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Machine Learning Prediction of Structural Response for Slabs Subjected to Blast Loading

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Abstract - In the field of structural engineering, there are several issues that are impacted by uncertainties, including those that are connected to design, analysis, condition monitoring, construction management, decision making. In order to solve the issues, calculations based on mathematics, physics, mechanics, and the practitioners experience plays a critical role in finding solutions. Machine Learning methods, can be used to improve these initiatives and may also be taken into account when examining the overall validity of laboratory or field test results. The use of data analysis and prediction is crucial in the discipline of civil engineering, used to examine information from research studies that forecast concrete lifespans. The IS Code principles expressions, rules, and concepts are too complex to apply to any activity involving a lot of data with a lot of variables from site surveys and lab testing. The construction sector uses machine learning and other multidisciplinary techniques for data management in order to keep up with the rest of the world and other technical fields. In Blast engineering, experiments are very time intensive and extremely cost prohibitive, it is vital that computational capabilities be developed to generate the required dataset that can be utilized to produce simplified design tools. The process of optimising a performance standard using programmed algorithms is known as machine learning (ML), and it is based on data that has already been gathered. In its simplest form, learning entails using existing data (pairs of inputs and outputs) to train an algorithm, then relying on the trained algorithm to make accurate inferences. Machine learning model can also be utilised to identify and extract significant connections between inputs and outputs.

Keywords: Machine Learning, Random Forest Algorithm (RFA), K- Nearest Neighbor (KNN), Decision Tree (DT), Reinforced concrete slab, Prediction, Blast loading.

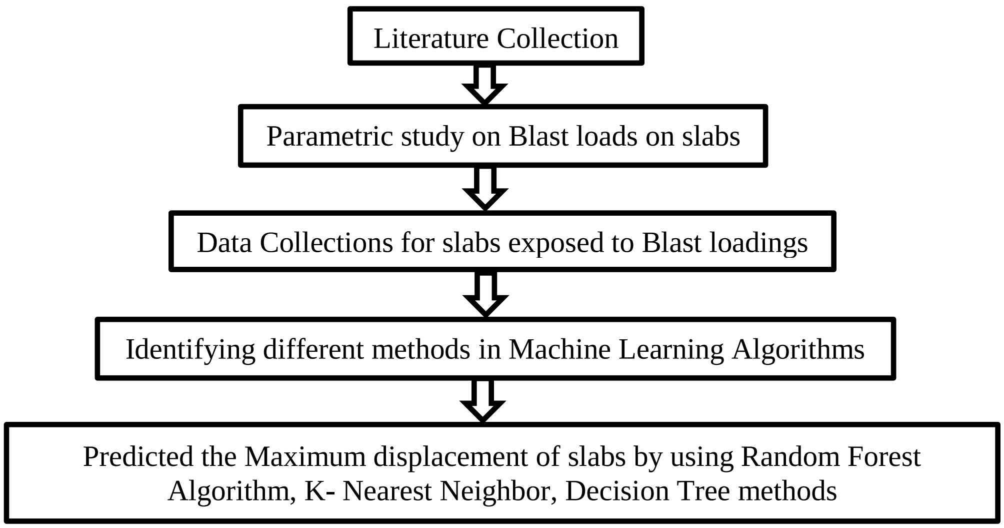
1. Introduction

Machine learning (ML), a type of artificial intelligence (AI), allows computer programmes to predict outcomes more accurately without being explicitly instructed to do so. Machine learning algorithms make new output predictions based on previously collected data. The ability for a machine to automatically learn from data, improve performance based on previous experiences, and make predictions is known as machine learning, which is a subset of artificial intelligence (AI). A group of algorithms used in machine learning operate on enormous amounts of data. These algorithms are fed data to train them, and then they use that training to create a model and carry out a specified task. These ML techniques support the resolution of numerous business issues, including clustering, associations, forecasting, classification, regression, and others [1]. Machine learning is primarily split into three types based on the techniques and modes of learning, which are: 1. Supervised Learning 2. Unsupervised Learning 3. Reinforcement Learning. Supervised learning is a sort of machine learning in which the output is predicted by the machines using well-labelled training data that has been used to train the machines. The term "labelled data" refers to input data that has already been assigned the appropriate output [21]. Regression analysis uses one or more independent variables to describe the relationship between a dependent (target) and independent (predictor) variables. A supervised learning method called a decision tree can be used to solve classification and regression problems, but it is typically favoured for doing so. Random Forest is a classifier that contains a number of decision trees on various subsets of the given dataset and takes the average to improve the predictive accuracy of that dataset. Instead, then depending on a single decision tree, the random forest uses forecasts from each tree and predicts the result based on the votes of the majority of predictions. Based on the supervised learning method, the K-Nearest Neighbor algorithm makes the assumption that the new case and the existing cases are comparable, and it places the new instance in the category that is most like the existing categories.

