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Study of Sustainable Options of Superstructure of Navigational Bridges on Major Rivers

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Abstract:** Inland waterways are one of the oldest mode of transportation between large cities which are build near rivers. These waterway are considered as a existing highways made by nature itself. Many countries recognizes this potential of inland waterways, that inland waterways important way of transportation and developed it for public as well as commercial purpose. Hence ,Government of Indian is also planning to develop inland waterways as they are most efficient , produces very low pollution , and requires very less amount of budget as compare to construction of highways or expressways , But one of major problem is that in development of these national waterways are the bridges which build on these waterways need to designed such that they allow crossing of cargo as well domestic ships underneath them. For that Indian Waterway Authority of Indian provided some guidelines for the vertical clearance between H.F.L and bottom of the bridge superstructure and horizontal clearances between two piers .In this study we considered that the stretch of NW1 from Prayagraj to Barhi.e build on river Ganga. In this stretch the average depth of river 2m according to EIA report for national waterways, may 2016. Hence as per IWAI regulation ,2006 section4 we provided 50 m span of truss bridge and 50 m span of pre- stressed box girder bridge and compare them on the basis of the cost of construction. From the study, it can be concluded that the Box girder bridges are more economical than truss Bridge and but it can be seen that the depth of the beam required is less in case of truss bridges, which leads to increase the vertical clearance of truss bridges.

***Keywords:** EIA, National waterways, Box-Girder, truss bridge, IWAI Introduction*

1. INTRODUCTION

Navigational spans are required to cross the river which are used for navigational purpose. These spans are need to designed as per the guidelines of IWAI. Generally, 40m to 50m spans are provided for navigational span especially in Uttar pradesh. There are following types of superstructure provides such as-

i. Open web girder bridge
ii Pre-stressed boxed girder bridge.
iii. Cantilever span bridge.

Generally, Open web girder and box girder bridges for spans upto 70m -80m, because cantilever spans are costlier to construct for span lesser then 70m to 80m. Hence here we compare the open web bridge with PSC Box girder bridge on basis of cost.

2. METHODOLOGY

To commence with the PSC Box Girder was manually designed by using limit state method based on IS 456:2000, IS 1343:2012, IRC 112:2011, IRC 18:2000. For designing of 50m box girder span the guideline are mentioned in IRC 112:2011, IRC1343:2012 and IRC18:2000, have been kept in mind while designing PSC Box -girder. For better understanding plan of the girder has also been made on AUTO CAD.

The Open Web Girder was also firstly designed based on IS 800:2007, IRC 112:2011, IRC 24:2010. For the design and analysis 50 m span all the guidelines as mentioned in IRC: 24-2010, IS:800-2007, have been kept in mind while designing girder. For better understanding plan of the girder has also been made on AUTO CAD.

Both the Girders are of 50m and subjected to same type of loading i.e 70R tracked vehicle load for 2 lane road .Hence after designing of both, calculated the cost of constructin both the spans.

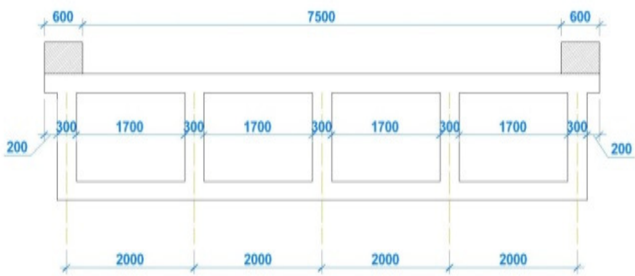
2.1 Design of PSC- Box Girder

2.1.1 Design Data of Box Girder

1. Span = 50m.
2. Cross section = multi celled box girder
3. Cell dimensions = 2 wide 2.5 m deep
4. Road width = 7.5m
5. Wearing coat = 75mm
6. Thickness of web =300mm
7. Thickness of top and bottom slabs = 300mm

8. Grade of concrete = M60.
9. 1Loss ratio = 0.82
10. Grade of Reinforcement = Fe-415 HYSD bars.
11. Maximum permissible stresses in concrete and steel
   i. Permissible stress in concrete at stage of transfer (f_{ct})=20N/mm^2
   ii. Permissible tensile stress (class 1 type structure) = f_{tt}=f_{tw}=0.
   iii. Yield strength of steel = f_y = 415 N/mm^2

