Available online at www.dergipark.gov.tr

INTERNATIONAL ADVANCED RESEARCHES and ENGINEERING JOURNAL

e-ISSN: 2618-575X

Journal homepage: www.dergipark.gov.tr/iarej

International Open Access

Volume 03
Issue 01

April, 2019

Research Article

The evaluation on the effect of effective and repetitive vibration to compressive strength with the fuzzy method

Mahmut Kahraman [a] **and *Ferhat Pakdamar*** [b, *]

[a]*Gebze Technical University, Department of Architecture, Gebze, Kocaeli/*TURKEY

[b]*Gebze Technical University, Department of Architecture, N Blok 1-17, Gebze, Kocaeli/TURKEY*

ARTICLE INFO

Article history:
Received 25 March 2018
Revised 20 October 2018
Accepted 27 November 2018

Keywords:
Vibration
Repetitive vibration
Compressive strength
Pressure endurance
Fuzzy logic

ABSTRACT

In this study, it was aimed to develop alternative prediction models for estimating the compressive strengths of concrete with different concrete classes and different slump values. An experimental study based on repetitive vibration application was performed in the laboratory environment and prediction models were developed on the basis of fuzzy logic with reference to this experimental study. In the experimental study, the concretes which are in C20 and C35 and have K3, K5 settlement values were produced and determined compressive strengths of the concretes which hides in suitable conditions after 30 minutes, 60 minutes and 90 minutes, 7 and 28 days, respectively. Other results are evaluated with considering the 28 day concrete strength of concretes which once-vibrated. The concrete pressure endurance of the vibration time and its repeated applications are predicted by the graphical representation of fuzzy logic methods. The compressive strength values obtained from the prediction models and the compressive strength values of the experimental data were compared and evaluated. As a result, it is seen that the prediction of the concrete pressure endurance with the fuzzy model is possible and the fuzzy model is predicted more accurately to the concrete pressure endurance.

1. Introduction

Throughout the world, as building material concrete is being used most commonly [1]. After its formula prepared according to its project, since the preparation of the ordered concrete consists of the stages such as preparation of the concrete in concrete plants, its transportation to concreting area, placing them into the molds according to the standards, it is certain that each of these stages affects the concrete resistance excessively. The preparation of correctly formulated concrete in the plant is very practical because it is made over computer programs today [2]. The ordered concrete can be produced in large quantities and with different specifications via fabrication system and can be reached to the construction site [3].

Today, depending on the developments in ready mixed concrete technologies, their pressure endurance generally provides good results. Generally, there is no problem faced with the loss of concrete strength when it is prepared via special computer programs in the plants and also during its transportation by horizontal mixers [4]. In addition, due to the use of high quality pumps in the ready-mixed concrete sector and employment of skilled technical personnel human-caused faults are minimized and very good results are obtained from pressure endurance of the 7 and 28 days old samples taken from the concrete on the construction site [5]. The placement of the concrete into the mold, repeated vibration applications and curing applications seriously affect the strength of the concrete [6]. Since the determination of vibration duration and repeated vibration applications on the concrete are completely dependent on the human factor, by reason of the fact that these intervals and applications are not made according to a certain standard are still seen as a serious problem for the concrete castings in the working sites [7].

* Corresponding author. Tel.:+90 262 605 1614; Fax: +90 262 653 8495.
E-mail address: mahmutkahraman23@gmail.com *(M. Kahraman)*, pakdamar@gtu.edu.tr *(F. Pakdamar)*
ORCID: *0000-0001-8022-3236 (M. Kahraman), 0000-0002-5594-3095 (F. Pakdamar)*

As a result of these casting deficiencies, it causes the loss on the concrete strength and the segregations and deterioration on the concrete surface causes serious quality losses, repair costs and loss of trust of the client companies.

A number of up-to-date methods can be applied for correct placement of the concrete into the molds and accurate determination of the application limits for repeated vibration [8]. Fuzzy solutions of engineering problems, artificial neural networks, genetic algorithms.

By subjecting two different concrete grades that have two different slump features to a revibration, the models calculating their compressive strengths have been tried to be identified and modelled by fuzzy logic methods [10].

Fuzzy logic modeling which has started to be one of the widely used methods is a new mathematical method that has been found by L.A. Zadeh in 1965 and called "Fuzzy Sets". This study of Zadeh L.A. was presented as published in the magazine named Information and Control in 1965. Since then, fuzzy cluster theory was quickly developed by both Zadeh himself and numerous researchers [11].

