Study and Design of Post-Tensioned Stress of T- Box Girder Bridge by IRC: 112-2011

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Abstract— The construction of the bridge has reached an important milestone worldwide today. Bridges are an essential element of any road network and the use of post-tensioned type girder bridges is gaining popularity in the bridge engineering brotherhood because of their better stability, usability, economy, aesthetic appearance, and structural efficiency. In this thesis, analysis and design of prefabricated concrete bridges (Deck Floor, T-Beam, and Box Beam) was performed using IRC: 112-2011. The integrated concrete code (IRC: 112), which includes a code for reinforced and pre-reinforced concrete structures, published by the Indian Road Congress in November 2011, represents a new generation code that differs significantly from previous codes (for example, IRC: 21 RCC). IRC: 18 buildings and structures of the PSC). IRC: 21 and IRC: 18 have been withdrawn with the release of IRC: 112. The main difference between IRC: 112 and legacy a code is that IRC: 112 are based on the limitations theory while the previous codes are based on the stress design philosophy.

Keywords: Post-Tensioned, Deck Flooring, T-Plate, Box Beam, IRC: 112

I. Introduction

Bridges are defined as structures that allow you to cross over a gap without closing the road below. It may be necessary for the railway line, road, crossing tracks, and even for the transport of liquids, the location of the bridge should be chosen to provide maximum commercial and social benefits, efficiency, efficiency, and equity. Bridges are the backbone of the nation in times of war. Bridges represent the ideals and aspirations of humanity. They overcame barriers that draw people, communities, and nations together and divide them. They reduce distances, speed up transportation, and facilitate trade. Bridges are a symbol of the heroic struggle of humanity to control the forces of nature and are a silent reminder of the invincible will of man. The construction of the bridge is an important factor in communication and is an important factor in the advancement of civilization, bridges commemorating the work of civil engineers.

A. Segmentation of bridges:

Bridges are classified according to different conditions as follows

- Using a canal (overhead), viaduct (highway or railway line, pedestrian, highway, railway line, railway line, or pipeline).
- In terms of superstructure materials, such as wood, masonry, steel, steel, reinforced concrete, reinforced concrete, composite bridge, or aluminum.
- Depending on the form or type of superstructure, such as slab, beam, truss, arch, fixed bridge.
- Simple, continuous bridge and cantilever depending on the relationship between the spaces.
- Depending on the base position of the bridge associated with the main structure such as deck, gutter, half-trough, or a fixed bridge.
- Depending on the length of the span such as culvert (less than 8m), smaller bridge (8m to 30m), or longer span bridge.

II. The Basic Observation of Pressure and Stress

Pressing is the use of the first load on the building so that it can withstand the pressures from subsequent loads throughout its service life. Compression has been practiced since ancient times, and the behavior of the spokes when the bike is loaded is also an example of pressure. Pressed concrete is concrete where the internal pressure of appropriate size and distribution is used to meet the stress from external loads at the required level. For reinforced concrete joints, post-tensioned is usually steel reinforcement.

The lowest quality concrete in the post-tensioned technique is the M40 pretense and the M35 for post-tensioning. The strength of concrete strength is only 8-14% of the compression strength of concrete.

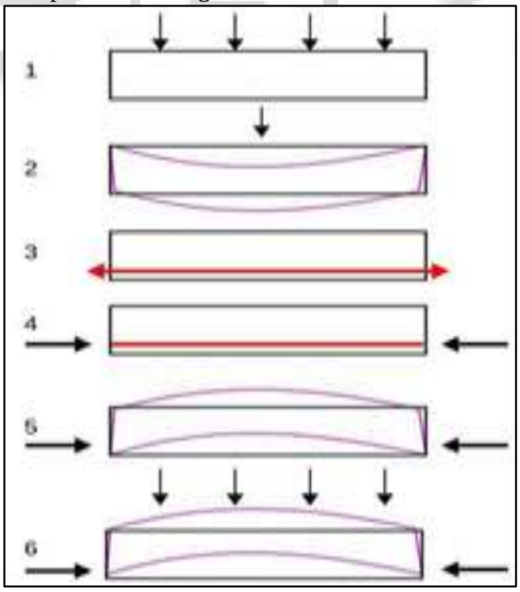
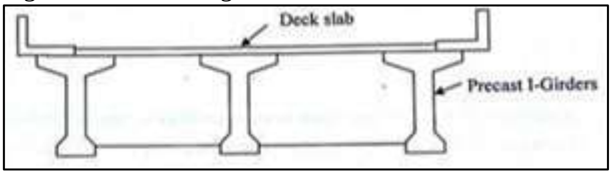


