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Seismic Analysis And Design Of Base Isolated Steel Buildings.

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Abstract - *Steel buildings often house critical infrastructure, and sensitive equipment, making their seismic resilience paramount to preventing immense economic and structural losses. Traditional fixed-base designs dissipate seismic energy through structural damage, which can risk operational continuity. Base isolation techniques offer an effective alternative by decoupling the superstructure from ground motion. This paper presents an initial review and the framework for a comprehensive comparative study focused on the seismic analysis and design of a G+10/G+20 steel building. The study evaluates and compares three distinct structural configurations: a conventional Fixed-Base system, a Lead Rubber Bearing (LRB) isolated system, and a High Damping Rubber Bearing (HDRB) isolated system. To assess their performance under varying seismic intensities, all three configurations are modeled and analyzed across Seismic Zones III, IV, and V using state-of-the-art structural analysis software (ETABS) in accordance with relevant Indian Standard (IS) codes. The primary objectives are to evaluate critical response parameters including fundamental time period, base shear, lateral displacement, and inter-story drift. This review synthesizes existing literature on Elastomeric Base Isolation systems applied to high-rise industrial frameworks, establishing the methodology for the upcoming parametric investigation. The ultimate outcome of this research aims to quantify the seismic vulnerability reduction offered by LRB and HDRB systems compared to fixed bases, providing optimal, zone-specific design recommendations for steel structures.*

Key Words: **[Base Isolation, LRB, HDRB, Steel Building, Seismic Zone, Vibration Control Methods, Comparative Study.]**

I. INTRODUCTION

Steel buildings are critical structures that house sensitive equipment. Traditional fixed-base buildings transfer all seismic forces directly to the structure, which can cause heavy structural damage and operational shutdown during an earthquake. To avoid this, base isolation technology is used to separate the building from the ground, drastically reducing the earthquake forces acting on it.

This project focuses on a comparative study of a

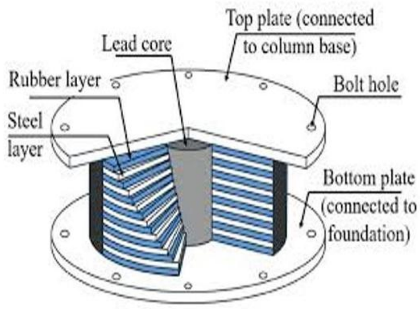


Fig.1 Lead Rubber Bearing Isolator

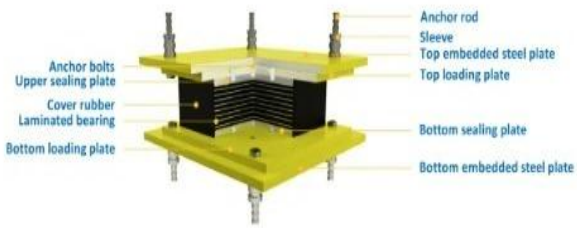


Fig.2 High Damping Rubber Bearing Isolator

Steel building using two popular isolation systems: Lead Rubber Bearings (LRB) and High Damping Rubber Bearings (HDRB).The performance of these systems will be evaluated against a conventional Fixed-Base structure. To understand their behavior under different earthquake intensities, the analysis is carried out across three seismic zones: Zone III, Zone IV, and Zone V using ETABS software as per IS 1893:2016 standards. The main goal is to compare key parameters like base shear, displacement, and time period to find the most efficient system for each zone.

II. METHODOLOGY AND MODELLING:

Design of G+10 LRB and HDRB Calculations:-

T_{fixed} = 0.528 sec (Fix base zone 5 rsult)
T_{target} = 2*0.528 = 1.056 sec (target time period should be 2 to 3 times of T_{fixed})

$(Sa/g) = 1.36 / 1.056 = 1.2879$ (0.55sec<T< 4.0 sec) IS 1893 part 1

$D_d = g.Sa.T^2 / 4\pi^2 B = (9.81*1.2879*(1.056)^2) / 4\pi^2*1.5 = 0.2378$ mm = 238 mm= 250mm

Fig 5.1 Mass Summary G+10 Fixed base zone 5
Source- Etabs Software

ΣMass=6779082.18Kg → W=M*g/1000 = 66502.80 kN.

Weight per Isolator = 66502.80kN / 35 isolators = 1900.08 kN.

