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Application of Taguchi method for mechanical properties of concrete containing fibers

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Abstract

Compressive strength is one of the most important characteristics of concrete for the classification of concrete in international regulations . The present study investigates the effect of fibers with different percentages on concrete cubic samples . Studies in this field indicate improvement of concrete properties and higher strength by adding fibers . . In this regard, 12 mixing designs with different amounts of these additives with three types of cement strength classes (525,425,325) and 36 cubic samples (10 * 10 * 10) were designed and tested to measure compressive strength, of which only 6 design have used the mixing plan in the research. The purpose of this study is to present a new method for concrete mix design using optimization principles . In this study, self-compacting concrete mix design was optimized using the Taguchi method for compressive strength . To this aim, the optimization model for the concrete mix design is defined as the effect of the experimental results. Optimization of mixing ratios Due to the fact that concrete contains several main components and often has several constraints, it is difficult and time consuming . Statistical empirical design and analytical methods to optimize the design of mixing products such as concrete whose ultimate strength properties depend on the relative amount of their components can be a very suitable method . Therefore, in this paper, with the help of Taguchi statistical methods, the optimal mixing plan for this type of concrete was determined and this method, by reducing the number of experiments, predicts the optimal composition of the materials. The results obtained from MINITAB software show that the fiber at 18 grams in cement class of 42.5 MPa has more compressive strength.

Key words: compressive strength , fibers , taguchi method , types of compressive strength class of cement

1. Introduction

In order to produce a concrete with a specific compressive strength, various factors such as the rate of application of the compound and its related additives, as well as the amount and time of rotation of the mixing machine at each stage, should be carefully considered [1] . Changes in each of these factors change the condition of the concrete. One of the factors is the amount of additive in concrete that we are referring to fibers here. Mansour et al. Made compression tests for concrete with high strength fibers in the range of 70 to 120 MPa and showed improvement in strength and pressure by adding fibers in high strength concrete[2] . Fibers and polymers are widely used in concrete to improve the performance and long-term performance of concrete [3-5] . Due to the importance of the fiber on the properties and compressive strength of the concrete, we used Taguchi statistical methods to give the optimal amount of each of the amounts of this additive. In late 1940, Dr. Taguchi introduced new statistical concepts, and it was later proved that these concepts is a valuable tool in controlling and improving quality [6]. Since then, many Japanese industrialists have used this method to improve product and process quality. Taguchi's method is quite different from conventional engineering methods [7] . Taguchi's methodology emphasizes the design of quality when designing products and processes, while the common methods are based on inspection and quality control during the production process or after the production of the product [8]. In the laboratory program, the kinematic method of Taguchi experiments was used to design samples and determine the optimal amount of materials. One of the main advantages of this method, in addition to lowering costs and increasing speed, is that optimal conditions are chosen so that the effects of uncontrollable factors cause minimal changes in system performance and the quality of output products Gets [9] . Taguchi experiments are among the statistical methods that, while maintaining the accuracy and accuracy of the results, can significantly reduce the number of experiments, and this method is able to optimize the process, production, or the desired conditions, Depending on the variables examined, even if they are not available in the experiments. And we found that the fibers in the amount of 18 grams in the cement category 425 had the highest compressive strength.

2. Experimental

In the manufacture of samples, fine aggregate and coarse aggregate were used in accordance with the grain size curve in accordance with the ASTM Code for the use of aggregates in concrete. It should be noted that the percentage of fine-grained food was 50% compared to the fine-grained aggregates. Nano silica, used as a nourishing liquid, is a super-plasticizer based on nanotechnology with a very impressive effect and low consumption. Polymer fibers (polypropylene) are used as secondary reinforcement of concrete or mortar. Polycarboxylate (PCE) based super-lubricant was also used and 0.2 to 1.2% cement weight was added to the material (depending on the slump). In this research, three types of strength class type 1-32.5 MPa (from Sabzevar cement factory) and 1-42.5 MPa (from Shahroud cement factory) and 1-52.5 MPa (from Zavv Torbat Heydarieh factory) were used. In this research, laboratory specimens were constructed in cylinders of 10 × 15 cm and a cube for 10 × 10 cm to determine the compressive strength in 12 mixing designs and 3 categories of strength cements. In total, the number of samples reached 36 cylinders and 36 cubes. The mixing plan for the composite concrete sample is weighted in Table 1.

Table 1: Concrete Mixing Design

Plan number	Superplasticizer (gr)	Fibers (gr)	nanosilica(gr)	Microsilica (gr)	Cement (gr)	Water (gr)	Aggregate (gr)
1	18	0	0	0	1330	665	3600
2	18	6	0	0	1330	665	3600
3	18	12	0	0	1330	665	3600
4	18	18	0	0	1330	665	3600
5	18	24	0	0	1330	665	3600
6	18	30	0	0	1330	665	3600
7	19	0	0	133	1197	532	3600
8	19	0	38	95	1197	532	3600
9	19	0	95	38	1197	532	3600
10	19	0	66.5	66.5	1197	532	3600
11	19	0	19	114	1197	532	3600
12	19	0	133	0	1197	532	3600