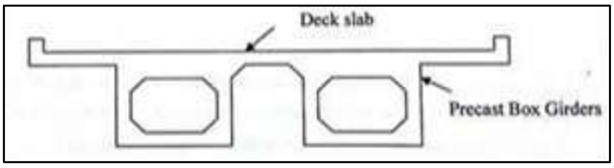
Fig. 1.1: The behavior of RRC members with and without post-tensioned

A. Types of Post-tensioned Beam and Its Purposes:

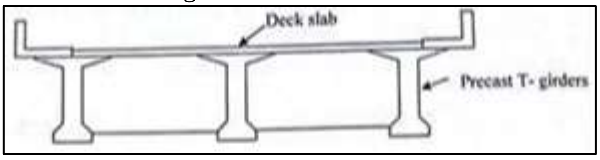
One of the most common forms of the superstructure in precast concrete beams is precast concrete with cast-in-situ slabs. This type of superstructure is usually used for spaces between 20 and 40 m. Most pre-compressed concrete bridges built in India are of the post-strength type. The span/depth ratio is usually kept at 20 for supported width and 25 for continuous steers 2 to 3 m wide beam. A slab deck overhang should be provided as needed to achieve the desired aesthetic effect and reduce transmission times. Different types of bridges as shown in Figure 2.1



A. I-Girder with a cast in situ deck



B. Box girder with a cast in situ deck



C. Box girder with a cast in situ deck

Fig. 2.1: Different types of girder sections

III. Determination Technique with Support of Finite Element Method

The limited feature method is a technique used to analyze a complex structure by nationality by dividing the continuity of a model into a series of smaller elements connected to different types called nodes. In each case, a fixed number of strengths is obtained that link the shift of nodes and the combined forces between the elements, and an electronic computer is used to solve this problem, just as slope deviation calculations can be solved for joints continuously. Beam a large number of simultaneous calculations relating to power knots and displacement.

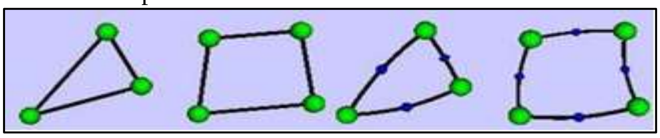


Fig. 3.1: 3 Noded Triangle, 4 Noded Quadrilateral, 6 Noded Triangle, 8 Noded Quadrilateral

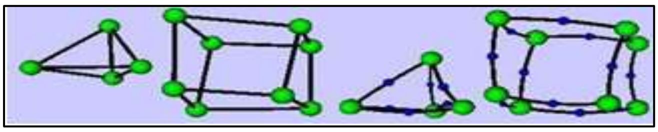


Fig. 3.2: 9 Noded Hexahedron, 10 Noded tetrahedra, 20 Noded Curved solid

IV. IRC Recommendations under the Bridge

The first and most important step in any bridge analysis is to choose the type of loading, this is the fixed load, live load, impact effect, wind load, the longitudinal force due to gravity, a longitudinal force due to car brake, earthquake effects ground pressure, car collision strength, etc. Apart from these loads, live load plays a major role.

A. Live Carriage Loads:

Live carloads are classified as IRC Class 70R, IRC Class AA (compliant and wheeled type), IRC Class A, and IRC Class B loads depending on their configuration and congestion.

B. Upload Combination:

All critical upload categories will be updated. The following stages are in the Post-tensioned stage

- Any periodic load during construction phases, including temporary loading, transport, handling, and assembly, or the introduction of beams.
- Design responsibilities per IRC: 6 include no longer service load, bias, and total loss and no longer service load, live load, and bias and total loss.
- For combinations of loads with different temperature effects, a 50 percent live volume will be considered.
- Total strength: Pressurized concrete joints are tested for failure conditions when heavy load.

A.1.25 G + 2 SG + 2.5 Q --- under moderate conditions

B.1.5 G + 2 SG + 2.5 Q --- under severe exposure conditions

In cases where a fixed load has the opposite effect of live load effects, the G + SG + 2.5 Q should be tested.

