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# Analysis of Prestressed Concrete Bridge I-Girder in Midas

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***Abstract-*** **The concept of pre-stressed concrete appeared in the year 1888. In this present engineering technology, durable and sustainable bridges play an important role for the socio-economic development of the nation. Owners and designers have long recognized the low initial cost, low maintenance needs and long life expectancy of pre-stressed concrete bridges. This is reflected in the increasing market share of pre-stressed concrete, which has grown from zero in 1950 to more than 55 percent today. This growth continues very rapidly, not only for bridges in the short span range, but also for long spans with excessive length which, here therefore, has been nearly the exclusive domain of structural steel. Many bridge designers are surprised to learn that precast, pre-stressed concrete bridges are usually lower in first cost than all other types of bridges coupled with savings in maintenance, precast bridges offer maximum economy. The precast pre-stressed bridge system has offered two principal advantages: it is economical and it provides minimum downtime for construction. This work presents a longitudinal and transverse design and analysis of PSC T-Girder which is 30m in span. The study focuses on PSC Beams, where the beam post-tensioning values, rate of elongation and behaviour can be defined after stressing. The software MIDAS is used to analyse the T-girder. PSC T-beam, have gained wide acceptance in freeway and bridge systems due to their structural efficiency, better stability, serviceability, economy of construction and pleasing aesthetics. PSC beam design is more complicated as structure is more complex as well as needed sophisticated from work. In the place of PSC T-beam if we talk about RCC T- beam geometry is simple and does not have sophisticated in construction. The main code followed in this course is IS: 1343 – 2012 entitled Code of Practice for Pre-stressed Concrete. It is published by the Bureau of Indian Standards. Some provisions of Code IS: 456 - 2000 entitled Code of Practice for Structural Concrete are applicable to Pre-stressed Concrete.**

**Key Words: Midas civil, I-girder, Deck, IRC standards**

## I.INTRODUCTION

Prestressed concrete bridge I-girder deck is a type of bridge construction technique that utilizes pre-tensioned or post-tensioned steel strands to strengthen and reinforced the concrete members. It is a popular and efficient method for constructing bridge decks due to its ability to handle heavy loads and span long distances. I-girder design is commonly used in prestressed concrete bridge decks due to its structural efficiency and aesthetic appeal. The shape of the I-girder provides excellent strength-to-weight ratio, allowing for longer spans and reducing the number of girders required. This, in turn, leads to cost savings and faster construction. Prestressed concrete bridge I-girder decks offer several advantages over traditional reinforced concrete decks. They provide improved durability, increased resistance to cracking, and enhanced resistance to corrosion. The prestressed members also help to reduce long-term maintenance requirements and improve the overall service life of the bridge. Overall, prestressed concrete bridge i-girder decks are a reliable and efficient solution for bridge construction. They offer superior structural performance, durability, and cost-effectiveness, making them a popular choice for various bridge projects worldwide.

Midas civil is the nation of artwork engineering software program that set a kind new prefer for the layout of bridges and civil structures. It capabilities a distinctively person pleasant interface and premiere layout answer capabilities which can account for production levels and time established properties. It's a noticeably evolved modelling and evaluation characteristic permit engineers to triumph over not unusual place demanding situations and inefficiencies of finite detail evaluation. With Midas civil, you may be capable of create excessive best designs with unparalleled stages of performance and accuracy. The post-processor can routinely create load mixtures according with designated layout standards. Changing the sort of show can produce numerous kinds of image output. Basically all of the outcomes may be animated, namely, mode shapes, and time records outcomes of displacements and member forces, dynamic evaluation outcomes and static evaluation outcomes. Midas Civil additionally affords outcomes which can be well matched with MS Excel, which permits the person to check all evaluation and layout outcomes systematically. Midas Civil affords numerous layout test and cargo score functions including: Euro code & AASHTO LRFD Bending, shear & torsional strengths Composite plate girder layout Member forces & stresses for every creation level and max & min strain summations Automatic load mixtures according with numerous layout codes MS Excel layout calculation report.

## II.OBJECTIVE

- ❖ To analysis a prestressed concrete bridge.
- ❖ Determining stresses on girders and deflection on the bridge deck slab using Midas Software.
- ❖ To compare manual analysis and computer aided analysis (Midas Civil).

