Influence of Fine Aggregate Grading on Some Properties of Self – Compacting Concrete

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Abstract

Self compacting concrete (SCC) can be classified as high – performance concrete .It does not require to be vibrated to achieve full compaction. This offers many benefits and advantages over conventional concrete. The main object of this work was to investigate the properties of SCC produced by locally available materials and to evaluate the effect of grading of fine aggregate (Coarse Grading CG , Medium Grading MG and Fine Grading FG) with fineness modulus ranging from (1.9 to 2.7) on some properties of SCC .To achieve this aim, three different mixes of SCC were designed and tested . The used cement content was (350 kg/m^3***) , the powder content material (cement + limestone dust) maintained constant (500 kg/m***^{3}***) and the water/powder content ratio was (0.34). To determine the workability , different test methods were adopted as slump flow , J-ring and L –box tests . It is found the workability of all studied mixes is good, with slump flow diameter greater than or equal to (600 mm), flow times range between (3 and 7.5)sec. while the step of blocking ranges between (0 and 1)mm. The mechanical properties of hardened SCC mixes are also assessed. (compressive strength, splitting tensile strength , modulus of rupture , static modulus of elasticity, and density) . The results of this study show the possibility of using different grading of fine aggregate with fineness modulus ranging from (1.9 to 2.7) to produce SCC . The grading pf fine aggregate has a significant effect on fresh properties of SCC while it has insignificant effect on mechanical properties of SCC.***

Keywords : SCC, Fine Aggregate Grading , limestone dust , J-ring , slump flow test, compressive strength , static modulus of elasticity , splitting tensile strength, modulus of rupture and density tests

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الخلاصـــــــة

يمكن تصنيف خرسانة الرص الذاتي على انها خرسنة عالية الاداء . ان هذا النوع من الخرسانة لا يحتاج الى الرج للوصول الى حالة الرص التام ، مما يوفر عد فوائد و مزايا تتفوق على الخرسانة الاعتيادية الهدف الرئيسي من هذا البحث هو لدراسة خواص الخرسانة الذاتية الرص المنتجة من مواد متوفرة محليا " و تقييم تاثير تدرج الركام الناعم (تدرج خشن ، تدرج متوسط ، تدرج ناعم) مع معامل نعومة تتراوح بين (1.9 – 2.7) على خصائص الخرسانة الذاتية الرص . و لتحقيق هذا الهدف ، تم تصميم و فحص ثلاثة خلطات مختلفة من الخرسانة الذاتية الرص ، نسب محتوى السمنت التي استعملت هي (350 كغم|م^3) ، محتوى مادة المسحوق (سمنت + الغبرة) كانت (500 كغم|م^3) و نسبة محتوى المسحوق الى الماء كان (0.34) . الفحوصات المختبرية التي استخدمت لايجاد قابلية التشغيل هي فحص جريان الهطول باستخدام االقمع و الشكل (J) و فحص الصندوق على شكل (L) . قابلية تشغيل الخلطات الخرسانية كانت جيدة حيث كانت انتشار الخرسانة كانت اكثراو يساوي 650 ملم ، زمن الجريان يتراوح بين (2.8 و7.5 ثانية) بينما درجة حجز الخرسانة بين(0 الى 15 ملم) . ان الخصائص الميكانيكية التي تم درساتها في هذا البحث هي (مقاومة الانضغاط ، مقاومة الانشطار ، مقاومة الشد بالكسر ، معامل المرونة و الكثافة) . النتائج اضهرت امكانية استعمال تدرج مختلف من الركام الناعم مع معامل نعومة تتراوح بين (1.9 – 2.7) في انتاج خرسانة ذاتية الرص و تاثير التغير في تدرج الركام الناعم ليس واضحا" على الخرسانة المتصلبة ، بينما كانت اكثر وضوحا" على الخرسانة الطرية .

1 - Introduction

Self Compacting Concrete (SCC) , a recent innovation in concrete technology , has numerous advantages over conventional concrete. SCC , as the name indicates, is a type of concrete that dose not require external or internal compaction, because it becomes leveled and compacted under its self-weight. [(1)]

The fine aggregate in SCC plays a major role in the workability and stability of the mix, the total fine in the mix is a function of filler and the fine aggregate content , the grading of fine aggregate in the mortar should be such that both workability and stability are simultaneously maintained [(2)]

Su . el at [(3)] , reported that , the grading , particle shape or angularity and fineness modulus of fine aggregate are significant factors in the production of SCC , the fine aggregate should be uniformly graded. If fine aggregate is too coarse, it will produce bleeding , segregation and harshness ,

Hussian , [(4)] concluded that , it is possible to produce SCC with satisfied fresh and hardened properties by using different superplastizizer dosages for the concrete mixes and using fine aggregate having fineness modulus ranging between 1.5 to 4.1 and coarse aggregate with 20mm and 10mm as maximum size . He reported that the flowability of SCC decreases with an increase of fineness modules of fine aggregate and maximum size of coarse aggregate. He also studied the effect of fineness modulus of fine aggregate on the mechanical property of SCC .He found that mix with fineness modulus (3.1) gave higher compressive strength , density, splitting tensile strength and modulus of ruptures than other mixes.

