International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 05 Issue: 05 | May-2018 www.irjet.net p-ISSN: 2395-0072

# Analysis and Design of Pre-stressed Concrete I-Girder Bridge

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**Abstract -** *Bridge construction today has achieved a worldwide level of importance. Bridges are the key elements in any road network and use of pre-stress girder type bridges gaining popularity in bridge engineering fraternity because of its better stability, serviceability, economy, aesthetic appearance and structural efficiency. I-beam bridges are one of the most commonly used types of bridge and it is necessary to constantly study, update analysis techniques and design methodology. Structurally they are simple to construct. Hence they are preferred over other types of bridges when it comes to connecting between short distances. This present paper describes the analysis and design of longitudinal girder bridge. In this case analysis is done using STAAD- Pro software.*

***Key Words***: Girder Analysis, STAAD PRO V8i, IRC 6:2010 (Section II) , PSC I-Girder, Principal Stresses, Shear And Moments.

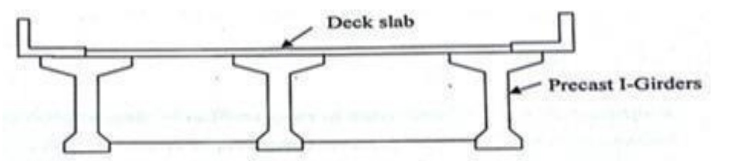
## 1. INTRODUCTION

A girder bridge can be defined as a crossing the road, railway and river (or) a natural obstacle (Water coarse, sound, valley etc...) and allowing people, vehicles etc... to go easily from a spot to another. There are different design shapes of bridges and each of them has a particular purpose. Bridges are classified on the basis of how principal stress, shear stress, bending moments, compression, tension are distributed in any type of structure.

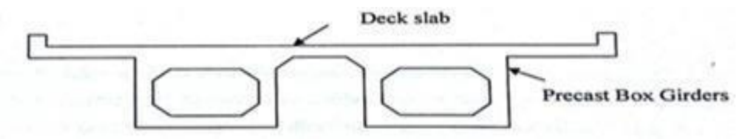
## 1.1 BASIC CONCEPT OF PRESTRESSING

One of the most commonly used forms of superstructure in concrete bridges is precast girders with cast-in-situ slab. This type of superstructure is normally used for spans between 20 to 40 m. Majority of pre-stress concrete bridges, constructed in India are post tension type. This is due to the fact that it helps to reduce the self weight of the structure due to which longer span members can be constructed by making the structures economical. Different types of girder bridges as shown in Figure 1.1

a. Cross section of I-Girder with cast in situ deck




b. I-Girder with cast in situ deck




c. Box girder with cast in situ deck

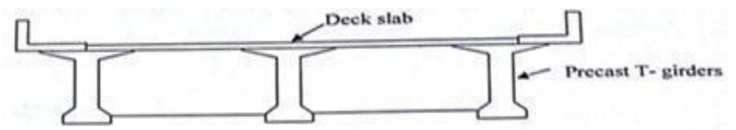



**Fig.-1.1:** *Different types of girder sections*

## 1.2 TYPE OF PRESTRESSING SYSTEMS

Prestressing System can be classified by two basic methods, as under:-

1. Pre-Tensioning
2. Post-Tensioning

Pre-Tensioning is a method where Prestressing Steels are tensioned, prior to casting of concrete, against two rigid abutments whereas in Post-Tensioning is a method where Prestressing Steels are stressed after casting of concrete to attains its preliminary strength. The minimum grade of concrete in prestressing technique is M40 for pre tensioning whereas M35 for post tensioning. The tensile strength of concrete is only 8-14% of its compressive strength of concrete.

