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A Heuristic Approach for Economical Analysis and Design of Steel - Concrete Composite Bridge

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ABSTRACT: The main objective of this research to find a heuristic approach for the economic analysis and design of steel – concrete composite bridge. In nowadays an economical bridge structure plays an important role to connect different parts of the country. With timely, durable and cost efficient completion of any project is the most optimistic expectation of any project. It is hard to achieve all structural requirements using a single material.Composites can satisfy these requirements where the combined effect of different materials can be used for the optimum performance of the structure.
KEYWORDS: Economical bridge structure, Composite structure, Durability.

I. INTRODUCTION

Composite steel bridge is a type of Girder Bridge that means the deck and girder counter load by composite action. The term “girder” is typically used to refer to a steel beam having a large span. The main function of the girder to support the deck and responsible for transferring load from superstructure to substructure. Material type, cross-section geometry shape, and weight per unit length affect how much load a beam can either hold or counter the load. The properties of the moment of inertia, the depth of a girder, is the most significant parameter to decide its load carrying capacity of a particular girder. Longer spans, heavy traffic, or wider spacing of the beams, directly result in a deeper beam. In truss and arch-style bridges, girders are the main support for the deck, but the load is mainly transferred through the truss or arch to the foundation. The designs of truss and arch style bridge allow bridges to span larger distances without requiring the depth of the beam increase beyond the permissible limit. However, with the comparison of a truss or arch is not the same for a girder bridge.

In current work an extensive comparative analysis of steel composite bridge deck using grillage analysis and finite element method to know the variation of stress parameters such shear force, bending moment and stress due to application live load as specified in IRC:6-2016 and dead load. Based on parametric study we get the stress parameter and design the I section girder according to finite element method and grillage analysis stress parameter as per IS 800:2007.

II. COMPOSITE BRIDGE

Composite structures consist of two or more engineering materials to get the feasible property of structure in all engineering aspects such as performance under adverse condition of load as well as environmental factors . Due composite action of steel and concrete are gaining a popularity in bridge engineering and construction of bridge steel composite bridge combine the advantage of steel and concrete bridge :the low cost of reinforce concrete roadway slab and reduce weight of main girder made up of steel Steel girders supporting concrete slab have been used to form the basic composite structure of a large number of deck bridges for many years. Composite bridge construction mainly used for medium and large spans. Composite bridges are the structure that constitute material like steel,concrete ,timber or masonry in some combination. The engineering property of the composite structure is heavily affected by the properties of its component material. For example use of concrete slab on a steel girder uses the strength of concrete in compression and the high tensile strength of steel.

[1].Many methods are used in analyzing bridges such as grillage and finite element methods. Generally, grillage analysis is the most common method used in bridge analysis. In this method the deck is represented by an equivalent grillage of

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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. If the load is concentrated on an area which is much smaller than the grillage mesh, the concentration of moments and torque cannot be given by this method and the influence charts described in Puncher can be used.

[2].The fatigue performance of structural welded members of high strength steel indicates the inverse material dependence. The biggest problem in high strength steel is to achieve a balance between tensile strength and fatigue performance without loosing good weldability. Another important problem is to overcome corrosion which is a drawback of steel bridges.

[3].Bridges are essential components of a road network that facilitate social connection and economic growth. In Australia, also known as "the Island Continent," ground transportation is the major means of freight movement across states. More than 80% of the existing bridges are designed as per old design codes, while bridge codes in Australia have undergone major changes over the last three decades.[1] Recent version of the Australian Bridge Code (AS 5100.7) recognizes the disparities between bridge design requirements and assessment philosophy, with two added sections for bridge rehabilitation and timber bridges to address the sustainability concerns.

[4].The application of high strength steel makes it possible to design not only lightweight structures, but also simple structures with simple weld details. As the spans of bridges are getting longer and longer, there is strong demand for steel with regard to the increased strength. However, careful attention must be paid for the fabrication of structural members using high strength steel due to their inherent poor weldability.

III. GRILLAGE ANALOGY METHOD

The grillage model is a common form of analysis model for composite bridge decks . In a grillage analysis the structure is idealized as a number of longitudinal and transverse beam elements in a single horizontal plane ,interconnected at nodes. Each beam allotted a flexural stiffness in horizontal plane and torsional stiffness. Vertical load applied only at nodes.

It is a computer oriented technique .This method consist of converting the bridge deck structure in to a network of rigidly connected beam at discrete node i.e idealizing the bridge by an equivalent grillage.. The shear and moment in all the beam element meeting at a node and fixed end reactions ,if any , at the node are summed up and basic equilibrium equation at each node Σ Fx = 0, Σ M = 0, and Σ Mt = 0.

