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A Study on Design and Analysis of Precast Box for Road Bridge Construction using STAAD Pro

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ABSTRACT

Transportation always plays an important role in economic growth & globalization for a country. Road transportation is one of the main transporting way in India. Therefore it requires connectivity of cities. Hence bridges & culverts are constructing to connect Roads.

Box Culvert can be defined as a structure having box shape which is constructed below the embankment to drain water from one side of the bank to the other side of the bank. Failure reasons of a Box Culverts are maintenance failure, erosion and increase in scour depth, and Installation Failures. To improve the problems occurring in the Structure are described briefly. Box Culverts are normally constructed without RCC cut off and curtain walls. Due to which structure gets damaged easily. In previous researches Box Culvert are constructed with PCC cut off & curtain walls while taking various parameters in design.

Movements of people and transportation will not be affected because structure will not be constructed number of times because life of structure will be very long. Seepage pressure is less in box culvert with RCC Cut off & curtain walls because the gripping in RCC structure is good as compare to PCC Structure, and Seepage pressure is directly proportional to voids that makes PCC structure unstable against seepage pressure. BM of PCC walls is also less than as compare to RCC walls. Life of structure will also increase around two times, & also Government planning will not be affected because project will be for long time period. In designing of structure the two major factors should be kept in mind i.e. economy and safety. If the load is overestimated than the structure will be uneconomical whereas if the load is underestimated the safety of structure will be compromised. Hence the calculation of load and their combination should be done very precisely The study included estimation of PCC & RCC Cut off & Curtain walls through comparative results in SOR 2017.

KEYWORDS: *BOX Culvert, CUT OFF Wall, Curtain Wall, Estimation, Structure, Analysis, & comparative Results*

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1. INTRODUCTION

It is well known that railway tracks need to cross through the roads in and around extremely populated, well - established cities and towns, so a level crossing is provided in those points but these level crossings may be manned or unmanned, and further causes a traffic jam whena train passes. As both population and traffic are increasing day by day, delays and the riskof accidents at the level crossings are also increasing. About 30-40 % of train accidents were atlevel crossings, in terms of causalities it contributes 60-70 %. So Indian Railways has to decide either go for road over bridges (ROB's) or road under bridges (RUB's) where ever necessary in populated areas.

In designing of structure the two major factors should be kept in mind i.e. economy and safety. If the load is overestimated than the structure will be uneconomical whereas if the load is underestimated the safety of structure will be compromised. Hence the calculation of load and their combination should be done very precisely. The total loads acting on the box are determined and the resulting bending moments, shear forces and axial forces actingon the box are calculated for each combination of loads and then it is designed for the most adverse combination of loads.

Various loads acting on a structure are given below:
1. Dead loads
2. Live loads
3. Dynamic effects
4. Longitudinal force
5. Earth pressure
6. Surcharge pressure

2. PROBLEM IDENTIFICATION & OBJECTIVES

No detailed study on suitability of materials has been done in past researches were conducted on different materials including RCC, prestress foam concrete however information on techno-economic feasibility of materials to be used in construct the tunnels and over-bridges using thebox culverts very rapid and the cost of construction is less and there is less risk and pushing technology.

The aim of present study is to do the complete analysis and design of Subway at levelcrossing by box pushing technique. So the objective of present work is as follows-

Detailed analysis of pre-cast box segment using STAAD Pro.
1. Design of box segment using Limit state method manually.
2. Design of Thrust bed and thrust wall using Limit state method manually.
3. Design of shear key using Limit state method manually.

3. METHODOLOGY

Some standard specifications and guidelines for analysis of box segment are taken from Bridge Rules and IRS code. Bridge rules specifying the loads for design of super-structure and sub-structure of bridges and for assessment of the strength of existing bridges.

In case of bridges having open deck provided with through welded rails, rail-free fastenings and adequate anchorage of welded rails on approaches (by providing adequate density of sleepers, ballast cushion and its consolidation etc., but without any switch expansion joints) the dispersion of longitudinal force through track, away from the loaded length, may be allowed to the extent of 25% of the magnitude of longitudinal force and subject to a minimum of 16t for BG and 12t for MMG or MGML and 10t for MGBL. This shall also apply to bridges having open deck with jointed track with rail-free fastenings or ballasted deck, however without any switch expansion or mitred joints in either case. Where suitably designed elastomeric bearings are provided the aforesaid dispersion may be increased to 35% of the magnitude of longitudinal force.

4. RESULTS AND DISCUSSION

4.1. ANALYSIS SOFTWARE

STAAD stands for Structural analysis and design computer Program originally developed by Research Engineers International in Yorba Linda, CA. Research Engineer International was bought by Bentley Systems. The different versions of the software are used in present time. STAAD III is used by Iowa State University for educational purposes for civil and structural engineers. Now we are using STAAD pro v8i software for structural analysis and design. It can perform various form of analysis in 2-dimension and 3-dimension subjected to different load combinations, support condition etc. depending on engineer's requirement. The provisions for steel design, concrete design, foundation design etc. are also provided according to their relevant codes. The problems of 1st order static analysis, 2nd order p-delta analysis, geometric non-linear analysis, buckling analysis, dynamic analysis, response spectrum etc. can be performed easily. In present work box segment is analyzed by using STAAD.pro software.

4.2. MODEL DESCRIPTION

The box is modeled as per the parameters given in Table 5.1 and the element considered as beam element. Model is shown in fig. 5.1.

