DESIGN AND ANALYSIS OF CHAMAKKAVU BRIDGE

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Abstract – *This project focuses on designing a unique, safe, Elegant and economic bridge that helps to make a mark in the field of structural art. The bridge is constructed over Achankovil River. It is constructed as both pedestrian as well as notional bridge. The bridge is located at Venmony Gram Panchayat. A new bridge is constructed at a new site. The absence of the old bridge also affects the life of 5596 families. Also the people visiting the Chamakkavu temple are facing difficulty in reaching the location. Since this is an issue of public importance, so we are planning to design a RCC T Beam bridge theoretically using IS codes such as IRC:6-2017 ,IRC:112-2011 and IRC:73-1980 and also by using STAAD Pro V8i software. A comparison should be made between manual and software designing.*

1. INTRODUCTION

The bridges have been used to cross the barriers, typically a river stream or valley by using locally available materials such as stones, timber. Since these early times bridge engineering has evolved into a major discipline in itself, one that benefits from the advances made in other engineering disciplines, such as engineering geology, water resources engineering, geotechnical engineering, and structural engineering. Based on these disciplines, modern bridge engineering mainly deals with (a) planning, (b) analysis, (c) design, (d) construction, (e) maintenance, and (f) Rehabilitation. Therefore, they are an integral part of the human life that aids a prospering trade and commerce in a city. Bridges are called lifeline structures because apart from the day-to-day services, during natural calamities such as earth quakes or floods, they facilitate in Providing emergency relief by enabling supply of food, medicine, etc., into hazard affected areas. The old bridge is constructed over river with a span of 75m. It was constructed as notional bridge and was a single lane road bridge. The bridge connected Edappon and Venmony Panchayat which provided easy access to hospitals, Schools, police stations, markets, etc. The unscientific way of design and construction lead to its failure during the last flood in 2017. Large sized logs struck the weakened the piers and resulted in the total demolition of the old bridge. The alternate way to reach the location is about 8km away Which lead to reduced availability of public transport services in the area. The absence of the bridge also affected the life of 5596 families. The type of bridge we adopt is the prestressed T beam bridge. The precast pre-stressed bridge system has offered two principal advantages: it is economical and it provides minimum downtime for construction. Pre–stressing is the application of an initial load on the structure so as to enable the structure to counteract the stresses arising during its service period. The grade of the concrete and steel used are M_{30} and Fe415 for substructure and superstructure respectively. The live load considered is IRC class AA loading. The software used is STAAD Pro V8i. The software designing is more accurate and convenient. It was less time consuming and chance of human error is less.

1.1 Literature Review

According to Fuyong Tang, with the continuous development of social economy y and the accelerating process of urbanization bridge construction will also become a new trend of social development. This will provide great convenience for people's daily travel. The construction material used is the concrete.

According to Keishi Evaluator, the project objective is to construct a two lane bridge to replace the existing the single lane bridge across the river for the traffic congestion and allowing the traffic to flow smoothly. .

According to the book Design and Analysis of substructure of bridge, by S.N. Krishna Kanth, the project deals with the design of minor bridge. This includes the actual replacement of bridge. We are also going to have to determine what the AASHTO design standards are and apply them to this bridge. STAAD Pro has the capability to calculate the reinforcement needed for any concrete section. The program contains a number of parameters Which are designed as per IS: 456 (2000). Beams are designed for flexure, shear and torsion.

2. OBJECTIVES

To design and analyze the bridge at Chamakkavu.

The primary objectives are:

1. Application of load on the member.
2. To design the structure manually by using IS and IRC codes.
3. To analyze the structure using STAAD Pro software.
4. To compare the manual designing and STAAD Pro designs.

