ANALYSIS AND DESIGN OF BRIDGE FOUNDATION

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Abstract - The bridge is a structure which includes too many structural components visible as well as below the ground, they may look simple but the analysis and the structural design of all those components, even the simplest bridge type can be a fairly laborious and cumbersome job especially with respect to the various elements of the bridge superstructure and substructure. For bridges located on major perennial rivers or non-perennial river will have to be made support on deep foundations like wells or pile foundations, the design of which involves lengthy computational effort. The bridge engineer should be equipped with a handy computational tool with the help of which he can quickly and reliably determine the suitability of various layouts and configuration of the substructure before finalizing the most optimum design of the substructure. In this thesis attempt has been made to analysis and design the substructure for bridges with simply-supported spans with the help of various structural engineering software available. The computer programs like Autodesk InfraWorks, STAAD Pro. BEAVA & Staad Foundation will be used for this purpose. These programs include the analysis of circular piers. Also, it includes the option for the complete analysis and design of pile foundations on the basis of the relevant IS Codes of Practice.

Key Words: Bridge engineering, bearing capacity, code of practice, pile foundation, Autodesk InfraWorks, Staad Pro.

1. INTRODUCTION

Bridges have been the most visible testimony to the contribution of engineers. Bridges have always figured prominently in human history. They enhance the vitality of the cities and aid the social, cultural and economic improvements of the locations around them. Bridge is a structure providing passage over an obstacle without closing the way beneath. The required passage may be for a road, a railway, pedestrians, a canal or a pipeline and the obstacle to be crossed may be a river, a road, railways or a valley. The portion of the bridge structure below the level of the bearing and above the founding level is generally referred to as the substructure. The design of bridge substructure is an important part of the overall design for a bridge and affects to a considerable extent the aesthetics, the safety and the economy of the bridge. Bridge substructure are a very important part of a bridge as it safely transfers the loads from the superstructure to the earth in such a manner that the stresses on the soil are not excessive & the resulting deformations are within the acceptable limits. The selection of the foundation system for a particular site depends on many considerations, including the nature of subsoil, location where a bridge is proposed to be constructed i.e. over a river, road, or a valley, etc. & the scour depth.

A bridge may have either have the following types of foundations:

1. Well foundations: It is the most common type of foundation in India for both road & railway bridges. Such foundation can be sunk to great depths and can carry very heavy vertical and lateral loads. Well foundations can also be installed in a boulder stratum. It is a massive structure and is relatively rigid in its structural behavior.

2. Pile foundations: It consist of relatively long and slender members, called piles which are used to transfer loads through weak soil or water to deeper soil or rock strata having a high bearing capacity. They are also used in normal ground conditions for elevated road ways. The analysis and the design of all the components of a bridge particularly with reference to the bridge substructure can become a very lengthy and laborious task if the calculations are attempted manually.

In this study an attempt has been made to avoid those lengthy manual calculations required for analysis of Super structure and the design of substructure by using various software used by structural engineer for the analysis and design of sub-structures for concrete bridges with simply supported spans.

1.1 Objective

To carry out analysis and design of sub-structures for concrete bridges with simply supported spans with the help of software: Autodesk InfraWorks, Staad Pro. Beava & Staad Foundation in following way:

1. Importing the location of on-going Kanhan Bridge in Autodesk InfraWorks using Google maps terrain
2. Analysis of span between 3rd, 4th and 5th piers in Staad Pro.
1.2 Introduction to Software

1) Autodesk InfraWorks 360

Autodesk InfraWorks is a planning and design platform that enables engineers to quickly and easily convey preliminary design intent in a real-world, contextual environment, increasing stakeholder buy-in and team decision-making. It leverages automated, rich 3D model building capability with web-based technology and vertically-specialized functionality to provide infrastructure engineers with the industry's most compelling conceptual design tool.

2) STAAD Pro Beava

STAAD Pro is comprehensive structural engineering software that addresses all aspects of structural engineering including model development, verification, analysis, design and review of results. It includes advanced dynamic analysis and push over analysis for wind load and earthquake load. The commercial version, STAAD.Pro, is one of the most widely used structural analysis and design software products worldwide. It supports several steel, concrete and timber design codes.

