IARJSET

ISSN (O) 2393-8021, ISSN (P) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

Impact Factor 8.066 ⪤ Peer-reviewed & Refereed journal ⪤ Vol. 11, Issue 6, June 2024

DOI: 10.17148/IARJSET.2024.11673

"PERFORMANCE-BASED SEISMIC DESIGN FOR G+30 BUILDING WITH MANSORY INFILL WALLS" (IN GUWAHATI CITY)

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Abstract: This study compares the Response Spectrum approach and Equivalent static methods with a performance-based seismic design for G+ 30. It was discovered that the building's story stiffness, story displacement, story shear, and story drift were all superior to those of the Response spectrum technique or Equivalent static approach, where the response spectrum, equivalent static, and performance basis design maximum narrative drifts were found to be 0.0009113, 0.000383, and 0.00113, respectively. Furthermore, performance-based design has been found to have the lowest building displacement value—28.4 mm on the top floor—when it comes to story displacement. In the performance comparison, the building that was found to have the highest stiffness was building number 58010171KN/m, building number 19517666KN/m for ESM, and building number 37269757KN/m for RSM. The greatest measured value for the tale shear is 18716.99KN, the ESM is 9985.45, and the response spectrum is 14030.019. They satisfy the ASCE 7-16 code and IS 1893 Pt-1 2016 acceptance standards. The findings demonstrated the superior efficiency of performance-based seismic design over RSM and ESM. The ASCE-7,16 Code's acceptance criteria for the hinge response in the beam, column, and shear wall have been seen to be met by the tabulated value, which is less than the IO level that is completely operational and fulfils the criterion value.

Keywords: Performance- Base Seismic Design, Story Displacement, Story Shear, Story Drift, Story Stiffness. Response Spectrum method, Equivalent Static Method. Fiber hinge, Plastic hinges.

I. INTRODUCTION

More than half of the world's 7.8 billion population live in cities and urban areas, and 2.5 billion more are expected to join them within the next 20-25 years. High-rise buildings, particularly residential ones, have proved to be beneficial in densely populated cities where vacant plots are almost impossible to find. space, thus maximizing land utilization and contributing to sustainable development. High-rise buildings are also adopted for solutions to density problems and lack of available land for development, as well as for power, prestige, status, and aesthetics. scarce, hence which can be achieved through performance-based seismic design.

1.1 Background:

Cost-Effectiveness: PBSD can be more cost-effective by reducing potential financial losses due to structural and non-structural damage during earthquakes

Enhanced Safety: It focuses on the actual performance of the building, ensuring that it meets the desired safety levels, thus potentially preventing loss of life

Design Consistency: Incorporating soil-structure interaction into PBSD results in more consistent design solutions, which may not be achievable with traditional force-based designs

Informed Decision-Making: Structural engineers can make informed decisions about the trade-offs between cost, safety, and functionality, leading to buildings that not only meet code requirements but also the needs of owners and society Height and Design Challenges: As the demand for taller and visually captivating structures continues to rise, traditional structural systems encounter limitations in terms of stability

Safe against Lateral force: Tall buildings are subjected to substantial lateral forces, such as wind and seismic loads, which exert significant pressure on the structure

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Flexibility: It provides flexibility in design, which is particularly beneficial for critical structures like hospitals and tall buildings, allowing them to remain operational after an earthquake

Performance-Based Seismic Design:
Performance Seismic Design (PBSD) is a seismic design methodology that allows the design team to determine the appropriate levels of ground motion and Performance Objectives for the building and the non-structural components. PBSD permits the design and construction of buildings with a realistic and reliable understanding of the risk to life, occupancy, and economic loss that may occur as a result of future earthquakes.

Fig 1 Performance building (Iman Hajirasouliha, et.al)

The two approaches utilized in performance-based seismic design analysis are the Fiber Hinge Approach and the Plastic Hinge Approach. The Plastic Hinge Approach predicts an inelastic action at the end, including axial, shear, and other behaviors. On the other hand, the Fiber Hinge Approach simply expects an inelastic action along the length in axial behavior.

Using the formula D/C <1, the ratio is provided in the following for both displacement-based and performance-based approaches. When the D/C ratio is greater than one, it indicates that the capacity is less than the demand, which is inappropriate for the structure's performance-based design. It also indicates that the demand is less than the capacity.

1.2 There are four established performance levels:

• Completely functional. The facility is still operational with very little damage.

• Direct occupancy. The facility is still operational, albeit with some minor damage and a slight interruption to non-essential functions.

• Safety of Life. Damage is mild to considerable, and life safety is well safeguarded.

• the avoidance of collapses. There is a risk to life safety, significant damage, and avertable structural collapse.

1.3 Project Objective:

• G+30 in Guwahati zone (v) was designed using a performance-based design approach.

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• To investigate the distinctions between displacement-based and forced-based seismic action methods.

• To comprehend how the seismic load affects the RCC structure's stiffness, reactions, and narrative drift.