3. RESULTS AND DISCUSSIONS

Basic design data:

1) Bridge type: prestressed T- Beam Bridge

2) Name of the stream: Achankovil river

3) Total span: 60m

4) Number of longitudinal girders: 4

5) Number of cross girders: 4

6) Grade of concrete: M_{30} for the whole structure

7) Grade of steel: HYSD Fe415

8) Spacing of girder: 2625mm

9) Carriage Way: 7.5m

10) Effective span of the bridge: 20m

Fig 3.1: Site Map of Chamakkavu Bridge

3.1 Details of Deck Slab:

Depth of deck slab= 250mm

Thickness of wearing coat = 800mm

Width of the slab= 10.5m

Width of main girder= 200mm

Breadth of cross girder= 200mm

Design of slab:

Dead weight of slab=6KN/m

Dead weight of wearing coat= 1.76KN/m

Total dead load= 7.76KN/m

Effect of concentrated load on Deck Slab (by Pigeaud's Curve):

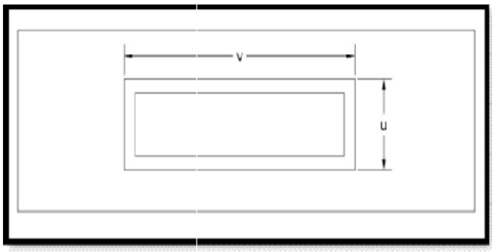

Fig 3.2: Effect of concentrated load on deck slab

u- Dispersion length along the short span

v- Dispersion length along the long span

weight of the vehicle is 350KN on IRC class AA loading on 850 x 3600mm contact area spaced at 2050mm c/c (IRC 6:2000)

u= 1.01m and v= 3.76m

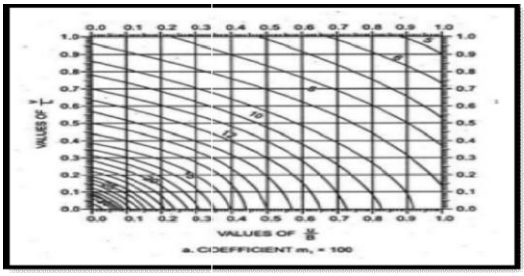

Fig 3.3: Pigeaud's curve for moment coefficients m1 for K=0.5

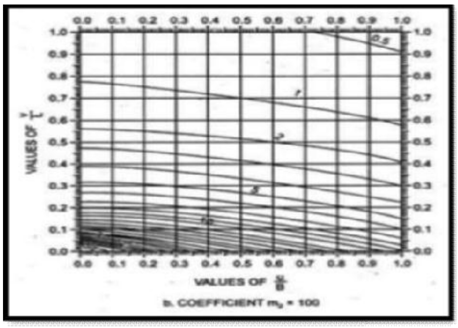

Fig 3.4:Pigeaud's curve for Moment coefficients m2 for K=0.5

m_1= 0.092, m_2= 0.025

Bending moment due to live load,

M_B= P(m_1+μm_2) = 33.51KNm

M_L =13.58KNm

Bending moment due to dead load,

M_B= 0.743KNm

M_L= 0.301KNm

Design Moments,

Total M_B= 34.253KNm

Total M_L= 13.881KNm

Shear force due to DL= (W x L)/(2) = 10.282KN

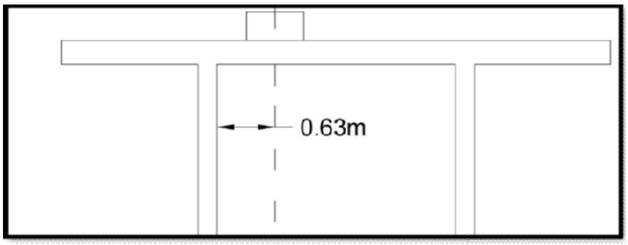

Fig 3.5: Position of the Maximum Shear Load on The Panel

Dispersion in the direction of the span = 1.26m

For a maximum shear, load is kept such that the whole dispersion is in span; the load is kept 0.63m from the edge of the beam.

Effective width = K_X\{1- X/L\} + B_W= 5.68m

Load per meter width = 61.609KN/m

Shear force = 23.481KN

Shear force with impact = 2 x 23.481= 46.962KN

Design of section:

Effective depth, D= $\sqrt{(\frac{M}{Qxb})}$ = 180mm

Overall depth= 250mm

Ast = M/ j x d x σst = 1057.19mm^2

Use 16mm dia HYSD bar @ 150mm c/c.