Aulia el at. [(5)] discussed the variations of the modulus of elasticity of SCC concrete with the versus fineness modulus of fine aggregate . They found that the modulus of elasticity increases with the increase in the fineness modulus of fine aggregate up to 3.1 .

In this study, an experimental work and statistical analysis have been carried out to achieve the following:-

1. Producing SCC according to the requirement for fresh and mechanical properties of concrete by using different fine aggregate grading (coarse grading, medium grading and fine grading) with fineness modulus ranging between (1.9 to 2.7) according to current Japanese and European specification [(6) (7)]
2. Evaluating the effect of grading of fine aggregate on fresh properties of produced SCC .
3. Evaluating the effect of grading of fine aggregate on the mechanical properties of SCC in its hardened state .

2 - Experimental Work

Tests were conducted in order to view the differences in behavior of SCC during the fresh state and hardened states. The slump flow , J-ring and L-box ,were performed on concrete in the fresh state while compressive strength, splitting tensile strength, , static modulus of elasticity modulus of rupture and density tests were conducted for hardened SCC.

2 -1 Materials ;-

a- Cement

Ordinary Portland cement, Type I, manufactured by Taasloja cement factory was used through out this investigation. It was stored in air tight plastic containers to avoid exposure to atmospheric conditions like humidity. Table (1) shows the chemical composition and physical properties of cement used thought this investigation respectively.

Test results indicated that the adopted cement conformed to the Iraqi specification No.5/1984.[8] Chemical and physical tests were made by the National Center for Construction Laboratories and Research (NCCLR).

Table 1. Chemical composition and physical properties of cement

Oxides	%	IOS 5:1984 requirements[9]
CaO	61.88	-
SiO_2	20.87	-
Fe_2O_3	3.98	-
Al_2O_3	4.88	-
MgO	2.16	<5
SO_3	1.99	<2.8
Loss on agent L.O.I%	3.3	<4
Insoluble residue I.R%	1.32	<1.5
Lime Saturation Factor, L.S.F	0.86	0.66 – 1.02
Main compounds (Bogue's equation)		
C3S	49.08	-
C2S	22.89	-
C3A	6.21	-
C4AF	12.09	-
Properties	**Cement**	**IOS5:1984 requirements[9]**
Fineness Blaine method (m^2 /kg)	337	≥ 225
Vicat set times(hr:min) Initial Final	 2: 35 4; 40	 ≥45 min ≤10 hours
Compressive Strength (N/mm^2) at 3 days 7 days	31.6 41.2	>15 >23
Soundness: autoclave %	0.16	<0.8

b - Fine Aggregate

Natural sand of (Al – Ukhaider) region with specific gravity and absorption of 2.6 and 0.75 % respectively is used in this work . three types of fine aggregate are used (fine grading , medium grading and coarse grading) Table (2) shows the physical properties of the fine aggregate it is conformed to the Iraqi specification No.45/1984 [9] .

Table 2: properties of fine aggregate*

Physical Properties	Test Results	Limit of the Iraqi specification[9]
Specific gravity	2.6	-
Sulfate content %	0.08%	$\leq$ 0.50 %
Absorption%	0.75%	-
Materials finer than 75µm sieve	1%	< 4%

- Physical tests were made by the National Center Laboratories for Construction and Research (NCCLR

These samples are separated by sieving; their grading satisfy the fine grading in accordance with the BS 882: 1992 [10] (fine grading , medium grading and coarse grading)with fineness modules 1.9, 2.3 and2.7respectively.The cumulative passing% are given in Table (3) .

Table3:Grading of fine aggregate samples compared with the requirements of BS882:1992[10]

Sieve Size(mm)	Cumulative passing %	BS 882:1992 Fine grading	Cumulative passing %	BS 882:1992 Medium grading	Cumulative passing %	BS 882:1992 Coarse grading
10	100	100	100	100	100	100
4.75	100	95 –100	100	90 –100	100	90 –100
2.36	100	95 – 100	100	85 – 100	80.4	75 – 100
1.18	100	90 – 100	89	75 – 100	86.9	55 – 90
0.600	81	80 – 100	66	60 – 79	46.5	35 – 59
0.300	24.5	15 – 50	18	12 – 40	14.9	8 – 30
0.150	1	0 – 15	1	0 – 10	2	0 – 10
fineness modules	1.9		2.3		2.7	

c - Coarse Aggregate

Crushed gravel with maximum size of 14 mm from AL-Niba'ee region was used . The tested characteristics of this gravel are given in Table (4) . It is conformed to the Iraqi specification No.45/1984 [(9)].Table (5) shows the physical properties of the used coarse aggregate.