Inital Input Values (G+10 Building):

Building Weight per Isolator (W): 1,900.08 kN
Target Design Displacement (D): 250 mm = 0.25 m
Target Effective Time Period (Ttarget): 1.056 sec
Outer Diameter (Do): 650 mm = 0.65 m
Lead Plug Diameter (Di for LRB): 130 mm = 0.13 m
Number of Rubber Layers (n): 22 layers
Thickness of single Rubber Layer (tr): 10 mm = 0.01 m
Thickness of Shim Plate (ts): 3 mm = 0.003 m
Shear Modulus (G): LRB = 0.4 N/mm² = 400 kN/m² and HDRB = 1.1 N/mm² =1100 kN/m²
Lead Yield Stress (σ_L): 10 N/mm² = 10,000 kN/m²
Bulk Modulus (K_{bulk}): 2,000 N/mm²
Damping Ratio (βeff): 20% = 0.20
Gravity Acceleration (g): 9.81 m/s²

Table 1 Steps to design LRB and HDRB Isolator for G+10 steel building

Sr. No.	Steps	LRB (Lead Rubber Bearing)	HDRB (High Damping Rubber Bearing)
1.	Total rubber thickness (Tr)	Tr=n.tr = 22×10 = 220mm	Tr=n.tr = 22×10 = 220mm
2.	Total Bearing height (h)	h=n.tr-(n-1)ts = (22×10) + (21×3) =283mm	h=n.tr-(n-1)ts = (22×10) + (21×3) = 283mm
3.	Bonded Rubber Area (A)	$A=\pi/4[(Do)^2] = \pi/4[(0.65)^2] = 0.33183$ m² $A=\pi/4[(Do)^2] = \pi/4[(0.13)^2] = 0.01327$ m² $A=\pi/4[(Do-tc)^2-Di^2] = \pi/4[(0.65)^2-(0.13)^2] = 0.031856$ m²	$A=\pi/4[(Do)^2] = \pi/4[(0.65)^2] = 0.33183$ m²
4.	Characteristic Strength (Qd)	$Qd= \sigma_L A_L$ = 10000×0.01327 =132.73kN	Qd=0
5.	Post yield/ horizontal stiffness (kd/kh)	Kh=kd= G.A/Tr =400×0.31856 / 0.22 =579.20 kn/m	Kh=kd= G.A/Tr =1100×0.33183 / 0.22 =1659.15 kN/m
6.	Effective Stiffness (keff)	$Keff=Kd + Qd/D_d$ = 579.20 +(132.73/0.25) =1110.12 kN/m =1.1101 kN/mm	$Keff=W/g (2\pi/Teff)^2$ =1900.08/9.81 × $(2\pi/2.196)^2$ =158 kN/m =1.5855 kN/mm
7.	Shape Factor (S)	S= (Do – Di) / 4tr = (650-130) / (4×10) = 13	S= Do / 4tr = 650 / (4×10) = 16.25
8.	Compression Modulus (Ec)	$Ec=(1/GS^2F+4/3 K_{bulk})^{-1}$ $=[(1 / 6×0.4×13^2 × 0.69) + (4/3×2000)]^{-1}$ = 235.57 N/mm²	$Ec=(1/GS^2F + 4/3K_{bulk})^{-1}$ $=[(1 / 6× 1.1 ×16.25^2 × 1.0) + (4/3×2000)]^{-1}$ = 806.0 N/mm²
9.	Vertical stiffness (Kv)	$Kv = A.E_c / Tr$ = 0.31856×235570 /0.22 =341105.36 kN/m	$Kv = A.E_c / Tr$ = 0.33183×806000 /0.22 =1215704.45 kN/m
10.	Effective Time period (Teff)	Teff = $2\pi\sqrt{W/Keff . g}$ $=2\pi \sqrt{1900.08/1110.12×9.81}$ =2.624 Second	Teff = $2\pi\sqrt{W/Keff . g}$ $=2\pi \sqrt{1900.08/1585.5×9.81}$ =2.196 Second
11.	Energy dissipated per cycle (W_D/E_{loop})	$W_D = 2\pi.keff.\beta.D^2$ $=2\pi × 1110.12 ×0.20×0.25^2$ =87.18 kN.m	$W_D = 2\pi.keff.\beta.D^2$ $=2\pi × 1585.50 ×0.20×0.25^2$ =124.52 kN.m
12.	Damping reduction factor (1/B)	$1/B = 0.25 (1-ln\beta_{eff})$ =0.25(1-(-1.6090)) =0.25(1-2.6094)= 0.65235 B = 1.533	$1/B = 0.25 (1-ln\beta_{eff})$ =0.25(1-(-1.6090)) =0.25(1-2.6094)= 0.65235 B = 1.533

