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Properties of Self Compacting Concrete Containing Limestone Powder as Replacement of Sand

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Abstract

In this paper the properties of Self Compacting Concrete (SCC) was investigated using white cement and lime stone powder as fine aggregate instead of sand. All mixtures were proportioned with constant amount of (cement, lime stone powder, coarse aggregate and silica fume). While the glass powder, ceramic powder and glue were used as additives in different proportions from cement weight. The study focuses on comparison of fresh properties for self compacting concrete using two types of testing flow test and J-ring test. Whereas the hard concrete properties tests limited to compressive strength.

The results leading to some developing in fresh properties and hard properties of self compacting concrete due to adding the additives. The best spread ability obtained at adding glue (4%) from cement weight. While the glass powder and ceramic powder affect to hard properties, adding ceramic powder increased the compressive strength at rates between (10-20) % from cement weight and adding glass powder modified the compressive strength at rates more than (20)% from cement weight.

الخلاصة

في هذا البحث تم دراسة خواص الخرسانة ذاتية الرص باستخدام السمنت الأبيض ومسحوق الحجر الجيري كبديل للرمل. تم تثبيت كميات السمنت ومسحوق الحجر الجيري والحصو ومسحوق بخار السيليكا لجميع الخلطات, في حين تم إضافة مسحوق الزجاج ومسحوق السيراميك والغراء كمواد مضافة بنسب مختلفة من وزن السمنت. ولغرض دراسة الخواص الطرية للخرسانة ذاتية الرص تم إجراء فحص الجريان وفحص ما يسمى (J-ring) للخرسانة, بينما اختصرت دراسة الخواص الصلبة على مقاومة الانضغاط.

النتائج التي تم الحصول عليها أظهرت بعض التطور في خواص الخرسانة ذاتية الرص الطرية والصلبة باستخدام المضافات, حيث أظهرت النتائج بأن افضل انتشار للخرسانة الطرية تحققت عند إضافة الغراء بنسبة (4%) من وزن السمنت. في حين كان تأثير استخدام مسحوق الزجاج ومسحوق السيراميك على الخواص الصلبة. فعند استخدام مسحوق السيراميك تبين أن إضافة السيراميك بنسب (10-20)% من وزن السمنت قد حسنت من مقاومة الانضغاط في حين بدأت مقاومة الانضغاط بالتحسن عند إضافة مسحوق الزجاج بنسب أعلى من (20%) كإضافة من وزن السمنت.

1. Introduction

Self Consolidating Concrete (SCC), also known as self compacting concrete, is a highly flowable, non-segregating concrete that can spread into place, fill the formwork and encapsulate the reinforcement without any mechanical consolidation. Some of the advantages of using SCC are; can be placed at a faster rate, improved and more uniform architectural surface finish, improved consolidation around reinforcement and reduction or elimination of vibrator noise potentially increasing construction hours in urban areas [1].

SCC, was first introduced in the late 1980's by Japanese researchers, is highly workable concrete that can flow under its own weight through restricted sections without segregation and bleeding. Such concrete should have a relatively low yield value to ensure high flow, a moderate viscosity to resist segregation and bleeding, and must maintain its homogeneity during transportation and placing to ensure adequate structural performance and long term durability. The successful development of SCC must ensure a good balance between deformability and stability. Researchers have set some guidelines for mixture proportioning of SCC, which include i) reducing the volume ratio of aggregate to cementitious material; (ii) increasing the paste volume and water-cement ratio; (iii) carefully controlling the maximum coarse aggregate particle size and total volume; and (iv) using various viscosity enhancing admixtures [2, 3].

For SCC, it is generally necessary to use super-plasticizers in order to obtain high mobility. Adding a large volume of powdered material or viscosity modifying admixture can eliminate segregation. The powdered materials that can be added are fly ash, silica fume, lime stone powder, glass filler and quartzite filler. Since, self-compatibility is largely affected by the characteristics of materials and the mix proportions, it becomes necessary to evolve a procedure for mix design of SCC [4&5]. Okamura and Ozawa have proposed a mix proportioning system for SCC. In this system, the coarse aggregate and fine aggregate contents are fixed and self-compactibility is to be achieved by adjusting the water /powder ratio and super plasticizer dosage.

The coarse aggregate content in concrete is generally about 50 percent of the total solid volume, the fine aggregate content is about 40 percent of the mortar volume and the water /powder ratio is assumed to be 0.9-1.0 by volume depending on the properties of the powder and the super plasticizer dosage. The required water /powder ratio is determined by conducting a number of trials. One of the limitations of SCC is that there is no established mix design procedure yet [6]. Several test procedures have been successfully employed to measure the plastic properties of SCC, such as slump flow, J-ring, V-funnel and L-Box are presented [7,8 ,9&10].

