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ANALYSIS AND DESIGN OF SEISMIC ISOLATED RC BRIDGE USING BEARINGS

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Abstract *Seismic isolation is recognized as one of the most effective strategies for mitigating earthquake hazards. In bridges, seismic isolation bearings are typically installed between the substructure and superstructure, effectively decoupling the superstructure from the horizontal components of ground motion. As a result, during an earthquake, inelastic deformations are concentrated in the isolation bearings, reducing the forces transmitted to the substructure and superstructure, thereby allowing them to remain elastic. This study focuses on an RC T-beam bridge equipped with different bearing systems, including elastomeric bearings and lead rubber bearings. Using Finite Element Analysis, the behavior of the isolated bridge is examined. The bridge's performance is assessed through modal and time history analyses, evaluating parameters such as fundamental time period, base shear, acceleration, and displacement. The findings suggest that elastomeric bearings can be effectively replaced with lead rubber bearings, as they increase the fundamental time period and significantly reduce the base shear coming on the piers.*

Key Words: Seismic isolation, Ground motion, Seismic isolation bearings, elastomeric bearings, lead rubber bearings, Finite element analysis, time history analysis.

1.INTRODUCTION

Bridges are structures built to span physical obstacles like water, valleys, or roads, providing a passage over them. They are essential for transportation, connecting people and places that would otherwise be inaccessible or require lengthy detours. Bridges play a crucial role in modern infrastructure, connecting communities and facilitating the flow of goods, services, and people. They are a testament to human ingenuity, embodying our ability to overcome obstacles and connect distant lands. Bridges are an important infrastructure because they allow people to cross waterways, canyons, and other obstacles easily and safely, which would otherwise be difficult or impossible to navigate. Bridges are critical links in transportation networks, connecting roads, highways, and railway systems, helping reduce traffic congestion and improve travel time. In addition, they help to spur economic growth by enabling the efficient movement of goods and people and facilitating the development of new business and residential areas. Whether a simple footbridge over a creek or a massive suspension bridge spanning a bay, the different types of bridges play an integral role in shaping our world and supporting the growth and prosperity of our communities.

1.1 Elastomeric bearing

Elastomeric bearings are one of the most common types of bridge bearings, made from elastomers, usually rubber, which may be reinforced with steel laminates. These bearings provide flexibility for bridges by allowing limited movement in multiple directions, accommodating small rotations, and providing essential resilience to handle minor displacements due to traffic loads, temperature changes, and seismic forces. elastomeric bearing isolators consist of upper and lower steel plates with a series of alternating layers of natural, or synthetic, rubber bonded to intermediate steel shim plates. The rubber provides lateral flexibility while the steel provides vertical stiffness.

1.2 Lead rubber bearing

Lead Rubber Bearings (LRB) are specialized seismic bearings designed to provide both load support and seismic isolation for structures like bridges and buildings in earthquake-prone areas. The bearing combines an elastomer (rubber) with a lead core, which together help isolate the superstructure from ground motion, reducing the amount of seismic force transmitted during an earthquake. Lead core is Positioned at the centre of the bearing, the lead core serves as an energy-dissipating element by absorbing seismic energy. Lead is used because it can undergo plastic deformation (permanent change in shape) repeatedly without losing its structural integrity. Rubber Layers Surrounding the lead core are layers of natural or synthetic rubber. These rubber layers absorb horizontal movements and provide flexibility. Steel plates are embedded within the rubber layers, reinforcing the bearing, controlling deformation, and increasing its load-bearing capacity. Outer steel plates are located on the top and bottom of the bearing, these plates connect the bearing to the bridge superstructure and substructure.

2. OBJECTIVES

1. To design the Elastomeric bearing for R C T Beam bridge in accordance with IRC 83 (Part 2) 2018

2. To design the Lead rubber bearing for R C T Beam bridge in accordance with AASHTO 2007
3. To perform Time history analysis using ground motion recorded at EL-Centro during 1940 Imperial valley earthquake and Bhuj earthquake.
4. To assess behavior of R C T Beam bridge with two different isolators
5. To evaluate seismic response of R C T Beam bridge with Elastomeric bearing and lead rubber bearing.
6. To evaluate Modal parameters, Base Shear, Acceleration and Displacements of R C T Beam bridge with two different isolators.
7. To compare R C T Beam bridge with Elastomeric bearing and lead rubber bearing.

