Performance Evaluation of Elastomeric Pads as Bridge Bearings under Earthquake Loads

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Abstract *The factors which are affecting the behavior and design of reinforced concrete bridges using precast concrete girders are investigated numerically. Precast I-girders are always supported at the end by isolators. These isolators affects the seismic behavior of the bridge structure. Csi bridge 2017 is used to model the bridge structure. As per numerical investigations isolators may positively affect the seismic response of the bridge structure. Reinforced concrete (RC) bridges with precast prestressed concrete girders are commonly used bridge configurations in highway bridges. The application as well as possibilities of such bridges are increasing because of their design, simplicity and construction and also ease of maintenance. AASHTO principles are used in the analysis.*

Key Words: **Concrete girder, seismic response, Csi bridge 2017**

1. INTRODUCTION

Reinforced concrete (RC) bridges with precast prestressed concrete girders are commonly used bridge configurations in highway bridges. The application as well as possibilities of such bridges are increasing because of their design, simplicity and construction and also ease of maintenance. AASHTO principles are used in the analysis. Various studies have been done on modeling, analysis, and design of bridge superstructures. From these studies they have presented an analytical model for elastomeric seismic isolation bearings. Afterwards that they have focused on the behavior of elastomeric seismic isolation pads. Elastomeric bearing pads are provided at the ends of I-girder bridges. The elastomeric pad bridges girder defines end conditions, may affect the seismic performance of the bridges.

1.1 Methodology

1) Design of elastomeric pad bearing.
2) Static and dynamic analyses of bridge with elastomeric pads and with RC bearing using CSi Bridge 2017.
3) Determining the fundamental time period, moment at pier bottom, shear force at pier, and total displacement of the bridge with elastomeric pads and with RC bearing using CSi Bridge 2017.
4) Comparison of bridge with elastomeric pads and with RC bearing.

2. Details of the elastomeric bearing

Table -1 Prosperities of the elastomeric bearing

Elastomer Bearing Length L (cm)	35
Elastomer Bearing Width W (cm)	45
Elastomer Bearing Height H (cm)	8.5
Total elastomer thickness hr (cm)	6.1
Thickness of one elastomer layer hri (cm)	0.8
Thickness of one steel reinforcement layer hs (cm)	0.3
Elastomer gross plan area A (cm2)	1575
Elastomer moment of inertia I (cm4)	1600
Shape factor S	12
Amount of bearing n (at end of girder)	10

2.1 Stiffness calculation of the elastomeric pad bearing

A typical elastomeric bearing has a shear modulus of G_{eff}=0.8MPa. Elastomeric bearings are considered as link elements in the structural analysis. Stiffness of the link element is computed in.

$$K_H = k_{eff} = \frac{G_{eff} A}{H_r}$$ = 800x0.1575/0.061 = 2065kN/m

$$K_V = \frac{E_c A}{H}$$

= 617263x0.1575/0.085
= 1143752kN/m

$$K_\theta = \frac{EI}{H_r}$$

= 617263x0.0016/0.061
= 16270kN/m

Where K_H, K_V, and K_q represents the lateral, vertical and rotational stiffness belonging to elastomeric pads used in this bridge.

2.2 Details and stiffness calculation of RC bearing

Plan dimensions of RC bearing = 350mm x 450mm
Thickness of RC bearing = 85 mm
Lateral stiffness, K_H = 0.5 x 2065 = 1033 kN/m
Vertical stiffness, K_v = 0.5 x 1143752 = 571876 kN/m
Rotational stiffness, K_θ = 0.5 x 16270= 9111.2 kN/m

3. Analysis of the bridges with elastomeric bearing and RC bearing using CSi Bridge 2017

3.1 Box girder bridge details

The dimensions of the box girder bridge which is used for model validation is as shown in Fig -1. The details of the box girder bridge is as given below
Length of the bridge = 20 m
Width of the bridge = 10 m
Carriageway width o = 7.5 m
Pavement Thickness = 80 mm
Imposed load = IRC Class 70R tracked vehicle
Characteristic strength of concrete = M 30
Characteristic strength of steel = Fe 500

