Software Development for Railway Bridge Deck Slab Using IRS Code

Manmohan Sharma[1], Shashikant Dhobale[2]

M.E Scholar[1], Assistant Professor[2]
Department of Civil Engineering, Jawaharlal Institute of Technology, Borawan, Khargone

ABSTRACT

Visual Basic has recently emerged as one of the most frequently utilized event-driven programming languages in the world. An event-driven language responds to events like as pressing a button, selecting an item from a list, navigating away from a control, and so on. Many programmes written in the Visual Basic programming language are effectively used in the banking and finance industries. The Visual Basic language has a lot of promise for developing software for the analysis and design of civil engineering structures. from traditional, linear programming approaches. The software is based on the idea that we must define the section, material of the bridge component, and apply the load that will have the most unfavorable effect on the component over its service life. The software will do calculations for stresses, deflection, and reinforcement. These stresses and deflections should be within the limits allowed by the appropriate IRS and IS codes. If the calculated values of stresses and deflection do not fall within acceptable limits, the section must be altered and the analysis procedure must be restarted. This exercise must be repeated until the safe section of the bridge component is reached.

Keywords– *Railway bridge, IRS Code, software development.*

INTRODUCTION

The deck slab of a railway bridge must be designed to meet the relevant wide gauge loading requirement. For analysis and design purposes, the deck slab is separated into two parts: cantilever slab and internal panel. For concentrated loads due to PQRS loading, the cantilever section of the deck slab must be assessed using the effective width approach as specified in clause 24.3.2 of IS 456:2000.

The inside panel of the deck slab is monolithic and continuous, made of PSC girder and diaphragm. The inside panel is susceptible to concentrated loads from train wheels as well as derailment loads in the event of a train derailment over a bridge. There are two ways for analysing such slabs: Pigeaud's theory and Westergaard's theory. Pigeaud's theory is used to assess the inside panel in this project. The software was created to analyse and design deck slabs.

OBJECTIVE

Software Development for Railway Bridge Deck Slab Using IRS CODES.

METHODOLOGY

In define section of software following inputs are to be provided.

(a) Design data

The following design data are to be provided as input in define section of the software. We have to click the Define button on menu bar to access the define section.

- Length of span
- Distance between centre line of bearings (Effective span)
- Overall length of deck slab
- Centre to centre spacing of girders
- No. of diaphragms
- Thickness of end diaphragm
- Thickness of intermediate diaphragm
- Out to out distance of girder flanges
- Overall width of deck slab

(b) Material properties

The material properties of Concrete are considered as per cl.5 of IRS Concrete Bridge code – 2004 and material properties of HYSD bars are considered as per IS 1786 – 1985.

The materials properties are to be defined in define section of the software. We have to click on Accept button on the Design data form to access the material properties form. The GUI of material properties form is illustrated in Figure 4.2. We have to select exposure condition, grade of concrete and grade of steel from combo box. The material properties will be provided by data base.

(c) Section

The section of deck slab is to be defined in define section of the software. We have to click on Accept button on the material properties form to access the section form. The GUI of section form is illustrated in Figure 4.7. We have to enter dimensions of deck slab, ballast retainer in input boxes.

(d) Loading

As per cl. 2.1 of IRS Bridge Rules, the following loads are considered for the purpose of analysis and design of deck slab.

- Dead Load (DL)
- Super Imposed Dead Load (SIDL)
- Super imposed dead load includes load due to track, ballast, wearing coat and ballast retainer.
- Live Load (LL)

The live load is to be considered as per cl. 2.3.4.1 and cl. 2.3.4.2 of IRS Bridge rules for relevant loading standard.

- Dynamic Augment (I)

The dynamic augment is considered as per cl.2.4.2.1 of IRS Bridge rules for relevant loading standard.