C. Final and Ultimate Stress calculation:

Two types of failures should be calculated with strength, the least of which should be considered in the design. Them

1) Failure with metal yield

More = 0.9 dB as fp (2.1)

2) Broken fractures

More = 0.176 b db2 fck (2.2)

V. Examination of Box Beam Blocks

The methods for analyzing box girder bridges are as follows:

- Simple line analysis or beam analysis grid analysis
- BEF Analysis (Pillars on an expandable basis)
- Space frame analysis method of limited feature
- Finite Element Method

The fixed feature method is a more accurate way to test the box bridges.

A. Model Description

1) Uploading at Box Girder Bridge:

The various loads, strengths and pressures to be considered in the analysis and design of the various sections of bridges are provided in IRC 6.

2) Web site:

The thickness of the bone should not be less than d / 36 and the double net cover in the reinforcement area and the double width of the channel hole, where the 'd' is the total depth of the box band measured from top to bottom of the Deck Plate. The bottom of 200 mm and the width of the pipe holes, depending on which is the largest.

3) Bottom Flange Size:

The thickness of the bottom flange of the box will be less than 1/20 of the net spacing where the bottom flange meets or 200 mm, depending on the size.

4) Extra Flange Size:

The minimum size of the deck plate, including the cantilever ends, should be 200 mm. For high and low flanges with pre-compressed wires, the thickness of the flange should not be less than 150 mm and the diameter of the pipe hole.

5) Pressure Loss:

When testing pressures on concrete and steel during pressure and later in service, all losses and variations of pressure due to concrete crawling, concrete cracks, metal loosening, and concrete shortening (elastic reversal) will be considered in transfers and conflicts and slippery anchors.

6) Final Stress calculation:

In these two separate fractures, the last-minute resistance of the segments will be calculated by the following formulas and the smallest of the two values will be considered as the last-minute resistance to the design.

Iron Harvest Failure

More = 0.9 DB As Fp

Failures Caused by Crushing Concrete

More = 0.176 b db2 fck (5.1)

VI. ANALYSIS AND DESIGN OF POST-TENSIONED DECK TYPE BOX GIRDER BRIDGE

A post-tensioned box bridge with a 30 m wide span and 7.5 m wide road is considered for analysis. Live loads are calculated according to IRC: 6. the cross-section of the box bean is shown in Figure 6.1, its mathematical model is made using SAP2000 and is shown in Figure 5.3. The overhang of the beam is 1.2 m and the thickness of the floor is 0.25 m. Subfloor thickness is 0.25 m, beam thickness is 0.35 m. The materials used are M50 quality concrete and Fe415 quality steel. The projected tendon profile is parabolic. Bridge analysis of different open depth (L / d) and different depth (L / d) from 15 to 19 is assumed to be:

Case1 L/d= 15, d= 2.0
Case2 L/d=16, d= 1.9
Case3 L/d=17, d= 1.8
Case4 L/d= 18, d= 1.7
Case5 L/d= 19, d= 1.6 (5.2)

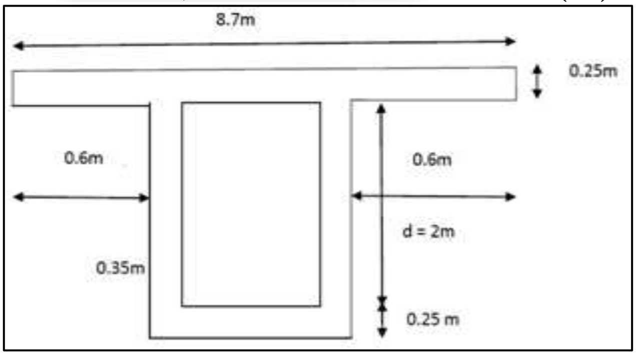


Fig. 6.1: Cross Section of Box-Girder

A. Mathematical Modelling

The mathematical model of a 30-meter-long box bridge is shown in Figure 6.2.

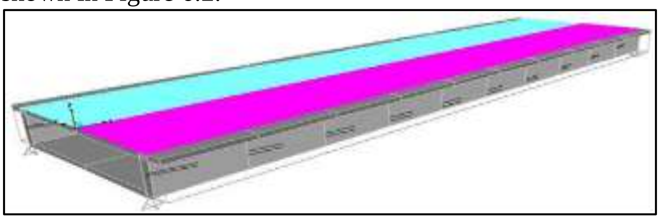


Fig. 6.2: Modelling of the box girder bridge

The profile of the tendon considered for the design of the post-tensioned girder bridge is parabolic and the mathematical model is shown in Figure 6.3.