2. Fuzzy Logic

Fuzzy Logic is a method used to identify and reveal unknowns in an existing system. The fuzzy functions adjust the data at hand to reduce these uncertainties. In addition, fuzzy logic is also being used for making decisions easier to control a system [12].

The most significant difference of fuzzy systems occurs when the inputs are not numerical. The non-digital data is composed of a blurring unit for blurring by processing and a clearing unit for digitizing the blurred output [13].

A common fuzzy inference system has 4 components as shown in Figure 1. These are fuzzification, rule base, inference motor and defuzzification [14].

The membership function for each data entered by fuzzification is transformed into one or more membership functions. It includes the rules covering all possibilities of fuzzy relations between inputs and outputs according to fuzzy rule base. [15].

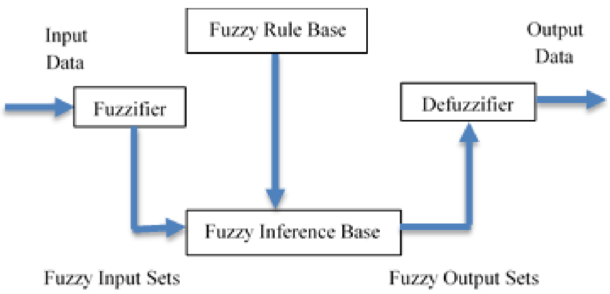

Figure 1. The structure of the fuzzy inference system [15].

These rules are expressed in the form of “if-so” format. The fuzzy inference motor, takes all fuzzy rules in the fuzzy rule base and the findings into consideration to be able to obtain the correct result from the inputs in the transferred set [16].

2.1. *Evaluation of Concrete Grades via Fuzzy Logic Method*

The following experimental study charts Table 1-4 and Figure 2 are taken from the article [17]. It was taken from the article study. In this section, two different classes of concrete have been tried to be constructed with fuzzy logic method to estimate the repetitive vibration and compression and compressive strength of two different concrete classes [18].

2.2. Experimental Study

Effect of first and second vibrations on the compressive strength in comparison with self-consolidating concrete was examined on the experiment samples which are in the quality classes of C20 and C35 and have slump values of K3 and K5 during the experimental study made in the laboratory environment. In the experimental studies, PC 42.5 type cement, natural Sakarya sand as aggregate and crushed stone aggregate which is also supplied from the same region were used. In the mixture, 0.8% ratio of plasticizer was used [17].

Mixture granulometry is chosen as to be closer to B32. The properties of the cement used are shown in Table 1. The concrete used in the study were C20 and C35 class concrete which were taken from the production facility and they were determined in a way that to obtain two different (K3 and K5) slumps. The compositions of the concrete produced are given in Table 2 and the slump ratios in Table 3 [17]. One side is 150 mm long cube samples from each series were produced [19], [20].

Experiments were carried out by taking samples for three different series for two different concrete grades. For the C20 class concrete, no vibration was applied to the concrete during the first sampling, and the settlement was achieved with its own weight. The concrete in the first series were subjected to vibration for 30 seconds immediately after the production. A single vibration was applied for the second series and for the other samples, a second vibration was applied for 20 seconds after 30, 60 and 90 minutes [17]. This application was repeated for C35 concrete too in the same way and the figures in Table 4 were obtained.

Table 1. Properties of the cement used in the experiment (PC 42.5)

Chemical Properties	Obtained Values	TS-19	
		LEAST	MOST
Chloride(Cl) %	0.0046		
Sulfur Trioxide(SO_3) %	2.26		
Magnesium Oxide(MgO) %	1.47		
Loss of Ignition %	1.28		
Insoluble Solids %	0.30		
C_3A %	-	-	-
2 C_3A + C_4AF %	-	-	-
PHYSICAL PROPERTIES			
Volume Expansion (mm)	6.0	-	10.0
Specific Surface (m^2/gr)	3598	2800	-
Initial Setting (hour:min)	03:00	01:00	10:00
End of the Setting (hour:min)	04:00	-	-
Pressure Endurance for 2 days (MPa)	21.6	20.0	-
Pressure Endurance for 7 days (MPa)	37.0	31.5	-
Pressure Endurance for 28 days (MPa)	51.9	42.5	-

