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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 Force Distribution Criteria

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Abstract: Earthquake-resistant design requires accurate estimation of seismic forces and structural response. IS 1893 (Part 1):2016 permits both Equivalent Static Analysis (ESA) and Response Spectrum Analysis (RSA) for regular medium-rise buildings; however, their predicted responses often differ significantly. This study presents a comparative seismic analysis of a G+5 reinforced concrete (RCC) building located in Seismic Zone III with medium soil conditions and 5% damping. The building is modelled and analysed using ETABS software following IS 1893 provisions. Force distribution due to static and dynamic analysis are evaluated in both X and Y directions. The equivalent static base shear is found to be higher than the unscaled dynamic base shear; therefore, response spectrum results are scaled to match static base shear as per code requirements. Numerical results indicate that static analysis equivalent static method produces conservative estimates of forces, while response spectrum analysis provides a more realistic distribution of seismic demand along the height. The study concludes that although both methods are applicable for G+5 buildings, dynamic analysis is preferred for reliable seismic performance evaluation.
Keywords: Equivalent Static Method, Response Spectrum Method, Base Shear, Storey Shear, ETABS, IS 1893

I. INTRODUCTION

Earthquake-induced lateral forces significantly influence the structural response of buildings, particularly in seismic-prone regions. Reinforced cement concrete (RCC) frame buildings constitute a major portion of urban infrastructure in India, making seismic analysis an essential component of structural design. IS 1893 (Part 1): 2016 provides guidelines for evaluating earthquake forces using both static and dynamic approaches.

The Equivalent Static Method simplifies seismic action into lateral forces based on seismic weight and height distribution, whereas the Response Spectrum Method considers the dynamic characteristics of structures such as natural time period, mode shapes, and modal mass participation. Although dynamic analysis is more realistic, static analysis continues to be widely used for low- and medium-rise buildings due to its simplicity. Therefore, a comparative evaluation is necessary to understand the variation in results obtained from both methods for medium-rise RCC buildings.

II. OBJECTIVE OF THE STUDY

The objectives of the present study are:

- To analyse a G+5 RCC building using the Equivalent Static Method as per IS 1893 (Part 1): 2016.
- To perform Response Spectrum Analysis considering modal properties and dynamic participation.
- To compare static and dynamic responses in terms of base shear, storey shear & Member forces in both X and Y directions.
- To study the effect of base shear scaling on dynamic results.
- To assess the suitability of static and dynamic analysis methods for medium-rise RCC buildings.

III. SCOPE OF THE STUDY

The scope of the present study is limited to:

- A regular G+5 RCC moment-resisting frame building.
- Linear elastic analysis using ETABS software.
- Seismic loading as per IS 1893 (Part 1): 2016 for Zone III and medium soil.
- Comparison restricted to structural response of force distribution.
- Nonlinear effects such as cracking, yielding, and plastic hinge formation are not considered.

IV. METHODOLOGY

A three-dimensional RCC building model was developed in ETABS with identical geometry, material properties, mass distribution, and loading conditions for both analyses. Seismic loads were applied in both X and Y directions.

A. *Equivalent Static Method*

The design base shear was calculated using codal parameters such as zone factor, importance factor, response reduction factor, and fundamental time period. The base shear was distributed along the height of the building as per IS 1893 provisions.

B. *Response Spectrum Method*

Modal analysis was performed to obtain natural periods and mode shapes. The design response spectrum for medium soil and 5% damping was used. Modal responses were combined using the SRSS method. As per IS 1893, dynamic base shear was scaled to match the equivalent static base shear

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V. MODELLING

The structure considered is a G+5 RCC moment-resisting frame with OHT and LMR, located in Seismic Zone III. The total height of the building is approximately 20.3 m with a uniform storey height of 2.9 m. Beams and slabs were modelled using M30 concrete, while columns and shear walls were modelled using M35 concrete. Fixed supports were assumed at the base and Semirigid diaphragm action was assigned at all floor levels.

