Solid State Science and Technology, Vol. 26, No 1 (2018) 60-69
ISSN 0128-7389 | *http://journal.masshp.net*

BY-PRODUCTS OF SEASHELLS IN FLUID CONCRETES: REPLACEMENT AS AN ADDITION AND A FINE AGGREGATE

Brahim Safi, Djamila Aboutaleb, Mohammed Saidi and Abdelbaki Benmounah

Research Unit: Materials, Processes and Environment (UR-MPE), M'hamed Bougara University of Boumerdes, Algeria

Corresponding author: safi_b73@univ-boumerdes.dz

ABSTRACT

The aim of this work is to study the rheological and physic-mechanical properties of a self- compacting concrete elaborated with seashells as an addition cementitious (total replacement of limestone fillers) and a fine aggregate (partial and total substitution of sand). Having crushed shells (obtaining fine aggregate) and also finely crushed seashells (obtaining fine powder), concretes will be manufactured using these two products. Rheological characterization tests (fluidity, flow and segregation) and physic-mechanical (density and mechanical strength) will be made on these concretes. The results obtained will be compared with the characteristics of a self-compacting concrete witness (fillers of limestone and fine aggregate). The obtained results show that the substitution of limestone fillers by the finely crushed sea shells (as an addition end) as well as the substitution of sand by crushed seashells (as fine aggregates) has greatly improved the concrete compactness causing an increase mechanical strength with a slight reduction of concrete fluidity.

Keywords: Sea Shells; sand; self-compacting concrete; fluidity; compressive strength; flexural strength; dynamic modulus of elasticity

INTRODUCTION

Today, recycling of marine wastes in concretes is considered an appropriate solution for their disposal because environmental and economic factors increasingly encourage using this waste type [1- 7]. Previous studies have been investigated the use of seashells in cement mortars or in concretes. These studies confirmed the potential of seashells to be used as adding (calcined seashells) or aggregates (coarse aggregates) in concrete [7-10]. However, few works have been conducted to study the substitution of mineral additions or sand by the seashells in special concretes such that the fluid concretes [6]. In 2015, a work was initiated by Safi et al. on the use of crushed seashells as fine aggregates by a partial or total substitution of sand but this study was carried on cement mortars (self- compacting mortars) [6]. Long before, Alan Elliott Richardson has also investigated the use of a product of seashells incorporated as aggregate in ordinary concrete by total replacement (sand or gravel). All these studies have shown that concretes made with shells have physical and mechanical characteristics acceptable for such construction. For this purpose, this study investigate the rheological and physic-mechanical properties of a self- compacting concrete elaborated with seashells as an addition cementitious (total replacement of limestone fillers) and a fine aggregate (partial and total substitution of sand).

EXPERIMENTAL

Materials used.

Portland cement (CEM II 42.5), limestone fillers, sand (0/5mm with 2, 61 g/cm3), the crushed seashells (powder and 0/5mm) and a superplasticizer were used in this present study. The cementitious materials characteristics (cement, limestone fillers and finely crushed seashells) are given in Table 1. The used sea shells were recovered, cleaned and dried in the open air and in a drying oven (at 105°C). After crushing of seashells in a jawbone crusher, these were sieved on the sieve 5 mm (see Figure 1).

The preparation steps of crushed seashells can be shown in Figure 1. The Particle size distribution of crushed seashells and natural sand is represented in Figure 2.

Table 1: Cementitious materials characteristics

Compounds	Cement % (by weight)	Limestone fillers % (by weight)	Seashells % (by weight)
SiO_2	17.45	4.27	0.32
Al_2O_3	4.29	0.73	0.26
Fe_2O_3	2.98	0.02	0.02
CaO	63.6	53.08	54.54
MgO	1.12	0.25	0.01
SO_3	2.08	0.01	0.14
$K_2O + Na_2O$	0.8	0.26	0.65
Loss of ignition	-	41.13	44.04
C_3S	60.50	-	-
C_2S	18.86	-	-
C_3A	6.45	-	-
C_4AF	12.26	-	-
Specific gravity (g/cm^3)	3.10	2.71	2.76
Specific surface (m^2/kg)	370	500	470

