Assessing Saturated Porcelinite As Internal Curing Agent In Self Compacted Concrete

Lecturer Dr. Abeer Abdulqadir Salih
Civil Engineering Department, Baghdad University, Iraq
E-mail drabeersalih@yahoo.com

Abstract:

*Self compacted concrete (SCC) describes concrete with the ability to compact itself only by means of its own weight without the requirement of vibration. It fills all recesses reinforcement spaces and voids even it highly reinforced concrete members and flow free of segregation nearly to a level balance. This research aims to assess the fresh and hardened properties of SCC using saturated porcelinite as curing agents for internal curing of SCC.Five mixes with different percentage of replacement of saturated porcelinite range from (0, 12, 16, 20, 24) % of fine aggregate volume of the same grading , were prepared ,each mix tested in fresh state with slump test .Then 120 concrete cubes of (100*100*100)mm for different mixes were tested for ,density and compressive strength, at (7,28,60 and 90) days of water and air curing. Results show that the slump decreases as saturated porcelinite content increase ,density and compressive strength increase with increasing saturated porcelinite for all age's .the rate of increasing is (10.1-30.0) % and (8.2-25.7) % for compressive strength of cubes cured in water and air respectively. The optimum percentage of saturated porcelinite which gave higher density and compressive strength was 20%.*

Keywords: saturated porcelinite, internal curing, curing agents, self compacted concrete, slump flow, compressive strength.

تقييم البورسيلنايت المشبع كعامل إنضاج داخلي في الخرسانة ذاتية الرص

م.د . عبير عبد القادر صالح
جامعة بغداد /كلية الهندسة /قسم الهندسة المدنية

الخلاصة :

الخرسانة ذاتية الرص هي الخرسانة التي لها القدرة على الرص تحت تأثير وزنها فقط دون الحاجة الى استخدام الهزازات كذلك لها القدرة على الانسياب خلال حديد التسليح الكثيف دون حدوث اي انعزال يهدف هذا البحث الى تقييم بعض خواص الحالة الطرية والمتصلبة للخرسانة ذاتية الرص عند استخدام بورسيلنايت مشبع بالماء كعامل انضاج للحصول على انضاج داخلي للخرسانة ذاتية الرص. تم تحضير 5 خلطات خرسانية باستخدام نسب استبدال مختلفة من البورسيلنايت المشبع بالماء تراوحت بين (0، 12، 16، 20، 24) % من حجم الركام الناعم وبنفس التدرج فحصت بحالتها

الطرية بفحص الهطول بعدها تم صب 120 مكعب خرساني باستخدام قوالب حديدية بابعاد (100×100×100)ملم وتم إجراء فحص الكثافة ومقاومة الانضغاط للخلطات أعلاه بأعمار (7، 28، 60 و90)يوم تحت ظروف إنضاج خارجي في الماء والهواء.أوضحت النتائج انخفاض الهطول وزيادة الكثافة ومقاومة الانضغاط بزيادة محتوى البورسيلنايت المشبع وفي كل الأعمار وتراوحت نسب الزيادة في مقاومة الانضغاط بين (30.0-10.1) %و (25.7-8.2) % عند الإنضاج بالماء والهواء على التوالي.النسبة المثلى لاستبدال البورسيلنايت المشبع والتي تعطي أعلى كثافة ومقاومة انضغاط كانت 20 %.

كلمات الدلالة: بورسيلينايت مشبع ، إنضاج داخلي، عوامل إنضاج، خرسانة ذاتية الرص، انسيابية الهطول، مقاومة الانضغاط.

Introduction:

Self compacting concrete SCC can be defined as a " a concrete that is able to flow under its own weight and completely fill the formwork, while maintaining homogeneity even in the presence of congested reinforcement, and then consolidating without the need for vibrating compaction" [**1**]

