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ANALYSIS AND DESIGN OF BRIDGE SUBSTRUCTURE PIER AND ITS FOUNDATION.

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ABSTRACT: - In this project, I aim to analyse and design a river bridge by using the theory of structure, bridge Engineering, and foundation engineering. Theories of foundation engineering for sub-structure and theories of bridge engineering and live loading recommended by IRC forms the base of our design. The knowledge of foundation engineering, Influence lines, and Theory of structures are essential for the analysis and design of this project. IRC and IS code guidelines were referred for the design purpose. The sub- structure pier and its open foundation have been designed using of design method under class A three lane, 70R Wheeled vehicle, 70R Wheeled vehicle Class 2 and Special Vehicle loading as prescribed by IRC. In this way with the help of supervision and available data & sources, I have designed the pier and open foundations for this project. The checks for the pier and the foundations as been done such as shear check, stress check, base pressure check etc.

Keywords: - IRC Codes, Foundation engineering, Open foundation, checks.

INTRODUCTION

The structure is termed as a "Bridge" which is a structure having a total length of above 6 m between the inner faces of the dirt walls for carrying traffic or other moving loads over a depression or obstruction such as channel, road or railway. One of the longest spans reinforced concrete bridges is the Sando Bridge built in Sweden in 1943 with a span of 264 metres. Only about a decade ago, the new Sydney Harbour Bridge which is an R.C.C. arch bridge having a span of 305 metres had been constructed.

In this project, I was assigned to design a bridge over Nanded River connecting the roads "Bhokar- Mhaisa - Road" at Nanded joining Parbhani District with Nizamabad and Latur District (5). As it is a quite busy urban road, two lanes for design are minimal. I am supposed to design the most economic bridge for this section based on the various data collected by us.

This report is prepared as a part of project work for the fulfilment of the Project as per the syllabus of Master's Degree of Structural Engineering. For this project purpose, I have also done Analysis on Staad.Pro and designed RCC T-beam Bridge for learning the bridge engineering skills and practice. The variation in design procedures for the superstructures, bearings and substructures has helped us to enhance our understanding of the essentials of Bridge Engineering.

After deciding the type of bridge, span arrangement and span lengths, assume suitable first-trial cross-sections of foundations and deck in concert with the method of construction. Hence, establish the loading sequence. For each load in the sequence see what it acts on, or what span or spans it acts on and under what end-conditions. From this find out what moments, etc. It causes at various sections, and which of these acts on what section properties at those sections, and hence cause what stresses. The resultant stresses at every load stage at each section must not exceed their permissible values that are set out in the relevant Code of Practice (the design specification). Calculations of the maximum reaction and moment due the vehicle load for Class A, 2Lane of Class A,3Lane of Class A, 70R W,70R + Class A (3). Considering Simply Supported beam on which all wheel load is acting which are mentioned in IRC-6 for different vehicle loading. Calculate the Bending Moment and Shear Force as we have done analysis in Simply supported beamThis, in a nutshell, is the essence of structural analysis and design.

As bridge consist of two components such as super structure and substructure.The part above the bearing level is known as superstructure which consist of deck,longitudinal girders,end and mid diaphragms etc. while stubstructure consist of pedestral pier and foundation.In this paper the analysis and the design pf the pier and its open foundation as beendescribed in detail.

LITERATURE REVIEW

Jagdish Chand et al. [1] 2016 The bridges are the super passage or a pathway over the obstacle without changing the alignment of the way beneath. The present study considers the design of bridge girders both longitudinal girders and cross girders. The span of the bridge is taken as 25m in which girders are constructed. The size of longitudinal girders is taken as2000x500 mm and cross girders is 1500x250 mm. There are three longitudinal girders are considered having spacing 2600 mm c/c and cross girders are considered as 5000mm c/c. The design of girders iscarried out using the software STAAD Pro. In this study of bridge girder design, three same models are prepared in the STAAD pro and then their loadings are changed according to IRC codes, Euro codes and AASHTO specifications respectively. According to these different loading we found the shear force, bending moment and area of steel in longitudinal girder as well as cross girder. The analysis is conducted in STAAD Pro and analysis results are comparedwith tables and graphs.