## III.DESIGN OF POST-TENSIONING PRESTRESSED CONCRETE BRIDGE DECK

Post-tensioned bridge decks are generally adopted for longer spans exceeding 20 m. Bridge decks with precast post-tensioned girders of either T-type in conjunction with a cast in situ slab are commonly adopted for spans exceeding 30 m. Post-tensioning facilitates the use of curved cables, which improve the shear resistance of the girders. The following data's are taken in my design:

Design data:
Span of bridge = 30 m
Width of road = 7.5 m
Kerbs = 600 mm on each side
Footpath = 1.5 m wide on each side
Thickness of wearing coat = 80 mm
Live load = IRC class AA tracked vehicle
For the deck slab, adopt M-20 grade concrete
For prestressed concrete girders, adopt M-50 grade concrete with cube strength at transfer as 40 N/mm$^2$
Loss ratio = 0.85
Spacing of cross girders = 5 m
Adopt Fe-415 grade HYSD bars. Seven-ply HT strands of 15.2 mm diameter
Conforming to IS: 6006–1983 are available for use.
Design the girder as class 1 type structure.
Permissible stress in concrete at transfer = 18 N/mm$^2$
Permissible stress in concrete at service loads = 16 N/mm$^2$
The design should conform to the specifications of the codes IRC: 6-2014,
IRC: 112-2011 and IS: 1343-2012.

Stresses in Concrete and Steel:
For M-20 grade concrete and Fe-415 HYSD bars adopt the following parameters.
$f_{ck}$ = 20 N/mm$^2$ and fy = 415 N/mm$^2$
Mu = 0.138 fck bd$^2$
For M-50 grade concrete and high tensile steel cables
fck = 50 N/mm$^2$
fct = 18 N/mm$^2$
fcw = 16 N/mm$^2$
Ec = 35 kN/mm$^2$
Freyssinet system H.T cables of Type 7K-15 (7 strands of 15.2 mm diameter) in 65 mm cable ducts conforming to IS: 6006-1983

Cross-section of deck
Four main girders are provided at intervals of 2.5 m.
Thickness of deck slab = 250 mm
Wearing coat = 80 mm

Kerbs 600 mm wide by 300 mm deep are provided.
The cross-section of the deck is shown in Fig. 3.1.
The main girders are precast and the slab connecting the girders is cast insitu.
Spacing of cross girders = 5 m
Spacing of main girders = 2.5 m

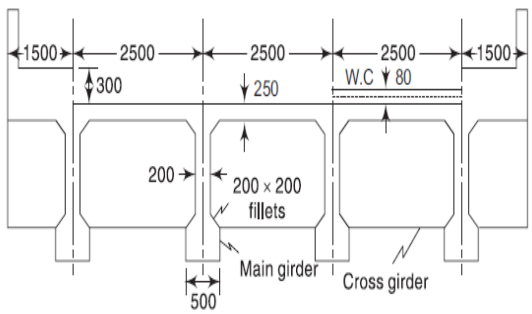


*Fig.3.1 Cross-section of bridge deck*

Design of the interior slab panel

(a) Bending moments

Dead weight of slab = (1 × 1 × 0.25 × 24) = 6.00 $kN/m^2$

Dead weight of WC = (0.08 × 22) = 1.76

Total dead load =7.76 $kN/m^2$

Live load is IRC class AA tracked vehicle. One wheel is placed at the centre of panel as shown in Fig. 3.2

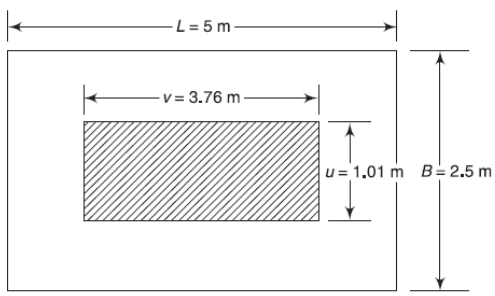


*Fig.3.2.Position of IRC class AA wheel load for maximum bending moment*

u = (0.85 + 2 × 0.08) = 1.01 m

v = (3.60 + 2 × 0.08) = 3.76 m

$$\left(\frac{u}{B}\right) = \left(\frac{1.01}{2.5}\right) = 0.404$$

$$\left(\frac{v}{L}\right) = \left(\frac{3.76}{5.0}\right) = 0.752$$

$$K = \left(\frac{B}{L}\right) = \left(\frac{2.5}{5.0}\right) = 5.0$$

Referring to Pigeaud's curves,

$m_1$ = 0.098 and $m_2$ = 0.02

$M_B = W(m_1 + 0.15\, m_2)$ = 350(0.098 + 0.15 + 0.02) = 35.35 kNm

As the slab is continuous, design BM = 0.8 MB. Design bending moment

Including the impact and continuity factor is given by,

$M_B$ (short span) = (1.25 + 0.8 +35.35) = 35.35 kNm

Similarly, $M_L = W(m_2 + 0.15\, m_1)$

= 350(0.02 + 0.15 +0.098) = 12.14 kNm

$M_L$ (long span) = (1.25 + 0.8 + 12.14) = 12.14 kNm

(b) Shear forces

Dispersion in the direction of span= [0.85 + 2 (0.08 + 0.25)] = 1.51 m

For maximum shear, load is kept such that the whole dispersion is in the span. The load is kept at (51/2) = 0.755 m from the edge of the beam as shown in Fig. 3.3

