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Comparitive Analysis and Design of PSC I-Girder and Double T-Girder at Platform Level in Elevated Metro Stations

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ABSTRACT-This project is todescribe a comparative analysis of I-girder and double T-girder with RCC deck slab of same sectional properties and loading conditions. This report explains about the general features, sectional properties, material strength, design basis, loading conditions (including dead and liveloads) temperature, differential shrinkage and detailed design calculations. In longitudinal design, separate grillage model is generated in STAAD and analysed. The design is performed using as per IRS: 1997 Concrete Bridge code.

I. INTRODUCTION-

This design note pertains to design of 18m span applicable for station platform level superstructure. The spans are in straight alignment. The structural system adopted is precast post tensioned I-girder with cast-in-situ deck slab superstructure and double T-girder with cast-in-situ deck slab superstructure. The superstructure is supported on elastomeric bearings. In longitudinal design, separate grillage model is generated in STAAD and analysed. Transverse analysis and Design of diaphragm are also presented. The superstructure consists of 2 pre cast post-tensioned I-girders carrying cast-in-situ deck slab of 3.45m width on either side of rail track. Two end diaphragms are provided.The span lengths are 18m c/c of piers and the depth of the pre cast girder is 1.0m with 0.200m thick deck slab. The superstructure load is transferred to substructure through elastomeric bearings. Same as the double T-girders is also analysed and design as above-mentioned specifications then compare two types of girders sectional properties and self-weight of the girders.

Construction method

- Precast post tensioned Girders are launched and placed in position on temporary supports.
- Shuttering is provided on the launched girders to receive in-situ slab and end diaphragms.
- Cast the deck slab and end diaphragms.
- Shuttering is removed and load is transferred to permanent bearings.

Project Description

The platform level superstructure consists of pre cast post-tensioned
girders carrying cast in-situ deck slab.
Width of Deck slab = 3.45 m
Depth of the pre cast girder = 1 m
Deck slab thickness = 0.200 m
Centre to Centre distance between piers = 18 m
Expansion joint thickness on both the sides = 0.05 m
Distance between face of the girder and centre line of bearings on both the sides = 0.25 m
Distance between centre line of pier to centre line of bearings = 0.3 m
Girder length = 18-2X0.05 = 17.9 m
Centre to Centre distance between bearings = 17.9-2X0.05 = 17.4m
Length of the girder = 17.9 m
Overhang on both sides = 0.25 m
Centre to centre distance between bearings = 17.4 m

Modelling

The superstructure is discretised into grillage model as given below

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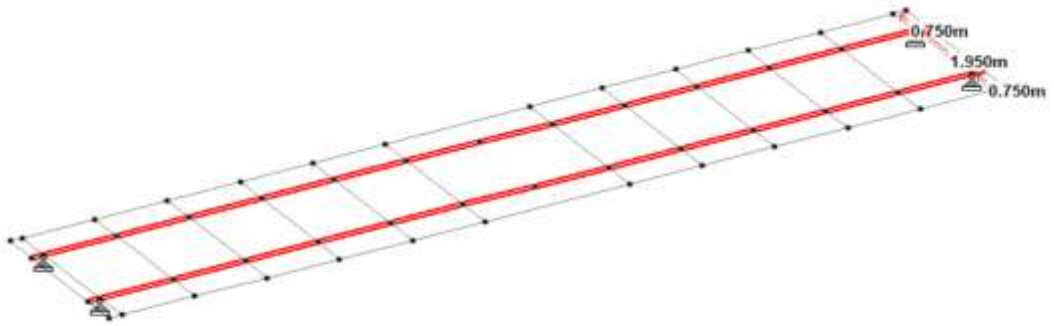
Fig.1 Grillage model of platform level Superstructure



The Grillage Model

The girder- deck system is modelled as a grillage in STADD pro and analysed for SIDL, DL and passenger live load.

The super structure is discretized into the Grillage as described below:

- The deck consists of 2 girders G1, G2 with section properties reflecting composite section. In the longitudinal direction two dummy girders are added at the edges. The dummy members are given very low section properties.
- In the transverse direction, the span is discretized and the corresponding properties of the deck slab are given in the transverse direction.
- Diaphragms- diaphragms are given section properties reflecting their sections.
- Support conditions are hinged and roller type.