Table 2. Concrete composition

Concrete Code	Cement kg/m^3	Water kg/m^3	Sand kg/m^3	B.Stone. I kg/m^3	B.Stone. II kg/m^3	S.Plasticizer kg/m^3	Water/ Cement Rate
C20-K3	310	170	912	580	400	2500	0.55
C20-K5	298	190	900	570	390	2500	0.64
C35-K3	390	180	770	515	530	3150	0.46
C35-K5	378	205	755	500	518	3150	0.54

Table 3. Fresh concrete features

Concrete Code	Slump (cm)	Concrete Temperature (˚C)	Unit Weight (kg/cm^3)
C20K3	9-11	18	2370
C20K5	20-22	16	2350
C35K3	10	14	2389
C35K5	22	11	2360

Table 4. Pressure test results (MPa)

Concrete Consistency		K3		K5	
		Slump(h)=100 mm		Slump(h)=200 mm	
Concrete Age		7 Days	28 Days	7 Days	28 Days
Concrete Code		Compressive Strength (MPa)			
A	C20-0	22.79 (60)	25.71 (67)	18.64 (59)	26.00 (83)
B	C20-V0	29.04 (76)	38.22 (100)	25.94 (83)	31.39 (100)
C	C20-V30	29.82 (78)	40.44 (105)	28.84 (92)	38.09 (121)
	C20-V60	31.92 (84)	40.33 (106)	29.67 (95)	38.84 (124)
	C20-V90	29.80 (78)	38.21 (100)	29.34 (93)	36.78 (117)
A	C35-0	25.40 (56)	38.42 (85)	22.48 (66)	32.70 (95)
B	C35-V0	39.18 (87)	45.00 (100)	26.00 (76)	34.25 (100)
C	C35-V30	35.37 (79)	46.97 (104)	27.30 (80)	39.74 (116)
	C35-V60	37.87 (84)	48.02 (107)	23.47 (68)	34.84 (102)
	C35-V90	37.54 (83)	43.31 (96)	27.58 (80)	36.84 (108)

*Percentage of single vibration to the 28-day value of the series and given in parentheses.

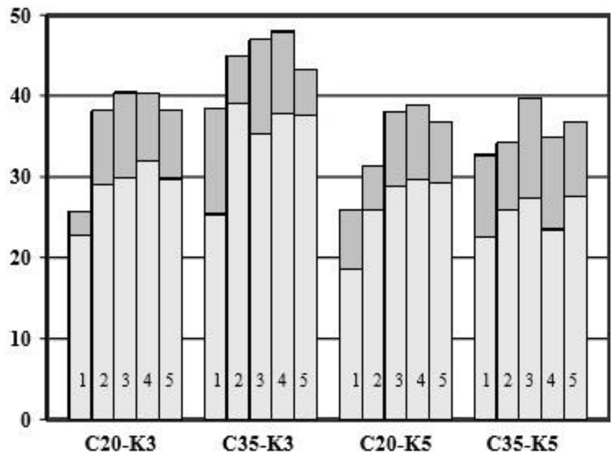

Figure 2. Uniaxial pressure test result changes on compressive strengths in 7 and 28 days as a result of vibration.

2.3. Effect Model of Effective and Repeated Vibration on the Concrete Pressure Endurance Values with Fuzzy Method (EMECSEM).

In this study, use of fuzzy logic in evaluating the effect of effective and repetitive vibration on the concrete pressure endurance has been examined by developing a model that allows the observation of more and qualitative results with diversification of related factors and classes of concrete grade, revibration and slump grades apart from the literature [21]. Thus, with the fuzzy logic model, a decision support system will be provided to be able to develop the limit value that can be obtained according to strength results based on the project sizes and risk-related strategies for determining the variations according to strength values and possible project changes.