Figure 1: Preparation steps of crushed seashells

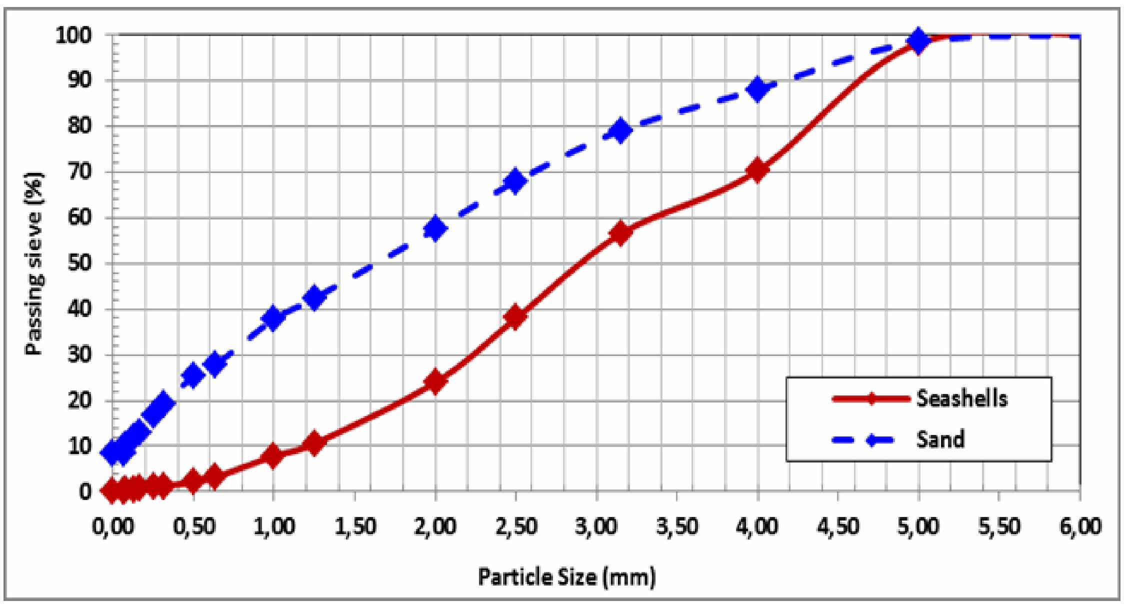

Figure 2: The Particle size distribution of crushed seashells and sand

Formulation of self-compacting concretes.

Using the Japanese method, six formulations of self- compacting concrete have been obtained with various substitution procedures of limestone fillers and sand by the seashells. Table 2 gives the control concrete SCC1 the compositions of self-compacting concretes studied. The water–binder ratio used is keep constant (W/B = 0.38) and the superplasticizer is also keep constant.

Test methods.

To conduct this work, prismatic (70x70x280 mm3) and cylindrical (160x320 mm2) samples were manufactured for each mixture (Figure 3). One day after casting, the concrete samples were stored in water under 21±1°C. A various tests and measurements were carried out in order to determine the properties of fresh and hardened concrete (slump test, bulk density, flexural strength and uniaxial compression and elastic modulus).

Table 2: Mix details of concretes [Kg/m3]

	SCC1	SCC2	SCC3	SCC4	SCC5	SCC6
Cement	430	430	430	430	430	430
Limestone fillers	43	-	43	-	43	-
Finely crushed seashells*	-	43	-	43	-	43
Fine aggregate	934	934	467	467	-	-
Crushed seashells**	-	-	467	467	934	934
Coarse aggregate	845	845	845	845	845	845
Water	180	180	180	180	180	180
Superplasticizer	7.10	7.10	7.10	7.10	7.10	7.10

*: Finely crushed seashells used as an addition;
**: Crushed seashells used as a fine aggregate.

The fluidity was evaluated by slump test by using the ABRAMS cone used for concretes. For the mechanical tests, bending test (at three-point) and uniaxial compression are carried out at 7 and 28 days on concrete samples. Three-point bending tests were carried on prismatic samples (70x70x280 mm3) according to ASTM C 78 – 02 [11]. Also, cylindrical samples (160x320 mm3) of each mixture were subjected to uniaxial compressive, according to ASTM C39 – 02 [12]. The dynamic elastic modulus for all concretes was determined by the acoustic method by using the ultrasonic pulse velocity testing (The UPV testing - ASTM C597-97) at age 28 days [13].