1.4 Floor plan and 3D Model of the G+30 Structure:

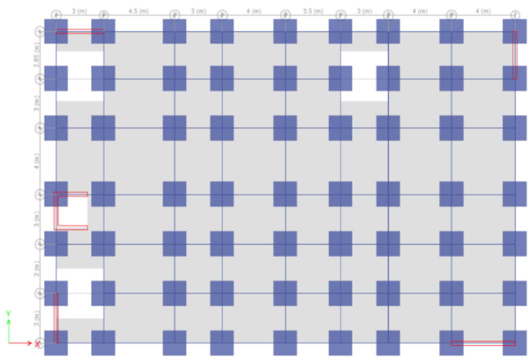

Fig: 2 Floor plan

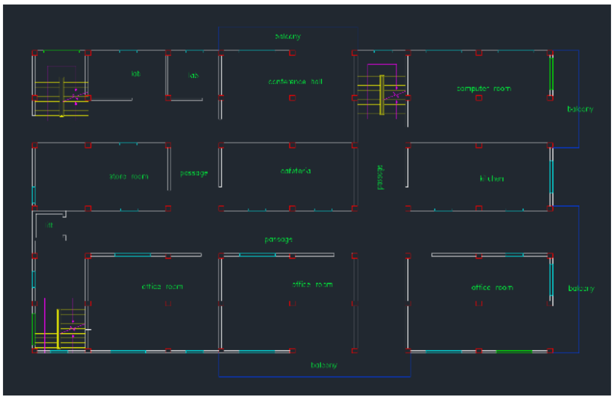

Fig 3 Etabs plan view

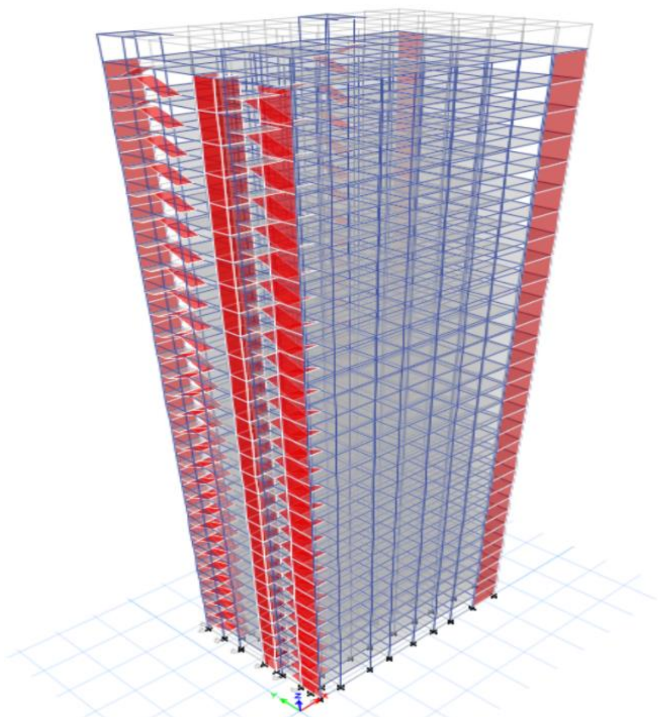

Fig 4 Etabs 3D building of G+30

II. METHODOLOGY

2.1 Flowchart:

The performance objective, which can be provided by the owner, designer, or building officials, is involved in the first step. The analysis that follows involves accessing the capability and determining whether the design meets the performance objective. If it does, construction can move forward; if not, the design and objective must be revised, and the analysis must continue until the goal is met.

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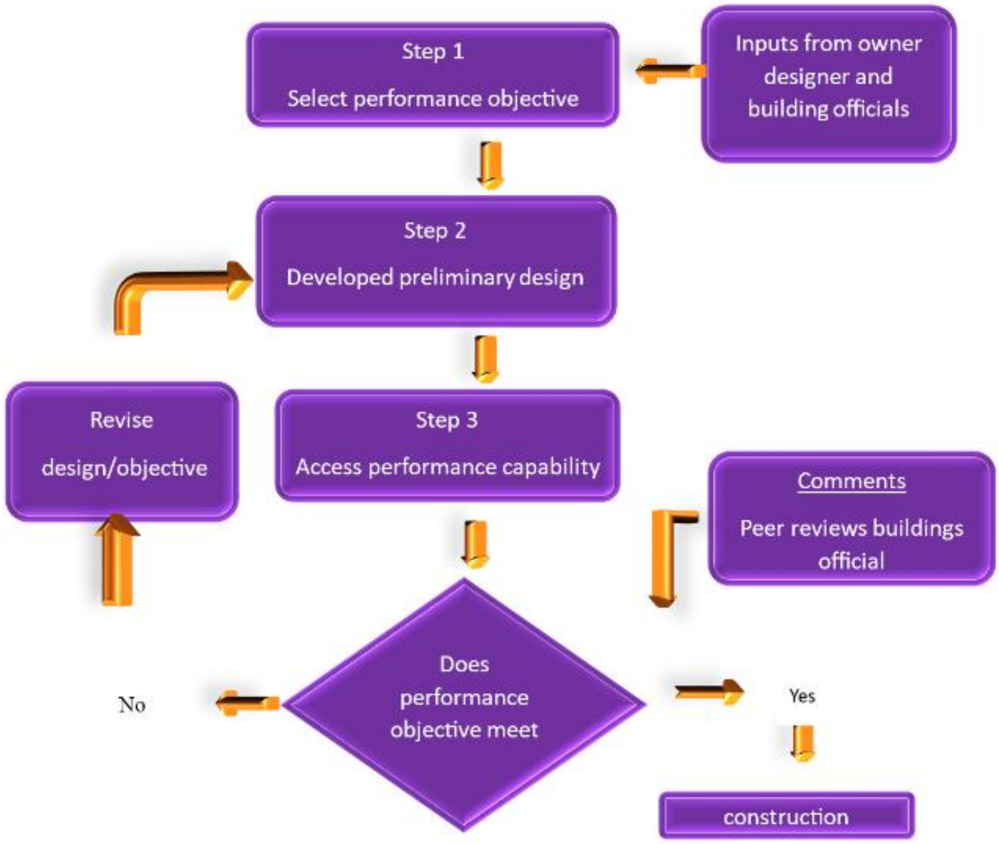

Fig 5 PBSD Flowchart

Planning
Site: Guwahati (zone v)

Performance-based design evaluation:

Performance level to be achieved

- SLE (seismic level evaluation) using response spectrum evaluation.
- Elastic model
- MCE (maximum considered earthquake) level, using history analysis ie., push-over analysis (outdated)

The currently used is non-linear dynamic analysis

Calculation on the behavior of the structure:

- Linear dynamic analysis
- Non-linear analysis (pushover analysis)
- Non-linear dynamic analysis

Setting up the acceptance criteria:

- For local element (individual)
- For global element (overall structure)
- For different performance levels

The Acceptance criteria for service level evaluation are given in Table 1

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Table 1 Acceptance Criteria for SLE