A. *Building Description*

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

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	Grade of Concrete (N/mm^2)	Grade of Steel (N/mm^2)	Grade of Steel (N/mm^2)	Width (mm)	Depth (mm)
			Longitudinal Bar	Confinement Bar		
Beam	B 150 X 300 M30	M30	Fe 500	Fe 415	150	300
Beam	B 150 X 400 M30	M30	Fe 500	Fe 415	150	400

Beam	B 230 X 450 M30	M30	Fe 500	Fe 415	230	450
Beam	B 230 X 500 M30	M30	Fe 500	Fe 415	230	500
Beam	B 230 X 600 M30	M30	Fe 500	Fe 415	230	600
Beam	B 300 X 600 M30	M30	Fe 500	Fe 415	300	600
Column	C 300 X 450 M35	M35	Fe 500	Fe 415	300	450
Column	C 300 X 600 M35	M35	Fe 500	Fe 415	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

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

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

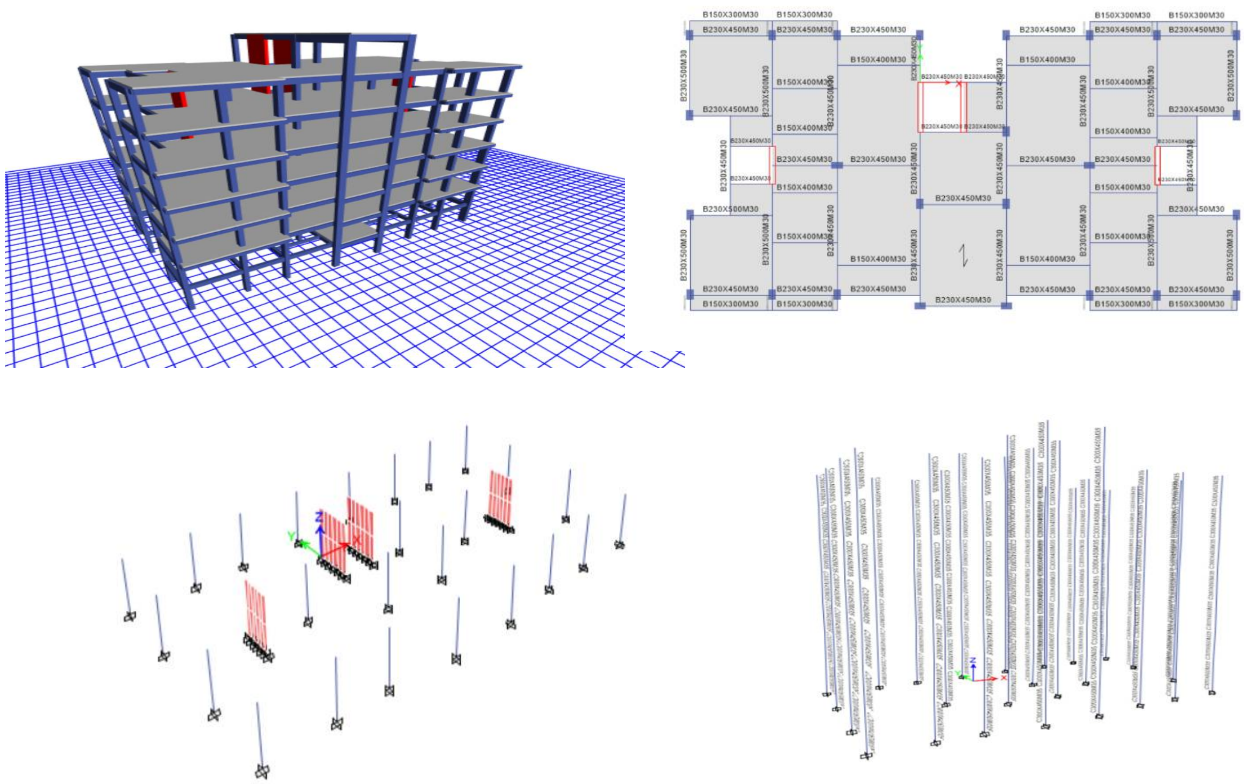

Figure 1 Building Overview

VI. ANALYSIS AND VALIDATION

Seismic analysis of the G+5 RCC building was carried out using both the Equivalent Static Method (ESM) and the Response Spectrum Method (RSM) in ETABS under identical modelling, material, mass, and loading conditions. Seismic forces were applied independently in the X and Y directions in accordance with IS 1893 (Part 1): 2016.

