Some Properties of Self Compacting Concrete by Using Different Types of Local Rocks as a Coarse Aggregate

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ABSTRACT

Self-Compacting Concrete (SCC) is new type of concrete that posses property of high flow ability, passing ability and stability.This research aims to investigate the properties of the SCC produced by using locally available materials and to study the effect of using local rocks as a coarse aggregate such as quartzite, dolomite and limestone with two replacement ratio 50% and 100% of traditional coarse aggregate (gravel).

The SCC mixes prepared with full and 50% replacement of quartzite gives higher compressive strength, splitting strength, flexural strength and ultrasonic pulse velocity compared with mix that contained gravel with percentage of enhancement (11.9%), (9.5%), (12.4%) and (2%); respectively for fully replacement at 28 day.On the other hand, it has been noticed that the concretes prepared with full and 50% replacement of dolomite give lower compressive strength, splitting strength, flexural strength and ultrasonic pulse velocity compared with mix that contained gravel with percentage of detraction (10.3%), (4.8%), (5.9%) and (1.2%); respectively for fully replacement. Also, for both full and 50% replacement; limestone exhibits the same behavior of dolomite but with larger percentages of detraction which are (24.2%), (33.3%), (27.1%) and (3.6%).

Keywords: Self-Compacting Concrete, Flow ability, Local Rocks, Quartzite.

بعض خصائص الخرسانة ذاتية الرص المحتوية على أنواع مختلفة من الصخور المحلية كركام خشن

الخلاصة

الخرسانة ذاتية الرص هي نوع جديد من الخرسانة التي تحقق خواص قابلية انسياب عالية, قابلية اجتياز وثباتية. هذا البحث يهدف الى دراسة خصائص الخرسانة ذاتية الرص المنتجة من مواد متوفرة محليا ولدراسة

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تأثير استخدام الصخور المحلية (كوارتزايت, دولومايت والحجر الجيري) كركام خشن, (50% نسبة استبدال, واستبدال تام) من الركام الخشن التقليدي (الحصى).

ان الخلطات الخرسانية ذاتية الرص ذات الاستبدال التام (100%)والاستبدال الجزئي (50%) من الكوارتز أعطت نتائج مقاومة انضغاط, مقاومة شد الانفلاق, مقاومة انثناء وسرعة الموجات فوق الصوتية اعلى مقارنة مع الخلطة المرجعية التي تحتوي على الحصى مع نسبة تحسين (11.9%) ,(9.5%), (12.4%), و (2%) على التوالي للاستبدال التام عند 28 يوم. من جهة اخرى, الفحوصات وضحت بان الخلطات الخرسانية ذات الاستبدال التام والاستبدال الجزئي (50%) من الدولومايت أعطت نتائج مقاومة انضغاط, مقاومة شد الانفلاق, مقاومة انثناء وموجات فوق الصوتية اقل مقارنة مع الخلطة المرجعية التي تحتوي على الحصى مع نسبة نقصان (10.3%), (4.8%), (5.9%) و (1.2%) على التوالي للاستبدال التام. الحجر الجيري أظهر سلوك مماثل للدولومايت لكن مع نسبة نقصان بالنتائج اكبر من الدولومايت والتي كانت (24.2%), (27.1%), (33.3%), (3.6%).

INTRODUCTION

This work is planned to achieve SCC from locally available materials according to the requirement of fresh properties of concrete (workability measurements). The main rezone for searching and studying the use of alternative coarse aggregate is the continued use of traditional coarse aggregate (gravel) without alternative, which may lead to reduce or carry out it in the quarry and the use of natural sources in Iraq and other country.

(Ozturan and Cecen 1997) [9] studied the effect of coarse aggregate type on mechanical properties of concrete with different strengths. They have concluded that normal strength concrete made with basalt and gravel gave similar compressive strength while limestone concrete attained a somewhat higher strength. Higher tensile strength is obtained with crushed basalt and limestone compared to the aggregate when used in high strength concrete.

Regarding the characteristics of different types of aggregates, crushed aggregates tend to improve the strength because of the interlocking of the angular particles whilst rounded aggregates improve the flow because of lower internal friction (EFNARC 2002) [6].

