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Seismic Analysis of Non-Isolated and Isolated Bridges

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Abstract:
Bridge modal of 3span of length 32m and width of 9.5mis considered for the present study. 3 models are used in this study one is non-isolated bridge modal and two models of base isolated bridges with different lead rubber bearings. Isolators are designed by considering suitable soil type and site conditions. And the properties of isolators are introduced between super structure and sub structure. Influence of the base isolator is studied. All three models are analyzed for seismic response spectrum method in both X and Y directions. The influence of the lead rubber bearing in the dynamic behavior of the bridge shows an extended time period, reduction in deck displacement and decreased deck acceleration in both isolated bridge models. Considerable difference is not observed in both isolated bridge models. Results of the analysis shows that certain amount of seismic energy is decimated by lead rubber bearing between sub structure and super structure.

Keywords: *base isolation, lead rubber bearing, displacement, time period, acceleration*

1. Introduction

Bridges are the most important parts of the transportation framework and an imperative segment, the interruption of which represent a danger to crisis reaction and recuperation and additionally genuine financial misfortunes after an in number seismic effect. Clearly, as the name suggests base isolation tries to decouple the structure from the harming impacts of ground movement at the time of earthquake. Most of the base isolation systems that have been developed over the years provide only 'partial' isolation. 'Partial' in the sense that much of the force transmitted, and the consequent responsive motions are only reduced by energy dissipation mechanisms with the addition of base isolation devices to the structure. Main targets of the seismic base isolation are to move the major recurrence of a structure far from the overwhelming frequencies of seismic ground movement and principal recurrence of the altered base superstructure.

2. Objectives of the Study

- To find out seismic response of isolated and non isolated bridges.
- To study the behaviour of the response spectrum curve.
- To design the suitable base isolator for different pga values
- To compare accelaration of the models.
- To compare modal participation factors models.
- To compare maximum displacement of models.

3. Lead Rubber Bearings

The second classification of elastomeric course are lead-elastic direction, which are comparative to the LRB aside from that a focal lead-center is utilized as a part of Figure 1, to give extra method for vitality dispersal, and beginning unbending nature against minor quakes and winds (Skinner et al., 1975; Robinson, 2000, Matsagar and Jangid, 2004, Jangid, 2010). Since this bearing is created, and broadly utilized as a part of New Zealand, it is for the most part alluded to as N-Z framework. The lead-center gave, decreases the disconnection level uprooting by prudence of its vitality retaining limit. The N-Z frameworks likewise give an extra hysteretic damping through the yielding of the lead-center. This seismic segregation framework gives the consolidated components of vertical burden bolster, level adaptability, restoring compel and damping in a single unit.

