Effect Of Skew Angle On RCC T- Girder Bridge Using STAAD PRO

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Abstract: Generally a bridge is defined as a structure spanning a river, road, valley, depression or any other type of obstruction with a purpose to provide through passage of communication. This project is taken to study the torsion moment of inertia effect on reinforced concrete (RCC) girder super structure for the three lanes and skew angles by 0°, 15°, 30°, 45°, and 60° Degree and compare the results to study the characteristics of skew deck and also to investigate the skew effect if the bridge is subjected to IRC 6-2014 Loading. The following analysis is going to be made using the software STAAD-PRO.

1. The effect of torsion moment of inertia in RCC T Girder with different skew angles.
2. The Effect of torsion moment due to torsion moment and with skew angles.
3. The effect of Skew angle in RCC girder.

The torsion moment of inertia is calculated based on the Timoshenko and Goodier. As skew increases the longitudinal bending moments are increased and the torsion moments also increased. Torsion moment is more at end girders compared to inner girder. For straight girder bridge no torsion moment is observed.

Keywords: Skew Angle; T-Beam Bridge; IRC Loading; Finite Element Analysis; Torsional Moment;

I. INTRODUCTION

The continuing expansion of highway network throughout the world is largely the result of great increase in traffic, population and extensive growth of metropolitan urban areas. This expansion has led to many changes in the use and development of various kinds of bridges. The bridge type is related to providing maximum efficiency of use of material and construction technique, for particular span, and applications.

Bridges are structures which are provided a passage over a gap without closing way beneath. They may be needed for a passage of railway, roadway, and footpath and even for carriage of fluid, bridge site should be so chosen that it gives maximum commercial and social benefits, efficiency, effectiveness and equality. Bridges are nation’s lifelines and backbones in the event of war. Bridges symbolize ideals and aspirations of humanity. They span barriers that divide, bring people, communities and nations into closer proximity. They shorten distances, speed transportation and facilitate commerce. Bridges are symbols of humanity’s heroic struggle towards mastery of forces of nature and these are silent monuments of mankind’s indomitable will to attain it. Bridge construction constitutes an importance element in communication and is an important factor in progress of civilization, bridges stand as tributes to the work of civil engineers.

Classification of Bridges:

• According to the inter-span relations as simple, continuous or cantilever bridges.

• Simply supported

Generally width of bridge is divided into number of individual spans. For each span, the load carrying member is simply supported at both ends. The plate girder and truss girders are used as this type of bridges. They are suitable at places where uneven settlements of foundations are likely to take place.

• Continuous

In continuous bridges spans are continuous over two or more supports. They are statically indeterminate structures. They are useful when uneven settlement of supports does not take place. In continuous bridges the bending moment anywhere in the span is considerably less than that in case of simply supported span. Such reduction of bending moment ultimately results in the economic section for the bridge. In continuous bridges the stresses are reduced due to negative moments developed at pier or supports. Thus continuous span bridges have considerable saving compared to simply supported bridge construction. Following are the advantages of RCC continuous girder bridges over simply supported girder bridges.

• As the bearings are placed on the centerline of piers, the reactions at piers are transmitted centrally.

• It is found that the continuous girder bridge suffers less vibration and deflection.

• The continuous girder bridge requires only one bearing at each pier as against two bearing for simply supported girder bridge.
• The depth of decking at mid span is reduced and it may prove to be useful for over bridges where headroom is of prime consideration.
• The expansion joints required will be less.
• There is reduction in cost as less quantity of concrete and steel are required.
• Following are the disadvantages of RCC continuous girder bridges over simply supported girder bridges.
• The design is more complicated as it is a statically indeterminate structure.
• The detailing and placing of reinforcements are to be carried out with extreme care.
• The placing of concrete and removal of formwork are to be executed carefully in proper sequence.
• According to the form or type of superstructure as arch, beam, truss, slab, rigid frame or suspension bridges.
• Girder

Effect of Skew:
Skewed bridges are often encountered in highway design when the geometry cannot accommodate straight bridges. The skew angle can be defined as the angle between the normal to the centre line of the bridge and the centre line of the abutment or pier cap, as described in Fig. 1.4. Skew bridges have become a necessity due to site considerations such as alignment constraints, land acquisition problems, etc. The presence of skew in a bridge makes the analysis and design of bridge decks intricate. For the Slab bridge decks with small skew angle, it is considered safe to analyze the bridge as a right bridge with a span equal to the skew span.

Fig 1.4: Skew Bridge

In non-skewed bridges, the load path is straight toward the support (Fig 1.5). In skewed bridges, the load tends to take a shortest path to the nearest support i.e. to the obtuse corners of the bridge here the maximum moments occurs at obtuse angled corner.