.When bridge deck is analyzed by method of grillage Analogy ,there are some steps to be follow for analysis of bridge deck :

i. Idealization of deck into equivalent grillage.
ii. Calculation of equivalent elastic interia of members of grillage.
iii. Application and transfer of loads to various nodes of grillage .
iv. Determination of stress parameters such as shear force ,bending moment and deflection.

Solid Slab Bridge

1. Right Bridge

The 3D render view and model of the slab bridge without footpath. The longitudinal and transverse grid are shown in figure. In the grillage model , dimensions used to make the equivalent grillage model longitudinal grid lines are considered as main girder ,edge grider and transverse grid line considered as beam ,end cross girder etc.

Length of longitudinal grid line = 30 meter.
Length of transverse grid line = 12 meter
Spacing of transverse grid line = 5.0 meter
Minimum spacing of longitudinal grid line = 0.75 meter
Maximum spacing of longitudinal grid line = 2.5 meter.
Size of grid =30m*12m
Size of mesh of the equivalent grillage = 2.5m*5m

Equivalent Elastic Properties:

In elastic properties mainly the area of girder and moment of inertia assign and for the slab element assign the property as rectangular beam.

Transverse members assigned as rectangular beams of dimension having width and depth are 5mtr and 0.250mtrrespectively. Material property given as concrete for the transverse members and steel given to the main girder as well as cross girder.

Support Condition

Support provided at ends of longitudinal members of a bridge deck according to bearing provided in a bridge structure. Bearing provides a bridge structure to counteract the thermal stress and sudden jerk of the vehicle , to reduce the effect of stress on bridge structure.

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Application of Load

Assign the self weight of longitudinal girder,end cross girder and deck slab in global Y direction in downward.

Self weight of structure = 2736.510kN

Moving Load Definition :

IRC 70R (Wheel Vehicle) : LiveLoad application on bridge due wheel vehicle is about a magnitude of 1000kN.After taking the impact effect the live load goes up about 10%.

Total Live Load = 1000+1000(Impact factor)

= 1000+1000*0.1

= 1100kN.

Width of vehicle 1.93mtr.

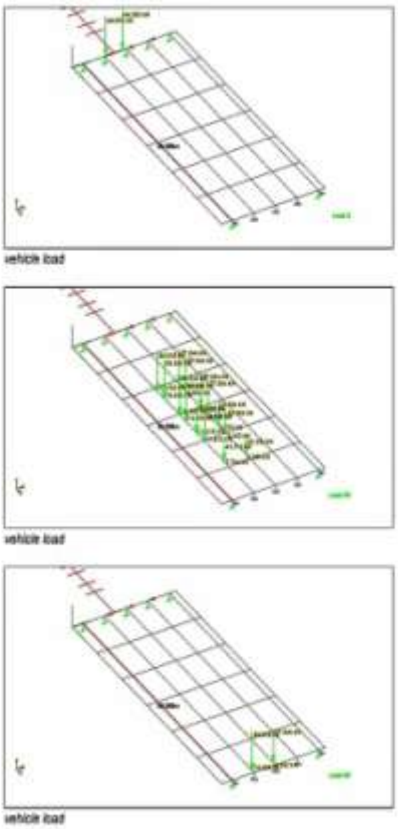

Fig 1.70R Wheel load distribution on grillage mesh

IRC CLASS A Loading

Live load application due to IRC Class A vehicles is about a magnitude of 554kN. Taking the effect of impact loading the live load increased upto 10%.

Total Live Load = 554+554(Impact Factor)

= 554+554(0.1)

= 609.4kN

In staad pro, vehicle definition with force of each wheel and distance between them enter. Load of each wheel is defined in such a way that the force on the rear wheel should be entered first then enter in moving consecutively beyond the rear wheel to front wheel .

