Design of Prestressed Concrete Bridge Cross Over A Cannol At Gandhi Janasangam

Shaik Nadhim[1], Vijaya Prathima[2], Rajeswari Isnakula[3]
[1, 2, 3] Department of Civil Engineering
[1, 2, 3] Geethanjali Institute of Science And Technology

Abstract- *The present project is about the design of Pre-stressed concrete two lane Road Bridge instead of single lane bridge over Kanigiri main canal at Gandhi Jana Sangam, which is in a condition of collapsing state. The bridge is damaged at several places and cracks appeared. The bridge was constructed in 1886 (i.e., 130 years ago). This bridge is the bomby highway bridge it is connected to different places such as Sangam, Atmakur, Udaygiri, Pamuru, Proddutur, Badvel, Bellary,Kurnool, Guntakal, Mantralayam, Hubli. First we went to the site and observed the bridge. We observed the bridge thoroughly and found cracks at several places. We did surveying to know the specifications of the bridge. We took photograhs of the damaged portion of the bridge. Then we decided to design a two lane pre-stressed concrete bridge in order to meet the traffic requirement as it is a single lane bridge with heavy traffic movement.*

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 in excess of 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 offered two principal advantages: it is economical and it provides minimum downtime for construction. Pre-stressing is the application of an initial load on the structure so as to enable the structure to counteract the stresses arising during its service period.

I. INTRODUCTION

A bridge is a structure built to span physical obstacles without closing the way underneath such as a body of water, valley, or road, for the purpose of providing passage over the obstacle. There are many different designs that each serve a particular purpose and apply to different situations. Designs of bridges vary depending on the function of the bridge, the nature of the terrain where the bridge is constructed and anchored, the material used to make it, and the funds available to build it.

Components of a Bridge:

The main components of a bridge are:
a) Super structure
b) Bearings, bed blocks
c) Substructure

Components which lie above the level of bearings are grouped as SUPERSTRUCTURE, these parts which lie below the level of bearings are classified as SUBSTRUCTURE.

Super structure: Comprises of decking consisting of bridge floor (a slab or a plate or a Grid), girders or trusses, cables, etc., supporting the floor, cables connected to pylons and the deck as in cable-stayed bridges, handrails, guard stones etc.

Bearings : The bearings transmit the load received from the decking on to the substructure and are provided for distribution of the load evenly over the substructure material, which may not have sufficient bearing strength to bear the super structure load directly. Bearings also facilitate the horizontal and angular deformation as per the analysis.

Sub structure: Piers, Abutments, wing walls, return walls and foundations for the same. The foundations may be of the open type, pile foundations and well or caisson foundations.

River training works like revetment of slopes at abutments, appprons at bed level. Approaches to the bridge to connect it properly to the lead embankments or roads on either side.

BRIDGE INVESTIATION

came to know that the bridge over Kanigiri main canal at Gandhi Jana Sangam, is in a condition of collapsing state. The bridge was constructed in 1886 (i.e., 130 years ago). The bridge is damaged at several places and cracks appeared.

This bridge is the part of bomby highway and it is way for different places such as Sangam, Atmakur, Udaygiri, Pamuru, Proddutur, Badvel, Bellary,Kurnool, Guntakal, Mantralayam, Hubli.

OBSERVATION OF THE BRIDGE:

First we went to the site and observed the bridge. We observed the bridge thoroughly and found cracks at several places and conducting non distractive test like rebound hammer test. In this time e observe bridge is near collapse condition and it cannot do any repair of this bridge.

Specifications of at present Bridge:

Length of the bridge = 60 m
Width of Bridge = 6 m
Single Lane Bridge
No. of Spans = 5

Figure 1.

Figure2.

Figure 3.

Figure 4.

II. FACTORS INFLUENCING SELECTION

The following are among the more important factors that should be considered when selecting the type of Road Bridge to be constructed at a particular site:

- Road geometry

- Bridge length
- Span length and configuration
- Method of construction
- Economics
- Durability/maintenance
- Aesthetics
- Possible future widening
- Type of crossing
- Site and foundation conditions
- Clearances (high/wide load route)

It should be recognised, however, that the above list is not exhaustive and the items are interrelated and selection of a bridge type should involve consideration of all relevant factors.