2.1.2 Preliminary Dimensions



CROSS SECTION OF DECK SLAB

2.1.3 Designing of Slab Pannel

- Maximum Bending Moment in shorter direction due to dead load = 3.086 kN-m.
- Maximum Bending Moment in shorter direction due to live load(i.e 70R tracked vehicle load) = 32.165 kN-m
- Maximum Shear force due to dead load = 7.871 kN
- Maximum Shear force due to live load = 56.052 kN
- The design moment and shear force are determined as per provisions provided in IRC :112-2011 are
- M_u= $[1.35M_{D.L}+1.5M_{L.L}]$ =52.41 kN-m
- V_u =$[1.35M_{D.L}+1.5M_{L.L}]$ =94.72 kN
- Effective depth of slab required = d = $\sqrt{\frac{Mu}{0.138\,.fck.b}}$
  $=\sqrt{\frac{52.41\times10^6}{0.138\times60\times1000}}$= 79.60 mm
- Overall Depth adopted (D) = 300 mm
- Adopt Effective depth, d = 250mm

2.1.4 Design of Web Girder

Design moment and shear forces at service and ultimate load are represented in table 1

(a) Bending moments (outer web girder)					
Section	Dead load B.M ($M_{D.L}$)	Live load B.M ($M_{L.L}$)	Service load B.M ($M_{D.L}$+$M_{L.L}$)	Ultimate load B.M (1.35 $M_{D.L}$ +1.5 $M_{L.L}$)	Unit
At Middle of span	14928	5775	20703	28815	kN-m
(b)shear force (Inner Girder)					
Section	Dead load Shear force ($V_{D.L}$)	Live Load Shear force ($V_{L.L}$)	Service load Shear force ($V_{D.L}$+ $V_{L.L}$)	Ultimate load B.M (1.35$V_{D.L}$+ 1.5 $V_{L.L}$)	Unit
At support end of span	1194.25	367	1561.25	2162.74	kN

2.1.5 Pre-stressing force

For simply supported span of 50m, cable profile is selected such that secondary moment generated becomes zero. Cable profile is selected as shown in figure.

$P=\frac{A.f_{br}.Z_b}{Z_b+Ae}.=\frac{1.77\times10^6\times14.62\times1.29\times10^9}{1.29\times10^9+1.77\times710^6\times25}$ = 12972.640 kN

By providing freyssinet system with anchorage 27K-15 (27 srtant of 15.2 mm dia)

In 110 mm dia duct of cables

Forces in each cable = $(27\times 0.8\times 265)=5724$

Provide 4 cables carrying the intialprestressing force of

P=$4\times 5000=20000\ kN$

- Area of every srtand of 15.2mm diatemdon =140 mm^2

Total area of four cables = A_P = 4×3780 = 15120 mm^2

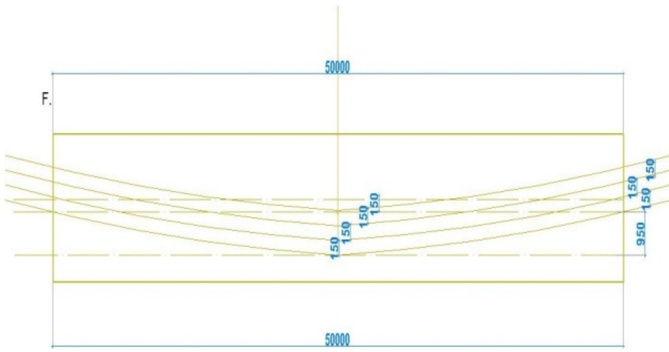
Area of Tension Reinforcement required to resist the moment is calculated by the equation, M_u = $0.87\times f_y\times A_{st}\times d\times\left(1-\frac{A_{st}\times f_y}{b.d.f_{ck}}\right)$

52.41×10^6= $0.87\times415\times A_{st}\times250\times\left(1-\frac{A_{st}\times415}{1000\times250\times60}\right)$

