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FUZZY LOGIC MODEL FOR PREDICTION OF COMPRESSIVE STRENGTH OF LIGHTWEIGHT CONCRETE MADE WITH SCORIA AGGREGATE AND FLY ASH

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Key words: Lightweight concrete, Fly ash, Ultrasonic pulse velocity, Fuzzy logic

Abstract

In this study, a fuzzy logic prediction model for 3, 7, 14 and 28 days compressive strength of lightweight concrete made with scoria aggregate and fly ash under different curing conditions (standard and air curing) was devised. In mixtures containing fly ash, 15% of Portland cement by weight was replaced with fly ash. The specimens were cured in standard curing conditions at temperature 20±2 °C and air curing conditions at temperature 20±2 ºC for periods of 3, 7, 14 and 28 days. Compressive strength and ultrasonic pulse velocity (UPV) were determined at the 3, 7, 14 and 28 day curing period. The obtained results with fuzzy logic were compared with the experimental methods and found remarkably close to each other. The results show that the fuzzy logic can be used to predict the compressive strength of lightweight concrete.

1. INTRODUCTION

Non-destructive testing of concrete is preferred because of its distinct advantage over the compression tests. The physical properties of concrete can be detected by, for example the speed of an ultrasonic pulse propagating through the concrete. The application of ultrasonic pulse velocity to the nondestructive evaluation of concrete quality has been widely investigated. Admixtures, such as fly ash (FA) and Silica fume (SF), are used as replacement for cement for improving the mechanical properties, decreasing the rate of hydration and decreasing the permeability of concrete. However, their effects on the ultrasound and the relationship between compressive strength and

UPV have received little attention. The relative performance of the FA in concrete depends on the brand of cement used. In addition, the age of the test is an important factor influencing the relative performance of the various cementing materials (Carette et al. 1993)

The effect of different cement dosages on the compressive strength was investigated by Sahin et al. (Sahin et al 2003). Strength properties of lightweight concrete made with basaltic pumice and fly ash was studied by Yasar et al. (Yasar et al 2003). Performance of fly ash concretes containing lightweight EPS aggregates was investigated by Babu et al. (Babu and Babu 2004). The effect of admixture on the pumice lightweight aggregate concrete was investigated by Sari and Pasamehmetoglu (Sari and Pasamehmetoglu 2005). Radjy and Vunic showed that the gel–space ratio can be used to predict the compressive strength development of concrete based on measuring the adiabatic heat signature to estimate the degree of hydration (Radjy and Vunic 1994). Prediction modelling studies, like regression and other mathematical models were also proposed (Tsivilis and Parissakis 1995, Tango 1998, Anderson and Seals 1981). Recently, artificial neural networks were developed a prediction model (Akkurt et al 2003, Sebastia et al 2003). A prediction model of elastic modulus by using fuzzy logic was developed by Demir (Demir 2005). A fuzzy logic prediction model for the 28-day compressive strength of cement mortar under standard curing conditions was created by Akkurt et al (Akkurt et al 2004). A new way of predicting of cement strength by using fuzzy logic was devised by Fa-Liang (Fa-Liang 1997).

In this study, a new fuzzy logic model has been devised to predict compressive strength of lightweight concrete made with scoria aggregate and fly ash under different curing conditions. Compressive strength and ultrasonic pulse velocity (UPV) were determined at the 3, 7, 14 and 28 day curing period. The obtained results from compressive strength tests were compared with fuzzy results.

2. EXPERIMENTAL STUDY

2.1. Materials

ASTM Type I Portland cement which produced as CEM I (PC 42.5) in Turkey was used in this study. Fly ash (F class according to ASTM C618) from Orhaneli power plant was selected for this work (ASTM C 618 1998). The chemical analysis properties of the cement and fly ash are presented in Table 1. Crushed stone with a maximum size less than 16 mm were used for producing concretes. In mixtures containing fly ash, 15% of Portland cement by weight was replaced with fly ash. A superplasticizer was used to keep the same workability. The mix proportions of binders are presented in Table 2.

