# Planning, Analysis & Design of Prestressed Concrete Flyover at Villivakkam Junction

**Mr. M. Murugalingam[1] A. G. Aiswarya[2] N. Anusuya[3] Mr. M. Rajendiran[4] Mrs. S. Dhatchayani[5]**
[1,4]Assistant Professor [2,3]Student [5]Associate Professor
[1,2,3,4,5]Department of Civil Engineering
[1,2,3,4,5]Loyola Institute of Technology, India

*Abstract*— This project deals with the Planning, Analysis & Design of a Prestressed Concrete Flyover which is planned to be constructed across a railway crossing in between Villivakkam and Perambur Loco Works railway stations. The location of the flyover is selected in such a way that it provides access to adjacent areas such as Anna Nagar, Kolathur, Korratur, GKM Colony, Periyar Nagar, Perambur and ICF. The loading conditions are taken as per IRC specifications and the design considerations are made from the IS code books. The loading is adopted to be class A loading since the major vehicles are trucks and cars.The design consists of various components such as Deck slab, Girders, Bearings, Pier and Foundation. All components are designed using prestressed concrete design. The tendons are used for reinforcements and the design is checked for any failure using prestressed design considerations.

***Key words:*** Prestressed Concrete

## I. Introduction

As vehicular traffic on roads has grown to an unmanageable rate making it chaotic, time consuming and unsafe, it is viable to opt for a flyover as it minimizes the risk of accidents and facilitates rapid traffic flow. A flyover may referred to a high-level road bridge that crosses over a highway intersection or railway crossing. The design of such bridges varies depending upon their function, nature of the terrain, materials used and also the funds available for its construction. When it comes to constructing such superstructures, it is preferable to use pre-stressed concrete as they are being subjected to prior compression beyond its own dead weight. The essence of pre-stressed concrete is that once the initial compression has been applied, the resulting material has the characteristics of high strength concrete when subjected to any subsequent compression forces, and of high ductile strength when subjected to tensional forces. Hence pre-stressed concrete has showed improved performance in longer spans with reduced structural thickness and material saving compared to reinforced concrete.

## II. Traffic Details

- Average annual traffic flow – 19,000 PCU
- No. of trains passing between two stations each day – 71
- No. of pedestrians crossing the level cross - 25persons/hour

## III. Design Components

- Deck slab
- Girder
- Bearing
- Pier
- Foundation

## IV. Differences of Prestressed Concrete over Reinforced Concrete

- In prestressed concrete member, steel plays active role. The stress in steel prevails whether external load is there or not. But in R.C.C., the steel plays a passive role. The stress in steel in R.C.C members depends upon the external loads, no stress in steel.
- In prestressed concrete, the stresses in steel is almost constant where as in R.C.C,the stress in steel is variable with lever arm.
- Prestressed concrete has more shear resistance.
- In prestressed concrete members, deflections are less because the eccentric prestressing force will induce couple which will cause upward deflection, where as in R.C.C deflections are more.
- In prestressed concrete fatigue resistance is more compared to R.C.C because in R.C.C stress in steel is dependent on external load where as in prestress it is load independent.
- Prestressed concrete is more durable as high grade of concrete is used. In R.C.C it is less durable.
- In prestresesed concrete, dimensions are less because external stresses are counter balanced by the internal stress induced by prestress, R.C.C is uneconomical for long span because in R.C.C dimension of sections are large requiring more concrete and steel.

