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A Study on Seismic Performance of Skewed Bridge Pier under different Skew Angles

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Abstract—*Skew bridges are mainly used at the highway intersection as an overpass. These bridges are essential component of modern transportation system. The load transfer mechanism of these bridges is very complex. These bridges are also vulnerable to earthquake motion. The intermediate support columns are mainly subjected to these earthquake induced loading. These bent columns can suffer severe damage if not properly designed. Therefore they should be designed with adequate strength so that safety of the bridge is ensured. FEM models of the bridge section are developed using CSI Bridge version 21 finite element software. The bent column forces which include axial force, vertical shear, torsion and bending moment about vertical axis of column are calculated for models with skewness ranging from 0 to 60 degrees. Models are created for both T-beam and Precast-I girder deck section. Response spectrum method of earthquake analysis is used for force calculation. Seismic zone IV and hard soil(Type-1) is considered. Combination of dead load, seismic load according to IS 1893- 2016 and IRC 6(IRC A, IRC AA and IRC 70R) vehicular loading is used. The results generated show that there is an increase in bent column forces i.e axial force, vertical shear, torsion and bending moment about vertical axis of column for both types of bridge section with the increase in skew angle. The results also conclude that earthquake induced bent column forces in the precast-I girder are less in comparison with T-beam section.*

Keyword: *Skew bridge, FEM models, Response spectrum method, Seismic behaviour, CSi bridge version 21.*

1. INTRODUCTION

Skew bridges are vulnerable to earthquake induced forces. The load transfer mechanism of these bridges is very complex. These bridges are also vulnerable to earthquake motion. The intermediate support columns are mainly subjected to these earthquake induced loading. Bridge columns are subjected to severe loading during the earthquake. For skew bridges it has been found that severe failure occurs in the column due to earthquake induced forces. It has been found from previous studies that flexure and torsion of the bridge deck results in excessive compression of the pier resulting in its failure. In this study the effect of skewness of the bridge deck on the earthquake induced forces in the column is studied. The earthquake response studied includes Axial force, Vertical Shear force, Torsion moment and Bending moment about the vertical axis of the column. The skew bridge is considered to be in earthquake zone IV and it is assumed that Type-I i.e hard soil type condition is present at the site. Moreover columns are assumed to be fixed at the bases. It is very important to study the skew angle effect on column performance because columns play the vital role of transferring all types of loads from the superstructure to the ground. Therefore they should be analysed for skewness as well as which deck section is more preferable.

1.1 Objective of study

I. To determine maximum values of earthquake induced axial force, vertical shear, torsion and bending moment about vertical axis in bridge pier for precast-I girder bridge section for skew angle of 0, 15, 30, 45 and 60 degrees.
II. To determine maximum values of earthquake induced axial force, vertical shear, torsion and bending moment about vertical axis in bridge pier for T-beam bridge section for skew angle of 0, 15, 30, 45 and 60 degrees.
III. To study the effect of change in skew angle on earthquake induced values for columns with precast-I girder bridge section.
IV. To study the effect of change in skew angle on earthquake induced values for columns with T-beam girder bridge section.
V. To draw a comparison between maximum values of earthquake induced forces in bridge pier(axial force, vertical shear, torsion and bending moment about vertical axis) for both Precast-I girder and T-beam bridge section.

VI. To find most suitable bridge section between precast-I girder and T-beam for skew bridge construction which will give lesser earthquake induced forces in the bridge pier.

2. STRUCTURAL MODELING

Structural modeling of the bridge section is done using the CSi Bridge version 21 software which works on finite element method. Total length of the bridge section is 40m. The bridge is divided into two spans of 20m each. The width of the deck section is 12m. Bridge is modeled for skew angle 0, 15, 30, 45 and 60 degrees for both type of deck section i.e Precast-I and T-beam type deck section in total ten bridge models are created. The columns are considered fixed at the bases. The diameter of each column is 1.5m and height is 8m. The length of the bridge section and its width is kept constant however cap beam length varies with the change in skew angle along the skew direction. One end of each span is supported on abutment while the other intermediate end is supported on bent which consist of three pier columns. The columns are considered fixed at the bases. The cap beam is modeled as a reinforced concrete beam with dimensions of 1.5m width and 0.6m depth. At the bent section the bearing is taken to be fixed in both transverse and vertical direction while at the abutment it is free for longitudinal and transverse direction but fixed in vertical direction.

