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Analysis and Design of U-shaped Prestress Concrete

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Abstract - *In India generally the bridges are constructed with cast in situ construction technique. In the bridges prestressing technique is used frequently due to cost effectiveness. The prestressed construction is of two type post-tension and pre-tension. The concept of pretension prestressed construction system is used in construction of precast element. Different types of the bridge superstructure are constructed in India such as Slab, T-shape, I-shape, Box shape, Arch type etc. Depending upon the requirement of the bridge selection of superstructure has been done. In present scenario, aesthetic of the bridge structure is the important aspect in design of bridge. Generally, in India rail- way bridges are constructed with steel section. During the Delhi Metro project and Mumbai Metro project the concept of precast prestressed bridge superstructure with U-shaped has been implemented. The precast construction reduces time duration of project which results in saving in the cost. The precast girder has good aesthetic as compare to cast-in situ girder due to quality management. Due to the U shape of girder it will obstruct view of machines part of rail which result in good view of rail. The prestressed precast U-shaped girder may be give new dimension to bridge superstructure. The U-shaped girder has better scope as it can replace current trend of design of bridge with I,T or Box shaped girder. In present study, the analysis and design of U-shaped girder for railway loading is done with specification of Concrete bridge rule under Indian Railway Standards. The parametric study of the superstructure for span with various depth for broad gauge and meter gauge loading is done and economical span to depth ratio is found out. The design sub structure is carried out which include design of bearing, pier cap, pier, pile cap, pile. The drawing of super structure and sub structure is prepared.*

Key Words: **U-shaped girder, Prestress**

1. INTRODUCTION

Transportation is essential requirement for development of particular area. Transportation is mainly of two type's highway and railway transportation. Bridge is key element in transportation. Bridge is consisting of many components such as girder, bearing, pier cap, pier, abutment, etc. The superstructure of bridge decides cost of bridge and its construction methodology. There are many superstructure sections currently in use in the bridges such as solid slab, voided slab, T-girder, I-girder, Box girder, U- girder, etc.

1.1 Principal of Prestressing System

The basic principle of prestressing system can be explained by example of blocks. When group of blocks joined together and allowed to deflect due to their own weight they deflect in downward direction, but when the external force is applied to blocks they came in their original condition. The prestressing of member can be achieved by transfer of force between prestressed strands and concrete. The strands are stretch and anchor against the concrete, that tension in strands result in the compression in the concrete.

1.2 Advantages over Conventional Section

Fine aggregate can be determined as passing through 4.75mm IS sieve and retained on 0.075mm sieve is termed as fine aggregate. Fine aggregates are obtained from river bed and it provides bulk, certain amount of strength and other properties to construction materials. Fine aggregate used in this experiment which is passing through 2.36mm IS sieve.

1.3 Objective of Study

The main objective of this study is to understand the design of U shaped precast prestressed girder. The objective of project is:

- To understand analysis and design of U shaped precast prestressed girder for railway loading as per Indian Railway Standard.
- To study effect of the various depth of section with span in cost of superstructure. To evaluate economical span to depth ratio for the superstructure.
- To study design of substructure for girder.

2. Literature Review

O.P.Singh, S.C.Gupta and A.Khare[1] presented a case study on Delhi Metro project construction using 25m long precast U girder. The paper discussed the ben- efits of use of precast member during construction process which helps in reduction of time duration of the project. The paper included the casting and erection process of precast girder and pile cap.

M.Singh, R.Kataria, A.Mhedden, S.Mohammad and P.Bajpai [2] dis- cussed future of elevated metro viaducts with full span precast deck. The case study included the benefits of U shaped girder, precast member in construction. The case study discussed the construction of precast girder and erection of full span girder over site.

Mary Lou Ralls, Luis Ybanez and John J.Panak[3] discussed development of precast prestressed U-beam by Texas Department of Transportation. The paper included development of U-beam with design, production and construction aspects. The two type of U-beam U54 and U40 with different section and design properties. The U54 beam was suitable for length of 36.6m and the U40 beam was suitable for length of 27.4m with spacing of beam ranging from 4 to 4.9m. The U-beam was prestressed with 12.7mm diameter strands in bottom slab with straight profile. The U-beam was design for AASHTO loading specification.

