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Investigating the effect of the amount of aggregates on the properties of self-compacting concrete

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ABSTRACT: Although about four decades have passed since the development of self-compacting concrete (SCC), its replacement with ordinary concrete, there are still problems in quality control and construction in large dimensions. These problems are partly due to the lack of complete understanding of the properties of SCC and partly due to the extreme sensitivity of the performance of this type of concrete to changes in the design parameters, climate, physical and chemical characteristics of the components of the mix design, the need for expert workers, the lack of design suitable and safe mixtures are contractors' reluctance and maintainability. In this research, To investigate the effect of the number of stone materials To achieve the optimal mixture design, the first step is to prove that concrete can be made with local materials of Behbahan, located in Khuzestan province, in the laboratory and then in a site. This stage was done by making 28 mixes in a trial and error manner on all concrete components to keep them stable, concrete tests in fresh and hardened conditions were carried out according to the standards of "Federation of European National Unions of Concrete Representatives" and "Japan". Finally, after reaching a reference mix design, new mixes were made by changing the amount of fine aggregates from 30% to 70% with a rate of 5% increase. Based on the results and statistical analysis, the optimal mix design is determined and introduced as a design with 65% fine aggregates compared to the total aggregates.

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1- Introduction

Self-compacting concrete (SCC), as one of the new generation concretes, is widely used due to its many advantages (no need for compaction and flow under its own weight, without spending energy and passing through the gaps between rebars). It is expanding in the world. One of the most important properties of SCC, which affects all its other properties, is determining the ratio of its construction components, which is known as the mixture design. The main difference between SCC design and normal concrete is the use of high amounts of powdery materials and strong superplasticizer in SCC. While in normal concrete in many cases, there is no need to use these materials. Also, in SCC, due to the high flow rate, the possibility of coarse aggregates being separated from the mortar is high, so its appropriate viscosity should be provided to reduce the risk of separation. Providing appropriate viscosity in SCC is achieved by using viscosity-modifying chemicals or powder fillers. So far, researchers have not reached a consensus method for SCC mix design [1].

This concrete can be produced and used in precast form or for pouring concrete on site. Among the advantages of SCC, which is a durable structural concrete, is the minimization of necessary labor and the absence of noise caused by concrete compaction [2-3]. The ACI 237 [5] committee, while presenting the procedures for determining the components of SCC, has also given recommendations for controlling the obtained values, although this method has weaknesses such as not being systematic and that the grading of aggregates and its recommendations It is not specifically considered. In 1998, Okamura et al. investigated the rational method of mixing design for SCC mortar and came to the conclusion that the large volume of coarse aggregates can reduce the resistance to separation and block concrete [11].

Considering the sensitivity of SCC in environmental and workshop conditions and the need for quality stone materials, in this article it was tried to first design laboratory mixes and then design suitable mixes for implementation, in a simple workshop format with percentage changes. Aggregates should be provided for local materials. For this purpose, tests related to the properties of concrete in fresh and hardened states using the guide mix design from ICAR Institute and by trial and error method on all its components to reach the basic mix design in the framework of valid SCC regulations were carried out. 9 final mix designs were made in which only the percentage of aggregates was changed and the rest

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Table 1. Details of the ICAR mixing design

amount (kg/m^3)	Concrete components
400	Cement
893	Sand
731	Gravel
200	Water
175	Stone powder
6	Super plasticizer
variable	Viscosity modifier admixture

Fig. 1. Slump flow test, sample made based on ICAR mixture design

Table 2. The details of the research mixing design based on the change in the percentage of aggregates (water and SP are in lit and the rest of the components are in kg)

F/T	0.70	0.65	0.60	0.55	0.50	0.45	0.40	0.35	0.30
Cement	400	400	400	400	400	400	400	400	400
Water	156	156	156	156	156	156	156	156	156
Stone powder	175	175	175	175	175	175	175	175	175
Sand	470	549	627	706	784	862	941	1019	1098
Pea gravel	769	713	659	603	549	494	439	384	329
Almond gravel	329	306	282	259	235	212	188	165	141
super plasticizer (SP)	6	6	6	6	6	6	6	6	6
Viscosity modifier Admixture (VMA)	0.166	0.166	0.166	0.166	0.166	0.166	0.166	0.166	0.166

of the parameters were constant.

2- Research methodology

Materials used in the research include cement, limestone powder, aggregates, water, and polycarboxylate-based superplasticizer with the brand name PC5000 (HR) in accordance with the European standard EN-934-2. The details of the ICAR mixing design on which the research was initiated are given in Table 1.

