DESIGN OF COMPOSITE GIRDER DECK TYPE BRIDGE

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Abstract

This report provides guidance on the design of steel-concrete composite bridges, which consist of steel girders and reinforced concrete slabs on top. Two common forms are considered: multi-girder and ladder deck bridges. Guidance is given on the general considerations for the preliminary and detailed design process, in addition to guidance on the verification of structural adequacy in accordance with manual and relevant design and material standards.

Though few such constructions have come up in India during the last few decades, there is now a sense of realization of the potential benefits of steel concrete composite construction. It is an ideal example wherein there is most effective utilization of materials i.e. concrete is in compression and steel in tension. Composite sections have higher stiffness and high ductility of steel ensures better seismic resistance.

The aim of the report is to provide guidance for both the novice and experienced bridge designer on the design of cost-effective steel-concrete composite bridges. The aim of the report is to provide guidance for both the novice and experienced bridge designer on the design Analysis and Design of Composite Bridge Structures.

Keywords — ridge structures, Steel main beams, GFRP deck, pultrude GFRP material

1. Introduction

1.1 General

Steel-concrete composite bridges provide an efficient and cost-effective form of bridge construction. By utilizing the tensile strength of steel in the main girder and the compressive strength of concrete in the slab, the bending resistance of the combined materials is greatly increased and larger spans are made possible. Steel bridges with a composite concrete deck is a means of circumventing this step. Indeed, the steel girder’s ability to support formwork, reinforcement and the deck concrete has greatly contributed to the increasing popularity of composite bridges, along with the reduced construction time compared to concrete bridge.

The guide assumes the reader is familiar with the general principles of limit state design and has some knowledge of structural steelwork. It provides advice on the general considerations for the preliminary and detailed design process, in addition to guidance on the verification of structural adequacy in accordance with the Bridge manual and relevant design and material standards.

1.2 Steel-concrete composite bridge girders

A composite steel composite girder consists of precast reinforced concrete deck slab or precast pre-stressed concrete deck slab with I steel section as beam. The steel structure of a bridge is fixed to the concrete structure of the deck so that the steel and concrete act together, so reducing deflections and increasing strength. This is done using 'shear connectors' fixed to the steel beams and then embedded in the concrete. Steel–concrete composite beams are widely used buildings and bridges due to their capability in developing high flexural strength and stiffness.
2. Objective :- Design of a composite girder of a deck type bridge

2.1 Structural Configuration

2.1.1 Multi-girder bridges

In multi-girder construction a number of similarly sized longitudinal plate girders are arranged at uniform spacing across the width of the bridge. The deck slab spans transversely between the longitudinal girders and cantilevers transversely outside the outer girders. The girders are braced together at supports and at some intermediate positions. Composite action between the reinforced concrete deck slab and the longitudinal girders is achieved by means of shear connectors welded on the top flanges of the steel girders.

2.1.2 Longitudinal girders :-

The steel girders are usually fabricated I-section plate girders; for smaller spans, it is possible to use rolled section beams (Universal Beams) but, for reasons discussed below, rolled sections are rarely used today. Usually, girders are spaced between about 3.0 and 4.0 m apart, and thus, for an ordinary two-lane over bridge, four girders are provided. This suits the deck which has to distribute the vertical loads from the wheels.

3. Bracing:-

3.1 Intermediate bracing:-

In the completed bridge, intermediate bracing is usually needed at discrete positions in the spans of multi-span bridges, to stabilise the bottom flanges adjacent to intermediate supports (where they are in compression). During construction, bracing is needed to stabilise both the bottom flanges adjacent to intermediate supports and the top flanges in mid span regions. Where the girders are curved in plan, bracing will also be needed to provide ‘radial’ restraint to the bottom flanges. In most cases,

Typical paired bracing arrangement

3.1.2 Cross girders at internal supports (pier diaphragms)

At the internal supports of continuous spans, the cross girders are very often deeper than the intermediate cross girders, providing a stiffer and stronger ‘pier diaphragm’, with bolted connections that can transfer the larger restraint forces at the supports.