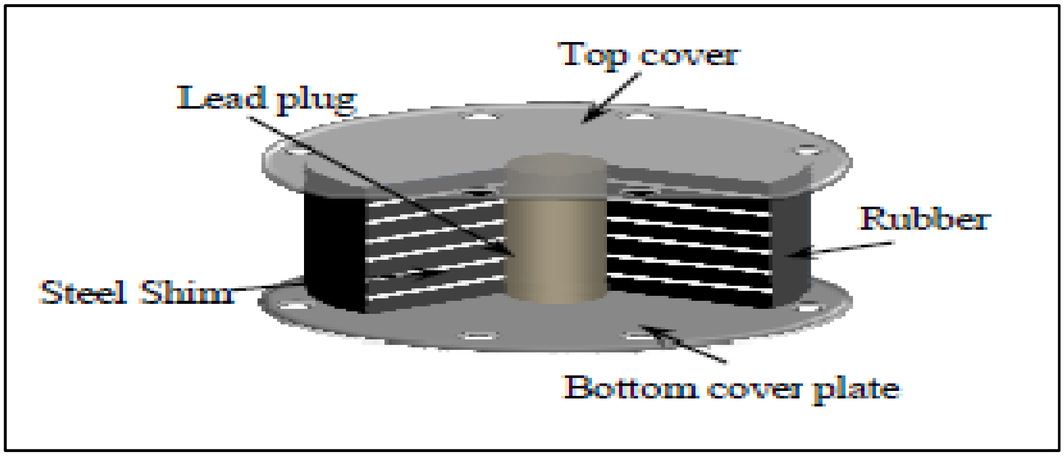

Figure 1

4. Methodology

Non-straight auxiliary investigation is turning out to be most vital in tremor safe outline, which requires more data about the floats, relocations and inelastic disfigurements of a structure than conventional configuration systems. SAP2000 V14 is a standout amongst the most refined and easy to understand programming. In present study two bridges of 96 m total length and width of 9.5 m is designed by LIMIT STATE OF DESIGN method. One is non-isolated and another one is isolated. Both models are analyzed by RESPONSE SPECTRUM METHOD in SAP2000. Base isolation system (LEAD RUBBER BEARING) for isolated bridge is designed as per AASTHO code. Dynamic responses of models are compared and studied.

Multi-level of flexibility (MDOF) frameworks are typically examined utilizing Model Analysis. This system when exposed to ground development encounters distortions in number of conceivable ways. These deformed shapes are recognized as strategies for mode shapes.

→ The equation of motion is given by

$$[m]\{\ddot{x}(t)\} + [c]\{\dot{x}(t)\} + [k]\{x(t)\} = -[m]\{r\}\ddot{x_g}(t)$$

$[m]$ = mass matrix, $[k]$ = stiffnes matrix, $[c]$ = damping matrix, $\{r\}$ = influencecoefficient matrix, $\{x(t)\}$ = relative displacement vector, $\{\dot{x}(t)\}$ = relative velocity vector, $\{\ddot{x}(t)\}$ = relative accelaration vector, $\ddot{x_g}(t)$ = earthquake ground acceleration

5. Description of Model

WIDTH OF BRIDGE	9.5 m
HEIGHT OF PIER	10m
CROSS SECTION OF PIER	2.5m×2.5m
CROSS SECTION OF PIER CAP	1.5m×2m
CLEAR SPAN LENGTH	32 m
CROSS SECTION OF LONGITUDINAL GIRDER	1.5m*2.2m
THICKNESS OF SLAB	300mm
WIDTH OF CARRIAGE WAY	7.5 m
DISTANCE BETWEEN PIERS	3.5m
Seismic parameters	
Seismic zone	V, II
Importance factor- I	1.5
Response reduction factor-R	3
Type of soil	II (Medium)
Damping of structure	5%
Codes Used	IS 456-2000, IS 1893-2002.

Table 1: Design Data Bridge

5.1. Design and Details of Lead Rubber Bearings

Acceleration coefficient PGA	0.4 , 0.2
Site class	0.3
Site factor	0.75
T_{eff}	1
β	30%
Shear modulus of rubber Gr	0.62MPa
Stiffness of bearing	1.1
Effective yield stress of leadfyL	11.4MPa
As=Fga×PGA	1.1×0.4 = 0.44
SDs=Fa×Ss	1.2×0.75=0.9
SD1=Fv×S1	2×0.3=0.6

Table 2: Input values for design of lead rubber bearing

	PGA (0.4G)	PGA (0.2G)
DIAMETER OF BEARING	624 mm	588 mm
TOTAL HEIGHT OF BEARING	250 mm	250mm
TOTAL THICKNESS OF RUBBER LAYERS	140 mm	140mm
LEAD CORE DIAMETER	156 mm	156mm
EFFECTIVE HORIZONTAL STIFFNES	1.53 kn/mm	1.2 kn/mm
YIELD DISPLACEMENT	150 mm	100 mm
VERTICAL STIFFNES	1047.8 kn/mm	590kn/mm
POST ELASTIC STIFFNESS	1.68 kn/mm	1.2 kn/mm

