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COMPRESSIVE STRENGTH OF SELF COMPACTING CONCRETE

BY

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Abstract. Self compacting concrete represents an innovation in the building industry due to its worbability. SCC is able to flow under its own weigh, filling perfectly the formwork even in a presence of congested reinforcement without vibration. The components of SCC are similar as conventionally vibrated concrete, but the mixture proportions for SCC differ essentially. The higher powder content, limited volume and nominal maximum size of coarse aggregate, larger quantity of superplasticisers represent design requirements in achieving the self compatibility. The changes of the concrete composition lead to a different properties in hardened state. The compressive strength of concrete represents one of the most important feature used in the design rules of the concrete structures. The results of the test showed that at the same cement content and water/cement ratio, SCC haves a higher compressive strength than the conventionnaly vibrated concrete, this is due packing effect of filler that reduces the porosity and lead to a denser microstructure, more uniform stress distribution during compression.

Keywords: self compacting concrete; workability; cube strength; cylinder strength.

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1. Introduction

The invention of self compacting concrete (SCC) is considered one of the most important developments in the construction industry. It is able to flow under its own weight due to its highly fluid nature and achieving a full compaction even in a formwork with complicated shapes and dense reinforcement. The elimination of vibration improves the productivity, shortens construction time, increases the safety of working environment and reduces the labor and equipment cost.

SCC consist of similar components as conventionally vibrated concrete: cement, aggregates, water, mineral and chemical admixtures. The passing ability and segregation resistance of SCC is achieved by the decrease of coarse aggregate content and the growing up of the powder quantities. The superplasticisers (high range water reducers) are responsible for the high fluidity of concrete mix, while the powder and viscosity modifying agents lead to a better stability and cohesion, reducing bleeding and segregation of the mix.

Mineral admixtures are used as an extra fine material, the most used is the limestone filler that represents a chemically inert by-product of limestone crushers. The addition of limestone powder improves the particle packing by filling the small pores between cement grains and augment the water retention of fresh mixes.

The compressive strength is calculated by the failure load divided with the cross sectional area resisting the load and reported mega pascals (MPa). Concrete hardens and acquires strength as it hydrates. This process occurs rapidly at first and slows down as time goes by, it continues over a long period of time. In this study is investigated the compressive strength at 28 days, age considering for design purposes, when a substantial percentage of the hydration has taken place. It was determined the cubes and cylindrs strength of SCC and of conventional vibrated concrete at the same w/c ration and cement content.

2. Experimental Procedure

2.1. Materials

The Portland cement (strength class 42,5 N) used in all mixes of this study complied with EN 197-1. A natural river sand was used as a fine aggregates, and river washed coarse aggregates with a maximum size of 16 mm and specific gravity 2,7. In order to accomplish the necessary powder content was used limestone filler with 2,6 specific gravity. The polycarboxilates ether based superplasticisers was used.

2.2. Mixture proportions

SCC and vibrating concrete were designed in order to evaluate the compressive strength at the same cement content and water/cement ratio. The aggregate with 0,…,4 mm; 4,…,8 mm; and 8,…,16 mm fractions was used in percentage 50%, 12% and 48% for self compacting concrete. The proportion of the produced mixtures are given in Table 1.

Table 1
Details of the Mix Proportions, [kg/m^3]

Material	Cement	Agregate	Sand	Filler	Water	HRWR
VC	360	1,031	810	–	180	1.8
SCC	360	853	853	120	180	5.8

2.3. Mixing and Casting Details

The mixing succession and duration are very important in the production of SCC, due to their influence on the properties of fresh concrete. The materials were blended in a free fall concrete mixer. The aggregates, cement and powder were efficiently mixed dry until attain a uniform distribution, sequential, 70% of water was added into the mixer and continued to blend and finally the superplasticisers with the remaining water was introduced and mixed to obtain an homogeneous mix.