Item	limit
Storey drift	0.004 X Story height(IS-1893 PART 1, Cl 7.11.1)
Coupling beam	Shear strength must remain elastic
Core wall (flexure)	Remain essentially elastic
Core wall (shear)	Remain essentially elastic
column	Remain essentially elastic

(As per Table 2.1 ASCE-41, ICC,2009)

The Acceptance criteria for the maximum considered earthquake is given in Table 2

Table 2 Acceptance Criteria for MCE

Item	**Limit**
Storey drift	0.007 (chapter 16 ASCE/SE 17-16) table 12.12.1
Coupling beam (diagonal reinforcement)	0.06 radiant rotation
Coupling beam (conventional reinforcement)	0.025 radiant rotation
Core wall reinforcement	Rebar strength <0.05 in tension <0.02 in compression

(As per ASCE 7-16, section-C, Cl 16.4.2.2)

The Design Evaluation of the beam, column, and shear wall for plastic hinge rotation, shear, and axial flexure is given in Table 3

Table 3 Design based evaluation

Element	**Action type**	**Classification**	**Expected behavior**	**Acceptance criteria**
Beams	Plastic hinge rotation	Ductile	Non-Linear	Hinge rotation should be less than or equal to the ASCE Code
	Shear	Brittle	Linear	D/C (demand) < D/C(capacity)
Column	Axial flexure	Ductile	Non-Linear	Hinge rotation should be less than or equal to the ASCE Code
	Shear	Brittle	Linear	D/C (rotation demand) < D/C (rotation capacity)
Shear wall	Axial flexure	Ductile	Non-Linear	The tensile strength in the bar should be less than or equal to 0-0.05 & for concrete is 0 - 0.004
	Shear	Brittle	Linear	D/C (demand) < D/C(capacity)

(As per ASCE 7-10, table 5)

III. RESULT/ DISCUSSION

3.1 General

The uses of a Performance-Based Seismic Design study to examine the outcome and reaction of the G+30 construction is observe. The displacement and shear of stories, structural stiffness, base reaction, and story drift have all been examined concerning seismic response.

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It has been mentioned to compare analytically the various methods for response spectrum, equivalent static approach, and performance-based seismic design. This analysis made use of the 7.6-magnitude Izmit earthquake (1999). The following is a list of the outcomes:

Table 4 (Data for building)

Name	Dimension
No of story	32
Story height	3m
Total height of the building	95.5m
Beam size	600x400mm
Column size	700x800mm
Slab thickness	210mm
Zone	(v) Ghy
Importance factor	1.2 IS-1893, Cl-7.2.3
Grade of steel	Fe 415 HYSD
Grade of concrete	M30, M25, M20
Soil type	(II) IS-1893, Cl 6.4.2.1
Dia of the bar in column	32 mm
Links dia for column	12 mm
Dia of the bar in the beam	25 mm
Stirrups dia for beam	12 mm
Dia of the bar in shear wall	25 mm
Spacing of stirrup in the beam	130mm
Spacing of stirrup in column	100 mm
Building type	Office building
Zone factor	0.36 IS-1893, Cl 6.4.2

3.2 Combine Story Response:

The red line indicates the highest deformation and the green line represents the minimum deformation in this graph, which shows the combined story response of the structure for displacement, drift shear, and overturning. In this case, the x-direction denotes the deformation, and the y-direction the structure's height. The input function of the structure is shown by the lower graph, where the time is represented in seconds (sec) and the acceleration is represented in m/sec2 in the x direction. The input time for determining the structure's maximum response was taken into consideration between 26 and 36 seconds, resulting in a minimum acceleration of 0–12 seconds and a maximum acceleration of 24-36 seconds. This graph's control data is the time history-x in the x-direction.

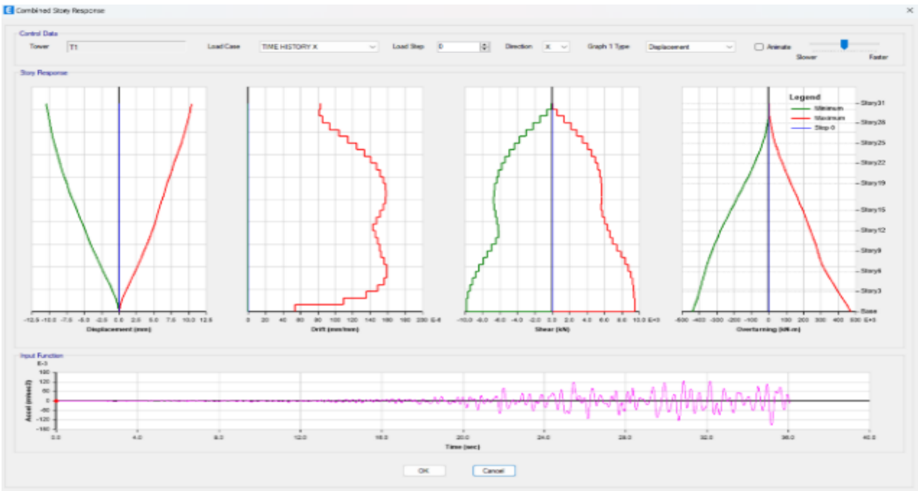

Fig 6 Combine story response

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3.3 Plastic Hinge Response for Beam:

Applicable in cases when axial, shear, or other types of behavior indicate that inelastic action is anticipated at or near the end. Figure 7 shows the beam's hinge reaction in time, which is 33.0018 seconds, according to Figure 6, which shows the maximum acceleration in 26–36 seconds. Here, the IO level is represented by the blue, and the LS level by the purple. Based on the graph, we can conclude that the structure is in immediate occupancy and completely operational because the frame hinge state is lower than the IO level.