PRE STRESSED CONCRETE BRIDGE

Bridge is life line of road network, both in urban and rural areas. With rapid technology growth the conventional bridge has been replaced by innovative cost effective structural system. One of these solutions present a structural PSC system that is T-Beam. 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. Bridge design is an important as well as complex approach of structural engineer. As in case of bridge design, span length and live load are always important factor. These factors affect the conceptualization stage of design. The effect of live load for various span are varied. In shorter spans track load govern whereas on larger span wheel load govern. Selection of structural system for span is always a scope for research. Structure systems adopted are influence by factor like economy and complexity in construction. The 24 m span as selected for this study, these two factor are important aspects. In 24 m span, codal provision allows as to choose a structural system i.e. PSC T- beam. This study investigates the structural systems for span 24 m and detail design has been carried out with IRC loadings and IS code books. The choice of economical and constructible structural system is depending on the result.

BRIDGE LOADING STANDARDS

Evolution of Bridge Loading Standards:

The first loading standard (IRC: 6) in India was published by the Indian Roads Congress in 1958 and subsequently reprinted in 1962 and 1963. The Section-II of the code dealing with loads and stresses was revised in the second revision published in 1964. The metric version was introduced in the third revision of 1966. The IRC: 6 Code has been revised to include the combination of loads, forces and permissible stresses in the Fourth revision published in 2000s

PRE-STRESSED CONCRETE BRIDGES

Pre-stressed concrete is ideally suited for the construction of medium- and long-span bridges. Ever since the development of pre-stressed concrete by Freyssinet in the early 1930s, the material has found extensive application in the construction of long-span bridges, gradually emplacing steel which needs costly maintenance due to the inherent disadvantages of corrosion under aggressive atmospheric conditions.

Solid slabs are used for the span range of 10 to 20 m. while T-beam slab decks are suitable for spans in the range of 20 to 40 m. Single or multi cell box girders ac preferred for larger spoils of the order of 30 to 70 m. Pre-stressed concrete is ideally suited for long -span continuous bridges in which precast box girders of variable depth are used for spans exceeding 50 m. Pre-stressed concrete has been widely used throughout the world for simply-supported, continuous, balanced cantilever, suspension, hammer-head and bridle-chord type bridges in the span range of 20 to 500 m.

III. DESIGN OF BRIDGE COMPONENTS:

(A) Design of Post tensioned Pre-stressed Concrete continuous beam and slab bridge deck for a highway crossing:

Two continuous spans of 30 m each.
Width of road =2 lane (7.5 m).
Kerb on each side = 1 m.
For pre stressed concrete girders adopt M-60 grade concrete with cube strength transfers as 40 N/mm².
For cast in-situ deck slab adopt M-20 grade concrete.
High tensile standards of 15.2 mm diameter conforming to IS:6006-1983 and FE-415 HYSD bars are used.
Live load = IRC class A-A tracked vehicles

(A) CROSS SECTION OF DECK:

4 main girders are provided at 2.5 m intervals
Thickness of deck slab = 250 mm
Wearing coat = 70 mm

Kerb 1000 mm wide by 300 mm deep are provided at each end .
The overall depth of main girders is assumed at 50 m per meter of span
Overall depth of girder = 50×430 = 1500 mm
Thickness of top and bottom flange is 800 mm
Thickness of web is = 200 mm
The main girders are pre cast and the slab connecting the girder is cast in-situ.

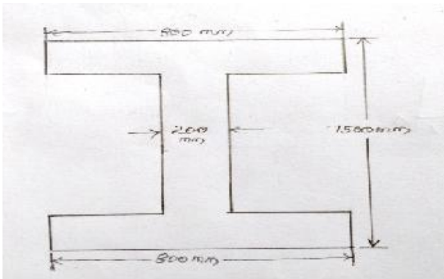

Figure 5.

