A Review on Behavior of Skew Bridges with Different Skew Angles

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Abstract: *Skew bridge is a bridge that built obliquely from bank to bank. An attempt has been made to understand the behavior of the skew bridges with different skew angles and FEM techniques from previously studied papers. This paper includes different techniques and related works that has been done for different skew angle on bridges by many authors before. Skewed bridges generally exhibit torsional displacements of the individual girders and of the overall bridge cross-section under load. The various load criteria on bridges were considered as per Indian Road Congress (IRC) 6 and its amendments.By studying the literature review it can be concluded that the change in the different dimensions of the bridge can affect the various parameters like bending moment, shear force and torsional effects.*

INTRODUCTION:

Highway and railway bridges play a vital role in transportation systems. The vibrations caused by the passage of vehicles have become an important consideration in the design of these bridges. In particular, the interaction problem between the moving vehicles and the bridge structures has attracted much attention during the last three decades. This is in part due to the rapid increase in the proportion of heavy vehicles and high-speed vehicles in the highway and railway traffic and the trend to use high-performance materials and therefore slenderer sections for the bridges.

Vehicle-bridge interaction is a complex dynamic phenomenon, which is a non-linear problem dependent on many parameters? These parameters include the type of bridge and its natural frequencies of vibration, vehicle characteristics, vehicle speed and traversing path, the number of vehicles and their relative positions on the bridge, roadway surface irregularities, the damping characteristics of bridge and vehicle etc. The first recorded research into bridge vibration appears to be a report published in the 19th century (Willis, 1849), which discussed the reasons for collapse of the Chester Railway Bridge. In the first half of the 20th century, investigations into bridge vibration were mainly concerned with developing analytical solutions for simple cases of moving force (Timoshenko, 1922; Lowan, 1935; Ayre et al1, 1950; Ayre and Jocobsen, 1950) and moving mass (Jeffcott, 1929).

The moving force model is the simplest model whereby researchers can capture the essential dynamic characteristics of a bridge under the action of a moving vehicle, although the interaction between the vehicle and bridge is ignored. Where the inertia of the vehicle camion is regarded assmall, a moving mass mode is often adopted instead. However, the moving mass model suffers from its inability to consider the bouncing effect of the moving mass, which is significant in the presence of road surface irregularities or for vehicles running at high speeds.

The advent of high-speed digital computer a few decades ago made it possible to analyze the interaction problem with more sophisticated bridge and vehicle models. The vibration of various types of bridges such as girder bridges, slab bridges, cable-stayed bridges and suspension bridges due to moving vehicles and trains could be studied by using moving vehicle model, in which a vehicle was modelled as a single-axle or multi-axle mass-spring-damper dynamic system. Although extensive studies have been done in this field, high-performance analysis methods are still required for accurate prediction of dynamic response of these bridges under moving vehicles and trains.

On the other hand, to allow for the dynamic effects resulting from the passage of vehicles, many design codes such as American Association of State Highway and Transportation Officials (AASHTO) Standard Specifications for Highway Bridges (1996) require that the static live loads be increased by an impact factor, which is defined as the ratio of the maximum dynamic response to the maximum static response of the bridge minus one. According to AASHTO Specifications (Standard 1996), the impact factor is specified as a function of span length only. It is certainly an oversimplification. It has been reported that the impact factors calculated according to these codes may not be conservative in many cases. There exists an urgent need to develop rational design formulae based on accurate prediction of the true behavior of the entire bridge-vehicle system.

The development of cost-effective analysis methods as well as the clear identification of the important parameters that govern dynamic response will certainly be of great help to better understanding of the true behavior of the entire bridge-vehicle system. This thesis therefore focuses on development of effective methods for analyzing the vibration of various types of bridges including girder bridges, railway bridges, slab bridges and cable-stayed bridges under the action of moving vehicles and trains. The vibration analysis of suspension bridges is excluded from this thesis due to the limitation of study period.

