International Journal of Research in Engineering, Science and Management
Volume-2, Issue-7, July-2019
www.ijresm.com | ISSN (Online): 2581-5792

Grillage Analysis of T – Beam Bridges

K. Pushpavathi[1], Premanand Shenoy[2]
[1]M.Tech. Student, Dept. of Civil Engg., Sahyadri College of Engineering & Management, Mangaluru, India
[2]Professor, Dept. of Civil Engg., Sahyadri College of Engineering & Management, Mangaluru, India

***Abstract*: Grillage analogy presents a sufficiently accurate method of analyzing bridge decks for estimation of design bending moment, torsion shear force etc, and has been adapted for use in most computer software around the world. Basically, analogy method uses stiffness approach for analyzing the bridge deck is divided into a number of longitudinal and transverse beams. In this paper a study is conducted on different spans of Grid Slab Bridge. A general purpose program has been developed in Visual Basic environment by combining the methodologies. The program was validated with results of standard software available for the intended purpose. The results obtained from the program are plotted for comparison and the conclusions are drawn.**

***Keywords*: T – Beam Bridge, Stiffness Matrix Method, Visual Basic, IRC Loadings, Courbon's Method, Spline Analysis.**

1. Introduction

A Bridge is a structure providing passage over an obstacle without closing the way beneath. The required passage can be also for a road, a railway, pedestrians, a canal or a pipeline. The obstacle to be crossed is also a watercourse, a road, railway or valley. The T-beam Bridge is by far the most commonly adopted type on the span range of 10 to 25 meters. The structure is named as a result of the main longitudinal girders. It designed as T-beams integral with part of the deck slab, which is cast monolithically with the girders. Simply supported T-beam spans of over 30 meter are rare because the dead load then becomes too significant.

2. Objectives of the Study

- Different methods for the design of T – Beam grid slabs are studied, namely Grillage Analysis method (stiffness matrix method), Courbon's Method.
- Grillage Analysis method is automated in Visual Basic environment.
- The results of the program will be verified against the Courbon's Method.
- The parametric study is conducted on the parameters such as bending moments, shear forces and deflections obtained from various methods.
- Discussions are held on the results and conclusions are drawn.

3. Loads on bridges

A. *Dead load*

The dead load is the weight of the structure and any permanent load fixed thereon. The dead load is initially assumed and checked after design is completed.

B. *Live load*

Bridge design standards specify the design loads, which are meant to reflect the worst loading that can be caused on the bridge by traffic, permitted and expected to pass over it. In India, the Railway bridges in bridge rules. For the highway bridges, the Indian Road has specified standard design loadings in IRC section II.

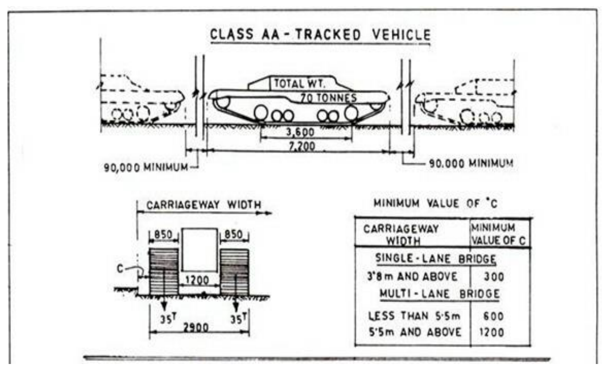

Fig. 1. Class AA – Tracked Vehicle

C. *Impact load*

The dynamic effect caused due to vertical oscillation and periodical shifting of the live load from one wheel to another when the locomotive is moving is known as impact load. The impact load is determined as a product of impact factor, I, and the live load.

For tracked vehicle – 25% for a span up to 5 m linearly reduced 10% for a span of 9 m.

4. Material properties

A. *Elastic modulus*

The elastic modulus of concrete is a component of the modulus of versatility of the totals and the bond framework and their relative extents. The elastic modulus of concrete is moderately consistent at low stress levels however it gets reduced at higher level of stress as the matrix cracks.

B. Poisson's ratio

Poisson's ratio is a measure of the Poisson's impact, the phenomenon in which a material has a tendency to expand in headings opposite to the course of pressure. The Poisson's proportion of a steady, isotropic, direct flexible material will be under 0.5 an account of the prerequisite for Young's modulus, the modulus and mass modulus to have positive esteems.

5. Automation of methods for analysis of grid slabs

A. Grillage method of analysis

The method consists of converting the structure into a network of skeletal members rigidly connected to each other at nodes. The load – deformation relationship at the two ends of a skeletal element with references to the member axis is expressed in terms of its stiffness property. This relationship which is expressed with reference to the member coordinate axis is then transferred to the structure global axis using transformation matrix, so that the equilibrium condition that exists at each node in the structure can be satisfied. The bridge structure is very stiff in the horizontal plane due to the presence of decking slab. The translational displacements along the two horizontal axes and rotation about the vertical axis will be negligible and may be ignored in the analysis. Thus a skeletal structure will have three degrees of freedom at every node i.e. freedom of vertical displacement and freedom of rotations connecting 2 manually perpendicular axes in the horizontal plane. In general, a grillage with 'n' nodes will have 3 degrees of freedom.