## V. Design Procedure Adopted

- Assume section
- Calculate section property
- Estimate bending moment and shear force
- Apply prestress force
- Determine stresses in concrete
- Check with permissible stresses
- Check ultimate moment and shear
- Design of end block

## VI. Design of Flyover Components

### *A. Design of Deck Slab*

1) Clear span= 12m
2) width of bearing= 400mm
3) Clear width of roadway= 7.5m
4) Foot path= 1.6m on either side
5) Kerbs= 600mm wide
6) Thickness of wearing coat= 80mm
7) Live load= I.R.C.class AA tracked vehicle

#### *1) Materials*

M40 grade concrete and 7mm diameter high tensile wires with an ultimate tensile strength of 1500 N/mm$^2$ housed in cables with 12 wires and anchored by Freyssinet anchorages of 150 mm diameter. For supplementary reinforcement, adopt Fe-500 grade HYSD bars. Compressive strength at transfer ($f_{ci}$)=35N/mm$^2$. Loss ratio= 0.8.The design should conform to the recommendations of codes IRC-6, IRC-18,IRC-21 and IS-1343.

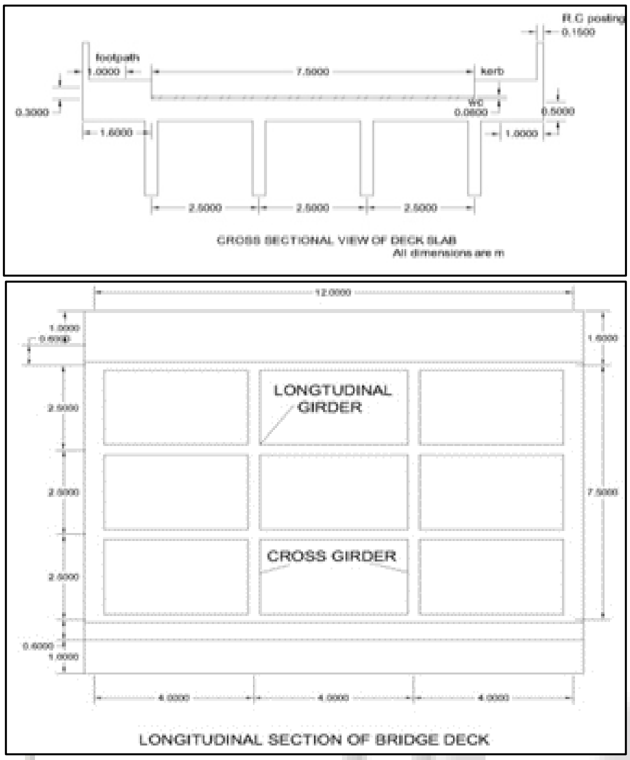



Fig.1

1) D.L bending Moment $M_g$= (wl$^2$/8) = 269.89KN-m.
2) L.L Bending Moment $M_{q=}$ 253.2 KN-m.
3) Total Design Shear V= 183 KN
4) Section modulus Z= 41.67 ×10$^6$mm$^3$
   The minimum section modulus
   $Z_b \geq [\ m_q + (\ 1\text{-}\eta)\ m_g)\ /f_{br}\ ]$
   ≥25.58 ×10$^6$ mm$^3$
   < 41.66 × 10$^6$ mm$^3$
   (Hence safe)
5) Minimum Pretressing Force
   P= [ A ( $f_{ing}$ .$z_b$ - $f_{sub}$.$z_t$ )/ $z_b$.$z_t$]
   P= 2305KN
6) The eccentricity of the cables
   e= [$z_t$.$z_b$($f_{ing}$ - $f_{sub}$ )/A( $f_{sub}$ - $f_{ing}$ ) ]
   e= 200mm
7) Check for permissible stress
   Direct stress= (P/A) = 4.16 N/mm$^2$
   Eccentric stress= (Pe/I) = 11.06N/mm$^2$
   Dead load stress= ($M_g$/z) = 6.45N/mm$^2$
   Live load stress= ($M_q$/z) = 6.07 N/mm$^2$

*2) Stresses at Transfer*

At top of slab= P/A - Pe/z + $M_g$/z= 0 N/mm$^2$
At bottom slab= P/A + Pe/z -$M_g$/z= 9.22N/mm$^2$

*3) Stress at Service Load Stage*

At top of slab= P/A - Pe/z + $M_g$/z +$M_q$/z
= 6.07 N/mm$^2$
At bottom slab= P/A + Pe/z -$M_g$/z -$M_q$ /z
= 3.15 N/mm$^2$
The actual stresses developed within the permissible limits.