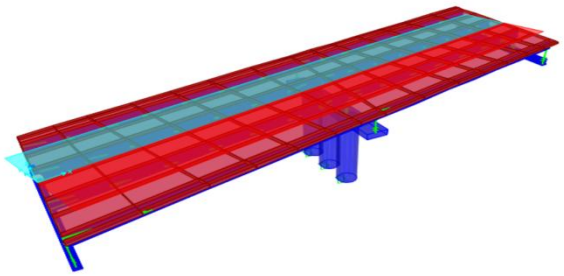


Fig. 1: 3-D view of skew bridge model

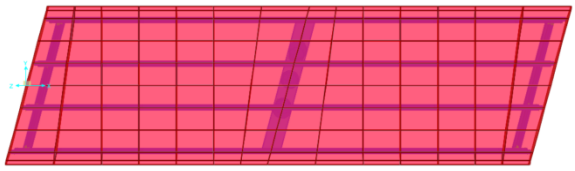


Fig. 2: Skew bridge plan.

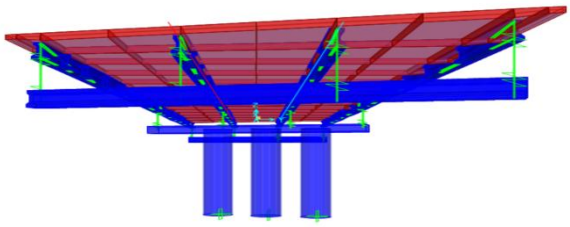


Fig. 3: Section view of Precast-I girder type bridge section

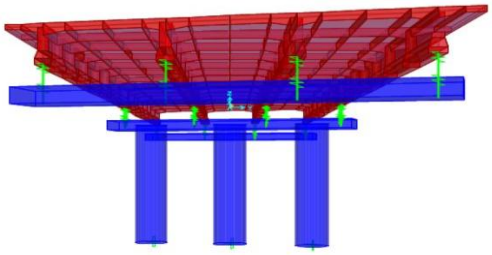


Fig. 4: Section view of T-beam bridge section

2.1 Description of bridge model

1.	Total length of the bridge	40m
2.	Number of span Span length	2 20m
3.	Skew angle considered	0°, 15°, 30°, 45° and 60°.
4.	Basic properties 1. Material • Grade of concrete considered • Rebar	 M30 HYSD415
	2. Frame sections • Column diameter • Column height • Cap beam length • Cap beam thickness • Cap beam depth	 1.5 8m 11m 1.5m 0.6m
5.	Deck section considered	Precast-I girder and T-beam type deck section
6.	Total deck width	12m
7.	Number of girders for both section	2
8.	Abutment length	11m
9.	Number of column	3
10.	Cap beam length at bent location	11m
11.	Lane data • Number of lane • Lane width	 2 3.75
12.	Vehicle class considereds	IRC A, IRC AA and IRC 70R.

3. SEISMIC ANALYSIS DATA

1.	IS code under consideration	IS 1893-2016
2.	Method of earthquake analysis	Response Spectrum function
3.	Seismic zone considered	Zone IV
4.	Soil type	Type 1(hard soil)
5.	Response reduction factor	5
6.	Function damping ratio	0.05

4. RESULTS AND ANALYSIS

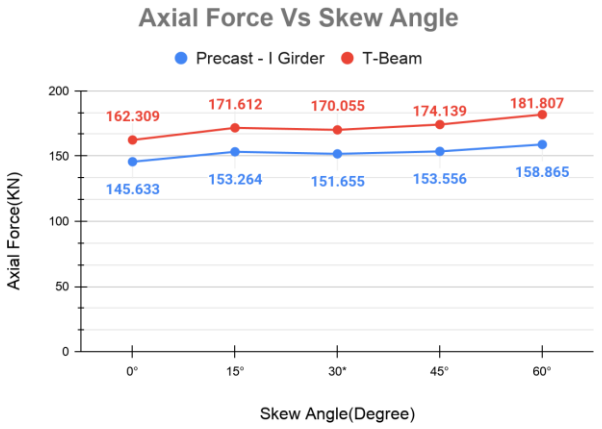
4.1 Maximum value of Earthquake induced forces in bridge pier for I-girder deck section.