Ast provided = 1340.41mm^2

3.2 Design of longitudinal girder:

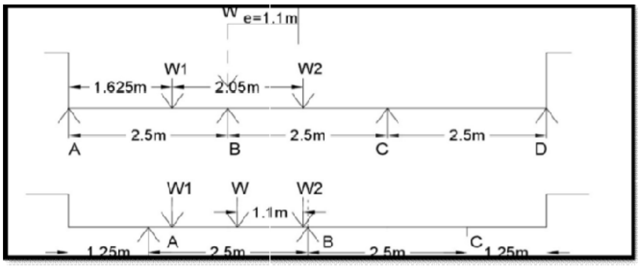

Fig 3.6: Arrangement of IRC class AA loads for maximum eccentricity

Reaction factor for outer girder, R_A= 1.107W_1

Reaction factor for inner girder, R_B= 2W_1/3

W =axial load = 700KN

W_1= 0.5W

R_A = 0.5536W

R_B = 0.33W

Dead load from slab per girder:

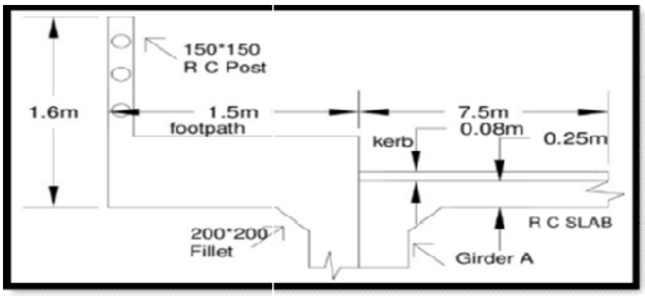

Fig 3.7: Details of footpath, parapet, kerb and deck slab

Weight of parapet railing= 0.92KN/m

Weight of footpath and kerb= 10.08KN/m

Weight of deck slab = 6KN/m

Total load on girder= 92.2KN/m

Dead load shared by all girders = 23.05KN/m

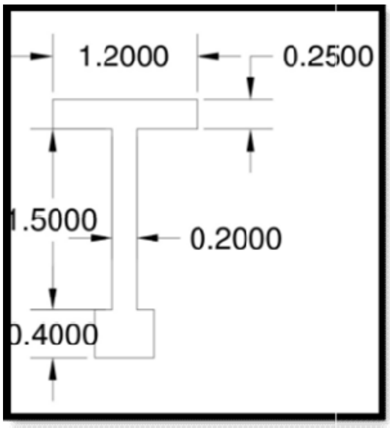

Fig 3.8: main girder section

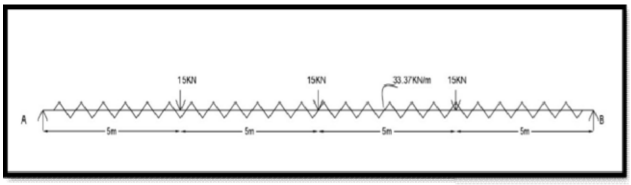

Fig 3.9: dead load on girder

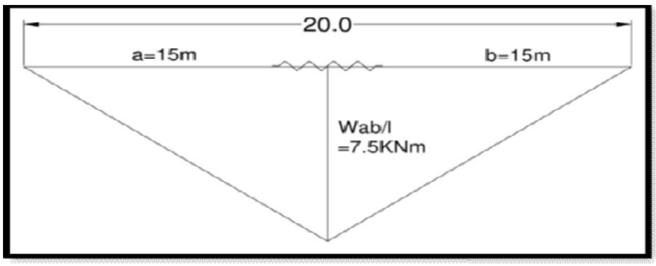

Fig 3.10: influence line diagram for bending moment

Impact factor is considered as 10% of live load in class AA loading.