Bharat Jeswani et al. [2] 2020 In this study the T-beam bridge is to be analysis on the staad pro software. A T-beam bridge is composite concrete structure which is composed of slab panel, longitudinal girder and cross girder. This project looks on the work of analysis and design of bridge deck and beam on software the specific bridge model is taken of a particular span and carriageway width the bridge is subjected to different IRC loadings like IRC Class AA, IRC Class 70R tracked loading etc. in order to obtain maximum bending moment and shear force. From the analysis it is observed and understand the behaviour of bridge deck under different loading condition and comparing the result. The different codes of design will be use in this project are IRC 5-2015, IRC 6-2016, IRC 112-2011, IRC 21-2000.

Mahantesh. S. Kamatagi [3] 2015, Worked on "Comparative Study of design of longitudinal girder of T- Beam Bridge" A simple span of T-beam bridge was analysed by using staad pro. The study show that maximum bending moment is obtain while apply for class 70R vehicles loading. After getting the result the T- beam bridge is design by both the method i.e. (IRC21 &IRC112). It is noted that results obtained from finite element method is less as compared to the result obtained by working stress method. It is also noted that the design of bridge with IRC 112-2011 is economically compared to IRC 21. It is noted that area of steel required is less in IRC 112-2011 as compared with the IRC 21. The modelling and analysis of RC T-beam bridge superstructure can be efficiently performed using staad pro and results in time saving. In design of concrete bridges IRC:112-2011 gives an economical design with a reliable safety margin since the design is based on probabilistic method of design. As comparedtoIRC:21-2000, designing the girders with IRC:112-2011, results in saving of longitudinal.

Ancy Joseph et al. [4] 2015 Modern day construction prefers prestressed girders over conventional RCC for long span bridge construction. This paper deals with the design of railway over bridge at Kumaranellur, Kerala. The bridge connects MC road and Kumaranellur temple road. The bridge has an overall length of 312m with a width of 12m and longest span of 33m. The major goal of this is to validate and recommend details for the design of durable and constructible details to achieve structural continuity between the standard precast,prestressed concrete girders for this proposed bridge. Along with it, this paper will be dealingwith the design of the pier.

Saireddygari Shashank Reddy et al. [5] 2016 The work on designing of proposed HLB across mandoddi river at CH 10/6 – 10/8 on R/F to R&B to pedda dhanwada via mandoddi of waddepalli (M) of mahboobnagar district was carried out. A Bridge is a structure providing passage over an obstacle without closing the way beneath. The obstacle to be crossed may be a river, a road, railway or a valley. The bridge we are dealing with is a high-level bridge which carries the roadway above the highest flood level. Highest flood level is the level of the highest calculated level for the design discharge. This HLB is proposed to reduce the severe problems of increasing traffic & to increase the transport system between the CH 10/6-10/8 to Pedda Dhanwada in Mahboobnagar District. The project is done with the collaboration of the Government of A.P., Roads and buildings department. We are going to do a case study on the present HLB which is proposed. All the design aspects are thoroughly analysed and are present in this report. Designing a high-level bridge includes: (i) Hydraulic design, (ii) Stability analysis, which includes design of pier, abutments and Wing wall, (iii) Component design i.e., design of Backing wall and Bed Block and the drawings With rapid increase in vehicle users in our country, we are facing many traffic problems in many areas. In the way of moving across a river it is highly difficult if the structure is just a normal bridge. So in order to make the traffic flow continuous and also avoid accidents, a High Level Bridge should be constructed across the major rivers. This is the only solution for elimination of such problem. This design of the bridge has been proposed to facilitate ease in commuting.

Abhinav Kumar et al. [6] (2014) Bridges are the life line of road network, both in urban and country zones. With fast innovation development, the commonplace bridge has been supplanted by creative practical structural system. One of these courses of action presents basic RCC framework that is T-Beam and ordinary Beam. Bridge design is a goal and what's more personalities boggling approach for a structural design. Just as there should rise an occasion of Bridge design, span length and live loads are consistently fundamental variables. These parts affect the conceptualization time of plan. The impacts of live load for different extents are moving. Choice of structural system for a cross is continually a range in which investigate should be possible. Structural system got is influenced by fragments like economy and fancy being created. Code strategy engages us to pick structural system i.e. T- Beam Girder. The decision of sparing and constructible basic framework relies on upon the outcome

Rajamoori Arun Kumar et al. [7] (2014) Bending moment and shear force for PSC T-Beam Girder are lesser then RCC T-Beam girder bridge. Which allow designer to have lesser heavier section for PSC T-Beam Girder then RCC T-Beam Girder for 24m span. Moment of resistance of PSC T-Beam Girder is more as compare to RCC T-Beam Girder for 24 m span. Cost of concrete for PSC T-Beam Girder is less then RCC T-Beam Girder.

