DESIGN OF COMPOSITE FLYOVER

[1]Chandrashekar M, [2]C Akshata, [3]Deepak Kumar M, [4]Darshan S Raj, [5]Santhoshkumar K

[1]Associate Professor, [2345]UG Student,
[1]Department of Civil Engineering,
[1]Maharaja Institute of Technology, Mysore, India

Abstract: Flyovers have been constructed since early seventies. They are mainly constructed for the purpose of traffic congestion elimination. For the short and medium span bridges, flyovers-concrete composite construction is gaining popularity. This paper is purely based on the design of a composite flyover. The manual analysis and design were carried out using different theories. The required drawings were plotted using AUTO CAD Software.

Index Terms – Interior panels, Main Girders, Cross girders, Stiffeners, Shear connectors, Abutment, Pier, Footing.

I. INTRODUCTION

A Flyover is a bridge that carries a road or railway line above another either with or without subsidiary roads, for communication between two sides. All Flyovers are Grade separators, but all Grade separators are not necessarily to be Flyover.
A composite flyover is a combination of both RCC and steel elements acting together. The strength of both RCC and steel together contributes to the strength of a composite flyover. Steel girders may be of rolled steel joists (like ISMB, ISWB, ISHB) for short spans up to about 10 m or can be of plate girders (built-up beams) for longer spans. The girders may be spaced about 3m. Composite beams are considered to be constructed with temporary supports (shoring). The composite action should preferably be proportional in such a manner that the neutral axis of the composite section is generally located below the in-situ concrete slab. The proposed site for the design of composite flyover is at Devegowda intersection which is a National Highway (NH 150A), VIDYARANYAPURA - NANJANGUD ROAD, MYSURU (ORR). In the case of connections between in-situ concrete and the prefabricated steel units, resistance to horizontal shear shall be provided by mechanical shear connectors at the junction of the concrete slab and the steel beam or girder. The connectors shall be capable of resisting the shear force between the slab and the structural steel member and at the same time prevent the vertical separation of the slab from the structural steel member at inner face. IRC CLASS AA WHEELED VEHICLE (400kN) are considered for the design of bridges/flyovers. Super structure design includes design of deck slab, interior panels, main girders, cross girders, stiffeners and their connections(weld). Design of sub structure includes abutment, piers, footing. Suitable bearings have been provided accordingly.

II. OBJECTIVE OF THE PAPER

The main objective is to design a Composite Flyover at the proposed location and deviate the vehicles in the intersection. The basic objective any structural analysis and design is to produce a structure capable of resisting all applied loads without failure during its intended life. Also, to satisfy Safety, Stability, Serviceability and Durability aspects.

III. METHODOLOGY

The design is carried out using Working Stress Method. This method is used for the reinforced concrete design where concrete is assumed as elastic, steel and concrete act together elastically where the relationship between loads and stresses is linear. The live load bending moment is calculated using Pigeaud’s method. In a T-beam Flyover deck with cross beams the slab may be regarded as supported on all four edges and stages and continuous over the beams many methods are available for analysis of such two ways slabs subjected to concentrated loads. Pigeaud’s method is widely used for the design of two-way slab subjected to concentrated loads in this method the short span and long span bending moment and coefficients are read from curves developed by Pigeaud’s. These curves are used for slabs supported along 4 edges with restrained corners and subjected to symmetrically placed loads distributed over some well-defined area. before using the graph, certain dimensionless ratios need to be considered. the loads dispersed through the wearing coat medium at an angle of 45^0. In order to allow for continuity, the values of maximum positive BM are multiplied by a factor 0.8, which is called a continuity factor.
The value of moment coefficient m_1 (for the slab) and m_2 (for long span) for the slab are given Pigeaud’s curves for various values of the aspect ratio.