I-Girder section model

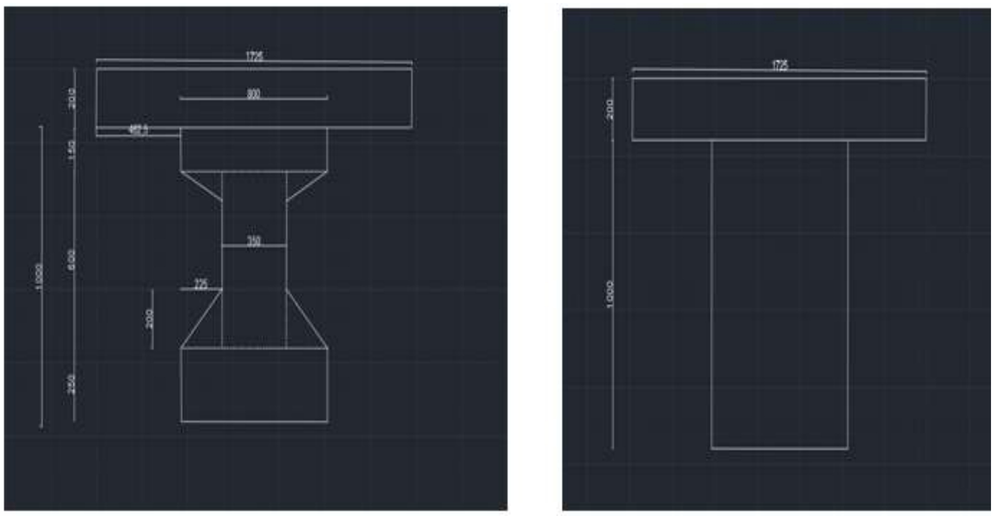


Fig.2 Section at Midspan&support (Outer)

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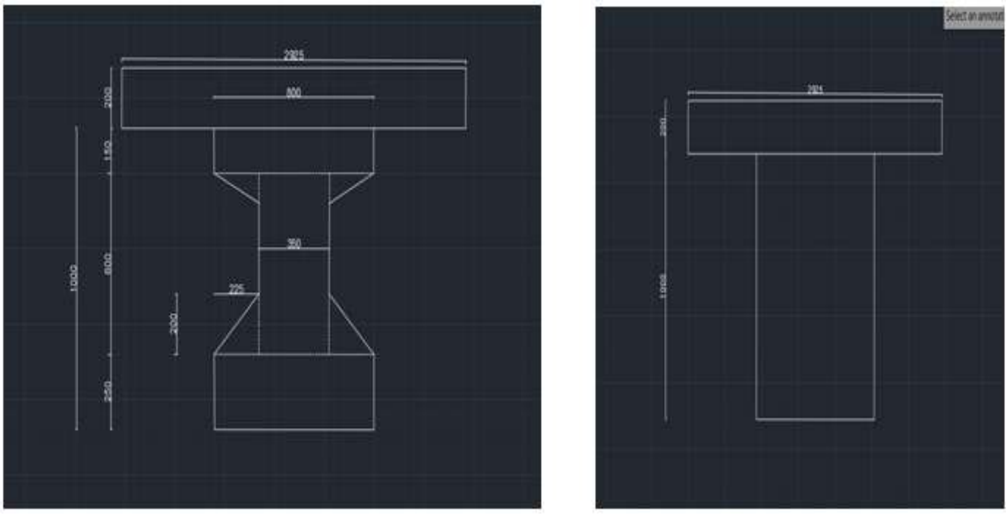

Fig.3 Section at Midspan & support (Inner)

Material Strength

Durability provisions for structure shall be as per "severe" conditions of environment in accordance with IRS-CBC: 1999, clause 5.4. Keeping the durability and structural requirements, the proposed strength of various elements will be as follows:

Pre cast post-tensioned girders M50

In situ deck slab and diaphragms M50

Differential Shrinkage

The differential shrinkage strain between the cast-in situ deck slab and pre cast girder causes the stresses in the pre cast girder & deck slab. The equivalent force, which causes the stress in the girder, is calculated the basic principles. The force is equal to product of modulus of concrete, area of flange and differential strain. The differential strain is calculated from IRS: cl:17.4.3.4.

The residual shrinkage strain for composite section is taken as $1*10^4$ and reduction coefficient 0.43.