Table 5.1 Details of structure

S. No.	Particulars	Details
1	Size of the box	7.5 m × 5.15 m
2	Thickness of top slab	0.6 m
3	Thickness of bottom slab	0.6 m
4		

Thickness of end vertical walls
0.75 m
5
Effective height
5.75 m
6
Effective span
8.25 m
7
Support condition
Simply Supported
27

4.3. SOFTWARE VALIDATION

Above model for dead load is taken to validate the STAAD results. Problem is solved by manually, STAAD. pro software and results are compared.

A box having Dead load on top slab = 7.755 t/m² = 7.755 × 9.81 = 76.051 kN/m² and Dead load on bottom slab = 11.0625 t/m² = 11.0625 × 9.81 = 108.486 kN/m².

4.4. MANUAL ANALYSIS

Problem Statement: Analyze the plane box frame shown in figure 4.2 using the moment distribution method and making use of symmetry.

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1
I_1 = = I
I_2 = = 1.95I 2I

The box frame is symmetrical and the centre line is passing through the mid span, then takes the stiffness of beam 1 and beam 4 as half of its original value and carry out the end moment distribution for half of the box only.

A. Fixed end moment

$Mf_{1\,2'}$ = - 43.98 tm
Mf_2
' = $wl2$
12
= 7.775×8.252
12
= 43.98 tm
$Mf_{1\,3}$ = 0 $Mf_{3\,1}$ = 0
$Mf_{3\,4'}$ =
Mf
$wl2$
12
$wl2$
= 11.0625×8.252
12
11.0625×8.252
= 62.74 tm
$_{4}$ ‘$_{3}$ =- = -
12 12
= - 62.74 tm
29

B. Distribution Factor

Table 5.2 Distribution factor
Joint
Member
Relative Stiffness
Total R S
DF
1
12'
38.75I
94.875
0.148
13
0.852
3
31
3875I
94.875
0.852
34'
0.148

C. Moment Distribution

Table 5.3 Moment distribution method
Joint
2'
1
3
4'
DF
1
0.148
0.852
0.852
0.148
1
FEM
43.98
- 43.98
0
0
62.74
- 62.74
Balanced
6.51
37.47
- 53.45
- 9.29
COM
3.255
-26.725
18.735

- 4.645
Balanced
3.955
22.77
- 15.96
- 2.775
COM
1.9775
- 7.98
11.385
- 1.3875
Balanced
1.18
6.8
- 9.7
- 1.685
COM
0.59
- 4.85
3.4
- 0.8425
Balanced
0.72
4.13 - 2.9
- 0.5
COM
0.36
- 1.45 2.065
- 0.25
Balanced
0.2146
1.2354 -1.76
- 0.305
COM
0.11
- 0.88 0.6177
- 0.1525
Final End Moments
50.27 - 31.4
30.52 - 47.56
48.185 - 70.02
30

4.5. STAAD ANALYSIS

Problem Statement: Analyze the plane box frame shown in figure 5.2 using STAAD Pro software.

Table 5.4 Comparison of BM between STAAD Pro and Moment Distribution Method

Joint
Manual
STAAD Pro
% Error
1
(31.4 + 30.52)/2 = 30.96 tm
304.031/9.81 = 30.99 tm
- 0.096
3
(47.56 + 48.185)/2 = 47.87 tm
467.366/9.81 = 47.64 tm
0.048

The Bending moment calculated by STAAD Pro is found to be approximately similar as calculated by Moment Distribution Method.
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4.6. ANALYSIS OF RUB USING STAAD PRO

In this chapter, analysis of box segments is done using STAAD Pro. Software and design of box segments, design of Thrust Bed, design of Thrust Wall, design of Shear keys is done by Limit State Method manually. The box design is based on approved GADs in which RL to top of box is kept 1705 mm to cater the track safety during box pushing operation. The opening of box and span as per approved GAD and Road level change accordingly. Box design is critical for less cushion i.e. considering DL of permanent way (which includes 300 mm ballast, Rail and Sleeper), the cushion of earth below the sleeper, vertical and longitudinal live loads due to train and lateral earth pressures and surcharge pressures on the walls of the box. Analysis for effects of wind and earthquakes has not been considered.

4.7. DESIGN BASIS

The Live loads due to train traffic is taken for 25 T Axle loading as equivalent uniformly distributed loads in the vertical direction as per tables in Appendix XXXII (a) and in the longitudinal direction as per Appendix XXIV IRS (Bridge Rules) respectively.

The outer vertical walls of the box are loaded with horizontal earth pressures for the retained earth and extra pressures due to surcharge as defined in Cl.5.8.2, P10 in IRS – Code of practice for the design of sub-structures and foundations of Bridges.

For pushing, barrel length is kept 22.05 m and two box of equal length i.e. 11.025 m is provided. Considering this, to evaluate critical condition, the different combinations of the following load cases have been considered.

A. Dead loads of box, soil cushion and track load.
B. Earth pressures on the outer walls due to soil and soil cushion.
C. Live loads on the box.
D. Earth pressures due to surcharge.
E. Longitudinal load due to Tractive / Braking.

From the analysis, the design values are taken out and design is done by the method of 32 limit state following the IRS – Design standards. For the design, Concrete of M35 grade and steel of Fe 500 grade have been considered.

