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Comparative Analysis and Design of Box Culvert by Using LSM and WSM

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ABSTRACT-Box culverts are the monolithic structure made to pass across a roadway, railway lines etc. Embankments are used to balance the flood water on both sides. Box takes various types of loads generated by water, traffic, cushion, soil etc. As per standard practice bridges (Short Span less than 6M) were designed by IRC: 6 – 2000 & IRC: 21 – 2000. Both the codes were based upon Working Stress Method. But IRC has revised IRC: 6 – 2000 as IRC: 6 – 2014 and published a new code IRC: 112 - 2011 for bridges design. These are based upon the Limit State Method. In the present study using these codes a RCC Box Culvert of 4M span & height is analyzed & designed with WSM approach as well as LSM approach. A MS – Excel sheet is also developed by manual calculation for the same. Results of manual analysis, MS – Excel sheet & Staad Pro are compared for design the problem. The Design based on both the approaches WSM & LSM are also compared & a parametric study is carried out by keeping Steel Grade as constant with different Grade of Concrete and finding the % reduction in Steel Reinforcement as well as % reduction in section dimensions due to LSM approach over WSM approach. This study will eventually comment on the design philosophy LSM & WSM regarding the design of RCC Box Culvert and discussed which one will perform better economically as well as structurally. The developed MS – Excel tool is user friendly, error free & fast for convenient-application for the RCC Box Culvert Design.

- To design the box culvert we have to analyse with the help of, in Bentley STAAD-PRO V8i.
- Modelling and analyse for different loading condition three analysis mentioned above using Staad Pro.
- software is done and the results so obtained are compared.
- Study of different IRC Codes which are useful during calculations.
- IRC-6-2017 for load calculation, IRC-112-2019, IRC-SP-13, IRC-21-2000.
- Design the box culvert manually on Ms-Excel according to WSM and LSM and Compare the result.

KEYWORDS: RCC Box Culvert, Limit State Method, Working Stress Method, IRC, STAAD PRO

I. INTRODUCTION

1.1 BACKGROUND OF THE STUDY

Box culverts are low rise bridge or structure which is used to discharge water in the proper channel in crossing of railway, flyover, roads etc. and is used where the bearing capacity of soil is low. Culverts are always economical than bridge where the discharge in the opening is 18 m² it depends on the number of cells which is generally used where roadway crosses the high embankment. Box culverts are generally cast in situ in India, but in other countries the box culverts are preferred due to low cost and economically with having fast workmanship. The box is just name given for its shape, can be found in various types of shapes and also it can be act as minor bridge when the number of cells increases and span greater than 6m in length. Its height depends on span. It can control all water coming from irrigation, surface water, river and canals they control all the storm water and flood water during rainy season.

Box culvert is one of the type of culvert that provide passage of traffic movement over an opening without closing of it and consisting a rectangular or square opening whose span and height of side walls is limited to 4m. It is suitable

where the bearing capacity of soil is poor or discharge in the cross drainage structure is less. In such situation a box culvert is an ideal structure. The road level can be at top of box culvert or may be at some height due to earth fill or cushion above the box culvert.

Box culverts which have four corners are monolithically jointed. In other cases the box will be of three sides means which has bottom slab (Raft) and vertical walls. Top slab needed to be made otherwise precast slab also available in market we cannot joint it monolithically. Cushioning is very important in every box culvert which decided by road profile and bearing capacity of soil available at site.

OBJECTIVES: -

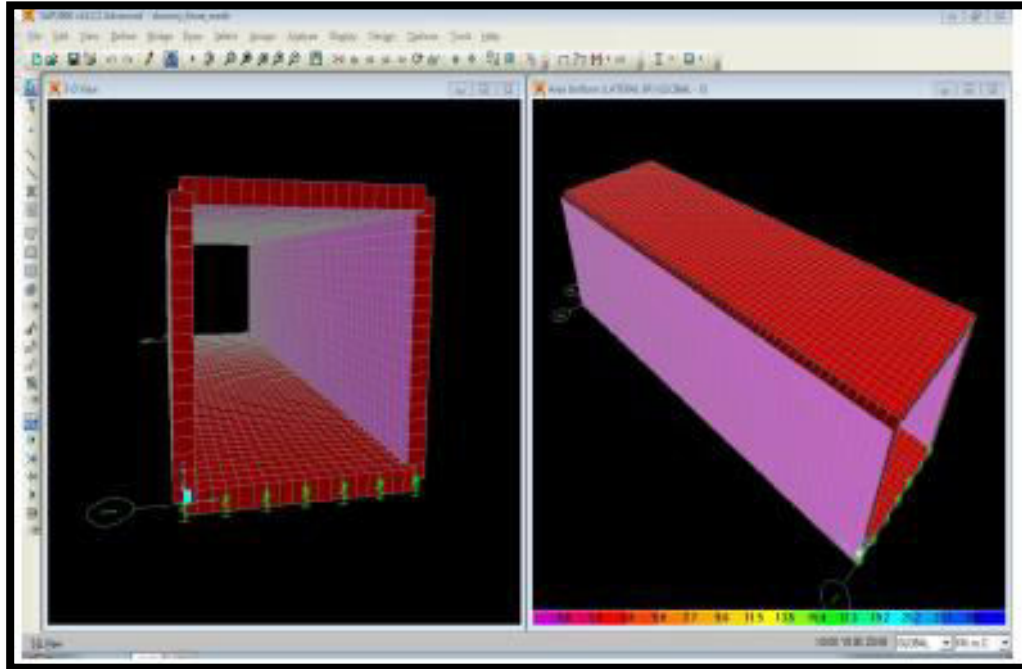
- To carry out extensive literature survey and This structure is proposed to analyze and design according IRC: 6 - 2017 & IRC: 112 – 2019 for LSM, IRC: 6 - 2000 & IRC: 21 – 2000 for WSM.
- Comparison between LSM and WSM for various configurations of box culvert which is more effective in strength and economical point of view.
- To compare the analysis and results of LSM and WSM for the design of box culver