3. METHODOLOGY

1. **Design of Elastomeric bearing and Lead rubber bearing:** The design of elastomeric bearing is done as per IRC 83(Part 2): 2018 The isolation design of a bridge with elastomeric bearings primarily involves the determination of cross-sectional area of the bearing, total thickness of rubber layers, instantaneous compression modulus of the elastomer, shear modulus of the elastomer, vertical and shear stiffness of the isolator. Design of lead rubber bearing is done as per American Association of State Highway and Transportation Officials (AASHTO):2007 The isolation design of a bridge with lead rubber bearings primarily involves the determination of the properties of the isolators themselves such as lead core diameter, isolator diameter, thickness and number of rubber layers, thickness and number of steel reinforcing plates.

2. **Bridge geometry:** the study focused on the RC T Beam bridge which is 48m long and 8.7m wide and consists of three span continuous reinforced concrete girders. Deck slab consists of 280 mm deep supported by three reinforced concrete girders of 1400 mm depth. Three main girders are provided at 2.5m centers. Solid piers of 1.6 m width and 1.2 m thick of rest on firm soil strata. The seismic analysis considered both elastomeric bearing and lead rubber bearing.

3. **Numerical Analysis:** Finite Element Method (FEM) software SAP2000 V14 was employed for numerical analysis. Time history analysis of ground motion recorded at EL-Centro during 1940 Imperial Valley earthquake and Bhuj earthquake during 2001 were defined. The RC T Beam bridge was modelled in the software. The analysis covered using both elastomeric bearing and lead rubber bearing.

4. **Seismic Analysis Parameters:** The evaluations included fixed base analyses,examining parameters such as base shear, acceleration, displacement, and modal characteristics for both elastomeric and lead rubber bearing.

5. **Analysis Sequencing:** The analyses were systematically arranged to cover seismic considerations for RC T beam bridge. Sequentially, the study investigated the seismic performance of RC T beam bridge with elastomeric bearing and lead rubber bearing.

4. PROBLEM FORMULATION AND ANALYSIS

The design of elastomeric bearing is done as per IRC 83(Part 2): 2018. Design of lead rubber bearing is done as per American Association of State Highway and Transportation Officials (AASHTO):2007 The seismic analysis considered both elastomeric bearing and lead rubber bearing. Finite Element Method (FEM) software SAP2000 V14 was employed for numerical analysis. Time history analysis of ground motion recorded at EL-Centro during 1940 Imperial Valley earthquake and Bhuj earthquake during 2001 were defined. The evaluations included fixed base analyses, examining parameters such as base shear, acceleration, displacement, and modal characteristics for both elastomeric and lead rubber bearing.

5. PRESENT STUDY

The bridge is 48 m long and 8.7 m wide and consists of three span continuous reinforced concrete girders. Deck slab consists of 280 mm deep supported by three reinforced concrete girders of 1400 mm depth. Three main girders are provided at 2.5m centers. Solid piers of 1.6 m width and 1.2 m thick of rest on firm soil strata. Bridge is located in seismic zone IV. Grade of concrete and steel are M25 and Fe500, respectively.

6 DESIGN OF BEARINGS FOR SEISMIC ISOLATION

Table -1: Design of elastomeric bearing

Design of an elastomeric bearing				
Sl no	**Parameters**	**Notation**	**Values**	**References**
1	Shear modulus of elastomer (MPa)	G	0.7	IRC 83 Table 2
2	Bulk modulus of elastomer (MPa)	E_b	2000	IRC 83 Clause 5.1
3	Yield stress of steel (MPa)	F_Y	235	IRC 83 Clause 4.2.5
4	Type loading factor	K_L	1	IRC 83 Clause 5.1.3
5	Co efficient for induced tensile strength	K_h	1	IRC 83 Clause 5.1.3.5
6	Stress correction factor	K_P	1.3	IRC 83 Clause 5.1.3.5
7	Partial safety factor	γ	1	IRC 83 Clause 5.1.3.5
8	Rotational factor	K_{rd}	3	IRC 83 Clause 5.1.3.5
9	Co efficient for concrete	K_f	0.6	IRC 83 Clause 5.1.3.5
10	Weight of super structure(N)	F_{zd}	4350000	Calculated
11	Max axial load (N)	F_{vd}	613000	From software SAP2000
12	Max vertical displacement of bearing(mm)	V_{yd}	4.4	
13	Width of bearing (mm)	(a)	450	Selected the dimensions from IRC 83 Table B
14	Length of bearing (mm)	(b)	630	
15	Width of steel plate (mm)	a′	440	
16	Length of steel plate (mm)	b′	620	
17	Effective thickness of an individual elastomer layer (mm)	t_e	12	
18	Total thickness of elastomeric layer (mm)	T_r	108	
19	Number of internal elastic layer	n	9	
20	Number of steel plate	n_s	8	