## 1.3 PSC I- Girder Details

In the present work Pre-stressed Concrete I shape Girder Bridges are analyzed. The details of the cross-sections are given below

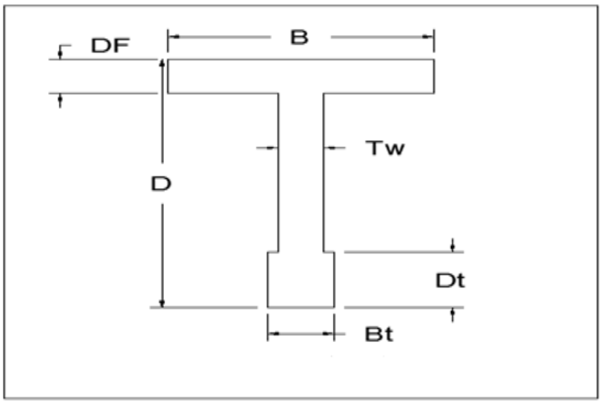



**Fig.-1.3:** Cross Section of Pre-stressed Concrete Girder

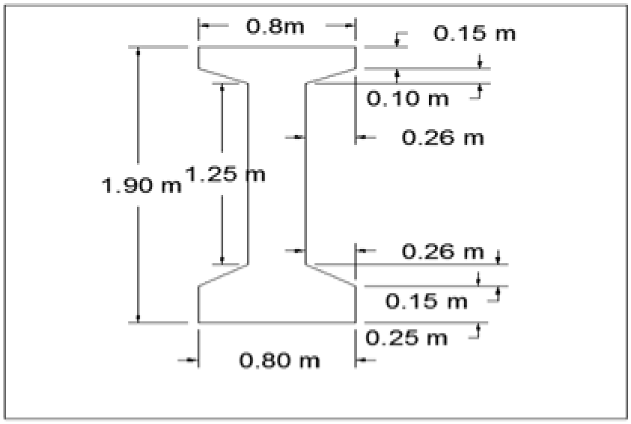



**Fig.-1.2:** Cross Section of Main Girder

## 2. Methodology

The Deck slab is designed for IRC loading with live load at different positions on the deck. The Bending moment and shear force are calculated by using Pigeaud's curve. The load from deck slab is transferred to the main girders by Courbon's method. The live load bending moment and shear force are calculated and the girder is designed for pre-stressed concrete girder.

The finite element 3D modeling is done in STAAD Pro with dead load and live load applied and the final stresses, principles, deflection, etc are tabulated.

### 2.1 Flowchart of Methodology

- 4 girder-I beam bridge is considered.
- Span of bridge slab is 28m
- Calculate dead load.
- Calculation of IRC loading-class A,70R load
- Design of bridge and calculation of reinforcements.
- Modelling of PSC-I beam girder in STAAD Pro (V8I Version 5).
- Calculation of deflection, reaction, bending moments, shear force and stresses etc.

## 3 Details of IRC Loading

### 3.1. Dead loads:-

For the purpose of dead load calculation self weight of the girder is considered. Cross sectional properties of the considered girder determines the dead load.

### 3.2 Vehicle loading details:-

### Figures of IRC loading

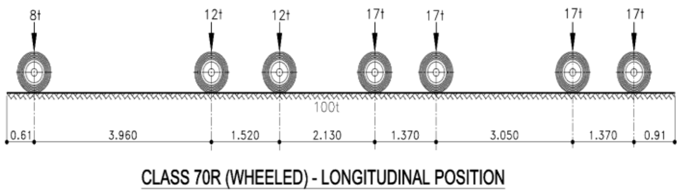
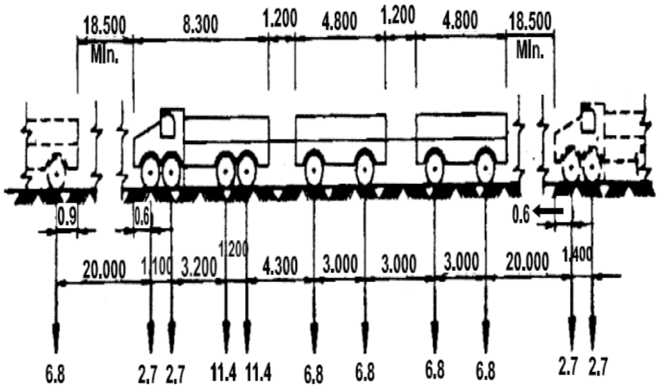



**Fig.-2.1:** Class '70R' (Clause 204)




Class A Train of Vehicles
**Fig.-2.2:** Class 'A' Train of Vehicles (Clause 204.1)

## 4. PROCEDURE FOR DESIGN AND ANALYSIS

- Given section.
- Calculate section properties.
- Estimate Bending moment / Shear force.
- Given no & size of cables.
- Apply pre-stress force.
- Estimate pre-stress losses.
- Determine stresses in concrete.
- Check with permissible stresses.
- Check ultimate moment / shear.
- Design shear reinforcement.