(Alexander and Prosk 2003) [4] found that the shape and size of coarse particles have a significant influence on the required mortar and paste content. Naturally rounded river gravel requires mostly less mortar or paste than limestone. Granite requires the highest mortar volume. Crushed aggregate tend to improve the strength because of the interlocking of the angular particles but reduce flow, whilst rounded aggregate improve the flow because of lower internal friction.

The content of coarse aggregate in the SCC is a vital parameter in ensuring that the mix has excellent flow characteristics and proper mechanical properties. A high coarse aggregate content can lead to a reduction in segregation resistance and also to blockage of the flow **(**Newman and Choo 2003) [5].

(Okamura and Ochi 2003) [7] found that the flow speed of concrete through a funnel with an outlet width of 55mm was largely influenced by the grading of coarse aggregate.

(Raheem 2005) [8] concludes that the flowability of the SCC decreases with an increase in volume ratio and maximum size of coarse aggregate. He also concludes that segregation tendency for mixes with a larger size of (20 mm) aggregate is significantly higher than a small size of (10 mm) aggregate.

The influence of aggregate type on the strength and abrasion resistance of high strength concrete was studied by (Kilic et al 2008) [3]. Five different aggregate types (gabbro, basalt, quartzite, limestone and sandstone) were used to produce high strength concrete containing silica fume. Gabbro concrete showed the highest compressive and flexural tensile strength and abrasion resistance, while sandstone showed the lowest compressive and flexural tensile strength and abrasion resistance. High abrasion resistance aggregate produced a concrete with high abrasion resistance. Three month compressive strength of concrete made with basalt, limestone and sandstone were found to be equivalent to the uniaxial compressive strength of their aggregate rocks. However, the concrete made with quartzite and gabbro aggregate showed lower compressive strength than the uniaxial compressive strength of their aggregate rocks.

Influence of crushed stone mineral aggregate on concrete consistency was studied by **(**Gordana et al 2010) [2]. River aggregate is used as a benchmark, and from crushed aggregates: limestone, and esite, diabase and basalt. The drawn conclusion is that fine crushed aggregate has an important influence on concrete consistency because it decreases concrete workability and placing. Replacement with river aggregate improves concrete consistency. Coarse aggregate type also has an influence on consistency.

The effect of coarse aggregate on fresh and hardened properties of self compacting concrete was studied by (Khaleel et al 2011) [1]. Three types of coarse aggregate are used, namely crusher gravel, uncrushed gravel and crushed limestone. It was found that by increasing the maximum size of coarse aggregate, flowability and passing ability redused. In addition it was observed that when uncrushed gravel was used in the concrete mixture, flow ability, passing ability and segregation resistance increased as compared to concrete with crushed gravel. It was noticed that concrete mixes prepared with crushed limestone showed higher strengths and modulus of elasticity than concrete mixes prepared with crushed and uncrushed gravel.

Experimental Program

Materials

Cement

Ordinary Portland cement (Type I) produced by an Iraqi cement factory, commercially known as (Tassloja) conforming to the IQS 5/1984[10] are used. The chemical analysis and physical properties are listed in Tables 1 and 2 respectively.

Fine Aggregate

The natural fine aggregate from Al-Ukhaider region are used. The grading satisfy the Iraqi specification IQS 45/1984[11] and confirm to the zone two. The sieve analysis is shown in Table 3. The sulfate content and the physical properties of fine aggregate are shown in Table 4.

Coarse Aggregate

Four types of crushed aggregates, natural gravel (from Al Nibaai region), quartzite (from Al Ruttba), dolomite (from Al Samawah) and limestone (from Al Najaf) with maximum size 14mm were collected and used as the coarse aggregates in the production of concrete. The aggregate satisfies the Iraqi specification IQS 45/1984[11]. The sieve analysis for the crushed aggregate is shown in Table 5. The sulfate content and the physical properties are shown in Table 6.

Mixing Water

Ordinary water is used for mixing and curing of the concrete, according to the IQS 1703/1992[12].

Silca Fume

Condensed silica fume was used to produce a SCC with reliable fresh concrete properties. The results in Tables 7and 8 shows the chemical and physical properties of silica fume used that conforms to the requirements of ASTM C1240-03 [13].

Chemical Admixture

A hyperplast PC200, which is a super plasticizing admixture, based on polycarboxylic ether polymers with long chains was used in this research as chemical admixture .It meets the requirements for superplasticizer according to ASTM C494[14] types A and G depending on dosage used.. The typical properties of superplasticizer are shown in Table 9.

