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Hydrological and Structural Design of a T-Girder Motorable Bridge Over Seti Khola

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***Abstract*—This detailed project report discusses hydrological design concerns and structural analysis for a motorable bridge. Beginning with a detailed assessment of the watershed and an estimate of design floods, topographic data obtained from the topographic survey and DHM Pokhara offices informs the selection of relevant hydrological methodologies. The research includes in-depth analyses of rainfall, topography, and land use to determine runoff volumes and peak flow rates. The report uses approaches such as the Rational Method, DHM Method, and WECS Method to compute the High Flood Level for design flood through stage-discharge curve analysis. Moving on to the structural element, the project completes a thorough limit state design of an RC T-beam bridge in accordance with Nepal Bridge Standards, Department of Road, Indian Standards, and Indian Roads Congress guidelines. The superstructure, bearing, substructure, and foundation components designed utilizing limit-state design concepts. The superstructure components are investigated under Class 70R Wheel, Class 70R Tracked, Single axle load, Bogie load, and Class A loading conditions, using plate bending theory for slabs and Courbon's approach for major girders. The limit state method is used while selecting and designing elastomeric bearings. The substructure design features two similar abutments and an open foundation to accommodate both basic and seismic load combinations. In addition, a stability study of the abutments is performed for specific load scenarios. The result of this effort is drawings and bar bending schedules and design of an RC T-Beam Bridge that incorporates many engineering disciplines and standards.**

***Index Terms*—T-Girder Bridge, Reinforced Concrete, Hydrological Analysis, Structural Design, Design Flood, Limit State Method, Finite Element Method, Courbon's Method, Nepal Bridge Standard, Seti Khola**

I. INTRODUCTION

Bridges are one of the most important structures in the road transportation system. A bridge is a structure that carries a service (which may be highway or railway traffic, a footpath, public utilities, etc.) over an obstacle (which may be another road or railway, a river, a valley, etc.) and then transfers the loads from the service to the foundations at ground level.

The bridge controls both the volume and the weight of the traffic carried. When it comes to design of the bridge it covers wide range of analysis and calculations from suitable site selection in river reach, geotechnical investigations and tests, hydrological analysis and design to the structural analysis and design. The bridges provide vital role in the transportation system. At every intersection of road and river networks a bridge will be required.

The development of the T-beam type in the early 20th century reflected a better understanding by engineers of the forces of compression and tension within reinforced concrete bridges. Development of Brides in Nepal Started around sixty years ago. During the starting phase, most of the major works for development of bridge network was done through the technical and financial assistance of donor agencies. Later, the task was taken up by the Different departments of Nepal Government like Department of Roads (DoR) and DoLIDAR (Sharma Wagle, Khakurel, & Poudel, 2022).

In most practices T-beam bridges provides ease both in terms of Design and economics when the span of the bridge is about 25m. It is so named as the main longitudinal girders are designed as T-beam, which is cast monolithically with deck slab. The top of the T-shaped cross section serves as a flange or compression member in resisting compressive stress (Johnson Victor, 2017). The web of the beam below the compression flange

II. STUDY AREA AND DATA COLLECTION

2.1 Study Area

The proposed bridge spans Seti Khola at Huwas, Parbat, with coordinates approximately 28° 3' 33.41" N, 83° 40' 28.96" E and an elevation near 740 m MSL. The region features mixed land use, steep slopes, and variable hydrological patterns. disk drive.‖ Avoid combining SI and CGS units, such as current in amperes and magnetic field in oersteds. This often leads to confusion because equations do not balance dimensionally. If you must use mixed units, clearly state the units for each quantity in an equation.

