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ANALYSIS AND DESIGN OF VEHICULAR UNDERPASS FOR DIFFERENT SPAN ARRANGEMENT SUBJECTED TO MODIFIED IRC LOADING

Sweety R.Nagarkar[1] , Amey Khedikar[2] , Sandeep Gaikwad[3]

[1]M – Tech, [2,3]Assistant Professor, Dept. of Civil Engineering

Tulsiramji Gaikwad-Patil College of Engineering & Technology, Nagpur (India)

ABSTRACT

The Underpass RCC Bridge is very rarely adopted in bridge construction but recently the Underpass RCC Bridge is being used for traffic movement. In this paper, the comparative analysis of the vehicular underpass RCC Bridge is carried out. The analysis of underpass RCC Bridge is done by applying spring constant i.e. modulus of subgrade reaction to the raft, calculated assuming the young's modulus of soil. 2D model is prepared considering unit meter width and comparison is made on the basis of design forces i.e. Bending Moment and Shear Forces. In this study we show a percentage difference in design values for new and old IRC loadings. 2D model can be effectively used for analysis purpose for all the loading condition mentioned in IRC:6-2014, "Standard Specifications and Code of Practice Road Bridges" The Indian Roads Congress.

Keywords-RCC Underpass Bridge, Spring Constants

I INTRODUCTION

The Underpass RCC Bridge is very rarely adopted in bridge construction but recently the Underpass RCC Bridge is being used for traffic movement. Main attribute to the design concept were speedy construction, least disturbance to the traffic during construction, enhanced aesthetics, effective drainage and confortable lighting The vehicular underpass may subjected to road traffic (IRC loading) or train traffic (IRS loading), in this paper underpass is analyzed for IRC loadings (IRC:6-2014).

In this paper 2D analysis of underpass RCC bridge is carried out considering different loading conditions and different loading combinations which are considering from IRC:6-2014, "Standard Specifications And Code Of Practice Road Bridges" The Indian Roads Congress. The analysis of underpass RCC Bridge is done by applying spring constant i.e. modulus of subgrade reaction to the raft, calculated assuming the young's modulus of soil as 3000t/m^2.

1.1 Modeling of system

For the study of Underpass RCC bridge, earth pressure acting on side walls of underpass RCC bridge because structure embedded as well as vertical loading due to imposed load and live load on the top of underpass RCC bridge is considered. Also the impact and braking load corresponding to live load is considered as per IRC:6-2014. As there is a top loading, there is reaction at bottom also. Spring constants are applied to the raft calculated from book Bridge Deck Behavior by E.C. Hambly.

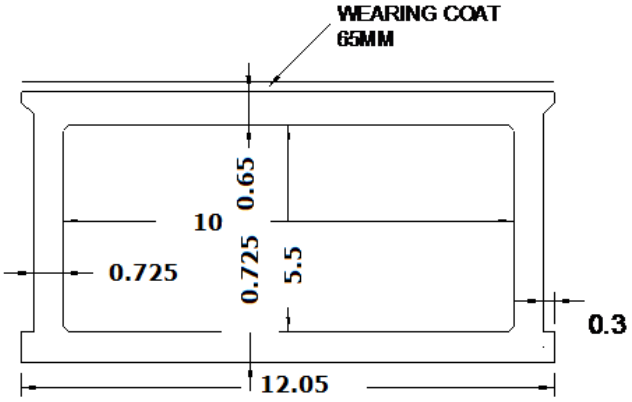

Figure 1: Schematic Diagram of RCC Underpass Bridge

Figure 1 shows the schematic drawing for RCC underpass which is analyzed in STAAD considering different load cases and combinations.

