Seismic Analysis of Substructure Irregularity of Reinforced Concrete Girder Bridges with Solid & Hollow Pier Sections

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Abstract— A large portion of modern infrastructure involves the construction of irregular shapes of structures. In the design of bridges this is a considerable problem to provide substructure irregularity in the structure. In this report we are using Csi Bridge 2016 for performing non-linear pushover seismic analysis of substructure irregularity with solid and hollow pier sections. We perform design of the structure and their numerical analysis where we get shear and displacement values for different aspect ratio. The results obtained from the analysis shows that the vernability of the structure due to base shear goes on increasing as increasing the substructure irregularity for both solid and hollow pier section. As the substructure irregularity increased there will be a decrement in displacement capacity of the bridge structure for both solid and hollow pier section. Therefore we can say that the performance of hollow pier sections are much better than the solid pier section in case of substructure irregularity and could be a better option as compare to solid piers.

Key words: Reinforced Concrete, Girder Bridges, Solid & Hollow Pier Sections

I. INTRODUCTION

A large portion of modern infrastructures involves the construction of irregular building and bridges. These structures are highly vulnerable to seismic forces during earthquakes. That will cause high damage or collapse to the structures. It has been found that the regular shapes perform better than irregular shapes during earthquake and are recommended over irregular structures. In the past, earthquake resistant constructions should be designed to have regular configuration because their behavior and analysis is simple to understand, but while designing bridges we have to satisfy site conditions which will not allow constructing regular shape bridges. It will deteriorate the aesthetic appearance and stability of the site. A common form of irregularities arises when it is constructed with a varying length of column. As the response over superstructures is uniformly distributed but its deformation over substructures varies non uniformly. This non uniformity will cause change in the bearing capacity and life of the structure. So there is a need to design irregular structures using software's and researches. In cases where the cross sections of the piers are identical, the shorter piers resist higher level of inertia forces than the longer piers. The shorter piers are subjected to increased ductility demand and consequent damage tends to localize in these relative piers. On the other hand, stiffening or strengthening of the high demand piers typically leads to the opposite result and attraction of large forces. Compared to solid piers, hollow piers have the advantage of having significant reduction in the volume of the material and large reduction of dead load. The economical convenience in the use of hollow columns is due to the cost saving afforded by reduced section area .Also, hollow columns are more efficient than solid ones from a structural point of view. When the weight of the vertical members is relevant in the performance of the entire structure, a significant reduction in the seismic mass may be attained by using this structural type.

II. OBJECTIVE OF STUDY

For this many research scholars are working on the project so that we will get economically aesthetic and strong structures. This can be done through various software and manual practices. Software used like Csi Bridge, SAP, Stadd.pro etc. are used for analysis of structures. In this analysis we are performing "Seismic analysis of substructure irregularity of Reinforced Concrete Girder Bridges with solid and hollow pier sections" The detailed objective for the following analysis shall be as follows:

a) To perform nonlinear static pushover analysis for different cases of substructure irregularity.
b) To determine base shear capacity and displacement capacity of piers.
c) To compare the result of seismic analysis of both solid and hollow pier sections.

III. METHODOLOGY & FORMULATION

A. *General Description of structure*

To study the effect of substructure irregularity of 3 span girder reinforced concrete bridge. Different Aspect ratio of pier height has been considered as shown in Table 1.

Length of Bridge	Deck	Main Girder	Cross Girder	Cap Beam	Pier
45m (3 spans of 15m each)	8.4m width and 0.41m deep	1.325mx0.6m	1.325mx0.3m	8m long, 1.5 m wide & 2m deep	1.5mx3m solid rectangular or hollow rectangular section

Table 1: Details of Bridge Structure

Five cases of substructure irregularity for each pier section has been considered and described here as shown in Table 2

Case	Short Pier Height H_1 (m)	Long Pier Height H_2 (m)	Aspect Ratio (H_1/H_2)
I	5	15	0.33
II	7.5	15	0.5
III	10.5	15	0.7
IV	12	15	0.8
V	15	15	1

Table 2: Various Cases for Pier Height Ratio

S. No.	Specifications	Details
1.	Type of Structure	Reinforced Concrete Girder Bridge
2.	Seismic zone	IV
3.	Zone Factor	0.24
4.	Importance factor	1.5
5.	Response spectra	As per IS 1893 (part 1):2002
6.	Response reduction Factor	2.5
7.	Type of Soil	II

Table 3: General Parameters of Structure

B. Methodology

Proposed methodology for seismic evaluation of Reinforced Concrete Girder Bridge having solid and hollow pier:

1) Modeling and Response Spectrum Analysis have been performed on different cases of RC Bridge using CSiBridge 2017 software.
2) Design of solid and hollow pier section.
3) Nonlinear Pushover Analysis has been performed on different cases of RC Bridge using CSiBridge 2017 software.