2. Objective

- The main objective is to predict the maximum displacement of slabs exposed to blast loading by using Random Forest Algorithm, K- Nearest Neighbor, and Decision Tree methods.
- To bring out the progress in the accuracy of the displacement forecasting for the given dataset.

2.1. Methodology



2.2. Colab Tool

The tool used for the prediction of maximum displacement of slabs exposed to blast loading, is a Google Research Product called as Colaboratory or Colab. A Google cloud-based platform for using machine learning frameworks and running Python code.

2.3. Data Collections

Data of experimental outputs were collected from literature. Only information that held true across all publications and thesis under study were included. Research thesis that particularly examined the behavior and mitigation strategies of RC slabs exposed to blast loading were also included in the database, which was built from a variety of research articles published in various journals. The parameters that effect the behaviour of RC slabs under blast loading include the slab type and dimensions, the quantities and properties of materials used, and the parameters of the blast. Therefore, the features considered in this work are the Length of the slab, Width of the slab, Thickness of the slab, Compressive Strength of concrete, Youngs's Modulus of Steel, Young's Modulus of Concrete, Yield strength of steel, Diameter of Bar, Scaled Distance, Maximum Displacement etc... These datasets were collected from the following journals [1-24], as shown in Fig. 1.

1		Experimental and Numerical study on the dynamic response of RC slabs under blast loading
2		Dynamic response of a reinforced concrete slab subjected to air blast load
3		Reliability analysis of direct shear and flexural failure modes of RC slabs under explosive loading
4		Experimental investigation of 50 Mpa reinforced concrete slabs subjected to blast loading
5		Damage mechanism and mode of square reinforced concrete slab subjected to blast loading
6		Experimental study on scaling the explosion resistance of a one - way square reinforced concrete slab under a close - in blast loading
7		Blast response of RC slabs with externally bonded reinforcement : experimental and analytical verification
8		Response of small scale ultra high performance fibre reinforced concrete slabs to blast loading
9		Fracture failure of reinforced concrete slabs subjected to blast loading using the combined finite - discrete element method
10		Experimental and finite element analysis of doubly reinforced concrete slabs subjected to blast loads
11		Experimental and numerical investigation of reinforced concrete slabs under blast loading
12		Analysis of direct shear failure mode for RC slabs under external explosive loading
13		Experimental study and numerical simulation of the damage mode of a square reinforced concrete slab under close - in explosion
14		Experimental research on blast - resistance of one - way cocncrete slabs reinforced by BFRP bars under close - in explosion
15		Experimental and numerical studies on dynamic behaviors of RC slabs under long duration near - planar explosion loadings
16		Influence of EBR on the structural resistance of RC slabs under quasi - static and blast loading : Experimental testing and numerical analysis
17		Experimental and numerical study on damage mode of RC slabs under combined blast and fragment loading
18		Full - scale field tests of concrete slabs subjected to blast loads
19		Concrete pavement slab under blast loads
20		Fragmentation from spallation of RC slabs due to airblast loads
21		Blast resistance of small-scale RCS in experimental test and numericalanalysis
22		Experimental and numerical studies on dynamic behaviors of RC slabs under long-duration near-planar explosion loadings
23		Blast Response Analysis of Reinforced Concrete Slabs: Experimental Procedure and Numerical Simulation
24		Fragment behavior of concrete slab subjected to blast loading

Fig. 1: Collection of datasets from the journals.

