PRODUCTION OF SELF COMPACTING CONCRETE FOR CIVIL ENGINEERING STRUCTURES

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Abstract

During the last decades new cementations materials were available, that led to new types of concrete. This represent a sort of technical revolution with respect to the traditional concrete. In this paper atraditional concrete (slump 170mm & little bleeding) , and two self compacting concrete(slump flow 700mm &neglectful bleeding) mixes were manufactured, ordinary Portland cement content(400kg/m^3) and w/c ratio 0.45 used in manufacturing concretes, in order to obtain the same 28 day compressive strength .SCC were made with different types of mineral additions as fillers ,in this paper ground limestone and very fine sand used. The concrete specimens were wet cured at room temperature till the test age. Compressive strength of SCC were higher than that of the traditional concrete ,this can be related with a change in the microstructure of the cement matrix caused by the small particles of the limestone and very fine sand, which increase the density of cement paste and reduce the voids in it.

Key words: Concrete, Self compacting concrete, new concrete materials ,limestone, super-plasticizer, fine sand.

إنتاج خرسانة ذاتية الرص لمنشات الهندسة المدنية

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الخلاصة

لقد تواجدت خلال العقود السابقة مواد إسمنتية جديدة أدت إلى ظهور أنواع جديدة من الخرسانة وهذا يمثل من أهم أنوع الخرسانة المبتكرة هي خرسانة ذاتية الرص. نوع من الثورة التقنية قياسا" إلى الخرسانة التقليدية. إن يشير مصطلح خرسانة ذاتية الرص إلى نوع خاص من خليط الخرسانة يتميز بالمقاومة العالية للانعزال والذي

يمكن إن يصب بدون رص أو رج. إن الخرسانة ذاتية الرص تحد من الحاجة إلى الرج الداخلي والخارجي. حيث أنها تجري بحرية في داخل وحول التسليح الكثيف وتملئ القالب بشكل كامل بدون أي تكتل حيث يمكن إن تكون مادة مثالية للصب ألموقعي للركائز والأسس ومنشآت خرسانية أخرى عندما يكون الرص غير ملائم. في هذا البحث تم عمل خرسانة تقليدية(هطول ١٧٠ملم ونضوح قليل) و نوعين من خرسانة ذاتية الرص (جريان الهطول ٧٠٠ ملم و نضوح مهمل) خلطت باستخدام محتوى سمنت ٤٠٠ كغم/متر مكعب ونسبة ماء/سمنت ٤٥% من اجل الحصول على نفس المقاومة بعمر ٢٨ يوم. يستخدم في عمل خرسانة ذاتية الرص أنواع عديدة من المضافان كمالئات. في هذا البحث استخدم حجر كلسي مطحون ورمل ناعم جدا. عولجت عينات الخرسانة معالجة رطبة في درجة حرارة الغرفة إلى حين عمر الفحص. تم دراسة مقاومة انضغاط الخرسانة ذاتية الرص باستخدام المواد المدرجة أعلاه فكانت اكبر من الخرسانة الاعتيادية وهذا ير جع للتغير الحاصل في هيكل بنية عجينة الاسمنت بسبب الحبيبات الصغيرة للحجر الكلسي والرمل الناعم جدا"و التي زادت من كثافة عجينة الاسمنت وقللت الفراغات فيها.

Introduction

The most important innovative concrete is Self-Compacting Concrete (SCC), the term Self-Compacting Concrete (SCC) refers to a special type of concrete mixture characterized by high resistance to segregation, that can be cast without compaction or vibration. SCC eliminates the need for internal or external vibration, as it freely flows in and around dense reinforcement and fills the mold completely without any blockages. it would be an ideal material for casting in situ piles, foundations, and other concrete constructions where compaction is infeasible. Concrete is the most widely consumed material in the world, after water. Placing the fresh concrete requires operatives using slow, heavy, noisy ,expensive, energy consuming mechanical vibration to adequate compaction to obtain the full strength and durability of hardened concrete**[European Union Growth , 2005]**. For several years beginning in 1983, the problem of the durability of concrete structures was a major topic of interest in Japan. To make durable concrete structures, sufficient compaction by skilled workers is required. However, the gradual reduction in the number of skilled workers in Japan's construction industry has led to a similar reduction in the quality of construction work **[Collepardi,2002]**.

One solution for the achievement of durable concrete structures independent of the quality of construction work is the employment of self-compacting concrete, which can be compacted into every corner of a formwork, purely by means of its own weight and without the need for vibrating compaction. The necessity of this type of concrete was proposed by Okamura in 1986,Studies to develop self-compacting concrete,

including a fundamental study on the workability of concrete, were carried out by Ozawa and Maekawa at the University of Tokyo **[Collepardi,2002]**.
The prototype of self-compacting concrete was first completed in 1988 using materials already on the market.