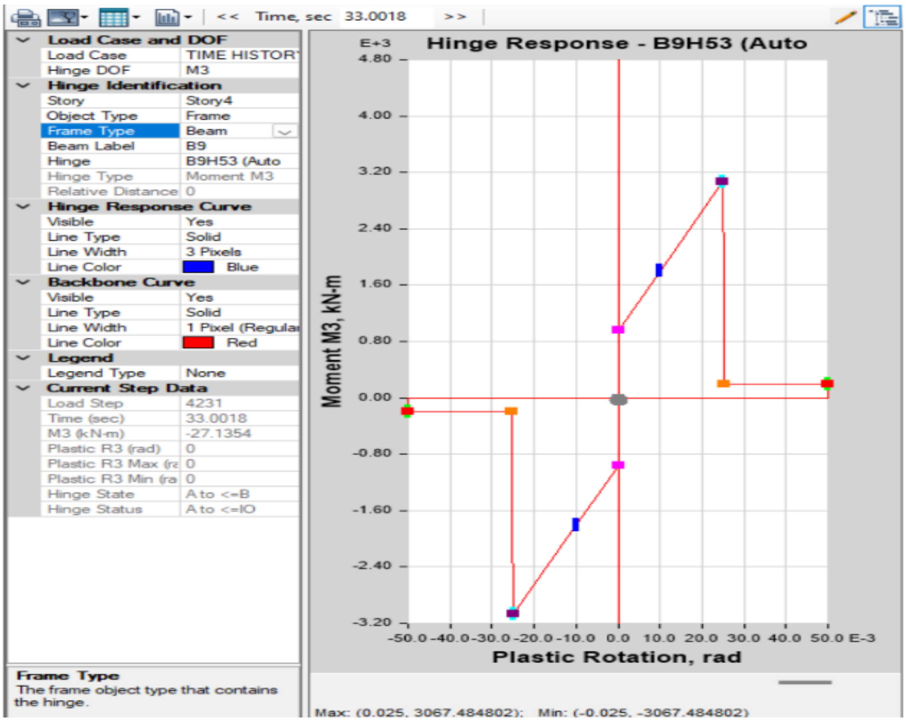

Fig 7 Plastic Hinge Response for beam

3.4 Comparison of Analytical data:

Based on the comparison of the building performance, as illustrated in Fig. 8, the most stiffened building had performance data of 58010171 KN/m, 19517666 KN/m for ESM, and 37269757 KN/m for RSM. The outcome demonstrated the superior efficiency of performance-base seismic design over RSM and ESM.

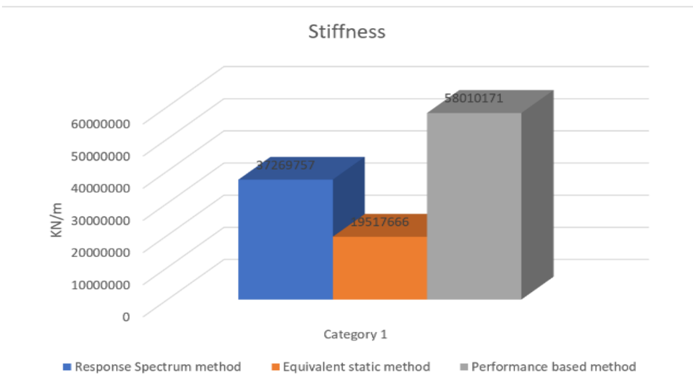

Fig 8 Comparison of story Stiffness

Furthermore, the maximum measured values for the narrative shear in Figure 9 are ESM = 9985.45, Response spectrum = 14030.019, and 18716.99KN. They meet the standards for IS 1893 Pt-1 2016 approval as well as the ASCE 7-16 code. The findings indicate that performance-base seismic design is more effective than RSM and ESM.

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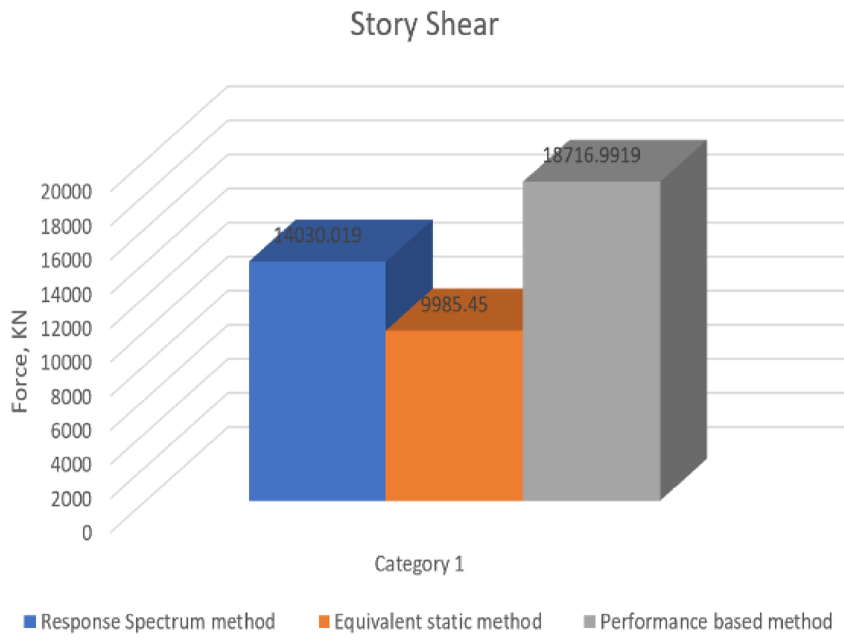

Fig 9 Comparison of story shear

Figure 9 revealed the values of the performance base design maximum drift, equivalent static maximum drift, and response spectrum maximum drift, which are 0.000383, 0.0009113, and 0.00113, respectively. The result showed that Performance-Base Seismic design is more efficient than RSM and ESM.

