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Analysis and Design of Earthquake Resistance Building

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ABSTRACT: Earthquakes represent a major threat to structures, especially those lacking proper seismic design considerations. The primary goal of earthquake-resistant design is to ensure life safety by providing a ductile failure mechanism and preventing catastrophic collapse [1]. This paper provides a comprehensive review of major seismic analysis procedures such as the Equivalent Static Force Method, Modal Response Spectrum Method, and Dynamic Time-History Analysis. Modern codes increasingly favour dynamic analysis for multi-storey or irregular buildings, while static methods remain applicable for low-rise structures in low-seismic zones. Findings from various studies show that seismic loads generate significantly higher bending moments, shear forces, and inter-storey drifts than static loads, often exceeding allowable limits. This paper highlights modelling considerations, the importance of shear walls, capacity design concepts, and recent trends in performance-based seismic design.

I. INTRODUCTION

Earthquakes generate ground shaking that can cause severe damage to structures, landslides, and soil liquefaction [1]. Reinforced concrete (RC) moment-resisting frames often perform poorly during moderate to strong earthquakes due to inadequate detailing, especially at beam-column joints, which play a critical role in transferring loads between structural components

Traditional seismic design philosophy requires that structures remain functional under minor earthquakes, sustain repairable damage under moderate earthquakes, and avoid collapse under severe earthquakes [1]. Modern building codes permit the use of simplified equivalent static load analysis for regular low-rise buildings, while emphasizing the need for dynamic analysis—particularly for irregular or tall buildings.Dynamic behaviour of

buildings depends on mass, stiffness, damping, and the characteristics of ground motion [1]. Although dynamic analysis provides more accurate results, it is complex and sensitive to assumptions regarding modelling, material behaviour, and ground motion input. As a result, capacity design concepts and advanced analysis methods like the Response Spectrum Method are widely adopted.

Shear walls are essential structural components that provide significant lateral stiffness and strength . They help resist wind and earthquake loads, reduce torsional effects, and maintain structural integrity. In high-rise buildings, shear walls are crucial for controlling deflections and preventing structural failure.

A. Objectives

The objectives of this research are:
1. To review and analyze modern seismic design methods for earthquake-resistant buildings
2. To perform comparative dynamic analysis for various ground motions using recorded earthquake data
3. To evaluate the influence of structural configuration and shear wall placement on seismic performance
4. To check post-dynamic behaviour of RC buildings subjected to specified ground motion records
5. To provide recommendations for optimal structural design in seismic zones

II. LITERATURE REVIEW

Shear Wall Performance and Placement

Studies by Ravi Kumar et al. (2017) demonstrated that shear walls effectively resist both earthquake and wind loads, with their placement significantly influencing the behaviour of multi-storey buildings [1]. Analysis of a ten-storey RC building in ETABS showed improved performance when shear walls were optimally located.

Research by Vaesha R. Harne et al. (2014) focused on determining the best shear wall locations for a six-storey building in seismic Zone II using STAAD.Pro [1]. Shear wall systems provide high in-plane stiffness and strength, and three configurations were analysed to highlight the importance of shear wall placement.

Seismic Analysis Methods

Response Spectrum Analysis has been widely employed in seismic assessment studies. A multi-storey RC frame analysed using the Response Spectrum Method revealed excessive inter-storey drifts and large increases in axial stresses in exterior columns due to earthquake effects [1]. Seismic loads produced bending moments and shear forces several times higher than static loads [1].

Recent studies by Reza Latifi et al. (2021) compared three popular seismic analysis methods (ELF, MRS, LRH) using ASCE 7-16 and ETABS [1]. The research demonstrated variations in base shear and storey shear distributions, providing insights for choosing effective analysis methods.

Structural Damage Assessment

Damage surveys conducted after major earthquakes provide valuable insights into building performance. Analysis of 1,005 buildings in the Wenchuan Earthquake showed that RC frame buildings performed best, while masonry buildings performed worst [1]. Taller buildings showed lower seismic resistance, whereas public buildings suffered more damage than residential ones [1].