Figure 3: Slump test and samples of concrete

After determining the speed of sound propagation of through the specimen, the dynamic elastic modulus is calculated using the following formula (1); $\boldsymbol{E_d}$**:** Dynamic modulus of elasticity [GPa] $\boldsymbol{\rho}$ **:** Density of specimen [Kg/m^3] and $\boldsymbol{V}$: Sound speed [m/s].

Solid State Science and Technology, Vol. 26, No 1 (2018) 60-69
ISSN 0128-7389 | *http://journal.masshp.net*

RESULTS AND DISCUSSIONS

Fluidity of concretes

Figure 4 shows the flow evolution of the studied self-compacting concretes. It is clear that the flow is almost the same for all mixtures of concrete, which is an acceptable fluidity for a SCC. However, SCC05 has a fluidity more or less low compared to other mixtures. This is explained by the used sea shells (as sand) has slightly reduced fluidity because they have a needle shape whiche gene the flow of concrete. These findings have been proved by the authors and Safi al. [6].

Flow of concrete

More fluidity concrete is best more the flow time of this latter will be reduced. The implementation of all developed concretes was estimated by flow time given in Figure 4. It is clearly remarkable that the flow of concrete is good (Figure 5) and that the implementation of these is acceptable for a self-compacting concrete. Indeed, the flow time recorded for all mixtures is almost the same; it is about 4 ± 1 sec.