$K = B/L$ and u/B and v/L

The bending moment in the slab can be calculated using the following equations

Short span, $M_b = W (m_1 + 0.15m_2)$

Long span, $M_l = W (m_2 + 0.15m_1)$

IV. DESIGN OF SUPERSTRUCTURE

4.1 PRELIMINARY DIMENSIONS

- Carriageway width = 16m (2 lane 7.5m + 1m Median)
- Footpath = 1 x 0.3m on either side
- Length of each Span = 20m
- Vertical clearance = 6m
- Main Girders = 6 No. @ 3m C/C
- Cross Girders = 6 No. @ 3.6m C/C
- Thickness of Deck slab = 250mm
- Cantilever slab thickness at the support = 250mm
- Cantilever slab thickness at the free end = 120mm

- Thickness of Wearing course = 80mm
- Density of Concrete = 25 kN/m3
- Density of Wearing course = 22 kN/m3
- Grade of concrete = M30
- Grade of steel = Fe500
- Neutral axis depth factor = 0.28d
- Lever arm factor = 0.91d

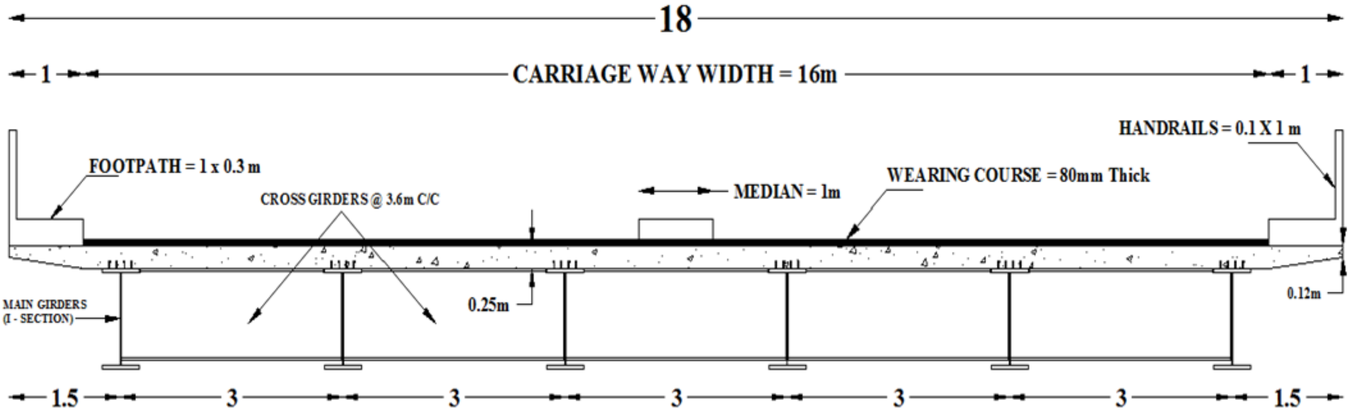

Fig. 1.1 Cross sectional details of Composite Flyover

4.2 DESIGN OF CANTILEVER

Dead Load Shear Force, S_{DL} = 16.07 kN
Dead Load Bending Moment, M_{DL} = 11.18 kN-m
Live Load Shear Force, S_{LL} = 4 kN
Live Load Bending Moment, M_{LL} = 3 kN-m
Main steel: 12mm Ø bars @ 300mm c/c
Distribution steel: 12mm Ø bars @ 300mm c/c

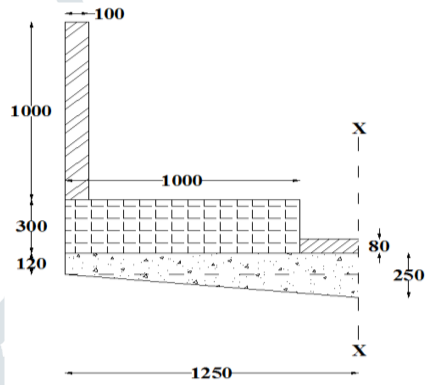

Fig. 1.2 Cross section of Cantilever portion

4.3 DESIGN OF INTERIOR PANELS

4.3.1 Dead Load Bending Moment and Shear Force

Dead Load of the slab	= 0.25 x 25	= 6.25 kN/m^2
Weight of wearing course	= 0.08 x 22	= 1.76 kN/m^2
Intensity of load		= 8.01 kN/m^2
Total Dead Load = (3 x 3.6) 8.01		= 86.51 kN