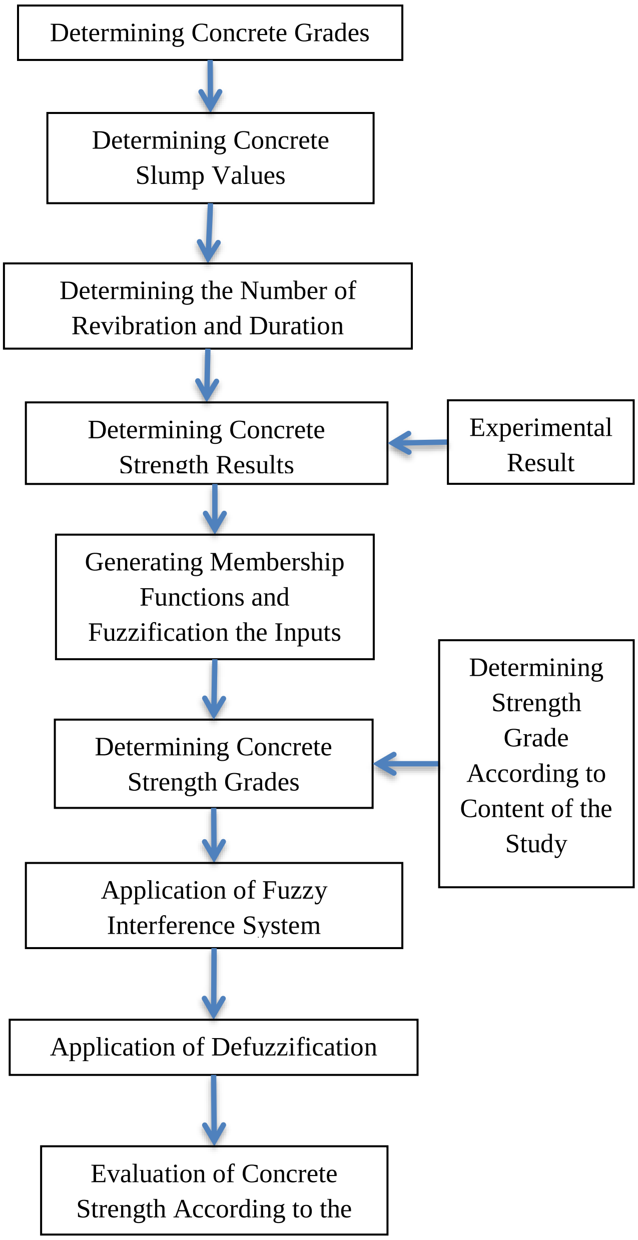

Figure 3. (EMECSEM) process steps of effect model to the concrete pressure endurance values with fuzzy method.

In Figure 3, the steps of the processes applied in the development of the fuzzy strength effect model (EMECSEM) are shown. The structure of the mamdani fuzzy inference system in the generated fuzzy system, determination of the concrete strength values is realizing at four steps according to the sequence of the flow chart given. The first stage is determination of membership functions based on the values such as concrete, slump, the number of revibration and fuzzification the inputs and determination of the concrete strengths obtained by the experiment. The second stage is determining concrete strength grades with reference to the strength values obtained by the experiment and application of the fuzzy inference system. The third phase is defuzzify process. The fourth stage is the evaluation of the concrete strength against the results.

Strength value results related to the variables defined in the studies in which the experimental results were obtained previously were taken and recorded. According to these results, the strength values according to different slump values and revibration applications of different concrete classes are given in Figure 2.

The values to be used in the model are defined in the experiment and their classifications are made. Strength values defined according to the experiment results were determined by simplifying them in a graphical system.

In the first stage of the EMECSEM, concrete grade defined in the model, slump grade, revibration and number of revibration, membership functions for experimental strength values and their fuzzy sets determined and fuzzy rules were generated and fuzzification and defuzzification methods were defined for digitizing the value of strength value obtained.

2.4. Determination of Fuzzy Membership Functions and Fuzzification of the Inputs

The grades of the strength factors that are forming the model inputs are mostly numerical values. For this reason, numerically expressed values must be represented by fuzzy subsets and membership functions in order to be defined in the fuzzy system. Fuzzy subset ranges and membership functions were determined by examining the experimental results.

In this modeling, fuzzy subset ranges and membership functions representing the input and output of the model were determined with reference to the study named "Importance of Active Vibration on Concrete Quality" which is conducted in 2002 by Kemalettin Yılmaz and Fetullah Canpolat and published in Osmangazi University Journal of Engineering and Architecture Magazine Issue XVI.

Fuzzy subset ranges and membership grades used in the model Concrete grades are seen in Figure 4, slump values are seen in Figure 5, vibration durations are seen in Figure 6 and strength values are seen in Figure 7.