Manjeetkumar M Nagarmunnoli et al. [8] (2014) Concentrate about on the effects of deck thickness in RCC T-Beam Bridge. For every decrement in deck segment thickness reduces the bending stiffness by around 40% to half. Stresses acting in the deck under truck wheel load are around 55 times more unmistakable than the allowable weights. For every decrement in the deck piece thickness from 280 mm to 150 mm would profoundly assemble the part slant by around 31% under the wheel stack. The uncracked depiction of inaction decays by around 45% for every decrement in the deck area thickness from 280 mm to 150 mm subjected to IRC Class A truck stacking. The Curve force made in the deck piece reduces by around 0.43% for every decrement in the deck segment thickness.

Tangudupalli et al. [9] (2017) In this project comparison of all loadings and all methods and same bridge is analysed using software STAAD Pro V8i. Analysis of the girder is done using the three rational methods (Hendry Jaegar, Guyon-Massonet, Courbons theory). The loadings assigned are IRC loadings Class A, Class AA, Class 70-R, Class-B). The different country loadings given are Saudi Arabia loading, AASHTO loading, and British Standard loading.

Weiwei Lin et al. [10] 2017 A bridge deck is the roadway, or the pedestrian walkway, surface of a bridge. The deck may be of either cast-in-situ or precast concrete, wood, which in turn may be covered with asphalt concrete or another pavement. The deck systems vary with different bridge types and bridge superstructure construction methods, particular attention of this chapter will be given to the bridge accessories with special emphasis on pavement, drainage system and waterproofing system, expansion joint, sidewalk, lamps post, handrail, guardrail, etc.

MohankarR.Het.al[11]The Underpass RCC Bridge is very rarely adopted in bridge constructi on but recently the Underpass RCC Bridge is being used for traffic movement. In this paper, t he analysis of the underpass RCC bridge is carried out. The analysis of this underpass RCC b ridge is done by considering fixed end condition. Finite Element Method (FEM)analysis is p erformed and results are presented. Comparison of different forces between 2D and 3D model s for fixed end condition is provided. In this study we show a 2D model can be effectively used for analysis purpose for all the loading condition mentioned in IRC6,Standard Specificatio ns and Code of Practice Road Bridges"The Indian Roads Congress and Directorate of bridges & structures (2004), "Code of practice for the design of substructures and foundations of brid ges" Indian Railway Standard.

Dr. Rakesh Mehar et al. [12] 2019 Bridges are structures spanning horizontally between supports. It provides connection over an obstacle without interrupting the way below. The required connection may be for a canal, road, railway, pedestrians or a pipeline and the hurdle below can be a valley, road or river. The basic function of bridges is to carry vertical loads. The overview of the bridge seems very simple having a beam resting on two supports. The main objectives of carrying out this research work is to identify the most economical superstructure for two-lane bridge with and without footpath. In the present study four types of super structure i.e. Rectangular box girder, Trapezoidal box girder, I– Beam girder and T- Beam girder have been considered for two-lane simply supported RCC bridge of span 15m with and without footpath. All the analysis and design have been done in STAAD.Pro. The study revealed that overall cost of the bridge is minimum when we considered trapezoidal boxtype super structure for span 15m with and without footpath.

Dr.S.V.Dinesh et al.[13] 2016 The effect of various span on single-span reinforced concrete bridges and PSC bridges are analysed using the finite-element method and the results are presented in this paper. Investigations are carried out on RC slab bridge decks and PSC bridge decks to study the influence of aspect ratio, span and type of load. The finite-element analysis results for bridges are compared to the reference analytical solution for dead load, IRC Class AA loading. Also, comparative analysis of response of RCC and PSC slab bridge decks with that of equivalent of FEM analysis of bridge deck is made. Number of bridge models is analysed and the variation of critical structural response parameters such as longitudinal bending moment, longitudinal stresses and support reaction with analytical solution is studied. The benefit of prestressing is reflected more significantly increase in longitudinal bending moment and longitudinal stresses.

