ANALYSIS AND DESIGN OF BRIDGE FOUNDATION

PRADEEP N. PAYGHAN[1], PROF. GIRISH SAWAI[2]

[1]M-tech, Student, Dept. of CIVIL V. M. Institute of Engineering and Technology, Nagpur
[2]Prof., Head-Dept. of CIVIL V. M. Institute of Engineering and Technology, Nagpur

---

Abstract - *The bridge is 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 sub-structure 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 vitalities 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.
3. Design of Pile foundation 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
- Top Width of simply supported girder: 1.1 m
- Bottom Width of simply supported girder: 0.7 m
- Type of Carriage way: Two lane carriage way
- Clear carriage way width: 7.5 m
- Type of girder: Precast I
- No of girder: 4

DETAILS OF PIER

- Type of Material used in Pier: Reinforced Concrete
- Type of Pier used in bridge: Hammer-head Type Pier
- C/s of pier: 3.0x2.0 m
- Height of Pier: 7 m
- No of Pier: 9

PIER CAP DETAILS

- Size of pier cap provided: 2.5x2.0m
- Depth of pier cap provided: 2.0m

COLUMN DETAILS

- Diameter: 2.0 m
- Width: 3.0 m
- Depth: 1.8 m

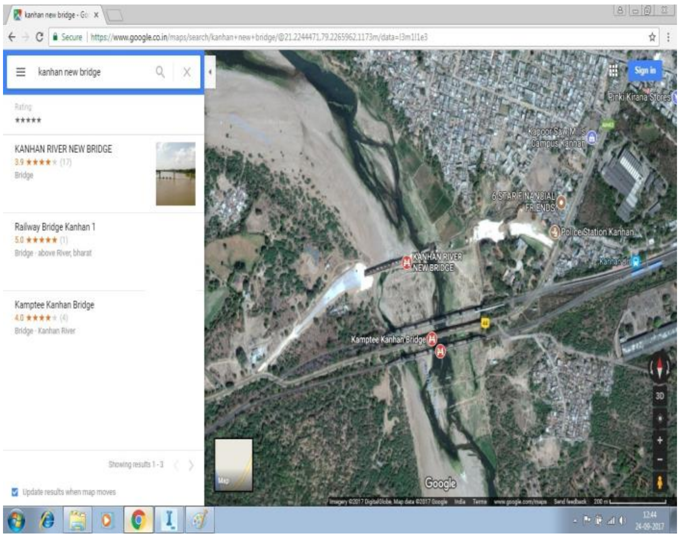


Fig 1. Existing Kanhan Bridge in Google Maps

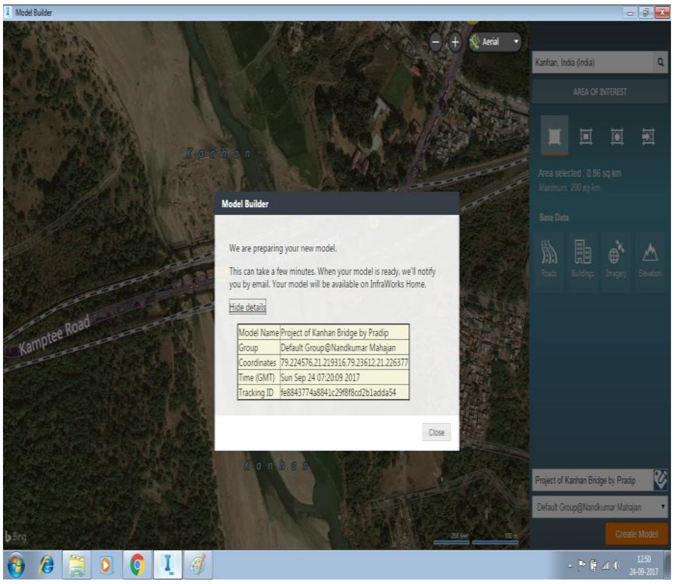


Fig 2. Coordinates of Kanhan Bridge located

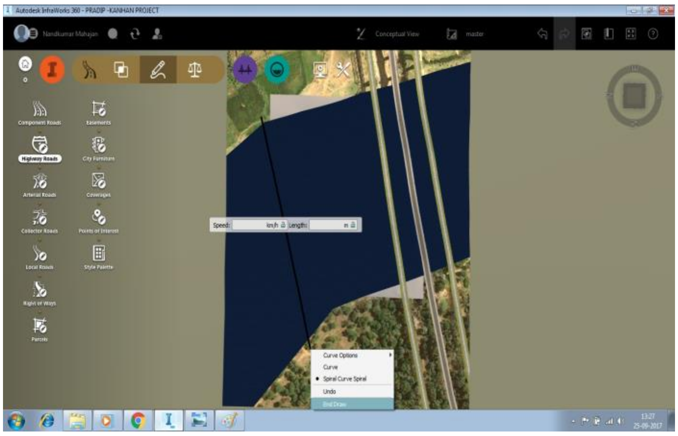


