ANALYSIS AND DESIGN OF RAILWAY BOX BRIDGE AND COMPARISON BETWEEN STAAD SOFTWARE AND MDM RESULTS

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***ABSTRACT*: Bridges are the structural components that are required for the efficient movement of Trains and locomotives and under earth embankment for crossing of water course like streams across the embankment as road embankment cannot be allowed to obstruct the natural water way. Bridges can be of different shapes such as arch, slab and box. These can be constructed with different material such as masonry (brick, stone etc.) or reinforced cement concrete. Since bridge pass through the earthen embankment, these are subjected to same traffic loads as the road carries and therefore, required to be designed for such loads. The cushion depends on rail profile at the bridge location. The structural design involves consideration of load cases (box empty, full, surcharge loads etc.) and factors like live load, effective width, braking force, dispersal of load through fill, impact factor, co-efficient of earth pressure etc. Relevant IRCs are required to be referred. The structural elements are required to be designed to withstand maximum bending moment and shear force. This paper provides discussions on the provisions in the Codes, considerations and justification of all the above aspects on design. The box bridge can be analysed either by Software or Computational methods. So it is necessary to study the effectiveness of results obtained from both the methods.**

KEYWORDS*: *Railway minor Bridge, Box Bridge, Analysis and design of Box Bridge

1. INTRODUCTION

A bridge is a structure providing passage over an obstacle without closing the way beneath. The required passage may be for a road, a railway, pedestrians, a canal or a pipeline. The obstacle to be crossed may be a river, a road, railway or a valley. In other words, bridge is a structure for carrying the road traffic or other moving loads over a depression or obstruction such as channel, road or railway. A bridge is an arrangement made to cross an obstacle in the form of a low ground or a stream or a river without closing the way beneath.
Bridges constitute an essential link of a Railway system. There were 127154 bridges on Indian Railways system as on 31 March 2002. A large number of these bridges are between 80 to 100 years old, and were constructed to handle the lighter standard of loading then prevalent. Indian Railways has seen a tremendous growth in both freight and passenger traffic since the construction of these bridges. From an originating traffic of 93 million tonnes in the early 50s, it has reached 522 million tonnes in 2001-2002. Similarly, passenger traffic has increased from 67 billion passenger kilometres to over 493 billion passenger kilometres. With the introduction of heavier axle loads and higher speeds, clubbed with aging and fatigue, bridges need special attention and care, including rehabilitation where warranted, so as to ensure safety of rail traffic. Any damage to a bridge may take considerable time for repairs and the financial implications may also be quite severe on account of high cost of repairs and interruptions to traffic. Greater emphasis on maintenance, proper and regular upkeep is, therefore, imperative for trouble-free existence of these bridges.
A culvert is defined in the Standard Specifications as any structure, whether of single or multiple-span construction, with an interior width of 6.096 m (20 ft.) or less when the measurement is made horizontally along the centre line of the roadway from face-to-face of abutments or sidewalls.

2. WHY BOX BRIDGE

Box Bridge which has got its name due to its orientation, shape and the way through which it looks like and its appearance defines its name. Box Bridge is a structure which provided the flexibility for the designer to design it in a very easy way, which is very feasible and easy to construct and design. It is highly capable for taking heavy loads coming on it from upper side without producing any cracks to it and is capable to distribute these loads to a wider area. Foundation requirement is very less and only little bit soil treatment will be required in case if the site consists of a soil having low bearing capacity and soil treatment required to be done as preferred by the site engineer.

FOUR SIDED BOX BRIDGE THREE SIDED BOX BRIDGE

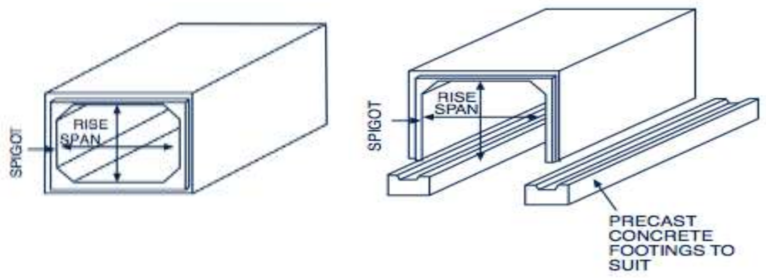


Figure 1: Box Bridge

Two or more lines of box Bridge may be placed side by side to create a twin barrel or multi-barrel installation. A multi-barrel installation provides additional flow capacity, which may be required for larger streams.

