# Study on behavior of Girder bridge

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***Abstract-*** *The curvilinear nature of box girder bridges along with their complex deformation patterns and stress fields have led designers to adopt approximate and conservative methods for their analyses and design. Recent literature on straight and curved box girder bridges has dealt with analytical formulations to better understand the behavior of these complex structural systems. In this paper Girder Bridge is analyzed using STAAD Pro software with application of Live Load, Dead Load, Wheel Load and Load Combination.*

## I. INTRODUCTION

### 1.1GENERAL

Roads are lifeline for the modern transport and bridges are an integral part of it. Bridges are the structures which are built over road, railway, etc. for the purpose of providing passage over the obstacles. Bridges undergo expansion and contraction due to temperature changes which is the major concern. Here durability is the major design consideration. Routine inspection and maintenance is required. Bridges are classified based on material of construction, Function, form of superstructure, inter span relation, method of construction, span and type of service and duration of use. The construction of bridge varies depending on material used. Bridges were existed since Paleolithic period and Stone Age. In 100B.C, 2104 years ago Romans constructed the arch bridge where arch design provides even distribution of stress and natural concrete was made of mud and straw. In 700 A.D, 1304 years ago in china great stone bridge which is low bridge,shallowarch,andallowsboatsandwatertopassthroughit.In 1900,trussbridgeswereconstructed using wood considering mechanics of design. In 1920, suspension bridges were constructed using steel in suspending cable. In 2000, prestressed concrete was constructed.

### 1.2 GIRDERBRIDGE

A girder bridge is a bridge that uses girders as the means of supporting its deck. The two most common types of modern steel girder bridges are plate and box.

The term "girder" is often used interchangeably with "beam" in reference to bridge design. However, some authors define beam bridges slightly differently from girder bridges.

A girder may be made of concrete or steel. Many shorter bridges, especially in rural areas where they may be exposed to water overtopping and corrosion, utilize concrete box girder. The term "girder" is typically used to refer to a steel beam. In a beam or girder bridge, the beams themselves are the primary support for the deck, and are responsible for transferring the load down to the foundation. Material type, shape, and weight all affect how much weight a beam can hold. Due to the properties of the second moment of area, the height of a girder is the most significant factor to affect its load capacity. Longer spans, more traffic, or wider spacing of the beams will all directly result in a deeper beam. In truss and arch-style bridges, the girders are still the main support for the deck, but the load is transferred through the truss or arch to the foundation. These designs allow bridges to span larger distances without requiring the depth of the beam to increase beyond what is practical. However, with the inclusion of a truss or arch the bridge is no longer a true girder bridge.

### 1.3 History of Girder bridge

Girder bridges have existed form illennia in a variety of forms depending on resources available. The oldest types of bridges are the beam, arch and swing bridges, and they are still built today. These types of bridges have been built by human beings since ancient times, with the initial design being much simpler than what we enjoy today. As technology advanced the methods were improved and were based on the utilization and manipulation of rock, stone, mortar and other materials that would serve to be stronger and longer.

In ancient Rome, the techniques for building bridges included the driving of wooden poles to serve as the bridge columns and then filling the column space with various construction materials. The bridges constructed by Romans were at the time basic but very dependable and strong while serving a very important purpose in social life.

As the Industrial Revolution came and went, new materials with improved physical properties were utilized; andwroughtironwasreplacedwithsteelduetosteel'sgreaterstrengt handlargerapplicationpotential.


Figure 1.2 Nice road, Bangalore

**1.4 Types of Girder bridge**

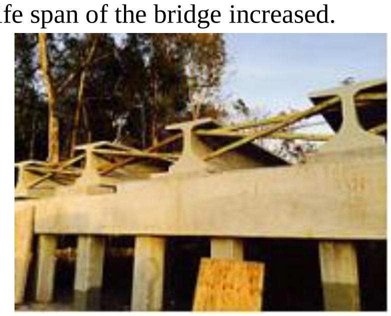
- Rolled Steel Girder.
- Plate Girder.
- Box Girder.
- A rolled steel girder is a girder hath as beenfabricatedbyrollingablankcylinderofsteelthroughaseri esofdies to create the desired shape. These create standardized I-beam and wide flange beam[7]shapes up to 100 feet in length.
- A plate girder is a girder that has been fabricated by welding plates together to create the desired shape. The fabricator receives large plates of steel in the desired thickness, then cuts the flanges and web from the plate in the desired length and shape. Plate girder scan have a greater height than rolled steel girders and are not limited to standardized shapes. The ability to customize a girder to the exact load conditions allows the bridge design to be more efficient. Plate girder can be used for spans between 10 meters and more than 100 meters (33 feet to more than 330 feet). Stiffeners are occasionally welded between the compression flange and the web to increase the strength of the girder.
- A box girder or"tub girder" is, as the name suggests, a box shape. They consist of two vertical webs, short top flanges on top of each web, and a wide bottom flange connecting the webs to gether. A box girder is particularly resistant to torsion and, while expensive, are utilized in situations where a standard girder might succumb to torsion or toppling effects.

**1.5 Design**

All bridges consist of two main parts: the substructure, and the superstructure. The superstructure is everything from the bearing pads, up - it is what supports the loads and is the most visible part of the bridge. The substructure is the foundation, transfers loads from the superstructure to the ground. Both must work together to create a strong, long-lasting bridge.

The superstructure consists of several parts:

- The deck is the roadway or walkway surface. In roadway applications it is usually a poured reinforced concrete slab, but can also be steel grid or wood plank. The deck includes any road lanes, medians, sidewalks, parapets or railings, and miscellaneous items like drainage and lighting.
- The supporting structure consists of the steel or concrete system supporting the deck. This includes the girders themselves, diaphragms or cross-braces, and (if applicable) the truss or arch system. In a girder bridge this would include only the girders and the bracing system. The girders are the primary load support, while the bracing system both allows the girders to act to gether as a unit, and prevents the beams from toppling.
- The job of the bearing pads is to allow the super structure to move some what independently of the substructure. All materials naturally expand and contract with temperature-if a bridge were completely rigid, this would cause unnecessary stress on the structure and could lead to failure or damage. By fixing the super structure at one end, while allowing the other end of as pan to move freely in the longitudinal direction, thermal stresses are alleviated and the life span of the bridge increased.



The substructure is made of multiple parts as well:

- An abutment is the foundation that transfers the bridge structure to the roadway or walkway on solid ground. Apier is an inter mediate support.
- The cap is the part that supports the bearing pads. Depending on the type of support structure, there may or may not be a cap. Wall piers and stub abutments do not require a cap, while a multi-column, hammerhead, or pile-bent pier will have acap.
- The stem or stub is the main body of the foundation. It transfers the load from the superstructure, through the cap, down to the footer.
- The footer is the structure that transfers the loads into the ground. There are two primary types of systems: a spread footer, which is a simple concrete slab resting on bedrock; or a piling cap, which utilizes steel piles to reach sound bedrock that may be deep underground. Another system

utilizes caissons or steel-reinforced concrete "pillars" below the stem.

1.8 Bridge Superstructure

Superstructure is the upper portion of the bridge system that starts with girder or T beam and deck slab which involves carriageway, crash barriers, medians, footpath and railings. This part of bridge receives the live load by traffic directly along the span of bridge. Types of bridges:

- Girder bridge
- Truss bridge
- Arch bridge
- Suspension bridge
- Cable stayed bridge
- Movable bridge

In the present study, “Girder bridge” type is considered. Here the beams may be made of concrete or steel or combination of both. In Concrete Girder Bridge, the compressive force is resisted well by the concrete and tension forces are resisted well by the steel rods within.