Moment along shorter span, M_b = 3.34 kN-m
Moment along longer span, M_l = 2.39 kN-m
Shear Force along shorter span, S_{DL} = 2.02 kN

4.3.2 Live Load Bending Moment and Shear Force

BM due to Wheel 1

$\frac{u}{B} = \frac{524}{3000} = 0.17$; $\frac{v}{L} = \frac{398}{3600} = 0.11$

$\Rightarrow m_1 = 21 \times 10^{-2}$; $m_2 = 20 \times 10^{-2}$

Total Load allowing for **25%** impact = 1.25 x 62.5 = 78.13 kN

Moment along Shorter span,
Poisson's ratio, $\mu = 0.15$
$M_b = W (m_1 + \mu m_2)\, 0.8$
$= 78.13 \times 10^{-2} (21 + 0.15 \times 20)\, 0.8$
M_b = 15 kN-m

Moment along Longer span
$M_l = W (\mu m_1 + m_2)\, 0.8$
$= 78.13 \times 10^{-2} (0.15 \times 21 + 20)\, 0.8$
M_l = 14.47 kN-m

BM due to Wheel 2

Pigeaud's curves have been derived for loads symmetrical about the centre. Hence, we can use an approximate device to overcome the difficulty. We imagine the load to occupy an area placed symmetrically on the panel and embracing the actual area of loading, with intensity of loading equal to that corresponding to the actual load. We determine the moments in the two/four desired directions for this imaginary loading. Then we deduct the moment for a symmetrical loaded area beyond the actual loaded area. Half /one-fourth of the resulting value is taken as the moment due to actual loading.

Intensity of Load = $\frac{(1.25)\,(37.5)}{(0.524)(0.398)}$ = 224.76 kN/m^2

$\frac{u}{B} = \frac{1724}{3000} = 0.57$; $\frac{v}{L} = \frac{398}{3600} = 0.11$

$\Rightarrow m_1 = 9.5 \times 10^{-2}$; $m_2 = 12.2 \times 10^{-2}$

Total Load, W = 224.79 x 1.724 x 0.398 = 154.24 kN

Moment along Shorter span, M_b = 13.98 kN-m

Moment along Longer span, M_l = 16.81 kN-m

$\frac{u}{B} = \frac{676}{3000} = 0.23$ $\frac{v}{L} = \frac{398}{3600} = 0.11$

$\Rightarrow m_1 = 9.5 \times 10^{-2}$; $m_2 = 12.2 \times 10^{-2}$

Total Load, W = 224.79 x 0.676 x 0.398 = 60.48 kN

Moment along Shorter span, M_b = 9.70 kN-m

Moment along Longer span, M_l = 9.50 kN-m

Net BM along Shorter span = $\frac{(13.98 - 9.70)}{2}$ = 0.94 kN-m

Net BM along Longer span = $\frac{(16.81 - 9.50)}{2}$ = 3.66 kN-m

By similar procedure the Net BM due to Wheel 3, 4, 5, 6, 7, 8 are computed.

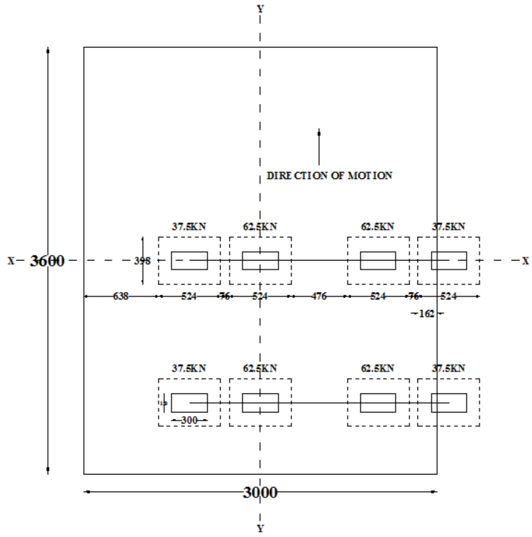

Fig. 1.3 Disposition of Class AA Wheeled Vehicle for Maximum Moment

The total effect is computed as summation of individual effects,

Total BM along short span, M_b = 15 + 0.94 + 2.42 + (-0.08) + 3.09 + 3.15 + 0.69 + (-0.06) = **25.15 kN-m**

