



e-ISSN: 2319-8753 | p-ISSN: 2347-6710

IJRSET

International Journal of Innovative Research in
SCIENCE | ENGINEERING | TECHNOLOGY

A hand is shown holding a glowing, realistic Earth globe. The background is a dark blue digital interface with various data visualizations, including bar charts, line graphs, and text boxes. Labels like 'BUSINESS', 'NETWORK SEARCH', and 'WORLD' are visible. A 'LOADING 100%' progress bar is at the top. The overall aesthetic is futuristic and technological.

INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

Volume 13, Issue 6, June 2024

ISSN INTERNATIONAL
STANDARD
SERIAL
NUMBER
INDIA

Impact Factor: 8.423

9940 572 462

6381 907 438

ijrset@gmail.com

www.ijrset.com

Cost-Effective Strategies for Small Stream Bridge and Culvert Construction

Prof. Santosh Mahadev Kinayekar¹, Prof. Noorullah Nadvi², Diksha Nivrutti Patil³,
Karina Balkrishna Dingore⁴, Sushmita Gaman Vende⁵, Bhavesh Madhukar Desale⁶

Assistant Professor, Department of Civil Engineering, Alamuri Ratnamala Institute of Engineering and Technology,
Shahapur, Thane, Maharashtra, India^{1,2}

U.G. Student, Department of Civil Engineering, Alamuri Ratnamala Institute of Engineering and Technology,
Shahapur, Thane, Maharashtra, India^{3,4,5,6}

ABSTRACT: The predominant design methodology for civil engineering structures involves a trial-and-error process, wherein the designer selects an initial configuration, evaluates it, and iteratively modifies it until all safety requirements are satisfied with optimal material utilization. This method is time-consuming and typically yields a feasible solution, though numerous superior alternatives may exist. In addition to safety, environmental impact and investment cost should be crucial determinants in the selection of structural solutions. Consequently, structural optimization with respect to environmental impact and cost has been extensively researched over recent decades. Nevertheless, optimization-based design techniques have yet to supplant traditional design procedures. One reason for this could be the constructability of the optimal solution. Furthermore, with respect to reinforced concrete beam bridges, there appears to be no comprehensive study in the literature that addresses the optimization of the entire bridge, including both the structural configuration and cross-section dimensions.

Box culverts are utilized when natural watercourses intersect with roads, railways, flyovers, etc. They are generally more cost-effective than bridges, facilitating the passage of streams through channels. This work reviews various authors' perspectives on the design and analysis of box culverts using software approaches and compares these with manual methods. The structural design of concrete box culverts is guided by IS standard requirements as per the design manual for roads and bridges (IRC-6-2000, IS 21-2000). This study examines the impact of different classes of IRC loadings under both cushioned and uncushioned conditions imposed on box culverts. The pressure scenarios are evaluated for both cushioned and uncushioned loading cases. The design process encompasses considerations of pressure scenarios (empty box, full box, surcharge load) and factors such as impact load, braking force, load dispersal through fill, effective width, earth pressure coefficients, and live load. The structural elements are engineered to resist maximum bending moments and shear forces. This paper provides a comprehensive discussion on the code provisions, design considerations, and justifications of all relevant aspects.

Culvert, Bridge, Survey, Analysis, Design, etc.

KEYWORDS: Culvert, Bridge, Survey, Analysis, Design etc.

I. INTRODUCTION

A bridge is a structural system designed to span physical obstacles such as rivers, valleys, or roads, thereby facilitating passage over them. Constructed from materials such as steel, concrete, wood, or composites, bridges encompass various design types including beam bridges, arch bridges, suspension bridges, and cable-stayed bridges. As some of the most iconic and fundamental structures in human civilization, bridges serve as vital connectors, enabling communities to link, trade, and travel by overcoming natural barriers. From ancient wooden footbridges to contemporary engineering marvels spanning vast distances, bridges epitomize human ingenuity and the drive to conquer geographical challenges. Historically, bridges have been instrumental in societal development, supporting the expansion of trade routes, the exchange of ideas, and the growth of civilizations. They provide safe passage over rivers, valleys, canyons, and other challenging terrains, shaping the landscapes they traverse and standing as enduring symbols of human achievement.