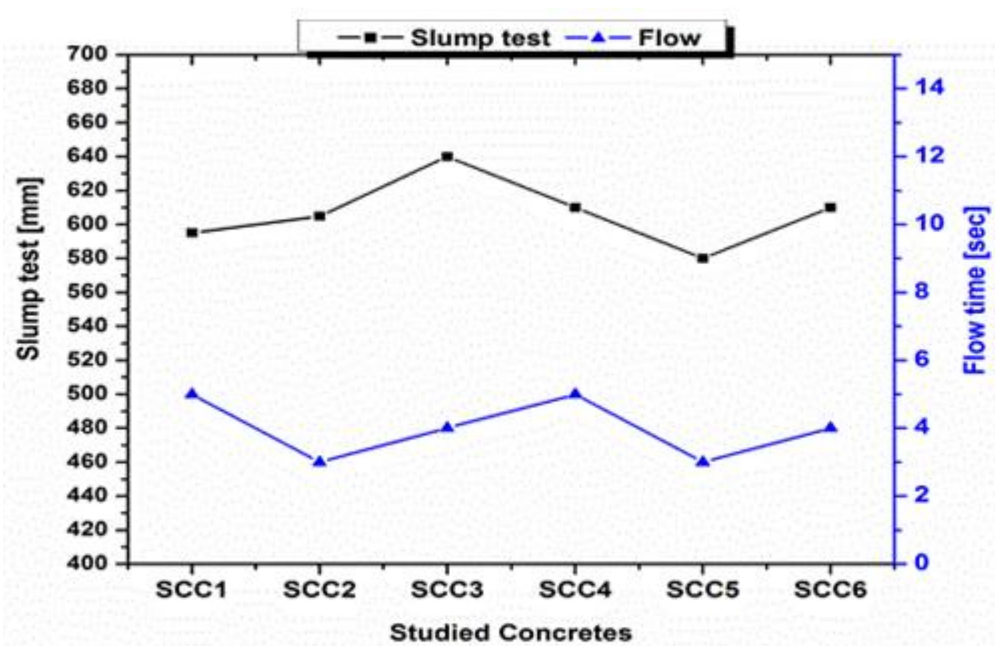

Figure 4: Fluidity and flow time of studied concretes

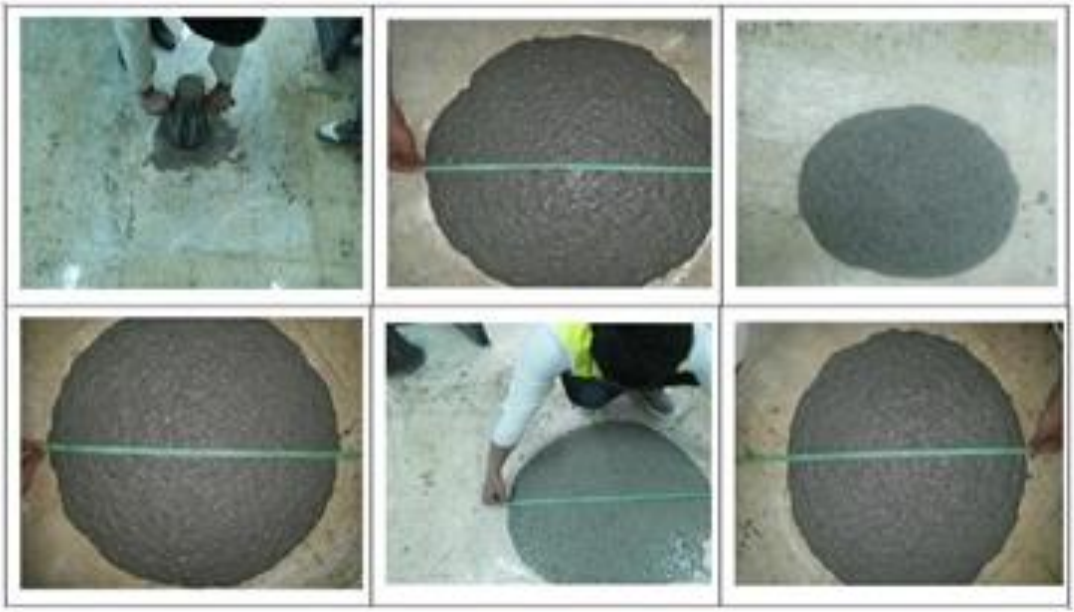

Figure 5: Slump test and implementation of concrete

Bulk density.

Figure 6 illustrates the bulk density of concretes as a function of the curing age measured at 28 days. It was noted that the concrete density has increased depending substitution of limestone filler by the finely crushed seashells and also depending on substitution of natural sand by crushed sea shells. It should be noted that the specific gravity of seashells is closer than that of the limestone fillers (2.71 g/cm3 for limestone filler) and also higher than that of sand (2.61 g/cm3 for sand).

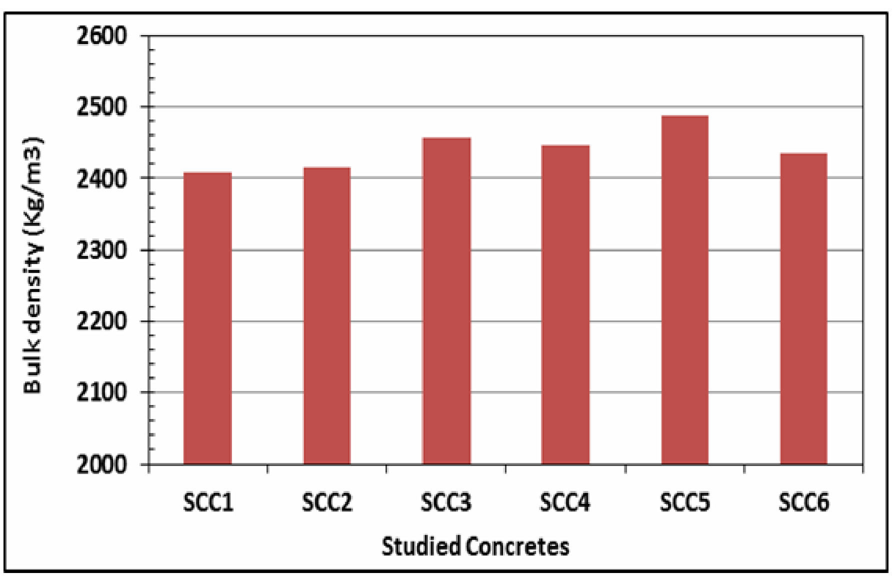

Figure 6: Bulk density evolution measured at 28 days

Solid State Science and Technology, Vol. 26, No 1 (2018) 60-69
ISSN 0128-7389 | *http://journal.masshp.net*

Flexural and compressive strength

The mechanical test results on concretes studied are given in Figure 7(a) and 7(b). This figure shows the evolution of flexural and compressive strength of the self-compacting concrete according to use of seashells. It was observed that the compressive and flexural strength remains the same for all concrete mixtures whatever curing age. Also, the compression strength values were almost identical regardless the use mode of seashells in concrete (as a fine powder or fine aggregates). However, compared to SCC1, a slight increase in resistance of concrete SCC2 and SCC5 was registered (see Figure 7(b)). For a total use of seashells, can gives a concrete having strength of 43 MPa which is identic to control concrete. This means that seashells can be used in self-compacting concrete without disturbed the mechanical performances [6-7].