4.8. MATERIAL PROPERTIES

1) Properties of concrete
Grade: M35
Modulus of Elasticity: 3.10E +04 Mpa
2) Properties of steel
Grade: Fe 500
Modulus of Elasticity: 2.10E +05 Mpa
3) Properties of soil
Density, γ: 1.8 t/m³
Angle of Internal friction, θ: 30 degree
Angle of Wall friction, δ: 10 degree Active Earth Pressure Coefficient, k_a: 0.308

4.9. DESIGN OF THE RCC BOX

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4.10. DESIGN DATA

A

2) Effective height
3) Ballast cushion
=
=
Clear height + slab thickness: 5.15 + 0.6 = 5.75m
(Rail level – Formation level) – Rail height – Sleeper height
=
1.705 – 1.005 – 0.16 – 0.254
=
0.286m
4) CDA value for Broad Gauge (BG) as per Cl. 2.4.2 of IRS, CDA
1) Size of the box
: 7.5 m × 5.15 m
2) Length of the box
: 22.05 m
3) Thickness of top slab
: 0.6 m
4) Thickness of bottom slab
: 0.6 m
5) Thickness of end vertical walls
: 0.75 m
6) R.L of Rail level
: 327.042 m
7) R.L of formation level
: 326.342 m
8) R.L of invert level
: 319.587 m
9) Rail level to top of box
: 1.705m
10) Formation level to top of box
: 1.005m
11) Clear height: 5.150m
12) Clear span: 7.500m
13) Width of pre-cast segment: 11.025m

4.11. CALCULATIONS

Geometric Calculation

1) Effective span = Clear span + wall thickness: 7.5 + 0.75 = 8.25m
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Where, L is the loaded length of span in meters for the position of the train giving the maximum stress in the member under consideration.
Span, L = 8.25m
CDA = 0.15 +
Depth of fill = Ballast cushion + Earth cushion
= 0.286 + 1.005
= 1.291 m

Formula of CDA

a) If the depth of fill is less than 900mm, the CDA shall be equal to-[2- (d/0.9)]×0.5×CDA as obtained from Clause 2.4.1.1(a)

Where, d = depth of fill in 'm'.

b) If the depth of fill is 900mm, the CDA shall be half of that specified in clause 2.4.1.1(a) subject to a maximum of 0.5. Where depth of fill exceeds 900mm, the CDA shall be uniformly decreased to zero within the next 3 meters.

Therefore,
CDA = ×0.5×0.711 = 0.309
35

5) Dispersion Width
The loads are for a width dispersed as shown in fig. below, as per Cl.2.3.4.2 (a) of IRS (Bridge Rules)

Dispersion through sleeper and cushion = sleeper width + 2× (slope × fill thickness)
= 2.745 + 2× (0.5 × 1.291)
= 4.036m

Dispersion through slab = Effective span/4 + Effective span/4
= 8.25/4 + 8.25/4
= 4.125m

Therefore, Total dispersion width = 4.036 + 4.125 = 8.161m

B. LOAD CALCULATION

1) Superimposed load
The superimposed dead loads per running meter of box is as below
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i) Weight of Permanent way
a) Rails
Weight of rail = No. of rail × Weight of rail per meter length (160 mm height)
= 2 × 60 = 120.00 kg/m

b) Sleepers
Spacing = 0.65 m
For 1m = (1/0.65) = 1.5385 no. of sleeper

Weight of sleeper = No. of sleeper × Vol. of sleeper × Density of concrete
= 2.745×0.254×0.254×2500×1.5385 = 681.16 kg/m

c) Fixtures = 56.00 kg/m Total load = 857.16 kg/m
Intensity of load = Total load/Dispersion width= 857.16/8.161 = 105.03 kg/m²

ii) Ballast
Height of ballast = Ballast Cushion + height of sleeper = 0.286 + 0.254 = 0.54 m Weight of ballast @ 1900 kg/m³ = 0.54× 1900 = 1026 kg/m²

iii) Soil weight above slab
Height of fill up to bottom of ballast = Rail level to top of slab – Rail height – Sleeper height – Ballast cushion
= 1.705 – 0.160 – 0.254 – 0.286
= 1.005 m

Intensity of DL per square meter = 1.005 × 1 × 1800 = 1809 kg/m² Total superimposed load intensity
= Track + ballast + Earth cushion = 105.03 + 1026 + 1809 = 2940.03 kg/m²)

2) Dead load of Box segment
i) Slab
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Slab thickness @ 0.60 m = 0.60 × 1 × 2500 = 1500 kg/m²

ii) Wall
Wall thickness @ 0.75 m = 0.75 × 6.35 × 2500 = 11906 kg/m²
Due to weight of wall UDL on base slab = 2 × 11906 / 9.0 = 2688 kg/m²

3) Live Load
i) EUDL for bending moment
Effective length = Centre to centre distance of walls = 8.25m

This is less than 10m and hence as per Appendix XXIII (a), of IRS (Bridge Rules), EUDL is the UDL that produces the maximum bending moment at the centre of the span equal to the absolute maximum bending moment developed under the BG load.

For 8.25 m span, EUDL = 105.11t

Reduced CDA = 0.309

EUDL ×(1+CDA)

Live load intensity =
Dispersion width × Effective span
= 105.11t ×1.0309 = 2.0435t/m²
8.161×8.25

Live load intensity = 2043.5 kg/m² ii) EUDL for Shear force

Vertical live loads on the slab top due to Train traffic:

Effective length = Clear span + Wall thickness + Wall thickness
= 7.5 + 0.75 + 0.75
= 9.0 m

For 9.0 m span, EUDL = 129 t Reduced CDA = 0.309
38
EUDL ×(1+CDA)

Live load intensity =
Dispersion width×Effective span
105.11t ×1.0309
= 8.161×8.25
= 2.2919t/m²