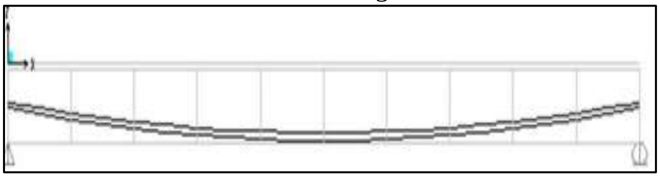


Fig. 6.3: Tendon profile

B. Results Authorisation

Bending moment, shaving power, and deviation effects were obtained using the SAP2000. Bending time and shear strength are determined by considering the different loading conditions including fixed load, overload load, and live load. The results are shown below.

Span (m)	0L	0.1L	0.2L	0.3L	0.4L	0.5L
DL	0	526	934	1226	1400	1459
LL	0	218	381	495	565	588
SIDE	0	62	110	145	165	172
Total	0	806	1425	1866	2130	2219

Table 6.1: Bending moment variation along span (KN)

Span (m)	0L	0.1L	0.2L	0.3L	0.4L	0.5L
DL	194	156	117	78	39	0
LL	80	72	57	41	23	0
SIDE	23	18	14	9	5	0
Total	297	246	188	128	67	0

Table 6.2: Shear variation along span (kN)

Moment due to DL+SIDL (Mg) = 1631 tm

Total Maximum moment (Mt) = 2219 tm

1) Initial Stresses:

fck = 50 MPa
fci= 40 MPa
fct= 20 MPa
fcw = 16.5 MPa
ftt= 2 MPa
ftw = 0 MPa
fbr= 16 Mpa
Loss ratio= 0.8

The variation of post-tensioned force, eccentricity, and number of cables for span to depth ratios are summarized in Table 6.3

L/d	15	16	17	18	19
fsup (MPa)	1.57	1.59	1.6	1.62	1.64
finf (MPa)	0.81	0.78	0.76	0.73	0.7
Post-tensioned ing Force P (kN)	5428	5370	5309	5251	5194
e (mm)	850	800	750	700	650
using the Freycinet	system, anchorage type 7K-15 in 65mm cable ducts (IS:6006-1983)				
No of Cables	4	4	4	4	4

Table 6.3: Calculation of post-tensioned force and eccentricity

The following checks are performed for the above-mentioned case1.

2) Check for Section Modulus:

Required section modulus Zreq = 571 x 106 mm3

Provided section modulus Zpro =341 x 108 mm3

Zpro> Zreq, Hence the section provided is adequate.

3) *Check for Stresses:*

At transfer stage
Stress at top = 1.52 MPa < fct
Stress at bottom = 0.87 MPa < ftt
At working stage
Stress at top = 1.4 MPa < fcw
Stress at bottom = 0.48 MPa (As per IS1343:1980 there is no tensile stress)

All the stresses at top and bottom fibers at transfer and service loads are well within the permissible limits.

4) *Check for Flexural Strength:*

For the center of span section
According to IRC: 18-2000,
Mu = 1.5 M(G)+ 2 M(SG)+ 2.5 M(Q)
Mu = 40025 kNm
The ultimate flexural strength is calculated as follows
Failure by Yielding of Steel
Mu = 0.9 dB Ap fp
Mu = 118244 km
Failure by Crushing of Concrete
Mu = 0.176 bw d2fck + (2/3) 0.8 (b-bw) (d-0.5Df) Df fck
Mu = 234556 kNm
The ultimate flexural strength Mu = 118244 > 40025 km, Hence safe.

5) *Deflection Check:*

Span/ Depth	Post-tensioned Force (kN)	Eccentricity (mm)	Deflection (mm)		
			DL+ SIDL	DL+ SIDL+ PRE	DL+ LL+ PRE+ SIDL
15	5428	850	14	11	18

Table 6.4: Check for deflection

Maximum permissible deflection according to IS: 1343-1980, Deflection due to self-weight + post-tensioned + live load = span / 350 or 20 mm, whichever is less Permissible deflection = minimum of (86 or 20) =20 mm > 18 mm Hence safe.

C. *Design of Reinforcement in Box Girder Bridge*

1) *Design of End Block*

P=5428 kN
bw=350 mm
d=1800 mm

Assume a 200 mm wide and 200 mm deep distribution plate, located concentrically at the center. Ypo/yo = 0.57
As per IRC18:2000, from table 8. Fbst/Pk = 0.149
Fbst = 404kN
Ast = 1119mm2

Provide 12 mm diameter bars @ 100 mm c/c in a horizontal direction and vertical direction also same reinforcement provided up to 750 mm in a longitudinal direction and the same reinforcement to another web.

