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A Comprehensive Review on Different Aspects on Current Scenario of Analysis of Box Culvert

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Abstract: Box culverts serve as essential structure for drainage relief, water passage and traffic route under roads. They have been constructed in various shapes and sizes, accommodating different waterway and traffic needs. This review paper provides an in-depth analysis of various research papers associated with the topic of box culvert and its various advancements. Through a thorough literature review and analysis of previous works in this field, this study has identified conclusive outcomes that form the basis of our research objectives for checking the box culvert with different skew angles along with different S/H ratios for 2 cell box culvert and aim to provide technical insights and recommendations for future research in this area.

Keywords: Box Culvert, IRC loadings, H/S ratio, Skew angles

I. INTRODUCTION

Box culverts serve as essential structures for discharging water properly, especially in crossings of railways, flyovers, and roads, where soil bearing capacity is low. They offer an economical solution compared to bridges, particularly when the discharge in the opening is 18 sq. m. or when roadway crosses a high embankment. In India, box culverts are generally cast in situ, but in other countries, they are preferred due to their low cost, economic efficiency, and fast construction. The term "box" refers to its shape, and it comes in various shapes depending on the specific needs. When the number of cells increases and the span exceeds 6m, box culverts can even act as minor bridges. Their height is determined by the span, and they effectively control all types of water, including irrigation, surface water, rivers, and canals, efficiently managing storm water and floodwater during the rainy season.

II. SKEWNESS OF BOX CULVERT

Skewness in the context of a box culvert refers to the angle between the longitudinal axis of the culvert and the perpendicular to the road or railway alignment. When a box culvert is not installed perpendicular to the road or railway, it is said to be skewed. Skewness can affect the hydraulic performance, structural behavior, and design considerations of the box culvert.

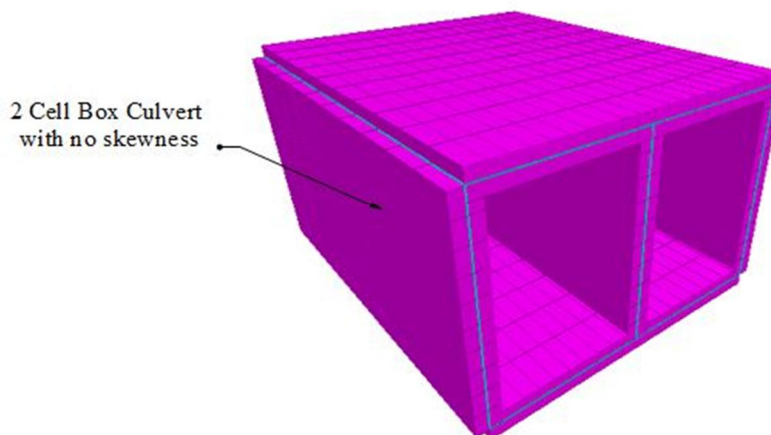


Fig. 1: 2 cell box culvert with no skewness

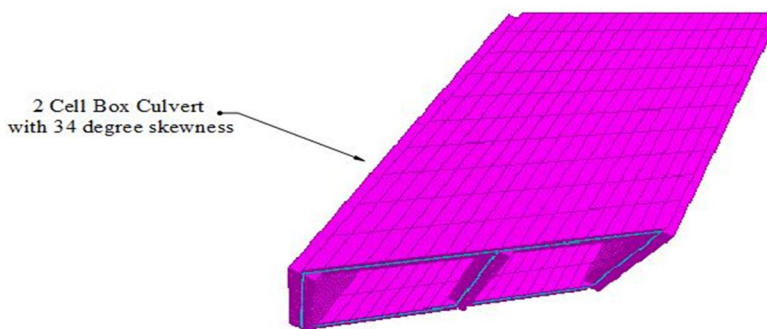


Fig. 2: 2 cell box culvert with 34 degree skewness

Skewed box culverts may experience different flow patterns and hydrodynamic forces, which can influence their hydraulic capacity and efficiency in handling water flow. Additionally, the structural design of the culvert needs to consider the impact of skewness on the distribution of loads and moments along its length.