Design of an elastomeric bearing				
Sl no	**Parameters**	**Notation/Formula**	**Values**	
21	Shape factor	$S = \frac{A_1}{l_p \times t_e}$	10.723	
22	Reduced effective plan area (mm^2)	$A_r = A_1 \times (1 - \frac{V_{x,d}}{a'} - \frac{V_{y,d}}{b'})$	270864	
23	Design strain due to compression	$\varepsilon_{c,d} = \frac{1.5 \times F_{z,d}}{G \times A_r \times S}$	3.209	
24	Design strain due to translatory movement	$\varepsilon_{q,d} = \frac{V_{xy,d}}{T_q}$	0.040	
25	Angle of rotation along width (rad)	$\alpha_{a,d}$	0.008	
26	Angle of rotation along length (rad)	$\alpha_{b,d}$	0.007	
27	Design strain due to angular rotation	$\varepsilon_{\alpha,d} = \frac{(a'^2 \times \alpha_{a,d} + b'^2 \times \alpha_{b,d}) \times t_i}{2\sum t_i^3}$	1.635	
28	Max design strain	$\varepsilon_{a,d}=\varepsilon_{c,d}+\varepsilon_{q,d}+\varepsilon_{a,d}$	4.88	
29	Thickness of steel plate (mm)	$t_s = \frac{K_p \times F_{z,d} \times (t_1 + t_2) \times K_h \times \gamma_m}{A_r \times f_y}$	2.132	
30	Check for thickness of steel plate	$t_s \geq 3mm$	4mm	provide
31	Rotational limitation	$\sum V_{z,d} = \sum \left[\frac{F_{zd} \times t_i}{A_1} \times \frac{1}{5 \times G \times S_1^2 + (1/E_b)}\right]$	4.279	
		$\frac{a'^2 \times \alpha_{a,d} + b'^2 \times \alpha_{b,d}}{K_{r,d}}$	2.62	
		Check	4.27>2.62	Hence OK

Design of an elastomeric bearing				
Sl no	**Parameters**	**Notation/Formula**	**Values**	
32	Buckling stability	$\frac{F_{z,d}}{A_r}$	16.059	
		$\frac{2 \times a' \times G \times S_1}{3 \times T_e}$	20.38	
		Check	16.059<20.38	Hence OK
33	Plan area(mm^2)	A	283500	
34	Mean compression stress	$\sigma_m = \frac{Fvd}{A}$	2.162	
35	Friction co efficient	$\mu_e = 0.1 + 1.5 \times \frac{K_f}{\sigma_m}$	0.516	
36	Horizontal stiffness (N/mm)	$K_H = \frac{GA}{T_r}$	1755.6	From journal paper author Ali Akbar Edalati (2019)
37	Instantaneous compression modulus	$E_c = 4GS^2$	321.967	
38	Vertical stiffness (N/mm)	$K_V = \frac{E_c A}{T_r}$	807495.445	

Table 2: Design of Lead rubber bearing

Design of a Lead Rubber Bearing				
Sl no	**Parameters**	**Notation**	**Values**	**References**
1	Acceleration co efficient for Zone IV	A	0.3	Table 3.10.4 AASHTO
2	Site coefficient for soil type III	S	1.5	Table 3.10.5.1 AASHTO
3	Shear modulus of rubber (MPa)	G_r	0.7	Seismic Isolation of Highway Bridges by author Ian Buckle Table 6.1
4	Bulk modulus of rubber (MPa)	K	2000	
5	Material constant for rubber	k	0.698	
6	Effective yield stress of lead (MPa)	f_{yl}	10	
7	Factor for effect of lead on post elastic stiffness of bearing	f	1.1	From journal paper Chauhan et al (2013)
8	Multiple presence factor for single lane	m	1.2	3.6.1.1.2 AASHTO
9	Number of design lane loaded in one direction	N	1	one lane is taken to be loaded in one direction
10	Number n for seismic loads	n	10	For seismic load From journal paper author Chauhan et al (2013)
11	Load factor accounting for creep in lead	Ψ	1	
12	Target effective time period (s)	T_e	1	Assumed
13	Damping coefficient for 15% damping	β	1.35	Assumed
14	Number of bearings	n_b	12	For each pier three & each abutment three
15	Acceleration due to gravity (mm/s^2)	g	9810	Standard value
16	Total axial load (N)	P_p	613000	From software SAP2000
17	Dead load of a structure (N)	P_d	438000	
18	Allowable compressive stress (MPa)	f_c	11	Clause 14.7.5.3.2 AASHTO
19	Height of slab + Barrier wall (mm)	h_{sb}	1280	From Bridge detail
20	Total weight of bridge superstructure (N)	W_s	4350920	Calculated

