

SEISMIC RESILIENCE OF G+19 COMPOSITE COLUMN STRUCTURE WITH BASE ISOLATION TECHNIQUE IN SAP

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ABSTRACT

Earthquakes are very destructive natural disasters that constantly ruin buildings, cause them to fall down. Thus, the corresponding study is very essential. A technique is used to protect building for earthquake damage that is base isolation. In the present work, G+19 composite column structure was analyzed using different base isolation techniques in severe seismic zone. As per Indian standard guidelines created various structural model using structural analysis program software. In present study, three types of models that were considered i.e. fixed base structure, lead rubber bearing isolation and friction pendulum isolation. Also, to analyze seismic response of structure time history analysis method was used. Four parameters were considered for comparison i.e. base shear, storey displacement, storey drift, natural time period seismic condition. While comparing base isolation with fixed base structure it reduces earthquake forces and displacement. Following result found in the present work: for high rise building, the friction pendulum isolator as compared to lead rubber bearing isolator provides greater seismic response and reduces effect of earthquake forces. By restricting force transmission and structural movement, base isolation improves seismic safety and resilience. Hence, base isolation is an effective strategy for protecting high-rise buildings located in severe seismic zone.

KEYWORDS: Base isolation, Seismic analysis, Friction Pendulum System, Lead Rubber Bearing Isolator, Composite Column Building, Seismic response

INTRODUCTION

Earthquakes are very destructive natural disasters that constantly ruin buildings, cause them to fall down, take many lives, and cost a lot of money (Zhang and Lu, 2024). An entire structure or a disproportionately significant chunk of it collapses as a result of an initial local failure spreading from element to element (Athira and Kolakkattil, 2025). This has given rise to engineers and scientists to develop innovative techniques and methods to defend the buildings and structures from the destructive forces of earthquakes (Subramani et. al., 2014).

Recent earthquakes give engineers and scientists high understanding into how different structures perform under unstable seismic and foundation conditions (Subramani et. al., 2014). Many researchers worked to functional the base isolation method so that it would work better and have fewer problems because it is so useful (Matteo et. al., 2019). Seismic isolation systems are at the forefront of these technologies, and they are placed between a building's structure and its foundation (Zhang and Lu, 2024). High-level seismic design strategies, namely seismic isolation and shaking control (dampers) design, have been used to produce (Gimenez, 2022).

Many buildings have been designed on several kinds of seismic bearings, and these structures have proven to perform better during earthquakes (Santhosh et al., 2013). In reality, this approach is put into action by placing low lateral stiffness devices between the structure and its foundations. This movement divides the structure being supported from the movement of the ground during seismic (Domenico et. al., 2020). A technique for helping structural performance that is based on the demand reduction program is seismic isolation of structures. In order to lessen the seismic response of that portion during seismic stimulation, it is used to remove entire or a member of the structure from the ground or other structural elements (Ghasemi and Talacitaba, 2020).

High damping rubber bearings, friction pendulum system, and other systems have been well reliable (Zhang and Lu, 2024). Currently there are five important types of isolators in use: lead rubber bearings, friction pendulum bearings, elastomeric rubber bearings, high damping rubber bearings, and low damping rubber bearings (Tanwer et. al., 2019). These have been carefully compared with structures that are fixed to the ground for time period, base shear, storey drift and storey displacement (Tanwer et. al., 2019). A base isolation system is a method introduced for divides the structure from hazardous seismic waves and it will save the super structures from absorbing earthquake force (Tanwer et. al., 2019). The most effective finding for a wide range of seismic design problems is proven to be the base isolation system (Tanwer et. al., 2019).

Isolation systems are generally used in both buildings and bridges, with rubber bearings and friction pendulum bearings understand as the two most commonly applied techniques (Wu and Ou, 2020). Rubber bearings specifically offer small

isolation (lateral) stiffness combined with good vertical bearing capacity (Wu and Ou, 2020). These bearings dissipate earthquake energy when their rubber layers go through cyclic deformation, changing mechanical energy into heat during earthquakes (Bermany et. al., 2025).