Design of interior slab panel:

The slab panel 2.5 m by 5 m is supported on all four sides

Loads:

Dead load of slab = 1×1×0.25×24 = 6.00 KN/m²
Dead load of wearing coat = 0.08×22 = 1.76 KN/mm²
Total dead load = 7.76 KN/m²

Bending Moment:

Live load is IRC class A-A tracked vehicle alone wheel is placed at the center of panel
As the slab is continuous design B.M = 0.8 Mb and ML. Design the including impact and continuity factor is given by
Mb (short span) = (1.25×0.8×35.35) = 35.35 KNm
ML (long span) = (1.25×0.8×12.14) = 12.14 KNm

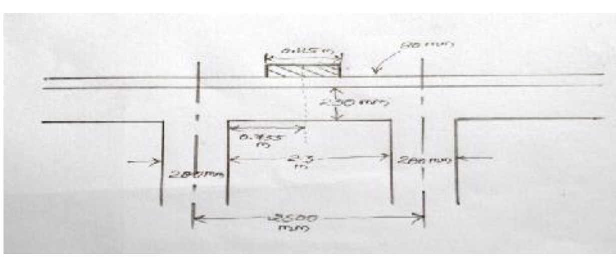

Figure 6.

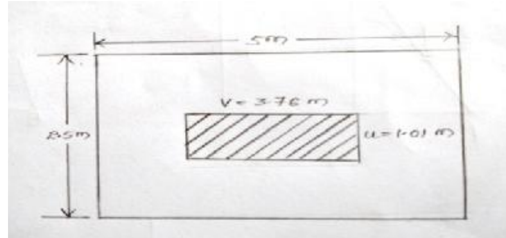

Figure 7.

Shear Force:

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 span . the load is kept at (1.51/2) = 0.755 m from the edge of the beam
Shear force / meter width = 71.150[2.3-0.755]/2.30 = 47.794 KN
Shear force with impact = 1.25×47.794 = 59.742 KN

Dead Load and Bending Moments and Shear Forces:

Design B.M including continuous factor MB = 0.8×4.70 = 3.76 KN m
ML = 0.8×1.65 = 1.32 KNm
Dead load shear force = 0.5×7.76×2.3 = 8.944 KN

Total Design Moment and Shear Force:

Total MB = (35.35+3.76) = 39.1 KNM
ML = (12.14+1.32) = 13.46 KNM
Total shear force Vx = 67.674 KN

Effective Depth:

D =√M/QB
= √39.11×10⁵×10/0.762×1000
= 226 mm≈ 230 mm
Adopt effective depth d = 230mm

Area Of Steel :

AST = [M/Σst×jd]
= 938 mm²
Use 12mm diameter bars
Spacing s = 1000ast/Ast
= [1000×Π/4×12²]/938
= 120.57mm≈ 120mm c/c
Provide 12 mm bars at 120 mm centers
Effective depth along long span using 12 mm diameter bars
Use 10mm diameter bars at 150 mm centers

Check for shear:

Nominal shear = Jv = V/bd=0.242 N/mm2
Jc = 0.25 N/mm² for a slab of overall depth 250mm read the value of constant k= 1.1 from table 3.10
The permissible shear stress in concrete slab = kJc = 0.275
As ζv < ζc Hence shear is safe.

(B) DESIGN OF GIRDER

Cross section of deck:
Four main girders are provided at 2.5 m intervals
Thickness of deck slab is 250 mm
Wearing coat = 80 mm
Kerb 1000 mm wide by 300 mm deep is provided at each end.
Spacing of girders =5 m
The overall depth of main girders is assumed at 50 mm per meter of span.
Overall depth = 50×30 =1500 mm
Thickness of top and bottom flanges = 350 mm
Width of flange = 600 mm
Thickness of web = 200 mm

Section properties of main girders:

Cross sectional area A = 0.58 m²
Second moment of area I= 1.516×1011 mm4 =0.1509 m4
yb = yt = (1500/20) = (1.5/2) = 0.75 m
Section modulus = ZB = Zt = (I/fb (or) yt) = 0.201×109 mm³
The main girders are precast and the deck slab is cast insitu.