Fig 3. Adding Roads using feature Roads

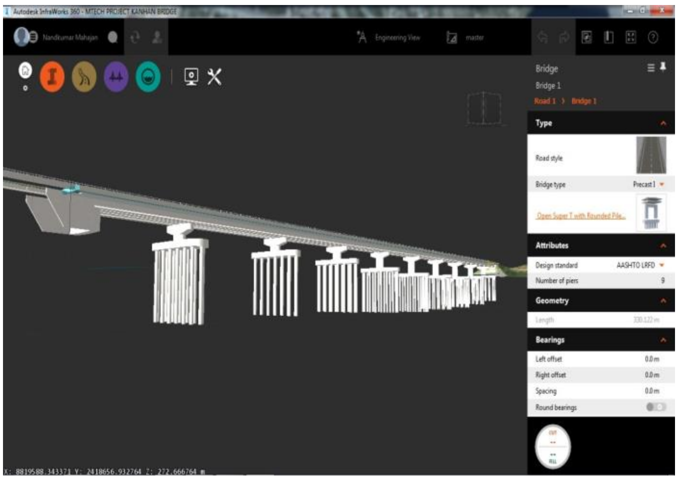


Fig 4. Bridge created

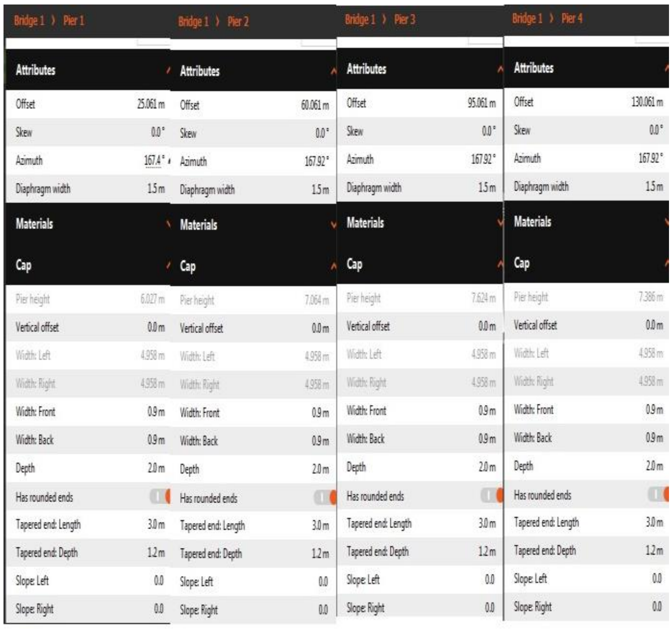


Fig 5. Bridge Result

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.

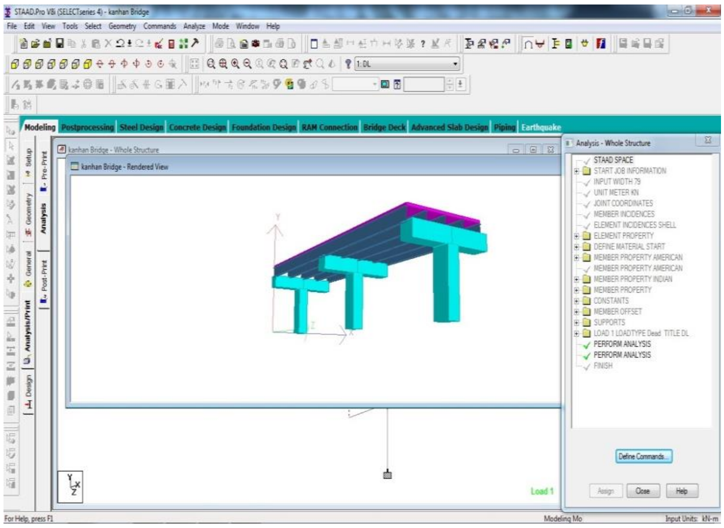


Fig 6. Bridge in Staad Pro

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 lime. 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:

Type	L/C	Name
Primary	1	DL
Primary	2	IRC: SLS Class 70R+A Loading N26: Disp Y -ve
Primary	3	IRC: SLS Class 70R+A Loading N6: React FY +ve
Primary	4	IRC: SLS Class 70R+A Loading N12: React FY +ve
Primary	5	IRC: SLS Class 70R+A Loading N18: React FY -ve

Section Properties

Prop	Section	Area (cm²)	I_{yy} (cm⁴)	I_{zz} (cm⁴)	J (cm⁴)	Material
1	Rect 2.00x3.00	60E 3	450 E 6	200 E 6	470 E 6	CONCRETE
2	Rect 2.00x2.50	50E 3	260 E 6	167 E 6	342 E 6	CONCRETE
4	I160016C50040	895.000	105 E 3	4.63 E 6	3.65 E 3	CONCRETE

Plate Thickness

Prop	Node A (cm)	Node B (cm)	Node C (cm)	Node D (cm)	Material
3	30.000	30.000	30.000	30.000	CONCRETE

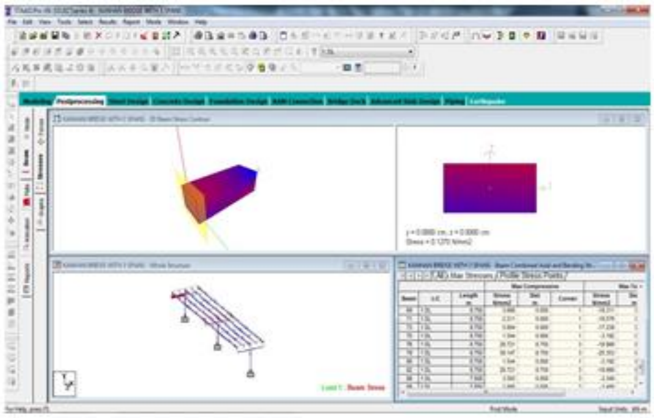
Materials

Mat	Name	E (kN/mm²)	[illegible]	Density (kg/m³)	(/°C)
3	STEEL	205.000	0.30	7.83E	12E -
4	STAINLESSSTEEL	197.930	0.300	7.83E 3	18E - 6
5	ALUMINUM	68.948	0.330	2.71E 3	23E - 6
6	CONCRETE	21.718	0.170	2.4E 3	10E - 6

