Design of Steel Fly-over

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Abstract - *Fly-overs have been constructed since early seventies. They are mainly constructed for the purpose of traffic congestion elimination. However planning, design, construction, and erection of fly-over consume great span of time. The same have been the case with the emerging fly-over over NH By-pass, Palarivattom, and spanning 600m with a width of 6.6m. Greater seismic resistance, life span, and lesser life cycle cost nullify the excess cost of construction of steel flyover. India has a rich history of steel bridges. Steel bridges are ideal solutions for long spans, construction in hilly areas or in the difficult terrain conditions. For the short and medium span bridges and flyovers Steel – concrete composite construction is gaining popularity. But Kerala lacks such steel bridges. Kerala is a small state, with high population density. Most of the cities are saturated and traffic congestion is one of the major problems faced by these cities. Construction of flyovers is a solution to this problem. But construction of fly overs using R.C.C is time consuming, and will affect existing traffic and it has low seismic resistance. Construction of fly overs using steel sections can overcome these disadvantages, even though its initial cost is high. This project involves study of plan, and design of Palarivattom- Vytilla flyover and further design, and analysis of steel flyover for the same span.*

1. INTRODUCTION

Bridges and fly-overs are structures providing passage over an obstacle without closing the way beneath. The required passage may be for a road, railway or a valley. Bridge design is a complex problem, calling for creativity and practicability, while satisfying the basic requirement of safety and economy. The basic design philosophy governing the design is that a structure should be designed to sustain, with a defined probability, all action likely to occur within its intended life span. In addition, the structure should maintain stability during unprecedented action and should have the adequate durability during its life span. India has a rich history of steel bridges. These are generally road or rail bridges over low terrains or waterways joining long distances through single large span or multiple span construction. Steel bridges are ideal solutions for long spans, construction in hilly areas or in the difficult terrain conditions. For the short and medium span bridges and flyovers Steel – concrete composite construction is gaining popularity. Some of the steel bridges in India are about 100 years old and yet going steady, demonstrating the long life performance of steel bridges.

But Kerala lacks such steel bridges. Kerala is a small state, with high population density. Most of the cities are saturated and traffic congestion is one of the major problems faced by these cities. Construction of flyovers is a solution to this problem. But construction of fly overs using R.C.C is time consuming, and will affect existing traffic and it has low seismic resistance. Construction of fly overs using steel sections can overcome these disadvantages, even though its initial cost is high.

The project involves study of planning, and design of Palarivattom- Vytilla (Kerala) flyover (RCC) and further design, and analysis of steel flyover for the same span.

1.1 Objective

The project area is having very high density of traffic flow. The public felt inconvenient to cross the busy palarivattom - vytilla highway & therefore the flyover is essentially required at the junction.

For easy traffic flow of vehicles without traffic congestion flyover or over bridges is essential to overcome the traffic congestion required. Our project deals with the Design of a steel flyover in the intersection. The location is at four roads junction at pipeline junction, which is facing major traffic problems due to the construction.

We have designed the longitudinal girder, cross girder and deck slab for this grade separator.

2. STRUCTURAL DETAILS OF THE PALARIVATTOM-VYTILLA RCC FLYOVER

The total span of the flyover is divided mainly into three sections:
(1) First trestle portion with 9 spans of each of 22.20m
(2) Middle obligatory span of 35m
(3) Second trestle portion with 8 spans each of 21.50m

A minimum vertical clearance of 6.00m is allotted for the obligatory span. Flyover has been designed as bi-directional (each two lane) with a design speed of 85kmph. Cast-in-situ RC girder and deck slab of grade M35 concrete is being used for the standard spans (the two trestle portions), whereas cast-in-situ prestressed concrete post tensioned girders and deck slab of grade M40 is being used for the obligatory span. Grade of concrete used for the sub structural components like pier, pier cap, and piles is M35. All the necessary reinforcement is provided using Fe500 confirming to IS: 1786. A solid ramp portion with slope of

1in 30 is provided on either sides of the flyover. An initial valley curve (100.00m), followed by a 1 in 30 slope (116.40m), a summit curve (280.00m), another 1 in 30 slope (135.441m), another valley curve (100.00m), and a 1 in 150.37m slope together comprises the entire section of flyover. Elastomeric bearings separate the superstructure from substructure.