2. Experimental Work

2-1. Materials

2-1-1. Cement:

The used cement was white Portland cement in order to product architectural purpose concrete; conform to standard Iraqi specifications, it produced in Adana factory in Turkey. The physical properties shown in table (2.1) and the chemical composition shown in table (2.2)

2-1-2. Gravel:

Local river gravel was used, passing sieve (12.5 mm). It has specific gravity (2.65), density (1.64 g/cm3) and absorption ratio (2.2 %). Table (2.3) shows the gravel sieve analysis.

2-1-3. Lime stone:

Lime stone powder passing sieve No. (2.36 mm) is used as fine aggregate and it's available in Iraq widely. Also it has low cost comparing with sand.

2-1-4. Silica fume:

Silica fume is an extremely fine, spherical powder, that was used as an additive for improving concrete performance. Gray colored un-deified silica fume was used percentage of Sio2 (98.5%).Table (2.2) shows it's chemical composition.

2-1-5. Viscocrete (super plasticizer):

Sika viscocrete (5W) is a new technology product suitable for water impermeability, at rate of (30-40%) in SCC production. Dosage of using (1-2%) of the cement weight for SCC. It's color light brown and the density (1.11 kg/l).

2-1-6. Glass powder :

Glass powder passing sieve No.(0.15 mm) was as additive to SCC mix. Waste glass is considered one of solid environmental pollution; it's crashed by Los Angeles Abrasion Machine. Table (2.2) shows glass chemical composition.

2-1-7. Ceramic Powder:

Ceramic powder passing sieve No.(0.15 mm) was as additive to SCC mix. Construction actions waste ceramic crashed by Los Angeles Abrasion Machine. This material gives the concrete mix more strength and connection between it's compound [11]. Table (2.2) shows ceramic chemical composition.

2-1-8. Glue:

glue which used in wood works, From local markets.

2-1-9. water:

drinking water .

Table (2.1) Physical Properties of Cement

Physical property	**Results obtained**	IQS 5/1984
Fineness (m^2/kg)	245	230 min
Vicat initial setting time (minutes)	55	45 min.
Vicat final setting time (hours)	6:45	10 max.
Compressive strength 7-days (MPa)	17.1	15 min
Compressive strength 28days(MPa)	27.3	23 min
Specific gravity	3.15	

Table (2.2) Chemical composition of Cement, glass, ceramic and silica fume.

Composition %	Portland cement	Glass powder	Ceramic powder	Silica fume
Sio_2	21.2	70.4	82.7	98.5
Al_2o_3	6.5	1.9	8.53	0.01
Fe_2o_3	2.5	1.2	4.88	0.01
Cao	63	10.3	0.36	0.25
Mgo	2.75	0.19	0.58	0.01
K_2o	0.45	0.46	1.4	0.01
Na_2o	0.24	14	0.02	0.01
So_3	3.1	----	---	0.24
C_3A	13.6	----	---	---

Table (2.3) Coarse aggregate grading

Sieve size	Percentage Retained	Cumulative Percentage Retained	Cumulative Percentage Passing	ASTM Range (C33) Size (12.5-2.36)
19	0	0	100	100
12.5	0	0	100	90 -100
9.5	53.8	53.8	46.2	40-70
4.75	44.8	98.6	1.4	0-15
2.36	1	99.6	0.4	0-5

2-2: Mix design

Self-compactability can be largely affected by the characteristics of materials and the mix proportion. A rational mix-design method for self-compacting concrete using a variety of materials is necessary. The main content of concrete (coarse aggregate, fine aggregate, cement) contents are fixed so that SCC can be achieved easily by adjusting waste materials powders additives and the water powder ratio only. In this work, different mixtures of SCC were casted and tested to find out the fresh properties such as value of slump flow, J-ring and hardened concrete properties such as 28 days compressive strength. Fresh properties amount are in acceptable limited from European Specifications and Guidelines for Self Compacting Concrete [9]. For the experiments, the mixture proportions adopted and are reported in Tables [2.4].

Table [2.4] Experiment Mixes

Mixes	Cement Kg/m^3	Lime stone powder Kg/m^3	Coarse Agg. Kg/m^3	Silica – fume % from cement	Visco-crete % from cement	W/c	Glue % from cement	Glass-powder % from cement	Ceramic-powder % from cement
A	470	700	1070	15	2	0.32	0	0	0
B	470	700	1070	15	2	0.32	(4%)	0	0
C	470	700	1070	15	2	0.32	(6%)	0	0
D	=	=	=	=	=	=	(8%)	0	0
E	=	=	=	=	=	=	0	(10%)	0
F	=	=	=	=	=	=	0	(20%)	0
G	=	=	=	=	=	=	0	(30%)	0
H	=	=	=	=	=	=	0	(40%)	0
I	=	=	=	=	=	=	0	0	(10%)
J	=	=	=	=	=	=	0	0	(20%)
K	=	=	=	=	=	=	0	0	(30%)
L	=	=	=	=	=	=	0	0	(40%)