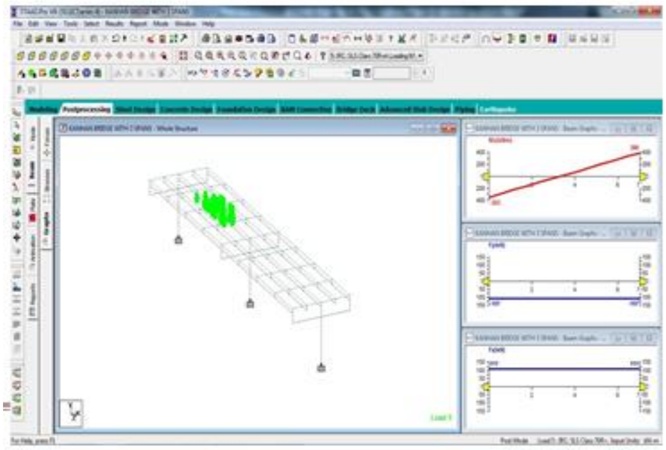
Self-weight: 1 DL

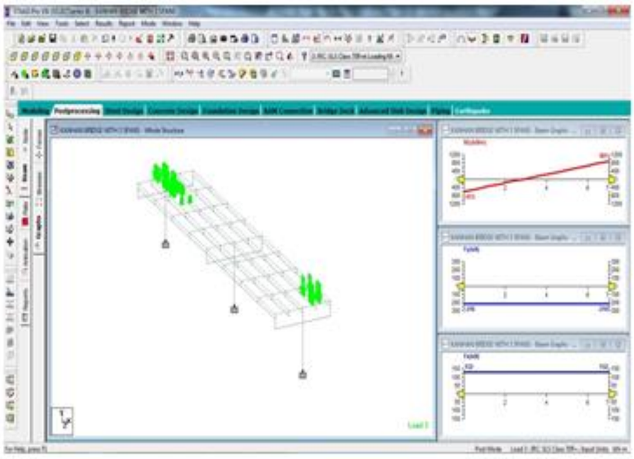
Direction	Factor
Y	-1.000

Beam Stresses



Beam Graphs-IRC loading





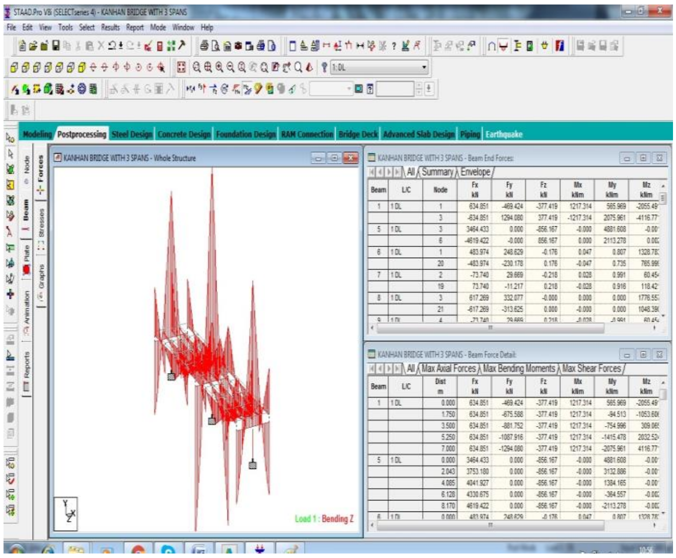
Out Put Report:

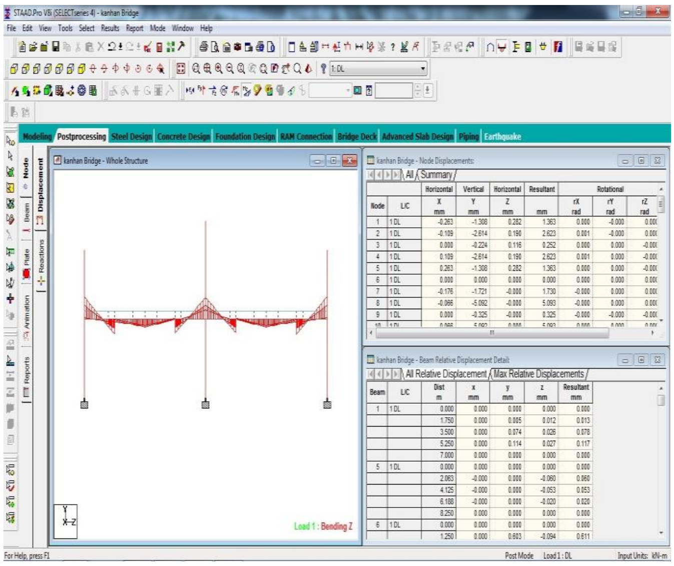
-

Node Displacement Summary

	Node	L/C	X (mm)	Y (mm)	Z (mm)	Resultant (mm)
Max X	17	3:IRC: SLS Class 70R+A Loading N6: React FY +ve	1.370	1.392	-0.201	1.963
Min X	1	4:IRC: SLS Class 70R+A Loading N12: React FY +ve	-3.016	3.281	0.727	4.515
Max Y	5	4:IRC: SLS Class 70R+A Loading N12: React FY +ve	-2.808	2.553	-0.487	3.826
Min Y	26	1:DL	0.000	53.066	0.130	53.067
Max Z	1	4:IRC: SLS Class 70R+A Loading N12: React FY +ve	3.016	3.281	0.727	4.515
Min Z	45	1:DL	0.033	31.702	0.582	31.707
Max rX	2	1:DL	0.132	0.540	0.486	0.739
Min rX	14	1:DL	0.132	0.540	0.486	0.739
Max rY	45	1:DL	0.033	31.702	0.582	31.707
Min rY	48	1:DL	0.033	31.702	0.582	31.707
Max rZ	27	5:IRC: SLS Class 70R+A Loading N18: React FY -ve	0.933	-16.021	-0.183	16.049
Min rZ	24	2:IRC: SLS Class 70R+A Loading N26: Disp Y -ve	0.538	-20.138	0.141	20.146
Max Rst	26	1:DL	0.000	-53.0	0.130	53.067

Beam Graphs-Forces on Beam





Beam Displacement Detail Summary

	Beam	L/C	d (m)
Max X	31	5:IRC: SLS Class 70R+A Loading N18: React FY -ve	8.750
Min X	26	2:IRC: SLS Class 70R+A Loading N26: Disp Y -ve	8.750
Max Y	10	4:IRC: SLS Class 70R+A Loading N12: React FY +ve	0.000
Min Y	29	1:DL	8.750
Max Z	75	1:DL	8.750
Min Z	7	1:DL	0.000
Max Rst	29	1:DL	8.750

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 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

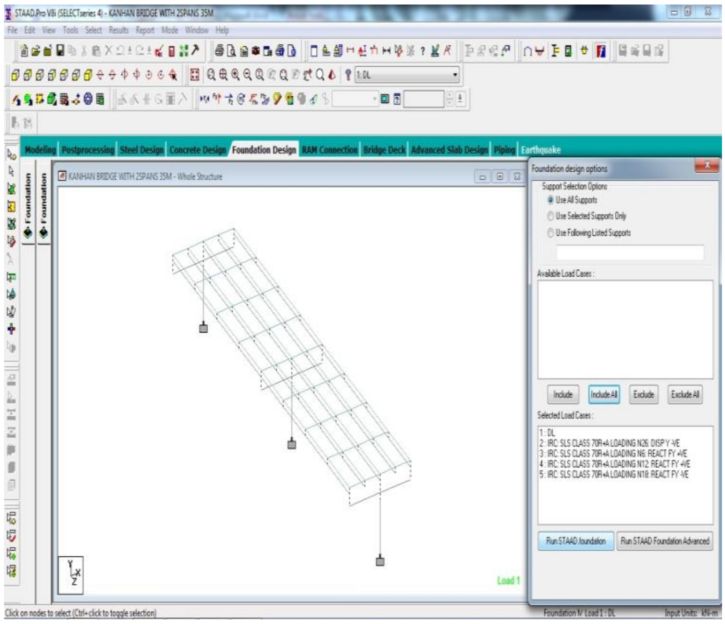
Simplify challenging scenarios such as vibrating machine foundation, lateral analysis of piers, or mat design using FEA

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

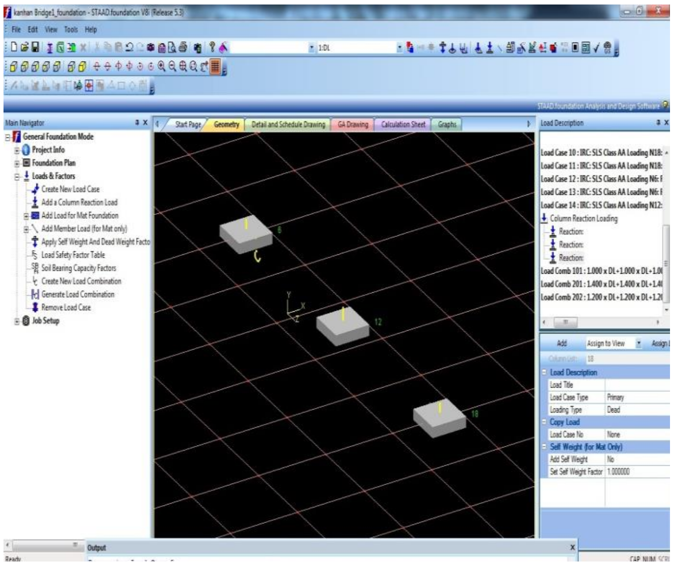
X (mm)	Y (mm)	Z (mm)	Resultant (mm)
2.033	-16.021	-0.374	16.154
-3.709	-20.138	0.264	20.479
-2.456	**2.553**	-0.497	3.577
0.000	**-53.067**	0.428	53.068
0.162	-0.540	**3.237**	3.286
0.162	-0.540	**-3.234**	3.283
0.000	-53.067	0.428	**53.068**