Reaction of W2 on girder B = 63KN

Reaction of W2 on girder A = 287KN

Total load on girder = 413KN

Maximum reaction in girder B= 375.83KN

Maximum reaction in girder A= 261.17KN

Maximum LL shear with impact factor in the inner girder B = 413.413KN

Maximum LL shear with impact factor in the outer girder A = 287.287KN

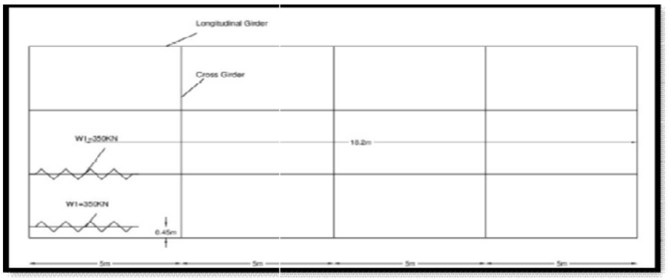

Fig 3.11: Position of IRC class AA loads for maximum shear

Table 1: abstract of design moment and shear force in main girder

Bending moment	Dead load bending moment	Live load bending moment	Total bending moment	Unit
Outer girder	3261	3005	6266	KNm
Inner girder	3261	1791	5052	KNm
Shear force	Dead load shear force	Live load shear force	Total shear force	Unit
Outer girder	437	413.413	850.4	KN
Inner girder	437	287.28	724.28	KN

Prestressing Force:

Allowing for two rows of cables, cover required = 200mm

Maximum possible eccentricity, e = 1050-200= 850mm

Prestressing force is obtained as, P= 5989KN

Using the Freyssinet system, anchorage type 7K-15 (seven strands of 15.2mm diam ter) in 65mm cables duct, (IS: 6006- 1983) (Appendix- 3).

Check for stresses:

At transfer stage,

σb= 14.784N/mm^2

σt= 3.684N/mm^2

At the working load stage,

σt= 12.29N/mm^2 (compression)

σb= -4.44N/mm^2(tension)

All the stresses at the top and bottom fiber at transfer and service loads are well within the safe permissible limits.

Check for ultimate flexural strength:

For the center of the span section,

Ap= 4900mm^2

b= 1200mm, d=1600mm, bw= 200mm,

fck= 50N/mm^2, fp=1862N/mm^2

Df= 250mm

According to IRC 18 2000,

M_U= 12404KNm

According to IRC 18 1985, the ultimate flexural strength is calculated as follows:

Failure by yielding of steel:

Mu= 13138KNm

Failure by crushing of steel:

Mu = 14343KNm

According to IS 13434- 1980, the ultimate flexural strength of the center of span section is computed as follows:

Apf= 3

Ratio= 0.218

For the post tensioned beams with effective bond, we have

(Fpu/0.87fp)= 0.93

X_u/d= 0.43

Fpu= 1506N/mm^2

Xu= 688mm

Mu= 12006KNm

Check for ultimate shear strength:

Ultimate shear force, Vu =

1373.7N/mm^2 According to IRC

18:2000,

bw=200mm, h=1800mm

Maximum principle tensile stress= 1.314N/mm^2

Compressive stresses at the centroidal axis = 6.973N/mm^2

Eccentricity of cables at the center of the span = 850mm

Eccentricity of cables at the support = 180mm

Net eccentricity, e= 670mm

Slope of the cable, θ= 0.089

The ultimate shear resistance of the support

section, Vcw = 1178.94KN

Shear resistance required = 1373.7KN

Shear capacity of the section =

1178.94KN Balance shear, V=

194.76KN

Using 10mm diameter 2 legged stirrups of Fe415 HYSD bars

Spacing, Sv= 509mm

Provide 10mm diameter 2 legged stirrups at 300mm c/c at support and center

Supplementary reinforcement:

Longitudinal reinforcement of not less than 0.15% of the gross cross sectional area are to be provided to safeguard against shrinkage cracking.

Ast= 1095mm^2

20mm diameter bar are provided and distributed in the compression flange

3.3Design of piers:

Height of pier= 10m

Height of flood level=

8m

Dead load of superstructure per span equal to dead load coming from outer and inner girders.

