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Comparative study-Seismic Performance of skewed RC box and T girder bridges

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Abstract - *Newly designed bridges are often skew. This is due to space constraints in congested urban areas. Skew bridges allow a large variety of solutions in roadway alignments. It may be needed due to geographical constraints such as mountainous terrains. However, the force flow in skew bridges is much more complicated than in right-angle bridges. And also they are more vulnerable during an earthquake than straight bridges. Linear dynamic analysis is minimum requirement for skew bridges according to many guidelines. For medium spans box girder or T girder bridges are adopted. Thus in this study for a particular span, seismic analysis of box and T girder bridges using response spectrum method is performed in SAP2000 varying skew angles. Responses in the substructure, girders and deck are studied. An attempt was made to determine skew angle upto which skew bridges have comparable characteristics with straight bridges and also establish best possible alternative among both the girder types with respect to earthquake response. It was concluded that upto skew angle of 15 degrees skew bridges have comparable responses with straight bridges and seismic performance of skewed box girder bridge is better than T girder bridge for the considered span.*

Key Words: *skew bridges, skew angle, seismic analysis, box girder, T girder.*

1. INTRODUCTION

The seismic vulnerability of highway bridges remains an important problem and has received increased attention as a consequence of the damage observed during several major earthquakes. In order to cater to greater speed and more safety of present day traffic, the modern highways are to be straight as far as possible. This requirement, along with other requirements for fixing alignment of the bridges, is mainly responsible for provision of increasing number of skew bridges. A skewed bridge is one whose longitudinal axis forms an acute angle with abutment. Skewed reinforced concrete bridges are commonly used as overcrossings in highway intersections and interchanges, especially in complex intersections and in crowded urban areas where lack of space necessitates the use of skew geometries.

Skew bridge differs from straight bridge with respect to its following characteristics such as significant torsional moments in the deck slab, decrease in longitudinal moment, increase in transverse moment, concentration of reaction forces and negative moments at the obtuse corners and uplift reaction forces at the acute corners. These special characteristics of skew bridges make their analysis and design more intricate than right bridges.

Global seismic behaviour of skewed bridges is affected by a number of factors, including bridge skew angle, deck width, deck flexibility, number of spans, number of columns per bent, column ductility, soil-abutment-superstructure interaction, abutment shear keys, soil-bent foundation-structure interaction, abutment bearing pads, and characteristics of the seismic source.

Many researchers have studied skew bridges varying different parameters. But there is lack of study in the area of seismic behaviour of skew bridges. The present study is an effort to understand seismic behaviour of skew bridge comparing T- beam girder and box girder for a particular span, considering responses in various components of the bridge.

2. LITERATURE REVIEW

Ahmed Abdel-Mohti and Gokhan Pekcan [2] assessed the seismic performance of skew reinforced concrete box girder bridges. In the study, three-dimensional improved beam-stick models of two-span highway bridges with skew angles varying from 0° to 60° were developed to investigate the seismic response characteristics of skew box girder bridges. The effect of various parameters and conditions on the overall seismic response was examined such as skew angle, ground motion intensity, soil condition, abutment support conditions, bridge aspect ratio, and foundation-base conditions. It was concluded that pinned foundation results in significantly larger deformations, whereas larger force demand on the bent component was introduced in the fixed foundation case. It was also observed that as the skew angle increases, the displacement also increases since the longitudinal stiffness of the bridge reduces with increasing skew angle

Billington C. J. and Dowling P. J. [3] studied the influence of skew supports on the behaviour of multibox bridges. Behaviour was illustrated by reference to theoretical and model analyses of a skew supported composite twin box structure. The effects of diaphragming systems were also studied.

The model represented to a scale of 1:30 part of a continuous structure and consisted of a single simply supported span of approximately 35m. The steel boxes of mild steel and model slab made from Araldite casting resin and sand mixture were used. Then finite element analysis was performed for the same were model.

It was concluded that the effects of the skew supports were to produce high differential deflections between the box girders. It was also found that introduction of internal diaphragms within the span in multibox structures increases the effective torsional rigidity of the boxes.

Demeke B. Ashebo, Tommy H.T. Chan, Ling Yu [4] evaluated dynamic loads on an existing skew box girder continuous bridge. This study covers experimental procedure, the data acquisition system, the calibration test, the modal analysis and the load distribution in a transversal direction.

A three-axle heavy truck was hired for use in the test to calibrate the field measurements. The static and dynamic bending moments of the tested bridge induced by the calibration truck were obtained. The relationship between the measured strain and bending moment were determined. Information on the dynamic behaviours of the bridge was obtained from an experimental and theoretical modal analysis. The influence of skewness on the static and dynamic behaviours of the bridge as well as on the load distribution in the transversal direction for the calibration truck and in-service vehicles was investigated.

It was found that the influence of skew in both the static and dynamic behaviours of the bridge within the skew angle range of 0°–30° is very small.

