# Analysis and Design of Box Culvert: A Review

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**Abstract: Box culverts are the structures which are used when the path of water in the natural stream crosses roads, railway lines, flyovers etc. They are normally cheaper than bridges, which make them the natural stream passes through channels. In this work, the review of various authors and their views in the design and analysis of box culvert with software approach and comparison between software and manual approach has shown. The IS standard requirements in the design manual for roads and bridges (IRC-6-2000, IS 21-2000) is used in the structural designing of concrete box culverts. In this paper study about the different classes of IRC loadings and their effect on without and with cushioning conditions imposed on box culvert. The pressure cases are then checked for both with cushioning and without cushioning loading cases. The structure designing includes the considerations of pressure cases (Box empty, Full, surcharge load) and factors such as Impact load, Braking force, Dispersal of load through fill, Effective width, Coefficients of earth pressure, Live load etc. The structural elements are designed to withstand the maximum bending moments and shear forces respectively. In the present study, this paper provides full discussion on the provisions in the codes, considerations and justifications of all the above aspects of design.**

***Keywords —Box Culvert, Design Coefficients, Loadings Types, Moment, Shear, Pressure Cases.***

## I. INTRODUCTION

Box Culvert is the arrangement made to cross an obstacle in the form of a stream, a river or a road to pass without closing the way beneath. A Culvert is defined as standard specifications as any structure whether made up of single and multiple cell construction with a clear span of 6m. Box Culvert which has got its name due to its shape & orientation and looks like a hollow rectangular box with two slab & two vertical walls which connects monolithically. Box culverts are easy to design and easy to construct economically. It is designed to carry all the loads comes from top slab and transferred with help of vertical walls to bottom slab which rest generally where the bearing capacity of soil is low. Box Culverts are economical due to their rigidity and monolithic action no separate foundation is required when bottom slab is rest on hard soil. The structure is designed such as rigid frame adopting moment distribution method for obtaining final distributed moments on the basis of the vertical walls and slabs. Box Culverts are generally found in three locations, the first is at the bottom of depressions where no natural water course exist, second is where natural stream intersect the roadway and third is at locations required for passing surface water carried in the ditches beneath roadways and driveways to adjacent property. There are many general problem occur with box culvert such as serviceability and strength, abrasion and deterioration of concrete. For masonry culverts there will be major cause due to sedimentation and blockage by debris.

There are two types of culverts which are rigid culvert for example concrete and flexible culvert for example steel. Rigid culverts are made to bear the bending moments where the flexible culverts are not.

The structural and hydraulic design of box culvert is different from the bridge design for construction, maintenance, replacement and repair procedure. The basic characteristics of box culverts the first on is hydraulic in which the culvert are design for highest flood level or peak value with a submerged inlet to improve hydraulic efficiency. Second is structural culverts are used take all the Dead load, live load, load due to pressure, Impact load and braking forces that are safely to be resist by structure and soil. The third one is maintenance there is a problem with the blockage by debris and sediment, especially when the culvert are subjected to seasonal flow. The fourth one is the construction in which culvert are made to take the vehicle load by combined strength of box and surrounding embankment. The last fifth one is Durability of materials are major problem in box culverts and other drainage structure. In counteractive environment can cause corrosion and abrasion of the available materials.

The culvert are divided into categories first is according to type of materials used in which first is concrete materials which the culvert are made either precast or cast in situ. The selection is depending on the size, type, flexibility etc. Precast concrete are easy to handle and installed. Cast in

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situ culverts are made on site requires more days for construction. Second is corrugated steel in which made by factory named as corrugated steel sheet this pipe culverts are made by steel pipe sections. This is used in steel pipe culverts with steel sheet for greater span. Third is corrugated aluminum corrugated aluminum culverts are constructed by factory made corrugated aluminum pipe this are available as the conventional structure plate for box culvert and long span structure. Fourth one is plastic pipe are made from various materials and have a good strength and properties which depend on the base resin made by formulation of chemicals and final resin is used to produce the pipe. According to the shapes of box the first one is circular pipes is the most common shape for pipe culverts. It is structurally and hydraulically efficient under many conditions for smaller opening the pipe is generally preferred. Second one is pipe arch or elliptical shape is generally used when distance from channel invert to pavement surface is limited pipe arch and elliptical shape are not structurally efficient as compared to as a circular shape it is used in the areas with the limited vertical clearance. Third one is arch culvert offer less obstruction to the waterway than pipe arches the structure is also safe for scour design requirements. Fourth one is box section or the square and rectangular section used generally nowadays due angular corner of the structure it is not hydraulically and structurally are not safe to solve this haunch is prefer at the corners. Fifth one is the multiple cells is used where channel is to wide and uses where span having more length by height used to give proper channel to waterways there is no problem of clogging when the discharge is more.