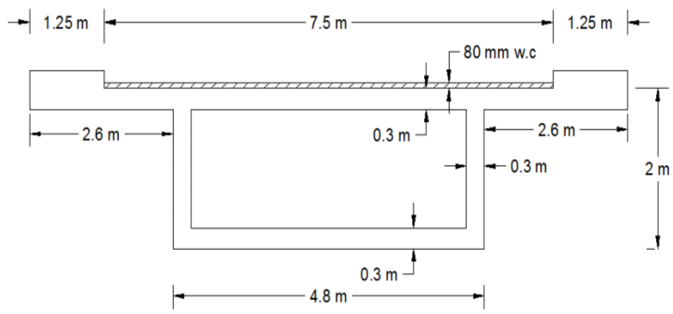

Fig -1: Cross sectional details of the box girder

3.2 Seismic inputs

Static and dynamic investigation of the box girder bridge is done utilizing CSi software 2017. Dynamic analysis is carried out using response spectrum method. The seismic inputs for the analysis are as follows.
Seismic zone = III
Zone factor = 0.16 (for zone III as per IS 1893-Part 2- 2002)
Soil type = II
Damping ratio = 0.05

4 Comparison of bridge with elastomeric bearing and the bridge with RC bearing

An analysis result of bridge with elastomeric bearing is compared with bridge with RC bearing. Comparison is done in terms of various parameters such as time period, moments in the piers, forces, shear force, lateral force, total base shear force, displacement of substructure, displacement of elastomeric bearing and total displacement of bridge for two pier heights 8m and 16m.

Results obtained from each bridge analyses are summarized below where T is the fundamental period, M is moment at pier bottom, V is shear force at pier, V_k is lateral force at one abutment, ΣV is total base shear force, d_{sub} is displacement of substructure, di is displacement of elastomeric bearing and d is total displacement of bridge.

4.1 For pier height 8 m

Table- 2 Comparison of numerical results for bridge with pier height 8m.

	Bridge with pier height= 8 m		
	With elastomeric bearing	With RC bearing	% variation
T (sec)	1.52	2.42	59.22
M (kN-m)	1295.32	1423.68	9.91
V (kN)	64.89	98.54	51.86
V_k(kN)	389.045	389.045	0
d_{sub}(mm)	5.4	6.7	24.08
di (mm)	3.4	4.95	45.59
d (mm)	8.8	11.65	32.39