2. RESULT AND DISCUSSION

Importing the location of on-going Kanhan Bridge in Autodesk InfraWorks using Google maps terrain

Using Autodesk InfraWorks, we have created, a rich 3D Bridge model on the line of New Kanhan bridge as a preliminary conceptual design with all superstructure as well as foundation component on the basis of AASHTO CODE. Detailed Dimension is as following.

We will be using this Bridge model as a reference for analysis in Staad Pro Beava which is meant for structural analysis of bridge.

The details required for the analysis and design for substructure are given below:

DETAILS OF ROAD

- Function: Freeway
- Speed: 110.0 km/h
- Design Standards: AASHTO LRFD

BRIDGE DETAILS

- Dead load on each span: 1500 Kn
- Length of end span: 25 m
- Length of mid span: 35 m
- Web thickness of simply supported girder: 0.2 m
Fig 2. Coordinates of Kanhan Bridge located

Fig 3. Adding Roads using feature Roads

Fig 4. Bridge created

Fig 5. Bridge Result

Analysis of Bridge span between 3rd, 4th and 5th piers in Staad Pro.

First create the beams in grid. Then Translational Repeat applied and span between pier 3, 4 & 5 is created Slab is created using Surface meshing. Then Section and Material is applied to piers, Beam caps, Girders and Plates using General (Properties). Provide fixed support to column. Beam offset feature is used to place girder under slab & girders on beams exactly. At last beam cap is placed over column properly. Proper placement will look lie in fig.

Fig 6. Bridge in Staad Pro
Apply loading (Self weight as Dead load) and Analyse it. In next steps, on Bridge Mode, Deck is created with roadways and using IRC loadings Class AA+R & Influence Surface Generator is activated. Now You ready to generate loading Using "Run Load Generator"

Here you will have to Provide Information like-1. Which deck? 2. IRC loading chapter 3, 3. Maximum displacement and on which, 4. Last step, you have to add maximum support reactions node and direction with impact.

Now use command "Create Loading in Staad Model" and Load generation is completed. Go to Staad pro and now you can see IRC load cases are added in Load Cases Details. Finally, analyze for the last time. After analysis following results are obtained. We are giving here, Report of Input Details as well as Output Details.

**Input Details**

Included in this printout are results for load cases:

<table>
<thead>
<tr>
<th>Type</th>
<th>L/C</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary</td>
<td>1</td>
<td>DL</td>
</tr>
<tr>
<td>Primary</td>
<td>2</td>
<td>IRC: SLS Class 70R+A Loading N26: Disp Y -ve</td>
</tr>
<tr>
<td>Primary</td>
<td>3</td>
<td>IRC: SLS Class 70R+A Loading N6: React FY +ve</td>
</tr>
<tr>
<td>Primary</td>
<td>4</td>
<td>IRC: SLS Class 70R+A Loading N12: React FY +ve</td>
</tr>
<tr>
<td>Primary</td>
<td>5</td>
<td>IRC: SLS Class 70R+A Loading N18: React FY -ve</td>
</tr>
</tbody>
</table>

**Beam Stresses**

<table>
<thead>
<tr>
<th>Direction</th>
<th>Factor</th>
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<tbody>
<tr>
<td>Y</td>
<td>-1.000</td>
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</tbody>
</table>

**Beam Graphs-IRC loading**

**Materials**

<table>
<thead>
<tr>
<th>Mat</th>
<th>Name</th>
<th>E (kN/mm²)</th>
<th>Density (kg/m³)</th>
<th>(°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>STEEL</td>
<td>205.000</td>
<td>7.83E-3</td>
<td>12E-6</td>
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<tr>
<td>4</td>
<td>STAINLESS STEEL</td>
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<td>7.83E-3</td>
<td>18E-6</td>
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<tr>
<td>5</td>
<td>ALUMINUM</td>
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<td>2.71E-2</td>
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<tr>
<td>6</td>
<td>CONCRETE</td>
<td>21.718</td>
<td>2.4E3</td>
<td>10E-6</td>
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</tbody>
</table>

