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Analysis and Design of Box Culvert with Manual Calculations and using STAAD-Pro: A Review

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Abstract - Box Culverts will be provided below the earth embankment to cross the watercourse such as streams, Nallas to prevent the road embankment from blocking the natural watercourse. Culverts should balance the floodwaters on both sides of the embankments to reduce the level of flooding on the other side of the road thereby reducing the water level and thus reducing flooding. The box culverts are with single or multiple cells can be used effectively as Underpasses, Grade Separator, and Bridges or as Flyover as well. The Culverts can be of different shapes such as arch, slab, U-shaped and box. These can be made of different materials such as bricks (bricks, stone etc.) or reinforced concrete. As the culverts passes through the embankment, they carry the same load as the road carries it, therefore, they need to be designed for those loads. The opening of the culvert is found based on the waterway required to accommodate the design flood, and the thickness and size of the culvert section is designed according to the upcoming loads on the culvert.

This project will focus on the study of the parameters of designing culvert boxes such as live load scattering angle, the effect of co-efficient of the earth pressure which acts laterally on the culvert walls and the depth of the cushion provided over the slab of the culverts. Depth of cushion, coefficient of earth pressure lateral pressure on walls, width or angle of scattering of live load on a box with cushion and without cushion which deform the structure and are important factors where designers' views vary and need to be addressed in detail. The design of structure involves consideration of load cases (box empty and full, surcharge loads etc.) and other factors such as live load, width, braking force, dispersal of load through fill, impact factor, co-efficient of earth pressure etc. IRC Codes needed for the analysis and design of the box culvert. The purpose of this project is to design and analyse the box culvert using STAAD PRO software. This software is an effective and easy-to-use tool for three-dimensional models, analysis and multidisciplinary design. The results obtained from STAAD PRO are compared to manual calculations for the correctness. The elements of the box culvert are designed to withstand the great length of bending and shearing force. The project will provide a full discussion of the provisions provided in the Codes, consideration and adjustment of all of the above aspects regarding the design.

***Key Words*:** Box Culvert, Earth Pressure, STAAD PRO

1.I NTRODUCTION

1.1 Overview

It is well-known that roads are often constructed on the embankment that come with the natural flow of floodwaters. As the flow cannot be prevented hence, some type of pumping operations needs to be provided to allow water to pass over the embankment and to take the electrical or other cables from one side to the other. The structures to achieve such a flow across the street are called culverts, small bridges and large bridges depending on the spans and also on the on the discharges.

1.1.1 Types of Culverts

i. Pipe Culvert (Single or Multiple)

Pipe culverts are round in shape which are widely used and made of concrete or metal. Culverts can be one in number or more. If only one pipe culvert is used then a larger diameter is culvert is used. If the width of the channel is greater than us we will go to the culverts of more pipes. They are suitable for very large flow. The pipes diameter ranges from 1 meter to 6m.

Photo 1. Pipe Culvert

i. Pipe Arch Culvert (Single or Multiple)

The Pipe Arch culverts look like half circular shaped culverts. These culverts are suitable for large water flows but the flow must be stable. Due to the formation of the arch the fish or sewage in the drainage is easily transported to the area without any obstruction at the entrance or deposition at the bottom of the tunnel. Such a type of culvert can also be constructed in as many numbers as needed. They also enhance the aesthetic beauty of the structure.

Photo 2. Pipe Arch Culvert

i. Box Culvert (Single or Multiple)

The Box Culverts are rectangular in shape and are usually made of reinforced cement concrete. These are used to drain off the rain or storm water. Therefore, these are of no use during the dry season. Hence, they can be used as railway or road corridors during the dry season for animals. Due to the sharp corners these are not suitable for high speeds. They can be provided in multiple numbers.

Photo 3. Box Culvert

i. Arch Culvert

The arch culvert and the pipe arch culvert are is similar but the floor of under the arch culvert is artificial. In narrow areas it is widely used. The artificial floor and the arch and the are made of reinforced concrete. Alternately Steel arch culverts are also available but they are an expensive option.

Photo 4. Arch Culvert

i. Bridge Culvert

The Bridge Culverts are provided over canals or rivers and are used as bridges for vehicles. In these culverts the foundation is laid underground. A series of culverts are placed and a pavement is laid over the top of these series of culverts. Normally these rectangular culverts can be replaced by the box culverts if the artificial floor is not required.

Photo 5. Bridge Culvert

1.1.2 STAAD Pro Software

The STAAD Pro is a structural design software program with a user interactive (UI) interface which makes the user functioning easy can be used for modelling, designing and analyzing different types of structures and structural orientations.

This programming is broadly utilized for the structural analysis and also designing the structures such as industrial structures, bridges, buildings, highway designing, utility and towers.