### 1.8.1 RCC T-beam girder:

In this study, the bridge is modeled as a T-beam bridge as it is suitable for small and medium span bridges. The RCCT-beam Bridge consists of concretes lab supported by a series of longitudinal concrete beams. Here the main longitudinal girders are designed as T-beam integral with part of decks lab. Number of longitudinal girders depends on the road span. Both static and dynamic loads may be considered on the bridge deck and foundation.

## II. LITERATURE REVIEW

**Bhavya R, Usha K N, Janardhan C, 2017** – This paper reports on the study on integral bridge with composite deck for IRC standards using finite element software (Staad Pro). In this paper, a composite integral bridge which is of concrete deck slab and a built-up steel girder are modeled using suitable finite element software to study the behavior of the bridge structure under different loads. The main objective of this paper is to show the performance of the integral bridge under temperature loads. Grillage method is used to model the bridge. This study concludes that, the seasonal and daily changes in temperature load effects the integral bridge. Temperature loads are most important considerations while analyzing an integral bridge. As this bridge is monolithic with deck and abutment the structure is stiffer than soil surrounding or pile itself results in constraint in motion thus it proves that the soil parameters alters the behavior of the structure and soil pile interaction. As there is continuity between bridge deck and abutment, temperature load transfer can happen better. Thus, concluded that, integral bridge model will behave well with temperature loads.

**Raj K K and Phani R G, 2017 –** In this paper, an attempt has been made to design and study on behavior of skew bridges with varying skew angles. This study reports that behavior of simply supported skew slab bridges with various skew angle 0 to 60 degrees. And studied on bending moment variation with various skew angle on simply supported skew slab bridge using STAAD PRO software and as per IRC-6. Then graphs are plotted for moment versus skew angle. Then from graphs it is observed that till 15-degree tilt angle effect is minimal and Mx value is small but with increase in tilt angle the effect also increases and Mx value also increases exponentially. Finally, they concluded that, as the tilting angle increases maximum deviation of inclined slab decreases and load capacity of inclined slab increases. And behavior of inclined slab is almost similar to straight bridge slab.

**O. Fatih Yalcin, 2016 –** In this paper, a comparative study of live load distribution in skewed integral and simply supported bridges. The effect of superstructure-abutment continuity and skew o live load distribution among the girder of skewed simply supported bridge and skewed integral abutment bridge are investigated comparatively. Numerous 3D and 2D finite element models of several single span skewed simply supported bridge and skewed integral bridges are modeled. Analyses of the models are done as per AASHTO live load. The parameters considered in the study are girder size and spacing, span length, number of girder and thickness of slab. Further results obtained are used to calculate live load distribution factors (LLDF) for girder of skewed simply supported bridge and skewed integral bridge as a function of parameters considered. Skew correction factors (SCF) are also obtained from AASHTO equations developed for skewed simply supported bridges. There LLDFs and SCFs are compared with calculated values from applicability of AASHTO equation to skewed integral bridges. The results obtained revealed that live load distribution of moment and shear among the girders is improved in skewed simply supported bridges compared to skewed integral bridges. Increase in skew generally decreases the live load effects among the girder of skewed integral bridges.

**Ajay D Shalvi, S.V. Joshi, and P.D. Pachpor, 2016 –** This paper studies on the analysis and behavior of skew bridge with different skew angle using STAAD.Pro v8i. For better result interpretation and variation in value of parameters for different skew angle increasing from 0o to 60o at intervals of 5o. This paper provides detailed study of skewed and non-skewed

R.C.C bridges. Various loading criteria on bridges are as per IRC-6. Parameters like bending moments, twisting moments, shear force under different skew angles varying from 0o to 60o at an interval of 5o are investigated. Under dead load, live load and combinations of both, results obtained for all 26 models with skew angle varying from 0o to 60o at an interval of 5o are shear force, axial force, torsion and moment. Graphs are plotted for 3 girders G1, G2 and G3 with respect to bending moment, bending moment due to torsion, equivalent design bending moment and equivalent design shear force. Finally, they concluded that as skew angle increases, torsion moment increases thus equivalent BM and SF increases for both live load and dead load conditions. For Live load condition BM decreases for all 3 girders. For dead load and live load combination bending moment, moment due to torsion and equivalent design BM increases gradually as the skew angle increase of $0^o$ to $60^o$. For dead load bending moment, moment due to torsion and equivalent bending moment increases gradually with increase in skew angle from $0^o$ to $60^o$ at an interval of $5^o$.

**Yamuna Bhagwat, R.V. Raikar and Nikhil Jambhale, 2015** – In this paper, finite element method analysis of integral abutment bridges with fixed and pinned pile head connections. A comparative study is carried out on the effect of pile head connections with abutment on integral bridges. Design parameters considered are bending moment, shear force and longitudinal stresses in deck slab. The results of dead load + live load + temperature combinations + temperature and dead load with varying span numbers are compared with single span number with dead load. The effect on exterior and interior girders is also studied. In case of dead load and single span integral bridge case, the negative maximum end bending moment is decreased by 10.5%, in case of two spans integral bridge decreased by 28.5% but for three spans integral bridge, no change is observed. Negative bending moment and positive bending moment are enhanced by increase in temperature. In deck slab, shear force is increased by 5.9% for two span bridge having pile head with pinned connection. Shear force is not changed in single span and three span integral bridges.

**Popoola, Oladele. O., Wasiu and John, 2015** studied on long term performance of skew integral bridge. In this study, four types of integral bridges were modeled using Midas civil software. The parameters considered were displacement, deflection, moments and torsion. Here the skew angles were increased as the abutment sizes varied. In this paper, it is observed that the abutment angle affects the skew bridge displacement. Thus, the deflection increases as the skew angle increases. Due to traffic loading considered during modeling hogging moments were observed. The end hogging moments variations were observed accordingly with the large skew angle. Finally, they concluded that the long- and short-term effects of shrinkage and creep is taken into account for pavement movement. The horizontal displacement of bridge is affected for a long period of time. Skew bridges have greater deflection when compared to straight bridge.

**Yaohua Deng, Brent M. Phares, Lowell Greimann, Gus L. Shryack, and Jerad J. Hoffman, 2015** – this paper reports on the investigation of effect and behavior of skewed and curved bridges with integral abutment through a field observation-oriented program and their numerical analysis. One lane, three spans, horizontally curved integral bridge was constructed and implemented using field monitoring system to record the behavior of bridge under change in surrounding conditions and tested using a dump truck travelling across the Bridge. A 3-dimensional model is established and its results were compared with the collected data. Under the design loadings conditions, a parametric study was conducted to investigate the effect of curvature and skew on the behavior of bridge. Finally, it was found that, stresses in girder varied with varying skew and curvature significantly. With 0.06 radian arc and $10^o$ skew span length to radius ratio, the skewed and curved integral bridges can be designed as a straight bridge.

**Nikhil V. Desphande1, Dr. U.P. Waghe2, 2013 –** This paper studies on analysis and design of skew bridges using CsiBridge computer software. Therefore, attentive investigation and numerical analysis needs to be performed in which a skew bridges cab be modeled in several ways. Here the study is carried on the behavior under uniform and moving loads to find the most appropriate force response for design. An IRC load combination of bridges has been implemented within CsiBridge software. Main objective of the study is to observe and conclude bending moment, torsional moment and shear force with respect to change in skew angle of bridge. The model configuration is kept same but skew angle is varied from $15^o$ to $45^o$ for different span lengths and class A loading is considered. They concluded that, for low skew angle, shear force increases linearly but there will be a sharp decrease in shear force for low span lengths. As skew angle and span length increases bending moment increases by about 20% in nature. The increment pattern of torsional moment is similar to the bending moment. To counteract the torsional moment in bridges, the torsional reinforcement may be required.