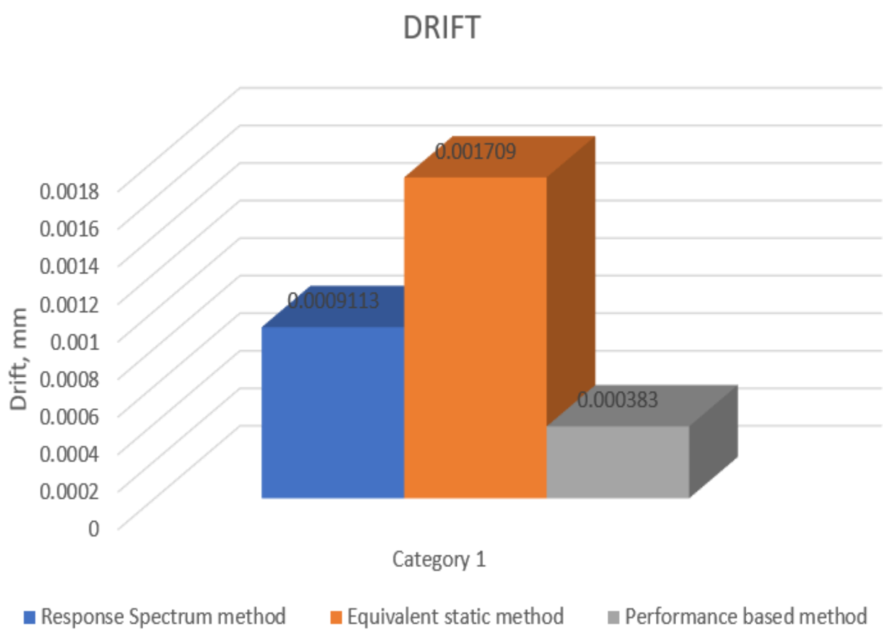

Fig 10 Comparison of story DrifT

Performance-based design has the least amount of building displacement, as seen by Figure 10 story displacement, which shows a top floor displacement of 28.4 mm. RSM is 40.2 mm, while ESM is 120 mm. The result showed that Performance-Base Seismic design is more efficient than RSM and ESM.

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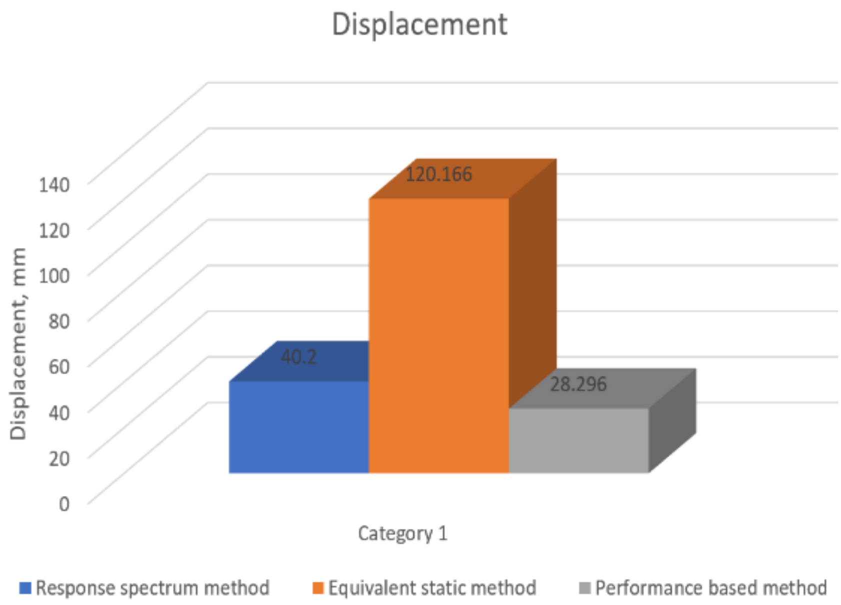

Fig 11 Comparison of story Displacement

3.5 Performance check for minor damage:
When the demand/capacity ratio is less than one, the performance check in frame hinges for minor damage has found that the performance objective for the immediate occupancy is safe against minor damage and that the structure is safe against any damage to the structure.

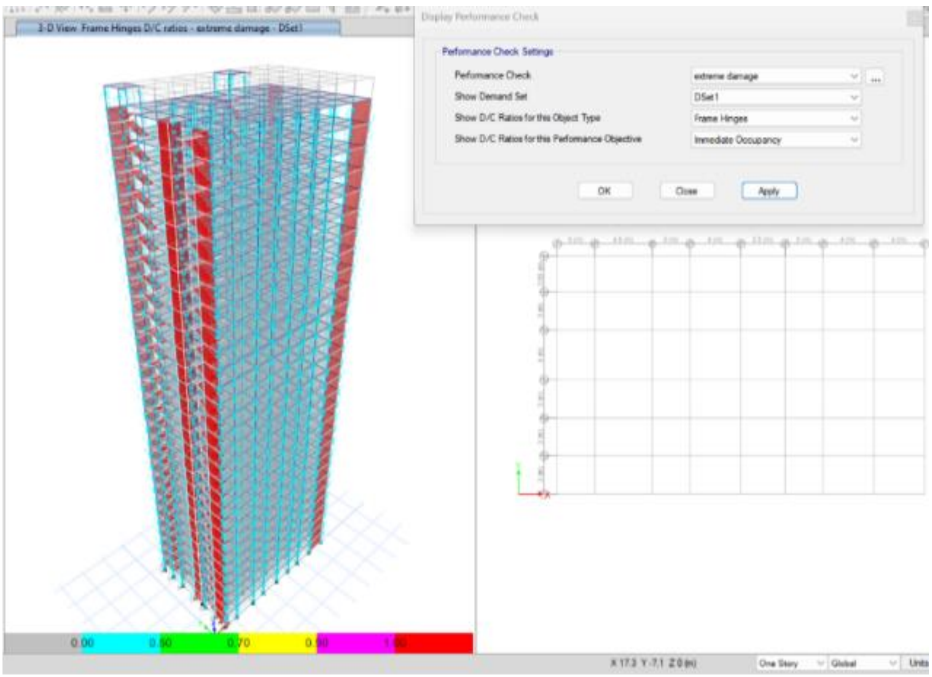

Fig 12 Performance check for minor damage

3.6 Performance check for extreme damage: The performance check-in frame hinges for extreme damage hve observed that the performance objective for the immediate occupancy is safe against minor damage and that the structure is safe against any damage to the structure, provided that the demand/capacity ratio is less than one.