3. OBJECTIVES

- Conceptualization of entire Project.
- Evaluation of various bridge parameters as per IRS codes and RDSO(Research Designs and Standards Organization) drawings.
- To analyzeR.C.C box bridge by using STAAD pro software and MDM.
- Comparison of analysis from STAAD pro and MDM to observed that which method is more competent.
- To Design all structural elements of box bridge.
- To check safety of bridge

4. METHODOLOGY

- Analysis and design by STAAD pro.
- Analysis method adopted for RCC box is MDM (Moment Distribution Method).
- Designing Box Bridge considering LSM.

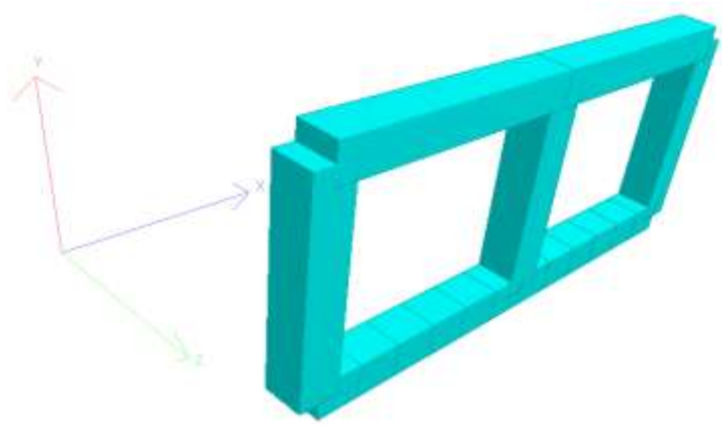
Various cases those are to be generally adopted for designing:
Case 1: Dead load and live load acting from outside as well as earth pressure, while no water pressure from inside (i.e. Design of Box Bridge by considering the box as in empty conditions, no water will flow from it)
Case 2: Dead load and live load acting from outside as well as earth pressure, while water pressure acting from inside (i.e. designing the by considering that it is half full)
Case 3: Dead load and live load acting from outside as well as earth pressure, while water pressure acting from inside (i.e. designing the box by considering that it is full.
Considering case one, as it is the worst possible case for designing bridge.
Serviceability Limit State– For the limitations given in 10.2.1.load combination only shall be considered. For the stress limitations given in 10.2.2, load combinations 1 to 5 shall be considered. The value of Y_{fL} for creep and shrinkage of concrete and prestressed (including secondary effects in statically indeterminate structures) shall be taken as 1.0.

Ultimate Limit State– To check the provisions of 10.3 load combinations 1 to 4 shall be considered. The value of YfL for the effects of shrinkage and, where relevant, of creep
shall be taken as 1.2. In calculating the resistance of members to vertical shear and torsion YfL for the prestressing force shall be taken as 1.15 where it adversely affects the resistance and 0.87 in other cases. In calculating secondary effects in statically indeterminate structures YfL for prestressing force may be taken as 1.0.

5. GEOMETRY AS PER GENERAL ARRANGEMENT DRAWING (GAD)

All the dimensions that have been decided for the designing of a bridge are as follows:

1. R.C.C. twin box
   Where
   - No. of Boxes= 2
   - Barrel length= 6m for both boxes
2. Internal height is of 6m.
3. Ballast Retainer height is 1.2m.
4. Ballast cushion height will be 0.4m for Broad gauge as per Bridge Manual.
5. Soil fill will be of 1m.
6. Bottom and Top slab thickness= 1m
7. Side wall thickness= 0.9m
8. Concrete grade= M35
9. Steel grade= Fe500



3D Rendering View

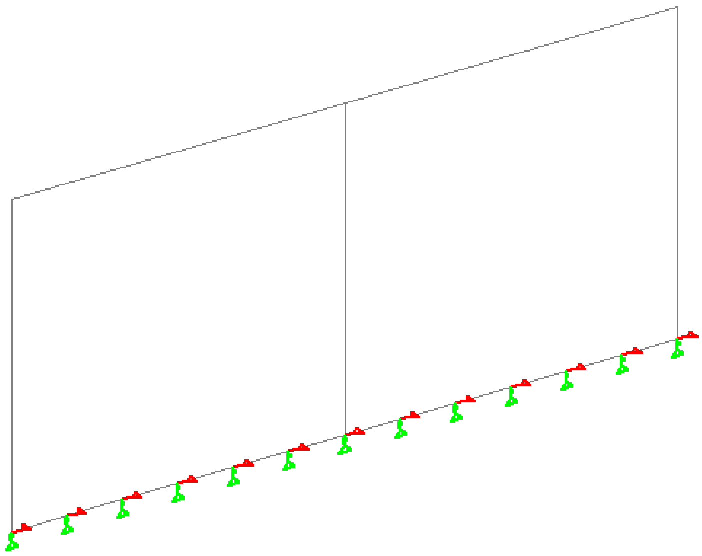


Figure 2: STAAD Modal

6. CODAL PROVISION

The values of loads and Combinations as given in IRS Bridge rules shall be taken as characteristic loads for the purpose of loading calculation. Creep and shrinkage of concrete and prestressed (including secondary effects in statically in-determinate structures) are load effects associated with the nature of structural material being used; where they occur, they shall be regarded as permanent loads.