In case of ballasted deck slab bridges,

Coefficient of Dynamic Augment = [2-(d/0.9)] x [0.15 + 8/(6+L)] x 0.5

Here,

d = depth of ballast cushion in metres

L = Loaded length of span in metres

- PQRS loading

The PQRS loading is considered as per cl. 2.15 of IRS Bridge rules for analysis and design of cantilever slab

- Derailment load

The Derailment load is considered as per cl. 2.14 of IRS Bridge rules for analysis and design of interior panel.

The loading on deck slab is to be defined in define section of the software. We have to click on Accept button on the section form to access define loading form. The GUI of define loading form is illustrated in Figure 4.7.

(e) Analysis

On completion of define process, we have to click the Analysis button on menu bar and select deck slab to access the analysis section of deck slab. In analysis section of software all calculations are performed by the software on clicking of Calculate button.

Load and moment calculations

The GUI of Load and moment calculations form is illustrated in Figure 5.1. Click on Calculate button to calculate Load and moment.

ANALYSIS AND DESIGN OF RCC DECK SLAB AND DIAPHRAGM

Description	Value	Unit	Reference
GENERAL : The super structure consists of the precast PSC (post tensioned) girder and cast in situ deck slab.			
The various assumptions made in the design and specification used are as below			
CONCRETE			cl. 5 of IRS Concrete Bridge code - 2004
Exposure condition - moderate			
Grade of concrete used for PSC girder and RCC deck slab = M- 40			
Characteristics compressive strength (f_{ck})	40.0	N/mm^2	cl.5.1 & Table 2 of IRS Concrete Bridge code -2004
Unit weight of concrete	25.0	KN/m^3	
Modulus of elasticity of concrete	31.0	KN/mm^2	cl. 5.2.2.1 of IRS Con. Bridge code - 2004
HYSD steel			IS 1786 - 1985
Fe 415 Grade HYSD bars to be used for RCC works			
Characteristics strength/Yield strength (f_y)	415.0	N/mm^2	
Modulus of elasticity of Steel	200.0	KN/mm^2	
Loading standard - MBG Loading - 1987			

Item No.	Description	Value	Unit	Reference
1.1	**DESIGN DATA**			
	Clear span (L)	12.200	m	
	C/C of bearing (L_1)	12.850	m	
	Overall length of girder (L_2)	13.360	m	
	Overall length of slab (L_3)	14.160	m	
	C/C distance of expansion joint of pier	14.200	m	
	Distance of widening point from bearing	2.055	m	
	C/C of girder	2.300	m	
	Formation level	291.541	m	(As per approved L.S.)
	Thickness of deck slab	0.220	m	cl.4.6.2.1 of IRS Con. Bridge code -2004
	Depth of girder	1.450	m	
	Depth of flange	0.150	m	
	Depth of slope portion of flange	0.050	m	
	Width of flange	0.750	m	
	Thickness of web of girder	0.300	m	
	Uniform depth of web below flange	0.925	m	
	Slope depth of bottom bulb of girder	0.150	m	
	Uniform depth of bottom bulb of girder	0.175	m	
	Width of bottom bulb of girder	0.500	m	
	No of girder per bridge	2	Nos	
	Out to out distance of flange of all girder	3.050	m	
	Hence overall length of diaphragm	3.050	m	
	Depth of diaphragm	1.275	m	
	Thickness of intermediate diaphragm	0.300	m	
	Thickness of end diaphragm	0.510	m	
	Overall width of deck slab	4.800	m	
	Effective width of flange of T - beam	2.400	m	cl.15.4.1.2 of IRS Con Bridge code -2004
	Partial load factor (Y_{fL})			cl.11.3 & Table 12 of IRS Concrete Bridge code -2004
	Partial safety factor for steel (Y_m)	1.15		cl.12.4.3 of IRS Con. Bridge code -2004
	Partial safety factor for concrete (Y_m) (Ultimate Limit State)	1.50		cl.12.4.3 of IRS Con. Bridge code -2004
	Partial safety factor for concrete (Y_m) (Serviceability Limit State)	1.25		cl.12.4.2 of IRS Con. Bridge code -2004