(Fig.1.1: RCC BOX CULVERT)

Box culverts are economical due to their rigidity and monolithic action and separate foundation are not required since the bottom slab resting directly on the soil, serves as raft slab. For small discharges, single celled box culvert is used and for large discharges, multicelled box culverts can be employed. The barrel of the box culverts should be sufficient length to accommodate the carriageway and the kerb.

For a box culvert, the top slab is required to withstand dead loads, live loads from moving traffic, earth pressure on sidewalls, water pressure from inside, and pressure on the bottom slab besides self weight of the slab. The structure is designed like a rigid frame adopting moment distribution method for obtaining final distributed moments on the basis of the relative stiffness of the slab and vertical walls. The method is well known and does not need any elucidation. A few things like depth of cushion, coefficients of earth pressure for lateral pressure on walls, width or angle of dispersion for live loads on box without cushion and with cushion for structural deformation are important items where opinion of the designers vary and need to be dealt in much detail. These affect the design significantly and therefore, required to be assessed correctly for designing a safe structure. Therefore an attempt is made to study the effects of cushion, co-efficient of earth pressure and angle of dispersion for live load.



(Fig.1.2 : Box Culvert Modelling using STAAD PRO)

The study has been conducted on a RCC Box Culvert up to 4M span. MS - Excel tool is designed as per IRC: 6 - 2000 & IRC: 21 - 2000 and IRC: 6 - 2014 & IRC: 112 - 2011 as applicable for 1-Lane to 8-Lane carriageway. In the developed tool, provisions are made for IRC Class 70R and IRC Class A loading. The results of analysis and design obtained through developed excel sheet are compared and check by manual method and through STAAD Pro.

II. LITERATURE REVIEW

David Z. Yankelevsky has analyzed Rigid Box Buried in Non-linear medium by considering different parameters. The study deals with the design parameters like compressibility, stiffness, settlement, slope of trench wall on displacement and stress variations with depth.

Kiangsi Kim and Chaih.Yoo has evaluated design loading on deeply buried Box Culverts. Linear and non linear finite element analyses were used to investigate the effective density or soil-structure interaction factor for deeply buried box culverts. ABAQUS (1998) and ISBILD were used primarily for the analysis and CANDE -89 for verification and comparison.

Richard M. Bennett, Scott M. Wood, Ericc Drumm and N. Randy Rainwater have analyzed vertical loads on concrete box culverts under high embankments. Vibrating wires, strain gages and pressure cells were used to determine the internal forces and pressures on the culvert due to backfill. Strong correlation was obtained between the height of fill and the pressure and internal forces in the culvert, suggesting that the soil structure interaction factor is independent of H/B ratio.

Ali Abolmaali and Anil K. Garg has evaluated the shear capacity of the precast reinforced concrete box culverts. Six full-scale 2.4 m (8 ft) span box culverts were tested to failure by subjecting each culvert to the AASHTO HS-20 wheel load. Each test specimen was loaded incrementally up to failure in which crack initiation and propagation were identified and recorded in each load step. In some specimens the top slab compression distribution steel was precluded during specimen fabrication the effect of which was shown to be insignificant to culvert's performance experimentally.

Sinha and Sharma (2009) have done a study in which they analyzed & designed a RCC Box Culvert by manual and computer application. The study told that effective width method mainly applicable for the top slab (particularly for the box without cushion) and the design of box is covered by three load cases. The fourth situation when whole box is submerged under water, provide design moments are less than given by the three load cases hence need not to be considered. This study also told amount of required Steel Reinforcement is confirmed by the required depth of section.

Zhu et al. (2012) have study on optimal design of a Box Culvert under road and find with the reduction in the size of proposed box culvert structure, the self weight of the concrete structure is obviously reduced. Therefore, the requirement for the soil bearing capacity is decreased. As a result, the use of concrete is significantly reduced. As such, the optimal design is much more cost efficient.

Meshram and Pajgade (2014) have done Comparative Study of Water Tank Using Limit State Method and Working Stress Method and obtained result shows that the steel quantity found more for a circular service reservoir design by WSM than that of LSM. The steel quantity found more for a square service reservoir design by WSM than that of LSM.

III. PROPOSED METHODOLOGY

Input parameters

Clear span $\ell = 4\text{M}$
 Clear height $h = 4\text{M}$
 Top slab thickness $t_{\text{top}} = 0.5\text{M}$
 Bottom slab thickness $t_{\text{bottom}} = 0.5\text{M}$
 Side wall thickness $t_{\text{wall}} = 0.5\text{M}$
 Unit weight of concrete $\gamma_{\text{conc.}} = 24 \text{ Kn/M}^3$
 Unit weight of soil $\gamma_{\text{soil}} = 18 \text{ Kn/M}^3$
 Unit weight of water $\gamma_{\text{water}} = 10 \text{ Kn/M}^3$
 Co efficient of earth pressure $K_{e.p.} = 0.5$
 Total cushion on top (If present) $t_{\text{cu.}} = 0\text{M}$
 Thickness of wearing course $t_{w.c.} = 0.08\text{M}$
 Carriage way width $B = 2 \text{ Lane } 7.5\text{M}$
 Concrete grade = M35
 Steel grade = Fe415
 Modular ration for bridge as per IRC: 6 – 2000 $m = 10$
 Live load
 IRC Class 70R Loading
 IRC Class A Loading
 All dimensions in M and force in Kn.