Design of a Lead Rubber Bearing				
Sl no	**Parameters**	**Notation/Formula**	**Values**	
21	Length of bridge (mm)	L	48000	
22	Height of the girder (mm)	h_g	1400	
23	Design wind pressure for girder (MPa)	P_{D1}=0.0024MPa	0.0024	Table 3.8.1.2.1 AASHTO
24	Design wind pressure for slab and barrier wall (MPa)	P_{D2}=0.0019MPa	0.0019	Table 3.8.1.2.1 AASHTO
25	Wind force (N/mm)	$F_w=P_D h_g$	3.36	shall not be taken < 4.4
		check	4.4	provided
26	Larger wind pressure for girder (MPa)	$P_{D1}=0.0024\times\frac{4.4}{3.36}$	0.0031	
27	Wind force on structure(N)	$WS=P_{Di}\times A_{Ei}$	327936	
28	Wind force on vehicles (N)	WL=1.46×48000	70080	
29	Braking force per lane (N)	BR_L=0.25(35000+145000+145000)	81250	Clause 3.6.1.2.2 AASHTO
30	Braking force (N)	$BR=B_{RL}mN$	97500	
31	Limit state: STRENGTH-I	F_T=1.75BR	170625	Select the maximum value
32	Limit state: STRENGTH-III	F_T=1.40WS	459110.4	
33	Limit state: STRENGTH-V	F_T=1.00WS+0.40WL	355968	
34	Factored braking load (N)	F_T=1.35BR	131625	
35	Total factored horizontal load (N)	$F=(F_T^2+F_L^2)^{0.5}$	379523.85	

Design of a Lead Rubber Bearing			
Sl no	**Parameters**	**Notation/Formula**	**Values**
36	Maximum horizontal load	Select maximum (STRENGTH-III)	459110.4
37	Characteristics strength (N)	$Q=\frac{\max horizontal\ service\ load}{number\ of\ bearings}$	38259.2
38	Minimum lead core diameter (mm)	$d_{L\min}=\sqrt{\frac{4n\psi Q}{\pi(n-1)\ f_{yL}}}$	73.588
39	Design displacement (mm)	$D_d = 250AS_1T_d/B$	83.33
40	Effective stiffness of bearings (N/mm)	$k_e=\frac{W_s}{n_b g}\left(\frac{2\pi}{T_e}\right)^2$	1459.116
41	Initial required characteristic strength (N)	$Q_i=\frac{1}{2}\pi\beta_e k_e D_d$	28635.153
42	Required lead core diameter (mm)	$d_L=\sqrt{\frac{4n\psi Q}{\pi(n-1)\ f_{yL}}}$	63.647
		For design purpose use	80mm
43	Initial required characteristic strength (N)	$Q_i=\frac{n-1}{n\psi}\ f_{yL}\frac{\pi d_{L\min}^2}{4}$	45238.896
44	Initial post elastic stiffness (N/mm)	$k_{di}=k_e-\frac{Q_i}{D_d}$	916.249
45	Nonlinear effective stiffness (N/mm)	$k_u=10k_{di}$	9162.493
46	Displacement (mm)	$D_y=\frac{Q_i}{k_u-k_d}$	5.486
47	Final characteristic strength (N)	$Q=\frac{\pi\beta_e k_e D_d^2}{2(D_d-D_y)}$	30668.630
48	Final post elastic stiffness (N/mm)	$k_d=k_e-\frac{Q_i}{D_d}$	916.249

