"STUDY & IMPROVEMENT OF DESIGN AND CONSTRUCTION METHODOLOGY OF PRECAST CONCRETE SEGMENTAL BOX CULVERT (PCSBC)"

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Abstract - *Bridges in today's era play an important role in transportation and connecting the important points of the road. Sometimes due to typical topography and site conditions, it is important to provide the structures through rivers/nala, which avoids obstruction to natural flow of water; such structures are most popularly known as bridges and culverts depending on their span arrangements. The rate of flow through the river is an important factor in the design of major, minor bridges and culverts. The present study is based on the design of precast box culvert by considering total six alternative design modules using fixed and hinged end conditions at top and bottom slab of single & double box cell in order to arrive at the optimum design of components of box culvert.*

Key Words: **Box Culvert, discharge, design modules, optimum section, economy.**

1. INTRODUCTION

It is observed that the construction of small culverts and minor bridges involve large scale planning, diversion roads, labour mobilization and machinery transport from one place to other. The number of these structures to be constructed for particular stretch of road project is alarming in comparison to major structures such as major bridges, grade separator, Rail over bridges, tunnel etc.
The quantity of construction material and process involved in comparatively less however shifting of material, machinery, formwork from one place to another consumes sizeable time and expenditure. More over at each location of construction, the diversion roads are to be provided for duration of construction of such structure which is again costly and hazardous from safety point of view. Repetitive diversion roads also result in to inconvenience to moving traffic for entire period of construction. It is therefore essential to minimize the period of construction, avoid repetitive transportation of labour, material and machinery from place to place and improve quality control on construction. Precast concrete segmental box culverts are one of the most versatile, cost effective, time saving and quality construction process for such type of repetitive construction elements. The process involves the casting of segmental box elements based on detail designs, curing in the casting yard, transporting the precast segments to the various construction sites, lifting and launching the segments and assembling in place at site. Connecting and jointing various elements together properly by cross prestressing if required and completing other components such as cut off walls, aprons, quadrant pitching, railing approaches etc.

Precast concrete box culvert segments can be manufactured in the yard and delivered captive or commercially as a finished section of required shape and modules as per designs and standards of construction. If the length and internal size of box cell is more, then it poses problem in hauling, lighting and placing. It is therefore essential to evolve various shapes and joints so that these sections can be easily transported and assembled at work sites. Various types of segments are tried and alternative designs are worked out by changing the end condition and shapes of the segments.

Following alternative segments with joints at alternative location are tried. Structural designs are carried out for each type of segment with various end condition as under.

[1] Single box cell with all rigid joint.
[2] Single box cell with bottom slab and detached inverted U-section of top slab & side walls with hinge joint at bottom.
[3] Single box cell with top slab and detached U-section of bottom slab & side walls with hinge joint at top.
[4] Double box cell with all rigid joint.
[5] Double box cell with bottom slab and detached inverted U-section of top slab & side walls with hinge joint at bottom.
[6] Double box cell with top slab and detached U-section of bottom slab & side walls with hinge joint at top.
[7]

2. CASE STUDY

Following parameters are used for designing of box cell with end conditions.

[1] Span Arrangement - Single cell – 1x5.0mx4.0m & Double Cell – 2x2.5mx4.0m
[2] Total width of structure – 12.0m
[3] Carriageway width – 11.0m
[4] Width of Crash barrier – 0.50m
[5] Thickness of wearing coat –65mm (40mm Bituminous Concrete + 25mm Mastic Asphalt)
[6] Coefficient of earth pressure – 0.50
[7] Grade of concrete – M30
[8] Grade of steel – Fe500
Section properties – The centerlines of top slab, side walls and bottom slab are used for computing section properties and for dimensional analysis. Standard fillets which are not required for moment or shear or both shall not be considered in computing section properties.
[9] Modules of subgrade reaction – Box Culvert is modeled and analysed in STAAD Pro software as a 3D model. Bottom slab is divided into equal parts and spring support is provided at base of slab and soil spring stiffness is provided as per "Foundation Analysis and Design" by Joseph E.Bowles.