Table 1 The chemical property of cement and fly ash

Chemical Analysis (%)									
	SiO_3	**AL_2O_3**	**Fe_2O_3**	**S+A+F**	**CaO**	**MgO**	**SO_3**	**K_2O**	**KK**
Fly ash	48.53	24.61	7.59	80.73	9.48	2.28	2.48	2.51	1.69
Cement	21.12	5.62	3.24	29.98	62.94	2.73	1.79	1.78	3.1

Table 2 Mix proportions used for experiments

Mixture type	Lightweight Concrete	Lightweight Concrete with Fly Ash
Cement, kg/m^3	400	340
Fly ash, kg/m^3	-	60
Aggregate, kg/m^3	1374	1374
Water, kg/m^3	308	308
Super plasticizer, kg/m^3	4.8	4.8

2.2. Ultrasonic pulse velocity (UPV) and Compressive strength

For each mixture, three samples of standard cube (150mmx150mmx150mm) were prepared and cured in lime-saturated water at 20 ±2 ºC and air at 20 ±2 ºC until the time of the testing. The samples were tested at 3, 7, 14 and 28 days for UPV and compressive strength in accordance with ASTM C 597 (ASTM C 597 1998) and ASTM C 39 (ASTM C 39 1998), respectively. A schematic diagram for UPV is shown in Fig. 1.

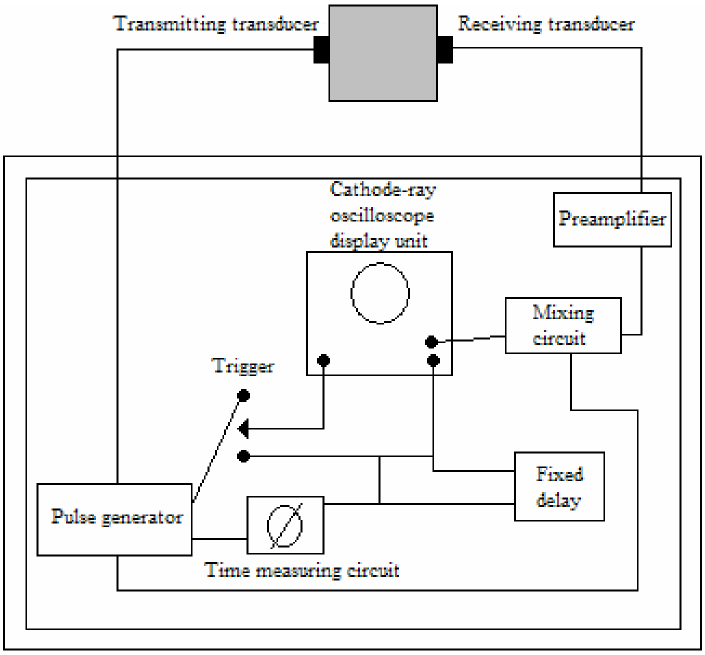

Fig. 1 Schematic diagram of pulse velocity testing

The pulse velocity can be determined from the following equation:

$$V = \frac{S}{t} \qquad (1)$$

where V= Pulse velocity (km/s)

S= Path length (cm)

t= Transit time (μs).

3. FUZZY ALGORITHM FOR PREDICTION OF COMPRESSIVE STRENGTH

There is no doubt that the ultrasonic pulse velocity increases with an increase in the compressive strength of lightweight concrete, but there is no a fuzzy model on the relationship between compressive strength, ultrasonic pulse velocity, curing conditions, curing time and fly ash for lightweight concrete.

The developed fuzzy logic-based model was applied to predict the cement strength data obtained from experimental. The fuzzy rules were written for this purpose. It can be seen from Fig. 2 that we devised the fuzzy logic-based algorithm model by using the fuzzy logic toolbox in MATLAB.

