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Seismic behaviour Assessment of Skew Highway Bridge

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Abstract—*Skewed bridges are an essential component of modern transportation system. These skew-bridges are more vulnerable to earthquake induced forces compared to straight bridges as their load transfer mechanism is complex. In this study seismic behaviour of skew bridge is studied at various angles ranging from 0 to 60 degrees. The effect of change in skew angle on bridge forces such as axial force, torsion and bending moment about vertical axis is studied. It is also studied which deck section between precast I-girder and T-beam bridge will give less values of axial force, torsion and bending moment so that suitable deck section can be considered in skew-bridge construction. For this purpose FEM model of two span simply supported bridge of 40m with each span 20m is modelled using CSi Bridge version 21. The dynamic response of the skew bridge is investigated through these FEM models. Combination of dead load, seismic load according to IS 1893- 2016 and IRC 6(IRC A, IRC AA and IRC 70R) vehicular loading is considered. Response spectrum method of analysis for earthquake forces is used to obtain earthquake forces. Seismic zone IV and hard soil(type-1) condition is considered. The result generated shows that there is considerable increase in the axial force, torsion and bending moment about the vertical axis with the increase in skew angle for both t-beam and precast i-girder bridge. It is also concluded that skew bridge with i-girder type deck section is subjected to less induced force value of axial force, torsion and bending moment about vertical axis compared to t-beam bridge. Therefore precast i-girder deck section is preferred over t-beam for a two span of 20m skew-bridge construction.*

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

1. INTRODUCTION

A bridge is an essential component of modern road transportation system. A bridge is constructed for carrying the road traffic and other moving loads to pass safely through the obstacle such as a valley, river, highway intersection, railway crossing, buildings etc. therefore bridge is the lifeline of any transportation system. It is very important to align the bridge in straight line relative to approach road so that safety is ensure and speed can be maintained. Due to this consideration sometimes it is not possible to align bridge pier normal to the bridge longitudinal axis instead they are at some degrees to this axis. These type of bridges are known as skew bridges. Due to this skewness these bridges are more vulnerable to earthquake induced forces compared to normal straight bridges due to its complex load transfer mechanism. In AASHTO LFRD Bridge Design Specification (2004) it is mentioned that upto 15 degrees skew angle, the effect of skew angle is not prominent but greater than this angle there is considerable effect of skewness on the bridge forces. Therefore the effect of skewness on bridge forces such as axial force, torsion and bending moment about vertical axis should be analysed properly. This is important so that effect of skewness can be taken into account during design consideration. It is also very important to know which deck section should be preferred for skew bridge construction so that less earthquake forces are induced. In this study Response spectrum method is used to determine earthquake forces. This method permits multiple modes of response of a bridge that can be taken into account. The response of the bridge can be defined as a combination of various special shapes i.e modes. CSi Bridge version 21 Finite Element Method program is used for this purpose. Combination of dead load, seismic load according to IS 1893- 2016 and IRC 6(IRC A, IRC AA and IRC 70R) vehicular loading is considered. The process of finding the earthquake induced forces is done for both the types of deck section i.e precast-I girder and T-beam so that comparison can be drawn between them. The earthquake forces are found for angles which vary between 0 to 60 degrees.

1.1 Objective of Study

I. To determine maximum values of earthquake induced axial force, vertical shear and bending moment about vertical axis in 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 and bending moment about

vertical axis in 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 force values for precast-I girder bridge section.

IV. To study the effect of change in skew angle on earthquake induced force values for T-beam bridge section.

V. To draw a comparison between maximum values of earthquake induced forces(axial force, 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.

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 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 diameter of each column is 1.5m and height is 8m. 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.

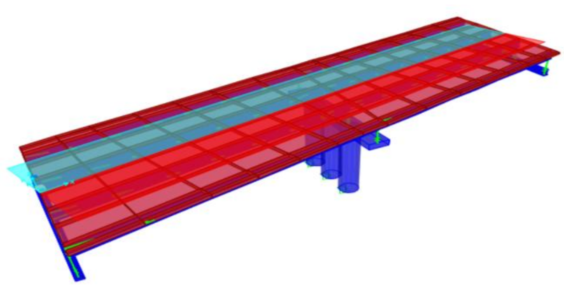


Fig. 1: 3-D view of skew bridge model

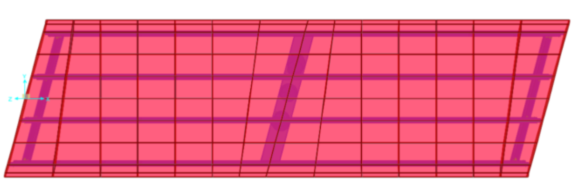


Fig. 2: skew bridge plan.