**Aslam Amirahmad and A. Rahman Al-Sinaidi, 2013 –** In this study the analysis of integral abutment bridge using finite element method. The finite element analysis is performed to obtain the detailed interactions between integral abutment, foundation piles, approach fills and foundation soil. Finite element shows the considerable rotations in integral bridge which results in moment and shear reductions in the piles. The bridges were modeled as a plain strain problem with symmetry around the centerline of the bridge. The mesh is coarser near boundaries and finer around the abutment. Between the approach fill and abutments zero thickness interferes elements are used.

**Arindam Dhar, Mithila Mazumdar, Mandakini Choudhury and Somnath Karmakar, 2013 –** this paper provides a study on effect of skew angle on longitudinal girder (support Shear, moment, torsion) and deck slab of an IRC skew bridge. This paper includes the evaluation of a skew bridge behavior with slab and longitudinal girder and compares them with aspects of straight counterparts using a 3D bridge model in finite element analysis software – ABAQUS. Here in this study simply supported RC bridge is adopted. Main objective of this project is to analyses the variation in the skew slab with increasing skew angle. The parameters considered in the present study are transverse and longitudinal bending moment, support shear and torsion of longitudinal girders along with deflection and stresses for the skew slab. Here study is done on effect of skew angle on lateral moment and torsion of the main girder and effect of slab deflection and slab stresses due to skew angle. Finally, the results obtained in this study shows that, increase in support shear, mid span longitudinal and lateral moments of obtuse longitudinal girder and decrease of the acute longitudinal girder due to increase in skew angle.

**Vikash Khatri, P.R. Maiti, P.K. Singh and Ansuman Kar, 2012 –** This paper reports the analysis of skew bridges using computational methods. In this study, a bridge deck consists of beam and slab is defined and modeled using grillage and finite element method. The effect of grid spacing on different skew angles on same span of reinforced concrete bridges using finite element method and grillage analogy method is compared. Parameters considered in this study are maximum reaction force, deflection bending moment and torsional moment are calculated and compared for both grillage and finite element methods. Main objective of this study is to determine the most appropriate and efficient grid sizes 14 to 12 divisions and skew angle of 30º, 45º and 60º. It is observed that results of both analysis methods are always not similar for every grid size. Bending moment for larger grid sizes obtained from finite element method overestimates the results from grillage analysis.

**Ibrahim S I Harba, 2011 –** In this paper, effect of skew angle on behavior of simply supported RC T-beam bridge decks is investigated by analytical method using 3-dimensional finite element method. Parameters investigated in this study were skew angle and span lengths. In this study, the FEA results of skewed bridges were compared with reference non- skewed bridge. AASHTO standard specifications followed in assigning the loads and for defining geometric dimensions of T-beam bridge decks. Maximum live load bending moment, shear, torsion and deflection are analyzed for 2 HS-20 truck wheel loads. A Maximum live load bending moment and deflection decreases in T-beam for skewed bridge for all span lengths. A maximum live load shear in T-beam Bridge decks increase for exterior beams and decrease for interior bridges for skewed bridges for all span lengths.

**Maher Shaker Qaqish, 2006 –** In this paper, effect of skew angle on distribution of bending moment in bridge slab. A finite element model was done for prestressed precast beams and cast in situ slab bridge. AASHTO truck loading, abnormal loading and AASHTO equivalent distribution loading was applied on this structural model. Many methods like grillage and finite element methods are used to analyze the skew bridges. The live load used for bridge design adopted from AASHTO specifications. This study is concerned of studying the bending moment variation in transverse and longitudinal direction in concrete slab of skew bridge. And they concluded that, the results obtained for the design of bridge slab as per AASHTO specifications is considered as safe and economical.

**L. F. Greimann, A M Wolde. Tinsae, and P S Yang**, studied on skew angled bridges with integral abutment. Here, this study includes survey on previous research work regarding detailing and design criteria used by state highway agencies. Study shows that thermally induced bending stresses will be induced to the web of piles but previous survey shows that the thermally induced bending stresses are ignored. Finally, they concluded that, magnitude of thermal movement will be reduced by restraint provided by integral abutment. More rigidity for earthquake loads is obtained by orientation of pile with strong axis parallel to centerline of bearings. For back fill and pile cap on skewed bridge no special treatment are made.

**Kassahun K. Minalu, 2010,** studied on finite element modeling of skew slab- girder bridges. Here in this study, the sensitivity in the performance of skew bridge with and without presence of end diaphragm beams in finite element model was studied. The study provides information regarding different methods for designing torsion reinforcement and general behavior of skew angle bridges and also potential failure mode when modeled as high skew angle bridge and straight bridge. The information regarding advantages and disadvantages of diaphragm beams consideration in the finite element model. And finally concluded that, decrease in the bending moment and twisting moment in girders and deck due to presence of end diaphragm beams but this reduction was not considerable as compared to the torsion moment in the diaphragm.

## III. OBJECTIVES AND METHODOLOGY

### 3.1 OBJECTIVES

- The behavior of 25m single span skew angled integral bridge is investigated with varying skew angle from 0 to 60 degree with interval of 15 degree.
- Comparison between various loads like dead load, moving loads and loads combination like ULS and SLS FC (referring to IRC-6) for bending moments, torsion moments, shear force and deflections.

### 3.2 METHODOLOGY

**Modeling procedure of girder bridge in Staad Pro**

Staad Pro – finite element analysis software. is integrated software for structural analysis and design. In this software complex models are meshed and generated with powerful built in templates like simple beams, storage vessels, 3D truss, different types of bridge structures, pipes and dam structures.
Procedure involved in modeling of girder bridges is as follows:

- Modeling and analysis of skew integral bridges is done using Staad Pro-Finite element analysis software.
- Totally five models are modeled with skew angle ranging from 0o to 60o with varying interval of 15o.
- Here the girder is modeled as a Deep beam and the Pier is modeled as Compression Member.
- Transverse and longitudinal girders are modeled using grillage method i.e in this method the deck slab is represented by an equivalent grillage of beams which provides more accuracy in results.
- The support condition considered in this present study is hinged support.
- The material and sectional properties are specified and assigned to frame and area elements respectively.
- Vehicles, vehicle classes are defined and assigned as per IRC-6 2014 and suitable lane dimensions are defined.
- Loads and load combinations are defined and assigned as per IRC-6 2014.

**Basic data for modeling**

Table 3.1 Basic data of the bridge model

| BRIDGE COMPONENTS | DETAILS |
|---|---|
| Effective span | 25m |
| Width of deck | 6m |
| Longitudinal girder spacing | 3m c/c |
| Cross girder spacing | 5m c/c |
| Inner girder | 2 |
| Outer girder | 2 |
| Main girder type | 1500X400mm |
| Cross girder type | 1000X400mm |
| Piers | 1000X1000 mm |
| Piers height | 6m |
| Lanes | 1 |
| Deck type | Reinforced cement concrete |
| Bridge type | Highway Bridge |
| Carriage way width | 3.6m |
| Code specification | IRC-6 2014 |

**Material properties**

Table 3.2 material properties assigned to the bridge

| CONCRETE and STEEL | |
|---|---|
| Mass per unit volume | 2549.3 kg/$m^3$ |
| Weight per unit volume | 25 KN/$m^3$ |
| Modulus of elasticity, E | 31.622 x $10^6$ KN/$m^2$ |
| Poisons ratio, U | 0.2 |
| Coefficient of thermal expansion, | 1.2 x $10^{-5}$ |
| Concrete compressive strength, fck | 40 N/$mm^2$ |
| Grade of steel, fy | 500N/$mm^2$ |