A. Equivalent Static Analysis

In the Equivalent Static Method, the design seismic base shear was calculated using codal parameters such as seismic zone factor, importance factor, response reduction factor, soil type, and the fundamental time period of the structure. The computed total base shear was then distributed along the height of the building based on 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 performed to evaluate the dynamic response of the structure by considering the contribution of multiple vibration modes. Modal analysis was first carried out to determine natural periods and mode shapes. A design response spectrum corresponding to medium soil conditions with 5% damping was defined as per IS 1893 (Part 1): 2016. 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 observed to be significantly lower than those obtained from equivalent static analysis. To enable a rational comparison of response parameters, the response spectrum results were scaled so that the total dynamic base shear matched the equivalent static base shear in both directions.

After scaling, the dynamic base shear values were adjusted 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. *Base Shear Comparison*

Table 11 Base Shear Comparison

Method	X-Direction (KN)	Y-Direction (KN)
Equivalent Static	806.1	806.1
Response Spectrum (Unscaled)	393.6	410.5
Response Spectrum (Scaled)	806.1	806.1

Dynamic base shear values are initially lower due to modal distribution of inertia forces and are scaled to satisfy code requirements.

B. *Storey Shear Distribution*

Storey shear values obtained from ESA are higher at upper storeys, following linear force distribution. RSA results show lower storey shear at upper levels and higher concentration of shear towards lower storeys. As shown in figure below ESA results in higher storey shear compared to RSA throughout in both direction. At ground level, both methods converge to the same value after scaling (806.1 KN). This indicates that RSA provides a more rational vertical distribution of seismic forces.

