Nonlinear Time History Analysis Of G+23 RCC And Composite High-Rise Structures with Base Isolation Using Bhuj Earthquake Ground Motion

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***Abstract*—This study presents a performance-based seismic evaluation of G+23 high-rise reinforced cement concrete (RCC) and steel–concrete composite structures subjected to nonlinear time history analysis using Bhuj earthquake ground motion. Four structural configurations are analyzed: RCC fixed-base, RCC with Lead Rubber Bearing (LRB), composite fixed-base, and composite with LRB. The models are developed in ETABS with identical geometry and loading conditions. Nonlinear time history analysis is carried out considering material and geometric nonlinearities. Key response parameters such as storey displacement, storey drift, base shear, overturning moment, and time-dependent response are evaluated. The results indicate that base isolation significantly reduces seismic forces while increasing structural flexibility. Composite structures demonstrate superior performance due to reduced mass and improved ductility. The composite structure with LRB shows the best seismic performance, achieving up to 30% reduction in base shear and 40% reduction in overturning moment while maintaining drift within permissible limits.**

***Index Terms*—Nonlinear Time History Analysis, Bhuj Earthquake, Lead Rubber Bearing (LRB), Base Isolation, RCC Structure, Composite Structure, High-Rise Building, Seismic Performance, ETABS.**

I. INTRODUCTION

Rapid urbanization and limited land availability have led to the increasing construction of high-rise buildings, particularly in seismic-prone regions such as India. These structures are highly susceptible to earthquake-induced forces due to their considerable height, mass, and flexibility [2]. Accurate evaluation of seismic response is therefore essential to ensure structural safety and performance. Conventional analysis methods such as equivalent static and response spectrum analysis provide simplified estimates of seismic demand but are limited in capturing the actual dynamic behavior of structures under real earthquake excitations [1].

Nonlinear time history analysis is considered one of the most reliable methods for seismic evaluation, as it incorporates the variation of ground motion with time along with material and geometric nonlinearities [1]. The Bhuj earthquake (2001), one of the most destructive seismic events in India, provides a realistic ground motion record for advanced structural analysis. Using such real earthquake data allows for a more accurate representation of structural response, particularly in high-rise buildings where dynamic effects are significant.

In addition to analysis techniques, the structural system and seismic protection strategies play a crucial role in performance. Reinforced cement concrete (RCC) structures, although widely used, tend to experience higher seismic forces due to their greater self-weight [3]. Steel–concrete composite structures offer improved performance through reduced mass and enhanced ductility [7]. Furthermore, base isolation systems such as Lead Rubber Bearings (LRB) effectively reduce seismic forces by increasing structural flexibility and dissipating energy [5] [6]. This study aims to evaluate the seismic performance of G+23 RCC and composite structures with and without base isolation using nonlinear time history analysis under Bhuj earthquake ground motion.

II. LITERATURE REVIEW

Previous research highlights the importance of nonlinear analysis in seismic evaluation. Chopra (2012) emphasized the need for time history analysis for accurate response prediction. Kelly (1997) [5] demonstrated that LRB significantly reduces seismic forces through energy dissipation. Recent studies (Patil & Pujari, 2024 [7]) showed composite structures outperform RCC under seismic loading. However, limited research combines nonlinear time history analysis with base isolation and composite systems using real earthquake data. This study addresses that gap.

III. METHODOLOGY

TABLE 1. Methodology Adopted in the Study

Step No.	Description of Methodology
1	Selection of geometry of G+23 building and structural configuration
2	Modelling of RCC and composite structures in ETABS software
3	Assignment of material properties as per IS 456 and relevant steel codes
4	Application of dead load, live load, and floor finish loads as per IS 875
5	Definition and input of Bhuj earthquake ground motion data (time vs acceleration) in ETABS
6	Assignment of nonlinear time history load case with appropriate time step and damping parameters
7	Modelling of Lead Rubber Bearings (LRB) at foundation level with nonlinear properties
8	Nonlinear Time History Analysis of fixed-base RCC and composite models
9	Nonlinear Time History Analysis of base-isolated RCC and composite models
10	Extraction and evaluation of response parameters such as storey displacement, storey drift, base shear, and overturning moment

IV. MODELING AND DESIGN

A G+23 building is modeled in ETABS for RCC and composite systems. Loads are applied as per IS codes. Bhuj earthquake data is used for nonlinear time history analysis. LRB is modeled with nonlinear properties. Effect and damping are considered.

