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Comparison of Plain Steel Bridge Plate Girder and Pre-Stressed Steel Bridge Plate Girder

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Abstract- **The need for conservation of important construction material like steel has motivated divergent thinking amongst Engineers. Pre-stressed Metal Structures have proved to be economical as compared to normal Metal Structures and many such structures have been existing in Europe and USA.**

There is a common notion that Pre-stressing can only be applied to concrete structures only, The same concept can be extended to steel also leading to considerable economy in rehabilitate existing bridges to carry higher loads.

In this research work an attempt is made to compare a pre-stressed bridge girder and a normal metal girder. Initially a metal girder is designed to carry specified IRC loading is designed to meet IS:800-2007 design criteria. This is than pre-stressed in such a manner that the effect of the dead load of the bridge is negated by the applied pre-stressing force. In the course of the study various cable profiles will be studied to give the optimum cable profile.

Index terms- **Construction material like steel, Pre-stressed Metal Structures, Pre-stressed bridge girder, Normal metal girder**

INTRODUCTION

Pre-stressing means the intentional creation of permanent stresses in a structure or assembly, for the purpose of improving its behavior and strength under various service conditions.

This basic principle of Pre-stressing was applied to construction perhaps centuries ago when ropes or metal bands were wound around wooden staves to form barrels. When the bands were tightened, they were under tensile pre-stress which in turn created compressive pre-stress between the staves and thus enabled them to resist hoop tension produced by internal liquid pressure. That is, the bands and the staves were both pre-stress before they were subjected to any service loads.

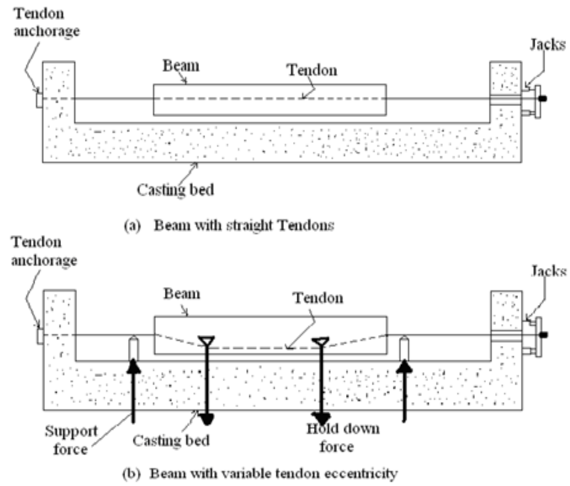

Fig .Method of Pre-tensioning

The shrink fitting, of metal tyres on wooden wheels used for carts indicates how ancient and common the art of Pre-stressing was, but it was done unknowingly.

The idea of Pre-stressing to counter act the stresses due to loads was first put forward by Austrian Engineer Mandl in 1896.

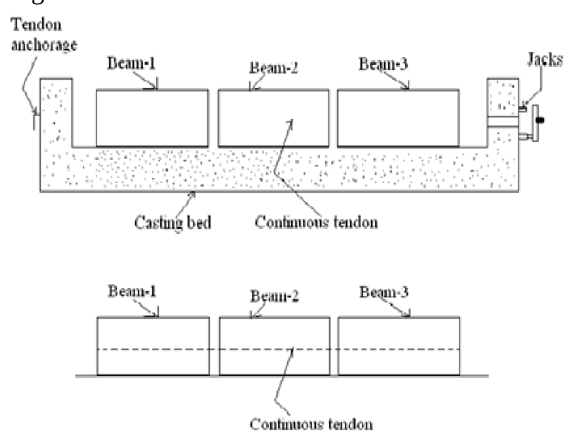

Fig. Hoyer's Long Line System of Pre-tensioning

Modern Development of pre-stressed concrete is credited to E.Freyssinet of France who started using high strength steel wires for Pre-stressing. Although Freyssinet also tried the scheme of pre-tensioning where steel was bonded to concrete without end anchorages, practical application of this method was first made by E.Hoyer of Germany. The Hoyer system consists of stretching wires between two buttresses several hundred feet apart, putting formwork between the units, placing the concrete and cutting the wires after the concrete hardened.