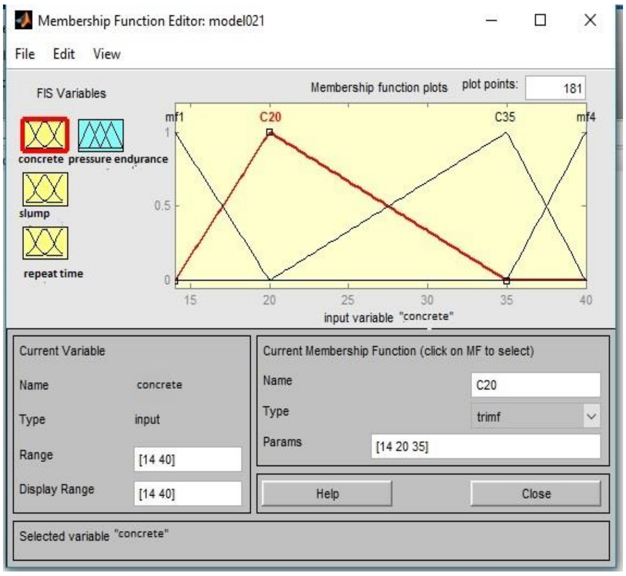

Figure 4. Determination of membership function according to concrete grades

In Figure 4, while determining the membership functions of concrete grades, C20 and C35 concrete were determined, and the input values determined as C14, C20, C35, C40 Concrete class range.

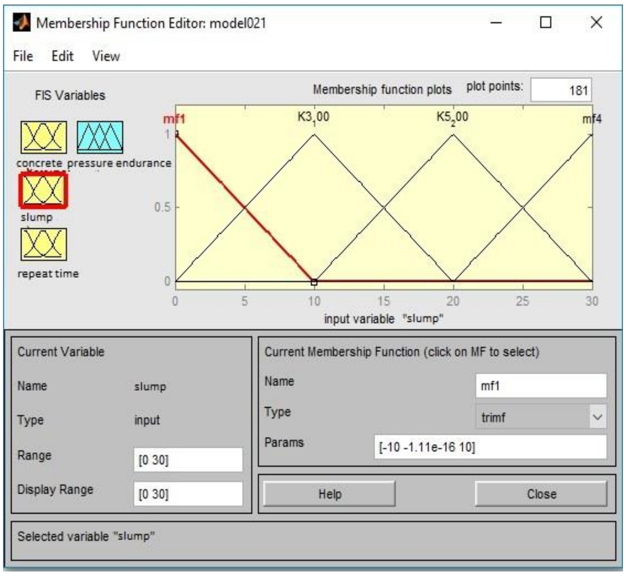

Figure 5. Determination of membership function according to concrete slump values

While determining membership functions according to slump values in Figure 5, K3:10 cm and K5:20cm slump values were determined and Input values determined as mf1:0, K3: 10 cm, K5: 20 cm , mf4: 30 cm concrete slump grade range.

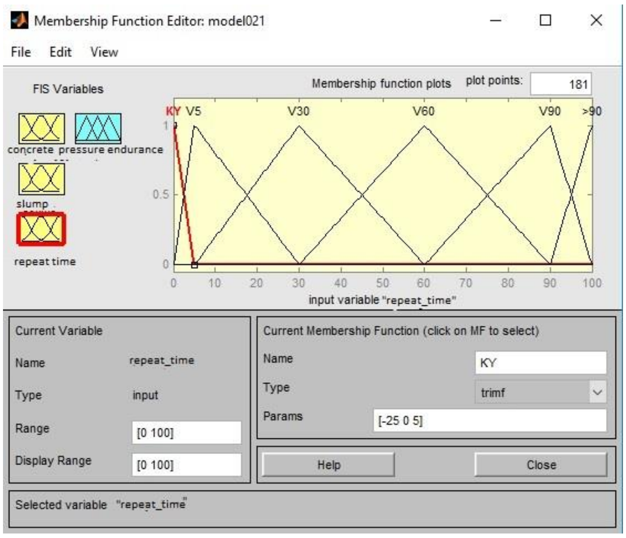

Figure 6. Determination of membership function of revibration number and duration

While the membership functions of membership values of revibration number and duration were being determined in Figure 6, the values determined as KY (Self-Grooving), V5, V30, V60, V90 and above 90 and Input values determined as KY 0 minute, V5: 5 minutes, V30: 30 minutes, V60: 60 minutes, V90: 90 minutes, above 100-minute concrete vibration ranges.