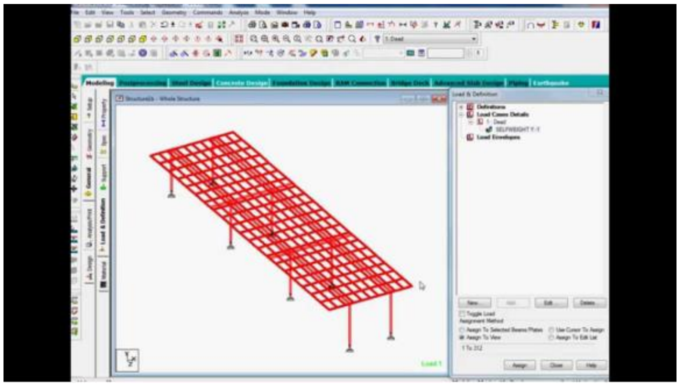


Fig 3.3 Girder Bridge in Staad Pro

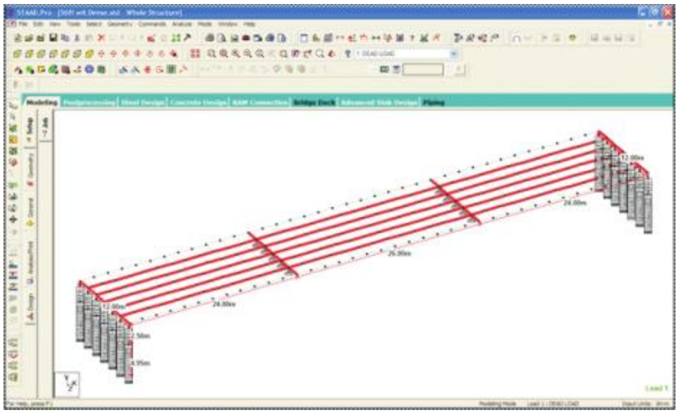


Fig 3.4 Staad Pro Model of Internal abutment of the bridge

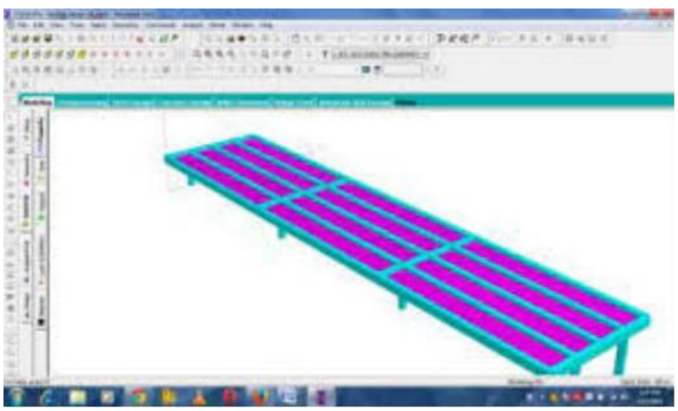
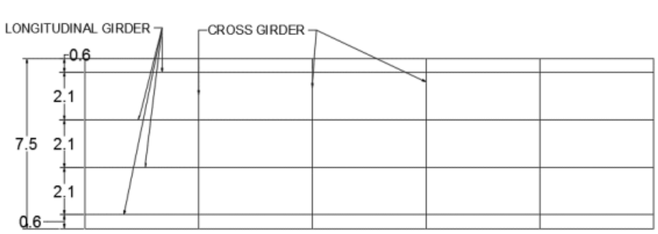


Fig 3.5 Analysis of Girder Bridge in Staad Pro



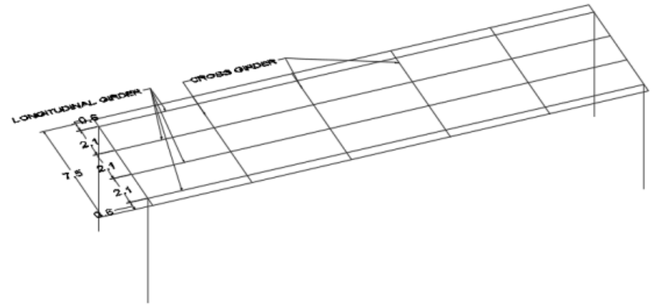




Fig 3.6 Plan view of $0^0$ skew integral bridge

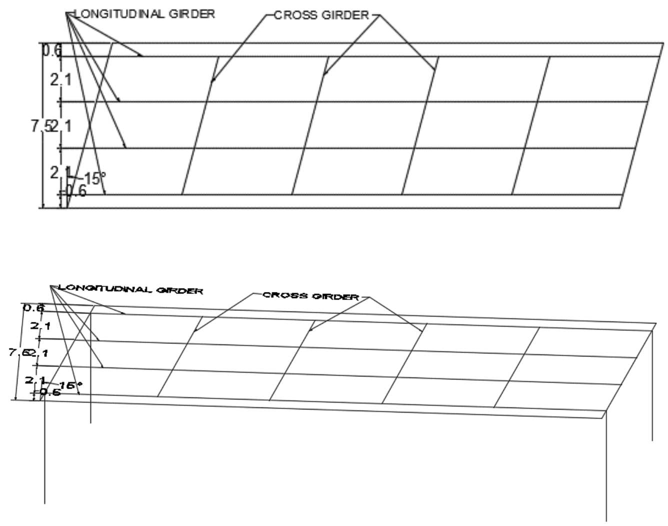



Fig 3.7 Plan view of $15^0$ skew integral bridge

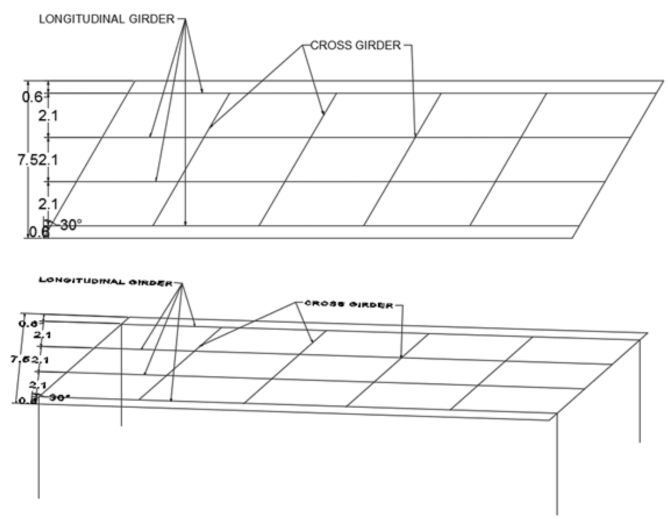
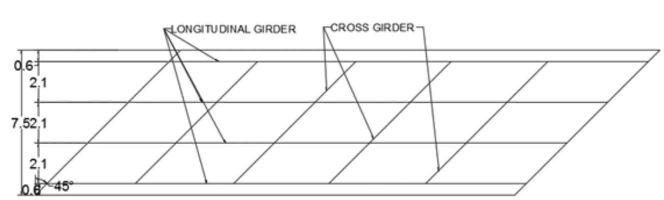