STEPS: -

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

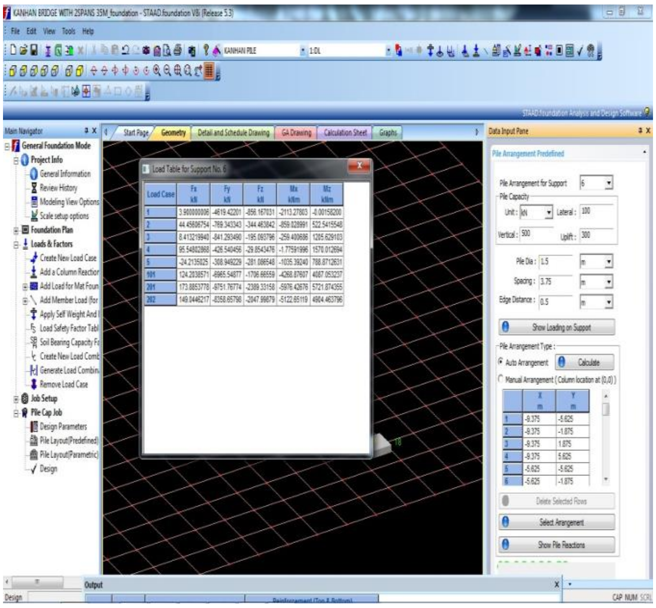


2. You can see the Geometry of Support as well Node numbers on graphic screen of Staad Foundation and Loads in Load description table.

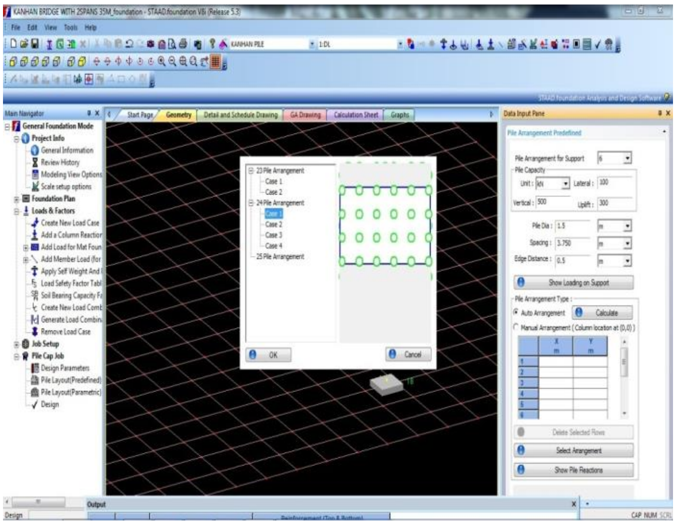


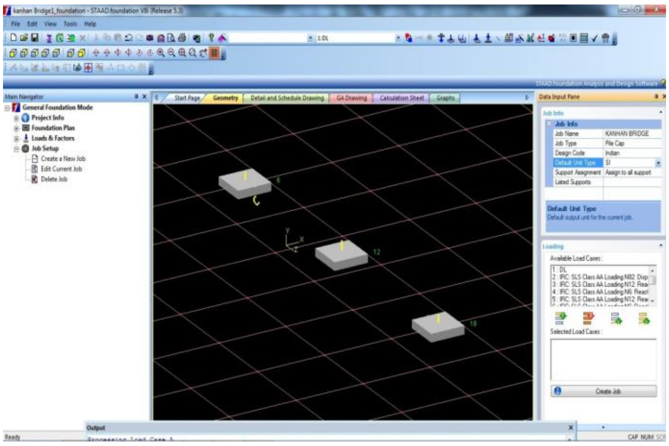
3. Generate the Load combination for Service Load & Ultimate Load
4. Job set up created as- **Nam**e-Kanhan Bridge, **Job Type-** Kanhan Bridge,**Design Code-** Indian,**Default Unit Type-** SI, **Support Assignment-**Assign to all supports.
5. **Under Loading-** Include all loads
6. New job is created- 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

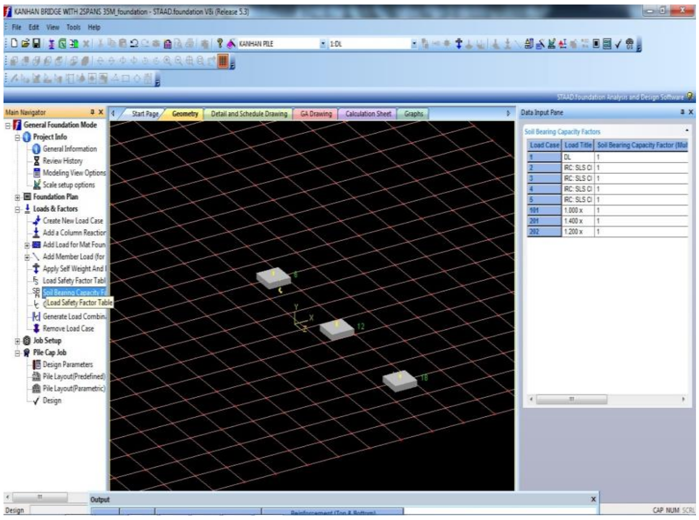


Pile Arrangement for Support no.6





Bearing Capacity of soil



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_L = 100.000 kN
Uplift Capacity P_U = 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