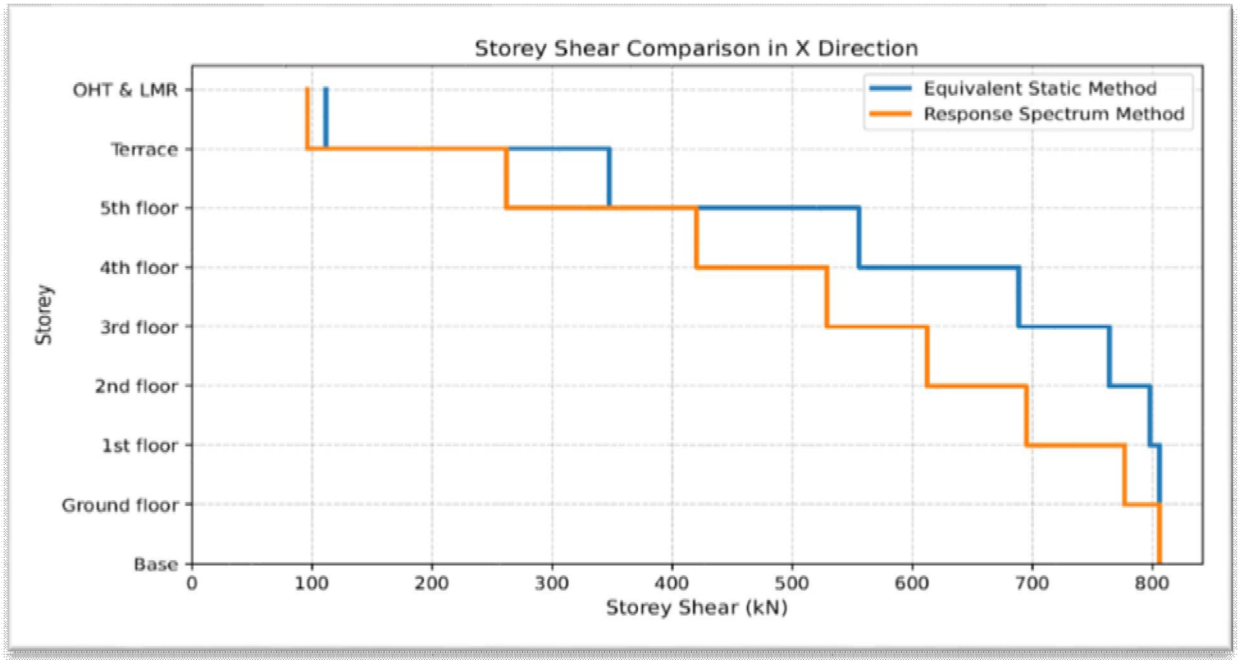

Figure 2 Storey Shear Comparison in X Direction

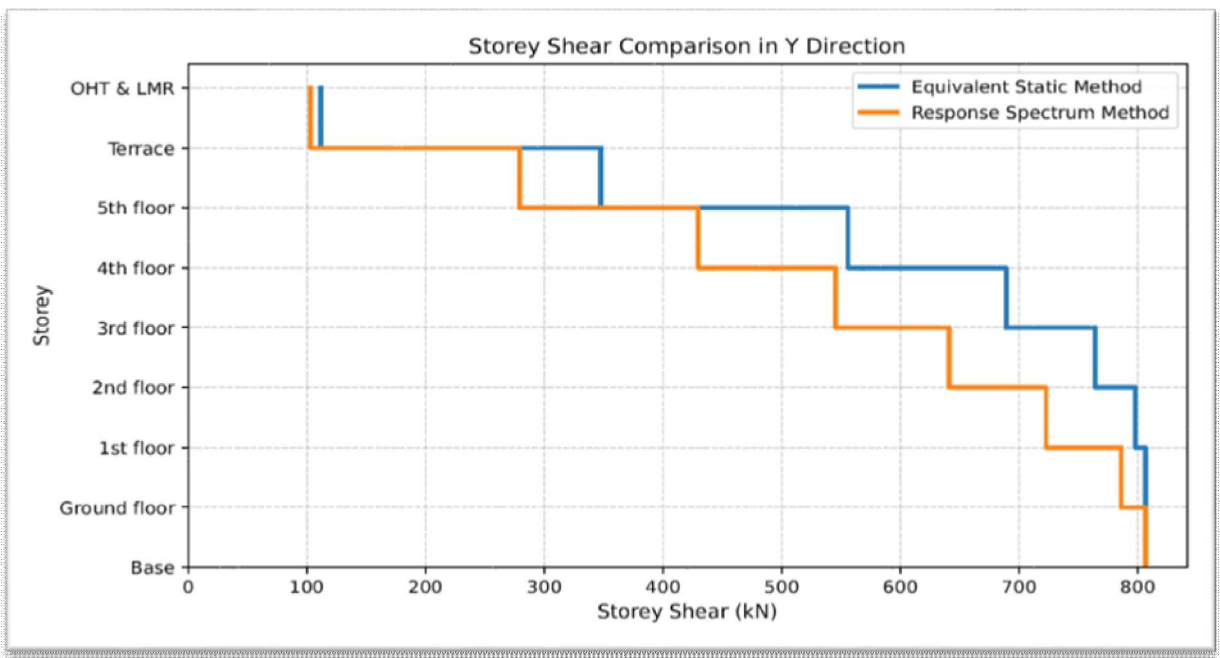

Figure 3 Storey Shear Comparison in Y Direction

C. Member force comparison(Bending Moment & Axial Force)

Beam bending moments (M3) obtained from ESA are consistently higher than those from RSA .For example, at ground storey level, the maximum beam bending moment is 58.98 KN-m (ESA) compared to 56.36 KN-m (RSA), with differences of 20–30% observed at upper storeys. This highlights the conservative nature of static analysis.

Column axial forces show relatively smaller variation between the two methods. Higher axial forces are observed in lower storeys due to gravity load dominance, while RSA captures smoother variation of axial forces along the building height. Dynamic analysis thus provides a more realistic estimation of member force distribution.

By Static Method

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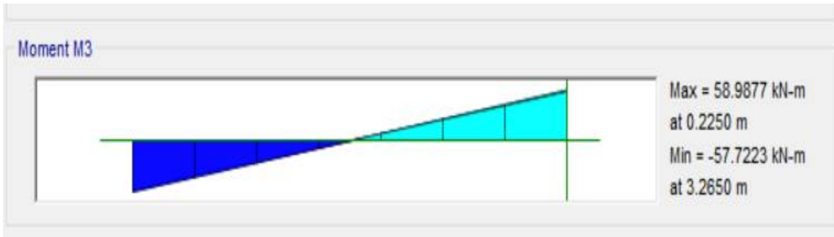

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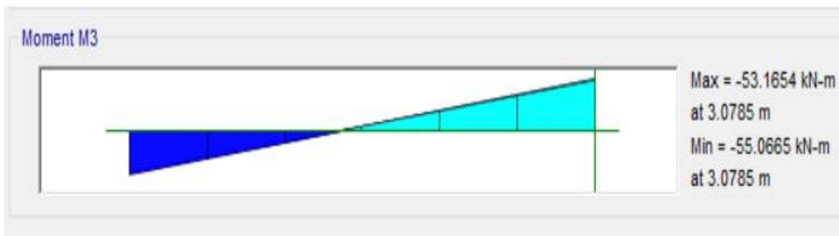

