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Static Analysis of RC Box Girder Bridge with skew angles using finite element method

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Abstract - *A bridge is an important component of the road transportation network. Its performance during and even after an earthquake event is quite crucial to provide relief as well as for security and defence purpose. Most of the past seismic studies on bridges have focused on regular bridges with no skew. However, past earthquakes and studies have shown that skewed bridges are more susceptible to earthquake damage, specifically caused due to coupled response. Therefore, there is a need for more research to study the effect of skew angle and the other relating factors on the performance of highway bridges. Present work involves the static analysis of a RC box girder bridge with skew angles, 0 and 15 degrees, analytically. The bridge will be modelled using finite element (FE) method using SAP2000. The results of finite element (FE) and modal analysis are presented to study the influence of skew angle on the natural frequency for the entire skewed bridge. On the other hand the structural response for the superstructure covering elemental stresses, base reaction and joint displacements will also be studied.The analytical results of skewed bridge will be studied and compared with non-skewed bridge with varying the skew angle.*

***Key Words*: RC Box girder, skew angles, finite element method, Base reaction, Joint reactions.**

1.INTRODUCTION

Bridges are one of the oldest structures built by man and even now they play a vital role in the development of the country by forming an important part of the infrastructure for both railways and Roadways. Today we can see many design codes and guidelines available for designing the static and dynamic analysis for straight normal bridges. However, structural responses with respect to skewed highway bridges still remain a point of uncertainty significantly. This may be to most extent because of lack of detailed procedures in current guidelines. A skewed bridge is one whose longitudinal axis is not at right angle to the abutment. Many factors such as natural or manmade obstacles, mountainous terrain, complex intersections or space limitations can result into skewness in bridge. Newly designed bridges are often skew as it allows a large variety of solutions in road construction projects. It consumes less space as compared to normal bridges and if properly designed can be constructed even in the most congested places. In fact, as evidenced by past seismic events, skewed highway bridges are particularly vulnerable to severe damage due to seismic loads.

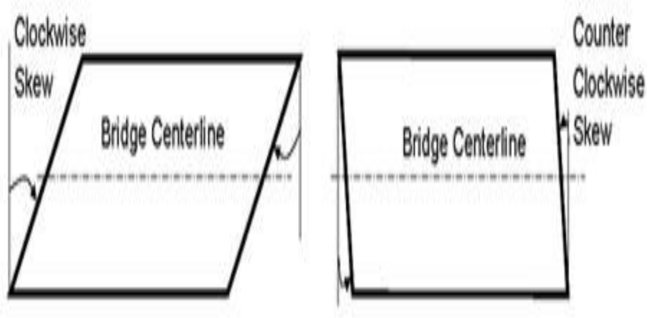

Fig.1 Representation of the skew angle.

The force flow in skew bridges is much more complex as compared to right-angle bridges. It exhibits a unique seismic response that is triggered by oblique impact. Skew bridges often rotate in the horizontal plane, thus tending to drop off from the supports at the acute corners. In right angle bridges the load path goes straight towards the support in the direction of the span. In skew bridges this is not the case. For a solid slab skew bridge the load tends to take a short cut to the obtuse corners of the bridge. This behavior results in a coupling of longitudinal and transverse responses at one of the obtuse corners. This finally results in subsequent rotation along the direction of increasing the skew angle.

Inspire of having large number of experiences from past earthquake failures, which gives the importance of this mechanism, as well as the empirical vulnerability methodologies that acknowledge skew as a primary Vaibhav Kothari, Pranesh Murnal vulnerability factor in bridges, there are only few attempts to comprehend this mechanism. K. J. Tao and Z. J. Jie tried to solve the problem of in plane rotation in skew bridges by doing a philosophical analysis. They brought forward an idea regarding the application of slant-leg frame skew bridges without abutment which can fundamentally solve the tough defect of skew bridges to utmost extent because of its structural characteristics.

However, it is well known that the acceptance of numerical results depends on how accurately the skewed highway bridge is idealized in the analytical treatment. The underlying assumptions in this regard may include material modeling, restraining conditions at the boundaries, component geometry, seismic mass, soil-structure interaction, etc. For instance the effects of skew angle on the seismic responses of a bridge to a great extent may be compensated by properly modeling boundary conditions. For the present study a simple span concrete deck girder skewed bridge for wide range of skew angles is modeled using FE method (SAP2000). Modal analysis and linear time history analysis for the same is carried out and finally the results are compared for various angles of skew angle.