Loads acting on main girder:

The total dead load (g) = 20 + 14.5 + 5 = 39.5 ≈ 40 KN/m

Dead Load Moment and Shear Force:

Dead load moment at mid support section MgB = 4500 KNm
Dead load moment at mid span section MgD = 2556 KNm
Dead load shear is maximum near support section and is computed as

$$V_g = 0.62 \times g \times L$$
$$= 744 \text{ KN}$$

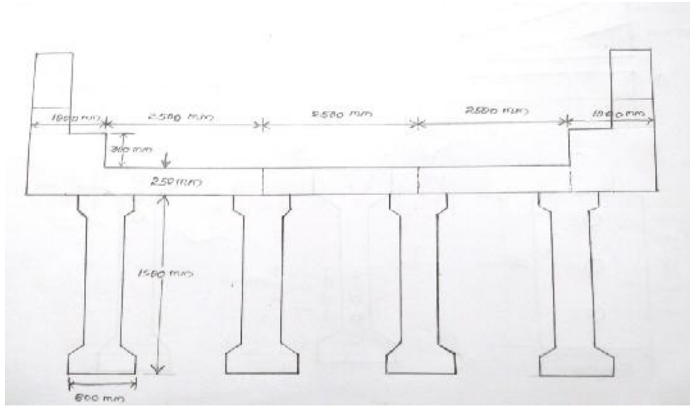
Figure 8. Bridge elevation

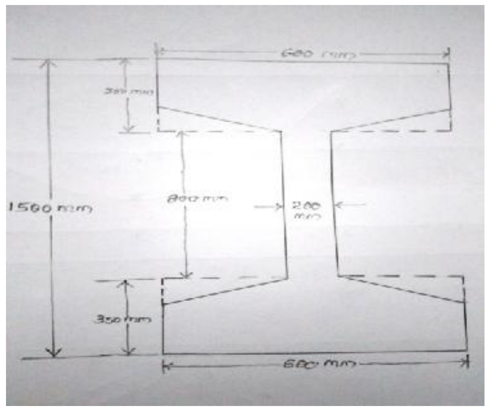

Figure 9. Girder cross section

Live load bending moment in girder:

Referring to the influence line for bending moment at mid span section D.

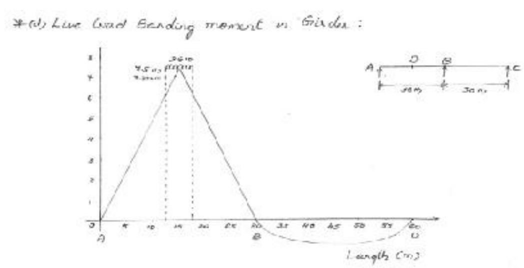
Figure 10.

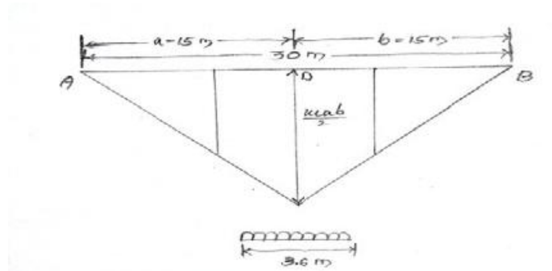

Figure 11.

The maximum live load moment at mid span is computed as

MD = (7.5+7.392)/2 ×700

= 5212.2 KNm

Similarly from figure using the influence line for bending moment at mid support. The live load bending moment at support B is computed as

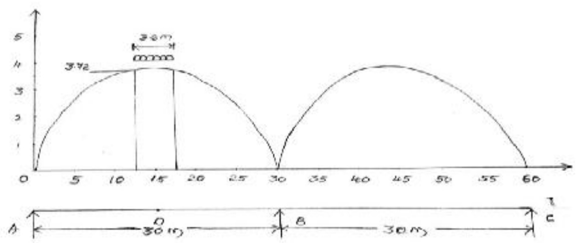

Figure 12.

