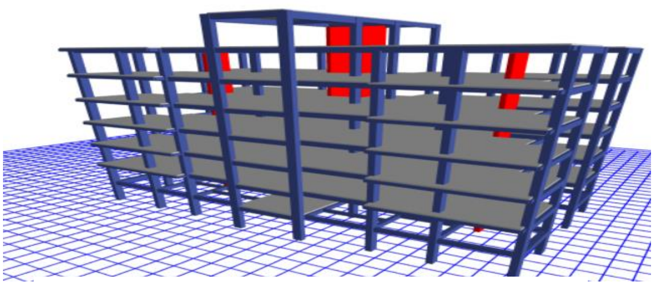

Figure 1 Building 3D view

### B. *Material Properties*

Table 2 Material Properties

| | |
|---|---|
| Grade of Concrete for Beams | M30 |
| Grade of Concrete for Slabs | M30 |
| Grade of Concrete for Columns | M35 |
| Grade of Concrete for Shear Walls | M35 |
| Main Reinforcement | HYSD 500 |
| Shear Reinforcement | HYSD 415 |

### C. *Section Properties*

Table 3 Beam & Column Properties

| Section | Name | Width (mm) | Depth (mm) |
|---|---|---|---|
| Beam | B 150 X 300 M30 | 150 | 300 |
| Beam | B 150 X 400 M30 | 150 | 400 |
| Beam | B 230 X 450 M30 | 230 | 450 |
| Beam | B 230 X 500 M30 | 230 | 500 |
| Beam | B 230 X 600 M30 | 230 | 600 |
| Beam | B 300 X 600 M30 | 300 | 600 |
| Column | C 300 X 450 M35 | 300 | 450 |
| Column | C 300 X 600 M35 | 300 | 600 |

Table 4 Slab Properties

| Section | Name | Grade of Concrete ($N/mm^2$) | Type | Thickness(mm) |
|---|---|---|---|---|
| Slab | S125M25 – General | M30 | Thin Shell | 125 |
| Slab | S200M25 – OHT&LMR | M30 | Thin Shell | 200 |
| Slab | ST200 – Staircase | M30 | Membrane | 200 |

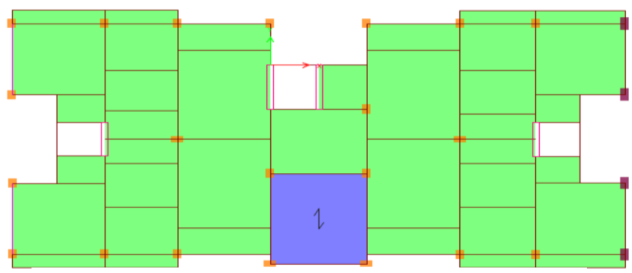

Figure 2 Building Plan view

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Table 5 Shear wall properties

| Section | Name | Grade of Concrete ($N/mm^2$) | Type | Thickness (mm) |
|---|---|---|---|---|
| Wall | SW 230 | M35 | Thin Shell | 230 |
| Wall | SW 300 | M35 | Thin Shell | 300 |

Table 6 Seismic parameters

| Parameters | Value | Code Reference | Table / Clause |
|---|---|---|---|
| Seismic Zone Factor | 0.16 | IS-1893 Part 1 (2016) | Table 3 Clause 6.4.2 |
| Soil Type | II | IS-1893 Part 1 (2016) | Table 4 Clause 6.4.2.1 |
| Importance Factor | 1 | IS-1893 Part 1 (2016) | Table 8 Clause 7.2.3 |
| Damping Ratio | 0.05 | IS-1893 Part 1 (2016) | Clause 7.2.4 |
| Response Reduction Factor | 5 | IS-1893 Part 1 (2016) | Table 9Clause 7.2.6 |
| Mass Source | D=1 L=0.25(Live Load<3) L=0.50(Live Load>3) | IS-1893 Part 1 (2016) | Table 10 Clause 7.3.1 |