Investigation of 43 RC shear wall buildings after the 2010 Chile earthquake revealed that brittle damage was concentrated on lower storeys and occurred mostly near vertical irregularities [1].

Evolution of Seismic Design Philosophy

Review of earthquake performance in Turkey revealed that structural deficiencies—not outdated codes—were primary causes of failure [1]. The evolution of seismic codes highlighted the increasing adoption of realistic seismic demand and capacity concepts[1].

Modern seismic design must also incorporate performance-based approaches that address downtime, functionality, and post-earthquake recovery [1]. Research presented a probabilistic post-earthquake recovery model, introducing recovery states such as stability, shelter-in-place, reoccupancy, and functional recovery [1].

III. METHODOLOGY

1. Determination of Ground Motion Parameters

The first step is to quantify the potential earthquake hazard at the site by determining ground motion parameters:

- Amplitude Parameters: Identify the Peak Ground Acceleration (PGA), Peak Velocity (PGV), and Peak Displacement (PGD). PGA is the most commonly used parameter for stiff structures.
- Frequency Content: Analyze the frequency components of potential ground motion using Response Spectra, Fourier Spectra, or Power Spectra.
- Duration: Determine the expected duration of strong motion, often defined as the interval contributing to 90% of the accelerogram's total energy.

A. Time History Analysis

Time history analysis is the study of the dynamic response of the structure at every increment of time, when its base is exposed to a particular ground motion [2]. Static techniques are applicable when higher mode effects. For tall structures, structures with torsional asymmetries, or structures with non-orthogonal frameworks, a dynamic method is needed.

In order to study the seismic behaviour of structures subjected to low, intermediate, and high-frequency content ground motions, dynamic analysis is required. E-TABS software is used to perform linear time history analysis [2].

Design Criteria

The total design lateral force or design base shear along any principal direction is determined by:
Vb = Ah × W ... (Equation 1)
Where:

- Ah = design horizontal seismic coefficient for a structure
- W = seismic weight of building

The design horizontal seismic coefficient for a structure is given by standard seismic codes and depends on:

- Z = zone factor (given in Table 2 of IS 1893:2002 Part 1 for the maximum considered earthquake)
- The factor 2 is used to reduce the MCE to the factor for design base earthquake (DBE)