Dead load coming from 4 longitudinal girders and 4 cross girders= 266.96KN/m

It was assumed in analysis that dead load is taken equally by all girders= 33.37KN

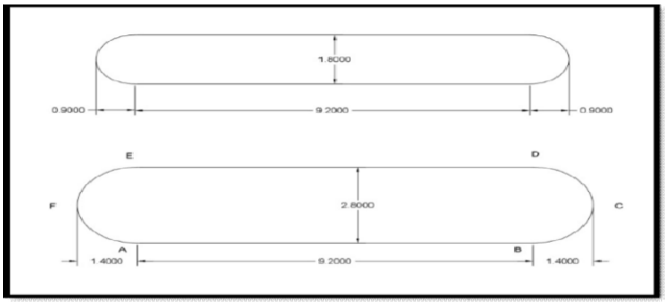

Fig 3.12: top view of the pier

Minimum pier length required at the top = 9.2m

Provide a top length of 9.2m in straight portion with semicircular ends.

Use 1:3:6 concrete mix for pier

Assume center between two girders as 1m.

Minimum width required at the top of the pier= 1.4m

Provide a concrete pier of top width of 1.8m for straight portion and width of 2.8m at bottom for straight portion.

Area of pier at top= 17.98m^2

Area of pier at bottom= 27.97m^2

Self- weight of the pier= 574.375KN/m

Design dead load for pier = 841.335KN

Stresses at base due to dead load = 9.54KN/m^2

Stress due to buoyancy= 254.56KN

Stress at base= 9.1KN/m^2

Stress due to live load = 5.74KN/m^2 and -0.916KN/m^2

Stress due to longitudinal force= 12.106KN/m^2

Stress due to wind force = 3.345KN/m^2 and 4.722KN/m^2

Stress due to water current,

Under dry conditions, @ end of straight portion max. = 35.323kg/m^2 and min. = -16.505kg/m^2

@ end of pier, max. = 14.131kg/m^2 and min. = 4.687kg/m^2

Under wet conditions, @ end of straight portion max. = 25.635kg/m^2 and min. = -15.03kg/m^2

@ end of pier, max. = 9.339kg/m^2 and min. = -3.919kg/m^2

Allowable compressive stress in 1:3:6 concrete is 2000kg/m^2 and 250kg/m^2 in tension. The stress in pier is within these permissible limits.

Reinforcement:

Pu = 758.312KN, fck= 20N/mm^2, fy = 415N/mm^2,

Ac =23mm^2

Pu= 0.4 fck Ac + 0.67 fy Asc

Asc = 4523.72mm^2

Assume 16mm diameter bar, spacing = 44.44mm

Provide 16mm diameter @ 40mm c/c

Pitch = 300mm

Provide lateral ties of 16mm diameter

Ast = 679.77mm^2

Provide an reinforcement area of 679.77mm^2

3.4Design of abutment:

Length of abutment is 7.6m for multilane bridges

Angle of internal tractive of the deck fill, Φ= 30°

Weight of the backfill, W= 1600kg/m^3

Depth of abutment below road level= 10m

Equivalent height of surcharge of earth= 1.5m

Angle of friction between soil and masonry = 20°

Density of masonry = 20KN/m^3

Density of concrete = 24KN/m^3

Density of soil = 18KN/m^3

Total dead load = 133.48KN

Live load per meter length of abutment= 87.587KN

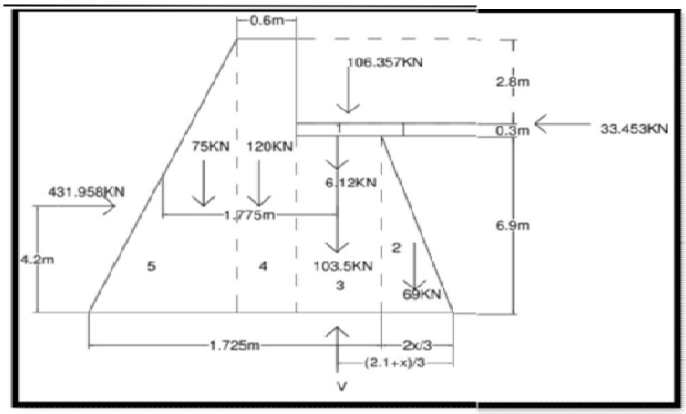

Fig 3.13: abutment

Self- weight of the abutment is divided into 5 segments. The weight per meter length is given by:

Segment 1=6.12KN

Segment 2= 69KN

Segment 3= 103.5KN

Segment 4= 120KN

Segment 5= 75KN

Total longitudinal force = 33.453KN

The earth pressure can be calculated by using Coulombs formula.

