# Bridge Deck Analysis through Grillage Method

**M.Tech Scholar Sunil Kumar, Prof. Rashmi Sakalle**
Department of Civil Engineering,
Truba Institute of Engineering & Information Technology,
Bhopal (M.P)

**Abstract- Various methods have been developed for structural analyses of bridge decks. Their differences are mainly in the idealization of structural behaviour of bridges with mathematical related models. The selection of bridge modelling approach depends on many parameters including deck characteristics, the required accuracy, and the available modelling tools such as computing software. Therefore, in this study, bridge deck analysis through grillage method has been done.**

**Keywords- Bridge deck, analysis, grillage method.**

## I. INTRODUCTION

Various methods have been developed for structural analyses of bridge decks. Their differences are mainly in the idealization of structural behaviour of bridges with mathematical related models. The selection of bridge modelling approach depends on many parameters including deck characteristics, the required accuracy, and the available modelling tools such as computing software.

Semi-continuum, distribution coefficient, grillage analogy (GA) and finite element (FE) methods are the most commonly used techniques for the modelling of bridge decks [1]. Among these methods, grillage is the most popular-aided method in the design offices. This is due to the fact that the GA approach is easy to comprehend, convenient to use and relatively inexpensive.

When it comes to computerized approach, a trade-off between speed of analysis, complexity of model and degree of accuracy always exist. For the purpose of bridge design, finite element (FE) analysis and grillage analogy (GA) have remained as valuable methods. In GA, the bridge superstructure is modelled by equivalent longitudinal and transverse beams, while FE analysis discretizes the deck into different elements connecting together based on equilibrium and/or compatibility conditions [2]. In short, system structural matrix in GA is formed using usual stiffness matrix approach as in FE method [3,4,5].

Generally, grillage analysis [6] is the most common method used in bridge analysis. In this method the deck is represented by an equivalent grillage of beams. The finer grillage mesh, provide more accurate results. It was found that the results obtained from grillage analysis compared with experiments and more rigorous methods are accurate enough for design purposes.

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The finer grillage mesh, provide more accurate results. It wasfound that the results obtained from grillage analysis compared with experiments and more rigorous methods areaccurate enough for design purposes. In the skew bridges, the effects of skew on the response of completed structures have been well documented [8, 9] with effects being shown to be more significant for skew anglesgreater than 30B. Critical values for vertical deflections and bending moments within in-service skewed bridgeshave been shown to be lower when compared against those in similar right bridges.

Conversely, torsionalrotations, shears and moments have been shown to be larger for skewed bridges. In addition, studies have alsodemonstrated that interaction between main support girders and transverse bracing members (diaphragms andcross frames) influences skewed bridge load distribution due to an increase in torsional rotations at certainsections of the longitudinal girders. Additional work has shown that the magnitude of torsional shear rotations Atskewed Bridge supports is largest at the obtuse corners [10, 11].

A bridge is said to be skew if the longitudinal axis of the bridge is not at right angles to the abutment. Skewangle is defined as the acute angle between the center line (or axis) of the bridge and the normal to the flow ofriver. Alternatively, it can also be defined as the angle between the free edge of the bridge and perpendicular tothe abutment. Mathematically it can be found by subtracting the acute angle of the parallelogram from 90º. The perpendicular distance between the abutments is defined as the right span, while the span along the free edge ofthe bridge is defined as the skew span [12].

## II. PAST STUDIES

**Gong, Mingyang et al. (2021)** investigated the mechanical response of the asphalt pavement on a concrete deck under complex load conditions through a three-dimensional finite element model. The effects of different curvature radii, inside and outside wheel groups,

driving speeds and temperature fields on the mechanical response of asphalt pavement were analyzed.

**Gong, Mingyang et al. (2021)** explored the effect of different meso-structure characteristics on the mechanical properties and damage behavior of asphalt pavement on a curved concrete deck using a meso-structure-based multiscale method.

**Lima et al. (2021)** presented three different species were used as laminates, which with the prestress effect made it really difficult to have optimal precision in the numerical analysis, then resulting in higher displacements than those from the tests in almost all comparisons. However, the results of the experimental and numerical displacements followed the same pattern and linearity with reasonable values and low deflections, which demonstrates that the system worked as an orthotropic plate equivalent to the same deck system constructed out of conifers, as widely used in North America for such structures. Further research should be performed with one species only, so that even better results could be found.