Abrar Ahmed [14]2017 "Comparative Analysis and Design Of T- Beam and Box Girder" The analysis of T-beam girder by IRC specification showed that the results obtained by FEM method is economical than the one dimensions analysis. The comparative design of Tbeam and Box Girder for span up to the 25m or below the result shows that the T-Beam Girder is more economical section but if span is greater than 25 m Box Girder is always suitable. By getting the result it is found that the torsional rigidity is higher in box girders as they have closed section. By the study it is also found that Comparative design of ISection and Box Section concludes that the Box girder is found to be Costlier for 16.3 m Span whereas for span 31.4 m the box girder is economical. Comparative design of RCC and PSC sections concludes that the Shear force and bending moments for PSC T-beam girder are lesser than RCC T-beam Girder Bridge so itis always preferable to adopt PSC sections rather than RCC, which is economical and Suitable for spans 24m and above. Life span of Prestressed concrete structures is very moreas compared to reinforced concrete structure sand Steel structures.

Anushia K Ajay [15]2017, "Parametric Study On T-Beam Bridge "In this study the Single span two lane bridge is subjected to IRC class AA tracked loading by varying the span is analysed using software. In this project parametric studies are conducted on various bridge super structural elements. The study is mainly focused on the economical depth of a longitudinal girder for different span of bridge. Graphs and diagrams are also developed which can be used as a handy tool in the design of T- Beam Bridge. The optimal of effective length to the effective depth (I/D) ratio for the economical design of longitudinal girder using LSM is obtained as 14. Cost of girder will be increases if there is increase in grade of concrete and decreases when it is increase in thickness of deck slab so It is preferable to keep the thickness in between 170 mm and 200 mm.

METHODOLOGY

In this the calculations regarding the bridge design are discussed. Which design of sub- structure which consist of design of pier and design of foundation.

IRC 112-2020 Code of Practice for Concrete Road Bridges is use for design of concrete structure, performing the checks calculations for shear, punching shear, torsion. In IRC 6-2017 standard specifications and code of practice for road bridges section: ii loads and load combinations (seventh revision) Is used to calculation of different load on the structures such as Vehicle load, Temperature Stresses wind load, seismic effect, etc. Below the Sub-Structuremember are discussed.

3.4 Design of Sub-Structural Member

The Sub-structure member consist of Abutment, Retaining Wall, Pier and Footing. In this we completed the complete analysis and design of pier and footing which is open foundation. The pre-analysis includes calculation of the Dead load calculation for the both super structure and Substructure for different condition of water levels. Live Load reaction and moment calculation, Wind effect, seismic effect, water current. etc. All this load is acting on pier and then transferred to footing.

3.4.1 Analysis of The Pier and Footing

Analysis of pier and footing is to calculate the loads acting on the structural member and calculation of the bending moment and shear force due to those loads. The calculation of analysis is explained below. All the calculations are performed on excel.

The details of the structure are as followsSuperstructure- RCC T-girder bridge overall width of deck = 12 m and

depth of girder = 1.6 m

Deck depth = 0.3 mSubstructure details

Pier = Capsule type pier

Width = 1.2 m

Length of pier = 4.6 m Foundation Type = Open Foundation

Width = 5.5 m (Along Traffic direction)

Depth = 8.8 m (Across Traffic direction)

3.4.1.1 Dead load Calculation

- Dead load of Super structural member and the sub structural member are calculated by multiplying its area by the density of the concrete. Calculate the bending moment in both transverse and longitudinal direction by multiplying force by lever arm. The calculated DL on LHS and RHS span is for superstructure and substructure,

ACB = 20 T

Deck + Girder =144.31 T

End Diaphragm = 18.20 TIntermediate Diaphragm = 3.58 T Pedestal= 2.5 T

Pier cap = 44.25 T

Pier = 165 T

Footing = 181.5 T

3.4.1.2 Live load Calculation

- Calculations of the maximum reaction and moment due the vehicle load for Class A, 2Lane of Class A,3Lane of Class A, 70R W,70R + Class A.
- Considering Simply Supported beam on which all wheel load is acting which are mentioned in IRC-6 for different vehicle loading.
- Calculate the Bending Moment and Shear Force as we have done analysis in Simply supported beam.