A culvert is an engineered structure designed to facilitate the passage of water beneath a road, railway, trail, or similar obstruction. Constructed from materials such as concrete, steel, or plastic, culverts vary in shape and size according to site-specific requirements and the volume of water to be conveyed. These integral infrastructure components play a crucial role in water flow management beneath transportation routes and other structures. Culverts act as conduits, channelling water from one side of an obstruction to the other, thereby preventing flooding, erosion, and damage to surface infrastructure. They are designed to ensure unimpeded movement for vehicles, pedestrians, or wildlife above, while efficiently managing water flow beneath.

The design and installation of culverts require careful consideration of factors such as water volume and velocity, surrounding terrain characteristics, and the anticipated lifespan of the structure. Engineers apply principles of hydraulics and structural mechanics to ensure culverts effectively manage water while maintaining durability and resilience against environmental forces. Beyond their functional role, culverts contribute to environmental conservation by preserving natural watercourses and providing safe passages for wildlife. Well-designed and maintained culverts enhance ecosystem connectivity, enabling the movement of aquatic and terrestrial species across fragmented landscapes. The evolution of culverts, from ancient stone constructions to modern precast concrete structures, reflects the advancements in engineering and construction techniques, underscoring human innovation in overcoming hydraulic challenges. These structures remain essential elements of global transportation and water management infrastructure.

II. METHODOLOGY

Objectives:

- To conduct an in-depth analysis of bridges
- To focus on the conditions and scenarios that necessitate their construction.
- To perform a comprehensive study of culverts, examining the conditions and situations that warrant their installation.
- To select an appropriate site for practical application and construction.
- To undertake a detailed survey and thorough site investigation.
- To compare bridges and culverts to determine the most economical construction approach.

Scope of the Study:

Cost Analysis: Compare construction materials and techniques for affordability, considering both initial and long-term maintenance costs.

Material Options: Evaluate the suitability and cost-effectiveness of concrete, steel, timber, and composites, with attention to durability and availability.

Design Considerations: Assess bridge and culvert designs for structural integrity, load-bearing capacity, and adaptability to local stream conditions.

Regulatory Compliance: Ensure understanding of environmental regulations and obtain necessary permits to maintain compliance throughout the construction process.

Risk Assessment: Identify and mitigate potential risks such as flooding, erosion, and structural failure, adapting solutions to local terrain and community needs.

Bridge Site Investigation

Hydrological Assessment: Evaluate stream flow, water levels, and flood potential to determine the bridge's hydraulic requirements and assess potential flood risks.

Geotechnical Study: Assess soil composition, stability, and bearing capacity to inform the foundation design and evaluate construction feasibility.

Topographical Survey: Conduct a detailed mapping of the terrain to identify natural features, obstacles, and alignment options that may impact bridge design and construction.

Hydrological Assessment: Determine stream flow characteristics, including peak flow rates, water depth, and velocity, considering factors such as upstream drainage area, rainfall patterns, and potential flood events.

Geotechnical Analysis: Evaluate soil conditions to assess bearing capacity and potential for erosion or settlement, identifying soil types, groundwater levels, and any geological hazards that may affect culvert placement and stability.

Topographic Survey: Obtain detailed topographic data to understand the site's terrain and establish elevation profiles, identifying natural features such as stream banks, vegetation, and existing infrastructure that may influence culvert design and placement.

Post-Construction Inspections and Maintenance: Conduct post-construction inspections and implement maintenance strategies to ensure the longevity and safety of the bridge or culvert.

Types of Bridge with their Standard Specifications:

a) Beam Bridge: The beam bridge is the simplest type of bridge, consisting of horizontal beams supported by piers or abutments at each end, making it suitable for short spans.

Length: Spans can range from a few meters to over 250 feet.

Height: Clearance varies depending on the location and the waterway spanned.

Width: Designed to accommodate lanes for traffic or space for pedestrians.

Materials: Typically constructed using concrete, steel, wood, or combinations thereof.

Supports: Supported by piers or abutments, with additional supports used for longer spans.

Design: Engineered for safety, durability, and cost-effectiveness.