III. LITERATURE REVIEW

Ye-Xin Chen, Bin Xi (2023), In this paper, the author focuses on the hydraulic performance of an outlet pressure box culvert, a commonly used drainage structure for pumping stations known for its compact design and efficient discharge capabilities. To tackle this challenge, a comprehensive investigation was carried out, employing a combination of physical model tests and numerical simulations. The objective was to analyze the hydraulic characteristics of an eccentric tapering outlet pressure box culvert and propose optimization strategies for enhancing the flow pattern, particularly addressing the suboptimal flow behavior observed within the culvert. Through a comparative assessment of various optimization approaches, the “diversion pier position and angle with deflecting flow baseplate” scheme emerged as the most effective solution. This scheme led to a reduction in the transverse velocity distribution ratio, achieved a uniform pressure distribution on both sides of the long diversion pier, improved axial velocity uniformity by 17.45%, and increased the average angle of the axial velocity by 8.23 degrees.

Hafiz Ahmed Waqas (2023), In this research, the primary focus is on enhancing precast reinforced box culverts through the application of numerical tools and the Finite Element Method (FEM). The study delves into the effects of haunch geometry and additional steel reinforcement on the load-bearing capacity. The research identifies critical stress areas and maximum damage locations, subsequently proposing recommended modifications that result in a remarkable 25% increase in load-carrying capacity. The introduced design technique not only promotes cost-effective solutions but also ensures the safety of concrete box culvert designs, enabling larger spans and improved water-flow capacity. These findings serve as valuable guidance for practitioners seeking to bolster the strength, structural stability, and drainage efficiency of box culverts.

Shimol Philip (2022), This study delves into the effects of skew angle and topsoil fill height on the live and dead load characteristics of a two-cell reinforced concrete (RC) skew box culvert designed for Road under Bridge (RUB) applications. The research encompasses skew angles spanning from 0° to 75° and soil fill heights ranging from 2 m to 10 m. Detailed analysis and comparison to a straight box culvert were conducted using dispersion diagrams. The findings demonstrate that skew angle had no impact on certain loads, while it did influence dynamic loads resulting from train movement and longitudinal forces arising from braking and traction. These results offer valuable insights for engineers involved in the design of RC skew box culverts for RUB projects.

Miranzadeh Azam (2022), This paper offers experimental insights into the temporal dynamics of blockage upstream of culverts caused by woody debris under unsteady flow conditions. To simulate flood scenarios, a synthetic flow hydrograph was employed in a laboratory setting. Two different diameters of cylindrical wooden dowels were used to represent woody debris during flood events. The study evaluated two culvert shapes: box and circular pipe culverts. The findings revealed that the highest blockage percentages occurred during the falling limb of the hydrograph. Notably, the feeding rate of smaller woody debris played a significant role in culvert blockage, whereas the feeding rate of larger debris had limited impact. Additionally, pipe culverts were found to be more prone to blockage compared to box-shaped culverts. The paper also introduces predictive equations, derived from regression analysis, to estimate culvert blockage percentages during flood events.

Kicheol Lee (2022), This research addresses the growing significance of underground spaces, particularly buried box culverts, as surface ground saturation increases. The interaction between these culverts and the surrounding soil is influenced by the soil type, making the study of earth pressure essential. The primary focus of this study lies in the analysis of horizontal earth pressure acting on buried box culverts, achieved through precise centrifuge model tests. While investigating the coefficient of earth pressure, it became evident that results exhibited substantial variability due to limitations in existing theories. Consequently, the research identified the need for a correction factor to accurately calculate the horizontal earth pressure applied to the box culvert's side, considering both the coefficient of earth pressure and the friction angle of the soil.