Width of vehicle = 1.80meter

For carriageway width 5.3mtr.to 9.6mtr. and number of lanes for purpose design is two. The load combination in such a way that one lane

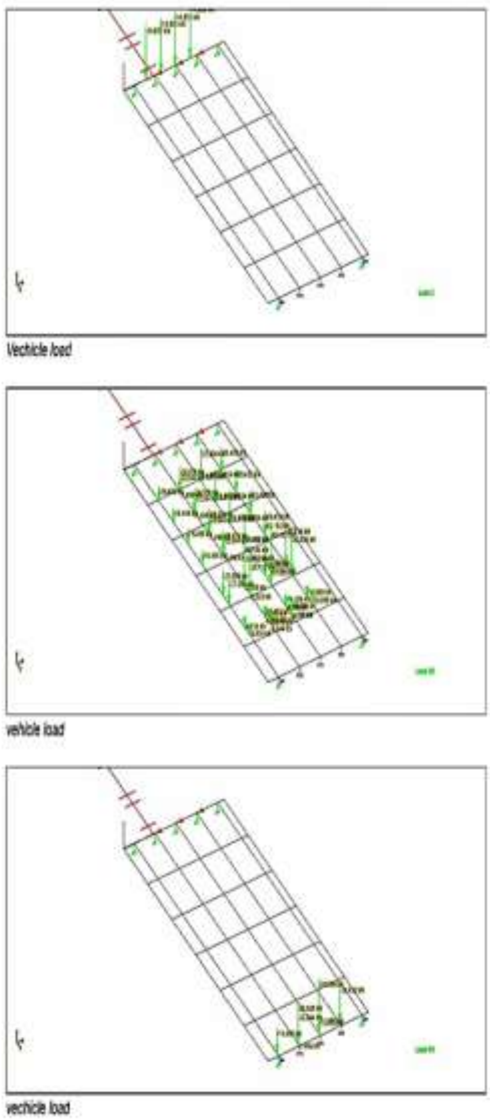

Fig.2 IRCclass A load distribution on equivalent grillage mesh

Determination of Force Responses and Design Envelopes

After application of load , Find out the values of different parameters such as bending moment ,shear force for a middle girder . Also, find out the diagram of shear force and bending moment along the span of the girder when the load moves over the bridge deck.

IV. IV. FINITE ELEMENT MODELING

It refers to a finite element, connected together at a number of nodes .It can be used to compute the plane stress and three dimensional stress. It is very useful to analyze complicated structure engineering problems. Due to availability of high speed computers in the market the use of design and analysis software also increases in the sector of civil engineering for design of complicated engineering structures.

When bridge deck analyzed by method of finite element analysis some step follow for analysis of bridge deck:

1. Preparation of Bridge Deck Model.
2. Idealization of Bridge Deck into Equivalent Finite Elements.
3. Define Sectional Properties of Superstructure Components.
4. Application of Load Transfer of live load to Node of Finite Element.
5. Determine the Stress Parameter and Design Envelope.

Preparation of Bridge Deck Model

Model of bridge consists of longitudinal and transverse grid lines, which is defined as the actual superstructure property of a bridge. Main girder members depicted by the longitudinal grid line and end cross girder depicted by the transverse grid line at the end support of the bridge. Equivalent bridge deck shown in model as the plate element laid over the longitudinal and transverse grid of bridge model.

Idealization of Bridge Deck into Equivalent Finite Elements

Idealization of physical deck into equivalent finite elements by the define the surface mashing ov mashing over the arrangement of longitudinal and transverse members. Giving the plate element to the finite mesh of the bridge slab.On dividing the bridge deck into finite elements ,the degree of precision and accuracy of bridge analysis goes up.

Size of mesh of the finite element = 1.2m*1.5m

Define Sectional Properties of Superstructure Component

The sectional properties of the superstructure component of the bridge are defined in such a way that it satisfies the standard of code practice used in bridge design. The cross section property of I
Section girder (main member) in longitudinal direction and also define property of I section end girder in transverse direction.

The thickness of plate elements is also defined which is equivalent to the thickness of deck slab by selecting the plate command in staad pro.
Thickness of Plate (concrete) =250mm

Support Condition

Support provided at the end of the longitudinal beam same as the grillage equivalent.

Application of load

Assign the self-weight of longitudinal girder, end cross girder and deck slab in global Y direction in downward.
Self-weight of structure =2664.388kN

Application of live load

Application of live load depends upon the number carriageway design for the bridge . For our bridge model ,two lane bridge design in practice. According to IRC:16-2016 , the definition of design live load specified for two lane carriage ways.After studied the IRC: 16-2016,the application live load has two case for design two lane bridge :

1 IRC Class AA (wheel vehicle).
2 IRC Class A and Class A

IRC CLASS A Loading : Live load application due to IRC Class A vehicles is about a magnitude of 554kN. Taking the effect of impact loading the live load increased upto 10%.
Total Live Load = 554+554(Impact Factor)
= 554+554(0.1)
= 609.4kN
In staad pro., vehicle definition with force of each wheel and distance between them enter.
Width of vehicle = 1.80meter
For carriageway width 5.3mtr.to 9.6mtr. and number of lanes for purpose design is two. The load combination in such a way that one lane of class 70R (wheel vehicle) or two lanes for class A.