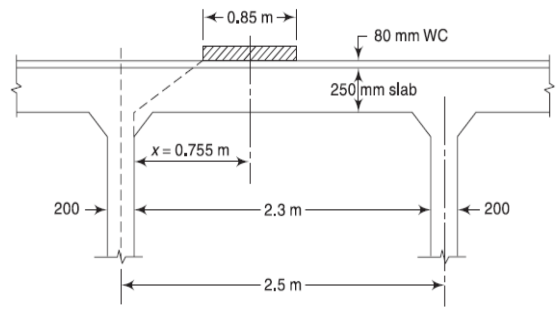


*Fig. 3.3 Position of wheel loads for max shear*

Effective width of the slab=$kx[1 - (x/L)] + b_W$

Breadth of the cross girder = 200 mm

Clear length of panel = (5 – 0.2) = 4.8 m

$$\left(\frac{B}{L}\right) = (4.8/2.3) = 2.08$$

K for the continuous slab is 2.60.

Effective width of the slab = 2.6 + 0.755 [1 – (0.755/2.3)] + 3.6 +

(2 + 0.08) = 5.079 m

Load per metre width = (350/5.079) = 70 kN

Shear force/metre width = 70 (2.3 – 0.755)/2.3 = 47 kN

Shear force with impact = (1.25 + 47) = 58.75 kN

(c) Dead-load bending moments and shear forces

Dead load = 7.76 $kN/m^2$

Total load on panel = (5 +2.5 + 7.76) = 97 kN

*(U/B)* = 1 and *(v/L)* = 1

As the panel is loaded with a uniformly distributed load.

$$k = \left(\frac{B}{L}\right) = \left(\frac{2.5}{5}\right) = 0.5 \ and \ \left(\frac{1}{k}\right) = 2.0$$

From Pigeaud's curves (refer to Fig. 3.5),

$m_1$ = 0.047, $m_2$ = 0.01

$M_B$ = 97 (0.047 + 0.15 + 0.01) = 4.70 kNm

$M_L$ = 97 (0.01 + 0.15 + 0.047) =1.65 kNm

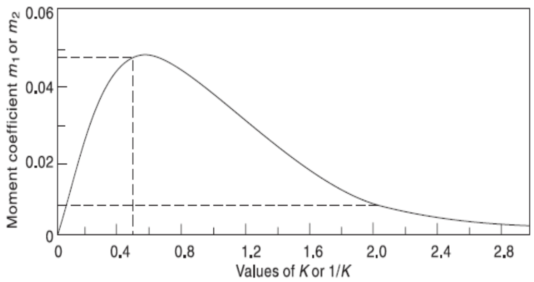


*Fig. 3.4 Moment coefficients for slabs completely loaded with uniformly distributed load, coefficient is $m_1$ for k and $m_2$ for 1/k*

Design BM, including the continuity factor,
$M_B$ = (0.8 + 4.7) = 3.76 kN m
$M_L$ = (0.8 +1.65) = 1.32 kN m
Dead-load shear force = (0.5 × 7.76 +2.3) = 8.924 kN

(d) Design Service Load Moments and Shear Forces
Short span moment = $M_B$ = (35.35 + 3.76) = 39.11 kNm
Long span moment = $M_L$ = (12.14 + 1.32) = 13.46 kNm
Shear Force = V = (Vg + $V_L$) = (8.92 + 58.75) = 67.67 kN
Design ultimate load moments and shear forces are computed by applying appropriate load factors to the service load moments.
Total design short span ultimate moment ($M_{Bu}$)
= [1.35 $M_d$ + 1.5 $M_L$]
= [(1.35 × 3.76) + (1.5 ×35.35)]
= 58.1 kN.m/m
Total design long span ultimate moment ($M_{Lu}$)
= [(1.35 × 1.32) + (1.5 × 12.14)]
= 20 kN.m/m
Total design ultimate shear force
= $V_u$ = [(1.35 × 8.92) + (1.5 × 58.75)]
= 90.26 kN

Design of Deck Slab and Reinforcements
Effective depth of slab required
=158mm
Adopt effective depth, d = 200 mm and overall depth of 250 mm.
Using 12 mm diameter bars,
Effective depth provided = 200 mm

For short span, provide 12 mm diameter bars at 120 mm centers ($A_{st}$ provided = 942 mm2)
For long span, provide 10 mm diameter bars at 150 mm centers.