Jiancong Xu (2022), In this paper, a model implemented in LS-DYNA is introduced and applied to assess the blasting construction of rock tunnels located in close proximity to sewage box culverts. Numerical simulations utilizing the proposed damage model revealed a substantial reduction in the blasting damage range in rocks with a damage degree exceeding 0.5. This reduction occurred as the spacing between the box culvert and the tunnel increased from 1.0 m to 4.0 m, with the range decreasing from 1.0 m to 0.3 m. The model accurately represented the evolution process of rock blasting damage. As a result, the research recommends a safe distance of no less than 4.0 m between the tunnel and the box culvert during blasting construction. These findings are of significant importance for guiding the blasting construction of rock tunnels located closely beneath sewage box culverts.

Shimol Philip (2021), This research investigates the influence of top filling properties on the bending moment characteristics of two-cell reinforced concrete skew box culverts designed for Road under Bridge (RUB) applications. The study encompasses a variation in the fill height above the top slab, ranging from 0.5 m to 10 m, and employs two different top filling materials: conventional soil and EPS geofoam. The findings reveal that the utilization of geofoam as a top fill material leads to a significant reduction in bending moments at critical locations, including the center of the top slab, midspan of the second cell's bottom slab, and the bottom edge of the outer wall of the second cell, with reductions of approximately 76%, 70%, and 73.3%, respectively, compared to conventional soil fill. Furthermore, the use of geofoam results in a reduction in earth pressure. However, it's noteworthy that beyond a fill height of 8 m, geofoam no longer impacts the bending moment values of the box sections.

Irpan Hidayat (2021), This study delves into an alternative design approach involving the use of a box culvert, accompanied by a detailed cost analysis. The budget estimation adhered to the Unit Price Analysis Guidelines (AHS) within the Public Works Sector and General Specifications, which categorizes work items into ten job divisions. The cost assessment revealed that the construction of a box culvert is a more cost-effective solution compared to building an I-girder bridge. Notably, the most substantial cost disparity was observed in the domains of earthworks and structural works. While earthworks for the box culvert incurred higher costs than those for the I-girder bridge, the structural works for the box culvert were found to be more economical than their counterparts for the I-girder bridge. As a result, this study suggests that opting for a box culvert construction could represent a more financially efficient choice for the specified highway location.

Z Patongloan (2020), This paper seeks to evaluate the bending capacity of a box culvert situated beneath a railway track. The study involved two precast concrete specimens, each measuring 2000 mm x 2000 mm x 1000 mm, with a wall thickness of 250 mm. These specimens underwent a monotonic static load test, yielding valuable insights. The results of the test revealed an initial crack load of 102 kN for BC-1 and 119.7 kN for BC-2, both surpassing the crack load design threshold (P_{crack}) of 76.8 kN. Although the loading was halted at 420 kN due to equipment limitations, it's important to note that the specimens had not reached their ultimate load capacity. Nevertheless, the maximum load achieved by both specimens exceeded the design ultimate load (P_{ult}) of 227.2 kN, underscoring their robust structural performance.

Osama Salem Hussien (2020), This research explores the economic implications of incorporating haunches in culvert design. The design of the culvert's section thickness is tailored to the specific applied loads. The study reveals the effects of haunches on the stresses within box culverts and offers predictive equations for different scenarios. Furthermore, the research encompasses a cost analysis comparing various haunch widths, contributing to a deeper understanding of how haunches can play a pivotal role in optimizing culvert design from both an engineering and economic perspective.

Osama S. Hussien (2020), This paper centers its attention on the comprehensive investigation of various design parameters affecting box culverts, encompassing factors such as haunch thickness, coefficient of earth pressure, box culvert thickness, and the depth of fill above the top slab. The primary goal is to scrutinize the influence of the haunch on the stress distribution within the box culvert structure. The study meticulously assesses stress variations and provides a comparative cost analysis for different haunch widths. It also offers insight into the percentage reduction in culvert cost achievable by incorporating a haunch in the design. The numerical findings yield substantial conclusions, firmly establishing that the integration of a haunch stands as the most economically advantageous solution for mitigating stress levels in the box culvert design.