DESIGN OF RCC DECK SLAB		
Overall depth of slab =	220	mm
Clear cover =	30	mm
Dia of bar =	12	mm
Effective depth of slab (d) =	184	mm
Width of slab (b) =	1000	mm
Characteristics compressive strength (f_{ck})	40	N/mm^2
Characteristics strength/Yield strength (f_y)	415	N/mm^2
A. CANTILEVER SLAB		
Design BM(Mu) =	42.82	kN.m
(2 SIDL + 1.4 DL + 2 LL)		
Ultimate moment of resistance (0.15 fck b d^2) =	203.14	kN.m
(Ref: IRS Con. Br. Code cl. 15.4.2.2.1)		
The overall depth provided is adequate and section is under reinforced.		
Area of main reinforcement (As) =	676	mm^2
$M_u = 0.87 f_y A_s \left(1 - \frac{1.1 f_y A_s}{f_{ck} b d}\right) d$		
c/c spacing of main bars =	167.30	mm
Provide 12 mm bar @150 mm c/c		

VALIDATION OF SOFTWARE

A.3 ANALYSIS AND DESIGN OF DECK SLAB

A.3.1 Material properties

Concrete (Ref: cl.5 of IRS Concrete Bridge code – 2004)

Exposure condition - Severe

Characteristics compressive strength (fck) = 40.0 N/mm2

Unit weight of concrete = 25 kN/m3

Modulus of elasticity of concrete = 31.0 kN/mm2

HYSD steel (Ref: IS 1786 – 1985)

Characteristics strength/Yield strength (fy) = 415.0 N/mm2

A.3.2Design data

C/C of girder = 2.300 m

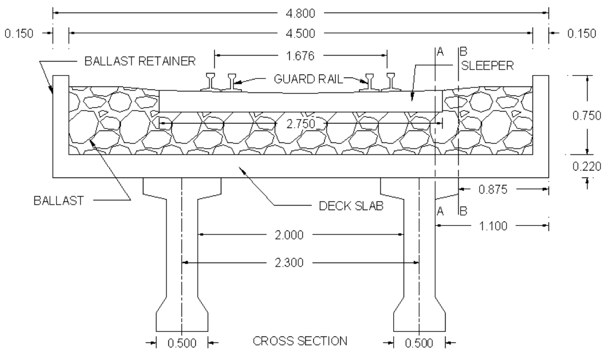
Overall width of deck slab = 4.800 m

Thickness of deck slab = 0.220 m (Ref: cl.16.9.6.1 of IRS Con. Bridge code -2004)

Width of flange = 0.750 m

Thickness of web of girder = 0.300 m (Ref: cl.16.9.6.2 of IRS Con. Bridge code -2004)

A.3.3 Load calculations



A.3.3.1 Cantilever slab

Dead load (DL)

Deck slab = 1 x 0.22 x 25 = 5.5 kN/m

Super imposed dead load (SIDL)

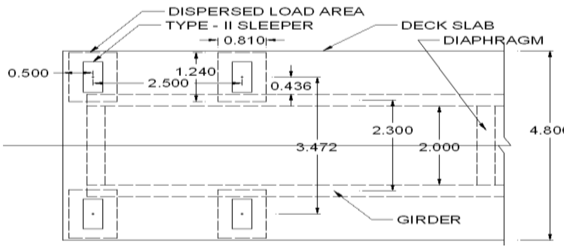
Ballast retainer = 0.15 x 0.75 x 25 = 2.81 kN

Wearing coat = 1 x 0.08 x 22 = 1.76 kN/m

Ballast = 1 x 0.6 x 19 = 11.4 kN/m

Live load (LL) due to PQRS

(Ref: IRS Bridge Rules cl. 2.3.4.2, cl. 2.15 and Appendix - X)



Calculations for section at B – B

Effective width method (Ref: IS 456: 2000 cl. 24.3.2)

Concentrated load (W) = 98.1 kN

a1= 0.211 m, a = 0.81 m

bef = 1.2 a1 + a = 1.0632 m

Distance of concentrated load from end (x1) = 0.5 m

Distance between concentrated loads parallel to supported edge(x2) = 2.5 m

Overhang (bef /2 - x1) = 0.0316 m

Overlap (bef - x2) = 0 m

e = 2bef - Overhang – Overlap = 2.0948 m

Effective load including impact (1.44 W/e) = 67.44 kN.