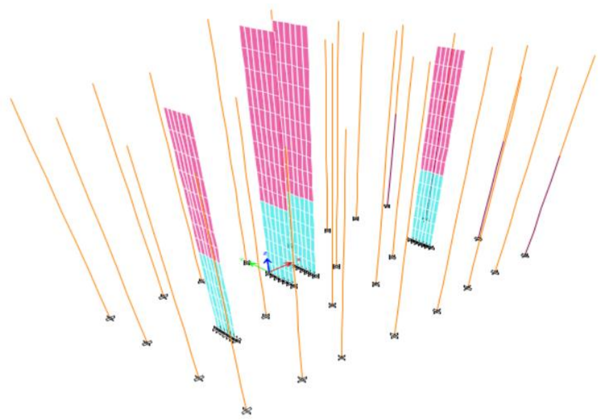

Figure 3 Columns and Walls

Table 7 Stiffness Reduction Parameters

| Element | Uncrack Model | Service Model | Strength Model |
|---|---|---|---|
| Beam | I22:1, I33:1 | I22:0.5, I33:0.5 | I22:0.35, I33:0.35 |
| Column | I22:1, I33:1 | I22:1, I33:1 | I22:0.7, I33:0.7 |
| Slab | F11:1, F22:1, F12:1 M11:1, M22:1, M12:1 | F11:1, F22:1, F12:1 M11:0.35, M22:0.35, M12:0.35 | F11:1, F22:1, F12:1 M11:0.25, M22:0.25, M12:0.25 |
| Wall | F11:1, F22:1, F12:1 M11:1, M22:1, M12:1 V13:1, V23:1 | F11:1, F22:1, F12:1 M11:1, M22:1, M12:1 V13:1, V23:1 | F11:0.7, F22:0.7, F12:0.7 M11:0.1, M22:0.1, M12:0.1 V13:0.1, V23:0.1 |

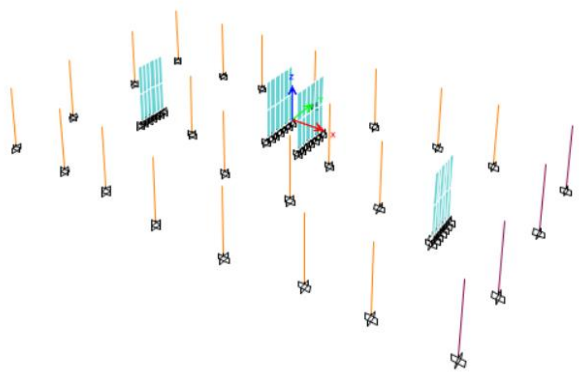

Figure 4 Supports

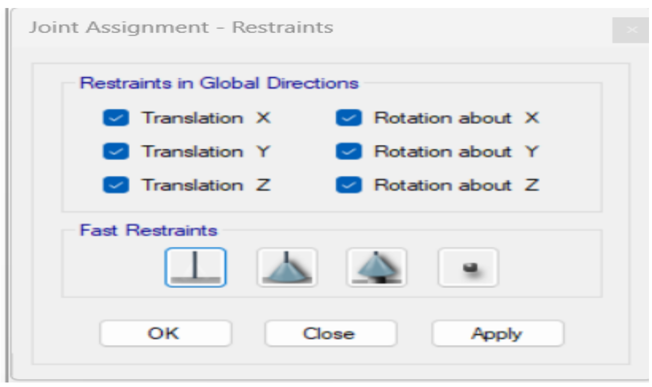


Figure 5 Support Restraints

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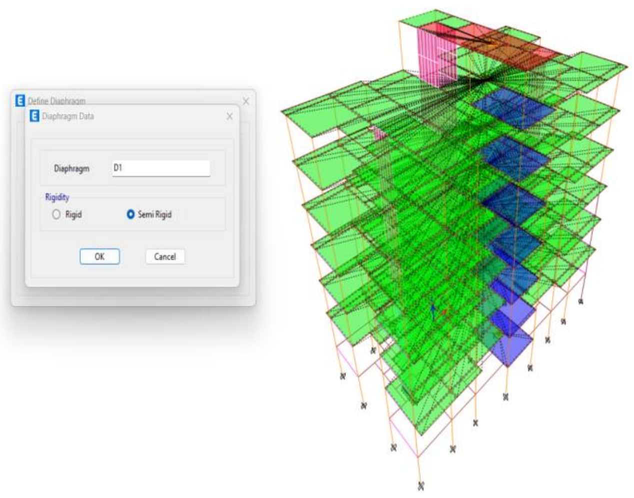


Figure 6 Semi Rigid Daiphragm

## VI. ANALYSIS AND VALIDATION

Seismic evaluation of the G+5 RCC building was performed in ETABS using both the Equivalent Static Method (ESM) and the Response Spectrum Method (RSM), while maintaining identical modelling assumptions, material properties, mass distribution, and loading conditions. Earthquake loads were applied separately along the X and Y directions in compliance with IS 1893 (Part 1):2016.