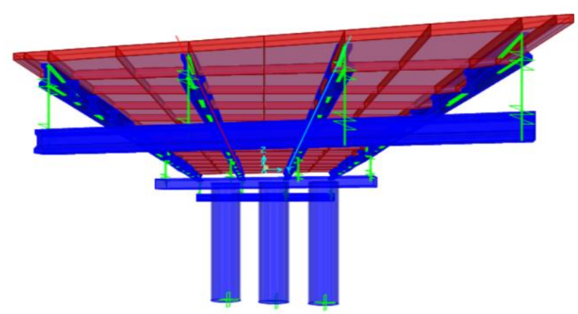


Fig. 3: Section view of Precast-I girder type bridge section.

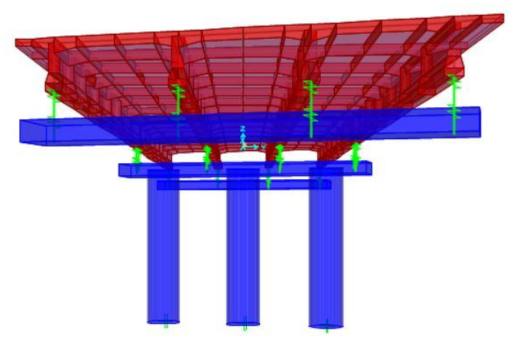


Fig. 4: Section view of T-beam bridge section.

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

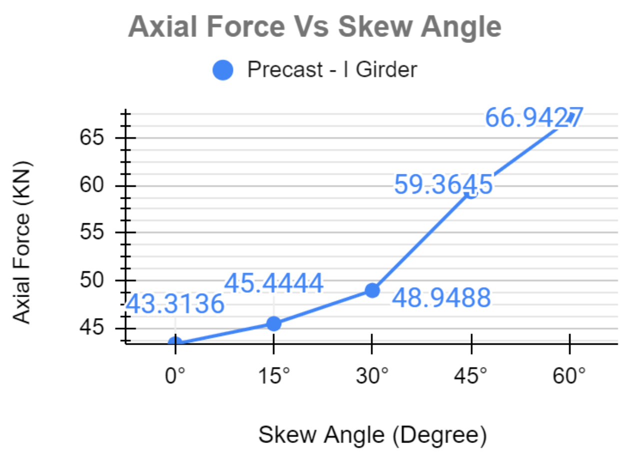
1.	IS code under consideration	IS 1893-2016
2.	Method of earthquake analysis	Response Spectrum function
3.	Seismic zone considered	Zone IV
4.	Soil type	Type 1(hard soil)
5.	Response reduction factor	5
6.	Function damping ratio	0.05

4. RESULTS AND ANALYSIS

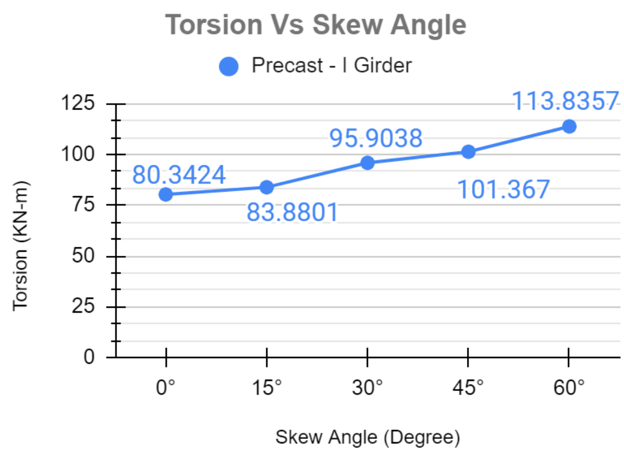
4.1 Earthquake induced forces for I-girder deck section.