Self compacting concrete (SCC), which have been developed and exploited over the past one a half decades eliminates the need for slow, heavy, noisy ,expensive ,energy-consuming and often dangerous mechanical vibration to compact the fresh concrete. In structural members with high percentage of reinforcement it fills also completely voids and gaps. it flows like "honey "and has nearly a horizontal concrete level after placing. self compacting concrete is defined so that no additional inner or outer vibration is necessary for the compaction.
SCC is compacting it self alone due to its weight and deaerated almost completely while flowing in the formwork**[Shah,2005]**.
Environmentally friendly (SCC) could be produced and used , with benefits to the construction process to the workers, and to people living near construction sites. With respect to the traditional concretes, the new cementations materials, thanks to the availability of new raw materials, allow the concretes to reach much higher performances in terms of execution on job sites, useful service life, and mechanical strength these new raw materials include:
• New synthetic polymers (poly-acrylates) which, with respect to naphthalene- or melamine-sulphonated polymers, are able to reduce even more effectively the amount of mixing water and then the water-cement ratio with all the consequent benefits **[Corinaldesi,Orlandi and Moriconi,2002]**
• Viscosity modifying agents based on Welan Gum to produce thixotropic mixes and then to obtain cohesive fresh concretes even when very fluid **[European Union Growth,2005]**
• Polymeric metallic fibers to increase the ductility and the fracture energy of concretes which usually are brittle materials **[Corinaldesi,Orlandi and Moriconi,2002]**
• Mineral additions characterized by amorphous silica such as silica fume (waste from silicium-iron alloys) in form of very fine particles (size of some nm/m) or UFACS

(Ultra-Fine Amorphous Colloidad Silica) synthetically produced in form of particles (size of some nm).

With regard to its composition, self-compacting concrete consists of the same components as conventionally vibrated normal concrete, which are cement, aggregates, water, additives and admixtures. However, the high amount of super-plasticizer for reduction of the liquid limit and for better workability, the high powder content as “lubricant” for the coarse aggregates, as well as the use of viscosity-agents to increase the viscosity of the concrete have to be taken into account. In principle, the properties of the fresh and hardened SCC, which

depend on the mix design, should not be different from normal concrete . One exception is only the consistency. Self-compacting concrete should have a slump flow s>65cm.

The present procedure for the production of self-compacting concrete is predominantly empirical. The mix design is based on experience from Japan, the Netherlands, France and Sweden. For the production of SCC, the mix design should be performed so, that the predefined properties of the fresh and hardened concrete are reached for sure. The components shall be coordinated one by one so that segregation, bleeding and sedimentation is prevented **[European Union Growth,2005]**.

The most important basic principle for flowing and cohesive concretes including SCC is the use of super plasticizer combined with a relatively high content of powder materials in terms of Portland cement, mineral additions, ground filler and/or very fine sand. Since the development of the prototype of self-compacting concrete in 1988, the use of self compacting concrete in actual structures has gradually increased. The main reasons for the employment of self-compacting concrete can be summarized as follows:

- to shorten construction period.
- to assure compaction in the structure: especially in confined zones where vibrating compaction is difficult.
- to eliminate noise due to vibration: this is effective especially at concrete products plants.

That means the current condition of self compacting concrete is a “special concrete” rather than standard concrete. Currently, the percentage of self compacting concrete in annual product of ready mixed concrete in Japan is around 0.1% **[Okamura and Ouchi,1999]** .

A typical application example of Self-compacting concrete is the two anchorages of Akashi-Kaikyo(Straits) Bridge opened in April 1998, a suspension bridge with the longest span in the world (1,991 meters) **[Okamura and Ozawa,1995]**.

One of the key obstacles preventing a faster and wider use of SCC in Europe was the absence of suitable test methods to identify its three key fresh properties: filling ability, passing ability and resistance to segregation. This was hindering the increased use of SCC **[European Union Growth,2005]**.

Experimental work

The most important basic principle for flowing and unsegregable concretes including SCC is the use of the super plasticizer combined with a relatively high content of powder materials in term of Portland cement , mineral addition , ground filler and/or very fine sand.

A partial replacement of Portland cement by fly ash was soon realized to be the most compromise in terms of rheological properties, resistance to segregations, strength level, and crack freedom. Some other alternative to fly ash , have been considered in the present paper, they are very fine sand and ground limestone. Two compacting concretes were manufactured using very fine sand (FSCC), and limestone(LSCC), in addition to the traditional concrete (TC). The following **Tables (1,2,3)** show the composition of each type of concrete. **Tables (A-C)**show the properties of materials that used in this research.