### *A. Equivalent Static Analysis*

Under the Equivalent Static Method, the design seismic base shear was evaluated using codal parameters including seismic zone factor, importance factor, response reduction factor, soil condition, and the fundamental natural period of the structure. The resulting total base shear was subsequently apportioned along the building height in accordance with the storey mass and elevation.

The total design base shear obtained from equivalent static analysis was:

Table 8 Static Base Shear

| STATIC BASE SHEAR | |
|---|---|
| EX | 806.1 KN |
| EY | 806.1 KN |

These values were used as the reference base shear for comparison with dynamic analysis results.

### *B. Response Spectrum Analysis*

Response spectrum analysis was carried out to assess the dynamic behaviour of the structure by accounting for the participation of multiple vibration modes. An initial modal analysis was conducted to obtain the natural time periods and corresponding mode shapes. The design response spectrum for medium soil conditions with 5% damping, as specified in IS 1893 (Part 1):2016, was adopted, and the Individual modal responses were combined using the Square Root of the Sum of Squares (SRSS) method.

The base shear values obtained from response spectrum analysis before scaling were:

Table 9 Dynamic Base Shear

| DYNAMIC BASE SHEAR | |
|---|---|
| SPECX | 393.6 KN |
| SPECY | 410.5 KN |

These values were found to be considerably lower than the corresponding results obtained from the equivalent static analysis. To facilitate a consistent comparison of seismic response parameters, the response spectrum results were scaled such that the total dynamic base shear equaled the equivalent static base shear in both principal directions. Following this scaling procedure, the dynamic base shear values were modified to:

Table 10 Base Shear Scaling

| STATIC BASE SHEAR | | SCALE FACTOR | DYNAMIC BASE SHEAR | |
|---|---|---|---|---|
| EX | 806.1 | 20090.88 | SPECX | 806.1 |
| EY | 806.1 | 19263.9 | SPECY | 806.1 |

## VII. RESULTS AND DISCUSSION

### *A. Storey Drift Comparison.*

Maximum storey drift values remain within the permissible limit of 0.004 times storey height as per IS 1893. Static analysis produces higher drift values in all storeys in X direction. In Y direction static analysis generally produces slightly higher drift values in upper storeys, whereas dynamic analysis shows higher drift in lower storeys. The value of drifts are taken from service model.

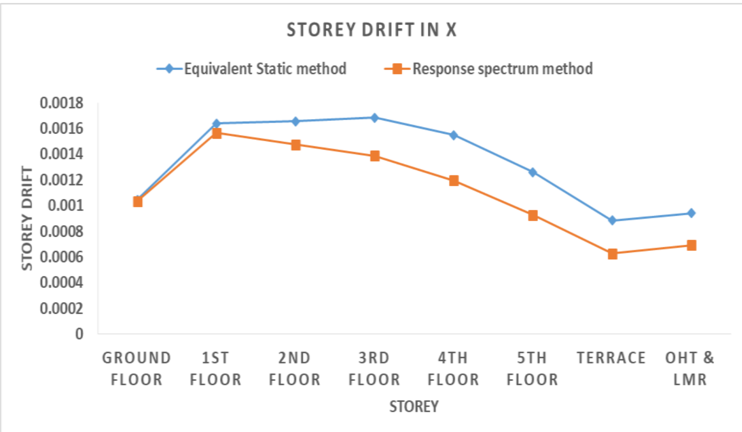


Figure 7 Storey Drift in X

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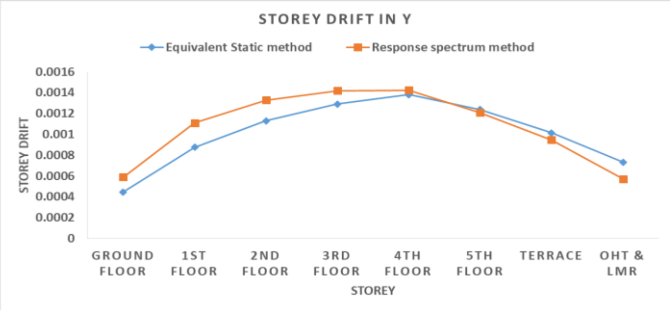