Table 3: Properties of lead rubber bearing

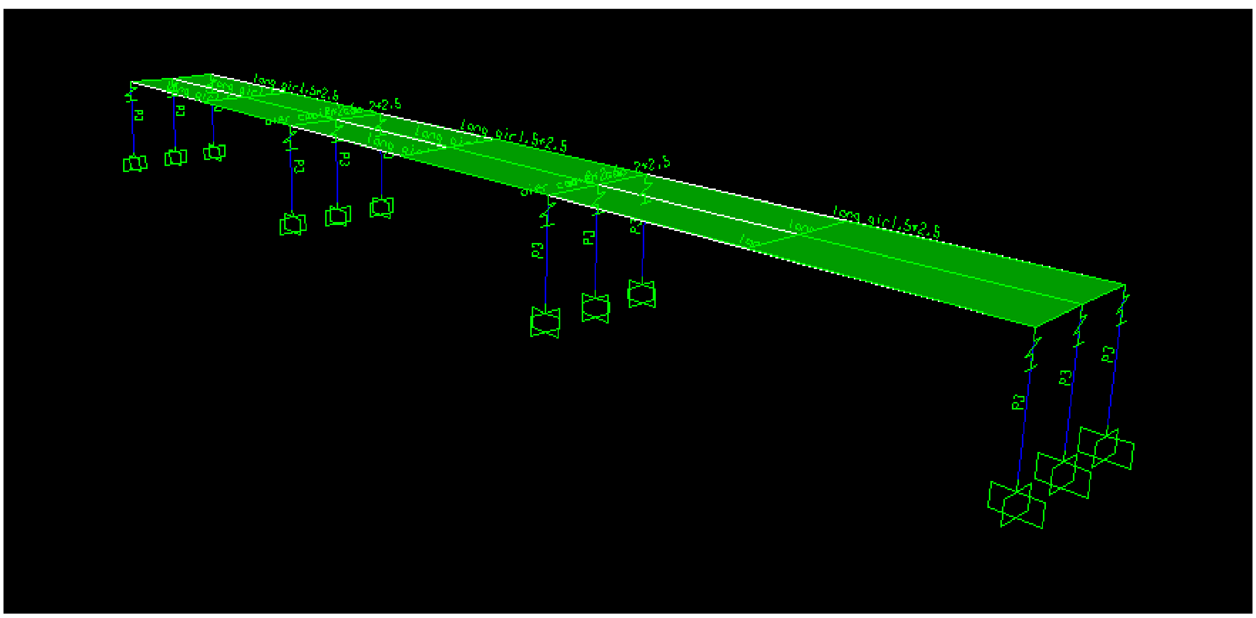

Figure 2

6. Analysis

6.1. Response Spectrum Method

Nonlinear investigation is broadly connected in the investigations of seismic reaction and dynamic breakdown of structures. A sound nonlinear investigation must consider stiff material and geometric nonlinear conduct, damping, component sort determination, acknowledgment criteria and appropriately scaled ground movements. In spite of the fact that a flexible investigation gives a decent comprehension of the versatile limit of structures and shows where first yielding will happen, it can't foresee disappointment instruments and record for redistribution of strengths amid dynamic yielding. Reaction spectra are bends plotted between greatest reaction of framework subjected to indicated seismic tremor ground movement and its time period (or recurrence). Reaction spectra

accordingly helps in getting the top auxiliary reactions under direct range, which can be utilized for acquiring horizontal powers created in structure because of quake hence encourages in seismic tremor safe outline of structures
Multi-level of flexibility (MDOF) frameworks are typically examined utilizing Model Analysis. This system when exposed to ground development encounters distortions in number of conceivable ways.

