International Journal of Scientific Research in Science, Engineering and Technology
Print ISSN: 2395-1990 | Online ISSN : 2394-4099 (www.ijsrset.com)
doi : https://doi.org/10.32628/IJSRSET229216

Development of Applicability of Distribution Factor for Single Cell Box Girder Bridges by Modifying Bakht and Mufti Method

Sreevar Ramesh[1], R K Ingle[2]

[1]M. Tech, Department of Applied Mechanics, Visvesvaraya National Institute of Technology Nagpur, India
[2]Professor, Department of Applied Mechanics, Visvesvaraya National Institute of Technology Nagpur, India

Article Info
Volume 9, Issue 2
Page Number : 143-148

Publication Issue :
March-April-2022

Article History
Accepted : 20 March 2022
Published: 30 March 2022

ABSTRACT

Live load distribution factors for simply supported single cell box girder by manual method has been studied. The distribution factor allows the designer to consider the transverse effect of wheel loads in determining the shear and moments of each beam for live load. The increased need of transporting very heavy loads by road haulage has given rise to the need for an easily applied and accurate method of calculating the division of loads between the main girders of highway bridge decks. The bridge is loaded with IRC 70 R and Class A loading so as to obtain maximum bending moment. Bakht and Mufti is close representation of semi-continuum idealization to obtain distribution factors for slab on girder bridges where shear deformation or more correctly cell distortion is neglected. An attempt is made to obtain distribution factor for single cell box girders by modifying the formula of Bakht and Mufti method with Cusens and Pama formula to consider distortional effects. Results are compared with spine beam method using Midas Civil Software which shows good agreement between both the methods.

Keywords : Single Cell Box Girder, Simply Supported, Distribution Factor

I. INTRODUCTION

A bridge is a structure designed to span over obstacles, and hence, they play important roles in the development of a city both in terms of transportation, aesthetics. The design of bridges has evolved over the years and a lot of solutions are considered when selecting the choice of bridge deck to adopt. Box girder is formed by joining two web plates by a common flange at both top and bottom. The closed cell has much greater torsional stiffness and strength than an open section and it is the reason for choosing a box girder configuration. Generally live load is applied as a concentrated load over the deck of superstructure. Load distribution takes place between girders/webs. This transverse distribution of the live load among the longitudinal girders/webs is known as distribution factor.

The main purpose of this research is to propose a more accurate and versatile analytical method for calculating load distribution factors for single cell box girder, which it comprises design parameters like the flexural and torsional stiffness for bridges. This method is based on harmonic series which derived from the semi-continuum method proposed by Bakht and Jaeger

(1989). Using Bakht and Jaeger method Bakht and Mufti have developed distribution factor for slab on I girder bridges. Where torsional effect is neglected. Hambly (1991) has given method to determine distribution factor for multicellular box girder assuming top and bottom having same thickness and not stated any applicability to single cell box girder bridges.

In this paper an attempt is made to develop a simplest and more accurate method to find out the distribution factor for single cell box girder bridges by modifying Bakht and Mufti method by including distortional effect of box girder bridges and also to consider n harmonic effect of loading in bridges.

II. Assumptions and Limitations

Modified Bakht and Mufti method is applicable only when following conditions are satisfied. Bridges having equally-spaced girders with equal stiffness i.e., only for single cell box girder bridges, harmonic analysis of beams as to be carried out separately, no diaphragms to be considered and bridge is simply supported.

III. Procedures for obtaining Distribution Factors

Step by step procedure to obtain the distribution factors by using modified Bakht and Mufti method as fallows. Figure 1 shows the slab on beam girder given by Bakht and Mufti and Figure 2 is considered for this study.