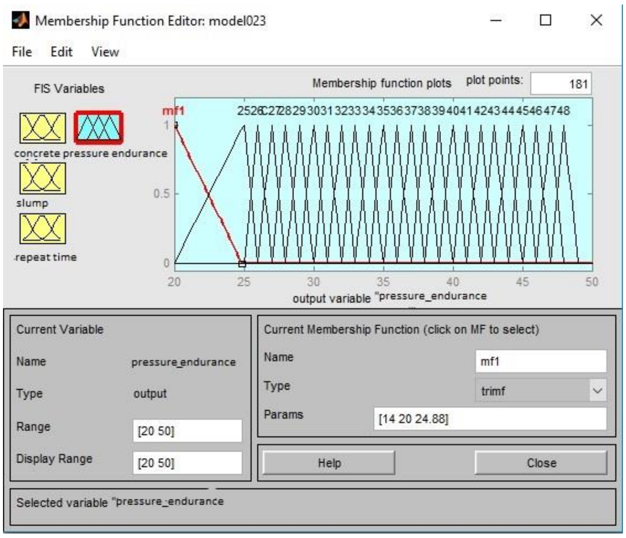

Figure 7. Membership function of concrete endurance values

In Figure 7, when the membership functions of the concrete strength values are determined, values between 20 MPa, 25 MPa, 30 MPa, 35 MPa, 40 MPa, 45 MPa, 50 MPa have been determined starting from 20 MPa, 25 MPa - The strength values of 30 MPa are allocated to the range of 25, 26, 27, 28, 29, 30. The strength values of 30 MPa to 35 MPa are allocated to the range of 30, 31, 32, 33, 34, 35. 35 MPa - 40 MPa strength values are assigned to the range of 35, 36, 37, 38, 39, 40. 40 MPa – Strength values of 45 MPa are allocated to the definition range of 40, 41, 42, 43, 44, 45. 45 MPa - Strength values of 50 MPa are allocated to the identification range of 45, 46, 47, 48, 49, 50.

2.5. Composing Fuzzy Rule Base (Preparing Fuzzy Systems)

For the creation of EMECSEM fuzzy systems; the rules which are stated as IF-THEN type were determined by using the figures close to the strength values which were determined via concrete grade, concrete slump values, revibration values experiment results which constitute the inputs. This is collated with the rules and operator. These rules are defined as "rule base". In Figure 8 and Figure 9, fuzzy outputs were obtained via combining the rules which were written by using the Fuzzy rule base and according to Mamdani fuzzy interference system.

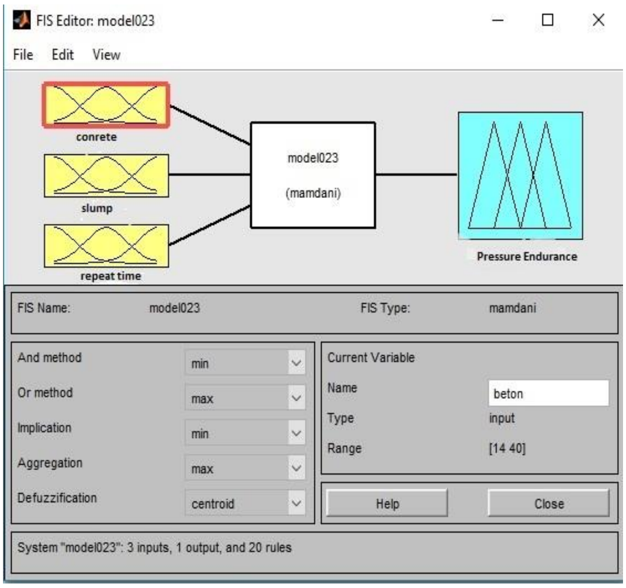

Figure 8. (EMECSEM) Structure of the effect system on concrete strength values with fuzzy method

