Performance of Self-Compacting Concrete With Different Sizes of Recycled Ceramic Aggregates

Ghasan Fahim Huseien
PhD Scholar
Faculty of Civil Engineering
Universiti Teknologi Malaysia
81310 UTM Johor Bahru, Johor, Malaysia

Mohammed Yahya Al-Fasih
PhD Scholar
Faculty of Civil Engineering
Universiti Teknologi Malaysia
81310 UTM Johor Bahru, Johor, Malaysia

Shariwati binti Mansor
PhD Scholar
Faculty of Civil Engineering
Universiti Teknologi Malaysia
81310 UTM Johor Bahru, Johor, Malaysia

Hussein Kadhim Hamzah
Master Scholar
Faculty of Civil Engineering
University Bucharest
Bucharest, Romania

***Abstract*—Recently, self-compacting concrete (SCC) has acquired widespread utilized for position in stuffed reinforced concrete structures with hard casting conditions. For such purposes, the fresh concrete needs to have high fluidity and excellent cohesiveness. Self-compacting concrete has ability consists of not merely high deformability of paste or mortar, but additionally resistance to segregation between coarse aggregate and mortar in the event the concrete passes throughout the confined region of reinforcing bars. In order to relieve the volume of ceramic waste materials from the construction industry, it will be possible, between additional applications, to utilize it as aggregates inside the production of self-compact concrete. Using detrimental waste materials within concrete-making will certainly produce to an eco-friendly environment and also sustainable concrete technology and so such concrete can also be called as 'green' concrete. This specific paper had been carried out to formulate the properties of self-compacting concrete (SCC) by using mineral admixture (fly ash), chemical admixture with different sizes of ceramic aggregate. Three self-compacting concrete (SCC) mixes and three control concrete have been researched in this study; compressive strength, expansion, shrinkage and flexure strength of reinforced concrete beam investigates. The results indicated the self-compacted concrete made with ceramic aggregate; 7mm maximum size show good workability and compressive strengths. Self-compacted concrete produced higher shrinkage and lower expansion comparing with normal concrete. Test on reinforced concrete beam show the self-compacted concrete beam performed better than normal concrete beam.**

Keywords*—component, formatting, style, styling, insert (key words)

I. INTRODUCTION

Technology in concrete has been developing in many ways to enhance the quality and properties of concrete, one of the ways in improving the quality of concrete by using self-compacting concrete. Self-compacting concrete (SCC) had been recommended in (1986) by Okamura in Japan [1].

Self-compacting concrete, due to its own weight, without the need for vibration, allows air bubbles out in Narrow and compact areas of reinforcement [2]. It also prevents separation of concrete bleed water and aggregates and evenly penetrates the total area at the same time [3]. In this case, the obtained concrete will be in integrated and appropriate mode. Another advantage of self-compacting concrete is very good pumping ability due to the slump at the long distances [4]. Moreover the use of this concrete will dramatically reduce concreting time and noise pollution and on the other hand reduces vibration costs [5]. Despite all the advantages, self-compacting concrete has disadvantages such as separation of aggregates and concrete bleeding [2, 5]. One of the solutions to this problem is the use of admixtures and increasing the viscosity of concrete using these materials [6, 7].

For self-compacting concrete (SCC), it can be generally important to utilize super plasticizers to be able to get higher mobility. Adding a sizable volume of powdered material or viscosity enhancing admixture could eradicate segregation. The powdered materials that could be added in usually are fly ash, silica fume, and lime stone powder, glass and quartzite filler [8].

Fly ash can be a professional by-product, created in the combustion involving fossil fuel in the thermal electric power crops. The actual growing scarcity involving recyclables plus the critical must defend environmental surroundings against air pollution offers accentuated the value involving developing brand-new developing materials dependent on professional squander created coming from fossil fuel fired thermal electric power programs creating unrestrainable fingertips problems this can probable to help dirty environmental surroundings. Fly ash, when utilized like a mineral admixture throughout real, enhances it's durability and strength qualities. Fly ash can be used both just as one admixture and even like an incomplete substitution involving cement. It is also utilized like a as a partial replacement of fine aggregates, as a total replacement of fine aggregates and as supplementary addition to achieve different properties of concrete [9].