3. METHODOLOGY

3.1 General :- Prestressed construction is ideally suited for long span bridges. The provisions for design of pre-tension prestressed girder are given in IRS Concrete Bridge Rule. A U-shaped section is analyzed and designed for broad gauge railway loading.

3.2 **Preliminary Data:-**

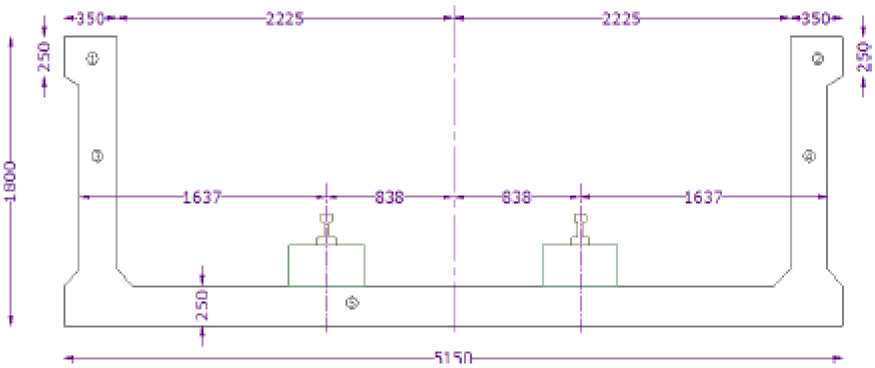
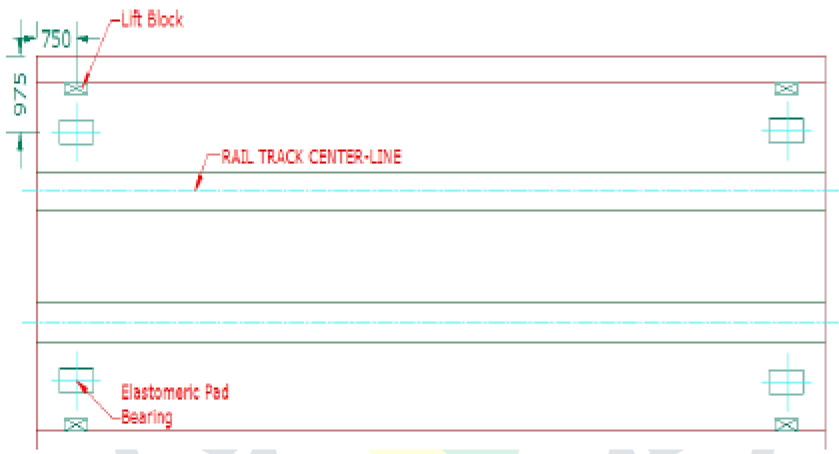


Figure 3.1: Cross Section of U- shaped Girder



Span of girder	=	15 m
C/c distant between bearing	=	15 - 2*0.75
	=	13.5 m
Loading	=	Railway Loading
Lane	=	Single Lane
Type of gauge	=	Broad Gauge
Location	=	Mumbai
Height from ground to bottom of girder	=	15 m
C/c distance between gauge	=	1676 mm
Compressive Strength of Concrete at Service (*fck*)	=	50 N/mm^2
Compressive Strength of Concrete at Transfer (*fci*)	=	35 N/mm^2
Tensile Strength of Prestressing Steel (*fpu*)	=	1860 N/mm^2
Tensile Strength of Non Prestressing Steel (*fy*)	=	415 N/mm^2