When a bridge is analyzed by the strategy of Grillage Analogy, there are basically 5 steps to be followed for getting design responses:

1. Idealization of physical deck into equivalent grillage
2. Evaluation of equivalent elastic inertias of members of grillage
3. Application and transfer of loads to various nodes of grillage
4. Determination of force responses and design envelopes
5. Interpretation of results.

B. Stiffness matrix method

The bridge deck structure may be considered as an assembly of structural members connected together at distance nodes forming a grid. The deformations and forces at nodes are inter – related by corresponding stiffness's.

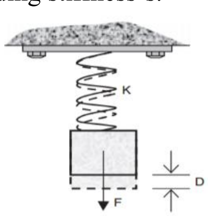

Fig. 2. Load held by linear spring

The spring framework appeared in Figure exhibits the utilization of the stiffness technique in its most straight forward shape. The single level of flexibility structure comprises of a mass supported by a straight spring complying with Hookes's Law. Foe auxiliary examination, the weight, F, known and the spring constant (or stiffness), K, are usually known.

The purpose of the structural analysis gets the vertical displacement, D, and the internal forces in the spring, P. From Hooke's law,

F = K x D

This is equilibrium equation of the system. Hence, the displacement, D, of the object can be obtained by,

D = F/K

The displacement, d of the spring is equal to D. That is,

D = d

The internal force in the spring, P, can be found by

P = K x d

In this illustration, the procedure for utilizing the stiffness matrix method is presented by Equations. For a structure comprised of n number of structural elements with n degrees of freedom, the equilibrium of the structure can be described by a number of equations analogous to Equation 4. These equations can be expressed in matrix form as,

$$\{F\}_{nx1} = [K]_{nxn} \text{ X } \{D\}_{nx1}$$

Where $\{F\}_{nx1}$ is the load vector of size nx1 containing the external loads, $[K]_{nxn}$ is the structure stiffness matrix of size (nxn) corresponding to the spring constant K in a single degree system shown in Figure 2, and $\{D\}_{nx1}$is the displacement vector of size (nx1) containg the unknown displacements at designed locations, usually at joints of the structure.

C. Courbon's method of analysis

Assumptions of courbon's method

1. Load distribution takes place in transverse direction perpendicular to the axis of the bridge.
2. Under the load the transverse section deflects uniformly and all the girders deflect uniformly.
3. Under a moment acting on the bridge axis the cross section undergoes a rotation about the bridge axis causing linear deflection of the entire girder.

Courbon's Method is applicable only when the following conditions are applied:

- The ratio of span to width of deck is > 2 but < 4.
- Longitudinal beams are interconnected at least at 5 locations using cross beams.
- The depth of cross girder is at least $3/4^{th}$ depth of longitudinal girder.
- Beams have equal spacing and equal cross sections.
- Problem is static linear elastic and principle of rigid cross section is valid.
- The analyzed cross section is infinitely rigid, when cross girder is connected.
- The cross section has the vertical axis of symmentry.

This is one of the earliest forms of rational analysis of bridge decks and is very popular in view of its simplicity. The expression for reaction factor for individual longitudinal girders (share of the total load by the individual longitudinal girders) according to this method is given by following equation,

$$R = P\left[\frac{1}{n} + \frac{ed_x}{\sum {d_x}^2}\right]$$

R = Reaction factor for the girder under consideration
P = Total concentrated live load
n = Number of longitudinal girders
d_x = Distance of the girder under consideration from the central axis of the bridge
e = Eccentricity of live load with respect to the axis of bridge

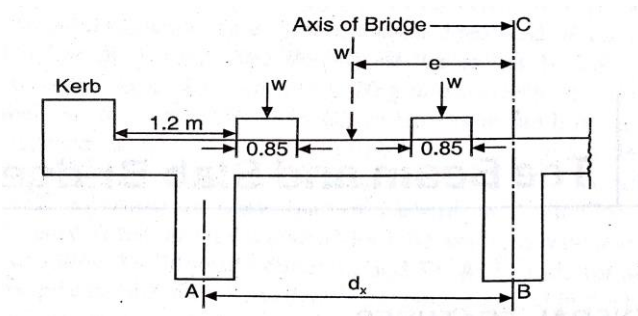

Fig. 3. Position of Live Loads for maximum BM in girder A

D. Analysis of T – beam bridge by grillage method and courbons method

Input Data
Span = 16 m
Carriageway width = 12 m
Kerbs = 1500 x 300 mm
No. of Longitudinal Girders = 5
Spacing of Longitudinal girders = 3 m c/c
No. of Cross Girders = 5
Spacing of Cross Girders = 4 m c/c
Loading IRC class AA tracked vehicle.
Thickness of Wearing coat = 80 mm
Depth of Deck slab = 200 mm
Depth of Longitudinal girder = 1600 mm
Thickness of Longitudinal Girder = 400 mm
Depth of Cross girder = 1500 mm
Thickness of Cross girder = 300 mm
Grade of Concrete = M30
Grade of Steel = Fe415