MB = 3.72 × 700 = 2604 KNm

The live load bending moment including the reaction factor and impact factor for the exterior girder are

MqD = 0.382×1.1×5212.2 = 2190.166 KNm

MqB = 2604×1.1×0.382 = 1094.20 KNm

Live load shear forces in girder:

The maximum live load shear develops in the interior girders when the IRC class AA loads placed near girder.

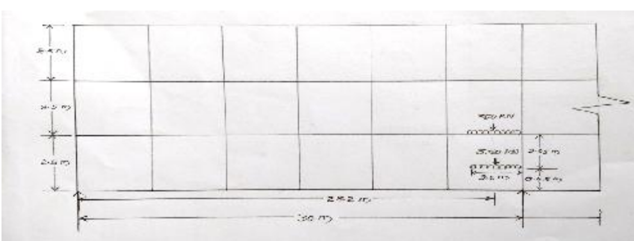

Figure 13.

Table 1.

	SHEAR FORCES(Inner girder)			
	Dead load shear force (V_g)	Live load shear force	Total shear force (V_g+V_q)	Required($1.5V_g$+ $2.5V_q$)
Near mid support section	744 KN	427.042 KN	1171.042 KN	1116+1067.605 =2183.605 KN
	BENDING MOMENTS (OUTER GIRDER)			
	Dead load bending	Live load bending moment (M_q)	Total working load bending moment(M_g+M_q)	Required bending moment ($1.5M_g$+$2.5M_q$)
Mid span section (D)	2556	2190.166KNm	4746.166 KNm	3834+5475.415 9309.415 KNm
Mid support section (B)	4500	1094.20 KNm	5594.2 KNm	6750+2735.5 9485.5 KNm

Check for minimum section modulus:

$M_d = (M_g+M_q)$ = 4500 + 1094.20 =5594.2KNm

$f_{br} = (\eta f_{ct} - f_{tw})$ = 16N/mm²

$f_{int} = \left(\frac{ftw}{\eta}\right) + \left(\frac{Md}{\eta Zd}\right)$ == 34.789 N/mm²

$Z_b \geq \left(\frac{Mq+(1-\eta)Mg}{fbr}\right)$

$Z_b \geq 0.124\times10^9$ mm³ < 0.201×10^9 mm³

Prestressing force:

Hence the provided section is adequate. For the two continous spans AB and BC a concordant cable profile is selected such that the secondary moments are zero

Assume cover is 250 mm

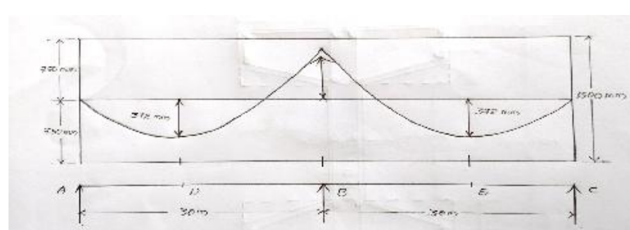

Figure 14.

Prestressing force is obtained from the relation:

$$P = \frac{A \times fint \times ZB}{Zb + Ae}$$

= 8258.655 KN

Using Freyssinet system anchorage type 19k -15 (19 standards on of 15.2mm diameter) in 95mm cable duct.
Force in each cable = 19×0.8×260.7 = 39.62 KN
Provide 3 cablescarrying an intial prestressing force

P = (3×3962) = 11886 KN

Area of each strand of 15.2 mm diameter= 140 mm²
Area of 19 strands in each cable = 19×140
= 2660 mm²

Total area in 3 cables Ap= 3×2660 = 7980 mm²

The cables are arranged in a parabolic concordant profile so that their centroid has an eccentricity of 500mm towards top fiber at mid support B are an eccentricity of 372 mm towards the bottom at mid span section D.

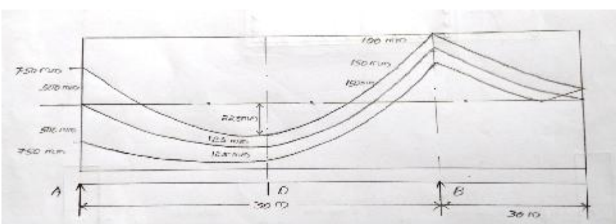

Figure 15.