3.1 WSM design parameters

Permissible flexural compressive stress in concrete for M35 concrete as per IRC: 21 – 2000

$$\sigma_{cbc} = 11.67 \text{ N/MM}^2$$

Permissible stress in steel in tension for Fe415 grade as per IRC: 21 – 2000

$$\sigma_{st} = 200 \text{ N/MM}^2$$

Neutral axis factor

$$k = \frac{m\sigma_{cbc}}{(m\sigma_{cbc} + \sigma_{st})} = \frac{10 \cdot 11.67}{(10 \cdot 11.67 + 200)} = 0.37$$

Lever arm factor

$$j = 1 - \frac{k}{3} = 1 - \frac{0.37}{3} = 0.88$$

Moment of resistance factor

$$q = \frac{1}{2} \times \sigma_{cbc} \times j \times k = \frac{1}{2} \times 11.67 \times 0.88 \times 0.37 = 1.89$$

3.2 LSM design parameters

Characteristics strength of concrete for M35

$$f_{ck} = 35 \text{ N/MM}^2$$

Yield strength of steel for Fe415

$$f_y = 415 \text{ N/MM}^2$$

Neutral axis factor

$$k = \frac{(700)}{(0.87f_y + 1100)} = \frac{(700)}{(0.87 \cdot 415 + 1100)} = 0.48$$

Lever arm factor

$$j = 1 - 0.42 \times k = 1 - 0.42 \times 0.48 = 0.80$$

Moment of resistance factor

$$q = 0.36 \times f_{ck} \times j \times k = 0.36 \times 35 \times 0.80 \times 0.48 = 4.82$$

3.3 Analysis

Load calculation for all members

1. Top slab load calculation

Self weight of Top Slab = $t_{top} \times \text{Concrete density for } t_{top}$ (24 Kn/M³)

$$= 0.5 \times 24 = 12 \text{ Kn/M}^2$$

Self weight of wearing course = $t_{w.c.} \times \text{Concrete density for } t_{w.c.}$ (22 Kn/M³)

$$= 0.08 \times 22 = 1.76 \text{ Kn/M}^2$$

Adopt minimum of 2 Kn/M² weight of wearing course as per MOST specifications

$$= 2 \text{ Kn/M}^2$$

Total dead load of top slab = self weight of top slab + self weight of wearing course

$$= 12 + 2 = 14 \text{ Kn/M}^2$$

Live load of top slab

IRC Class 70R Loading

Moment calculation for all members-

1. Top slab and bottom slab moment calculation (Kn-M)

Slab Type →	Top Slab Moment Calculation		Bottom Slab Moment Calculation	
Load Type ↓	IRC Class 70R Loading	IRC Class A Loading	IRC Class 70R Loading	IRC Class A Loading
Dead Load Moment $\frac{wL^2}{12}$	$\frac{14 \times 4.5^2}{12} = 23.63$	$\frac{14 \times 4.5^2}{12} = 23.63$	$\frac{33.2 \times 4.5^2}{12} = 56.03$	$\frac{33.2 \times 4.5^2}{12} = 56.03$
Live load Moment $\frac{wL^2}{12}$	$\frac{18.95 \times 4.5^2}{12} = 31.98$	$\frac{21.38 \times 4.5^2}{12} = 36.08$	$\frac{9.56 \times 4.5^2}{12} = 16.13$	$\frac{9.56 \times 4.5^2}{12} = 16.13$
Total Load Moment	55.61	59.71	72.16	72.16

Design

IRC Class 70R Loading

WSM design approach with constant depth of section

1. Top slabEffective depth required $d = \sqrt{\frac{M}{q \times b}}$

$$d = \sqrt{\frac{84.90 \times 10^6}{1.89 \times 1000}} = 212.17 \text{ MM}$$

Let us provide 20MM Φ bars @ 40MM clear cover so effective depth provided

$$d = 450 \text{ MM}$$

$$\text{Area of steel} = \frac{M}{\sigma_{st} \times j \times d} = \frac{84.90 \times 10^6}{200 \times 0.88 \times 450} = 1071.96 \text{ MM}^2$$

Shear force at effective depth from face of wall

$$V = \frac{\text{Total load of top slab} \times (\text{effective span} - 2 \times \text{effective depth})}{2}$$

$$V = \frac{32.95 \times (4.5 - 2 \times 0.450)}{2} = 59.30 \text{ Kn}$$

$$\text{Shear Stress } \tau_v = \frac{(\text{shear force at effective depth from face of wall})}{(b \times \text{effective depth})} = \frac{59.30 \times 10^3}{1000 \times 450} = 0.13 \text{ N/MM}^2$$

$$\text{Steel percentage } p = \frac{A_{st} \times 100}{(b \times \text{effective depth})} = \frac{1071.96 \times 100}{(1000 \times 450)} = 0.24$$