Earth pressure is assumed to act at 0.42 of height from base= 0.42 x 10 = 4.2m

Total active earth pressure= 473.774KN/m^2

Horizontal component of earth pressure= 431.809KN/m^2

Vertical component of earth pressure = 194.923KN/m^2

Maximum pressure at the base= 230.96KN/m^2

This is within permissible limits.

Provide overall base width = 2.1+ 2.6= 4.7m

3.5Design of well foundation for abutment:

Discharge intensity= 35cumecs

Total vertical load= 1650ton= 16500KN

Total lateral thrust= 431.859KN

Submerged unit weight of soil= 18KN/m^2

Silt factor assumed as 1

Assuming the shape of well as single circular dump bell type, k= 0.03

GRIP of well length= 7.5m

Total depth of well= 30m

The internal diameter of well may be adopted as 10m as per dimensions of the abutment
Assume external diameter, D as 12m

A thickness of 2m is adopted for steining

Use 159 numbers of 20mm diameter at 275mm

Adopt 9 numbers of hoops at 300mm spacing and provide bottom plug of 1m thickness

Hence stress is safe being within the permissible limits.

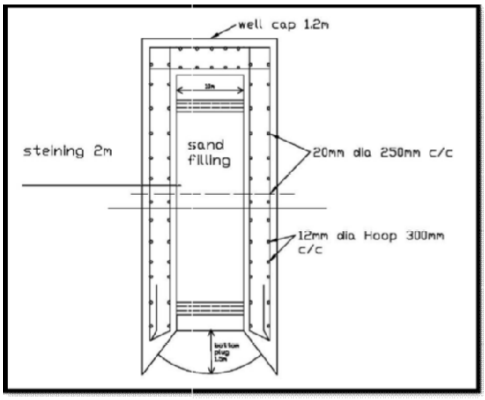

Fig 3.14: well foundation

3.6Design of Foundation for pier:

Width of pier= 2.8m

Length of pier= 9.2m

Size of piles= 300mm x 300mm

Spacing of piles = 1.3m

8 piles are arranged at a spacing of 1.3m

Load on each pile = 1078.7KN

Pile reinforcement:

Longitudinal reinforcement:

Total length of the pile = 8.6m

L= 8.6m and b= 0.3m

L/b ratio= 28.66

12< 28.66

Hence pile is designed as a long column.

Reduction co-efficient= 0.654

Safe permissible stress in concrete, σcc= 3.27N/mm^2

Safe permissible stress in steel = 124.26N/mm^2

Load carrying capacity of the pile, P= $\sigma ccAc+\sigma scAsc$ as per IS 456:2000

Asc = 2662.203mm^2

According to IRC 78- 1983, the longitudinal reinforcement Asc should not be equal to 1.25% of gross cross sectional area for pile with a length less than 30 times the least width. Hence, Asc not equal to 1125mm^2.

Adopt 8 bars of 20mm diameter,

Provide an area of 2513.27mm^2 with a clear cover of 40mm.

Lateral reinforcement:

In the body of pile, the lateral reinforcement should not be equal to 0.2% of the gross volume.

Use 8mm diameter ties,

Volume of ties= 44000mm^3

If 'p' is the pitch of the pile,

Volume of pile per pitch length= 90000p mm^3

p= 244mm

Maximum permissible pitch= 150mm

Hence provide 8mm diameter ties @ 150mm c/c in the main of piles.

Provide a clear cover 40mm to the main longitudinal reinforcement with 20mm diameter bars.

Adopt 8mm diameter ties at 80mm centers for a length of 900mm from the ends of the piles both at the top and bottom.

Pile cap:

Maximum bending moment= 462.3KNm

d=600mm and overall depth= 650mm

Adopt 16mm diameter bars @200mm c/c distribution steel

Provide 10mm diameter bar for stirrup @60mm spacing.