Table 4: Grading of coarse aggregate

sieve size (mm)	%Passing by weight	Limitations of the Iraqi SpecificationNo.45/1984[(9)]
20.0	100	100
14.0	100	90 - 100
10.0	88	85 - 100
5.00	10	0 - 10
2.36	0	-

Table 5: Physical properties of coarse aggregate

Physical Properties	Test Results	Limit of the Iraqi specification[(9)]
Specific gravity	2.6	-
Sulfate content %	0.06	$\leq$ 0.1 %
Absorption%	0.63	-

d- Water

Tap water was used for both mixing and curing of concrete.

e - High range water reducing

A superplasticizer type sulphonted melamine and naphthalene formaldehyde condensates, which is know commercially as Gleniume 51 , was used in this work. Gleniume 51 is differential from conventional superplasticizers in that it based on a unique carboxylic ether polymer with long lateral chains. This greatly improves cement dispersion. Table (6) indicates the technical description of aqueous solution of the superplasticizer used in this investigation; it is free from chlorides and complies with ASTM C494 types A and F.

Table 6: Typical properties of (Glenium 51)*

NO.	Main action	Concrete super plasticizer
1	Color	Light brown
2	PH. Value	6.6
3	Form	Viscous liquid
4	Subsidiary effect	Hardening
5	Relative density	1.1 at 20°C
6	Viscosity	128 ± 30 cps at 20°C
7	Transport	Not classified as dangerous
8	Labeling	No hazard table required

* from producer

f - Mineral Admixtures

Limestone powder has been used as filler for concrete production. It has been found to increase workability and early strength, as well as to reduce the required compaction energy. The increased strength is found particularly when the powder is finer than the Portland cement particles The cement in SCC is generally partially replaced by fillers like limestone powder in order to improve certain properties such as [(11)].

I - Avoiding excessive heat generation

II - Enhancing fluidity and cohesiveness

III - Enhancing segregation resistance

IV- Increasing the amount of powder (cement + filler) so it becomes more economical than using cement alone.

A fine limestone powder (locally named as Al-Gubra) with fineness (3100cm^2/gm) is used . the chemical composition of limestone is listed in Table (7)

Table 7: Chemical composition and physical properties of Limestone dust*

Oxides	%
SiO_2	1.37
Fe_2O_3	0.12
Al_2O_3	0.72
CaO	54.1
MgO	0.13
SO_3	0.21
L.O.I	42.56

*The chemical and physical test were conducted by the National Center for Geological Survey and Mines

2-2 Concrete Mixes

In order to achieve the scope of this study , three mixes based on the mix design method (EFNARC 2002) [(6)]. , have been prepared in this study . SCC containing different type of aggregate grading with fines modulus of (1.9, 2.3 and 2.7) have been prepared . Each mix contains 70% cement and 30% dust of the total powder content . Table (8) shows the details of mixes .

Table 8: Details of concrete mixes

Mix	Water kg/m^3	Cement kg/m^3	Ld kg/m^3	Sand kg/m^3	Type of sand	Gravel kg/m^3	SP L/ m^3	w/c ratio	w/p ratio
M1	170	350	150	780	FG	885	7.7	0.49	0.34
M2	170	350	150	780	MG	885	7.7	0.49	0.34
M3	170	350	150	780	CG	885	7.7	0.49	0.34

2-3 Determination of Optimum Dosage of Superplasticizer (SP)

To clarify the effect of F.M on the fresh state characteristics of SCC , the percentage ratio of the SPD by powder weight for each mix was kept constant throughout this work for all investigated mixes

A dosage of 5.5 liters per 100 kg of the total weight of the powders was used for the first trial mixtures . Table (9) shows an example of trial mix for M1 .

Table 9: Example of trial mix for M1 with fine aggregate of fine grading

Dosage of SP liter per 100 kg of powder	Slump flow D (mm)	T500 sec	J – ring DJ (mm)	TJ500 sec	Segregation index (visual)
5.5	580	8.5	550	9.6	homogeneous
6.5	600	7.8	590	8.5	homogeneous
7.7	620	6	600	7.5	homogeneous

After trial mixes , the percentage ratio of SP by power weight for each mix was kept 1.44% , which satisfies a maximum spread under the following condition : " slump flow D should not be less than 600 mm and not more than 770mm to avoid segregation " [12].

3- Results and Discussions

3-1 Fresh Concrete Properties

After preparing the three mixes, fresh properties of each mix were measured the workability test were made on fresh concrete immediately after mixing including slump flow, J-ring , and L – box tests . The tests were carried out to determine the effect of fineness modules of fine aggregate on fresh properties.

a- Slump – flow and T500 [13] .

The consistency and workability of SCC were evaluated using the slump flow test . Because of its ease of operation and portability, the slump flow test is the most widely used method for evaluating concrete consistency in the laboratory and at construction site, Table (10) shows the slump flow (final diameter D) values and T500 for SCC mixes. Mix containing grading (finer grading) gave lower slump flow diameter from other mixes because of the higher surface area of the used sand.