Design of a Lead Rubber Bearing				
Sl no	**Parameters**	**Notation/Formula**	**Values**	
49	Check for minimum restoring force	$k_d \geq \frac{W_s}{40 n_b D_d}$	108.773	K_d>108.77 hence OK
		$k_d \geq \frac{4\pi^2 W_s}{36 n_b g}$	40.531	K_d>40.53 hence OK
50	Contribution of rubber (N/mm)	$K_r=K_d/f$	832.953	
51	Bonded plan area (mm^2)	$A_b = \frac{P}{f_c}$	55727.272	
52	Bonded diameter of rubber (mm)	$d_b = \sqrt{\frac{4A_b}{\pi} + d_L^2}$	266.372	
		For design purpose use	340mm	
53	Final Bonded plan area (mm^2)	$A_b = \frac{\pi\left(d_b^2 - d_L^2\right)}{4}$	90791.951	
54	Total diameter of bearing (mm)	$D=d_b+2$(Cover)	350	
55	Total thickness of rubber (mm)	$T_r = \frac{GA_b}{k_r}$	76.299	
		For design purpose use	122mm	
56	delta (rad)	$\delta = 2\cos^{-1}\left(\frac{D_d}{d_b}\right)$	2.646	
57	Area required at design displacement (mm^2)	$A_r = \frac{d_b^2}{4}(\delta - \sin\delta)$	62744.985	
58	Max shear strain due to compression	γ_c	2	From journal paper, author Chauhan et al (2013)

Design of a Lead Rubber Bearing				
Sl no	**Parameters**	**Notation/Formula**	**Values**	
59	Required shape factor	$S=\frac{3P\pm\sqrt{9P^2-32(\gamma_c A_r G)^2 k'}}{8\gamma_c A_r G k'}$	7.401	if $S \leq 15$
		$S=\frac{\gamma_c A_r K}{12P}\pm\sqrt{\left(\frac{\gamma_c A_r K}{12P}\right)^2-\frac{K}{8Gk'}}$		if $S > 15$
60	Check for S	$S \geq \frac{P}{1.66GA_b}$	5.810	S>5.8 hence OK
61	Maximum layer thickness (mm)	$t_i=\frac{d^2-d_L^2}{4dS}$	11.821	
		Provide any less thickness	6mm	Selected
62	Number of intermediate layers	Nr	19	
63	Total rubber thickness(mm)	Tr	122	Including top & bottom cover 4mm
64	Critical buckling load of bearing	$S=\frac{d^2-d_L^2}{4dt_i}$	15.012	
		$E_c=\frac{1}{\left(\frac{1}{6GS^2}+\frac{4}{3K}\right)}$	580.334	(MPa)
		$I=\frac{\pi\left(d_b^4-d_L^4\right)}{64}$	655971846	(mm^4)
		$P_{cr}=\sqrt{\frac{\pi^2 E_c I G A}{3T_r^2}}$	2312511.8	(N)
65	Factor of safety against buckling	$FS = P_{cr}/P$	3.77	
		Check FS >3	3.77 >3	Hence OK

Design of a Lead Rubber Bearing				
Sl no	**Parameters**	**Notation/Formula**	**Values**	
66	Critical buckling load of bearing in deformed state	$\delta = 2\cos^{-1}\left(\frac{1.5D_d}{d_b}\right)$	2.388	(rad)
		$A_r = \frac{d_b^2}{4}(\delta - \sin\delta)$	49269.857	(mm^2)
		$P_{cr}^{'} = P_{cr}\frac{A_r}{A_b}$	1254925.4	(N)
	Check	$1.2P_D + P_{SL}$	525600	(N)
		$P'_{cr} > 1.2P_D + P_{SL}$,	1254925>525600	Hence OK
67	strain due to vertical loads	$\gamma_c = \frac{3SP}{2A_rG(1+2k'S^2)}$	0.995	
68	shear strain due to non-seismic lateral displacement	$\Delta_s = \alpha\,\Delta T\,L$	2.112	
		$\gamma_{s.s} = \frac{\Delta_s}{T_r}$	0.017	
69	shear strain due to lateral displacement	$\gamma_{s.eq} = \frac{D_d}{T_r}$	0.683	
70	Rotation	R	0.008	
71	Shear strain due to design rotation	$\gamma_r = \frac{d_b^2\theta}{2t_iT_r}$	0.631	
72	Final characteristic strength of bearing (N)	$Q_L = \frac{n-1}{n\psi}\,f_{yL}\,\frac{\pi d_{L\min}^2}{4}$	45316.8	
73	Final post elastic stiffness of bearing (N/mm)	$k_d = \frac{f.GA_b}{T_r}$	573.031	
74	vertical stiffness (N/mm)	$K_V = \frac{E_cA}{T_r}$	376355.752	
75	Yield strength (N)	$F_y=Q_l+K_d\times D_y$	48460.449	