IV. ANALYSIS & DESIGN OF BRIDGES

A. Problem Considered

T Girder Bridge, as shown in fig.1, of total length 45m (3 spans of 15m each) is taken for case study with deck width of 8.4m and depth of 0.41m. Two solid pier of rectangular size 1.5m wide and 3m deep and aspect ratios 0.33, 0.5, 0.7, 0.8,1 are considered. Cap beam of depth 2m and 1.5m width is designed. Live load of IRC class 70-R loading is taken. The reinforced concrete bridge is designed as per IS 456:2000. Earthquake force is calculated as per IS 1893:2002. Seismic zone IV (zone factor 0.24) and medium soil is considered.

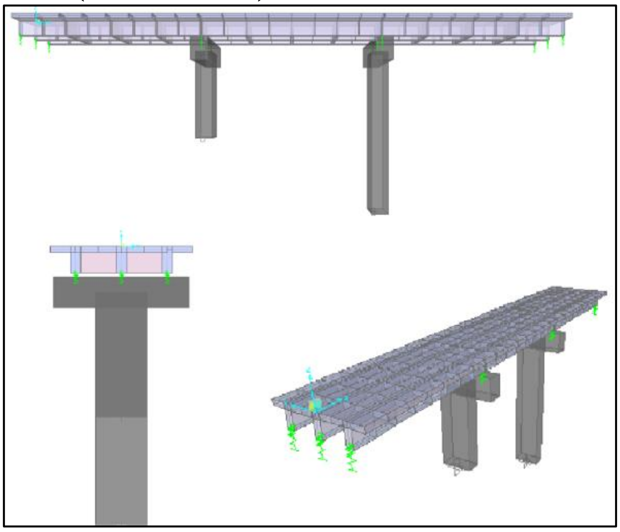

Fig. 1: Extrude View Solid Pier Bridge Model

B. Pushover analysis at Short and Long, Hollow and Solid Pier Section of the bridge structure as follows

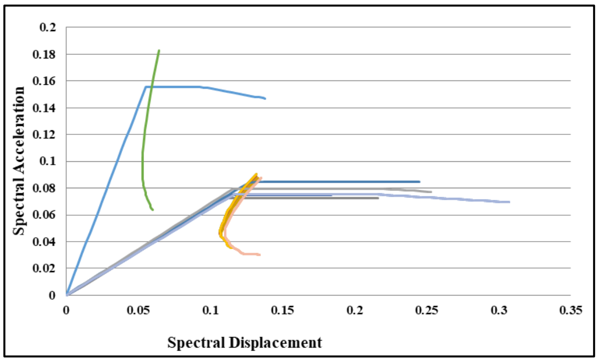

Fig. 2: Capacity and Demand Curve for Short and Long Hollow Pier in Transverse Direction for A. R. 0.33 to 1

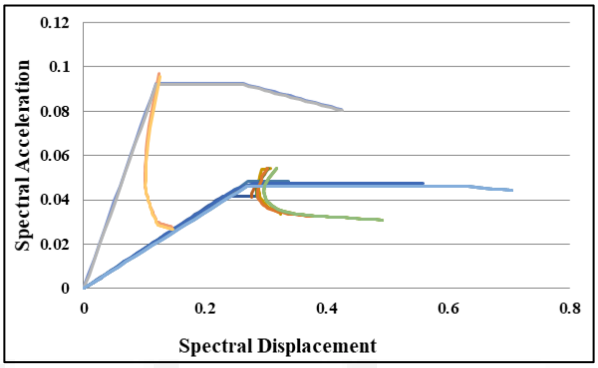

Fig. 3: Capacity and Demand Curve in Short and Long hollow Pier in Longitudnal Direction for A.R.0.33 to 1