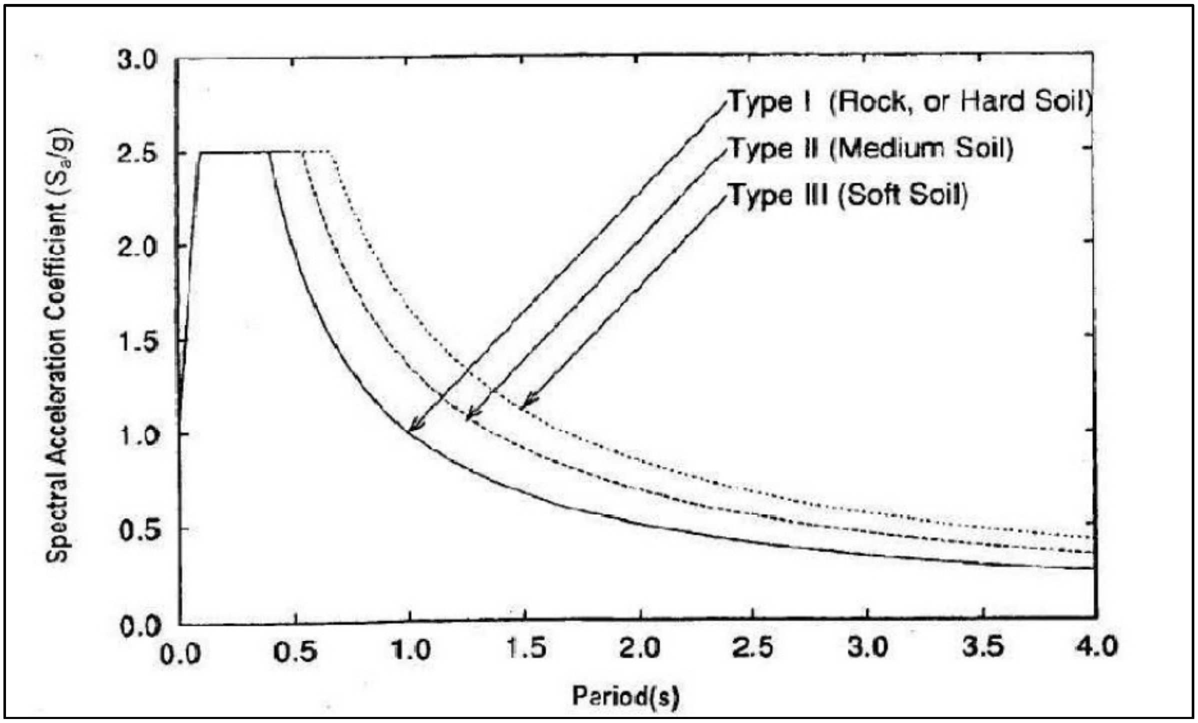

Figure 3

7. Results and Discussions

7.1. Time Period and Frequencies for Non Isolated

MODEL 1-NON ISOLATED		MODEL 2- ISOLATED (0.2g)		MODEL 3- ISOLATED (0.4g)	
TIME PERIODE in sec	FREQUENCY	TIME PERIODE in sec	FREQUENCY	TIME PERIODE in sec	FREQUENCY
0.170386	5.869	0.218625	4.574	0.218625	4.574
0.163763	6.1064	0.202535	4.9374	0.202535	4.9374
0.161022	6.2103	0.199159	5.0211	0.199159	5.0211
0.130352	7.6715	0.176551	5.6641	0.176551	5.6641
0.130222	7.6792	0.176413	5.6685	0.176413	5.6685
0.095182	10.506	0.132352	8.2732	0.138352	8.1732
0.070518	14.181	0.103541	10.691	0.115041	10.691
0.059263	16.874	0.088849	12.682	0.103445	12.682
0.046351	21.574	0.068676	17.043	0.087076	17.043
0.04327	23.11	0.066487	17.703	0.085487	17.703
0.040349	24.784	0.062943	18.888	0.082943	18.888
0.038179	26.192	0.060012	19.995	0.080012	19.995
0.036431	27.449	0.056999	21.74	0.075999	21.74
0.034852	28.693	0.056176	22.637	0.074176	22.637
0.031587	31.658	0.054562	24.06	0.071562	24.06
0.029538	33.854	0.053564	26.622	0.067564	26.622
0.029082	34.385	0.052955	27.812	0.065955	27.812
0.02906	34.411	0.052928	27.834	0.065928	27.834
0.027426	36.461	0.051986	29.424	0.064986	29.424
0.027389	36.511	0.051356	29.464	0.063939	29.464

