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The prediction of the abrasion resistance of mortars modified with granite powder and fly ash using artificial neural networks

S. Czarnecki, A. Chajec, S. Malazdrewicz and L. Sadowski

Department of Materials Engineering and Construction Processes, Wroclaw University of Science and Technology, Wroclaw, Poland

Abstract

The paper predicts the abrasion resistance of a cementitious composite containing granite powder and fly ash replacing up to 30% of the cement weight. For this purpose, intelligent artificial neural network (ANN) models were used and compared. A database was build based on and mix composition, curing time and curing method. The model developed to predict the abrasion resistance of the cementitious composites containing granite powder and fly ash was shown to be accurate. This method can be used especially for designing cement mortars with granite powder and fly ash additives replacing cement in the range of 0% to 30% of its weight. These mortars can be used for floors in industrial buildings.

Keywords: eco-friendly cement composites, artificial neural networks, granite powder, fly ash, modelling structures.

1 Introduction

Abrasion resistance is one of the most important features for objects where forces act on the surface causing rubbing top layers away [1]. For the purpose of this work, the Bőhme disc method that complies with European Standard EN 13892-3 [2] was used to determine the depth of wear. The samples used were mortars containing fly ash, granite powder and their combinations as partial substitutes for cement. Fly ash can contribute to improvement of several mortar properties like water requirement, workability, setting time, compressive strength and durability [3]. Granite powder can

be used as a filler to improve the packing density of the aggregate [4]. This results in reduction of the cement content, together with carbon footprint [5].
Current methods of determining abrasion resistance in use share similar disadvantages, including damaging samples surfaces and time-consuming testing. Application of artificial intelligence could contribute to optimization of non-destructive testing of abrasion resistance. Only few researches have been investigating this topic [6], [7]. This study is looking for an answer to the following question: is it possible to build the system predicting the abrasion resistance of mortars with granite powder and fly ash with satisfactory accuracy?

2 Methods

Cementitious mortars were prepared with using cement CEM I 42,5R (Górażdże, Poland), fine aggregate (Byczeń, Poland), water from water supply, granite powder waste (Strzegom, Poland) and siliceous fly ash (Hranice, Czech Republic). Sieve size development of used granular materials shows Figure 1.

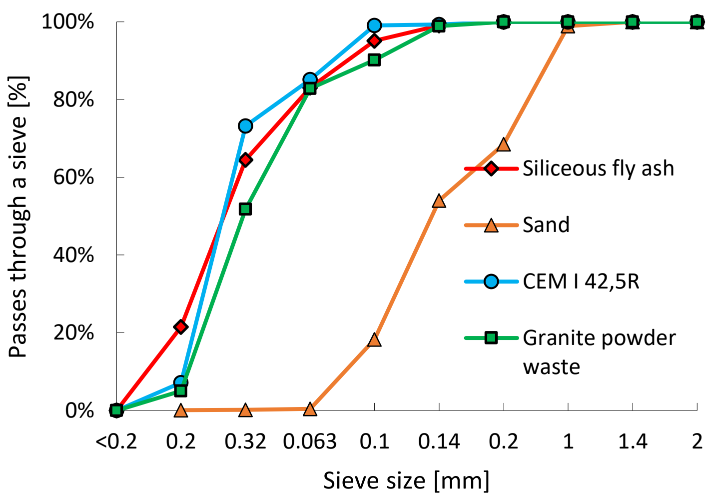

Figure 1 Sieve size development of granular materials used in research

Measured dry ingredients of cementitious mix were placed in the mixer, and mixing for 3 minutes. After that, measured amount of water was added to mix and mixing for 5 minutes. There was not any plasticizer used. After mixing, fresh mortar was placed in the prepared molds. Cubic specimens with dimensions 71x71x71mm were prepared. After 24 hours, samples were put into water and water-cured for 28 days. After this time, others research were performed. To determine the bulk density of hardened cementitious mortars, used the test described in standard PN-EN 12350-6. To determine the abrasion resistance of hardened cementitious mortars, used the test described in standard PN-EN 13892-3 (Boehme method). Prepared samples were abraded on Boehme machine. First, the initial abrasion was performed (4 cycles with 22 rounds), after that samples were weighed. Next the abrasion resistant tests were investigated. Performed 4 stages the test, consisting in performing 4 cycles of 22 rounds (for each samples). After every stage, samples was weighed and measured.