Curing is maintenance of satisfactory moisture content and temperature in concrete for a period of time immediately following placing and finishing so that the desired properties may develop. Curing has a strong influence on the properties of hardened concrete proper curing will increase durability, strength, water tightness, abrasion resistance, volume stability, and resistance to freezing and thawing and deicers. Internal moist curing refers to methods of providing moisture from within the concrete as opposed to outside the concrete. This water should not affect the initial water to cement ratio of the fresh concrete. Lightweight (low-density) fine aggregate or absorbent polymer particles with an ability to retain a significant amount of water may provide additional moisture for concretes prone to self desiccation when more complete hydration is needed for concretes, with low water to cement ratio (around 0.3 or less) 60 kg/m^3 to 180 kg/m^3 of saturated lightweight fine aggregate can provide additional moisture to extend hydration, resulting increase in strength and durability. All of the fine aggregate in the mixture can be replaced with saturated lightweight fine aggregate to maximize internal moist curing. Internal moist curing must be accompanied by external curing methods[2].Jagannadha Kumar et al (2012) refer that there are two major methods available for internal curing of concrete. The first method uses saturated porous light weight aggregate (LWA) in order to supply an internal source of water, which can replace the water consumed by chemical shrinkage during cement hydration. The second method uses poly – ethylene glycol (PEG) which reduces the evaporation of water from the surface of concrete and also helps in water retention.[3]. IC (internal curing) attracted widespread research interest and was experimentally proved capable to eliminate or considerably diminish autogenously shrinkage. It was demonstrated that it could be successfully applied to obtain improved high performance concrete with reduced sensitivity to crack. Later, IC was extended to utilize additional materials as IC agents. Super absorbent polymer (SAP), wooden- derived materials, and recycled aggregates were reported as appropriate curing agents for IC of HPC.The function of IC agent is to serve as internal storage for curing water. For this reason, IC agents are usually very porous materials with weak mechanical properties. In the most cases, detrimental effect of IC on early- age strength is reported. However, the effect of IC on the strength of matured concrete is variable and depends on the IC agent type and content, presence of chemical admixtures and aggregate content. A considerable reduction of elasticity modulus is reported in the literature, when IC was applied even in cases where strength was not reduced[4].

Al-Feel and Al-Saffar 2008 were studied the effect of curing methods on the compressive, splitting and flexural strength of SCC in comparison to normal concrete. The results showed that the water cured specimens gave highest compressive, splitting and flexural strength than specimens cured by air about 11%, 10% and 11% for SCC at 28 days respectively, results also show that SCC gave higher compressive strength of 30% at 28 days as compared to that of normal concrete cured in water and this value increased for specimens cured in air[5]. Laith (2009) studied effect of saturated light weight aggregate (porcelinite and thermostone), as internal curing materials, on properties of fresh and hardened concrete. Based on his results, 15% and 10% of porcelinite and theromstone aggregate as partial sand replacement realize better properties of concrete respectively[6]. Famili,H. et al (2012) study the effect of internal curing on properties of high strength self consolidating concrete, they replaced 25% of normal weight coarse aggregate volume with saturated light weight aggregate of the same grading with W/B 0.28 and 0.33. Two modes of external curing moist and sealed were applied to test specimens after demolding. They concluded that there is a moderate reduction of 28 days compressive strength when using W/B 0.28, 18% reduction for moisture specimens and 11% reduction for sealed cured specimens. The corresponding values for 0.33 W/B mixture were 5% and 15% .They indicated that their conclusion agree with some researchers (Lam, H. and Hooton) and disagree with others (Kovler, K. and Jensen O.M)[7]. Igor et al (2012) were replaced (40, 60, 80) % of cement volume with glass C fly ash. To overcome concerned associated with slow set and early age strength development that are often expressed with the high volume fly ash mixtures (HVFA) the W/B by mass has been reduced from a conventional value of 0.42 to 0.3. Internal curing(IC) with pre wetted light weight aggregate was used to reduce shrinkage and increase hydration. By adopting this approach (lowering the W/B and using IC) IC HVFA mixtures show additional benefit that should permit their broader application[8].

Objective of the Study

The objective of this research is assessing the fresh and hardened properties of SCC using saturated porcelinite as curing agent for internal curing of SCC. The main aim is studying the effect of using saturated porcelinite, as internal curing agent by partial replacement of fine aggregate, on slump flow, density and compressive strength of SCC.

Characteristics Materials

Cement: Ordinary Portland cement manufactured by Tasluja cement factory was used in this research. **Tables (1& 2)** show the chemical and physical properties of the cement respectively. Tests are performed by the State Company of Geological Survey and Mining. The test results show that the cement confirms to the Iraqi specification No.5/1984[**9**].