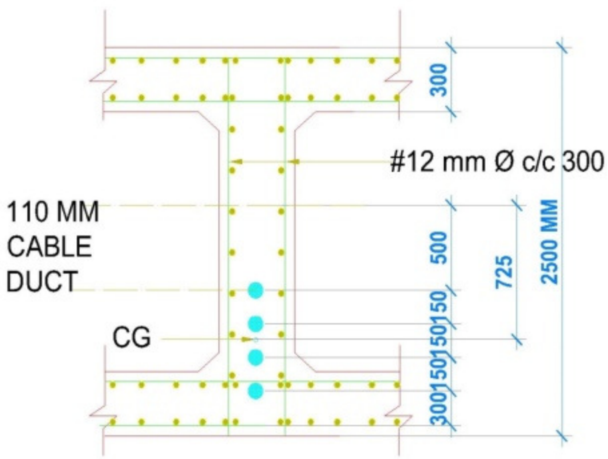
Solving, A_{st}=590 mm^2

Area of 27 srtands in every cable =(27×140) =3780 mm^2

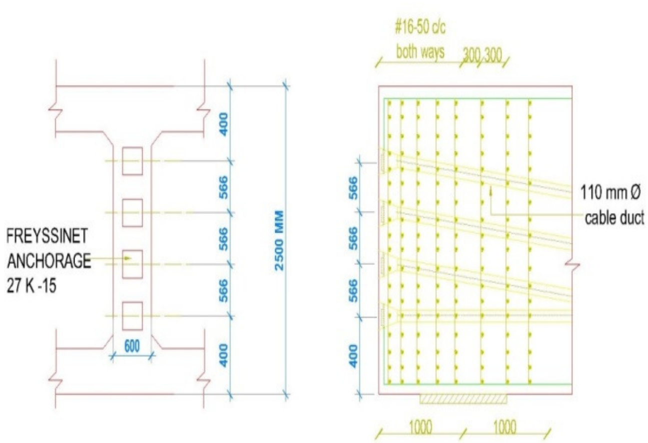
Provide, 14 mm bars at 150 mm spacing center to center (i.eA_{st}= 1056 mm^2) as main reinforcements and 12 mm diameter bars at 150mm centers as distribution reinforcements.



2.1.6 Details of longitudianalreinforcent to avoid shreinkage cracks reinforcement



2.1.7 Details of extra reinforcemt in end bock zone



2.1.8 Estimate of Box Girder Bridge

The total cost of for the given cross section of box- girder is estimate as per Schedule rate of cpwd, and it is approximately 90 lakhs rupee.

3. OPEN WEB GIRDER

3.2.1 design data :

1. Effective span = 50 m.

2. Roadway = 7.5 m(two lanes).

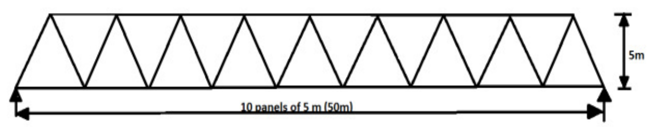
3. Kerbs = 600 mm.

4. Loading : IRC 70R tracked vehicle.

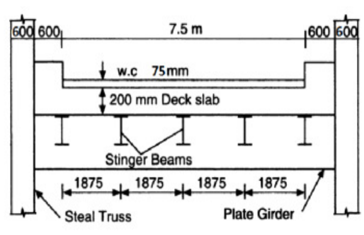
5. Materials: M-25 Grade Concrete and Fe-415 HYSD bars for deck slab. Rolled steel sections with an yield stress of 236N/mm^2 confirming to IS: 226 and IRC:24 are available for use.

3.2.2 Arrangement of Members

The configuration of the Warren truss and the arrangement of cross girders and stringers are shown in



(a) WARREN TRUSS



(b)CROSS SECTION OF DECK

2.2.3 Design of Slab Section

The total design ultimate load moments are

Short span moment=M_{Bu}=[1.35 M_{DL} +1.5M_{LL}]=48.525 kN.m/m

Long span Ultimate moment M_{Lu} =6.22kN.m/m

Effective depth of slab = d = $\sqrt{\frac{M_u}{0.138\, f_{ck}.\mathrm{b}}}$=118.597 mm