MEANS OF CREATING PRE-STRESS IN METAL STRUCTURES

The known methods for Pre-stressing metal structures are:

1. Stressing separate bars or whole units by means of tendons from high strength materials.
2. Creating, when assembling the structural units, forced elastic deformations in some or their component parts to cause internal stresses in a unit after it is completed.
3. Forced displacement of the bearings of statically indeterminate structures during erection with a view to redistribute loading moments or obtain in component bars forces of the sign opposite to that of forces arising from loads.
4. In course of erection a part or whole of the structure is temporarily loaded so as to rationally distribute the forces.
5. Inserting a high strength wire in rolled sections, the latter being pre-stressed once the wire is released.

6. Location of Parabolic Tendons

End Anchorages

Structures can be fully pre-stressed at the manufacturing plant, partly at plant and partly at erection site or fully on erection site during preassembly or after they are placed in position. The Pre-stressing may be single stage or multi stage.

DESIGN DATA

The super structure consists of RCC T-beam deck slab type. It consists of Pre-stressed plate girder having overall depth of girder is 1944mm. In which 1750 mm as a precast girder and 250 mm as cast in situ deck slabs. The overall width of deck is 13,625 mm, which consists of 11,000 mm carriage way, and footpath on one side. Intermediate diaphragms 300 mm thick spaced at 6000 mm c\c. End diaphragms are 300 mm thick provided at center of bearing.

- Distance between center of expansion joint to center of pier 19500 mm
- Overall length of Slab 19460 mm
- Overall length of Girder 18755 mm
- C\C of Bearing 18000 mm
- C\C of Girder 3100 mm
- Thickness of deck slab 250 mm
- Depth of girder 1944 mm
- Overall width of the deck 13650 mm

Sectional Parameters of Girder

- C\C of Girder 3.1 mm
- Depth of girder 1944 mm
- Width of flange 650 mm
- Thickness of web of girder 12 mm
- Uniform depth of web below flange 1150 mm
- Slope depth of bottom bulb of girder 150mm
- Uniform depth of bottom bulb of girder 300 mm
- Width of bottom bulb of girder 600 mm
- No of girder per bridge 4.
- Out to out distance of flange of all girder 10200 mm

