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Prior to Commencing Bridge Construction: The Design Process

Prof. Santosh Mahadev Kinayekar¹, Prof. Rakesh Narayan Salunke², Prof. Sukant Kumar Chauhan³
Sajyot Vilas Gharat⁴, Mukesh Bhagwan Yede⁵, Abhishek Narayan Thakur⁶,
Zeeshan Shaikh⁷

Assistant Professor, Department of Civil Engineering, Alamuri Ratnamala Institute of Engineering and Technology,
Shahapur, Thane, Maharashtra, India^{1,2,3}

U.G. Student, Department of Civil Engineering, Alamuri Ratnamala Institute of Engineering and Technology,
Shahapur, Thane, Maharashtra, India^{4,5,6,7}

ABSTRACT: The proposed abstract delineates a pioneering design methodology for a contemporary bridge structure, prioritizing innovation, sustainability, and structural robustness. By leveraging cutting-edge materials like high-strength concrete and carbon fiber composites, the design aims to amalgamate aesthetic allure with structural resilience. Employing parametric modelling and computational analysis allows for the optimization of bridge geometry, enhancing efficiency and cost-effectiveness. Additionally, integration of smart sensor technologies facilitates real-time monitoring of structural health, ensuring safety and longevity. The design ethos underscores synergy with the environment, emphasizing minimal ecological impact and augmented community connectivity. In essence, this abstract heralds a progressive approach tailored to meet the evolving demands of modern infrastructure, while championing sustainability and innovation.

KEYWORDS: Bridge construction process, Site survey, Hydrology data, IRC Loading etc.

I. INTRODUCTION

A bridge is a structure that spans horizontally between supports, functioning to carry vertical loads. The prototypical bridge is simple structure of two supports holding up a beam, yet it must overcome inherent engineering challenges: the supports must be robust enough to sustain the structure, and the span between supports must be strong enough to bear the loads. Spans are generally minimized; longer spans are justified when good foundations are scarce, such as over deep-water estuaries.

Bridges, financed by public funds, must serve the public interest with a threefold goal: efficiency, economy, and elegance, while maintaining safety. Efficiency is a scientific principle focused on maximizing performance with minimal materials. Economy, a social principle, values reducing construction and maintenance costs while preserving efficiency. Elegance, a symbolic or visual principle, emphasizes the designer's personal expression without compromising performance or economy. While efficiency and economy are well-defined, elegance is more contentious. Since the early 19th century, modern designers, starting with Scottish engineer Thomas Telford, have written about elegance or aesthetics. Bridges belong to the public, who ultimately judge their elegance. Professionals generally hold three views: some believe bridge structure is solely the engineer's domain, with beauty achieved through architectural additions. Others argue that the most efficient use of materials inherently results in beauty. A third perspective suggests that engineers, without adding significant materials or costs, should consider aesthetics, given the various choices of similar efficiency and economy.

Bridges are generally categorized as either standard overpass bridges or unique-design bridges over rivers, chasms, or estuaries. This article describes common features of both types but focuses on unique bridges due to their greater technical, economic, and aesthetic significance.

II. RELATED WORK

Objectives:

1. To obtain the basic ideas of bridge building.
2. To be familiar with the different types of bridges and their design principles.
3. To understand various types of loading and their forms of application.
4. To comprehend various methods used in the design of the structural components of bridges and their limitations.
5. To be familiar with the design standards and code specifications for bridges.
6. To understand the standard specifications regarding the design of bridges.

III. METHODOLOGY

Preliminary Data Collection for Bridge Design:

Site Selection Survey

site selection process based on following criteria.

1. includes a straight reach of the river with Steady river flow without whirls and cross currents.
2. A narrow channel with firm banks.
3. Sustainable high banks above the high flood level on each side.
4. Rock or other hard, in-erodible strata close to the river bed level.
5. Proximity to a direct alignment of the road to be connected.
6. Absence of sharp curves in the approaches.
7. Absence of expensive river training works.
8. Avoidance of excessive underwater construction.

In selecting the site, it was essential to investigate multiple potential sites and choose the one that would serve the bridge's needs at the least cost.