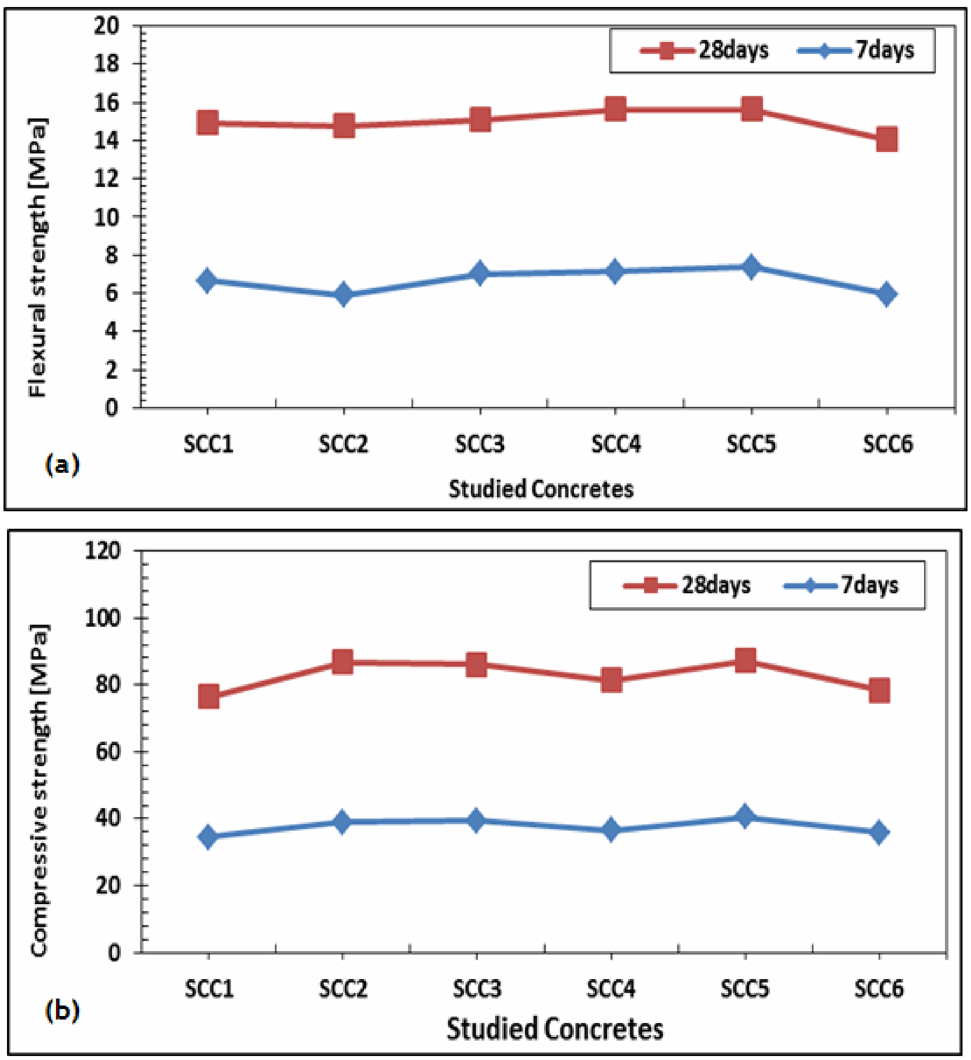

Figure 7: Mechanical strength of studied concretes (a) flexural strength (b) compressive strength

Dynamic elastic modulus

According to the obtained results, it can be observed that the concretes SCC4, SCC5 and SCC6 have values of elastic dynamic modulus higher compared to the reference concrete (SCC1). The substitution of limestone fillers by the finely crushed seashells (as an addition) as well as the substitution of sand by crushed seashells (as fine aggregates) has greatly improved the compactness of the concrete and causing a slightly increase of dynamic modulus of elasticity (see Figure 8).

Macroscopic aspect of concrete with seashells

It is clear that according to Figure 9, the grain shape of sea shells has promoted the distribution of the latter in the concrete. The concretes SCC1 and SCC2 have practically the same macroscopic structure this can be explained that the limestone powder and the seashell powder are almost identical thus these two powders have played the same role that is filling of the voids [8]. Also, SCC3 and SCC4 have the same macroscopic structure in the case where the sand is partially substituted by the crushed seashells. However, for a total substitution of limestone fillers and sand by seashells (powder or crushed) has significantly promoted the grain distribution in the cementitious matrix [6]. Indeed, the angular shape of seashell has a positive effect for obtaining an improved compactness of concrete.