Total BM along long span, M_l = 14.47 + 3.66 + 0.83 + 0.17 + 1.36 + 1.71 + 0.99 + (-0.44) = **22.75 kN-m**

4.3.3 Structural Detailing

Design BM along short span, M_b = 3.34 + 25.15 = 28.49 kN-m

Use 12mm diameter bars at 180mm C/C along short span

Design BM along long span, M_l = 2.39 + 22.75 = 25.14 kN-m

Use 12mm diameter bars at 190mm C/C as longitudinal reinforcement

4.4 DESIGN OF MAIN GIRDERS

4.4.1 Dead Load Bending Moment and Shear Force

Load due to self-weight of RC slab	= (1 x 0.25) 25 = 6.25 kN/m
Load due to self-weight of wearing course	= (1 x 0.08) 22 = 1.76 kN/m
Self-weight of main girder	= (0.2L + 1) = (0.2 x 20 + 1) = 5.0 kN/m
Assuming, Cross girder self-weight as 1 kN/m	
Total load (UDL)	= 14.01 kN/m
Load due to footpath (Cantilever)	= 16.07 kN/m

Moment distribution method is applied to get final moments and reactions are computed accordingly. The obtained maximum reaction is converted to UDL and spread along the length of the main girder (20m). Hence, BM and SF are calculated.

Bending Moment, M_{DL} = 2408.83 kN-m

Shear Force, S_{DL} = 482.20 kN

4.4.2 Live Load Bending Moment and Shear Force

In this case, we position the vehicle such way that maximum reaction is attained due to higher magnitude of load. For this moment distribution method is applied to get final moments at each girder and reactions are computed. Since the live load consists of two axles the obtained maximum reaction will be of 2 concentrated loads of equal magnitude. If 2 concentrated loads of equal magnitude are moving, we get absolute maximum bending moment under one of these loads when that load and the resultant of the 2 loads are at equidistant from midspan of the girder. Hence, the design bending moment should be considered the junction which gives severer effect.

Bending moment, M_{LL} = 1722.72 kN-m

To arrive at maximum shear, the loads are taken to supports.

Shear force, S_{LL} = 366.26 kN

4.4.3 Depth and Thickness of Web

Design Bending Moment, $M_D = M_{DL} + M_{LL} = 2408.83 + 1722.72 = 4131.55$ kN-m

Design Shear Force, $S_D = S_{DL} + S_{LL} = 482.20 + 366.26 = 848.46$ kN

The Economical depth, $= 5 \times \sqrt[3]{\frac{M}{\sigma_b}} = 5 \times \sqrt[3]{\frac{2408.83 \times 10^6}{165}} = 1222.02$mm

$\therefore$ Dimensions of web plate = 1200 x 10mm

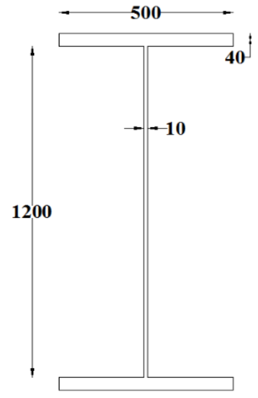

Fig. 1.4 Main girder I-section

4.4.4 Flange Plates

We shall adopt a flange plate of 500mm x 40mm

4.5 DESIGN OF INTERMEDIATE STIFFENERS

$\frac{d}{t_w} = \frac{1200}{10} = 120 \nless 85$

Hence, web stiffeners required

We shall provide 150 x 10 mm intermediate stiffeners on both sides of the web @ 1500mm c/c