E. Visual basic form developed for study on T – beam bridge grid slab

An interactive general purpose program is developed for the study of T – Beam Grid slab. The task has been achieved by automating Grillage analogy method. Results are in the form of tabs. Output of the form is made to store in a Notepad file. The figure below shows the developed for the study of T - Beam Grid slab.

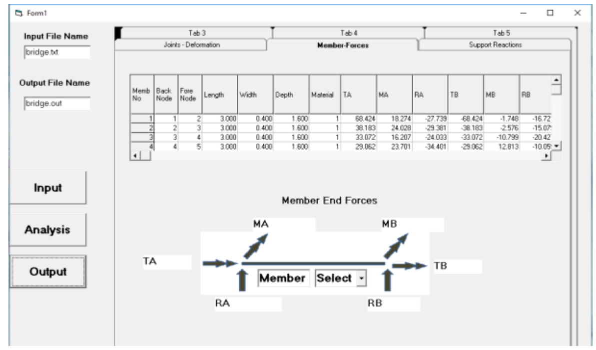

Fig. 4. Visual Basic form study on T – Beam Grid Slab

6. Results and discussions

The following are the results obtained from the various methods used for the analysis of T - Beam Bridge Grid slab, which are automated in Visual Basic Software. The values are considered from the beams at the outer and internal girders. Results obtained are plotted in the form of Graph. Discussions will be held and the conclusion will be drawn.

A. Comparison of results of Grillage Method and Courbon's Method for Bending Moment

Table below shows the variation of bending moment in span of the outer and internal girder along the width, where X axis represents the spacing of girders and Y axis represents bending moment.

Table 1
Bending Moment for Outer Girder

Length	Grillage Method	Courbon's Method
X axis in m	Y axis in kN - m	
0	0	0
4	1295.10	1642.03
8	2526.50	2854.11
12	1290.01	1645.21
16	0	0

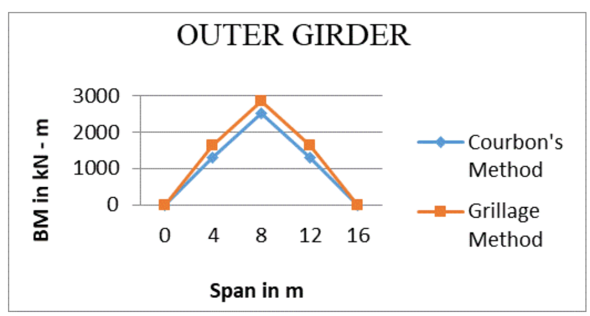

Fig. 5. Bending Moment for Outer Girder

Table 2
Bending Moment for Internal Girder

Length	Grillage Method	Courbon's Method
X axis in m	Y axis in kN - m	
0	0	0
4	1273.50	1422.13
8	2022.41	2471.52
12	1211.50	1425.13
16	0	0

International Journal of Research in Engineering, Science and Management
Volume-2, Issue-7, July-2019
www.ijresm.com | ISSN (Online): 2581-5792

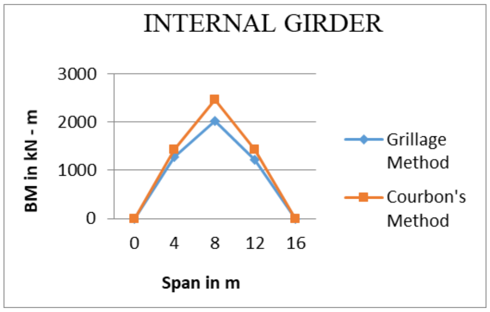

Fig. 6. Bending Moment for Internal Girder

B. *Comparison of results of Grillage Method and Courbon's Method for Shear Force*

Table below shows the variation of shear force in span of the outer and internal girder along the width, where X axis represents the spacing of girders and Y axis represents shear force.