## 5. ANALYSIS OF POST TENSION GIRDER BRIDGE

**Table No.1:** Geometric details of Precast PSC Girder Bridge

| Sr. No. | Parameter | Design Value |
|---|---|---|
| 1 | No Of Overhang Sides(Z) | 2 |
| 2 | Effective Span(L) | 28 m |
| 3 | Carriage Way(L) | 9.25 m |
| 4 | Thickness Of Wearing Coat(T) | 0.065 m |
| 5 | Kerb Width(Kb) | 0.5 m |
| 6 | Parapet Hight(T) | 1.2 m |
| 7 | Overhang Beam(Ob) | 1.225 m |
| 8 | Number Of Longitudinal Girder(N) | 4 No's |
| 9 | Totalwidth Of Bridge (B) | 10.25 m |
| 10 | Distance Between Longitudinal Girder | (Tl-2*Ob )/(N-1) = 2.6 m |

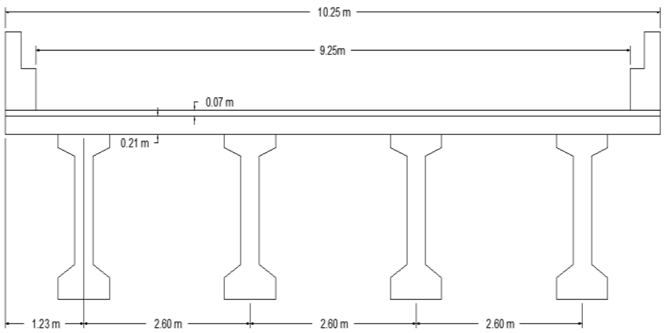



**Fig.-2.3:** Cross Section of Pre-stressed Concrete Girder

## 6. DESIGN OF POST TENSION GIRDER BRIDGE

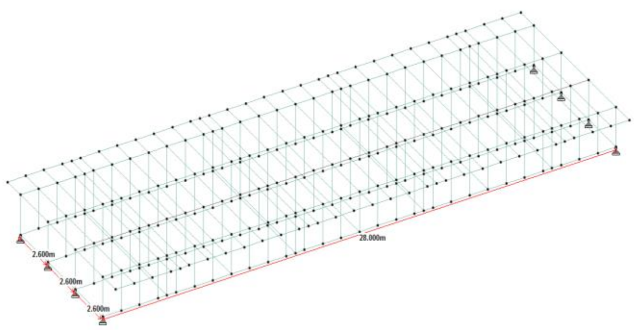