Skew angle (Degree)	Axial force (KN)	Vertical shear (KN)	Torsion-T (KN-m)	Moment about vertical axis (KN-m)
0	145.633	63.618	3.153	275.39
15	153.264	66.899	9.200	288.670
30	151.655	65.213	17.737	280.102
45	153.566	62.824	20.0261	270.243
60	158.865	68.504	22.6804	313.758

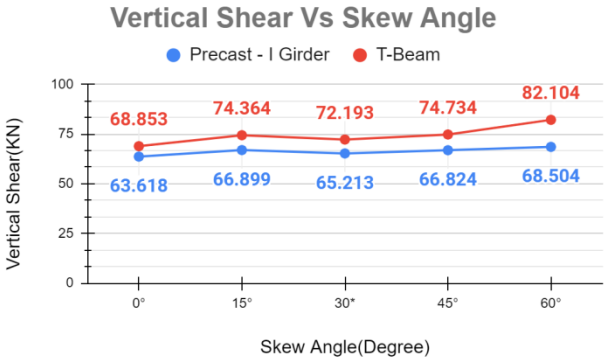
4.2 Maximum value of Earthquake induced forces in bridge pier for T-beam deck section.

Skew angle (Degree)	Axial force (KN)	Vertical shear (KN)	Torsion-T (KN-m)	Moment about vertical axis (KN-m)
0	161.309	60.086	3.805	321.807
15	171.612	64.402	7.322	377.014
30	170.055	72.193	12.704	325.561
45	174.139	74.734	22.6747	285.632
60	181.807	82.104	24.5479	364.406

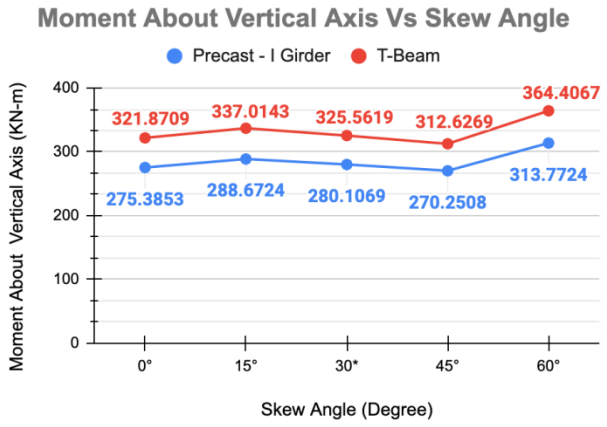
4.3 Graphical representation of Maximum value of earthquake induced forces in bridge pier for both precast-I girder and T-beam deck section.



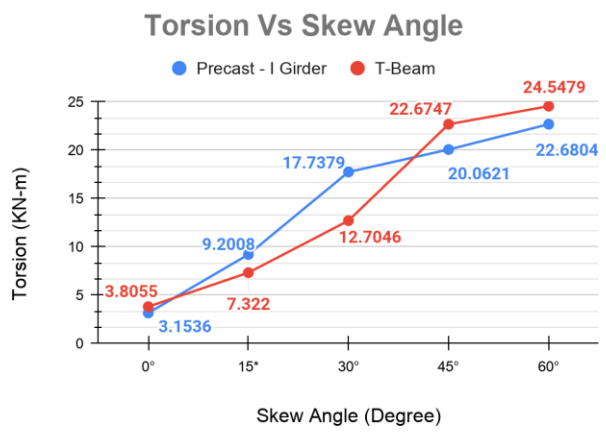
Graph-1 Between Axial Force and Skew Angle



Graph-2 Between vertical shear and Skew Angle.

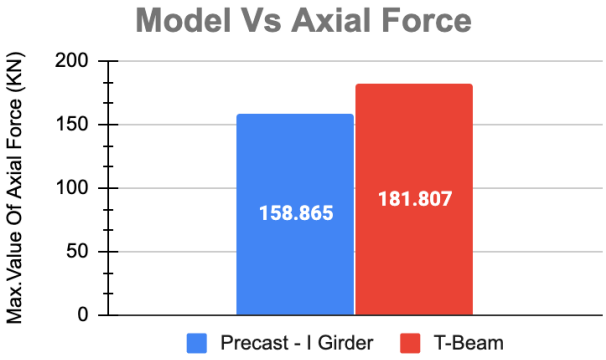


Graph-3 Between Moment about vertical axis and Skew Angle.

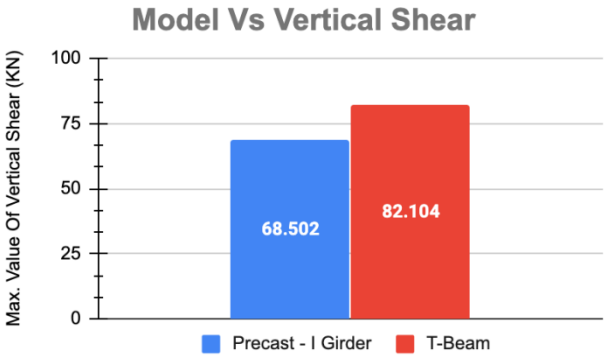


Graph-4 Between Torsion and Skew Angle.

