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Genetic programming approach for prediction of compressive strength of concretes containing rice husk ash

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ABSTRACT

Soft computing techniques have recently been widely used to model some of human activities in many areas of civil engineering applications. In this paper, two models in gene expression programming (GEP) approach for predicting compressive strength of concretes containing rice husk ash have been developed at the age of 1, 3, 7, 14, 28, 56 and 90 days. For purpose of building the models, experimental results for 188 specimens produced with 41 different mixture proportions are obtained from the literature. According to these experimental results, the models are arranged by using seven different input variables in GEP approach. In according to these input variables, the compressive strength values from mechanical properties of concretes containing rice husk ash are predicted in GEP approach models. The results of training, testing and validation sets of the models are compared with experimental results. All of the results showed that GEP is a strong technique for the prediction of compressive strength values of concretes containing rice husk ash.

1. Introduction

In recent years, a large number of researches have been directed towards the utilization of pozzolanic materials. These pozzolanic materials are used for decreasing the cement content in mortar and concrete production. These pozzolans from industrial and agricultural by products such as silica fume, fly ash, metakaolin and rice husk ash (RHA) are receiving more attention recently since their use generally improve the physical and mechanical properties of the blended cement concrete, the cost and the reduction of negative environmental effects [1]. These materials, when used as mineral admixtures in high performance concrete, can improve either or both the strength and durability properties of the concrete [2,3]. RHA is a highly reactive pozzolanic material produced by controlled burning of rice husk [4]. When rice husk is burnt at temperatures lower than 700 °C, RHA with cellular microstructure is produced. RHA contains high silica content in the form of noncrystalline or amorphous silica. Therefore, it is a pozzolanic material and can be used supplementary cementitious materials [1,5]. But before the RHA is added to cementitious materials, it is pulverized or ground to required fineness.

In some experimental studies, it has been shown that the presence of RHA in concrete seems to increase the compressive strength (f_c) as compared to that of conventional concrete [4,6–12]. Bui et al. [4] studied on 24 different concrete mixtures by using two kinds of Portland cement (PC). In the study, three levels of the water to binder ratio were investigated, i.e., 0.30, 0.32 and 0.34. RHA was used to replace 10%, 15% and 20% by mass of PC. The f_c of concretes produced with PC30 was significantly higher when compared to the strength of concretes produced with PC40. Also, these researchers observed that f_c of concretes containing RHA increased with decreasing of water-binder ratios. It is concluded that the employment of RHA content in concrete has a positive effect on increasing the f_c. Ganesan et al. [6] obtained the eight different proportions of concrete mixtures (RHA ranging from 5% to 35% by weight of cement) including the control mixture with water-binder ratio of 0.53. These researchers observed that the f_c increases with RHA up to 20% and then at 30% RHA, the f_c of concrete attained values equivalent to that of control concrete. They also reported that at 35% RHA, the f_c decreased to a value which was lower than that of the control concrete. Therefore, these researchers suggested that 30% RHA was to be the optimal limit. Ramezanianpour et al. [7] produced concrete mixtures with 7%, 10% and 15% RHA, which showed increase f_c at ages up to 90 days when compared with the control concrete. Giaccio et al. [8] obtained the four series of concrete with water-binder ratios of 0.50, 0.40, 0.32 and 0.28. Each series included a concrete with 10% RHA as cement replacement and a control concrete without RHA for comparison. They clearly reported that f_c increased in the later case, particularly for lower water-binder ratios, comparing control and RHA concrete. de Sensale [9] obtained the three groups of specimen series with 15 different mixes with water-binder ratios of 0.32, 0.40 and 0.50. Each group included mixtures

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with 0%, 10% and 20% replacement by volume of cement with RHA. It is reported that f_c of concretes increased with decreasing of water-binder ratios. In another study, Saraswathy and Song [10] produced concrete specimens by replacing cement with RHA at the ratios of 5%, 10%, 15%, 20%, 25% and 30%. Additionally, they prepared these specimens using 1:1.5:3 mixes with water–cement ratio of 0.53. They reported that RHA blended concrete showed higher f_c than control concretes beyond 5% replacement levels. Also, they reported that up to 30% replacement level of RHA there was no decrease in f_c observed when compared to conventional ordinary PC concrete. Zhang and Malhotra [11] observed that the f_c of concrete containing up to 30% RHA was higher than that of control concrete at the age of 7, 14, 28 and 90 days. Bhanumathidas and Mehta [12] also confirmed that in general, the 90 days f_c with RHA up to 40% was higher than the control concrete mixtures without RHA.