Table 4

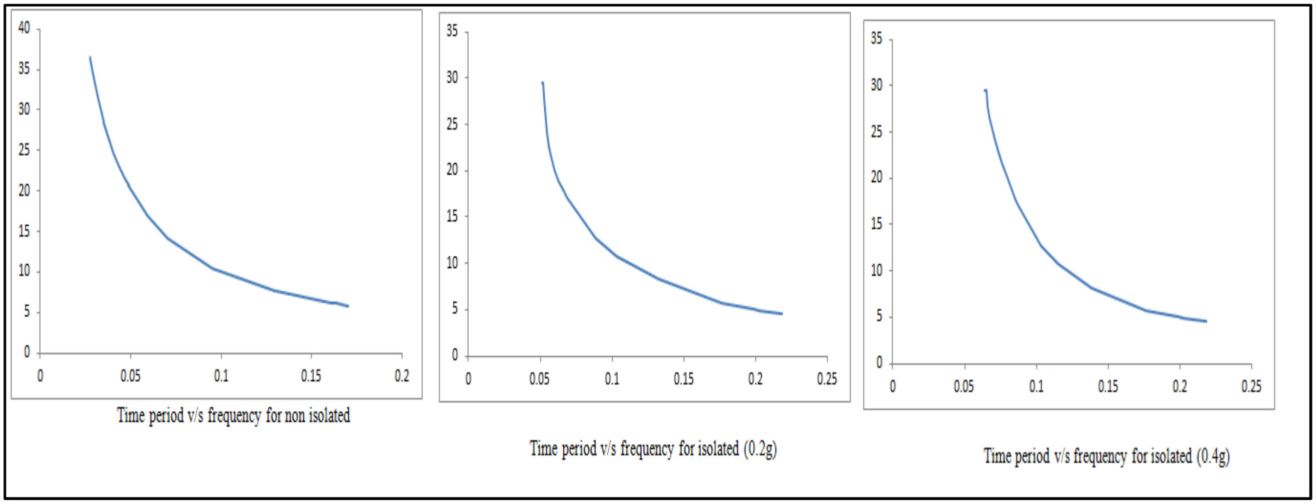

Figure 4: Response spectrum curves

7.2. Displacements

MODEL 1-NON ISOLATED		MODEL 2- ISOLATED (0.2g)		MODEL 3- ISOLATED (0.4g)	
X DIRECTION	Y DIRECTION	X DIRECTION	Y DIRECTION	X DIRECTION	Y DIRECTION
26.76 mm	28.74 mm	19.7 mm	21 mm	19 mm	20 mm

Table 5

7.3. Acceleration

MODEL 1-NON ISOLATED		MODEL 2- ISOLATED (0.2g)		MODEL 3- ISOLATED (0.4g)	
X DIRECTION	Y DIRECTION	X DIRECTION	Y DIRECTION	X DIRECTION	Y DIRECTION
0.53 mm/sec2	0.53 mm/sec2	0.51 mm/sec2	0.51 mm/sec2	0.5 mm/sec2	0.5 mm/sec2

Table 6

7.4. Modal Participation Factor

		MODEL 1-NON ISOLATED		MODEL 2- ISOLATED (0.2g)		MODEL 2- ISOLATED (0.4g)	
Type	Direction	STATIC PERCENTAGE	DYNAMIC PERCENTAGE	STATIC PERCENTAGE	DYNAMIC PERCENTAGE	STATIC PERCENTAGE	DYNAMIC PERCENTAGE
Acceleration	UX	99.9987	99.9371	99.9983	99.9296	99.9983	99.9296
Acceleration	UY	100	99.9997	100	99.9997	100	99.9997
Acceleration	UZ	71.4472	61.298	63.585	57.0207	63.585	57.0207

Table 7

8. Summary and Conclusion

1. Base isolation is very best method to protect bridges from seismic excitation.
2. In x direction due to decrease in transfer of seismic load, displacement of the superstructure is reduced. 26.39 percentage reduction is observed for Model-2. And for Model-3 29 percentage is reduced.
3. In y direction due to decrease in transfer of seismic load, displacement of the superstructure is reduced. 26.94 percentage reduction is observed for Model-2. And for Model-3 30.41 percentage is reduced.
4. For Model-2-time period of the isolated structure is extended 0.05136 sec and for Model-3-time period is shifted to 0.063939 sec.
5. Acceleration of superstructure for Model-1 is 0.53 m/sec2, for Model-2 is 0.51 m/sec2 and for Model 3 is 0.5 m/sec2.
6. Modal load participation factor for static and dynamic in x and y direction is same for all three models. Where as in z direction for Model-1 static is 71.4472 and dynamic is 61.298 and for Model-2 and 3 static is 63.585 and dynamic is 57.0207.
7. In isolated bridges considerable reduction in member forces are observed.

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