Check for Ultimate Flexural Strength

$$M_u = (0.87 \times 415 \times 942 \times 200)\left[1 - \frac{942 \times 415}{1000 \times 200 \times 20}\right]$$

=61.42kNm>58.1kNm
Hence safe.

Check for Ultimate Shear Strength
The ultimate shear strength of the reinforced concrete deck slab is checked by using the equation specified in IRC: 112-2011, Clause 10.3

$V_{dc}$=96kN>90.26kN
(Hence safe)

Design of longitudinal girders

**(a)** Reaction factors Using Courbon's theory, the IRC class AA loads are arranged for maximum eccentricity as shown in Fig. 3.6. Reaction factor of outer girder A is

$$R_A = \frac{W}{4}\left\{1 + \frac{4I \times 3.75 \times 1.1}{(2I \times 3.75^2) + (2I \times 1.25^2)}\right\}$$

=0.764$W_1$

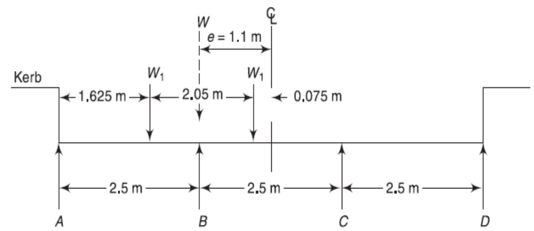


*Fig. 3.6 Transverse disposition of IRC class AA tracked vehicle*

Reaction factor for inner girder B

$$R_B = \frac{2W}{4}\left\{1 + \frac{4I \times 3.75 \times 1.1}{(2I \times 3.75^2) + (2I \times 1.25^2)}\right\}$$

=0.588$W_1$

If W = axle load = 700 kN
$W_1$ = 0.5 W
$R_A$ = (0.764 + 0.5 W) = 0.382 W
$R_B$ = (0.588 + 0.5 W) = 0.294 W

(b)Dead load from slab per girder
The dead load of the deck slab is calculated with reference to Fig. 3.7.

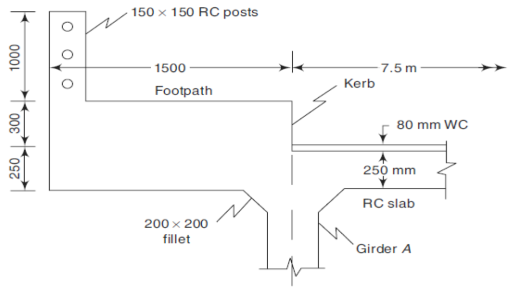


*Fig. 3.7 Details of footpath, kerb, parapet and keck slab*

Weight of
(i) Parapet railing =0.92 kN/m
(ii) Footpath and kerb = (0.3 × 1.5 × 24) = 10.08
(iii) Deck slab = (0.25 × 1.5 × 24) = 9.00
Total = 20.00 kN/m

Total dead load of the deck = [(2 × 20) + (7.76 × 7.5)] = 98.2 kN/m. It is assumed that the deck load is shared equally by all the four girders.
= (98.2/4)=24.55kN/m

(a)Dead load of the main girder
The overall depth of the girder is assumed to be 1800 mm at the rate of 60 mm for every metre of span.
Span of the girder = 30 m
Overall depth = (60 × 30) = 1800 mm
The bottom flange is selected so that four to six cables are easily accommodated in the flange. The section of the main girder selected is shown in Fig. 3.8.

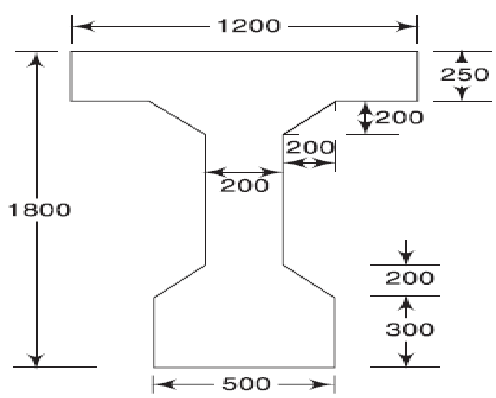


*Fig. 3.8 Cross-section of prestressed concrete girder*

Dead weight of the rib = (1.15 × 0.2 × 24) = 5.52 kN/m
Dead weight of the bottom flange = (0.5 × 0.4 × 24) = 4.80
Total = 10.32 kN/m