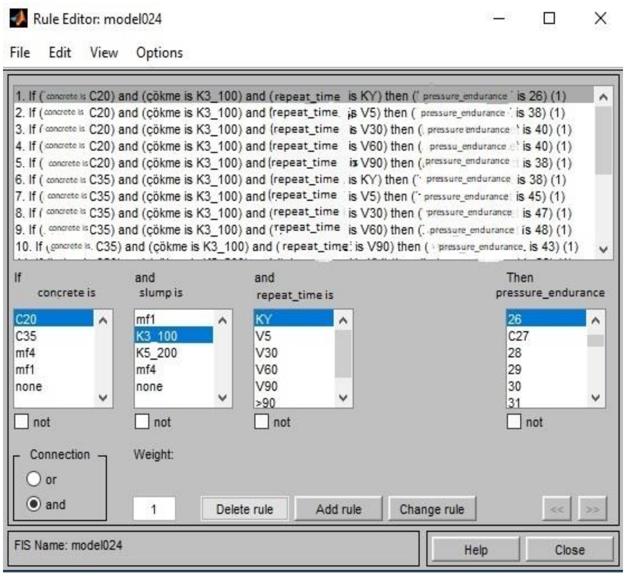

Figure 9. Combining written rules using fuzzy rule base according to fuzzy inference system

Fuzzy Outputs were obtained through combining the rules mixed by using fuzzy rule base according to Mamdani fuzzy inference system. For defuzzification on the outputs which were obtained as fuzzy, "center of gravity" method was used and strength values were determined.

2.6. Application of Defuzzification Process

According to the rules written by using the fuzzy rule base, the strength tables which can be read according to the functions and different variations emerged depending on the fuzzification are shown in Figure 10.

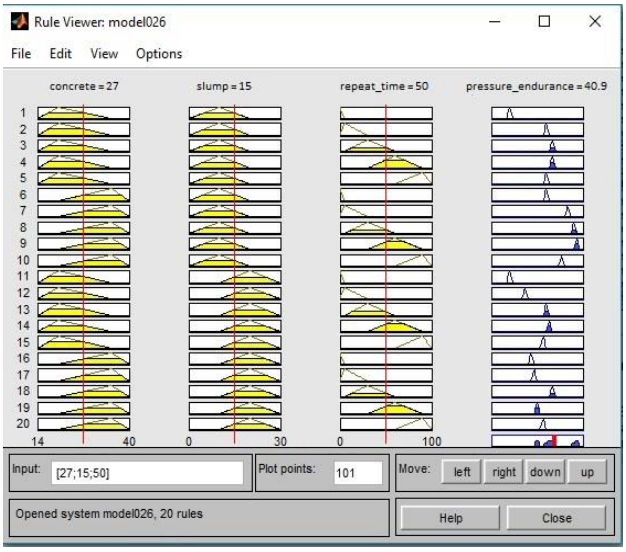

Figure 10. Evaluation of concrete strength according to results

As a result of the defuzzification process, a three-dimensional graph where maximum and minimum values are placed is shown in Figure 10 and Figure 11.

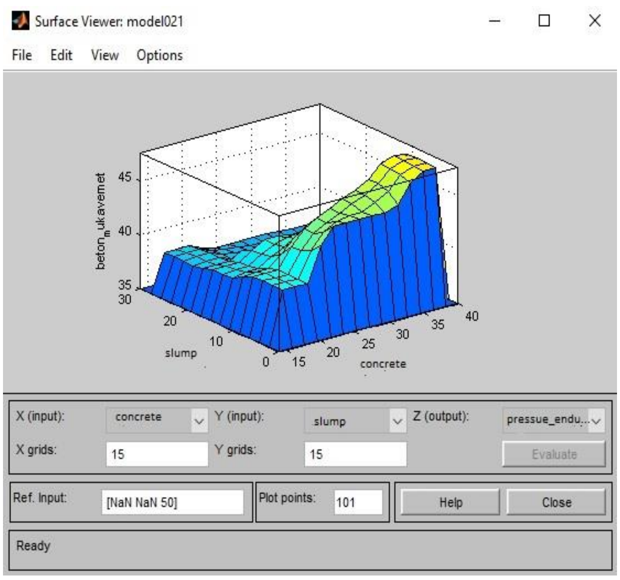

Figure 11. Three dimensional model showing concrete class, slump values and concrete strength values

3. Conclusions

In the study, C20 and C35 fresh concrete samples were subjected to revibrations at K3 and K5 slump values and with 0, 5, 30, 60, 90 min intervals. As a result of revibration applications, their fuzzy logic models are created. Obtained conclusions are listed below:

- A fuzzy logic model is created for revibrations using graphical representation.
- The data in which modeling was obtained with Fuzzy Logic and Pressure Endurance results obtained through experiments were evaluated comparatively. It is believed that this decrease in Pressure Endurance after 60 min of excessive vibration is due to segregation. According to the fuzzy logic model, the error rate was seen as 5-6%.
- With this study, results for no-data values can be found. Computers can make a faster calculation for this method.
- Especially when it comes to the large-budget projects (depending on static calculations, by considering various desired Pressure Endurance and different grades of concrete formulas, different water ratios, different slump values, repetitive vibration applications with different durations, different concrete grates etc.), considering the preparation of appropriate concrete formulas through using fuzzy logic method will provide a great ease.
- Fuzzy logic will expand technical personnel's horizon in terms of preparing different formulas in the construction as well as provide serious economic gains thanks to different formulas obtained for different sections of the construction.
- With this study, clarification of the limits of effective vibration application for accurate concrete casting by the help of fuzzy method will provide serious contributions to architects and engineers in terms of proceeding in line with the work schedule and eliminating repair and correcting costs.

References

1. Erdoğan T. Y., Concrete, 2003, Ankara: METU Press, 1st Edition, pp. 66-67, 191-198, 652-677.
2. TS 802, "Design Concrete Mixes". Turkish Standards Institute, Ankara, March 2016.
3. TS 1247, Mixing, Placing and Curing of Concrete (Normal Weather Conditions), Turkish Standards Institute, Ankara, 1984.
4. TS EN 206:2013+A1, Concrete - Specification, Performance, Production and Conformity Standard", January 2017.
5. TS EN 12390-2, Concrete – Testing Hardened Concrete", Part 5: Compressive strength of test specimens, Turkish Standards Institute, Ankara, 2003.
6. Uyan M., Pekmezci B.Y. Effect of Revibration on Concrete Properties, Prefabrikasyon Magazine, 2001. 60 (October): p. 5-8.
7. Vollick C. A., Effect of Revibrating Concrete, ACI Journal, Proceedings, 1958. 54(9): pp.731-732.
8. Khalaf M. N., Yousif M. H. A., Effect of Revibration on the Stability and Compactibility of Concrete, Cement and Concrete Research, 1985. 15: pp. 842-848.
9. Çakıroğlu M.A., Terzi S., Kasap S., Çakıroğlu M.G., Estimating the Concrete Pressure Strength with Fuzzy Logic Method, Yapı Teknolojileri Elektronik Magazine, 2010. 6 (2): 1-8.
10. Terzi, S., Modeling the Effect of Bitumen Amount on Asphalt Concrete Strength with Fuzzy Logic Method, 4th International Advanced Technologies Symposium, 2005: Konya. 28-30 September.
11. Kuşan H., Aytekin O., Özdemir İ. Risks Assessment in Construction Projects with Fuzzy Logic Model, Engineering Sciences, 1A0359, 2016. 11(1): 1-14.
12. Şen Z. Modeling Principles in Engineering with Fuzzy Logic, Su Foundation Publications, Istanbul, 2004. pp:191.
13. Şen Z. Fuzzy algorithm for estimation of solar irradiation from sunshine duration. Solar Energy, 1998. 63(1): pp:39-49.
14. Pakdamar F., Güler K., (2011) "Flexible performance of reinforced concrete beams" ITU Journal Series D: Engineering, 2011. 10(5): pp. 59-70.
15. Özdemir İ., Aytekin O., Kuşan H. Calculating Betterment Fee with Fuzzy Logic Approach, 4th Construction Management Congress, Istanbul, 2007. pp.181-190.
16. Yılmaz K., Canpolat F. Importance of Active Vibration on Concrete Quality, Eng. & Arch. Fac. Osmangazi University Magazine, 2002. 15(2): pp. 1-10.
17. Akan R,, Keskin S.,N. Investigation of the Contribution of Jet Grouting to Soil Improvement and the Effects of the Parameters Used in This Method, Suleyman Demirel University Journal of Natural and Applied Science, 2014. 18(2): pp. 22-26.
18. ACI 309R-96, Guide for Consolidation of Concrete, ACI Manual of Concrete Practice, Detroit, 1996.
19. ACI 309.1 R-98, Behavior of Fresh Concrete During Vibration", ACI Manual of Concrete Practice, Detroit, 1998.
20. Subaşi S.,Beycioğlu A., Çullu M., Prediction Of Compressive Strength On Revibrated Concrete Using Fuzzy Logic And Statistical Based Methods" SDU International Journal of Technologic Sciences, 2010. 2(3): pp. 46-52