Topographical Survey

A topographical survey was conducted for a detailed engineering survey of the proposed bridge site. Total stations, reflectors, and measuring tapes were typically used for this detailed survey. After consultations with technical personnel and local villagers, and guided by river morphology, an axis line joining the left and right banks was established. The bridge site detailing area covers a suitable region along the river's length, both upstream and downstream, as well as the left and right banks along the existing approach roads.

Geotechnical Investigation

Geotechnical investigation is a crucial component of the project for designing the proposed bridge. The geotechnical investigation included core drilling, test pitting, and visual site inspection. For our project, direct geotechnical data collection was not feasible, so we used data suitable for our locality based on similar regional projects. However, we conducted a sieve analysis of the bed soil, determining its mean size, specific gravity, and water content.

Vertical Clearance Above H.F.L

For high-level bridges, vertical clearance should be maintained between the High Flood Level (H.F.L) and the lowest point of the superstructure. This allowance accommodates possible errors in estimating the H.F.L. and design discharge and ensures floating debris can pass under the bridge without causing damage. The difference between vertical clearance and freeboard is often misunderstood. Vertical clearance is the difference in level between the H.F.L. and the lowest point of the superstructure. In contrast, freeboard refers to the difference between the highest flood level (after allowing for afflux) and the formation level of the embankment on the approaches or the top level of guide bunds. For high-level bridges, the freeboard should be at least 600 mm.

Scour Depth

Scour depth refers to the erosion depth of the stream bed during flood discharge when the stream velocity exceeds the bed material's limiting velocity. Scour depth should be measured with reference to existing structures near the proposed bridge site if possible. Adjustments should be made for additional scour due to the designed discharge being greater than the observed flood discharge and increased velocity caused by bridge construction. If practical measurement is not

feasible, the normal depth of scour can be computed using equations for natural streams in alluvial beds ($d=0.473(Qf)^{0.33}$).

Hydrology Data

The hydrological data was acquired from secondary sources, and the calculation of the maximum discharge of the river was carried out using several methods.

A) Rational Method

The rational formula for flood discharge considers the intensity, distribution, and duration of rainfall, as well as the area, shape, slope, permeability, and initial wetness of the catchment. The catchment area is a major factor in runoff. The shape of the catchment affects peak discharge, with long and narrow basins yielding less peak discharge than pear-shaped basins. Steep slopes result in shorter times of concentration compared to flatter slopes. A typical rational formula is $Q=A \cdot I_o \cdot \lambda$.

B) Area Velocity Method

This method is based on the hydraulic characteristics of the stream and is considered reliable for determining flood discharge. The velocity of the stream under flood conditions is calculated using Manning's formula. The discharge Q is given by $Q=A \cdot v$.

C) Inglis Formula

Based on flood data from catchments in the Western Ghats in Maharashtra, the peak flood Q in m^3/s is expressed as $Q=124AA+10.4$ Where A = catchment area (km^2).

D) WECS Formula

In the Nepalese context, the Water and Energy Commission Secretariat (WECS) developed empirical relationships for analysing floods of different frequencies. The discharge formula for a 100-year return period is $Q=14.63(A3000+1)^{0.7342}$. Where Q = maximum discharge (m^3/s) & $A3000$ = basin area below 3000 m elevation (km^2)

E) Ryves Formula (1884)

Developed for the Tamil Nadu region, this formula is used in Tamil Nadu and parts of Karnataka and Andhra Pradesh. The maximum discharge Q is $Q=CR \cdot A^{2/3}$. Where Q = maximum discharge (m^3/s), A = catchment area (km^2), CR =Ryves coefficient (6.8 for areas within 80 km from the east coast, 8.5 for 80-160 km, 10.2 for limited areas near hills).

F) Dickens Formula (1865)

This formula is widely used in Central and Northern India. The discharge Q is $Q=CD \cdot A^{3/4}$
Where Q = maximum flood discharge (m^3/s), A = catchment area (km^2), CD = Dickens constant (6 for North Indian plains, 11-14 for North Indian hilly regions, 14-28 for Central India, 22-28 for Coastal Andhra and Orissa).

IRC Loads for Bridge Design

According to IRC: 6-2014, road bridges and culverts are classified based on the loadings they are designed to carry.

IRC Class AA Loading

Adopted within certain limits, in existing or contemplated industrial areas, and along specified highways and areas. Bridges designed for Class AA loading should also be checked for Class A loading in each lane.

IRC Class A Loading

Normally considered for all important bridges and culverts, with one train of Class A loading in each lane.