Table (1) Chemical Composition of cement

Oxides	% by weight	Iraqi specification (I.Q.SNo.5/1984) [9]
CaO	60.78	--------
SiO_2	20.54	--------
Al2O3	5.88	--------
Fe2O3	3.28	--------
MgO	1.93	$\leq$ 5.0
SO3	1.87	$\leq$ 2.80
Na2O	0.28	--------
K2O	0.54	--------
Loss on ignition	3.47	$\leq$ 4.0
Insoluble residue	0.15	$\leq$ 1.5
Lime saturated Factor	0.85	0.66 - 1.02
Main compounds (Bogue's equations)		
C3S	41.74	--------
C2S	27.65	--------
C3A	10.04	--------
C4AF	9.97	--------

Table (2) Physical properties of cement

Physical properties	Test result	Iraqi specification (I.Q.S No.5/1984)
Specific surface area, Blain's method, m²/kg	**320**	**$\geq$ 230**
Soundness, Autoclave's Method, %	**0.03**	**< 0.8**
Setting time, Vicat's method Initial setting hr:min Final setting hr:min	**2:30** **5:45**	**$\geq$ 45 min** **$\leq$ 10 hours**
Compressive strength 3 days N/mm² 7 days N/mm²	**19.2** **25.1**	**$\geq$ 15** **$\geq$ 23**

Fine Aggregate:

Natural sand brought from Al-ukhaider region was used. **Tables (3&4**) show the gradation and physical properties of fine aggregate respectively. Test results show that the fine aggregate confirm to the Iraqi specification No.45/1984[**10**].

Table (3) Grading of fine aggregate

Sieve No. (mm)	% passing	Iraqi specification (I.Q.S No.45/1984) Zone (2)
4.75	93.8	90-100
2.36	77.9	75-100
1.18	65.3	55-90
0.6	55.1	35-59
0.3	20.7	8-30
0.15	5.6	0-10

Table (4) Physical properties of fine aggregate

Physical properties	Test results	Iraqi specification (I.Q.S No.45/1984)
Fineness modules	2.82	
Specific gravity	2.57	
Sulfate content %	0.27	0.5 % (max.)
Absorption %	2.8	

Coarse Aggregate:

Rounded coarse aggregate with maximum size (10mm) was used in this research. Tables (5&6) show the gradation and physical properties of coarse aggregate respectively. Test results show that the coarse aggregate confirm to the Iraqi specification No.45/1984.

Table (5) Gradation of coarse aggregate

Sieve size (mm)	% Passing by weight	Iraqi specification (I.Q.S No. 45/1984) (5-20) mm
20	100	95-100
10	45.7	30-60
5	4.3	0-10

Table (6) Physical properties of coarse aggregate

Physical properties	Test results	Iraqi specification (I.Q.S No. 45/1984)
Specific gravity	2.65	
Sulfate content %	0.06	0.1% (max.)
Absorption %	0.83	

Porcelinite:

It is a light weight aggregate used as a partial replacement of fine aggregate in this research with (0, 12, 16, 20, 24) % of fine aggregate volume. **Table (7&8)** show physical and chemical properties of porcelinite aggregate which supplied from State Company of Geological Survey and Mining.

Table (7) Physical properties of porcelinite

Physical properties	Test results
Specific gravity	1.38
Loose density Kg/m3	810
Absorption %	32

Table (8) Chemical Composition of porcelinite

Oxides	% by weight
SiO_2	72.7
Fe_2O_3	0.85
Al_2O_3	3.3
TiO_2	6.9
CaO	5.9
MgO	0.18
SO_3	0.08
L.O.I	8.92

Mineral Admixture:

Silica fume (S.F.) used as mineral admixture in this research with 3% by weight of cement. **Table (9&10)** show the chemical composition and physical properties of silica fume respectively. Tests are performed by the State Company of Geological Survey and Mining

Table (9) chemical composition of silica fume

Oxides	% by weight
SiO_2	92.9
Al_2O_3	0.18
CaO	0.07
Fe_2O_3	0.004
SO_3	0.74

Table (10) physical properties of silica fume

Physical Properties	Test result
Specific surface area m^2/g	18
Bulk density g/cm^3	0.65
Specific gravity	2.02

Chemical Additives:

Viscosity modifying agent (VMA) used in this research was Glenium (51) with (0.9 %) by weight of cement. **Table (11)** shows some properties of this material according to data sheet of product.