8) Check For Ultimate Strength ( IRC:18-1985) :
   Failure by yielding of steel
   $M_u$= 0.9 d $A_p$ $f_p$
   = 888.15 KN-m
   Failure by crushing of concrete :
   $M_{u=}$ 0.176 bd$^2$ $f_{ck}$= 1460 ×10$^6$ KN-m
   Take lesser value of $M_u$
   $M_{u=}$ 888.15 KN-m
   Required to ultimate moment= 1.5$M_g$ + 2.5$M_q$
   = 1036.5 KN-m
   Hence the ultimate moment capacity of the section ($M_u$=888.15KN-m) is greater than the required ultimate moment 1036.5 KN-m.
9) Check For Ultimate Shear Strength :
   Ultimate shear force $V_{u=}$ ( 1.5 $V_g$ + 2.5$V_q$ )
   = 361. 24 KN
   According to IRC 18 -1985 the ultimate shear resistance of support section uncracked in failure.
   $V_{co}$= 0.67 bh ($f_t^2$ + 0.8 $f_{cp}$ .$f_t$ )$^{1/2}$ + ηp sin ɵ
   $V_{co}$= 988.34 KN
   Since the ultimate shear $V_u$ is greater than $V_c$ hence safe.
10) Supplementary Reinforcement:
   Secondary reinforcement= 0.15 % of gross section area
   $A_{st}$= 750 mm$^2$
   $a_{st}$= 78.54 mm$^2$
   Spacing= 150mm
   Provide 12mm diameter @ 150 mm c/c spacing in both top and bottom face.
11) Design Of End Block Reinforcement :
   $A_{st=}$ 474 mm$^2$
   No of rod= 4rods

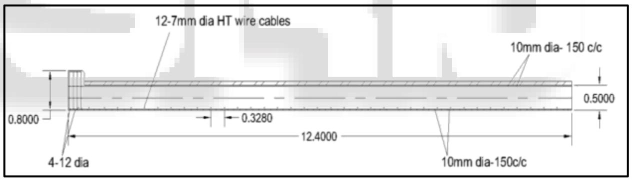



Fig. 2:

*B. Design of Longitudinal Girder*

Using Courbon's theory the IRC clause A A loads are arranged for maximum eccentricity.

1) Reaction Factor:
   $R_{A=}$ 0.533W
   $R_{B=}$ 0.399W
2) Dead Load From Slab Per Girder
   Total dead load of deck= 168.28KN/m
   Dead load per girder= [168.28/3]= 56.09KN/m
3) Dead Load Of Main Girder
   Dead wt. of rib= [1×0.2×24]= 4.8 KN/m
   Dead wt. of bottom flange= [0.5×0.3×24]= 3.6 KN/m
   Total load= 8.4 KN/m

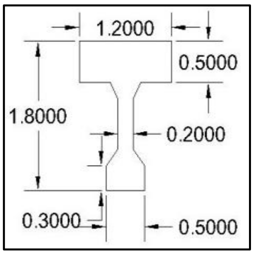



Fig. 3: Cross Section of Prestressed Concrete Girder

4) Dead Load Moments and Shear in Main Girder
Reaction from deck slab on each girder= 56.09KN/m
Wt. of cross girder= 6KN/m
Total dead load on girder=[8.4×56.09]= 64.49KN/m

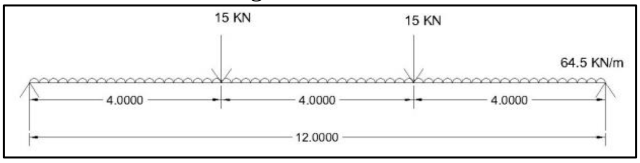



Fig. 4:

$M_{max=}$ $(64.5\times12^2/8)+(15\times8/4)+(15\times4)=1251$KN-m
$V_{max=}$ $(64.5\times12/2)+(15\times2/2)=$ 402 KN

5) Live Load BM in Girder
BM at center of span= 1785KN-m
Outer Girder BM= [1785×1.25×0.533]= 1190 KN-m
Inner Girder BM= [1785×1.25×0.399]= 898 KN-m

6) Properties of Main Girder:
$a_{1=}$ 500 × 300 mm. $y_{1=}$ 150 mm.
$a_{2=}$ 200 × 1000 mm. $y_{2=}$ 800 mm.
$a_{3=}$ 1200 × 500 mm. $y_{3=}$ 1550 mm.
$Y_{b=}$ 1172mm
$Y_{t=}$ 1800-1172= 628mm

a) Moment of Inertia:
$I_{1=}$ $1.57\times10^{11}$ $mm^4$
$I_{2=}$ $4.43\times10^{10}$ $mm^4$
$I_{3=}$ $9.82\times10^{10}$ $mm^4$
$I= 2.995\times10^{11}$ $mm^4$

b) Section Modulus
$Z_{T=}$ $I/Y_T= 476.9\times10^6$ $mm^3$
$Z_{b=}$ $I/Y_b= 255.5\times10^6$ $mm^3$

7) Check for Section Modulus
$Z_b= \{[m_q+(1-\eta)m_g]/f_{br}\}$
$= 190\times10^6<255.5\times10^6$ (Hence safe)

8) Prestressing force
$P= [A.f_{inf}.Z_b]/[Z_b+A.e]=$ 4753KN

9) Permissible Tendon Zone at Support Section:
$E \leq (Z_b.f_{ct}/p)-(Z_b/A)$
$\leq$ 698.6mm
$E \geq (Z_b.f_{tw}/\eta p)-(Z_b/A)$
$\geq$ -268.9 mm

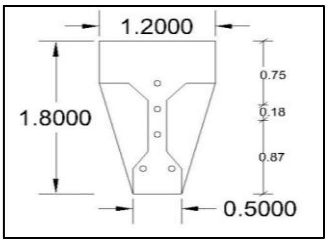



Fig. 5:

10) Check
For Stresses
$(P/A)= [(4753\times10^3)/(950\times10^3)]= 5.003N/mm^2$
$(Pe/Z_t)= [(4753\times10^3)/(476.9\times10^6)]= 8.47N/mm^2$
$(pe/Z_b)= [(4753\times10^3\times850)/(255.5\times10^6)]= 15.81N/mm^2$
$(m_g/Z_t)= [(1257\times10^6)/(476.9\times10^6)]= 2.62N/mm^2$
$(m_g/Z_b)= [(1251\times10^6)/(255.5\times10^6)]= 4.89N/mm^2$
$(m_q/Z_t)= [(1190\times10^6)/(476.9\times10^6)]= 2.49N/mm^2$
$(m_q/Z_b= [(1190\times10^6)/(255.5\times10^6)]= 4.66N/mm^2$
At transfer stage
$\sigma_{t=}$ $(P/A)-(P.e/Z_t)+(m_g/Z_t)=$ - 0.85N/mm²
$\Sigma_{b=}$ $(P/A)+(P.e/Z_b)-(m_g/Z_b)=$ 15.923N/mm
At working load stage
$\sigma_{t=}$ $[\eta(P/A)-\eta(P.e/2t)+(m_g/Z_t)+(m_q/Z_t)]$
$= 2.16N/mm^2$ compression.
$\sigma_{b=}$ $[\eta(P/A)+\eta(P.e/Z_b)-(m_g/Z_b)-(m_q/Z_b)]$
$= 8.14N/mm^2$
All the stresses at top and bottom fibers at transfer and Service loads are well within the safe permissible limits.