**Figure 3.1:** Isometric view of 4 Girder Bridge

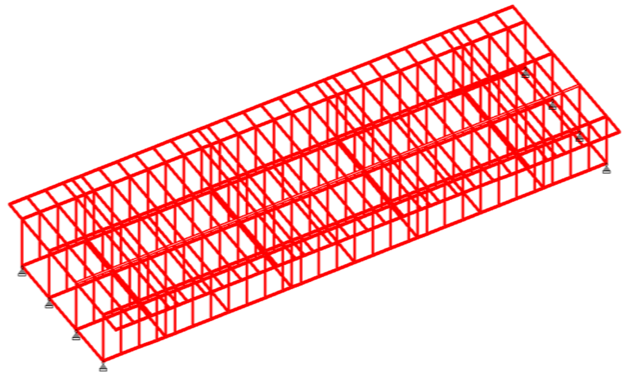


**Figure 3.2:** 3D view of 28m T Beam Bridge

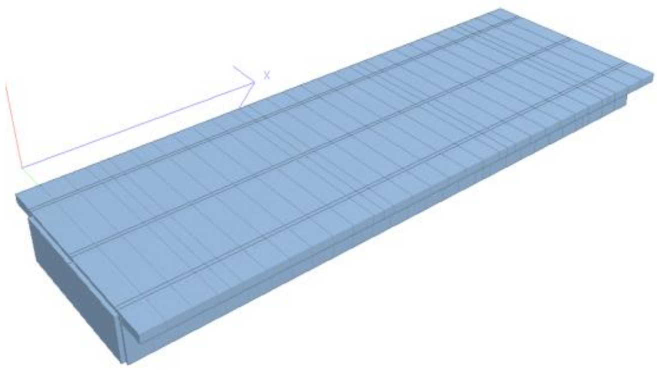


**Figure 3.3:** Self weight load diagram of 28m T beam bridge

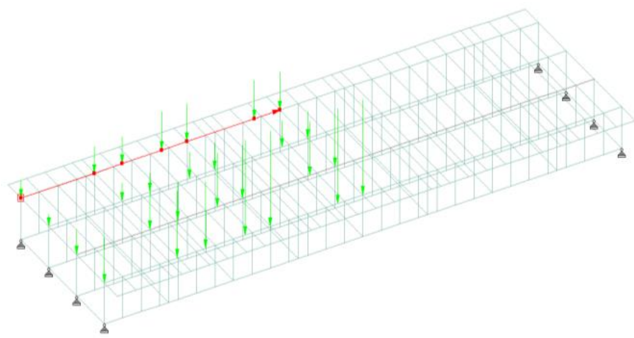
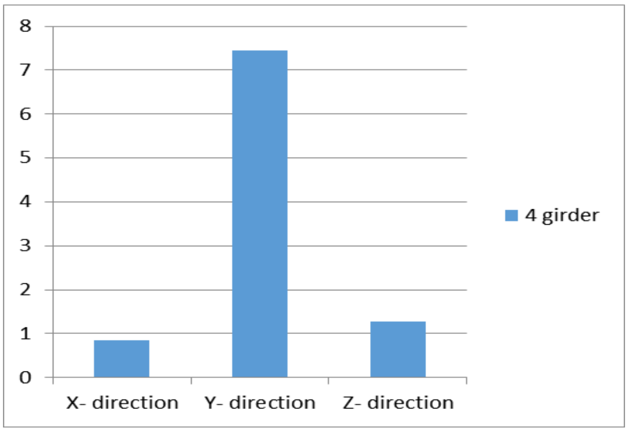


**Figure 3.4:** Rolling vehicle load as per IRC 70R loading diagram of 28m PSC beam bridge

## 7. RESULTS

**Table No. 2:** Maximum Deflection in bridge in mm

| Type of girder | X-direction | Y- direction | Z- direction |
|---|---|---|---|
| 4 girder | 0.845 | 7.441 | 1.27 |




**Graph No. 1:** Maximum Deflection in bridge in mm

**Table No. 3:** Principal stresses in deck slab in N/mm$^2$

| Type of girder | SMAX N/mm2 | SMIN N/mm2 | TMAX N/mm2 |
|---|---|---|---|
| 4 girder | 1.065 | 3.293 | 1.712 |