Figure 8 Storey Drift in Y

*B. Storey Displacement Comparison*

Maximum top storey displacement in the X-direction is 30.843 mm (ESA) and 24.498 mm (RSA), indicating that the static method yields higher lateral displacement. In the Y-direction, RSA produces higher displacements in all storey except OHT & LMR compared to ESA, reflecting directional stiffness variation and higher-mode effects. Static analysis shows a more uniform but conservative displacement profile, whereas RSA captures realistic deformation behaviour. The values of displacement are taken from service model.

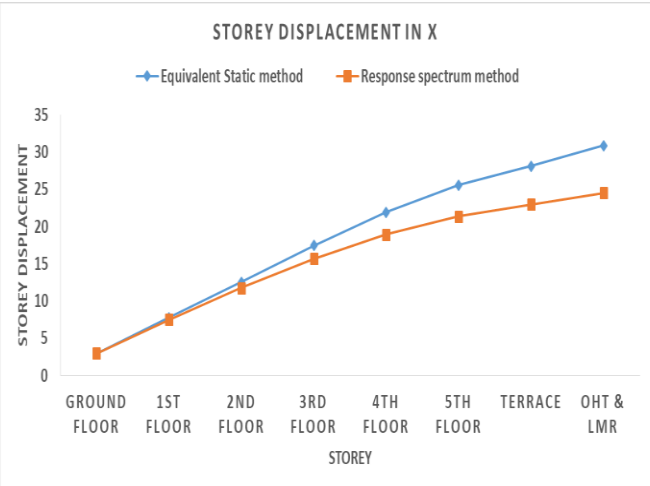


Figure 9 Storey Displacement in X

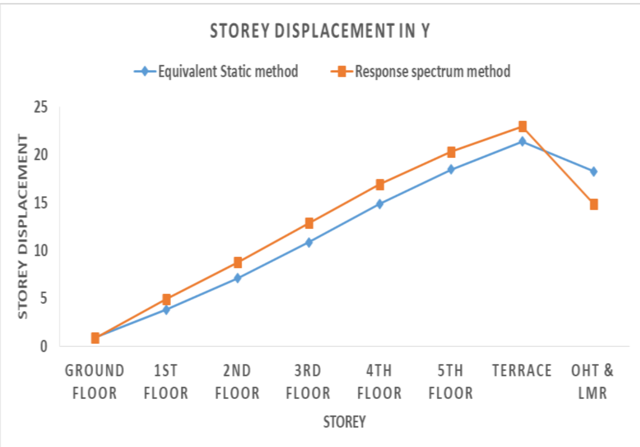


Figure 10 Storey Displacement in Y

## VIII. CONCLUSIONS

From the present study, the following conclusions are drawn:

1. The base shear obtained from the response spectrum analysis was observed to be lower than that from the equivalent static method. This difference arises because the dynamic analysis accounts for the contribution of multiple vibration modes in distributing seismic inertia forces, rather than assuming the structure's response to be governed solely by the fundamental mode. Consequently, the combined modal response results in a reduced dynamic base shear. To ensure compliance with the provisions of IS 1893, the response spectrum results were subsequently scaled such that the total dynamic base shear matched the equivalent static base shear.
2. Equivalent static analysis resulted in higher storey displacement and drift in the X-direction.
3. Response spectrum analysis governed the displacement in all storeys except OHT&LMR in Y direction and also drift response in the Y-direction are higher at upper storey levels while equivalent static method produces higher drift in lower storeys thus RSA responses indicating the influence of dynamic effects.
4. Overall, response spectrum analysis provides a more accurate representation of seismic demand and is preferable for detailed seismic assessment of G+5 RCC buildings.

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