A.3.3.2 Interior panel

Dead load (DL)

Deck slab = 1 x 0.22 x 25 = 5.5 kN/m2

Super imposed dead load (SIDL)

Wearing coat = 1 x 0.08 x 22 = 1.76 kN/m2

Ballast = 1 x 0.6 x 19 = 11.4 kN/m2

Track = 3.87 kN/m2

Live load (LL) due to heaviest axle of MBG loading

Concentrated load = 245.2 kN

Derailment load

(Ref: IRS Bridge Rules cl. 2.14 and Appendix IX)

Concentrated load = 100.0 kN

A.3.4 Bending moment calculations

A.3.4.1 Cantilever slab

Table A.23: Bending moment for cantilever slab

BM due to	At section B - B		
	Load (kN)	Span (m)	Moment (kN - m)
DL			
Deck slab	5.5	0.875	2.11
SIDL			
Ballast retainer	2.813	0.8	2.25
Wearing coat	1.76	0.725	0.46
Ballast	11.4	0.725	3.00
LL	67.44	0.211	14.23

A.3.4.2 Interior panel

Bending moment due to DL and SIDL (Pigeaud's theory)

Panel size L = 6.02 m, B = 2.0 m

Total dead load (W) = 22.53 x 6.02 x 2.0 = 271.3 kN

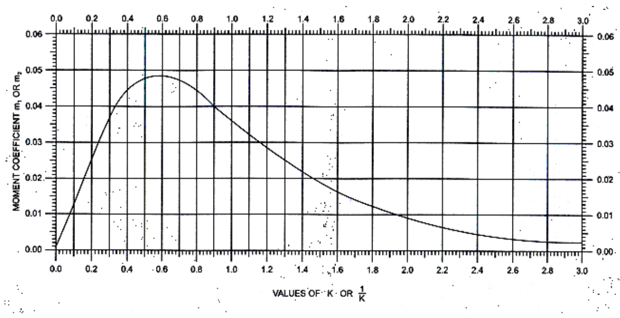
Constant k and (1/k)

k= (short span/long span = B/L) = 0.33

(1/k) = 3.01

Assuming Poisson's ratio = 0.15

m1 and m2 from graph



m1 = 0.04, m2 = 0.003

Moment along short span = (m1 + 0.15 x m2) W = 10.97 kN - m

Moment along long span = (m1 x 0.15 + m2) W = 2.44 kN.

Bending moment due to LL (Pigeaud's theory)

MBG Loading - with type - I sleepers

(Ref: IRS Bridge Rules cl. 2.3.4.1 and cl. 2.3.4.2)

