Analysis Of Box Culvert Usining Stadd Pro: A Review

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***Abstract*— The present study focuses on the analysis and design of a reinforced concrete box culvert using STAAD Pro software in accordance with relevant IRC and IS code provisions. Box culverts are important hydraulic structures used for the safe passage of water beneath roadways and railway embankments. Proper design and analysis are essential to ensure structural stability, durability, and hydraulic efficiency under various loading conditions. In this study, hydraulic calculations were carried out as per IRC SP 13:2004 to determine the waterway requirements and discharge capacity of the culvert. Various loads acting on the structure, including dead load, live load, earth pressure, and water pressure, were calculated according to IRC 6: Section 2. The structural components of the box culvert such as top slab, bottom slab, side walls, and base slab were designed based on IS and IRC specifications. The complete structural analysis was performed using STAAD Pro software to evaluate bending moments, shear forces, axial forces, and deflections under different load combinations. The software-based analysis provided accurate and efficient results for safe and economical design of the culvert structure. Based on the analysis and design results, reinforcement detailing and General Arrangement Drawing (GAD) were prepared.**

***Index Terms*— Box Culvert, STAAD Pro, Hydraulic Analysis, IRC SP 13:2004, IRC 6**

I. INTRODUCTION

The evolution of box culvert analysis through STAAD. Ro represents a transition from manual design procedures to advanced computer-based analysis for improved precision and efficiency. In earlier times, engineers performed lengthy and complex hand calculations, which made the process slow and less accurate. The introduction of STAAD. Ro revolutionized this practice by enabling detailed structural analysis, including soil–structure interaction and various loading scenarios. This advancement not only enhanced accuracy but also promoted cost-effective and optimized designs. Studies have shown that using limit state design methods in combination with computational tools significantly reduces material requirements compared to the traditional working stress approach.

In the past, engineers depended on traditional methods such as the short-term distribution approach, which involved lengthy and complex manual calculations. The introduction of finite element analysis software like STAAD. Ro transformed this process by enabling rapid and accurate evaluation of complex structures such as box culverts under various load conditions. Studies comparing STAAD. Ro results with manual computations have shown strong agreement, confirming its reliability. Modern analysis techniques now also consider the interaction between soil and the culvert, which earlier methods could not effectively capture. Additionally, the use of computational tools allows engineers to conduct parametric studies and optimize designs, resulting in more efficient, economical, and reliable culvert structures.

A. Components of Box culvert

Deck Slab (Top Slab): The deck slab, or top slab, is the upper horizontal component of a box culvert that directly carries traffic loads from vehicles and pedestrians. It transfers both live and dead loads to the vertical side walls and functions similarly to a bridge deck when a roadway passes over the culvert.

Bottom Slab: The bottom slab forms the base of the culvert and rests directly on the foundation or supporting soil. It resists upward soil pressure and effectively transfers the structural loads to the ground, thereby ensuring the overall stability and integrity of the culvert.

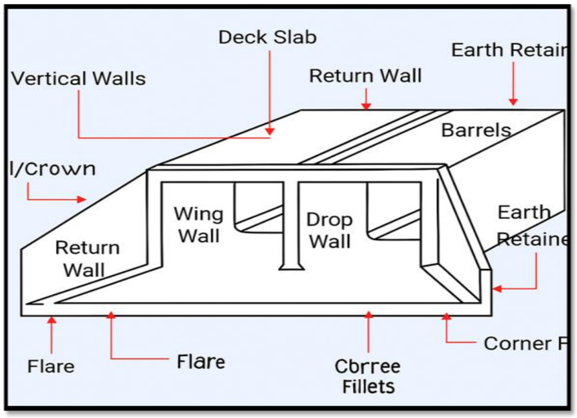

Fig 1 Components of Box Culvert.

Vertical Walls (Side Walls): The vertical or side walls serve as the main supporting components connecting the top and bottom slabs of the culvert. They resist lateral earth pressures exerted from the surrounding soil and assist in directing the flow of water through the culvert channel.

Haunch: The haunch is the triangular or curved transition region formed at the junction between the slab and the wall. It helps to minimize stress concentrations at this connection point and enhances the overall strength and rigidity of the culvert structure.

Wing Wall: Wing walls are positioned on either side of the culvert's inlet and outlet. Their primary function is to retain the adjoining earth embankment and to guide the flow of water smoothly into and out of the culvert, preventing erosion and ensuring hydraulic efficiency.

Return Wall: The return wall is a short vertical wall constructed at the end of the wing wall. It assists in retaining the adjacent soil and provides a neat and stable termination to the culvert structure, enhancing both its strength and appearance.

Drop Wall: The drop wall is a vertical structural element constructed at the downstream end of the culvert floor. Its main function is to prevent bed scouring and to regulate the difference in water levels between the inlet and outlet, thereby ensuring stable hydraulic performance.