3. Taguchi statistical method

The Taguchi experimental design method was introduced in 1960 by Professor Taguchi. This method can determine the optimal conditions with a minimum number of tests and reduce the time and cost of performing the required tests [10]. The loss function is determined to calculate the deviation between the laboratory value and the required value, and the loss function is converted to signal-to-noise or S / N ratio. Typically, depending on the type, there are three types of S / N ratios: the lower - the better, (LB) the higher - the better (HB) the nominal - the better (NB). Fiber and cement strength were introduced as control factors for optimizing compressive strength. The signal-to-noise ratio in a simple definition is the ratio of the average (signal) to the standard deviation (noise), which is the inverse of the coefficient of response of the process response, and the rate of variation of the response, which is the result of repetition of the tests [11]. Given that the ratio is proportional to the inverse of the coefficient of variation, this increase leads to a decrease in the variation. Considering that the goal is to obtain the highest compressive strength, the higher-the better (HB) criterion was chosen in this study.

4. Discussion and conclusion

Graph [1] shows the relationship between the response and the variables. The contour graph is useful to find the optimal output value.

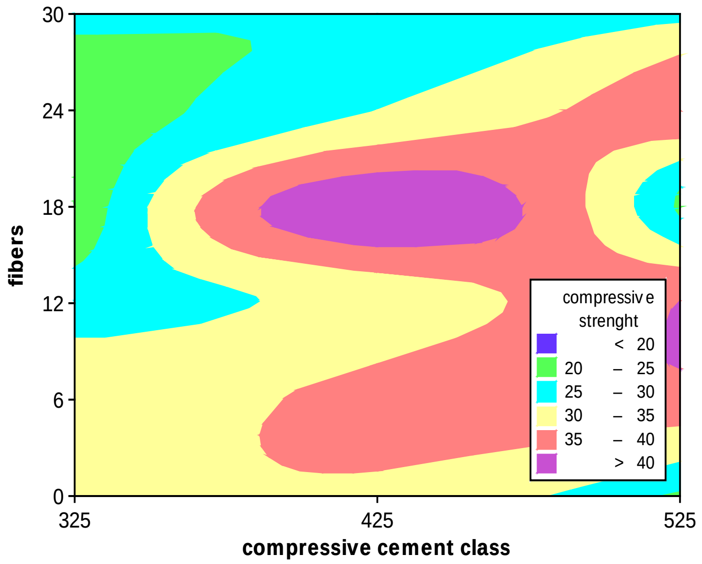

Figure 1 .contour plot of compressive strength vs fibers, compressive cement class

The contour graph shows the strengths and weaknesses of each model and helps to select the optimized combination design for the desired purpose [12, 13]. In this graph, we can see the simultaneous effect of fiber and cement strength. From Figure1, we conclude that when using Portland cement 425, the compressive strength is optimized when the fiber is 18 g.

The interaction charts are used to interpret the meaningful interaction between process parameters [14] . According to the graph, when we do not use the fiber, the compressive strength in the cement category 425 reaches its maximum value. The 30-gram fiber line is almost horizontal because the impact of the cement strength on the compressive strength is negligible, but in the amount of fiber 30 g and the 525 cement category, we have the highest compressive strength. The fiber is 12 grams the most effective factor in compressive strength because its slope is higher than other surfaces. In char [2] t, we find that in18 grams fibers and cement grade 425 have the highest compressive strength .

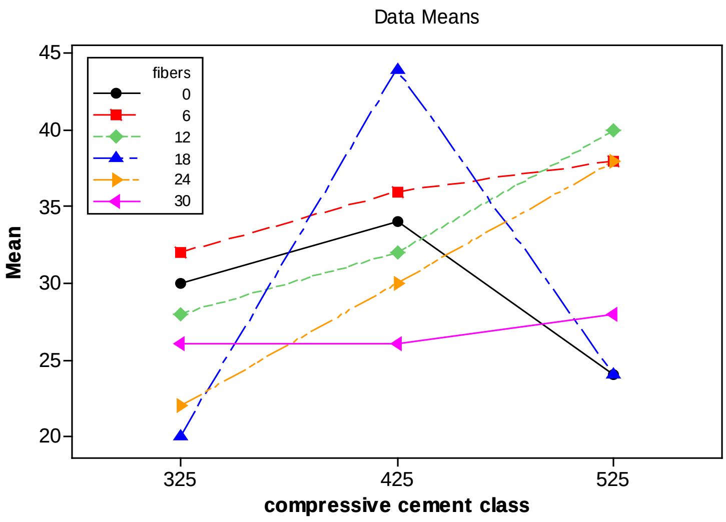

Figure 2. Interaction plot for compressive strength

5. Conclusion

In this research, the relationship between fiber and cement strength class with concrete compressive strength has been investigated. One of the important activities in this study was the use of the systematic design of the experiments (DOE), which uses the Taguchi method here . By choosing two factors (strength to cement fiber) as effective factors and assigning six different levels to each of them, the optimal combination of these factors as well as the effect of variables and even the severity of these effects were obtained. The results show that at the optimum fiber points, we have the highest compressive strength, and in the mixing plan of self-compacting coniferous fibers, increasing the amount of fiber increases the compressive strength, increasing the compressive strength caused by the increase of the fiber can be due to the proper placement of the fibers And their uniform distribution in the cement matrix, or in other words, the optimal amount of fiber in the concrete.

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