Self-compacting concrete (SCC) doing extremely well with precast applications or even intended for concrete put on site. It can be manufactured in a site batching plant or even in the ready blend concrete plant and also sent to site simply by truck. It can and then become positioned either simply by water removal or even putting straight into horizontal or vertical structures. Throughout building this blend, this size and also the type of this construction, the size and the form of the structure, the dimension and density of reinforcement and cover should be taken in consideration [10].

Self-compatibility is basically impacted by the characteristics of materials and also the mix proportions; it becomes necessary to advance a procedure for mix design of self-compacting concrete (SCC) [3, 4]. The coarse and fine aggregates contents are steady and self-compatibility will be achieved by modifying the w/c ratio and super-plasticizer dosage. The gravel content in concrete is often set at 50 percent of the total solid volume, the sand content is fixed at 40 percent of the mortar volume and the water/binder ratio is assumed to be 0.9-1.0 by volume depending on the properties of the binder and the super plasticizer dosage [3-6]. Industrial waste materials managing constitute one of the important global problems of our times. Recycling of non-biodegradable waste is very complicated. Ceramic wastes have been categorized in this group. Mainly because, that biodegradation period of ceramic is very long (up to four thousand years) and ceramic industry waste comprises important share in the total manufacturing, recycling of ceramic waste materials is a very big problem [11]. One of the normal options of reusing inorganic industrial wastes materials is their utilization in the production of building materials, especially as raw materials inside concrete production. This manner of recycling provides beneficial influence on the environment – it decreases the quantity of deposited waste materials and limitations exploration of mineral aggregate deposits. Inorganic ceramic waste materials have an additional advantage – it needs no special processing when utilized as a coarse aggregate [12]. The technological of producing the concrete combine with aggregate using recycled ceramic waste materials is the same as in the case of production of concrete mix with classic aggregate [13].

This paper explains a process exclusively formulated to achieve self-compacting concrete. Additionally, the test results for popularity characteristics for self-compacting concrete such as slump flow, T50 sec and L-Box test are shown. Even more, the strength characteristics in terms of compressive strength for (7, 28 and 56) days are also offered.

II. Materials

A. Ordinary Portland cement (OPC)

From Holcim Cement Manufacturing Company of Malaysia the ordinary Portland cement is obtained conforming to ASTM C150 standard is used [14]. The chemical composition of OPC used is as shown in TABLE 1.

B. Minerail admixture

Low calcium content fly ash is used as an additive in accordance to ASTM C 618 [15]. Cement is replaced by 30% of fly ash by weight. The physical and chemical properties of fly ash are given in the TABLE 1.

TABLE I. Chemical and Physical Properties of cement and fly ash (class-F)

Type	OPC	Fly ash
SiO_2	20.1	46.7
Al_2O_3	4.9	35.9
Fe_2O_3	2.4	5.0
CaO	65.1	3.9
MgO	3.1	0.8
Na2O	0.2	0.6
K2O	0.5	0.5
LOI	2.4	1.0
Color	Grey	Grey
Specific Gravity	3.15	2.13

C. Fine Aggregate

Through production of self-compacting concrete (SCC), testing of aggregate grading and wetness content need to be carried out more frequently compared to normal, since self-compacting concrete (SCC) is actually more sensitive than normal concrete to variations. Local sand with specific gravity of (2.62) and fineness modulus of (2.85) in saturated surface dry condition was utilized in this research.

D. Chemical Admixtures

Super plasticizer SP1100 was used as chemical admixture in producing SCC, ASTM C-494 type F is used [16].

E. Coarse Aggregate

Crushed Ceramic waste Materials from construction industrial; size (7, 12 and 20) mm are used as coarse aggregate (Fig. 1.)

Fig. 1. Ceramic after crushing.

III. Mix Proportion

Six different mixes of concrete were prepared, the water-cement ratio, fine aggregate were kept constant. Ceramic coarse aggregate used with different sizes 7, 12 and 20mm. fly ash used to replaced cement binder. The mix properties showed TABLE 2.

Laboratory test was carried out to investigate the fresh and hardened properties of self-compacted concrete (SCC). The properties of fresh self-compacted concrete mixes were examined through slump flow, slump flow [T50] and L-box test.

The compressive strength test has been executed at the age 7, 28 and 56 days examine the strength development hardened self-compacted concrete mixes. Expansion and shrinkage test were carried out on self-compacted and normal concrete.