Load Case	F_x (kN)	F_y (kN)	F_z (kN)	M_x (kNm)	M_y (kNm)	M_z (kNm)
1	0.000	-4369.106	-579.838	-1698.317	0.000	-0.001
2	31.502	-673.606	-243.203	-668.478	0.000	-2343.145
3	3.130	-776.250	-190.920	-503.129	0.000	1026.802
4	-44.766	-101.116	-81.313	-246.367	0.000	651.060
5	-14.454	7.390	9.811	57.020	0.000	194.729
6	79.592	12.182	23.176	67.614	0.000	-858.705
101	55.004	-5900.507	-1062.286	-2991.657	0.000	-1329.260
201	77.006	-8260.710	-1487.200	-4188.319	0.000	-1860.963
202	66.005	-7080.609	-1274.743	-3589.988	0.000	-1595.112

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

PILE CAP DESIGN CALCULATION

Pile Reactions

Total pile number **N** = 18

	Arrangement		Reaction		
Pile No.	X (m)	Y (m)	Axial (kN)	Lateral (kN)	Uplift (kN)
1	-5.625	-6.495	-565.779	82.733	0.000
2	-5.625	-0.000	-490.668	82.733	0.000
3	-5.625	6.495	-415.557	82.733	0.000
4	-3.750	-3.248	-541.445	82.733	0.000
5	-3.750	3.248	-466.334	82.733	0.000
6	-1.875	-6.495	-592.223	82.733	0.000
7	-1.875	0.000	-517.111	82.733	0.000
8	-1.875	6.495	-442.000	82.733	0.000
9	0.000	-3.248	-567.889	82.733	0.000
10	0.000	3.248	-492.777	82.733	0.000
11	1.875	-6.495	-618.666	82.733	0.000
12	1.875	0.000	-543.555	82.733	0.000
13	1.875	6.495	-468.444	82.733	0.000
14	3.750	-3.248	-594.332	82.733	0.000
15	3.750	3.248	-519.221	82.733	0.000
16	5.625	-6.495	-645.110	82.733	0.000
17	5.625	0.000	-569.998	82.733	0.000
18	5.625	6.495	-494.887	82.733	0.000

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

Critical Load Case: 201

Pile No.	Moment along x_1-x_1(kNm)	Moment along x_2-x_2(kNm)
1	-2616.681	0.000
2	-2269.297	0.000
3	-1921.914	0.000
4	-1488.947	0.000

5	-1282.395	0.000
6	-518.185	0.000
7	-452.464	0.000
8	-386.743	0.000
9	0.000	0.000
10	0.000	0.000
11	0.000	-541.323
12	0.000	-475.602
13	0.000	-409.881
14	0.000	-1634.384
15	0.000	-1427.832
16	0.000	-2983.578
17	0.000	-2636.194
18	0.000	-2288.811

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

Depth of neutral axis for balanced section(x_u)=$\frac{700X d_{eff}}{1100+0.87X f_y}$= 0.291m

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

Ultimate moment of resistance(M_{ulim})= $0.36X f_c X bX x_u X(d_{eff} - 0.416X x_u)$= 17796.223 kNm

We observed M_u <= 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

Pile No.	Moment along y_1-y_1(kNm)	Moment along y_2-y_2(kNm)
1	-2826.015	0.000
2	0.000	0.000
3	0.000	-2075.667
4	-946.158	0.000
5	0.000	-814.904
6	-2958.098	0.000
7	0.000	0.000
8	0.000	-2207.750
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 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)=$\frac{700X d_{eff}}{1100+0.87X f_y}$= 0.291m

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

Ultimate moment of resistance(M_{ulim})=

$0.36X f_c X bX x_u X(d_{eff} - 0.416X x_u)$= 15582.826 kNm

We observed M_u <= M_{ulim} hence

singly reinforced and under reinforced section can be used

Check for One Way Shear (Along Length)

Pile No.	Shear Force x_1-x_1(kN)	Shear Force x_2-x_2(kN)
1	-495.154	0.000
2	-430.773	0.000
3	-366.392	0.000
4	-474.297	0.000
5	-409.915	0.000
6	-351.427	0.000
7	-307.734	0.000
8	-264.041	0.000
9	0.000	0.000
10	0.000	0.000
11	0.000	-366.810
12	0.000	-323.116
13	0.000	-279.423
14	0.000	-519.628
15	0.000	-455.247
16	0.000	-563.152
17	0.000	-498.771
18	0.000	-434.390
TOTAL	-3099.733	-3440.537

Design Shear Force for One-Way Action V_u= -3440.537 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 kN/m^2

Allowable Shear Stress (T_c)

=$\frac{0.85X\sqrt{0.8Xf_c}}{6X\beta}X(\sqrt{1+5X\beta}-1)$= 544.703 kN/m^2

Where Beta =$\max(\frac{0.8Xf_{ct}}{6.89Xpt},1)$ =4.438

and percentage of steel required (p_t) =$\frac{A_{st}}{BXd}X100$=0.654

Here T_v <= T_c Hence safe

Check for One Way Shear (Along Width)

Pile No.	Shear Force y_1-y_1(kN)	Shear Force y_2-y_2(kN)
1	-495.154	0.000
2	0.000	0.000
3	0.000	-366.392
4	-474.297	0.000
5	0.000	-409.915
6	-517.820	0.000
7	0.000	0.000
8	0.000	-389.058
9	-496.962	0.000
10	0.000	-432.581
11	-540.486	0.000
12	0.000	0.000
13	0.000	-411.724
14	-519.628	0.000
15	0.000	-455.247
16	-563.152	0.000
17	0.000	0.000
18	0.000	-434.390
TOTAL	-3607.500	-2899.307

Design Shear Force for One-Way Action V_u= -3607.500 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 kN/m^2