Combinations of loads – (IRS code of plain, reinforced and prestressed concrete clause no 11.2)
Following five combinations of loads are considered.
Combinations 1– The permanent loads i.e. dead load, superimposed loads etc. together with the appropriate live loads.
Combinations 2– The load to be considered are the loads in combination 1, together with those due to wind/earthquake, and where erection is being considered temporary erection loads.
Combinations 3–The load to be considered are the loads in combination 1, together with those arising from restraint due to the effect of temperature range and difference and where erection is being considered temporary erection loads.
Combinations 4– The load to be considered are the permanent loads, together with the loads due to friction at bearings.
Combinations 5- Dead load, superimposed dead load, together with derailment loads.

For design process only combination 1 is considered as per IRS code of plain, reinforced and prestressed concrete clause no 11.2.1.1
Partial Load Factors – The factors by which the design loads are obtained from the characteristic loads are specified below Design loads, Q are the loads obtained by multiplying the characteristics load, Qk by Yfl the partial safety factor for loads which takes into account the following:-

1. Possible unfavourable deviations of the loads from their characteristic values.
2. Inaccurate assessment of the loading, unforeseen stress distribution in the structure and variation in dimensional accuracy achieved in construction.
3. Reduced probability that various loads acting together will all attain their characteristic values simultaneously.

7. LOAD CALCULATION FOR STAAD ANALYSIS

Size of RCC Box Bridge =3m (Formation width) x14.7m (Length) x 8m (Height)
(Outer to outer dimension)
Design span of Bridge = 14.7 m (clear)
Thickness of Raft Assumed =1m
Thickness of Side walls =0.9m
Thickness of Deck slab =1m
Span c/c = 6.9m (Outer span)
Height of Box c/c = 7m
Width of load dispersion B = 3m (For Live load due train)
Width of load dispersion B1 =3m (For SIDL due self-weight of rails)
Live load consider =25 t loading ballast)

LOAD 1:- Dead Load
For Top and bottom Slab: b x d x γ =25KN/m
For Side walls and Intermediate Walls = b x d x γ=150KN/m
Total Dead load of a structure = (2x75) + (3x450) = 500 KN/m

LOAD 2:- Super Imposed Dead Load (SIDL)
Load of Rails, ballast etc. = 60kN/m
SIDL / m =20 KN/m2
UDL = 20kN/m

LOAD 3:- Live Load (as per IRS, BR, Appendix XII(a))
CDA factor = 0.15 + 8 / (6+L) = 0.7702
EUDL for Bending Moment
Cushion =400 mm

L	EUDL
6	839
6.9	920.09
7	929.1

EUDL (B M) =920.09kN
Load / m^2 =44.449 KN/m2
Consider 1 m width load = 44.449 KN/m
UDL with CDA factor = 78.681 KN/m
EUDL for Shear Force
Cushion = 400mm

L	EUDL
6	937.6
6.9	1006.27
7	1013.9

EUDL (SF) =1006.27kN
Load / m2 = 48.612kN/m2
Consider 1 m width load =48.612kN/m
UDL with CDA factor =86.051kN/m

LOAD 4:-Earth Pressure EP (As per IRS, BS&FC, and clause no 5.7)
Density of soil =18kN/m3
Design height =7m

$$Ka = \frac{\cos^2(\phi - \alpha)}{\cos^2\alpha \times \cos(\alpha + \delta) \times \left(1 + \sqrt{\frac{\sin(\phi + \delta) - \sin(\phi - i)}{\cos(\alpha - \delta) - \cos(\alpha - i)}}\right)^2}$$

φ	=	30	deg	0.524	rad
δ	=	10	deg	0.175	rad
α	=	0	deg	0.000	rad
i	=	0	deg	0.000	rad

Ka = 0.472
Triangular Earth pressure =59.524kN/m on side wall @ Base

LOAD 6:- Surcharge Load Due to Earth Filling (Formation)