11) Check For Ultimate Flexural Strength :
Failure by yielding of steel
$M_{u=}$ $0.9\ d\ A_p\ f_p$
= 0.9×1600×4900×1600= 11289.6KN-m
Required Ultimate Moment
$M_u= (1.5m_g)+(2.5m_q)$
= (1.5×1251)+(2.5×1190)
$M_u$=14857KN-m
Hence the ultimate moment capacity of the section ($M_u$=11289.6KN-m) is greater than the required ultimate moment ($M_{u=}$ 14857 KN-m.)
Failure by Crushing of Concrete:
$M_{u=}$ $(0.176b_wd^2f_{ck})+((2/3)(0.8)(b-b_w))(d-d_f/2)D_ff_{ck}$
= 22505.6KN-m
According to IS 1343 1980 the ultimate flexural strength of the center span section is computed as follows
$A_{p=}$ $(A_{pw}+A_{pf})$
$A_{pf=}$ $0.45f_{ck}(b-b_w)(D_f/f_p)= 2031mm^2$
$A_{pw}= 4900-2031= 2869mm^2$
$(A_{pw}.f_p)/(b_w.f_{ck}.d)= 0.287$
From Table 11 IS- 1343 post tensioned beams
$f_{pu}/(0.87f_p)= 0.863$
$f_{pu=}$ $1201.3N/mm^2$
$X_u/d= 0.492$
$X_{u=}$ 788 mm
$M_{u=}$ $[f_{pu}A_{pw}(d-0.42x_u)]+[0.45f_{ck}(b-b_w)D_f(d-0.5D_f)]$
$M_{u=}$ 19553 KN-m
Require ultimate moment= 14851<19553 KN-m (Hence safe)

12) Check For Ultimate Shear Strength
Ultimate shear force $V_{u=}$ $[(1.5V_g+2.5V_q)]$
= (1.5×402)+(2.5×252)
$V_u$= 1233KN
$V_{cw}= 0.67b_wh(f_t^2+0.8f_{cp}.f_t)^{1/2}+(\eta P.\sin\theta)$ $V_{cw}$= 1611KN
Since the ultimate shear $V_u$ is greater than $V_c$ hence safe.
Using 10 mm dia 2 legged stirrups of Fe- 415 HYSD bars
The spacing $S_v$
Provide 10 mm dia stirrups at 200 mm c/c near support and gradually increased to 300 mm towards the center of span.

13) Supplementary Reinforcement :
$A_{st=}$ $1425mm^2$
Using 20 mm dia bars are provided and distributed in the compression flange

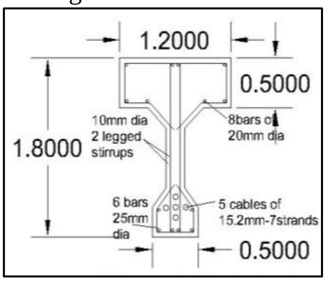



Fig. 6:

### *C. Design of Elastomeric Bearing*

This design conforms IRC83 PART –II.
Provide 3 Nos of laminated elastomeric bearing between concrete pedestals of 500×320×30 mm
It offers flexibility between pier and deck slab during earthquake

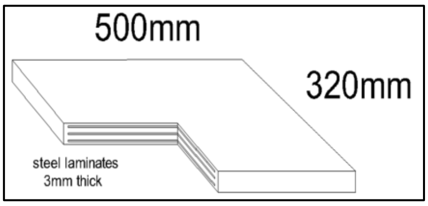



Fig. 7:

### *D. Design of Piers*

- Span length= 12m
- Carriage way width= 7.5m
- Thickness of uniform wearing Coat= 80mm
- Dead load of pier= 274.4 KN /m