The higher surface area lead to decreases the slump flow (D) and to increase the time T500 when a constant SP and water content are used i.e. decreasing the fillingability of the mix. Fig.(1) and (2) show the effect of grading of fine aggregate on slump flow . With constant superplasticizer dosage and water , the finer grading of fine aggregate leads to increase in slump flow (D) and decreases in the flow time of T500 . This result is different from previous studies done by other researchers [(4) (14)] that because they used a higher dosage of superplasticizer for mixes of higher finer grading to get the same passing ability .

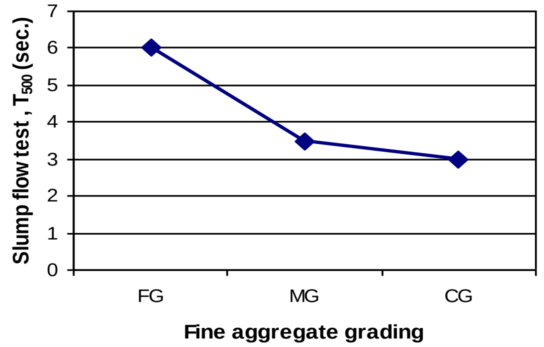

Fig. 1:Relationship betweenT500 and fine aggregate grading

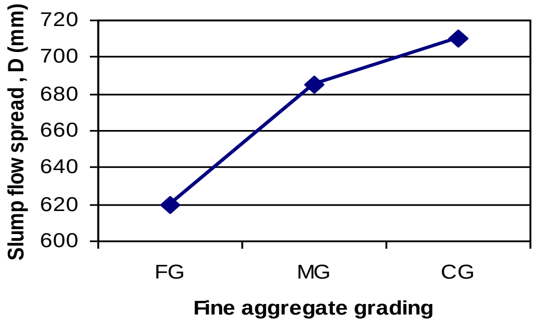

Fig. 2: Relationship between D(mm) and Fine aggregate grading

b- L –box Test[(15)].

The L- box test gives an indication about the filling ability and the passing ability of SCC . It measures the reached height of fresh SCC after passing through the specified gaps of steel bars and flowing within a defined flow distance. Table (10) shows the value of BL (H1/H2) which represents the blocking ratio and the value of T400 represents the time of concrete to reach 400 mm flow . This table Fig.(3) and (4) show the effect of grading of fine aggregate on L- box test .It can be noticed that mixes containing fine aggregate with coarser grading has higher blocking ratio and lower value of T400 . This deformability depends on the size and shape of aggregate and the volume of the mortar . This is in complete agreement with the studies carried out by Tviksta [(16)].

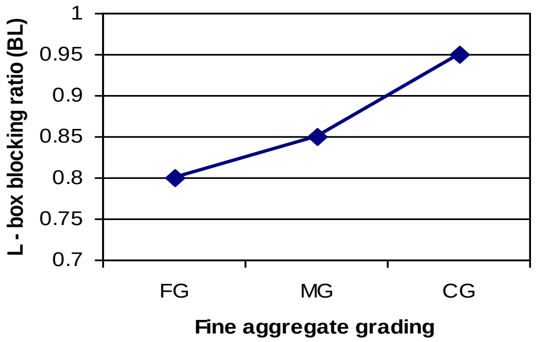

Fig.3: Relationship between BL and Fine aggregate grading

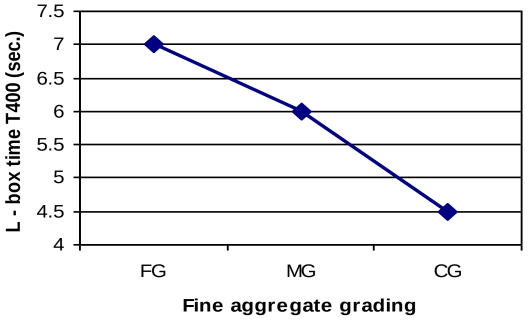

Fig.4: Relationship betweenT400 and Fine aggregate grading

c- J- Ring Test [7]

The J- ring test aims at investigating both the filling ability and the passing ability of SCC. It can also be used to investigate the resistance of SCC to segregation by comparing test result from two different portions.

Table (10) shows the value of J –ring flow spread (DJ) which indicates the restricted deformability of SCC due to blocking effect of reinforcement bars and the flow time TJ_{500} which indication the rate of deformation within a defined flow distance and BJ which represent the step of blocking { the difference in height between concrete inside and outside the ring }

