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Seismic Behaviour of Reinforced Concrete Skew Deck Bridges for Different Aspect Ratios

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Abstract: **The deck is an essential component of the bridge which allows the continuous movement of vehicles from one point to the other. The present study was focused on the response of the skew deck bridge during the seismic disturbances using the time history analysis. A comparison between the decks having aspect ratio less than and greater than 1 having different skew angles (0°, 15°, 30°, 45°, 60°) was done as per the dimensions specified in the 'Standard Plans for Highway Bridges' published by Ministry of Shipping and Transport, India. The decks were modelled using finite element analysis. The effectiveness of skew angles was concluded after the analysis of parameters such as total deformation, equivalent plastic strain, maximum principal stress and shear stresses. There are variations found in the results as the angle of skew changes from 0° to 60° for both the aspect ratio less than and greater than 1.**

Keywords: skew angle, seismic behaviour, aspect ratio.

INTRODUCTION

Since the deck is an essential component of the bridge and is responsible for the movement of the vehicles hence it should be designed in such a way so as to provide safety. The behaviour of the bridge deck during seismic disturbances becomes more important as it becomes the source of movement for rescue works and for army movement. Sometimes due to space constraints or due to the presence of some physical features such as mountains or an already existing building the straight shape of the deck cannot be maintained, for which skew decks are constructed having different skew angles. The design becomes more complicated for the skew deck bridges. The Ministry of Shipping and Transport, India have published the 'Standard Plans for Highway Bridges' for different spans having different skew angles (0°, 15°, 30°, 45°, 60°).

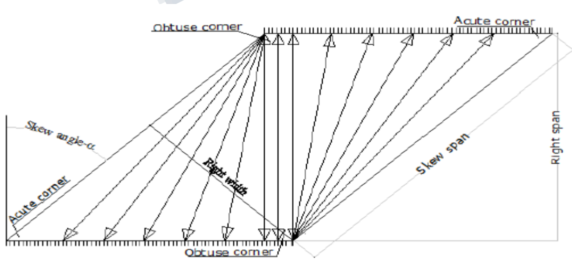

Fig 1 : Figure showing the basic structure of the skew deck.

Various studies have been conducted on the response of the skew deck on the seismic disturbances few of which are discussed as follows, Jamshid Mohammadi, 2012 in his study concluded the percentage increase in critical stresses in the superstructure of skewed bridges as the angle of skew increases compared with a comparable non skewed bridge. The study showed that cases in which the angle of skew is approximately 40°, the percentage increase in stress due to the skew effect at the end girders can be as high as 50–60%. %. Vaibhav Kothari ,2015 considers a 3-D model bridge using the finite element method (SAP2000) subjected to linear time history analysis with skew angles varying from 0 to 50 degrees, it can be seen that the effect of skew angle and interacting parameters were found to have significant effect on the behaviour of skewed highway bridges. The analytical results have indicated that the skewed bridge responses are quite different from the non-skewed bridge and varying with the skew angle. Lakavath Ramesh, 2017 in his study focused to compare and analyse the normal and skew bridge with different angles (30°, 45°, and 60°) for IRC Class A loading to determine the deflection, bending moment and shear force. The result clearly show that the skew bridge with 60° reduced deflection up to 40% to 50% compared to normal bridge. The skew bridge with 60° exhibited similar trend in the reduction of both bending moment and shear force up to 30% to 35% for wheel load. Haymanmyitmaung, 2017 concludes that the Finite Element Analysis results indicate that under static live load, integral

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bridge girder shear force was minimum in skew 60° but maximum in skew 15^0 for integral pier board pile.

METHODOLOGY

The models having aspect ratio less than and greater than 1 was generated analytically as recommended by 'Standard Plans for Highway Bridges' published by Ministry of Shipping and Transport, India. A total of 10 models have been generated with skew angles 0°(straight bridge), 15°, 30°, 45°, 60° using ANSYS Workbench.
For aspect ratio less than 1, a span of 5.37 m with the width of 7.5 m having a depth of 0.465 m is modelled for skew angles 0°,15°, 30°, 45°, 60°.
For aspect ratio more than 1, a span of 8.37 m with the width of 7.5 m having a depth of 0.650 m is modelled for skew angles 0°,15°, 30°, 45°, 60°.

Table 1: Material properties of concrete used

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

Table 2: Material properties of structural steel used

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 is the finite element method and the analysis has been done by using the time history analysis. Time history of Bhuj earthquake has been applied on the generated models.