**Self-weight: 1 DL**

**Section Properties**

<table>
<thead>
<tr>
<th>Prop</th>
<th>Section</th>
<th>Area (cm²)</th>
<th>I_y (cm⁴)</th>
<th>I_z (cm⁴)</th>
<th>J (cm⁴)</th>
<th>Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Rect</td>
<td>60E3</td>
<td>450</td>
<td>200</td>
<td>470</td>
<td>CONCRETE</td>
</tr>
<tr>
<td>2</td>
<td>Rect</td>
<td>50E3</td>
<td>260</td>
<td>167</td>
<td>342</td>
<td>CONCRETE</td>
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<tr>
<td>4</td>
<td>I160016C50040</td>
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<td>105</td>
<td>4.63</td>
<td>3.65</td>
<td>CONCRETE</td>
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</tbody>
</table>

**Plate Thickness**

<table>
<thead>
<tr>
<th>Prop</th>
<th>Node A (cm)</th>
<th>Node B (cm)</th>
<th>Node C (cm)</th>
<th>Node D (cm)</th>
<th>Material</th>
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<tbody>
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<td>30.000</td>
<td>30.000</td>
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<td>CONCRETE</td>
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</table>
**Output Report:**

**Node Displacement Summary**

<table>
<thead>
<tr>
<th>No</th>
<th>L/C</th>
<th>X (m)</th>
<th>Y (mm)</th>
<th>Z (mm)</th>
<th>Resultant (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max X</td>
<td>17</td>
<td>3:IRC: SLS Class 70R+A Loading N6: React FY+ve</td>
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<td>1.392</td>
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<tr>
<td>Min X</td>
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<td>4:IRC: SLS Class 70R+A Loading N12: React FY+ve</td>
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<td>3.281</td>
<td>0.72</td>
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<tr>
<td>Max Y</td>
<td>5</td>
<td>4:IRC: SLS Class 70R+A Loading N12: React FY+ve</td>
<td>-2.80</td>
<td>-2.55</td>
<td>-0.48</td>
</tr>
<tr>
<td>Min Y</td>
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<td>1:DL</td>
<td>0.00</td>
<td>53.0</td>
<td>0.13</td>
</tr>
<tr>
<td>Max Z</td>
<td>45</td>
<td>1:DL</td>
<td>0.03</td>
<td>31.70</td>
<td>0.582</td>
</tr>
<tr>
<td>Min Z</td>
<td>2</td>
<td>1:DL</td>
<td>0.13</td>
<td>0.540</td>
<td>0.486</td>
</tr>
<tr>
<td>Max rX</td>
<td>14</td>
<td>1:DL</td>
<td>0.13</td>
<td>0.540</td>
<td>0.486</td>
</tr>
<tr>
<td>Min rX</td>
<td>45</td>
<td>1:DL</td>
<td>0.03</td>
<td>31.70</td>
<td>0.582</td>
</tr>
<tr>
<td>Max rY</td>
<td>48</td>
<td>1:DL</td>
<td>0.03</td>
<td>31.70</td>
<td>0.582</td>
</tr>
</tbody>
</table>

**Beam Graphs: Forces on Beam**
Beam Displacement Detail Summary

<table>
<thead>
<tr>
<th>Beam</th>
<th>L/C</th>
<th>d (m)</th>
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</thead>
<tbody>
<tr>
<td>Max X</td>
<td>31</td>
<td>5:IRC: SLS Class 70R+A Loading N18: React FY -ve</td>
</tr>
<tr>
<td>Min X</td>
<td>26</td>
<td>2:IRC: SLS Class 70R+A Loading N26: Disp Y -ve</td>
</tr>
<tr>
<td>Max Y</td>
<td>10</td>
<td>4:IRC: SLS Class 70R+A Loading N12: React FY +ve</td>
</tr>
<tr>
<td>Min Y</td>
<td>29</td>
<td>1:DL</td>
</tr>
<tr>
<td>Max Z</td>
<td>75</td>
<td>1:DL</td>
</tr>
<tr>
<td>Min Z</td>
<td>7</td>
<td>1:DL</td>
</tr>
<tr>
<td>Max Rst</td>
<td>29</td>
<td>1:DL</td>
</tr>
</tbody>
</table>

**PILE FOUNDATION-**

We will use Staad Foundation platform for Pile Foundation Design.