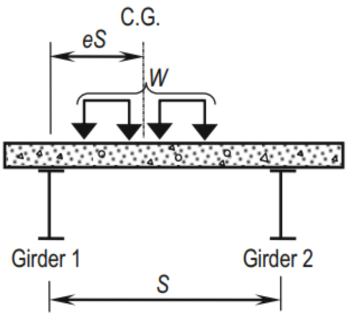


Figure 1. Slab and Beam Girder (Bakht and Mufti 2015)

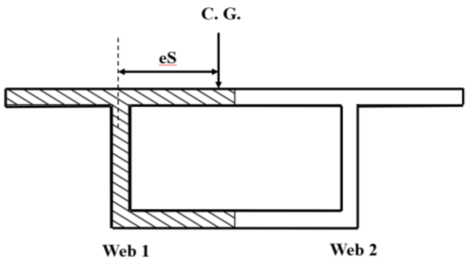


Figure 2. Single Cell Box Girder

Step 1. Divide the single box girder into two equal parts as shown in Figure 2. Calculate the moment of inertia I for individual beams (Shaded portion). Torsional constant per unit width of cell is given by Eq. (1). Torsional constant for shaded portion is given by Eq. (2) by multiplying half of web spacing.

$$J_{cell}^{t} = \frac{2h^2 d_t d_b}{d_t + d_b} \tag{1}$$

$$J = \frac{2h^2 d_t d_b}{d_t + d_b} \times \frac{l}{2} \tag{2}$$

Step 2. For a single cell box girders three dimensionless parameters which are defined in the following for structures with equally-spaced girders of equal stiffness are given by Eq. (3), Eq. (4) and Eq. (5).

$$\eta = \frac{12}{\pi^4}\left(\frac{L}{l}\right)^3 \frac{LD_{ye}}{EI} \tag{3}$$

$$\lambda = \frac{1}{\pi^2}\left(\frac{L}{l}\right)^2 \frac{lD_{yx}}{EI} \tag{4}$$

$$\mu = \frac{1}{\pi^2}\left(\frac{L}{l}\right)^2 \frac{GJ}{EI} \tag{5}$$

Where D_{ye} effective value of transverse flexural rigidity of the deck given by Cusens and Pama (1975) Eq. (6). Which consider the distortional effect of single cell box girder by shear area a_s which is given by Eq. (7).

$$\frac{1}{D_{ye}} = \frac{1}{D_y} + \frac{18}{Ga_s l^2} \tag{6}$$

$$a_s = \frac{E}{G} \times \frac{d_w^3 \left(d_t^3 + d_b^3\right)}{d_w^3 l^2 + lh(d_t^3 + d_b^3)} \tag{7}$$

Step 3. Bakht and Mufti method will consider D_y and D_{yx} i.e., Flexural and torsional rigidities of top slab only.

Here in this case consider both top and bottom slabs about its own axis as given in equation Eq. (8) and Eq. (9).

$$D_y = E\left(\frac{d_t^3}{12} + \frac{d_b^3}{12}\right) \quad (8)$$

$$D_{yx} = G\left(\frac{d_t^3}{6} + \frac{d_b^3}{6}\right) \quad (9)$$

Step 4. Expressions for distribution coefficients in a two web box girder bridges, the cross section of which is shown in Figure 2, ρi,j is the distribution coefficient for girder/web when the load is on girder j. e is eccentricity of resultant of loads from left most girder/web and l is girder/web spacing is given by Eq. (10) and Eq. (11)

1. For load on web 1

$$\rho 1 = \frac{\frac{\eta}{2}(1 - e + \lambda + 2\mu) + \mu(1 + \lambda - 3e^2 + 2e^3)}{\frac{\eta}{2}(1 + 2\lambda + 4\mu) + \mu(1 + 2\lambda)} \quad (10)$$

2. For load on web 2

$$\rho 2 = \frac{\frac{\eta}{2}(e + \lambda + 2\mu) + \mu(1 + \lambda + 3e^2 - 2e^3)}{\frac{\eta}{2}(1 + 2\lambda + 4\mu) + \mu(1 + 2\lambda)} \quad (11)$$

IV. Modelling

The results obtained by Modified Bakht and Mufti method are compared with the computer aided engineering software Midas civil. Beam element is used for the finite element modelling of box girder bridges. Bridge is simply supported at both the ends. In spine model, the bridge is modelled using a single girder i.e., beam element which represents the whole cross section of the bridge. Since the centroid of the single girder which represents the whole cross section of the bridge is not located at the bottom side of the box-girder, it thus gives improper supports location. Therefore, the location of the supports is modified with the addition of elastic rigid links which connect the single girder and the supports. The typical finite element model of a straight box girder bridge is as shown in the Figure 3.