IARJSET

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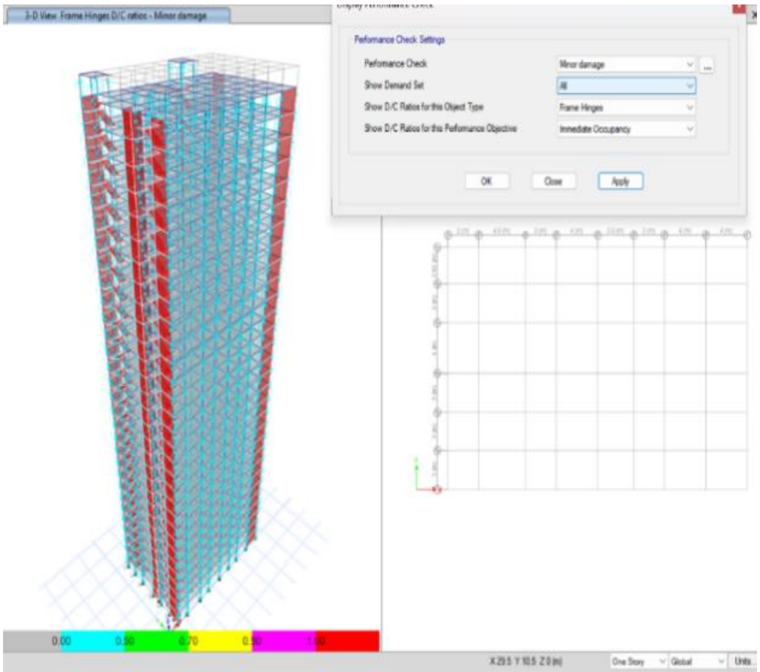

Fig 13 Performance check for extreme damage

3.7 Fiber Hinge Response for the Shear Wall:

An Inelastic hinge is expected along the length, which is valid only for axial behaviour. In the fig: 14 represents the hinge response of a beam in time, sec 33.0018 sec as per the Fig: 6 which observed the maximum acceleration in 26-36 sec. In below fig: 14, B represent the IO level so the fiber hinge for share wall is immediate occupancy and fully operational. As per ASCE 7-16 table 6 the maximum Plastic Rotation Angle radian is 0.02 which is at the CP level, and for IO level is 0.005, but here we can observe that the plastic rotation rad in the below graph is 0.000011 which is less than IO level. However, it represents that the shear wall will have permeant deformation at-12.328 KN-m

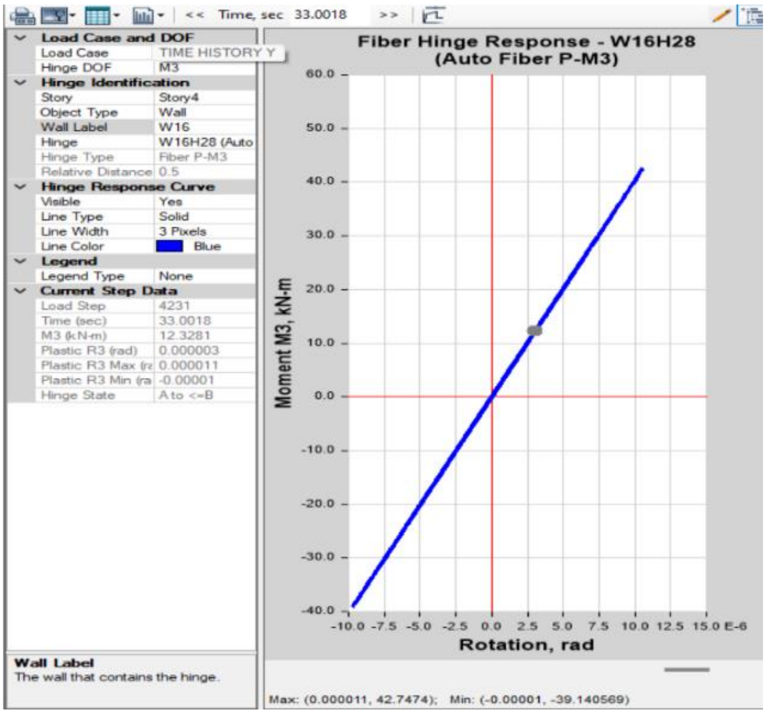

Fig 14 Fiber Hinge Response for shear wall:

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3.8 Fiber Hinge Response for column:

An Inelastic hinge is expected along the length, which is valid only for axial behavior. In the fig: 6 represents the hinge response of a beam in time, sec 33.0018 sec as per the fig: 14 which observed the maximum acceleration in 26-36 sec. in the below fig: 4.9, B represent the IO level so the fiber hinge for share wall is immediate occupancy and fully operational. As per ASCE 7-16 table 6 the maximum Plastic Rotation Angle radian is 0.02 which is in CP level, and for IO level is 0.005, but here we can observe that the plastic rotation rad in the below graph is 0.000002 which is less than IO level. However, it represents that the column will have permanent deformation at-17.849.KN-m

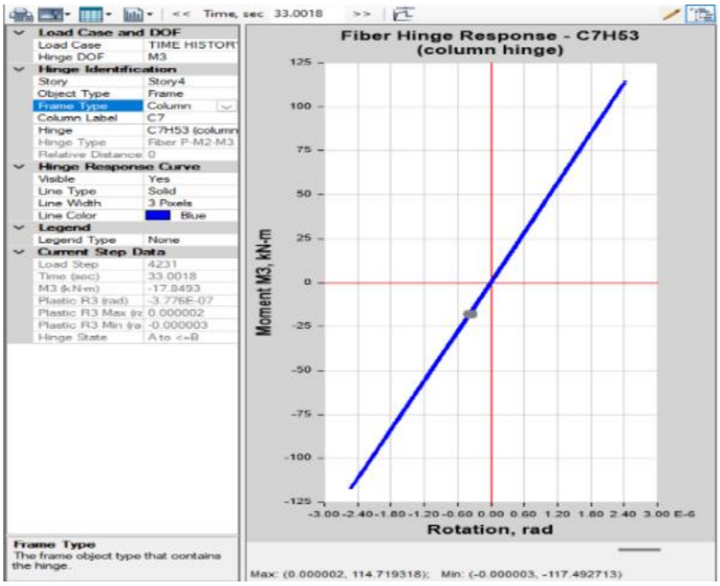

Fig 15 Fiber Hinge Response for column:

3.9 Story stiffness:

Story stiffness is defined as the measure to find how much force is required to displace a building. Here the y-axis represents the height of building and in x- axis it represents the force in KN/m, From the below graph in Fig 4.11 it has been observed that 58010171.879 KN/m is required for the building to be displaced.