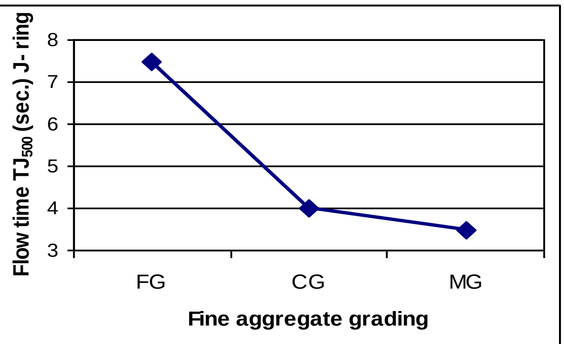

Fig. 5: Relationship between TJ_{500} and Fine aggregate grading

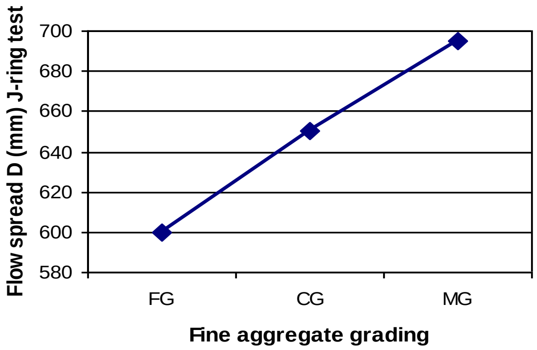

Fig.6: Relationship between D(mm) and Fine aggregate grading

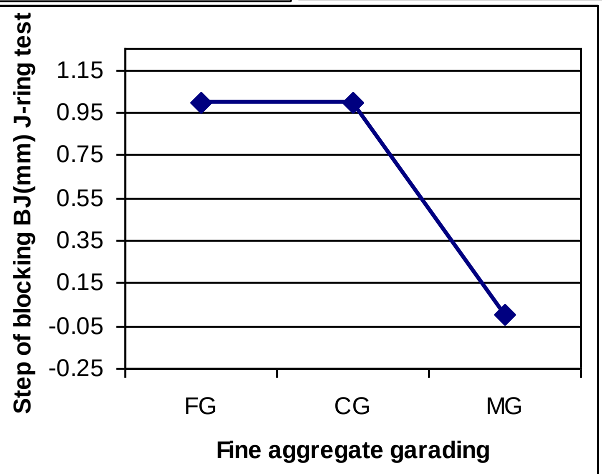

Fig.7: Relationship between BJ and Fine aggregate grading

Fig.(5),(6) and (7) show the effect of fine aggregate grading on J- ring test .It can be noticed that mixes containing fine aggregate with coarser grading has higher blocking ratio and flow spread and lower value of T_{500}.

Figs. (8) and (9) indicate a relationship between slump flow test and J-ring test . It can be seen that , the relationship between these two test is liner and there is a correlation coefficient R2 for both of them .Therefore, it can be said that what have been inferred from the behavior of these mixes in slump flow tests seem to be adequate to explain the behavior of these mixes in J- ring test.

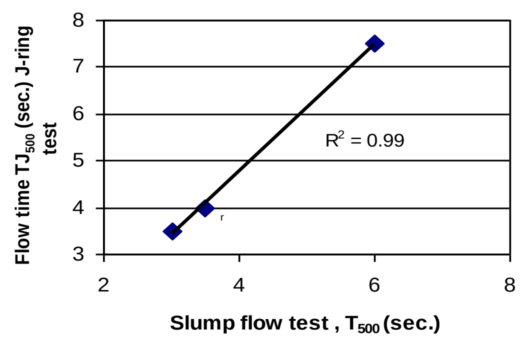

Fig.8: Relationship between T_{500} and TJ_{500}

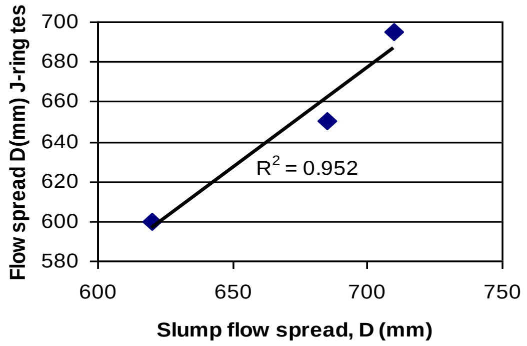

Fig.9: Relationship between Dand DJ

Table 10 : Result of fresh properties of SCC for all mixes

Mix	SP L/m^3	Type of sand	Slump flow		J - ring			L - box	
			T_{500} (sec)	D mm	TJ_{500} sec	DJ mm	BJ mm	BL H1/H2	T_{400} sec
M1	7.7	FG	6	620	7.5	600	1	0.8	7
M2	7.7	MG	3.5	685	4	650	1	0.85	6
M3	7.7	CG	3	710	3.5	695	0	0.95	4.5

3-2 Hardened Concrete Properties

Five test were carried out on hardened SCC mixes. They were Compressive Strength , Density , Static Modulus of Elasticity , Splitting Tensile Strength and Modulus of rupture .

a- Compressive Strength

The compressive strength was measured in compliance with B.S.1881 [17]. To study the effect of grading of fine aggregate on the compressive strength of SCC , standard cubes measuring 100 mm are used. Table (11) shows the average of the results of compressive tested cubes 7 , 28 and 90 days .

Table 11: Results of compressive strength test (MPa)

Mix	Type of sand	Compressive Strength Test (MPa) For ages		
		7 days	28 days	90 days
M1	FG	21	44	49
M2	MG	29	47.5	53
M3	CG	36	49	56

Fig (10) shows the increase in compressive strength with time, for all mixes . From the result , It can be noticed that mix with fine aggregate (coarse grading) gave higher compressive strength at 28 days (11.4 — 3.15) % compared with other mixes. This may be attributed to the good interlocking between the paste of cement and aggregate particles which lead to higher density and lower void ratio, hence improving the compressive strength .