Various researchers have carried out studies on the topic of seismic resilience of G+19 composite column structure with base isolation technique in structural analysis program are as follows: Sarno et. al. 2011, Lipte et. al. 2018, Sahu and Sahu 2019, Domenico et al 2020, Patil and John 2021, Vaiana et. al. 2021, Shakouri et. al. 2021, Tanwer et. al. 2019, Forcellini and Kalfas 2023, Gambiro et. al. 2023. Also, the following reviewed literature on the corresponding topic are given in detail: Zhang and Lu (2024) demonstrated that high damping rubber bearings with better stiffness properties successfully restrict maximum deformations, as their equal stiffness coefficient increases across deformation validated through numerical and experimental testing. Akazawa et al. (2025) conducted full-scale shaking table tests were supervised on a three-story base-isolated hospital model. Experiments revealed that while low-contact pressure and low-velocity conditions maximize the sliding coefficient, a low friction coefficient protects medical equipment throughout near-fault and long-period ground motions. Santhosh et al. (2013) demonstrated that the effectiveness of seismic isolation of six storey structure under both fixed and isolated condition. The comparison shows that isolated structure considerably lower floor acceleration, inter-storey drifts and storey shear forces. Ghasemi and Talaeitaba (2020) analyzed twelve structures of eight to twenty-four floors were designed in fixed and isolation. The results also exhibited that, unlike fixed-base structures, the seismic design level of beams and columns did not affect the response modification factor of isolated structures. Subramani et al. (2014) exhibited an overall overview of base isolation techniques, highlighting that incorporating additional damping effectively lowers seismic responses through diverse ground motions. Reddy and Ramesh (2015) analyzed two models of G+5 and G+13 structures, using base isolation system in ETABS. The mode period, base shear, acceleration and displacement are compared for response spectrum and time history analysis for fixed base and base isolated buildings.

On the basis of aforementioned reviewed literature following research gap were found: a) None of the reviewed studies have analyzed high-rise G+19 composite column structures using base isolation; b) none of the reviewed studies have analyzed combined behaviour of lead rubber bearings and friction pendulum bearings with composite columns using structural analysis program tool; and c) none of the reviewed studies have analyzed and compared the fixed-base and base-isolated G+19 composite structures under near-fault and long-period ground motions.

On the aforementioned research gaps following objectives are performed in the present study: a) To prepare and analyze the model corresponding to the G+19 composite column structure with fixed-base and base-isolated bearings; b) to assess the seismic response of the structure in terms of storey displacement, storey drift, base shear, and natural time period under fixed-base and base-isolated conditions; c) to compare the effectiveness of lead rubber bearings and friction pendulum bearings for improving the seismic performance of the G+19 composite structure; to assess the structural behaviour of the fixed-base and base-isolated G+19 composite buildings under near-fault and long-period ground motions.

METHODOLOGY

In this study, the seismic performance of a multi-storey composite column building consisting of nineteen storeys (G+19) was examined. Lead rubber bearing isolators and friction pendulum isolators both are base isolation system was analyze in structural analysis program software. The building is in seismic zone V, and the analysis was done with the provisions of Indian standard. Time history analysis methos was used to assess the earthquake loading.

Lead Rubber Base Isolation System

Three essential parts such as rubber, steel and lead plug are included in lead rubber bearing, which are commonly placed in layers. Flexibility and the capability to transfer and recover its original condition are provided by rubber. If structure has not returned to its original condition when disturbance ends, the rubber bearings will bring it back slowly to its initial condition (Agrawal et. al., 2025).

Friction Pendulum Isolation System

Combination concept of sliding bearings with a pendulum type response generates a theoretically seismic isolation system known as a friction pendulum system. A bearing material faces the slider and contacts the polished chrome surface, generating a maximum sliding friction coefficient of 0.1 or less at high sliding velocities, and a minimum friction coefficient of 0.05 or less at very low sliding velocities (Sahu and Sahu, 2019).

The study consists of structural configuration of building height 60m, G+19 composite column framed structure (ISHB 350), plan of 5x4 bays each 3m wide all summarised in table 1.