7. FINITE ELEMENT ANALYSIS

Finite Element Analysis (FEA) of a bridge is a methodical process that involves modeling the structure, defining its material properties, loads, and boundary conditions, and performing a computational analysis to evaluate its performance. FEA can be used to simulate the structural behavior of a bridge, and to optimize its design to ensure it is safe, stable, and cost-effective. FEA works by dividing a complex structure into smaller, simpler parts, called finite elements. By simulating the behavior of each element individually. The process of dividing a continuous domain (like a structure or object) into smaller subdomains, or "elements".

8. RESULTS AND DISCUSSIONS

The purpose of this section is to investigate and compare the influence of the LRB and the ERB bearings on the seismic responses of a RC T Beam bridge.

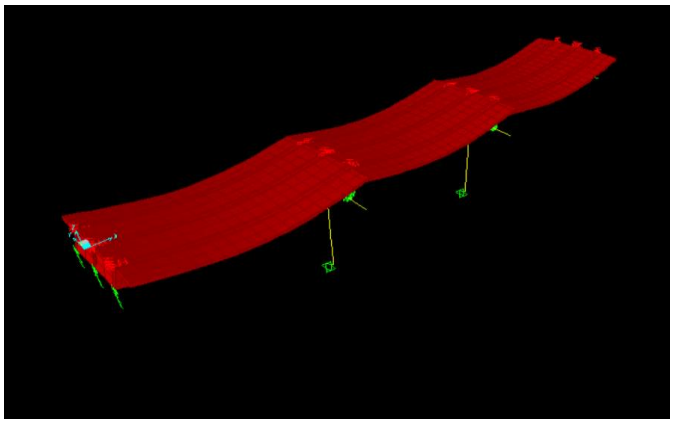


Fig 1. Deformed RC Bridge

Fundamental time period of the Bridge

The purpose of seismic isolation is the reduction of forces in the structure and the foundation. In which, one of the solutions is to increase the vibration period of the structure. Increasing the vibration period reduces the structural response according to the design spectrum, which has been investigated in many studies as the effect of structural period transitions. However, increasing the period of the structure reduces the lateral stiffness of the bridge that increases the lateral displacement of the structure. As expected, LRB isolation system increases the period of the structure in comparison with the ERB isolation.

Table 3: Fundamental time period in sec

Output Case	Time period in sec	
	ERB	LRB
Mode-1	0.51	1.35

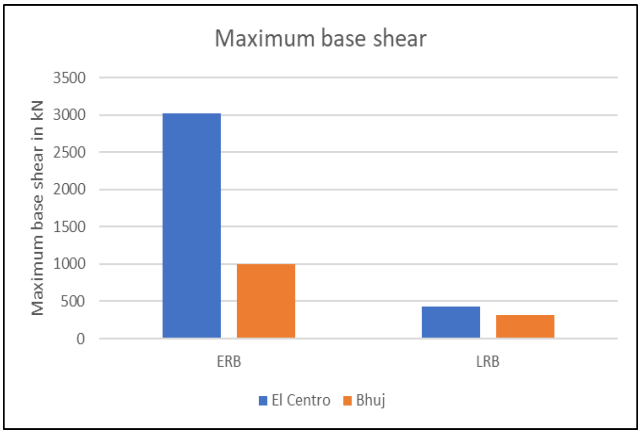
Base shear force in Bridge

Using the LRB isolator, the base shear is sharply decreased in earthquake ground motions, which causes less force to enter the bridge. The reasons for reducing the base shear are the increase in the period and damping of the bridge. The results show that under the El Centro earthquake record during 1940 the rate of reduction of the base shear is 85% and under Bhuj earthquake record during 2001 the rate of reduction is 68%. It can also be inferred that the bridge response is ground motion dependent and varies in different earthquake motions.

Table 4: Maximum base shear force in bridge

Ground motion	Maximum Base shear force in kN	
	ERB	LRB
El Centro (1940)	3019	429
Bhuj (2001)	1000	321

Fig 2 Maximum Base shear force in bridge



Maximum absolute deck acceleration

The absolute acceleration of the bridge was significantly reduced using the LRB so that the amount of this reduction is up to 82% for EL Centro record during 1940 and 55% for Bhuj earthquake record during 2001. The reason for the differences between the accelerations is the frequency content of the selected earthquake ground motions.