4) Earth pressure
a) Earth pressure due to soil cushion and height of earth retained will be acting on both the side walls.
Earth pressure on side walls due to earth retained the soil properties considered are asbelow:
1. Density of soil: 1.8t/m³
2. Coefficient of friction between concrete andsoil, u: 0.5 iii)Angle of internal friction of backfill soil, ϕ: 30
3. Angle of friction between wall and earth fill, δ: 10
4. Angle of surcharge, I: 0
5. Angle of batter with vertical face of wall, α: 0 ̊
6. Height of wall, h = 5.15 + 0.6 = 5.75 m

With reference to CI.5.7.1 of IRS (Bridge Substructures and Foundation Code), k_a

Substituting the values of ϕ, α, δ and i. cos²(ϕ - α) = 0.750

cos(α + δ) = 0.985 cos α = 1.000

sin(ϕ + δ) = 0.643 cos(α - i) = 1.000 sin(ϕ - i) = 0.500

k_a

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k_a = 0.3085

Coefficient of active earth pressure, k_a = 0.3085

Earth cushion at c/c of bottom slab, h = Effective height + Earth cushion + Slab thickness/2

= 5.75 + 1.005 + 0.30 = 7.055 m

1) Earth pressure at c/c of bottom slab = k_a γh
= 0.3085 × 1.8 × 7.055
= 3.917 t/m²

Earth cushion at c/c of top slab, h = Earth cushion + Slab thickness/2

= 1.005 + 0.30 = 1.305 m

2) Earth pressure at c/c of top slab = k_a γ h
= 0.3085 × 1.8 × 1.305
= 0.7246 t/m²

a) Earth Pressures due to Surcharge

Earth load due to dead load and live load surcharge considered as equivalent loads placed at formation level are considered as per Cl. 5.8.1 and 5.8.2 of IRS (Bridge Substructure and foundation code). In this case, the following values are used for the notations:

L = Length of abutment / wall = 11.025 m

B = Width of udl at formation level = 3.00 m

h = Depth of section below formation level = 5.75 + 0.3 + 1.005 = 7.055 m

Case – 1: When depth of section h is less than (L - B)

L – B = 11.025 – 3 = 8.025 m > 7.055 m, OK

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Hence the surcharge diagrams will be as per Case 1 of Cl. 5.8.2 of IRS (Bridge Substructure and Foundation Code) at formation level.

S = Live load surcharge for unit length = 13.7 t/m

V = Dead load surcharge for unit length = 6.0 t/m

4. Dead load surcharge

i) Intensity at c/c of bottom slab = k_a

= 0.184 t/m²

Intensity at formation level =

= 0.617 t/m²

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x = 0.353 ii) Intensity at c/c of top slab = 0.184 + 0.353 = 0.537 t/m²

5) Live load surcharge

i) Intensity at c/c of bottom slab = k_a

= 0.42 t/m² Intensity at formation level =

= 1.408 t/m²

42

x= 0.805 t/m² ii) Intensity at c/c of top slab = 0.42 + 0.805 = 1.225 t/m² 6) Longitudinal loads

Longitudinal force is not required however it is considered in design which is on conservative side. Longitudinal loads (without deduction for dispersion), as per Appendix XXIV

For L = Loaded length = 9.0 m

Tractive Force = 41.7 t Braking Force = 28.10 t

Braking force is lesser and hence neglected. Dispersion of longitudinal force through rail is considered

Net longitudinal force = 41.7 – 16 = 25.7 t

Assuming this load to be acting at the bottom of the sleeper and assuming a similar distribution width as the vertical loads as per Cl. 2.3.4.2(a) of IRS – Bridge Rules, the lateral loads per meter length are as below:

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Longitudinal Force = = 3.149 t/m

This longitudinal force is resisted by earth filled behind wall. Ordinate of earth pressure= 3.149 × = 1.095t

Summary of forces
1) Dead load On top slab:

Ultimate load = 2.0 × Superimposed load + 1.25 × Dead load UDL

= 2.0 × 2.940 + 1.25 × 1.5 = 7.755 t/m²

On bottom slab:

Ultimate load = 1.25 × Weight of walls + UDL on top slab UDL = 1.25 × 2.646 + 7.755 = 11.0625 t/m²

Ultimate load factor = 1

2) Live load (LL intensity for BM) UDL = 2.0435 t/m² Ultimate load factor = 1.75

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3) Live load(LL intensity of Shear Force) UDL = 2.2919 t/m²

Ultimate load factor = 1.75

4) Earth Pressure

i) Earth pressure at c/c of top slab = 0.7246 t/m²

ii) Earth pressure at c/c of bottom slab = 3.917 t/m²

Ultimate load factor = 1.7

45

5) Dead load surcharge

i) Intensity at c/c of top slab = 0.537 t/m²

ii) Intensity at c/c of bottom slab = 0.184 t/m²

6) Live load surcharge

i) Intensity at c/c of top slab = 1.225 t/m²

ii) Intensity at c/c of bottom slab = 0.42 t/m²

Ultimate load factor = 1.7

46

7) Longitudinal Forces

i) Longitudinal load = 3.149 t/m

ii) Ordinate of Earth pressure = 1.095 t

Analysis of the Box

From the above loads, the different load cases considered for the analysis & STAAD Pro. is used to evaluate the maximum bending moment and shear forces in the various members of the box are described below. The analysis is done for the railway loading of **25t Loading 2008.**

1. Load cases and combinations

1) Dead Load (DL)

2) Live Load for BM (LLbm)

3) Live Load for SF (LLsf)

4) Earth Pressures (EP)

47

5) Dead Load Surcharge (DLS)

6) Live Load Surcharge (LLS)

7) Longitudinal force (LF)

8) DEAD LOADS DL + EP + DLS

9) COMBINATION 8 + LLbm +LLS DL + EP + DLS + LLbm + LLS

10) COMBINATION 8 + LLbm + LLS + LFDL + EP + DLS + LLbm + LLS + LF

11) COMBINATION 8 + LLsf + LLS DL + EP + DLS + LLsf + LLS

12) COMBINATION 8 + LLsf + LLS+ LF DL + EP + DLS + LLsf + LLS +LF

The numbering for members and nodes considered in the analysis is as below

From STAAD output, combination 9-10 are used for getting Maximum BM in members and for maximum SF, combination 11-12 are used.