3.3 Section Properties

Top width of section (B_t)	=	5150 mm
Bottom width of section (B_b)	=	5150 mm
Total height of section (H)	=	1800 mm
Top flange width (b_{f1})	=	350 mm
Top flange thickness (t_{f1})	=	250 mm
Top flange width (b_{f2})	=	350 mm
Top flange thickness(t_{f2})	=	250 mm
Vertical web thickness (t_w)	=	250 mm
Bottom flange width (b_{f3})	=	5150 mm
Bottom flange thickness (t_{f3})	=	250 mm
Neutral Axis distance from bottom (Y_b)	=	491.86 mm
Neutral Axis distance from top (Y_t)	=	1308.14 mm
Neutral Axis distance from left (X_l)	=	2575 mm
Neutral Axis distance from right (X_r)	=	2575 mm
Area of section (A)	=	2112500 mm^2
Moment of Inertia @ X-X axis (I_{xx})	=	626000000000 mm^4
Moment of Inertia @ Y-Y axis (I_{yy})	=	7450000000000 mm^4
Section Modulus of Top section (Z_t)	=	478000000 mm^3
Section Modulus of Bottom section (Z_b)	=	1270000000 mm^3

3.4 Dead Load Calculation

The dead load carried by a bridge member consists of self weight of the girder and any extra fixed load supported by the girder. The following are the dead loads considered during calculation of the bending moment and shear force. The dead load due to deck shuttering, wearing coat, railings, crash barrier, and water main are directly assumed. Self weight of girder

- Weight of Ballast cushion
- Railings, kerb or crash barrier
- Water main, if any

Self weight of girder	=	52.81 kN/m
Superimposed dead load	=	2.00 kN/m
Total dead load	=	54.81 kN/m

Longitudinal Bending Moment $= \frac{54.81 * 13.5^2}{8}$

$= 1248.64$ kN-m

Transverse Bending Moment $= \frac{54.81 * (5.15 - 0.35)}{8}$

$= 32.89$ kN-m

Shear Force $= \frac{54.81 * 13.5}{2}$

$= 369.96$ kN

3.4.2 Live Load Calculation

Railway bridge loadings should conform to the specification of the Indian Railway Standards (IRS) prescribed by the Ministry of Railways, Government of India. The railway tracks are classified according to the importance of of traffic as main and branch lines. The three types of gauges used in the Indian railways as follows,

- Broad Gauge (BG) :- 1676 mm (5’6”)
- Meter Gauge (MG) :- 1000 mm (3’3.375”)
- Narrow Gauge (NG) :- 762 mm (2’6”)

EUDL for Bending Moment	=	1558 kN
EUDL for Shear Force	=	1740 kN
Co-efficient of Dynamic Auggement	=	0.55

Longitudinal Bending Moment $= \frac{1.55 * 1558 * 13.5}{4}$

$= 8150.29$ kN-m

Transverse Bending Moment =

45.46

kN-m Shear Force = 2

1.55∗1740

= 1348.5 kN

3.4.3 Wind Load Calculation

Wind load calculation is done as per Indian Standard IS 875 (part-3). For basic wind pressure calculation with choice of wind velocity due consideration shall also be given to degree of exposure appropriate to locality and to local meteorological data. The wind pressure provided to bridge shall not be considered to be carrying any live load when the wind pressure at deck level exceeds the following limits,

Bridges	Wind Pressure (kN/m^2)
Broad gauge Bridges	1.47
Meter and Narrow gauge Bridges	0.98
Foot Bridges	0.74

4. RESULT AND DISCUSSION

The various span to depth ratio are required to evaluated for quantity and cost analysis of the superstructure to get economical span to depth ratio of section. To evaluate economical span to depth ratio parametric study is done for 15m, 20m and 25m span with various depth. The parametric study is done for broad gauge and meter gauge loading

4.1 ANALYSIS

The analysis of superstructure is done with manual calculation. The bending moment, shear force and torsional moment for broad gauge are