Length of the weld $= 10t_s = 10 \times 10 = 100$mm

we shall provide a minimum weld size of **s =** 3mm

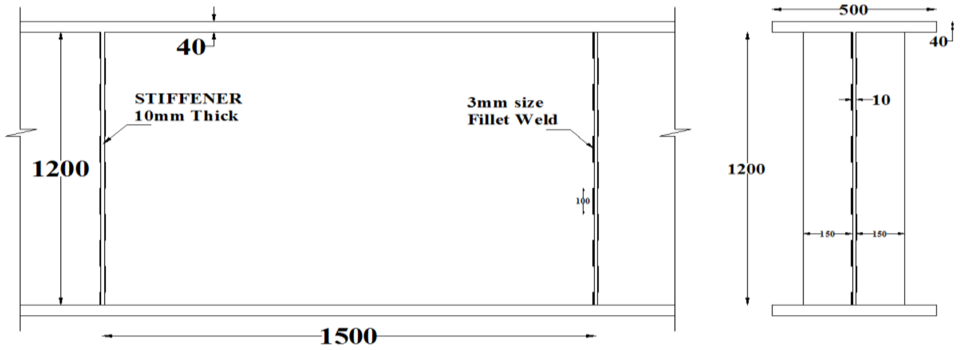

Fig. 1.5 Connection Between the Intermediate Stiffener and The Web

4.6 DESIGN OF CROSS GIRDERS

Load distributed area $= 2(\frac{1}{2} \times 3 \times 1.5) = 4.50$ m^2

Self-weight of the slab = 0.25 x 4.5 x 25 = 28.13 kN

Self-weight of the wearing course = 0.08 x 4.5 x 22 = 7.92 kN

Dead Load on each Cross girder = 36.05kN

Dead Load as UDL $= \frac{36.05}{3} = 12.02$ kN/m

Self-weight of Cross girder = 1 kN/m

Total Dead Load = 13.02 kN/m

Design bending moment, $M_D = 4.88 + 79.37 = 84.25$ kN-m

Design shear force, $S_D = 39.06 + 126.67 = 165.73$ kN

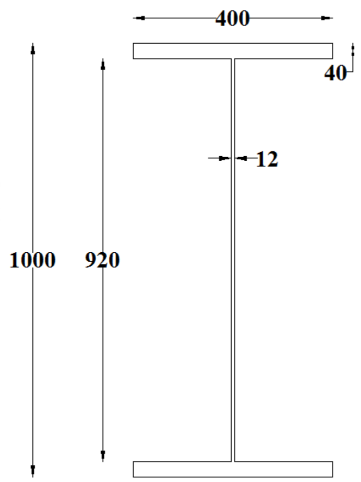

Fig. 1.6 Cross girder I-section

4.6.1 Depth and Thickness of Web

The Economical depth, $= 5 \times \sqrt[3]{\frac{M}{\sigma_b}} = 5 \times \sqrt[3]{\frac{4.88 \times 10^6}{165}} = 154.63$mm

But we shall provide a minimum 0.75 times overall depth of Main girder

i.e. Cross girder depth = 0.75 x 1280 = 960mm

Hence, we shall adopt overall Cross girder depth = **1000mm** by taking **12mm** thick web plate

4.6.2 Flange Plates

We shall adopt a flange plate of 400 x 40mm

4.7 DESIGN OF END BEARING STIFFENERS

Design Shear Force, $\mathbf{S_D} = V_{max} = 848.46$ kN

Allowable load for the Stiffeners = 136 x A_c = 136 x 6800 = 925 kN > 848.46 kN

Connection between the bearing stiffeners and the web: We shall provide 5mm size fillet weld

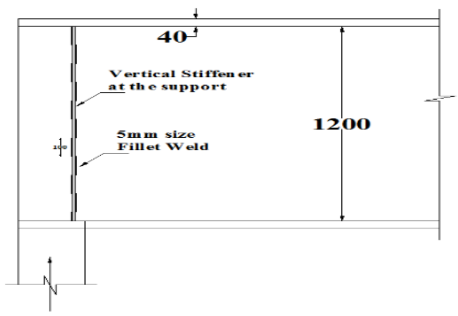

Fig. 1.7 Connection between End bearing stiffener and the web

V. ANALYSIS AND DESIGN OF COMPOSITE SECTION

5.1 COMPOSITE ACTION

The composite section shall be designed for all the loads imposed on the member taking note of the fact that the composite action of the member is effective only for the loads imposed after the composite action has started to function.