The research were carried out for cementitious mortars modified with different types and amount of additives. Reference mortar was modified with siliceous fly ash and granite powder waste in amount of them 0-30% of cement mass. 11 different series were prepared and their composition were shown in Table 1.

lp	Series	Cement	Water	w/c	w/b	FA	GP	Binder	Sand
1	Ref	1	0.5	0.50	0.50	0	0	1	3
2	FA10	0.9	0.5	0.56	0.50	0.1	0	1	3
3	FA20	0.8	0.5	0.63	0.50	0.2	0	1	3
4	FA30	0.7	0.5	0.71	0.50	0.3	0	1	3
5	GP10	0.9	0.5	0.56	0.50	0	0.1	1	3
6	GP20	0.8	0.5	0.63	0.50	0	0.2	1	3
7	GP30	0.7	0.5	0.71	0.50	0	0.3	1	3
8	5FA+5GP	0.9	0.5	0.56	0.50	0.05	0.05	1	3
9	10FA+10GP	0.8	0.5	0.63	0.50	0.1	0.1	1	3
10	20FA+10GP	0.7	0.5	0.71	0.50	0.2	0.1	1	3
11	10FA+20GP	0.7	0.5	0.71	0.50	0.1	0.2	1	3

Table 1 Composition of cementitious mortars series

3 Results

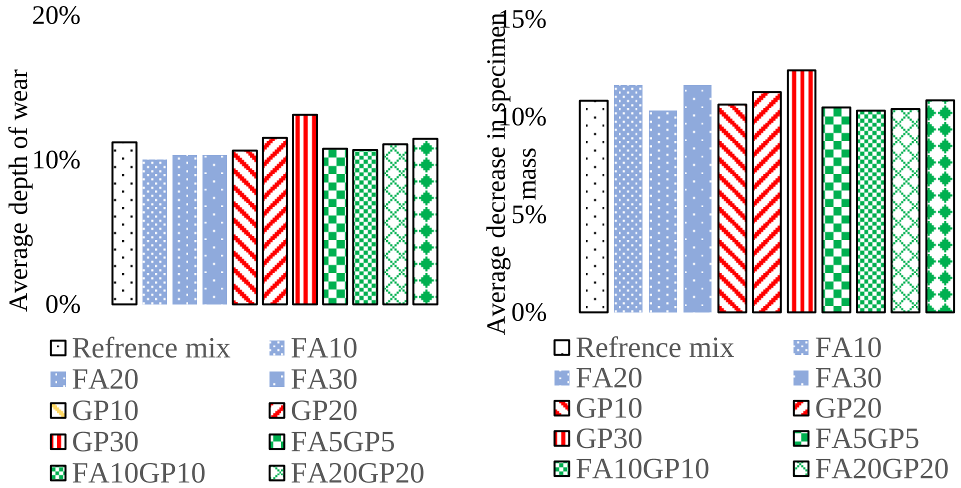

Fig 2. Results presenting average a) depth of wear b) loss of mass for all samples

The results were based on the loss of two parameters, sample weight and height. As seen from **Fig 2a,** fly ash content contributed to the lesser loss of height. For 30% granite powder content the loss had the greatest overall value. The graph indicates that combination of fly ash with granite powder, both up to 30% of binder mass with cement gives promising results. **Fig 2b** presents again the greatest lost, this time of mass when using granite powder at 30%. Surprisingly, the loss of mass for fly ash at

10% and 30% was very similar, with the drop at 20%. Again, application of fly ash with granite powder for all configurations give promising results. Created artificial neural network (ANN) was based on selected mortar components with the cycles of testing and mass of a sample after drying (**Table 2**). The output was assumed as the depth of wear. Water and sand were omitted as the content for all samples stays the same. The total database consisted of 88 cases.