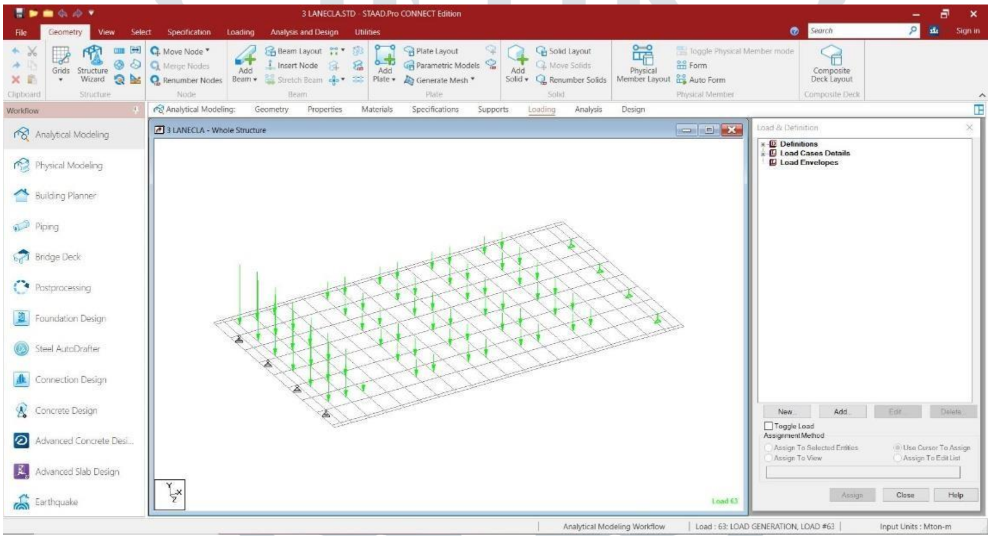


Figure- Live Load calculation

3.4.1.3 Braking Force Calculation

- Calculation of Braking Force as per IRC:6-2017 Clause. No. 211.5.1.2 P.N.45.
- Total load is multiplied by percentage which is different for different Lane which is given in IRC-6.

3.4.1.3 Bearing Force Calculation

- Bearing force is the 10% variation of the braking Force in movement of span as perCl.211.5.1.4
- Shear modulus of Elastomer (G) MPa
- Shear rating of elastomer Bearing = Vr = G x A / h
- Horizontal Movement Due to Deck Movement = Vr x ltc x N

3.4.1.4 Wind Force Calculation

- Wind Load Calculations and the effect and formulas are given in IRC-6-PG-33
- The hourly mean wind speed shall be obtained by multiplying the corresponding wind speed value by

the ratio of basic wind speed at the location of bridge to the value corresponding to Table 12, (i.e., 33 m/sec.)

- The hourly mean wind pressure at an appropriate height and terrain shall be obtained by multiplying the corresponding pressure value for base wind speed as indicated in Table 12 by the ratio of square of basic wind speed at the location of wind to square ofbase wind speed corresponding to Table 12 (i.e., 33 m/sec).
- For highway bridges up to a span of 150 m, which are generally not sensitive to dynamic action of wind, gust factor shall be taken as 2.0.
- Coefficient of drag and lift is taken from Cl 209.3.3 IRC 6 pg-36
- Calculation of force = F_T = Pz x A x G x CD
- Calculate the bending moment in both transverse and longitudinal direction by multiplying force by lever arm.

3.4.1.5 Seismic Force Calculation

- Seismic Load Calculations and the effect and formulas are given in IRC-6 pg.60
- Calculation of Seismic coefficient Ah.
- $$Ah = \frac{(Z/2) \times (Sa/g)}{R/I}$$

Where,

Z = Zone Factor as given in IRC-6-Table 16I = Importance Factor IRC-6-Table 19

R = Response reduction Factor for Transverse DirectionSa/g = Average response Acceleration Coefficient

- Bearing are Free in Longitudinal Direction and Fixed in Transverse Direction,
- Hence for Longitudinal Seismic Force = Ah1 (Rg)
- In Transverse Direction bearing will be subjected to full Seismic Force = Ah1 (Rg + 0.2 Rq)
- Calculate the bending moment in both transverse and longitudinal direction by multiplying force by lever arm.