13.	Maximum Displacement (D)	D = g.(Sa/g) . $Teff^2/4\pi^2B$ =(1.36*9.81*2.624) / ($4\pi^2$*1.5) = 591 mm For β=20% → B=1.5 (ASCE 7) 0.55s< T_{eff} < 4.0s → (Sa/g) = 1.36/T_{eff} {IS 1893(1)}	D = g.(Sa/g) . $Teff^2/4\pi^2B$ =(1.36*9.81*2.196) / ($4\pi^2$*1.5) = 495 mm For β=20% → B=1.5 (ASCE 7) 0.55s< T_{eff} < 4.0s → (Sa/g) = 1.36/T_{eff} {IS 1893(1)}

Design of G+20 LRB and HDRB Calculations:-
T_{fixed} = 1.098 sec (Fix base zone 5 etabs result)
T_{target} = 2*1.098 = 2.196 sec (target time period should be 2 to 3 times of T_{fixed})
(Sa/g) = 1.36 / 2.196 = 0.6193 (0.55sec<T< 4.0 sec) IS 1893 part 1
D_d = g.Sa.T^2 / $4\pi^2B$ = (9.81*0.6193*$(2.196)^2$) / $4\pi^2$*1.5 = 0.0.4947 mm = 495 mm= 500mm

Fig 5.2 Mass Summary G+20 Fixed base zone 5
Source- Etabs Software
ΣMass=10477195.61 Kg → W=M*g/1000 = 102781.29 kN.
Weight per Isolator = 102781.29kN / 35 isolators= 2936.6 kN.
Inital Input Values (G+20 Building):
Building Weight per Isolator (W): 2936.6 kN (From Fixed base zone 5 etabs)
Target Design Displacement (D): 500 mm = 0.500 m
Target Effective Time Period (Teff for HDRB): 2.196 sec
Outer Diameter (Do): 650 mm = 0.65 m
Lead Plug Diameter (Di for LRB): 130 mm = 0.13 m
Number of Rubber Layers (n): 22 layers
Thickness of single Rubber Layer (tr): 10 mm = 0.01 m
Thickness of Shim Plate (ts): 3 mm = 0.003 m
Shear Modulus (G): LRB = 0.4 N/mm² = 400 kN/m² and HDRB = 1.1 N/mm² =1100 kN/m²
Lead Yield Stress (σ_L): 10 N/mm² = 10,000 kN/m²
Bulk Modulus ($K_{bulk)}$: 2,000 N/mm²
Damping Ratio (βeff): 20% = 0.20
Gravity Acceleration (g): 9.81 m/s²