- **Staad Foundation-Comprehensive Foundation Design Software**

It gives efficient foundation design and documentation using plant-specific design tools, multiple design codes including Indian codes and metric bar sizes, design codes and optimization, and automatic drawing generation. STAAD Foundation Advanced provides you with a streamlined workflow through its integration with STAAD.Pro or as a stand-alone application. You can design virtually any type of foundation, from basic to the most complex.

Easily model complex or simple footings, such as plant foundations supporting vertical vessels, horizontal vessels, tanks and other footings.

Quickly model common foundations such as isolated, combined, strip, pile caps, and many more.

Simplify challenging scenarios such as vibrating machine foundation, lateral analysis of piers, or mat design using FEA.

Efficiently use your structural model with the foundation model through integration with STAAD.Pro, including automatically synced changes in both models.

**STEPS:**

1. The Bridge model is exported to **Staad Foundation** under mode "Foundation Design"

2. You can see the Geometry of Support as well Node numbers on graphic screen of Staad Foundation and Loads in Load description table.

<table>
<thead>
<tr>
<th>X (mm)</th>
<th>Y (mm)</th>
<th>Z (mm)</th>
<th>Resultant (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.033</td>
<td>-16.021</td>
<td>-0.374</td>
<td>16.154</td>
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<tr>
<td>-3.709</td>
<td>-20.138</td>
<td>0.264</td>
<td>20.479</td>
</tr>
<tr>
<td>-2.456</td>
<td>2.553</td>
<td>-0.497</td>
<td>3.577</td>
</tr>
</tbody>
</table>
3. Generate the Load combination for Service Load & Ultimate Load
4. Job set up created as: Name-Kanhan Bridge, Job Type- Kanhan Bridge, Design Code- Indian, Default Unit Type- SI, Support Assignment- Assign to all supports.
5. Under Loading- Include all loads
6. New job is created- Pile Cap Job
7. Provide Pile cap diameter and Spacing in Design Parameters for all supports- 6, 12, 18

Load Table for support no. 12

Bearing Capacity of soil

Pile Arrangement for Support no.6

RESULTS:

Design for Pile Cap P6

Column Shape: Rectangular Column
Length - X (Pl): 2.000 m
Column Width - Z (Pw): 3.000 m

Pedestal
Include Pedestal? No Pedestal Shape: N/A
Pedestal Height (Ph.): N/A
Pedestal Length - X (Pl): N/A
Pedestal Width - Z (Pw): N/A

Pile Cap Geometrical Data
Pile Cap Length $P_{CL} = 12.250$ m
Pile Cap Width $P_{CW} = 13.990$ m
Initial Pile Cap Thickness $t_i = 0.300$ m
Pile Geometrical Data
Pile spacing $P_s = 3.750$ m
Pile Edge distance $e = 0.500$ m
Pile Diameter $d_p = 1.500$ m

Pile Capacities
Axial Capacity $P_p = 500.000$ kN
Lateral Capacity $P_{pl} = 100.000$ kN
Uplift Capacity $P_{pu} = 300.000$ kN

Material Properties
Concrete $f'_c = 25000.004$ kN/m$^2$
Reinforcement $f_y = 415000.070$ kN/m$^2$

Concrete Cover
Bottom Clear Cover $CC_B = 0.050$ m
Side Clear Cover $CC_S = 0.050$ m
Pile in Pile Cap $PC_p = 0.075$ m