2-3: Testing and specimens

2-3-1: Fresh concrete tests

2-3-1-1 Slump Flow Test:

The slump flow test aims to investigate the filling ability of SCC. It measures two parameters: flow spread and flow time T50 (optional). The former indicates the free, unrestricted deformability and the latter indicates the rate of deformation within a defined flow distance. The equipments composed of:

- Base plate of size at least (900 × 900 mm), made of impermeable and rigid material (steel or plywood) with smooth and plane test surface, and clearly marked with circles of (Ø200mm) and (Ø500mm) at the centre, as shown in figure(1).
- Abrams cone with the internal upper/lower diameter equal to (100/200 mm) and the height of (300 mm).
- Stopwatch with the accuracy of (0.1) second for recording the flow time T50.
- Ruler (graduated in mm) for measuring the diameters of the flow spread.

The cone is then filled with concrete. No tamping is done. Any surplus concrete is removed from around the base of the concrete. After this, the cone is raised vertically and the concrete is allowed to flow out freely. The time of spread to (500 mm) circle measured T50 and the diameter of the concrete in two perpendicular directions is measured. The average of the two measured diameters is calculated. This is the slump flow in mm. This test according to European Research project "Testing-SCC" (GRD2-2000-30024/G6RD-CT-2001-00580)[9].

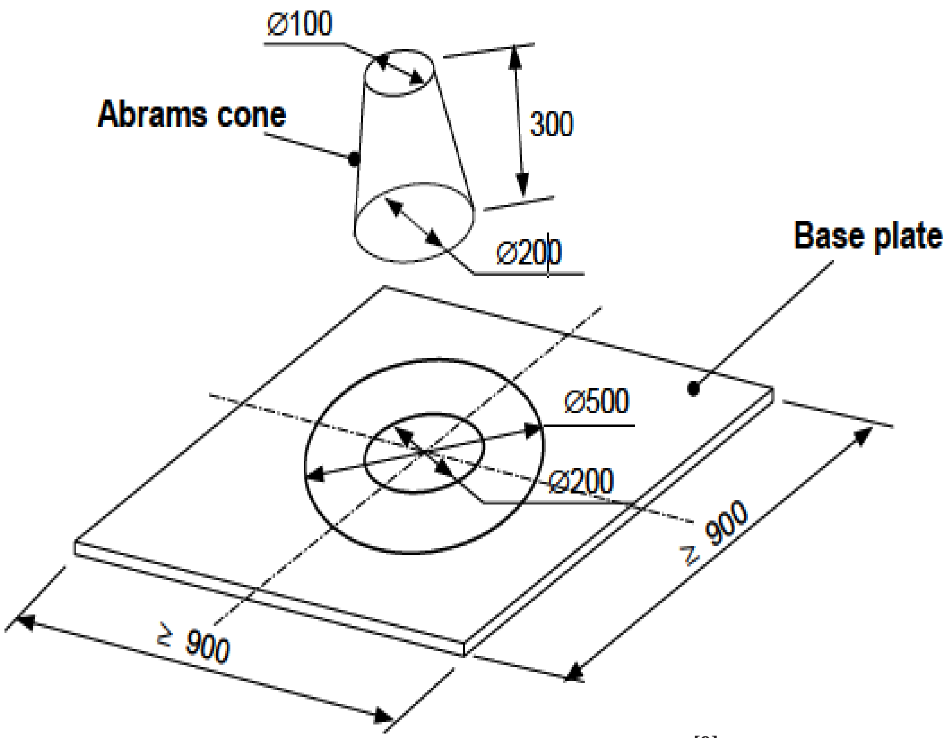
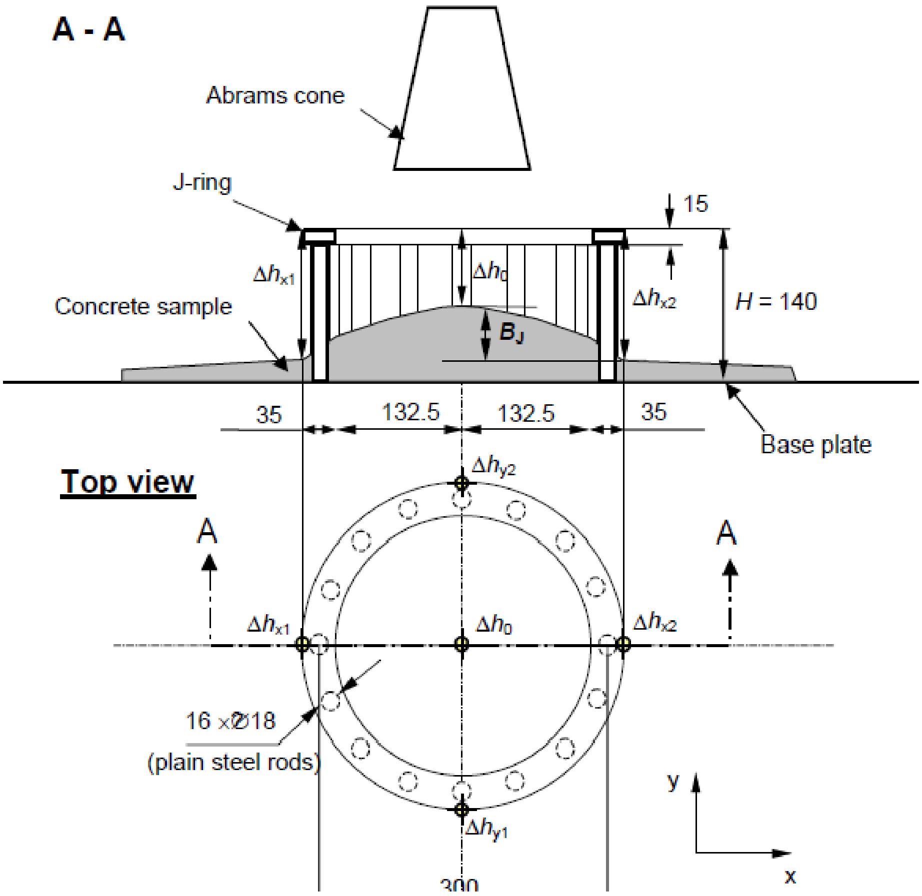