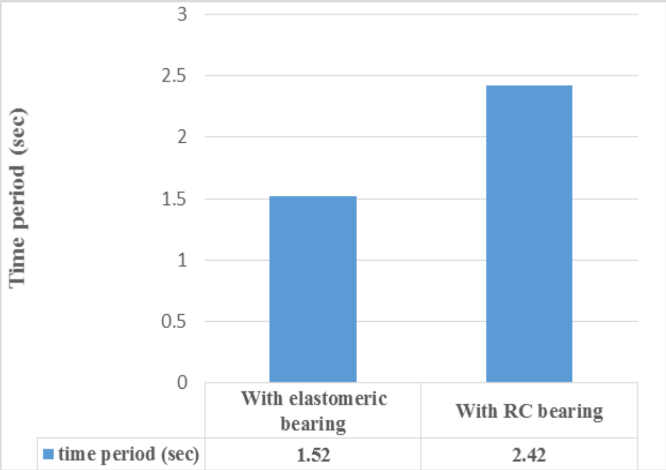

Fig. 2 Variation of time period for 8 m pier height

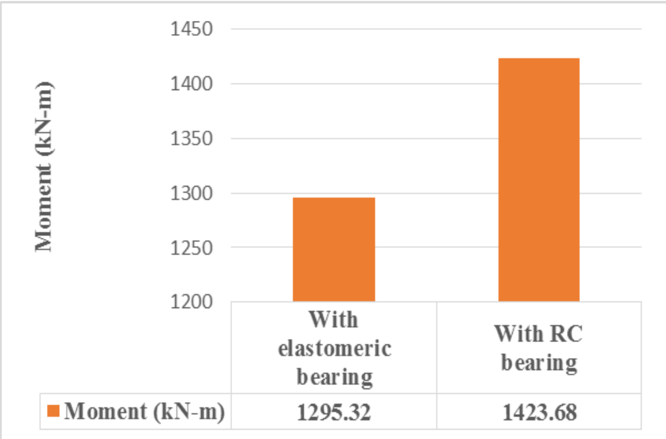

Fig. 3 Variation of moment for 8 m pier height

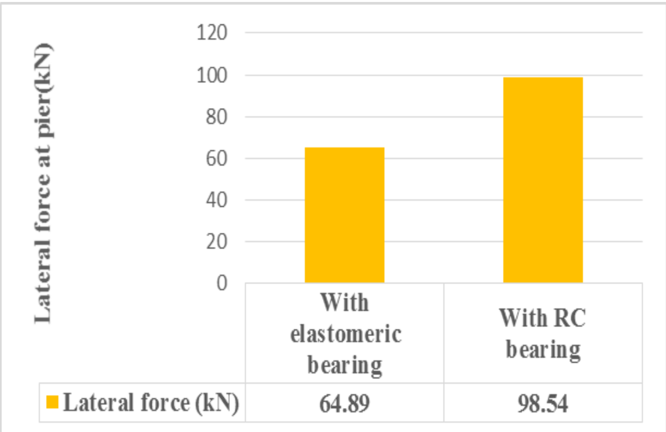

Fig. 4 Variation of lateral force for 8 m pier height

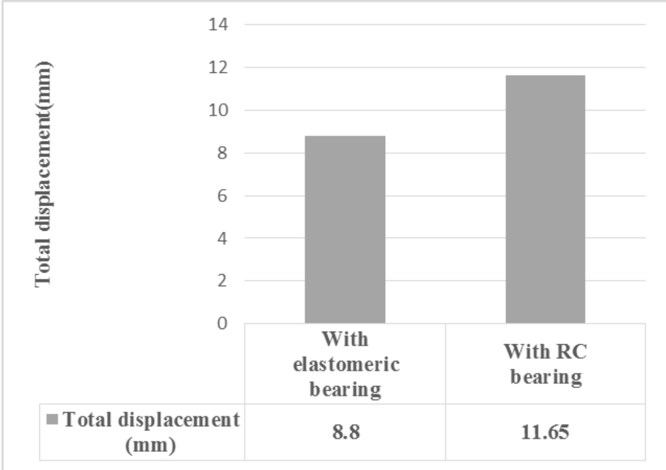

Fig. 5 Variation of total displacement for 8 m pier height

Table 1 and fig. 2to fig. 5 shows the variation of time period, moment at the bottom of the pier, lateral force at pier and total displacement of structure for bridge with elastomeric bearing and RC bearing (8 m pier height). Time period for bridge with RC bearing is 59.22 % higher than bridge with elastomeric bearing. Moment at the pier bottom and lateral force at the pier for bridge with RC bearing is 9.91% and 51.86% higher than the bridge with elastomeric bearing respectively. Total lateral displacement of the bridge with RC bearing is 32.39% more than the bridge with elastomeric bearing.

4.2 For pier height 16 m

Table 2 Comparison of numerical results for bridge with pier height 16m

	Bridge with pier height= 16 m		
	With elastomeric bearing	With RC bearing	% variation
T (sec)	1.62	2.2	35.81
M (kN-m)	1510.43	1690.239	11.91
V (kN)	82.17	112.56	36.99
Vk(kN)	410.54	410.54	0
dsub(mm)	19.4	21.6	11.35
di (mm)	18	23.7	31.67
d (mm)	37.4	45.3	21.13