Allowable Shear Stress (T_c)

=$\frac{0.85X\sqrt{0.8Xf_c}}{6X\beta}X(\sqrt{1+5X\beta}-1)$= 632.278 kN/m^2

Where Beta =$\max(\frac{0.8Xf_{ct}}{6.89Xpt},1)$ =3.016

and percentage of steel required (p_t) =$\frac{A_{st}}{BXd}X100$=0.962

Here T_v <= T_c Hence safe

Check for Two Way Shear (Along Length)

Pile No.	Two-way Shear at column face (kN)
1	-495.154
2	-430.773
3	-366.392
4	-474.297
5	-409.915
6	-517.820
7	-399.480
8	-389.058
9	-496.962
10	-432.581
11	-540.486
12	-419.448
13	-411.724
14	-519.628
15	-455.247
16	-563.152
17	-498.771
18	-434.390
TOTAL	-8255.279

Design Two-Way Shear force= -8255.279kN
As Per IS 456 2000 Clause 31.6.2.1
Two Way Shear Stress(T_v) =$\frac{V_t}{b_oXd_{eff}}$=-1094.314 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 =K_sXt_c=1250.000 kN/m^2
Where, k_s =$\min(0.5+\beta,1)$ =1.000
Ratio of shorter to longer dimension(B_c)= 0.667
and, T_c = $0.25X\sqrt{f_c}XbXd$=1250.000 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(d_b) =40.000 mm
As Per IS 456 2000 Clause No 26.2.1
Development Length(l_d) =$\frac{0.87Xd_bXf_y}{4X\tau_{bd}}$=1.612m
Allowable Length(l_{db}) =$0.85X(B-b)-C_s$=5.075m
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
Development Length(l_d) = $\frac{0.87 X d_b X f_y}{4 X \tau_{bd}}$=1.612m
Allowable Length(l_{db}) =$0.5X(H-h)-C_s$=5.445m
$l_{db} > l_d$ 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}) =$0.12\% X B X h_{cap}$=12288.817mm^2
As Per IS 456 2000 ANNEX G, G-1.1 b
Area of steel required (A_{sq}) = $0.5\left(\frac{f_c}{f_y}\right)X(1-\sqrt{1-\frac{4.5977XM_u}{f_cXbXdXd}}$)X b X d= 67786.125 mm^2
Area of steel provided (A_{st}) = 67786.125 mm^2

A_{stmin}<= A_{st} Steel area is accepted

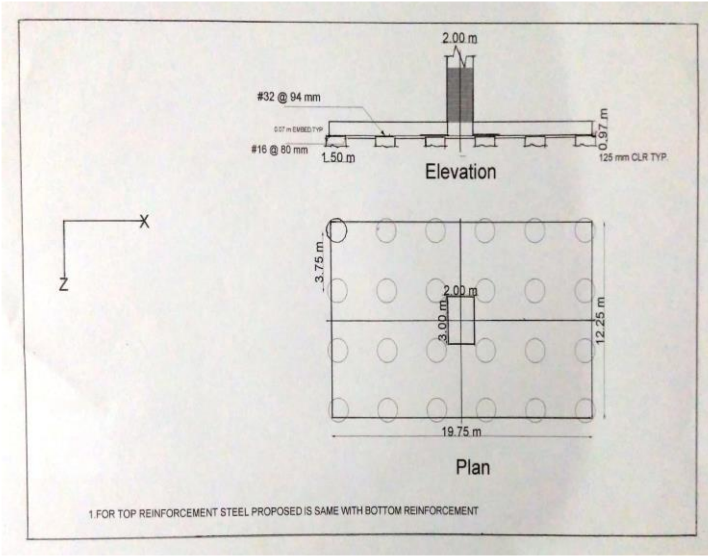
Minimum spacing allowed (S_{min}) = 40 + d_b= 65 mm
Selected spacing (S)= 100.47 mm
S_{min} <= S <= 450 mm and selected bar size < selected maximum bar size...
The reinforcement is accepted.

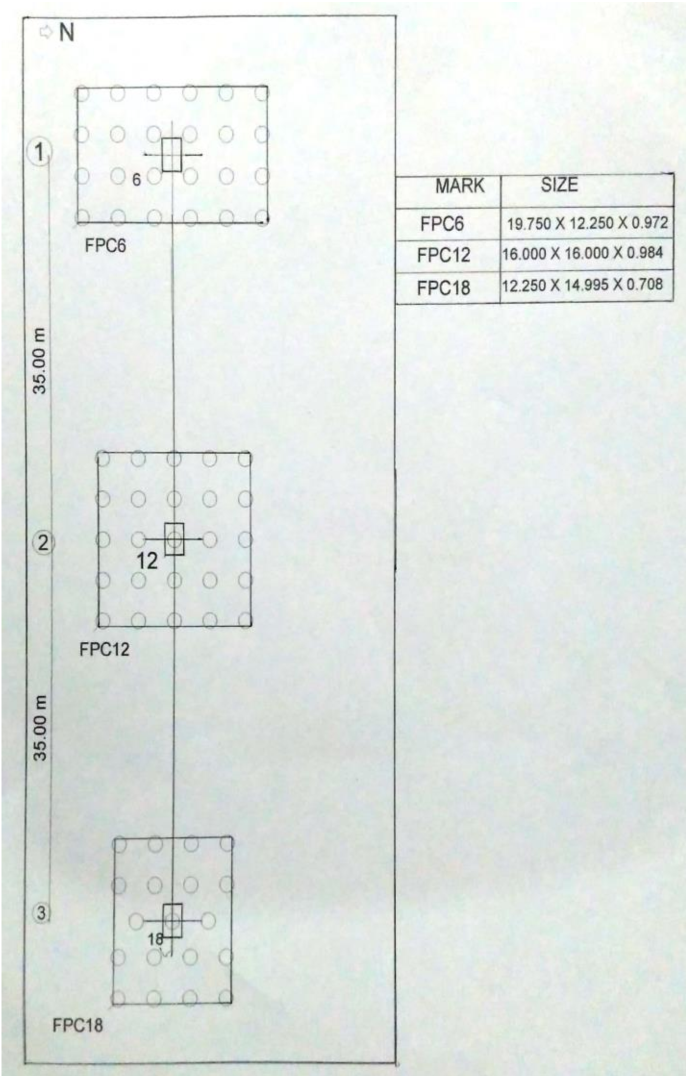
Along Width
Critical Load Case: 201
As Per IS 456 2000 Clause 26.5.2.1
Minimum Area of Steel (A_{stmin}) =$0.12\% X B X h_{cap}$=10922.101mm^2