Permissible Shear Strength of Concrete τ_c corresponding to $p = 0.23 \text{ N/MM}^2$ Since $\tau_v < \tau_c$ hence design is safe.**2. Bottom slab**Effective depth required $d = \sqrt{\frac{M}{q \times b}}$

$$d = \sqrt{\frac{101.12 \times 10^6}{1.89 \times 1000}} = 231.30 \text{ MM}$$

Let us provide 20MM Φ bars @ 40MM clear cover so effective depth provided

$$d = 450 \text{ MM}$$

$$\text{Area of steel} = \frac{M}{\sigma_{st} \times j \times d} = \frac{101.12 \times 10^6}{200 \times 0.88 \times 450} = 1276.76 \text{ MM}^2$$

Shear force at effective depth from face of wall

$$V = \frac{\text{Total load of top slab} \times (\text{effective span} - 2 \times \text{effective depth})}{2}$$

$$V = \frac{42.76 \times (4.5 - 2 \times 0.450)}{2} = 76.97 \text{ Kn}$$

$$\text{Shear Stress } \tau_v = \frac{(\text{shear force at effective depth from face of wall})}{(b \times \text{effective depth})} = \frac{76.97 \times 10^3}{1000 \times 450} = 0.17 \text{ N/MM}^2$$

$$\text{Steel percentage } p = \frac{A_{st} \times 100}{(b \times \text{effective depth})} = \frac{1276.76 \times 100}{(1000 \times 450)} = 0.28$$

Permissible Shear Strength of Concrete τ_c corresponding to $p = 0.24 \text{ N/MM}^2$

Since $\tau_v < \tau_c$ hence design is safe.

Since moments at junctions of side wall are same as that of top slab and bottom slab.

Hence same reinforcement is to be continued for side wall.

Check for shear for side walls

R_A = reaction at point A

$$= \frac{\text{earth pressure at base due to live load surcharge} \cdot \text{effective height of side wall}}{2} + \frac{\text{Mearth pressure at base due to earth fill} \cdot \text{effective height of side wall} \cdot \frac{1}{3}}{2}$$

$$= \frac{10.8 \cdot 4.5}{2} + \frac{45 \cdot 4.5 \cdot \frac{1}{3}}{2} = 58.05 \text{Kn}$$

R_D = reaction at point D

$$R_D = \frac{\text{earth pressure at base due to live load surcharge} \cdot \text{effective height of side wall}}{2} + \frac{\text{Mearth pressure at base due to earth fill} \cdot \text{effective height of side wall} \cdot \frac{2}{3}}{2}$$

$$= \frac{10.8 \cdot 4.5}{2} + \frac{45 \cdot 4.5 \cdot \frac{2}{3}}{2} = 91.8 \text{Kn}$$

$$\text{Pressure at } t_{\text{top}} \text{ from face A} = \frac{45}{4.5} \cdot 0.25 = 2.5 \text{ Kn/M}^2$$

$$\text{Pressure at } t_{\text{top}} \text{ from face A} = \frac{45}{4.5} \cdot 4.25 = 42.5 \text{ Kn/M}^2$$

$$\text{Effective height of side wall} = \frac{\text{clear height of side wall} + \text{thickness of top slab} + \text{thickness of bottom slab}}{2}$$

$$d_{\text{wall}} = 4 + 0.5 = 4.5 \text{M}$$

Effective depth for side wall = effective depth for bottom slab = 450MM

Shear force at effective depth from face A

$$V_A = R_A - \frac{2.50}{2} \cdot d_{\text{wall}} - 10.8 \cdot d_{\text{wall}} = 58.08 - \frac{2.50}{2} \cdot 0.450 - 10.8 \cdot 0.450 = 52.63 \text{Kn}$$

Shear force at effective depth from face D

$$V_D = R_D - \frac{45+42.5}{2} \cdot d_{\text{wall}} - 10.8 \cdot d_{\text{wall}} = 91.8 - \frac{45+42.5}{2} \cdot 0.450 - 10.8 \cdot 0.450 = 67.25 \text{Kn}$$

$$\text{Maximum shear stress } \tau_v = \frac{(\text{shear force at effective depth from face of wall})}{(b \times \text{effective depth})} = \frac{67.25 \cdot 10^3}{1000 \cdot 450} =$$

$$0.15 \text{ N/MM}^2$$

Permissible Shear Strength of Concrete τ_c corresponding to $p = 0.24 \text{ N/MM}^2$

Since $\tau_v < \tau_c$ hence design is safe.

IRC Class 70R Loading

LSM design approach with constant depth of section

3. Top slab

Effective depth required $d = \sqrt{\frac{M_u}{q \times b}}$

$$d = \sqrt{\frac{1.5 \times 84.90 \times 10^6}{4.82 \times 1000}} = 162.54 \text{ MM}$$

Let us provide 20MM Φ bars @ 40MM clear cover so effective depth provided

$d = 450 \text{ MM}$

$$\text{Area of steel} = \frac{M_u}{0.87 f_y \times j \times d} = \frac{1.5 \times 84.90 \times 10^6}{0.87 \times 415 \times 0.80 \times 450} = 979.78 \text{ MM}^2$$

Shear force at effective depth from face of wall

$$V_u = \frac{\text{Total load of top slab} \times (\text{effective span} - 2 \times \text{effective depth})}{2}$$

$$V_u = \frac{1.5 \times 32.95 \times (4.5 - 2 \times 0.450)}{2} = 88.95 \text{ Kn}$$

$$\text{Shear Stress } \tau_{vu} = \frac{(\text{shear force at effective depth from face of wall})}{(b \times \text{effective depth})} = \frac{88.95 \times 10^3}{1000 \times 450} = 0.20 \text{ N/MM}^2$$

$$\text{Steel percentage } p = \frac{A_{st} \times 100}{(b \times \text{effective depth})} = \frac{979.78 \times 100}{(1000 \times 450)} = 0.22$$

Permissible Shear Strength of Concrete τ_c corresponding to $p = 0.34 \text{ N/MM}^2$

Since $\tau_{vu} < \tau_c$ hence design is safe.