Weight of the cross girder = (0.2 × 1.25 × 24) = 6 kN/m

(d) Dead-load moments and shears in the main girder
Reaction from deck slab on each girder = 24.55 kN/m
Weight of the cross girder = 6 kN/m
Reaction on the main girder = (6 × 2.5) = 15 kN/m
Self-weight of the main girder = 10.32 kN/m
Total dead load on the girder = (24.55 + 10.32) = 34.87 kN/m
The maximum dead-load bending moment and shear force is computed using the loads shown in Fig. 3.9. Thus,
$M_{max}$ = [(0.125 × 34.87 × 302) + (0.25 × 15 × 30) + (15 × 10) + (15 × 5)]
= 4261 kN m

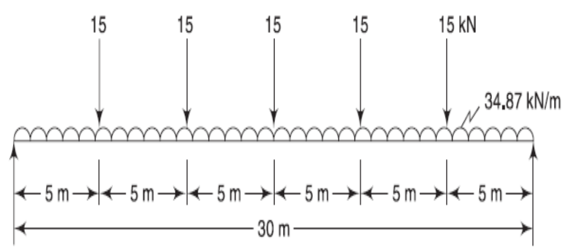


*Fig. 3.9 Dead load on main girder*

Dead-load shear at support,
$V_{max}$ = [(0.5 ×34.87× 30) + (0.5 × 75)] = 561 kN

(e) Live-load bending moments in the girder
Span of the girder = 30 m
Impact factor (class AA) = 10%
The live load is placed centrally on the span as shown in Fig. 3.10. Bending moment at the centre of span = 0.5(6.6 + 7.5) 700 = 4935 kN/m

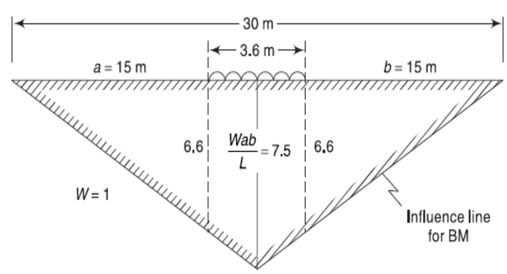


Fig. 3.10 Influence line for bending moment in girder

BM, including the impact and reaction factors, for the outer girder is,

Live-load BM = (4935 × 1.1 ×0.382) = 2074 kN m
For inner girder, BM = (4935 × 1.1 × 0.294) = 1596 kN m

(f) Live-load shear forces in girders
For estimating the maximum live load shear in the girders, the IRC class AA loads are placed as shown in Fig. 4.11.

Reaction of W2 on girder B $=\left[\frac{(350\times0.45)}{2.5}\right] = 63kN$

Reaction of W2 on girder A = (350 × 2.05)/2.5 = 287 kN
Total load on girder B = (350 + 63) = 413 kN
Maximum reaction in girder B = [((413×28.2))/30] =388kN
Maximum reaction in girder A = [((287×28.2))/30] =63kN

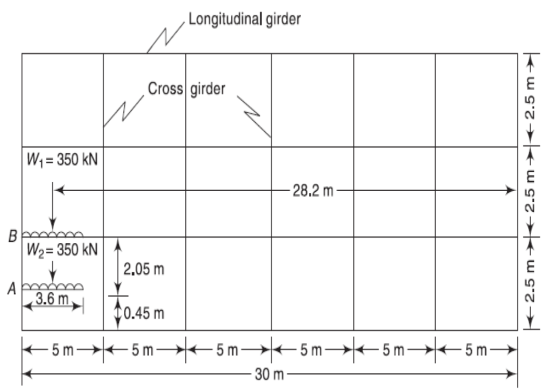


*Fig. 3.11 Position of IRC class AA loads for maximum shear*

Maximum live-load shear with impact factor in the inner girder
= (388 ×1.1) = 427 kN
Outer girder = (270 × 1.1) = 297 kN

Table 3.1 Design And bending moments in main girder

| Bending moment | DL BM | LL BM | Total BM | Units |
|---|---|---|---|---|
| Outer Girder | 4261 | 2074 | 6335 | kNm |
| Inner Girder | 4261 | 1596 | 5857 | kNm |
| Shear Force | DL BM | LL BM | Total BM | Units |
| Outer Girder | 561 | 297 | 858 | kNm |
| Inner Girder | 561 | 427 | 988 | kNm |

Properties of main girder section
The main girder section is as shown in Fig. 3.12 for computational purposes.