1) The maximum (+) Ultimate BMat mid span BM due to load combination 9 is

48

BM due to load combination 10 is

i) Top slab = 454.171/9.81 = 46.3 tm ii) Bottom slab = 563.32/9.81 = 57.42 tm

2) The Maximum (-) Ultimate BM at support BM due to load combination 9 is

49

BM due to load combination 10 is

j) Top slab = 527.211/9.81 = 53.74 tm

ii) Bottom slab = 680.663/9.81 = 69.38 tm

3) Maximum Ultimate Shear force at node Shear force due to load combination 11 is

50

Shear force due to load combination 12 is

i) Top slab = 47.73 t

ii) Bottom slab = 61.7 t

4) Maximum Designed Bending Moment Mu

i) BM (+ve) = 57.42 tm at mid span ii) BM (-ve) = 69.38 tm at node

For design maximum (-ve) BM will be worked out at face of wall Maximum BM at face of wall i.e. at distance = 0.375m from node

Mu = Maximum BM – Reaction × wall thickness/2 + (DL + LL) × (wall thickness/2)² × 0.5

= 69.38 – 48.53 × 0.75/2 + (7.755 + 2.2919 × 1.75) × (0.75/2)² × 0.5

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= 69.38 – 18.198 + 0.83 = 52.012 tm

5) Maximum Shear force Vu

Maximum Shear force at node = 61.7 t

For design, SF is critical at distance equal to Effective depth but it is considered at face of wall.

Vu = Maximum SF – (DL + LL) × (wall thickness/2)

= 61.7 – (7.755 + 2.2919 × 1.75) × 0.75/2

= 57.28 t

6) Wall

i) Maximum BM Mu at node

a) At top slab = 53.74 tm

b) At bottom slab = 69.38 tm

Therefore, Designed Max. BM = 69.38 tm at node

ii) Corresponding

Axial load, Pu = 47.545 t

Critical BM will be at face of slab and calculated as follows Maximum BM at face of slab

= Mu at node - Reac^{n} due to (EP+DLS+LLS) × lever arm + (EP+DLS LLS) × (lever arm)²/2

= 69.38 – (0.7246+0.184+0.42)/2 × 5.75 × 0.3 + (0.7246+0.184+0.42) × (0.3)²/2

= 68.29 tm

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5.12 RESULTS

Final design values of bending moment, shear force and axial force are presented below in the tables:

Table 5.5 Design values for slab

S. No.	Force	Value
1	Max. BM(+ve)	57.42 tm
2	Max. BM(-ve)	52.012 tm
3	Max. Shear force	57.28 t

Table 5.6 Design values forwall

S. No.	Force	Value
1	Max. BM	68.29 tm
2	Max. Axial load	47.545 t

5.13 DESIGN OF MEMBERS

The design of the sections is done by using limit state method as provided in the IRS. The design parameters as obtained from IRS for M35 grade of concrete and Fe500 grade of steel. The slab/ wall are designed for BM as per STAAD Pro. Output for load combination 9 & 10 and for shear combination 11 & 12 are used.

Design of slab

Grade of concrete = M 35

Grade of reinforcement = Fe 500

Overall depth of slab = 600 mm

53

Clear cover = 50 mm

Dia. of main reinforcement = 25 mm Dia. of shear stirrups = 12 mm

Design formulas are used as per CL. 15.4.2.2.1 of IRS Concrete Bridge code.

$Mu = 0.15Fck\ bd^2$

d

Ast

1. Moment at mid span

Mu = 57.42 tm = 57.42 × 9.81 = 563.32 kN-m

Effective depth required, d=

d = 327.56 mm

Effective depth provided = 600 – 50 – 12.5 = 537.5 mm > Effective depth required

Ok Singly reinforced section

Main reinforcement, Ast =

Ast = 2609.58 mm²

Provide 25 mm bar @ spacing of 200 mm c/c (Ast = 2454.37 mm²) Provide 16 mm bar @ spacing of 200 mm c/c (Ast = 1004.8 mm²) Curtailed Total Ast provided = 2454.37 + 1004.8 = 3459.17 mm²

Reinforcement in other face of slab provide minimum reinforcement (0.12%) Provide 16 mm

54

bar @ spacing of 200 mm c/c (Ast = 1004.8 mm²)

2. Moment at support (Face of wall)

Mu = 52 tm = 52 × 9.81 = 510.12 kN-m

Effective depth required, d=

d = 311.71 mm

Effective depth provided = 600 – 50 – 8 = 542 mm > Effective depth required, OK

Main reinforcement, Ast =

Ast = 2320.88 mm²

Provide 16 mm bar @ spacing of 200 mm c/c (Ast = 1004.8 mm²)

