

DESIGN AND ANALYSIS OF AN OVER-BRIDGE

S Satish¹, M Satish², B. Sri Priya³

Civil Dept, Nagole Institute of Technology and Science, Hyderabad, Telangana.

ABSTRACT

In many countries Composite bridges have become a popular solution as they have many advantages because of the steel girders, as they can carry the weight of the formwork and the wet concrete. The competitiveness of composite bridges has been growing in recent years. Composite girders not only have less deflections and economical sections but also reduce the construction time, which is an added advantage for the constructor.

This project gives brief information about bridges highlighting composite bridges. Our work includes design of a road over bridge with composite welded steel girder-RCC deck slab for the requirements of a two-lane heavy traffic road. A detailed design is presented for RCC deck slab, main girders, cross girders, stiffeners, bracings, bearings, connections along with partial analysis using STAAD.VI8. Codes referred were IRC- 22, IRC- 24, IRC- 21, IRC - 6, IRC- 83 and IS- 456 and steel tables for selection of steel sections. The design details and results obtained are included.

1.0 Introduction

A bridge may be a structure, engineered to span physical obstacles like water bodies, valleys, or roads to provide passage upon an obstacle. The specified passage could also be a road, a railway, pedestrian or a pipeline. Technically it's a structure carrying traffic or the other moving hundred over associated obstruction.

First bridge ever seen may be a tree lying on the bank of a water course impressed by the power of nature, man has engineered bridges by mistreatment stone, logs, wood planks, employing straightforward support and cross beam arrangement. Around 320 B.C, Alexander the good engineered floating bridges for the passage of his army. The amount between two hundred B.C and 260 A.D witnessed the widespread use of stone arches by Romans mistreatment large piers. The medieval amount bridges were loaded with ornamental and defensive towers, chapels, statues, retailers and dwellings. The Arkadiko Bridge is one in

every four Mycenaean arch bridges a part of a former network of roads, it's one in every oldest arch bridge still existing and use.

In middle nineteenth century, demand for stronger and {larger|and greater} bridges over larger rivers resulted within the use of forged iron and iron commutation timber and stone for bridges.

Forged iron being terribly brittle wasn't found terribly appropriate for building massive span bridges. The Iron Bridge in Coalbrookdale, European country in 1779 used forged iron for the primary time as arches to cross the Severn. a good combination of forged iron for compression members and iron for tension members was 1st utilized in tied bridge around 1840 particularly in railway bridges.

Many new constructions came into image by the invention of steel. Post war years saw the emergence of concrete as an appropriate material for brief and medium span bridges with the more advantage of sturdiness against aggressive Environmental conditions as compared with steel.

The enormous leap with construction of George Washington Bridge with a span of 1060 m. Since the start of twentieth century, the employment of concrete has

become in style for each road and railway bridges commutation steel primarily because of low maintenance prices and sturdiness concrete Bridge decks having varied structural configurations like block and box culverts, Tee beam end block, Continuous beam, Bowstring, Balanced cantilever, Open surface, and Rigid Frames etc.

Extensively used for medium to long spans.

New era of prestressed concrete bridges started with the invention of PSC in 1950. The invention of cable stayed bridges transpire within the struggle to cut back the depth of girders of enormous span bridges.

1.2 PROBLEM STATEMENT

Consequently, the exploration from the above literature stating FRP efficiency, in which the discussion on analysis of RCC is limited, thus provoking to analyze the RCC bridge. Additionally, this helps to develop a composite bridge in a minimized cost and increased efficiency by using lower cost materials i.e., concrete and steel (as the fibres and polymers inclusion may be costly) which are usually available at cheaper rates (as compared to the fibres, polymers etc.,) in the Indian market. Hence, the efforts are extended to develop a composite bridge comprising R.C.C deck slab, steel girders and with provision of bearings to reduce the Shear Force in the section.

1.3 Objectives and Scope of work

Objectives

- a) To design composite I-girder bridge for two lane vehicular traffic considering class-AA loading and check its safety.
- b) To know the behavior of composite bridge.
- c) To know the steps involved in the design of composite steel girder bridge.