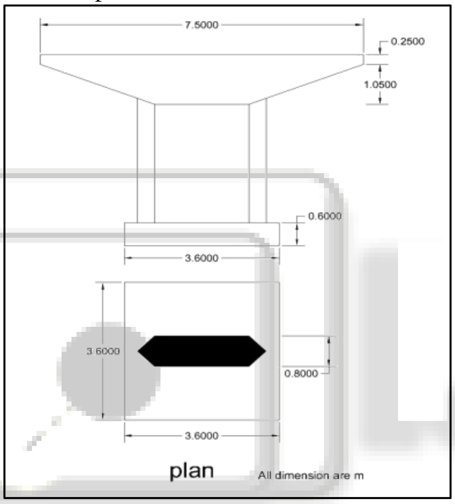



Fig. 8:

- Weight of rectangular portion= 48.75 KN/m
- Weight of tapered portion= 145.675 KN/m
- Weight of caping beam= 192.4 KN/m

*1) Dead Weight Of Pier*

Weight of pier= 2.48 × 5 × 25= 310KN
Dead Weight of Footing
Weight of footings= 216KN

*2) Live load reaction from super structure*

Class 70-R Wheeled Vehicle

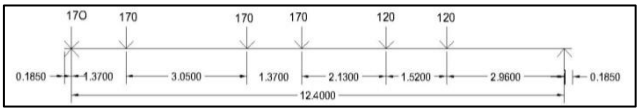



Fig. 9: Class 70R Vehicle Loading

C.G of loads= [170(1.37+4.42+5.79)+120(7.29+9.44)/(4×170 )+(2×120)]
= 405.18 / 92=4.404m.

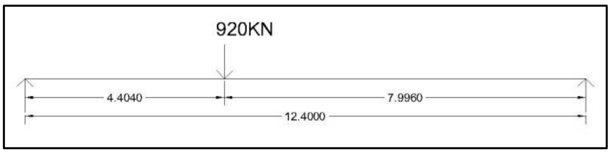



Fig. 10:

Maximum reaction without impact= 593.25 KN
Maximum reaction with impact= 326.75 KN

*Class-A loading:*

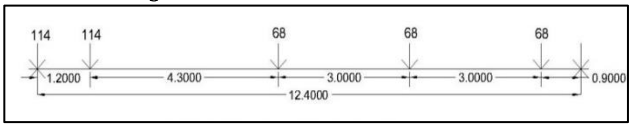
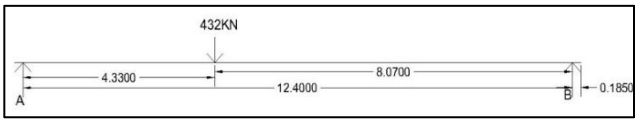



Fig. 11:

Class A Loading of Tracked vehicle
C.G of loads= [114(1.2)+68(5.5+8.5+11.5)/(114×2)+(68×3)]
= 4.33m




Maximum reaction without impact= 281.15 KN
For two lane maximum reaction without impact= 562.29KN
Maximum reaction with impact= 150.85 KN

### *E. Design of Pile Foundation*

The pier of Flyover Bridge transmit a load of 8000 KN
Width of pier= 1m
Length of pier= 5m
Size of piles= 300×300 mm
Spacing of piles=1.5m

*1) Materials*

M20 grade of concrete
Fe500 HYSD bars
$\sigma_{cbc=}$ 7 N/mm$^2$
$\sigma_{st}$= 230 N/mm$^2$

a) Pile Reinforcement

1) Longitudinal reinforcement

Length of pile above group level= 0.6m
Total length of pile= (6+0.6) = 6.6m
Size of pile= 300×300mm

2) Arrangement Of Piles And Pile Cap

Fourteen piles are arranged at a spacing of 1.5m
Load on each pile= (8000/14) =572 KN