This Load is Under EP
Height of Surcharge load =1m
Load on Deck slab =18kN/m2
Load / m =18kN/m
(1 m width)

Load Combinations
CASE I) For Live Load Due to Moving Train
Load Combination 1 (Ultimate Limit State, ULS)
1.4 DL + 2 SIDL + 1.7 EP+1.7SURCH + 2 LL
Load Combination 1 (Serviceability of Limit State, SLS)
1DL + 1.2 SIDL + 1 EP+1SURCH + 1.1 LL

8. DESIGN SUMMARY

a) Base Raft:

Table 1: Design Summary for Base Raft

Thik of Raft	1000 mm	
Longitudinal Steel	**@Top**	
	25 Φ	125mm c/c
	@Bottom	
	25Φ	100 mm c/c
Transverse Steel	**@Top and Bottom**	
(Distribution Steel)	12Φ	100mm c/c
Links	10Φ	175mm c/c
	in both direction	

b) Side Wall:

Table 2: Design Summary for Side Wall

Thik of Wall	900 mm	
Vertical Steel	**@Inner Face**	
	20 Φ	200mm c/c
	@Outer Face	
	20Φ	200 mm c/c
Horizontal Steel	**@Both Sides**	
(Distribution Steel)	20Φ	200mm c/c
Links	10Φ	200mm c/c
	in both direction	

c) Deck Slab:

Table 3: Design Summary for Deck Slab

Thik of Slab	1000 mm		
Longitudinal Steel	**@Top (support)**		**@Top (Mid)**
	25Φ	100mm c/c	25Φ @ 200mm c/c
	@Bottom		
	20Φ	100 mm c/c	

Transverse Steel	**@Top & Bottom**		
(Distribution Steel)	12Φ	100mm c/c	
Links	10Φ	175mm c/c	
	in both direction		

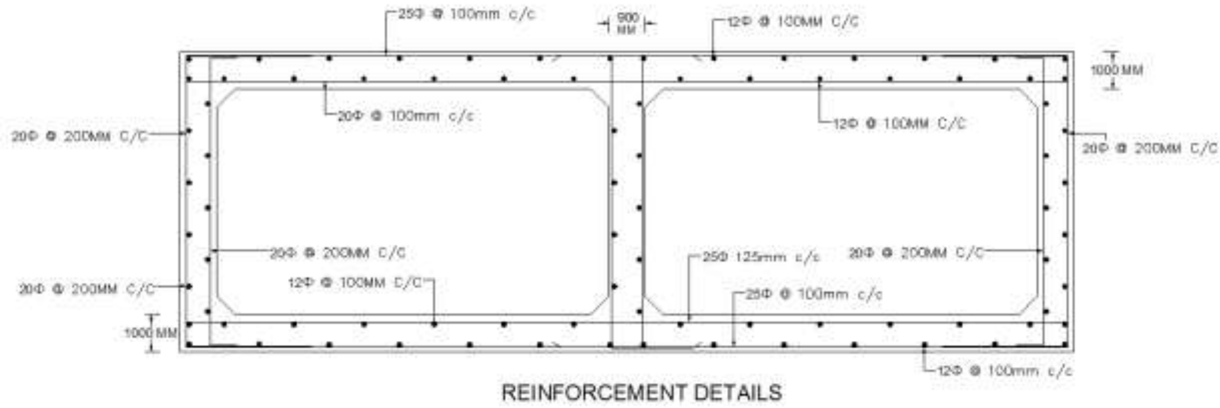


Figure 3: Reinforcement Details

9. COMPARISON BETWEEN STAAD AND MDM RESULTS

For Deck Slab:

Position	STAAD Values (KN-m)	MDM values (KN-m)
At Support	670.703	166.165
At Mid Span	796.48	554.46

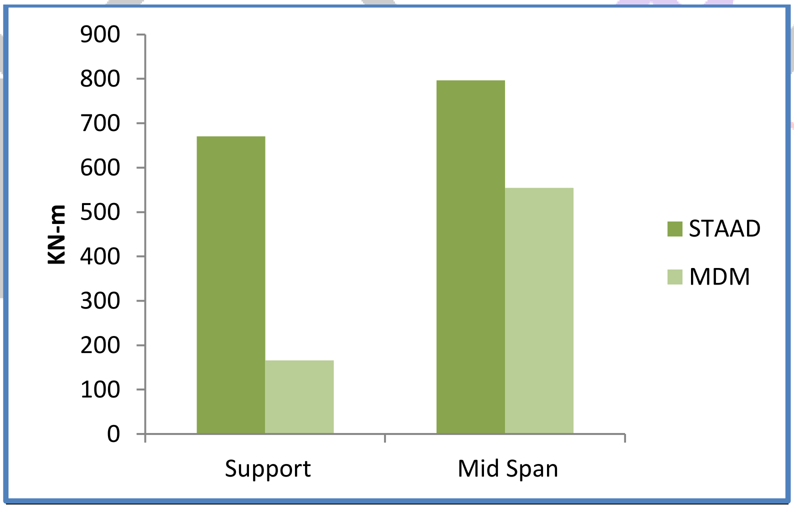


Figure 4: Comparison of STAAD and MDM results for Deck Slab

For Side walls:

Position	STAAD Values (KN-m)	MDM values (KN-m)
At Top	346.389	166.165
At Base	471.968	308.074
At Mid	35.199	-

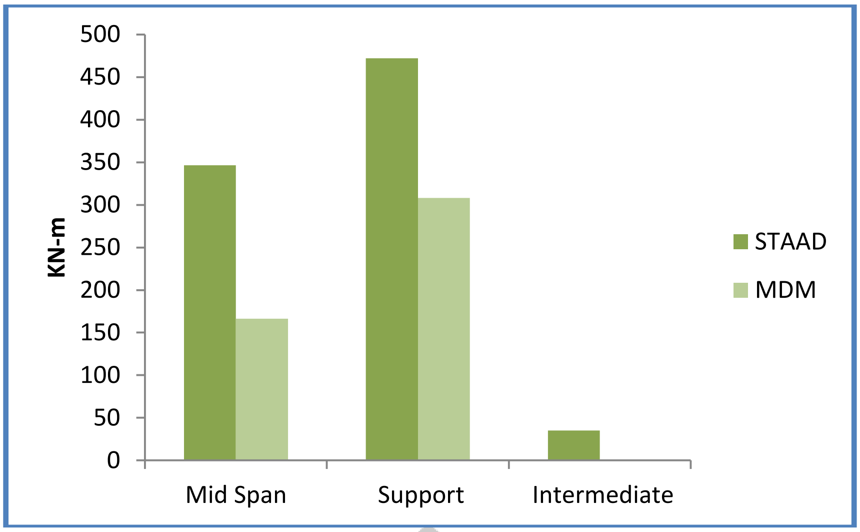


Figure 5: Comparison of STAAD and MDM results for Side Walls

For Base Raft:

Position	STAAD Values (KN-m)	MDM values (KN-m)
At mid span	121.741	-
At support	828.751	308.074
At Intermediate	770.687	802.278

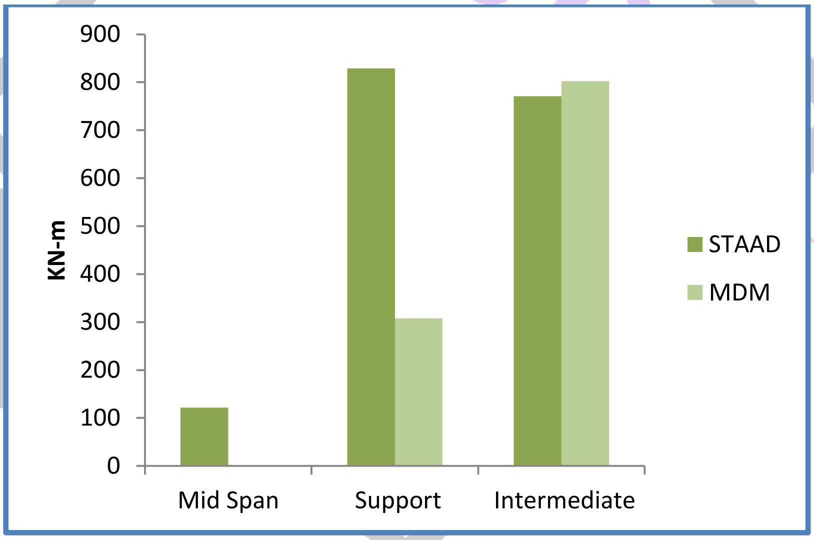


Figure 6: Comparison of STAAD and MDM results for Base Raft

10. CONCLUSION

- All the structural components are analyzed by using STAAD Pro software.
- Structure is manually analyzed by MDM method.
- Design is completed by using Ultimate Limit State method and Serviceability Limit State method.
- From above it can be observed that STAAD Pro software is much more competent than MDM.
- The dimension of a bridge plays a governing role for the involvement of various loads and there cases for the designing purpose.
- It is found that for designing any railway bridge relevant IRS codes are to be very meticulously followed.

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