3. DESCRIPTION OF THE MATERIALS

3.1Concrete

Concrete of grade M35 is adopted in the design of RC deck slab and isolated footing.

3.2Steel

Steel of grade Fe 415 is adopted for the reinforcement and E250 Steel is adopted for the girder design.

4. LOADS ON THE STRUCTURE

4.1 Dead Loads

The dead loads of the structure consists of the self-weight of the various components such as deck slab, intermediate girders, cross girders, crash barriers, hand rails, wearing coat.

- D.L due to self-weight of the structure which is incorporated by SAP software
- D.L due to crash barriers and hand rails = 7.5 kN/m
- D.L due to wearing coat = 1.76kN/m^2

4.2 Live Loads

In SAP, the bridge loads can be assigned in the form of moving loads and impact loads. IRC: 6-2014 is used to verify all values. The governing loading types are:

i. Class AA wheeled type vehicle
ii. Class AA Tracked type vehicle

4.3 Vehicles

Vehicles are defined for Class AA wheeled and tracked in accordance to IRC 6, 2014

5. DESIGN OF OBLIGATORY SPAN (35m)

Obligatory span is the central most portion of the fly-over. A minimum vertical clearance of 6.00m is allotted for the obligatory span.

5.1 Design of Deck Slab

Spacing of cross girders (c/c) = 4.25m
Width of cross girder = 700mm
Spacing of Longitudinal girder = 2.06m
Width of Longitudinal girder (c/c)= 700mm
Thickness of slab = 250mm
Thickness of wearing coat = 80mm
Effective span in transverse direction = 1.36m
Effective span in longitudinal direction = 3.55m

5.1.1 Maximum Bending Moment Due to Dead Load

Weight of deck slab = 6.25kN/m^2
Weight of wearing coat = 1.76kN/m^2
Total weight = 8.01kN/m^2
Total dead load = 38.67kN
Moment along short span = 1.744kNm
Moment along long span = 0.413kNm

5.1.2 Live Load Bending Moment Due to IRC Class AA Tracked Vehicle

Size of one panel of deck slab= 4.25m x 2.06m
One track of the tracked vehicle is placed symmetrically on the panel. Track contact length taken from IRC: 6-2010
Impact factor fraction = 10%
Total load per track including impact = 385kN
Effective load on the span = 363.497kN
Moment along short span = 20.99kNm
Moment along long span = 4.925kNm

5.1.3 Live Load Bending Moment Due To IRC Class AA Wheeled Vehicle

i) Bending moment due to wheel 1
Load, W = 62.5kN
Moment along short span= 12.56kNm
Moment along long span= 10.44kNm
ii) Bending moment due to wheel 2
Equivalent load, W = 546.37kN
Moment along short span = 52.71kNm
Moment along long span = 13.14kNm
Bending moment due to middle portion,
Equivalent load, W = 421.37kN
Moment along short span = 47.11kNm
Moment along long span = 12.01kNm
Net bending moment along short span = 2.795kNm
Net bending moment along long span = 0.535kNm
Total short span bending moment, M_1 = 15.355kNm
Total long span bending moment, M_2 = 10.975kNm
Impact factor = 19%
Therefore, $M_1 = 1.19 \times 15.355$ = 17.29kNm
$M_2 = 1.19 \times 10.975$ = 11.45kNm
Absolute maximum bending moments,
M_1= 20.99kNm (tracked)

M_2= 11.45kNm (wheeled)
Total design bending moments,
M_1= 22.73kNm
M_2= 11.86kNm
Thus, M_1= 18.184kNm
M_2 = 11.86 × 0.8 = 9.489kNm

5.1.4 Reinforcement

Use 12mm diameter at 200mm c/c as main reinforcement along short span and 8 mm diamater bars at 170 mm c/c as longitudinal reinforcement.