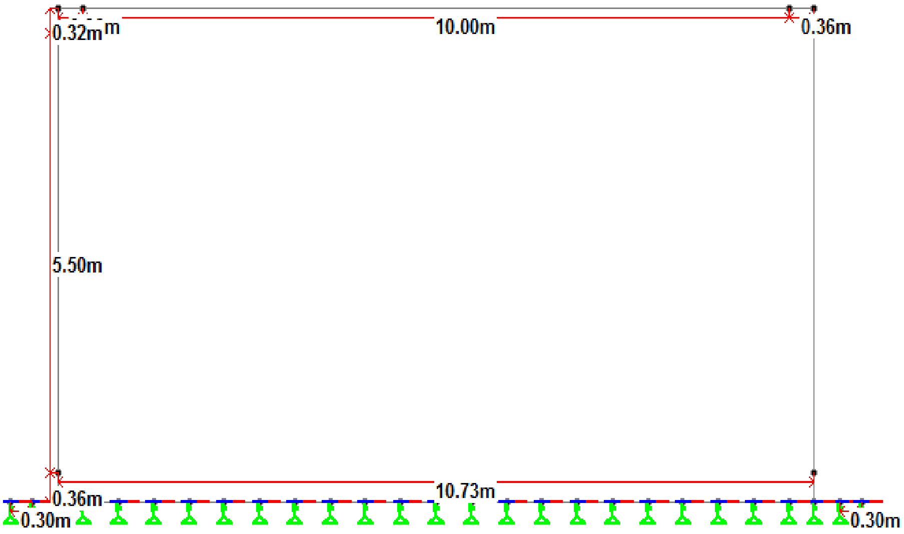

Figure 2: 2D Model of RCC Underpass Bridge

2D underpass RCC bridge model shown in figure 2 is analyzed considering soil structure interaction.

II FORMULATION

2.1 Loads on the top of slab

Total load for bending moment and shear force is considered from IRC code rules specifying the loads for designing the superstructure and substructure of bridges and for assessing the strength of existing bridges.

Dead load of box = Area x thickness x density - - 1.1

Total vertical pressure on top slab = Imposed load + Dead load + Live load - - 1.2

2.2 Loads on sidewalls

The coefficient of active earth pressure of the soil is given by the equation

$$Ka = \frac{\cos^2(\emptyset - \propto)}{\cos^2 \propto \times \cos(\propto + \delta) \times \left(1 + \sqrt{\frac{\sin(\emptyset + \delta) - \sin(\emptyset - i)}{\cos(\alpha - \delta) - \cos(\alpha - i)}}\right)^2} \quad \text{- - } 1.3$$

where,

γ = Density of soil, ϕ = Angle of internal frictional δ= angle of friction between wall and earth fill

Where value of δ is not determined by actual tests, the following values may be assumed.

(i) δ = 1/3 ø for concrete structures.

(ii) δ = 2/3 ø for masonry structures.

i = Angle which the earth surface makes with the horizontal behind the earth retaining structure (*i* =0 0 for embedded structure).

Since this concrete structure is embedded in soil, the value of δ is considered as 1/3 ø (for concrete structures) considered for calculation of coefficient of active earth pressure of the soil.

2.3 Earth pressure acting on the sidewalls:

2.3. a) Earth pressure due to backfill

Earth pressure center of top slab = $Ka \times \gamma \times H$ --1.4

Earth pressure center of bottom slab = $Ka \times \gamma \times H$ --1.5

2.3. b) Earth pressure due to dead load surcharge

Earth pressure acting on sidewalls:

At Top = Imposed load + Earth pressure on the top of slab + Live load --1.6

AT Bottom = Horizontal effect of surcharge + Earth pressure center of bottom slab --1.7

2.4 Reaction at the bottom of box

Self weight of box = Weight of top slab + Weight of bottom slab + Weight of side walls - -1.8

Total reaction at bottom=Self weight of box +Weight of imposed load +Weight of live load - -1.9

The boundary condition considered is fixed.

III ANALYSIS OF 2D UNDERPASS RCC BRIDGE MODEL

A 2D underpass RCC bridge (Figure 2) is modeled considering 1m width for the following details shown below. Box dimensions: 10.725m x 1m x 6.35m (L x W x H) (Center to center). In addition to the dimensions mentioned in Figure 1, following parameters are considered for the 2D analysis. Keeping all the parameters same, the analysis is carried out using STAAD.Pro (V8i) (programming software). The live load position for maximum bending moment at mid-span and at support and shear force at support is worked out by running the live load in STAAD model thought the span. The dispersed load area is calculated as per IRC:112-2011 Annex.B-3. In final model all live load with dispersed load is added with other load in different load combinations as per IRC:6.

Dimension of underpass RCC bridge considered for analysis are

Side wall thickness, = 725mm
Clear height of box, = 5500mm
Clear Span of VUP, , =
Thickness of deck slab, = 650mm
Thickness of base slab, = 725mm
Base slab projection, = 300mm
Thickness of fill over deck = 65mm
Idealised span of cell, = 10725mm L = Clear Span + Dsw
Idealised height of box, H = 5500 + 650 / 2 + 725 /2
=
6187.5mm

Cantilever length of base slab Lc = 300 + 725 /2 = 663mm
Width of super structure b = 8500 mm
(2 lane carriage–way is considered in paper i.e. 7.5m + 0.5m crash barrier on both side)
Thickness of crash barrier = 500mm

The max BM obtained for 2D underpass RCC bridge model considering soil stiffness are shown in Table 1. bending moment diagram for dispersed for 70R Wheeled Vehicle load for 10m span after combining with other load such as DL, earth pressure, Impact, braking is shown in Figure 3 (a) & for 11m span in fig.3 (b)