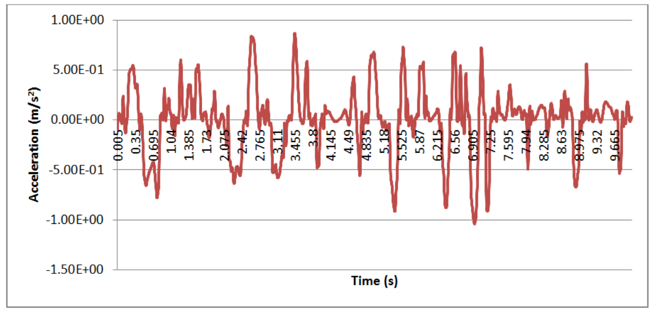

Fig 2: Acceleration vs Time graph for Bhuj Earthquake.

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 were analysed. Comparison of such parameters was done and their relation with different angles were also analysed.

RESULTS

For aspect ratio less than 1
Total deformation decreases by 0.45% for 15°, 7.9% for 30°, 8.37% for 45°and 18.67% for 60° skew angle as compared to the straight bridge.

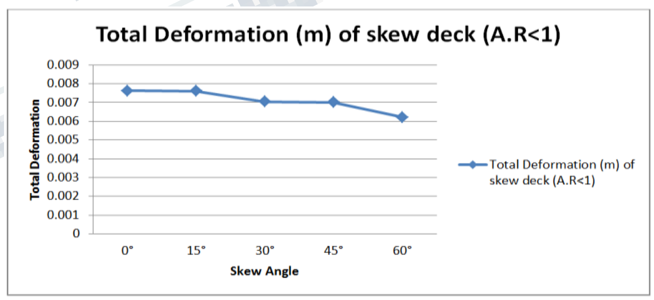

Fig 3: Total deformation of skew deck for aspect ratio less than 1.

Equivalent plastic strain decreases by 3.93% for 15°, 20.47% for 30°, 19.63% for 45° and 49% for 60° skew angle as compared to the straight bridge.

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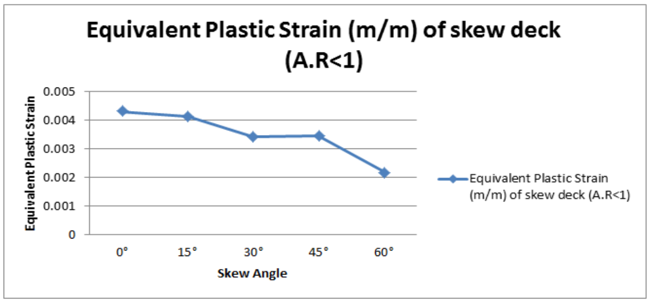

Fig 4: Equivalent plastic strain of skew deck for aspect ratio less than 1.

Maximum principal stresses decreases by 0.54% for 15°, 14.90% for 30°, 11.12% for 45° and 36.13% for 60° skew angle as compared to the straight bridge.

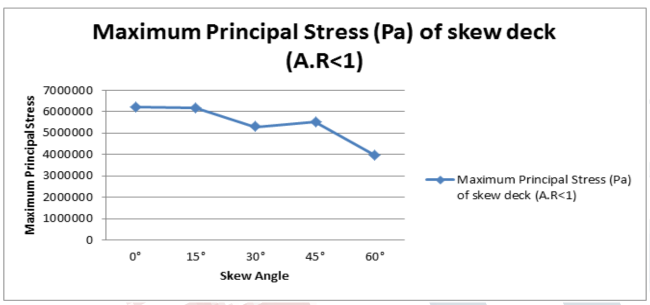

Fig 5: Maximum principal stresses of skew deck for aspect ratio less than 1.

Shear stress increases by 14.06% for 15°, 38.33% for 30°, 36.68% for 45° and 6.42% for 60° skew angle as compared to the straight bridge.

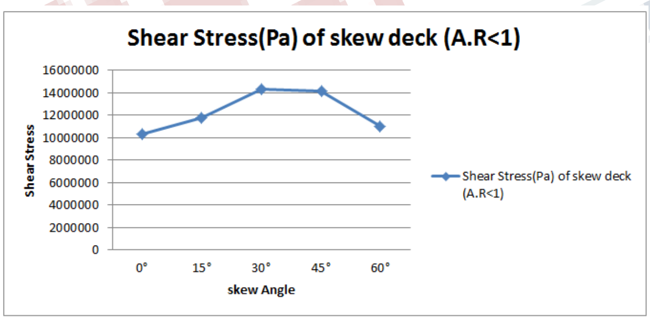

Fig 6: Shear stress of skew deck for aspect ratio less than 1.