Curtain Wall: The curtain wall is constructed below the floor slab at both the inlet and outlet of the culvert. Its primary purpose is to prevent undercutting and seepage of water beneath the structure, thereby protecting the foundation and maintaining the stability of the culvert.

Earth Retainer: The earth retainer functions to hold back the surrounding soil and prevent erosion near the culvert structure. It contributes to the overall stability of the approach embankments, ensuring safe and durable performance of the culvert system.

Flare: The flare is the angled section provided near the inlet and outlet of the culvert. It ensures a smooth transition of water flow, minimizing turbulence and energy loss as water enters or exits the structure

II. STATE OF DEVELOPMENT

Box culverts are important hydraulic structures widely used in highway and railway engineering for safe passage of water beneath embankments. Proper analysis and design of box culverts are essential to ensure structural safety, durability, and economical construction. With the advancement of structural analysis software, STAAD Pro has become one of the most commonly used tools for analyzing RCC box culverts under different loading conditions. Various researchers have carried out studies on box culverts considering hydraulic behavior, earth pressure, live loads, cushion effects, and optimization techniques using IRC and IS code provisions.

Dr. Swati Ambadkar et. al. (2025) studied the modelling and analysis of RCC box culvert bridges using STAAD Pro and Excel software for comparative analysis. The study highlighted the importance of box culverts as economical alternatives to bridges in transportation networks. Different IRC loading conditions such as IRC Class AA and IRC 70R tracked loading were considered to determine maximum bending moments and shear forces. The authors observed that STAAD Pro provides accurate structural behavior under various loading conditions and simplifies the design process. The study concluded that the software-based approach is efficient and reliable for the analysis and design of box culvert structures.

Naveen Kumar S. M. et. al. (2024) carried out the analysis and design of a single vent box culvert under different loading conditions using STAAD Pro software. The study considered dead load, live load surcharge, impact load, braking force, and soil pressure according to IRC Class AA loading. Internal and external water pressures were also included in the analysis. The authors evaluated bending moments and shear forces developed in the structure and compared computational results. The study concluded that STAAD Pro helps in obtaining precise structural responses and improves the accuracy of box culvert design.

Saurabh Rangari, et. al. (2024) conducted a comparative analysis and design study of deck bridge culverts for different mix designs and spans using software analysis. The research focused on the effect of earth pressure coefficient, angle of load dispersion, and cushion depth on the behavior of box culverts. The study compared IRC 21:2000 and IRC 112:2011 design methods and observed that the limit state method provides more economical and preferable results. Finite element analysis was also used to improve design effectiveness. The authors concluded that optimized software-based analysis leads to economical and structurally efficient culvert designs.

Ravish Chandra Chaudhary et. al. (2024) discussed the design and analysis of box culverts with emphasis on economic and structural advantages. The study highlighted that box culverts reduce construction time and cost while improving safety and durability in road projects. The moment distribution method was used for analyzing structural forces and moments. The authors observed that culverts with cushion provide better structural performance compared to culverts without cushion. The study concluded that proper load consideration and cushion depth significantly influence the structural behavior and safety of box culverts.

Ravish Chandra Chaudhary et. al. (2024) also presented a study on optimization and detailed design analysis of box culverts. The research mainly focused on the effect of length-to-height ratio and soil internal friction angle on structural performance. The authors observed that these parameters directly affect bending moments, stability, and load distribution in reinforced concrete culverts. The study concluded that optimization techniques can improve structural efficiency and reduce material consumption while maintaining safety requirements.

Rohit Kados et. al. (2022) analyzed different types of box culverts using STAAD Pro software. The study considered loading conditions such as water pressure, soil pressure, live load, braking force, and cushion effects according to IRC provisions. Comparative analysis was performed for culverts with and without cushion under different IRC load classes. The authors observed variations in bending moments and shear forces depending on cushion depth and loading conditions. The study concluded that cushion significantly affects the structural response of culverts and must be properly considered during design.

Mr. Aakash Jain et. al. (2022) carried out the analysis and design of box culverts using STAAD Pro software. The study focused on live load dispersion, earth pressure coefficients, cushion depth, and soil interaction effects. Various load combinations were analyzed according to IRC specifications. The authors compared STAAD Pro results with manual calculations and found close agreement between them. The study concluded that STAAD Pro is an efficient and user-friendly tool for accurate three-dimensional modelling and structural design of box culverts.

Hardeep Pilania, et. al. (2022) studied the analysis and design of a single-cell RCC box type vehicular underpass using STAAD Pro. The structure was modeled using beam elements connected at common nodes to represent the rigid frame behavior. IRC 6 loading conditions were adopted for the analysis. The authors compared software results with manual and Excel calculations and observed satisfactory agreement. The study concluded that STAAD Pro simplifies the modelling and design process while providing reliable structural analysis results.

Puneet Kumar Pandey, et. al. (2021) performed a comparative analysis of box culverts with cushion and without cushion using STAAD Pro software. The study considered shear force, bending moment, axial force, and deflection under different load combinations. AutoCAD was used for drafting and detailing work. The authors observed that maximum design moments varied significantly depending on cushion conditions. The study concluded that cushion depth plays an important role in reducing stresses and improving overall structural performance.