Design of superstructure

The superstructure is designed for an orthotropic behaviour, with the longitudinal beams designed as pre stressed concrete elements and the deck slab as RCC member in both directions. The analysis is carried out in the form of grillage in the STAAD Pro Software. The dead load effects of beams slab and diaphragms are analysed separately as simply supported as per the construction sequence.

Loading

The various loads shall be combined in accordance with the stipulations in IRS: 1997 Concrete bridge codes.

Dead loads

Dead load of the structure is calculated based on the unit weight given below.

Concrete (RCC) = 25kN/m^3

Concrete (PSC) = 25 kN/m^3

The girder supported at the bearing supports carries the dead load effects due to weight of girder, deck slab. Hence the analysis is done by considering the loads as uniformly distributed loads on a simply supported beam.

Superimposed Dead loads

The superimposed dead load is calculated based on the Design Basis Report. For Platform slab, the following loads are considered.

Floor finishes = 3.6 kN/m^2 uniform load (24kN/m^3*0.15m)

Suspension load = 2 kN/m^2 uniform loads

Light partition wall load = 1 kN/m^2 uniform load

Live load

The live load is calculated based on the Design Basis Report. For Platform slab, following loads are considered.

Platform and Ticket Hall = 5 kN/m^2

Detailed design calculations

Section property of I-girder and double T-girder

Summary of Section property of I-girder and Double T-girder

	I-girder		**Double T-girder**
	Mid-section	Support section	Sections

Property	Pre cast section	Composite section	Pre cast Section	Composite section	Pre cast Section & Composite section
Overall Depth (mm)	1000	1200	1000	1200	1200
Area (m^2)	0.598	1.182	0.800	1.385	1.590
CG of section from bottom (m)	0.499	0.796	0.500	0.753	0.781
Moment of inertia (m^4)	0.061	0.122	0.067	0.072	0.199
ZTop Slab (m^3)	---	0.233	---	0.161	0.913
ZTop girder (m^3)	0.121	0.399	0.133	0.293	
ZBottom (m^3)	0.122	0.156	0.133	0.095	0.255

Table 1-Section property of I girder & Double T-girder

Load Calculation for platform Girders
Self-weight of I-girder
End span (outer girder & inner girder)
Length of end span = 18 m
Length of precast girder = 17.9 m
Distance Between the temperature support = 17.4 m
Unit weight of concrete girder (PSC) = 25 kN/m^3
Insitu concrete (RCC) = 25 kN/m^3
Section at Midspan
C/S Area at midspan section = 0.598 m^2
Uniformly distributed load at mid-section = 0.598 X 25
= 14.938 kN/m
Section at Support
C/S Area at support section = 0.800 m^2
Uniformly distributed load at support section = 0.800 X 25
= 20 kN/m
Uniformly distributed load at varying section = (20+14.938)/2
= 17.468 kN/m
Length of thickened portion of rib = 1.30 m
Length of varying portion = 1.60 m

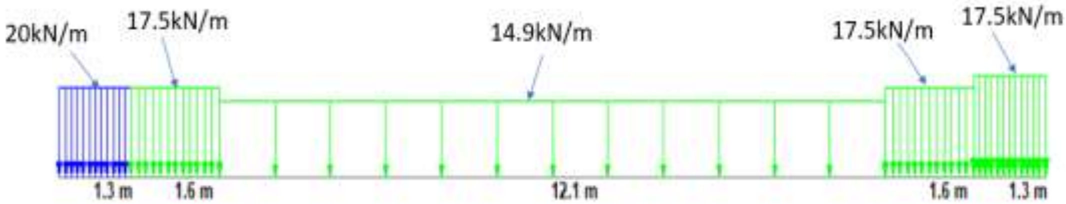

Fig.4Self-weight of girder

Total vertical load = 285.35 kN
Reaction at one support = 142.67 kN
Longitudinal eccentricity from center of pier = 0.3 m
Longitudinal moment = 43 kN/m
For Two I-girders = 285.35 X 2
= 570.70 kN

Self-weight of Deck slab
Girder from center 1 (Outer)

