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ANALYSIS AND DESIGN OF FLYOVER SUB-STRUCTURE

Vivekananda Swamy Hiremath[1], R Shanthi Vengadeshwari[2]

[1]PG Student, Department of Civil Engineering, Dayananda Sagar College of Engineering, Bengaluru,560078, India

[2]Associate Professor, Department of Civil Engineering, Dayananda Sagar College of Engineering, Bengaluru,560078, India

Abstract: Our project deals with design and analysis and design of Bridge Sub-Structures consists of Pier, Pier cap, Abutment, Foundation. According to IRC: 6-2017. This paper aims to understand the concepts involved in the analysis and design of Flyover Substructure subjected to different loadings namely Dead load, Super Imposed Dead Loads, Carriageway Live loads. The bridges are subjected to different live load cases namely IRC Class A, IRC Class 70R wheeled& tracked. Also the braking load, impact load, wind load, longitudinal forces are to be considered in the analysis. Here the structural analysis is carried out by using STAAD Pro V8i software. Structures are designed for critical loading combinations. Moment of inertia and neutral axis are the key components in calculating the moment of resistance, however moment of resistance should always be greater than design bending moments for a structure to be safe. The Serviceability limit state checks are very essential in providing additional reinforcement to resists shear and torsion.

Keywords: Pre-stressed Concrete, Flyover, Sub-Structures, STAAD Pro, IRC Codes.

INTROUDUCTION

Normally, flyovers are constructed over water basins like rivers, but they may also be constructed over a railway line or even beneath the flyover to offer a highway for pedestrians and even automobiles. The flyover is a strategy in today's age of heavy traffic that allows roads to be built over highways to allow vehicles as well as individuals to pass more swiftly. The flyover, also known as an overpass, is a structure that is constructed over an existing road or railway and spans another road or railway. It aids commuters in saving time, whether they are pedestrians or driving vehicles. However, critics of flyovers argue that they waste valuable area by constructing massive pillars on the existing road. However, their advantages exceed their disadvantages since they allow for more efficient and quicker transportation of people and vehicles.

1.1Type of Flyover.

Classification of Flyover according to Form
• Overpass Flyover
• Underpass Flyover
Classification of Flyover according to Material
• Composite Flyover
• Steel Flyover
• Concrete Flyover
Flyover is a structure that is constructed to provide passage over the natural obstacles without closing the way below it. The obstacles may be rivers, canals, valleys, or roads. The development of the country is based on the infrastructure available in the country. Highways are the major part of infrastructure allowing the flow of human beings, goods, and vehicles. T-beam flyovers are most widely used for the flyovers constructed on highways. IRC codes are developed and updated from time to time based on the research work carried out all over the world. There are different types of designs that serve a particular purpose and apply to various circumstances. The design of the flyover mainly depends: on the purpose of the flyover, the location where the flyover is constructed, the materials used for construction, and the capitals available. The flyover consists of mainly two parts, superstructure, and substructure. The Superstructure consists of a longitudinal girder, cross girder, deck slab, cantilever portion, footpath handrails, and wearing coat. Substructure consists of pier, pier cap, abutment, foundation. The flyover superstructure and other components of the flyover are subjected to a set of loading conditions for which the structure must withstand. The design of the flyover is based on the loadings which may vary depending on the duration of load acting, direction of action, type of deformation, and nature of structural behaviour. To form a consistent basis for design, the Indian road congress (IRC) has developed a set of standard loading

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conditions, which are taken into account while designing a flyover. account while designing a flyover. Most common types of construction pertaining to substructures are abutment, pier, and foundation. Where appropriate, piers and abutments shall be designed to withstand dead load, erection loads, live loads on the roadway, wind loads on the superstructure, forces due to stream currents, floating ice and drift, temperature and shrinkage effects, lateral earth and water pressures, scour and collision, and earthquake loading.