## II. LITERATURE REVIEW

**A. D Patil, A. A Galatage (2016)**, had done analysis by using manually work the design and analysis factors of box can be done with cushioning and without cushioning the maximum bending moment in each and every loading can be determined. The result is the load combination to be found very critical for all aspect ratio bending moments for different ratio or aspect is varying or constant for with and without cushion. The effect of water ratio 1:1.5 is negligible and for 2:3 is empty.

**Afzal Hamif Sharif (2016),** had done study by using moment distribution method and Staad pro software. Compared them and check out all the structural elements for safety of bridge. The results are the advantage of box culvert and their design critical and span length according by ratio of cell and number of cell.

**Ajay R. Polra, Pro. P. Chandresha, Dr. K.B Parikh (2017)**, had done the analysis and comparison by using design consideration in mind of box coefficient of earth pressure, cushion, width or angle of dispersion and load case for design. The result is without cushion or with cushion and angle of dispersion is zero there will be maximum live load greater stresses are created without cushion.

**Ayush Tiwari, Dr. Sudhir S. Bhadouria (2017)**, had done study of solid slab and R.C.C Box which is evaluated by estimation of quantities and specifications and SOR detailing of each work. The result is for span up to 9m RCC Box type bridges should be implemented after which the solid slab should be preference for the span range up to 15m.

**B. Sravanthi, G. Ramakrishna Rao, Dr. M. Kameshwara Rao (2015)**, had done manually design and check all the design factor and coefficients by using codes IRC& IS Codes somewhat using Staad pro software also. A Result is the advantages of box culvert either it is single or double depends on the span length and some other factors.

**Ketan Kishor Sahu, Shraddha Sharma (2015)**, had study by using software hydraulic parameters, graphs, charts, tables are showing variations in test result for different ratio which are aspect bending moment, shear force, discharge capacity, loads etc are find out. Result is declared on the basis of the software analysis tables for hydraulic parameter, bending moment for bottom slab, side walls and top slab are shown in tables for different aspect ratio of cell.

**Mahesh D. Kakade, Rajkumar A. Dubai (2017)**, had study by using FEM (ANSYS) Software and IRC guidelines. The problem taken of 3m×3m box culvert the braking force, design moments, total loads all calculated and check for deformation normal stress, principle stress, Von miss stress for without and with cushion conditions. The result is the deformation without cushion is more, maximum principle stress without cushion is more, also normal stress, shear stress, and equivalent stress are more without cushioning.

**M. Bilal Khan, M. Parvez Alam (2015)**, This paper includes the hydraulic design which the catchment area, maximum HFL, longitudinal area, cross section, velocity observation and estimation of discharge by rational method empirical formula (dickens formula), critical depth and height of jump also decides the area and length of apron. The culvert are designed by manual calculations which gives size and shape of box according to discharge and depth of scour deciding the jump is undular jump and required to be made of 2m×2m box culvert.

**Neha Kolate, Molly Mathew, Snehal Mali (2014)**, had study by using manually calculation and IRC code for bridges and roads taken all the design considerations factors and also design of typical box done manually. The result is the box culvert are economical than the pipe drain and also it have various advantage and design factor may be affected if it is done properly.

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**Saurav, Ishaan Pandey (2017)**, had done comparative analysis study of analysis of conventional method using Staad pro software and FEM using ANSYS Software. The result are by using both analysis they conclude that 16.8% FEM through ANSYS Software saves large amount of money and gives the more economical design.

**Sujata Shreedhar, R. Shreedhar (2013)**, had find out the coefficients for moment, shear and thrust of single and two cell box culvert by using Staad Pro software. The result is The design of box culvert includes the information regarding the effect different ratio L/H=1.0, L/H=1.25 etc. Also moments and loads are found out.

**Vaishali Turai, Ashish Waghmare (2016)**, had study the Berackeven Method / Pay Back period cost, time, labor and material by analytic method. The result is by using both method they conclude cost and time of precast structure is less than the cost in situ structure.

**Vasu Shekhar Tanwar, M. P Verma, Sagar Jamle (2018)**, had study by using Staad Pro software the culvert are subjected to certain cases and providing the values in the form of graph and tables in which reduction in displacement and reduction in bending moment are shown. The result is by using software result came to know about bending moment and displacements are declined to minimum value taken in percentage. For flared portion structure change gets a positive response.