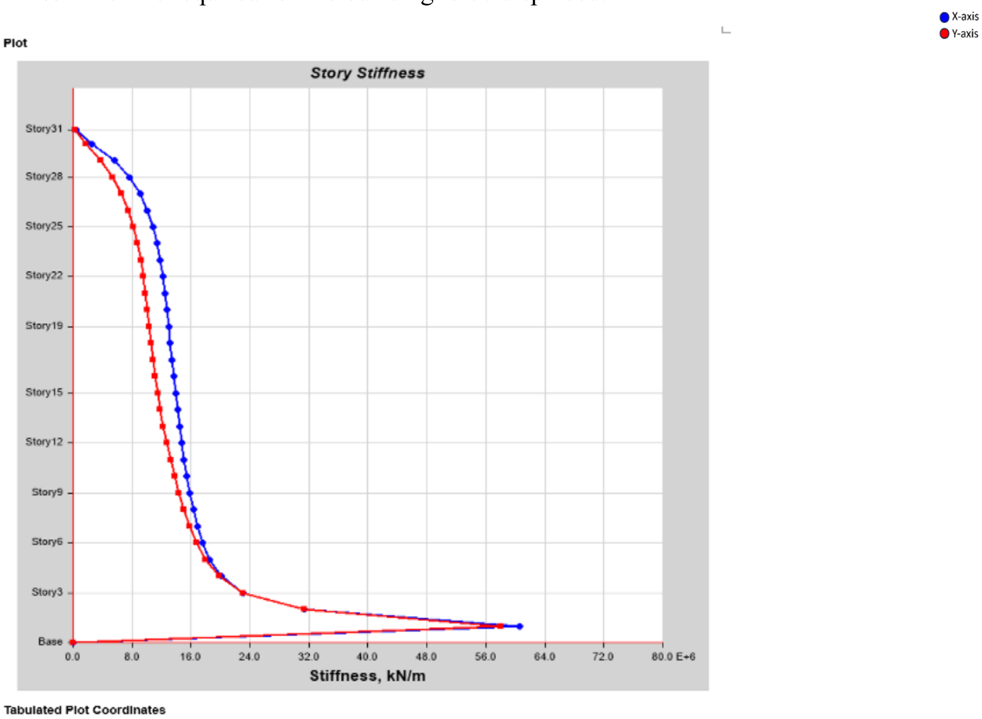

Fig 16 Story Stiffness

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3.10 Displacement:

Story displacement is the overall displacement of the story with respect to ground, in the figure: 4. 12 the maximum story displacement was 28.19 mm in y direction and the minimum story displacement was observe to be in the base of the structure. The allowable displacement as per the ASCE 7-16 TABLE 12.12.1 is 0.007 in height of the building is 665mm therefore this structure displacement is within the limit.

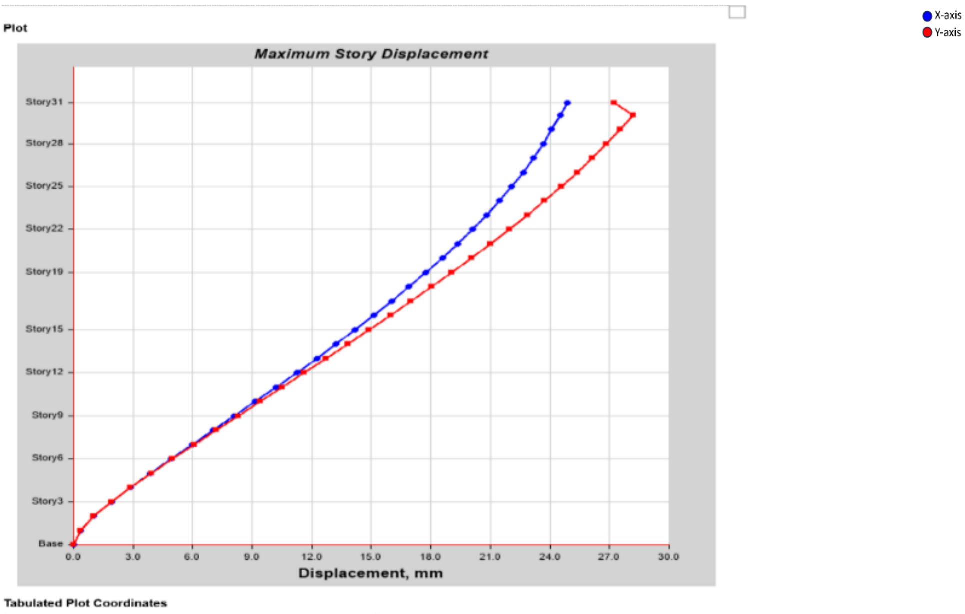

Fig 17 Story Displacement

3.11 Story Drift:

The lateral displacement at the top of the tale in relation to the bottom of the story is known as the "story drift." The story drift at any story should not be more than 0.004 times the story height according to IS1893 for the earthquake load, and it should not be more than 0.007 times the story height according to ASCE code 7-16. As a result, the highest drift in the figure was less than the permitted drift, at 0.000383.