Mix Proportion

Mix design of the SCC must satisfy the criteria of filling ability, passing ability and segregation resistance. The mix design method used in the present study is according to (EFNARC 2002) and then the proportions of materials are modified after obtaining a satisfactory self-compactability by evaluating fresh concrete tests. SCC mixes with cement: sand: gravel ratio of (1:1.6:1.64) by weight, were used. The W/P ratio for each mix design was adjusted taking into account the superplasticizer dosage.

Super plasticizer was added in (1.2-2.5) liters per 100 kg of powder depending on the type and replacement ratio of coarse aggregate to satisfy the requirement of achieving SCC. The mix proportion is presented in Table 10.

Mixing, Casting and Curing of Concrete

The Concrete is mixed in electrical drum laboratory mixer, with a capacity of $0.05m^3$. Cast iron cube moulds, with dimensions of 100x100x100mm are prepared, cleaned and oiled before starting mixing of concrete. The procedure of mixing follows the laboratory mixing procedure outlined by (Emborg 2000)[15] which is briefly stated in the following point:

1- Adding the fine aggregate to the mixer with 1/3water, and mixing for 1 minute.

2-Adding the powder (cement+SF) with 1/3mixing water, and mixing for 1 minute.

3-After that, the coarse aggregate is added with the last 1/3 mixing water and 1/3 of superplasticizer, and mixing for 1 ½ minutes then the mixture is left for 1½ minutes for rest.

4-Then, the remaining 2/3 of the superplasticizer is added and mixed for 1½ minutes.

5-The mixture is then discharged, cast and tested.

The molds were covered with nylon bag and polyethylene sheets for nearly 24hr, and then placed in the curing tank filled with water until the time of testing (7, 28 and 90 day).

Tests Performed

The following are the standard tests that were carried out on the fresh concrete, and hardened concrete.

Testing of Fresh Concrete

Slump Flow Test and T50cm Test

The slump flow is used to assess the horizontal free flow of SCC in the absence of obstructions. It was first developed in Japan for use in assessment of underwater concrete. The test method is based on the test method for determining the slump. The diameter of the concrete circle is a measure for the fillingability of the concrete. (EFNARC 2002) [6].

V-Funnel test and V-Funnel Test at $T_{5minutes}$

The test was developed in Japan. The V-funnel test is used to determine the filling ability (flowability) of the concrete with a maximum aggregate size of 20mm. The funnel is filled with about 12 liter of concrete and the time taken for it to flow through the apparatus measured. After this the funnel can be refilled concrete and left for 5 minutes to settle. If the concrete shows segregation then the flow time will increase significantly, this test can be used in lab and field (EFNARC 2002) [6].

L-Box Test

This test, based on a Japanese design for underwater concrete. The test assesses the flow of the concrete, and also the extent to which it is subject to blocking by reinforcement. This is a widely used test, suitable for laboratory, and perhaps site use. It assesses filling and passing ability of SCC (EFNARC 2002) [6].

Testing of hardened Concrete

Compressive Strength Test

Compressive strength was determined according to B.S 1881: part 116, 1989[16]. Total number of 63 cubes (100mm) was tested by universal testing machine with a capacity of 2000 KN. The average results of three cubes were recorded for each time of exposure.

Splitting Tensile Strength

Cylinders of 100 mm diameter and 200 mm high were used in this test and the load was applied continuously up to failure. Test was done according to ASTM C496 –07[17].This test was conducted at ages of (7, 28 and 90) days.

Flexural strength

Flexural strength test was conducted according to ASTM C-78, 2005 [18] by using concrete prisms of dimensions (100x 100x400)mm. Modulus of rupture tests was performed by using a prism with third-point loading. The capacity of machine is 2000kN.

Ultrasonic Pulse Velocity (UPV)

According to ASTM C597-02[19] the Portable Ultrasonic Non – Destructive Digital Indicating Tester (PUNDIT) (direct way) was used. Standard cubes were used to measure the propagation of velocity for longitudinal stress wave pluses through concrete. Testing was carried out at7, 28 and 90 days.

Results And Discussion

Fresh Concrete

The D values of mixes that contain gravel are lower than these of mixes containing (50%) and (100%) crushed rock, this behavior is attributed to the fact that when using crushed gravel in mixes we need to less superplasticizer dosage (SPD) than other mixes that contain crushed rock and that for workability requirements for other test. Slump flow values ranged between 665 -770 mm and the T50 cm of slump flow values range between 2.5 -5 sec.