TABLE II. MIX PROPERTIES

Materials		Size	M1	M2	M3	M4	M5	M6
Binder Kg/m^3	Cement		520	520	520	365	365	365
	Fly ash		-	-	-	155	155	155
Aggregate Kg/m^3	Fine		895	895	895	895	895	895
	Coarse	7	765					
		12		765				
		20			765			
	Ceramic	7				765		
		12					765	
		20						765
Water/Binder			0.48	0.48	0.48	0.48	0.48	0.48
Water, liter			250	250	250	250	250	250
SP, % weight cement			-	-	-	1.5	1.5	1.5

To assessment the flexure strength two simply supported beams prepared, the details of beams shown in TABLE 3 and Fig. 2.

TABLE III. MIX PROPERTIES

Type of Mix concrete			Dimension, mm			Reinforcement H and R	
			L	D	W		
1	B-M1	NC	1800	155	125	4H10	R6-75
2	B-M4	SCC	1800	155	125	4H10	R6-75

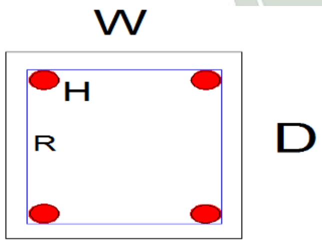

Fig. 2. Beam details.

IV. TEST METHODS

Filling ability, passing ability and resistance to segregation is characterization of Self- Compacting Concrete method. Various methods are already developed to characterize the properties of (SCC). Table 4 showed the recommended values for different tests given by different researchers for mix to be characterized as self-compacting concrete (SCC) mix.

TABLE IV. RECOMMENDED LIMITATIONS FOR VARIOUS PROPERTIES

No.	Method	Property	Unite	Range
1	Slump-flow	Filling ability	mm	500-700 [17]
2	T_{50cm}slumpflow	Filling ability	sec	2-5 [17]
3	L-box	Passing ability	ratio	≥0.8 [18]

The slump flow test shown in Fig 3 is used to measure the horizontal free flow of (SCC) inside absence of interferences. On lifting the slump cone, filled with concrete, the concrete flows. The average diameter of the concrete circle is determined for the filling ability of the concrete. The time T50cm is a secondary indicator of flow. It measures the time taken in seconds from the instant the cone is lifted to the immediate when horizontal flow reaches diameter of (500)mm.

Fig. 3. Slump flow test.

The moving ability is established by using the L- box test [19] as shown in Fig 4. The vertical section of the L-Box is filled with concrete, after which the gate elevated to let the concrete stream into the horizontal area. The height of the concrete at the end of the horizontal area is indicated as a percentage of that remaining in the vertical section [H2/H1]. This is an indication of passing ability. [The specified requisite is the ratio between the heights of the concrete at each end or blocking ratio to be ≥ 0.8].

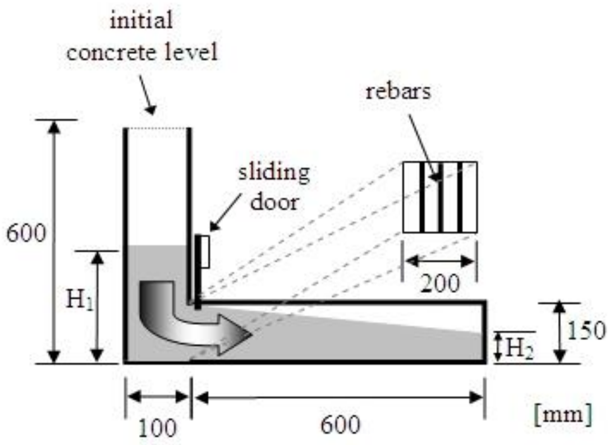

Fig. 4. L-box test [20].

V. RESULTS AND DISCUSSION

A. Slump flow test

The slump flow test is the most favored method for measure concrete reliability in the laboratory and at construction sites. The results of the fresh-state are displayed in this section. The increase of the size of ceramic aggregate led a reduction in the flow ability and passing ability of the SCC, which is especially noteworthy as time goes by. Three different size of ceramic aggregate was evaluated. Furthermore, the mixes with 20mm and 15mm lost SCC characteristics more than mix with 7 mm. The results of the slump-flow test exhibit a clear decreasing trend of the increase size of aggregate, different size of ceramic considered (chart -1). However the reduction workability is more intense for higher size utilized.