Table 2 Steps to design LRB and HDRB Isolator for G+20 steel building

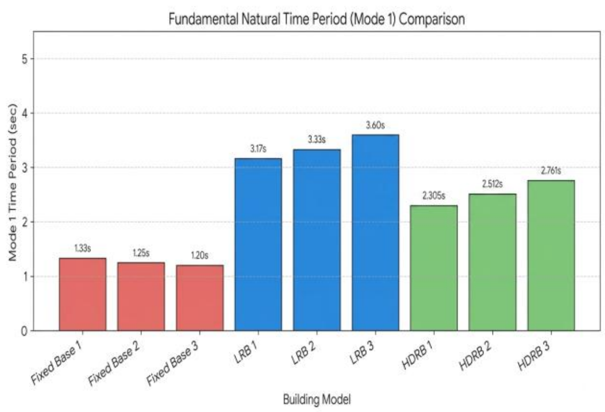
Sr. No.	Steps	LRB (Lead Rubber Bearing) Zone 5	HDRB (High Damping Rubber Bearing) Zone 5
1.	Total rubber thickness (Tr)	Tr=n.tr = 22×10 = 220mm	Tr=n.tr = 22×10 = 220mm
2.	Total Bearing height (h)	h=n.tr-(n-1)ts = (22×10) + (21×3) =283mm	h=n.tr-(n-1).ts = (22×10) + (21×3) = 283mm
3.	Bonded Rubber Area (A)	A=π/4[(Do)²] = π/4[(0.65)²] =0.33183 m² A=π/4[(Do)²] = π/4[(0.13)²] =0.01327 m² A=π/4[(Do-tc)²-Di²] = π/4[(0.65)²-(0.13)²] =0.031856 m²	A=π/4[(Do)²] = π/4[(0.65)²] =0.33183 m²
4.	Characteristic Strength (Qd)	Qd= σ_L A_L = 10000×0.01327 =132.73kN	Qd=0
5.	Post yield/ horizontal stiffness (kd/kh)	Kh=kd= G.A/Tr =400×0.31856 / 0.22 =579.20 kn/m	Kh=kd= G.A/Tr =1100×0.33183 / 0.22 =1659.15 kN/m
6.	Effective Stiffness (keff)	Keff=Kd + Qd/D_d = 579.20 +(132.73/0.500) =844.66 kN/m =0.8446 kN/mm	Keff=W/g $(2\pi/Teff)^2$ =2936.6/9.81 × $(2\pi/2.196)^2$ =2450.44 kN/m =2.4504 kN/mm
7.	Shape Factor (S)	S= (Do – Di) / 4tr = (650-130) / (4×10) = 13	S= Do / 4tr = 650 / (4×10) = 16.25
8.	Compression Modulus (Ec)	Diameter ratio (rd)=Do/Di =650 130 =5 →central hole factor F=0.69 Ec=(1/GS²F+4/3 K_{bulk}) $^{-1}$ =[(1 / 6×0.4×13² × 0.69) + (4/3×2000)] $^{-1}$ = 235.57 N/mm²	No central hole → F=1.0 Ec=(1/GS²F + 4/3K_{bulk}) $^{-1}$ =[(1 / 6× 1.1 ×16.25² × 1.0) + (4/3×2000)] $^{-1}$ = 806.0 N/mm²

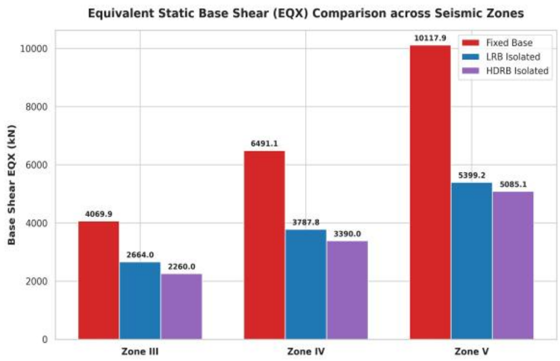
9.	Vertical stiffness (Kv)	$Kv = A.E_c / Tr$ = 0.31856×235570 /0.22 =341105.36 kN/m	$Kv = A.E_c / Tr$ = 0.33183×806000 /0.22 =1215704.45 kN/m
10.	Effective Time period (Teff)	$Teff = 2\pi\sqrt{W/Keff.g}$ $=2\pi\sqrt{2936.61/844.66 \times 9.81}$ =3.740 Second	$Teff = 2\pi\sqrt{W/Keff.g}$ $=2\pi\sqrt{2936.61/2450.44 \times 9.81}$ =2.196 Second
11.	Energy dissipated per cycle (W_D/E_{loop})	$W_D = 2\pi.keff.\beta.D^2$ $=2\pi \times 844.60 \times 0.20 \times 0.50^2$ =265.36 kN.m	$W_D = 2\pi.keff.\beta.D^2$ $=2\pi \times 2450.44 \times 0.20 \times 0.50^2$ =769.83 kN.m
12.	Damping reduction factor (1/B)	$1/B = 0.25\ (1-\ln\beta_{eff})$ =0.25(1-(-1.6090)) =0.25(1-2.6094)= 0.65235 B = 1.533	$1/B = 0.25\ (1-\ln\beta_{eff})$ =0.25(1-(-1.6090)) =0.25(1-2.6094)= 0.65235 B = 1.533
13.	Maximum Displacement (D)	$D = g.(Sa/g) . Teff^2/4\pi^2B$ $=(1.36*9.81*3.740) / (4\pi^2*1.5)$ = 591 mm For β=20% → B=1.5 (ASCE 7) $0.55s < T_{eff} < 4.0s$ → $(Sa/g) = 1.36/T_{eff}$ {IS 1893(1)}	$D = g.(Sa/g) . Teff^2/4\pi^2B$ $=(1.36*9.81*2.196) / (4\pi^2*1.5)$ = 495 mm For β=20% → B=1.5 (ASCE 7) $0.55s < T_{eff} < 4.0s$ → $(Sa/g) = 1.36/T_{eff}$ {IS 1893(1)}