Case no [-]	**Cement [-]**	**Fly ash [-]**	**Granite Powder [-]**	**Cycle of testing [-]**	**Mass of specimen [g]**	**The depth of wear [mm]**
1	1	0	0	4	356,56	0,79
16	0,9	0,05	0,05	4	380,16	1,08
28	0,8	0,2	0	4	370,63	3
42	0,7	0,2	0,1	8	375,29	2,00
50	0,8	0,2	0	12	370,63	2,54
61	0,9	0,05	0,05	12	349,80	2,62
88	0,5	0,1	0,2	16	354,42	4,47

Table 2. Selected input and output parameters

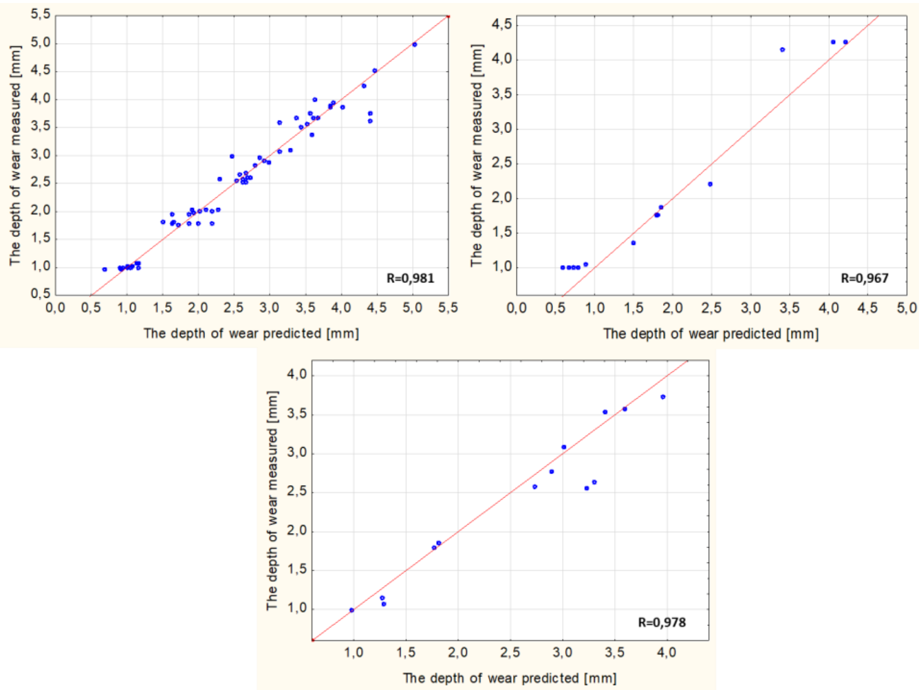

Fig 3. Results of prediction for a) learning b) test c) validation set

The results (**Fig 3**) were presented using automatic network parameters adjustment. Despite the lack of manual optimization and with a fairly small database, the prediction results are satisfactory. The linear coefficient of correlation *R* represents the quality of the network and as it can be seen from the graphs it has not dropped below 0,96. Due to limited space, in the detailed version of the paper analysis will include optimization processes like choosing the learning algorithm with the number of neurons in a hidden layer. The results confirm that it is possible to create the model predicting the abrasion resistance of mortars with granite powder and fly ash with satisfactory accuracy, as proved by others for concrete [8].

4 Conclusions and Contributions

According to gathered sources [9, 10], only a few attempts have been made to predict abrasion resistance for cementitious composites. As proven by the most similar study [8], it is possible to predict the abrasion resistance for self-consolidating concrete, based on the components content. However, no research on prediction the abrasion resistance for mortars with fly ash and/or granite powder as partial cement replacement was found. Fly ash can contribute to improvement of several mortar properties while granite powder contribute to reduction of the cement content, together with carbon footprint. Current knowledge of examining abrasion resistance for such mortars involve several disadvantages, including application of devices that destroy surface with the need to repair it afterwards, examining samples created especially for testing to avoid damaging the pavement, which makes them differ in properties from the main structure or long lasting laboratory tests. Application of artificial neural network in abrasion resistance prediction can contribute to optimization of the process. The assumption of input values into the network as mainly mortar components avoids much of the experimental part and allows the end result to be predicted even before the mix is made. It was proven that the accuracy of the analysis is at satisfactory level.

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