Scope of work

- a) Bridge is designed for a span of 32m. which can be done for longer spans
- b) The bridge is designed for class AA loading.
- c) The bridge design is suitable for normal environmental conditions, where it can be done for extreme weather conditions.
- d) The design is carried out for Indian conditions according to Indian Codes (IRC 24, 21, 83 etc).

LITERATURE REVIEW

2.0 Introduction

Theories are developed by practical experiences and practices are the implementations of theories. Therefore, the records of these experiences and theories which form a literature, plays a vital role in researches. Further, literature review can save lot of time for researchers by eliminating the redundancy. In view of this

an attempt is made to review the literature in this field to check the work carried out in the contemporary period.

In addition, since, the literature review can also help finding the research gaps, this chapter becomes a pathfinder for this project.

2.1 Literature Survey

2. Dr. Sabeeh Z. Al-Sarraf, Dr. Ammar A. Ali & Rana A. Al-Dujaili, on a whole described the Analysis of Composite Bridge Superstructures Using Modified Grillage Method to analyze anisotropic plates (having various elastic properties and geometries in various directions), the model has four side beams with only flexural rigidity. The substitute grid framework is studied to provide the same deformations and deflections of the orthotropic plate elements of the modeled bridge. Application of the procedure suggested in the study of actual bridge decks is checked out using STAAD Pro.V8i program. The results supported the suggested procedure and admissible to adapt to this kind of bridge deck. It is found that the modified grillage method gives simpler method and adequate results when compared with the Finite Element Method or orthotropic plate theory solved using

Finite Difference Method for this type of bridges.

3. Y. Okui(2014) has written on Design Issues for Steel-Concrete Composite Girders, which deals with the 2-I steel concrete composite girder bridge design. Also states the time dependent behavior of the composite girder, crack-width control design procedure and flexural strength of composite sections.

2.1.2 Literature from papers published

1. Peter Collin, Anders Stoltz, Mikael Moller (2002) explained on Innovative Prefabricated Composite Bridges, how the composite girder bridge is best alternative to conventional RCC Bridge based on the erection time, quality, working environment and deck surface in the paper.

2. **Hu Zhendong Wang Hualin,** focused on the effect of bridge vibration on vertical acceleration of the vehicles and presenting the Analysis of Comfort Properties for high-speed Vehicle Moving Over Bridge based on the model of simply supported beam on moving load. Also, the maximal accelerations of the vehicles at both the ends and at critical states were

analyzed.

3. **ZHONG Ming-quan, YANG Guang, WANG Xu-jun, SHI Shangwei, LU Ya-ni** discussed on the high amounts of creeping camber of simply supported prestressed concrete plate girder bridge which influences the travel comfort of the vehicle and the Analysis of Influence of Creeping Camber of PC Plate Girder Bridge on Riding Comfort of High-Speed Traveling Vehicle was given. The model of vehicles and relation between plate girder bridge deck and the mathematical relations between the vehicle vertical vibration response and creep, span and vehicle speed on the bridge are determined using half-sine curve and $\frac{1}{4}$ sine curve simulations.

4. **Tomasz Siwowski, Damian Kaleta** (2018) investigated on Structural behaviour of an all-composite road bridge, developed a super structure of U-shaped girders and sandwich deck slab were fabricated using vacuum infusion, the bridge configuration was given in Finite Element Model for design and the results were discussed. The changes in the structural behavior of the bridge were assessed using fiber-optic sensors to understand the long-term performance of FRP and the paper states that an all-composite bridge can meet

the relevant strength, deflection design criteria.

5. Kvamme, Jeffrey David (2018) gathered information over about 1500 studied to examine time domain trends on bridge decks in service that undergo treatments. They studied the average improvement on decks post-treatment and pre-treatment condition.

