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Experimental Investigation on Mechanical Properties of Concrete Containing Nano Wollastonite and Modeling with GMDH- type Neural Networks

M. Miri[1*], H. Beheshti Nezhad[2], M. Jafari[3]

1- Assistant professor, Civil Engineering Dept., University of Sistan and Baluchestan, Zahedan, Iran
2- Ph.D. Student, Civil Engineering Dept., University of Sistan and Baluchestan, Zahedan, Iran
3- M.Sc. Student, Civil Eng. Dept., Birjand Branch, Islamic Azad University, Birjand, Iran

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ABSTRACT

Wollastonite is a natural and low cost material, which can be replaced by cement in concrete. In the present paper, the influence of Nano Wollastonite on mechanical and durability of concrete was investigated using the measurement of compressive and flexural strength and water penetration on concrete specimens after 3, 7, 28 and 60 days. The results show that flexural strength increases 63%, compressive strength 9% and water penetration resistance with around 50% by substitute of 10% Nano Wollastonite. GMDH-type neural networks were used for modeling of these concrete properties. The aim of such modeling is to make a model for predicting of compressive and flexural strength of concrete with the different percentage of Nano Wollastonite. The age and percent of Nano Wollastonite were used as input variables. The results show that the outputs of neural network model have a good agreement with experimental data.

KEYWORDS

Concrete, Nano Wollastonite, Pressure Strength, Water Penetration, GMDH-Type Neural Network.

* Corresponding Author, Email: Mmiri@eng.usb.ac.ir

1- INTRODUCTION

Wollastonite or calcium meta-silicate is a natural mineral of acicular structure and high elastic modulus. A recently published scientific study tested a low aspect ratio Wollastonite as a partial substitute of cementitious material or sand in concrete [1]. From the results of this study it was evident that incorporation of Wollastonite in concrete increased the flexural and compressive strength of concrete. In another study was conducted by Ransinchung and Kumar [2], investigations were made on pastes and mortars to evaluate the effect of Wollastonite on the mechanical strength of mortar. Improvement in compressive strength of mortar mixes with replacement of cement by Wollastonite and microsilica was observed.

In the present study, a portion of cement particles was substituted with Wollastonite Nano particles (Fig. 1) in concrete and indicated improvements of concrete properties. Finally, genetic algorithm (GA) and singular value decomposition (SVD) were deployed simultaneously for optimal design of both connectivity configuration and the values of coefficients, respectively [3], involved in GMDH-type neural networks which were used for modeling of mechanical properties of concrete.

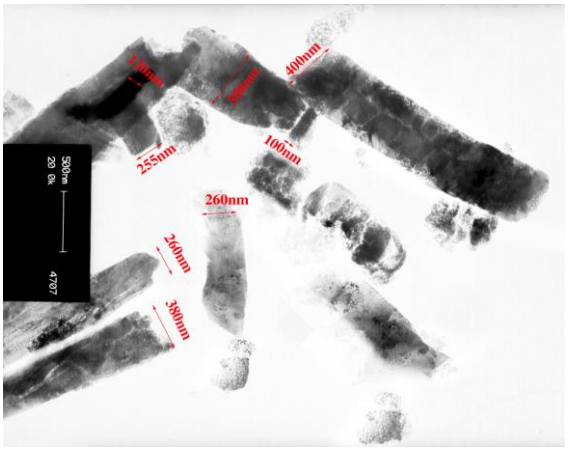

FIGURE 1. TEM IMAGE OF THE NANO WOLLASTONITE

2- MATERIAL, METHODS AND RESULTS

In this study, two series of concrete mixtures were prepared according to ACI 211. In the first set (control specimens) natural aggregates, water and cement were used while in the second type, Nano Wollastonite was substituted for some portion of cement that is usually used. The Wollastonite replacements were 5, 10 and 15 % by mass and the ratio of water to binder for all concrete mixes was 0.45. The binder content in all specimens was 400 kg/m^3. After curing, the specimens cured in two different aggressive and normal conditions. Pressure strength, flexural strength and penetration of water were measured. Finally, GMDH-type of neural network was used to predict the mechanical properties of concrete. Input variables include the percentage of Nano Wollastonite and the age of specimens. Output variables include pressure strength in aggressive environment (f'_{cagg}), 28-day pressure strength (f'_c) and flexural strength (f_b) in normal curing condition. The GMDH model for estimation of the flexural strength of concrete containing Nano Wollastonite was presented in (1).

$$\begin{aligned} y_1 &= 15.982 + 2.7820655(NW) + 2.868170(age) - \\ &\quad 0.17148(N.W)^2 - 0.0283(age)^2 - 0.0192(N.W)(age) \\ y_2 &= -14.2155 - 0.24018289(age) + 1.56471(y_1) + \\ &\quad 0.012467(age)^2 - 0.00177(y_1)^2 - 0.01024\,(age)(y_1) \\ f_b &= -1.440210 - 0.3087021(N.W) + 1.097806(y_2) - \\ &\quad 0.021466(N.W)^2 - 0.00071(y_2)^2 - 0.00234(N.W)(y_2) \end{aligned} \qquad [1]$$

The results of the experiment indicate that the substitution of up to 10% of cement with Nano Wollastonite can increase the pressure and flexural strength and the strength is reduced if higher amounts of substitution are applied. Nano Wollastonite is more effective to flexural strength than pressure strength and efficacy is higher at the early ages of concrete. The results show that compared to control specimens, there was a 9% increase of pressure strength and a 63% increase of flexural strength at the age of 3 days. Increase of Nano Wollastonite can reduce the water penetration in concrete up to 50%. For comparison of models in this study, statistical evaluation criteria were used in table 1.

TABLE1. COMPARISON OF MODELS WITH EXPERIMENTAL DATA

Model	RMS	CF	RMSE	MAE	R^2
f'_{cagg}	1.63	0.9988	3.31	2.67	0.9516
f'_c	2.89	0.9955	9.89	8.35	0.9798
f_b	1.41	0.9948	2.41	2.01	0.9980

The results obtained from the GMDH-type neural network models showed a high degree of coherence with the experimental results.

3- CONCLUSIONS

Based on the test results and modeling the following conclusions were drawn:

(1) Flexural strength, compressive strength and water penetration resistance of concrete increased by 63%, 9% and 50% respectively by replacement of cement with 10% Nano Wollastonite.

(2) Based on the overall effects of Nano Wollastonite, it seems that 10% replacement of Nano Wollastonite can be regarded as a suitable replacement.

(3) The results obtained from GMDH-type neural network showed a high degree of coherence with the experimental results for all considered models.

4- REFERENCES

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