Skew angle (Degree)	Axial force-P (KN)	Torsion-T (KN)	Moment about vertical axis (KN-m)
0	43.3136	80.3424	707.0784
15	45.4444	83.8801	721.6705
30	48.9488	95.9038	660.0016
45	59.3645	101.367	585.4786
60	66.9427	113.8357	500.4169

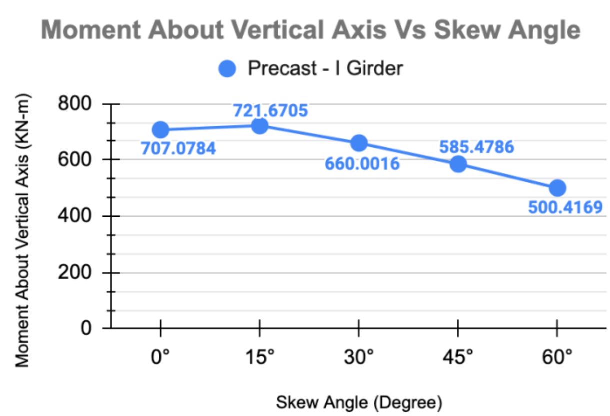
4.2 Graphical Representation of Earthquake Induced Forces.



Graph-1: Between Axial Force and Skew Angle



Graph-2: Between Torsion and Skew Angle.

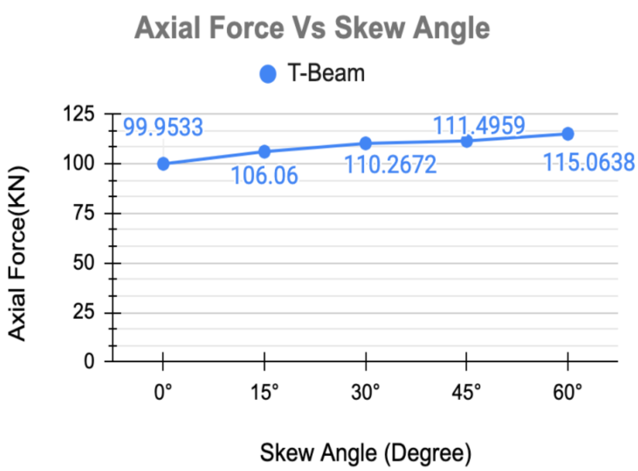


Graph-3: Between Moment About Vertical Axis Vs Skew Angle.

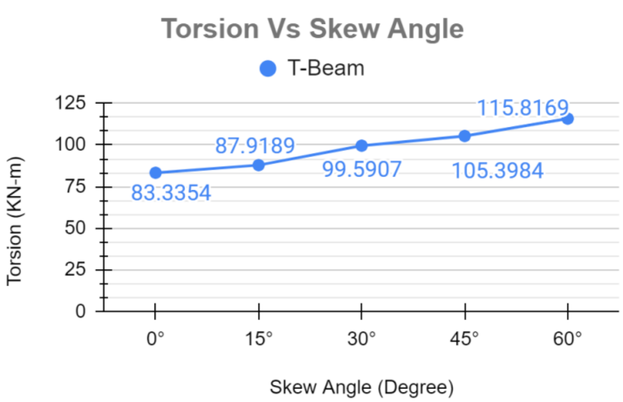
4.3 Earthquake induced forces for T-Beam deck section.

Skew angle (Degree)	Axial force-P (KN)	Torsion-T (KN)	Moment about vertical axis (KN-m)
0	99.9533	83.3354	955.3237
15	106.06	87.9189	987.1017
30	110.2672	99.5907	898.0829
45	111.4959	105.3984	759.1407
60	115.0638	115.8169	651.1828

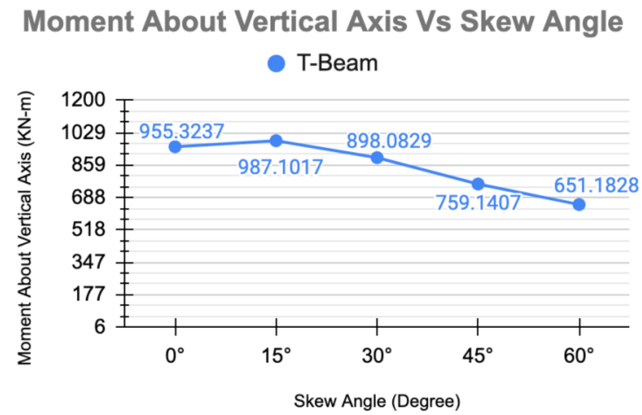
4.4 Graphical Representation of Earthquake Induced Forces



Graph-4: Between Axial Force and Skew Angle.