Loading applied at top of cap

<table>
<thead>
<tr>
<th>Load Case</th>
<th>$F_x$ (kN)</th>
<th>$F_y$ (kN)</th>
<th>$F_z$ (kN)</th>
<th>$M_x$ (kNm)</th>
<th>$M_y$ (kNm)</th>
<th>$M_z$ (kNm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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<td>-3369.106</td>
<td>-579.838</td>
<td>-1698.317</td>
<td>0.000</td>
<td>-0.001</td>
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<tr>
<td>2</td>
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<td>3.130</td>
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<td>-190.920</td>
<td>-503.129</td>
<td>0.000</td>
<td>1026.802</td>
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<tr>
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<td>-101.116</td>
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<td>-246.367</td>
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<td>651.060</td>
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<tr>
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<td>-14.454</td>
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<td>0.000</td>
<td>194.729</td>
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<td>6</td>
<td>79.592</td>
<td>121.182</td>
<td>23.176</td>
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<td>-3589.988</td>
<td>0.000</td>
<td>-1595.112</td>
</tr>
</tbody>
</table>

Pile Cap size (in investigated direction) $H = 12.250$ m
Pile Cap size (in investigated perpendicular direction) $B = 13.990$ m

PILE CAP DESIGN CALCULATION

Pile Reactions

Total pile number $N = 18$

Critical Load Case: 201

Reinforcement Calculation
Maximum bar size allowed along length # 40
Maximum bar size allowed along width # 40

Bending Moment at Critical Section = -12397.603 kNm (Along Length)
Bending Moment at Critical Section = -15073.662 kNm (Along Width)

Pile Cap Thickness $t = 0.744$ m
Selected bar size along length # 25
Selected bar size along width # 32
Selected bar spacing along length = 100.47 mm
Selected bar spacing along width = 112.20 mm

Pile Cap Thickness Check

Calculated Thickness $(t) = 0.744$ m

Check for Moment (Along Length)
Critical load case for thickness is reported only when required thickness is more than the given minimum thickness
Effective Depth \( d_{ef} \) = \( h_{cap} - (p_{id} + cc + 0.5Xd_b) \) = 0.607m

Depth of neutral axis for balanced section \( x_u = \frac{700Xd_{eff}}{1100+0.87Xf_y} = 0.291m \)

As per IS 456 2000 ANNEX G, G-1.1 C Ultimate moment of resistance \( M_{ulim} = 0.36Xf_eXbXx_uX(d_{eff} - 0.416Xx_u) = 17796.223 \text{kNm} \)

We observed \( M_u \leq M_{ulim} \) hence singly reinforced and under reinforced section can be used

Check for Moment (Along Width)
Critical load case for thickness is reported only when required thickness is more than the given minimum thickness

Critical Load Case: 201

<table>
<thead>
<tr>
<th>Pile No.</th>
<th>Moment along ( y_1-y_1 ) (kNm)</th>
<th>Moment along ( y_2-y_2 ) (kNm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-2826.015</td>
<td>0.000</td>
</tr>
<tr>
<td>2</td>
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<td>6</td>
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<tr>
<td>8</td>
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<td>-2207.750</td>
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</table>

9 -992.368 0.000
10 0.000 -861.113
11 -3090.181 0.000
12 0.000 0.000
13 0.000 -2339.833
14 -1038.577 0.000
15 0.000 -907.322
16 -3222.264 0.000
17 0.000 0.000
18 0.000 -2471.916

Governing moment \( M_u = -15073.662 \text{kNm} \)

We assume singly reinforced and under reinforcement section

Effective depth \( d_{ef} = h_{cap} - (p_{id} + cc + 0.5Xd_b) \) = 0.607m

Depth of neutral axis for balanced section \( x_u = \frac{700Xd_{eff}}{1100+0.87Xf_y} = 0.291m \)

As per IS 456 2000 ANNEX G, G-1.1 C Ultimate moment of resistance \( M_{ulim} = 0.36Xf_eXbXx_uX(d_{eff} - 0.416Xx_u) = 15582.826 \text{kNm} \)

We observed \( M_u \leq M_{ulim} \) hence singly reinforced and under reinforced section can be used

Check for One Way Shear (Along Length)
Design Shear Force for One-Way Action \( V_U = -3440.537 \text{kN} \)
As Per IS 456 2000 ANNEX B, B-5.1 and Clause No 34.2.4.2