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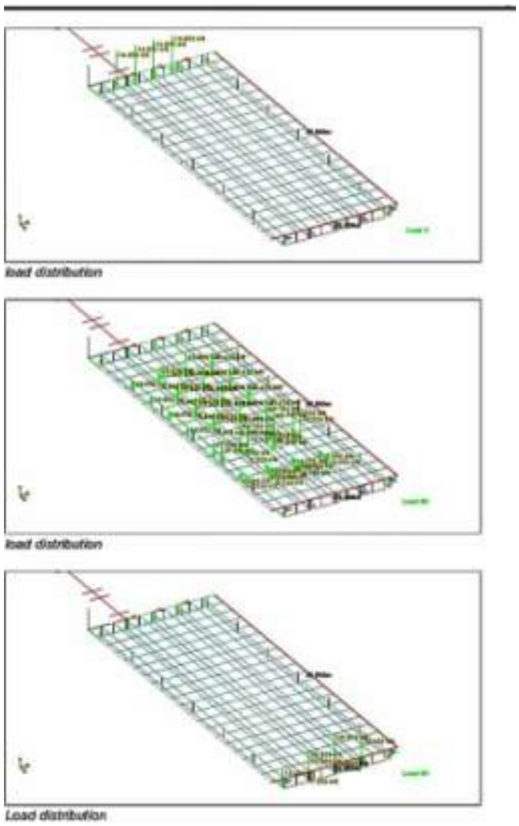

Fig. 3IRC class A load distribution on equivalent finite mesh

V. INTERPRETATION OF RESULTS

The output and result obtained from grillage analogy and finite element analysis of a composite bridge deck .The magnitude of bending moment and shear force obtained from both methods is almost similar. In our bridge model, the result obtained from grillage analogy is much more as compared to finite element analysis.

Result obtain from different method of analysis

In our analysis method ,the design envelope parameter obtained for the design of bridge girder is safe under the bending moment and shear force due live load (vehicle load) and dead load .

Different design parameters obtain ,when analysis is done by the grillage analogy and Finite element method . The vehicle position varies in longitudinal as well as transverse direction.

Result Obtain From Grillage Analogy

The Maximum shear force and maximum bending moment obtained for the middle girder for given loading specified by IRC 16:2016 and also position of vehicle varies along the transverse direction when analyzed by grillage analogy.

Result Obtain From Finite Element Modelling

The Maximum shear force and maximum bending moment obtained for the middle girder for given loading specified by IRC 16:2016 and also position of vehicle varies along the transverse direction when analyzed by the finite element analogy.

TABLE 1. Result Obtain From Grillage Analogy

Position (m)	Loading	Maximum shear force(kN)	Distance (m)	Load Case	Maximum Bending (kN-m)	Distance (m)	Load Case
3.88	70R(wheel)	456.18	00.00	29	3267.61	15.00	50
7.87	70R(wheel)	218.16	00.00	29	1574.43	15.00	50
2.65,6.15	IRC classA	401.28	30.00	70	2832.89	17.50	48
5.55,9.05	IRC classA	339.71	30.00	70	2400.69	17.50	48

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TABLE 2. Result Obtain From Finite Element Modelling

Position (m)	Loading	Maximum shear Force (kN)	Distance (m)	Load Case	Maximum Bending (kNm)	Distance (m)	Load Case
3.88	70R(wheel)	449.59	0.00	29	3218.18	15.00	50
7.87	70R(wheel)	211.57	0.00	29	1525	15.00	50
2.65,6.15	IRC classA	394.69	30.00	70	2784.83	17.50	48
5.55,9.05	IRC classA	333.12	30.00	70	2352.63	17.50	48

VI. CONCLUSION

- The magnitude of shear force and bending moment obtained from grillage analogy and finite element method is approximately the same varying the position of load in transverse direction.
- Analysis and assign the property of a simple bridge model is different way in grillage analogy and finite element method the result obtaining of stress parameter not vary much.
- Load transfer mechanism in grillage analogy through course mesh while in finite element method load transfer through fine mesh and better accuracy in FEM.
- As data obtained from above use as reference use for analysis of composite bridge models.
- Dimension of the I Section girder obtained after design is approximately the same as assumed before analysis of bridge model.
- Comparative analysis of both methods has different approaches for assigning the property and analysis of composite bridge model but parameter of analysis is obtained approximately the same for simple structural analysis.
- This is an application base project in which I found out how the input data given in STAAD software and the variation of analysis parameters when different approaches are used.

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