4. Bottom slab

Effective depth required $d = \sqrt{\frac{M_u}{q \times b}}$

$$d = \sqrt{\frac{1.5 \times 101.12 \times 10^6}{4.82 \times 1000}} = 177.39 \text{ MM}$$

Let us provide 20MM Φ bars @ 40MM clear cover so effective depth provided

$d = 450 \text{ MM}$

$$\text{Area of steel} = \frac{M_u}{0.87 f_y \times j \times d} = \frac{1.5 \times 101.12 \times 10^6}{0.87 \times 415 \times 0.80 \times 450} = 1166.96 \text{ MM}^2$$

Shear force at effective depth from face of wall

$$V_u = \frac{\text{Total load of top slab} \times (\text{effective span} - 2 \times \text{effective depth})}{2}$$

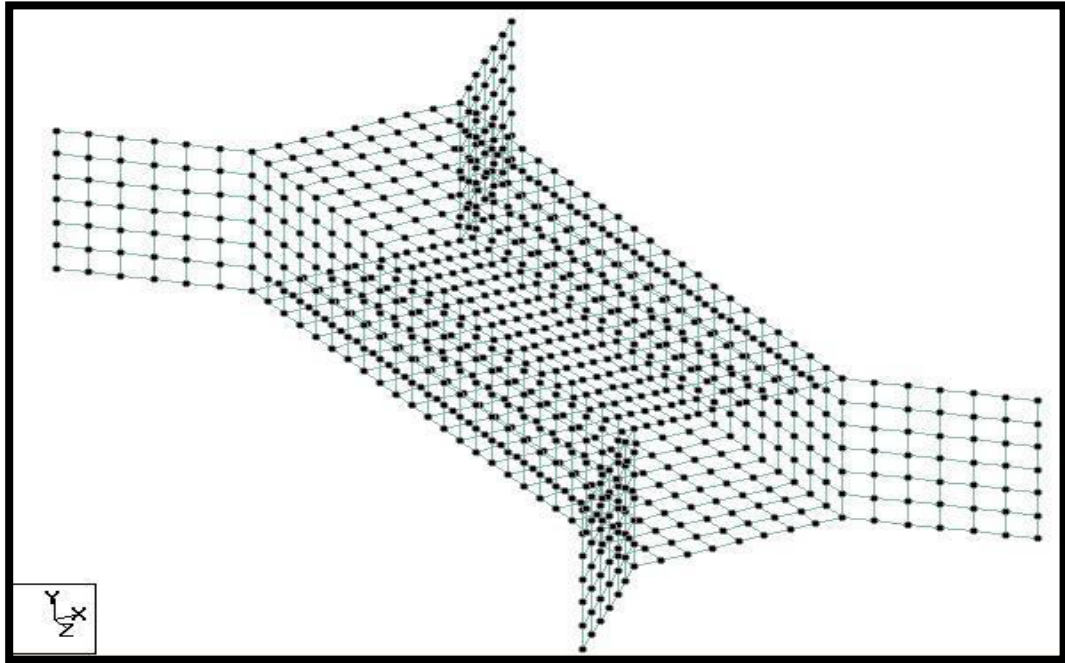
$$V_u = \frac{1.5 \times 42.76 \times (4.5 - 2 \times 0.450)}{2} = 115.46 \text{ Kn}$$

$$\text{Shear Stress } \tau_{vu} = \frac{(\text{shear force at effective depth from face of wall})}{(b \times \text{effective depth})} = \frac{115.46 \times 10^3}{1000 \times 450} = 0.26 \text{ N/MM}^2$$

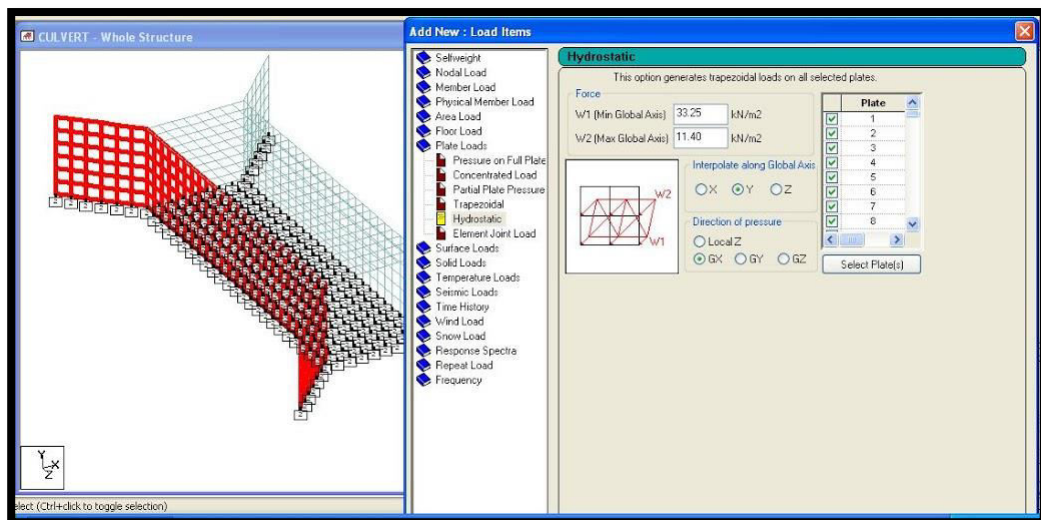
$$\text{Steel percentage } p = \frac{A_{st} \times 100}{(b \times \text{effective depth})} = \frac{1166.96 \times 100}{(1000 \times 450)} = 0.26$$