LITERATURE REVIEW:

Mallikarjun I.G, Ashwin K.N, Dattatreya, J.K, Dr. S.V Dinesh (2015) Studied Influence of skew angle on static behaviour of RCC and PSC slab bridge decks. The authors have studied the influence of aspect ratio, skew angle and type of load on RC slab bridge decks and PSC bridge decks. The finite-element analysis results for skewed bridges were compared to the reference straight bridges for dead load, IRC Class A loading. They have also carried out comparative analysis of response of skewed RCC and PSC slab bridge decks with that of equivalent right bridge deck for 120 bridge models. The variation of maximum longitudinal bending moment, maximum transverse moment, maximum torsional moment and maximum longitudinal stresses with skew angle was studied for all 120 bridge deck models. The authors have concluded that the FEA results of Dead load and Live load longitudinal bending moments decreases with increase in skew angle, whereas maximum transverse moment increase with increase in skew angle and also maximum torsional moment increases with increase in skew angle and the maximum longitudinal stresses decrease with skew angle up to 30 degrees and there after increases. The benefit of pre-stressing is reflected in significant decrease in longitudinal bending moment and transverse moment and longitudinal stresses. [1]

Vaibhav Kothari, PraneshMurnal (2015) studied Seismic analysis of skew bridges. The authors have considered 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. The authors have considered the earthquake ground motion recorded for Northridge earthquake and Imperial Valley earthquake are applied in the longitudinal as well as transverse direction of the bridge. From the analysis results they have concluded that the seismic responses of the bridge are significantly affected by skew angles of the bridge. the effect of skew angle and interacting parameters were found to have significant effect on the behavior 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. [2]

Punit Patel, Hardik Solanki, Bhanuprasad N Kadia (2016) studied Behaviour of Skew Bridge Using Grillage Anology Method. The authors have analysed skew bridge with different skew angles of 0°, 15°, 30°, 45°, 60° respectively. They have considered single-span T-Beam Reinforced Concrete Girder under Indian Road Congress (IRC) loading. Dead Load, Vehicular Live Load, along with live load combination is considered. T-Beam girder of 20 m span length with 2 lane of carriage way width is 7.5 m is considered. Analysis has been done by using Staad Pro software. The authors have concluded that Bending moment has decreased with increasing skew angle, it was decreased around 40.47 % as compared to right bridge in case of class A loading. Shear force and torsion moment has increased with increase in skew angles. [3]

Ajay D. Shahu, S.V. Joshi, P. D. Pachpor (2016) studied Analysis and behaviour of skew bridges with different skew angle. Authors have considered intervals of skew angle of 10°, 15°, 20° and 30° and to optimize the result interpretation and variation in values of parameters for different skew angle, the interval of skew angle was kept as 5°. They have used IRC 6 loading condition and amendments made recently, different parameters like bending moment, twisting moment, shear force under different skew angles. From the tests they have concluded that as the skew angle increases, torsional moment, bending moment increases with increase in skew angles. For the combination of dead load and live load, it was observed that, bending moment, moment due to torsion, and equivalent design bending moment was increased gradually with increase of skew angle from 0° to 60°. [4]

AnaghaManoharan and Glynez Joseph (2016) studied Analysis of Skew Bridge with Varying Skew Angles. The authors have considered finite element modelling of simply supported skew slab with varying skew angles using ETABS 2013 software.The behavior of the simply supported skew slab under point load applied at the center depends on the ratio of short diagonal to its span. They have analyzed the simply supported skew slab with a concentrated load at the center and knife edge load. The analysis is done on the varying span length and the skew angles, Moment, shear force and Torsional variations were analyzed. From the analysis results the authors have concluded that the bending moments in the concentrated load condition and the knife edge load condition were decreased up to 65% and 75% respectively as the skew angle increases to 60. The increment of torsional moments is of 60% in both the conditions. [5]

Sayli D. Madavi, Divya S. Patle, Sumit G. Dhundalwar, Vinayak R. Kullarkar (2018) studied Comparison of Skew Bridges with Different Skew Angles. The authors have considered T-beams for studying the effect of skew bridges. They have considered bridge length of 20 m, skew angle with variations from 0° to 20° with 5° of difference. Parameters like bending moment, shear force, torsion in longitudinal girders for same position of load were investigated. The design parametric studies have been done by using STAAD.Pro software and IRC class AA tracked Vehicle loading was applied and loading criteria on bridge as per IRC 6: 2014. They have concluded by the results that bending moment increases with decreases in skew angle, shear force and torsional moment increases with increases in skew angle. [6]