**Goswami et al. (2021)** presented the theoretical principles on which this kind of modeling is based are recalled; the equivalent condition between three-dimensional Beam Elements and corresponding grillage models are imposed through the use of a kinematics and an energetic criterion. Secondly, the same technique is generalized to three-dimensional structures and specialized to the case of cellular decks. For this kind of deck, structural behaviors usually neglected by the current technical approaches, like shear lag, distortion and warping, are considered. The chapter presents the method introducing these effects in a grillage analysis; the method provides a series of criteria with which it's possible to define the rigidities of the equivalent model. These criteria are applied with finite element solutions. Finally, the application is executed in order to obtain the desired results for forces developed in the nodes/joints and beam elements/members.

## III. GRILLAGE ELEMENT MODELLING

The straight mesh element model of grillage decks the transverse members of the longitudinal girders should be arranged perpendicular to the cross members and the transverse cross girders must be perpendicular to the longitudinal girder of the deck slab to achieve the correct magnitude for moments and deflections. Essentially the computer aided method for the analysis of bridge decks. The total number of longitudinal members varies depending on width of deck.

The spacing should not less than two times the thickness of the slab or three times the thickness of the slab and the spacing of the grillage model should not greater than 1/4 to 1/8 of effective span for isotropic slab. The spacing of the slab should be enough to represent the loads distribution

along longitudinal members closer spacing required in regions of sudden change e.g internal supports. The deck with contiguous beams at very close centres. Since a grillage with longitudinal members coincident with all the beams can easier to use a fine mesh than to work out the characteristics of grillage members representing two or more beams.

Since beam-and Slab decks have poor distribution characteristics, it is important not to place longitudinal grillage members much further apart than about 1/10 of the span. Since during the transverse flexure, the thin slab flex with most of the bending over the width of the thin slab.

Accordingly the transverse members representing the thin slab will behave much lower stiffness's than the members representing the thin-thick slab of the prototype. However, processing of the grillage output is then much more cumbersome. It is place longitudinal members of nominal stiffness along the outer edges of the deck to define the overall width for loading.
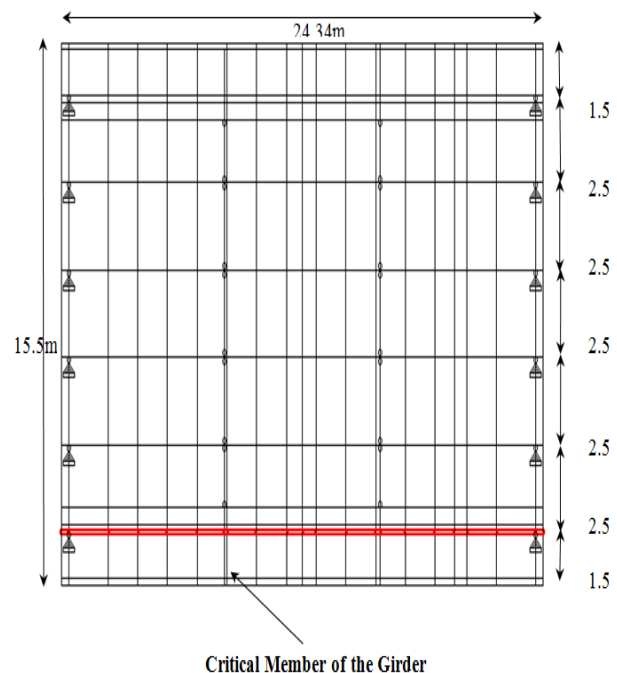


Fig 1. Geometry of Straight Mesh Element.

## IV. RESULTS AND DISCUSSION

This sections deals with the loads acting over the bridge structure and position of loads as per IRC-6-2010. In this section the loads were applied over the property assigned girders the position of placing the live load over the deck slab was done as per IRC-6-2010.

From the grillage mesh element analysis critical member were found and the maximum downward bending moment of the choosen section for the given load were calculated.

Frictional resistance offered to the movement of free bearings due to change of temperature or any other cause. In the case of single lane or a two lane bridge twenty present of the first train load plus ten percent of the load of the succeeding trains or part thereof, the train loads in one lane only being considered.

