# ANN modeling using ultrasonic test results and neutral axis in RC beams

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## ABSTRACT

An experiment on reinforced concrete beams using four-point bending test under nonlinear ultrasonic test was conducted. After the collection of data, Feed-forward Backpropagation Artificial Neural Network (ANN) was used to investigate the sensitivity of two types of concrete mixtures with water cement ratio (WC) of 40% and 60%. Three reinforcement schedules as “design A” comprising of two top bars and two bottom bars, “design B” with two bottom bars, and “design C” with one bottom bar. The concrete beam had a size of 100mm x 100mm x 400mm length with plain reinforcement bar of 9mm in diameter. There were 18 beams casted and ultrasonic test with pitch-catch configuration was conducted at each loading with transducers oriented in direct transmission across its length. Recordings of nonlinear test results and strains at the top and bottom surfaces subjected with multiple step loads in the experiment were done. Each concrete beam contained 68 data points to represent the load and the ultrasonic parameters needed for the ANN modeling. The input parameters used for training, validating, and testing the ANN models were neutral axis (NA), fundamental harmonic amplitude (A1), 2$^{nd}$ harmonic amplitude (A2), 3$^{rd}$ harmonic amplitude (A3), and peak to peak amplitude (PPA) while the output parameter was the load. After training, validating, and testing sixty ANN models, six optimum models were chosen as the optimum model where it reached the highest Pearson’s Correlation Coefficient (R) and soundness of model. Classification of sensitivity was investigated using simulations from developed optimum models

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## 1. INTRODUCTION

In modern infrastructure, structural health monitoring is essential to assess and diagnose the current situation before retrofit and repair commences. The common building material used is reinforced concrete. Reinforced concrete can be assessed in different with factors including time, cost, and idle period. For practical reasons, researchers focus on developing a non-destructive test for fast and economical assessment of structure.

However, reinforced concrete comprises of two main materials that when combined together perform well against aging and applied load. The first material is concrete which is very good in compression and comprises of water, cement, sand, aggregates, and sometimes admixtures. This material by in itself is very complex because different mixtures, curing methods, sizes of aggregates, and method of placements can arrive at inconsistent voids, segregation of aggregates, variable interfacial transition zones, and varying compressive strengths. The second material in reinforced concrete is the addition of reinforced steel bars to increase the tensile capacity of the structure. There are continuous studies in the development of non-destructive ultrasonic test in plain concrete, but there are still limited studies on the application of this test in reinforced concrete structures.

An example of ultrasonic test in plain concrete is the use of SONREB, where ultrasonic pulse wave velocity and rebound hammer is considered to assess in-situ concrete without considering the effect of the steel bars embedded in the structure. In addition, this combination is not sensitive to micro-damage or cracks inside concrete. It becomes more complex when crack propagation inside the concrete with reinforcing bars is predominantly occurring. This behavior give ultrasonic test inconsistent results that led to poor investigation of reinforced concrete structures. The analysis of ultrasonic test results is very complicated since regression analysis cannot be well established. In this paper, with the aid of experimental results, the sensitivity of ultrasonic test results and neutral axis in assessing damage are simulated from the optimum ANN model developed.

### *1.1 ULTRASONIC TEST*

Combination of the use of linear ultrasonic by ultrasonic pulse velocity (UPV) and rebound hammer to test on site strength of concrete is introduced (Breysse 2012). Another method is the combination of UPV and ultrasonic pulse amplitude in predicting the compressive strength of concrete (Liang and Wu 2002). From studies, UPV's application is limited due to its insensitivity to the changes in load (Daponte *et al.* 1995).