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Seismic Performance of Long Span Open Spandrel Concrete Arch Bridge

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Abstract
This paper presents the seismic performance evaluation of an open spandrel long span concrete arch bridge. A 120 m long span open spandrel reinforced concrete arch bridge with and without bracing has been constructed in (SAP2000). Different time history which has been scaled to match IS code Response spectra and has been applied to study the variation of the forces and the displacement. Both the models were evaluated using pushover analysis to obtain the capacity and time history analysis to obtain the displacement and the results were interpreted. The seismic performance has been satisfactorily improved by using bracing in between the spandrel.

Keywords
long span – arch – seismic performance – bracing

1. Introduction

Nepal is particularly prone to earthquakes. It lies on the boundary of two massive tectonic plates – the Indo-Australian and Asian plates. Bridges are the life line structures that should be properly designed to resist the earthquake. Many arch bridges were damaged in the Wenchuan Earthquake(2008) and studies were carried out to study the damage after the earthquake [1].

The Highway bridges are such structures whose damage will have direct effect on the rescue operation as well as on the restoration activities, after the earthquake. Thus they should be in working condition even after the major shaking due to earthquake. This necessitates the seismic vulnerability assessment of highway bridges as to fore see its availability for use in post-earthquake activities [2].

It has been found that the transverse direction of arch bridge is more dangerous than the longitudinal direction under earthquake and therefore, the behavior of this direction should be paid more attention [3].

The seismic upgrading method for steel arch bridges using buckling-restrained braces shows that there is considerable reduction in the forces as well as the decrease in the displacement. With buckling restrained, BRB members can provide stable energy dissipation capacity and thus damage of the whole structure under major earthquakes can be mitigated [4].

2. Bridge Description

For the study, long span arch bridge with span of 120m as shown in Figure 1 has been considered which is going to be built at Mungling. This bridge will be a reinforced concrete fixed arch bridge, with three numbers of arch ribs. Total length of the bridge is 160 m with arch being span of a 120m and rest will be the T-Beam Bridge. Carriageway width is 7.5 m and clear width of the footpath on either side is 1.4 m, making total width of the bridge as 11.2 m. A new model which is unbraced has also been prepared which is the modified version of old model, where the spandrel size has been decreased to 20 percent of its original size and the transverse bracing has been introduced in the spandrels.

3. Finite element Modelling

The finite element model of the bridge was prepared as shown in Figure 2 and Figure 3 in SAP2000. The deck is modeled as a shell element, the girders and columns with beam elements and the arch as line beam element, and the bracing as a frame element.

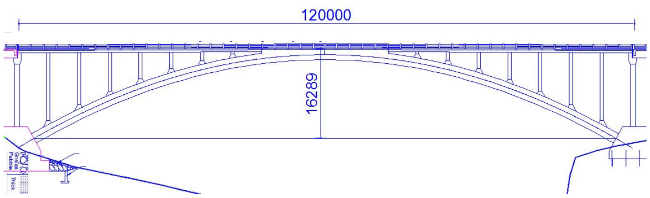

Figure 1: Sectional Elevation of the Bridge

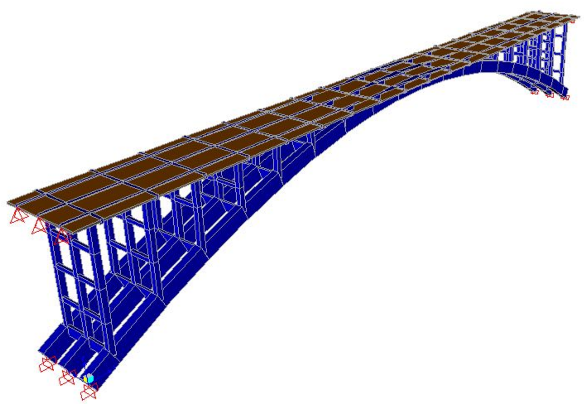

Figure 2: Unbraced model

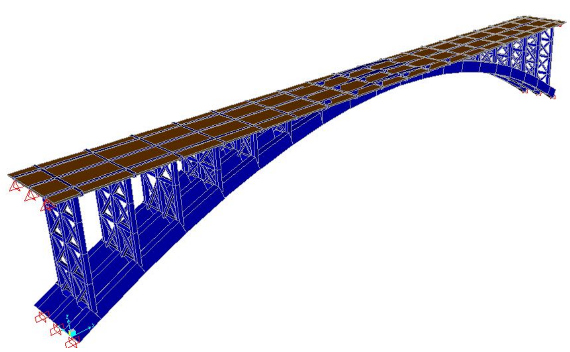

Figure 3: Braced model

4. Analysis and Result

Modal Analysis: Modal analysis was carried out in both the models for the determination of time period and the mode shapes during the free vibration. The fundamental time period of the original model was found to be 1.27s which has been decreased to the 1.03s after the installation of the bracing in the model.

For the original model, the first deflection mode was found to be out of plane. The second mode time period was found to be 0.56s with deflection mode as in plane. The third mode was with time period of 0.54s and was found to be out of plane.

For the braced model, the deflection mode of the first mode is out of plane. The second mode deflection is still in plane with time period of 0.58s, there was negligible increase in the time period which is due to the decrease in the size of the spandrel. The third mode shape of the braced bridge was same as the original model. The higher mode shape of the braced bridge was found to be different than that of original model.