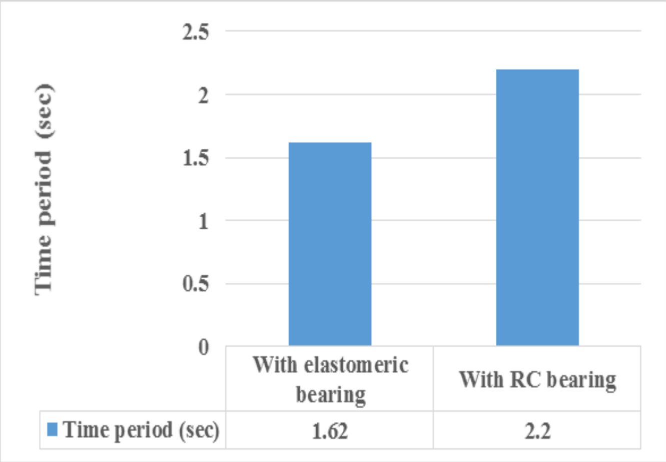

Fig. 6 Variation of time period for 16 m pier height

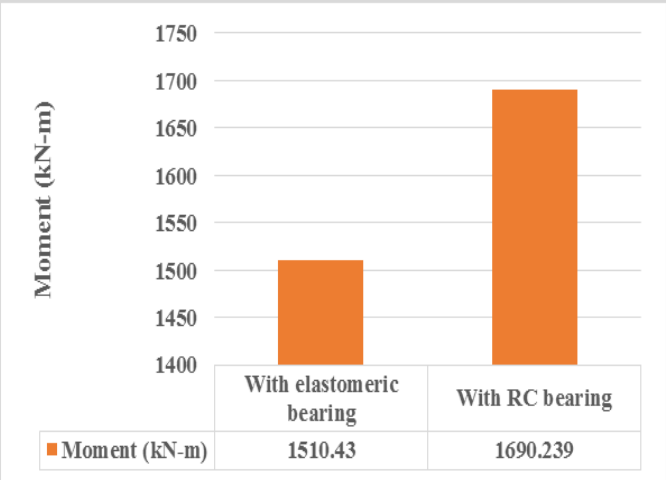

Fig. 7 Variation of moment for 16 m pier height

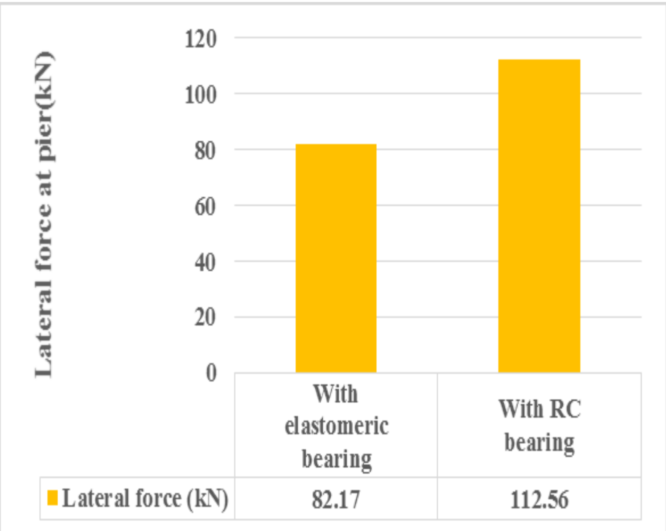

Fig. 8 Variation of lateral force for 16 m pier height

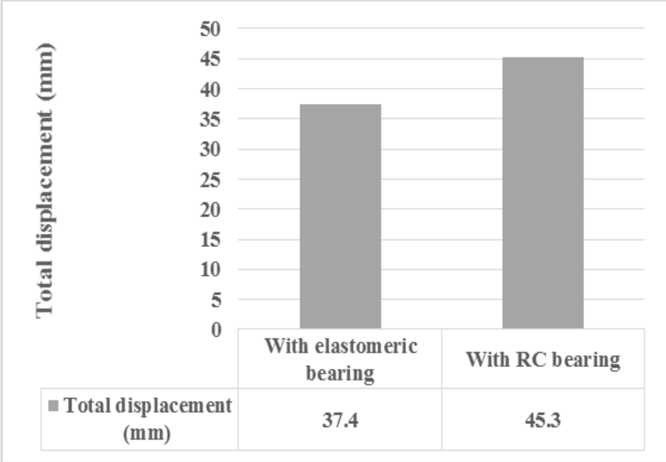

Fig. 9 Variation of total displacement for 16 m pier height

Table 2 and fig. 6 to fig. 9 shows the variation of time period, moment at the bottom of the pier, lateral force at pier and total displacement of structure for bridge with elastomeric bearing and RC bearing (16 m pier height). Time period for bridge with RC bearing is 35.81 % higher than bridge with elastomeric bearing. Moment at the pier bottom and lateral force at the pier for bridge with RC bearing is 11.91% and 36.99% higher than the bridge with elastomeric bearing respectively. Total lateral displacement of the bridge with RC bearing is 21.13% more than the bridge with elastomeric bearing.

5 Conclusions

Time period for bridge with RC bearing is 59.2% and 35.81 % higher than the bridge with elastomeric bearing for pier height 8 m and 16 m respectively. Moment at the pier bottom for bridge with RC bearing is 9.91% and 11.91% higher than the bridge with elastomeric bearing for pier height 8 m and 16 m respectively.

Lateral force at the pier for bridge with RC bearing is 51.86% and 36.99% higher than the bridge with elastomeric bearing for pier height 8 m and 16 m respectively. Total lateral displacement of the bridge with RC bearing is 32.39% and 21.13% more than the bridge with elastomeric bearing for pier height 8 m and 16 m respectively.

It can be observed that the percentage increase of time period, lateral force at pier and lateral displacement decrease as the pier height increases. Time period, moment at the pier bottom, lateral force at pier and lateral displacement is higher in bridge with RC bearing as compared to bridge with elastomeric bearing. Finally it can be concluded that elastomeric bearing perform better than the RC bearing.

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