Permissible Shear Strength of Concrete τ_c corresponding to $p = 0.38 \text{ N/MM}^2$

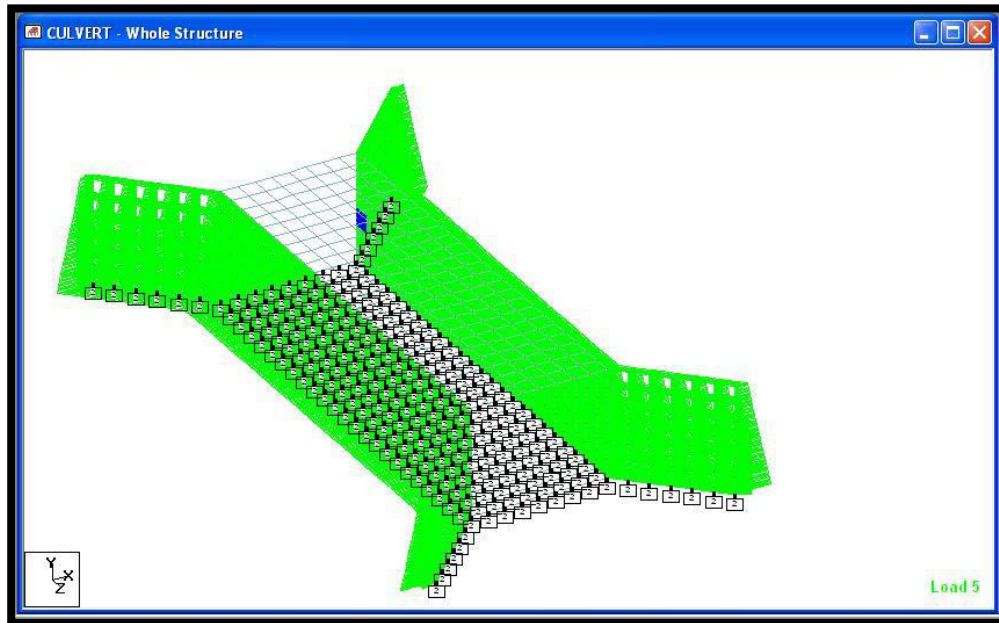
Since $\tau_{vu} < \tau_c$ hence design is safe.



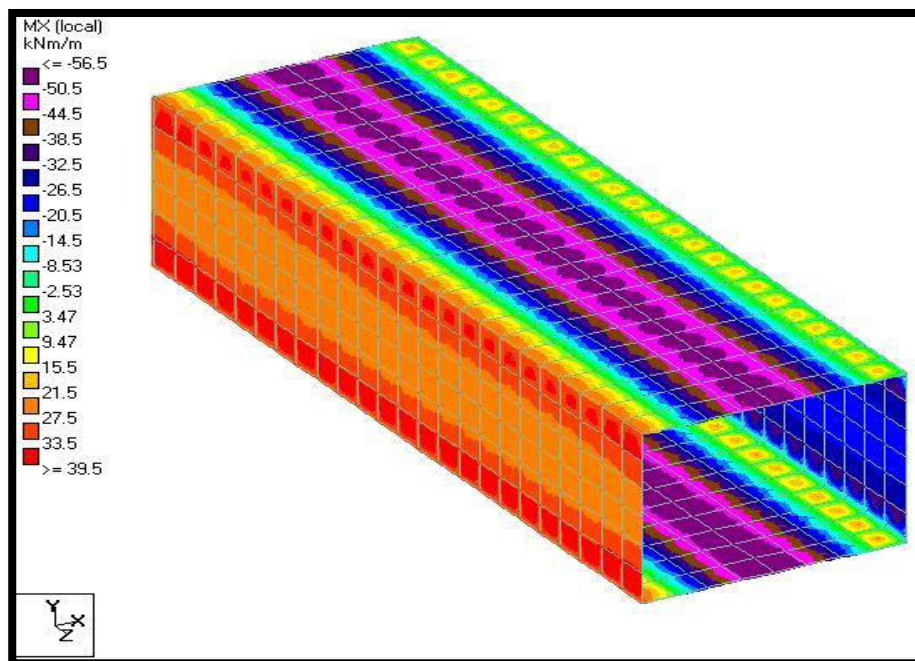
(Fig.3.1 : Fully Meshed Box Culvert)