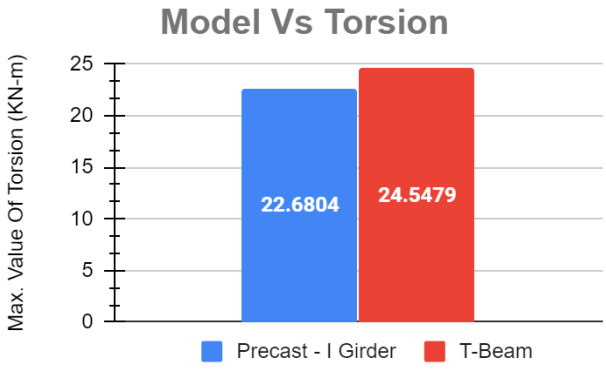
4.4 Comparison Of Maximum Earthquake Induced Force Value in bridge pier Between I-Girder and T-Beam deck Section.



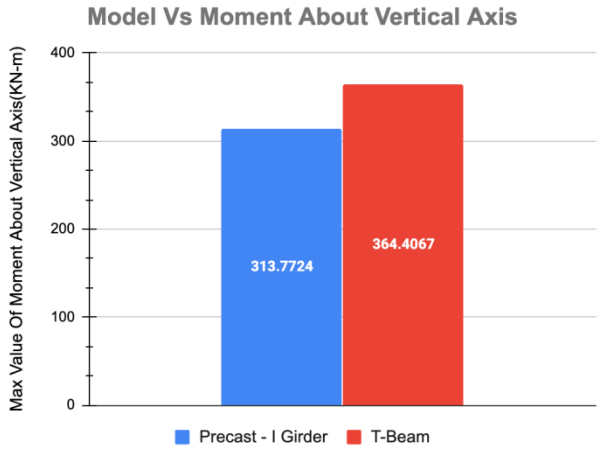
Graph-5 Comparison of Maximum Earthquake Induced Value in bridge pier.



Graph-6 Comparison of Maximum Earthquake Induced Value in bridge pier.



Graph-7 Comparison of Maximum Earthquake Induced Value in bridge pier.



Graph-8 Comparison of Maximum Earthquake Induced Value in bridge pier.

5. SUMMARY AND CONCLUSION.

There are several conclusions that can be drawn from this study which are as follows:

- With the increase in skew angle from 0° to 60° there is considerable increase of earthquake induced axial force in the bridge pier for both the I-girder and T-beam deck section. The axial force value increases from 145.633 KN to 158.865 KN for the I-girder deck section and for T-beam it increases from 99.9533 KN to 111.4959 KN.
- With the increase in skew angle from 0° to 60° there is considerable increase of earthquake induced torsion in the bridge pier for both the I-girder and T-beam deck section. The torsion value increases from 3.153 KN-m to 18.0261 KN-m for the I-girder deck section and for T-beam it increases from 3.805 KN-m to 19.547 KN-m.
- With the increase in skew angle from 0° to 60° there is considerable increase of earthquake induced vertical shear in the bridge pier for both the I-girder and T-beam deck section. The vertical shear value increases from 63.618

KN to 68.504 KN for the I-girder deck section and for T-beam it increases from 60.086 KN to 82.104 KN.

- With the increase in skew angle there is an increase in the value moment about the vertical axis in the bridge pier for both I-girder and T-beam deck section. The moment about the vertical axis value increases from 275.39 KN-m to 313.758 KN-m for the I-girder deck section and for T-beam it increases from 321.807 KN-m to 364.406 KN-m.
- The maximum Axial force value in bridge pier for I-girder was found to be 158.865 KN while for the T-beam section it was 181.807 KN.
- The maximum vertical shear value in bridge pier for I-girder was found to be 68.504 KN while for the T-beam section it was 82.104 KN.
- The maximum moment about vertical axis value in bridge pier for I-girder was found to be 313.758 KN-m while for the T-beam section it was 364.406 KN-m.
- The maximum Torsion value in bridge pier for I-girder was found to be 18.0261 KN-m while for the T-beam section it was 19.547 KN-m.
- Therefore to ensure the safety of the bridge structure I-girder should be preferred over T-beam deck section as lesser earthquake forces are induced in the bridge pier for a 40m two span bridge construction.

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