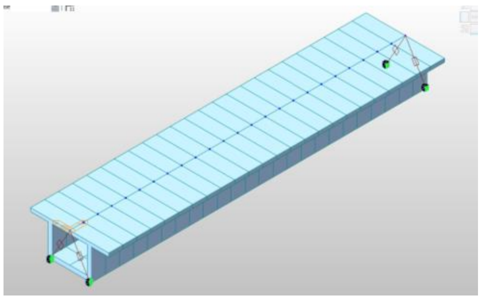


Figure 3. Spine Beam Model of Single Cell Box Girder in Midas Civil

V. Calculation of Distribution Factor in Spine Beam Model

The load distribution among longitudinal webs for this study is computed as the ratio of the total reaction at the supports of web under consideration to the total load applied on the bridge deck. The expression given by Eq. (12) to calculate distribution factor, where (D.F.) web is distribution factor for girder under consideration, Ri is the total reaction at the supports of longitudinal girder under consideration and P is the total load applied on bridge deck can be understood from Figure 4.

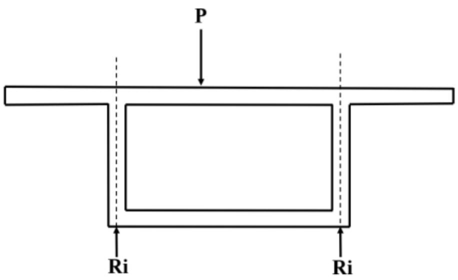


Figure 4. Calculation of Distribution Factor in Spine Beam Model

$$(D.F.)\, web = \frac{Ri}{P} \quad (12)$$

VI. Accuracy Check

To find the accuracy of this methods 4 different sections with different deck width are taken as shown in Table 1 in comparison with Figure 5. M40 grade of concrete is consider with thickness of top slab 0.2m, thickness of bottom slab 0.25m, thickness of web 0.25m, depth of box girder 2m and span length of 25m is kept constant for all cases. Position of loading for all cases are same as shown in Table 2 and Table 3. Class 70 R and two class A are considered as per IRC-6:2017.

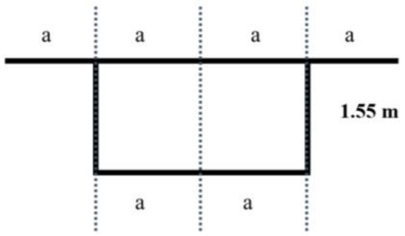


Figure 5. Center to Center Dimensions of Single Cell Box Girder

Table 1. Dimensions of Single Cell Box Girder

Cases	1	2	3	4
Dimension a (m)	1.4	1.6	1.8	2
Width (m)	5.6	6.4	7.2	8

Table 2. Loading Position for Class 70 R Loading

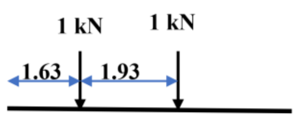
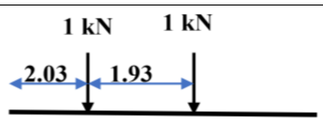
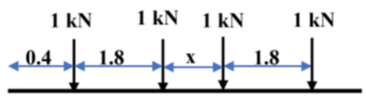
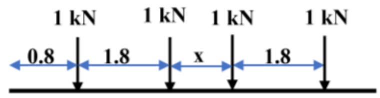
Load Position	Dimensions in m
LP 1	
LP 2	

Table 3. Loading Position for Two Class A Loading

Load Position	Dimensions in m
LP 3	
LP 4	
Value of x for Case 1 = 1m (As width of top slab is 5.6m) Case 2, 3, 4 = 1.7m	

VII. Results

Results are tabulated for all the different cases and position of loading in bar chart from Figure 6 to Figure 13.