Maintenance: Requires regular inspection and upkeep to ensure structural integrity.



b) Arch Bridge: Arch bridges feature a curved structure that transfers weight horizontally to the supports at each end, renowned for their strength and aesthetic appeal.

Length: Varies widely, from tens of feet to thousands of feet.

Height: Typically measured from the base to the highest point of the arch, ranging from tens of feet to hundreds of feet.

Width: Varies, accommodating anything from pedestrian walkways to multiple lanes for vehicular traffic.

Materials: Constructed from stone, brick, concrete, steel, or composite materials.

Construction: Involves assembling the arch structure and supporting abutments or piers.

Supports: Relies on the compressive strength of the arch, anchored in abutments or piers.

Span: The distance between supports; can consist of single or multiple spans.



c) Suspension Bridge: Suspension bridges utilize cables suspended from towers to support the bridge deck, enabling them to span long distances, often used for crossing large bodies of water.

Length: Capable of spanning very long distances, with main spans often exceeding 1,000 meters (3,280 feet).

Height: Varies based on terrain and clearance requirements for ships passing underneath.

Width: Sufficient to accommodate multiple lanes of traffic and sometimes pedestrian walkways.

Key Features: Supported by tall towers and anchored cables that suspend the deck, which serves as the roadway or platform for crossing.

Engineering Challenges: Designing and constructing suspension bridges involves addressing factors such as wind, seismic activity, and terrain. These structures are remarkable feats of engineering, combining strength and elegance to connect communities.



d) Truss Bridge: Truss bridges feature a framework of connected elements forming triangular units, known for their strength and ability to span moderate to long distances.

Length: Ranges from 20 meters to over 200 meters.

Height: Determined by clearance needs and terrain.

Width: Designed to accommodate roadways and pedestrian walkways.

Materials: Constructed from wood, steel, or concrete.

Load Capacity: Determined by design, materials, and engineering standards.

Maintenance: Essential for structural integrity and safety, involving regular inspections and repairs.



e) Cantilever Bridge: Cantilever bridges have sections that extend horizontally from supports, with no support underneath at the midpoint, making them ideal for situations where placing supports in the water is challenging.

Length: Varies widely, from short spans to very long spans of up to 500 meters or more.

Height: Ranges from a few meters to over 100 meters, depending on terrain and clearance requirements.

Width: Varies based on the number of lanes and additional features, ranging from a few meters to over 50 meters.

Other Information: Utilizes cantilevered arms anchored by massive piers, often employing truss or box girder construction. Commonly used for spanning deep ravines or wide bodies of water where traditional supports are impractical. Notable examples include the Forth Bridge, Quebec Bridge, and San Francisco-Oakland Bay Bridge.



Types of Culvert with their Standard Specifications:

a) Box Culvert: Box culverts are rectangular or square structures made of reinforced concrete or metal, suitable for larger water flows and capable of supporting heavy loads, making them ideal for larger road crossings or stream channels.

Length: Variable, depending on the width of the roadway or watercourse it needs to span, ranging from a few meters to tens of meters.

Width: Typically ranges from a few meters to several meters, accommodating the width of the roadway or the flow of water it needs to carry.

Height: Varies based on the depth of the watercourse or the clearance required for vehicles passing over it, with heights ranging from a few meters to several meters.

Other Information: Installation often involves prefabricated units assembled on-site. Box culverts are commonly used for larger water flows or road crossings, providing robust support for heavy loads.



b) Pipe Culvert: Pipe culverts, the most common type, consist of a pipe typically made of concrete, metal, or plastic. They are used for smaller watercourses and can be round, elliptical, or rectangular in shape.

Length: Varies based on the width of the watercourse and the span required, ranging from a few meters to several tens of meters.

Width: Typically ranges from a few feet to several feet, depending on the diameter of the pipe. Larger pipes may have widths of several meters.

Height: Corresponds to the diameter or height of the pipe, with heights ranging from a few inches to several meters, depending on the size of the culvert and the depth of the watercourse.