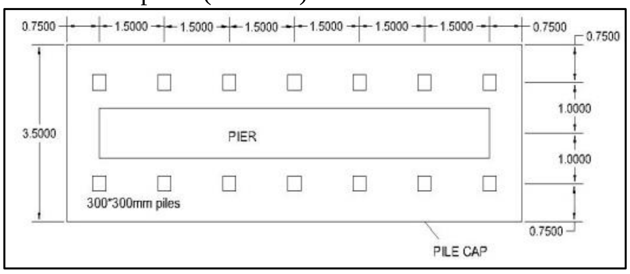



Fig. 12:

Arrangement of piles and pile cap
Ratio (L/B) = (6.6/0.3)= 22 >12
Hence the pile is designed as a long column
Reduction co-efficient= (1.25-L/48B) = 0.792
Safe permissible stress in concrete
$\sigma_{cc=}$ (0.792×7)=5.54N/mm$^2$
Safe permissible stress in steel $\sigma_{sc=}$ (0.792×230)
=182.16 N/mm$^2$
Load carrying capacity of pile is expressed as(IS:456)
P= ($\sigma_{cc}$ $A_{cc}$ +$\sigma_{sc}$ $A_{sc}$)
$A_{sc=}$ 1643mm$^2$

3) Lateral reinforcement

Volume of tie= 50[4(300-80)]= 44000 mm$^3$
Maximum permissible pitch= (0.5×300)= 150mm.

Hence provide 8mm diameter ties at 150mm centers in the main body of the pile.

4) Lateral Reinforement Near Pile Head

P= [circumference of spiral × As/540]

P= 50mm

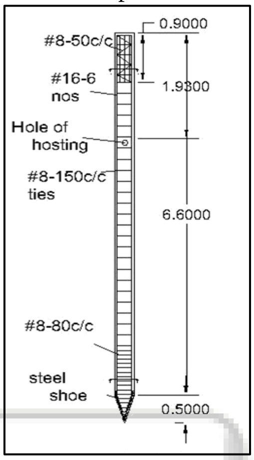
Adopt 8mm diameter spirals at a pitch of 50mm for a length of 900mm at the top of pile.

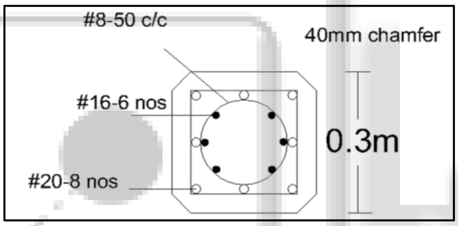
5) Lateral Reinforcement Near Pile Ends

Volume of each tie= 50[4(300-80)]= 44000 $mm^3$

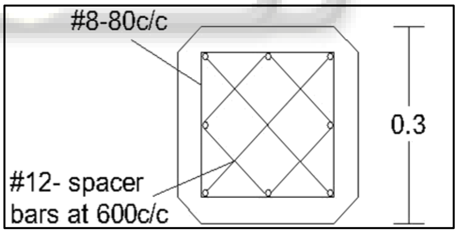
P= 80mm

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




Section X-X




Section Y-Y

Fig.13

*2) Pile Cap*

Maximum bending moment

M zz= (0.375×1200 = 450 KN-m

Effective depth

d= √m/Qb

d=570 mm.

Ast= ( M/σst×j×d)

= [429 ×10^6/230×0.9×600]

= 3454.1mm ≈ 3455$mm^2$

Spacing= 200mm

Adopt 25mm dia bars at 200mm c/c

Distribution reinforcement= 0.12 percent of gross area

= 780 $mm^2$/m

Spacing= 257.7 mm

Adopt 16mm dia bars at 250mm c/c

Maximum shear force V= 572 KN.

Shear stress $\tau_v$= v/bd= 0.4N/$mm^2$

Table 17 IS456

$\tau_{c=}$ 0.28 N/$mm^2$

$V_{us}$= (V-$\tau_{cbd}$)

$V_{us}$= 348 kN

Using 10mm diameter stirrups (8 legged), spacing is given by

Sv= 250mm

Adopt 10mm diameter stirrups at 200mm centers in a width of 1500mm.