Fig 3.8 Plan view of $30^0$ skew integral bridge



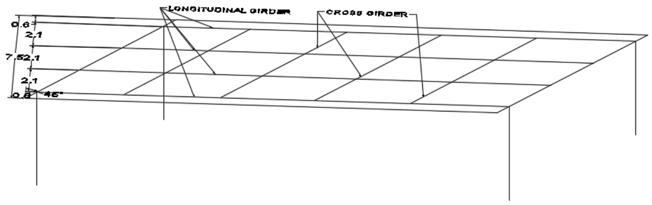



Fig 3.9 Plan view of $45^0$ skew integral bridge

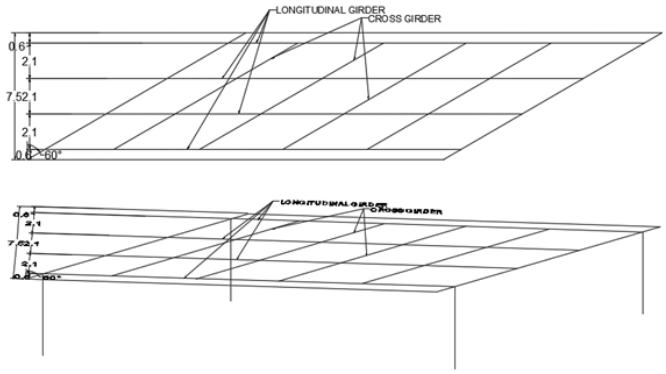



Fig 3.10 Plan view of $60^0$ skew integral bridge

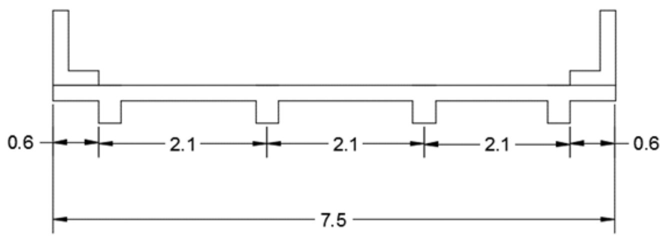



Fig 3.11 Cross Sectional view of skew integral bridge

**Dead Load**

Dead loads are the permanent loads acting on the structure. These are the loads which are transferred throughout the lifespan of structure. It involves the loads of its own weight and superimposed load of footpaths, wearing coat. The values of dead loads are considered according to Indian standard codes i.e. IS 875 (PART-1).

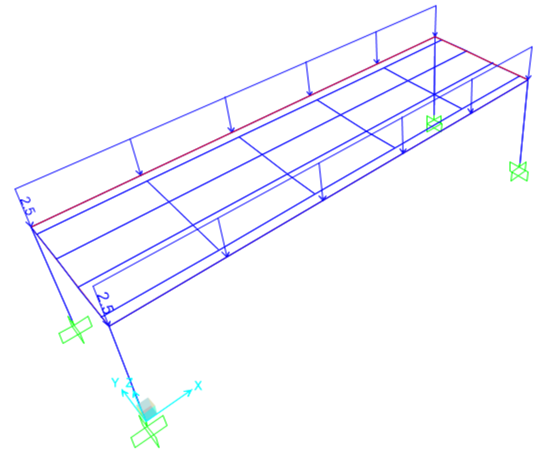



Fig 3.12 Application of parapet wall load.

**Live Loads**

Live loads applied on bridge are vehicle loads which includes brake load and impact load as per IRC 6 2014. As specified in IRC 6 Table 2-live load combination, for carriage width more than 5.3m and more than 9.6m one lane of class 70R or two lanes of class A TR can be considered. Class 70R loading can be adopted for all roads where permanent bridges and culverts are constructed. But bridges designed for this loading should also be checked for class A loading under certain conditions such as heavier stresses that may occur under class A loading.

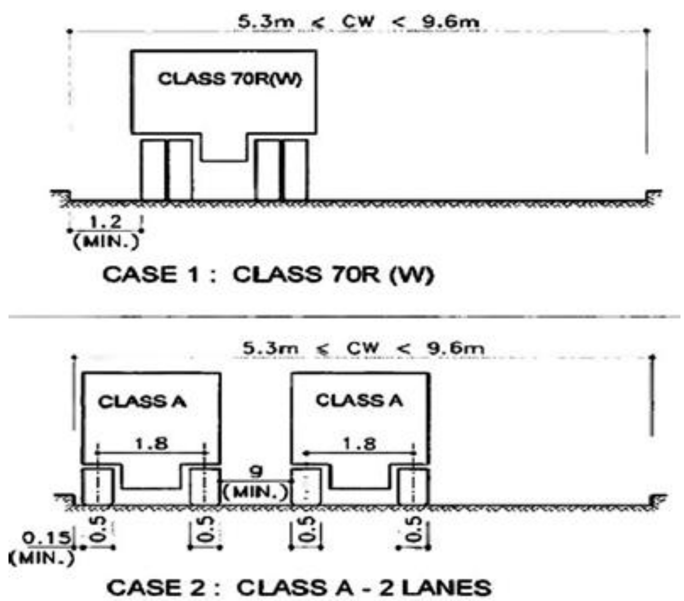



Figure 3.18 Live Load combination as per IRC 6 2014 code.

ForspanlengthsmorethanЗ9mforRCCstructurestheimpactloadof10%incrementoftheliveloadasperIRC6 clause208. Pedestrian load is considered referring to IRC 6 206, for spans of 30m and above below formula is used to calculate the pedestrian load. The load is applied due to pedestrian traffic should be treated to uniformly distributed over the pathway. The live load on footpath for designing main girder should be taken as, for span length of more than 7.5m and not exceeding 30m, the intensity of load is reduced from 4.25 KN/m2to 3 KN/m2.

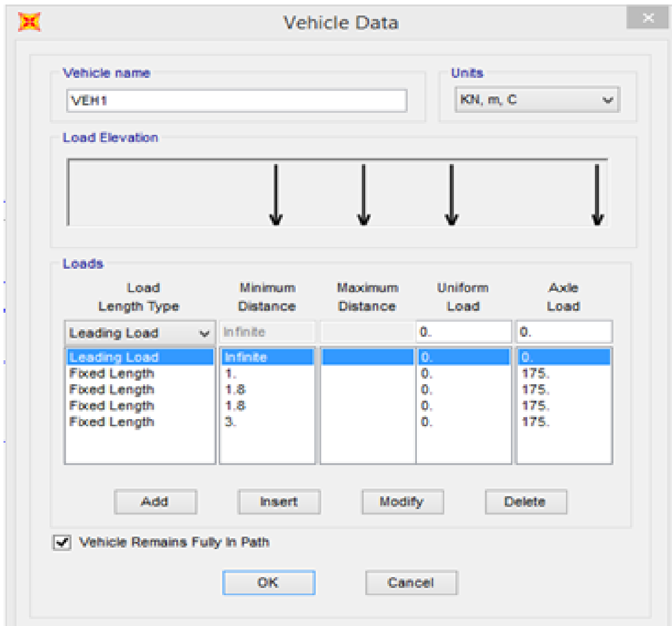



Fig 3.13 Application of vehicle live load.

### Longitudinal Force

The provisions made for braking effect due to application of brakes to wheels. This braking effect is greater than the traction effort. As specified in IRC 6 clause 211, in case of one- or two-lane bridge, 20 percent of first train loads plus 10 percent of load of succeeding trains.

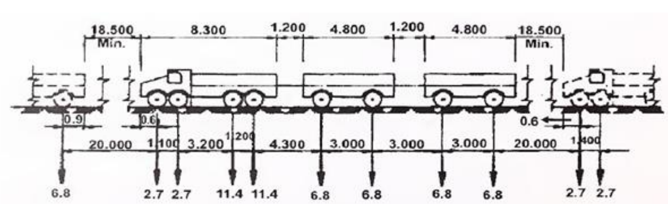


Figure 3.14 Class A tracked vehicle loading (IRC 6-2014)

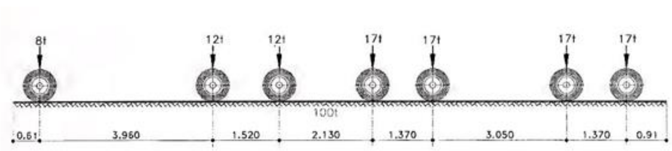


Figure 3.15 Class 70R wheeled loading (IRC 6-2014)

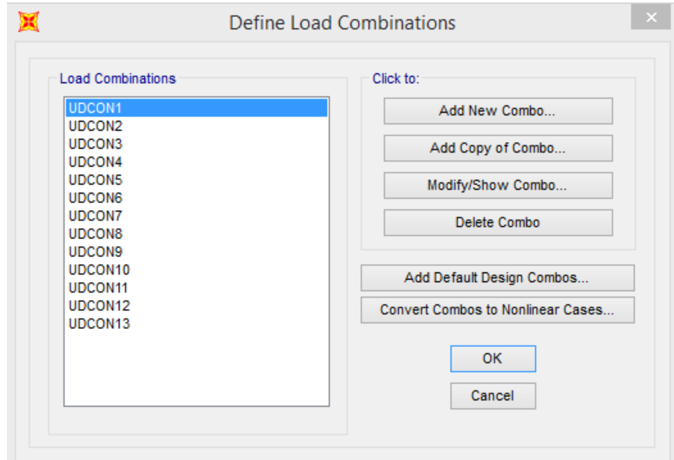



Fig 3.16 Application of load combination.