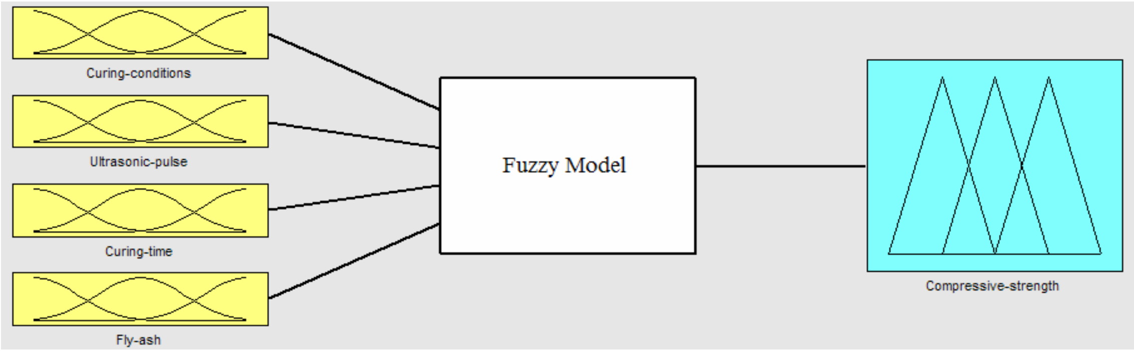

Fig. 2 Block diagram used for fuzzy modeling

Membership functions for input and output parameters used for fuzzy modeling are given in Fig. 3-7. The choice of the membership functions is based on the experiences gained, and their base values are selected so that they are concentrated on more sensitive regions.