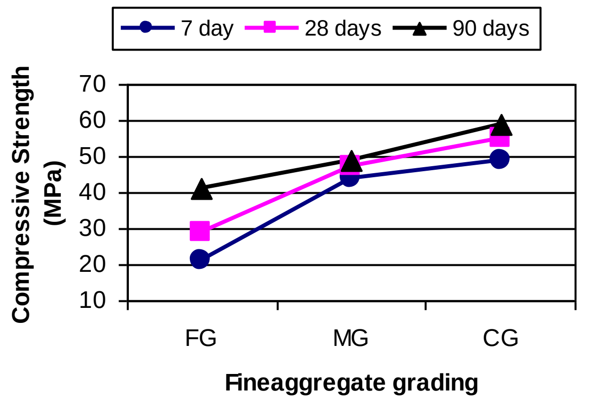

Fig.10: Relationship between compressive strength and Fine grading

b- Density test

According to the ASTM 642-97 [18] , the bulk dry density of the concrete was determined and listed in Table (12) . 100mm cube specimens were used in this test.. The density is measured at ages 7,28 and 90 days . Table (12) indicated that the concrete bulk dry density of the studied mixes at 28 days are in the range of (2441 – 2461) kg/m^3 , this range is higher than conventional concrete densities which is (2300 – 2400) kg/m^3 .This increase is due to the high powder content and the use of superplasticizer which lead to higher compatibility .

Table 12: Results of Dry density test (kg/m^3)

Mix	Type of sand	F.M of sand	Dry density (kg/m^3)For ages		
			7 days	28 days	90 days
M1	FG	1.9	2424	2441	2450
M2	MG	2.3	2450	2455	2460
M3	CG	2.7	2459	2461	2468

Fig (11) shows the effect of grading of fine aggregate on densities of all SCC mixes. From the result of density test , it can be noticed that the uses of coarse grading of fine aggregate in mix gives higher density values about (0.24— 0.8)% compared with the use of fine aggregate grading with finer grading in mixes which leads to more homogeneity mixes , and interlocking lead to lower voids in mixes.

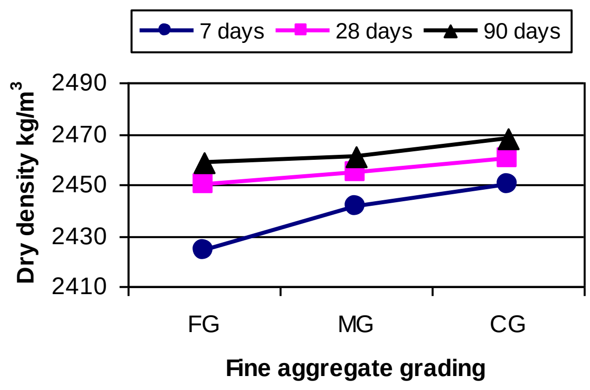

Fig.11: Relationship betweenDry density and Fine aggregate grading

c- Static Modulus of Elasticity

The static modulus of elasticity was measured in compliance with ASTM C 469 – 87a [19] . The (150 × 300 m) cylinder specimens were cured in water and tested at 28 days . Table (13) showed the average result of this test .

Table 13: Results of Static Modulus of Elasticity test (GPa)

Mix	Type of sand	F.M of sand	Static Modulus of Elasticity GPa at 28 days
M1	FG	1.9	28.6
M2	MG	2.3	29.2
M3	CG	2.7	34.4

Fig.(12) showed that , the modulus of elasticity of concrete versus grading of fine aggregate it can be noticed that the uses of coarse grading of fineness modulus (2.7) in mix gives higher modulus of elasticity values about (20— 17.8)% at 28 days compared with other mixes. This agrees with the studies carried out by Hussian[4] Fig.(13) shows that , the compressive strength of concrete and the elastic modulus of concrete are related ; the increase in one is similarly reflected in an increase in the other . This agrees with the studied carried out by Hussian [4].

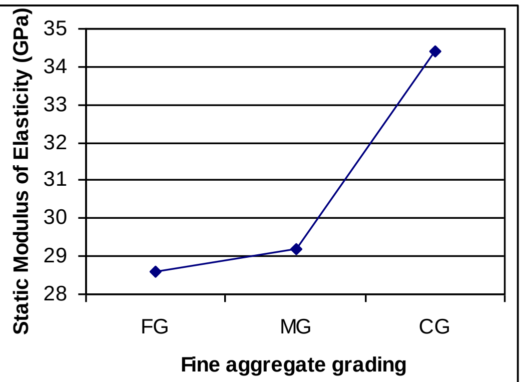

Fig.12: Relationship between Static Modulus of Elasticity and Fine aggregate grading