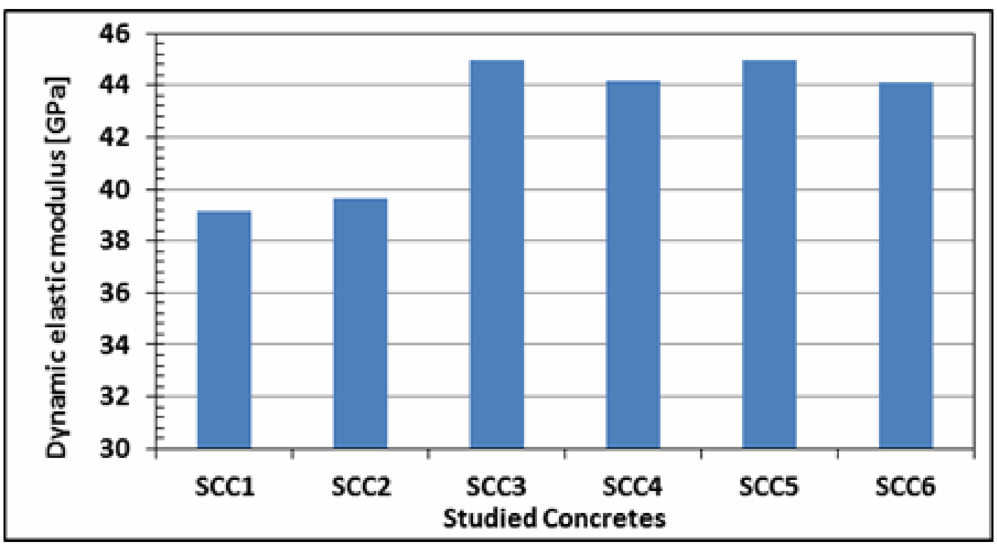

Figure 8: Dynamic elastic modulus (Ed) of concretes (at 28 days)