The results of slump flow, V-funnel and L-box that presented in Table (11) are within the acceptable criteria for SCC (EFNARK 2002) [6] and indicate also excellent deformability and filling ability without any segregation, bleeding and blocking.

Hardened Concrete

Compressive Strength

Table 12 shows the results of compressive strength of the SCC mixes for different types of aggregate with 50% and 100% replacement. The compressive strength of SCC that contains crushed quartzite is higher than the reference mix (gravel) as shown in Fig. 1. This behavior may be because the strength of quartzite (abrasion value = 17; impact value = 16.7) are higher than strength of gravel (abrasion value = 18.5; impact value = 21.9) and the surface texture of quartzite is more rough than the surface texture of gravel and the angularity of its crushed rock is higher than that of the gravel which improves the bond strength between the aggregate and cement paste this agree with (**Neville 2002)[20]**. The percentages of increasing when using 100% CQ and 50% CQ compared with reference mix (gravel) are 11.9% and 10.6% at 28day respectively. On other hand, the results of compressive strength of SCC mixes that contain crushed dolomite are less than compressive strength of SCC mixes that contain crushed gravel as shown in Fig. 2. This is due to the strength of gravel (impact value = 21.9; abrasion value = 18.5) higher than the strength of dolomite (impact value = 26.5; abrasion value = 21.5). The percentages of reduction when using 100% CD and 50% CD compare with reference mix (gravel) are 10.3% and 9.7% at 28 days respectively. Also, the presence of crushed limestone in the SCC mixes leads to reduction in compressive strength value compared with SCC mixes that contain gravel as shown in Fig.3. But the percentages of reduction are larger than that of the mixes with crushed. This may be attributed to strength of gravel whose (impact value = 21.9; abrasion value = 18.5) which are higher than those of limestone (impact value = 29; abrasion value = 26) and the angularity of crushed gravel is more than the angularity of crushed limestone that leads to increase the bond between the aggregate and cement paste so higher compressive strength is produced. The percentages of reduction when using 100% CLS and 50% CLS compared with reference mix (gravel) are 24.2% and 11.8% at 28 days respectively.

Splitting Tensile Strength

The results presented in Table 12 shows the splitting tensile strength of SCC mixes for different types of aggregate with 50% and 100% replacement. The SCC mixes that contain crushed quartzite is higher than the splitting tensile strength of SCC mixes with crushed gravel at all ages as shown in Fig.4. There is an increase due to using of Quartzite. This behavior may be attributed to fact that the surface texture of crushed quartzite has more roughness than the surface texture of crushed gravel and the angularity of its crushed rock is so higher than that of the crushed gravel which improves the bond strength between the aggregate and cement paste. The percentages of increasing in splitting tensile strength of SCC mixes with (100% CQ) and (50%CG+50%CQ) compared with reference mix (100% CG) are 9.5% and 4.5% at 28 days respectively. On the other hand, the results of splitting tensile strength of SCC mixes that contain crushed dolomite are less than the splitting tensile strength of SCC mixes that contain crushed gravel (reference mix) as shown in Fig.5. This is because the strength of gravel is higher than the strength of dolomite. The percentages of reduction in splitting tensile strength of SCC mixes with (100% CD) and (50%CG+50%CD) compared with reference mix (100% CG) are 4.8% and 2.9% at 28 days respectively.

Also, the presence of crushed limestone in the SCC mixes leads to reduction in splitting tensile strength value compared with mixes that contains crushed gravel with percentage of reduction higher than the dolomite availability as shown in Fig.6. This may be attributed to strength of gravel which is higher than strength of limestone and the angularity of crushed gravel which is more than the angularity of crushed limestone. That leads to increase the bond between the aggregate and cement paste. The percentages of reduction in splitting tensile strength of SCC mixes with (100%

CLS) and (50%CG+50%CLS) compare with reference mix (100% CG) are 33.3% and 18.1% at 28 days respectively.