TABLE 2. Parameters of the developed RCC and Composite models

Parameter	Remarks	
	RCC	Composite
Structure type	G+23	G+23
Total No. of stories	23	23
Total height of building from ground floor to terrace	69m	69m
Size of column	700X300mm	600X500mm (ISHB 400)
	750X300mm	600X500mm (ISHB 450)
Size of beam	600X230mm	ISWB 550
	650X230mm	ISWB 450
Thickness of slab/deck slab	150mm	150mm
Wall thickness	230mm	230mm
Typical storey height	3m	3m
Height of parapet wall	1.5m	1.5m
Grade of concrete	M40	M40
Grade of steel (rebar)	Fe 500	Fe 500
Density of RCC	25 kN/m3	25 kN/m3
Density of steel	7850 kg/m3	7850 kg/m3
Live load on each floor except terrace	2 kN/m2	2 kN/m2
Floor finish on each floor	1.5 kN/m2	1.5 kN/m2
Soil type	Soft	Soft
Importance factor (EQ)	1.2	1.2
Response factor value	5 (SMRF)	5 (SMRF)
Damping ratios	0.05	0.05
Composite Stee	-	(Fe 345 grade)
Density of brick	20 kn/m3	20 kn/m3
Wind speed	47 m/sec^2	47 m/sec^2
Scale Factor	1176.12	1176.12

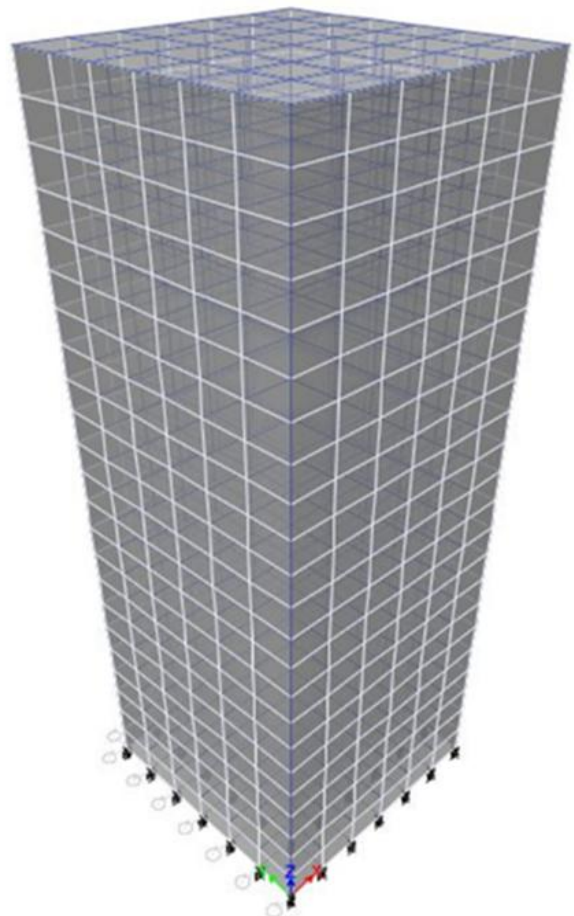

Fig. 1, Model in Etabs

V. RESULTS AND DISCUSSION

1. Base Shear

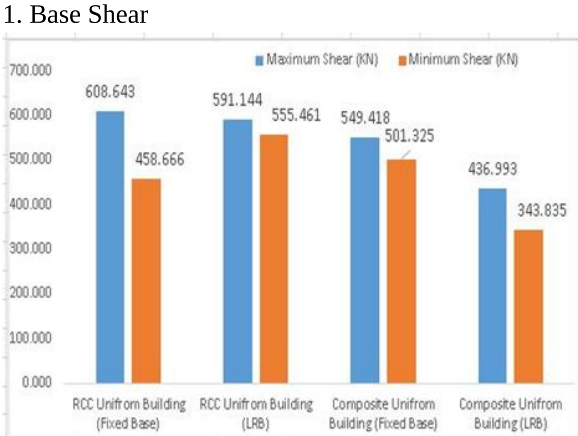

Fig. 2, Base Shear

The variation of base shear for all four models is presented in Fig. 1. The RCC fixed-base structure shows the highest base shear values of 608.64 kN (maximum) and 458.67 kN (minimum) due to its higher mass and stiffness. With the introduction of base isolation, the base shear in the RCC structure reduces to 591.14 kN, indicating the effectiveness of Lead Rubber Bearings (LRB) in reducing seismic force transmission.

Composite structures exhibit comparatively lower base shear, with 549.42 kN for fixed-base and a significantly reduced value of 436.99 kN for the LRB model. This represents an overall reduction of approximately 28–30% compared to the RCC fixed-base model. The reduction in base shear is primarily due to the increased flexibility and energy dissipation capacity provided by the isolator, along with the reduced mass of composite structures.

2. Storey Displacement

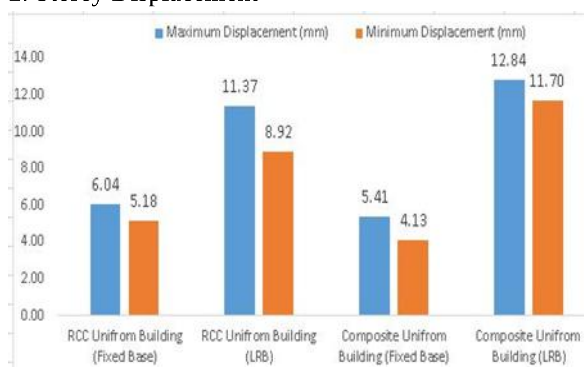

Fig. 3, Storey Displacement

The maximum and minimum storey displacement values are shown in Fig. 2. The RCC fixed-base structure records a maximum displacement of 6.04 mm, which increases to 11.37 mm after the introduction of base isolation. Similarly, composite structures show a displacement of 5.41 mm under fixed-base conditions, which increases significantly to 12.84 mm with LRB.