The properties of the section are:
$A = (73 \times 10^4)\ mm^2$
$y_t = 750$ mm
$y_b = 1050$ mm
$I = (2924 \times 10^8)\ mm^4$

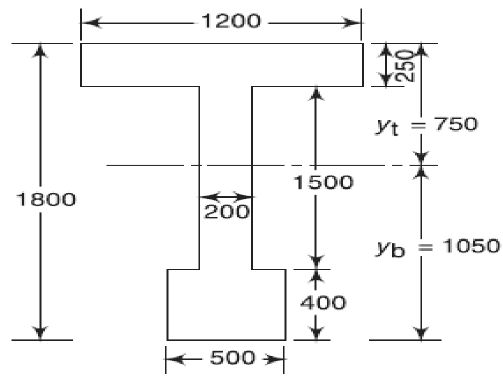


*Fig.3.12 Cross-section of main girder*

(i) Check for minimum section modulus
$f_{ck} = 50\ N/mm^2$
h = 0.85
$f_{ct} = 18\ N/mm^2$
$M_g = 4261$ kN m
$f_{ci} = 40\ N/mm^2$
$M_q = 2074$ kN m
$f_{tt} = f_{tw} = 0$
$M_d = (M_g + M_q) = 6335$ kN m
$f_{cw} = 16\ N/mm^2$
$f_{br} = (hf_{ct} - f_{tw}) = (0.85 \times 18 - 0) = 15.3\ N/mm^2$
$f_{tr} = (f_{cw} - hf_{tt}) = 16\ N/mm^2$
$f_{inf}=26.80 N/mm^2$
Hence, the section provided is adequate.

(ii) Prestressing force
Allowing for two rows of cables, cover required = 200 mm
Maximum possible eccentricity, e = (1050 – 200) = 850 mm
Prestressing force is obtained as,
P=6053kN

Using the Freyssinet system, anchorage type 7K–15 (seven strands of 15.2 mm diameter) in 65 mm cables ducts, (IS: 6006–1983) (Appendix-3),
Force in each cable = (7 × 0.8 ×260.7) = 1459 kN
Number of cables $=\left(\frac{6053}{1459}\right)=5$
Area of each strand = 140 $mm^2$
Area of seven strands in each cable = (7 ×140) = 980 mm2
Area of strands in five cables $A_p$ = (5 × 980) = 4900

mm2

The cables are arranged at the centre of span section as shown in Fig. 3.13.

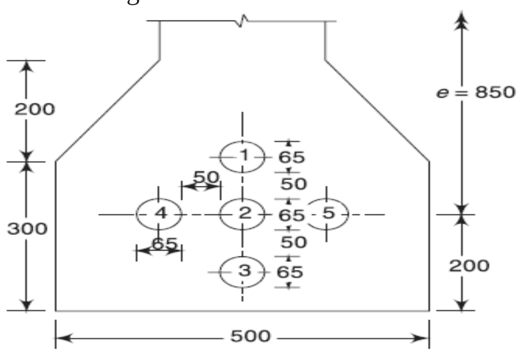


*Fig. 3.13 Arrangement of cable at centre-of-span section*

(iii) Permissible tendon zone

At the support section,

e=445mm

The five cables are arranged to follow a parabolic profile, with the resultant force having an eccentricity of 180 mm towards the soffit at the support section.

The position of cables at the support section is shown in Fig. 3.14.

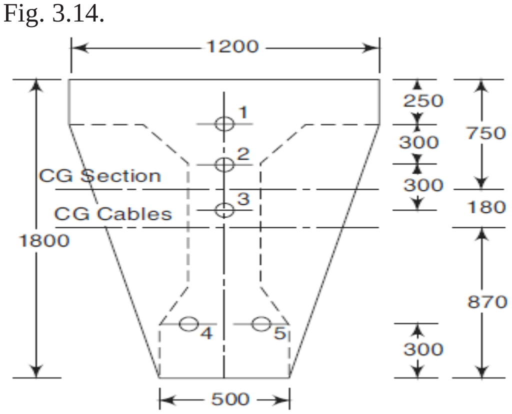


*Fig. 3.14 Arrangement of cables at support section*

Check for stresses

For the centre of span section, we have

P = 6053 kN

$Zt = 3.89 \times 10^8 \, mm^3$

e = 850 mm

h = 0.85

$A = 0.73 \times 10^6 \, mm^2$

Mg = 4261 kN m

$Zb = 2.78 \times 10^8 \, mm^3$

Mq = 2074 kN m

At transfer stage,

$\sigma_t = 6.02 N/mm^2$

$\sigma_b = 11.47 N/mm^2$

At working load stage,

$\sigma_t$ =12.09N/mm2

$\sigma_b$ =-0.01N/mm2 (Tension)