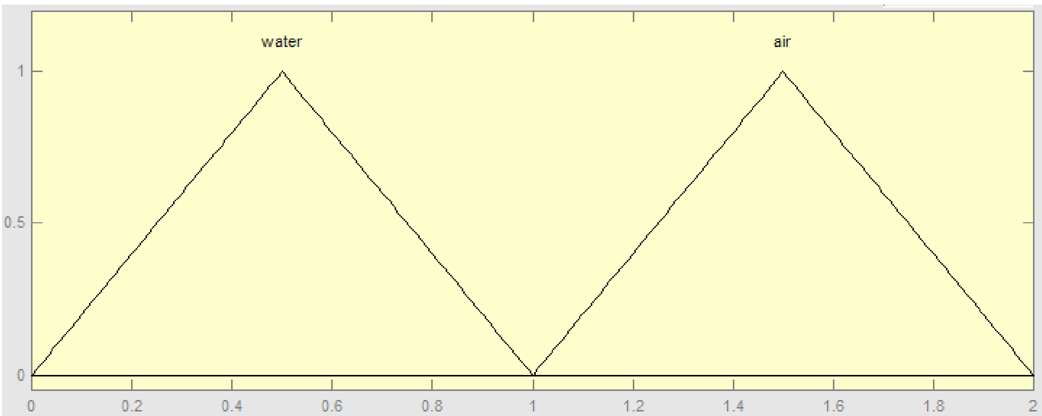

Fig. 3 Fuzzy input membership functions used for curing conditions

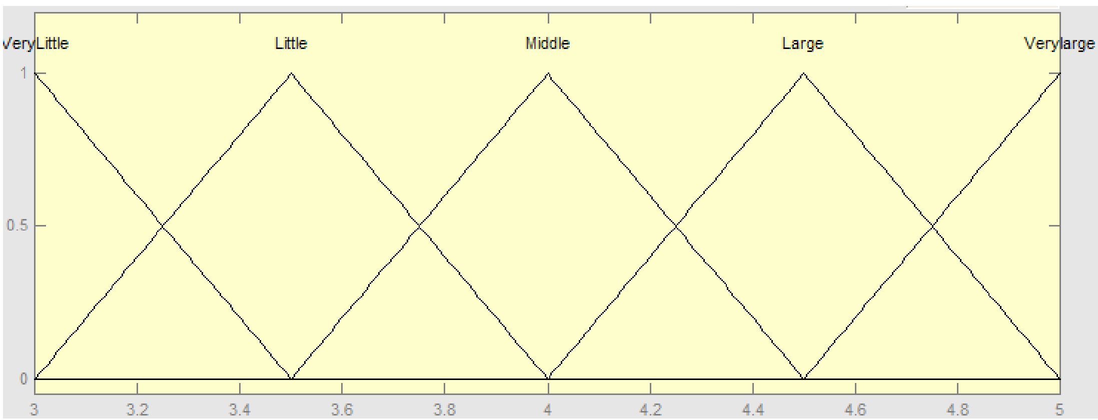

Fig. 4 Fuzzy input membership functions used for ultrasonic pulse velocity

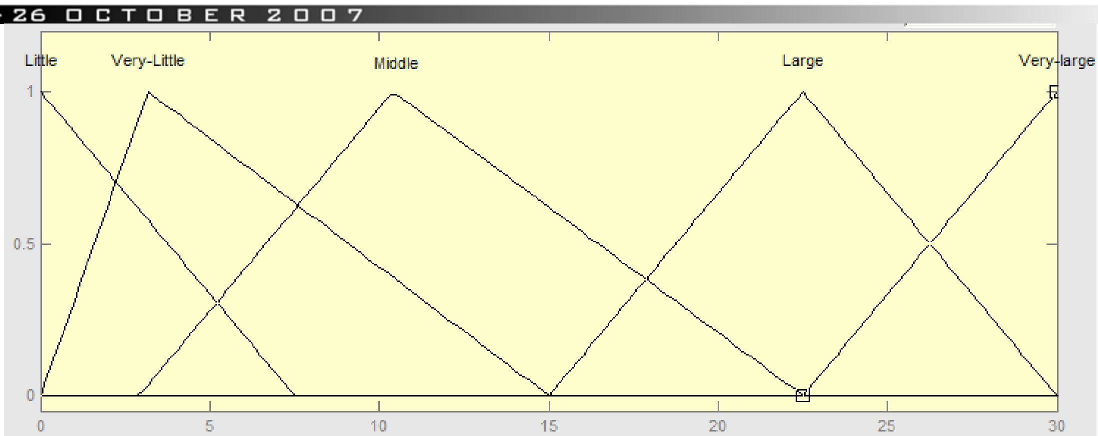

Fig. 5 Fuzzy input membership functions used for curing time (days)

