

Damage Detection of Post-Tensioned Concrete Girder Bridge Using Deep Learning Approach

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Structural health monitoring (SHM) is recognized as crucial for ensuring infrastructure safety and longevity. Structural instability has been attributed to material degradation and crack propagation. Therefore, understanding the combined effects of material degradation and crack propagation across various damage scenarios is essential for early damage detection in concrete structures. This study aimed to develop an effective method for detecting damage in post-tensioned concrete girder bridges using a deep learning approach (for damage of crack propagation and material degradation combinedly). Ambient vibration responses were collected from field measurements and vibration responses generated using finite element models (FEM) of a selected post-tensioned concrete girder bridge. The deep learning (DL) models were developed using numerically generated data, validated through hyperparameter tuning and cross-validation, and used to identify material degradation percentage, crack locations, crack paths, and damage severity within the structure. Initially, ambient vibration data were measured at selected locations on the bridge. A damage parameter was developed using natural frequency and modal curvature shifts from undamaged to damaged scenarios, varying uniquely for crack damage and material degradation. In the FE model, crack and material degradation were implemented by reducing cross-section and elastic modulus, respectively, and data were collected for various damage combinations. The DL models were trained using numerically simulated data and fed with vibration responses from the field to predict damages. The training and validation processes achieved nearly zero, with training accuracy above 95% and validation accuracy of 98%. Mean square error was below 0.0001, and standard deviation was less than 0.005 over K-Fold cross-validation. Fracture mechanics model developed for concrete structures found from the literature was utilized to effectively represent the combined effects of damages, crack orientation, and stress distribution on severity. Finally, damage severity was indicated through a 2D plot for easy on-site accessibility.

Keywords: Damage Detection, Structural Health Monitoring, Post-Tensioned Concrete Girder Bridges, Deep Learning