IRC Class B Loading

Typically considered for temporary structures and bridges in specified areas. Structures with timber spans are regarded as temporary.

key steps in the design process include:

Preliminary Planning: Detailed site investigations, feasibility studies, and environmental impact assessments lay the groundwork for a viable project.

Conceptual Design: Developing and evaluating multiple design alternatives ensures that the most effective and economical solution is selected.

Detailed Design: Through rigorous structural analysis, design calculations, and the use of methods like influence lines and Pigeaud's method, the integrity and safety of the bridge are assured.

Review and Approval: Peer reviews, authority approvals, and stakeholder consultations add layers of scrutiny and input, enhancing the design's robustness.

Construction Planning: Developing a comprehensive construction schedule, resource allocation plan, risk management strategy, and contracting process ensures readiness for the execution phase.

Mobilization: Preparing the site, procuring materials, and deploying personnel set the stage for the actual construction activities.

IV. EXPERIMENTAL RESULTS

Influence Line Diagram:

Structures are typically analysed for loads with fixed points of application. However, in many cases, such as bridges, structures must be analysed for moving loads that change positions. This scenario is common with bridges subjected to multiple moving vehicles, forming a train of wheel loads. To design such structures, it is insufficient to analyze for a single load position and calculate stress resultants like bending moments, radial and normal shear forces. Instead, engineers need to determine the maximum stress resultants, both positive and negative, at any section of the structure. They may also need to know the maximum deflection at a specific point under moving loads. Finding these values through trial and error for various load positions is time-consuming and uncertain. The process is simplified by using the concept of an influence line. An influence line is a graph showing the variation of a function, such as reaction, bending moment, shear force, or deflection, at a given point of a structure as a unit load moves across it. The direction of the moving unit load is determined by the expected nature of loading on the structure.

Use of Influence Line Diagram:

Using the principle of superposition, influence lines can solve two main types of problems:

If the influence line for a function is known, its value for any position of several parallel moving loads can be determined. Influence lines can identify the specific position of parallel moving loads that produce the maximum positive or negative value of a function at a given point on the structure, which is crucial for practical applications.

Design of Deck Slab:

Pigeaud's Method: Pigeaud's method is used for analyzing slabs spanning in two directions in bridge design, which often encounters heavy patch loads, making it suitable for deck slab design.

Analysis of Slab Decks:

I. Slab Spanning in One Direction: For slabs spanning in one direction, dead load moments can be computed assuming the slab is simply supported. Bridge deck slabs are designed for Indian Roads Congress (IRC) loads, specified as class AA or A based on the bridge's importance. For slabs supported on two sides, the maximum bending moment caused by a wheel load is assumed to be resisted by an effective width of slab parallel to the supports. The effective width of dispersion for a single concentrated load is calculated using:

$$b_{eff} = K \times (1 - xL) + bw$$

Where:

b_{eff} = Effective width of slab

L = Effective span

x = Distance of the centre of gravity from the nearer support

bw = Breadth of concentration of load

K = Constant depending on the ratio (B/L) as per IRC 21

II. Slab Spanning in Two Directions: For bridge decks with tee beams and cross girders, the deck slab is supported on all four sides and spans in two directions. The moments in both directions can be calculated using design curves developed by M. Pigeaud. This method applies to rectangular slabs supported freely on all four sides and subjected to a symmetrically placed concentrated load. The design procedure involves using Pigeaud's curves to determine moments in two directions for accurate and effective deck slab analysis.

V. CONCLUSION

The bridge design process is a complex and multifaceted endeavour that requires meticulous planning, analysis, and coordination. By following a structured approach, engineers and project managers can ensure that every aspect of the design and construction is addressed comprehensively, leading to the successful completion of the project.

By adhering to this thorough design process, the likelihood of encountering unexpected challenges during construction is minimized, leading to a more efficient and successful project. The ultimate goal is to deliver a bridge that is not only structurally sound and functional but also cost-effective and environmentally sustainable.

In conclusion, the design process prior to commencing bridge construction is critical to the project's success. It ensures that the bridge will meet all technical requirements, withstand anticipated loads, and serve the needs of the community effectively. Through diligent planning, analysis, and collaboration, engineers can create infrastructure that stands the test of time, contributing to the safety and development of society.

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