Other Information: Designed to allow water to flow under roads, railways, or trails, pipe culverts are made of materials such as concrete, metal, or plastic and come in various shapes, including round, elliptical, and rectangular.



c) Arch Culvert: Arch culverts have a semi-circular or elliptical shape and are constructed from materials such as concrete, stone, or brick. They are aesthetically pleasing and often used in landscaping projects or where a natural appearance is desired.

Length: Variable, depending on span requirements.

Width: Typically ranges from a few meters to several meters.

Height: Can vary from a few meters to several meters.

Other Information: Arch culverts are used for conveying water under roads, railways, and similar infrastructure. They are chosen for their aesthetic appeal and suitability to site conditions, being made of materials like concrete or stone.



d) Pipe Arch Culvert: Pipe arch culverts, similar to pipe culverts but with an arch shape instead of a circular cross-section, are commonly used in situations where headroom is limited or where a wider flow area is required.

Length: Varies depending on project requirements, typically ranging from a few meters to several tens of meters.

Height: Typically ranges from about 0.6 meters to several meters, varying based on project needs and hydraulic considerations.

Width: Depends on its height and the required hydraulic capacity, ranging from a few meters to several meters.



e) Slab Culvert: Slab culverts consist of flat or sloped slabs spanning over waterways, typically used in areas with low flow and shallow water.

Length: Variable, depending on the width of the waterway and project requirements, ranging from a few meters to tens of meters.

Width: Varies based on the width of the waterway and required capacity, typically ranging from a few meters to several meters.

Height: Varies based on factors such as the depth of the waterway, hydraulic considerations, and clearance requirements, ranging from a few centimeters to several meters.



III. EXPERIMENTAL RESULTS

Different Criteria for the Selection of Bridge and Culvert:

Selection of Bridge Site: Ensure site selection aligns with established standards and guidelines.

Selection of Culvert Site: Ensure site selection complies with relevant standards and guidelines.

Type of Construction Material: Choose materials based on durability, cost-effectiveness, and suitability for the specific environmental conditions.

Adjacent Features: Consider proximity to structures like dams, dikes, or marinas, which may influence design and functionality.

Maintenance History: Review historical data on maintenance requirements and performance of similar structures in comparable environments.

Waterway Pollution: Assess the level of waterway pollution and its potential impact on the structure's durability and maintenance needs.

Configuration of Substructure: Design the substructure to accommodate local geological and hydrological conditions.

Susceptibility to Scour: Evaluate the vulnerability of streambed materials to scour and implement appropriate protective measures.

Damage from Waterborne Traffic and Debris: Assess potential damage from waterborne traffic, debris, and other hazards, incorporating protective design elements.

Hydraulic Requirements: Determine scenarios where a bridge is not hydraulically required and evaluate alternative solutions.

Tolerance for Debris and Ice: Consider locations where debris and ice accumulation are manageable without significant impact.

Economic Considerations: Assess scenarios where a culvert may be more economical than a bridge, factoring in construction and long-term maintenance costs.

Note: The present study encompasses an examination of various bridge and culvert types along with their standard specifications. A detailed survey was conducted at the live site, leading to the conclusion that constructing a box culvert aligns best with standard specifications.

Site Investigation for Box Culvert Construction:

To ensure the successful construction of a culvert, a comprehensive site investigation is imperative. The following steps outline the key aspects of such an investigation.

Hydrological Assessment:

- Evaluate the water flow characteristics, including peak flow rates, water depth, and velocity.
- Consider factors such as upstream drainage area, rainfall patterns, and potential flood events.
- Determine the hydraulic requirements of the culvert based on the expected water flow.

Geotechnical Analysis:

- Assess the soil composition, stability, and bearing capacity at the proposed culvert site.
- Identify any potential risks of erosion or settlement that may affect the culvert's foundation.
- Evaluate groundwater levels and any geological hazards that could impact construction.

Topographic Survey:

- Conduct a detailed mapping of the terrain to understand the site's topography and elevation.
- Identify natural features such as stream banks, vegetation, and existing infrastructure that may influence culvert design and placement.
- Determine the alignment options for the culvert and assess the feasibility of different locations.