Dead Load of Concrete slab = (3 x 0.25) 25 = 18.75 kN/m

Self-weight of Main girder = (0.2 x 20) + 1 = 5 kN/m

∴ Total Load = 23.75 kN/m

$M_{x\text{-}x} = 237.5 \times 10 - 23.75 \times 10 \times \frac{10}{2} = 1187.50$ kN-m

$f_t = \frac{1187.50 * 10^6}{1.68 * 10^{10}} \times 640$

$\Rightarrow 45.24$ N/mm$^2 <$ 165 N/mm^2

5.2 EQUIVALENT SECTION

The effective gross area of the concrete shall be converted into corresponding equivalent area of steel. This is done by dividing the effective area of the concrete slab by modular ratio (m)

Flange width of Composite beams is least of the following three,

- $\frac{1}{4}$ x Span of beam = $\frac{1}{4}$ x 20000 = 5000mm
- Centre to Centre distance between beams = **3000mm**
- Web thickness (b_f) + 12 x Slab thickness = 500 + 12 x 250 = 3500mm

Equivalent area of Steel = $\frac{\text{Area of concrete}}{\text{modular ratio (m)}} = \frac{3000}{9.33} \times 250$

= 322 x 250 = **80500 mm^2**

$I_{comp} = 3.57 \times 10^{10}$ mm^4

5.2.1 Check for Compressive stress in Concrete

We have, $f = \frac{M}{I} \times y$

$f_c = \frac{M_D}{I_{comp}} \times y_c \times \frac{1}{m} = \frac{4131.55 \times 10^6}{3.57 \times 10^{10}} \times 425.23 \times \frac{1}{9.33}$

$\Rightarrow \mathbf{5.27\ N/mm^2} < 10\ \mathrm{N}/\mathbf{mm^2}$

∴Compressive stress in concrete is within allowable limits

5.2.2 Check for Tensile stress in steel

$f_t = \frac{M_D}{I_{comp}} \times y_t = \frac{4131.55 \times 10^6}{3.57 \times 10^{10}} \times 1104.77$

$\Rightarrow \mathbf{127.85\ N/mm^2 < 165\ N/mm^2}$

∴Tensile stress in steel is within allowable limits

5.3 DESIGN CONNECTION

Welded connection is provided between the Web and the Flange of 5mm size fillet weld on both sides of the Web

5.4 DESIGN OF SHEAR CONNECTORS

We shall provide 20mm Ø x 80mm height Shear connectors with a spacing of 100mm c/c along the spans and with 4 studs in a row along the flange width.

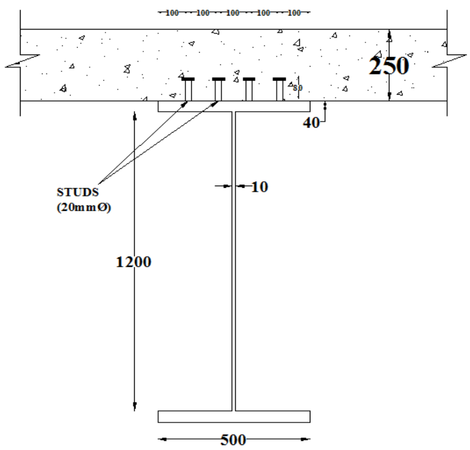

Fig. 1.8 Section elevation

VI. DESIGN OF SUBSTRUCTURE

6.1 DESIGN OF ABUTMENT

- Depth of foundation = 1m
- Safe bearing capacity of soil = 200 kN/m^2
- Width of base slab = 6m
- Thickness of base slab = 0.6m
- Overall height of abutment = 6.74m
- Toe projection = 1.8m
- Heel slab = 3m
- Width of breast wall = 1.2m
- Total reaction = 745 kN
- Vertical load = DL + LL = 161.30 + 46.56 = 207.86 kN/m

Firstly, the abutment is check for stability dealing with loaded condition. Hence, the abutment is safe against overturning and sliding. Also, the maximum and minimum stress at the base is less than SBC of soil.