2. Literature review

More recently in a study by **Wilson et.al** (2003), it was found that for three-span finite element model of curved and skewed reinforced concrete (RC) bridges to identify the behavior under seismic activity. It also found that amplification and reduction of axial compression forces particularly associated with vertical ground motion accelerations in the pier-columns of the bridge substructure and found that subsequent reduction in the column capacity to resist shear and bending demand.

Deng et.al (2003) studied thermal behavior, it carried parametric study to investigate the influence of curvature and skew angle on the stresses induced in the girders and found the impact of having two fixed piers on the design of these curved and skewed bridges.

According to **Charlie et al.** (2006), data collected from independent earthquakes yields a mean recurrence interval of 420 years for an earthquake of magnitude 6.5 ML or larger. Applying a Gutenberg-Richter magnitude-recurrence relation developed by Charlie et al. (2002) yields that a magnitude 6.6 ML or larger earthquake will have a corresponding return period of 500 years. Applying the same relationship, a 1000-year return period corresponds to a 7.0 ML event, and a 2500-year return period corresponds to a 7.5 ML event. In comparison, by current AASHTO design criteria, Colorado falls into a Seismic Design Category A for a 1000 year return period, which dictates that seismic design is not required. Comparing the estimated earthquake magnitudes by seismologists and AASHTO seismic hazard maps for comparable return periods, there appears to be a significantly larger estimated hazard by seismologists than what is estimated by AASHTO structural code.

The focal point of recorded seismic activity has been centered just west of the Rocky Mountain Front Range and in Southern Colorado near Trinidad. The largest earthquake to date was recorded on November 7, 1882 and measured a magnitude of 6.6 ± 0.6 ML on the Richter Scale (Spence et al. 1996; Kirkham & Rogers 2000). The ground motion was observed throughout several neighboring states, as shown in Figure 2.3, and is estimated to have affected an area of 850,000 km2 (Spence 1999). The unified estimate on the Modified Mercalli Intensity (MMI) scale was assessed by seismologists at an intensity of VII (R. Kirkham 1986). Colorado is one of only fourteen states across the country to have documented an earthquake of magnitude 6.0 or greater (Stover & Coffman 1993).

In addition **Zoghi et al.** (2008), observed that concrete bridges are expected to crack in the tensile and extreme deflection regions, under heavy truck load conditions and, therefore, the proper reinforcement with high tensile strength material must be provide. To this purpose, the stress and deflection distribution of bridges on transverse and longitudinal direction should be determined. Although many investigations were performed to predict the live load distribution factor of skewed bridges, only limited numbers concentrated on determining the maximum distribution of tensile and compressive stress, and deflection of skewed bridges. In many bridge design procedure, the maximum positive and negative stress of bridges are obtain using the corresponding moment distribution factor formulas in corresponding cross sections. It should be noted that maximum tensile and compressive stress on the cross section are indeed localized, while the moment distribution factors formulas were obtained based on uniformly distribution of stress on bridge cross section.

3. Objectives of the work

The following are the main objectives of the present study analysis are:

Present work involves the static analysis of RC box girder bridge with skew angles, 0 and 15 degrees.
The results of finite element (FE) and modal analysis are presented to study the influence of skew angle on the natural frequency for the entire skewed bridge.
Structural response for the superstructure covering elemental stresses, base reaction and joint displacements will also be studied..
The analytical results of skewed bridge will be studied and compared with non-skewed bridge with varying the skew angle.

4. Modeling and Analysis

Analysis is performed for dead load and live load on skew bridges. The results have contributed to understanding the behaviour of skew bridges based on the maximum loads. The results are extracted in excel and further used for plotting the graph such as skew angle versus bending moment, shear force and torsion. Comparison is made for all the models and a comprehensive conclusion is drawn.