6. J Prakash Arul Jose, P Rajesh Prasanna, Fleming Prakash (2018) investigated on the bridges made of timber-concrete (deck and pile foundations of massive timber and vertical supports of fibre reinforced concrete) and conducted several tests on stability and durability.

3. METHODOLOGY

3.0. Specifications

The specification of the required bridge are to be considered as follows

Clear span available = 26m

Number of main girders = 6

Number of cross girders = 7

Total length of main girders = 32m

Total length of cross girders = 10m

Spacing between main girders = 2m

Spacing between cross girders = 4m

3.1. Methods of analysis

3.1.1. Working stress method

This is conventionally employed method to RCC design with an assumption that concrete is elastic, and therefore steel and concrete act together elastically. The loads are linearly related to stresses up to the structural collapse. The fundamental point of this method is that the maximum allowable stress for concrete and steel do not exceed throughout the structure though subjected to the undesirable combination of working loads. The sections are so designed according to the elastic theory of bending presuming obedience of Hooke's law by both materials. The elastic theory specifies a linear variation of strain and stress from basic (zero) at the neutral axis to a maximum at the extreme fibre. Typical stress and strain distributions in a rectangular section are shown in fig.

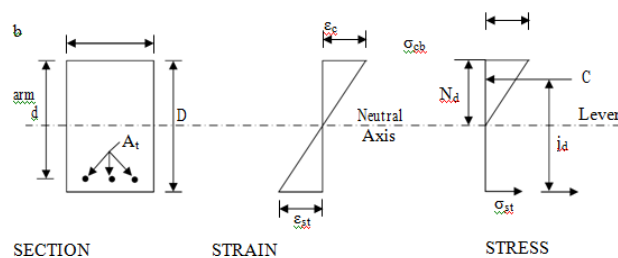


Figure 3.2.1.1 Stress-strain curve in working stress design

4.1. Design of deckslab

Adopting working stress method for shorter

span, Depth of the slab $d = \sqrt{\frac{M}{R_b}}$

$$\sqrt{\frac{28.809 \times 10^6}{2.104 \times 1000}}$$

117.015 mm

Hence provide an overall depth $D=200$ mm and $d=160$ mm (assuming 40mm cover)

Area of steel $A_{st} = M / (\sigma_{st} \times d)$

$$= 28.809 \times 10^6 / 200 \times 0.857 \times 16$$

$$= 1050.503 \text{ mm}^2$$

Provide 16mm ϕ bars @ 200 mm c/c for main reinforcement

For longer span,

Effective depth $d = 160 - 16/2 = 152$

Depth of the slab $d = \sqrt{\frac{M}{R_b}}$

$$= \sqrt{\frac{8.625 \times 10^6}{2.104 \times 1000}} = 64.025 \text{ mm}$$

Hence 200mm depth provided is ok

Area of steel $A_{st} = \frac{M}{\sigma_{st} \times d}$

$$= \frac{28.809 \times 10^6}{200 \times 0.857 \times 160} = 331.058 \text{ mm}^2$$