Figure (1) shows the percentage of fine particles for traditional concrete and self compact concrete, it is clear that the percentage of fine particles of self compacting concrete is higher than that for traditional concrete, which represent one of most important criteria of SCC.

Slump test for TC was made according to ASTM C143-99, and the slump flow for SCC was made using the cone of the slump test , by measuring the diameter of concrete circle after lifting the filled cone with concrete. Bleeding of concrete was measured using the test described by ASTMC232-99. Concretes were casted into

15*15*15cm cub without any compacting or vibration for SCC ,and with compacting for TC. all concrete cubes were wet till the age of testing.

Disussion of Results

Table(4) describes the properties of fresh concrete for self-compacting concrete. Self compacting concrete with very fine sand shows slump flow of 650mm after 30 minute less than the self compacting concrete with limestone which shows slump flow of 700mm after 30minut, in addition the segregation for FSCC could be described as fair comparing to no or legible segregation for LSCC .

Figure (2)shows the bleeding capacity as a function of the slump level fortraditional concrete (TC) with a cement factor 400 kg/m3 in the absence of superplasticizer. The slump was increased by increased the amount of mixing water. When the slump is over 175 mm the bleeding increases too much and this was the reason why ACI in 1973 did not recommend slump higher than 175 mm .

With the advent of super plasticizers, SCC concretes with slump flow up to 700 mm were manufactured with no or negligible bleeding provided that an adequate cement factor was used. The self compacting concrete (FSCC),and (LSCC)show no or legible bleeding as shown **Figure (3)**. **Figure (4)** describe the compressive strength of (TC) ,(FSCC) and(LSCC) it is clear that the compressive strength of self compacting concrete was higher than the compressive strength of traditional concrete . that because using super plasticizer which led to reduce the mixing water ,the reduction of water lead to increase of the compressive strength. in addition the use of fine particles of (fine sand &limestone) led to reduce the voids in the mix and make it strong. in addition the compressive strength of(LSCC) was higher than the strength of (FSCC), that because, the fine particles of limestone are more effective than the particles of very fine sand.

Conclusions

1. The results obtained in the present paper show the extra-ordinary properties which can be obtained by using the innovative concretes recently developed in the field of SCC. SCC appears to be very successful because it is easy to place in a safe way independent of the quality and reliability of the workmanship available today on the jobsites.

2. The high-strength SCC studied in this paper can be considered as particularly suitable in the field of Civil Engineering.
3. The combined use of Cement type I (400kg/m3), super plasticizer (1.1-1.5%), Limestone or very fine sand (130-160 kg/m3), and aggregate with a maximum size of 20 mm allow the manufacture of self-compacting concretes suitable for concrete structures.
4. the most important progress achievable in the future for SCC technology depends on the availability and use of some new ingredients such as:

a) Powder materials including (recycled aggregate from demolished concrete , etc.).
b) more effective super plasticizers those based on acrylic polymers.
c) viscosity modifying admixtures based on organic polymers and ultra fine amorphous colloidal silica.

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table (1) the composition of traditional concrete (TC)

Ingredients	kg/m3
Ordinary Portland cement type I	400
Coarse aggregate 20-5mm	1040
Fine aggregate Zone 2	760
Water	180
w/c	0.45

table (2) the composition of self compacting concrete with very fine sand(FSCC):

Ingredients	kg/m3
Ordinary Portland cement type I	400
Coarse aggregate 9.5-20mm	875

5-9.5mm	440
Fine sand Zone 2 Very fine sand 0.075-0.6mm	430 100
limestone	-
Water	180
w/c	0.45
Super plasticizer	9.6

table (3) the composition of self compacting concrete with limestone (LSCC):

Properties	FSCC	LSCC
Specific mass kg/m^3	2350	2400
Slump flow mm after: 0 min. 30 min. 60min.	 680 650 620	 740 700 680
Concrete aspect (segregation)	Cohesive (fair)	Cohesive (no)

table (4) the fresh concrete properties of self compacting concrete

Ingredients	kg/m3
Ordinary Portland cement type I	400
Coarse aggregate 9.5-20mm 5-9.5mm	 875 440
Fine aggregate Zone 2 Limestone 0.15-0.6mm	430 180
Water	180
w/c	0.45
Super plasticizer	8.6