The SI unit for magnetic field strength H is A/m. However, if you wish to use units of T, either refer to magnetic flux density B or magnetic field strength symbolized as µ0H. Use the center dot to separate compound units, e.g., —A·m^2.‖

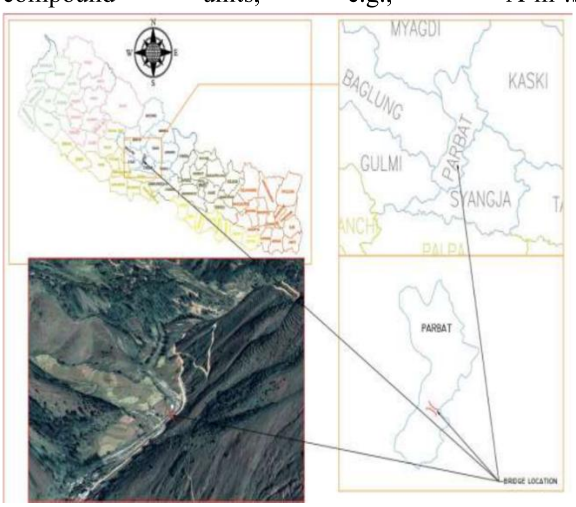


Figure 1. Site Location Map

2.2 Data Collection and Processing

Primary Data:

- Field surveys provided topographic details and hydraulic parameters (e.g., river velocity, cross-section measurements).

Secondary Data:

- Rainfall data from the Office of Hydrology and Metrology and geotechnical reports from LRBSU.
- DEMs acquired from NASA's Earth Data Portal were processed using GIS software (ArcGIS, Geopandas) for catchment delineation and land-use analysis.

2.3 Data Processing Tools:

Python scripts (using libraries such as pandas, geopandas, and matplotlib) were employed for statistical analyses (Gumbel's and Weibull's methods) and for plotting key figures such as rating curves.

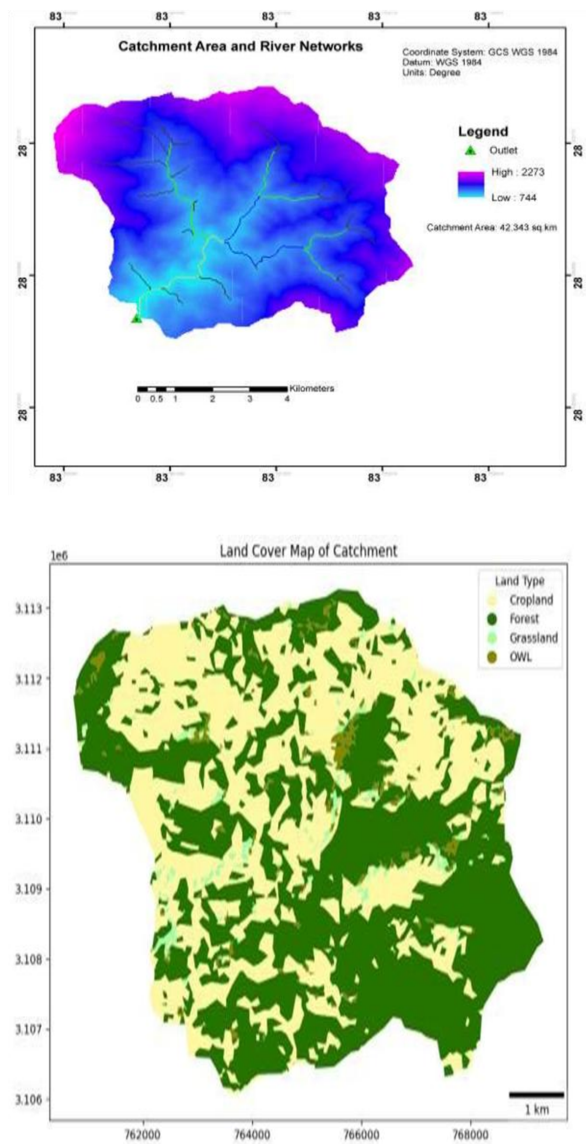


Figure 2. Catchment Delineation and Land Cover Map

III. HYDROLOGICAL ANALYSIS

- Rainfall Frequency and Design Discharge Calculation
- To estimate the 100-year design rainfall, two complementary statistical methods were used:
- Gumbel's Method:
- Extreme rainfall xTx_TxT was computed as: xT=x‾+K×σx_T = \bar{x} + K \times \sigmaxT=x‾+K×σ where x‾\bar{x}x‾ is the sample mean, σ\sigmaσ the standard deviation, and KKK the frequency factor.