Center Of Span Section:

(P/A) = $(11886\times10^3)/(0.58\times10^6)$ = 20.49mm²

(Pe/Z)= $(11886\times10^3\times372)/0.201\times10^9$ = 21.99mm²
(Mg/Z)= $2556\times10^6/0.210\times10^9$ = 12.716mm²
(Mq/Z) = $2190.166\times10^6/0.201\times10^9$ = 10.896mm²
At the stage of transfer
At top σ_t = (P/A - Pe/Z + Mg/Z) = 11.216mm²
At bottom σ_b = (P/A + Pe/Z – M_g/Z) = 29.764N/mm²
At the service load state σ_t = (η(P/A) – η(Pe/Z)+(Mg/Z)+(Mq/Z)) = 22.412 mm²
σb = (η(P/A) +(Pe/Z) –(Mg/Z) – (Mq/Z)) = 10.328N/mm²

Mid Support Section:

P/A = 20.49 N/mm² Pe/Z = 21.99 N/mm²

Mg/Z = $(4500\times10^6)/0.201\times10^9$ = 22.38 N/mm²

Mg/Z = $(1094.20\times10^6)/0.201\times10^9$ = 5.443 N/mm²

At the stage of transfer

σt = (20.49 + 21.99 – 22.38) = 20.1 N/mm²

σb = (20.49 – 21.99 + 22.38) = 20.88 N/mm²

At the service load stage

σt = (0.8(20.49+21.99) – 22.38 – 5.443) = 6.161N/ mm²

σb = (0.8(20.49 – 21..99) + 22.38 + 5.443) = 26.623 N/mm²

The stresses are within permissible limits.

Check for ultimate flexural strength:

Table 2.

Type of failure	centre span section	Mid Support section
Failure by yielding of steel Mu	15004 KNm	16716.105 KNm
Failure by crushing of concrete Mu	6901 KNm	8821.60 KN m

The ultimate strength is nearly equal to the mid span.

A_{us} = $(M_{bal}/0.87f_y(d-0.5D_f))$ = 5336.46 mm²

Provide 9 bars of 25mm dia (A_s = 5750 mm²)

Check for ultimate shear strength:

Design shear force = V_u = 2183.605 KN

According to IRC: 18 – 1985 the ultimate shear resistance of the support section un cracked in flexure is given by
V_{cw} = 742.824KN < 2183KN

Unbalance shear = 2183 – 742.824 = 1440.176KN

Using 16mm diameter 2 legged stirrups at a spacing of 80mm centers near supports gradually increased to 200mm towards the centre of span.

Design of end blocks:

Solid end blocks of 600mm by 1500mm are provided for a length of 2m from each of the two end faces.
Brusting tension $F_{bst} = 0.17 \times 3962 = 673.54$KN
Use Fe-415 HYSD bars

$$A_{st} = \frac{673.54 \times 10^3}{0.87 \times 415} = 1865.50\text{mm}^2$$

Provide 16mm diameter bars at 150mm centers in the horizontal plane distributed in the region from $0.2y_o$ to $2y_o$.

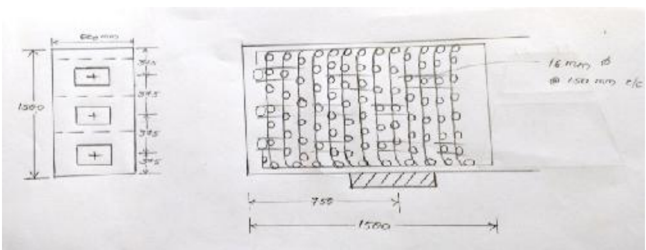

Figure 16.

(C) DESIGN OF PIER:

Dead load from each pier = 40KN
Reaction due to live load on one span = 700 KN
Breaking forces = 140KN
Wind pressure on the pier = 2.4KNm²
Materials of pier 1:3:6 cement concrete
Density of concrete = 25KN/m²

Maximum and minimum stresses are in table:

Table 3.