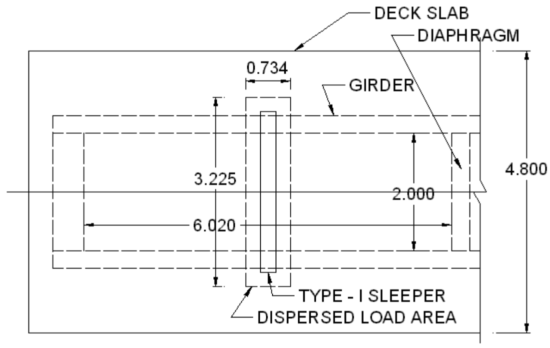


Figure A.21: MBG Loading - with type - I sleepers

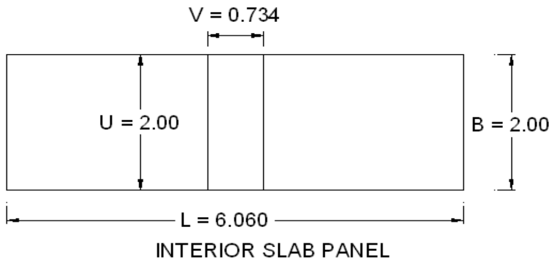


Figure A.22: Interior slab panel

Panel size L = 6.02 m, B = 2.0 m, U = 2.0 m, V = 0.734 m

Effective load on panel (W) = (245.2 x 1.44 x2.0/3.225) = 219.0 kN

k=(short span/long span = B/L) = 0.33

Assuming Poisson's ratio = 0.15

m1 and m2 from graph for U/B = 1 and V/L = 0.12

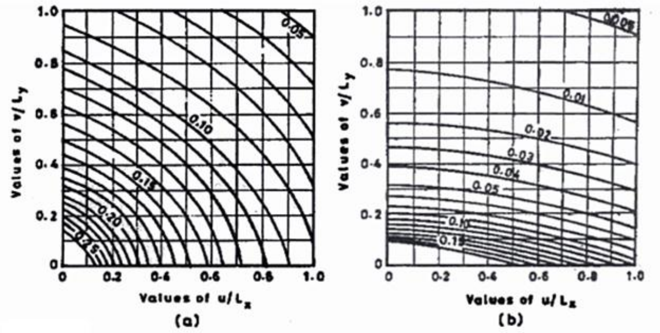

Moment coefficients by Pigeaud's Method L_y/L_x = 2.5: (a) Coefficient m_x, (b) Coefficient m_y.

Figure A.23: Graph for m1 and m2

m1 = 0.10, m2 = 0.05

Moment along short span = (m1 + 0.15 x m2) W = 23.54 kN - m

Moment along long span = (m1 x 0.15 + m2) W = 14.24 kN – m

Bending moment due to Derailment load (Pigeaud's theory)

Panel size L = 6.02 m, B = 2.0 m, U = 0.48 m, V = 0.48 m

Effective load on panel (W) = (1.44 x 100) = 144.0 kN

k=(short span/long span = B/L) = 0.33

Assuming Poisson's ratio = 0.15

m1 and m2 from graph for U/B = 0.24 and V/L = 0.08

m1 = 0.22, m2 = 0.14

Moment along short span = (m1 + 0.15 x m2) W = 34.70 kN - m

Moment along long span = (m1 x 0.15 + m2) W = 24.91 kN – m

A.3.5 Design of Deck slab

Overall depth of slab = 220 mm

Clear cover = 30 mm

Dia of bar = 12 mm

Effective depth of slab (d) = 184 mm

Width of slab (b) = 1000 mm

A.3.5.1 Cantilever slab

Design BM due to ultimate load (M) = 43.0 kN.m

(2 SIDL + 1.4 DL + 2 LL)

Ultimate moment of resistance (0.15 fck b d2) = 203.14 kN.m

(Ref: IRS Con. Br. Code cl.15.4.2.2.1)

The overall depth provided is adequate and section is under reinforced.

$$M_u = 0.87\, f_y A_s\left(1 - \frac{1.1 f_y A_s}{f_{ck} b d}\right) d$$

Area of main reinforcement (As) = 676 mm2

C/C spacing of main bars = 167.3 mm

Provide 12 mm bar @150 mm c/c

A.3.5.2 Interior panel

Calculation of reinforcement along short span

Design BM due to ultimate load (M) = 69.03 kN.m

(2 SIDL + 1.4 DL + 2 LL)

Ultimate moment of resistance (0.15 fck b d2) = 203.14 kN.m

(Ref: IRS Con. Br. Code cl. 15.4.2.2.1)

The overall depth provided is adequate and section is under reinforced.

Area of main reinforcement (As) = 1116 mm2

C/C spacing of main bars = 101.3 mm

Provide 12 mm # bars @ 90 mm c/c

Calculation of reinforcement along long span

Design BM due to ultimate load (M) = 33.35 kN.m

(2 SIDL + 1.4 DL + 2 LL)

Ultimate moment of resistance (0.15 fck b d2) = 177.5 kN.m

(Ref: IRS Con. Br. Code cl. 15.4.2.2.1)

The overall depth provided is adequate and section is under reinforced.