Provide 25 mm bar @ spacing of 200 mm c/c (Ast = 2453mm²) extra from

column Total Ast provided = 3457.8 mm²

a) Distribution reinforcement

Provide 0.12 % of gross section as distribution reinforcement and provide half at each

faces. Distribution reinforcement = 0.12 % of bD

= 0.12 × 1000 × 600/100

= 720 mm²

Reinforcement provided at each face = 720/2 = 360 mm²

Provide 12 mm bar @ spacing 200 mm c/c (Ast provided = 565.2 mm²)

b) Shear (At face of wall)

Maximum Shear force, Vu = 57.28 t = 57.28 × 9.81 = 561.92 kN

Effective depth, d = 537.5 mm b = 1000 mm

55

Vu

Shear stress in concrete, τ =

bd

=

561.92×1000

1000×537.5

τ = 1.044 N/mm

Shear stress in concrete should be lesser of 0.75 = 4.141 N/mm² or = 4.75 N/mm² as

per CL.15.4.3 of IRS

Concrete Bridge Code.

τ = 1.044 N/mm < 4.141 N/mm Ok

Assume main reinforcement Ast are curtailed = 50 %

Percentage of reinforcement, P%

Ast×100

bd

=

561.92×1000

1000×537.5

P % = 0.321%

Depth factor, s = (500/d) ^{5} = (500/537.5)^5

s = 0.982

Ultimate shear stress in concrete (ζc) as per CL.15.4.3.2.1 of IRS Concrete Bridge Code

ζc =

γ□ = 1.25

ζc =

ζc = 0.484 N/mm

Permissible shear stress in concrete = Depth factor × ζ

= 0.982 × 0.484

= 0.475 N/mm²

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Since, τ = 1.044 N/mm > s × ζc = 0.475 N/mm² Shear reinforcement required Use 12 mm dia. 5 leg stirrups (Area Asv = 5 × 113.04 = 565.2 mm²)

Spacing of stirrups =

Sv = 253.8 mm

Maximum spacing = 0.75d = 0.75 × 537.5 = 403.13 mm

Use 12 mm dia. 5 leg stirrups at spacing of 200 mm c/c up to 2.6m from face of wall.

Let at x is distance from support where shear reinforcement is not required. In such

condition shear force will be equal to shear capacity of section.

SF at x distance = s × ζc × bd

= 0.982 × 0.484 × 1000 × 537.5

= 255.71 kN (Eq - 1)

Or

SF at x distance = Max. SF – x × (Ultimate DL + Ultimate LL Shear)

= 561.92 – x × (1 × 77.55 + 1.75 × 22.92)

= 561.92 – 117.66x (Eq - 2) From

Equation 1 & 2, we get

x = = 2.6 m

Remaining distance i.e. 8.25 – 2 × 2.6 = 3.05 m

Use 12mm dia. 5 leg stirrups at spacing of 200 mm c/c in mid portion.

Design of wall

Vertical walls of the box are checked for min. Axial load and corresponding max. BM. The

minimum axial forces and corresponding bending moments in the walls are taken from

STAAD output.

Max. BM at face of slab, Mu = 68.29 tm = 68.29 × 10 = 682.9 kN-m

57

Axial load, Pu = 47.545 t = 47.545 × 10 = 475.45 kN

As per clause 15.7.1.1 of IRS concrete bridge code if axle load is less than 0.1Fck×Ac, the

wall will be designed as flexural member.

In this case 0.1Fck×Ac = 0.1 × 35 × 1000 × 600/1000 = 2100 kN > 475.45 kN

Hence member will design as flexural member.

Mu = 682.9 kN-m

Effective depth required, d=

d = 360.66 mm

Effective depth provided = 600 – 50 – 12.5 = 537.5 mm

Effective depth provided > Effective depth required Ok Singly reinforced section

Main reinforcement, Ast =

Ast = 3222.84 mm²

Provide 25 mm bar @ spacing of 200 mm c/c (Ast =

2454 mm²) And 20 mm bar @ spacing of 200 mm c/c (

Ast = 1570 mm²) Total Ast provided = 4023 mm²

Main reinforcement will provided at outer face

of wall. At inner face provide min.

reinforcement.

Provide 25 mm bar @ spacing of 200mm c/c (Ast provided = 2453 mm²)

58

a) Distribution reinforcement

Provide 0.12 % of gross section as distribution reinforcement and provide half at

each faces. Distribution reinforcement = 0.12 × 1000 × 750/100 = 900 mm²

Reinforcement provided at each face = 900/2 = 450 mm²

Provide 12 mm bar @ spacing 200 mm c/c (Ast provided = 565.2 mm²)

Reinforcement details of box segment is shown in figure below:

59

60

Table 5.7 Schedule of reinforcement

Bar

Nos.

