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Effect of reducing the amount of coarse aggregate on some properties of self-compacting concrete

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Abstract: In recent years, self compacting concrete (SCC) has become widely used especially in crowded reinforced concrete structures with difficult casting conditions. For such applications, fresh concrete must possess high fluidity and good cohesion. One of the most important projects in which this type of concrete was used is the foundation system for Khalifa tower in Dubai, which is the most important high-rise building in the world. The content of coarse aggregate has a significant impact on the properties of the required concrete. Some studies have suggested that the total volume of coarse aggregate be within 50% of the solid concrete volume.

In this research, six mixtures were studied with different combinations of water-cement ratio and coarse aggregate quantity. Slump test (flow test) , (J-RING test) and concrete strength determination test were performed to determine the effect of reducing the amount of coarse aggregate in the mixture on some fresh and hardened properties of self compacting concrete (SCC).

The results showed that reducing the amount of coarse aggregate used in concrete requires increasing the amount of water required for mixing to achieve the required flow of self-tamping concrete, which leads to a decrease in the strength of concrete, and that the best ratio of coarse aggregate to the total aggregate is 65%, as it provides the highest resistance to concrete and achieves flow required, and using a percentage higher than that leads to not achieving the required flow and crossing completely.

Keywords: : (SCC , flow test , J-RING test, ratio of coarse aggregate)

Introduction

High Performance Concrete (HPC) is concrete that is characterized by containing the best quality of materials with distinct proportions and properties to produce high performance concrete, which has become important in engineering and architectural applications, and the components of this type of concrete are chosen carefully according to standard specifications, What is known as chemical additives (superplasticizers) are added to the main components of concrete.

Self-compacting concrete is one of the types of high-performance concrete, and it is the product of technological progress in the field of concrete additives, where both the addition of viscosity improvement and the additives to reduce mixing water (superplasticizer) are the two basic elements required for its production, and Self-compacting concrete is used as the primary building material for all applications in many global markets, It is the concrete that has a high degree of fluidity and flow and has a high resistance to granular separation and can be cast successfully in narrow and crowded sectors with reinforcing steel without the use of any external compaction method.

Okamura [6] indicated that SCC can flow at any angle and pass through the spaces between the reinforcing steel without vibration. The most important characteristic of SCC over conventional concrete is : fast flow, high resistance to separation and does not require vibration. Okamura and Ozawa [7] also indicated in SCC that the total coarse content is not limited but pozzolans and superplasticizers can also be used to prevent segregation and increase flow. Yurugi et al. [9] reported that the aggregate coarse content has a significant effect on the packing capacity of concrete and Okamura [6] suggested that the total volume of coarse aggregate be within 50% of the solid volume of concrete.

Materials used and experimental mixtures :

The purpose of the experimental mixtures is to determine the appropriate quantities of materials included in the mixtures so that the required results are given, which is obtaining self-compacting concrete in which the technical conditions are met, the most important of which is that the slump diameter (flow) is not less than 650 mm and not more than 800 mm without the occurrence of granular separation. These mixtures were according to the following principles:

1. The total content of cement binders = 450 kg / m3, which is made up of ordinary Portland cement (Zliten Factory).
2. The amount of coarse aggregate is variable, starting with a large amount and then gradually being reduced.
3. The largest nominal size of coarse aggregate is 14 mm.
4. The dosage of the super-plasticizer is 0.8 liters per 100 kg of cement.
5. The ratio of water to cement is variable according to the needs of each mixture.
6. The superplasticizer is injected into the concrete during mixing after adding 70% of the water.

Our aim is to test the mixtures and whether they meet the technical conditions and properties of the self-compacting concrete or not. Fast and sequential to avoid possible errors and obtain the most accurate possible results of this study.

The first experimental mixture was carried out using superplasticizer RHEOBUILD 561E and its quantity, where 0.8 liters / 100 kg of cement was used, and the ratio of coarse aggregate to total aggregate was 45%, and the ratio of water to cement was 48%. One that is similar to normal concrete, but without the occurrence of granular separation or exudation, and through this result it became clear to us that the reason for this could be one of the following possibilities:

The ratio of water to cement is low and must be increased to obtain the required flowability of concrete, especially since there is no granular separation or exudation.

The amount of super-plasticizer used is high and should be reduced.