table (a) chemical analysis of cement

Oxides	Content %
CaO	61.5
SiO_2	19.6
MgO	2.78
Fe_2O_3	3.9
Al_2O_3	5.52
SO_3	2.01
L.O.I	2.95
Compounds	
C_3S	54.34
C_2S	15.00
C_3A	8.2
C_4AF	11.55

table (b) physical properties of cement

Properties	Results	IOS No.5/1984
Fineness(Blaine)m^2/kg	235	>230
Initial setting time	1:55	>0:45 min.
Final setting time	4:00	<10:00 hours
Compressive strength 3days	19.92	>15 N/mm^2
Compressive strength 7 days	26.4	>23 N/mm^2

table (c) the properties of aggregate and limestone

properties	Coarse aggregate	sand	limestone
Specific gravity	2.63	2.53	2.69
SO3%	0.09	0.19	-
Bulk density kg/m^3	1637	1590	1700
Fineness modulus	2.86	-	-
absorption	0.6	0.9	0.8

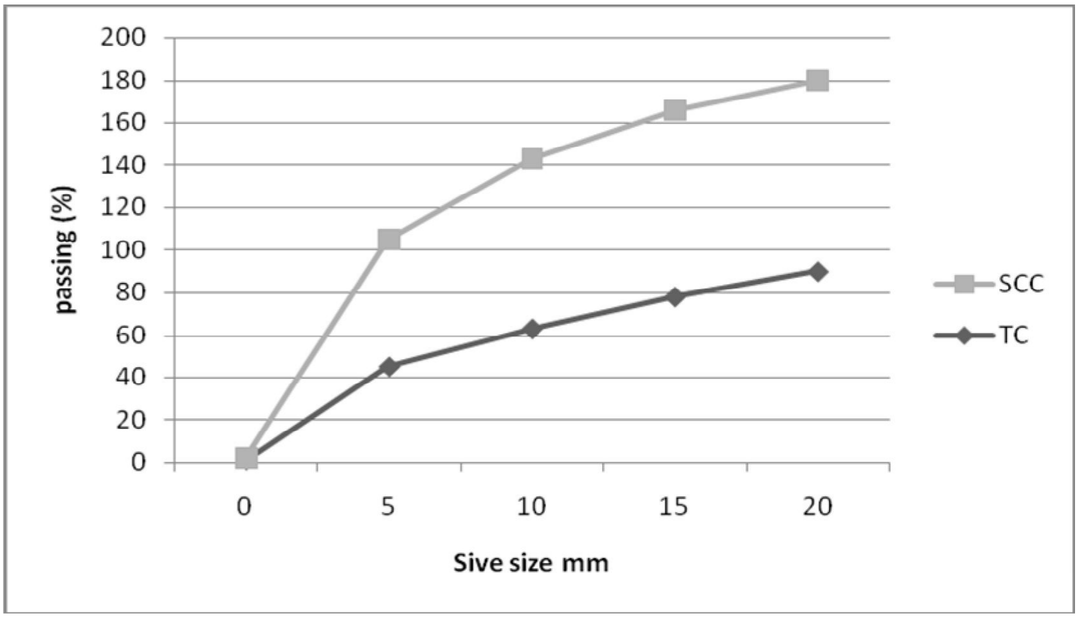

figure (1) particle size distribution of the aggregate in SSC and TC.