The workability of VC was measured through slump cone test and of SCC was determined by slump flow, V-funnel and L-box test, the resultats of testing are presented in Table 2. The fresh concrete was placed in a steel cylinder (100 × 200 mm) and cube moulds (100 × 100 mm). SCC speciments were casting without any vibration or compaction, VC samples were compacted using a vibrating table. After 24 h of casting, they were demoulded and stored in water for 28 days.

2.3. Test Procedure

The workability is defined as the ease of placement and it is considered the noticeable feature of SCC as the final quality of the structure will strongly depend on it. In order to appreciate the self compatibility properties, EFNARC standards recommend using the slump flow, *V*-funnel and *L*-box test.

The testing apparatus for slump flow and T_{500} consists of steel plate with the dimensions of 900 × 900 mm, with the marked centre and two concentric circles of 200 mm and 500 mm diameter, Abrams cone, stop watch and rule. The test procedure is described in EN 12350-8:2010, the cone is filled with fresh concrete, when it is upwards, the time from commencing move up the cone until the concrete has spread to 500 mm in diameter is measured, this is T_{500} and at the end, the mean of the final slump flow diameter in the two orthogonal directions is determined.

The apparatus for V-funnel test is detailed in EN 12350-9:2010. The concrete is poured to the top of the cleaned funnel whithout any agitation. After a delay of 10 ± 2 s the bottom gate is opened, and the time to when is possible to see vertically through funnel, is measured.

The test procedure for *L*-box test is described in EN 12350-10:2010. The apparatus represents a box in the shape of *L*, with two sections: vertical and horizontal, separated by a movable gate and a vertical length of reinforcement bar. The concrete is poured in vertical section and allow to stand for 60 ± 10 s. When the gate is lifted, concrete flow through reinforcement bar into the horizontal section. When the flow has stopped, the height difference of the extremity of the horizontal section are measured.

The results of tested fresh properties are presented in Table 2.

Test procedure to determine compressive strength complied with SR EN 12390-3. The cube speciments were charged perpendiculary to the direction of casting, the loading rate was 0.4 MPa/s.

Table 2
Workability Tests Results

Test	Slump cone cm	Slump flow mm	T_{500} s	*V*-funnel s	*L*-box
VC	16	–	–	–	–
SCC	–	700	2,5	9,4	0,85

3. Results and Discussion

3.1. Fresh Properties of SCC

SCC represents a mixture with high flowability and capability to fill the formwork uniformly, denser and without segregation. The mortar should have a sufficient deformatibility to ensure the self compactibility with no external mechanical compaction. A required viscosity is necessary to maintain the stability of the fresh concrete during the placement. The classifying system to cover requirements for SCC in the fresh are showed in Tables 3,…,5.

The slump flow test (Fig. 1) express the filling ability in the absence of obstruction, visual observations during the test can offers additional information about bleeding capacity and segregation potential. The T_{500} time represent a measure of the speed of flow, its value should be submitted between 2 and 5 s.

Table 3
Slump Flow Classes, (1)

Class	Slump flow, [mm]
SF1	550 to 650
SF2	660 to 750
SF3	760 to 850

In order to attain a higher quality of concrete elements, it is recommended to select the slump-flow class according to the structural condition of applications, geometry of elements, degree of reinforcement.

SF1: large cross-sectional areas and with slightly reinforcement;

SF2: is suitable the most common applications;

SF3: structures with congested reinforcement and complicated shapes, mainly is produced with maximum size of coarse aggregates slammer than 16 mm.

Fig. 1 – The slump flow test.

The *V*-funnel test (Fig. 2) ss used to evaluate the viscosity of SCC, whereby the flow time is estimated, the results obtained for SCC – 9.4 s, confirms to the standard requirements, and can be classified as VF2.

Table 4
V-Funnel Classes (1)

Class	T_{500}, [s]	*V*-funnel time, [s]
VS1/VF1	<2	<8
VS2/VF2	>2	9 to 25

The SCC classified as VS1/VF1 has sufficient ability to fill the formwork even with congested reinforcement and usually has a perfectly surface finish.

The concrete of VS2/VF2 classes is characterized by a higher viscosity and improved segregation resistance, that lead to a increasing flow time and a lower formwork pressure.