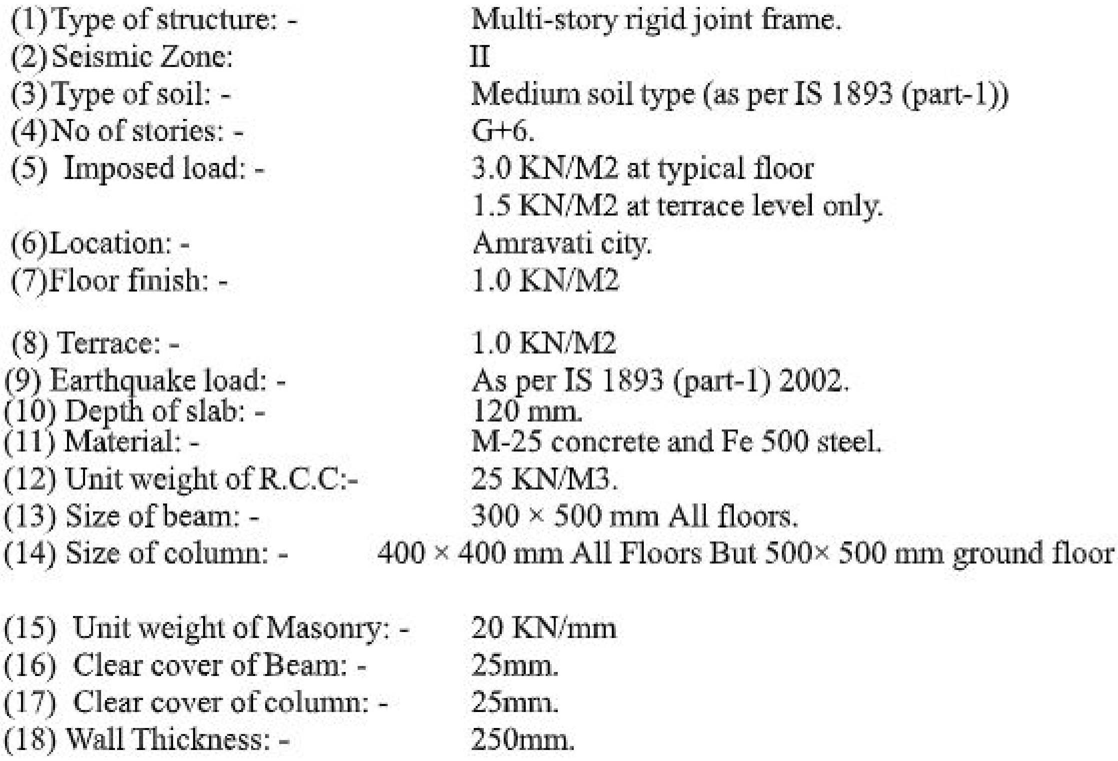
B. Building Configuration

For this analysis, we consider a **multi-storey reinforced concrete building** with the following characteristics:

Parameter	**Value**
Number of Stories	2 to 5 (variable)
Building Dimensions	Length × Width (varies)
Floor Height	3.5 m typical
Seismic Zone	Zone III or higher
Structural System	RC Moment-Resisting Frame with Shear Walls
Material	M30 Concrete, Fe415 Steel
Software	ETabs

IV. MODEL AND ANALYSIS E-TABS

A G+6 Building is taken for analysis. The salient features of the building are:



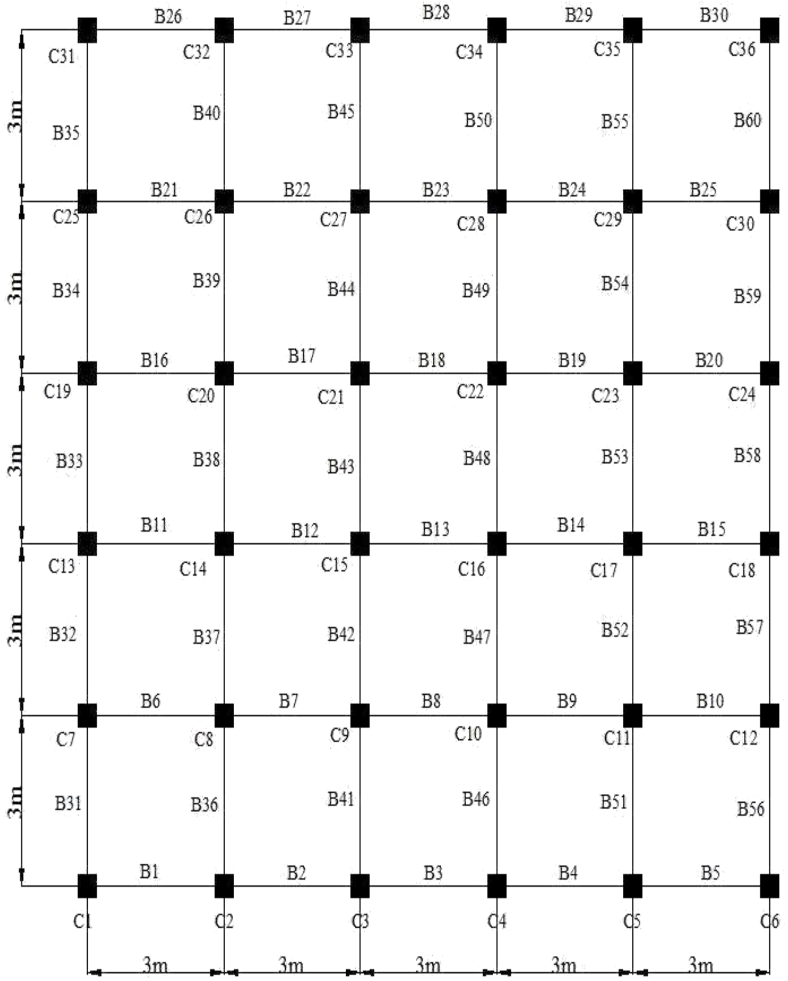
(1) Type of structure: - Multi-story rigid joint frame.
(2) Seismic Zone: II
(3) Type of soil: - Medium soil type (as per IS 1893 (part-1))
(4) No of stories: - G+6.
(5) Imposed load: - 3.0 KN/M2 at typical floor
1.5 KN/M2 at terrace level only.
(6) Location: - Amravati city.
(7) Floor finish: - 1.0 KN/M2