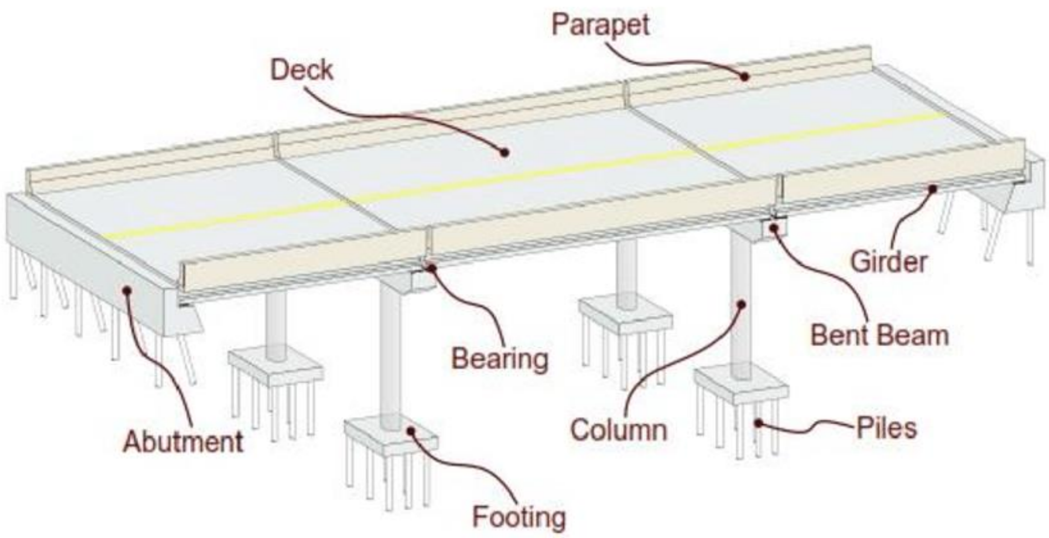

Figure: Components of Flyover

I.OBJECTIVES

The overall aim of the project is analyze the flyover for different load cases and to design the same for the worst load case i.e. for the load resulting on maximum bending moment and shear force.

- To assess and analyze the effect of loads acting on the Flyover according to IRC-6 2017.
- To design the substructure for critical loading case.
- To prepare the complete details of all the components of the substructure.

II.METHODOLOGY

- Conducting the Preliminary Survey.
- Calculation of Critical Loads as per the IRC 6-2017

The dead loads are calculated manually.

- Self-weight of girder & slab = cross-sectional area x density of concrete
- Density of concrete = 25 KN/m3
- Weight due to crash barrier = 9 KN/m
- Density of wearing coat = 22 KN/m3
- Braking load = 20% of live loads.

- Calculation of Wind Load acting on the Flyover for basic design wind seed of 42m/s as per the IRC 6-2017.
- Calculation of Seismic Load acting on the Flyover for Zone III as per the IRC 6-2017.
- Designing the Pier Cap for Max Bending Moment and Max Shear Force.
- Analysing the Pier in Staad Pro for various load combinations of the critical loads acting on the Pier.
- Designing the Pier for the Max Bending Moment and Max Shear Force acquired form Staad. Pro software.
- Designing the Dirt wall as per the IRC 6-2017.
- Designing the Foundation of Pier for Max Reaction & Max Moments from the Pier.
- Detailed drawings are to be prepared for the structure considered.

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A. PROBLEM IDENTIFICATION

- Chennai to Vijayawada Flyover
- Total length of the Flyover = 60 m
- Span Arrangement = 2 x 30 m
- PSC girder = 30 m
- Overall deck width = 14.5 m
- Number of longitudinal girders = 4
- C/C of longitudinal girders = 3.6 m
- No. of Lanes = 4
- Carriageway width = 13.5 m
- Depth of girder = 2 m
- Depth of deck slab = 0.24 m
- Length of cantilever slab = 1.725 m
- c/c Distance between Expansion Joint = 30 m
- c/c Distance between Bearings = 28.8 m
- Thickness of end cross girder = 0.4 m
- Width of Crash Barrier on both sides of carriageway = 0.5 m
- Width of RCC Kerb + Railing at outer ends = 0.5 m
- W.C Thickness = 0.065 m
- No. of bearings = 4 (POT-PTFE)
- Size of Pedestals = 0.5m x 0.8m x 0.315m
- Grade of concrete = M35
- Grade of steel = Fe500