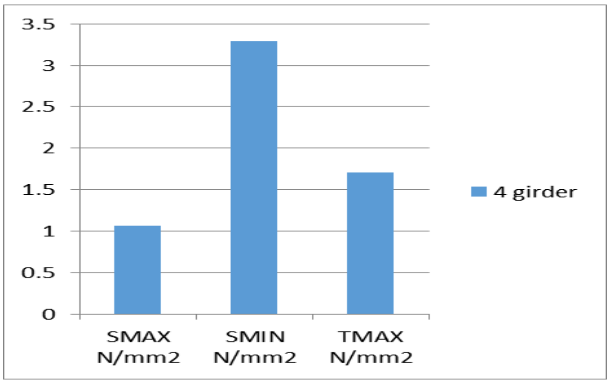


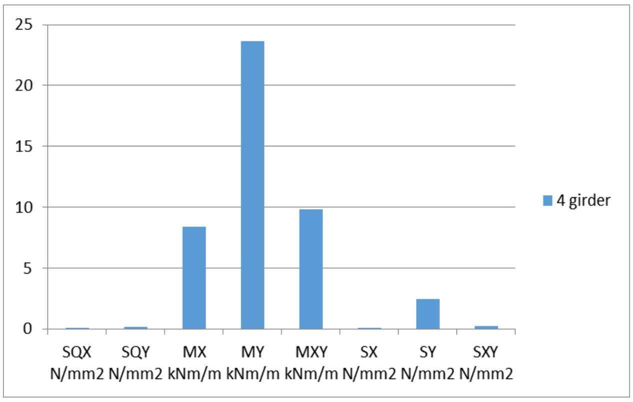

**Figure 4.8 :** principal stresses in deck slab in N/mm$^2$

**Table No. 4:** Shear values in deck slab in N/mm$^2$

| Type of girder | SQX N/mm2 | SQY N/mm2 | SX N/mm2 | SY N/mm2 | SXY N/mm2 |
|---|---|---|---|---|---|
| 4 girder | 0.083 | 0.149 | 0.107 | 2.442 | 0.238 |

**Table No. 5:** Moments in deck slab in N/mm$^2$

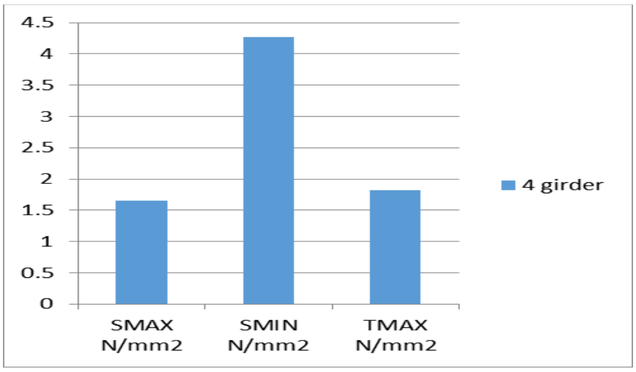
| Type of girder | MX kNm/m | MY kNm/m | MXY kNm/m |
|---|---|---|---|
| 4 girder | 8.428 | 23.683 | 9.846 |




**Graph No. 2:** Shear and moments in deck slab in N/mm$^2$

**Table No. 6:** principal stresses in main girder

| Type of girder | SMAX N/mm2 | SMIN N/mm2 | TMAX N/mm2 |
|---|---|---|---|
| 4 girder | 1.649 | 4.266 | 1.827 |



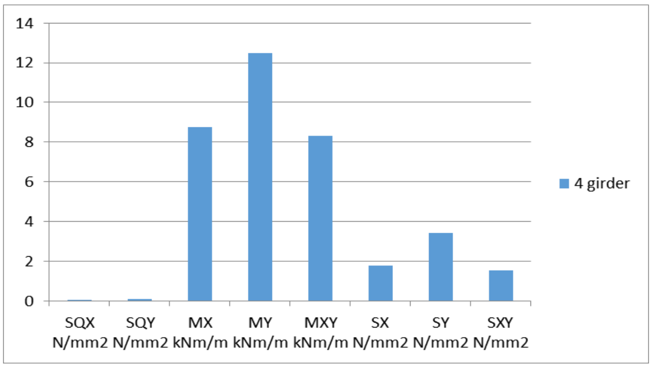

**Graph No. 3:** Shear and moments in deck slab in N/mm$^2$

**Table No. 7:** Shear values main girder in N/mm$^2$

| Type of girder | SQX N/mm2 | SQY N/mm2 | SX N/mm 2 | SY N/mm 2 | SXY N/mm 2 |
|---|---|---|---|---|---|
| 4 girder | 0.036 | 0.107 | 1.775 | 3.421 | 1.528 |

**Table No. 8:** Moments in main girder in N/mm$^2$

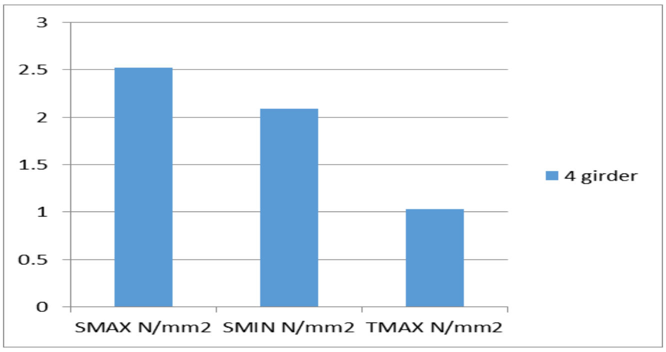
| Type of girder | MX kNm/m | MY kNm/m | MXY kNm/m |
|---|---|---|---|
| 4 girder | 8.743 | 12.475 | 8.331 |