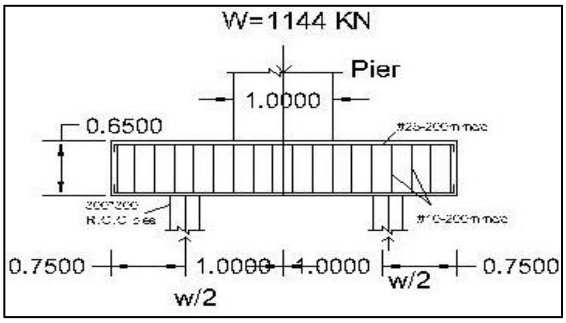



Fig. 14: Reinforcement Details in Pile Cap

## VII. Analysis

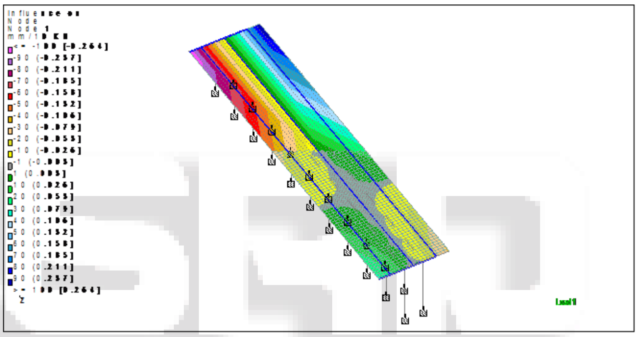


Fig .15: Influence Diagram

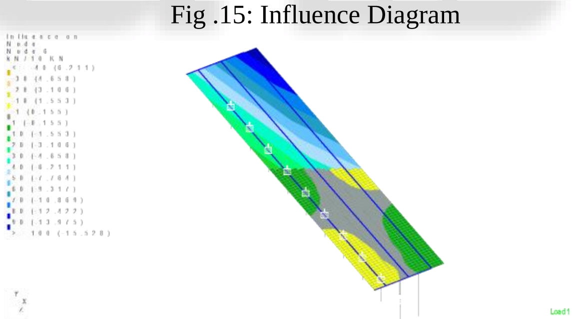


Fig.16: Support Reaction

## VIII. Conclusion

- To design the flyover using Auto CAD and analyse the deck slab using STAAD.Pro software's.
- To study the loading configuration of IRC.
- To manually design the flyover components using pre-stressed concrete considerations.
- Streamlining the traffic at villivakkam junction.

## References

[1] I.R.C:5-1970 standard specifications and code of practice for road bridges, section1- general features of design, Indian Road Congress,1975

[2] Guidelines for the design of small bridges and culverts, special publication No.13, Indian Road Congress,1973
[3] I.R.C:6-1966 Standard specifications and code of practice for road bridges, section II-loads and stresses,Indian Road congress, New Delhi 1974
[4] I.R.C:21- 1972 Standard specifications and code of practice for road bridges,section III-Cement concrete (plain and reinforced),Indian Road Congress,New Delhi,1972
[5] I.R.C:14- 1972 Standard specifications and code of practice for road bridges,section V-Steel Road Bridges,Indian Road Congress,New Delhi 1967
[6] I.R.C18 -1965 design criteria for prestressed concrete road bridges (post tensioned concrete), Indian Road Congress,New Delhi1969.
[7] IS:456-2000, Indian Standard Code of Practice for plain and reinforced concrete, Indian standards Institution,New Delhi
[8] IS:1343-1980, Indian Standard Code of Practice for prestressed concrete (first revision), Indian Standard Institution, New Delhi 1981
[9] Krishna Raju.N.,prestressed concrete,tata McGraw-Hill Publishing co.,fifth edition,November 2012
[10] I.R.C:83-1982 Standard specifications and code of practice for road bridges,section IX,Bearings: part –I metallic bearings(1994),part –II Elastomer Bearings (1991), Indian Road Congress,New Delhi.