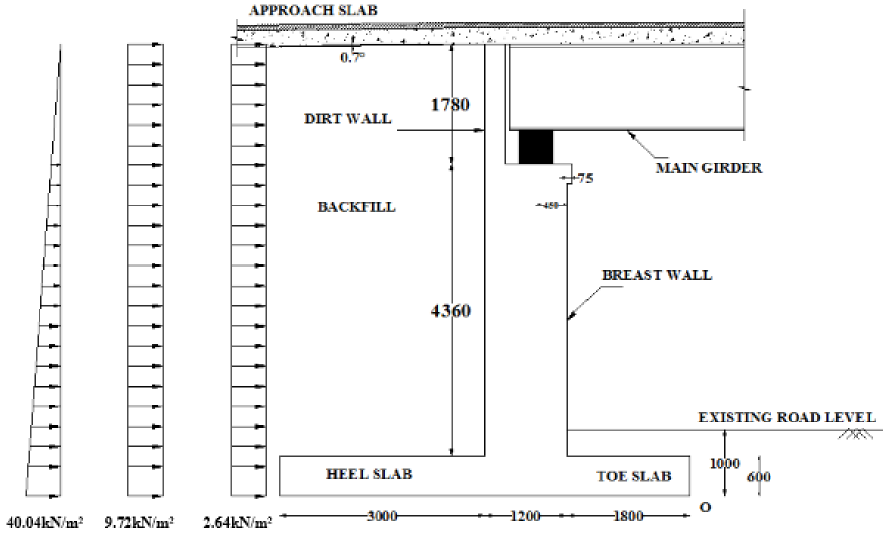

Fig. 1.9 Cross-sectional details of Abutment (Retaining wall)

6.2 DESIGN OF PIER

- Top width = 2m
- Top length = 16m

Circular projection is provided at both corners with a radius of 1m

It is normally sufficient to provide a batter of 1 in 25 on all sides for the portion of the pier between the bottom of the bed block and top of the footing.

The pier is checked for adequacy. It satisfies the stresses due to dead load, eccentricity of live load and longitudinal forces.

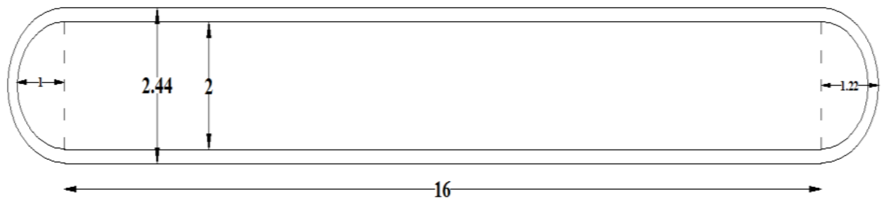

Fig. 1.10 Top plan of Pier

6.3 DESIGN OF FOOTING

- Total load to be transferred = 10606.14 kN
- Length of footing = 20m
- Width of footing = 4m
- Depth of footing = 0.5m

9 number of 12mm diameter bars are provided along shorter dimensions.

Hence, the footing is safe under one-way and two-way shear.

CONCLUSIONS

Construction of flyovers using RCC is time consuming, and will affect existing traffic. Construction of composites have overcome these disadvantages, even though its initial cost is high. Some of the advantages of composite flyovers are fast-track construction, prefabrication possibility, durable structures, improved life cycle performance, ensured quality of material and construction.

REFERENCES

[1] "ESSENTIALS OF BRIDGES" by JOHNSON VICTOR
[2] "STANDARD SPECIFICATIONS AND CODE OF PRACTICE FOR ROAD BRIDGES", IRC: 21-2000 (WSM)
[3] Indian Standard CODE OF PRACTICE FOR COMPOSITE CONSTRUCTION (IS: 3935 – 1966)
[4] IRC: SP:84-2014
[5] GEOMETRIC DESIGN STANDARDS FOR URBAN ROADS IN PLAINS (IRC: 86-1983)