Table 1: Structural configuration parameters

Model parameters	Values
	G+19
Structure type	Composite Column Framed Structure (ISHB 350)
Total number of stories	G+19
Height of ground storey	3.0 m
Height of upper stories	3.0 m
Total height of the building	60 m
Number of bays in x direction	5
Number of bays in y direction	4
Width of bay in x direction	3 m
Width of bay in y direction	3 m

Table 2, including columns of 500 mm × 400 mm, beams of 350 mm × 600 mm, and a slab thickness of 130 mm. The Geometric properties inculcate for the G+19 model.

Table 2: Geometric Properties for all three models

Elements	Cross-sectional area
	G+19
Column	500mm × 400mm
Beam	350mm × 600mm
Slab thickness	130 mm

After determining the building's geometric layout, the next stage involve measuring the intrinsic properties from table 3 to the structural models.

Table 3: Intrinsic Properties of Concrete and Reinforcement

Properties (Concrete)	Values	Properties (Rebar)	Values
Grade	M40, M60	Grade	HYSD 500
Unit weight	25 KN/m ³	Mass per unit volume	7810 kg/m ³
Poisson ratio	0.2	Modulus of Elasticity	2.5×10^5 MPa
Coefficient of thermal expansion	5.5×10^{-6} /°C	Coefficient of Thermal Expansion	11.7×10^{-6} /°C
Shear modulus	11,410 MPa	Minimum Yield Strength (fy)	500 MPa
Modulus of elasticity	27,386 MPa	Minimum Tensile Strength (fu)	545 MPa
Damping ratio	5%	—	—
Compressive strength (fck)	40 MPa, 60MPa	—	—

As per Indian standard provisions in structural models (G+19) different load combination is applied in table 4.

Table 4: Examined loads

Loads	Values
	G+19
Dead load	Self-weight of beams, columns and slabs
Live load	2.5 kN/m ²

Table 5 shows the lateral load distributions used for seismic analysis according to Indian standard provisions. Special observation was made to the base-isolated models (G+19), where lower seismic forces were applied above the isolation.

Table 5: Lateral force

Parameters	G+19
Seismic zone	V
Zone factor	0.36
Importance factor	1.0
Site type	II
Response reduction factor	3
Damping	5%

Prepared three working model in which base isolation and fixed support used at base. Figure 3a shows the condition at base is fixed support (model 1), Figure 3b and 3c shows the condition used at base is lead rubber isolator (model 2) and friction pendulum isolator (model 3) respectively. By analysing models, got the following results.

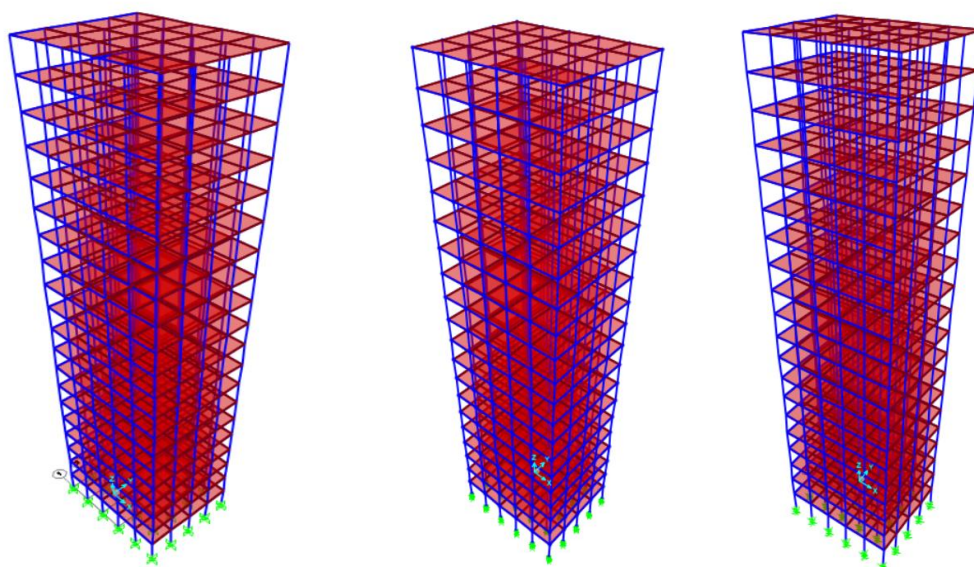


Fig 3(a, b, c): 3(a) Building Model with fixed supports, 3b) Building Model with lead rubber isolator at supports and 3(c) Building Model with friction pendulum isolator at supports.