(8) Terrace: - 1.0 KN/M2
(9) Earthquake load: - As per IS 1893 (part-1) 2002.
(10) Depth of slab: - 120 mm.
(11) Material: - M-25 concrete and Fe 500 steel.
(12) Unit weight of R.C.C:- 25 KN/M3.
(13) Size of beam: - 300 × 500 mm All floors.
(14) Size of column: - 400 × 400 mm All Floors But 500× 500 mm ground floor

(15) Unit weight of Masonry: - 20 KN/mm
(16) Clear cover of Beam: - 25mm.
(17) Clear cover of column: - 25mm.
(18) Wall Thickness: - 250mm.

A. Analysis of 3D-RC frame:

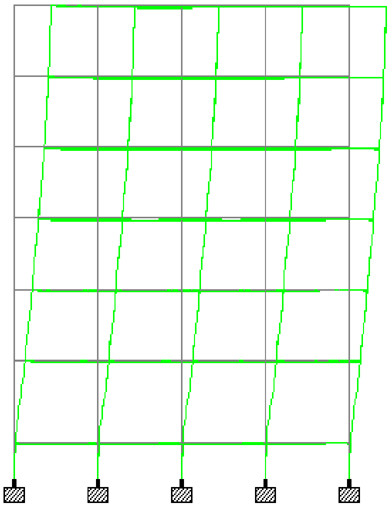
Multi storied RC Frame



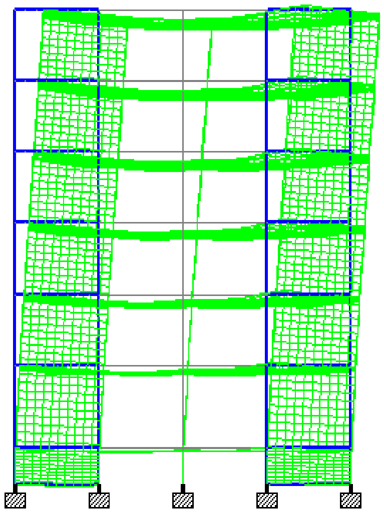
PLAN

Table 1: Computation of lateral forces at each floor of building.

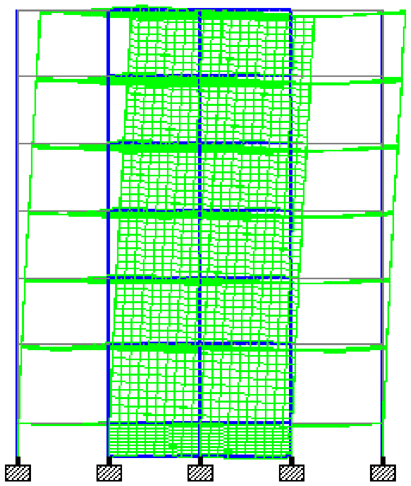
Sr. No.	**Level**	**Lateral Force**			
		Model I	**Model II**	**Model III**	**Model IV**
1	Roof	253.03	237.431	237.431	251.502
2	5th Floor	289.18	269.539	269.539	289.498
3	4th Floor	187.06	174.905	174.905	188.174
4	3rd Floor	108.44	101.394	101.394	108.562
5	2nd Floor	50.60	47.317	47.317	50.662
6	1st Floor	15.36	13.519	13.519	15.38