For aspect ratio greater than 1

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

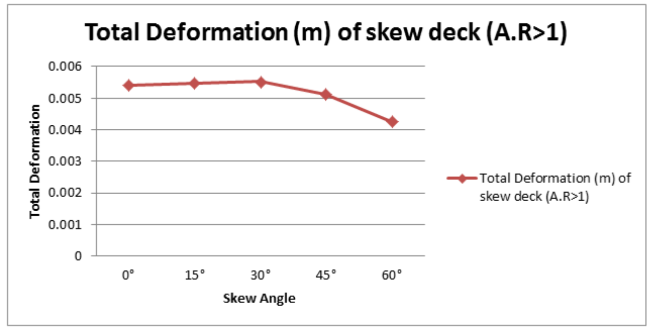

Fig 7: Total deformation of skew deck for aspect ratio greater than 1.

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

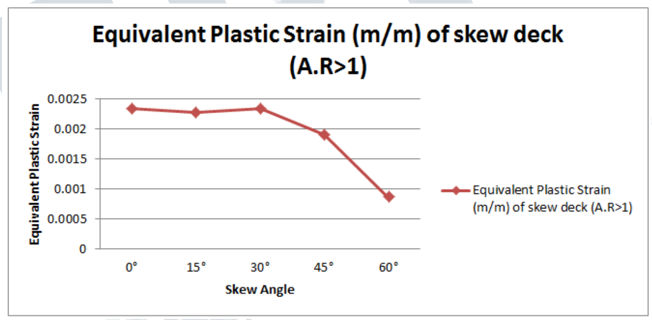

Fig 8: Equivalent plastic strain of skew deck for aspect ratio greater than 1.

Maximum principal stress increases by 6% for 15°, 1% for 30°, 5% for 45° and decreases by 50% for 60° skew angle as compared to the straight bridge.

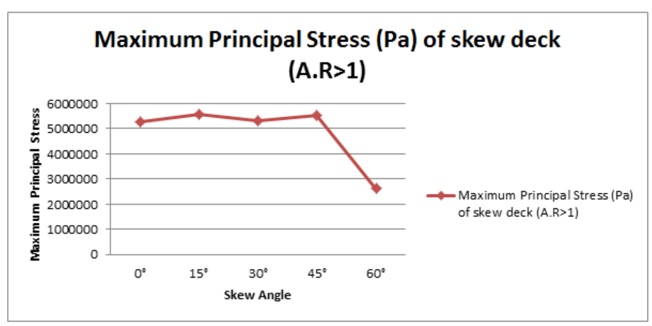

Fig 9: Maximum principal stress of skew deck for aspect ratio greater than 1.

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Shear stress increases by 3% for 15°, 10% for 30°, 26% for 45° and decreases by 11% for 60° skew angle as compared to the straight bridge.

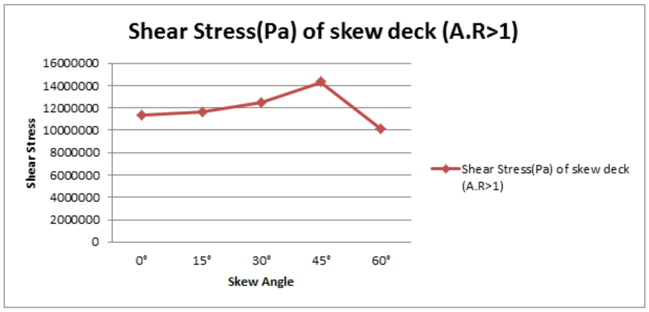

Fig 10: Shear stress of skew deck for aspect ratio greater than 1.

Comparison between models of aspect ratio less than and greater than 1.
Higher values of Total deformation are obtained for aspect ratio less than 1 as compared to aspect ratio greater than 1.

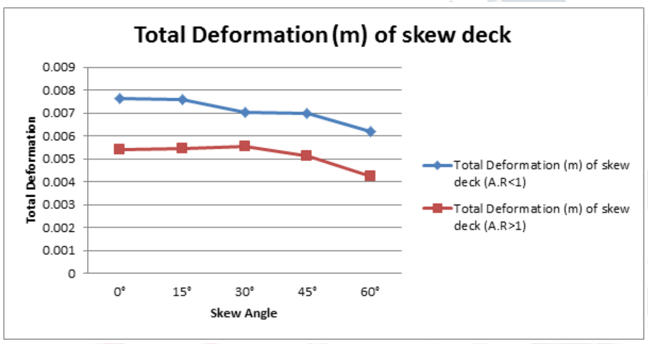

Fig 11: Comparison of Total deformation of skew deck for different aspect ratio.