Roshan Patel (2019), This technical document offers an extensive manual for the design of box culverts, meticulously investigating a range of design parameters. The study delves into the influences of factors such as earth pressure, cushion depth on the top slab of the culvert, as well as considerations like braking force, impact load, live load, load dispersion via tracked or wheeled vehicles, and effective width. The analysis covers both culvert designs, with and without cushioning, while addressing various classes of IRC loadings. Conclusions are drawn based on the bending moments and shear forces observed in both scenarios. Additionally, the paper thoroughly explores the stipulations outlined in Indian Standards, providing justifications and insights into the considerations that guide the design process.

Roshan Patel (2019), This review paper provides an in-depth exploration of the effects of different classes of IRC loadings on box culverts, considering both cushioned and non-cushioned scenarios. The study rigorously evaluates pressure cases for each loading condition, taking into account a range of influential factors, including impact load, braking force, load dispersion through the fill, effective width, coefficients of earth pressure, live load, and more. The structural design aims to ensure the ability of the elements to withstand maximum bending moments and shear forces. The paper offers an extensive discussion of the provisions specified in the relevant codes, along with justifications and the considerations that inform all aspects of the design, providing a comprehensive insight into the structural analysis and design process.

Prashant Kumar Tripathi (2019), This paper explores the effects of varying skew angles on a skew slab bridge using the CSI Bridge software. The analysis encompasses a range of skew angles, specifically 15°, 30°, 45°, and 60°. The study scrutinizes a 6 m skew slab box culvert, which is fixed at two ends and free at the other two sides. The loading scenario under consideration involves IRC class 70r tracked loading. The analysis primarily centers on the behavior of the skew slab, aiming to assess how it responds to different skew angles and loading conditions.

Saurav (2017), This paper introduces a finite element analysis of a box culvert, conducted for parametric investigations that involve changes in aspect ratio. The primary goal is to illustrate how finite element analysis can lead to economical and efficient designs. The study involves a comparison of analysis results obtained through the traditional approach using STAAD software with those obtained through finite element analysis using ANSYS software. The comparative study seeks to highlight the advantages of employing Finite Element Methods (FEM) in box culvert design and how this approach can facilitate the development of more efficient and cost-effective designs.

Siva Rama Krishna (2017), The study examined the behavior of a box culvert under two conditions: one with soil-structure interaction and the other without it. In the absence of soil interaction, significant changes were observed. The top slab exhibited a 19% increase in bending moment, while the side walls experienced a 15% increase in bending moment compared to the condition with soil interaction. Conversely, the base slab's bending moment showed a negligible change without soil interaction. Additionally, the shear force values saw notable variations. For the top slab, there was a 27% increase in shear force, and for the side walls, a 31% increase in the absence of soil interaction. However, the shear force values for the base slab remained nearly unchanged without soil interaction. These findings highlight the substantial impact of soil-structure interaction on the behavior of the box culvert's different components.

IV. CONCLUSION AND OUTLINE OF PROPOSED WORK

A research gap appears to exist in the existing literature regarding the analysis and design related to box culverts. There is a clear need for further research to explore the influence of this factor and to formulate appropriate design guidelines aimed at addressing its impact on the behavior of box culverts. Based on the literature review, we have reached a conclusion that highlights the key findings of the research and lists the necessary outcomes:

- 1) Analyzing the box culvert with varying skew angles is crucial.
- 2) Conducting a comprehensive study on box culverts considering different H/S ratios alongside a range of skew angles.
- 3) Utilizing IRC loadings is essential, as Indian Standards offer standardized loading criteria for precise analysis.
- 4) To enhance analysis accuracy, it's advisable to include results for both 2-cell and 3-cell box culvert configurations.
- 5) Assessing various parameters, including displacements, stresses, shear forces, bending moments, and base reactions, is vital for understanding the box culvert's behavior.

The primary objective of this study is to determine the feasibility of 2 cell box culvert and its analysis over different S/H ratios under certain unit weight of soil that has going to be a major study for upcoming proposed work.

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