Minimum area of steel $= 0.85bd / f_y$
 $= 327.711 \text{ mm}^2$

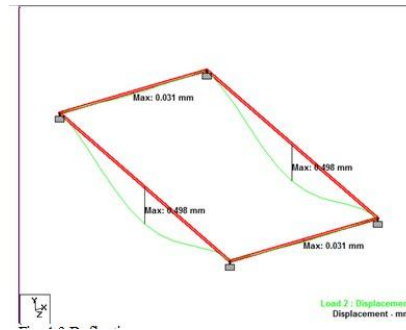


Fig. 4.3 Deflection

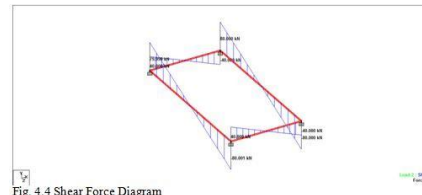


Fig. 4.4 Shear Force Diagram

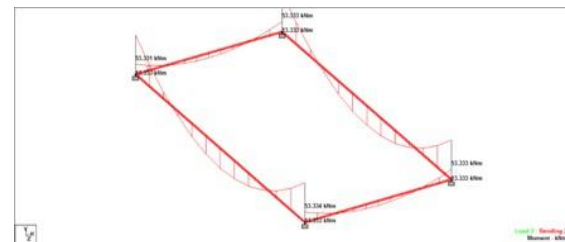
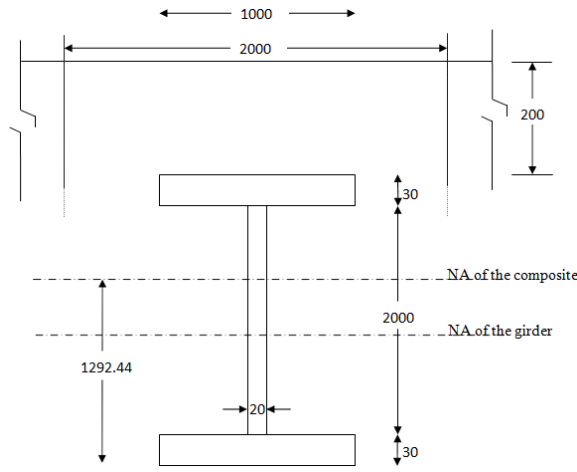


Fig 4.5 Bending Moment Diagram

4.1. Design of the composite section



Equivalent Area of concrete = actual area of
concreteslab/modular ratio

$$= \frac{2000 \times 200}{13} = 30769.23 \text{ mm}^2$$

Total horizontal shear force on the width =
159.648 x 1000

$$= 159648 \text{ N} \approx 159.648 \text{ kN}$$

4.2. Loading details

Using class AA loading,

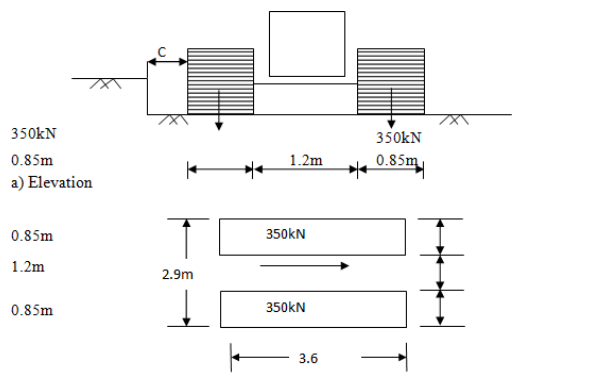
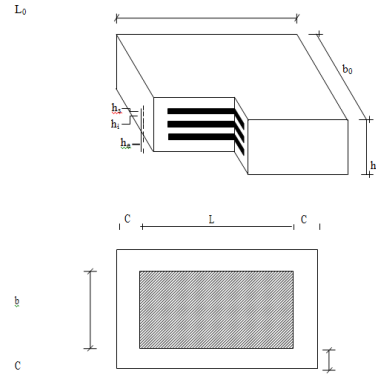


Figure 4.1 for tracked vehicle



SELECTION OF BEARING PAD DIMENSIONS

Max vertical Load on bearing

$$N_{max} = 338.8 + 330.312 = 669.112 \text{ kN}$$

$$\text{Min vertical load } N_{min} = 330.312 \text{ kN}$$

Table ref IRC- 83-1987(part II) clause 916.2 (ref APPENDIX A-IV)

Adopt plan dimensions of bearing pad as 320 x 630 mm

$$B_o = 400 \text{ mm};$$

$$l_o = 800 \text{ mm};$$

$$\text{Loaded area } A_2 = 30.6 \times 10^4 \text{ mm}^2$$

From IRC-21, clause 307.1, (ref APPENDIX A-II)

$$\text{Allowable contact pressure} = 0.25 f_c \sqrt{\frac{A_1}{A_2}}$$

Where,

A_1 – concrete bed block area over pier

A_2 - elastomeric pad area

$$\text{But, } A_1 / A_2 = 2$$

$$\text{Allowable contact pressure } \sigma_{ac} = 0.25 \times 20 \times \sqrt{2}$$

$$= 7.07 \text{ MPa}$$

$$\text{Effective bearing area required} = \frac{N_{max}}{\sigma_{ac}} = \frac{669.112 \times 10^3}{7.07}$$

$$= 9.461 \times 10^4 \text{ mm}^2 < 23.9 \times 10^4 \text{ mm}^2$$

Hence safe.