M. S. Hora (2018) studied Effect of skew angle on structural behavior of RC ribbed skew slab. The authors have carried out parametric studies of RC un-stiffened and ribbed skew slabs (stiffened by rib beams) with skew angles ranging from 20° to -50° in interval of 5°. The analysis was carried out for un-stiffened and ribbed skew slabs, having two short edges simply supported and two long edges free. Total 14 cases were analysed for un-stiffened and ribbed skew slabs by creating models in ANSYS software. The comparison of results was made with respect to displacements, bending moments, twisting moments, von-Mises stress, bending stresses, bending moment and shear stresses. From the analysis result they have concluded that the value of maximum deflection and shear stress in un-stiffened and ribbed skew slabs decreases significantly with increase in skew angle. Increase in twisting moment with increase in skew angle for ribbed skew slabs. [7]

Nishant Sharma, Parmod Kumar (2016) studied Seismic Analysis of Reinforced Concrete Skew Bridge. The authors have considered different skew angles of 15˚,30 ˚,45˚ and 60˚, four bridges were designed in CSI BRIDGE 2014 and their results compare with normal bridge. Three equal span of 15 m each and an overall width of 12 m along skew direction was considered. From the test results they have concluded that all bridge models considered in this study, the longitudinal displacement is 0.157 m maximum for 60˚ skew model. As the skewness of a bridge increased the amount of longitudinal displacement increased during ground motions.[8]

BhaswatiBarkakati, Susanta Kr. Sethy, Dr. Vijay Raj and Dr. Vikas Garg (2018) studied Torsion and displacement on skew girder bridges. The authors have considered four lane RC girder bridge deck, span of 72 m, slab thickness of 200mm. They have considered different skew angles varied from 0°to 50° at intervals of 10°, studied using CSI bridge software and loading conditions as per IRC 6:2000 guidelines. From the analysis result they have concluded that Torsional moment increased for both exterior and interior girders, as the skew angle increases under dead load and moving load. The value of maximum transverse displacement in both girders increased with increase in skew angle, value of torsional moment& transverse displacement increases as the skew angle was increased. [9]

Ansumankar, Vikash Khatri, P. R. Maiti, P. K. Singh (2012) studied Effect of Skew Angle in Skew Bridges. The authors have considered bridge span of 12 m, deck slab with skew angles of 0 ˚, 30 ˚, 45 ˚, and 60 ˚ and carriage way of 7.5 m. The Longitudinal moment, reaction at support, deflection and transverse moment were computed by FEM and grillage analogy method and results are compared for different skew angles. The authors have concluded by the test results that as skew angle increases, reaction increases, bending moment decreases but torsion and transverse moment increases up to a certaintorsional moment in angle, after which it decreases. Maximum deflection occurs nearer to obtuse angled corner but as aspect span is more it comes nearer to the middle of the span and shifts towards obtuse angled corner as skew angle increases. [10]

Nikhil V. Deshmukh, Dr. U. P. Waghe (2013) studied Analysis and design of skew bridges. The authors have considered span of 6m, 8, 10m and 12m bridge for each IRC Class A Loading and skew angles changed from 15° to 45°. Skewed slab bridges were modelled using finite-element methods using CsiBridge computer software to study their behavior under uniform and moving loads and to determine the most appropriate force response for design. Based on analysis of different configurations of bridges thay have concluded that for Class A Loading the increase in shear force for low skew angle (<15°) the shear force had increased linearly. As the shear force increased the bending moment increases with increase of skew angle and spans of bridges. [11]

CONCLUSION:

The behavior of the skew bridges with the different length, skew angles are generally inter-related. The change in the different dimensions of the bridge can affect the various parameters like bending moment, shear force and torsional effects. By studying the literature review it can be concluded that the

1. FEA results of Dead load and Live load longitudinal bending moments decreases with increase in skew angle, maximum transverse moment increase with increase in skew angle and also maximum torsional moment increases with increase in skew angle and the maximum longitudinal stresses decrease with skew angle up to 30 degrees and there after increases.

2. For the combination of dead load and live load, it was observed that, bending moment, moment due to torsion, and equivalent design bending moment was increased gradually with increase of skew angle from 0° to 60°.

3. In case of the ribbed skew slabs, the value of maximum deflection and shear stress in un-stiffened and ribbed skew slabs decreases significantly with increase in skew angle. Increase in twisting moment occurs with increase in skew angle for ribbed skew slabs.

4. The analysis of the skew bridge can be carried out by using the software's like ANSYS, STAAD.Pro, SAP2000 and CSi bridge. The analysis of bridge in CSi bridge and SAP are of

the same expected results and the whole components of bridge can be designed and analyzed.

5. Generally the value of bending decreases with increase in the skew angle, the value of shear force and Torsion increases with increase in skew angle.

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