RESULTS AND DISCUSSION

This study finds the seismic performance and strength of a composite column structure under lateral loading using time history analysis. The analytical study calculates the structural reaction of the building under lateral loading. Seismic actions of structures we have studied and got results based on key seismic response parameters such as base shear, storey displacement, storey drift, and natural time period.

Base Shear

In the present study, lowest base shear is observed in model 3 followed by model 2 and model 1. The lowest base shear is stable for the structure. Figure 6 and 7 shows, variation of base shear for the fixed base and base isolated models in X and Y direction, respectively. Figure 6 and 7 shows that, friction pendulum isolator (i.e. Model 3) is having significant performance rather than remaining. Lead Rubber isolation shows lower value of base shear compare to fixed based and higher value than friction pendulum.

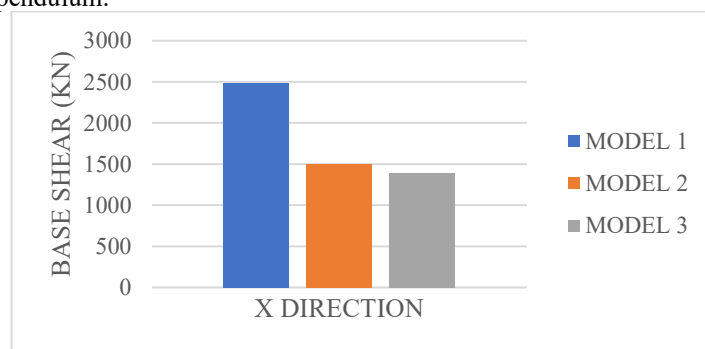


Fig 6: Variation of base shear for fixed-base and base-isolated models in X-direction.

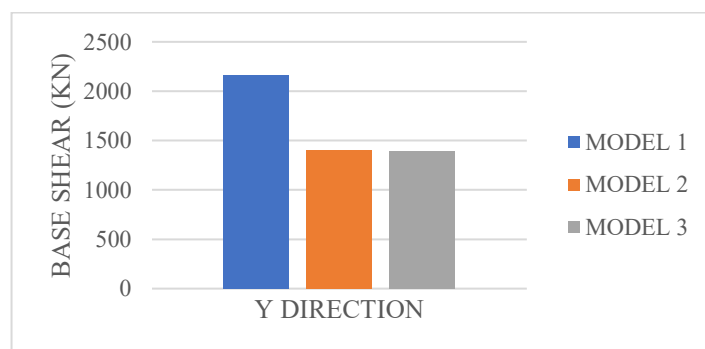


Fig 7: Variation of base shear for fixed-base and base-isolated models in Y-direction.

Storey Drift

Figure 8 shows variation of storey drift for fixed base and base isolated models (i.e., model 1, 2 and 3, respectively). From the figure 8, it is observed that, storey drift is different for all corresponding models along the height of structure. The

maximum story drift is observed in the model 1 as compared to the remaining models i.e., model 2 and 3 as given in figure 8. However, the model 3 is having lowest storey drift. It is indicated that the corresponding model 3 is suitable for the construction the structure in the seismic zones too.

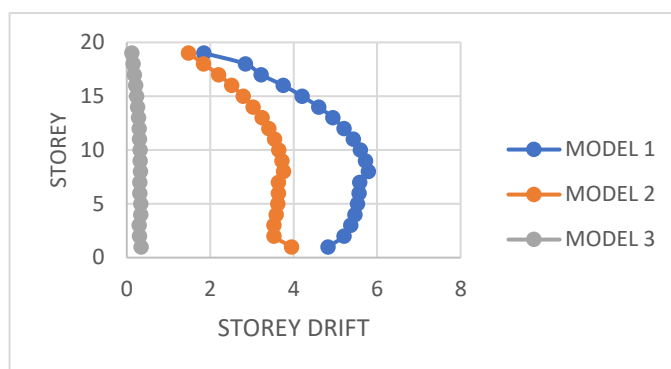


Fig 8: Variation of storey drift for fixed-base and base-isolated models.