Accordingly, we first reduced the amount of superplasticizer used in several attempts, but the result did not change much, so we had the only option is to increase the ratio of water to cement, although it will affect the resistance of concrete. The flow of self-compacting concrete is as shown in Figure (1). In the same way, the ratio of water to cement was determined for other mixtures, with an increase in the ratio of coarse aggregate to total aggregate.

Figure (1) shape of the flow of concrete with a coarse aggregate percentage of 55%.

Thus, the final mixtures which will be used in this study, have been determined. The following table No. (1) shows the ratios of water to cement required for all mixtures that will be used in this study.

Table 1: Water cement ratio and ratio of coarse aggregate required for all mixtures

Mix. No.	1	2	3	4	5	6
Ratio Of Coarse Aggregate	70%	65%	60%	55%	50%	45%
w/cm	50.17%	50.47%	50.67%	50.84%	53.03%	54.88%

After the experimental mixtures program was completed, through which the necessary quantity of all materials included in the mixtures was determined, the final laboratory mixtures program was started, which will be the focus of research in this study.

1) Mixture No. (1), in which the ratio of coarse aggregate to total aggregate is 70%, and the ratio of water to cement is (50.17). Simple granular separation due to the accumulation of coarse aggregate and its complete immersion in the cement mortar.
2) Mixture No. (2), in which the ratio of coarse aggregate to total aggregate is 65%, and the percentage of water to cement is (50.47). It is a medium operational mixture compared to the rest of the mixtures, and it is better than the first mixture. Coarse aggregate and its complete immersion in the cement mortar.
3) Mixture No. (3), in which the ratio of coarse aggregate to total aggregate is 60%, and the ratio of water to cement is (50.67).
4) Mixture No. (4), in which the ratio of coarse aggregate to total aggregate is 55%, and the ratio of water to cement is (50.84), and it is a mixture of good to very good performance compared to the rest of the mixtures, and the flow diameter condition is met without the occurrence of clear granular separation
5) .Mixture No. (5), in which the ratio of coarse aggregate to total aggregate is 50%, and the ratio of water to cement is (53.03), and it is a very good operational mixture compared to the rest of the mixtures.
6) Mixture No. (6), in which the ratio of coarse aggregate to total aggregate is 45%, and the ratio of water to cement is (54.88).

The components of the mixtures mentioned above can be summarized in the following table :

Table 2. Mix proportions of concrete

Mix. No.	Ratio OF Coarse Aggregate %	w/cm %	Water (Kg/m3)	Cement (Kg/m3)	Aggregate (Kg/m3)		superplasticizer Litter/100 Kg Cement
					Fine	Coarse	
1	70	50.17	225.8	450	509.76	1190.24	0.8
2	65	50.47	227.1	450	593.22	1101.47	0.8
3	60	50.67	228	450	676.19	1014.28	0.8
4	55	50.84	228.8	450	758.92	927.75	0.8
5	50	53.03	238.6	450	829.05	829.05	0.8
6	45	54.88	246.9	450	897.82	734.72	0.8

Tests of concrete mixtures in their solid state:

The compressive strength test was carried out according to the specifications [4] for different concrete mixtures.

Results :

Several tests were carried out for the final mixtures in the plastic state (fresh) immediately after the mixing process was completed, which is the slump test to measure the flow diameter) Ds) and the (J-RING) test to measure the ability of concrete crossing through narrow spaces by the flow diameter) Dj). In both tests, the rates of granular separation and exudation of concrete were observed and evaluated.The following table No. (3) shows the results of the tests in the soft case as follows:

Table 3 : Test results of fresh concrete

Test results	Mix. No. and Ratio Of Coarse Aggregate)					
	1 %70	2 %65	3 %60	4 %55	55 %50	6 %45
Diameter of flow (Ds) mm	660	695	690	690	700	700
Diameter of flow (Dj) mm	630	685	680	680	690	690
(Dj-Ds) mm	30	10	10	10	10	10
Limits	10 mm					
1-(Dj/Ds) %	4.55	1.44	1.45	1.45	1.43	1.43