Table (11) properties of Glenium

Specific property	Properties of (VMA)
color	Light brown
Density gm/cm3	1.1 @20 °C
pH	6.6
Viscosity	128±30 cps@20 °C

Water: Tap water is used of both mixing and curing of concrete.

Experimental program

The experimental program was designed to study the effect of using saturated porcelinite, as internal curing agent by partial replacement of fine aggregate, on slump flow, density and compressive strength of SCC. The SCC mixes were designed according to (The European Guidelines for Self Compacting Concrete 2005) [11]. The mix proportion for SCC mixes were (430:680:750) kg/m3 and w/p ratio was 0.39 by weight. The silica fume (S.F.) was 3%by weight of cement and the super plasticizer (SP) was 0.9% by weight of cement. Five mixes tested as slump flow, then 120 cubes mold of (100x100x100) mm were casted. After 24 hours of casting, some specimens were immersed in water and others were left in air until they were tested at (7, 28, 60 and 90) days after casting. Averages of three cubes were taken for each mix and age for density and compressive strength.

Results and Discussion

Properties of fresh concrete (slump flow)

Table (10) shows the results of slump flow test with different percentage of saturated porcelinite. It can be noticed that the slump flow of SCC mixes slightly decrease as saturated porcelinite increases. The rate of decreasing was (7.8%) when replaced saturated porcelinite with 24%.This agree with Famili ,H. et al (2012) [7].According to (The European Guidelines for Self Compacting Concrete 2005),these mixes have slump flow class SF1 (550-650)mm which use in housing slab, tunnel lining, piles and some deep foundation.

Table (10) Results of slump test with different percentage of saturated porcelinite

Saturated porcelinite (%)	0	12	16	20	24
Slump flow (mm)	605	594	582	571	558

Effect of Saturated Porcelinite on Bulk Density:

Table (11) and figures (1&2) show the bulk density results of hardened SCC cured in water and air respectively. Results show that the density slightly increases as saturated porcelinite increases until reaches an optimum value at 20% of saturated porcelinite, then it decreases with further increasing of this material. The rate of increasing at 20% saturated porcelinite is (0.8-1.1) % and (1.2-1.7) % for water and air curing respectively. Also the density slightly increases with curing time and the rate of increasing is (0.4-1.5) % and (0.4-0.6) % for water and air curing respectively. This may be attributed to that moisture in light weight aggregate (saturated porcelinite) causes increase in degree of hydration and decrease in porosity of the matrix and as a result the density increase. This agree with (Weber, S. and Reinhardt, H.W.1997) [12].The bulk density decreases up to 20% replacement of saturated porcelinite that because high replacement percentage of lightweight materials.

TABLE (11) Effect of saturated porcelinite on bulk density of SCC

Curing state	Porcelinite %	Bulk density (kg/m³)			
		7(day)	28(day)	60(day)	90(day)
Water curing	0 %	2490	2520	2530	2541
	12 %	2497	2531	2542	2553
	16 %	2505	2539	2550	2560
	20 %	2510	2545	2552	2562
	24 %	2493	2527	2536	2549
Air curing	0 %	2468	2475	2488	2502
	12 %	2486	2497	2506	2515
	16 %	2497	2514	2524	2539
	20 %	2500	2517	2526	2543
	24%	2485	2494	2503	2512