Figure (1): Flow test apparatus [9]

2-3-1-2 J-ring (Reference method for filling and/or passing ability)

The J-ring test aims to 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 results from two different portions of sample. J-ring with the dimensions and compositions as shown in Figure (2) , where the positions for the measurement of height differences are also given. Straight rod for aligning the reference line in the measurement, with a length of about (400 mm) and at least one flat side having the flexure less than 1 mm. This test according to European Research project "Testing-SCC" (GRD2-2000-30024/G6RD-CT-2001-00580)[9]



Figure(2) :J-ring Flow test apparatus [9]

2-3-2: Hardened concrete tests

In general, in national and international Codes concrete is classified on the base of its compressive strength, because compressive strength is the most important mechanical property of concrete for the most applications. Specimens (100×100×100 mm) were used to test compressive strength at two ages (7 and 28) days. This test according to (BS 1881:part 116:1983).

3: Results and Discussions

3-1: Fresh Concrete Test Results:

Table [3] presents the results of workability tests, conducted to achieve SCC. Preparation of the quantitative substances first is complete, which enters in forming of the concrete mixture, which includes (white cement, lime powder, course Aggregate, water, super- plasticizers, silica fume and additive powders).

Table (3) Fresh concrete test results

Mix	Slump test		Jring				
	T50 sec	Max dia. (mm)	T 50 Sec.	Dia (mm)	Center height (mm)	Average edge (mm)	B_J mm
A	3:43	700	6:31	700	110	130	20
B	2:32	700	8:44	710	110	130	20
C	4:02	730-680	3:24	720-680	110	130	20
D	4:41	720-760	3	700-670	105	130	25
E	3:44	670-630	5:03	600-640	90	125	35
F	4:17	690-640	5:44	660-670	100	135	35
G	4:05	680-650	4:51	680-640	105	135	30
H	3:23	700-670	4:18	670-640	95	120	25
I	5:46	690-690	5:16	680-660	90	120	30
J	6:31	680-700	6:08	670-650	95	125	30
K	5:44	670-700	4:56	660-660	100	135	35
L	5:02	680-700	4:12	680-660	100	125	25

3-1-1: Slump Test

For the reference mix the slump flow time T50 was (3.43 sec) and the spread diameter (700 mm), the slump flow for all mixes Based on the inter laboratory test organized in the EU-project "Testing-SCC" (GRD2- 2000-30024/G6RD-CT-2001-00580) range of SCC represented in figures [3,4,5&6]. The results of slump flow show that the adding Glue increased flow ability at (4%) then decreased it for more dosages, while the spread ability increased clearly and gives more cohesion between the compounds of the concrete and it was increase the consistency. Adding Glass and ceramic powders in different percentages (10, 20, 30 and 40 %) besides the other materials decreased the flow ability and spread ability.

3-1-2: J-ring Test

Compared to reference mix the figures [7,8,9&10] discern that the adding the glue and the waste powder (glass , ceramic) have the same effect to flow ability and spread ability that behavior during test by slump flow test, while at testing the passing ability which express aggregate segregation the glue pronounce a good behavior to prevent aggregate segregation.