By Dynamic Method

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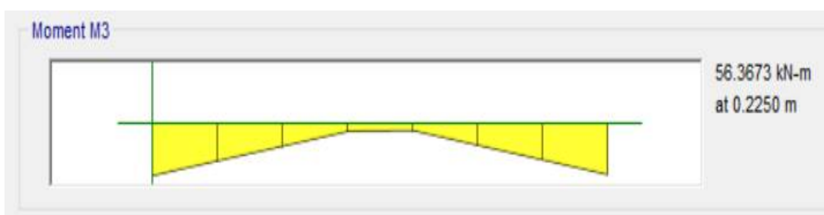

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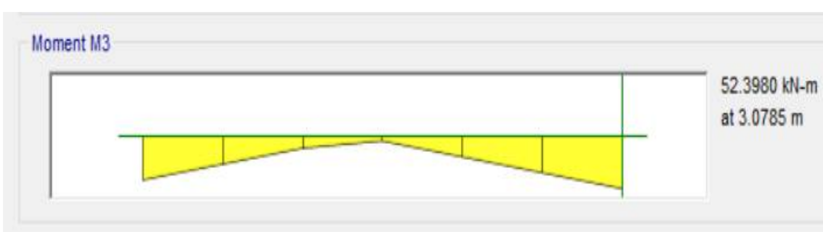

Figure 4 Critical beams bending moment diagram (Major M3) due to seismic in X direction

By Static Method

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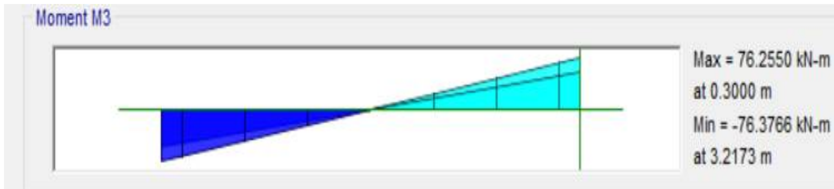

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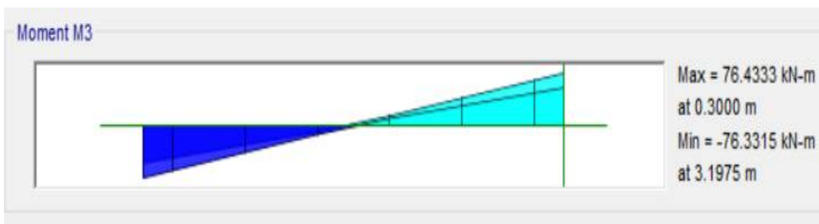

By Dynamic Method

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Unique name 729

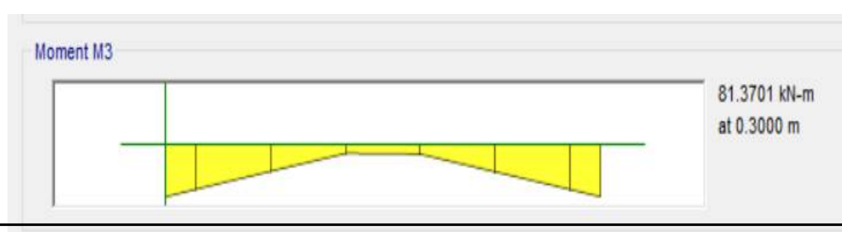

Figure 5 Critical beams bending moment diagram (Major M3) due to seismic in Y direction

<u>By Static Method</u>

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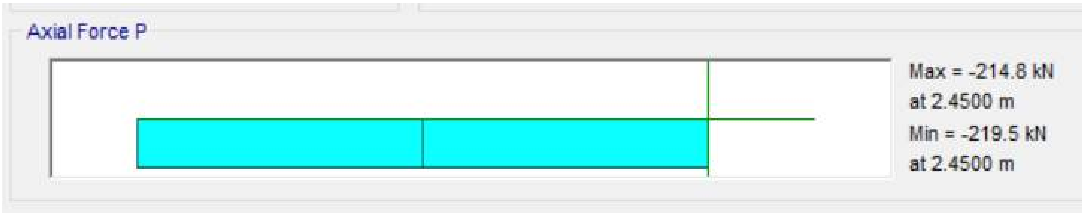