3.4.1.6 Water Current Calculation

- The Pier shall be designed to sustain horizontal pressure due to Force of Water current. Intensity of pressure shall be calculated for Pier parallel to direction of the water currentfrom Equation IRC-6-Cl.No.210.2

$P = 52 \times K \times V^2$

Where,

P = Intensity of Pressure due to water current in Kg/m^2

V = Velocity of current at the point where Pressure Intensity is Calculated m/sec K = Constant =1.5 For Square Ended Pier

= 0.66 For Circular Pier or Piers with Semi-Circular Ends.

- Calculate the bending moment in both transverse and longitudinal direction by multiplying force by lever arm.

3.4.2 Design of Pier

- After calculations of all forces mentioned above the load combinations are done.
- Load Combination include the Limit State of Strength and Limit State of Serviceability And also the Seismic Combination which are mentioned above in superstructure whichare taken from the IRC-6.
- All the combinations are taken for both Low Water Level and High Flood Level Conditions.
- All the Design data are assumed such as Clear cover, bar diameter, Lateral reinforcement.

3.4.2.1 Check for Slenderness Limit (As Per IRC: 112-2011 Cl 11.2.1) λ_{lim} = 20. ABC / √ n

Where,

A= 1/ / (1 + 0.2ϕ_{ef})

ϕ_{ef} = effective creep ratio= ϕ (∞, t0) M_{oEqp} / M_{oEd}

M_{oEqp} = First order B.M. in quasi-permanent load combination in SLS. M_{oEd} = First order B.M. in design load combination in U.L.S.

B = √ (1 + 2w)

ω = As x fyd /Ac x fcd

C = 1.7 - r_m

r_m = M_{01} / M_{02} moment ratio, M01, M02 are the first order end moments at two ends of member as calculated from the analysis of structure, where |M02|≥|M01|.

3.4.2.2 Interaction Ratio Check

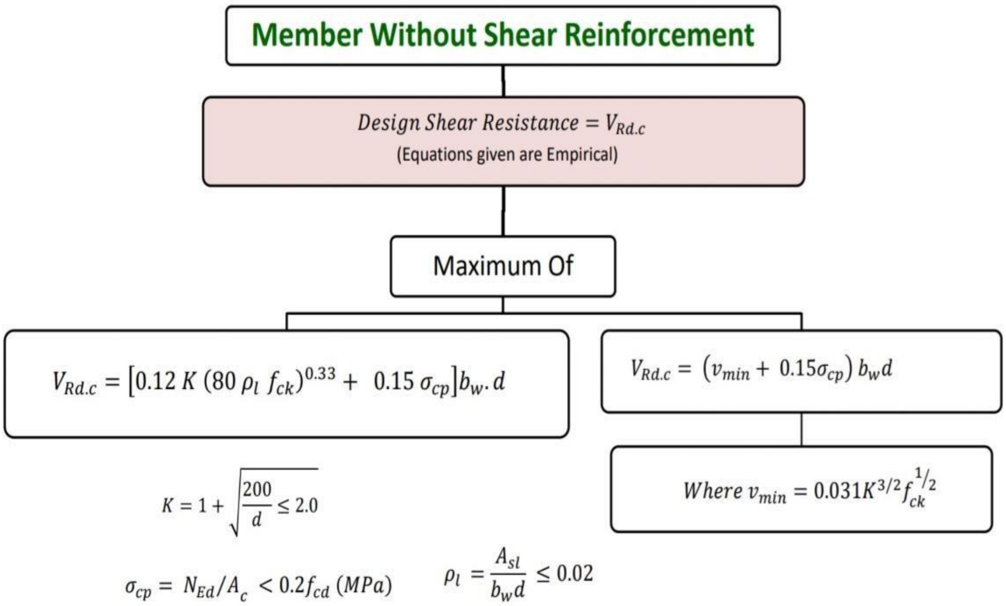
- Calculating the stresses due to concrete and stresses due to steel.
- Calculating Forces through the stresses and moment.
- Assume the Neutral axis in such a way that the axial force should be equal to the summation of the axial force calculated through stresses.
- The summation of all moment will give the resisting moment
- Calculate Puz = Ac fcd + As fy