Aakash Jain, et. al. (2021) reviewed the analysis and design of box culverts using manual calculations and

STAAD Pro software. The study focused on parameters such as live load scattering angle, lateral earth pressure, and cushion depth. The authors highlighted the importance of considering cushion and soil interaction effects during structural design. The study concluded that software analysis provides better accuracy and efficiency compared to conventional manual methods.

Sudhir Kushwaha, et. al. (2020) presented a review paper on the analysis and design of box culverts using STAAD Pro. The study discussed various loading cases including surcharge loads, braking force, earth pressure, and impact loads according to IRC provisions. The authors compared software analysis results with manual calculations and found them nearly similar. The study concluded that STAAD Pro provides reliable and economical design solutions for RCC box culverts subjected to traffic and hydraulic loads.

Abdul Kareem Shammaa et. al. (2018) proposed a simplified model for the design of RCC box culverts using STAAD Pro. The study used Winkler's spring model to represent soil interaction and analyzed a single-cell culvert as a plane structure instead of a space structure. The author observed that the simplified method reduces computational effort while maintaining design accuracy. The study concluded that the proposed method provides a quick and economical solution for RCC box culvert analysis and design.

Prof. K. S. Patil, et. al. (2018) carried out the design and analysis of RCC box culverts using STAAD Pro software. The study considered culverts with and without cushion and analyzed the effect of hydraulic and traffic loads. The authors observed that structural behavior changes considerably with cushion depth and loading conditions. The study concluded that proper hydraulic considerations and structural analysis are essential for safe and economical box culvert design.

Pooja Shende et. al. (2018) studied RCC culvert analysis for different length-to-height ratios and soil friction angles using software analysis. The research focused on moments, shear forces, and thrust developed due to different loading conditions. The authors observed that the L/H ratio and soil properties significantly affect structural performance. The study concluded that proper selection of geometric proportions and soil parameters is necessary for effective culvert design.

Dr. K. Rajasekhar et. al. (2018) analyzed and designed RCC box culverts using STAAD Pro software and compared the results with MATLAB-based manual calculations. The study observed that STAAD Pro provides accurate results for bending moments and shear forces with reduced computational time. The structural elements were designed to resist maximum stresses safely. The author concluded that STAAD Pro is a reliable and efficient software for the analysis and design of reinforced concrete box culverts.

III. FINDINGS FROM LITERATURE

- Most researchers concluded that STAAD Pro is an efficient and reliable software for the analysis and design of RCC box culverts under various loading conditions.
- Studies showed that the results obtained from STAAD Pro are very close to manual calculations, which confirms the accuracy of software-based analysis.
- Researchers observed that box culverts are economical and suitable alternatives to small bridges for highways and railway crossings.
- The effect of cushion depth significantly influences bending moments, shear forces, axial forces, and deflections in box culvert structures.
- Different loading conditions such as dead load, live load, surcharge load, braking force, soil pressure, and water pressure play a major role in structural behavior.
- Several studies highlighted that IRC loading standards such as IRC Class AA and IRC 70R are essential for safe and accurate design of culverts.
- It was observed that the coefficient of earth pressure and angle of live load dispersion affect the structural response of culvert walls and slabs.
- Researchers found that culverts with cushion perform better structurally than culverts without cushion due to reduced stress concentration.
- Finite element analysis and software modelling help in optimizing the design and reducing material consumption while maintaining structural safety.
- The studies confirmed that hydraulic considerations and soil interaction are important parameters in the planning and design of box culverts.

IV. GAP IDENTIFICATION

- Most of the previous studies focused mainly on structural analysis, while limited attention was given to integrated hydraulic and structural design approaches.
- Comparative studies considering different soil conditions and varying foundation parameters are limited in available literature.
- Very few researchers have focused on the preparation of complete General Arrangement Drawings (GAD) along with detailed reinforcement detailing based on software analysis.
- Limited studies are available on optimization of box culvert dimensions for achieving economical and sustainable designs.
- Most studies analyzed single-cell box culverts, whereas limited research has been carried out on multi-cell box culvert systems.
- The influence of varying cushion depths and traffic loading combinations on long-term structural performance requires further investigation.
- Few studies considered detailed comparison between manual calculations, Excel analysis, and STAAD Pro results under identical loading conditions.
- Research related to advanced finite element modelling and real field performance validation of box culverts is limited.
- The effect of seismic loading and dynamic loading on RCC box culverts has not been extensively studied in earlier research works.
- There is scope for further research on automated and optimized design procedures using modern analysis software for faster and economical culvert design.

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- IRC SP 13:2004 – Guidelines for the Design of Small Bridges and Culverts.
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- IRC 112:2020 – Code of Practice for Concrete Road Bridges.
- IRC 78:2014 – Standard Specifications and Code of Practice for Road Bridges, Foundations and Substructure.