Flexural strength

Table 13 shows the results of flexural strength of the SCC mixes for different types of aggregate with 50% and 100% replacement. The SCC mixes that contain crushed quartzite have higher flexural strength than mixes that contain crushed gravel (reference) at all ages. There is an increase due to using the quartzite rock. This behavior is because the strength of quartzite (abrasion value = 17; impact value = 16.7) are higher than strength of gravel (abrasion value = 18.5; impact value = 21.9) and the surface texture of crushed quartzite has more roughness than the surface texture of crushed gravel and the angularity of its crushed rock is so higher than that of crushed gravel which improves the bond strength between the aggregate and cement paste. The percentages of increase in flexural strength of SCC mixes with (100% CQ) and (50%CG+50%CQ) compared with reference mix (100% CG) are 12.4 and 9.4% at 28 days respectively. Table 13 also shows that the flexural strength of the SCC mixes that contain crushed gravel is higher than the flexural strength of mixes that contain crushed dolomite.

This is because the strength of gravel (impact value = 21.9; abrasion value = 18.5) is higher than the strength of dolomite (impact value = 26.5; abrasion value = 21.5). The percentages of reduction in flexural strength of SCC mixes with (100% CD) and (50%CG+50%CD) compared with reference mix (100% CG) are 5.9% and 3.5% at 28 days respectively.

On the other hand, the presence of crushed limestone in SCC mixes leads to reduction in flexural strength value compared with mixes which contain crushed gravel (reference) as shown in Table 13. This may be attributed to strength of gravel (impact value = 21.9; abrasion value = 18.5) which is higher than strength of limestone (impact value = 29; abrasion value = 26) and the angularity of crushed gravel is more than the angularity of crushed limestone. That leads to increase the bond between the aggregate and cement paste so producing higher compressive strength. The percentages of reduction in flexural strength of SCC mixes with (100% CLS) and (50%CG+50%CLS) compared with reference mix (100% CG) are 27.1% and 13% at 28 days respectively.

Ultra Sonic Pulse Velocity (UPV)

Table 13 show that the SCC mixes that contain (100% and 50%) crushed quartzite give higher UPV results than SCC mixes that contain crushed gravel (reference). This behavior may be attributed to surface texture of quartzite has more roughness than the surface texture of gravel and the angularity of its crushed rock is much higher than that of the natural gravel. That improves the continuity of concrete components as concrete density as which gives higher UPV. On the other hand, it is noticed that the SCC mixes containing (100% and 50%) crushed dolomite or (100% and 50%) crushed limestone give less UPV results than mixes with crushed gravel. This may be attributed to the mixes that contain dolomite and limestone aggregate have density less than mixes that contain gravel.

CONCLOSIONS

The following conclusions can be drawn based on the results of each test:

1. The workability of the SCC mixes containing crushed gravel is better than that of mixes containing crushed rocks for the same w/p ratio and superplasticizer dosage.
2. The SCC mixes made with crushed quartzite as coarse aggregate give higher strength than SCC mixes made with crushed gravel and the SCC mixes made with crushed gravel give higher strength than SCC mixes made with crushed dolomite and crushed limestone as coarse aggregate for all ages.
3. The SCC mixes made with crushed quartzite as coarse aggregate give higher splitting strength than SCC mixes made with crushed gravel and SCC mixes made with crushed gravel give higher splitting strength than SCC mixes made with crushed dolomite and limestone as coarse aggregate for all ages.
4. The SCC mixes made with crushed quartzite as coarse aggregate give higher flexural strength than SCC mixes made with crushed gravel and SCC mixes made with crushed gravel give higher flexural strength than SCC mixes made with crushed dolomite and limestone as coarse aggregate for all ages.
5. The SCC mixes made with crushed quartzite as coarse aggregate show higher ultrasonic pulse velocity than SCC mixes made with crushed gravel and SCC mixes made with crushed gravel show higher ultrasonic pulse velocity than SCC mixes made with crushed dolomite and limestone as coarse aggregate for all ages.

Table (1): Chemical composition of cement used

Oxide	**Content (percent)**	**Limits of Iraqi Specification No.5/1984[10]**
CaO	62.44	---
SiO_2	20.25	---
Al_2O_3	4.73	---
Fe_2O_3	4.32	---
MgO	1.90	≤5.0%
SO_3	1.88	≤ 2.8%
L.O.I.	3.50	≤4.0%
I.R.	0.80	≤1.5%
L.S.F.	0.93	0.66-1.02
Na_2O+0.658 K_2O	0.519	≤0.6%
Bogue potential compound composition, %		
Tricalcium silicate (C_3S)		56.90
Dicalcium silicate (C_2S)		15.13
Tricalcium aluminate (C_3A)		5.23
Tetracalcium alumino-ferrite (C_4AF)		13.15

*Chemical tests were made by the National Center for Construction Laboratories and Researches (NCCLR).