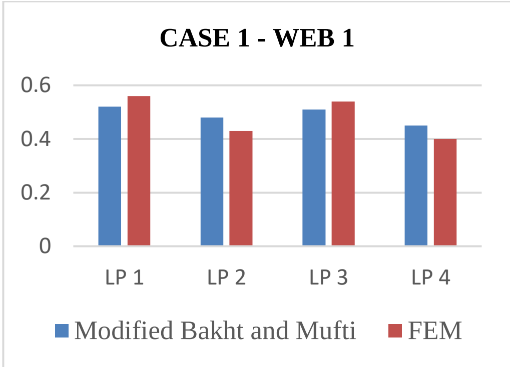


Figure 6. Distribution Factor for Case 1 – Web 1

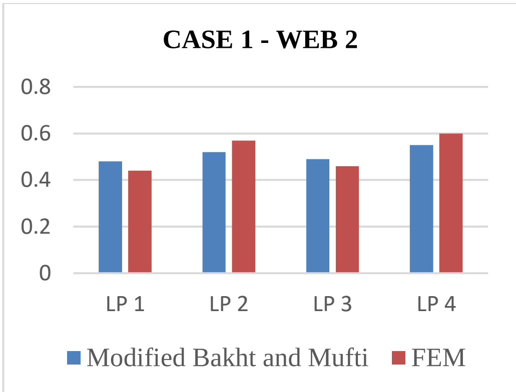


Figure 7. Distribution Factor for Case 1 – Web 2

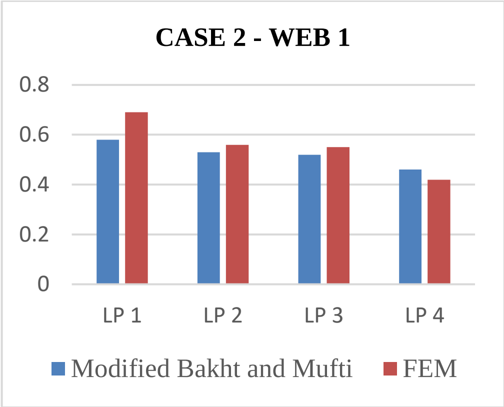


Figure 8. Distribution Factor for Case 2 – Web 1

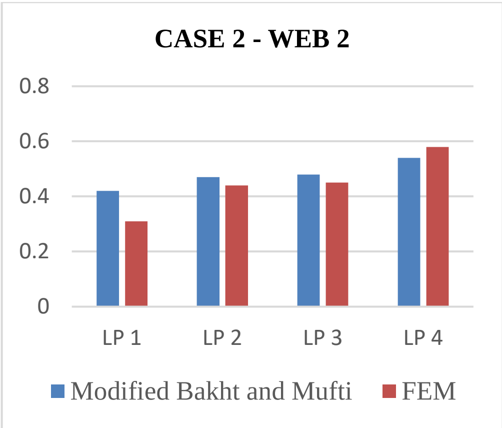


Figure 9. Distribution Factor for Case 2 – Web 2

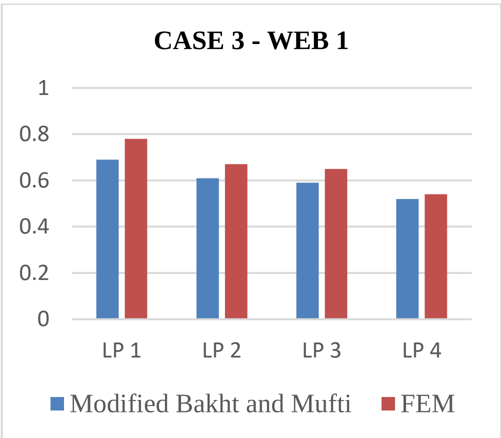


Figure 10. Distribution Factor for Case 3 – Web 1

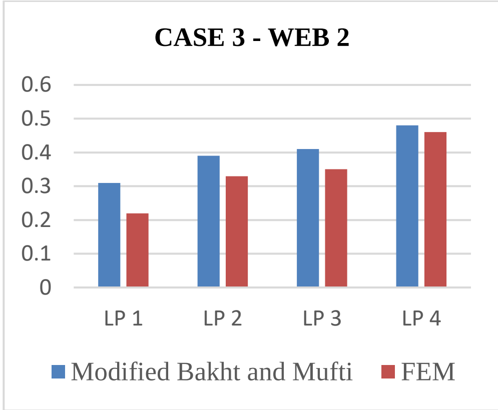


Figure 11. Distribution Factor for Case 2 – Web 2

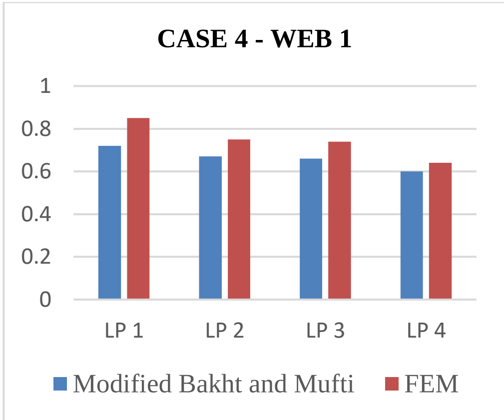


Figure 12. Distribution Factor for Case 1 – Web

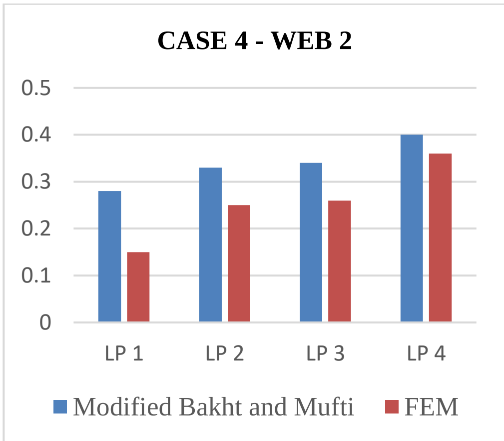


Figure 13. Distribution Factor for Case 2 – Web 2

VIII. Conclusion

Form the bar chats it is clear that error between FEM model and Modified Bakht and Mufti method is less than 15%. Accurate results without errors cannot be obtained by using manual method. Whereas FEM method is time consuming and requires knowledge of modelling in any software to obtain accurate results.

It can be concluded from the present study that Modified Bakht and Mufti method is approximation for analysis of single cell box girder sections. It is believed that this method will be helpful in analysis of single cell box girder as no manual method is existed to obtain distribution factor.

It can also be believed that this method presented in this paper will be of valuable guidance to the designers for the preliminary analysis of single cell box girder.