Adopt effective depth, d =200mm and overall depth of 250mm

Using 12mm diameter bars

Effective depth provided= 200mm

$\left(\frac{M_u}{b.d^2}\right)= \left(\frac{48.525\times10^6}{1000\times200^2}\right)$ =1.213, using M-25 grade concrete and Fe-415 HYSD bars

Read out the percentage of reinforcement required from Table 3 of SP:16 Design Aids

$p_t=0.36 = \frac{100A_{st}}{bd}$

therefore, $A_{st} = 720mm^2$

For short span, Provide 12 mm diameter bars at 120 mm centers (A_{st} provided =942mm^2)

For long span, provide 10mm diameter bars at 150mm centers

3.2.4 Design of Stringer Beams

Maximum B.M. due to dead load = 50.29 kN-m

Maximum B.M. due to live load including impact factor =296.953 kN-m

Maximum shear force due to dead load =40.235 kN

Maximum S.F. due to live load including impact factor = 237.5625 kN

Design B.M. = (1.35×50.29+1.5× 296.953) = 513.30 kN-m

Design S.F=(1.35× 40.35+1.5× 1.25 × 190.05)= 410.82 kN

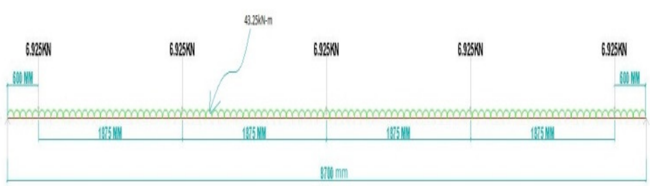
Section Modulus Z =(M/σ_b) =($513.30\times 10^6/236$) = $3.422\times 10^6 mm^3$

Use ISWB-600 (Z= 3.54×10^6 mm^3)

Shear stress =(410.82×10^3) / (11.2×600) =61.14N/mm^2< 85N/mm^2(Safe)

3.2.7 Design of Cross Girders:

The maximum dead load bending moments and shear force is computed as;

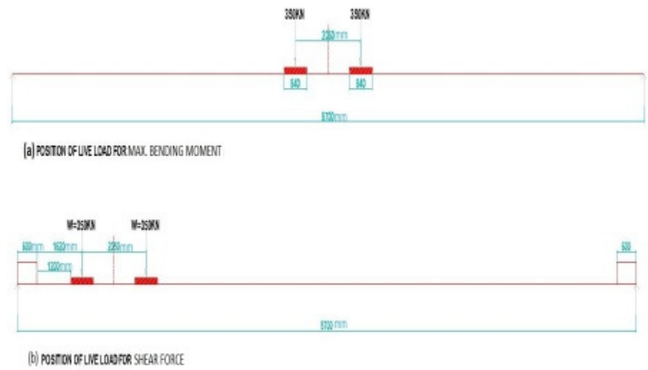


M_{DL} = [(205.45 × 8.7 × 0.5) – 43.25 ×4.35×0.5 ×4.35) – (6.925×3.75)− (6.925×1.875)]

= 419.60 kN-m

V_{DL}= 205.45kN

The maximum live load bending moment including impact occurs when the two tracks are spaced symmetrically from the centre of cross girder.



Maximum bending moment due to live load occur when the CG of load passes the center of span

M_{LL} =1.4 [(0.5 ×350×8.7) – (0.5 × 350×2.05)]

=1630KN-m

Maximum shear force due to live loads occur when one of the edges of the track is 1.2m from the kerb.

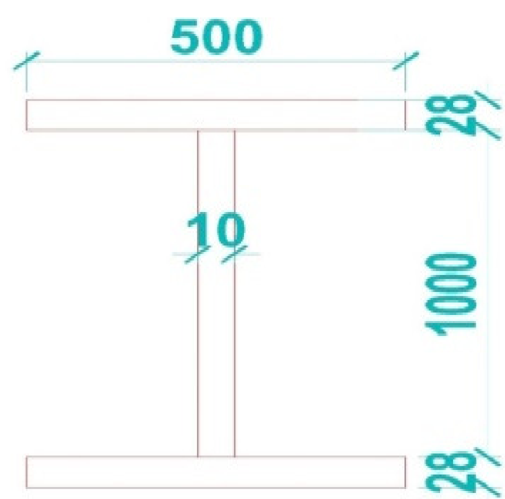
Maximum shear force including impact is computed as:

V_{LL}= 1.4[(350 × 6.475)/8.7 + 1.4[(350×4.425)/8.7]

= 613.8kN

Total design B.M = (419.58 + 1630) = 2049.58 kN-m

Total design S.F. = (205.45 + 613.8) = 819.25 kN



3.2.8 Design of Steel Truss

A warren truss with 10 panels of 5m each is used Span of the truss = 50m

Height of Truss = (1/10)span = (50/10) =5m

a) Loads:

Dead loads due to deck slab, wearing coat, stringer beams and cross girders acting at each node = 205.45 kN≈ 206 kN

Self – weight of stress = (0.15L + 5.5)

= (0.15 ×50 + 5.5) = 13 kN/m

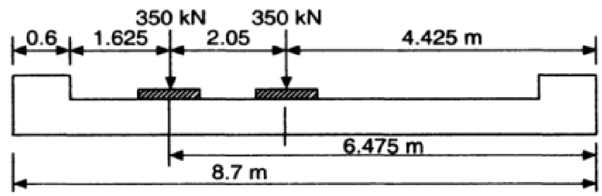
Self – weight at each node point = 5 × 13 = 65 kN

Total dead load = (206 + 65) = 271 kN

Live loads : I.R.C. Class 70R loading

Maximum B.M. is produced when the class 70R vehicle is closet to main girder.

Maximum load transferred when one track is at 1.625m from the edge of the kerb as shown in figure



Load Position for Truss Design.

Maximum load transferred when one track is at 1.625 m from the edge if the kerb W = [(350 × 6.475)/8.7]+[350 ×4.425)/8.7] = 439kN

Impact factor =10%

Live load including impact = (439 ×1.1) = 483kN

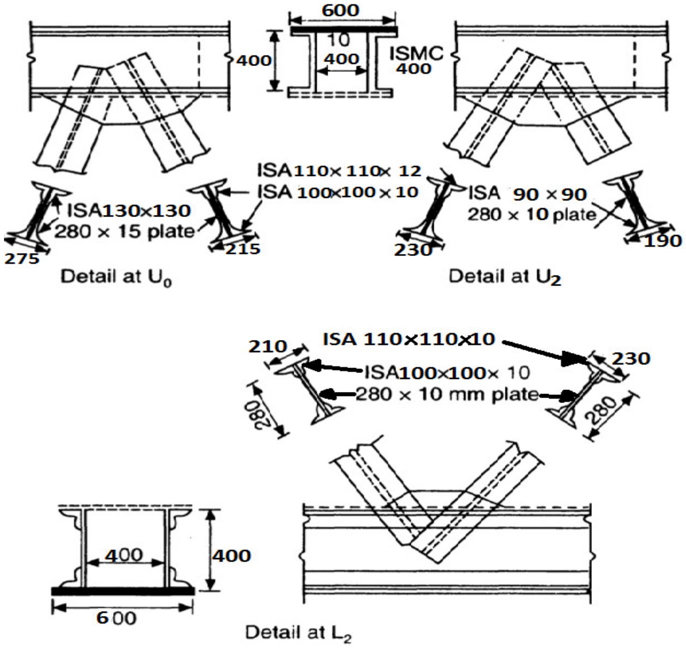
Therefore Average u.d.l = 483/4.57 = 105.68 kN/m

b) Forces in Truss Members

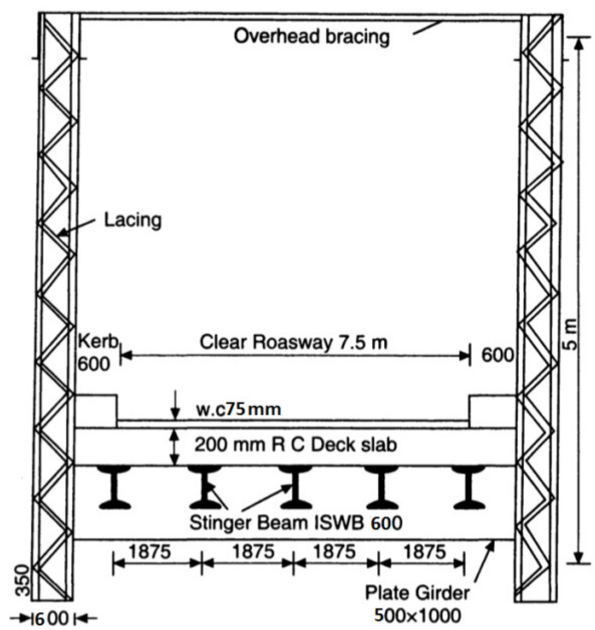
Influence lines are drawn for forces in the various members are calculated .as shown im table 2