Fig 1.5: Direction of moment flow in straight and skewed bridge decks

II. RELATED WORK

The main bridges were made by nature itself — as basic as a log fallen over a stream or stones in the river. The principal bridges made by people were most likely traverses of cut wooden logs or boards and inevitably stones, utilizing a straightforward help and crossbeam course of action. Some early Americans utilized trees or bamboo shafts to cross little caves or wells to get starting with one place then onto the next. A typical type of lashing sticks, logs, and deciduous branches together included the utilization of long reeds or other gathered filaments woven together to shape a connective rope fit for authoritative and holding together the materials utilized as a part of early bridges.

The Arkadiko Bridge in Greece (thirteenth century BC), one of the most established curve bridges in
presence. The Arkadiko Bridge is one of four Mycenaean corbel curve bridges some portion of a previous system of roads, intended to oblige chariots, between Tiryns to Epidaurus in the Peloponnese, in Greece. Dating to the Greek Bronze Age (thirteenth century BC), it is one of the most seasoned curve bridges still in presence and utilize. A few in place angled stone bridges from the Hellenistic period can be found in the Peloponnese in southern Greece. The best extension manufacturers of days of yore were the old Romans. The Romans manufactured curve bridges and reservoir conduits that could remain in conditions that would harm or wreck prior plans. Some stand today. An illustration is the Alcántara Bridge, worked over the river Tagus, in Spain. The Romans additionally utilized cement, which diminished the variety of quality found in common stone. One kind of cement, called pozzolana, comprised of water, lime, sand, and volcanic shake. Physical bridges were worked after the Roman time, as the innovation, for cement was lost then later rediscovered.

The Arthashastra of Kautilya notices the construction of dams and bridges. A Mauryan connect close Girnar was studied by James Princep. The extension was cleared away amid a surge, and later repaired by Puspagupta, the main modeler of Emperor Chandragupta I. The extension likewise fell under the care of the Yavana Tushaspa, and the Satrap RudraDaman. The utilization of more grounded bridges utilizing plaited bamboo and iron chain was obvious in India by about the fourth century. Various bridges, both for military and business objects, were developed by the Mughal organization in India.

Amit Saxena, Dr. Savita Maru The motivation behind present investigation is the outline of extension structure for 25 m of traverse. The most evident decision of this traverse is T-Beam and Box Girder.

They have their own attributes and restrictions as T-Beam has simple construction folklore, though Box brace has refined and expensive formwork. In exhibit examine a two path essentially upheld RCC T-Beam Girder and RCC Box Girder Bridge was dissect for dead load and IRC moving burden. The dead load computation has been done physically and for live load straight examination is done on Staad Pro. The objective of study is to decide most great alternative from over two. The choices in view of evident component of designing that are security, serviceability and economy. Following these perspective an outline for both T-Beam and Box Girder has been performed. After count two nuts and bolts material utilization steel and cement the most conservative has been chosen. This examination is on the premise of snapshot of protection of segment, shear limit of area and financially savvy arrangement from both T-Beam and Box Girder Bridge. The investigation gives the arrangement in view of the predominant rates of construction cost to be embraced by configuration Engineer

Omkar Velhal, J.P. Patankar With the expanding rate of urbanization and quick framework development, the requirement for complex transportation frameworks has likewise expanded. This prerequisite, alongside different necessities for settling arrangement of the bridges, is for the most part in charge of arrangement of expanding number of skew bridges. Skew bridges are regularly experienced in expressway plan where geometry can't suit right bridges. In this paper behavioral parts of skew Tbeam bridges are considered and contrasted those and straight bridges utilizing Finite Element Analysis programming. The impact of skew point is seen on most extreme twisting minute, greatest shear power and greatest torsional minute, most extreme diversion because of dead load and live load at basic areas. Live Load “IRC Class AA Tracked Vehicle” is connected according to IRC 6:2000 guidelines. This examination demonstrates that the impact of skew point on torsional snapshot of longitudinal support is extensively high so that, it is imperative to consider torsional minute while outlining skew bridges.

III. METHODOLOGY

Reinforced concrete slab on top of PSC girders, also come under the purview of Composite construction. But due to practical problems composite construction using a reinforced concrete slab on top of steel girders are more familiar nowadays & RDSO also insists Railways to go with reinforced concrete slab on top of steel girders in ROB areas.

Thus using a reinforced concrete slab on top of steel girders is an economical and popular form of construction for highway & in Railway bridges. It can be used over a wide range of span sizes.