## IV. RESULTS AND DISCUSSIONS

A study on integral bridge with varying skew angles ranging from 0° to 60° with an interval of 15° is carried out for bending moment, Time period and Base shear variations for load cases such as dead load and vehicle load i.e. class 70R or class AA.

### BENDIMG MOMENT AT MID AND END SPAN OF THE GIRDER.

Table 4.1: Mid span bending moment for dead load.

| BENDING MOMENT FOR DEAD LOAD | | | | |
|---|---|---|---|---|
| SKEW | GIRDER1 | GIRDER2 | GIRDER3 | GIRDER4 |
| 0 | 496 | 463 | 463 | 496 |
| 15 | 488 | 457 | 457 | 488 |
| 30 | 502 | 492 | 492 | 502 |
| 45 | 626 | 576 | 576 | 626 |
| 60 | 756 | 711 | 711 | 756 |

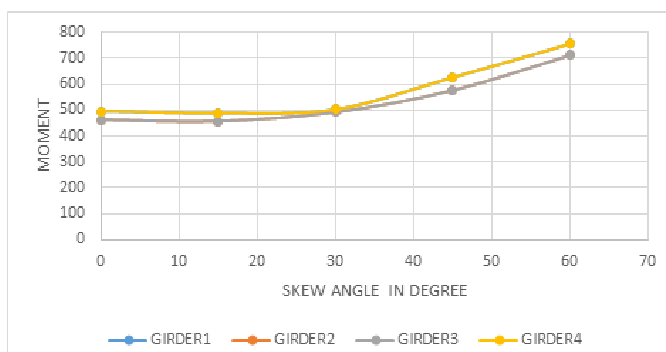



Fig 4.1: Moment v/s skew angle.

From above graphs it can be observed that, the mid span moment variations, for dead load case is increasing as the skew angle increases due to variation in symmetry of the main girder. There is considerable decrease in bending moment in inner girders G2 and G3 as compared to outer girders G1 and G4. Thus, the zero-degree model has a bending moment of 496KN-m and 60-degree model has 756 KN-m.

Table 4.2: Mid span bending moment for vehicle load.

| BENDING MOMENT FOR VEHICLE LOAD | | | | |
|---|---|---|---|---|
| SKEW | GIRDER1 | GIRDER2 | GIRDER3 | GIRDER4 |
| 0 | 333.13 | 277.01 | 283.09 | 328.94 |
| 15 | 360.87 | 292.39 | 293.06 | 352.44 |
| 30 | 368.97 | 293.06 | 297.07 | 366.59 |
| 45 | 392.02 | 310.91 | 313.01 | 388.22 |
| 60 | 393.98 | 315.96 | 314.73 | 393.98 |

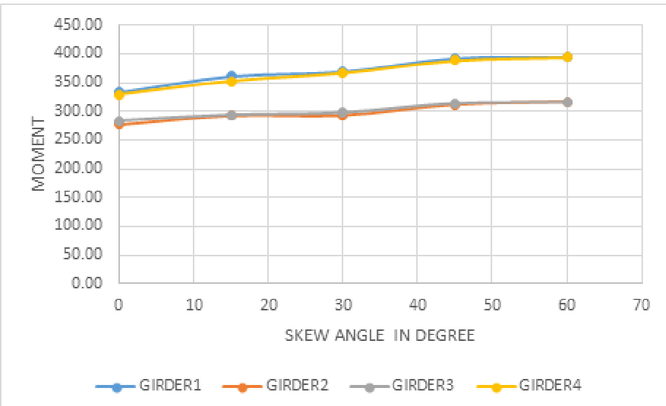



Fig 4.2: Moment v/s skew angle.

From above graph it can be observed that, the mid span moments variation for vehicle class AA loading increases as the skew angle increases due to varying in symmetry and improved distribution of live load among the girders. There is considerable decrease in bending moments in inner girders G2 and G3 as compared to outer girders G1 and G4. Thus the zero degree model has a bending moment of 333.13KN-m and 60 degree model has a bending moment of 393.98 KN-m.

Table 4.3: Mid span bending moment for UDCON.

| BENDING MOMENT FOR UDCON | | | | |
|---|---|---|---|---|
| SKEW | GIRDER1 | GIRDER2 | GIRDER3 | GIRDER4 |
| 0 | 742 | 693 | 693 | 742 |
| 15 | 727 | 686 | 686 | 727 |
| 30 | 730 | 686 | 686 | 730 |
| 45 | 790 | 757 | 757 | 790 |
| 60 | 1058 | 853 | 853 | 1058 |

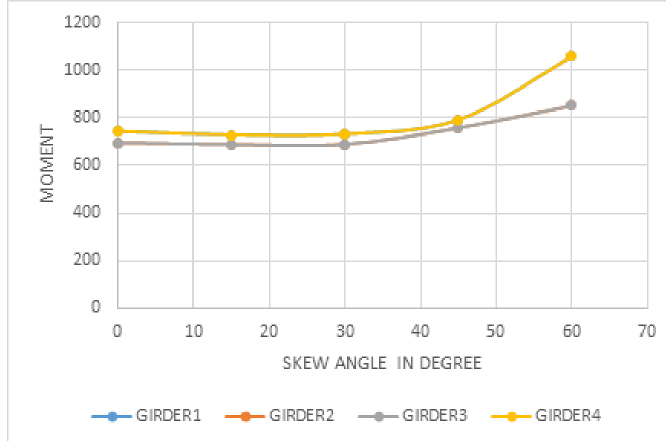



Fig 4.3: Moment v/s skew angle.

From above graph it can be observed that, the mid span moment variation for load combination (IRC-6) increases as skew angle increases due to varying symmetry. There is considerable decrease in bending moment in inner girders G2 and G3 as compared to outer girders G1 and G4. Thus the zero degree model has bending moment of 742KN-m and 60 degree model has 853 KN-m

Table 4.4: Mid span bending moment for Modal load.

| BENDING MOMENT FOR MODAL LOAD | | | | |
|---|---|---|---|---|
| SKEW | GIRDER1 | GIRDER2 | GIRDER3 | GIRDER4 |
| 0 | 2193 | 2067 | 2067 | 2193 |
| 15 | 2214 | 2060 | 2060 | 2214 |
| 30 | 2205 | 2086 | 2086 | 2205 |
| 45 | 2279 | 2086 | 2086 | 2279 |
| 60 | 2496 | 2086 | 2086 | 2496 |

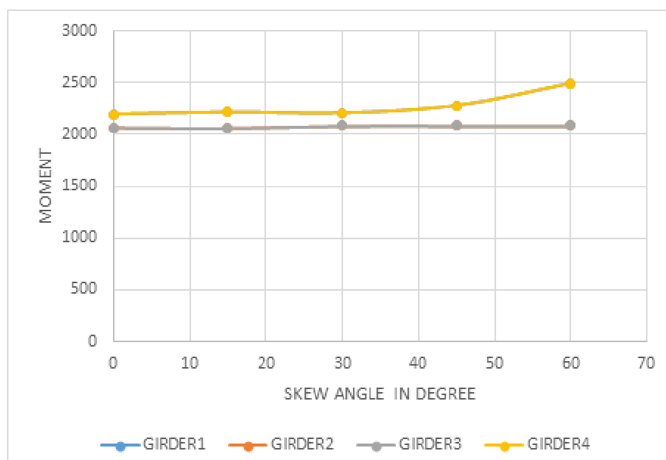



Fig 4.4: Moment v/s skew angle.