Design Shear Stress \( (T_V) = \frac{V_U}{bXd} = -405.154 \text{kN/m}^2 \)

Allowable Shear Stress \( (T_C) = \frac{0.85X\sqrt{0.8f_c}}{6X} X \left(1 + \frac{5\sqrt{f_c}}{f_p} \right) - 1 \) = 544.703 kN/m^2

Where Beta = \( \max \left( \frac{0.8f_c}{6f_p}, 1 \right) \) = 4.438

and percentage of steel required \( (p_t) = \frac{A_s}{BXd} X 100 = 0.654 \)

Here \( T_V \leq T_C \) Hence safe

Check for One Way Shear (Along Width)

<table>
<thead>
<tr>
<th>Pile No.</th>
<th>Shear Force ( y_1 ) (kN)</th>
<th>Shear Force ( y_2 ) (kN)</th>
</tr>
</thead>
<tbody>
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<td>1</td>
<td>-495.154</td>
<td>0.000</td>
</tr>
<tr>
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<tr>
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<tr>
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<tr>
<td>18</td>
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<tr>
<td>TOTAL</td>
<td>-3607.500</td>
<td>-2899.307</td>
</tr>
</tbody>
</table>

Design Shear Force for One-Way Action \( V_U = -3607.500 \text{kN} \)
As Per IS 456 2000 ANNEX B, B-5.1 and Clause No 34.2.4.2

Design Shear Stress \( (T_V) = \frac{V_U}{bXd} = -424.815 \text{kN/m}^2 \)

Allowable Shear Stress \( (T_C) = \frac{0.85X\sqrt{0.8f_c}}{6X} X \left(1 + \frac{5\sqrt{f_c}}{f_p} \right) - 1 \) = 632.278 kN/m^2

Where Beta = \( \max \left( \frac{0.8f_c}{6f_p}, 1 \right) \) = 3.016

and percentage of steel required \( (p_t) = \frac{A_s}{BXd} X 100 = 0.962 \)

Here \( T_V \leq T_C \) Hence safe

Check for Two Way Shear (Along Length)

<table>
<thead>
<tr>
<th>Pile No.</th>
<th>Two-way Shear at column face (kN)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-495.154</td>
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<tr>
<td>2</td>
<td>-430.773</td>
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<td>-455.247</td>
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<td>-563.152</td>
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<tr>
<td>17</td>
<td>-498.771</td>
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<tr>
<td>18</td>
<td>-434.390</td>
</tr>
<tr>
<td>TOTAL</td>
<td>-8255.279</td>
</tr>
</tbody>
</table>

Design Two-Way Shear force = -8255.279 kN
As Per IS 456 2000 Clause 31.6.2.1
Two Way Shear Stress \( (T_V) = \frac{V_U}{bXd} = -1094.314 \text{kN/m}^2 \)

Where, perimeter of critical section \( (b_0) = 2X(b+h+2Xd) \) = 12.48m

As Per IS 456 2000 Clause 31.6.3.1
Allowable shear stress \( = \frac{k_sXt_c}{b_0Xdf} = 1250.000 \text{kN/m}^2 \)

Where, \( k_s = \min \left(0.5 + \frac{b}{1}, 1 \right) = 1.000 \)
Ratio of shorter to longer dimension \( (B_c) = 0.667 \)
and, \( T_C = \frac{0.25Xf_ybXd}{b_0Xdf} = 1250.000 \text{kN/m}^2 \)

\( T_V < k_sT_C \) hence Safe

Calculation of Maximum Bar Size (Along Length)
Selected maximum bar size = 40 mm
Bar diameter corresponding to max bar size \( (db) = 40.000 \text{mm} \)
As Per IS 456 2000 Clause No 26.2.1
Development Length \( (id) = \frac{4Xf_yb}{0.87XdbXf_y} = 1.612 \text{m} \)
Allowable Length \( (l_{db}) = \frac{0.85X(B - b)}{C_e} = 5.075 \text{m} \)
\( l_{db} > l_d \) hence, safe
Calculation of Maximum Bar Size (Along Width)