$$Ks = 40 \times SF \times qo$$

Where,
SF = Factor of safety = 2.50,
q_o= Safe bearing capacity of soil

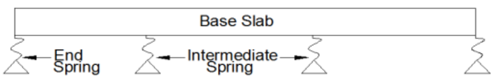

Fig.1-Modules of sub grade reaction & spring stiffness

[10] Dead Loads - The design loading for the box cell has been considered in accordance with IRC: 6 -2016 (Loads and Stresses), so as to sustain the most critical combinations of various loads, forces and stress.
Total dead load includes self-weight, weight of wearing coat and crash barrier.
[11] Live Load Surcharge - As per IRC 6:2016, clause 214.1.1.3, live load surcharge at a height of 1.2 m is considered. The live load surcharge is considered at both sides of box for maximum bending moments.

$$\Delta = k_o \times \gamma \times h$$

Where, k_o = Coefficient of earth pressure

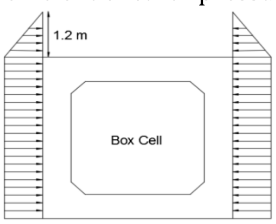

Fig.2-Live load surcharge at both sides

[12] Earth Pressure Loads –For calculating the earth pressure on side walls, five soil conditions are used which are as under.
Moist condition, Dry condition, Saturated condition, Submerged condition and Partially submerged condition.

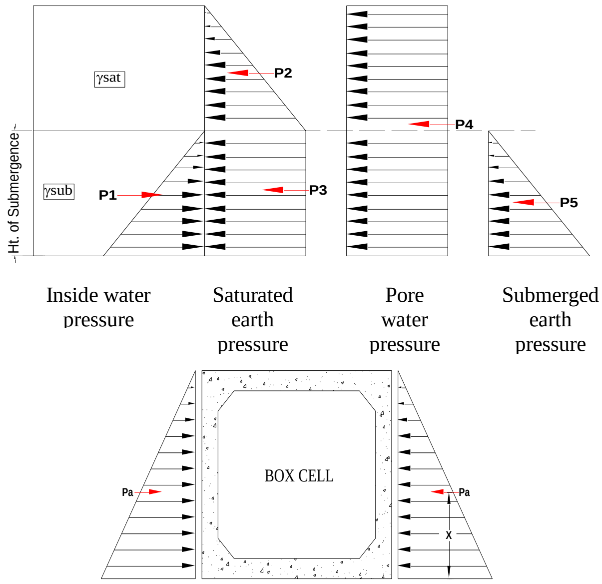

Fig.3- Earth Pressure at side wall in Partially Submerged condition

[13] Live Loads – For analysis of 3D model, wheel loads are taken. The following live loads are considered for the design.

Case I - IRC Class A-1 Lane + Class 70R – wheeled vehicle
Case II - IRC Class A-3 Lanes
As per IRC: 112:2011, the dispersion of loads through fills and wearing coat shall be assumed at 45 degree both along transverse and longitudinal direction. Length of dispersion of load is calculated by equation, wtd = B+2(Dd + t)
Where,
wtd = Length of dispersion
B = Tire contact length
D = Top slab thickness
t = Fill over slab including wearing coat

As per IRC:6-2016/ Table no. B.2, three combinations are used i.e. Basic, Rare & Quasi combination. Basic Combination is used for verification of structural strength whereas, Rare & Quasi Combination are used for verification of serviceability of limit state.

3. OPTIMUM SECTIONS

On the basis of software analysis & above design considerations, optimum sections of box cell with various end conditions are as given in table 1.

Table: 1- Optimum section of box culvert

Sr. No.	Type of box cell with end conditions	Thickness of section (m)		
		Top Slab	Bottom Slab	Side Wall / Middle wall
1	Single box cell with all rigid joint.	0.40	0.50	0.25
2	Single box cell with hinge joint at bottom.	0.40	0.55	0.25
3	Single box cell with with hinge joint at top.	0.45	0.40	0.25
4	Double box cell with all rigid joint.	0.20	0.25	0.15
5	Double box cell with with hinge joint at bottom.	0.30	0.25	0.15
6	Double box cell with hinge joint at top.	0.35	0.25	0.15

4. RESULT & INTERPRETATION

The analysis has been carried out by choosing suitable resultant actions such as maximum bending moment, shear force and principal stressed in all the alternative designs chosen so far. Fig. 4 shows the variation of the bending moment in all six alternative designs considered so far. It has been observed that the values of the design bending moment in top and bottom slab is found to increase in case of single box cell with various end conditions and decrease in case of double box cell with all rigid joint.