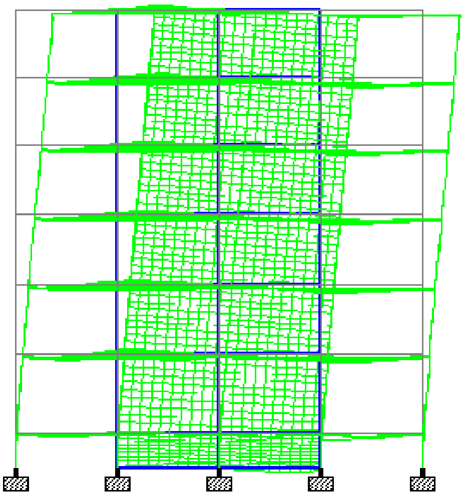
Model I: Structure without shear wall



Model II: Structure with L type shear wall



Model III: Structure with shear wall along periphery



Model IV: Structure with cross type shear wall

V. RESULT AND DISCUATION

Table 1: Maximum Deflection at the Roof without Shear Wall.

software	Load combination	Calculated deflection (mm)
E-TABS	1.5DL+1.5EQX	52.948
	1.2DL+1.2LL+1.2EQX	42.491
	1.5DL+1.5EQZ	38.172

Table 2: Maximum Bending Moment of Various Models.

LEVEL	Bending Moment (kN.M)			
	MODEL I	MODEL II	MODEL III	MODEL IV
AT 20m	-7.896	-10.607	17.207	-12.129
AT 8m	-2.365	-2.132	12.412	-5.204
AT 3.5m	-0.315	1.119	3.321	-0.363

Table 3: Comparison of Shear forces-Y (KN) for Beam of different models.

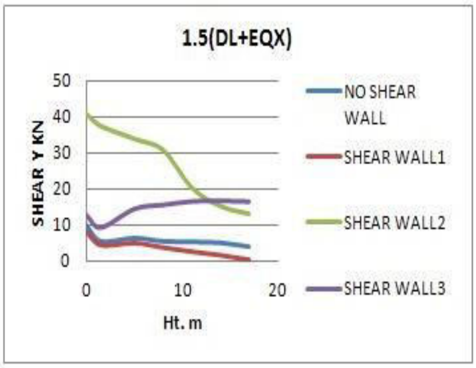
COMPARISON OF SHEAR FORCE FOR BEAM					
BEAM NO.	**LOAD COMBINATION**	**SHEAR FORCE (KN)**			
		NO SHEAR WALL	**SHEAR WALL 1**	**SHEAR WALL 2**	**SHEAR WALL 3**
7	1.5DL+1.5EQX	10.007	8.221	40.717	12.735
72	1.5DL+1.5EQX	5.424	4.508	37.386	9.332
417	1.5DL+1.5EQX	6.336	5.045	33.784	14.451
1784	1.5DL+1.5EQX	5.406	3.813	30.739	15.561
1849	1.5DL+1.5EQX	5.221	2.638	20.287	16.508
1914	1.5DL+1.5EQX	4.969	1.623	15.156	16.664
1979	1.5DL+1.5EQX	3.866	0.343	12.987	10.438

Table 4: Maximum Drift in Frame X-direction.