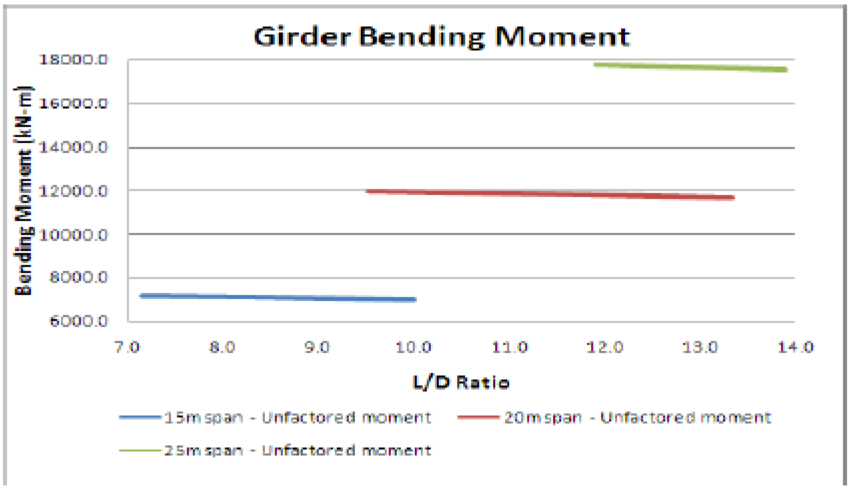


Figure 4.1.1: Bending moment of girder along L/D ratio for Broad Gauge Loading

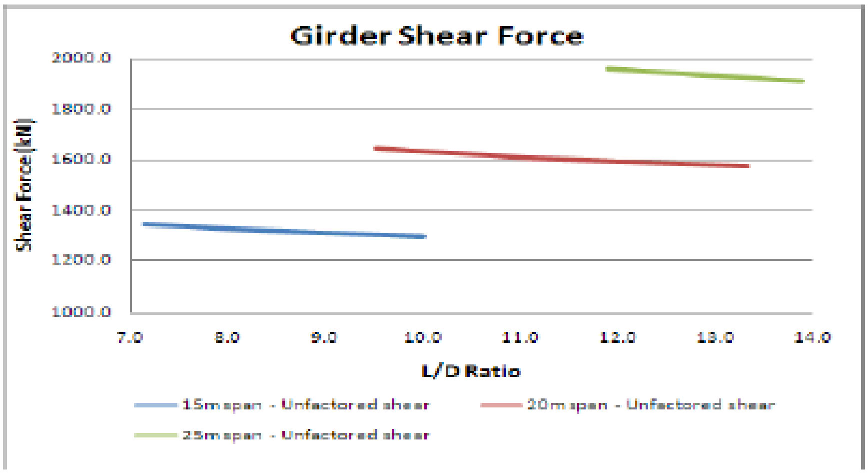


Figure 4.1.2: Shear force of girder along L/D ratio for Broad Gauge Loading

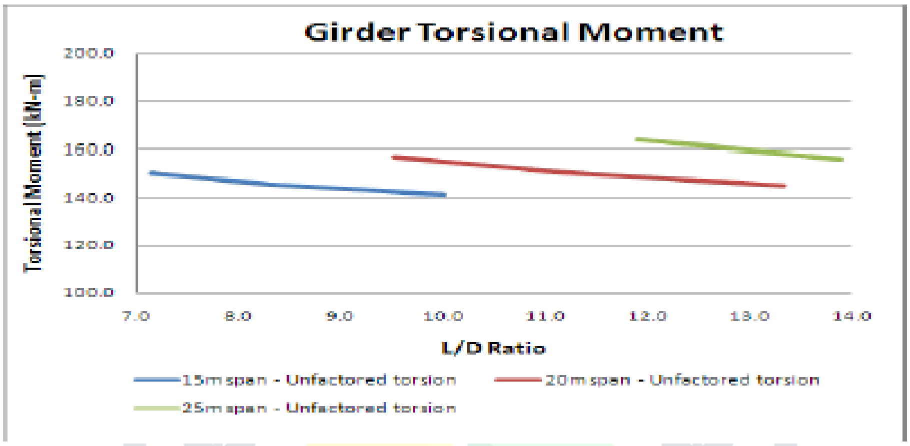


Figure 4.1.3: Torsional Moment of girder along L/D ratio for Broad Gauge Loading

4.2 Cost Analysis:-

The design is done by prepared spreadsheet. The overall analysis and design method- ology is described in chapter 3. For all the various spans and span to depth ratio girder is designed. In the cost analysis the cost of concrete, prestressing steel, Non- prestressing steel, finishing and handling are included. For different span to depth ratio Figures show that the cost of girder did not affect due to Non-prestressing steel and Handling cost, but the cost is affected by concrete, prestressing steel and finishing cost. It is observed that as the depth increased the cost of concrete and finishing increased and the cost of prestressing steel decreased. The cost analysis for different span with different span to depth ratio for Broad gauge and Meter gauge loading is described as below,