Influence of using RHA on the f_c is well known in the technique literature. However, there exist no explicit formulations for predicting the f_c of concrete containing RHA. For this purpose, GEP approach is used to build empirical models to predict the f_c of concretes containing RHA. For building the models, 41 different mixtures with 188 specimens at the age of 1, 3, 7, 14, 28, 56 and 90 days f_c results of concretes containing RHA used in training, testing and validation sets for GEP approach models were obtained from the literatures [4,6,7,13]. In the sets of the models constituted with two different number of genes the age of specimen (AS), Portland cement 30 (PC30), Portland cement 40 (PC40), rice husk ash (RHA), water (W), superplasticizer (SP) and aggregate (A) were entered as input variables while compressive strength (f_c) values were used as output. The models were trained with 112 data of experimental results and then remainders were used as only experimental input values for testing. The models were also validated with 20 data of experimental results from the literature [13]. All of the results obtained from the models very similar to the experimental results were obtained.

2. Genetic programming approach

Genetic programming (GP) approach is an extension to genetic algorithms proposed by Koza [14] who defines GP as a domain independent problem solving approach in which computer programs are evolved to solve, or approximately solve, problems based on the Darwinian principle of reproduction and analogs of naturally occurring genetic operations such as reproduction,

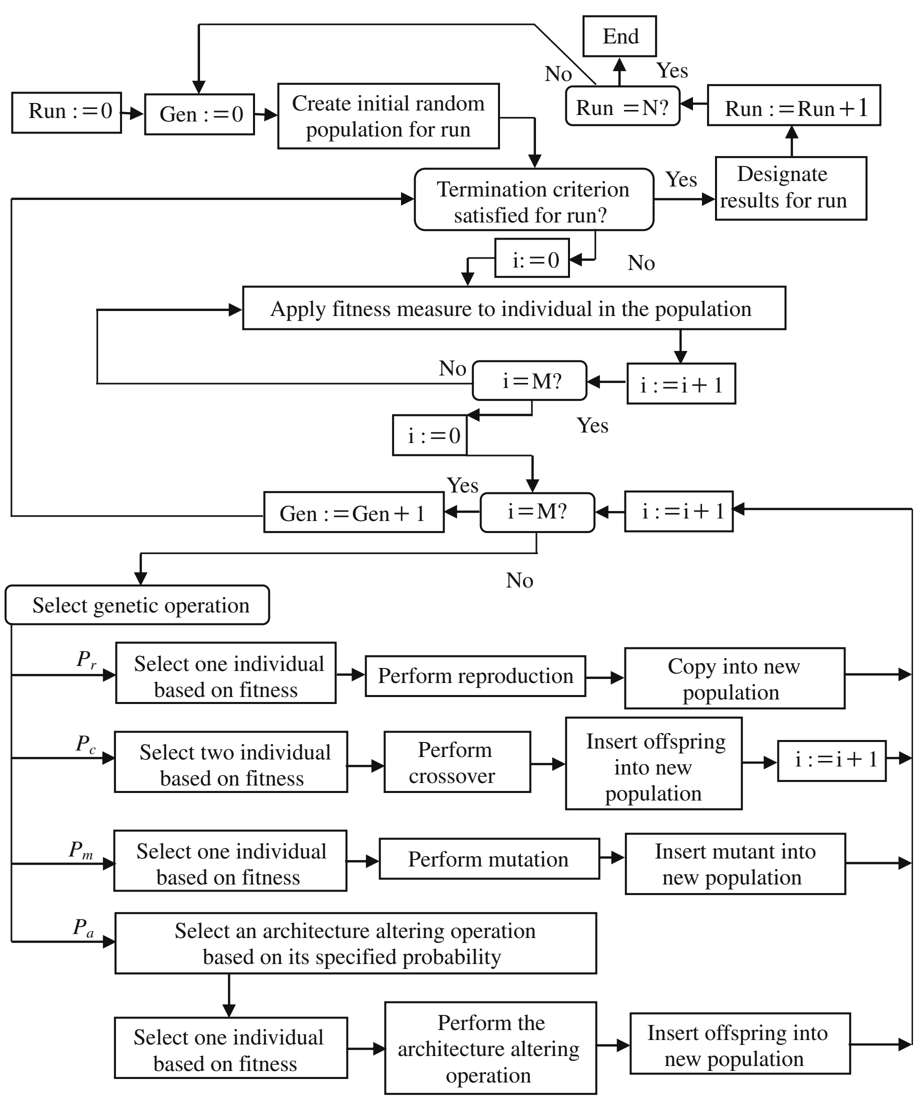

Fig. 1. Genetic programming flowchart [14].