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Passing Ability Testing for Self-Compacting Concrete

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Abstract- The self-compacting concrete is a special type of concrete that eliminates the need for mechanical agitators and devices that require particle vibration. It presents, as its main characteristic, a self-completion procedure by its own weight. Passing ability is one property among the ones required in a self-compacting concrete, which verifies the concrete flowing capacity over the form, by passing through the concrete reinforcement without segregation or outflow obstruction occurrence. The self-compacting concrete passing ability is test verified by the followings: L-box test, L-box [4] J ring test, J ring test [3] and U-Box test, U-Box [4] .The study methodology consists of a bibliographic review of the self-compacting concrete, as well as the tests used to assess its passing ability. The experimental tests performed were the Slump-flow test scattering [2] and L-box test, L-box [4]. The value of 605 mm was obtained in the scattering test, which ranks the concrete as the SF1concrete, which has a lower cost, but requires a strict quality control. In the L-box test, a 0.95 value permitted height ratio [4] was obtained, characterizing a suitable concrete for using in high density concrete reinforcement structures.

Keywords- *Self-Compacting Concrete, Passing Ability, Segregation*

I. Introduction

The self-compacting concrete (SCC) is defined according to the ABESC as a special type of concrete that does not require the use of mechanical agitators or other apparatus for vibrating the particle. Furthermore, it is characterized by a self-completion procedure by its own weight. The SCC presents good levels of deformability when in fresh and it has high resistance to segregation, what is stated by [5].

The first SCC was produced in 1988 at the University of Tokyo, by Japanese researchers, such as Okamura, Osawa and Maekawa. Osawa presented the SCC in the 2nd East-Asia and Pacific Conference on Structural Engineering and Construction (EASEC - 2) in January 1989. The SCC has been studied and used in several places in North America, Japan and the UK since the late 90’s.

In 2000 [15] this concrete corresponded to only 0.15% of machined concrete used in Japan, and 0.55% of the prefabricated, as it’s been reported.

According to [9], the self-compaction property is obtained when it reaches a certain degree of viscosity and higher fluidity rates. For such high fluidity to be achieved, plasticizers and superplasticizers additives are needed. For viscosity parameters, a thin mineral particle size must be brought into the mixture. Moreover, it is important to observe that the volume of slurry is high, but the volume of aggregates is lower.

Among the advantages of the SCC, there is the vibration process elimination [11], and also, according to the same author, this may lead to concrete quality improvement, as well as economic efficiency by reducing working hours and concreting process, and also increasing security of the concrete that is being used. Besides the fact that no need of vibration makes the final product a higher quality one, it also presents less failing [10]. In addition, the author also states that the manufacture of the SCC assists in the reduction of noise from vibrating and thus, the exposure of workers to this unhealthy environment is decreased.

The SCC production has the same components as used in conventional concrete, but the dosage is different, since it increases the proportion of fines and reduces the proportion of coarse aggregates. Furthermore, in order to achieve the required fluidity and viscosity levels, plasticizers and additives should be used and also viscosity controllers, in some cases [6].

The workability ([12], [11]) is one of the essential properties presented in the fresh state SCC that is responsible for achieving the hardened state. According to the authors already mentioned in this study, there are three SCC requirements for it to be called self-compacting: fluidity, segregation resistance and passing ability. The first is achieved when the concrete can fill the entire area of the forms using only its own weight, without the need of mechanical agitators. The second refers to the concrete's ability to maintain a homogeneous material, retaining the coarse aggregate of the mixture in suspension. The last mentioned relates to the ability of the concrete to pass through the steel bars so that the aggregates are not held by the same ones.

II. MATERIALS AND METHODS

The experimental method consists of an evaluation of the Slump-flow tests, L-Box and simple compression used in SCC, also analyzing its properties and applicability in construction works.

A. Materials

Samples of the experiments were made from Portland cement CP V-ARI (CP-V), and high resistance could be noticed in the first seven days [1] (potable water according to Ordinance No. 518 of the Ministry of Health), quartz origin natural sand grain size Table 01; 0 natural gravel source gneiss particle size between 5.0 mm to 9.5 mm from polycarboxylate superplasticizer. Three different types of SCC were produced from such materials, in which the features are shown in Table 02.

TABLE I. SAND PARTICLE SIZE

Sieve(mm)	Retained Mass (g)	Retained Mass (%)	Cumulative mass (%)
4.8	18.6	1.86	1.86
2.4	18.6	1.86	3.72
1.2	19.4	1.94	5.66
0.6	252.2	25.22	30.88
0.3	387.1	38.71	69.59
0.16	219.3	21.93	91.52
Bottom	84.8	8.48	100
Total	1000	100	100

TABLE II. FEATURES COMPOSITION

Feature	Cement	Water	Sand	Gravel	Superplasticizer ratio to cement
1	1	0.45	0.88	1.65	2%
2	1	0.50	0.88	1.65	2%
3	1	0.55	0.88	1.65	2%

A concrete mixer used for designing the homogeneous mixing of the materials was responsible for structuring the features. After the mixture was done, the mortar was tested in the Slump-flow and L-box tests. Concrete mixtures compressive strength test was made as cylindrical samples 10 x 20 established after 14 days.