The designs include building structures incorporating petrochemical plants, culverts, bridges, tunnels, piles; and construction materials such as timber, cold-formed steel steel, concrete, and aluminum. Also, foundation design and analysis. The Shear wall feature is also incorporated into the software for design facilitation. The Steel Structures and the connections can also be analyzed and designed and a rendered view of the real-time resembling images for detailed information of the structure.

1.2 Objective of Study

i. The main objectives of this study are to investigate the effect of basic parameters like shear force and bending moments of culvert with and without use of cushion.

ii. In this study we are considering the effect of cushion various cases like traffic conditions, soil conditions & Hydrological conditions

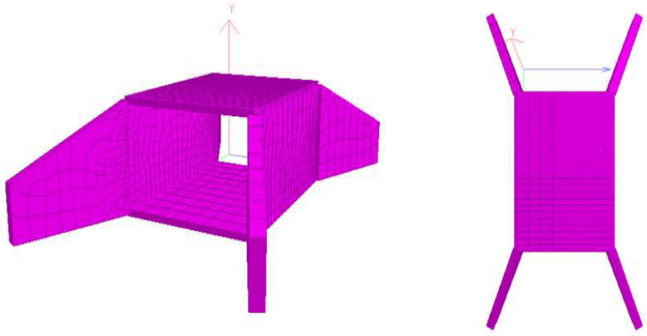
iii. In this study we are considering the effect of load effects like live load, effective width & coefficient of earth pressure for structural designing of box culvert.

1.3 Aim of Study

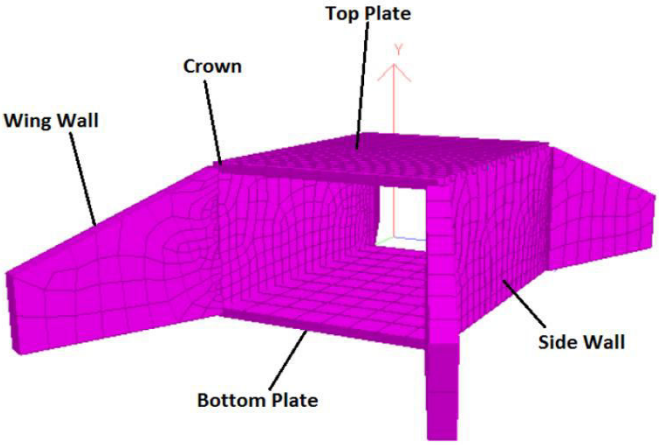
i. We are considering the effect of load effects like live load, effective width & coefficient of earth pressure for structural designing of box culvert.

ii. Calculation of Net ultimate bearing capacity(q_{nu}), Earth pressure on side walls, Deck slab Axial forces, Side Wall Axial forces, Deck slab Shear forces, Side wall Shear forces, Base slab Shear forces & Deck slab Bending moments.

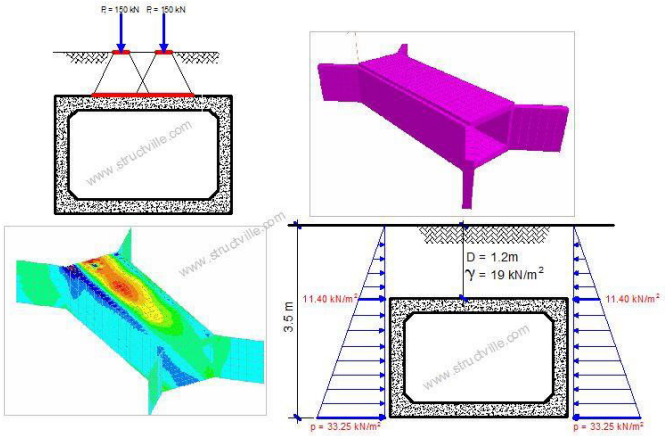
iii. Modelling and analysis of Box Culvert with and without cushion by the help of structural analysis software STAAD Pro.



Geometry and Modeling using STAAD Pro



Modelling of Component Parts of Box Culvert using STAAD Pro



Modelling, Analysis and Design of Box Culvert using STAAD Pro

2. Literature Survey

1. Vasu Shekhar Tanwar, Dr. M. P Verma, Sagar Jamle (2018): He has researched using the Staad Pro software the culvert is subject to certain conditions and provides values in the form of graphs and tables where migration is reduced and reduced during bending it is shown. The result is the use of a software result that you get to know about the bending time and the rejection of the rejection being the smallest percentage taken.

Changes in the structure of the flammable part get a positive response. This analysis of the paper increases the pressure level in the combustible component and the cutting costs decrease with the increase in the combustion component. Systemic pressures are low and provide a positive response to structural change. The result is a paper that gives a graph and its variance in values in relation to stress using the flammable part the amount of stress decreases in different conditions.