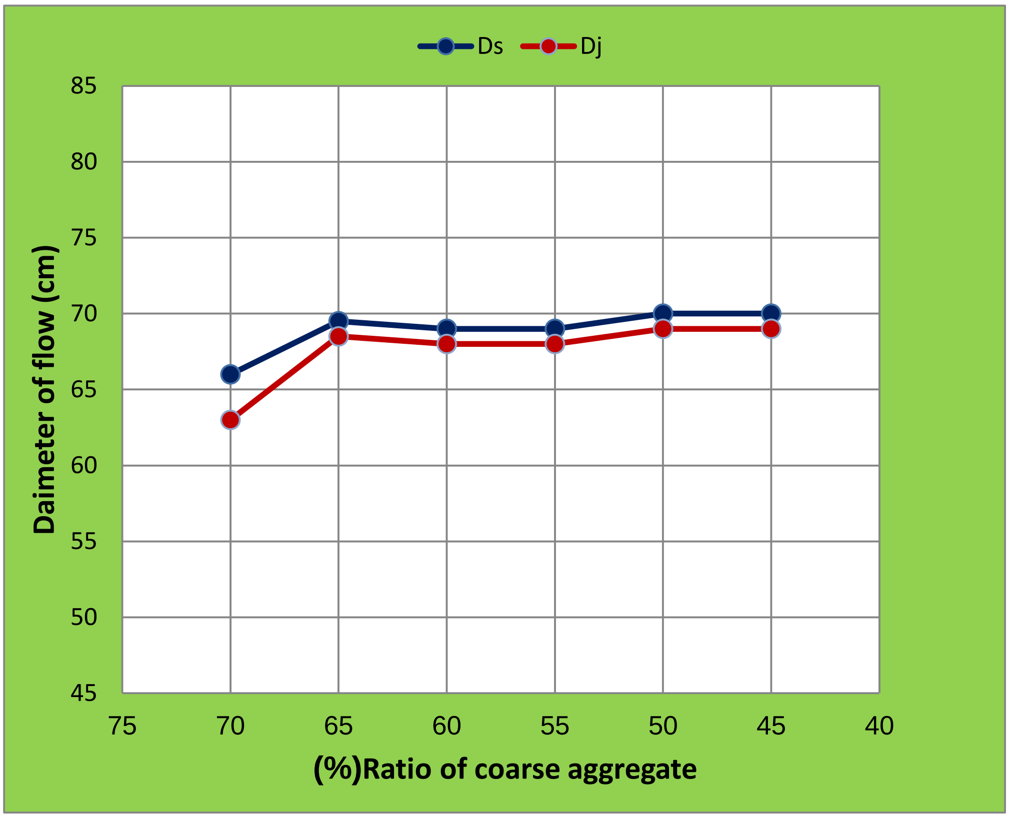

Fig 2 : The Relation between Ratio Of Coarse Aggregate and Diameter of flow

Table 4 : Test results of concrete Compressive strength

Mix. No. and Ratio Of Coarse Aggregate	Compressive strength		
	3 days	7 days	28 days
(70%) 1	16	28.44	40.95
(65%) 2	15.56	29.33	41.84
(60%) 3	15.56	25.78	35.44
(55%) 4	13.78	25.78	33.47
(50%) 5	12.44	24.44	31.43
(45%) 6	11.56	20	29.21