The force due to braking effect shall be assumed to act along a line parallel to the roadway and 1.2m above it while transferring the force to the bearings, the change in the vertical reaction at the bearings should be taken into account. The distribution of longitudinal horizontal forces among bridge supports is effected by the horizontal deformation of bridges, flexing of the supports and rotation of the foundations. For spans resting on stiff supports, the distribution may be assumed as given in clause 201.2 IRC-6-2010 Page-58.

- One lane of 70R(wheeled)+One lane of class A
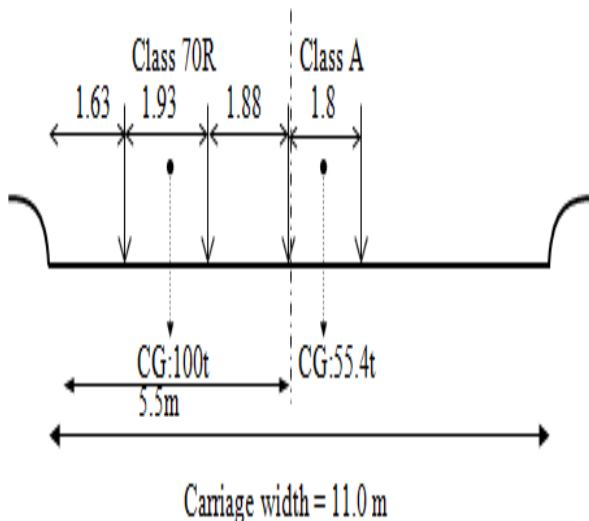- The lane of Class A



Fig 2. One Lane of 70R Wheeled +One lane of class A in Transverse Loading Position.
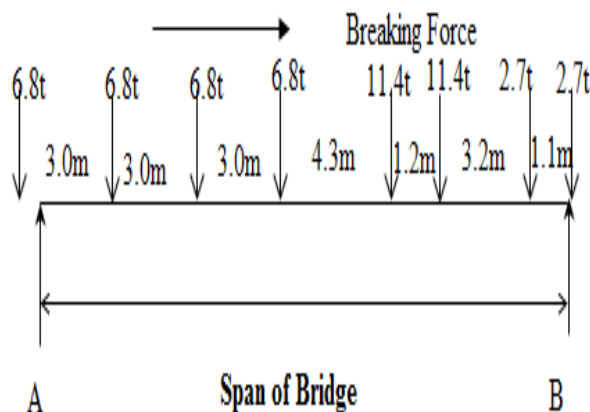


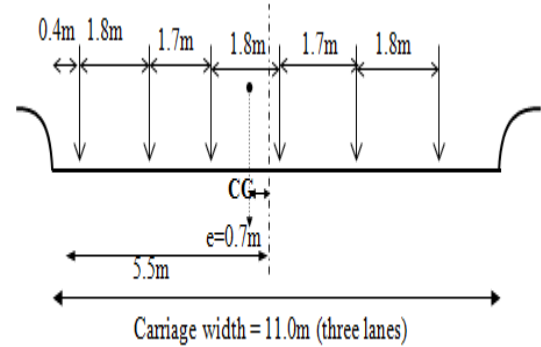Fig 3. One Lane of Class A in Longitudinal Loading Position.



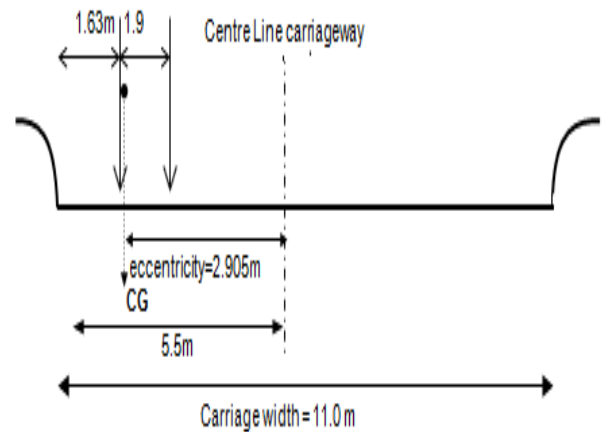Fig 4. Three lane of Class A in Transverse Loading Position.