3-2: Hardened Concrete Test Results (Compressive Strength):

Figure [11] shows the compressive strength for SCC with different dosages of glue (4,6 and 8 %) at two ages (7) days and (28) days. The mixtures containing glue are indicate lower compressive strength, at (7) days age the reduction in compressive strength around (10- 20%) of without glue mix SCC, but at (28) days age the reduction in compressive strength between (5-8%) only, this reduction may be caused due to blockage the porosity in the aggregate surface which deal to low cohesion between cement paste and gravel partials. Whereas, figure [12] shows the compressive strength for mixes containing ceramic powder at two ages (7&28) days, the ceramic powder added as percentage from cement weight with rates (10,20,30 and 40)%. The figure explain, adding ceramic powder 10 % increased the compressive strength about (25%) from the reference mix, but with more quantities until (40%) additive the compressive strength decreased in bout ages (7 &28) days. This behavior may be causes to ceramic powder ability to water absorption which lead to negative affect with large rate adding. Also the glass powder added as percentage from cement weight with rates (10,20,30 and 40)%). The figure [13] shows the effect of adding glass powder increased the compressive strength at (20%) or more rates, this increase in compressive strength arrived to (20%) when glass powder added (40%). This behavior may be causes to the low water absorption for glass powder.

4: Conclusions

1- SCC was produced from limestone powder as replacement of sand gives low cost SCC with good efficiency.

2- The results show that the adding Glue increased flow ability at (4%) then decreased it for more dosages, while the spread ability and consistency increased. Whereas, compressive strength decreased with increasing glue dosages.

3- During flow test the results show that, adding Glass and ceramic powders in different percentages (10,20,30 and 40%) as additives decreased the flow ability and spread ability.

4- The results show that, the good added proportion for ceramic powder was (10%), this proportion increased the compressive strength about (25%).

5- The results show that, adding glass powder increased the compressive strength at (20%) or more proportion, this increase in compressive strength arrived to (20%) when glass powder adding (40%).

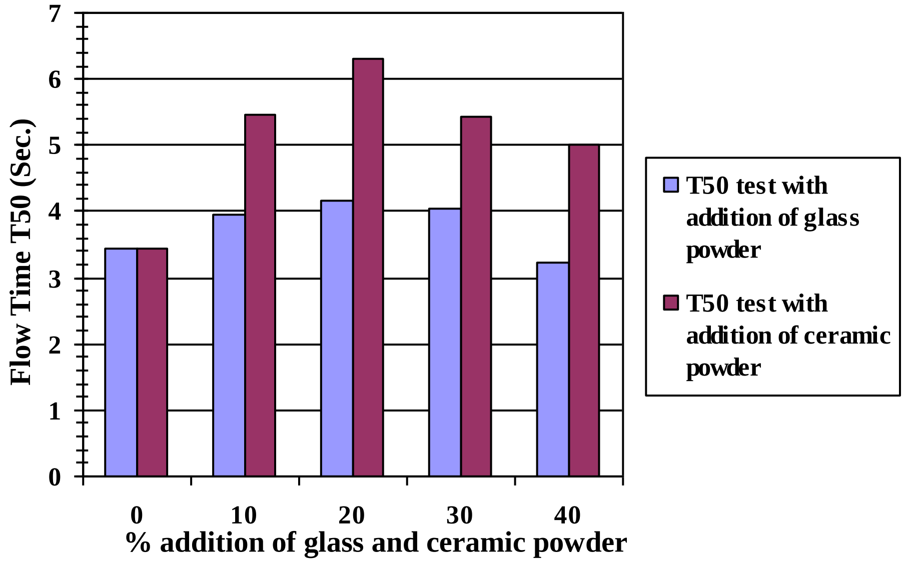


Figure (3): Relationship between flow time of slump test and (%) of addition of glass and ceramic powder

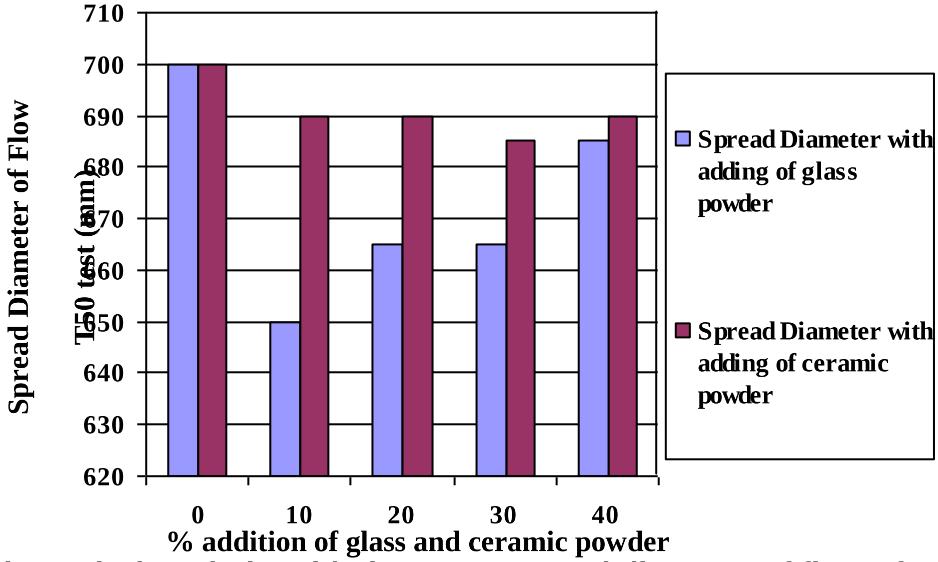


Figure (4): Relationship between spread diameter of flow of slump test and (%) of addition of glass and ceramic powder