Depth of diaphragm= depth of girder- depth of bottom bulb= 1450

AT Mid Span

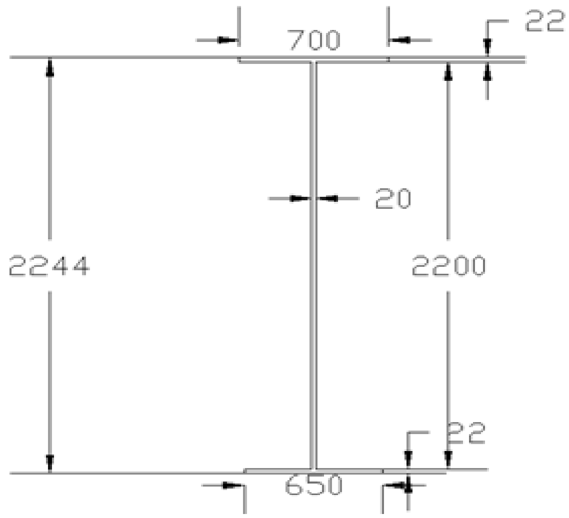

Fig. Plain Steel

D.L. = 64.79 kN/m

S.F. = 1097.81 kN

L.L.(B.M.) = 2792.7 kN.m

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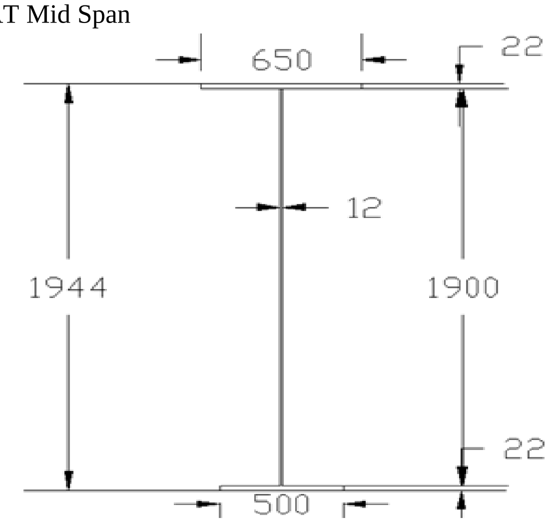

Fig. Pre-stressed Steel

D.L. = 62.78 kN/m

S.F. = 1096.00 kN

L.L.(B.M.) = 2792.7 kN.m

Ultimate pre-stressing force = 3388 kN

fp = 1200 N/mm2

Dia of tendon = 15 mm

Section parameters	Plain Steel
Area A (mm^2)	73700
yb (mm)	1138.58
yt (mm)	1105.42
I (mm^4)	5.439E10
Z (mm^3)	4.777E07

Maximum Stresses	Top Flange	Bottom Flange
Top flange	-110.13	110.13
Bottom flange	-113.4	113.4
Shear stress (N/mm^2)	48.21	
Axial stress (N/mm^2)	-	-
Due to PF (N/mm^2)	-	
Due to DL (N/mm^2)	53.33	54.93
Due to LL (N/mm^2)	56.80	58.47
Total stresses (N/mm^2)	Top	Bottom
Due to PF (mm)	-	
Total Deflection		
DL+PF (mm)	-	
DL+LL (mm)	14.19	
DL+LL+PF (mm)	-	

Section parameters	Pre-stressed Steel			
Area A (mm^2)	48100			
yb (mm)	1037.93			
yt (mm)	906.07			
I (mm^4)	3.002E10			
Z (mm^3)	2.892E07			
Maximum Stresses	At Transfer Stage		At Service Stage	
	Top Flange	Bottom flange	Top Flange	Bottom flange
Axial stress (N/mm^2)	-70.44	-70.44	-57.47	-57.47
Due to PF (N/mm^2)	94.09	107.78	76.77	87.94
Due to DL (N/mm^2)	76.75	87.92	76.75	87.92
Due to LL (N/mm^2)	-	-	84.30	96.57
Total stresses (N/mm^2)	Top Flange	Bottom Flange	Top Flange	Bottom Flange
Top flange	-53.09	-87.78	-141.75	26.81
Bottom flange	-50.57	-90.30	-154.02	39.08
Shear stress (N/mm^2)	87.99			
Deflection	Pre-stressed Steel			
Due to DL (mm)		15.59		
Due to LL (mm)		20.82		
Due to PF (mm)		15.59		
Total Deflection				
DL+PF (mm)		0		
DL+LL (mm)		36.41		
DL+LL+PF (mm)		20.82		

COMPARISON

Comparison of plain steel bridge, plate girder and pre-stressed steel, bridge plate girder

TITLE	PLAIN STEEL GIRDER	PRESTRESSED STEEL GIRDER
Overall Depth	2244 mm	1944 mm
Depth of Web	2200 mm	1900 mm
Thickness of Web	20 mm	12 mm
Width of Top Flange	700 mm	650 mm
Depth of Top Flange	22 mm	22 mm
Width of Bottom Flange	650 mm	500 mm
Depth of Bottom Flange	22 mm	22 mm
Weight of pre-stressed steel	-	0.4 t
Weight	10.42 t	8.4 t
Cost	7,26,482 Rs	6,17,600 Rs

Cost Difference = 1,08,882 Rs

Weight Difference = 1.62 t

CONCLUSIONS

It is preferable to use M.S. Structural Sections for a pre-stressed plate girder because there is approximately 12% reduction in weight which makes handling easier and transportation cheaper, although the saving in cost is about 15%

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