Bar Dia. Spacing Remarks

1 25 mm 200 mm c/c Main reinforcement

2 16 mm 200 mm c/c Curtailed reinforcement

3 16 mm 200 mm c/c Distribution reinforcement slab

4 25 mm 200 mm c/c Wall – inside

5 25 mm 200 mm c/c Wall – outside

5A 20 mm 200 mm c/c Wall – outside

6 20 mm 200 mm c/c Haunch

7 12 mm 200 mm c/c Distribution reinforcement of

slab along the barrel length

8 12 mm 200 mm c/c Distribution reinforcement of

wall along the barrel length

9 12 mm Long. = 200 mm c/c

Trans. = 200 mm c/c

Shear stirrups

10 12 mm Long. = 200 mm c/c

Trans. = 400 mm c/c

Links

DESIGN OF THRUST BED FOR BOX

a) Basic data

Box clear horizontal opening

=

7.5 m

Wall thickness = 0.75 m

Box outer vertical opening = 6.35 m

Box outer horizontal opening = 9.0 m

61

Box inner vertical opening = 5.15 m

Slab thickness = 0.60 m

No. of segment = 2

Size of haunch = 0.5 m

Max. Length of segment = 11.025 m

Length of thrust bed = 13.025 m

No. of pocket = 36

Size of pocket = 0.5 m

Width of thrust bed = 10 m

Proposed cushion = 1.005 m

Depth of thrust bed = 1 m

Coefficient of friction b/w concrete & soil = 0.5

Surcharge angle at top = 0

Earth face angle of box wall = 0

Coefficient of active earth pressure, ka = 0.3085

Coefficient of passive earth pressure, kp = 4.143

Density of soil = 1.8 t/m³

Density of concrete = 2.5 t/m³

No. of key proposed in thrust bed = 2

b) Dead load calculation

Load on top of box

Track load = (0.10503 + 1.026) × 11.025 × 9 = 112.23 t

Earth cushion = 1.8 × 1.005 × 11.025 × 9 = 179.5 t

Total weight on top surface = 112.23 + 179.5 = 291.73

62

Total weight on bottom surface = load on top surface + self-weight of box

Self weight of box c/s area of top & bottom slab = 2 × 0.6 × 9 = 10.8

m^2

c/s area of vertical wall = 2 × 0.75 × 5.15 =

7.725 m^2 c/s area of haunch = 1 m^2

Total c/s area = 19.525 m^2

Weight of box/meter run = 2.5 × 19.525 = 48.8125

t/m Weight of one segment = 48.8125 × 11.025 =

538.157 t

Total weight on bottom surface = load on top surface + self-weight of box

= 291.73 + 538.157

= 829.88 t

c) Earth pressure

Earth pressure at top of box = 0.7246 t/m^2

Earth pressure at bottom of box = 3.917 t/m^2

Therefore, Total earth pressure on wall = 0.5 × (0.7246 + 3.917) × 6.35

= 14.74t/m

Total earth pressure on wall = 14.74 × 11.025 =

162.47 t Force on box segment

On top surface = 291.73 t

On bottom surface = 802.32 t

Earth pressure on two side wall = 2 × 162.47 =

324.94 t Live load of one train = 25 t

Total load = 1443.99 t

63

Coefficient of friction = 0.5

Total jacking force = 0.5 × 1443.99 = 722t

d) Thrust bed and thrust wall

Depth of back thrust wall = 2 m

Depth of front thrust wall = 1.5 m

Thickness of wall = 0.7 m

Depth of key = 0.6 m

Size of pocket = 0.5 m

Width of key = 0.5 m

Weight of thrust bed

Volume of concrete

Thrust bed = 13.025 × 10 × 1 = 130.25 m^3

50 mm Screeding = 13.025 × 10 × 0.05 = 6.5125 m^3

Thrust wall = (2 × 10 × 0.7) + (1.5 × 10 × 0.7) = 24.5 m^3

Key = 2 × 0.5 × 0.6 × 10 = 6 m^3

Pocket = 0.5 × 0.5 × 0.5 × 36 = 4.5 m^3

Total vol. of concrete = 130.25 + 6.5125 + 24.5 + 6 – 4.5 = 163.51

m^3 Total weight of thrust bed = 163.51 × 2.5 = 408.78 t

Resistance offered by bed = 0.5 × 408.78 = 204.4 t

Neglecting friction forces caused by earth pressure on side wall of thrust

bed. Additional resistance required

= 722 – 204.4 = 517.61 t

The additional resistance will be available from thrust wall.

64

e) Passive pressure on thrust wall

a) Passive pressure available from back thrust wall

Passive pressure at above of thrust bed = kp γ H

= 4.143 × 2 × 1.7 = 14.086 t/m^2

Passive pressure at below of thrust bed = kp γ H

= 4.143 × 2 × 3.7 = 30.66 t/m^2

Length = 10 m

Passive resistance on back wall = 2 × 10 = 447.46t

b) Passive pressure of front wall

Passive pressure at above of thrust bed = kp γ H

= 4.143 × 2 × 1 = 8.286 t/m^2

Passive pressure at below of thrust bed = kp γ H

= 4.143 × 2 × 2.5 = 20.715 t/m^2

Resistance on front wall = × 10 = 217.51 t

c) Passive pressure available from keys

Passive pressure at above of thrust bed = kp γ H

= 4.143 × 2 × 1 = 8.286 t/m²

Passive pressure at below of thrust bed = kp γ H

= 4.143 × 2 × 1.6 = 13.257 t/m²

Passive resistance on key = × 0.6 × 10 =

64.63 t Total resistance on key = 2 × 64.63 = 129.26 t

Total passive resistance available = 447.46 + 217.51 + 129.26

= 794.23 t

65

FOS against sliding = = 1.53 > 1.5 Ok

f) Back thrust wall

Passive pressure at above of thrust bed = 14.086 t/m²

Passive pressure at below of thrust bed = 30.66

t/m² Max. BM = 11.18 tm

Ultimate BM = 1.7 × 11.18 = 19.01

tm Max. SF = 25.135 t

Ultimate SF = 1.7 × 25.135 = 42.73 t

g) Front thrust wall

Passive pressure at above of thrust bed = 8.286

t/m² Passive pressure at below of thrust bed =

20.715 t/m² Max. BM = 4.07 tm

Ultimate BM = 1.7 × 4.07 = 6.93 tm

Max. SF = 12.43 t

Ultimate SF = 1.7 × 12.43 = 21.13 t

h) Shear key

Passive pressure at above of thrust bed =

8.826 t/m² Passive pressure at below of thrust

bed = 13.257 t/m² Max. BM = 0.4845 tm

Ultimate BM = 1.7 × 0.4845 = 0.82

tm Max. SF = 3.48 t

Ultimate SF = 1.7 × 3.48 = 5.92 t

66

i) Design of thrust bed (Limit State Method)