Table 5: Maximum absolute deck acceleration

Ground motion	Maximum absolute acceleration in mm/s²	
	ERB	LRB
El Centro (1940)	12397	2116
Bhuj (2001)	5589	2524

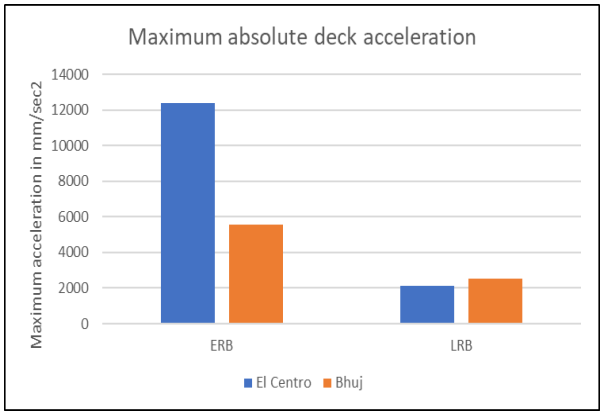


Fig 3 Maximum Base shear force in bridge in mm/s^2

Maximum pier head displacement

The LRB isolator reduces the bridge displacement against the ERB isolator and the amount of this reduction is up to 80% for EL Centro ground motion during 1940 and 50% for Bhuj earthquake ground motion during 2001. Generally, the displacement reduction depends on the earthquake ground motion. It can also be inferred that the bridge response is ground motion dependent and varies in different earthquake motions.

Table 6: Maximum pier head displacement

Ground motion	Maximum displacement in mm	
	ERB	LRB
El Centro (1940)	36.2	7.06
Bhuj (2001)	11.9	5.84

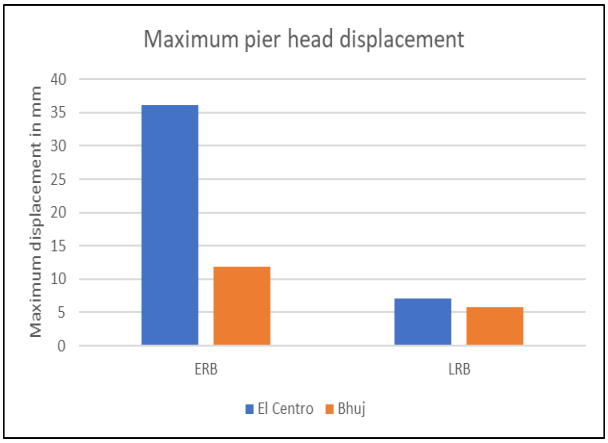


Fig 4 Maximum pier head displacement in mm

9. CONCLUSION

1. The design of elastomeric bearing is done as per IRC 83(Part 2): 2018 The isolation design of a bridge with elastomeric bearings primarily involves the determination of cross-sectional area of the bearing, total thickness of rubber layers, instantaneous compression modulus of the elastomer, shear modulus of the elastomer, vertical and shear stiffness of the isolator.

2. Design of lead rubber bearing is done as per American Association of State Highway and Transportation Officials (AASHTO):2007 The isolation design of a bridge with lead rubber bearings primarily involves the determination of the properties of the isolators themselves such as lead core diameter, isolator diameter, thickness and number of rubber layers, thickness and number of steel reinforcing plate, Vertical stiffness, Effective stiffness of bearings, and Yield strength.

3. The use of an LRB isolator instead of the ERB increased the fundamental period of the bridge by a factor of 2.

4. The base shear of the bridge using the LRB isolator is significantly reduced compared to the ERB. The maximum rate of reduction of the base shear is 85%.

5. The absolute acceleration of the bridge was significantly reduced using the LRB so that the maximum amount of this reduction is up to 82%.

6. The LRB performance is suitable for reducing the displacement so that the maximum reduction is up to 80%.

7. The seismic isolation reduces the seismic response in the superstructure and controls the distribution of the reduced lateral forces among the substructures.

8. The elastomeric bearing can be replaced with lead rubber bearings as it increases the fundamental time period and reduces significant amount of the base shear coming on pier.

REFERENCES

1. AASHTO (1991) “Guide Specifications for Seismic Isolation Design”, American Association of State Highway and Transportation Officials, Washington, DC.

2. AASHTO (1998) “LRFD Bridge Design Specifications”, Second Edition, American Association of State Highway and Transportation Officials, Washington, DC.