S:NO	TYPE OF LOAD	STRESSES	
1.	Dead load and self weight	203.13	203.13
2.	Buoyancy	–	-76.49
3.	Eccentric live load	55.56	55.56
4.	Breaking force	109.8	109.8
5.	Wind pressure	8.30	8.30
	Maximum stress	376.79	300.39
	Minimum stress	258.69	182.29

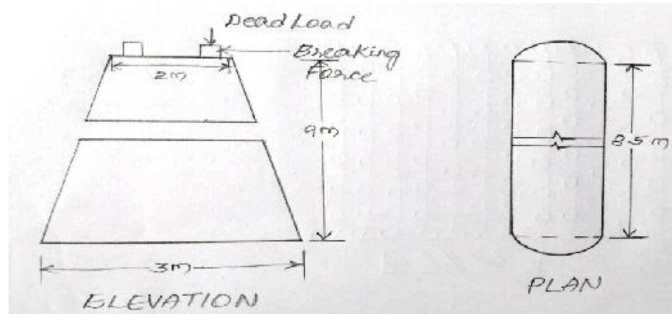

Figure 17.

(D) DESIGN OF ABUTMENT:

Dead and live load of the abutment = 700+40 = 740KN
Soil bearing capacity of soil = 150KN/m²
Vertical load due to earth = 15KN
Coefficient of friction between masonry of soil = 0.5
Density of masonry = 25KN/m²
Horizontal load = 20KN

Total vertical forces (W)= W1+W2+W3+W4 = 1317.5KN

Consider the moment of all the forces at A

M = (740×1)+(450×1)+(112.5×2.33)+(15×2.67) – (20×2) = 1452.18KN

Maximum and minimum stresses = $\frac{W}{b}(1 \pm \frac{6e}{b})$

$$= \frac{1317.5}{3}\left(1 \pm \frac{6 \times 0.4}{3}\right)$$

σ_A = 790.5KN/m²
σ_B= 87.83KN/m²

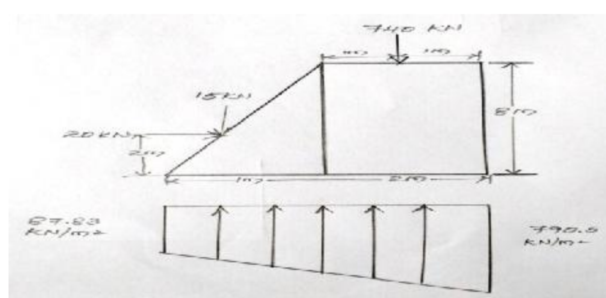

Figure 18.

Factor of safety = $\frac{\mu w}{\sum H} = \frac{658.75}{20} = 32.94 > 2$

Hence the abutment has sufficient factor of safety against sliding.

(E) ELASTOMETRIC PAD BEARING:

Maximum dead load reaction for bearing = 40KN
Maximum live load reaction for bearing = 70KN
Longitudinal frictional force for bearing = 45KN (Assume)
Effective span of the girder = 30m
Estimated rotation at bearing of the girder due to dead and live load = 0.002 radians
Total estimated shear stress due to creep, shrinkage and temperature = 6×10^{-4}
Concrete for beam and bed block = M_{20} grade

Allowable contact pressure (σ_c) $=0.25\times20\times\sqrt{2} = 7.07$N/mm²

Effective bearing area = $\frac{\text{Maximum working load}}{\text{Allowable contact pressure}}$

$$= \frac{Nmax}{\sigma c} = \frac{740\times10^3}{7.07} = 10.46\times10^4 < 15\times10^4$$

Hence it is safe.
Hence it is safe.

Bearing stress (α_m) = $\frac{Load}{Area}$

$$= \frac{700\times10^3}{15\times10^4} = 4.67\text{N/mm}^2$$

Refer Table 15.2 and IRC 83 clause 916.2
Elastomer layer (h_i) = 10mm
Thickness of outer layer (h_e) =5mm
Thickness of steel laminates (h_s) =3mm
Side covering (C) = 6mm
Adopt 3 laminates with 2 internal layer

Therefore, Total thickness of elastometric pad

$(h_o) = (2\times h_e + 2\times h_i + 3\times h_s)$
$= (2\times5 + 2\times10 + 3\times3) = 39$mm

Total shear stress = 0.915+0.53+0.765
= 2.21 < 5N/mm²
Shear stress is within permissible limit.