According to the mix design that was taken from ICAR, an attempt was made to make SCC using the existing materials whose rheological properties are within the framework of valid regulations; according to Figure 1, the desired result was not achieved, so by examining and testing all construction components, a basic SCC mix design was made. After conducting various tests, finally, the best reference SCC was made by trial and error and was used in the next steps.

From this mixture design, the ratio of its components is given in Table 2; it was made 9 times under the same conditions, and only the ratio of fine aggregates to total aggregates used (F/T) was changed in them. The results of different tests in fresh and hardened concretes were measured in order to evaluate different percentages of aggregates and determine their optimal amount.

Fresh concrete tests including slump flow, T50, V hopper, checking the passability of L box and J ring tests, and hardened concrete tests including compressive strength and splite tensile strength were carried out in the research.

3- Results and discussion

According to the statistical information, the correlation between different tests on SCC is presented in Table 3.

For example, if the correlation between slump flow and J ring is 0.845, it can be said that the correlation between these two indicators is significant and inverse; That is, as the amount of slump flow increases, the value of J ring decreases, which according to the value of determination coefficient $R^2 = 0.714$, so 70% of the changes of J ring number can be estimated from the slump flow.

Based on the results of all the experiments, the mixed design with F/T = 0.65 has provided the best results. Prioritization of the design of research mixtures based on TOPSIS method is given in Table 4.

4- Conclusions

The key results of the research are as follows:

- The type and size of coarse and fine aggregates cause a change in the percentages of concrete materials used, especially super-plsticizer and viscosity-modifying admixtures.

- According to the standard deviation and average charts, in terms of rheological properties, compressive strength and tensile strength, the optimal mixture design based on the results and statistical analysis is F/T=65%.

- Due to the workshop design of the research mixtures, it is better to consider the maximum size of coarse aggregates as 12.5 mm.

Table 3. Correlation between different tests with change of percentage of aggregates

WSPG	SPT	CS at different ages			J ring	L box	V Funnel	T50	Slump flow	Type of test
		90-day	28-day	7-day						
0.117	-0.155	0.225	-0.019	-0.062	-0.845+	0.801+	-0.813+	-0.915+	1	Slump flow
-0.184	0.164	-0.275	-0.024	0.055	0.881+	-0.842+	0.887+	1	-0.915+	T50
0.033	0.139	-0.036	0.152	0.237	0.901+	-0.879+	1	0.887+	-0.813+	V Funnel
0.054	-0.063	0.33	0.075	0.057	-0.964+	1	-0.879+	-0.842+	0.801+	L box
-0.11	0.027	-0.269	-0.032	0.027	1	-0.964+	0.901+	0.881+	-0.845+	J ring
0.003	0.194	0.725+	0.699+	1	0.027	0.057	0.237	0.055	0.062	CS at 7-day
0.135	0.405*	0.832+	1	0.699+	-0.032	0.075	0.152	-0.024	-0.019	CS at 28-day
0.208	0.384*	1	0.832+	0.725+	-0.269	0.33	-0.036	-0.275	0.225	CS at 90-day
-0.079	1	0.384*	0.405*	0.194	0.027	-0.063	0.139	0.164	-0.155	SPT
1	-0.079	0.208	0.135	0.003	-0.11	0.054	0.033	-0.184	0.117	WSPG

CS= compressive strength; SPT= splite tensile strength; WSPG= wet specific gravity

*: Significant difference at the 5% error level; +: Significant difference at the 10% error level

Table 4. Prioritization of the design of research mixtures based on TOPSIS method

rank	slenderness ratio	F/T (%)
2	0.76	70
1	0.79	65
4	-0.68	60
5	0.63	55
3	0.69	50
6	0.55	45
7	0.41	40
8	0.28	35
9	0.07	30

- The use of both 3/4 and 3/8 inch sizes of gravel in the mix plan is mandatory so that it can create a lock and provide a proper connection; In addition, a certain percentage of each type of gravel should be used in the mixture design. The ratio of 70% fine gravel and 30% coarse gravel is the optimal option.

- One of the other characteristics of this type of concrete is the visual inspection that when the concrete is resting in the mixing pot, some of it should be turned over with a trowel in orders to check the quality of the concrete. If the results below and above the concrete in the pot are the same, the quality of the concrete is good, and if the above concrete is smooth and below it is similar to the hardened state, the concrete has settled and the mix design should be modified.

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