Table (2): Physical properties of cements used

Physical properties	**Test results**	**Limits of Iraqi Specification No.5/1984[10]**
Specific surface area (Blaine method), (m^2/kg)	372	≥ 230
Soundness (Auto clave), (%)	0.01	≤ 0.8

Setting time (Vicat's apparatus) Initial setting time, (hrs: min.) Final setting time, (hrs: min.)	 3:58 5:50	 ≥ 45 min ≤ 10 hrs
Compressive strength 3days, (MPa) 7days, (MPa)	 16.90 28.70	 ≥ 15 ≥ 23

* Physical tests were made by the National Center for Construction Laboratories and Researches (NCCLR).

Table (3): Sieves analysis of fine aggregate.

Sieve Size (mm)	**%Passing by weight**	**Limits of the Iraqi Specification No.45/1984 zone (2)[11]**
10	100	100
4.75	97	90-100
2.36	87	75-100
1.18	70.2	55-90
0.60	50	35-59
0.30	25.4	8-30
0.15	3.8	0-10

Table (4): Physicals properties and sulfate content of fine aggregate used in experimental work.

Physical properties	**Test result**	**Limit of Iraqi specification No.45/1984[11]**
Specific gravity	2.65	-
Sulfate content	0.09	≤ 0.5%
Fine material passing from sieve (75 µm)	4.2%	≤ 5%
Fineness modulus	2.61	-
Absorption	1.75%	-

*Chemical and physical analyses were conducted by Central Organization of Standardization and Quality Control.

Table (5): Sieves analysis of coarse aggregate with 14mm maximum size.

No.	**Sieve Size (mm)**	**Passing by weight (%)**				**Limits of Iraqi Specification No.45/1984[11]**
		Natural Crushed	**Quartzite**	**Limestone**	**Dolomite**	
1	20	100	100	100	100	100
2	14	94.5	95	95	95	90-100
3	10	61.6	68	68	68	50-85
4	5	0	5	5	5	0-10
5	2.36	0	0	0	0	-

Table (6): Physical properties and sulfate content of coarse aggregate.

Physical Properties	Test Results				Specification
	Natural Crushed	Quartzite	Limestone	Dolomite	
Specific gravity	2.64	2.67	2.56	2.64	according to ASTM C97[21]
Sulfate content	0.06%	%0.07	%0.25	%0.04	≤ 0.1% according to IQS No.45/1984[11]
Absorption	0.8%	2.5%	4.00%	2.5%	according to ASTM C97[21]
Impact Value	21.9%	16.7%	29%	26.5%	according to BS 812-112[22]
Abrasion index	18.5%	17%	26%	21.5%	≤ 50% according to ASTM C131[23]
So_3 total	2.149 %	2.167 %	2.496 %	2.113%	≤4% for cement≥300kg according to IQSNo.45/1984[11]

*Tests are carried out in the Material Laboratory of the College of Engineering-Baghdad University

Table (7): Chemical analysis of silica fume*

Oxide composition	Oxide content (%)	ASTM C1240-03
SiO_2	93.47	Min. 85%
Al_2O_3	2.15	--
Fe_2O_3	0.65	--
CaO	0.69	--
SO_3	Nil	--
$K_2O + Na_2O$	1.37	--
L.O.I	2.14	Max. 6%
MgO	0.69	--

*Tests were carried out by the Building Research Center.

Table (8): Physical properties of silica fume *

Property	Result	ASTM C1240-03
Strength activity index	130%	≥ 105 %
Specific gravity	2.2	--
Physical form	Powder	--

Color	Grey	--
Density	0.5	0.5±0.1kg/liter (dry bulk)
Moisture	0.68%	< 3%
Specific surface (Blaine method) m^2/kg	20000	≥ 15000

* Tests were carried out by the Building Research Center.

Table (9): Typical properties of hyperplast PC200 (Don Construction Products)

Form	Viscous liquid
Color	Light yellow
Freezing point	-3 @ 25 °C
Specific gravity	1.05∓0.02 @ 25 °C
Dosage	0.5-2.5 L/100 kg of cementations materials
Air entrainment	Typically less than 2%additional air is entrained above control mix at normal dosages.