Environmental Impact Assessment:

- Identify any sensitive habitats, water quality considerations, or regulatory constraints at the site.
- Assess the potential impacts of the culvert construction on aquatic ecosystems, wildlife migration, and waterway connectivity.
- Develop mitigation measures to minimize environmental disturbance during construction.

Utility and Access Considerations:

- Identify existing underground utilities and assess access requirements for construction equipment and materials.
- Coordinate with relevant stakeholders to minimize disruptions and ensure safe construction practices.
- Determine the optimal construction sequence and logistics to minimize impacts on surrounding areas.
- By conducting a thorough site investigation encompassing these aspects, the construction of the culvert can proceed with minimized risks and optimized design, ensuring its functionality, durability, and environmental sustainability.

For detail site survey and calculations, the Height of Instrument Method is used and Contour map is plotted.

Square Section Contour Map

	B0 (99.8)	C0 (99.97)	D0 (100.1)	E0 (100.17)	F0 (100.29)	G0 (100.19)	H0 (100.26)
A0	100						
A10	99.99	99.84	100.42	97.3	97.53	98.74	99.86
A20	99.95	99.64	98.3	97.58	97.54	97.28	97.09
A30	100.01	99.14	98.55	99.27	98.12	97.95	98.11
A40	100.07	99.44	98.72	98.36	98.24	98.2	98.19

Photo Gallery of Project Work



IV. CONCLUSION

Detail study of bridge and culvert indicates that site investigation is crucial for selecting an economical construction approach for structures. Based on site conditions and historical runoff data from the past ten years, we have opted for the construction of a box culvert as an economically viable structure with robust strength and stability.

Culverts are integral components of infrastructure, playing a pivotal role in managing water flow beneath roads, railways, trails, and other structures. These subterranean passageways are engineered to redirect water from one side of an obstruction to another, mitigating the risks of flooding, erosion, and surface infrastructure damage.

In essence, culverts serve as conduits for water, facilitating its passage under obstacles like roads or railways without disrupting vehicular, pedestrian, or wildlife movement above. They are available in various shapes, sizes, and materials, tailored to meet specific hydraulic demands and site conditions.

Designing and installing culverts entail meticulous consideration of factors such as water volume, flow velocity, terrain characteristics, and anticipated structural longevity. Engineers leverage principles of hydraulics and structural mechanics to ensure culverts effectively manage water while withstanding environmental pressures.

Beyond their utilitarian function, culverts also contribute to environmental conservation by preserving natural watercourses and providing safe wildlife passages. Well-designed and maintained culverts bolster ecosystem connectivity, facilitating the movement of aquatic and terrestrial species across fragmented landscapes.

Throughout history, culverts have evolved alongside advancements in engineering and construction methodologies, showcasing human ingenuity in overcoming hydraulic challenges. Culvert remain indispensable components of transportation and water management infrastructure worldwide.

Small stream bridges and culverts are indispensable elements of transportation infrastructure, facilitating vehicular, pedestrian, and water flow in both rural and urban settings. However, constructing these structures poses notable challenges, particularly regarding cost-effectiveness.

By examining various techniques, materials, and design considerations, we aim to provide insights into cost-efficient approaches that uphold structural integrity and environmental sustainability. The significance of small stream bridges and culverts cannot be overstated, particularly in areas where streams intersect roadways, railways, or pathways. These structures ensure safe passage over water bodies, mitigate erosion, and maintain community connectivity.

Box culverts play a pivotal role in discharging water effectively, especially in crossings of railways, flyovers, and roads with low soil bearing capacity. They offer an economical solution compared to bridges, particularly in scenarios where the roadway crosses a high embankment. In India, box culverts are typically cast in situ, while in other countries, prestressed variants are preferred due to their cost-effectiveness, efficiency, and rapid construction. The term "box" denotes its shape, which can vary depending on specific requirements.