Abbreviations

FEM – Finite Element Modelling
LP 1 – Load Position 1
LP 2 – Load Position 2
LP 3 – Load Position 3
LP 4 – Load Position 4

d_t = Thickness of top slab
y_t = Centroidal distance from top slab
d_b = Thickness of bottom slab
y_b = Centroidal distance from bottom slab
d_w = Thickness of web
a_s = Shear area
l = Web spacing
h = Height of web between midplanes of slabs
E = Modulus of elasticity
G = Modulus of rigidity

IX. REFERENCES

[1]. Bakht, B., and A. Mufti. (2015). Bridge, Analysis, Design, Structural Heath Monitoring and Rehabilitation. Singapore: Springer.
[2]. Bakht, B., and L. G. Jaeger. (1985). Bridge Analysis Simplified. New York: McGraw-Hill Book
[3]. Cusens, A. R., and R.P. Pama. (1975). Bridge Deck Analysis. New York: Wiley.
[4]. IRC (Indian Road Congress). 2017. Standard Specifications and Code of Practice for Concrete Road Bridges-Loads and Stresses. IRC 6, New Delhi, India: IRC.
[5]. Jaeger, L. G., and B. Bakht. (1989). Bridge Analysis by Microcomputer. Singapore: McGraw Hill.

Cite this article as :

Sreevar Ramesh, R K Ingle, "Development of Applicability of Distribution Factor for Single Cell Box Girder Bridges by Modifying Bakht and Mufti Method", International Journal of Scientific Research in Science, Engineering and Technology (IJSRSET), Online ISSN : 2394-4099, Print ISSN : 2395-1990, Volume 9 Issue 2, pp. 143-148, March-April 2022. Available at doi : https://doi.org/10.32628/IJSRSET229216
Journal URL : https://ijsrset.com/IJSRSET229216