From above graph it can be observed that, the mid span moment variation Modal increases as skew angle increases due to varying symmetry. There is considerable decrease in bending moment in inner girders G2 and G3 as compared to outer girders G1 and G4. Thus, the zero-degree model has bending moment of 2193 KN-m and 60-degree model has 2496 KN-m.

Table 4.5: Bending Moment at end span for dead load.

| BENDING MOMENT FOR DEAD LOAD AT ENDS | | | | |
|---|---|---|---|---|
| SKEW | GIRDER1 | GIRDER2 | GIRDER3 | GIRDER4 |
| 0 | -1033 | -129 | -129 | -1033 |
| 15 | -984 | -129 | -129 | -984 |
| 30 | -984 | -129 | -129 | -984 |
| 45 | -907 | -142 | -142 | -907 |
| 60 | -396 | -416 | -416 | -396 |

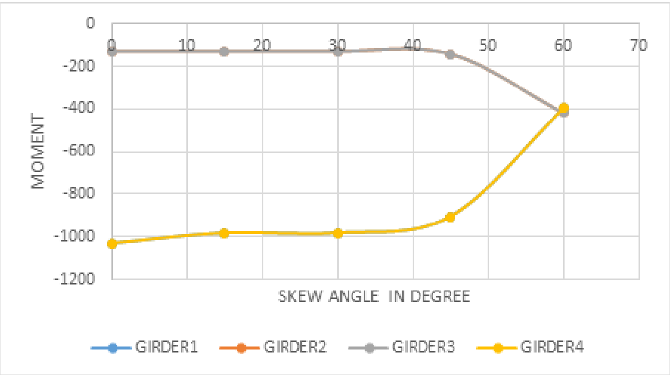



Fig 4.5: Moment v/s skew angle.

From above graphs it can be observed that, the mid span moment variations, for dead load case is increasing as the skew angle increases due to variation in symmetry of the main girder. There is considerable decrease in bending moment in inner girders G2 and G3 as compared to outer girders G1 and G4. Thus, the zero-degree model has a bending moment of -1033KN-m and 60-degree model has -396 KN-m.

Table 4.6: Bending Moment at end span for Vehicle load.

| BENDING MOMENT FOR VEHICLE LOAD AT ENDS | | | | |
|---|---|---|---|---|
| SKEW | GIRDER1 | GIRDER2 | GIRDER3 | GIRDER4 |
| 0 | -189 | -157 | -157 | -189 |
| 15 | -218 | -187 | -187 | -218 |
| 30 | -245 | -198 | -198 | -245 |
| 45 | -264 | -238 | -238 | -264 |
| 60 | -231 | -273 | -273 | -231 |

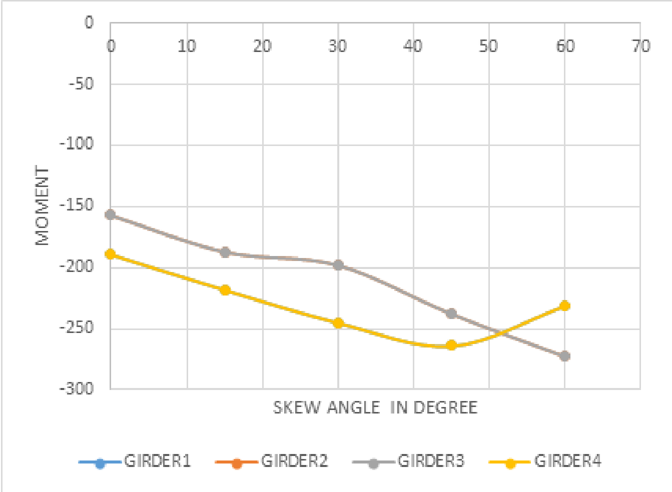



Fig 4.6: Moment v/s skew angle.

From above graph it can be observed that, the mid span moments variation for vehicle class AA loading increases as the skew angle increases due to varying in symmetry and improved distribution of live load among the girders. There is considerable decrease in bending moments in inner girders G2 and G3 as compared to outer girders G1 and G4. Thus, the zero-degree model has a bending moment of -189 KN-m and 60-degree model has a bending moment of -231 KN-m.

Table 4.7: Bending Moment at end span for UDCON load.

| BENDING MOMENT FOR UDCON AT ENDS | | | | |
|---|---|---|---|---|
| SKEW | GIRDER1 | GIRDER2 | GIRDER3 | GIRDER4 |
| 0 | -1550 | -194 | -194 | -1550 |
| 15 | -1477 | -194 | -194 | -1477 |
| 30 | -1414 | -186 | -186 | -1414 |
| 45 | -1360 | -213 | -213 | -1360 |
| 60 | -594 | -122 | -122 | -594 |

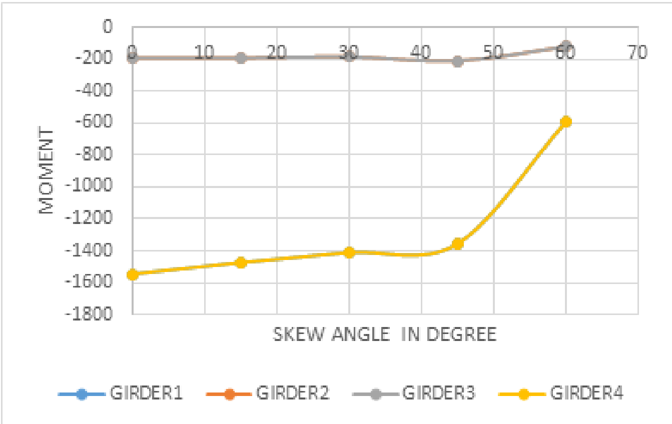



Fig 4.7: Moment v/s skew angle.

From above graph it can be observed that, the mid span moment variation for load combination (IRC-6) increases as skew angle increases due to varying symmetry. There is considerable decrease in bending moment in inner girders G2 and G3 as compared to outer girders G1 and G4. Thus, the zero-degree model has bending moment of -1550KN-m and 60-degree model has -594 KN-m. Table 4.8: Bending Moment at end span for Modal load.

Table 4.8: Bending Moment at end span for Modal load.

| BENDING MOMENT FOR MODAL AT ENDS | | | | |
|---|---|---|---|---|
| SKEW | GIRDER1 | GIRDER2 | GIRDER3 | GIRDER4 |
| 0 | 4199 | 540 | 540 | 4199 |
| 15 | 4013 | 554 | 554 | 4013 |
| 30 | 3958 | 598 | 598 | 3958 |
| 45 | 3795 | 621 | 621 | 3795 |
| 60 | 3922 | 843 | 843 | 3922 |

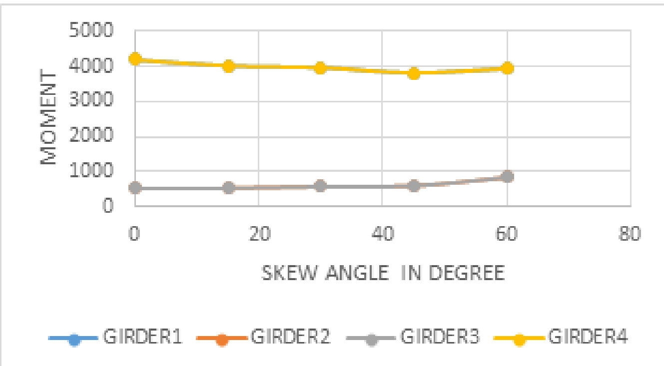



Fig 4.8: Moment v/s skew angle.