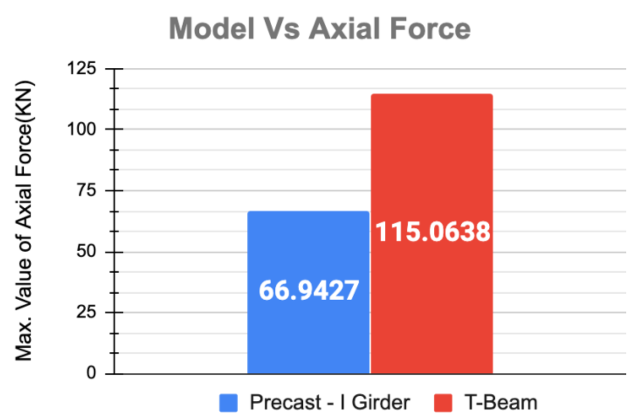


Graph-5: Between Torsion and Skew Angle.

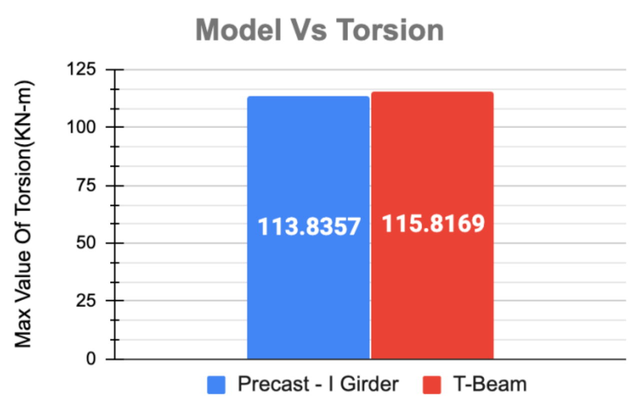


Graph-6: Between Moment About Vertical Axis and Skew Angle.

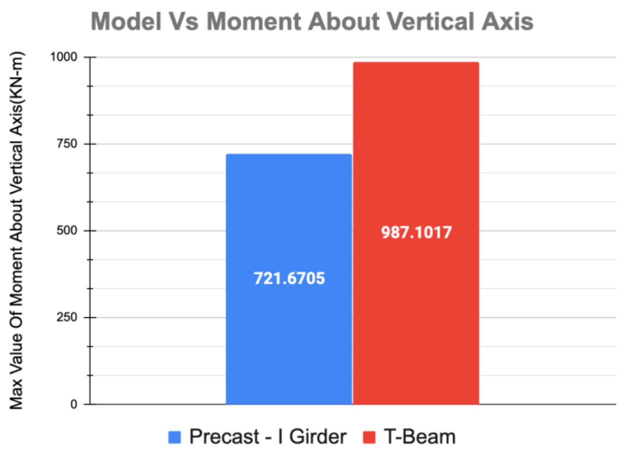
4.5 Comparison Of Maximum Earthquake Induced Force Value Between I-Girder and T-Beam Deck Section.



Graph-7: Comparison of Maximum Earthquake Induced Value.



Graph-8: Comparison of Maximum Earthquake Induced Value.



Graph-9: Comparison of Maximum Earthquake Induced Value.

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 for both the I-girder and T-beam deck section. The axial force value increases from 43.3136 KN to 66.9427 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 the skew angle the value of torsion for the bridge section increases considerably for both the I-girder and T-beam section. Torsion increases from 80.3424 KN-m to 113.8357 KN-m for I-girder deck section and 83.3354 KN to 115.8169 KN for T-beam deck section.
- With the increase in skew angle there is a decrease in the value moment about the vertical axis for both I-girder and T-beam deck section. This could be possible due change in the arrangement of the skew column.
- On comparing the maximum values of earthquake induced forces i.e axial force, torsion and moment about vertical axis between I-girder and T-beam, it was found that the earthquake induced forces are more for the T-beam section than the I- girder deck section.
- The maximum Axial force value for I-girder was found to be 66.9427 KN while for the T-beam section it was 115.0638 KN.
- The maximum Torsion value for I-girder was found to be 113.8357 KN-m while for the T-beam section it was 115.8169 KN-m.
- The maximum value of Moment about the vertical axis for I-girder was found to be 721.6705 KN-m while for the T-beam section it was 987.1017 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 this section for a 40m two span bridge construction.

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