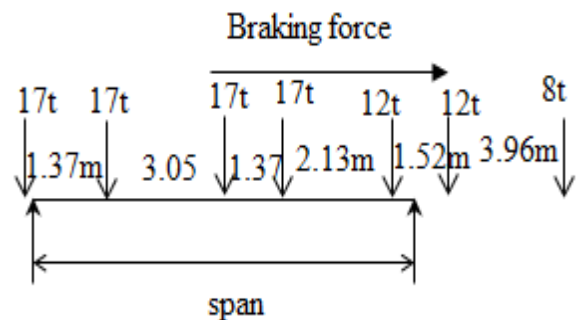Fig 5. One lane of 70R wheeled Transverse loading position.



Fig 6. One lane of 70R wheeled in Longitudinal Loading Position.

After assigning the sectional properties dead load and live load to the chosen section of the grillage deck model, then the chosen section of the grillage bridge deck are then analysed by using STADDV8i software to find the critical element in grillage mesh model. The critical element was found, then the maximum bending moment of the grillage element analysis for straight mesh element is 11.8m from support. The geometry of the mesh element was analyzed and the results of maximum bending moment were summarised below.
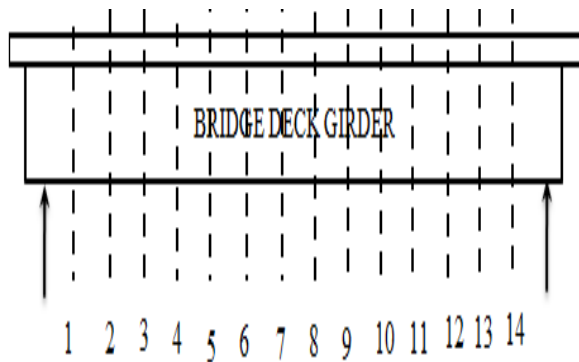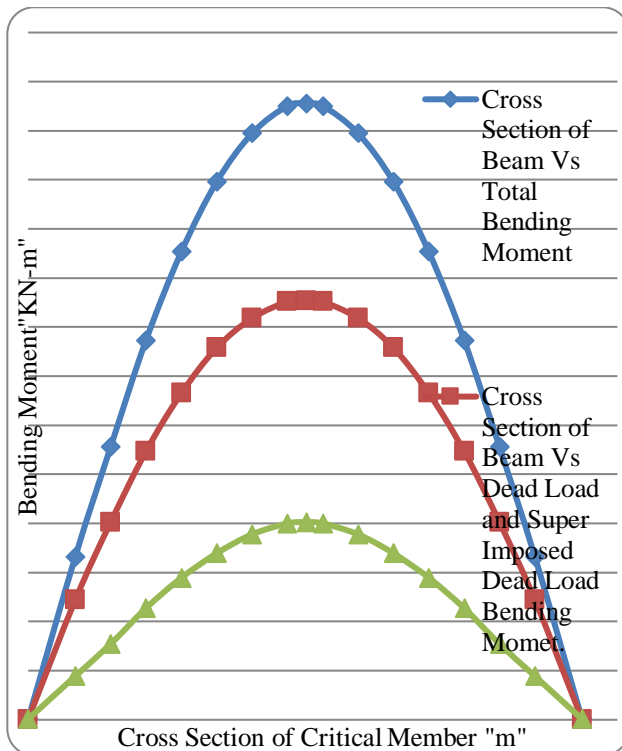
Fig 7. Longitudinal Section of Girder.



Fig 8. Total Downward Bending Moment from Grillage Analysis.

The total bending moment of the critical element bridge deck girder were received from the grillage straight mesh element analysis results is as follows.

- The maximum bending moment due to dead load and super imposed load of the bridge deck outer girder of the critical element as 4264.10KN-m
- The maximum bending moment due to live load(moving load) of the outer girder critical element of the bridge deck girder from grillage mesh element are taken from Table 5.1=2007.04KN-m
- Total Downward Bending Moment = Dead and Super Imposed Load Moment+Live load Moment=6271.10KN-m.

## V. CONCLUSION

Grillage model is the most popular computer-aided method for analyzing bridge decks. This is because it is easy to comprehend and use. This has been proved to be accurate for a wide variety of bridge types. Grillage model values are dependent upon the property specification of individual grillage beams.

The maximum values of bending moment are 6271.10KN-m. The finer grillage mesh, provide more accurate results.

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