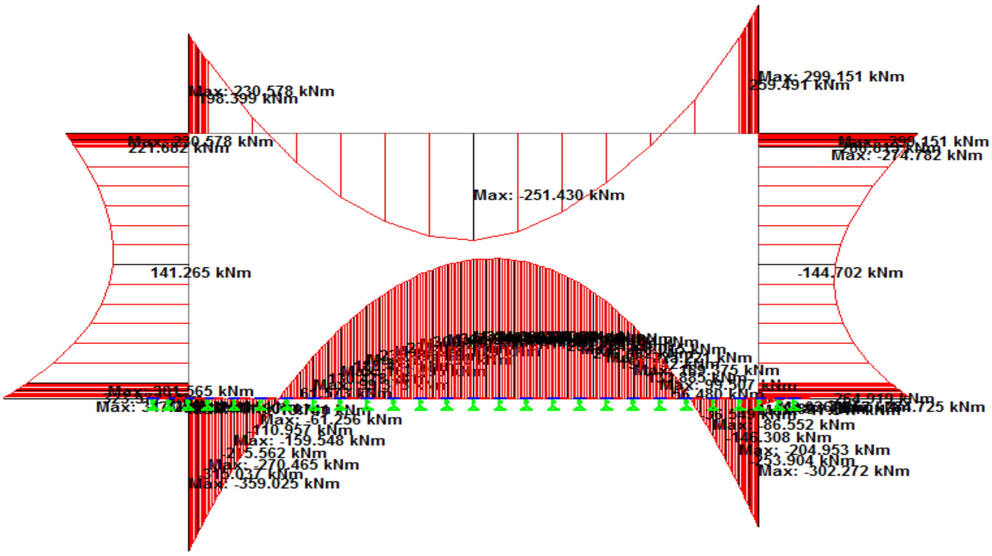

Figure 3: **(a) BMD for 70R Wheeled Vehicle Load(for 10m span)**

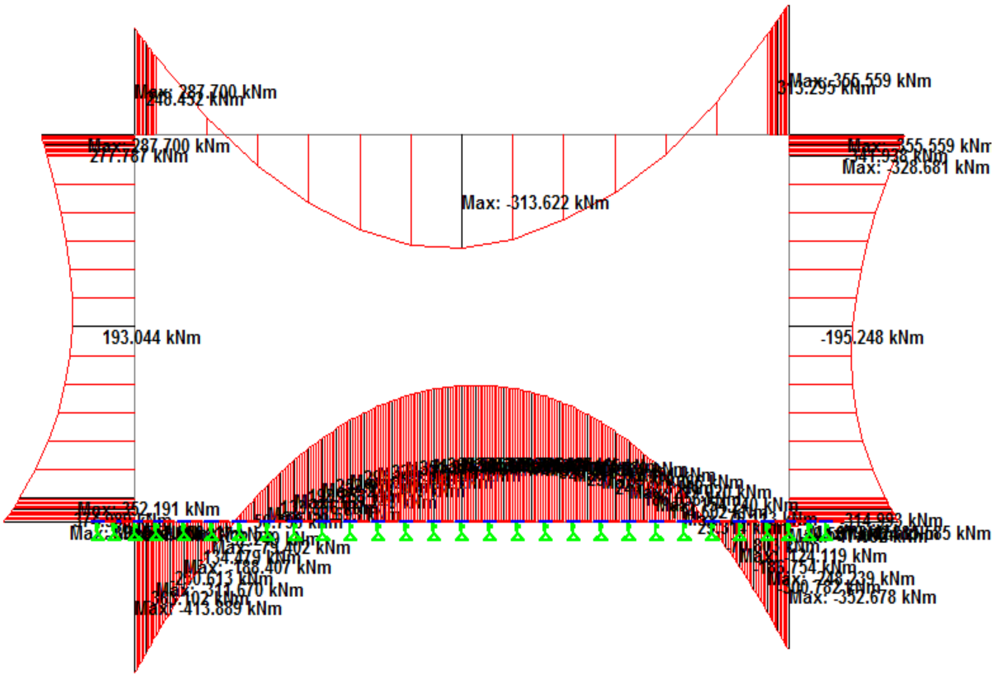

Figure 3: (b) BMD for 70R Wheeled Vehicle Load(for 11m span)

3.1 Validation of results

The bending moment results obtained by slope deflection method and STAAD program for 2 dimensional model of underpass RCC bridge are approximately same. The slight variation of results may be due to the variation of moment of inertia values. Based on this validity of results further analysis of same 2D model for various combinations of loading cases was carried out.