M.N. Haque and M.A.R. Bhuiyan[9] studied seismic response of a simple span concrete deck girder skewed bridge for a wide range of skew angles. In this regard, a 3-D model bridge using the finite element method was considered in linear time history analysis. A standard direct time integration approach is employed in the time history analysis. An earthquake ground motion record complying with the design acceleration response spectrum obtained from low to moderate magnitude earthquakes was applied in the longitudinal direction of the bridge. It was observed that the bearings of the exterior girders are seen seismically more vulnerable than the interior girders. The mode shapes for skewed and non-skewed decks were studied and are as shown in Fig. 2.4. The analytical results indicated that the skewed bridge responses are quite different from the non-skewed bridge and varying with the skew angles and also on ground motion characteristics

3. MODELLING AND ANALYSIS

For seismic analysis two bridges of 30m span i.e box girder bridge and T girder bridge are considered. A comparative assessment of the seismic responses is carried out for varying skew angles from 0 to 60 degrees with 15 degree interval. Bridge models were developed using SAP2000.

4. RESULT AND DISCUSSIONS

Responses in deck, girder and columns were studied for various skew angles and few are compiled as below:

4.1 Influence of skew angle on natural frequency

Influence of skew angle on fundamental frequency for skewed box girder and T-beam girder has been represented graphically in Fig. 1.

From Fig. 1 it is evident that fundamental frequency for box girder bridge increases with increase in skew angle. While for T-beam girder bridge it decreases with the increase of skew angle.

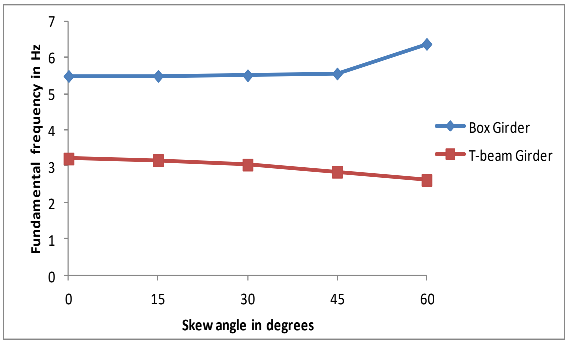

Chart -1: Variation of fundamental frequency over skew angles

4.2 Torsion

Torsion induced obtained is minimum for zero skew and it increases with increase in skew angle for both type of girders.

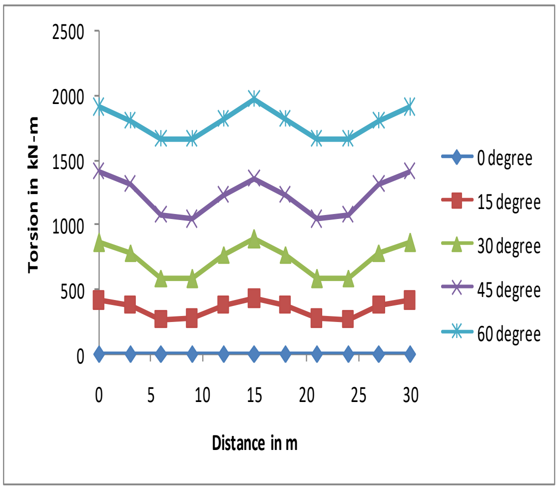

Chart – 2: Torsion over skew variation along span of T girder

TABLE -1: COMPARISON OF RESULTS

Sl No	Parameter	Skew angle in degrees	Box girder bridge	T girder bridge	Percentage difference
1	Fundamental frequency	0	5.4936	3.2141	41.4937
		15	5.4965	3.1721	42.2887
		30	5.5136	3.0459	44.7566
		45	5.5621	2.849	48.7783
		60	6.3797	2.6227	58.8899
2	Torsion kN-m (max)	0	0	0	0
		15	1245.492	424.9462	65.8812
		30	2258.691	885.6934	60.7873
		45	2789.038	1353.358	51.4758
		60	2457.184	1973.271	19.6938

Comparing the box girder and T girder bridge results, inferences can be summarized as follows:

1. Modal frequency increases with increase of skew angle for box girder bridge whereas it decreases for T girder bridge. Frequency obtained for skewed box girder bridge, for all skew angles, is more than skewed T girder bridge having a maximum of 59% difference for 60° skew.
2. Large skewness induces vibratory modes such as torsion and lateral flexure, which causes an increase in axial forces, shears, moments and torques in the supporting columns.
3. The torsion induced in columns of skewed T girder bridges is more than that in skewed box girder bridge. Skewed box girder bridge resists the shear - torsion combined effect more efficiently than skewed T girder bridge.
4. Skew supports act as eccentric loads on adjacent boxes thus accentuating the distortional stresses in box girders and transverse moments in the slabs.
5. Skeweness induces both translatory (linear) and rotator (curvilinear) deformations in the bridge bearings [1]. It can be noted that box girder bearings have less deformations than T girder bearings.
6. As skew angle increases displacement of the deck also increases since the longitudinal stiffness of bridge reduces. As it can be noted that for 60° skew maximum displacement in box girder deck is 77% less than T girder deck. Because of torsional resistance of box girder it accommodates skew effects better. Thus significantly fewer displacements occur.

3. CONCLUSIONS

Following conclusions are drawn based on the present study. Upto skew angle of 15 degrees the responses of skew bridge are comparable to straight bridge. Overall seismic performance of skewed box girder bridge is better than skewed T girder for a given span.

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