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

Check for ultimate flexural strength

For the centre-of-span section,

$A_p = (5 \times 7 \times 140) = 4900 \, mm^2$

b = 1200 mm

d = 1600 mm

$b_w = 200$ mm

$f_{ck} = 50 \, N/mm^2$

$f_p = 1862 \, N/mm^2$ and $D_f = 250$ mm

According to the specifications of IRC: 6-2014, the design ultimate moments and shear forces in the girder are calculated by applying the partial safety factors for dead and live loads as follows:

The required design ultimate bending moment in the outer girder is evaluated as,

$M_u = [1.35 \, M_d + 1.5 \, M_L]$

$= [(1.35 \times 4261) + (1.5 \times 2074)$

= 8864 kN.m

According to IS: 1343–2012, the ultimate flexural strength of the centre-of span section is computed as follows:

Ap = (Apw + Apf)

$A_{pf} = 3021 mm^2$

$A_{pw} = 1879 mm^2$

Post-tensioned beams with effective bond, we have

$f_{pb} = (0.93 \times 0.87 \times 1862) = 1506 \, N/mm^2$

$x_u = (0.43 \times 1600) = 688$ mm

$Mu = [f_{pb}A_{pw}(d - 0.42 \, x_u) + 0.45 f_{ck}(b - b_w)D_f \, (d - 0.5D_f)]$

$= [1506 \times 1879 \, (1600 - 0.42 \times 688) + 0.45 \times 50 \times 1000 \times 250 \, (1600 - 0.5 \times 250)]$

$= 12006 \times 10^6$ N mm = 12006 kN m

Mu = 12006 kN.m > 8864 kN.m

(Hence safe)

Check for Ultimate Shear Strength

Ultimate shear force = Vu = $[(1.35 \, V_g + 1.5 \, V_q)]$

$= [(1.35 \times 561) + (1.5 \times 4.27)]$

= 1398 kN

The design shear resistance of the support section is calculated by using the equation specified in IRC: 112-2011 clause 10.3 as,

Provide nominal stirrups of 10 mm diameter 2 – legged stirrups of Fe-415 HYSD bars at a maximum spacing of 300 mm throughout the span according to the specifications of IRC: 112-2011.

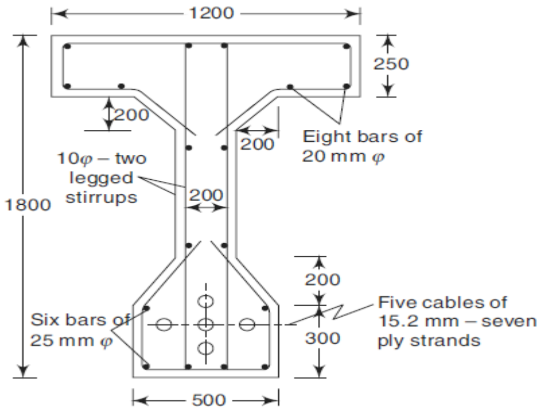


*Fig. 3.15 Reinforcement details at centre-of-span section*

Design of End Block

Solid end blocks are provided at end supports over a length of 1.5 m. Typical equivalent prisms on which the anchorage forces are considered to be effective are detailed in Fig. 21.26.

In the horizontal plane, we have the data,

$$PK = 1459 \text{ kN},$$

$$2Y_{po} = 225 \text{ mm}$$

$$2Y_o = 900 \text{ mm}$$

Hence, the ratio $(Y_{po}/Y_o) = (112.5/450) = 0.25$

Interpolating from Table 21.3, the bursting tension is computed as,

$F_{bst} = (0.26 \times 1459) = 380$ kN

Area of steel required to resist this tension is obtained as,

$A_s = [(380 \times 10^3) / (0.87 \times 415)] = 1052 \text{ mm}^2$

Provide 10 mm diameter bars at 100 mm centres in the horizontal direction.

Reinforcements are provided in the form of a mesh both in the horizontal and vertical directions as shown in Fig. 3.16.

