

**Transportation Infrastructure Precast Innovation Center**

**(TRANS-IPIC)**

**University Transportation Center (UTC)**

*Evaluating Prestressed Concrete Beams with Cracks using Machine Learning*

*UB-23-RP-01*

Quarterly Progress Report

For the performance period ending *March 31, 2024*

**Submitted by:**

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**Collaborators / Partners:**

*None*

**Submitted to:**

TRANS-IPIC UTC

University of Illinois Urbana-Champaign

Urbana, IL

**TRANS-IPIC Quarterly Progress Report:**

**Project Description:**

1. Research Plan - Statement of Problem

*Bridge owners face difficult decisions on whether a bridge should be posted, repaired or replaced when prestressed concrete members have shear related cracks due to overloading. The decisions are currently made based on engineering judgment, costly load-testing or time consuming and complex modeling. Guidance is needed to interpret cracks and their impact on shear capacity to avoid overly conservative load ratings and to keep bridges operational, without compromising safety and economy. This project will develop a reliable and efficient tool through machine learning (ML) to relate cracking to load history of bridge members.*

1. Research Plan - Summary of Project Activities (Tasks)

*The project is composed of the following tasks:*

*Task 1. Compile and filter test data: Existing data in the literature on the shear behavior of prestressed concrete beams will be compiled and curated to create a comprehensive dataset. Existing databases will be reviewed to obtain crack and design information. Any gaps in data will be documented to plan for additional tests as needed.*

*Task 2. Investigate ML algorithms: ML will be used to train a supervised learning model. The model will determine relationships between structural design parameters, crack information and shear capacity from historical data presented in a training dataset. Linear and non-linear ML models will be explored.*

*Task 3. Predict load history and capacity: Using a suitable ML algorithm, shear capacity and loading that corresponds to given crack widths will be predicted. Input will be geometric properties, material properties, reinforcement details and crack widths under increasing loading for prestressed concrete beams for which test data is available. The models will be fine-tuned using a cross-validation analysis.*

*Task 4. Verify predictions: The predictions of ML will be tested on four beams that will be selected from the existing databases but are not part of the ML training. Shear load history and capacity of the beams predicted with ML will be compared to the ones obtained from testing. The beams will also be modeled using finite element analysis.*

*Task 5. Develop software for implementation: To facilitate the use of the evaluation method, a software tool with a simple user interface will be developed.*

**Project Progress:**

1. Progress for each research task

*Task 1 progress [90% completed]: A database that consists of 941 shear test results for prestressed concrete beams was compiled, building up on existing databases in the literature. This database was filtered based on factors such as support conditions, type of prestressing, and shear reinforcement amount. Deep beams, beams with external prestressing and segmental beams were excluded considering differences in the shear behavior of these beams and prestressed beams that are more common in bridge construction. The ranges of features of the beams in the database were documented to understand the types of beams for which the ML predictions will be applicable.*

*Task 2 progress [100% completion]: The literature was reviewed for ML algorithms suitable for the objectives of this project. Ordinary linear regression (OLR), support vector regression (SVR) and Gaussian process regression (GPR) algorithms were selected to be investigated as they can be applied to smaller datasets such as the ones available for prestressed concrete beams. Computational efficiency and prediction error in these algorithms have been quantified. It was determined that the three algorithms are computationally efficient, but their accuracy varies. GPR is determined to provide the most accurate estimates, comparable to or better than the ones provided by design codes.*

*Task 3 progress [50% completion]: Shear capacity is predicted for the beams in the database using OLR, SVR and GPR algorithms. Features that have a significant influence on the predictions are determined and compared to the features considered by design codes. A combination of features that lead to the least error when compared to test data is determined. When effective prestress, strand area, location of strands in the cross-section, longitudinal reinforcement, shear reinforcement, section dimensions, concrete strength, and shear span were used as predictive features, the OLR, SVR and GRP had less than 40%, 20%, and 15% mean average percentage error in predicting the shear strength of the beams, respectively. The error was evaluated using cross-validation. The error in GPR is less than the ones of ACI 318 and AASHTO LRFD Design Specifications.*

*Task 4 progress [30% completion]*: Four beams (with features well and poorly represented by the training dataset, and with more and less than the minimum shear reinforcement areas required by design codes) were selected for the verification process. Shear capacity was predicted for these four beams using GPR. The results show between 8% and 21% error in predictions.

1. Percent of research project completed

*At the end of this quarter, 50% of the project is completed.*

1. Expected progress for next quarter

*In the next quarter, Task 1 will be completed. Task 3 and Task 4 will be continued to include predictions of shear load history using the GPR algorithm. Task 5 on developing a software tool will be initiated for predicting capacity. Prediction of shear load history will be added to the software later.*

1. Educational outreach and workforce development

*The research team hosted 30 high school students from across Western New York for Science Exploration Day. Students were introduced to concrete bridges, potential uses of machine learning in bridge engineering and bridge evaluation during their visit.*

1. Technology Transfer

*The project has not resulted in any patents, guidelines or specifications yet. At the conclusion of the project, a software tool will be developed to facilitate technology transfer.*

**Research Contribution:**

1. Number of papers

*None.*

1. Number presentations (when, where)

*Lasheen, M., Okumus, P., Elhami Khorasani, N. (2024). “Predicting Shear Strength of Prestressed Concrete Beams Using Machine Learning”, poster presentation, Transportation Research Board Annual Meeting, presented at the reception by Institute of Bridge Engineering, University at Buffalo, January 7-11.*

**References:**

*None*