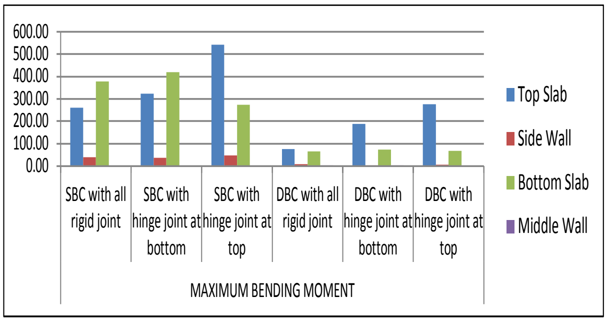

Fig.4- Comparative bending moment of optimum section of box cell with end conditions

Moreover, Fig. 5 shows the variation of shear force of all components of box culvert. It has been observed that Maximum shear force values of top and bottom slab in single box cell with all rigid joint type are maximum in comparison to other type of box cell. Plate shear stress on X-face in top slab is maximum in case of double box cell with hinge joint at top and in bottom slab is found to be maximum in single box cell with hinge joint at top. Plate shear stress on Y-face in top slab is found to be maximum in case of double box cell with hinge joint at top and in bottom slab is maximum in double box cell with hinge joint at bottom.

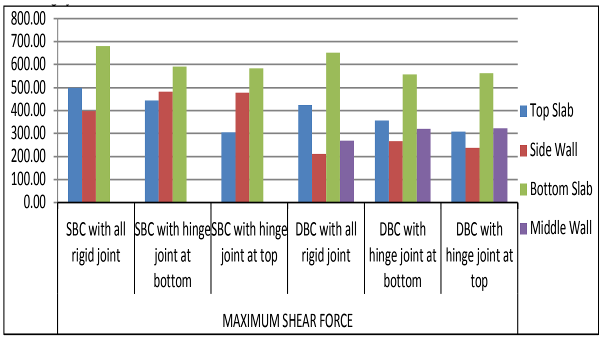

Fig.5- Comparative shear force of optimum section of box cell with end conditions

Fig. 6 shows the variation of principal stress in the optimum section of box cell, it has been observed that that principal stresses is maximum in top slab in Single box cell & double box cell when hinge joint at top, and minimum at top slab of single box cell with all rigid joint.

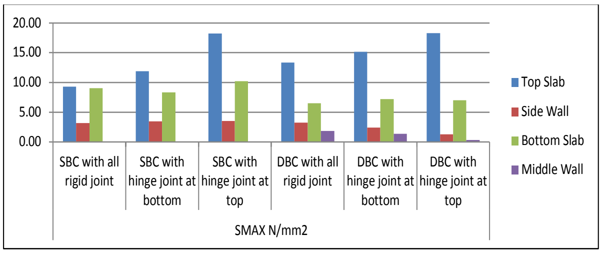

Fig.6- Comparative maximum principal stress of optimum section of box cell with end conditions

Lastly an analysis has been carried out in order to compare the cost of each design unit considering all the stresses, all the practical aspects such as handling, transportation and erection. It has been found that transportation cost is least in case of double box cell with hinge joint at top and bottom. Fig. 7 shows the cost comparison of various alternatives considered so far.

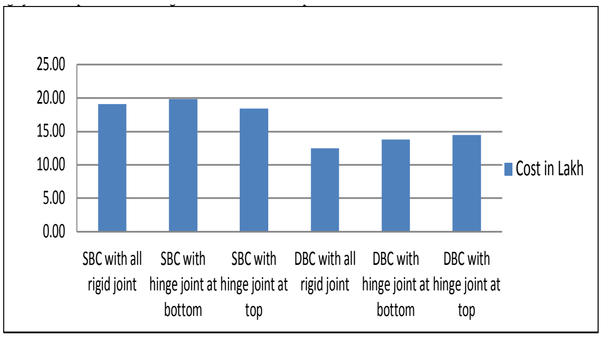

Fig.7- Comparative costing optimum section of box cell with end conditions

5. CONCLUSION

The main objectives of this paper is to compare various modules, establish the various end conditions by providing joints at different location and minimize the handling & transpiration cost and to arrive at the economical and practical precast element for ease of construction at sites. Modeling and analysis has been done by using STAAD Pro software. So from analysis and design we concluded that,

1. Double box cell with all rigid joint is one of the most economical module.

2. Handling and transportation cost will be minimum in case of double box cell with hinge joint at bottom as well as double box cell with hinge joint at top.

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