2. R. Polra, et al. (2017), presented a review on the analysis and comparison of the cost of a culvert box for a different aspect of cell size. They concluded that greater pressure is found on the culvert structures of cushion less boxes, compared to the cushion-covered culvert box. Alternatively, if the scatter angle is 0 °, the magnitude of the live load is too large.

3. Venkata Shiva Reddy and Chandan Kumar (2016), Conducted research by turning a concrete box belt and a pre-pressed box belt under a moving load and maintaining the width of the cart consistently. The study was about the analysis of RCC and PSC box girder using the MIDAS CIVIL software. The analysis included the production of influence lines and areas to detect the behavior of the waves under the living and dead load and to assess bending times, shear strength and removal.

4. Afzal Hamif Sharif (2016), Conducted research using the short-term distribution method and Staad pro software. Compare and check all the bridge safety features. The results are the advantage of the culvert box and their important design and duration depending on the size of the cell and the number of cells.

5. Sandeep Kumar Ahirwar, Mohd. Afaque Khan, Abhishek Kumar (April-2016), attempted to explain various ways of understanding the conduct of the Box Girder Bridges. According to the study, the main beam of the Box Girder Bridge consists of belts in the form of an empty box which is an economical and durable solution as well. These are mostly made up of medium and short spans. They are designed to carry load in Shear and Flexural bending. The design and analysis of box-girder bridges is extremely complex because of its three-dimensional behavior that includes folding, twisting, and bending at opposite directions. The need for this study is to understand the behavior of box girder bridges with the help of various analytical methods to understand the behavioural aspect.

6. Ms. Patil M.B. 1, C.M. Deshmukh2, Dr. C. P. Pise3, Y.P. Pawar2, S. S. Kadam, D. D. Mohite2, S.V. Lale2 (March-2016), Explained in their study that the behavior of a composite structure is strongly influenced by the properties of its components. The use of concrete slab in steel grid uses concrete strength in compression and high steel strength. Solid materials such as steel are equally more load-bearing than materials such as concrete. If there is no connection then things will behave independently, leaving good results, but if they are connected enough things act as one complete structure. In this study they determined three bands that can work effectively on composite bridges and their analysis is done using software.

7. P. Sachithanantham, D. Ebenezer Anburaj (June-2015), Addressed the experiment using models of the shell section and the span column of the straight and curved box. This work involves analyzing examples of concern that have found limited use of three-dimensional demonstration. Testing was performed between straight and curved box brackets, starting from the model of the shell segment and the segment model for each column. Finally, a parameter test was performed on a curved steel box model to assess the impact of a few key parameters on support management. The paper states that the distribution of longitudinal bending stresses on wide flange lines is still distributed evenly across the width.

It stays high on the edge and descends to the center, and is often unable to be detected accurately from the original foundation theory.

8. R. Shreedhar and Shivanand T (2015), conducted a comparative study using IRC112-2011 and IRC 21-2000 T-beam RCC bridge. The T-beam bridge was analyzed to determine the various spaces under different live loads and tested the economic value of L / d. The study concluded that an L / d ratio of 14 may be adopted on the T-beam bridge using the IRC 112 and L / d ratio of 10 using IRC 21. There were 25 to 30% of the L / d concrete value is equal to 14.

9. M.G. Kalyanshetti and S.A. Gosavi (2014), Analysis is performed using a robust matrix method and a computer program in language C is designed for cost evaluation. Research is being done related to the variability of the bending moment; next the cost estimates are made for different measurements.

A percentage reduction in the cost of a single cell, double cell and triple cell based on high density is shown. The appropriate

thickness presented here is used to achieve the economical design of the culvert box. Based on this large size the maximum cost per meter diameter of one cell, double cell and triple cell is tested. Studies show that the cost of a box culvert decreases when the large size presented in this study is considered.

3. Discussions & Conclusions

i. The above literature analysis and design of box culvert is under the influence of different kinds of loading conditions.
ii. It has been observed that effect of cushion depth, impact loadings, braking forces, angle of dispersive loads due to LL & earth reassure coefficient are the major factors in this study.
iii. In the analysis part of box culvert the pressure variation for different cases are considered. It has been observed that maximum B.M occurs for dynamics loading conditions.
iv. The analysis and design of box culvert can be performed by using the Indian Standard Codes IS456-2000, Indian Road Congress (IRC 6-2000 & IRC 21-2000)
v. The result will be analyzed by the variations in shear force, bending moment, impact load, braking force etc.
vi. From the study of above literature, it can be concluded that the performance of box culvert is depend upon the Live load, effective width, impact factor coefficient of earth pressure, depth of cushion and flow of water through it.
vii. All the above literature shows the study of RCC box culvert.
viii. Hence, the interest arises to design and analyse the box culvert by changing the material.
ix. Steel box culvert may be the next choice for further studies.
x. A number of different specific elements will appear for each general category.

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