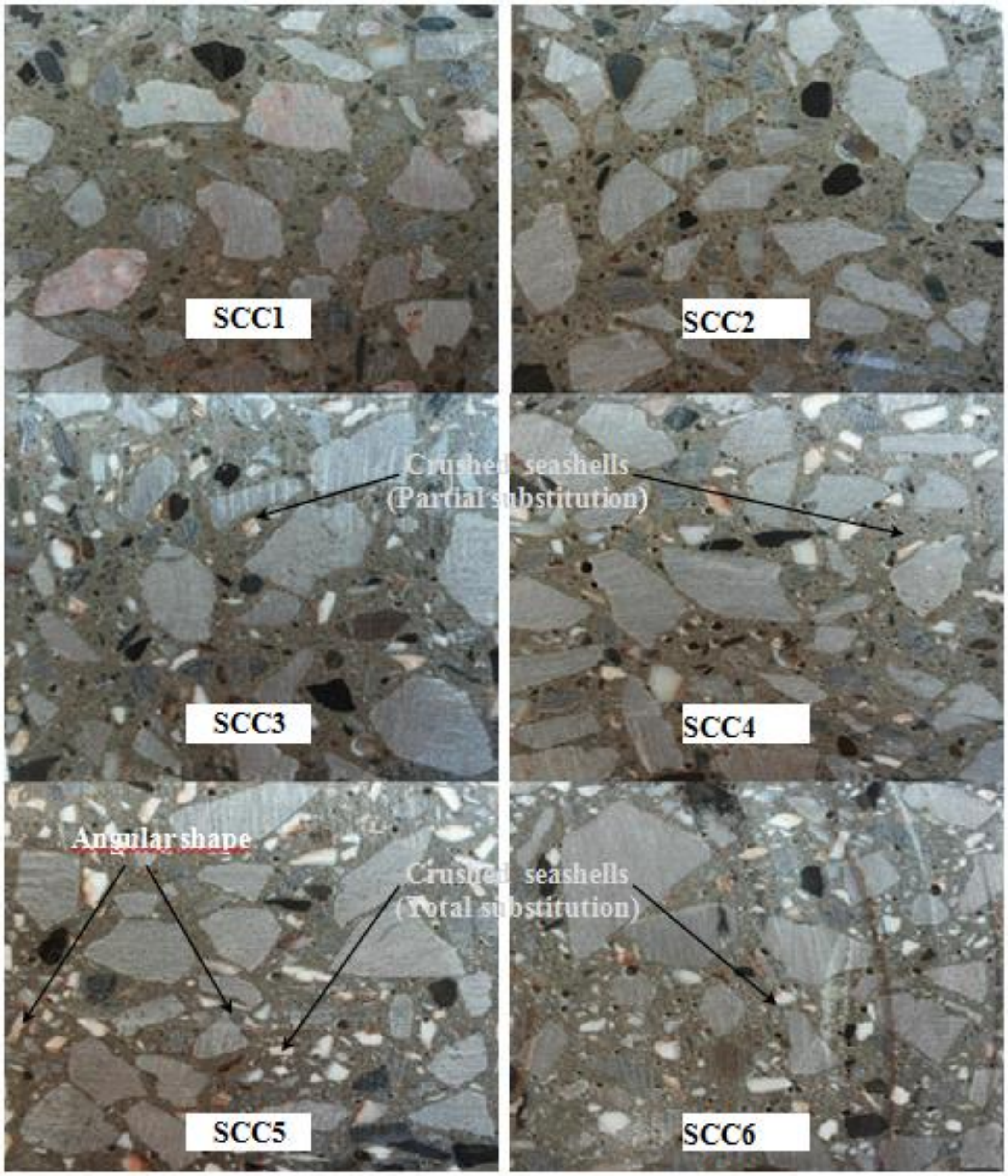

Figure 9: Images taken on concrete samples (28 days)

CONCLUSION

This investigate had the aim to estimate the potential of use of seashells in self-compacting concretes. In this present study, the seashells are used as cementitious materials by substitution of limestone fillers and as fine aggregates by sand substitution. Regardless of the mode use of seashells in a self-compacting concrete, it can gives a concrete having strength of 43 MPa which is used for construction. Indeed, the obtained results have shown that seashells can be used in self-compacting concrete without disturbed the mechanical performances.

Also, the seashell powder has played the same role than limestone fillers which is the filling of the voids. However, for a total substitution of limestone fillers and sand by seashells (powder or crushed) has significantly promoted the grain distribution in the cementitious matrix. Indeed, the angular shape of seashell has a positive effect for obtaining an improved compactness of concrete.

REFERENCES

[1] Robillard C., Valorisation study of marine by-products shellfish as additions and aggregates in cementitious materials. Ph. D thesis. University of Caen-Basse Normandie; (2012), 246.

[2] Yang E.I., Yi S.T., Leem Y.M., *Cement and Concrete Research* **35** 2175-2182 (2005)

[3] Yoon H., Park S., Lee K., Park J. *Waste Manage. Res.*, **22** (3) 158–170 (2004)

[4] Jung, J.H., K.S. Yoo, H.G. Kim, H.K. Lee and B.H. Shon. *J. Ind. Eng. Chem.*, **13** (4) 512-517 (2007)

[5] Nguyen D.H., M. Boutouil, N. Sebaibi. *Construction and Building Materials* **49** 151–160 (2013)

[6] Brahim Safi., Mohamed Saidi, Abdelhakim Daoui, Bellal Ahmed, Mechekak Ali, Toumi Kamel, *Const. Build. Mater.* **78** (1) 430–448 (2015)

[7] Nguyen D. H., N. Sebaibi, M. Boutouil, L. Leleyter, F. Baraud. *Journal of Civil Science and Engineering* **7** (11) 385-392 (2013)

[8] Namdar A., Yahaya F.M., *International Journal of Civil, Architectural Science and Engineering,* **8** (2) 169-172 (2014)

[9] Richardson A. E., *Structural Survey,* **31** (5) 347-354 (2013)

[10] Neves N.M., Mano J.F., *Materials Science and Engineering C,* **25** 113–118 (2005)

[11] ASTM C78 – 02, Standard Test Method for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading), which appears in the Annual Book of ASTM Standards Vol 04.02, (2002).

[12] ASTM C39 – 02, Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens, which appears in the Annual Book of ASTM Standards Vol 04.02, (2002).

[13] ASTM C597-97. Standard Test Method for Pulse Velocity through Concrete, Annual Book of ASTM Standards, 04.02 Concrete and Concrete Aggregate; (1993).