Fig. 2 – The *V*-funnel test.

The passing ability of SCC through narrow spaces, even with congested area of reinforcement, can be assessed by the *L*-box test (Fig. 3). The blocking ratio expresses the capability of fresh mix to spread among the reinforcement and fill the mould.

Fig. 3 – The L-box test.

Table 5
Passing Ability Classes (1)

Class	Passing ability
PA1	>0.80 with 2 rebars
PA2	>0.80 with 3 rebars

3.2. Compressive Strength

The compressive strength of concrete represents one of the most important feature used in the design rules of the concrete structures, and many of other mechanical characteristics (*e.g.* tensile strength, modulus of elasticity, compressive strain) and physical properties (*e.g.* related to durability) of concrete are moreover expressed as a function of this parameter. In Eurocodes 2 concrete is classifield only on the basis of cube ($f_{c,\text{cub}}$) and cylinder strength ($f_{c,\text{cyl}}$).

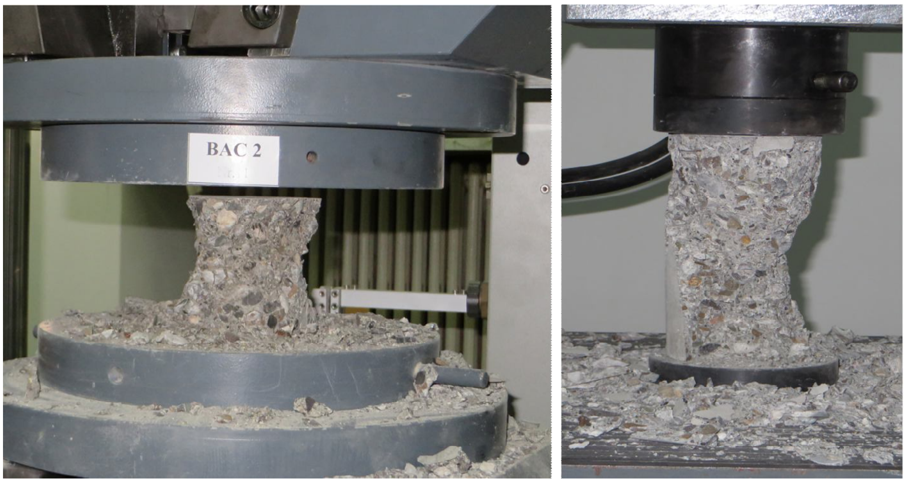

Fig. 4 – Testing cube and cylinder speciments.

The compressive strength of concrete is affected by many factors, most of them being interdependent, such as the W/C ratio, cement compressive strength, properties of the aggregates (shape, grading, surface texture mineralogy, strength, stiffness, and maximum grain size), air-entrainment, curing conditions, testing parameters, speciment parameters, loading conditions, and test age.

At a same water cement ratio, SCC have a higher strength up to 15% for $f_{c,\text{cub}}$ and 5% for $f_{c,\text{cyl}}$ compared to the traditional vibrated concrete, due to the improved interface between the aggregate and hardened paste, the results are showed in Figs. 5 and 6.

The substantial difference in mixture composition between SCC and VC lead to a distinct behavior under stress. The higher powder content and less coarse aggregate produce smoother crack surfaces.