3. IRC:83 Part-II (2018). “Standard specifications and code of practice for road bridges”.

4. Ghobarah, A., & Ali, H. M. (1988). Seismic performance of highway bridges. Engineering Structures, Vol. 10, issue 3, pp. 157-166.

5. Ghobarah, A. (1988). Seismic behaviour of highway bridges with base isolation. Canadian Journal of Civil Engineering, Vol. 10, issue 3, pp. 72-78.

6. Abé, M., Fujino, Y., & Yoshida, J. (1998). Seismic Performance Evaluation of Base-Isolated Bridges. IFAC Proceedings, Vol. 31, issue 28, pp. 117-121.

7. Chaudhary, M. T. A., Abe, M., & Fujino, Y. (2001). Performance evaluation of base-isolated Yama-age bridge with high damping rubber bearings using recorded seismic data. Engineering structures, Vol. 23, issue 8, pp. 902-910.

8. Kunde, M. C., & Jangid, R. S. (2003). Seismic behavior of isolated bridges: A-state-of-the-art review. Electronic journal of structural engineering, Vol. 31, pp. 140-170.

9. Jangid, R. S. (2004). Seismic response of isolated bridges. Journal of Bridge Engineering, Vol. 9, issue 2, pp. 156-166.

10. Matsagar, V. A., & Jangid, R. S. (2006). Seismic response of simply supported base-isolated bridge with different isolators. International Journal of Applied Science and Engineering, Vol. 4, issue 4, pp. 53-69.

11. Hameed, A., Koo, M. S., Do, T. D., & Jeong, J. H. (2008). Effect of lead rubber bearing characteristics on the response of seismic-isolated bridges. KSCE Journal of Civil Engineering, Vol. 12, pp. 187-196.

12. Haque, M. N., Bhuiyan, A. R., & Alam, M. J. (2010, August). Seismic response analysis of base isolated highway bridge: Effectiveness of using laminated rubber bearings. In IABSE-JSCE Joint Conference on Advances in Bridge Engineering-II Vol. 4.

13. Olmos, B. A., Jara, J. M., & Roesset, J. M. (2011). Effects of isolation on the seismic response of bridges designed for two different soil types. Bulletin of Earthquake Engineering, Vol. 9, pp. 641-656.

14. Chauhan Kalpesh M, Dr. B. J. Shah. (2013). Excel spreadsheet for design of lead rubber bearing uses for seismic isolation of bridges. International Journal of Advanced Engineering Research and Studies, Vol. 2, issue 3.

15. Anajafi, H., Zandi, A. P., & Khanmohammadi, M. (2013). Seismic-isolation effect on bridge seismic performance, a case study. In 13th World Conf. on Seismic Isolation, Energy Dissipation and Active Vibration Control of Structures Commemorating JSSI 20th Anniversary. Sendai, Japan: JSSI. Vol. 2

16. Nitin Chavan, Pranesh Murnal. (2015). A Comparative Study on Seismic Response of Bridge with Elastomeric Bearing and Elastomeric Isolator. Journal of Civil Engineering and Environmental Technology, Vol. 2, issue 10.

17. Zellat, K., & Kadri, T. (2015). Influence of seismic isolation system on bridge responses. Revista Ingenerate de Construction Vol. 4, issue 4.

18. Roy, S. S., & Dash, S. R. (2018). Dynamic behavior of the multi span continuous girder bridge with isolation bearings. International Journal of Bridge Engineering (IJBE), Vol. 6, issue 2, pp. 01-23.

19. Edalati, A. A., & Tahghighi, H. (2019). Investigating the performance of isolation systems in improving the seismic behavior of urban bridges. a case study on the Hesarak bridge. Archives of civil engineering, Vol. 12, pp. 155-175.

20. Ashwini Satyanarayana, Dattatreya J. K. (2020). Investigation of Seismic Performance of RC T-Beam Bridges Using Isolation Technique. International Advanced Research Journal in Science, Engineering and Technology, Vol. 7, issue 8.

21. Zhang, Y., Li, J., Wang, L., & Wu, H. (2020). Study on the seismic performance of different combinations of rubber bearings for continuous beam bridges. Advances in Civil Engineering, 2020, Vol. 1, pp. 880.

22. Hassan, A. L., & Billah, A. M. (2020). Influence of ground motion duration and isolation bearings on the seismic response of base-isolated bridges. Engineering Structures, Vol. 222, pp. 111.