Push over Analysis: For the performance of the bridge, pushover analysis has been carried out. Auto hinge properties of concrete as per FEMA 356 were used. For Beam, Concrete-beam flexure with M3 DOF and for column, flexures with P-M2-M3 DOF were assigned. A deformation control pushover analysis was carried out and the result of the structure was obtained in terms of base shear force versus crown displacement that is referred to as the capacity curve of the bridge structure. From the analysis, displacement capacity of the unbraced bridge was found to be 103 mm in longitudinal direction and 336 mm in transverse direction for the original model while as for the braced model the displacement capacity was increased to 103 mm in longitudinal and 368 mm in transverse direction. The displacement capacity of the bridge in the longitudinal direction is increased considerably which is due to the bracing which has been introduced in the original model.

Time History Analysis: Linear time history analysis was carried out considering the following earthquake shown in Figure 4. The ground motion obtained was scaled to match our IS code based response spectra, as shown in Figure 5 and then was applied to our model and the maximum displacement and the top displacement of two models were compared, the maximum displacement was considerably reduced which is shown in Figure 6. The axial force and the bending moment in the spandrel was also compared which has been shown in Figure 7 and Figure 8.

S.N	Earthquake	Mw	Station	Pga(g)
1	Gorkha	7.8	Kanitpath, Nepal	0.177
2	Imperial	6.53	El-Centro Array 6	0.449
3	Irpina	6.93	Stuna	0.32
4	Kobe	6.9	Fukushima	0.21
5	Loma	6.93	Oakland	0.29

Figure 4: Ground motion considered for the study

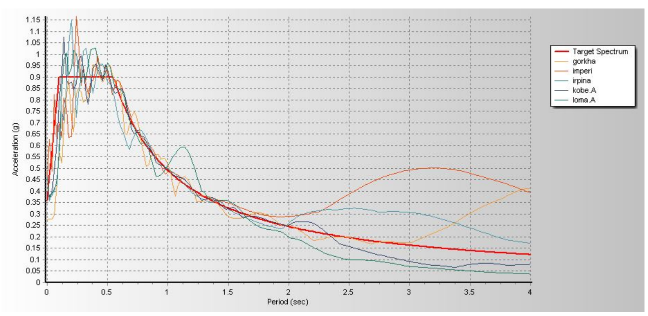

Figure 5: Scaling of the ground motion in Sesismomatch software

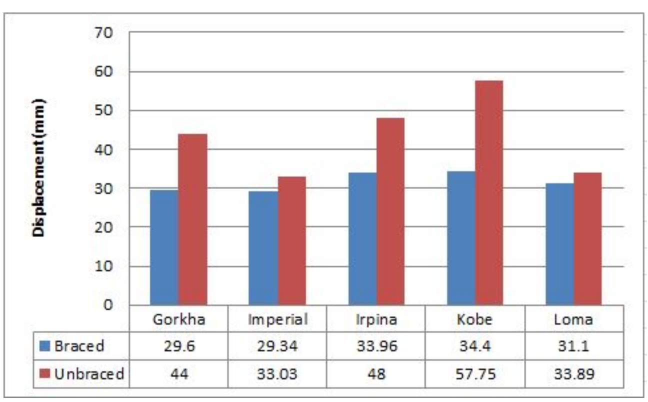

Figure 6: Comparison of maximum displacement in transverse direction with braced and unbraced model

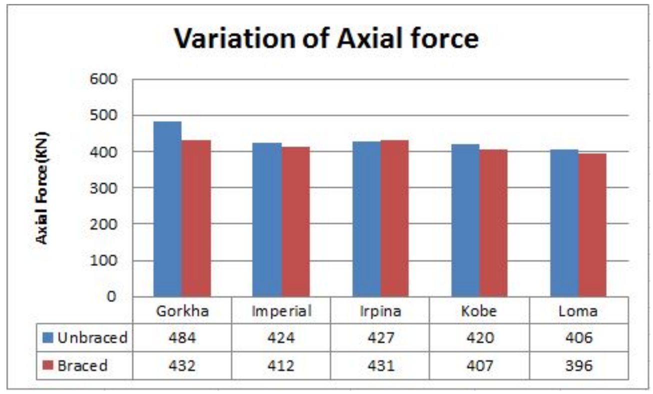

Figure 7: Comparison of Axial force in the spandrel with braced and unbraced model

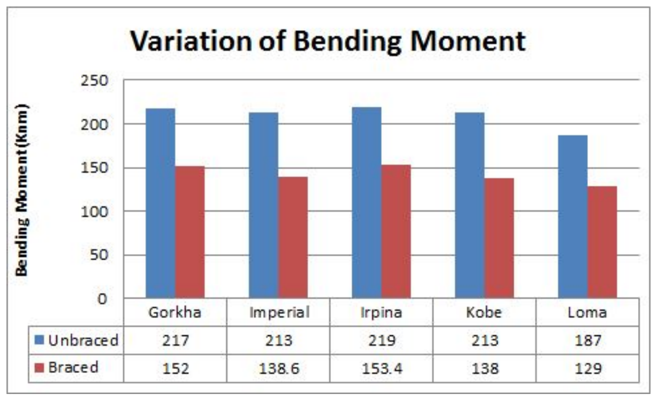

Figure 8: Comparison of Bending Moment in the spandrel with braced and unbraced model

5. Conclusions

1. The conventional bridge model shows the considerable displacement along lateral direction in the first mode of vibration, which is considered to be critical, it also shows that the failure of the bridge might be in lateral direction. Thus, providing the bracing can be a better solution to prevent the failure in transverse direction.

2. Installation of the bracing in between the spandrel decreases the fundamental time period from 1.27s to 1.03s which shows that the bracing has increased the considerable lateral stiffness.

3. Due to the installation of the bracing, the seismic capacity along the transverse direction has increased from 336 mm to 368mm.

4. Installation of bracing in the spandrel shows the considerable decrease in the Bending Moment, while there is slight decrease in case of axial force in the spandrel.

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