**Vasu Shekhar Tanwar, Dr. M. P Verma, Sagar Jamle (2018)**, This paper analysis the stress value increases in the flared portion and shear values decreased on increment of flared portion. Principle stresses declined and give a positive response for structural change. The result is the paper gives the graph and their variations in values with respect to stress by using the flared portion the stress value are dropped for different cases.

**Virendra Singh D. Chauhan, Gunvant Solanki, Minu Tressa (2017)**, This paper gives the information regarding the skew box culvert of any angle in which how reinforcement changes analytical and experimental study of skew bridge model, seismic response, dynamic response etc. and different aspect inspections. The result is longitudinal moment decrease in skew approach as compared to straight approach deflection deck slab decrease with increase skew angle, abutment stiffness also increases with increase in skew angle which significantly contribute to stiffness of the bridge.

**Zengabriel Gebremedhn, Guofu Qiao, Jilong Li (2018)**, This paper includes the modeling and analysis of precast reinforcement box culvert with FEM and using ABAQUS and tested the box the stress and deflections and check the box how its behave by plotting the load deflection graph and loads stress graph. The result shows the Modeling and analysis of prefabricated box and knowing the steel requirements and main things is load and deflection curve and load stress curve are showing using the F.E.M analysis there is warning of structure before failure of structure is getting.

## III. METHODOLOGY

The complete work will be done manually without any use of software, then the cases taken with respect to different loading types are then solved and the final result will guide the whole work to the result and conclusion section. Following are the methodology approach in which cases are taken into account for with cushion and without cushion cases for loading Class 70 (R), Class A along with Class B.

### Cases Taken Into Account:-

**For Without Cushion**:- 350 kN of Tracked vehicle using Class 70(R) will be Case A, 114 kN of Wheeled vehicle of Class A will be Case B, 68 kN of Wheeled vehicle of Class B will be Case C.

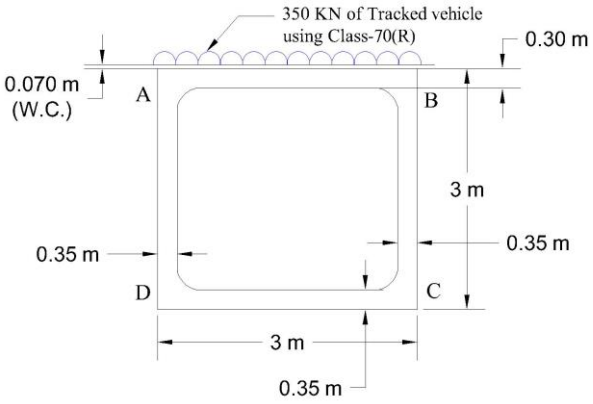


Fig 1: Graphical Representation of Case A

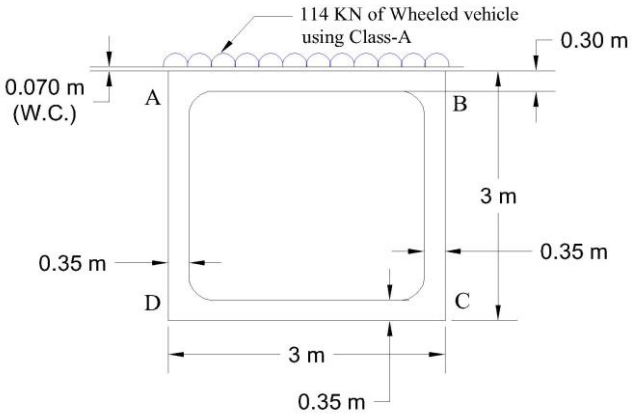


Fig 2: Graphical Representation of Case B

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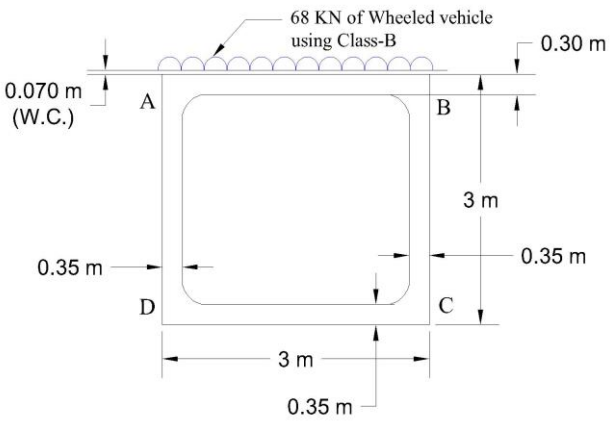


Fig 3: Graphical Representation of Case C

**For With Cushion**:- 350 kN of Tracked vehicle using Class 70(R) will be Case D, 114 kN of Wheeled vehicle of Class A will be Case E, 68 kN of Wheeled vehicle of Class B will be Case F.