Cross girder at an intermediate support of a ladder deck bridge
4. Methodology:-

4.1. Hydrological:-

Peak rainfall in given catchment area \( Q = 61.6 \text{m}^3/\text{sec} \)

Discharge over the river \( Q_{\text{max}} = 38.94 \text{m}^3/\text{sec} \)

Total discharge = \( Q + Q_{\text{max}} = 100.54 \text{m}^3/\text{sec} \)

Velocity in river water in flood condition;

MANNING FORMULA = \( \frac{1}{N} \times M^{2/3} \times \sqrt{1 + \frac{\sin \theta}{1 - \sin \theta}} \)

\[ D = \left( \frac{15000}{1200} \right) \times \left( 1 + \frac{\sin 30^\circ}{1 - \sin 30^\circ} \right)^2 \]

\[ D = 11 \text{ m} \]

Load Calculation:

Dead Load = Deck slab + Girder + side walls

\[ W = 12.2 + 3.64 \times L = 740 \text{kg/m}^2 \]

Live load

For wheel load: 50 tons (By according to traffic survey (A’-A’) IRC loading)

Impact load of live load

\[ 9/13.5 + L (L = \text{Length of span}) = 9470 \text{kg/m}^2 \]

Wind load :- By wind load specification at 28 m height = 141 kg/m²

Lateral loads:- On rolling and parapet = 150 kg/m²

On kerb = 750 kg/m²

Longitudinal force :-

Tentative effort = 20% of live load

\[ = \frac{20}{100} \times 5000 = 10000 \text{kg/m²} \]

Design of RCC deck Slab

Data selected: Overall width of bridge = clear width + (2xwidth of kerb) + drains

\[ = 7.5 + (2 \times 1.2) + (2 \times 3) \text{ mtrs.} = 10.5 \text{ m} \]
Thickness of slab be selected as 80 mm per meter of span
\[ D = 80 \times 40 = 3200 \text{ mm} \]
Effective depth \( d = 3200 - 50 = 3150 \text{ mm} \).

**Effective Span**

Clear span + effective depth = 7.5 + 3.15 = 10.65 m
Centre to center of supports = 7.5 + 3.2 = 10.7
Therefore Effective span = 10

**Dead Load Bending Moment per Meter Width**

Dead load of slab = 3.200 \times 24 = 76.8 \text{ KN/m}^2
Dead load of wearing coat = 0.080 \times 22 = 1.76 \text{ KN/m}^2
Total = 78.56 \text{ KN/m}^2
\[ \frac{WL^2}{8} = \frac{(78.56 \times 10.65)}{8} = 103.7 \text{ KN/m} \]

**Live load BM**

\( W = 500 \text{ mm} = 0.5 \text{ m} \)
Therefore Distance between centers of two vehicles = 1.2 + 0.5 = 1.42 m
Minimum distance of wheel from the kerbs = 0.15 + (0.50/2) = 0.4 m
Moment which occurs at centre of span = 28.35\(X\) – 23.25\(X\) = 58.74 \text{ kN/m}

**Impact factor** = 0.35
\[ = 158.45 \text{ kN-m} = 158.45 \times 106 \text{ N-m} \]

**Distribution Reinforcement**: As per the recommendation of IRC, distribution steel is to be provided to resist 0.3 times the live load moment including impact contribution and 0.2 times the dead load moment.
\[ M = 0.3 \times 58.74 + 0.2 \times (40.29 + 23.5) = 30.38 \text{ kN-m} = 30.38 \times 106 \text{ N-mm} \]

Effective depth for distribution steel
\[ = 350 - \text{ thickness of distribution steel} \]
\[ = 350 - \times 12 = 344 \text{ mm} = 350 \text{ mm take (if 12 mm bars are used)} \]
Ast = 522 mm² = 550 mm²

Take Spacing of 12 mm bars

S = x (122) x 1000/522
   = 216  Provide 12 mm bars at 200 mm c/c.

