ISSN (Online) 2456-1290

International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
Vol 3, Issue 4, April 2018

Effect of Skew Angle on the Seismic Behaviour of Reinforced Concrete Skew Deck Bridges

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***Abstract:*-- The effect of various skew angles during a seismic disturbance on a single reinforced concrete deck of a bridge has been presented in this paper using finite element analysis. The time history of Bhuj earthquake, India has been applied on the models. This study focuses on parameters such as total deformation, equivalent plastic strain, maximum principal stress and shear stress and a comparison between the behaviour at the time of seismic disturbances on a normal reinforced bridge deck and skew reinforced bridge deck at different angles such as 15°, 30°, 45°, 60°. The deck considered is of dimensions as recommended by the 'Standard Plans for Highway Bridges' published by Ministry of Shipping and Transport, India. According to the results as obtained from analysis clearly shows that there is a change in behaviour of the reinforced concrete deck as the angle of skew changes from 0° to 60°.**

I. INTRODUCTION

A bridge is a superstructure which plays an important role in the road transportation structure. Its performance at the time of seismic disturbance becomes more important for both providing relief as well as for providing defence and security for the nation. Till date many studies have been performed for the seismic analysis of the normal bridges which do not have any skew angle but many bridges due to space constraints are constructed having skew angles. Since there is a difference between the behaviour of both the bridges, the effect of the skew angles should be taken into consideration. Hence there is a need of study of the effect of skew angle on the seismic performance of the highway bridges. Skew angle is the angle which is provided between the line normal to the flow of traffic and the alignment of the bridge deck. Reinforced concrete skew deck are widely used in the construction of the bridge where there is an obstruction for a right bridge such as presence of a permanent structure, when the road crosses the canals and streams other than 90°. With the increasing population and urbanisation in India there is an emerging need for the highway bridges which due to space constrains should be designed as skew bridges. Skew bridges allow a large variety of solutions in roadway alignments. However the force flow in skew bridges is much more complicated than right angle bridges. To maintain steady flow of traffic at these intersections it will be necessary that they be designed with grade separation, which indicates that more skew deck bridges will be constructed in future.

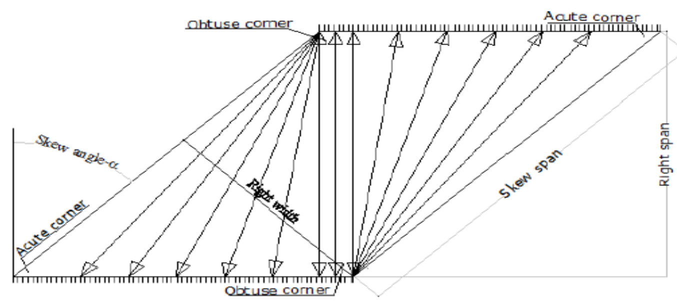


Fig 1: Basic structure of a skew slab

India has witnessed many earthquakes till date but the most destructive amongst them is the Bhuj earthquake which took place on January 26, 2001 with a magnitude of 7.7 recorded on moment magnitude scale, with its epicentre at about 9 km south-west of the village of Chobari in Bhachau Taluka of Kutch district of Gujrat, India. The intensity recorded on Mercalli intensity scale was X (Extreme). Thousands of people lost their lives and there was a large amount of destruction to the buildings and other structures. As the bridge in an important structure for providing relief through road, it should be analysed for its seismic behaviour. Many researchers have analysed the seismic behaviour of reinforced skew bridges with respect to the seismic records in their countries with their codes of design.

METHODOLOGY

The models of a certain span and detailing were generated analytically as recommended by 'Standard Plans for Highway Bridges' published by Ministry of Shipping and Transport, India. A total of 5 models were generated with skew angles 0°(straight bridge), 15°, 30°, 45°, 60° using ANSYS Workbench.

Material properties of concrete used:

Table 1:

Density	2314	kg m^-3
Specific Heat	654	J kg^-1 C^-1
Compressive Strength	35000000	Pa
Shear Modulus	16700000000	Pa
Bulk Modulus	35270000000	Pa

Material properties of structural steel used:

Table 2:

Density	7850	kg m^-3
Young's Modulus	2E+11	Pa
Poisson's Ratio	0.3	
Bulk Modulus	1.66667E+11	Pa
Shear Modulus	76923076923	Pa
Specific Heat	434	J kg^-1 C^-1

The method adopted was the finite element method and the analysis was done by using the time history analysis. Time history of Bhuj earthquake was applied on the generated models. The support conditions were kept fixed at all the corners.

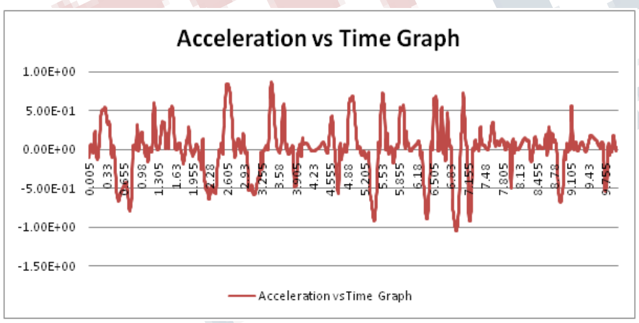


Fig 2: Graph showing the acceleration vs time variation for the Bhuj earthquake.