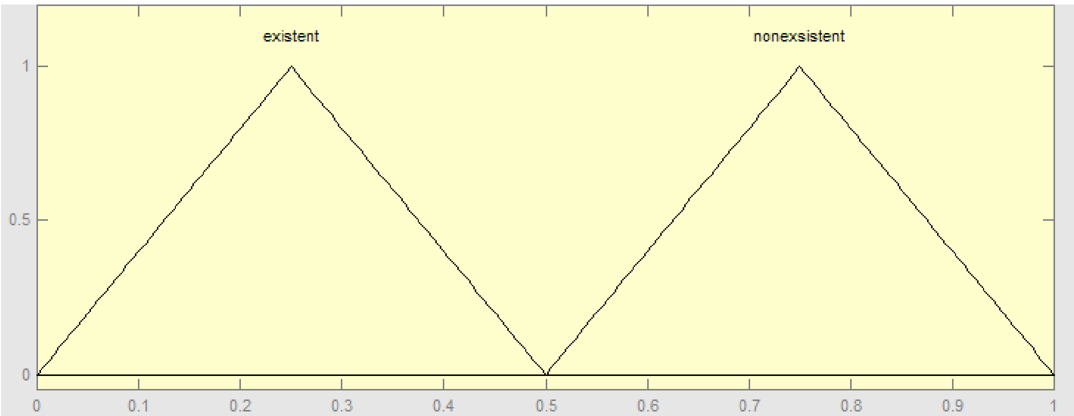

Fig. 6 Fuzzy input membership functions used for fly ash

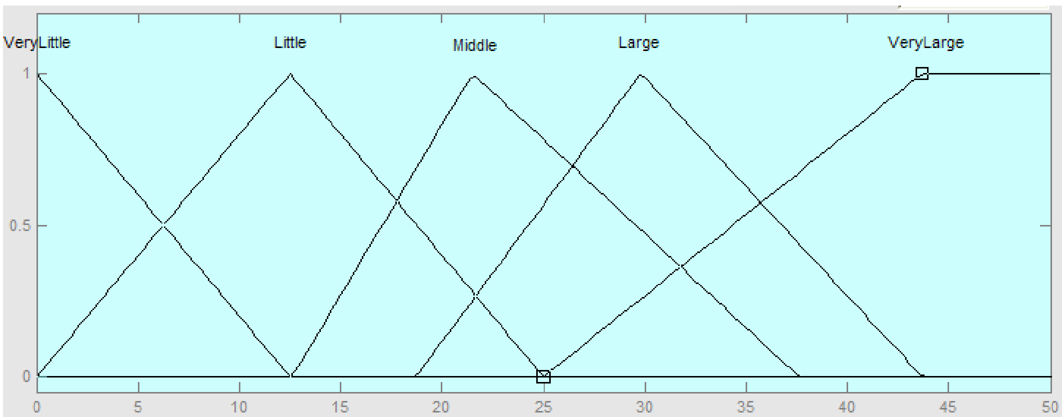

Fig. 7 Fuzzy output membership functions used for compressive strength

4. RESULTS AND DISCUSSIONS

In this study, compressive strength prediction was done using fuzzy logic. The fuzzy algorithm was devised for lightweight concrete and lightweight concrete with fly ash under different curing conditions. Ultrasonic pulse velocity measures (UPV) for different curing conditions are given in Fig 8 and Fig. 9. Although ultrasonic pulse velocity of samples with fly ash were the lowest following by at the ages 3 days, its ultrasonic pulse velocity increasingly developed relative to another mixture at the ages of 7, 14 and 28 days of curing period. It can also be seen in tables that the highest ultrasonic pulse velocity values were obtained from water cured specimens followed by the air cured specimens regardless of the concrete types. This shows the role of curing methods on the early age ultrasonic pulse velocity of concretes, i.e. the higher the moisture level the specimens was exposed to the higher the ultrasonic pulse was achieved.

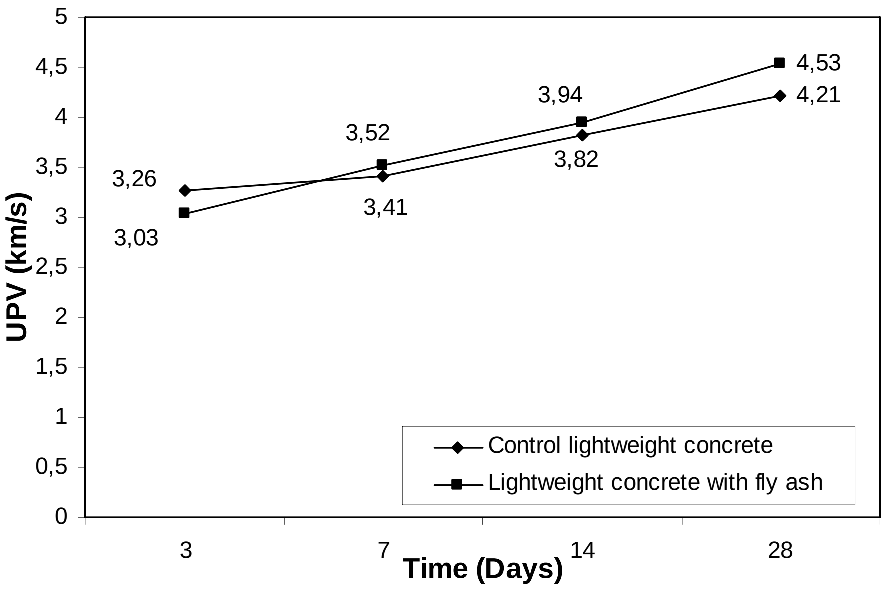

Fig. 8 UPV measurements of lightweight concrete with fly ash for water curing periods