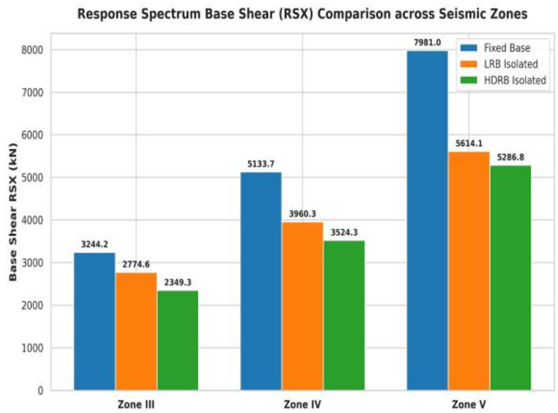
III. RESULTS:

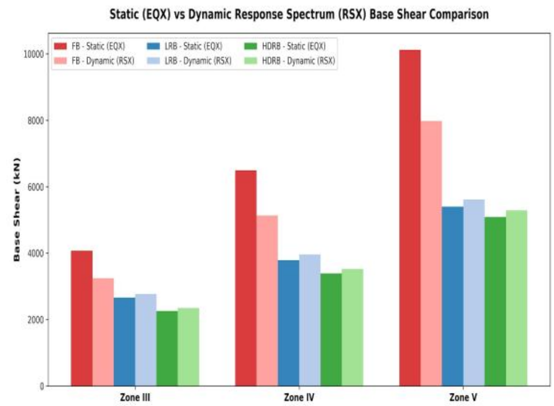
G+10 Results:

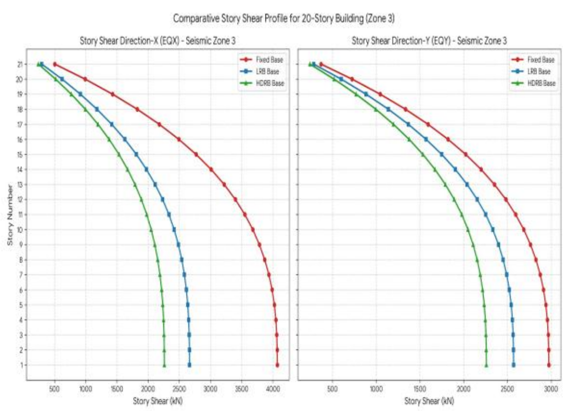
Time period comparison

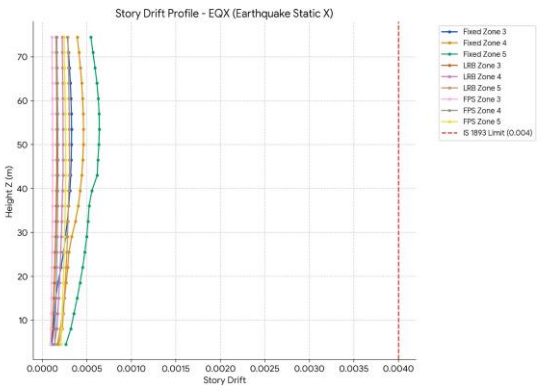




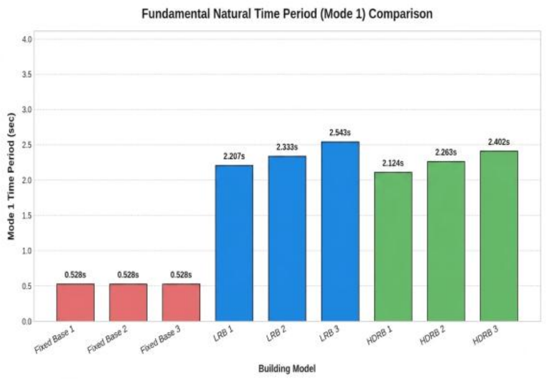


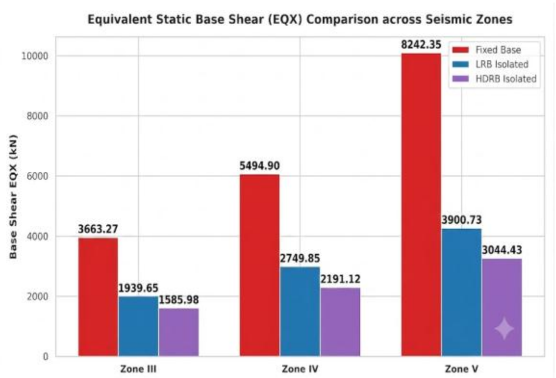


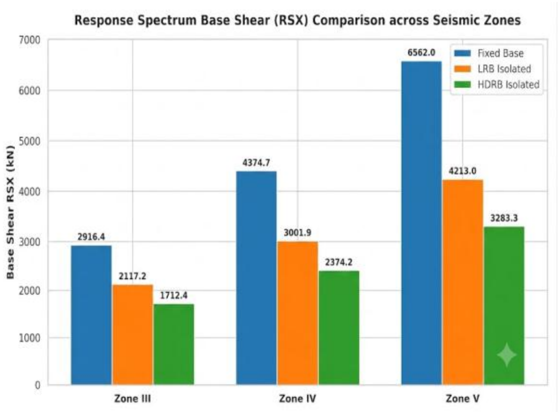


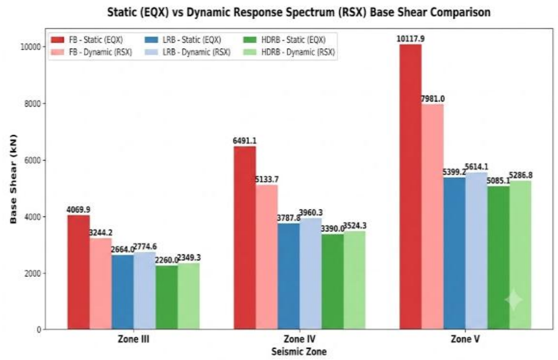


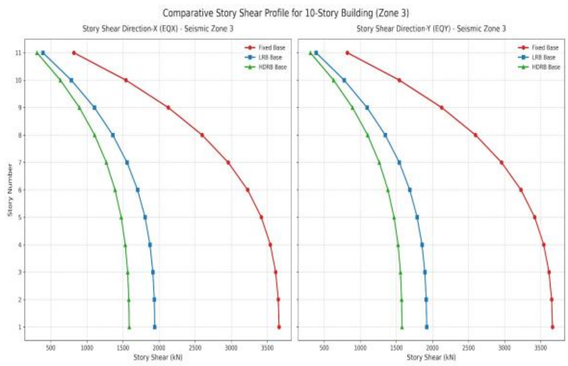
G+20 Results:

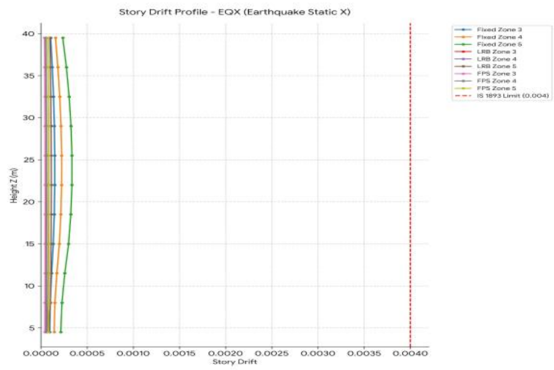












IV. GAPS IN LITERATURE REVIEW

1. Most existing studies focus on residential or high-rise buildings, while detailed seismic studies on steel buildings are comparatively limited
2.Many studies analyze base isolated buildings but do not provide a direct comparison between fixed base and base isolated steel structures.
3. Insufficient attention is given to the seismic response of steel buildings with base isolation systems.

IV. CONCLUSION

The comparative study confirms that base isolation is an effective and reliable seismic protection technique for low-rise steel buildings, especially in moderate to high seismic zones. Overall, the base isolated G+10/G+20 steel building demonstrates superior seismic performance.

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