Result: The computed design rainfall was approximately R100=316R_{100} = 316R100=316 mm.

- Weibull's Method:
- Rainfall data were rank-ordered, and return periods were computed using:

T=N+1mT = \frac{N+1}{m}T=mN+1

Result: The design rainfall estimated using Weibull's method yielded a value close to 310310310 mm, confirming the Gumbel estimate.

- Additional methods, such as the Rational and Dicken's methods, were used to derive the corresponding design discharge:
- Design Discharge:

Using the WECS/DHM formula,

Q100=14.63×(A+1)0.7342,Q_{100}=14.63 \times (A + 1)^{0.7342},Q100=14.63×(A+1)0.7342,

where A is the catchment area (in sq. km), the design discharge was found to be approximately 858585 m³/s.

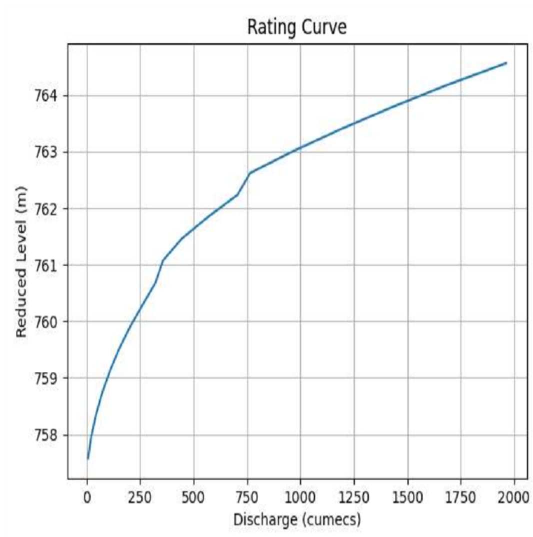


Figure 3. Rating Curve and Discharge Estimation

3.1 Scour, Afflux, and Flood Level

Scour Depth Calculation: Using the formula, dsm=1.34(q2f)1/3,d_{sm}=1.34\left(\frac{q^2}{f}\right)^{1/3},dsm=1.34(fq2)13,

where q is the unit discharge and f is the silt factor, the mean scour depth was estimated at 1.2m; with a maximum scour depth near abutments of approximately 1.5 m.