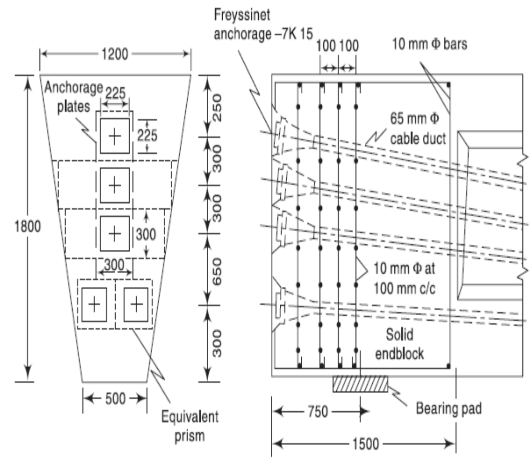


*Fig. 3.16 Equivalent prisms and anchorage zone reinforcement*

## IV.ANALYSIS OF POST-TENSIONING PRESTRESSED CONCRETE BRIDGE DECK

The analysis of post- tensioned prestressed concrete bridge deck is analysed using MIDAS software. In this, the results obtain in the software can be discussed.

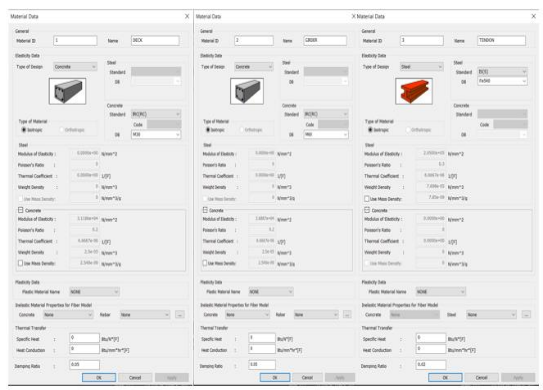

*Fig 4.1 Material data*

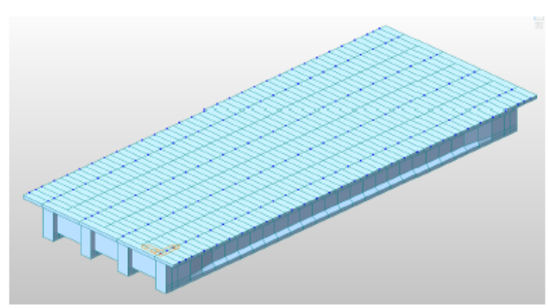

*Fig 4.2- 3D model*

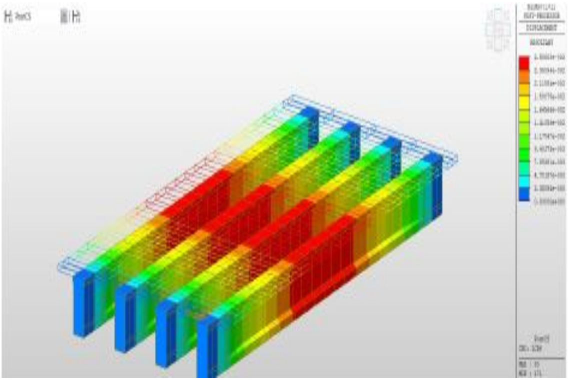

*Fig 4.3 Girder deflection*

## V.CONCLUSION

From the comparison of result obtained from MIDAS and manual analysis almost all the elements carried out on them including the deflections, shear forces and bending moment.

- ❖ It is very easy and safe to design and analysis the prestressed post tensioned girders and deck slab using Midas civil.
- ❖ Midas civil is the one step solution for the analysis and design of any model of structures and especially bridges.
- ❖ When compared to manual analysis and MIDAS software gives large volumes of data and time also saved.
- ❖ In manual analysis sometimes errors will occurred, when we use software it works FEM method so errors can be reduced.

## REFERENCE


1. IS 456-2000: Plain and Reinforced Concrete – Code of practice
2. IS 1343:2012 (part-1 ): Code of Practice of Prestressed Concrete
3. IRC 6-2016: Standard Specification and Code of Practise for Road Bridges (Load and Stresses)
4. IRC 18-2000: Design criteria for Prestressed Concrete Road Bridges (Post-Tensioned Concrete)
5. IRC 21-2000: "Standard Specification and Code of Practice or Road Bridge section 3, cement concrete (plain and reinforced) The Indian road congress, New Delhi, India, 2000.
6. IRC 112-2011: "Code of Practice for Concrete Road Bridges", Indian road congress, New Delhi, India 2011.
7. IS 1343-1980" Indian Standard Code of Practice for Pre-stressed concrete".
8. IS 1785-1983 "Indian Standard Specifications for Plain and hard drawn steel wire".
9. "Design of prestressed concrete structure" – N. Krishnaraju
10. "Design of bridges" -N. Krishna raja.