3. Results

3.1 Random Forest Result

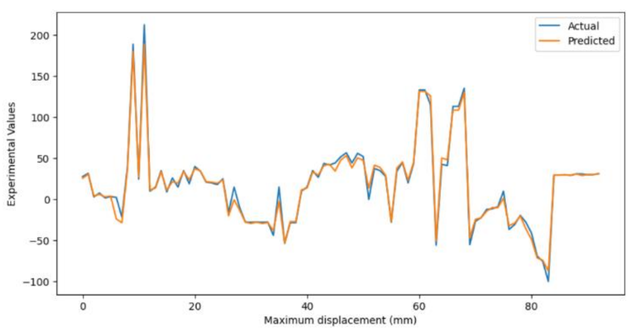


Fig. 2: Comparison Between Actual and Predicted Responses Using RFA

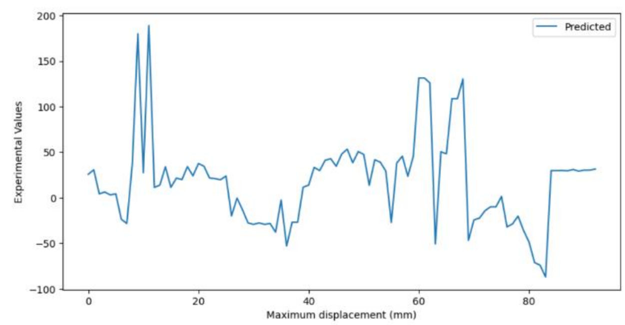


Fig. 3: Predicted the Maximum Displacement using RFA

3.2 KNN Result

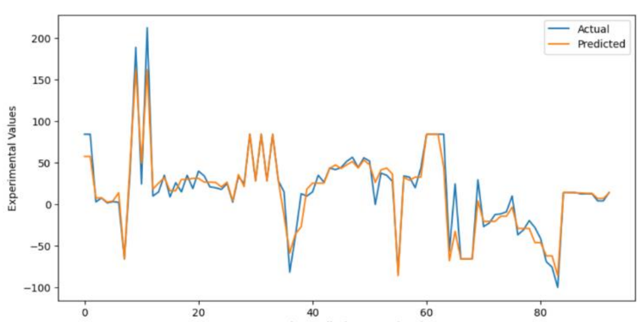


Fig. 4: Comparison Between Actual and Predicted Responses Using KNN

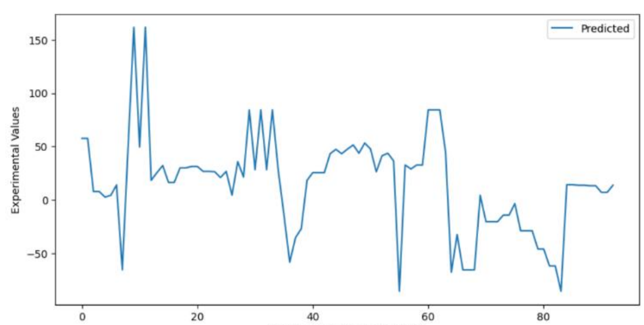


Fig. 5: Predicted the Maximum Displacement using KNN

3.3 Decision Tree Result

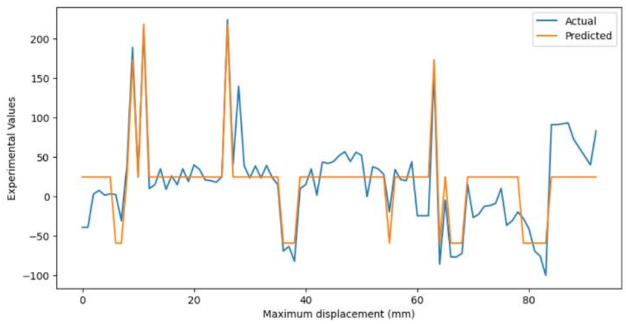


Fig. 6: Comparison Between Actual and Predicted Responses Using DT

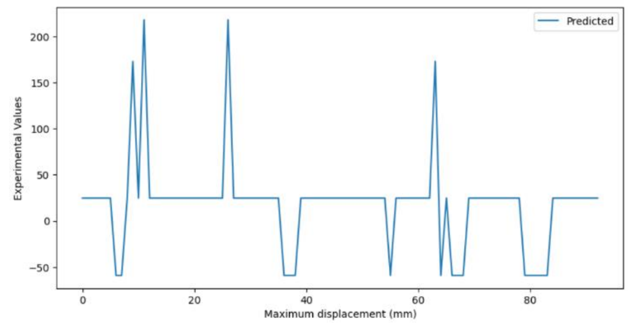


Fig. 7: Predicted the Maximum Displacement using DT

4. Conclusion

In order to forecast the Maximum displacement of reinforced concrete slabs subjected to blast loading, this work introduces a machine learning algorithm. Following a thorough review of the pertinent literature, 93 points were gathered to form a dataset. These datasets includes thirty four features, namely the Length of the slab, Width of the slab, Thickness of the slab, Compressive Strength of concrete, Youngs's Modulus of Steel, Young's Modulus of Concrete, Yield strength of steel, diameter of Bar, Spacing, Reinforcement Ratio, Tensile Strength of Steel, Tangent modulus, Ultimate Strength of Concrete, Ultimate Strength of Steel, Density (Concrete), Density (Steel), Maximum Plastic strain, Poisson's Ratio (Concrete), Poisson's Ratio (Steel), Mass, Height of burst, Scale Factor, Weight of Gelatin explosive, Explosive Mass, Standoff Distance, Scaled Distance, Time, Peak pressure, Damage Radius, Spall radius, Damage Factor, Damage area, Impulse, along with one output: the Maximum displacement. The Random Forest Algorithm model, which resulted Mean Absolute Error (MAE) value of 9.236(10.464), R^2 value of 99%. The KNN model resulted MAE value of 16.912(21.525), R^2 value of 90.6%, and the Decision tree model resulted MAE value of 27.898(27.177), R^2 value of 56.1%. From the above results, it is concluded that Decision tree has accuracy compared to the K- Nearest Neighbor algorithm, and the Random Forest Algorithm also demonstrates higher accurate than the K- Nearest Neighbor algorithm. Decision tree and Random Forest are superior in terms of accuracy when compared to K- Nearest Neighbor.

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