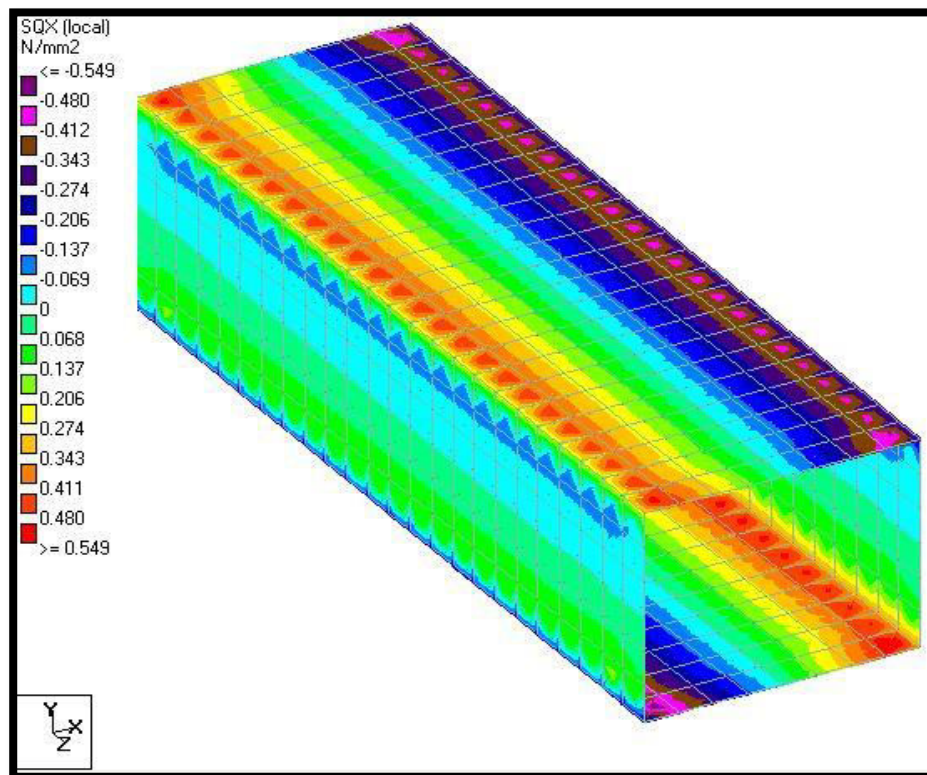
(Fig.3.2 :Staad Pro Interface)



(Fig.3.3 : Earth Pressure On Culvert)



(Fig.3.4 : Transverse Bending Moment)



(Fig.3.5 : Transverse Shear Stress)

IV. RESULT AND DISCUSSION

4.1 Results of Analysis by MS-Excel & STAAD Pro

The result of moment analysis by manual calculation, by developed MS-Excel Sheet and STAAD Pro.

Table 4.1 Design Moments by MS-Excel tool and STAAD.Pro

Loading →	Bending Moments (Kn-M)			
	IRC CLASS 70R LOADING		IRC CLASS A LOADING	
Member ↓	By MS-Excel Analysis	By STAAD.Pro Analysis	By MS-Excel Analysis	By STAAD.Pro Analysis
Bottom Slab	68.15	72.2	67.64	72.2
Top Slab	51.93	53.00	54.45	55.6
Side Wall	68.15	72.2	67.64	72.2

4.2 Design by MS-Excel tool

Effect on Area of Steel in WSM and LSM Approach-

A design of a RCC Box Culvert with Span & Height 4M is prepared with the help of developed MS-Excel tool. This design is based on the WSM as well as LSM approaches. From the developed MS-Excel tool the saving in the amount of steel area required while keeping a constant depth of section from WSM to LSM approaches.

Table 4.2 Saving in Steel using LSM approach over WSM for Fe415 Steel Grade

Fe 415	IRC CLASS FOR LOADING	IRC CLASS A LOADING
CONCRETE GRADE	% DECREASEMENT IN REINFORCEMENT	% DECREASEMENT IN REINFORCEMENT
M30	7.54%	7.54%
M35	8.75%	8.75%
M40	9.84%	9.84%
M45	10.84%	10.84%

Table 4.3 Saving in Steel using LSM approach over WSM for Fe 500 Steel Grade

Fe 500	IRC CLASS FOR LOADING	IRC CLASS A LOADING
CONCRETE GRADE	% DECREASEMENT IN REINFORCEMENT	% DECREASEMENT IN REINFORCEMENT
M30	7.67%	7.67%
M35	8.80%	8.80%
M40	9.82%	9.82%
M45	10.76%	10.76%

Saving in Depth of Section in LSM over WSM with constant Steel Area-

A design of a RCC Box Culvert with Span & Height 4M is prepared with the help of developed MS-Excel tool. This design is based on the WSM as well as LSM approaches. From the developed MS-Excel tool the variation in the amount of depth of section with keeping a constant steel area required from WSM to LSM approaches.

Table 4.4 Saving in Material using LSM approach over WSM for Fe415 Steel Grade

Fe 415	IRC CLASS 70R LOADING	IRC CLASS A LOADING
PERCENT	% DECREMENT IN DEPTH OF THE SECTION	% DECREMENT IN DEPTH OF THE SECTION
MBE	6.86%	6.85%
MBE	7.91%	7.85%
MBE	8.94%	8.93%
MBE	9.90%	9.71%

Table 4.5 Saving in Material using LSM approach over WSM for Fe 500 Steel Grade

Fe 500	IRC CLASS 70R LOADING	IRC CLASS A LOADING
CONCRETE GRADE	% DECREMENT IN DEPTH OF THE SECTION	% DECREMENT IN DEPTH OF THE SECTION
MBE	6.82%	6.74%
MBE	7.87%	7.65%
MBE	8.89%	8.55%
MBE	9.70%	9.42%

V. CONCLUSION

In the present study on "Analysis & Design of RCC Box Culvert using WSM & LSM" the analysis & design of box culvert under different loading conditions has been carried out. A sample problem of 4M span with Empty Box Condition is analysed by manual and STAAD Pro software. The design for the same is carried out with conventional WSM approach & as per latest guidelines of IRC: 6-2014 using LSM approach.