As Per IS 456 2000 ANNEX G, G-1.1 b
Area of steel required (A_{sq}) = $0.5\left(\frac{f_c}{f_y}\right)X(1-\sqrt{1-\frac{4.5977XM_u}{f_cXbXdXd}}$)X b X d= 86947.638 mm^2
Area of steel provided (A_{st}) = 86947.638 mm^2

A_{stmin}<= A_{st} Steel area is accepted

Minimum spacing allowed (S_{min}) = 40 + d_b= 72 mm
Selected spacing (S)= 112.20 mm
S_{min} <= S <= 450 mm and selected bar size < selected maximum bar size...
The reinforcement is accepted.





Pile Positions and Dimensions

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 super structure data required for foundation design. For that we used Autodessk Infraworrks 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 sub structure for bridge

REFERENCES

1. IS: 456 2000; "Plain and Reinforced Concrete – Code of Practice (Fourth Revision)"; BIS, New Delhi.

2. AASHTO, AASHTO LRFD Bridge Design Specifications, AASHTO,Washington, DC, USA, 2004.

3. Design and Analysis of Sub-Structure of Bridge-A Review by M.Prabu, R.Vijayasarathy Journal of Civil Engineering and Construction Technology Vol. 2(5), pp. 101-118, May 2011

4. Design and analysis of bridge design using STAAD PRO by S. N. Krishna Kanth and DR. V. Anjaneya Prasad International Journal of Research Sciences and Advanced Engineering Volume 2, Issue 12, PP: 211 - 224, OCT - DEC' 2015.

5. Design and analysis of bridge foundation with different codes by Hussein Yousif Aziz* and Jianlin Ma Journal of Civil Engineering and Construction Technology Vol. 2(5), pp. 101-118, May 2011

6. Analysis of Water Flow Pressure on Bridge Piers considering the Impact Effect by Yin-huiWang, Yi-song Zou, Lue-qin Xu, and Zheng Luo, Hindawi Publishing Corporation Mathematical Problems in Engineering Volume 2015.

7. https://www.autodesk.com/products/infraworks/features

8. https://en.wikipedia.org/wiki/STAAD

9. https://www.bentley.com/en/products/product-line/structural-analysis-software/staadpro

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.

11. IS: 2911 (Part III**)** – 1980**;** "Code of Practice for Design and Construction of Pile Foundations, Under-reamed Piles (First Revision)"; BIS, New Delhi.

12. IRC: 6 – 2000; "Standard specifications and code of practice for road bridges, Section: II, Loads and Stresses (Fourth Revision)"; The Indian Road Congress, New Delhi.

13. IRC: 78 – 2000; "Standard specifications and code of practice for road bridges, Section: VII, Foundations and Substructure"; The Indian Road Congress, New Delhi.

14. IRC: 6 – 2000; "Standard specifications and code of practice for road bridges, Section:II, Loads and Stresses (Fourth Revision)"; The Indian Road Congress, New Delhi.

15. IRC: 78 – 2000; "Standard specifications and code of practice for road bridges, Section:VII, Foundations and Substructure"; The Indian Road Congress, New Delhi.

16. Saran, S. (1996); "Analysis and Design of Substructure - Limit State Design (SecondEdition)"; Oxford & IHB Publishing Co. Pvt. Ltd., New Delhi

17. Ramamrutham, S. (2005); "Theory of Structure (Eighth Edition)"; DhanpatRaiPublishing Company (P) Ltd., New Delhi.

18. Arora, K. R. (2003); "Soil Mechanics and Foundation Engineering (Sixth Edition)"; Standard Publishers Distributors, New Delhi.

19. Das, B. M. (2004); "Principles of Foundation Engineering (Fifth Edition)"; Brook/ColesPub. Co., CA.

20. Jain, A. K. (1993);" Reinforced Concrete – Limit State Design (Fourth Edition)"; NemChand & Bros., Roorkee, Fourth Edition.

21. SP: 34 (S & T) (1980); "Hand Book on Concrete Reinforcement and Detailing"; BIS,New Delhi.

BIOGRAPHIES

Pradeep N. Payghan
M-tech(Structure),
V.M.Institute of Engineering and Technology,
Dongargaon, Wardha Road, Nagpur