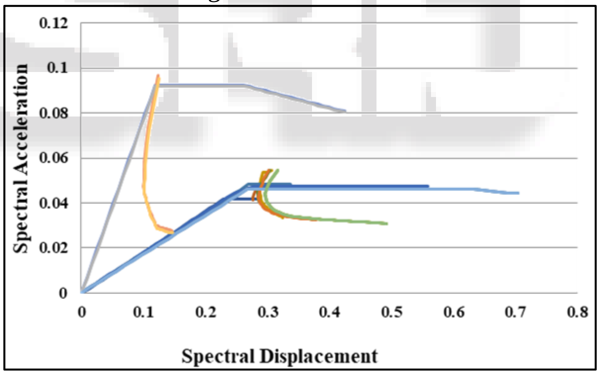

Fig. 4: Capacity and Demand Curve in Short and Long Hollow Pier in Longitudnal Direction for A.R.0.33to1

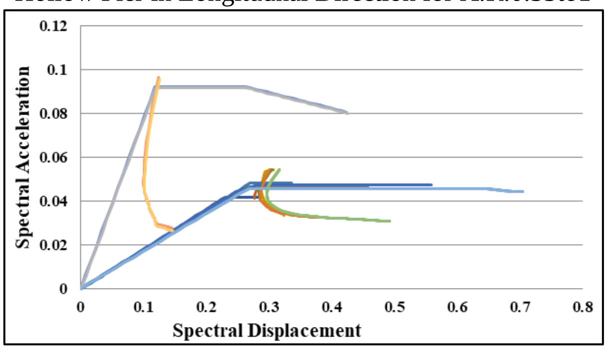

Fig. 5: Capacity and Demand Curve in Short and Long Hollow Pier in Longitudnal Direction for A.R.0.33to1

V. Result & Discussion

For the present study five cases of irregularity for each solid rectangular and hollow rectangular pier section has been considered and analysis has been performed using CSiBridge 2017. The results of the above analysis are compared for the different cases of irregularity and described here. Base Shear and Displacement for Solid and hollow Pier at Performance Point is as follows:

A. Result

Aspect ratio	TR1	LG1	TR2	LG2
0.33	6413.88	4061.07	2000.73	1146.39
0.5	4595.52	2671.20	1986.25	1159.24
0.7	3462.58	1980.91	2018.20	1177.16
0.8	2758.83	1380.23	2009.96	1177.26
1	2019.07	1175.08	2019.04	1175.02

Table 4: Base Shear for Solid Pier

Aspect ratio	TR1	LG1	TR2	LG2
0.33	0.029	0.098	0.128	0.193
0.5	0.042	0.108	0.128	0.201
0.7	0.073	0.127	0.123	0.206
0.8	0.087	0.162	0.130	0.215
1	0.132	0.219	0.132	0.219

Table 5: Displacement for Solid Pier

Aspect ratio	TR1	LG1	TR2	LG2
0.33	4737.07	2752.77	1640.32	997.85
0.5	3492.55	2074.30	1618.79	999.70
0.7	2910.59	1740.89	1619.31	1025.11
0.8	2403.50	1436.09	1667.88	1009.51
1	1489.90	934.998	1479.56	934.94

Table 6: Base Shear for Hollow Pier

Aspect ratio	TR1	LG1	TR2	LG2
0.33	0.062	0.094	0.131	0.298
0.5	0.073	0.136	0.133	0.306
0.7	0.086	0.162	0.133	0.302
0.8	0.105	0.203	0.133	0.304
1	0.142	0.305	0.142	0.305

Table 7: Displacement for Hollow Pier

B. Discussion

1) The result shows that the base shear and spectral displacement goes on increasing and decreasing respectively when aspect ratio goes on decreasing.
2) Base shear found to be less in case of hollow pier as compare to solid pier section for all cases of substructure irregularity.
3) Spectral Displacement found to be more in case of hollow pier as compare to solid pier section for all cases of substructure irregularity.
4) Base shear and displacements shown in the table are shown on the basis of directional forcing.
5) Forces are provided in the transverse and longitudinal direction in both hollow and solid pier section.
6) The analysis showed in graphs shows that there are large variations in some cases of displacement.

VI. Conclusion

a) The results obtained from the analysis shows that the vernability of the structure due to base shear goes on increasing as increasing the substructure irregularity for both solid and hollow pier section.
b) As the substructure irregularity increased there will be a decrement in displacement capacity of the bridge structure for both solid and hollow pier section.
c) From the above analysis the conclusion obtained is that the performance of hollow pier sections are much better than the solid pier section in case of substructure irregularity and could be a better option as compare to solid piers.

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