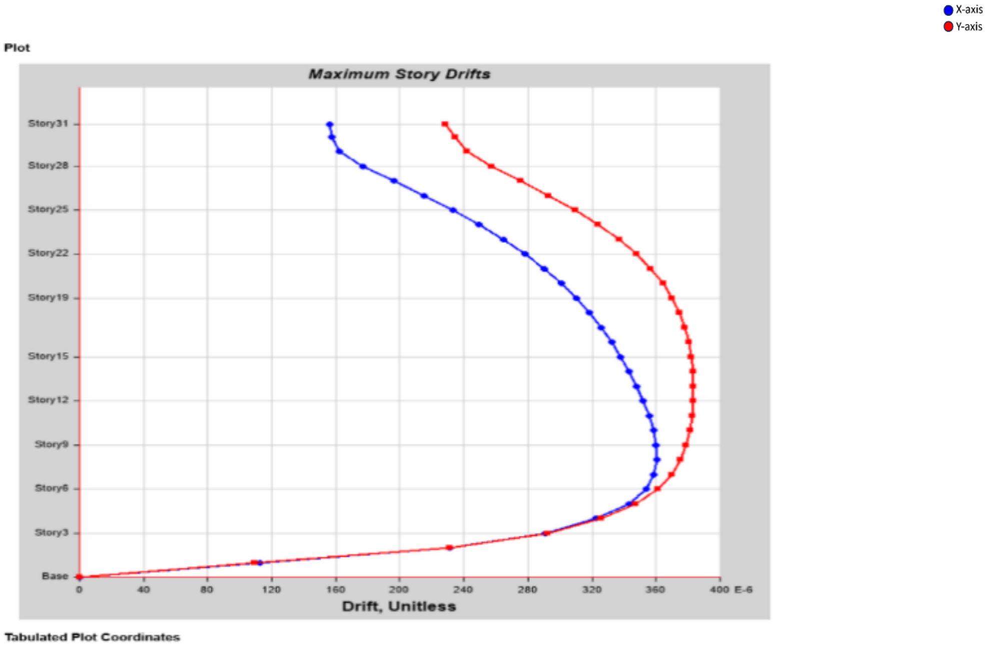

Fig 18 Story Drift

IARJSET

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3.12 Story shear:

the lateral force applied to a story by forces like wind and seismic activity. According to Figure 21, the highest story shear at the bottom of the tale shear is 18716.99KN. As we can see, the shear in the story keeps decreasing as the story level rises, reaching a maximum at the bottom and a minimum at the top floor. This is because the shear force is greatest at the fixed end, and since the structure is resting on the ground, it has maximum shear at the bottom story. The x-direction in this graph represents the story height, and the y-direction represents the force in KN.

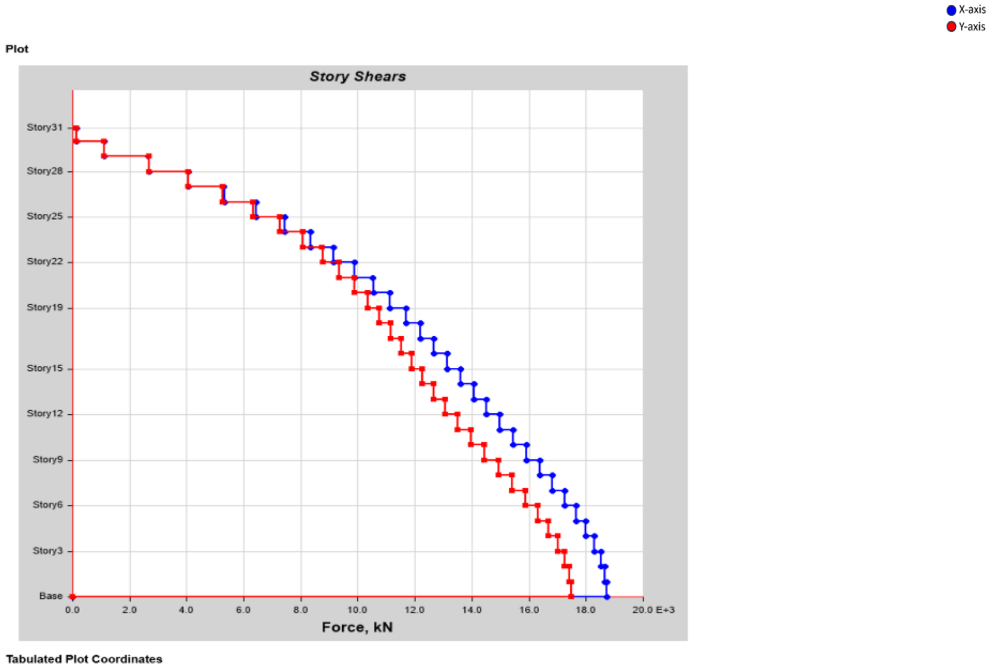

Fig: 21 Story Shear

When comparing the narrative shear data for the Limit State method, Response Spectrum method, and Performance-Based seismic design analysis, it can be shown that the latter has more shear than the former, making it possible to counteract a greater number of lateral forces.

IV. CONCLUSION AND FUTURE SCOPE

A performance-based seismic design for G+ 30 has been completed based on the seismic study, and it has been compared to the Response Spectrum approach and Equivalent static methodology.

- The reaction spectrum, equivalent static, and performance basis design maximum narrative drifts were found to be 0.0009113, 0.000383, and 0.00113, respectively.

- Additionally, it has been noted that performance-based design, which has a top floor displacement of 28.4 mm, results in the least amount of building displacement.

- The building that was found to have the highest stiffness performance-wise was the one with performance data of 58010171 KN/m, 19517666 KN/m for the Equivalent static method, and 37269757 KN/m for the Response spectrum method.

- As for the narrative shear, the highest observed values are 18716.99KN, 14030.019 for the response spectrum, and 9985.45 for the ESM. They satisfy the ASCE 7-16 code and IS 1893 Pt-1 2016 acceptance standards. The outcome demonstrated the superior efficiency of Performance-Base Seismic design over RSM and ESM.

- Additionally, it has been observed that the hinge response in the shear wall, beam, and column is less than the ASCE-7,16 Code's acceptance criteria, which meets the criterion value and the structure if less than the IO level, which is fully operational, life safety, and collapse prevention.

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