Among the tests for verifying the self-compacting concrete properties, there is the passing ability, which comprehend the L-box test. The rheological properties of the concrete were evaluated by conducting the scattering tests (slump flow) and flow time t50 according to [2], assessing whether the actual water dosage was appropriate and also its resistance to simple compressive.

B. Methods

1) Scattering test (Slump-flow test)

According to rules [2] and [7], Slump-flow test - Figure 1, is a test to measure the fluidity of the SCC without segregating. The SCC fluidity measurement test is expressed by the diameter of the circle formed by the concrete. It takes approximately 6 liters of concrete to perform the test. The metal plate used in the test shall be moistened, in advance, with truncated cone, in order not to absorb water from the concrete during the test and, then, possibly altering the results.

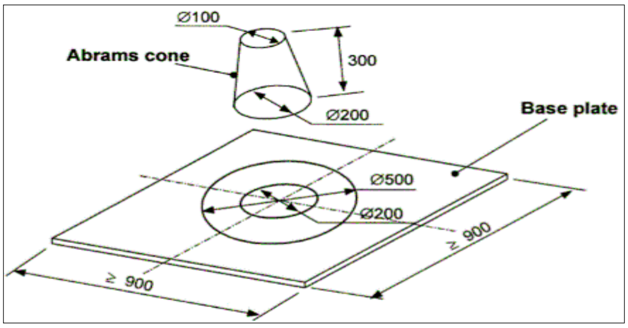

Figure 1. Slump- flow test - apparatus [8]

The plate is placed on a firm, leveled floor, and the truncated cone is placed in the center of the base. A marking process is carried out in a circle of 200 mm and 500 mm diameter to facilitate correct positioning. The concrete must be filled with a concave scoop, and a spatula is used for removing exceeded concrete from the top of the cone. The consolidation occurs under the force of gravity. The cone is vertically lifted and the measures for the scattering diameter in two directions are added to the average of these measurements is the value of the Slump-flow. The flow time uses a timer to measure the scattering time till it reaches 500 mm mark; this specific time should be around 3 to 7 seconds. [14] A few important notes: verify the occurrence of segregation and very low scattering, which indicates that the concrete is poorly fluid, and the opposite can also be observed.

Through the results obtained in the test, the SCC could be classified in 3 scattering classes. Table III shows that, according to the scattering class, there is a particular type of application.

2) L-box test (L-box)

The L-box test is used to determine the concrete passing ability through the form with the use of obstacles that simulates real conditions [4]. The box is of rectangular section, with an L profile and with two vertical and horizontal compartments; it must be made of non-absorbent materials, non-reactive and non-deformable concrete components. The standard specifies that the box should preferably be made of sheet metal but can also be made from other materials. The concrete should be enough for the box to be filled at once.

The box must be structured with two or three flat metal bars with a diameter of (12.5 ± 0.2) mm. The bars must be equidistant (40 ± 1) mm. The fresh concrete sample must be approximately 15 L of concrete. The test should preferably be performed in the laboratory with an approximate temperature of (23 ± 2) with a humidity of 50. First, you must apply the release agent, then close the L-box and place the box on a flat surface. The concrete must be released on the L-box, removing the exceeding with a trowel. After 30 to 60 sec from the filling end, the gate must be quickly opened, allowing the flow of the concrete for the horizontal chamber. Once the flow is ceased, the heights H1 and H2 should be measured – Figure 2, and the passing ability HP = H2 / H1 should be calculated. They must be established between 0.80 and 1.0, always taking into account the no occurrence of concrete segregation.