Selected maximum bar size = 40 mm

Bar diameter corresponding to max bar size \(d_b\) = 40.000 mm

As Per IS 456 2000 Clause No 26.2.1

\[
\text{Development Length} (l_d) = \frac{4 \times f_y \times f_y}{0.87 X d_b} = 1.612 \text{m}
\]

Allowable Length \((l_{db}) = 0.5X(H - h) - C_z = 5.445 \text{m}

\(l_{db} > l_d\) hence, safe

Selection of Bottom and Top Reinforcement

Top reinforcement is provided same as bottom reinforcement

---

Along Length

Critical Load Case: 201
As Per IS 456 2000 Clause 26.5.2.1

Minimum Area of Steel \((A_{stmin})\)

\[
A_{stmin} = 0.12 \% \times X B X h_{cap} = 12288.817 \text{mm}^2
\]

As Per IS 456 2000 ANNEX G, G-1.1 b

Area of steel required \((A_{sq})\)

\[
A_{sq} = 0.5 \left( \frac{f_y}{f_y} \right) X (1 - \sqrt{1 - \frac{4597.77 M_x^2}{f_y^2 X b X d^2}}) X b X d = 67786.125 \text{mm}^2
\]

Area of steel provided \((A_{st})\)

\(A_{st} = 67786.125 \text{mm}^2\)

\(A_{stmin} \leq A_{st}\) Steel area is accepted

Minimum spacing allowed \((S_{min})\) = 40 + \(d_b\) = 65 mm

Selected spacing \((S) = 100.47\) mm

\(S_{min} \leq S \leq 450\) mm and selected bar size < selected maximum bar size...

The reinforcement is accepted.

---

Along Width

Critical Load Case: 201
As Per IS 456 2000 Clause 26.5.2.1

Minimum Area of Steel \((A_{stmin})\)

\[
A_{stmin} = 0.12 \% \times X B X h_{cap} = 10922.101 \text{mm}^2
\]

As Per IS 456 2000 ANNEX G, G-1.1 b

Area of steel required \((A_{sq})\)

\[
A_{sq} = 0.5 \left( \frac{f_y}{f_y} \right) X (1 - \sqrt{1 - \frac{4597.77 M_x^2}{f_y^2 X b X d^2}}) X b X d = 86947.638 \text{mm}^2
\]

Area of steel provided \((A_{st})\)

\(A_{st} = 86947.638 \text{mm}^2\)

\(A_{stmin} \leq A_{st}\) Steel area is accepted

Minimum spacing allowed \((S_{min})\) = 40 + \(d_b\) = 72 mm

Selected spacing \((S) = 112.20\) mm

\(S_{min} \leq S \leq 450\) mm and selected bar size < selected maximum bar size...

The reinforcement is accepted.
3. CONCLUSIONS

This paper discussed the design and analysis of bridge foundation subjected to Indian Standard code. The study focused on the design and analysis of bridge’s foundation using STAAD Pro. In project we create the superstructure data required for foundation design. For that we used Autodesk Infraworks in which, we create the whole bridge and analyze it. After analysing the results’ details taken for designing pile foundation in STAAD Pro. Beava. In this for 3rd, 4th and 5th span we design foundation.

- From the project it is concluded

1. We can create/built bridge using Autodesk Infraworks software without using survey data.
2. STAAD PRO has the capability to calculate the reinforcement needed for any concrete section.
3. It is possible to analyze and design the bridge substructure with the help of software and time can be saved by avoiding lengthy calculations required for analysis and design of bridge substructure.

SCOPE FOR FURTHER WORK

For more convenience in analysis and design of bridge substructure little software can be developed performing all the calculation on one platform instead of using many software. This will help the structural designer to save his effort and time in case of more complicated design of substructure for bridge

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10. IS: 2911 (Part I/Sec 2) – 1979; “Code of Practice for Design and Construction of Pile Foundations, Concrete Piles, Bored Cast In-situ Piles (First Revision)”; BIS, New Delhi.


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