Table 3
Shear Force for Outer Girder

Length	Grillage Method	Courbon's Method
X axis in m	Y axis in kN - m	
0	564.41	719.01
4	393.81	580.23
8	197.22	312.54
12	369.41	520.21
16	412.23	634.10

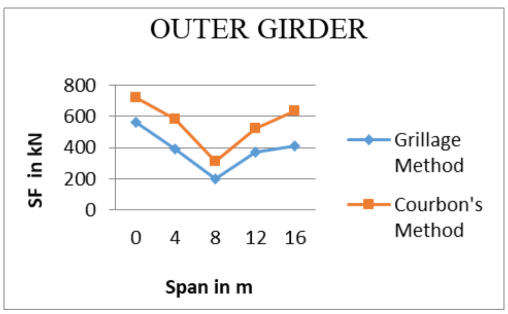

Fig. 7. Shear Force for Outer Girder

Table 3
Shear Force for Outer Girder

Length	Grillage Method	Courbon's Method
X axis in m	Y axis in kN - m	
0	365.33	504.11
4	283.98	412.03
8	160.32	221.12
12	225.58	341.51
16	306.21	410.02

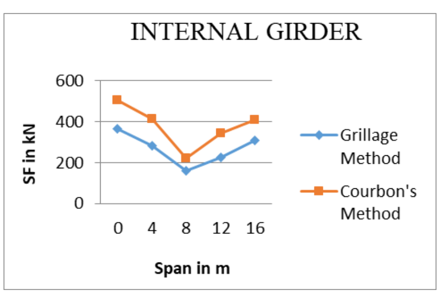

Fig. 8. Shear Force for Internal girder

C. *Discussions*

- Grillage analogy presents a sufficiently accurate method of analyzing bridge decks for estimation of design bending moment and shears force etc, and has been adopted for use in most computer software around the world.
- For bending moment obtained by Corbon's theory is 11.4% more than the bending moment obtained by Grillage method for all the spans.
- For shear force obtained by Courbon's theory is 21.5% more than the shear force obtained by courbon's theory for all the spans.

7. Conclusion

- The comparative study was conducted based on the analysis of T – Beam Bridge Grid slab by Grillage analysis and Corbon' s Method.
- Based on this study Courbon's Method gives the good results with respect BM values in the longitudinal girder as compared to Grillage Analysis Method.
- Courbon's Method always over estimates the outer reactions & underestimates the inner reactions.
- The Visual Basic result almost matches with the values obtained by Courbon's method. The analogy method, based on stiffness matrix approach, is a reliably accurate method for a wide range of bridge decks. The method is versatile, easy for a designer to visualize and prepare the study for a Grillage.

Acknowledgement

I have taken efforts in this project. However, it would not have been possible without the kind support and help of many individuals and organizations. I would like to extend my sincere thanks to all of them.

References

[1] Alaa C. Galeb and Zainab F. Atiyah, "Optimum Design of reinforced Concrete Waffle Slabs", IJCE, Vol. 1, No. 4, pp 862 – 880, 2011.
[2] M. G. Kalyanshetti and R. P. Shriam, "Study of Effectiveness of Courbon's Theory in the Analysis of T – Beam Bridges", IJSER, Vol.4, Issue 3, 2013.
[3] Muhammed Yoosaf K. T, Ramadas and Jayasree Ramanujan, "Finite Element Analysis of Grid of Floor Frame", IJESI, Vol. 3, pp 1 – 73, 2014.
[4] R. Shreedhar, Rashmi Kharde, "Coparative study of Grillage method and Finite Element Method of RCC Bridge Deck", IJSE, Vol. 4, Issue 2, 2013.
[5] S. A. Halkude and S. V. Mahamuni, "Comparison of various Methods of Analysis of Grid Floor Frame", IJESI, Vol. 3, pp 1 – 73, 2014.
[6] Indrajith Chowdhury and Jitendra P. Singh, "Analysis and design of waffle Slab with Different Boundary Conditions", ICJ, Vol. 5, pp 1 – 10, 2014.
[7] Praful N K and Balaso Hanumat, "Comparative Analysis of T – Beam Bridge by Rational Method and STAAD Pro", ISRA, 2015.
[8] Ivan Micovic and Dr. Khaled Sennah, "Investigation of Live Load moment and Shear for the Design of Bridge Deck Slab Cantilevers with Unstiffned edge or Built with TL – 5 Barrier wall", Resilient Infrastructure, London, 2016.
[9] Bharath Nishan, Dr. Premanand Shenoy and Rohith Kumar A S, "Automated Analysis and Parametric Study of Grid Floors", IJSRET, Vol. 6, Issue 11, 2017.

[10] Pooja C, Arun L and Thejashwini, "Analysis and Design of Bridge Deck Using Grillage Method – As per IRC", IRJET, Vol. 5, Issue 12, 2018.
[11] IRC:6 – 2010, "Standard Specification and Code of Practice for Road Bridges", Section: II, Loads and Stresses, Indian Road Congress, New Delhi.
[12] IRC:21 – 2000, "Standard Specifications and Code of Practice for Road Bridges", Section: III, Cement concrete (Plain and Reinforced), Indian Road Congress, New Delhi.