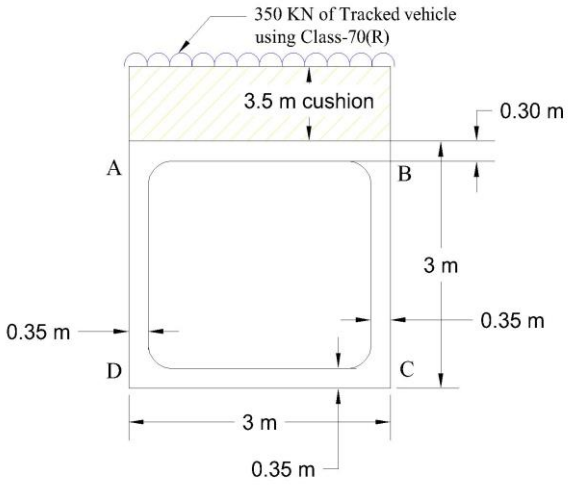


Fig 4: Graphical Representation of Case D

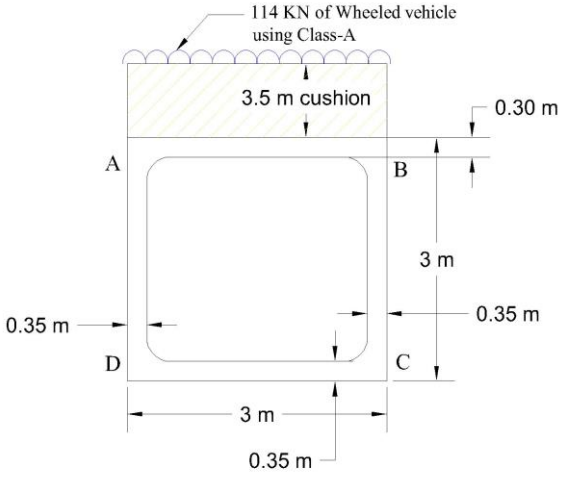


Fig 5: Graphical Representation of Case E

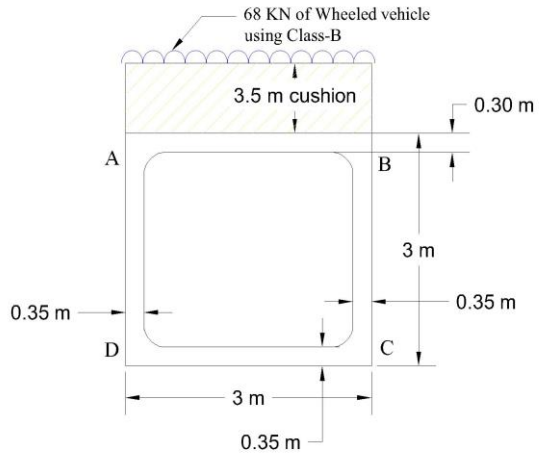


Fig 6: Graphical Representation of Case F

## Steps to solve Without Cushion Cases:-

First to have silent features of data then the next is calculation of loadings on top slab, bottom slab, side walls and base pressure then the moment is calculated then distribution factors are carried out then by moment distribution method after finding out the fixed end moment due to dead, live and total load. Then braking force is calculated as load due to braking with different class and moment due to braking is calculated. In last design for top slab, bottom slab, side wall is done.

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## IV. Results and Discussions

The above literature analysis and design of box culvert is under the influence of different kinds of loading conditions. It can be noted that effect of depth of cushion, impact load, braking forces, coefficient of earth pressure and the angle of load dispersion due live load are important factors. Box culverts are analyzed for different cases of pressure and their variations. It is seen that maximum bending moment occur for dynamic load case. The analysis and design of box can be done by using the Indian Standard Codes IS456-2000, Indian Road Congress, IRC 6-2000 & IRC 21-2000. The result will be analyzed by variations in shear force, bending moment, impact load, braking force etc.

## V. Conclusions

There are many varieties of materials, Size and Shapes. Concrete hollow box culverts are the best for the durability

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and economical satisfaction. To design and analysis of box saves time and money improving planning of road and management also reduces the risks when selection is based on whether condition. It is easy to construct the box with fast workmanship and cost effectiveness can be achieved. The result of analysis for given parameters can be solved by using moment distribution method. There is more stresses produces in without case with compare to cushion case. The box culvert includes three pressure cases for designing. The Class-70(R) Loading is also been used as calculation of Class A Loading.

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