$$\text{Bearing stress } \sigma_m = \frac{669.112 \times 10^3}{9.5 \times 10^5}$$

$$= 3.435 \text{ MPa}$$

FRAME STRUCTURE



Fig. 4.13, structure of frame – 3D Model

RESULTS AND DISCUSSION

Moving a step ahead from the conventional Bridge, a detailed design of composite girder bridge for the given load and traffic conditions as mentioned in the data of project details has been proposed.

- The bridge design is done by referring to the IRC codes has come out to be safe in all respects.
- Considering all the assumptions and obstructions at the site with a clear span of 26m, adopting class-AA loading, a composite bridge of 32m long steel girders with a 200mm thick RCC deck slab along with cross girders, stiffeners, bracings and elastomeric bearings are designed to suit the requirements.
- The bridge will be a well-established alternative to concrete bridge, if the deck is

prefabricated several advantages like faster erection time, higher quality, reduced deflections and longer life can be expected.

- Added to that, this composite bridge maybe adopted for economical purposes as the FRP's which are used in the developed countries are uneconomical in the Indian market and also concrete and steel are readily available in this area.
- Composite bridges become a solution as they have many advantages because of the steel girders, as they can carry the weight of the formwork and the wet concrete.
- The competitiveness of composite bridges has been growing in recent years. Composite girders not only have less deflections and are economical sections but also reduce the construction time, which is an added advantage for the constructor.
- The use of elastomeric decreases the shear strain due to longitudinal force, creep and shrinkage in the section.

REFERENCES

1. N.Krishna Raju, Professor, Civil Engineering, "Design of Bridges", fourth edition.

2. Ashok.K. Jain, Professor of Civil Engineering, IIT, Roorkee, “Reinforced Concrete limit state design” sixth edition.
3. Dr. Ram Chandra, Professor, Department of Structural Engineering, M.B.M.Engineering College University of Jodhpur, “Design of Steel Structures-II”, tenth edition.
4. Hu Zhendong Wang Hualin,Tongji University, Shanghai,Analysis of ComfortPropertiesforHighSpeed Vehicle Moving Over Bridge.
5. Palermo A, Liu R, Rais A, McHaffie B, Pampanin S, Gentile R, Nuzzo I, Granerio M, Loporcaro G, McGann CR, Wotherspoon LM, Andisheh, K University of Canterbury, Performance of Road Bridges During the November 14th Kaikoura Earthquake published in Bulletin of New Zealand Society for Earthquake Engineering,50(2):253-270 • June 2017.
6. David Collings, Fellow Birmingham University, U.K., “Steel-concrete composite bridges”2nd revised edition.
7. . Dr. Sabeeh Z. Al-Sarraf, Dr. Ammar A. Ali & Rana A. Al-Dujaili, Engineering & technology journal, vol.5, 2009, Analysis of Composite Bridge Superstructures Using Modified Grillage Method.
8. Y. Okui, professor Saitama University, Design Issues for Steel-Concrete Composite Girders.
9. PeterCollin,AndersStoltz, Mikael Moller,Lulea University of Technology, InnovativePrefabricatedComposite Bridges, Structural engineering International Journal 19(1):69-78.
10. Tomasz Siwowski, Damiankaleta,Rzeszow University of Technology, “Structural Behaviour of an All-Composite Road Bridge, Composite Structures journal.
11. Kvamme, Jeffrey David, University of Colorado at Boulder, Performance of Common Treatments for Reinforced Concrete Bridge Decks (2018), CU Scholar Civil Engineering Thesis and Dissertations.