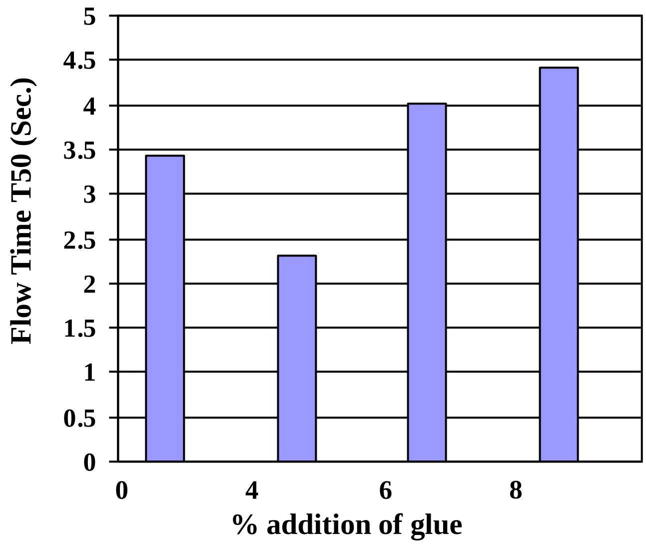


Figure (5): Relationship between flow time of slump test and (%) of addition of glue

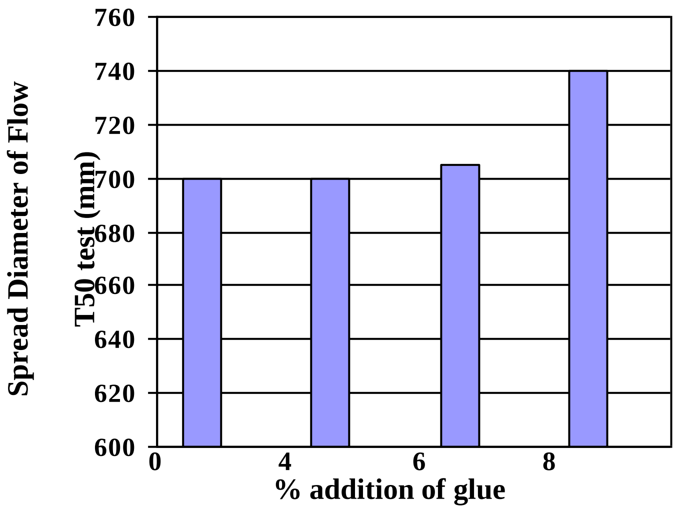


Figure (6): Relationship between spread diameter of flow of slump test and (%) of addition of glue

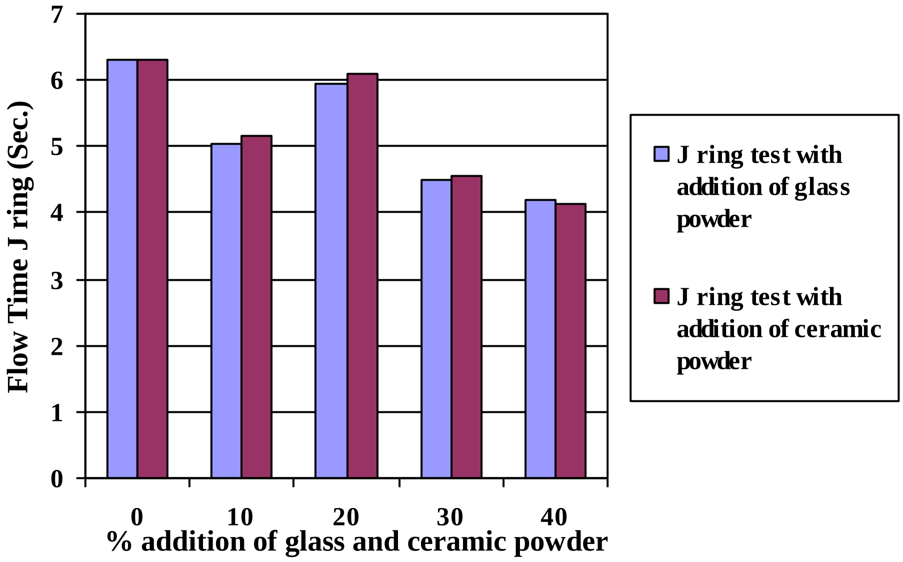


Figure (7): Relationship between flow time of J ring test and (%) of addition of glass and ceramic powder