IV COMPARISON OF RESULT OF UNDERPASS RCC BRIDGE MODEL FOR DIFFERENT LIVE LOADS FOE DIFFERENT SPAN ARRANGEMENT

The comparison of the maximum bending moment and shear force values obtained for different live load cases for 2D underpass RCC bridge models which are considered with soil stiffness are compared. The comparison between newly added Special Vehicle with old vehicles such as class A, 70R trains are made and results for 10m span are tabulated in Table and for 11 m span are tabulated in Table 2, for 12 m span are tabulated in Table 3. The values of bending moment and shear force for 2D model for all loading cases and combinations considered for the analysis purpose from IRC: 6-2014, “Standard Specifications and Code of Practice Road Bridges” The Indian Roads Congress.

Table1 :Analytical Results for 10.0m Span Vehicular Underpass

1	2	3	4	5	6	7	8
Member	2 Class A Trains	70R Wheeled Vehicle	70R Tracked Vehicle	70R Boggie Vehicle	Values as per Old IRC Loading (max. of 2,3,4,5)	Values as per New IRC Loading (Special Vehicle)	% Difference (in 6 and 7)
Bending Moment at Mid-Span (KN.m)							
Top Slab	235.91	251.43	239.25	226.87	251.43	249.85	**-0.63**
Raft Slab	278.26	329.28	285.82	264.05	329.28	335.77	**1.94**
Bending Moment at Support (KN.m)							
Top Slab	262.15	302.53	272.58	243.78	302.53	272.00	**-11.22**
Raft Slab	327.64	365.31	352.12	321.69	365.31	340.71	**-7.22**
Side Wall	314.32	352.11	335.71	306.42	352.11	325.39	**-8.21**
Shear Force (KN)							
Top Slab	174.90	224.50	214.50	190.80	224.50	213.70	**-5.05**
Raft Slab	237.60	271.70	265.80	246.40	271.70	269.00	**-1.00**
Side Wall	136.70	135.00	137.60	137.30	137.60	124.80	**-10.26**

Table 2 :Analytical Results for 11.0m Span Vehicular Underpass

1	2	3	4	5	6	7	8
Member	2 Class A Trains	70R Wheeled Vehicle	70R Tracked Vehicle	70R Boggie Vehicle	Values as per Old IRC Loading (max. of 2,3,4,5)	Values as per New IRC Loading (Special Vehicle)	% Difference (in 6 and 7)
Bending Moment at Mid-Span (KN.m)							
Top Slab	293.06	313.62	295.35	278.83	313.62	311.89	**-0.56**
Raft Slab	326.86	371.23	319.77	306.97	371.23	382.57	**2.97**
Bending Moment at Support (KN.m)							
Top Slab	308.41	355.56	317.39	284.02	355.56	324.55	**-9.55**
Raft Slab	384.23	414.57	382.59	371.96	414.57	394.57	**-5.07**

Side Wall	369.97	399.86	367.34	355.67	399.86	378.38	**-5.68**
Shear Force (KN)							
Top Slab	194.80	246.90	202.30	208.90	246.90	237.20	**-4.09**
Raft Slab	259.60	394.50	263.50	266.40	394.50	291.90	**-35.15**
Side Wall	140.50	137.10	136.90	141.00	141.00	126.70	**-11.29**

Table 3 :Analytical Results for 12.0m Span Vehicular Underpass

1	2	3	4	5	6	7	8
Member	2 Class A Trains	70R Wheeled Vehicle	70R Tracked Vehicle	70R Boggie Vehicle	Values as per Old IRC Loading (max. of 2,3,4,5)	Values as per New IRC Loading (Special Vehicle)	% Difference (in 6 and 7)
Bending Moment at Mid-Span (KN.m)							
Top Slab	336.53	360.48	337.60	318.56	360.48	359.78	**-0.19**
Raft Slab	381.32	422.45	369.79	357.71	422.45	449.74	**6.07**
Bending Moment at Support (KN.m)							
Top Slab	373.20	424.76	373.48	338.02	424.76	396.76	**-7.06**
Raft Slab	450.72	470.78	445.57	432.53	470.78	470.67	**-0.02**
Side Wall	435.05	454.96	428.78	414.84	454.96	452.21	**-0.61**
Shear Force (KN)							
Top Slab	211.90	265.90	219.60	224.60	265.90	258.60	**-2.82**
Raft Slab	282.00	318.30	285.80	287.70	318.30	318.90	**0.19**
Side Wall	143.60	138.40	139.60	144.30	144.30	128.40	**-12.38**

V CONCLUSIONS

From the results, it is seen that the design values by Old IRC loading (i.e. max of 2 Trains of Class A Vehicle, 70R Wheeled Vehicle. 70R Tracked Vehicle, 70R Boggie Vehicle) are comparatively higher than that of Special Vehicle. So it can be concluded for 10 m to 12.0m span the special vehicle can move safely from all Vehicular Underpass which are designed for old IRC vehicle loading.

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