Member	Forces due to Dead loads (kN)		Forces due to live load (kN)		Combined loads (kN)		Design forces (in kN)
	Tensile	Compressi- -ve	Tensile	Compressive	Maximum	Minimum	
L_0L_1	610	-	219	-	−829	−610	−829
L_1L_2	1694	-	588	-	−2282	−1694	−2282
L_2L_3	2506	-	871	-	−3377	−2506	−3377
L_3L_4	3048	-	1058	-	−4106	−3048	−4106
L_4L_5	3320	-	1150	-	−4470	−3320	**−4470**
U_0U_1	-	1220	-	417	+1637	+1220	+1637
U_1U_2	-	2168	-	738	+2906	+2168	+2906
U_2U_3	-	2846	-	968	+3814	+2846	+3814
U_3U_4	-	3252	-	1106	+4358	+3252	+4358
U_4U_5	-	3388	-	1152	+4540	+3388	**+4540**
U_0L_0	-	1364	-	464	+1828	+1364	**+1828**
U_0L_1	1364	-	464	-	−1828	−1364	**−1828**
U_1L_1	-	1061	32	410	+1471	−32	+1471 −32
U_1L_2	1061	-	410	32	−1471	+32	−1471 +32
U_2L_2	-	758	86	356	+1114	−86	+1114 −86
U_2L_3	758	-	356	86	−1138	+86	−1114 +86
U_3L_3	-	454	140	302	+756	−140	+756 −140
U_3L_4	454	-	302	140	−756	+140	−756 +140
U_4L_4	-	152	194	248	+408	−198	+400 −194
U_4L_5	152	-	248	194	−400	+194	−400 +194

3.2.9 Members designed for the maximum axial force are such as show in figure



3.2.10 Cross- section of steel truss bridge



2.3.11 Cost of the construction of truss –bridge

The total cost of for the given cross section of open web girder is estimate as per Schedule rate of cpwd, and it is approximately 140 lakhs rupee.

4. RESULT

a) Total depth of the box girder is 2.5 m.

b) Total depth of open web girder bridge is 1m.

c) Cost of construction of 50m box girder bridge of 8.7m width is 90 lakhs.

d) Cost of the construction of 50 m open web girder bridge of width 8.7 m is 140 lakhs.

5. CONCLUSION

a) Depth of open web girder bridge is very less as compare to the box girder, therefore the can be used where very good vertical clearance required.

b) PSC- Box girder require almost 35% less amount then open web girder bridges for span of 50m. but this percentage is goes on decreasing as we increase the required span length .

REFERENCES

[1] IRC: 18. (2000). Design criteria for prestressed concrete road bridges (post tensioned concrete), IRC, New Delhi, India.

[2] IRC: 6. (2010). Loads and stresses, IRC, New Delhi, India.

[3] IRC: 112. (2011). Code of practice for concrete bridges, IRC, New Delhi, India.

[4] IS1343. (1980). Indian Standard code of practice for prestressed concrete (First Revision), BIS, New Delhi, India

[5] N. Krishna Raju,. (1995). Prestressed Concrete, Tata McGraw-Hill Publishing company Limited, New Delhi.

[6] N. Krishna Raju,. (2015), Design of bridges, oxford & IBH publishing Co.Pvt.Ltd., New Delhi.

[7] S. Maleki (2002). “Effect of deck and support stiffness on seismic response of slab girder bridges”, Engineering Structures, 24, 219-226.

[8] Vikash Khatri, Pramod Kumar Singh and P.R.Maiti (2012). “Comparative study of prestressed steel concrete composite bridge of different span length and girder spacing”, International Journal of Modern Engineering Research, 2(5), 3917-3922.