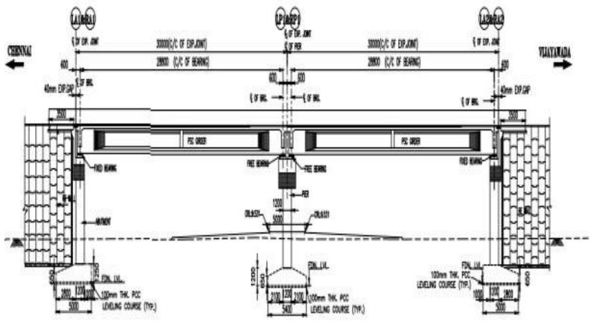

Fig 1: Sectional Elevation of the Flyover

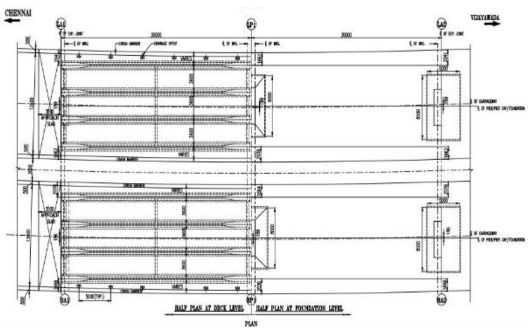

Fig2 : Longitudinal Section of the Flyover

III.ANALYSIS AND DESIGN

A. LOAD CALCULATIONS:

1. DEAD LOAD:

- Self-weight of girder = 21.56 KN/m
- Self-weight of deck slab = 21.15 KN/m

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- Self-weight of cross girder = 19.52 KN/m
- Self-weight of crash barrier + pipe = 10.500 KN/m
- Shuttering & construction load = 12.69 KN/m
- Crash barrier = 9 KN/m
- Wearing coat = 7.125 KN/m

Total DL reaction from Superstructure = **3300 kN**

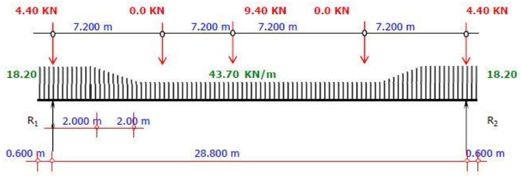

Fig3 : Loading Diagram

2. CARRIAGEWAY LIVELOAD CALCULATIONS:

Details of Load Cases	Vertical Reaction (KN)		Vertical Reaction (KN)	Longitud. Moment wrt CL of Footing	Load on spans (KN)		Braking Force (KN)		Reaction at free end (KN)
	LHS Span	RHS Span			LHS Span	RHS Span	LHS Span	RHS Span	
70 RW	0.00	842.92	842.92	632.19	0.00	1000.00	0.00	200.00	157.08
1 LCA	0.00	390.65	390.65	292.99	0.00	554.00	0.00	110.80	163.35
2 LCA	0.00	781.30	781.30	585.98	0.00	1108.00	0.00	110.80	326.70
3 LCA	0.00	1054.76	1054.76	791.07	0.00	1495.80	0.00	174.51	441.05
4 LCA	0.00	1250.08	1250.08	937.56	0.00	1772.80	0.00	177.28	522.72
70RW+1 CLA	0.00	1110.21	1110.21	832.66	0.00	1398.60	0.00	204.93	288.39
1 CLA+70RW	0.00	1110.21	1110.21	832.66	0.00	1398.60	0.00	144.72	288.39
70RW + 70RW	**0.00**	**1348.67**	**1348.67**	**1011.50**	**0.00**	**1600.00**	**0.00**	**200.00**	**251.33**

3. HORIZONTAL FORCES

- Total HF due to Temp & Shrink = 60 kN
- Max. Hf due to Breaking = 100 kN
- Max. Hf due to Centrifugal Force = 58.2 kN
- Max. Transverse Moment = 3502.3 kNm
- Max. Hf due to Friction = 223.5 kN

4. WIND LOAD CALCULATIONS:

For Basic Wind Speed = 42 m/s, Height of a structure =10m

- Wind force in longitudinal direction = 36.18 KN
- Wind force in transverse direction = 144.70 KN

5. SEISMIC LOAD CALCULATIONS:

Data :

Seismic zone = III

- Type of Structure = Important
- Soil type = Hard Strata
- Reduction factor R = 3

Results:

Longitudinal direction

- Max Moment =6620 kNm
- Max Horizontal force = 791 kN

Transverse direction

- Max Moment =4490 kNm
- Max Horizontal force =493 kN

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B. DESIGN

1. PIER CAP

- Cross sectional width of Pier cap = 1550 mm
- Design Bending Moment M_{ED} = 7732 kN-m
- Eccentricity of Torsional Force = 0.3 m
- Torsional Moment t_{ED} = 734.8 kN-m
- Torsional shear stress = 414.6 kN/m2
- Shear Due to Torsion = 184.7 kN
- Overall Depth considered D =1500mm
- Effective Depth deff =1386mm
- Area of Steel Required Ast =14159mm

Reinforcement details:

Top

- Layer I = 12-#32mm
- Layer II = 12-#32mm

Bottom = 12-#16mm

Side Safe = 10-#16mm

2. PIER

The ULS check of the pier has been done in STAAD converting the moments in to equivalent horizontal forces in respective direction by dividing with height of pier and applying the forces at the top of pier in both directions. Forms the 28 Load cases combinations

Design forces from the Staad.pro:

- Worst Load case = 21
- Design axial force (pu) = 8376.0 kN
- Initial Moments = 1117.20 kNm
- Moments Due To Minimum Ecc. = 1457.42 kNm
- Shear force = 1478 kN
- Deflection = 1.470 mm

Reinforcement Details

Main reinforcement:

- Along L-L direction = 10-#20mm
- Long T-T direction = 42-#20mm

Shear Reinforcement

- 10mm Rect Ties @ 150 mm c/c & 1L-10mm Ties @ 150mm c/c

3. FOUNDATION

Data:

- Type of Soil Strata = Weathered Rock
- Net SBC in Normal Case = 450.00 KN/m^2
- Net SBC in Seismic Case = 562.50 KN/m^2
- Net SBC in Wind Case = 562.50 KN/m^2
- Type of Footing = Open Spread Footing
- Design speed of the vehicle = 100 kmph
- Size of Footing along T-T Axis = 8.500 m
- Size of Footing along L-L Axis = 4.700 m
- Length of Heel = 2.500 m
- Length of Shaft = 1.200 m
- Length of Toe = 1.00 m
- Radius of Curvature = 1200 m

  (High Radius of Curvature is meant for Straight)
- Area of Footing A = 4.700 x 8.500 = 39.95 m^2
- Section Modulus along L-L Axis Z_L = 8.500 x 4.700^2 / 6 = 31.29 m^3
- Section Modulus along T-T Axis Z_T = 4.700 x 8.500^2 / 6 = 56.60 m^3
- Base Pressure = $P / A \pm M_L / Z_L \pm M_T / Z_T$
- Grade of Concrete = M 35
- Grade of Steel = Fe 500

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Design:

1) Toe	L-L direction	T -T direction
• Net Avg. pressure along AB =	274.6 kN/m^2	425.4 kN/m^2
• Net Avg. pressure along GH =	310.9 kN/m^2	396.6 kN/m^2
• Bending Moment =	1219 kNm	3345 kNm
• Shear Force =	38831 kN	13189 kN
• Main Area of steel to be prov =	1845mm^2	1845 mm^2
• Ast req & provided at Bottom	= #16mm @ 100mm c/c	#16mm @ 100mm c/c
• Ast req & provided at Top	= #12mm @ 100mm c/c	#16mm @ 100mm c/c
• Provided Shear Reinforcement =	#8mm Dia @ 150mm c/c	#10mm Dia @ 200mm c/c

2) Heel		
• Net Avg. pressure along AB =	476 kN/m^2	421.5 kN/m^2
• Net Avg. pressure along GH =	427.9 kN/m^2	393.6kN/m^2
• Bending Moment =	8354 kNm	2921 kNm
• Shear Force =	35597 kN	14967 kN
• Main Area of steel to be prov =	2309mm^2	1845 mm^2
• Ast req & provided at Bottom	= #20mm @ 100mm c/c	#16mm @ 100mm c/c
• Ast req & provided at Top	= #16mm @ 100mm c/c	#16mm @ 100mm c/c
• Provided Shear Reinforcement =	#8mm Dia @ 150mm c/c	#8mm Dia @ 200mm c/c