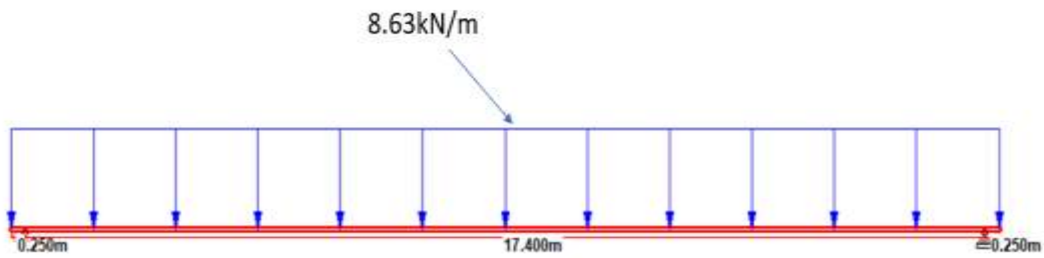

Fig.5 Self-weight of deck slab

Thickness of deck slab = 0.20 m
Width of deck slab = 0.4+(2.54/2)
= 1.67 m
Uniformly distributed load at support section = (0.20 X 1.67 X 25) + (0 X 1.67)
= 8.35 kN/m
Total vertical load = 149.46 kN
Reaction at one support = 74.73 kN

Girder from center 2 (Inner)
Thickness of deck slab = 0.20 m
Width of deck slab = 0.4+(2.54/2)
= 1.67 m
Uniformly distributed load at support section = (0.20 X 1.67 X 25) + (0 X 1.67)
= 8.35 kN/m
Total vertical load = 149.46 kN
Reaction at one support = 74.73 kN

Self-weight of deck slab (Outer &Inner) = 149.46 + 149.46
= 298.92 kN
Total self-weight of I-girder = 570.70 + 298.92
= 869.63 kN

Self-weight of Double T-girder
Length of end span = 18 m
Length of precast girder = 17.9 m
Distance Between the temperature support = 17.4 m
Unit weight of concrete girder (PSC) = 25 kN/m^3
Insitu concrete (RCC) = 25 kN/m^3
C/S Area at midspan section = 1.59 m^2
Uniformly distributed load at mid-section = 1.59 X 25
= 39.75 kN/m

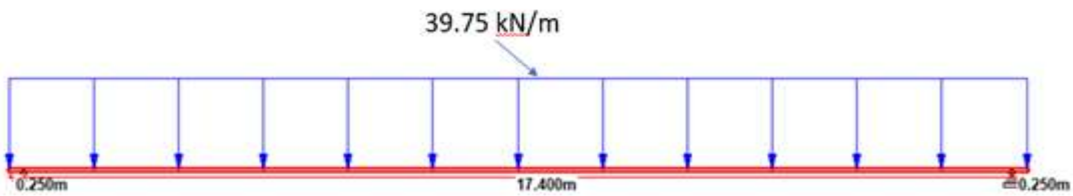

Fig.6 Self-weight of Double T-girder

Total vertical load = 17.9 X 39.75
= 711.525 kN
Reaction at one support = 355.76 kN
Total self-weight of Double T-girder = 711.525 kN

Self-weight of Diaphragm
Thickness of cast in-situ diaphragm = 0.4 m
Depth of cast in-situ diaphragm = 0.65 m
Weight of cast in-situ diaphragm = 0.4 X 0.65 X 25
= 6.5 kN/m

II. RESULT AND DISCUSSION

In regular form, we made I-girder as precast then shuttering is done then place the RCC deck slab over the girder. It is a two-type process. The time of Construction is also more while casting the system, hence we go with Double T-girder. Here both deck slab as well as girder the entire system is precast. It is a single process.

The form work and the construction time period are reduced. The main objective of this project is to compare both the I-girder and Double T-girder and to find out the reduction of construction time period and making the structures economical. Based on the calculations of sectional properties of the element, Centroid and self-weight of both structures has to be compared.The results are as follows.

III. CONCLUSION

- From the calculations, Centroid of Outer & Inner I-girder is 499.372 mm and Centroid of Double T-girder is 781.341 mm. By comparing two systems of centroid values, the double T-girder value is increases for total system. If the value of CG increases (i.e., eccentricity value) then it is easy to place the number of wires/strands in the section.
- The total self-weight of the system is calculated as self-weight of I-girder with slab is 869.636 kN and self-weight of double T-girder with slab is 711.525 kN. Here the self-weight of double T-girder with deck slab has lesser value when compared to the self-weight of I-girder with deck slab. If the self-weight of the system is reduced then the material used for this section is also reduced. So, the material consumption of double T-girder with deck slab is lesser amount while compared to I-girder.
- Due to the fact that it helps to reduce the construction time period and these systems can be constructed by making the structures economical.