5.2 Design of Longitudinal Girder

The design of longitudinal girders is done as I plate girder. Hence it is necessary to determine minimum depth required which is further used for determination of moment capacity.

5.2.1 Preliminary Dimensioning

5.2.1.1 Depth of girder

Adopted girder depth is 1800 mm.

5.2.1.2 Web thickness

Adopted web thickness is 20mm.

5.2.1.3 Flanges

Adopted b_f= 700mm and t_f = 70mm
b_f/t_f = 10mm < 13.6

5.2.2 Optimum Girder Depth and Thickness of Web

The Maximum bending moment obtained from analysis is 13231.705 kNm.
The optimum value of depth is obtained as
d= ((M k)/f_y)^0.33 = 1562.11mm
t_w= 18.15mm
Thus a web thickness of 20mm is adopted.

5.2.3 Design of End Bearing Stiffeners

Total compressive force,
F_{psd}=1845.34kN
As per Clause 8.7.5.2, IS 800-2007
F_{psd} = $(A_q \times f_{yq})/(.8 \times \gamma_{mo})$
$A_q >$ 6495.6mm^2
Thus provide two flats of size 200 x 20 mm on each side.
Area provided =16000mm^2 > 6495.6mm^2

5.3 Design of Cross Girder

The girder is designed as I plate girder. Hence it is necessary to determine the minimum depth required which is further used for the determination of moment capacity.

5.3.1 Preliminary Dimensioning

5.3.1.1 Depth of the girder

Adopted girder depth is 2000mm.

5.3.1.2 Web thickness

Adopted web thickness is 20mm.

5.3.1.3 Flanges

Flange width adopted is 700mm and the thickness of flange is 70mm, so b_f/t_f=10 < 13.6

5.3.2 Optimum Girder Depth

Maximum bending moment obtained from analysis is 4100.3kNm.
The optimum value of depth is obtained as = 1133.89mm

5.3.3 Design of End Bearing Stiffeners

As per Clause 8.7.5.2, IS 800-2007

$$F_{psd} = \frac{A_q \times f_{yq}}{.8 \times \gamma_{mo}}$$

A_q > 7139.62mm^2
Thus provide two flats of size 200 x 40 mm on each side
Area provided =16000mm^2 > 7139.62mm^2

6. DESIGN OF TRESTLE SPAN (22.2m)

Trestle spans are the portion of the fly-over on either side of the obligatory span. Design of trestle portions is similar to that of the obligatory span.

6.1 Design Of Deck Slab

Spacing of cross girders (c/c)=4.04m
Width of cross girder= 700mm
Spacing of Longitudinal girder= 3.6m
Width of Longitudinal girder (c/c)=700mm
Thickness of slab= 250mm
Thickness of wearing coat= 80mm
Effective span in transverse direction= 2.9m
Effective span in longitudinal direction= 3.34m

6.1.1 Maximum Bending Moment Due to Dead Load

Weight of deck slab = 6.25 kN/m^2
Weight of wearing coat = 1.76 kN/m^2
Total weight = 8.01 kN/m^2
Total weight = 77.58kN
Moment along short span = 3.68kNm
Moment along long span = 2.83kNm

6.1.2 Live Load Bending Moment Due to IRC Class AA Tracked Vehicle

Size of one panel of deck slab= 4.04m x 3.6m
One track of the tracked vehicle is placed symmetrically on the panel.
Total load per track including impact = 385kN
Effective load on the span = 341.99kN
Moment along short span = 29.97kNm
Moment along long span = 23.72kNm