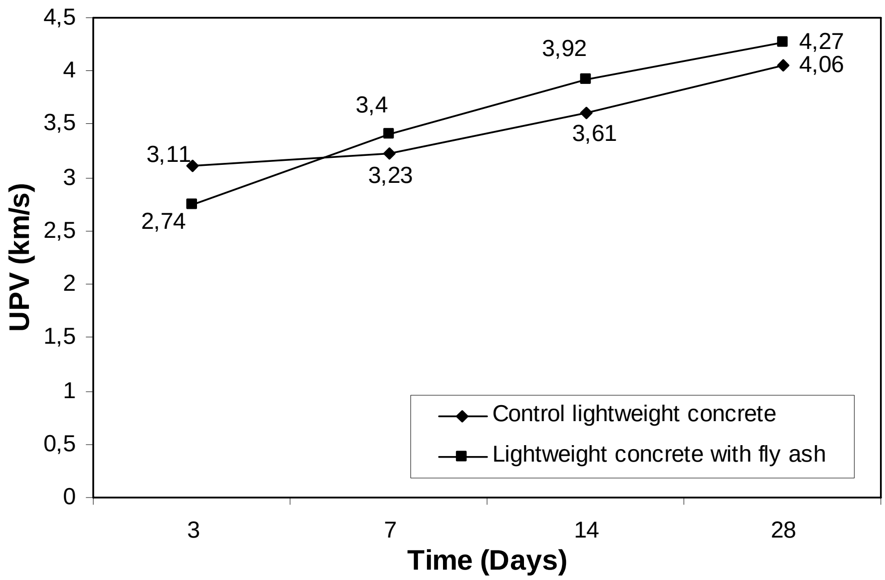

Fig. 9 UPV measurements of lightweight concrete with fly ash for air curing periods

The prediction results of the developed fuzzy model and the experimental results are given in Table 3 and Table 4. The obtained results with fuzzy logic were compared with the experimental methods and found remarkably close to each other. These results show that the fuzzy logic can be used to predict the compressive strength of lightweight concrete.

Table 3 Measured and predicted compressive strength results for water curing periods

	3	7	14	28
Lightweight concrete	13.41	20.12	28.4	30.94
Fuzzy logic results for lightweight concrete	12.8	20.5	23.9	31.1
Lightweight concrete with fly ash	11.73	23.99	29.9	33.99
Fuzzy logic results for lightweight concrete with fly ash	12	23.4	26.6	36.8

Table 4 Measured and predicted compressive strength results for air curing periods

	3	7	14	28
Lightweight concrete	12.32	14.73	20.14	24.87
Fuzzy logic results for lightweight concrete	12.5	14	23.1	25
Lightweight concrete with fly ash	9.09	18.2	22.35	27.32
Fuzzy logic results for lightweight concrete with fly ash	10	21.8	24.2	31.1

5. CONCLUSION

A fuzzy logic prediction model for 3, 7, 14 and 28 days compressive strength of lightweight concrete made with scoria aggregate and fly ash under different curing conditions (standard and air curing) was devised. It was utilized from fuzzy logic to predict compressive strength of lightweight concrete based on curing conditions, ultrasonic pulse velocity, curing time (days) and fly ash. In mixtures containing fly ash, 15% of Portland cement by weight was replaced with fly ash. The specimens were cured in standard curing conditions at temperature 20 ±2 °C and air curing conditions at 20 ±2 ºC for periods of 3, 7, 14 and 28 days. Compressive strength and ultrasonic pulse velocity (UPV) were determined at the 3, 7, 14 and 28 day curing period. The obtained results with fuzzy logic were compared with the experimental methods and found remarkably close to each other. Furthermore, the average error for predicted compressive strengths is 7.16 %. Thus, the present study suggests an alternative approach of compressive strength of lightweight concrete assessment against destructive testing methods.

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