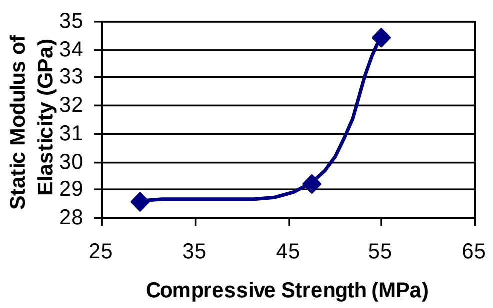

Fig.13: Relationship between staticModulus of Elasticity andCompressive Strength

d- Splitting Tensile Strength

The Splitting Tensile Strength was carried out at 7 , 28 , and 90 days on cylinders measuring (100 ×200) mm according to ASTM C 494- 86 [20] , The results are shown in Table (14) . The bond between aggregate and paste is an important factor in the strength of concrete, especially the tensile strength . The failure of concrete in tension is governed by microcracking, associated with interfacial transition zone (ITZ) [21].

Table 14: Results of splitting tensile strength test (MPa)

Mix	**Type of sand**	**F.M of sand**	**Splitting Tensile Strength (MPa) For ages**		
			7 days	28 days	90 days
M1	FG	1.9	3.2	3.46	4.9
M2	MG	2.3	3.46	4.5	5.2
M3	CG	2.7	4.3	5.2	6

Fig. (14) shows that mixes with finer grading gave lower splitting tensile strength at 28 days (30 – 50)% compared with other mixes . This is attributed to the fact that its specific surface (ITZ) is lower and hence, the lower is the bond strength over the aggregate cement interface . This agrees with the studies carried out by Druta [21].

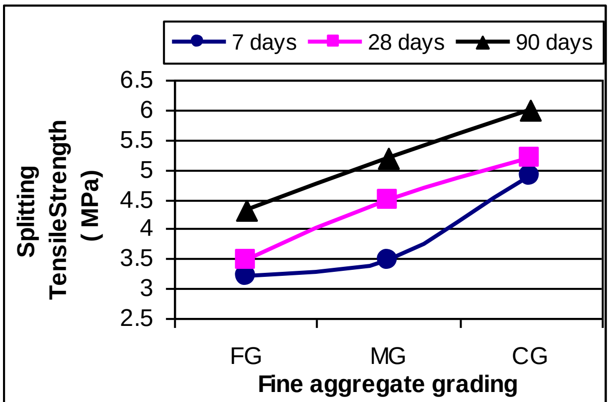

Fig.14: Relationship between SplittingTensile Strength and Fine aggregate grading

e- Modulus of Rupture

The flexural strength , expressed as the modulus of rupture , is calculated using the result obtained from a simple beam with third – point loading test according to ASTM C 78-84 [22]. The result of the average modulus of rupture test are shown in Table (15) for all mixes cared in 28 days .

Table 15: Results of flexural strength test (MPa)

Mix	Type of sand	F.M of sand	Modulus of rupture (MPa)at 28 days
M1	FG	1.9	4.59
M2	MG	2.3	6.34
M3	CG	2.7	7.2

Fig. (15) shows that the use of coarser grading of fine aggregate of fineness modulus (2.7) in the mix gives higher values at 28 days (56 – 13.6)% compared with the uses of other type of fine aggregate.

Fig.(16) indicate the relationship between the modulus of rupture and tensile strength , from this figure, it can be seen that the properties of grading fine aggregate affect the modulus of rupture with the same manner as the tensile strength . The high degree of correlation (R^2 = 0.99) between the modulus of rupture and tensile strength for all mixes is illustrated in this figure.