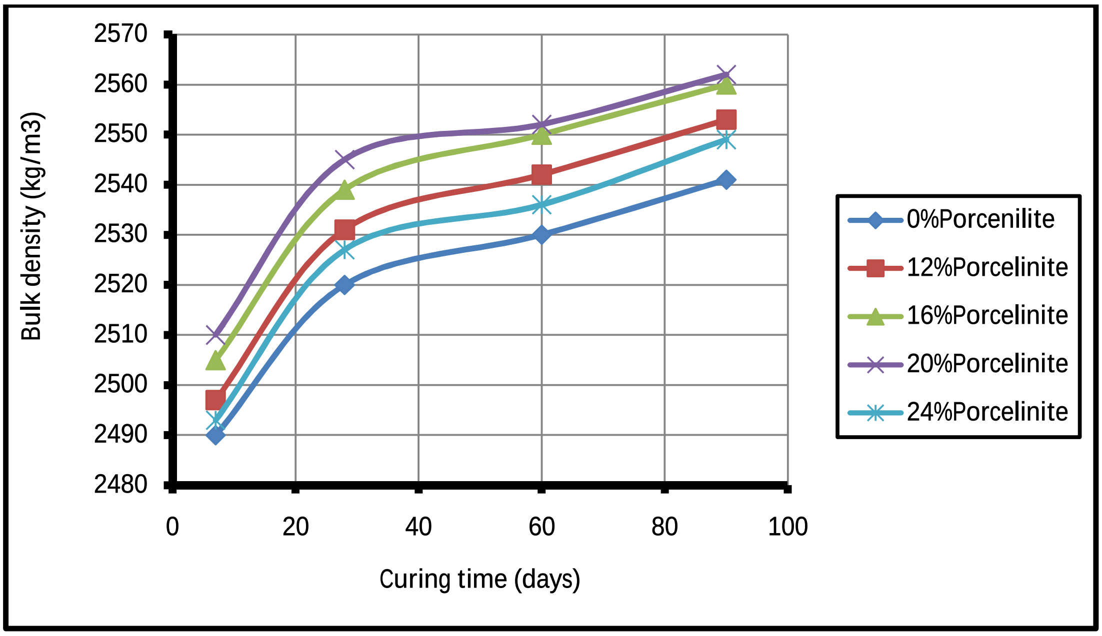

Fig. (1) Effect of saturated porcelinite on bulk density of SCC cured in water

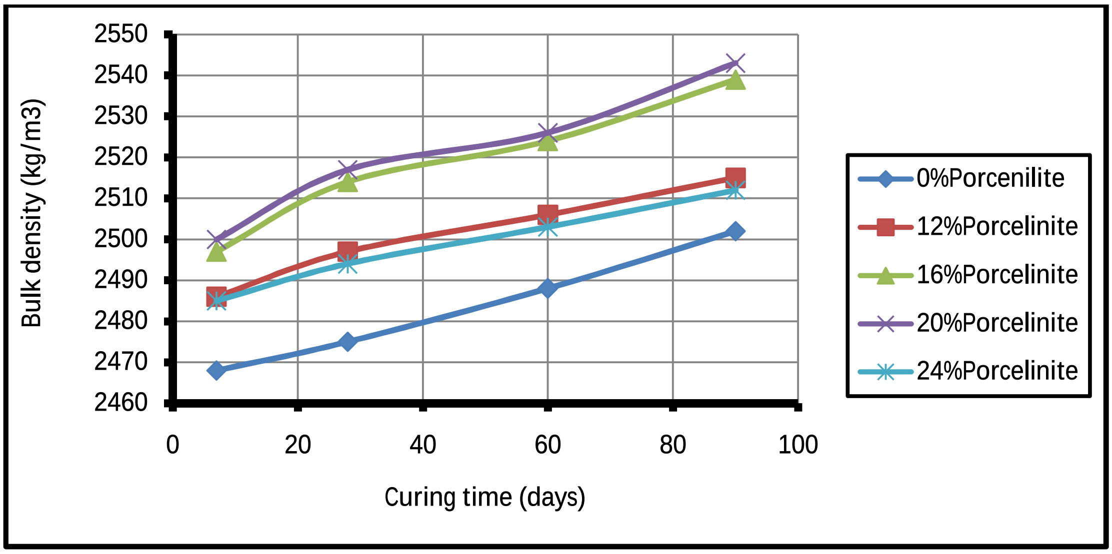

Fig. (2) Effect of saturated porcelinite on bulk density of SCC cured in air

Effect of Saturated Porcelinite on Compressive Strength:

Table (12) and **Figures (3&4)** show the results of compressive strength using saturated porcelinite in SCC. It can be noticed that the compressive strength increases as curing time and replacement percentage of porcelinite increase until reaches an optimum value at 20% porcelinite, it decreases with further increasing of this material. The rate of increasing at 20% saturated porcelinite is (10.1-30) % and (8.2-25.7) % for water and air curing respectively. Also the compressive strength increases with curing time and the rate of increasing is (25-62) % and (18.2-48.9) % for water and air curing respectively .This can be explain according to

Bentz et al (2005)) [13] who refer to that the presence of saturated porcelinite promote the hydration process because some of water in lightweight aggregate is readily available to migrate to the hydrated cement paste during curing and acts as internal curing agent which increase degree of hydration and increase compressive strength.