6.1.3 Live Load Bending Moment Due To IRC Class AA Wheeled Vehicle

i) Bending moment due to wheel 1
Moment along short span = 15.09kNm
Moment along long span = 15.09kNm
ii) Bending moment due to wheel 2
Net bending moment along short span =3.77kNm
Net bending moment along long span = 3.485kNm
iii) Bending moment due to wheel 3
Net bending moment along short span = 1.401kNm
Net bending moment along long span = 1.62kNm
iv) Bending moment due to wheel 4
Net bending moment along short span =5.52kNm
Net bending moment along long span = 1.59kNm
v) Bending moment due to wheel 5
Net bending moment along short span = 3.77kNm
Net bending moment along long span = 3.485kNm
vi) Bending moment due to wheel 6
Net bending moment along short span = 1.401kNm
Net bending moment along long span = 1.62kNm
Total short span bending moment, M_1= 30.95kNm
Total long span bending moment, M_2 = 26.89kNm
Impact factor = 25%
Therefore, M_1 = 1.25 × 30.95 = 38.69kNm
M_2 = 1.25 × 26.89 = 33.61kNm
Absolute maximum bending moments,
M_1= 38.69kNm (wheeled)
M_2= 33.61kNm (wheeled)
Total design bending moments, M_1 = 33.89kNm
M_2 = 23.77kNm

6.2 Design of Longitudinal Girder

The design of longitudinal girders is done as I plate girder. Hence it is necessary to determine minimum depth required which is further used for determination of moment capacity.

6.2.1 Preliminary Dimensioning

6.2.1.1 Depth of girder

Adopted girder depth is 1800mm.

6.2.1.2 Web thickness

Adopted web thickness is 20mm.

6.2.1.3 Flanges

Adopted b_f = 700mm and t_f = 70
b_f/t_f = 10mm < 13.6

6.2.2 Optimum Girder Depth

The optimum value of depth is obtained as $d = \left(\frac{M\,k}{f_y}\right)^{.33}$

Maximum bending moment obtained from analysis is 14070.907kNm.
d = 1228.26mm
t_w= 19.12mm
Thus a web thickness of 20mm is adopted.

6.2.3 Design of End Bearing Stiffeners

As per Clause 8.7.5.2, IS 800-2007

$$F_{psd} = \frac{A_q \times f_{yq}}{.8 \times \gamma_{mo}}$$

$$A_q > \frac{0.8 \times 2462.68 \times 1.1 \times 10^3}{250}$$

$$A_q > 8668.63\text{mm}^2$$

Thus provide two flats of size 200 x 40 mm on each side
Area provided = 16000mm^2 > 8668.63mm^2

6.3 Design of Cross Girder

The girder is designed as I plate girder. Hence it is necessary to determine the minimum depth required which is further used for the determination of moment capacity.

6.3.1 Preliminary Dimensioning

6.3.1.1 Depth of the girder

Adopted girder depth is 2000mm.

6.3.1.2 Web thickness

Adopted web thickness is 20mm.

6.3.1.3 Flanges

The flange width adopted is 700mm and the thickness of flange is 70mm, so b_f / t_f=10 < 13.6

6.3.2 Optimum Girder Depth

Maximum bending moment obtained from analysis is 7463.3kNm.
The optimum value of depth is obtained as = 1381.67mm

6.3.3 Design of End Bearing Stiffeners

As per Clause 8.7.5.2, IS 800-2007

$$F_{psd} = \frac{A_q \times f_{yq}}{.8 \times \gamma_{mo}}$$

A_q > 7297.31mm^2

Thus provide two flats of size 200 x 40 mm on each side
Area provided =16000mm^2 > 7297.31mm^2

3. CONCLUSIONS

Construction of fly overs using R.C.C is time consuming, and will affect existing traffic. Construction of fly overs using steel sections can overcome these disadvantages, even though its initial cost is high. Steel bridges offer wide range of solutions to choose from based on the design/site requirements. Truss type or girder type, deck type or through type, arch type or frame type, simple or continuous span type, all-steel or composite construction options are only a few examples. Some of the advantages of steel intensive bridges and flyovers are:

1. Fast – track construction
2. Prefabrication possibility and minimum disruption to public life in urban areas
3. Cost competitiveness, easy construction, maintenance and up-gradation
4. Sleek, strong and long span structures, lighter foundation
5. Durable structures, longer life and improved life cycle performance
6. Ensured quality of material and construction

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