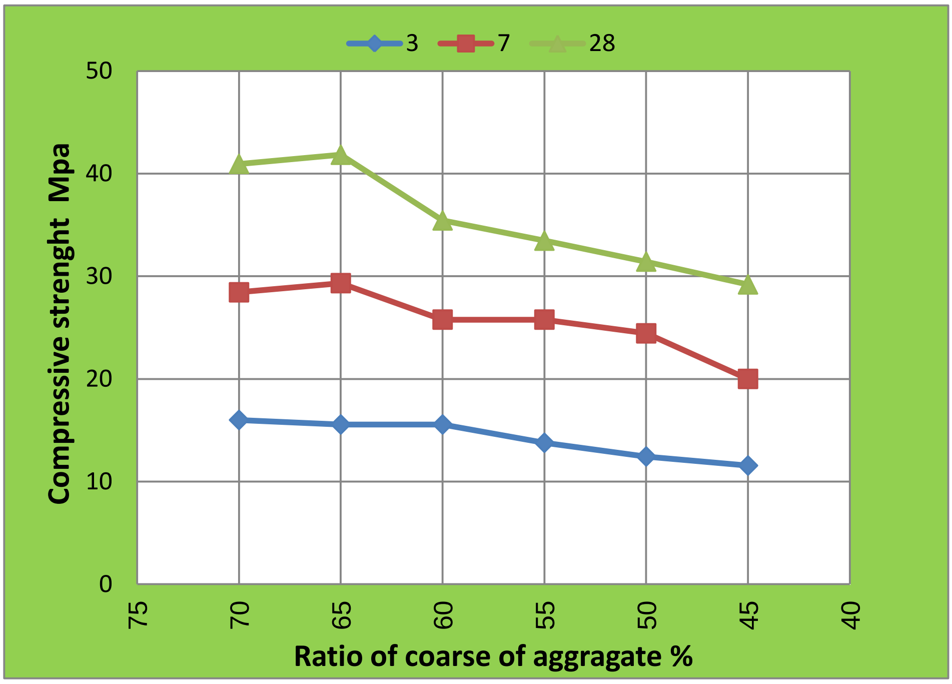

Fig 3 : The Relation between Ratio Of Coarse Aggregate and Compressive strength

The table No. (4) shows the results of the tests in the hard condition, which is the strength of concrete after 3 days, 7 days, and 28 days for each mixture.

For further clarification of these results, it was presented in a graph in Figure (2), which summarizes the relationship between the proportion of coarse aggregate in the concrete mixture and the diameter of its flow in the absence of obstacles and in the case of the presence of obstacles.

From figure (2), we notice the following:

1) The lower the percentage of coarse aggregate in the mixture, the greater the flow diameter Ds, and there is no noticeable change, and therefore the relationship is positive in all cases, and this also applies to the flow diameter Dj.
2) The flow diameter Ds in all cases is higher than 650 mm, and therefore all mixtures fulfill the condition of the flow diameter in the absence of obstacles.
3) The difference between the diameter of flow, Ds and Dj, decreases as the percentage of coarse aggregate decreases in all cases, and this expresses that the crossing property improves as the percentage of coarse aggregate decreases.
4) The difference between the diameter of flow, Ds and Dj, fulfills the condition stipulated in the specifications in all mixtures, except for the mixture that contains 70% coarse aggregate, as it is the only one in which the crossing property is not achieved, and therefore this mixture does not meet all the technical conditions of self-compacting concrete.

For further clarification of the results presented in Table (4), they are presented in a graph in Figure (3), which summarizes the relationship between the proportion of coarse aggregate in the concrete mix and the strength of the concrete.

Through Figure No. (3) we note that the lower the percentage of coarse aggregate in the mixture, the lower the concrete strength, due to the mixtures needing a larger amount of water to achieve the flow diameter condition, which in turn led to a significant decrease in its resistance.

Conclusion and recommendations

The aim of this research was to study the effect of reducing the amount of coarse aggregate used in concrete on the properties of self-compacting concrete.

Conclusion

After completing the implementation of the practical program in this study and discussing the obtained results, this can be summarized as follows:

1) The decrease in the amount of coarse aggregate used in concrete requires an increase in the amount of water required for mixing, that is, an increase in the proportion of water to the cement used to achieve the required flow of self-compacting concrete.
2) When using the super-plasticizer (R561) and using the ratio of coarse aggregate to total aggregate in concrete more than 65%, the extruded concrete did not fully fulfill the conditions of flow and passage, although it did not notice the presence of granular separation or exudation of the concrete when testing the diameter of its flow without the presence of obstacles.
3) The strength of concrete is inversely proportional to the decrease in the proportion of coarse aggregate in concrete.
4) When using the super-plasticizer (R561), the best ratio of coarse aggregate to total aggregate is 65%, as it provides the highest resistance to concrete and has the properties of self-compacting concrete
5) The use of superplasticizer (R561) provides high workability of concrete, but at the same time produces concrete with less strength compared to some other plasticizers

.**Recommendations:**

Based on the results obtained in this study, we recommend the following :

1) In the event that what is required is the production of self-compacting concrete with high performance and the sufficiency of concrete resistance is not high, the best is to use the plasticizer (R561).
2) It should be noted that decreasing the ratio of coarse aggregate to total aggregate in the mixture gives the concrete a better performance, but weakens its resistance.
3) When a coarse aggregate percentage greater than 65% is used, care must be taken because this may cause granular separation of the concrete in the event that there are obstacles such as reinforcing steel or narrow places through which the concrete passes.
4) Focusing on coarse aggregate ratios greater than 65% in other studies to try to improve their properties by replacing part of the used coarse aggregate with another material such as greenilia, for example, or improving the quality of the used sand by mixing it with another material that reduces or increases the coefficient of fineness of the sand, or by using other super plasticizer. It contributes to increasing the workability of concrete or replacing part of the cement with another soft material, and this is all in order to benefit from the high resistance feature that results from the use of these proportions of aggregate

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