The loading combination considered is as per IRC: 6-2014 and a maximum tyre pressure of 5.273 kg/cm2 was considered. The live load along with the seismic load was applied on the models and parameters such as total deformation, equivalent plastic strain, maximum principal stress and shear stress generated were analysed. Comparison of such parameters was done and their relation with different angles were analysed.

RESULTS AND CONCLUSION

i. Total deformation increased by 1% for 15°, 2% for 30° and decreased by 5% for 45°, 21% for 60° skew angle as compared to the straight bridge.

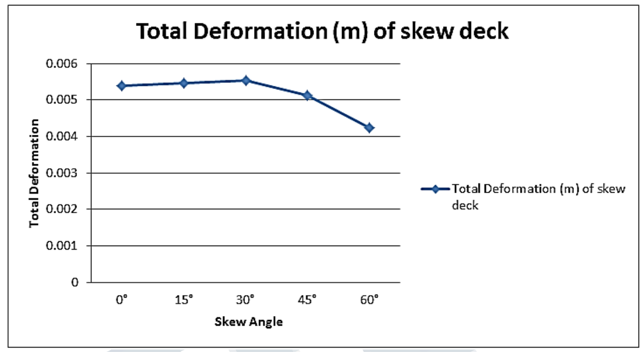


Fig 3: Variation of Total Deformation vs Skew angle.

ii. Equivalent plastic strain decreased by 2.5% for 15°, increased by 1% for 30°, decreased by 18% for 45° and 63% for 60° skew angle as compared to the straight bridge.

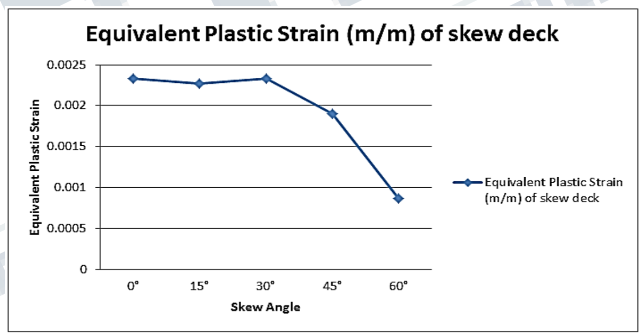
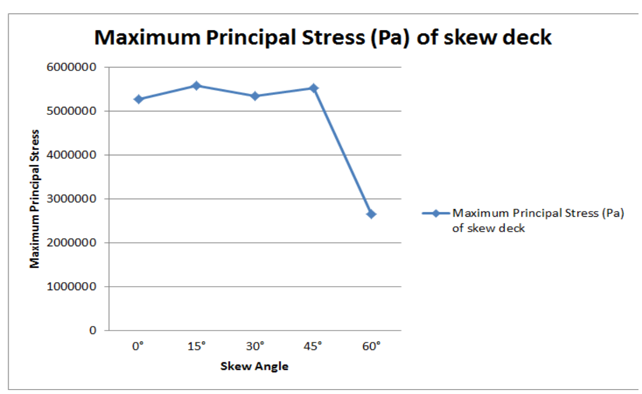


Fig 4: Variation of Equivalent Plastic Strain vs Skew angle.

iii. Maximum principal stress increased by 6% for 15°, 1% for 30°, 5% for 45° and decreased by 50% for 60° skew.



ISSN (Online) 2456-1290

International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
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Fig 5: Variation of Maximum Principal Stress vs Skew angle.

iv. Shear stress increased by 3% for 15°, 10% for 30°, 26% for 45° and decreased by 11% for 60° skew.

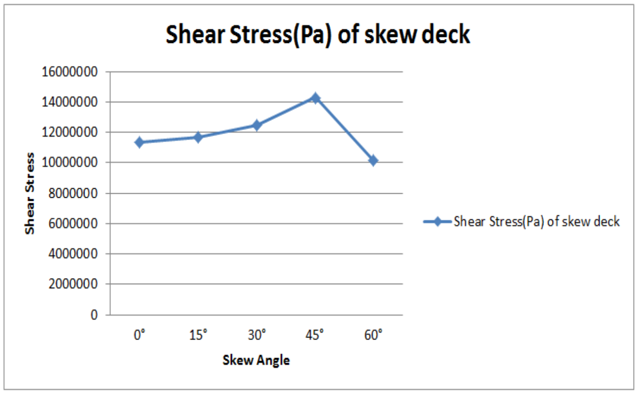

Fig 6: Variation of Shear Stress vs Skew angle.

v. It can also be concluded that more stress generates on the obtuse corners of the bridge deck as compared to the acute corners.

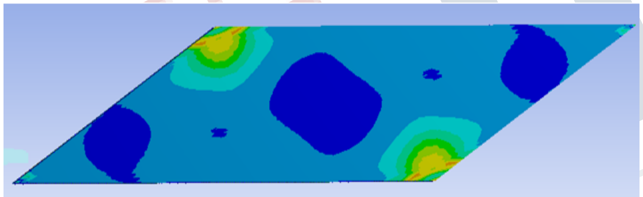

Fig 7: More stresses are generated on the obtuse corners as compared to acute corners.

vi. It can be concluded that the values for such parameters change with the change in skew angles, however there is not much difference between the straight bridge and skew angle bridge upto 30°.