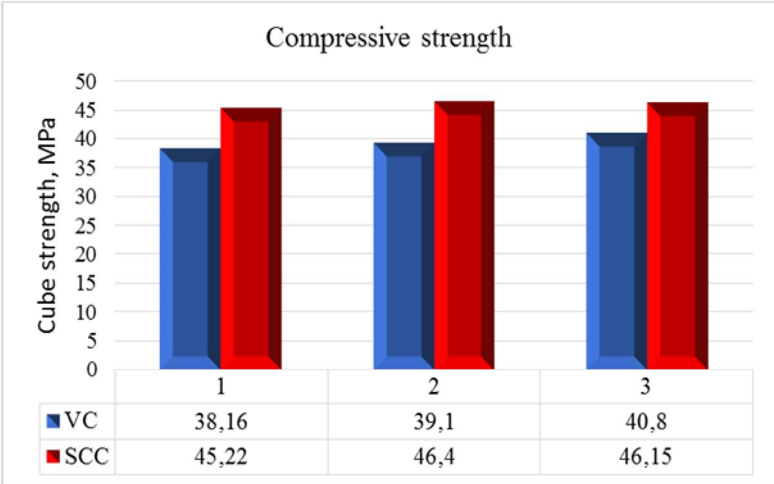

Fig. 5 – Compressive cube strength of SCC *vs*. VC.

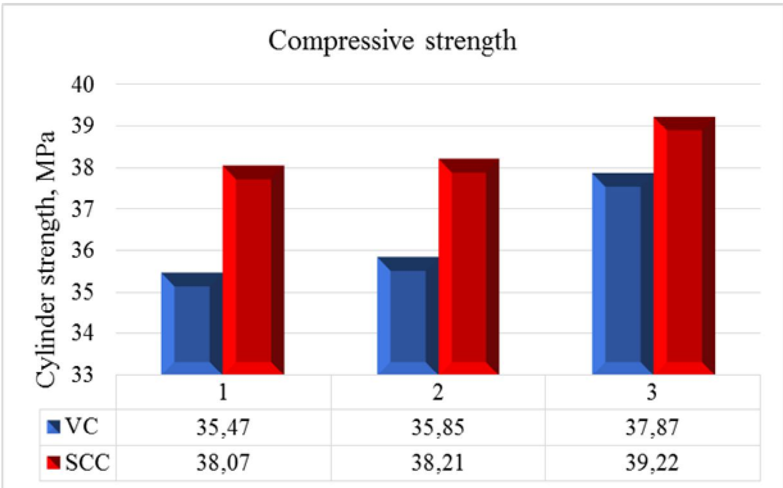

Fig. 6 – Compressive cylinder strength of SCC *vs*. VC.

Adition of limestone filler supplies the gaps among coarses particles, reduces the porosity and increases the density of concrete that lead to an improved mechanical properties. The denser microstructure of SCC (Fig. 7) and increased bonding to the aggregates contribute to a more uniform stress distribution during compression, hence the chance of premature failure decreases.

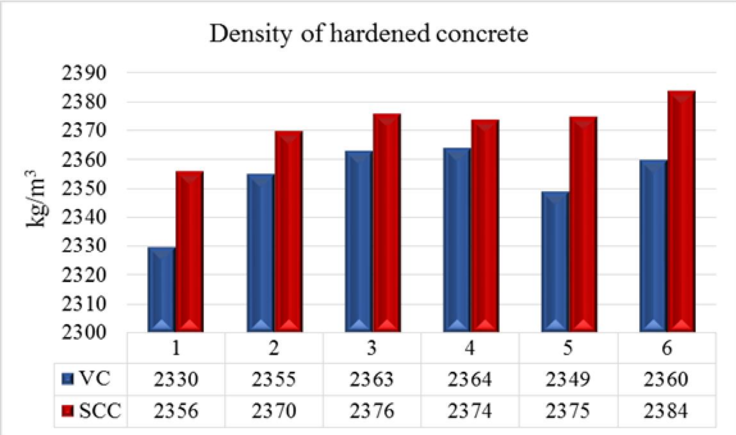

Fig. 7 – Density of hardened SCC *vs.* VC.

4. Conclusions

On the basis of the scope of research it can be concluded that:

1º The hardened properties of SCC differ to VC due to the changed mix desigh, even are used similar materials.

2º The high powder content contributes to a filler effect, supplining the small pores between cement particles.

3º The density of SCC is higher than VC due to the better compaction of the mixture in fresh state.

4º The compresive strength of SCC was higher then VC with 15% for cube speciments and 5% for cylinder speciments at the same cement content and water/cement ratio.

REFERENCES

Beeralingegowda B., Gundakalle V. D., *The Effect of Addition of Limestone Powder on the Properties of Self-Compacting Concrete*, Internat. J. of Innovative Res. in Sci., Engng. a. Technol., **2**, *9* (2013).