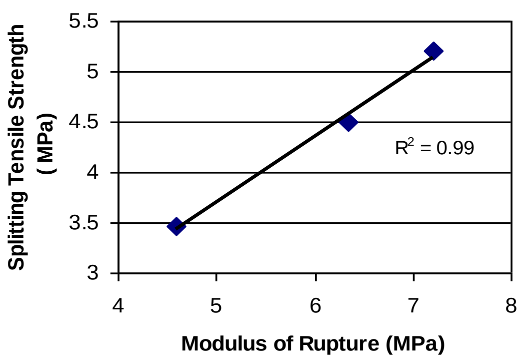

Fig. 15 :Relationship betweenSplitting Tensile Strength and Modulus of Rupture

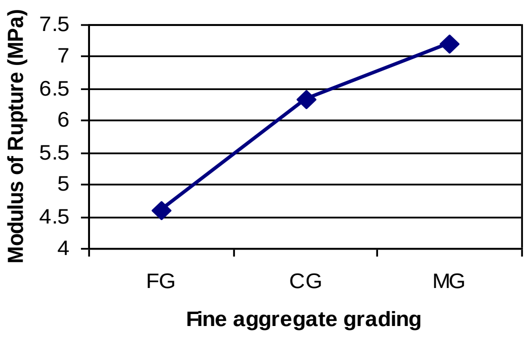

Fig. 16:Relationship between Modulus of Rupture and Fine aggregate grading

Conclusion

From this study , the following conclusion can be drawn from this work **:**

1. It is possible to produce SCC with satisfied fresh properties using different grading of fine aggregate (fine , medium and coarse grading)
2. Self – compacting concrete can be obtained by adding suited superplastizier and very fine mineral admixture (limestone dust) . These two materials provide a sufficient balance between the yield and viscosity of the mix. The inclusion of 30% limestone dust as a partial replacement by weight of powder content requires 7.7% superplastizier to produce SCC.
3. The workability of all studied mixes is adequate in terms of SCC requirements, with slump flow diameter ranges between (600 - 710) , flow times ranges between (3 – 7.5) sec. , while the blocking ranges between (0–1)
4. Concrete mixes made with different grading of fine aggregate (fine , medium and coarse grading)had slightly effects on compressive strength for all ages for constant w/c ratio
5. The effect of the change in fine aggregate is more clear on the fresh concrete properties .The use of coarser grading of fine aggregate lead to decrease the flow time (60)% and increasing the flow spread , (18)% .
6. Due to homogeneity mixes , and interlocking lead to lower voids in mixes, the studied mixes show high compressive , splitting tensile strength , modulus of rupture, static modulus and density at 28 days with range of (44 – 49) MPa , (3.46 – 5.2) MPa , (4.59 – 7.2) MPa , (28.6 – 34.4) MPa and (2441 – 2461) kg/m^3 respectively .

References

1. Okamura, H., " Self – Compacting High Performance Concrete " Concrete International , Vol. 19, No. 7, 1998 PP .50-54.
2. Newman J.,and Choo B., S.,"Advanced Concrete Technology",Elsevier Ltd., 2003 .
3. Su, J. K., Cho, S. W., and Huang, R., “Effect of Sand Ratio on the Elastic Modulus of Self-Compacting Concrete”, Journal of Marine Science and Technology, V.10, No.1, 2002, PP.8-13.
4. Hussian Z., M., A., " The Effect of Aggregate on the Properties of Self-Compacting Concrete " M.Sc. Thesis, Department of Civil Engineering, College of Engineering, AL – Mustansirya University , January ,2008
5. Aulia T. B., and Deuys C. K., " Effect of Mechanical Properties of Aggregate on the Ductility of High Performance Concrete"Leipzig University,No.4, 1999
6. EFNARC, “Specification and Guidelines for Self-Compacting Concrete”, www.efnarce.org , February 2002, pp.32.
7. The self-compacting concrete European project group ,The European Guidelines for Self-Compacting Concrete, May 2005, PP43-56
8. IOS NO. 5 : 1984 , Iraqi cement standard for Portland cement
9. IOS NO. 45: 1984 , Iraqi Aggregate standard for Aggregate form Natural Sources for Concrete and Building Construction
10. British Standards Institutions, U.K., "British Standards Specification for Aggregates from Natural Sources of Concrete" BS: 1992, PP. (4-5).
11. Tsivilis, S., Chaniotakis, E., Badogiannis, E., Pahoulas, G., and Ilias, A., “A Study on the Parameters Affecting the Portland Limestone Cements”, Cement and Concrete Composites, V. 21, No. ,1999 ,P.115
12. Wüstholz, T., “Fresh Properties of Self- Compacting Concrete”, Otto-Graf- Journal, V. 14, 2003, PP.179-188.
13. ASTM C1611-05, “Standard Test Method for Slump Flow of Self-Consolidating Concrete”, Annual Book of ASTM Standard, Vol. 04-02, September 2005, P.6.
14. Al – Jadiri R. S. F., " A Method for Proportioning Self-Compacting Concrete Based on Compressive Strength Requirements " M.Sc. Thesis, Department of Civil Engineering, College of Engineering, AL – Mustansirya University , October ,2008
15. Teknik, D. B., “Measurement of Properties of Fresh Self- Compacting Concrete”, Final Report, September 2005, PP.15, 55,
16. Tviksta L.G., " Guideline for SCC " , Brite Euram , Task 9 End Product, 2000.
17. B.S.1881, Part 116, 1989, “Method for Determination of Compressive Strength of Concrete Cubes”, British Standard Institution, P.3
18. ASTM C642-97,“Standard Test method for Density, Absorption, and Voids in Hardened Concrete” ,Annual Book of ASTM Standards, V.04.02,2003,PP.1-3
19. ASTM C469-87a, “Test Method for Static Modulus of Elasticity and Poisson's Ratio of Concrete in Compression”, Annual Book of ASTM Standard, Vol. 04-02, 2002.

20. ASTM C496-86, “Standard Test Method for Splitting Tensile of Cylindrical Concrete Specimens”, Annual Book of ASTM Standard, Vol. 04-02, 1989, pp.259-262

21. Druta C., "Tensile Strength and Bonding Characteristics of Self—Compacting Concrete " M..Sc. Thesis , the Louisiana State University Agricultural and Mechanical College, August , 2003

22. ASTM C78-84, “Test Method for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading)”, Annual Book of ASTM Standard, Vol. 04-02, February 2003, pp.182-186.