From above graph it can be observed that, the mid span moment variation Modal increases as skew angle increases due to varying symmetry. There is considerable decrease in bending moment in inner girders G2 and G3 as compared to outer girders G1 and G4. Thus, the zero-degree model has bending moment of 4199 KN-m and 60-degree model has 3922 KN-m.

**1. TIME PERIOD.**

A system is said to be vibrating in a normal mode when all its masses attain maximum values of displacements and rotations simultaneously, and pass through equilibrium positions simultaneously.

Table 4.9: Modal time period for all skew bridges.

| Modal Periods | | | | | |
|---|---|---|---|---|---|
| MODAL | 0 DEGREE | 15 DEGREE | 30 DEGREE | 45 DEGREE | 60 DEGREE |
| 1 | 0.336 | 0.339 | 0.339 | 0.347 | 7.504 |
| 2 | 0.303 | 0.301 | 0.301 | 0.295 | 4.857 |
| 3 | 0.269 | 0.265 | 0.265 | 0.253 | 1.716 |
| 4 | 0.203 | 0.203 | 0.203 | 0.204 | 0.428 |
| 5 | 0.199 | 0.197 | 0.197 | 0.189 | 0.220 |
| 6 | 0.164 | 0.164 | 0.164 | 0.163 | 0.212 |
| 7 | 0.132 | 0.132 | 0.132 | 0.132 | 0.135 |
| 8 | 0.106 | 0.105 | 0.105 | 0.103 | 0.122 |
| 9 | 0.095 | 0.095 | 0.095 | 0.095 | 0.097 |
| 10 | 0.081 | 0.081 | 0.081 | 0.079 | 0.096 |
| 11 | 0.079 | 0.079 | 0.079 | 0.079 | 0.084 |
| 12 | 0.059 | 0.059 | 0.059 | 0.057 | 0.079 |

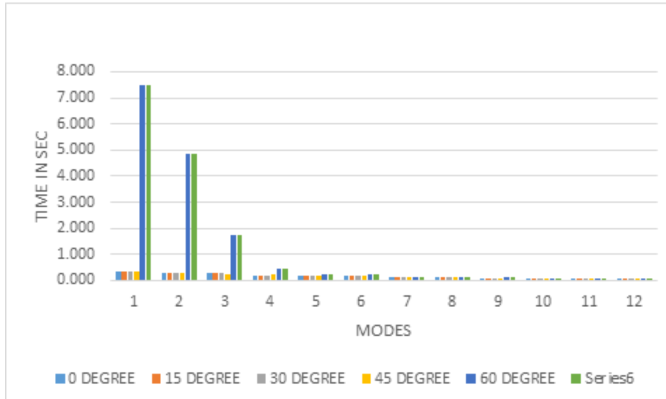



Fig 4.9: Plot mode v/s time period.

From above graph it can be observed that, the Modal time period increased by increasing the angle for the bridge structure. There is considerable Increase in model with skew 50 degree. Compare to 0-degree bridge.

**2. Base Shear.**

Base shear is an estimate of the maximum expected lateral force on the base of the structure due to seismic activity.

Table 4.10: Base shear for all skew bridges.

| **Base Shear** | | | | | |
|---|---|---|---|---|---|
| LOADS | 0 DEGREE | 15 DEGREE | 30 DEGREE | 45 DEGREE | 60 DEGREE |
| DEAD | 4247.68 | 3756.295 | 3151.851 | 2483.714 | 2691.143 |
| EQX | -148.041 | -132.426 | -132.426 | 12.667 | -87.008 |
| EQY | -148.041 | -132.426 | -132.426 | -12.667 | -87.008 |
| UDCON1 (1.5*DL) | 6371.52 | 5634.442 | 4727.776 | 3725.571 | 4036.714 |
| UDCON4 (1.2*(DL+EQX)) | 5097.216 | 4507.554 | 3782.221 | 2980.457 | 3229.371 |
| UDCON10(0.9DL+1.2EQX) | 3822.912 | 3380.665 | 2836.665 | 2235.343 | 2422.028 |

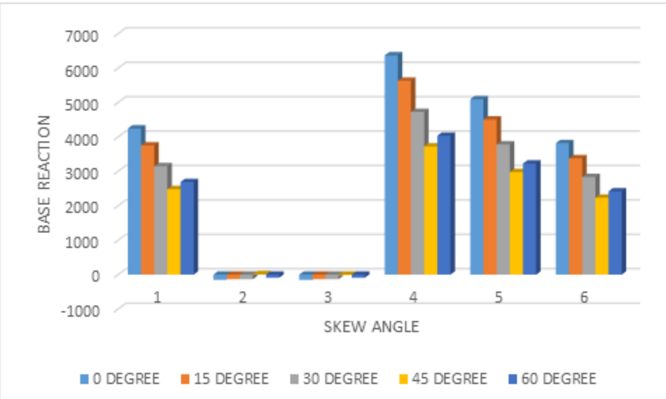



Fig4.10: Moment v/s skew angle.

From above graph it can be observed that, the base shear decreases with increase in the angle for different load case we can observe that for dead load 4247.68 KN for 0 degree and 2691 for the 60-degree variation. Similarly, for earth quake in X-Direction and Earth quake in Y-Direction, load combinations according to IRC-6, base shear decreases with increase in the skew angle.

## V. CONCLUSION

**Conclusions obtained from the present study.**

**Based on the results of the project done, the following conclusion may be drawn:**

1. Conventional 1D girder and 2D gird methods of analysis are capable of predicting accurate construction responses in many situations, however, there are definite bridge geometries where significant reductions inaccuracy can be expected.
2. As in present day traffic situations in many areas of India, construction of skew integral bridges caters high speed and efficient traffic movements and are explored more than even before. Thus, in some cases of construction, providing skew angle to the bridges become necessary thus taking into account of the variation in parameters such as bending moments, torsion, Base shear and Considering Seismic analysis with respect to varying skew angle in correctly designing of bridges with skew becomes important.
3. In the present study IRC Class AA/70R Vehicle is considered, because of its maximum load we can take from the codal provisions to find the bending moment and shear at mid and end spans of the bridge.
4. Varying the angles, we can see that increase in moments at mid span, for 0-degree 496KN and 756 for 60 degree for Dead load.
5. Varying the angles, we can observe that increase in moments at mid span, for 0 degree 333 KN and 393 for 60 degree for Vehicle load.
6. For varying angles, we can observe that increase in moments at mid span, for 0 degree 742 KN and 1058 for 60 degree for Load combination.
7. Similarly, for the end moment reactions for the longitudinal girder we can observe that the moments are more for the varying the angles.
8. For seismic evaluation we can see that modal the model time period obtained is within the limits i.e., for 0 degree 0.336 and for 60 degree 7.504.
9. Similarly, base shear results are considered for the evaluation of the structure here we can observe that increase in the angle decreases in the base shear for 0 degree 4247.68 and for 60 degree 2691.14 KN.

**Scope for future study:**

1. Study can be done for steel skew bridges.
2. More parameters can be considered such as varying span lengths, girder type and number of girders.
3. Seismic analysis comparison can be done and compared with integral bridge without skew angle.
4. Behavior of skew bridge can be done for lesser skew angle intervals.

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