VALIDATING NUMERICAL MODEL FOR BRIDGE PIER SCOUR ESTIMATION THROUGH PHYSICAL MODELLING – CASE STUDY OF KELANISIRI BRIDGE

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Bridge scour is the erosion of sediment around bridge piers by flowing water, causing a significant risk to bridge stability and safety. Scour depth, the extent of sediment erosion around bridge piers or other structures caused by flowing water, is a critical parameter in bridge engineering. Generally, there are three types of scour phenomena that impact the performance and safety of bridges as local scour, contraction scour, and degradational scour. Understanding these are essential for identifying and reducing any dangers to the stability and safety of bridges.

This research aims to investigate the scouring phenomenon around the bridge piers of the Kelanisiri Bridge in Sri Lanka, understand its mechanisms, develop predictive models, and propose effective mitigation measures. The Kelanisiri bridge spans 134 m and is 10.4 m wide, has two cylindrical piers with a diameter of 2.5 m and has undergone scouring around piers, posing a severe danger to its stability. Also, this aims to contribute to the creation of sustainable solutions by examining the scouring processes and assessing the effects of variables like sediment types, flow velocities, and hydrological conditions through a combination of field investigations, laboratory experiments, and numerical modelling techniques. Further, this research will help to improve Sri Lanka's transportation infrastructure by ensuring the country's road network remains resilient and connected in the face of changing hydraulic conditions and sediment transport processes in river systems.

In this research, a laboratory scale physical model is developed to validate the results obtained from a numerical model developed using HEC-RAS software. The physical model replicates the bridge pier and surrounding riverbed at a scaled-down size, using similar materials. This allows for direct visualization of the scour process and the collection of detailed scour depth data at various locations around the pier. In the numerical model, HEC-RAS has capability to incorporate sediment transport equations, conduct extensive flow pattern studies, simulate complex river geometries, and offer a broad array of analytical tools. Comparing the scour depths obtained in the physical model with the predictions from the numerical model allows for an assessment of the validity and limitations of the numerical simulations.

The performance of the HEC-RAS model in replicating the physical model's scour depth measurements was assessed using R-squared (R^2) and Root Mean Squared Error (RMSE). R^2, ranging from 0 to 1, indicates the proportion of variance in the observed scour depths explained by the model's predictions. A good model exhibits both a high R^2 (strong correlation) and a low RMSE. The outcomes of the physical model comply well with the HEC-RAS numerical model results, with R^2 value of 0.87 and RMSE value of 0.12. Therefore, the accuracy of the numerical model, which had been designed to predict scour depth for the bridge piers at Kelanisiri bridge can be validated through this laboratory-scale experimentation. Finally, these discoveries will be critical in assuring the safety and durability of bridge constructions in Sri Lanka.

Keywords: Bridge pier, Scour depth, Sediment, Physical modelling

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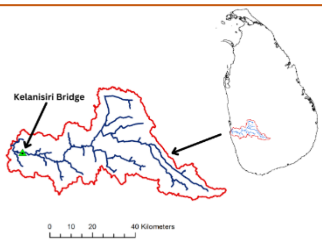
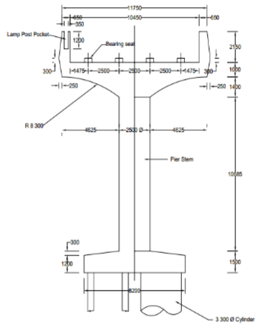
01. Background

Bridge scouring — Cause a significant risk to stability and safety of the bridges

Scour phenomena
- Local scour
- Contraction scour
- Degradational scour



Location map of Kelanisiri bridge



Details of Kelanisri bridge pier (Dimensions in mm)

Aim of the research

To investigate the scouring phenomenon around the bridge piers of the Kelanisiri Bridge, understand its mechanisms, develop predictive models, & propose effective mitigation measures.

02. Methodology

Several equations were used to determine Froude number, velocity and time

Froude Number: $$Fr = \frac{U}{(gH)^{\frac{1}{2}}}$$

Velocity: $$E(U) = E(H)^{\frac{1}{2}}$$

Time: $$E(T) = \frac{E(L)}{E(H)^{\frac{1}{2}}}$$

Physical model setup

Calculation of scale factors

Horizontal Scale	Vertical Scale
The width of the Kelani River near the bridge is about 81 meters. Width of flume = 0.9 m Selected scale = 81/0.9 = 90	Average height of bridge piers = 13.5 m Height of flume = 0.85 m Selected scale = 13.5/0.85 = 16

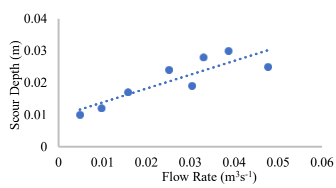
A PVC tube and an acrylic tube were used to model the bridge pier.


Model of bridge pier (PVC)

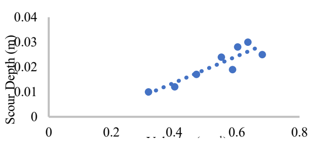

Model of bridge pier (Acrylic Plastic)

02. Methodology

Flow rate vs scour depth graph

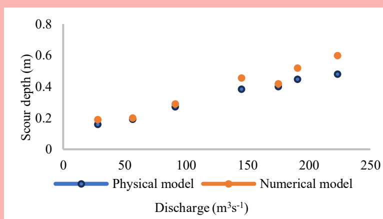


Velocity vs scour depth graph



Comparison between the Physical Model and the Numerical Model

Flow Rate (m^3/s)	Scour depth (m) Physical model	Numerical model
27.89	0.16	0.185
56.44	0.192	0.2
91	0.272	0.28
144.9	0.384	0.441
175.15	0.4	0.43
190.5	0.448	0.51
223.11	0.48	0.58



Scour depth vs discharge comparison between the numerical and physical model

The R^2 value between the two datasets was 0.87 indicating a strong positive correlation. Additionally, the RMSE was 0.12, suggesting a good agreement between the measured and modelled values. This high level of consistency between the physical and numerical models strengthens the confidence in the applicability of the HEC-RAS model for this study.