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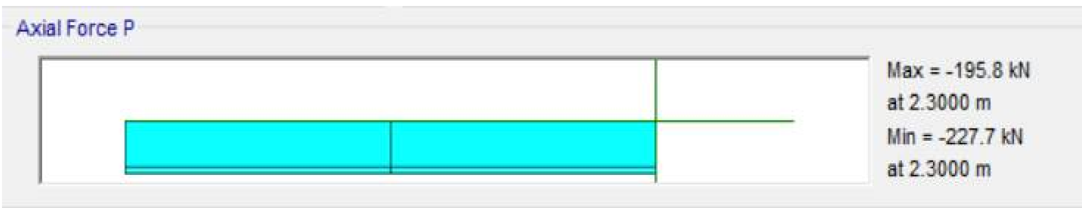

<u>By Dynamic Method</u>

Unique name 847

Unique name 113

Figure 6 Critical columns axial force diagram (P) due to seismic in X direction

By Static Method

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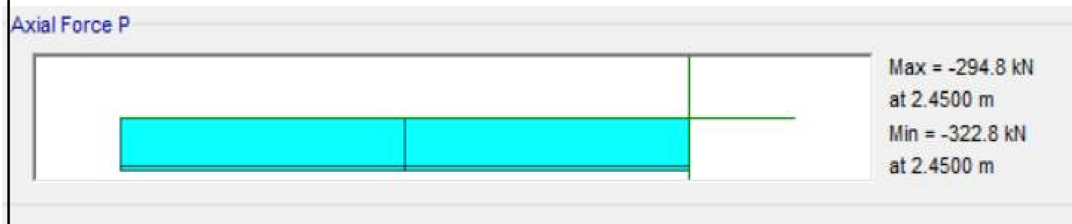

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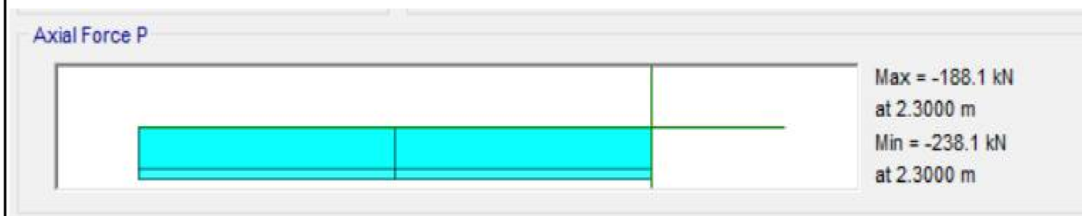

By Dynamic Method

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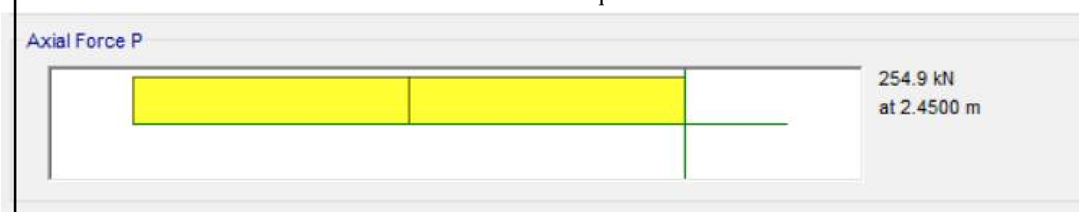

Unique name 113

Figure 7 Critical columns axial force diagram (P) due to seismic in Y direction

VIII. CONCLUSIONS

From the present study, the following conclusions are drawn:

1) The base shear obtained from response spectrum analysis was lower than that from the equivalent static method because dynamic analysis distributes seismic inertia forces among multiple vibration modes rather than assuming dominance of the fundamental mode. As a result, the cumulative modal response leads to reduced base shear, which was subsequently scaled to match the equivalent static base shear as required by IS 1893.
2) Beam bending moments (BM) obtained from the equivalent static method were higher than those from the response spectrum method, indicating conservative estimation of flexural demand.
3) Column axial forces showed comparatively smaller variation between static and dynamic analyses, with response spectrum analysis capturing a more rational redistribution of axial forces along the building height.

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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