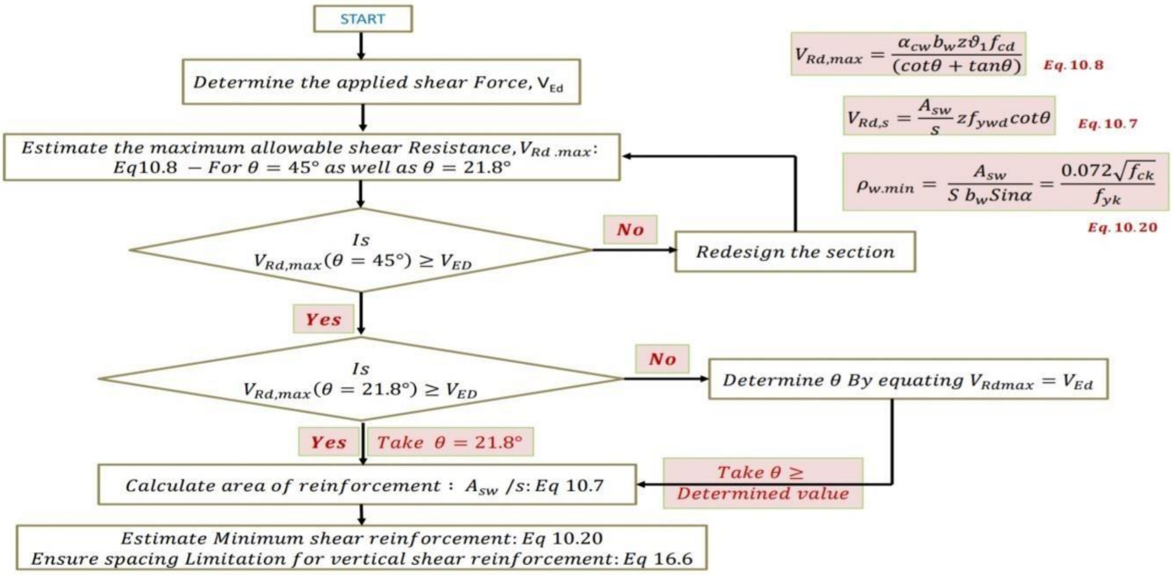
Pu/Puz	0.1	0.7	1
α	1	1.5	2

Table 3.3.2.2 - Value Of α

- Calculate α value by interpolation.
- Check for Interaction Ratio $\left(\frac{MT}{MRT}\right)^{\alpha} + \left(\frac{ML}{MLT}\right)^{\alpha} \leq 1$

3.4.2.3 Shear Check





3.4.2.4 Stress Check

- Stresses Are calculated through the first principles.
- The stresses in concrete and steel should be less than limiting stresses in concrete and steel.
- Also, the CRACK WIDTH should be less than 3mm which are mentioned in IRC-112.
- Cracking takes place in tensile regions of concrete structures due to load effects, such as bending, shear, torsion and direct tension.

- Cracks may also be caused due to internal deformations such as shrinkage and temperature effects.
- The value of SLS Quasi Permanent load combination are used for Design Bending Moment and Shear Force
- The intent of the following provisions is to ensure, with acceptable probability, that the cracks will not impair the proper functioning or durability of the structure or cause its appearance to be unacceptable.

Condition of Exposure As per Clause 14.3.1	Reinforced members and prestressed members with un-bonded tendons	Prestressed members with bonded tendons
	Quasi-permanent load combination (mm)	Frequent load combination (mm)
Moderate	0.3(2)	0.2
Severe	0.3	0.2(3)
Very Severe	0.3	0.2 and decompression(4)
Extreme	0.2	0.2 and decompression(4)