Beam and slab construction (Composite Bridges)

The form of construction considered in this publication is the beam and slab type, where a reinforced concrete deck slab sits on top of several I-section steel girders, side-by-side, and acts compositely with them in bending. It is one of the most common types of recent highway bridge in construction. A typical cross section, for a composite bridge two-lane road with footways, is shown in Figure 1.
Steel girder / PSC girder Deck slab

**Figure 2.1: Typical cross section of a composite bridge two-lane road with footways**

Composite action is generated by shear connectors welded on the top flanges of the steel girders. The concrete slab is cast around the connectors. This effectively creates a series of parallel T-beams, side by side. The traffic runs on a non-structural wearing course on top of the slab (there is a waterproofing membrane between). The load of the traffic is distributed by bending action of the reinforced concrete deck slab, either transversely to the longitudinal beams or, in some cases, by longitudinal bending to cross-beams and thence transversely to a pair of longitudinal main beams. The steel girders can be of rolled section, for fairly short spans, or can be fabricated from plate.

**Figure 2.2: Composite steel girder bridge of span 32m and skew 12 degree at Singaperamolkovil Railway station near Chengalpet (work under construction)**

Greater spans can be achieved if the bridge is lightly loaded a farm access bridge or a footbridge, for example. In both the latter cases, where the beam is shallow relative to the span, considerations of deflection and/or oscillations may control the design. Very little fabrication is necessary with Universal Beams, usually only the fitting of stiffeners over support bearings and the attachment of bracing. Beams can be curved in elevation (camber) by specialist companies using heavy rolling equipment.

For highway bridges where spans exceed the limits dictated by the maximum size of Universal Beams, girders must be fabricated from plates. Even for smaller spans, plate girders may be more suitable, because thicker webs and flanges can be provided. Also, Universal Beams of 762 mm serial size and above can often be more economically replaced by a similar plate girder. The use of plate girders gives scope to vary the girder sections to suit the loads carried at different positions along the bridge. A wide variety of different forms in elevation and section has developed.

**Figures 2.3: Composite Construction of Bridge no 1449A –between Samayanllur & Sholavandan in Madurai District**

**Figure 2.4: South India longest Composite Girder Bridge. Over all span 51m.Skew 62°**

**Advantages of Composite Steel Girder**

The composite girders have several advantages as they can reduce the use of concrete as well as steel; offer greater strength; lesser floor sections and greater speed of construction. The work involves fabrication of steel girders in reputed workshop, transportation, assembling the individual girder with splice joints, erection of ‘I’ girders one by one with support arrangements & diaphragms and then casting the deck slab at site. Fabrication is done in work shop and the quality can be achieved. No temporary staging and continued speed restriction required only line block is required for erection and hence all the activities can be planned independently. Light weight and therefore easy, fast and safer method of launching and mobilization of heavier capacity cranes can be avoided resulting to very fast construction.

**Some of the guidelines available for Composite (Steel) Construction**

i. These girders are welded type.

ii. End diaphragm girders should be provided along the alignment of the bearing so that the entire span at one end can be lifted with help of synchronous jacks for attending bearings etc. Cross bracing should be provided square to the girder alignment.

iii. All field joints of cross bracings and end diaphragms are planned with High Strength Friction Grip Bolts.

iv. Stud type/ flexible shear connectors are provided. Rigid shear connectors of structural
v. Provision of Abutment/pier at railway boundary is not mandatory. Standard span should be planned over the railway track. Adjacent spans can also be of required standard span.

vi. General Arrangement Drawing (GAD) for skew crossing may be planned with skew angle in increment of 5 deg. normally the skew angle more than 45 degree should be avoided. However any skew angle can be provided with proper design and calculation.

IV. SKEW BRIDGES

Bridge deck slabs by its nature have their supports only at two edges and the remaining 2 edges are free. They carry traffic on top and cross an obstruction. The supports for such slabs are sometimes not orthogonal for the traffic direction necessitated by many reasons. Such bridge decks are defined as skew bridge decks.

From analytical point of view, knowledge on design and behavior is limited and from practical point of view, detailing is quite involved and visibility is restricted. Several practices exist in reducing the skew effects, as there are many apprehensions (anxiety) about the correct prediction of the behavior and proper designs of the skew bridges especially if the skew angle is very high. In some cases skew effects are avoided by proper choice of orientation of supports. Foundations and substructures could be oriented in the direction of flow of river or rail track in a skew crossing. But trestle cap could be provided in such a way so that deck system forms a right deck (not a skew deck). This could also be achieved in a simple way by choosing single circular column pier as shown in figure 3.1.