Table (10): The mix proportions used in preparing the test specimens

Mix Notation	W l/m^3	C kg/m^3	SF kg/m^3 (11% of cement)	W/(C+P)	F.A kg/m^3	CG kg/m^3	CQ kg/m^3	C D kg/m^3	CLS kg/m^3	S.P l/100kg cement
M1 (100%G)	175	450	50	0.35	820	840	---	---	---	1.2
M2 (100%Q)	175	450	50	0.35	820	---	840	---	---	2.5
M3 (100%D)	175	450	50	0.35	820	---	---	840	---	2.5
M4 100%LS	175	450	50	0.35	820	---	---	---	840	2.5
M5(50%G +50%Q)	175	450	50	0.35	820	420	420	---	---	2.0
M6(50%G +50%D)	175	450	50	0.35	820	420	---	420	---	2.0
M7(50%G +50%LS)	175	450	50	0.35	820	420	---	---	420	2.0

Table (11): Fresh concrete test results (slump flow, T 50cm slump flow, V-funnel and L-box)

Mix symbol	Type of aggregate	Slump flow		V-funnel		L-box
		T50cm (sec)	T50cm (sec)	Tf sec	Tf_{5min} sec	BR(h_2/h_1)
M1(Ref.)	Gravel	665	5	9	12	0.81
M2	Quartzite	770	2.5	17	19	0.93
M3	Dolomite	750	3	18	21	0.947
M4	Limestone	745	3	16	19	0.957

M5	50%G+50%Q	725	3.5	11	14	0.9
M6	50%G+50%D	720	4	12	16	0.89
M7	50%G+50%LS	710	4	10	13	0.9

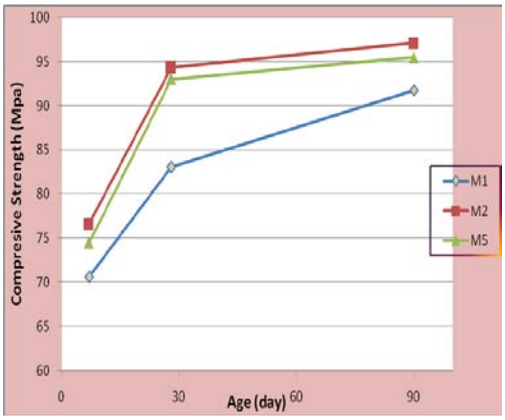
*Permissible limits according to EFNARK **2002** guidelines

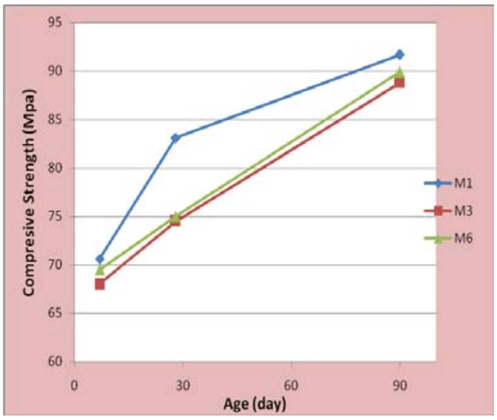
Table (12): Compressive strength and splitting tensile strength results for all SCC mixes.

Mix symbol	Type of aggregate	Compressive strength (MPa)			Splitting tensile ft (MPa)		
		7-day	28 day	90-day	7-day	28 day	90-day
M1(Ref.)	Gravel	70.6	83.1	91.7	4.35	5.25	5.9
M2	Quartzite	76.6	94.3	97.1	5	5.8	6.5
M3	Dolomite	68	74.5	88.8	4.1	5	5.5
M4	Limestone	56	63	75	3.2	3.5	4.4
M5	50%G+50%Q	74.5	93	95.5	4.5	5.5	6.1
M6	50%G+50%D	69.5	75	89.9	4.2	5.1	5.6
M7	50%G+50%LS	63	73.3	78.1	3.55	4.3	5

Table (13): Ultrasonic pulse velocity results for all SCC mixes.