Table 3.3.1.4 -Recommended Values of Wmax

- $S_{r.max} = 3.4c + \frac{0.425 k_1 k_2 \phi}{\rho_{\rho.eff}}$

c = Clear Cover to Longitudinal R/F k_1 = Coeff. Depend on bond

k_2 = Coeff. Depend on Strain distribution ϕ = Equivalent Bar Diameter

$\rho_{\rho.eff}$ = % of Reinforcement

$A_{c.eff}$ = Effective area of concrete in tension7 $h_{c.eff}$ = min [2.5(h-d), (h-x)/3, or h/2]

$$\varepsilon_{sm} - \varepsilon_{cm} = \frac{\sigma_{sc} - \frac{k_t f_{ct\,eff}}{\rho_{\rho.eff}}(1 + \alpha_e \rho_{\rho eff})}{E_s}$$

kt = Factor depend on duration of load $f_{ct,ef} = 0.259 \times f_{ck}^{2/3}$

$\alpha_e = E_s / E_{cm}$

- Crack Width = $S_{r.max} (\varepsilon_{sm} - \varepsilon_{cm})$

3.4.3 Design of Footing

All the analysis and the load combinations part are same as in the design of pier which is explained above. Assuming the required data for the design purpose.

3.4.3.1 Check for Overturning

- Factor of safety against Overturning are in accordance with Cl.706.3.4 of IRC:78-2014 Normal Condition = 2

Wind & Seismic Condition = 1.5

- Factor of Safety = Overturning moment / Resisting Moment

3.4.3.2 Check for Sliding

- Factor of safety against Sliding are in accordance with Cl.706.3.4 of IRC:78-2014Normal Condition = 1.5

Wind & Seismic Condition = 1.3

- Factor of Safety = Sliding moment / Resisting Moment

3.4.3.3 Check for Base Pressure

- Allowable Tension area = 33%
- Increase in allowable stress for Wind & Seismic Load Combinations as per IRC 78-Cl.706.1.2

= 25%

- Calculate stresses at each corner point of footing and check the contact area $\sigma = \frac{P}{A} \pm \frac{MT}{ZT} \mp \frac{ML}{ZL}$
- Calculate the base pressure at every face of the pier and the corner of footing.

3.4.3.4 Flexure Check

- Calculation of Neutral axis $= \frac{d}{2\beta_2} - \text{Sqrt}\left(\frac{d^2}{(2\beta)^2} - \frac{M_{ED}}{\beta_1\beta_2 bf_{cd}}\right)$
- Calculation of Lever Arm (z) = d-0.416 Xu
- Calculate Area of steel provided = $\frac{M_{ED}}{0.87xfyxZ}$
- Calculate Minimum Reinforcement = 0.13%bt x d OR 0.26x(fctm/fyk)xbtxd
- Calculate moment of resistance = 0.87xfyxAsxZ

3.4.3.5 Shear Check

The Shear Check calculation are same as the shear check in in pier for the particular design shear force calculated at footing.

3.4.3.6 Stress Check

- The Shear Check calculation are same as the shear check in Pier the stresses in concrete and steel should be less than limiting stresses in concrete and steel.
- Also, the CRACK WIDTH should be less than 3mm which are mentioned in IRC-112.

Conclusion

As this project is based on design of bridge I have done throughout the period of internship. I have done the Hydraulic Calculations, Drawn the general arrangements drawing (GAD) of Bridge structure, Analysis and Design of superstructure and substructure, which included the external and internal girder, end and mid transverse member, deck slab, pier and open foundation structural member. In this paper I have mentioned the design and analysis process of the Pier and Open foundation. The results mentioned below as per the calculation done.

- Pier Concrete and Reinforcement Design Results- Width of Pier (Longitudinal Direction) = 1.5 m Depth of Pier (Transverse Direction) = 5.542 m Longitudinal Direction = 16 mm of 2 x 13 Nos, Transverse Direction = 16 mm of 2 x 55 Nos., Stirrups = 10 mm @ 100 mm c/c.

- Footing Concrete and Reinforcement Design Results - Length of Footing (Longitudinal Direction) = 5.5 m Width of Footing (Transverse Direction) = 8.8 m Longitudinal Direction = 20 mm @ 160 c/c Transverse Direction = 20 mm @ 160 c/c

Top face bar

Longitudinal Direction = 10 mm @ 200 c/cTransverse Direction = 10 mm @ 200 c/c

Main Reinforcement 20 mm at160 mm c/c Top face 10 mm at 200 mm c/c No Requirement of shear reinforcement.

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