IV.DETAILING

1. Reinforcement Details of Abutment Pier Cap:

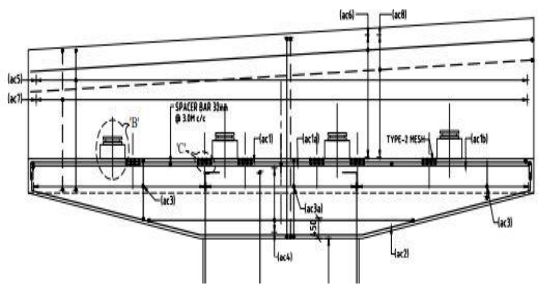

Fig3 : Longitudinal Section of Pier Cap

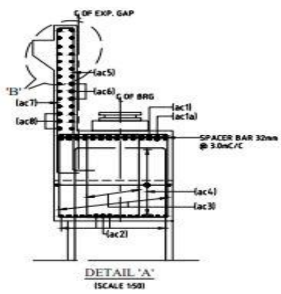

Fig4 : Cross Section of Pier Cap

2. Reinforcement Details of Abutment Pier:

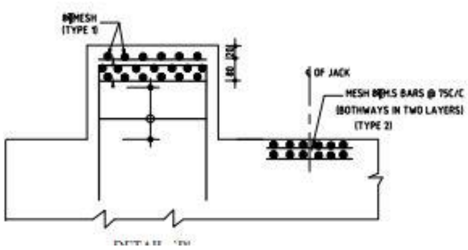

Fig5 : Cross Section of Pedestal

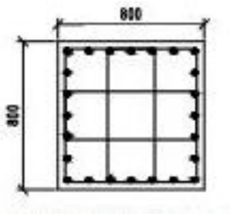

Fig6 : Plan of Pedestal

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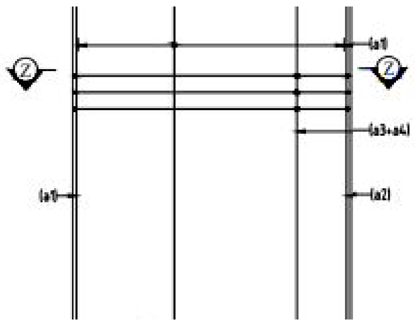

Fig7 : Sectional details of Abutment Pier along Longitudinal Direction

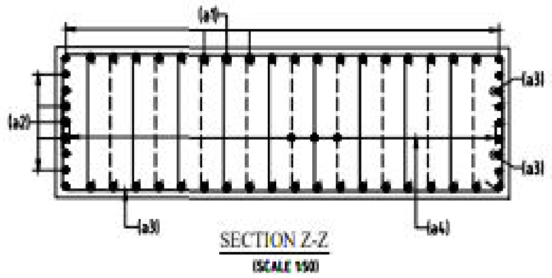

Fig8 : Cross Section of Abutment Pier

3. Reinforcement Details of Foundation:

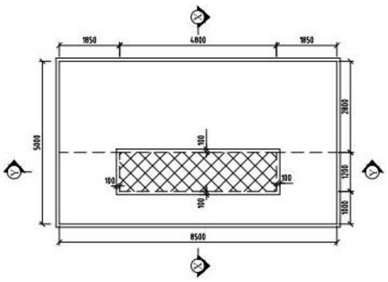

Fig9 : Plan of Foundation of Pier

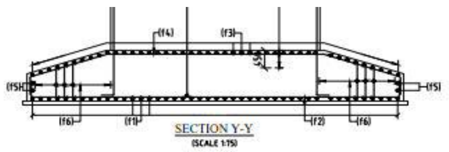

Fig10 : Sectional details of Pier Foundation along Longitudinal Direction

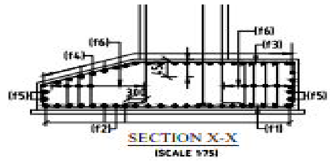

Fig11 : Cross Section of Pier Foundation

V.CONCLUSION

- The proposed project could help rectify the traffic conjunction problems and improve safe driving.
- Dead loads were calculated considering self-weight, crash barrier, wearing coat, construction & shuttering loads. The Max reaction from DL is 3300 kN.
- Carriageway Live loads were calculated for the following load case combinations IRC Class 70RWheeled, IRC Class 70RTracked, IRC Class A, Ultimately IRC Class 70R +70R wheeled vehicle load combination produces the Max reaction 1348.67kN, and max longitudinal moment 1011.50 kNm.
- For the basic wind speed 42m/s condition, Max wind load of 245 kN is at the super structure.
- For the Seismic Zone III category, at the longitudinal direction for the Max live load combination produces the Max Horizontal reaction -791.0 kN, Max Vertical reaction 317.2 kN & Max Moment of 6620 kNm.
- Pire Cap is Designed for the Max Bending moment of 7732 kNm, Torsional moment of 734.8 kNm & Max Shear force of 1899.8 kN, Pier is designed in the Staad.Pro for the 24 load combinations from the critical loads, from the analysis it found that load case 21 i.e Seismic at transverse direction as a leading is worst case.
- Foundation is designed for the Max reaction 17576.4 kN, clockwise Moments 6033.6kNm and anticlockwise Moments 1384.8 kNm , shear Force 11051.3 kN & base Pressure 440kN/m^2 from the Pier,
- Serviceability limit state being important criteria, crack width was found to be within the permissible limits.
- Detailed drawings were prepared for obtained sections and Steel Reinforcement.

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