TABLE (12) Effect of saturated porcelinite on compressive strength of SCC

Curing state	Porcelinite %	Compressive strength (MPa)			
		7(day)	28(day)	60(day)	90(day)
Water curing	0 %	35.6	44.5	50.7	53.3
	12 %	39.2	49.9	58.7	62.0
	16 %	40.9	52.5	61.9	66.0
	20 %	42.7	54.9	65.5	69.3
	24 %	41.4	52.8	60.5	64.5
Air curing	0 %	34.1	40.3	45.2	47.0
	12 %	36.9	44.1	51.2	54.1
	16 %	38.4	45.6	53.1	56.1
	20 %	39.7	47.6	55.5	59.1
	24%	37.9	45.9	52.8	55.6

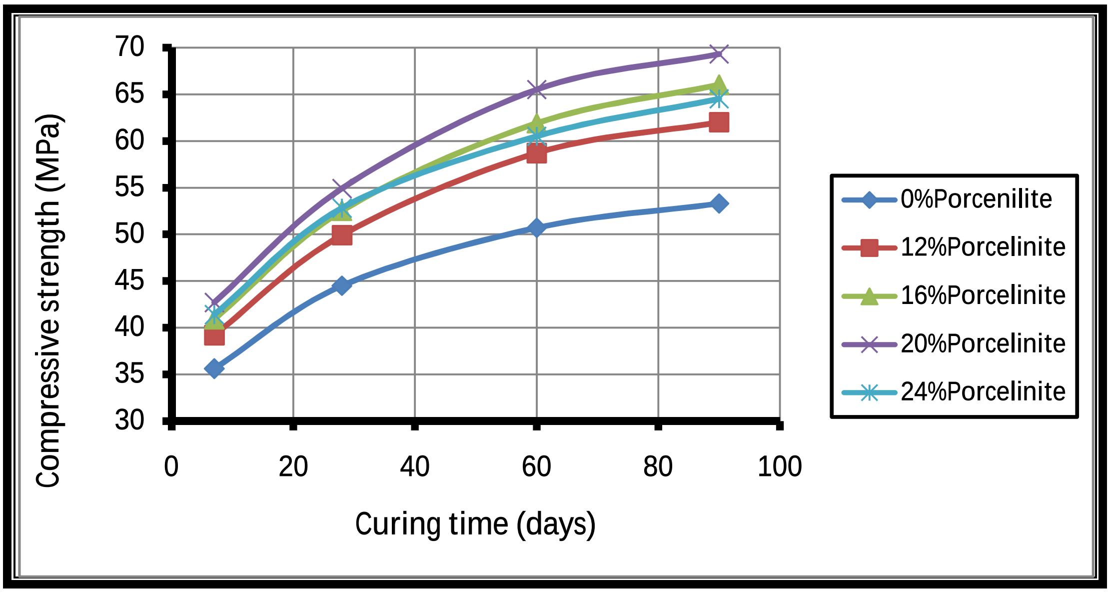

Fig. (3) Effect of saturated porcelinite on compressive strength of SCC cured in water

