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EXPERIMENTAL AND NUMERICAL INVESTIGATION OF REINFORCED CONCRETE DAPPED-END CONNECTIONS WITH NEURAL NETWORK-BASED OPTIMISATION

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M.Sc. (Major Component of Research)

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Thesis/Dissertation submitted in partial fulfilment of the requirements for the degree M.Sc. (Major Component of Research)

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DECLARATION

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ABSTRACT

This study focuses on both an experimental investigation and a data-driven approach to advance the understanding and design of dapped-end connections, which are widely used yet structurally vulnerable elements in precast concrete buildings and bridge structures. The first part of the study presents an experimental investigation conducted on four large-scale dapped-end connection specimens to examine the influence of bond deterioration on strength and service behaviour. Bond deterioration near the re-entrant corner was simulated by de-bonding a 100 mm length of either the hanger or flexural reinforcement using a plastic sleeve. Full-field Digital Image Correlation measurements were employed to capture deformation and crack kinematics, which were used to quantify key resistance mechanisms. Detailed deformation measurements enabled an in-depth discussion of specimen behaviour. Each specimen was modelled using the VecTor2 finite element software to further examine its response. The finite element models predicted peak resistance with an average experimental-to-predicted ratio of 1.01 and a coefficient of variation of 7.34%. The second part of the study focused on data-driven approaches. Although previous studies have investigated dapped-end connections using analytical and experimental methods, the application of machine learning remains limited due to the scarcity of experimental data, which constrains predictive accuracy and model generalisation. To address this limitation, a novel framework combining numerical simulation with Conditional Tabular Generative Adversarial Network (CTGAN) -based data augmentation was proposed. A numerical database of 720 cases was developed and expanded to 1,400 instances using CTGAN. Artificial Neural Network (ANN), Genetic Algorithm-ANN (GA-ANN), and Particle Swarm Optimisation-ANN models were trained and evaluated. Validation using 64 unseen experimental datasets demonstrated improved model generalisation. shapley additive explanations analysis indicated that GA-ANN predictions were consistent with deformation compatibility principles. Finally, a machine learning-assisted design model was developed to provide multiple solutions for a given design problem, supporting the optimisation of dapped-end connection design.

Keywords: Dapped-end connections; Orthogonal reinforcement layout; Re-entrant corner cracks; Predictive Modelling; Generative Adversarial Networks

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LIST OF ABBREVIATIONS

Abbreviation	Description
2D	Two-Dimensional
ANN	Artificial Neural Network
COV	Coefficient of Variation
CTGAN	Conditional Tabular Generative Adversarial Network
D	Discriminator
DIC	Digital Image Correlation
DSFM	Disturbed Stress Field Model
F-DEB	Flexure De-bonded
FE	Finite Element
FEA	Finite Element Analysis
G	Generator
GA	Genetic Algorithm
GANs	Generative Adversarial Networks
H-DEB	Hanger De-bonded
KDE	Kernel Density Estimate
KNN	K-Nearest Neighbour
LVDT	Linear Variable Differential Transformer
MCFT	Modified Compression Field Theory
ML	Machine Learning
MLP	Multilayer Perceptron
NMAE	Normalised Mean Absolute Error
NRMSE	Normalised Root Mean Squared Error
PCI	Precast/Prestressed Concrete Institute

PLN	Plain
PSO	Particle Swarm Optimisation
REF	Reference
SHAP	SHapley Additive exPlanations
STM	Strut-and-Tie Models
SVM	Support Vector Machine