Area of main reinforcement (As) = 560 mm2

C/C spacing of main bars = 202.0 mm

Provide 12 mm # bars @ 120 mm c/c

Shrinkage and temperature reinforcement (minimum reinforcement)

(Ref: IRS Con. Br. Code cl. 15.9.9)

As >= Kr (Ac - 0.5 Acor)

Kr = 0.005

Ac (Area of gross concrete section) = 220000 mm2

Acor (Core area of concrete) = 0

As = 1100 mm2

Shrinkage and temperature reinforcement (minimum reinforcement) shall be distributed uniformly around the perimeter of the concrete section and spaced at not more than 150 mm.

Area of reinforcement required at each face o deck slab (As / 2) = 550 mm2

C/C spacing of 10 # bars = 142.80 mm

CONCLUSION

The accuracy of software is primary requirement of any software development work. To validate the results of software, the analysis and design of 4.8-meter-wide deck slab PSC of railway bridge is done by hand calculations and results are presented in paper. The analysis and design results for various components of this bridge are also obtained by the software. The results of software are in conformity with results obtained by hand calculations. So it can be concluded that the accuracy of software is beyond doubt. It is possible to design another bridge with different span, loading standard and design data, without rigorous hand calculations, with the help of software. The detailed design report can be obtained from software and can be used without further formatting. It means the software is useful in saving time and effort during accurate analysis and design of railway bridges.

REFERENCES

1. Anil kumar H and B S Suresh Chandra (2015), “Flexural Behaviour of Longitudinal Girders of RC T-Beam Deck Slab Bridge”, Int. J. for Sci. Res. & Develop., Volume 3, Issue 5, pp. 639-642, Available at: http://www.ijsrd.com/articles/IJSRDV3I50447.pdf.

2. Budi Ryanto Widjaja (1997), “Analysis and Design of Steel Deck– Concrete Composite Slabs”, Ph. D, Polytechnic Institute and State University, Virginia Tech., Available at: https://vtechworks.lib.vt.edu/handle/10919/307 59.

3. Haymanmyintmaung and Kyawlinnhtat (2011), “Investigation of Integral Bridge Effect under Dynamic Loading”, Int. J. of Sci. and Res. Publi., Volume 7, Issue 5, pp. 567-574, Available at: http://www.ijsrp.org/research- paper-0517/ijsrp-p6565.pdf.

4. Ibrahim S. I. Harba (2011), “Effect of Skew Angle on Behavior of Simply Supported R. C. T-Beam Bridge Decks”, ARPN J. of Engg. and Appli. Sci., Volume 6, Issue 8, pp. 1-14, Available at:http://www.arpnjournals.com/jeas/research_papers/rp_2011/jeas_0811_532.pdf.

5. Kearthi. S, Kalpana Mohan Sivasubramanian.S. L, Deepan. R and Gopinath. M (2016), “Analysis of T – Beam Bridge Deck Slab”, Int.J. of Res. and Innov. in Engg. Tech., Volume 2, Issue 12, pp. 22–27, Available at: https://www.researchgate.net/publication/305113203_ANALYSIS_OF_T_-_BEAM_BRIDGE_DECK_SLAB.

6. Kalpana Mohan and S. P. Vijay Kumar (2016), “Analysis of Bridge Girder with Beam and Without Beam”, Int. J. of Civil Engg. and Tech., Volume 7, Issue 5, pp. 337–346, Available at: http://www.iaeme.com/MasterAdmin/Journal_uploads/IJCIET/VOLUME_7_ISSUE_5/IJCIET_07_05_038.pdf.

7. Lindsay Edward Klein Piers (2006), “Finite Element Analysis of a Composite Bridge Deck”, Ph.D. dissertation, Dept. of Engineering & Surveying Research Project, University of Southern Queensland, Available at: https://core.ac.uk/download/pdf/11036283.pdf.\