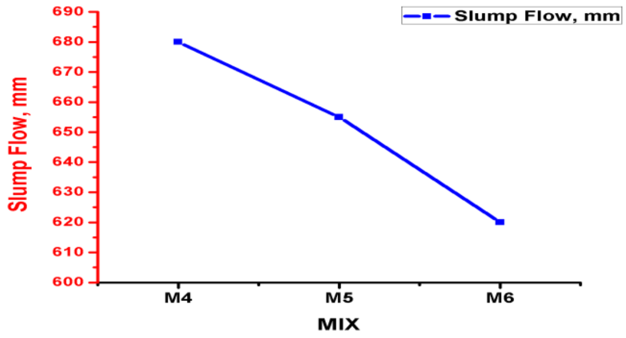

Chart. 1 Slump flow test.

The slump and T50 values for various mixes are shown in chart.1, 2 this helps to know the bellyful ability of [SCC]. From slump flow and T50 tests, 7mm ceramic size behaves better compared with other sizes of aggregate.

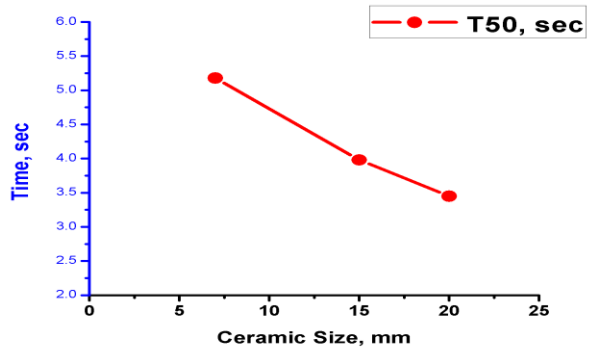

Chart. 2 T 50 test.

The passing ability of [SCC] beyond the reinforcing bars can be found by using L-box test. The mixture possessing high powder content and lower coarse aggregate passes easily through the reinforcing bars. The ratio of [H2/H1] is utilized to appear the magnitude of the result of L-box. The minimum value of [H2/H1] can be (0.8) and the maximum value (1.0).

Chart-3 mention the smaller size of ceramic aggregate produce better fresh properties for the mix, because the voids between aggregate will reduce and due to that the mix will be dense and homogenous. From other hand, the use of ceramic aggregate with large size such as 20 mm, the filling, passing ability and stability will decrease.

The results shown the mixes 4 and 5 were subjected to the passing filling ability test in the flow, T50 and L-box test. M6 failed in passing ability test.

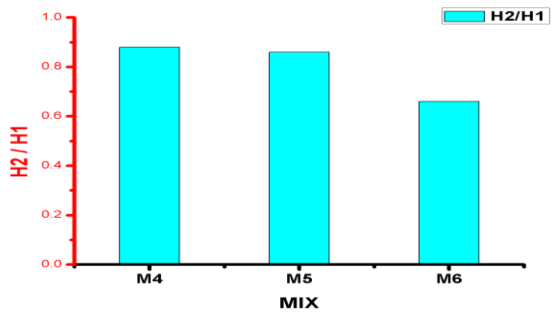

Chart. 3 L - Box test.

B. *Compressive strength*

The compressive strength of the assorted concrete mixes is shown in chart-4. The control concrete (M1) evolve compressive strengths of 37.66, 45.85 and 48.36MPa, at 7, 28 and 56 days, respectively. The self-compacting concretes developed compressive strengths ranging from 29.62, 41.78 and 49.73 MPa at 7, 28 and 56 days.

The compressive strength increased with a decrease in the size of the ceramic. 7 mm ceramic aggregate (M4) shown the maximum strength with compare with Mixes M5 and M6 also achieved compressive strength more than control mixes concrete M1, M2 and M3.

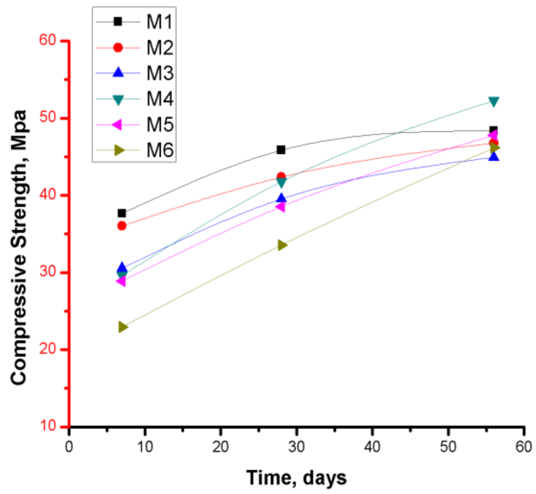

Chart. 4 Compressive strength test.

