ANN-BASED APPROACH FOR SELECTION OF OPTIMUM FLOOR SYSTEM OF MULTI-STORIED BUILDINGS IN THE PRELIMINARY DESIGN STAGE

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DECLARATION

I declare that this is my own work, and this thesis does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any other University or Institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text. I retain the right to use this content in whole or part in future works (such as articles or books).

Signature: Date: 26-08-2025

The above candidate has carried out research for the Masters thesis/dissertation under my supervision. I confirm that the declaration made above by the student is true and correct.

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Signature of the Supervisor: Date: 26-08-2025

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Signature of the Supervisor: Date: 26-08-2025

ACKNOWLEDGEMENT

I would like to express my sincere gratitude to my research supervisors, Prof. H.M.Y.C. Mallikarachchi and Dr. H.M.S.T. Herath for their invaluable support, continuous guidance and encouragement throughout this research. Their constructive feedback and follow-ups are the driving force owing to this completion of research.

I am also sincerely grateful to the research panel members in each of the progressive meetings and the research coordinator for giving valuable comments and encouragement that motivated me to finish this research within the allocated time. My appreciation extended to my colleagues and friends who shared with me their fullest support in completing this research by sharing valuable data and guidance.

A special thanks to my family and especially my husband for his unwavering support, love and patience which has been driven to the completion of my research thesis.

ABSTRACT

Eco-friendly and climate-resilient building concepts are globally emerging with increasing Greenhouse Gas (GHG) emissions from the building sector. Addressing the embodied carbon of floor systems becomes essential as these contribute more than 50% of the embodied energy of the building footprint. Whereas, in the Preliminary Design Stage (PDS), striving for the best alternative satisfying performance, economic and environmental criteria is challenging within a limited time while decision-making is generally from the expertise's design sense and intuition. Engineers in design firms have been encountering these recursive design processes over the years; however, the rate of reutilization of the previous design information and experience is very rare. Machine Learning (ML) techniques can offer smart decision-making tools in the PDS. Nevertheless, only a few addressed the optimization in the PDS while none of the studies comprehensively addressed the optimum floor system considering all three criteria simultaneously. This study utilized a human brain mimicking algorithm, Artificial Neural Network (ANN) in the optimization of reinforced-concrete floor systems of a multi-storied building in the PDS encapsulating the performance, economic and environmental considerations with the aid of data collection from the constructed buildings in Sri Lanka. The eight distinct models are proposed to predict each quantity in both Beam-Slab System (BSS) and Flat-Slab System (FSS). The proposed models in the BSS database are recorded predictions with R^2 values of above 0.8 demonstrating reasonable performance in the heterogeneous real-world data while the models in the FSS database show superior performance which yields R^2 values greater than 0.95 with synthetic data. Also, the predictions from all the models fall below a 30% error margin and the models in the FSS database demonstrated the higher performance with significantly lower error margins of 10 to 20%. Further, a conducted comparative analysis with the range of alternative ML models demonstrates the performance and capabilities of human-brain-inspired ANN under heterogeneous and high-dimensional data with inherently qualitative in nature. SHAP explanations demonstrated the relative contribution of each feature in the quantity predictions which in turn streamlined the confidence in the end-users. The trained ANN model is finally transformed into a design tool to facilitate the engineers to predict quantities that offer a platform to select the optimized floor system in the PDS.

Keywords: Optimization, Reinforced-concrete floor systems, ANN, SHAP explanations

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

Abbreviation	Description
AdaDelta	Adaptive Delta
AdaGrad	Adaptive Gradient
Adam	Adaptive Moment Estimation
AI	Artificial Intelligence
ANN	Artificial Neural Network
API	Application Programming Interface
BSS	Beam-Slab System
CART	Classification And Regression Trees
CO2	Emissions CO_2 Global Warming Potential
CPU	Central Processing Unit
CSS	Combined Slab System
CUI	Concrete Usage Index
CV	Cross-Validation
DT	Decision Tree
ECE	Embodied Carbon Energy
ELU	Exponential Linear Unit
FSS	Flat-Slab System
FTRL	Follow The Regularized Leader
GELU	Gaussian Error Linear Unit
GHG	Green House Gas
GL	Grid Length
GPU	Graphics Processing Unit
GWP	Global Warming Potential
ICE	Inventory of Carbon and Energy
IQR	Inter Quartile Range
MAD	Mean Absolute Deviation
MAE	Mean Absolute Error
ML	Machine Learning
MSE	Mean Square Error

Nadam	Nesterov-accelerated Adaptive Moment Estimation
NLP	Nonlinear Programming
NRMSE	Normalized Root Mean Squared Error
PDS	Preliminary Design Stage
ReLU	Rectified Linear Unit
R/F	Reinforcement
RF	Random Forest
RMSProp	Root Mean Square Propagation
ROC AUC	Receiver Operating Characteristic Area Under the Curve
RUI	Reinforcement Usage Index
SELU	Scaled Exponential Linear Unit
SGD	Stochastic Gradient Descent
SHAP	Shapley Additive Explanations
SLS	Serviceability Limit State
VC	Volume of Concrete
VRF	Volume of Reinforcement
ULS	Ultimate Limit State
XAI	Explainable Artificial Intelligence