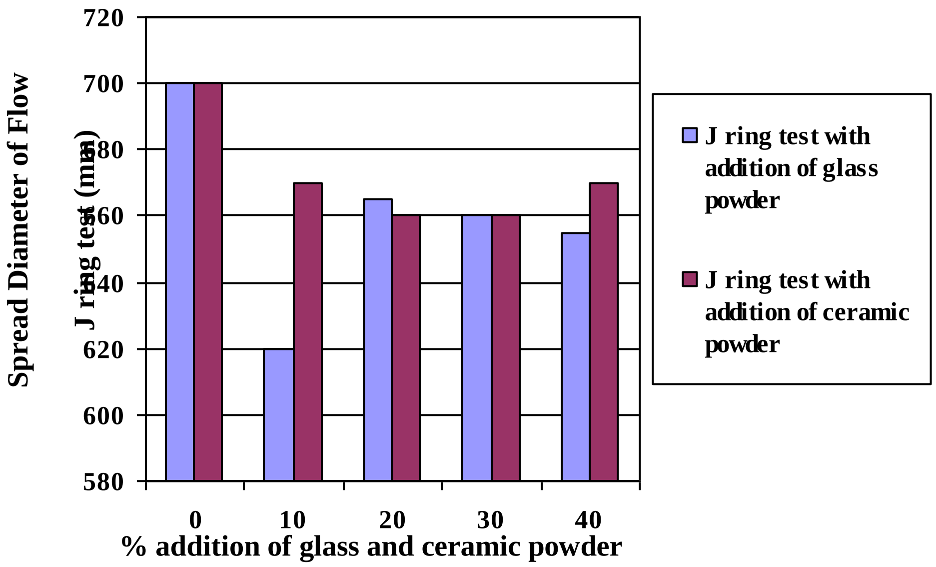


Figure (8): Relationship between spread diameter of flow of J ring test and (%) of addition of glass and ceramic powder

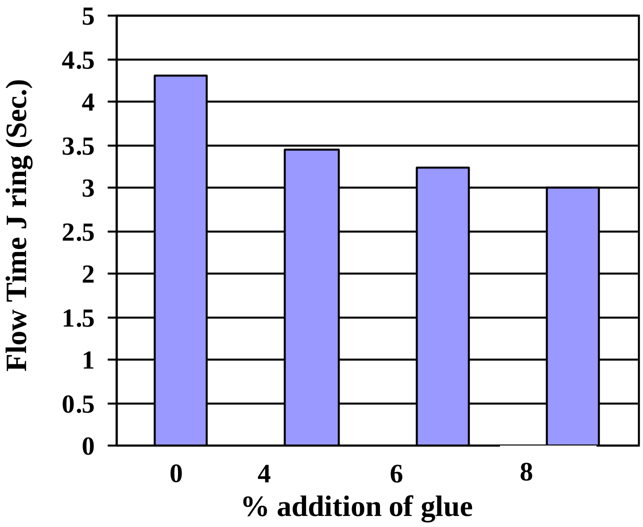


Figure (9): Relationship between flow time of J ring test and (%) of addition of glue

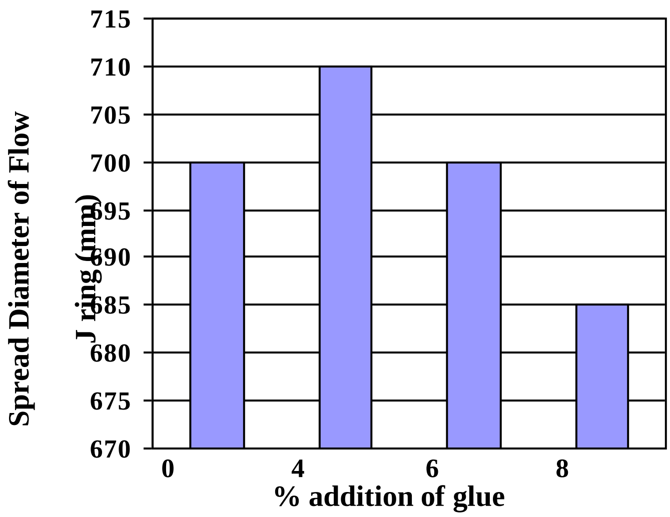


Figure (10): Relationship between spread diameter of flow of J ring and (%) of addition of glue