C. *Flexure Strength Test*

The final loads with normal concrete (B-M1) and self-compacting tangible beam (B-M4) ended up 15.12 KN and 16.54 KN respectively. The volume of crack to the support with (B-M1) order is 268 mm when it's in (B-M4) order is 290mm. the absolute maximum deflection with (B-M1) and (B-M4) cross-bow supports are 20.38 and 26.58 mm, respectively (chart-5). Finally the actual flexure overall performance of self-compacting tangible beam (B-M4) was a lot better than normal tangible beam (B-M1) with term of loading, numbers of cracks and deflection.

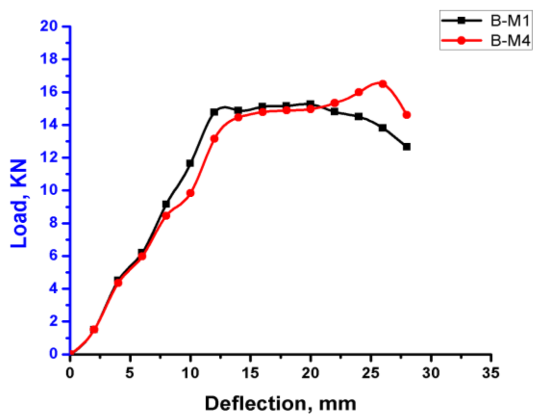

Chart. 5 Beams flexure strength test.

D. Expansion and Shrinkage

Chart 6 and 7 indicted the normal concrete in expansion was higher than self-compacting concrete. However inside shrinkage the self-compacting concrete was higher than normal concrete.

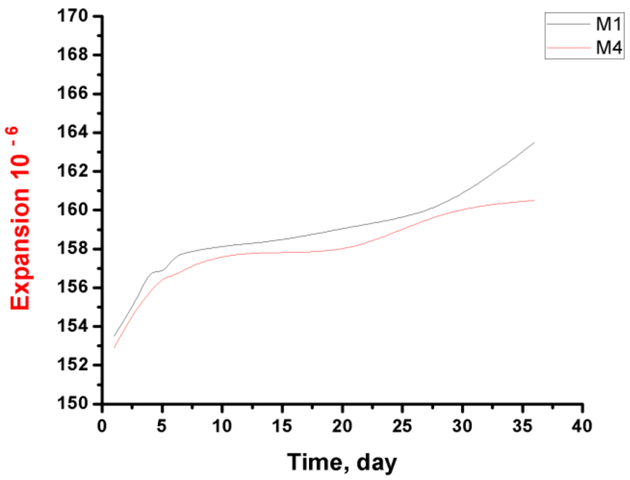

Chart. 6 Expansion test.

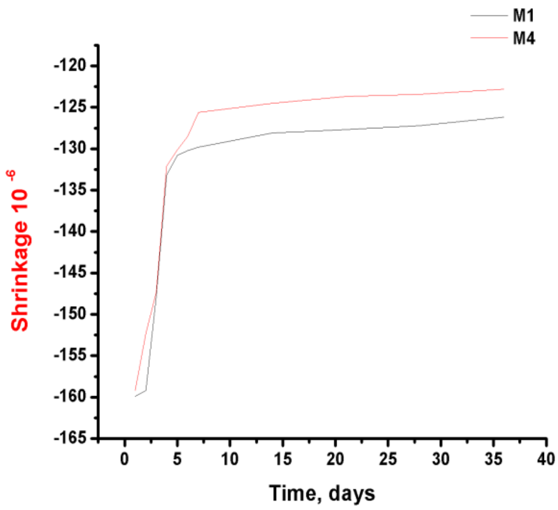

Chart. 7 Shrinkage test.

Conclusions

Self-compacting concrete (SCC) could possibly be developed with utilizing ceramic aggregate as was done in this study.

Adding of fly ash develops filling and moving ability of [SCC].

Regarding the mechanical performance, in terms of compressive and flexure strength, the use of ceramic recycled aggregates for concrete is suitable.

Self-compacting concrete average compressive strength at 56 days is higher than normal concrete.