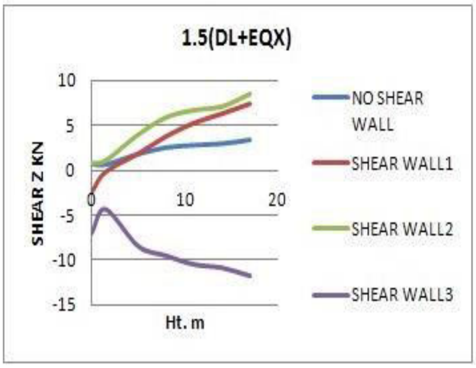
Load Combination	**Displacement 'mm'**				**Allowable Displ. mm**
	MODEL I	**MODEL II**	**MODEL III**	**MODEL IV**	
(1)	(2)	(3)	(4)	(5)	(6)
1.2DL+1.2LL+1.2EQX	42.215	11.187	9.798	11.892	80
1.5DL+1.5EQX	52.737	13.924	7.785	14.76	80
1.5DL+1.5EQZ	38.005	13.559	9.488	13.18	80

Table 5: Maximum Drift in Frame Y-direction.

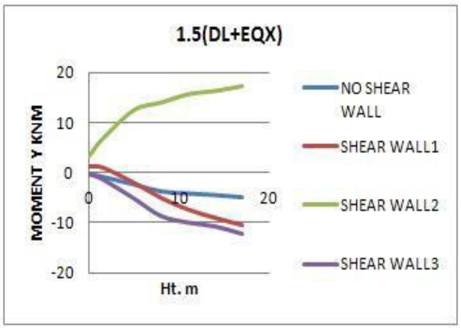
Load Combination	**Displacement 'mm'**				**Allowable Displacement mm**
	MODEL I	**MODEL II**	**MODEL III**	**MODEL IV**	
(1)	(2)	(3)	(4)	(5)	(6)
1.2DL+1.2LL+1.2EQX	42.215	11.187	9.798	11.892	80
1.5DL+1.5EQX	52.737	13.924	7.785	14.76	80
1.5DL+1.5EQZ	38.005	13.559	9.488	13.18	80



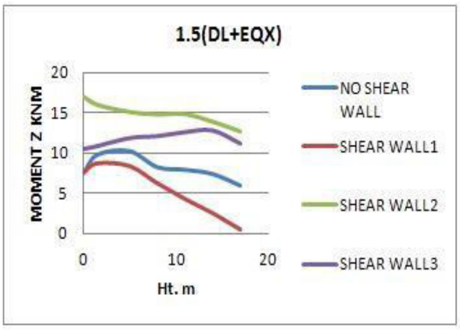
a: Graph of Shear Force Y



b: Graph of Shear Force Z



c: Graph of Bending Moment Y



d: Graph of Bending Moment Z

Discussion:-

Maximum Deflection

The lateral deflection of column in the model of shear wall provided along periphery is reduced as compared to other two models. It reduces up to 33.33% and 32.06% as compared to models with L type shear wall and cross type shear wall respectively.

Maximum Shear Force In Beams

The effect of earthquake for model III at ground storey is more as compare to top storey and middle level. e.g. for a particular beam at ground storey increases shear force up to 21.21% compared to shear wall at middle storey.

Maximum Bending Moment in Beams

The effect of earthquake for model III at top storey is more as compare to middle storey and ground level. e.g. for a particular beam at top storey increases bending moment up to 41.67% compared to bending moment at middle storey.

VI. CONCLUSION

Earthquake-resistant design requires a transition from simplified static methods to advanced dynamic procedures for accurate prediction of structural behaviour during earthquakes. Shear walls significantly improve seismic performance by increasing lateral stiffness and reducing torsional effects. Proper modelling, material characterization, and adherence to capacity design principles are essential for preventing catastrophic failure. The primary objective of earthquake-resistant design is to ensure life safety by preventing catastrophic collapse through ductile failure mechanisms rather than total rigidity. Achieving this requires a combination of accurate dynamic analysis—such as the Response Spectrum Method for multi-storey buildings—and the strategic placement of Lateral Load Resisting Systems (LFRS) like shear walls to control inter-storey drift. Ultimately, structural resilience depends on the integration of proper seismic detailing, high-quality construction materials, and, for critical structures, modern technologies like base isolation to act as seismic shock absorbers.

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