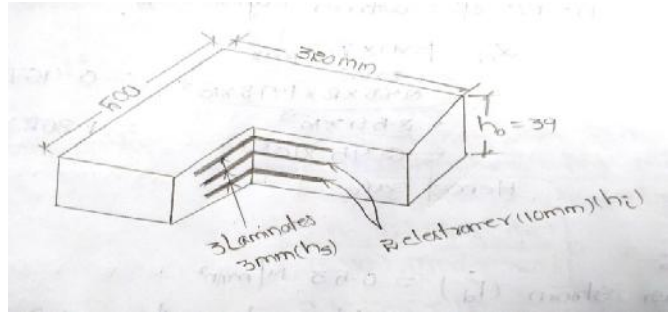

Figure 19.

IV. CONCLUSION

The following conclusions are drawn upon:

1. Bending moments and Shear force for PSC T-beam girder are lesser than RCC T-beam Girder Bridge. Which allow designer to have lesser heavier section for PSC T-Beam Girder than RCC T-Girder for 60 m span
2. Construction of this bridge is reducing the traffic problems at peak hours.
3. Moment of resistance of steel for both has been evaluated and conclusions drawn that PSC T-Beam Girder has more capacity for 60 m and more than 60 m of span.
4. Shear force resistance of PSC T-Beam Girder is more compared to RCC T- Girder for 60 m span.
5. As we go Total Super structure of a Bridge Project the Quantity of steel and the Cost of concrete for PSC T-Beam Girder is less than RCC T-Beam Girder as quantity required by T-beam Girder.
6. Deflection for PSC T-beam Girder is less than RCC T-Beam Girder Bridge.
7. Durability for PSC T-beam Girder is more than RCC T-Beam Girder Bridge.

V. CODES & STANDARDS

1) The design of various components of the structure, in general are based on provisions of IRC/IS Codes.
2) Wherever IRC code is silent, reference is made to other Indian/International codes and standards. The list of IRC Codes (latest revisions) given below will serve as a guide for the design of structures.
3) IRC: 5-1998 Standard Specifications and Code of Practice for Road Bridges, Section I – General Features of Design.
4) IRC: 6-2000 Standard Specifications and Code of Practice for Road Bridges, Section-II – Loads and Stresses.
5) 5.
6) IRC: 21-2000 Standard Specifications and Code of Practice for Road Bridges, Section-III – Cement Concrete.
7) 7.

8) IRC: 18-2000 Design Criteria for Pre-stressed Concrete Road Bridges (Post Tensioned Concrete) (Third Revision).
9) IRC: 22-1986 Standard Specifications and Code of Practice for Road Bridges, Section-VI –Composite Construction..
10) IS: 6006-1983 Indian Standard Specification For Uncoated Stress Relieved Strand For Pre-Stressed Concrete.

REFERENCES

[1] Bridge Engineering by V.V.Sastry

[2] Prestressed Concrete by N Krishna Raju

[3] Bridge engineering by N Krishna Raju

[4] Miyamoto proposed in 1997 to study the effect of prestressing using external tendons to strengthen the Misaka Bridge in Hyogo Prefecture, Japan

[5] Dezi (2002) proposed a model for analyzing the non-linear behaviour of steel-concrete composite beams prestressed by external slipping cables, taking into account the deformability of the interface shear connection.

[6] Analysis of prestressed composite beams using both elastic assumptions and approximate ultimate strength methods was also discussed in papers by Szilard and Hoadley(1963).

[7] Stras (1964) tested three simply-supported, prestressed composite beams, all of them prestressed along their full length with 10mm diameter high-strength tendons at an eccentricity of 22mm from the tension flange

[8] Ng Chee Khoon (1997) tested a series of 18 beams ranging from 1.5m to 9m using L/dpso ratio between 15 and 30 for their second order effect.