Total jacking force required = 722 t

No. of jacks = 5

Hence force per pin = 144.4

t Eccentricity = 0.30 m

Max. Force for thrust bed = 216.6 tm

Factored moment, Mu = 1.7 × 216.6 = 368.22 tm

j) Data available

Ultimate bending moment, Mu = 3682.2

kN-m Ultimate shear force, Vu = 0

Overall depth, D = 1000 mm

Effective clear cover, dc = 50

mm

Permissible stress in concrete, Fck = 30

N/mm² Permissible stress in steel,

Fy = 500 N/mm² Width of slab = 10000mm

k) Calculation

Effective depth provided = Overall depth – Effective cover

= 1000 – 50

Check for effective depth

d =

67

d = 904.58 mm

Effective depth provided > Effective depth required, Ok

Main reinforcement, Ast =

= 11326.36 mm²

Area of steel required per meter = 11326.36/10 = 1132.6 mm²

Provide 20 mm dia. bar @ 250 mm c/c at bottom & 16 mm dia. bar @ 200 mm c/c at top.

l) Distribution reinforcement

Provide 0.12 % of gross section as distribution reinforcement and provide half at

each faces. Distribution reinforcement = 0.12 % of bd

= 0.12 × 1000 × 950/100

= 1140 mm²

Provide half on each face = 1140/2 = 570

mm²

Provide 12 mm dia. bar @ 200 mm c/c (Ast provided = 678.58 mm²)

A) Design of thrust wall (Limit State Method)

a) Data available

Ultimate bending moment, Mu = 190.1

kN-m Ultimate shear force, Vu = 427.3

kN

Overall depth, D = 750 mm

68

Effective clear cover, dc =

50 mm

Permissible stress in concrete, Fck = 30

N/mm² Permissible stress in steel, Fy =

500 N/mm² Width of slab = 1000 mm

b) Calculation

Effective depth = Overall depth – Effective clear cover

= 750 – 50

= 700

mm

Check for effective depth

d =

d = 205.53 mm

Effective depth provided > Effective depth required Ok

Main reinforcement, Ast

= 628.83 mm²

Provide 20 mm dia. bar @ 250 mm c/c (Ast provided = 1256.63 mm²)

b) Distribution reinforcement

69

Provide 0.12 % of gross section as distribution reinforcement and provide half at each

faces. Distribution reinforcement = 0.12 % of bd

= 0.12 × 1000 × 700/100

= 840 mm²

Provide half on each face = 840/2 = 420

mm²

Provide 12 mm dia. bar @ 250 mm c/c (Ast provided = 452.38 mm²)

c) Shear

Percentage of reinforcement, Pt % = × 100 =

Pt % = 0.09 %

Shear stress = = 0.61 N/mm², For M 30 concrete and Pt % = 0.09

τc = 0.29 N/mm²

Depth factor, s = $(500/d)^{.5}$ = $(500/700)^{.5}$ = 0.919

Shear taken by concrete = s × τc × b × d

= 0.919 × 0.29 × 1000 × 700

= 186.62 kN < 427.3 kN

(Shear reinforcement required) Provide 10 mm dia. bar @ 250 mm c/c (Ast provided =

314.16 mm²)

B) Design of Shear key (Limit State Method)

a) Data available

Ultimate bending moment, Mu = 8.2 kN-m

Ultimate shear force, Vu = 59.2 kN

Permissible stress in concrete, Fck = 30

70

N/mm² Permissible stress in steel, Fy = 500

N/mm² Depth of key = 600 mm

Width of slab = 1000 mm

b) Calculation

Effective depth = Overall depth – Effective cover

= 600 – 50

= 550 mm

Check for effective depth

d =

d = 42.68 mm

Effective depth provided > Effective depth required Ok

Main reinforcement, Ast=

= 34.33 mm²

Provide 12 mm dia. bar @ 200 mm c/c (Ast provided = 565.48 mm²)

c) Distribution reinforcement

Provide 0.12 % of gross section as distribution reinforcement and provide half at

each faces. Distribution reinforcement = 0.12 % of bd

= 0.12 × 1000 × 550/100

= 660 mm²

Provide half on each face = 660/2 = 330

mm²

71

Provide 12 mm dia. bar @ 250 mm c/c (Ast provided = 452.38 mm²)

The reinforcement detail of Thrust bed is shown in figure below:

5. CONCLUSIONS AND FUTURE SCOPE OF THE STUDY

Conclusions

From the literature review, it is concluded that the comparison to the years ago technology in construction world was quite developed. So we construct the tunnels and over-bridges using the box culverts very rapid and the cost of construction is less and there is less risk and pushing technology is widely used nowadays and gives very good results of work.

1. With the box pushing technique, there is no interruption to the traffic moving around.
2. Better quality control due to the provision of precast boxes.
3. Quantities will be less as compared to the conventional method of construction.
4. The cost of construction is less as compared with the conventional method.

Future Scope of the Study

1. Above analysis and design was done for present need i.e. design of RUB was done for single rail track. For future design of RUB can be done for two rail tracks or three rail tracks.
2. The present work is done on RCC box but pre-stressed concrete can also be used.

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