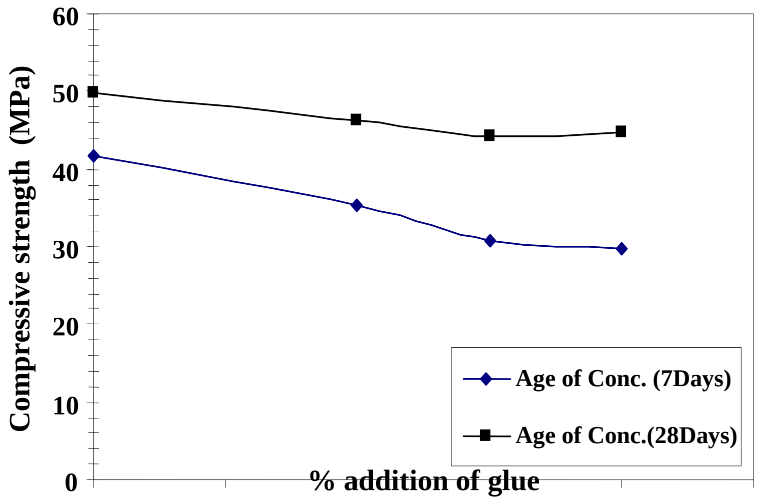


Figure (11): Effect of addition of glue on the compressive strength for SCC at (7days)

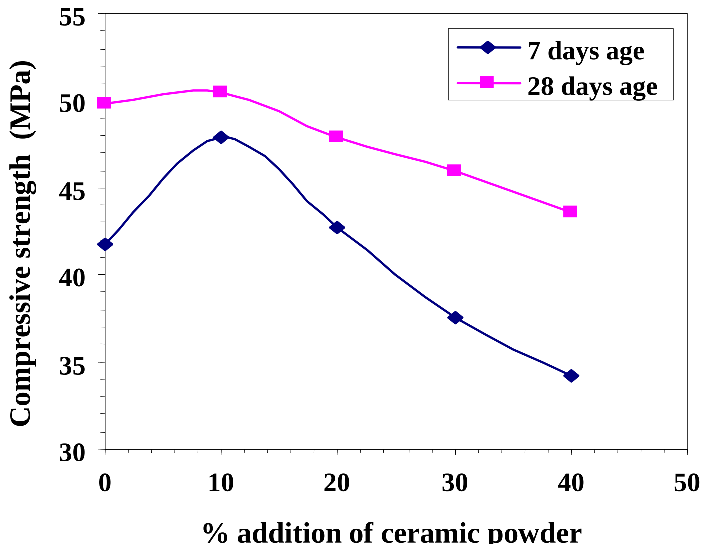


Figure (12): Effect of addition of ceramic powder on the compressive strength for SCC

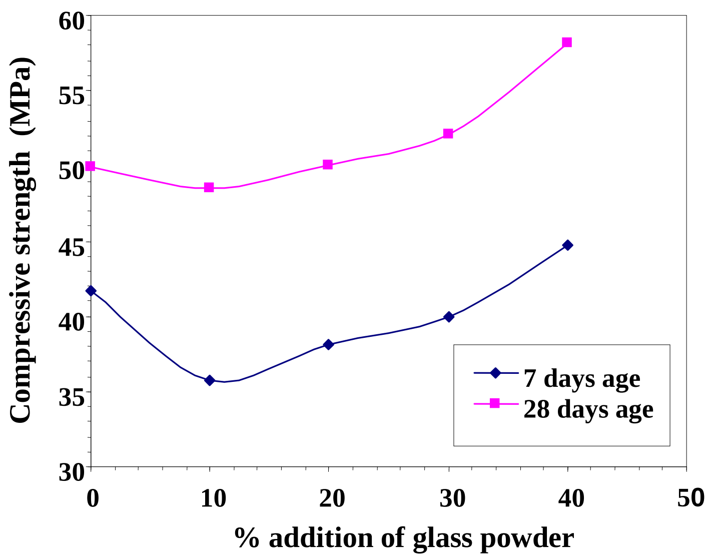
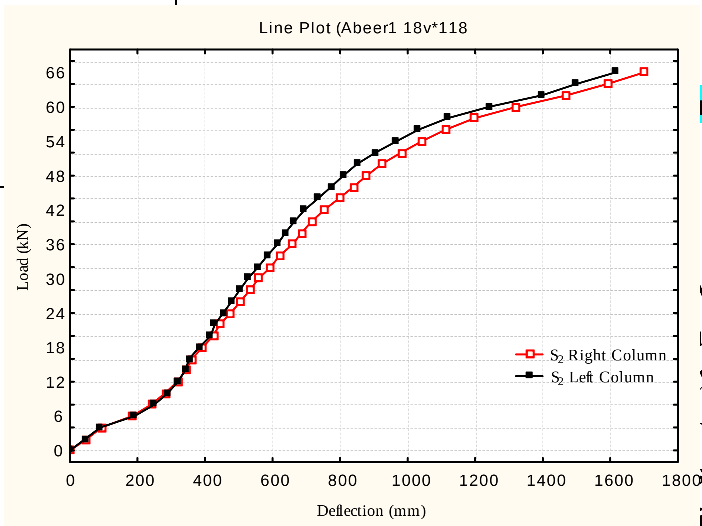


Figure (13): Effect of addition of glass powder on the compressive strength for SCC



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