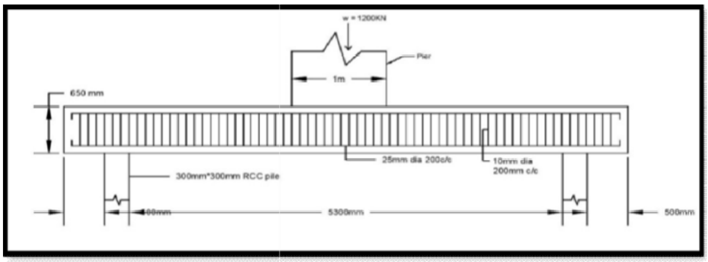

Fig 3.15: reinforcement details in pile cap

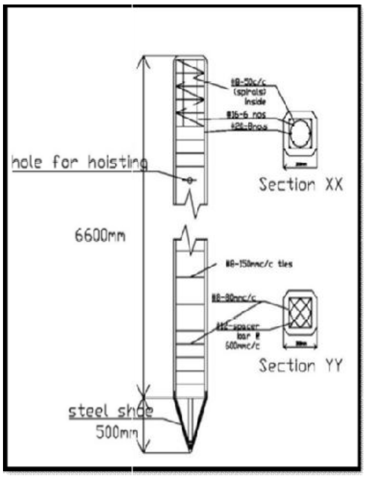

Fig 3.16: reinforcement details in precast piles

3.5 STAAD Analysis:

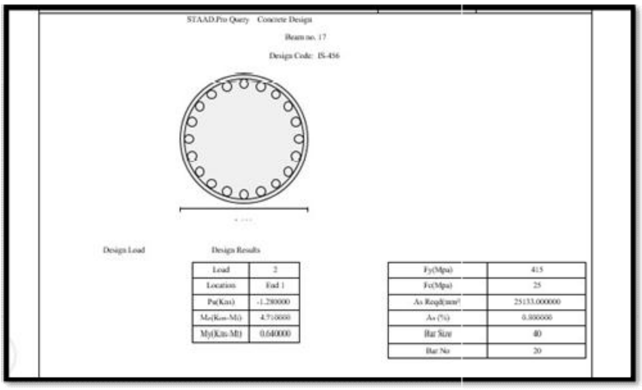

Fig 3.17: reinforcement details of column

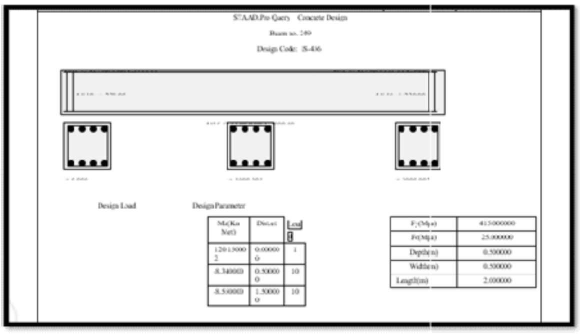

Fig 3.18: reinforcement details of long beam

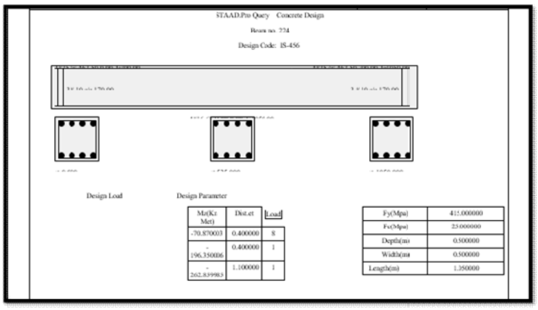

Fig 3.19: reinforcement details of short beam

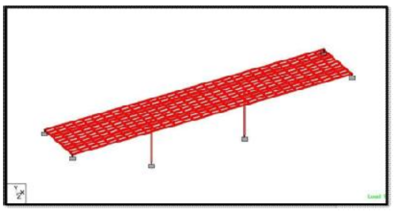

Fig 3.20: dead load of the structure

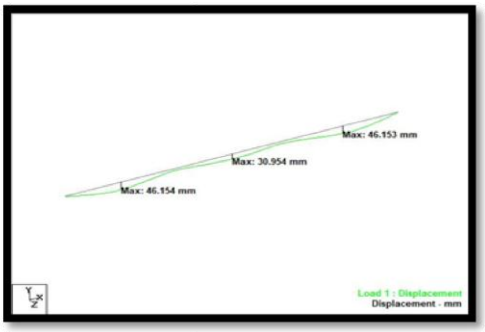

Fig 3.21: displacement details of the structure

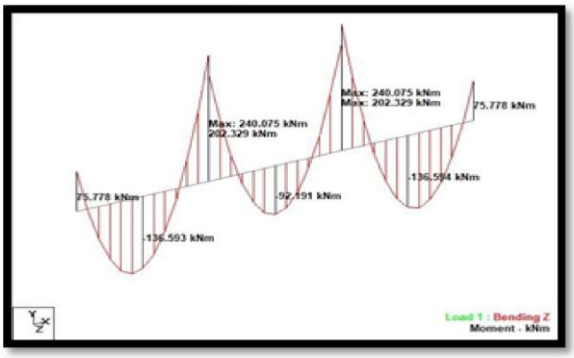

Fig 3.22: bending moment of the structure

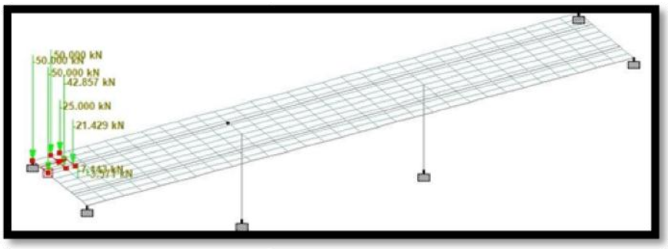

Fig 3.23: moving load details of the structure

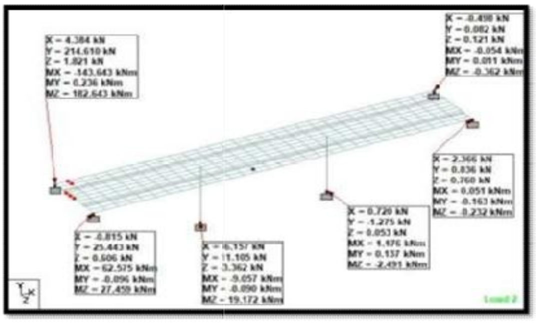

Fig 3.24: magnitudes of the reaction and bending moments about X, Y, and Z axes

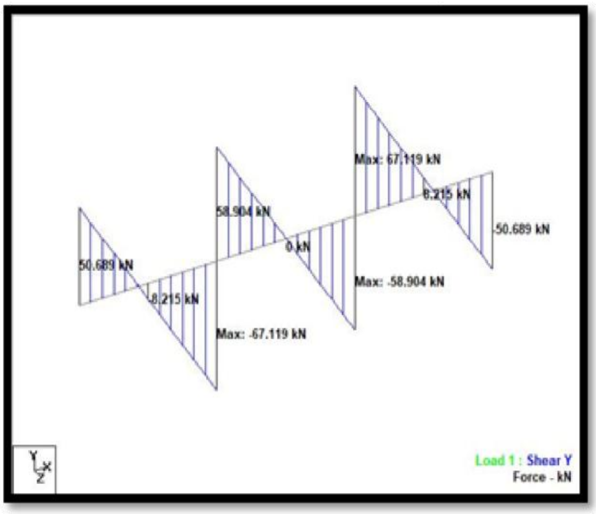

Fig 3.25: shear of the structure

4. CONCLUSIONS

In this project, we have done the analysis and the design of superstructure and the substructure of the proposed bridge at Chamakkavu.

The analysis was done by using STAAD Pro.V8i by considering Class AA loading and design was done manually using relevant codes.

- The present issue at the site can be solved with the new bridge.
- The new site was analyzed and a new bridge of two lane traffic with foot path on either side is adopted.
- New bridge is a continuous type With pre-stressed members.
- From manual and STAAD design, STAAD design is found to be more accurate and modification of design is also possible in STAAD.
- The Prestressing technique has eliminated the weakness of concrete in tension and hence crack free members are obtained.
- In addition to general advantages, such as excellent fire resistance, low maintenance cost, elegance, high corrosion- resistance, adaptability etc., the prestressed concrete is found to sustain the effects of impact or shock and vibrations.

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