**Graph No. 4:** Shear and moments in main girder in N/mm$^2$

**Table No. 9:** principal stresses in cross girder

| Type of girder | SMAX N/mm2 | SMIN N/mm2 | TMAX N/mm2 |
|---|---|---|---|
| 4 girder | 2.521 | 2.091 | 1.034 |



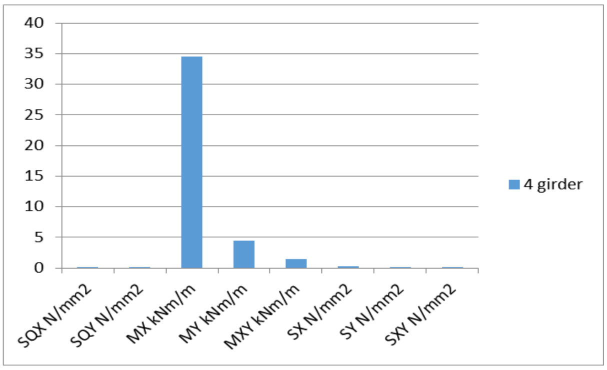

**Graph No. 5:** principal stresses in cross girder

**Table No. 10:** Shear values cross girder in N/mm$^2$

| Type of girder | SQX N/mm2 | SQY N/m m2 | SX N/m m2 | SY N/m m2 | SXY N/mm 2 |
|---|---|---|---|---|---|
| 4 girder | 0.046 | 0.04 | 0.213 | 0.174 | 0.093 |

**Table No. 11:** Moments in cross girder in N/mm$^2$

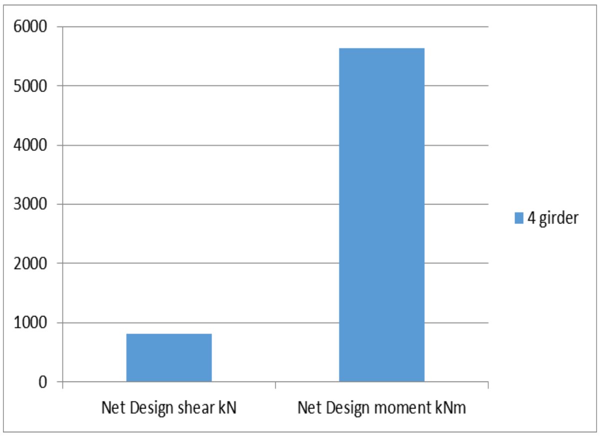
| Type of girder | MX kNm/m | MY kNm/m | MXY kNm/m |
|---|---|---|---|
| 4 girder | 34.55 | 4.46 | 1.446 |




**Graph No. 6:** Shear and moments in cross girder in N/mm$^2$

**Table No. 12:** Net Shear and moment in girder

| Type of girder | Net Design shear kN | Net Design moment kNm |
|---|---|---|
| 4 girder | 818.376 | 5634.05 |




**Graph No. 7:** Net Shear and moment in girder

## 8. CONCLUSIONS

- 28 m Length Bridge is considered for analysis of precast pre-stressed concrete girder bridges, and for all the cases, deflection and stresses are within the permissible limits.
- We can clearly see the effectiveness of using precast pre-stressed concrete girder configuration as it gives us most of the design parameters within permissible limits of serviceability, deflection and shear compared to ordinary deck slab configuration.
- To obtain even better working results the precast pre-stressed concrete girder configuration deck slab can be subjected to pre/post tensioning. The pre-stressing force can be applied more easily and

calculation of required jacking force is also simple. This however is not the case in ordinary configuration as it is required to come up with a composite design in case prestressing is considered in the design/construction phase.

- Ordinary configuration of deck slab creates long term maintenance and serviceability problems as it has more number of exposed components in the structure. This problem can be overcome conveniently in case of precast pre-stressed concrete girder deck slab configuration.

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