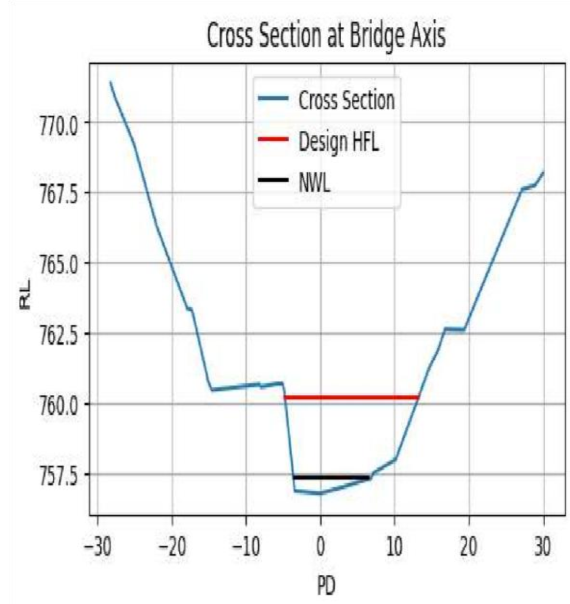


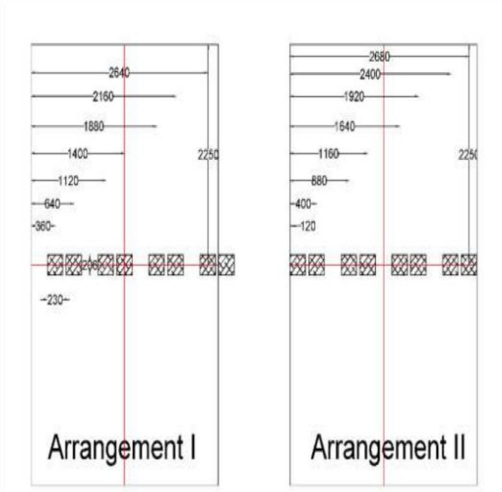
Figure 4. Scour and Afflux Analysis

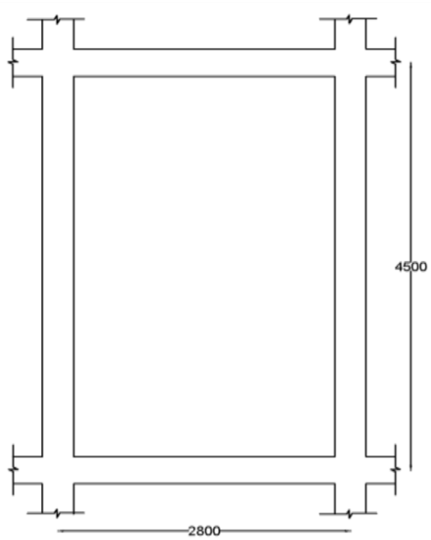
IV. STRUCTURAL DESIGN OVERVIEW

Bridge Configuration and Components:

The proposed T-girder bridge consists of:

- Deck Slab: Cast monolithically with T-girders, serving both as traffic deck and integral flange in compression.
- Main Girders: Designed as T-beams that resist bending moments and shear forces.
- Bearings and Substructure: Elastomeric bearings selected for flexibility and resistance to rotational and translational movements; abutments and foundations sized to safely transfer loads to the ground.





Analysis Methods and Load Combinations

- Finite Element Modeling (FEM):

A detailed FEM simulation was employed to analyze the response of the bridge under different load scenarios—including dead load, IRC Class 70R loading, IRC Class A loading, and dynamic axle loads.

- Load Combination Results:

Maximum Bending Moment: Calculated to be approximately 350 kN·m in critical regions. o Maximum Shear Force: Estimated at around 110 kN. These values were verified against the allowable limits prescribed by IRC and NBS codes.

Table 1. Summary of Key Structural Analysis Results

Parameter	Value Unit
Maximum Bending Moment	350kN·m
Maximum Shear Force	110 kN
Deck Slab Deflection (ULS) Abutment Foundation Depth m	< 20 mm ~2.5

V. RESULTS AND DISCUSSION

Hydrological Findings

- The hydrological analysis converged on a design rainfall of approximately 315 mm and a corresponding design discharge near 85 m³/s.
- Scour and afflux studies indicate that while the mean scour is 1.2 m, conservative design practices require a maximum expected scour near abutments of 1.5 m.
- The rating curve (Figure 3) and cross-sectional analysis validate the computed HFL at 5.8m.

Structural Analysis Outcomes

- Finite Element Results:

FEM analysis confirmed that under the worst-case loading scenarios, the maximum bending moment and shear forces remain within the specified limits.

- Serviceability Check:

Deflections in the deck slab and girders are satisfactorily low (less than 20 mm), ensuring long-term durability and minimal user discomfort.

- Load Combinations:

Detailed load combination studies, incorporating IRC Class A and Class 70R loadings, verify that the bridge's design safety factors are adequate.

VI. DISCUSSION

The integration of advanced hydrological analysis with robust structural modeling confirms that the T-girder bridge design can safely withstand extreme environmental and loading conditions. The careful consideration of regional design standards and the use of open-source analytical tools ensure that the design is both cost-effective and highly resilient. This combined approach serves as a model for future bridge projects in similarly challenging terrain.

VII. CONCLUSION

The project includes a hydrological study and the structural design of a motorized bridge. It involves estimating floods, evaluating watersheds, and applying various peak flow determination techniques. It entails the limit state structural design of an RC T-beam bridge, accounting for different loading scenarios and adhering to relevant requirements. Both structural stability and adherence to technical requirements are guaranteed by the complex designs of the foundation, substructure, and superstructure.

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