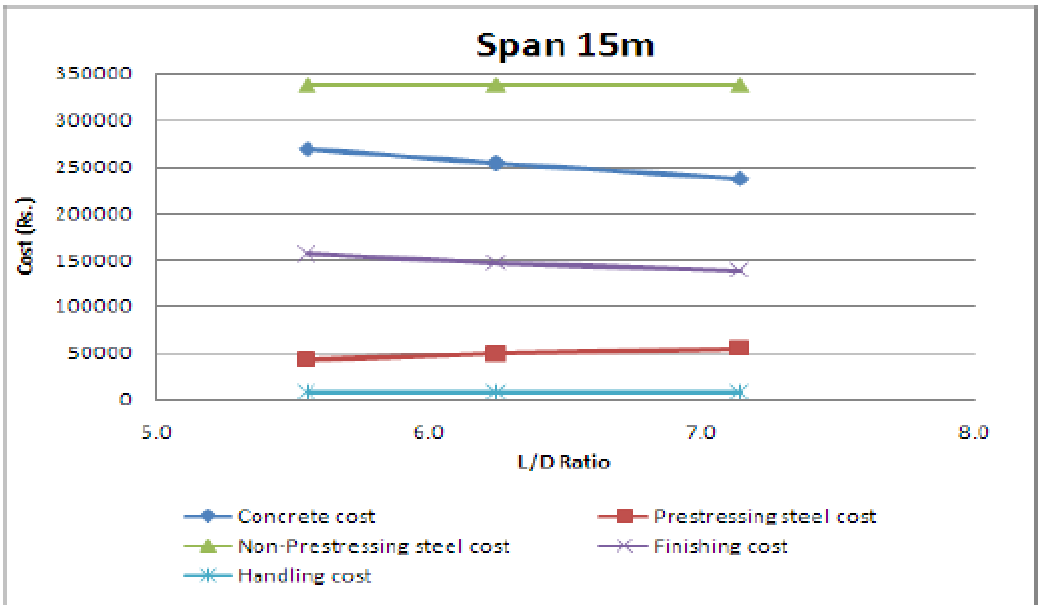


Figure 4.2.1: Cost analysis for 15m span with L/D ratio for Broad Gauge Loading

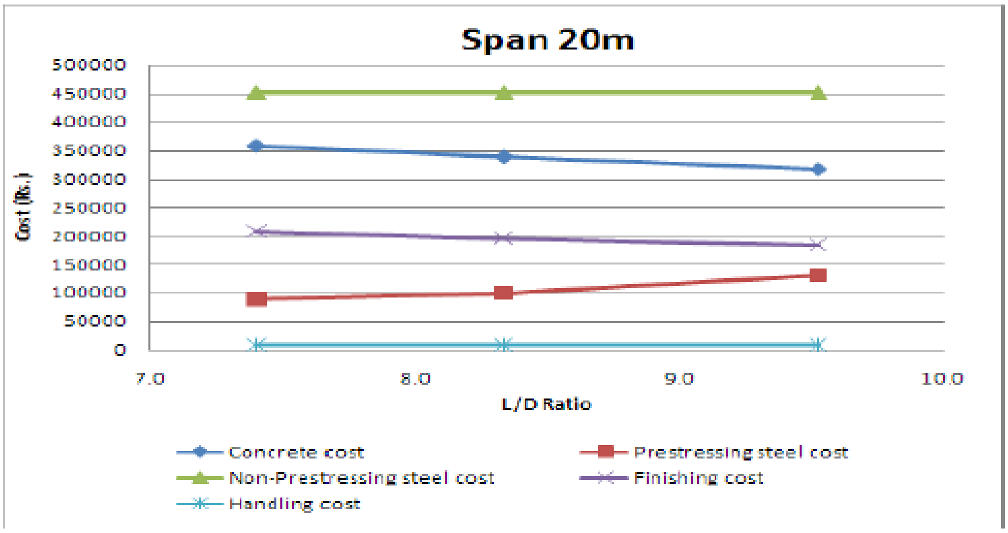


Figure 4.2.2: Cost analysis for 20m span with L/D ratio for Broad Gauge Loading

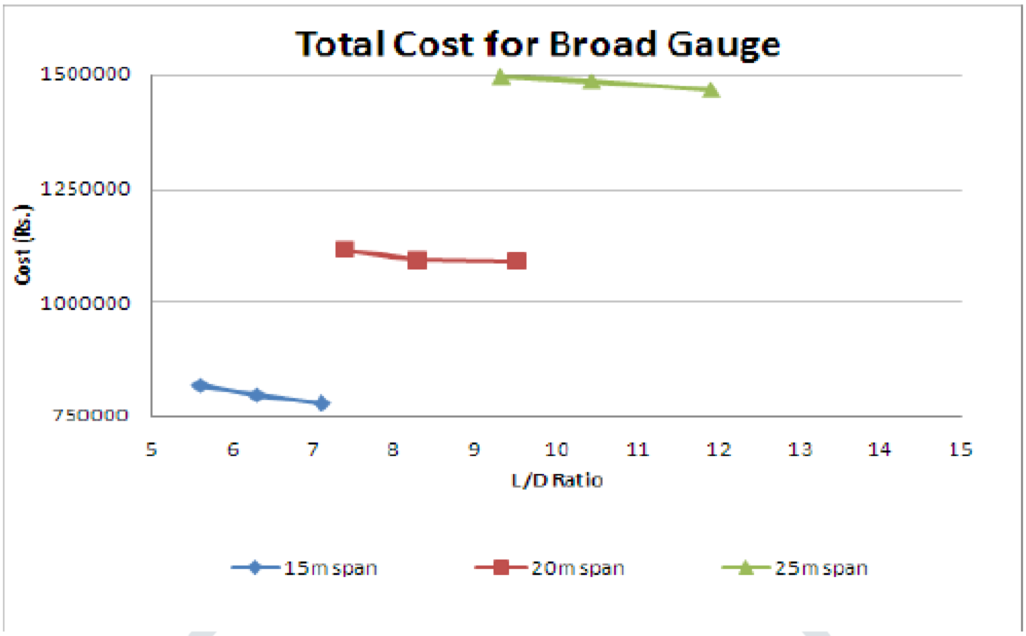


Figure 4.2.3: Cost analysis for 20m span with L/D ratio for Broad Gauge Loading

5. Conclusions:-

Based on the study carried out in this report the following conclusions can be drawn.

- The girder is subjected to flexural moment and shear force due to dead load, superimposed dead load and live load and torsional moment due to wind load and derailment load.
- The loss of prestress is 19.2 percent in 15m girder with broad gauge loading, which is approximately same as it is assume 20 percent.
- The L/D ratio 7.1, 9.5 and 11.9 are economical L/D ratio for 15m, 20m and 25m span respectively under Broad gauge loading.

5.1 Future Scope of Work:-

The study in this report is limited to analysis and design of U-girder with single track under broad gauge and meter gauge loading. The present study can be extended to include following aspects.

- Present study can be studied with two rail track in girder.
- The study is limited to broad gauge and meter gauge loading, which can be studied with standard gauge loading for metro rail.
- The study is limited to railway bridges, which can be studied for highway bridges.

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