The increase in displacement is attributed to the flexibility introduced by the isolator, which allows the structure to undergo larger movements while reducing force demand. Although the composite structure with LRB exhibits the highest displacement, this behavior is desirable in seismic design as it indicates improved energy absorption and reduced structural damage.

3. Overturning Moment

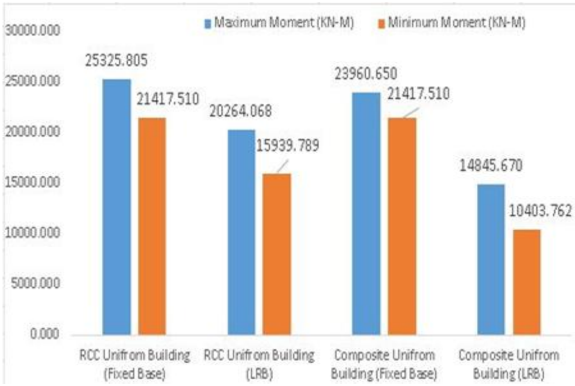

Fig. 4, Overturning Moment

The overturning moment values for all models are illustrated in Fig. 3. The RCC fixed-base structure shows the highest overturning moment of 25325.81 kN-m, indicating maximum seismic demand. With base isolation, the overturning moment reduces to 20264.07 kN-m, demonstrating the effectiveness of LRB.

Composite structures also show reduced overturning moments, with 23960.65 kN-m for fixed-base and a significantly lower value of 14845.67 kN-m for the LRB model. This corresponds to an approximate reduction of 40%, indicating improved structural stability. The reduction is mainly due to decreased inertia forces and increased time period of the structure.

4. Storey Drift

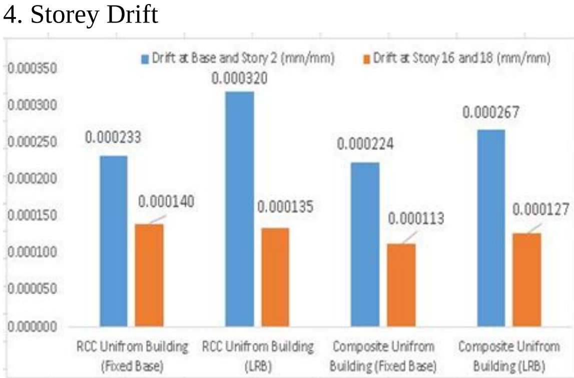

Fig. 5, Storey Drift

The storey drift variation is presented in Fig. 4 for both lower (base to 2nd storey) and higher levels (16th to 18th storey). The RCC fixed-base structure shows drift values of 0.000233 at lower storeys and 0.000140 at higher storeys. With base isolation, the drift increases at lower levels to 0.000320, while it slightly reduces at higher levels.

Composite structures show improved performance with drift values of 0.000224 (fixed-base) and 0.000267 (LRB) at lower storeys, and comparatively lower values at higher storeys. Despite the increase in drift in base-isolated models, all values remain well within permissible limits as per IS 1893, ensuring structural safety. The results indicate that drift is more concentrated in lower storeys, while upper storeys experience reduced deformation all values remain within permissible limits as per IS 1893 (Part 1): 2016 [2].

VI. CONCLUSION

The present study evaluates the seismic performance of G+23 high-rise RCC and steel–concrete composite structures using nonlinear time history analysis under Bhuj earthquake ground motion, considering both fixed-base and base-isolated conditions. The results demonstrate that nonlinear time history analysis provides a realistic representation of structural behavior by capturing time-dependent response under actual earthquake excitation.

The RCC fixed-base structure exhibits the highest seismic demand in terms of base shear, displacement, and overturning moment due to its higher self-weight and stiffness. The introduction of Lead Rubber Bearings (LRB) significantly reduces seismic forces by increasing structural flexibility and dissipating energy, although it leads to an increase in displacement. This increase in displacement is acceptable and desirable, as it indicates improved energy absorption capacity and reduced force transmission to the superstructure.

Composite structures consistently show better performance compared to RCC structures due to their reduced mass and enhanced ductility. The composite structure with base isolation achieves the most efficient seismic response, with a reduction of approximately 28–40% in base shear and overturning moment while maintaining storey drift within permissible limits. Therefore, the combined use of steel–concrete composite construction and base isolation is highly effective for improving the seismic performance and safety of high-rise buildings in earthquake-prone regions.

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