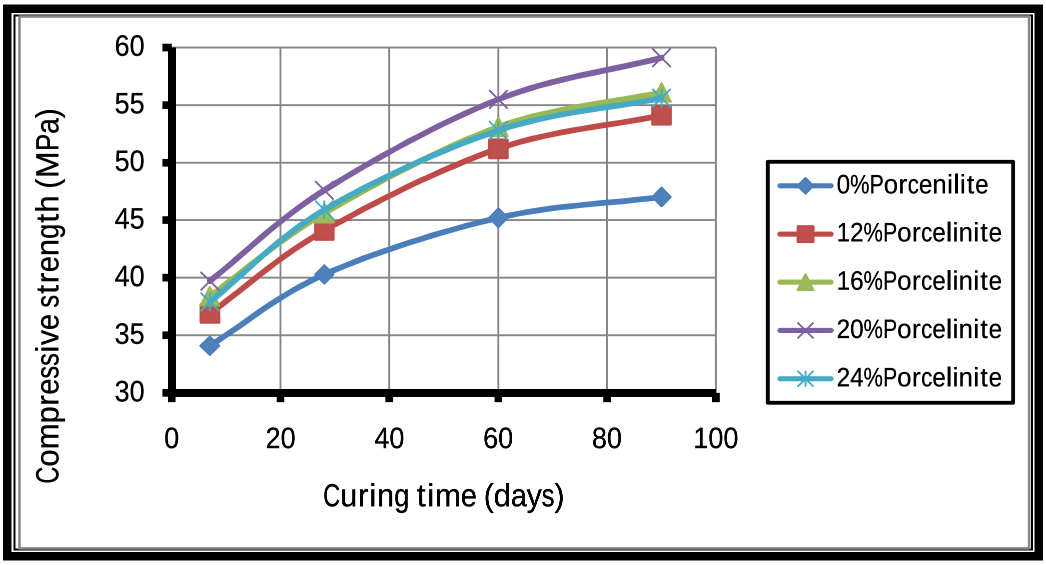

Fig. (4) Effect of saturated porcelinite on compressive strength of SCC cured in air

Conclusions

1. It can be possible to produce SCC with replacing of fine aggregate with saturated porcelinite, as internal curing agent, compatible with European guidelines for self compacting concrete.
2. The slump flow decrease with increasing the percentage replacement of fine aggregate with saturated porcelinite.
3. Bulk density increases as saturated porcelinite increases until reaches an optimum value at 20% of saturated porcelinite, then it decreases with further increasing of this material.
4. Compressive strength increases as curing time and replacement percentage of porcelinite increase until reaches an optimum value at 20% porcelinite, it decreases with further increasing of this material.

References:

1. **Rahman , M.M, Rashid, M.H, Hossain , M.A, Adrita, F.S., and Hossain, T. " Mixing time effects on properties of self compacting concrete"ARPN Journal of Engineering and Applied Science, Vol.6, No.8,August 2011, PP108-114.**
2. **Kosmatka, S.H., Kerkhoff, B.and Panarese, W.C." Design and Control of Concrete Mixtures" PCA, USA 2003 PP 219-224.**

3. **Jagannadha Kumar, M.V., Srikanth, M. and Jagannadha Rao , K." Strength characteristics of self curing concrete" IJRET Sep. 2012, Vol.1, ISSN 2319-1163, PP 51-57.Available at http://www.ijret.org/**
4. **Semion Zhutovsky and Konstantin Kovler "Effect of internal curing on durability – related properties of high performance concrete" Cement and concrete research, No.42, 2012, pp20-26 www.ivsl.org**
5. **Al-Feel , J.R. , and Al-Safar , N.S. " Properties of self compacting concrete at different curing condition and their comparison with properties of normal concrete" Al-Rafidain Engineering , Vol.17, No.3, June 2009, pp 30-38**
6. **Laith, M.M." Improvement some properties of concrete with internal curing by using light weight aggregate" MSc. Thesis, Civil Engineering Department, College of Engineering, University of Baghdad 2011.**
7. **Famili, H., Saryazde, M.K. And Parhizkar, T." Internal curing of high strength self Consolidating concrete by saturated light weight aggregate – effects on material properties" International Journal of Civil Engineering, Vol.10, No.3, Sept.2012, pp 210-220.**
8. **Igor, D. V. , Castro, J., Bentz, D. and Weiss , J. " Application of internal curing for mixtures containing high volumes of fly ash " cement and concrete composite, No.34 ,2012, pp1001-1008.**
9. **Iraqi Standard Specification, No.5, (1984),"The Portland Cement".**
10. **Iraqi Standard Specification, No.45, (1984), "Natural Aggregate Uses in Concrete and Building".**
11. **The European Guidelines for Self Compacting Concrete Specification, production and use May 2005.**
   www.efnarc.org
12. **Weber, S.Reinhardt, H.W. "A new generation of high performance concrete: concrete with autogeneses curing" Advanced Cement Based Materials, Vol.6, No.2, 1997, pp59-68.**
13. **Bentz, D.P., Lura, P. and Roberts, J. "Mixture Proportioning For Internal Curing" Concrete International, February, 2005, pp35-40.**