Normal concrete higher expansion and lower shrinkage than self-compacting concrete [SCC].

The flexure strength of self-compacting concrete [SCC] beam indicates a comparable behavior to normal concrete beam at lower. However, the self-compacting beam concrete achieves higher ultimate strength and there is significance difference in ductile behavior compared to normal concrete beam.

Consequently, it can be reported to the mix (M4) has beneficial effects on both (fresh and hardened) properties of self-compacting compared to the other five mixes in normal and self-compacting concrete.

Acknowledgment

Authors are thankful to the Malaysian Ministry of Education (MoE) and Unversiti Teknologi Malaysia (UTM) for providing the financial support and facilities to complete this work.

References

[1] Okamura, H. and Ouchi, M. Self-compacting concrete. Journal of advanced concrete technology, 1(1), (2003): 5-15.

[2] Sorkhabi, R. and Naseri, A. Studying the Strength of Self Compacting Concrete According to the Ratio of Plasticizers and Slump Flow Using Experimental Method. Life Science Journal; 10(6s), (2013): 39-42.

[3] Jawahar, J. G., Sashidhar, C., Reddy, I. R. and Peter, J. A. A simple tool for self-compacting concrete mix design. Int J Adv Eng Technol, 3(2), (2012): 550-558.

[4] IUREŞ, L. and Bob, C. The Future Concrete Self-Compacting Concrete. Bul. Inst. Polit. Iaşi, t. LVI (LX), f. 1, (2010): 95-100.

[5] Grdić, Z., Despotović, I. and Topličić-Ćurčić, G. Properties of self-compacting concrete with different types of additives. Facta universitatis-series: Architecture and Civil Engineering, 6(2), (2008): 173-177.

[6] Patel, M. D. H., Patel, M. D. D., Patel, M. D. P., Patva, M. V. A. and Patel, M. Y. R. Literature Review on Self Compacting Concrete. IJTRE, 1 (9), (2014): 662-666.

[7] Kennouche, S., Zerizer, A., Benmounah, A., Hami, B., Mahdad, M., Benouali, H. and Bedjou, S. Formulation and characterization of self-compacting concrete with silica fume. Journal of Engineering and Technology Research, 5(5), (2013): 160-169.

[8] Aggarwal, P., Siddique, R., Aggarwal, Y. and Gupta, S. M. Self-compacting concrete-procedure for mix design. Leonardo electronic journal of practices and technologies, 12, (2008): 15-24.

[9] Dhiyaneshwaran, S., Ramanathan, P., Baskar, I. and Venkatasubramani, R. Study on durability characteristics of self-compacting concrete with fly ash. Jordan Journal of Civil Engineering, 7(3), (2013): 342-352.

[10] Okrajnov-Bajić, R. and Vasović, D. Self-compacting concrete and its application in contemporary architectural practice. Spatium, (20), (2009): 28-34.

[11] Halicka, A., Ogrodnik, P. and Zegardlo, B. Using ceramic sanitary ware waste as concrete aggregate. Construction and Building Materials, 48, (2013): 295-305.

[12] Senthamarai, RM., Devadas, P. and Gobinath, D. Concrete made from ceramic industry waste: durability properties. Constr Build Mater 25, (2011): 2413–9.

[13] Medina, C., Sánchez de Rojas, MI. and Frías M. Reuse of sanitary ceramic wastes as coarse aggregate in eco-efficient concretes. Cem Concr Compos (2012); 34:48–54.

[14] ASTM C150. Standard Specification of Portland cement, (2012).

[15] ASTM, C618. Standard specification for coal fly ash and raw or calcined natural pozzolan for use in, concrete, (2003).

[16] High-Range, W. R. A. and Admixture, R. ASTM C 494/C 494M. Type F.

[17] Nagataki, S. and Fujiwara, H. Self-compacting property of highly flowable concrete. ACI Special Publication, (1995): 154.

[18] Khayat, K. H. and Manai, K. Lesbetons autonivlants: proprietes, charcterisation et applications, colloque sur les betons autonivlants. Universite de Sherbroke, Canada, 8, (1996).

[19] Petersson, O., Billberg, P. and Van, B.K. A model for Self-Compacting Concrete, Proceedings of Production Methods and Workability of Concrete, E & FN Span, London, (19960: p. 483-492.

[20] Doka, S. G. The European Guidelines for Self-Compacting Concrete Specification Production and Use, (2005).