Side Face Reinforcement
Ast = 315 mm2
Provide 6-12 mm diameter on each face of the web.

Design of Deck Slab
Bending moment = 2219 kNm
Depth required= 201 mm
Depth provided= 250 mm safe.

Main Reinforcement
Ast = 4256 mm2
Providing 16 mm diameter bars 100 mm c/c

Design of Transverse Reinforcement
M = 0.3 ML + 0.2 (MDL + MSIDL) M = 503 kNm Ast = 1235 mm2
Providing 12 mm diameter bars @ 160 mm c/c

The detailing of side face reinforcement is as shown in Figure 6.4 and cross-sectional detailing is shown in Figure .6.

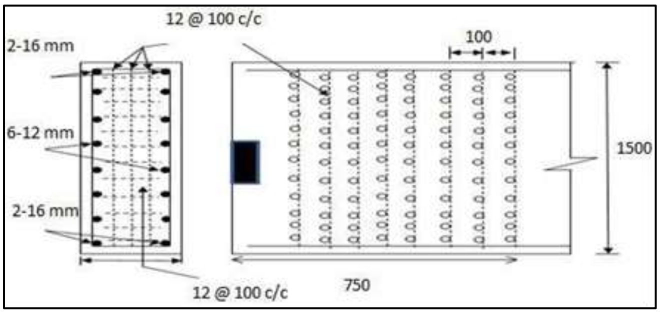


Fig. 6.4: Side face reinforcement detailing

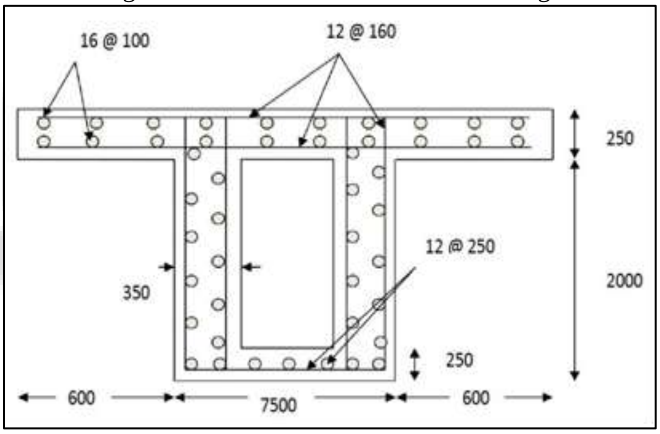


Fig. 6.5: Cross-sectional view (all dimensions are in mm)

D. *Comparison of Results for Various Spans to Depth Ratio*

The comparison of post-tensioned force, deflection and stresses values are obtained for various span/depth ratios for box Girder Bridge as shown in Table 6.5.

Span/ Depth	Post-tensioned Force (kN)	Eccentricity (mm)	Deflection (mm)		
			DL+ SIDL	DL+ SIDL+ PRE	DL+ LL+ PRE+ SIDL
15	5428	850	14	11	18
16	5370	800	16	12	20
17	5309	750	17	13	23
18	5251	700	19	16	26
19	5194	650	22	18	29

Table 6.5: Comparison of post-tensioned force and deflection for various spans to depth ratio

Span/ Depth	15	16	17	18	19	units
At the Transfer Stage						
Stress at Top	1.52	1.51	1.5	1.49	1.48	Mpa
Stress at Bottom	0.87	0.87	0.87	0.87	0.88	Mpa
At the Working Stage						
Stress at Top	1.41	0.43	0.43	0.42	0.41	Mpa
Stress at Bottom	0.48	-0.48	-0.47	-0.46	-0.45	Mpa

Table 6.6: Comparison of stresses for various span/ depth ratio

VII. Discussion and Conclusion

- The following observations were made from the analysis and design of the post-tensioned girder bridge of various span/depth measurements.
- Various spans to depth measurements are taken to analyze box bridges, and deviation and stress are within the permissible limits of all conditions.
- As the depth of the box decreases, the compression force decreases, and the number of strings decreases.
- Due to the pressure, more concrete strength is used and also controls the efficiency.
- The new code (IRC: 112) requires additional coverage of pre-stress cables and post-tensioned ducts, increasing net thickness and floor level/floor of PSC beams / PSC box bridges.

At the same cross-section and the same working moment, the metal difference is more important compared to WSM, LSM consumes less metal than WSM, and to get an additional p% difference it is better to change the metal distance than to increase the concrete distance.

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