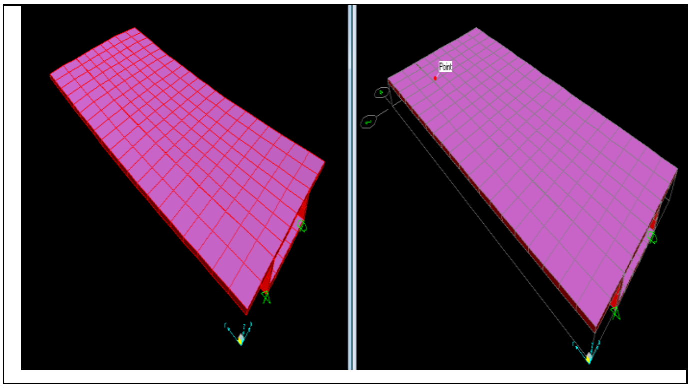

Fig-2: 3D View of RC box girder bridge with zero degree skew angle

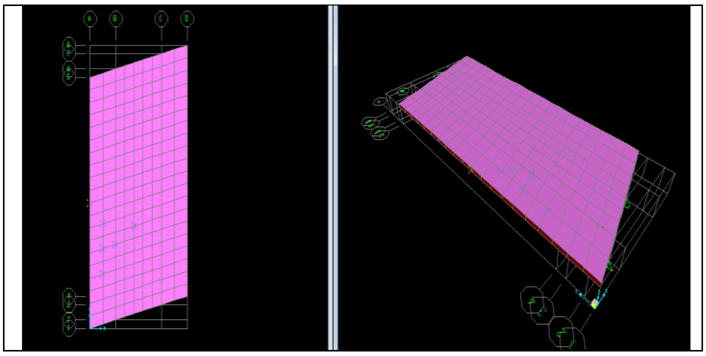

Fig-3: 3D View of RC box girder bridge with 15 degree skew angle

Table -1: Joint Reactions for different load cases

Joint Numbers	Load cases	Joint reaction (KN)
22	DEAD	786.549
24	DEAD	625.32
27	DEAD	786.549
29	DEAD	625.32
22	PARAPET WALL	62.825
24	PARAPET WALL	49.675
27	PARAPET WALL	62.825
29	PARAPET WALL	49.675
22	SDL	135.246
24	SDL	107.454
27	SDL	135.246
29	SDL	107.454
22	VECL-1	1823.79
24	VECL-1	1710.61
27	VECL-1	1826
29	VECL-1	1708.27
22	VECL-2	868.574
24	VECL-2	836.587
27	VECL-2	869.955
29	VECL-2	835.077

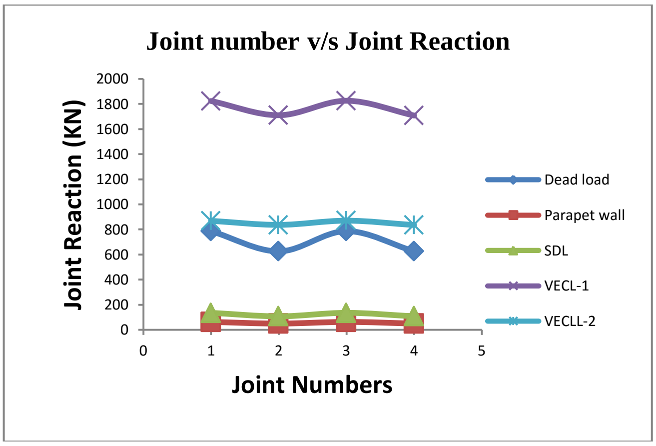

Chart-1: variation of joint number v/s joint reaction

Table -2 Base Reactions for 0 and 15 Degree skew

Base Reaction for 0 degree		Base Reaction for 0 degree	
Load case	**Reaction**	**Load case**	**Reaction**
DEAD	2823.738	DEAD	3075.898
SDL	485.4	SDL	528.746
VECL-1	2400	VECL-1	2400
VECL-1	0	VECL-1	0
VECL-2	1200	VECL-2	1200
VECL-2	0	VECL-2	0
PARAPET WALL	225	PARAPET WALL	245.092

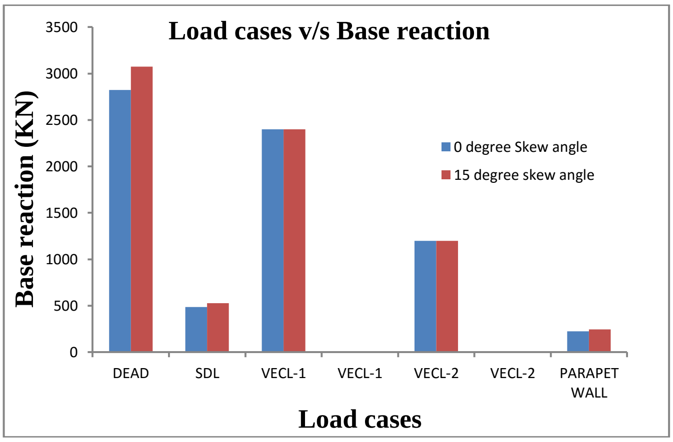

Chart -2 Load cases v/s Base Reactions for 0 and 15 Degree skew

5. Conclusion

The following conclusions are obtained from the outcomes of the investigation:

The joint reactions is found to be higher in case of vertical loads.

The joint reactions is found to be least in case of parapet wall.

For the varying load cases, as the skew angle increases, base reactions also increases.

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BIOGRAPHIES

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