Bensalem S., Amouri1 C., Houari1 H., Belachia M., *Elaboration and Characterization of Self-Compacting Concrete Based on Local By-Products*, Internat. J. of Engng., Sci. a. Technol., **6**, *1*, 98-105 (2014).

Deepa Balakrishnan S., Paulose K.C., *Workability and Strength Characteristics of Self Compacting Concrete Containing Fly Ash and Dolomite Powder*, American J. of Engng. Research (AJER), **2**, 43-47 (2013).

Filho A., Barragán F.M., Casa J.R, *Hardened Properties of Self Compacting Concrete-A Statistical Approach*, J. Construction and Building Materials, *24*, 1608-1625 (2010).

Grdić Z, Despotović I., *Properties of Self Compacting Concrete with Different Types of Addives*, University of Niš, Serbia Architecture and Civil Engineering, **6**, 173-177 (2008).

Khayat K.H., Schutter G., *Mechanical Properties of Self Compacting Concrete*, State – of-the-art report of RILEM tehnical committee 228-MPS, 2014.

Łazrniewska-Piekarczyk B., *The Influence of Chemical Admixtures on Cement Hydration and Mixture Properties of Very high Performance Self-Compacting Concrete*, J. Construction and Building Materials, **49**, 643-662 (2013).

Okamura H., Outchi M., *Self Compacting Concrete*, J. of Adv. Concrete Technol.y, **1**, *1*, 5-15 (2003).

Pai B.H.V., Nandy M., Krishnamoorthy A., Sarkar P.K., *C, Experimental Study on Self Compacting Concrete Containing Industrial by-Products*, European Sci. J., **10**, *12* (2014).

Schutter G., *Effect of Limestine Filler as Mineral Addition in Self-Compacting Concrete*, 36th Conf. on Our World in Concrete & Structures, Singapore, August, 2011.

Uysal M., *Self-Compacting Concrete Incorporating Filler Additives: Performance at high Temperatures*, J. Construction and Building Materials, **26**, 701-706 (2012).

* * * *The European Guidelines for Self-Compacting Concrete Specification, Production and Use*, BIBM, CEMBUREAU, EFCA, EFNARC, ERMCO, May 2005.

* * * *Testing Fresh Concrete. Self-Compacting Concrete. Slump-Flow Test*, EN 12350-8:2010.

* * * *Testing Fresh Concrete. Self-Compacting Concrete. V-Funnel Test*, EN 12350-9:2010.

* * * *Testing Fresh Concrete. Self-Compacting Concrete. L-Box Test*, EN 12350-9:2010.

REZISTENȚA LA COMPRESIUNE A BETONULUI AUTOCOMPACTANT

(Rezumat)

Betonul autocompactant reprezintă o inovație în industria construcțiilor datorită lucrabilității sale. BAC posedă capacitatea e a curge sub influența greutății proprii, umple perfect cofrajele chiar şi în prezența unei armări intense fără a fi necesară vibrarea acestuia. Materialele componente ale BAC sunt similare betonului tradițional vibrat, însă dozajul acestora diferă esențial. Conținutul sporit de parte fină, limitarea volumului de agregate grosiere şi a diametrului nominal maxim ale acestora, întrebuințarea unei cantități mai mari de aditivi superplastifianți reprenzintă exigențe necesare pentru obținerea abilității de auto compactare. Rezistența la compresiune a betonului este considerată una din cele mai importante caracteristici mecanice utilizate la proiectarea structurilor din beton. În rezultatul experimentelor efectuate, a fost stabilit că rezistența la compresiune a BAC este mai mare decât cea a betonul vibrat, la un raport apă/ciment constant şi aceeaşi cantitate de ciment, acest lucru se datorează adaosului de pulberi în compoziția BAC, care contribuie la reducerea porozității, formarea unei microstructurii mai dense şi răspândirii uniforme a tensiunilor în timpul solicitării elementelor.