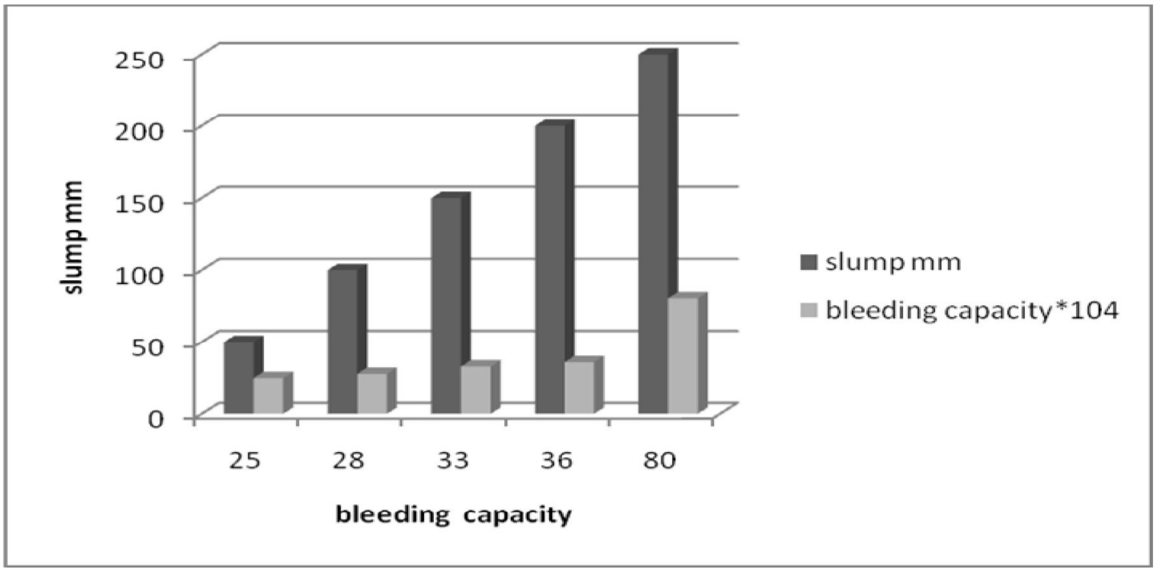

figure (2) bleeding capacity*104. as a function of slump for traditional concrete.

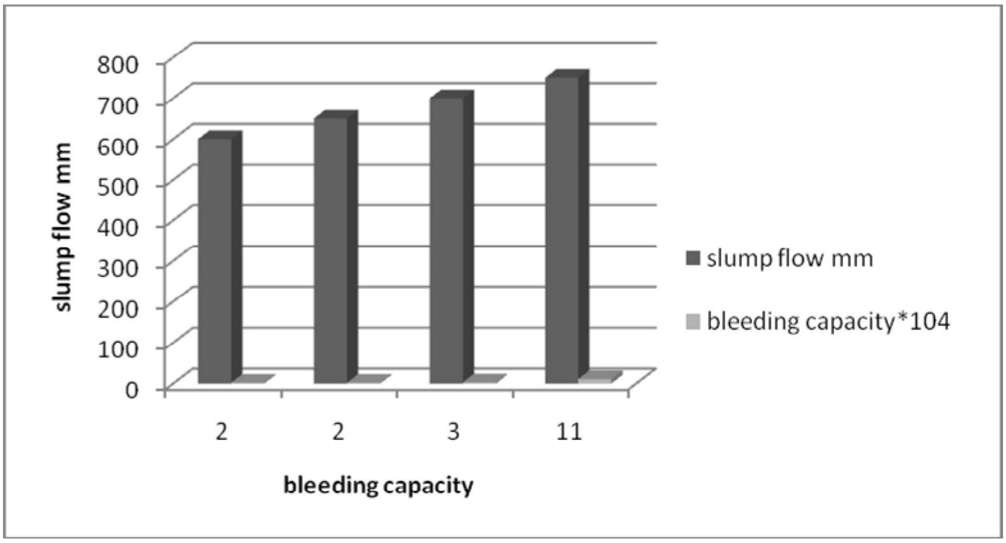

figure (3) bleeding capacity *104 as a function of slump for self compacting concrete.

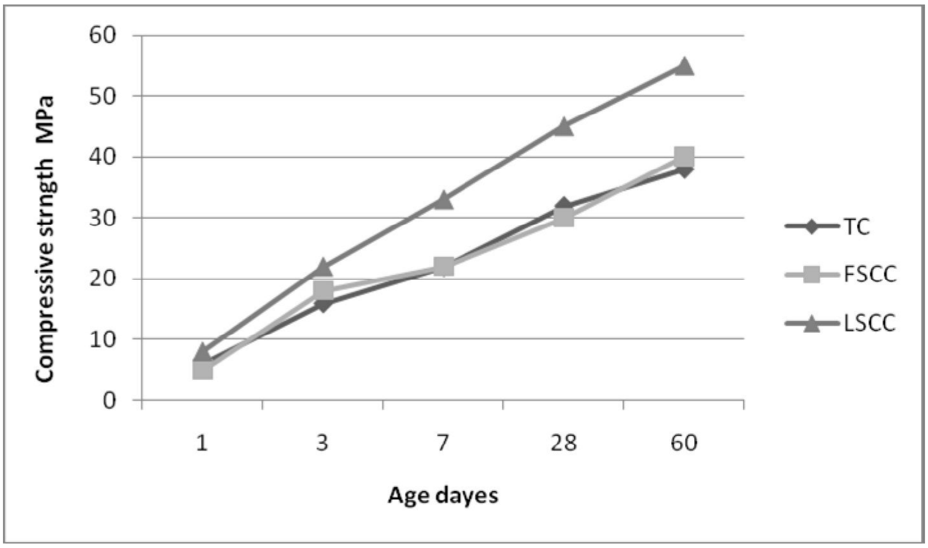

figure (4) development of compressive strength with time for traditional concrete(TC) and for self compacting concrete with very fine sand(FSCC) and with limestone(LSCC).