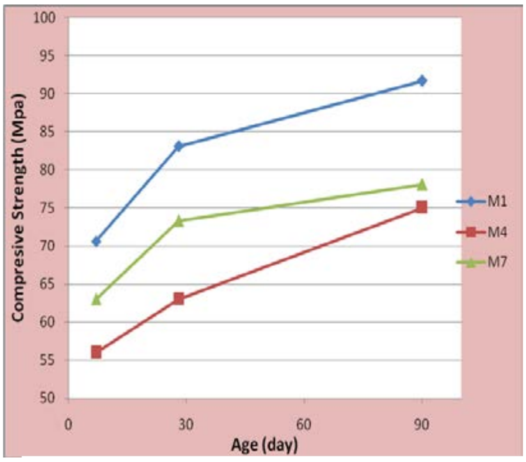
Mix symbol	Type of aggregate	Flexural strength fr (Mpa)			U.P.V (km/sec)		
		7-day	28 day	90-day	7-day	28 day	90-day
M1(Ref.)	Gravel	7.6	8.5	9.2	4.84	4.98	5.08
M2	Quartzite	8.7	9.7	10.6	4.95	5.08	5.14
M3	Dolomite	7.2	8	8.6	4.76	4.92	5.04
M4	Limestone	5.4	6.2	6.5	4.7	4.8	4.99
M5	50%G+50%Q	8.4	9.3	10.1	4.9	5.06	5.12
M6	50%G+50%D	7.4	8.2	8.8	4.84	4.93	5.05
M7	50%G+50%LS	6.5	7.4	8	4.7	4.88	5.02

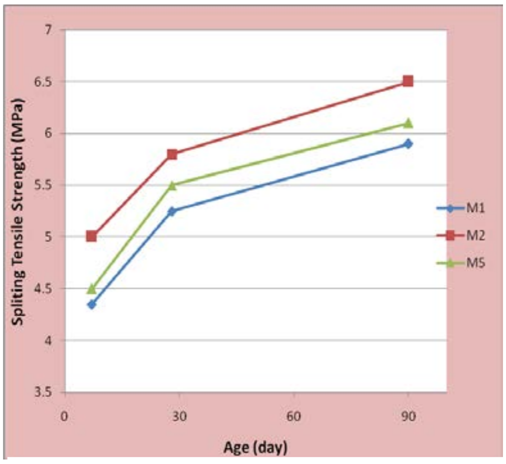




Figure(1): Development of compressive strength with age for mixes contain crushed quartzite.

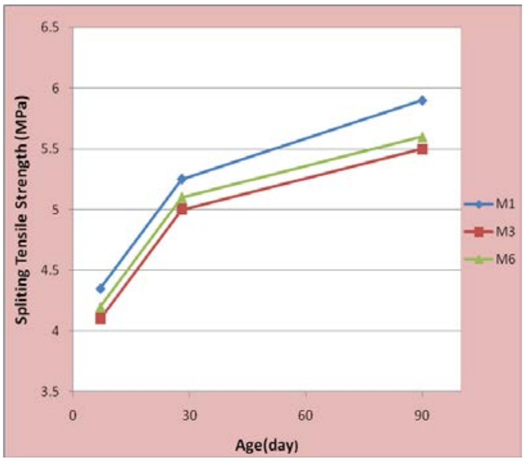
Figure(2): Development of compressive strength with age for mixes contain crushed dolomite.

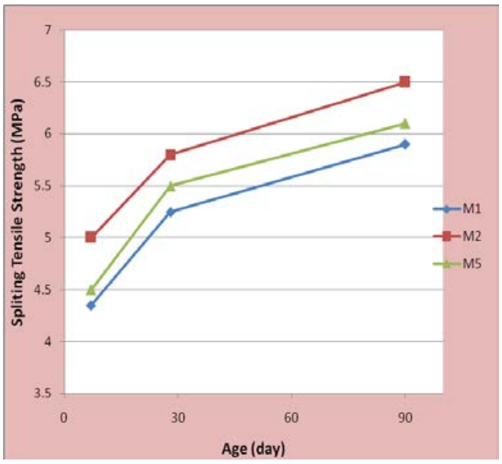




Figure(3): Development of compressive strength with age for mixes contain crushed limestone.

Figure(4): Development of splitting tensile strength with age for mixes contain crushed quartzite.





Figure(5): Development of splitting tensile strength with age for mixes contain crushed dolomite.

Figure(6): Development of splitting tensile strength with age for mixes contain crushed limestone.

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