Higher values of Equivalent Plastic Strain are obtained for aspect ratio less than 1 as compared to aspect ratio greater than 1.

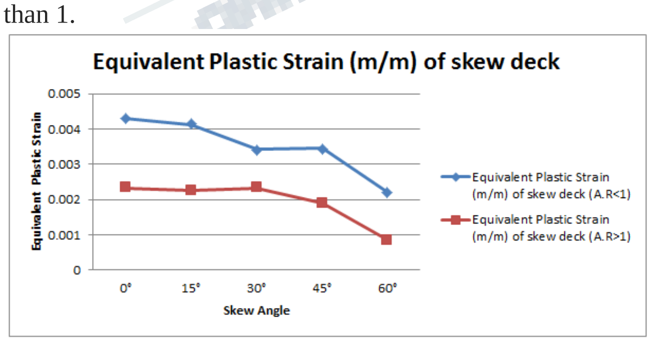

Fig 12: Comparison of Equivalent Plastic Strain of skew deck for different aspect ratio.

Higher values of Maximum Principal Stress is obtained at 30° skew angle for aspect ratio less than 1 but almost same values of maximum principal stress are obtained from skew angle 30° to 45° for both aspect ratio less than and greater than 1. For 60° skew angle again higher value of maximum principal stress is obtained for aspect ratio less than 1.

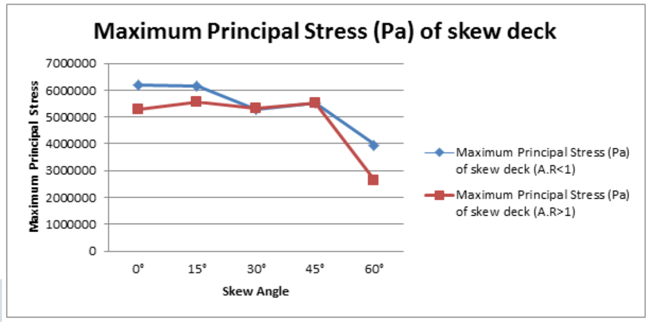

Fig 13: Comparison of Maximum Principal Stress of skew deck for different aspect ratio.

A minimum value of shear stress is obtained at 0° for aspect ratio less than 1 whereas minimum value of shear stress is obtained at 60° for aspect ratio greater than 1. Almost the same values of shear stress are obtained at 15° and 45° for both aspect ratio less than and greater than 1.

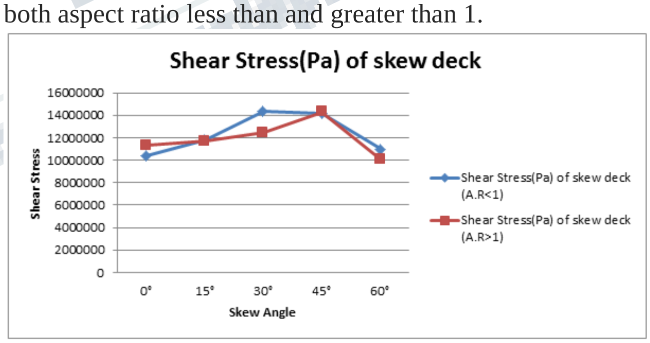

Fig 14: Comparison of shear stress of skew deck for different aspect ratio.

CONCLUSION

- From the results it can be concluded that the behaviour of a skew deck having aspect ratio less than 1 is different from the behaviour of a skew deck having aspect ratio greater than 1.
- Since the most of the values for aspect ratio less than 1 is higher than that of aspect ratio greater

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than 1, it is recommended to construct spans having aspect ratio greater than 1.

- Minimum values of total deformation, equivalent plastic strain, maximum principal stress and shear stress are obtained for 60° except for the shear stress obtained at 0° for aspect ratio less than 1 which is 6.42% less as compared to 60°.
- Previous studies shows that skew bridge with 60° exhibited reduction of both bending moment and shear force up to 30% to 35% for wheel load. The load carrying capacity of skew slab increases as skew angle increases. Torsion moment follows same pattern and it decreases after 45°.
- It can be concluded that 60° skew angle is the best amongst all the considered skew angles.

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