Behavior of Skew Bridge Decks

Normally a rectangular slab bridge deck behaves in flexure orthogonally in the longitudinal and transverse direction. The principal moments are also in the traffic direction and in the normal to the traffic. The direction and the principal moment can well be recognized by the deformation pattern as shown in fig.2.2, which is reality.

The slab bends longitudinally leading to a sagging moment. Hence deflection of the middle longitudinal strip will be less than the deflection of edge longitudinal strip. The middle longitudinal strip along xx is supported by adjoining strip on either side. The longitudinal strip near free edges say along x1x1 is supported by adjoining strip only on one side, the other side being a free edge.

For skew slabs the force flow is through the strip of area connecting the obtuse angled corners and the slab primarily bends along the line joining the obtuse angled corners. The width of the primary bending strip is a function of skew angle and the ratio between the skew span and the width of the deck (aspect ratio). The areas on either side of the strip do not transfer the load to the supports directly but transfer the load only to the strip as cantilever. Hence the skew slab is subjected to twisting moments. This twisting moment is not small and hence cannot be neglected. Because of this, the principal moment direction also varies and it is the function of a skew slab.

The transfer of the load from the strip to support line is over a defined length along the support line from the obtuse angled corners. Then the force gets redistributed for full length. The force flow is shown in fig 3.4 (a&b). The thin lines in fig.3.4 (a) indicate deformation shape. The distribution of reaction forces along the length of the supports is also shown on both the support sides.

The deflection of the slab also is not uniform and symmetrical as it is in a right deck. There will be warping leading to higher deflection near obtuse angled corner areas and less deflection near acute angled corner areas. Fig. 2.3 & 2.4 show the deformation pattern of a right slab deck and also the skew slab deck.
The characteristic differences in behavior of skew deck with respect to right deck are:

i. High reaction at obtuse corners.

ii. Possible uplift at acute corners, especially in case of slab with very high skew angles.

iii. Negative moment along support line, high shear and high torsion near obtuse corners.

iv. Sagging moments orthogonal to abutments in central region.

v. At free edges, maximum moment nearer to obtuse corners rather than at center.

vi. The points of maximum deflection nearer obtuse angle corners. (This shift of point of maximum deflection towards obtuse corners is more if the skew angle is more).

vii. Maximum longitudinal moment and also the deflection reduce with increase of skew angle for a given aspect ratio of the skew slab.

viii. As skew increases, more reaction is thrown towards obtuse angled corners and less on the acute angled corner. Hence the distribution of reaction forces is non-uniform over the support line.

It is generally believed that for skew angle up to 15o, effect of skew on principal moment values and its direction is very small. The analysis considering the slab as if it is right deck with skew span as one side and right width as another side is adequate for design purposes. When skew angle increases beyond 15o, more accurate analysis is required since change in the behavior of slab is considerable. It may be understood that behavior is not only dependent on skew angle but also on aspect ratio, namely skew span to right width ratio.

If the width of the slab is large, the cantilevering portion from the primary bending strip connecting the obtuse angled corner will also be large. The bending strip also will be very nearly orthogonal to supports. To reduce the twisting moment on the load-bearing strip connecting the obtuse angled corners, an elastic support can be given along the free ends for the slab and this support is achieved by provision of an edge beam. If stiff edge beam is provided, it acts as a line support for the slab, which effectively extends right up to the abutment.

V. ANALYSIS & RESULTS

Bending Moment & Shear Force Results:

From the analysis of grillage model the bending moment and shear force results for different girders are given in following table. We consider the maximum bending moment for internal and external girders.

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VI. CONCLUSION

• Torsion moment of inertia effect on the RCC 1-girder Bridge with different skew angles i.e. 0o, 15o, 30o, 45o, and 60o were studied in this research.

• Torsion moment of inertia is calculated based on Timoshenko and Goodier as described in chapter 4.

• All the properties of girder sections are inserted in the grillage model.

• Bending moment, shear force and torsion moments are obtained from the STAAD grillage analysis results.
• As skew increases the longitudinal bending moments are increased and the torsion moments also increased.

• The results tables show that bending moment, shear force and torsion moment at different sections of each girder.

• Torsion moment is more at end girders compared to inner girder.

• For straight girder bridge no torsion moment is observed.

• Hence it is concluded that, without torsion moment of inertia property there is no torsion moment is occurred.

• As skew changes the center of gravity of bridge also changes so maximum moment does not occur at center of the girder for skew bridges.

VII. REFERENCES

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[2]. IRC:21-2000; Standard Specifications and code of practice for road bridges; Section III: Cement Concrete (Plain and Reinforced, 3rd revision); The Indian Roads Congress (New Delhi, 2000).