Storey Displacement

Figure 9 shows that Variation of storey displacement for fixed base and base isolated models. It is observed that, fixed base (i.e., model 1) is having more displacement as compared with remaining models i.e. model 2 and 3. Model 3 (i.e., friction pendulum) is having lowest displacement values under seismic conditions. So, it is indicated that the model 3 is good for the corresponding conditions.

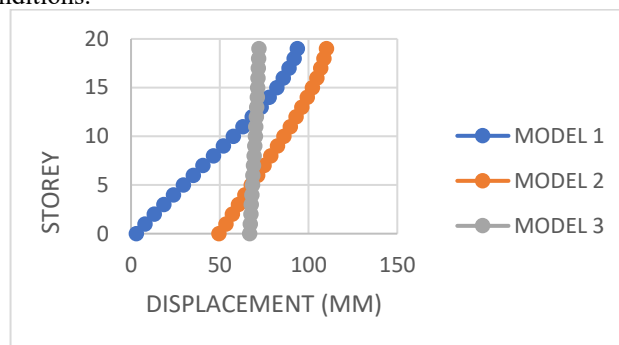


Fig. 9: Variation of storey displacement for fixed-base and base-isolated models

Time Period

Figure 10 shows comparison of natural time period for fixed base and base isolated models. Model 3 shows maximum natural time period (i.e., 0.19 to 11.72 seconds) as compared to the remaining models i.e., model 2 (0.19 to 3.96 seconds) and models 1 (0.18 to 2.68 seconds). Also, it shows that this model is best as compare to others in the corresponding conditions.

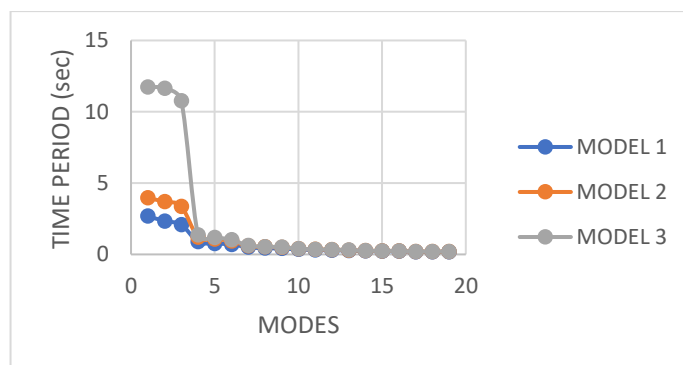


Fig 10: Comparison of natural time period for fixed-base and base-isolated models

CONCLUSION

This study assessed the lateral performance of G+19 composite column structure by structural analysis program tool. A comparable analysis was organized through fixed-base and base-isolated structural systems inclusion lead rubber bearing and friction pendulum isolation method. The outcome shows that the performance of base isolation absolutely improves the structure by lowering key impact parameters under seismic loading. Among the isolation systems thoughtfully, the friction pendulum isolator showed very good performance with the lead rubber bearing isolator in terms of reducing structural responses such as base shear, storey displacement, and storey drift. Hence, the use of base isolation series can

be considered an effectiveness for strengthening the dynamic safety and as of high-rise buildings located in earthquake-prone regions.

It is observed that after comparing all three support conditions friction pendulum isolation has significantly performed well against both, achieving up to 43.94%, 94.09%, 23.16%, loss in base shear, storey drift, and storey displacement respectively relatively fixed-base structure, we get an increase of 37.15% in natural time period. After comparing the lead rubber bearing system (Model 2) also lowered base shear (up to 39.30%) and drift (31.78%) relatively to fixed base, it noted that 17.52% higher top-storey displacement compared to fixed-base model. Generally, these results confirm that as compared to fixed support and lead rubber isolator the friction pendulum isolation system gives the most balanced and enhanced in seismic performance for the G+19 composite column structure.

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