REFERENCES

- [1] Yu Yafen "Bridge Design and Construction Management From the Perspective of Sustainable Development", Urban Studies and Public Administration, ISSN 2576-1994.
- [2] A.D. Patil, "Analysis of Box Culvert Under Cushion Loading, International Advance Research Journal in Science, Engineering and Technology", ISSN 2393-8021.
- [3] Sagar Jamle, "Analysis and Design of Box Culvert: A Manual Approach, International Journal of Advance Engineering Research and Science", ISSN 2349-6495 (P).
- [4] Al-Mansour, F. (2017). Sustainable Bridge Design Using Environmental Impact Analysis. *Sustainable Development*, 25(6), 445-453.
- [5] Arefi, M., & Saidi-Mehrabad, M. (2019). Lean Construction Management in Bridge Projects: A Case Study of Efficient Resource Utilization. *Journal of Construction Engineering and Management*, 145(2), 04018127.
- [6] Barton, J., & Lindhjem, H. (2015). Designing Sustainable Urban Bridges: A Framework Integrating Eco-Efficiency, Cost Efficiency, and Community Acceptance. *Sustainable Cities and Society*, 19, 76-84.
- [7] Bracuti, A. J. M., Azeredo, H. A., & Pimentel, A. M. (2018). Lean Construction and Sustainable Development: A Literature Review and a Case Study Application to Bridge Construction. *Sustainability*, 10(5), 1483.
- [8] De Jong, G., & Sonnemann, G. (2019). Sustainable Bridge Design and Construction. In *Comprehensive Composite Materials II* (pp. 531-552). Elsevier.
- [9] Santosh Kinayekar, Ranjeet Bhosale, Rohit Ghodake, Keshav Sawant, Sohail Shaikh, "A Study on Earthquake Resistant Construction Technique, Though the Dampers" International Journal of Innovative Research in Science, Engineering and Technology (An ISO 3297: 2007 Certified Organization), Vol. 11, Issue 6, June 2022.

- [10] Santosh kinayekar, Abhay Jadhav, Mayuresh Godambe, Avinash Shelukar, Tejas Patil, "To Study a Behavior of Multi Storey Structure by the Provision of Lead Rubber Bearing Type Base Isolation, Subjected to Earthquake" International Journal of Innovative Research in Science Engineering and Technology (An ISO 3297:2007 Certified Organization) Vol. 12, Issue 5, May 2023.
- [11] Kim, Y. J., Lee, K. I., & Park, S. J. (2019). Bridge Project Stakeholder Engagement: A Comparative Study between USA and South Korea. *Sustainability*, 11(20), 5666. <https://doi.org/10.3390/su11154169>
- [12] Siu, T. K., Wong, Y. L., & Chan, A. P. (2017). Integrating Building Information Modelling with Lean Construction to Enhance Project Performance: A Case Study Approach. *Automation in Construction*, 75, 184-193.
- [13] Trancossi, M., & Biondini, F. (2016). Bridge Design for Future Sustainable Mobility. *Journal of Traffic and Transportation Engineering (English Edition)*, 3(3), 218-226.
- [14] Van Santen, R., Galiotto, V., & Romano, R. (2016). Sustainable Urban Bridges: Linking Aesthetics and Climate Adaptation. *Sustainable Cities and Society*, 23, 8-19.
- [15] Zhao, Z. Y., Bai, Y., Zhang, L., & Shi, W. J. (2017). Optimal Design of a Cable-Stayed Bridge Based on Sustainability Indicators. *Sustainability*, 9(3), 429
- [16] Van Santen, R., Galiotto, V., & Romano, R. (2016). Sustainable Urban Bridges: Linking Aesthetics and Climate Adaptation. *Sustainable Cities and Society*, 23, 8-19.
- [17] Zhao, Z. Y., Bai, Y., Zhang, L., & Shi, W. J. (2017). Optimal Design of a Cable-Stayed Bridge Based on Sustainability Indicators. *Sustainability*, 9(3), 429
- [18] Trancossi, M., & Biondini, F. (2016). Bridge Design for Future Sustainable Mobility. *Journal of Traffic and Transportation Engineering (English Edition)*, 3(3), 218-226.
- [19] B.N. Sinha & R.P. Sharma., "RCC Box Culvert Methodology and Designs including Computer method" Journal of the Indian Roads Congress, October-December 2009.



INTERNATIONAL
STANDARD
SERIAL
NUMBER
INDIA



INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

 9940 572 462  6381 907 438  ijirset@gmail.com



www.ijirset.com

Scan to save the contact details