Design of flange

Flange area req. = m/Ωbct xd
Af = 160400 x 106 / 165 x 2500
Af = 1850.8 mm²
Flange outstand = 500 - 8/2 = 246 mm
Flange are provide by plate = 500 x t
   = 500 x 40
   = 20000 mm²

Check = moment of inertia of the plate girder
Ixx = 8x 2500³/12 + 2x (500x40³ /12 + 500x40 x (2500/2+20)²
Ixx = 7493800 x 10⁴ mm⁴

Moment of resistance = Ωbct x I/ y
M g = 165 x 7493800 x 10⁴/ (2500/2+30)
   = 7531.42 x 10⁶ N/mm.

Design of welding:

Horizontal shear/mm. = Vay / Ixx

V = 16040 kN
Ay = 500 x 16 x (2500/2 + 16/2)
Ay = 1006.4 x 10⁴ mm⁴
Ixx = 7943800 x 10⁴ mm⁴

Horizontal shear = 16040 x 10³ x 1006.4 x 10⁴ / 7493800 x 10⁴
   = 349.20 N/mm

Size of weld = welding is done on both side
349.20 = 2 x (.7 x S x 10⁸)
= 2.47 mm.

Permissible pitch = 96 + 40 = 136 mm

Provide 40 mm long fillet weld at pitch of 80 mm, the 40 mm, 30 mm, 16 mm

Design of bearing stiffeners:

Max. Shear force V = 16040 kN.

Allowable bearing stress = .75 FY
Bearing area req. = 160400 x 10³ / 187.5
   = 8577 mm²

Let’s try two plate 200 mm wide as stiffeners.
Thickness of plates = (8577 / 2) x 200
     = 20560 mm²

Out stand = 200 mm
Bearing area provide = 2 x 200 x 20
   = 10560 mm²
Ixx = 2 x (20 x 2003 / 12 + 20 x 200 (100+8)/2)
I_{xx} = 11319.46 \times 10^4 \text{mm}^4

Radius of gyration \( r \) = \( I_{xx} / A \)
= \( 11319.46 \times 10^4 / 10560 \)
= 103.5 \text{ mm}

Effective length = .7 \times 2500 = 1750 \text{ mm}

\( \lambda_b = I/r \), \( \lambda_b = 1750/103.5 \)

\( \lambda_b = 16.90 \text{ mm} \)

By I.S. 800-1984 \( I/r = 16.90, F_Y = 250 \text{N/mm}^2 \)
\( \Omega_{ac} = 148.67 \text{N/mm}^2 \)
Safe load = 148.62 x 10^560
= 15694.4 \text{kN} < 16040 \text{ Hence Safe.}\n
So that provides 400mmx20mm plates as stiffeners

So that spacing is provide = 300 mm.
Model of a composite I girder bridge

Bridge Load Distribution Factors
5. Conclusions

A detailed numerical investigation of the behavior of skew composite bridges with steel girders under truck loads was conducted for this study. The numerical approach applied included an extensive study of continuous bridges to determine the effect of various key parameters of bridges on the live load distribution factors for both shear and bending moment. Empirical expressions for the shear and bending moment distribution factors were derived that are suitable for use with current bridge design codes. The proposed expressions are a function of the girder spacing, number of lanes loaded, and span length of bridges.

Analytical procedures for determining the residual shear capacity of damaged web panels, which were based on an assumed plastic collapse mechanism, were found to be unrepresentative of the fracture failures exhibited by the maraging steel test girders. Further development of the analytical procedures will probably require consideration of material fracture. Areas of particular interest include the magnitude of the applied stress field in the web panel (accounting for damage) and appropriate stress intensity factors due to the approximate size and type of crack.

6. REFERENCES

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