The results from the develop tool analysis & design are compared with manual & STAAD Pro analysis/calculation. From the study following conclusions may be drawn:

1. The develop MS - Excel tool for analysis & design of box culvert is accurate, fast, easy to use & user friendly application.



2. No software and additional knowledge to run software is required for the analysis and design of box culvert.
3. Empty box culvert condition is found to be most critical loading combination as in this case no counterbalancing moments are available because of non availability of water head.
4. Although IRC Class 70R Loading are higher as compared to IRC Class A Loading but due to higher impact factor in case of IRC Class A Loading sometimes shear check becomes critical.
5. From the parametric study it is observed that for a constant section, a saving of tune of 6-10% may be achieved by using LSM approach, amount of saving is higher for higher grades of concrete.
6. From the parametric study, it is also observed that for a constant Steel Area a saving of the tune of 7-12% may be attained in concrete by using LSM approach over WSM design approach. For higher grades of concrete saving is higher.

VI. FUTURE SCOPE

Based on the experience of present study, work can also be extended for the other type of bridges such as (i) Slab Culvert Bridge (ii) T-Beam Bridge and (iii) Plate Girder Bridge. The study may be carried out for the bridge abutment, bridge pier & bridge foundation also.

VII. ACKNOWLEDGMENTS

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REFERENCES

1. Neeta K. Meshram and P.S.Pajgade 'Comparative Study of Water Tank Using Limit State Method and Working Stress Method' International Journal of Research in Advent Technology, Volume 2, Issue 8, 2014
2. Neha Kolate, Molly Mathew and Snehal Mali 'Analysis and Design of RCC Box Culvert' International Journal of Scientific & Engineering Research, Volume 5, Issue 12, 2014
3. Paul Tom P. 'Analysis and Design of RCC Bridges and Box Culvert' Research Report, 2015
4. Shivanand Tenagi and R. Shreedhar 'Comparative Study of Slab Culvert Design using IRC 112:2011 and IRC 21:2000' International Journal for Scientific Research & Development, Volume 3, Issue 05, 2015
5. Y. Vinod Kumar and Chava Srinivas 'Analysis and Design of Box Culvert by using Computational Methods' International Journal of Engineering & Science Research IJESR, Volume 5, Issue 7, 2015
6. Sudip Jha, Cherukupally Rajesh and P.Srilakshmi 'Comparative Study of RCC Slab Bridge by Working Stress (IRC: 21-2000) and Limit State (IRC: 112-2011)' International Journal & Magazine of Engineering, Technology, Management and Research, Volume 2, Issue 8, 2015
7. IRC: 6 - 2000 Standard Specifications and Code of practice for Road Bridges Section-II Loads and Stresses (Fourth revision)
8. IRC: 21 - 2000 Standard Specifications and Code of practice for Road Bridges Section-III Cement Concrete (Plain and Reinforced)
9. IRC: 6 - 2014 Standard Specifications and Code of practice for Road Bridges Section-II Loads and Stresses (Revised edition)
10. IRC: 112 - 2011 Code of practice for Concrete Road Bridges
11. IS: 456 - 2000 Plain and Reinforced Concrete- Code of practice (Fourth revision)
12. Ravindra Bhimarao Kulkarni and Rohan Shrikant Jirge 'Comparative Study of Steel Angles as Tension Members Designed by Working Stress Method and Limit State Method' International Journal of Scientific & Engineering Research, Volume 2, Issue 11, 2011
13. B.N. Sinha and R.P. Sharma 'RCC Box Culvert - Methodology and Designs including Computer Method' Paper no. 555 Journal of Indian Road Congress, 2009
14. B.H. Solanki and M.D. Vakil 'Comparative Study for Flexure Design using IRC 112:2011 & IRC 21:2000' International Journal of Scientific & Engineering Research, Volume 4, Issue 6, 2013
15. Sujata Shreedhar and R. Shreedhar 'Design Coefficients for Single and Two cells Box Culverts' International Journal of Civil and Structural Engineering, Volume 3, Issue 3, 2013



17. Paul Tom P. 'Analysis and Design of RCC Bridges and Box Culvert' Research Report, <https://www.researchgate.net/publication/275272796>, 2015
18. ShivanandTenagi and R. Shreedhar 'Comparative Study of Slab Culvert Design using IRC 112:2011 and IRC21:2000' International Journal for Scientific Research & Development, Volume 3, Issue 05, 2015
19. Neeta K. Meshram and P.S.Pajgade 'Comparative Study of Water Tank Using Limit State Method and Working Stress Method' International Journal of Research in Advent Technology, Volume 2, Issue 8, 2014
20. Neha Kolate, Molly Mathew and Snehal Mali 'Analysis and Design of RCC Box Culvert' International Journal of Scientific & Engineering Research, Volume 5, Issue 12, 2014
21. SudipJha, Cherukupally Rajesh and P.Srilakshmi 'Comparative Study of RCC Slab Bridge by Working Stress (IRC: 21-2000) and Limit State (IRC: 112-2011)' International Journal & Magazine of Engineering, Technology, Management and Research, Volume 2, Issue 8, 2015
22. N Krishna Raju, 'Design of Bridges, Oxford and LBH publishing co. Pvt. Ltd., New Delhi, Fourth edition.



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