TABLE III. SCC SCATTERING CLASS ACCORDING TO ITS APPLICATION

Scattering class	SF1	SF2	SF3
Scattering (mm)	550-650	660-750	750-850
Application	unarmed or low reinforcement ratio and built structures, which concreting is performed from the highest point to free displacement pumped self-compacting concrete, structures requiring a short self-compacting concrete horizontal scattering	Suitable for most common applications	Structures with high density reinforcement and / or complex architectural form, with the use of concrete with coarse aggregate of small (less than 12.5 mm)
Example	Slabs, stakes, tunnel lining and some deep foundations	Walls, beams, columns and other	-Wall pillars, walls and pillars diaphragm

Source: [2]

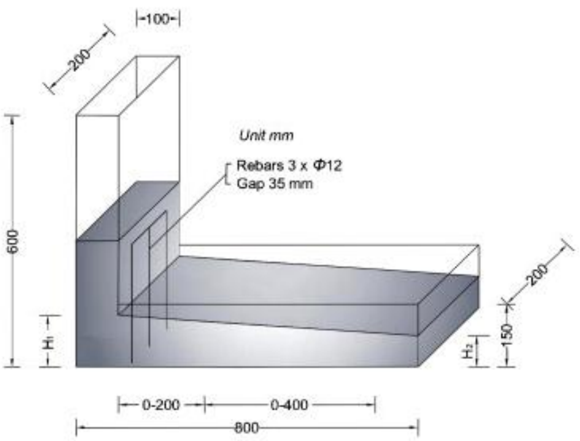

Figure 2. Heights calculating checking for self-compacting concrete passing ability [8]

III. RESULTS AND ANALYSYS

Fresh concrete results tests are shown in Table 4, and it can be observed that for the Slump-flow test, the scattering occurred in the SF1 range where slabs, stake, tunnel lining and some deep foundations can be structured.

The T50 time and the time that the concrete takes to reach the scattering of 500 mm in a diameter comprised between 3 to 7 s [14] are taken into consideration to measure the viscosity of the mixture [8].

TABLE IV. TEST RESULTS OBTAINED BY FRESH CONCRETE MEASUREMENT

Features	Slump-flow test (mm)	T50 (s)	L-box test	WC (water-cement factor)
T1	570	3.5	1.07	0.45%
T2	605	4	0.95	0.50%
T3	780	4	1.71	0.55%

The three features have been implemented to assess the flow and segregation properties, and viscosity and cohesion of the scattering time for each concrete mix. For the T1 Slump-flow test shown in Figure 3a, a higher concentration of aggregate, visible segregation [13], mortar aureole and perceptive exudation were obtained at the center of the scattering, even though they did not fit in the parameters of a concrete that could be used; its flow time is characterized by a short time and for being more cohesive. For the T2 in Figure 3b, the concrete remained homogeneous along with the mortar with no visible segregation, and with its cohesion characteristics reported in a classification that still requires attention, especially because it appears in the first lane, according to Table III. When considering the three features, that is the most recommended due to a no-observation of any changes in its scattering. \For the T3 in Figure 3c, it could be noticed a scattering which is not in accordance [2] with a diameter above the acceptable; there is a noticeable segregation and there is no cohesion between the coarse aggregate and fine aggregates and slurry, although the scattering time occurred as expected.

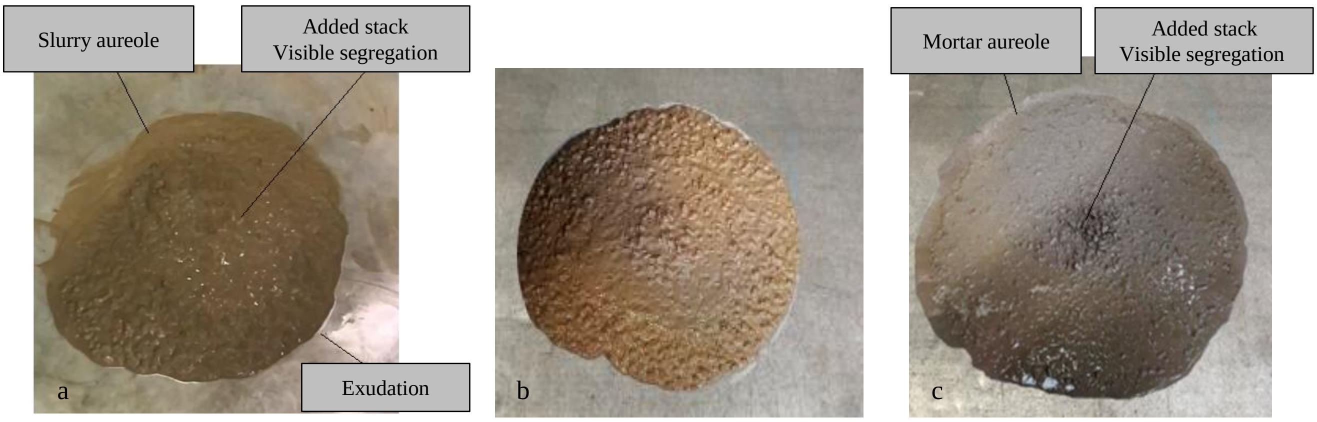

Figure 3. Slump-flow test a, b, c

In the scattering tests, an irregular thickness of the concrete could be observed, according to Table IV. When observing the TE1 there could be noticed a much higher accumulation of material in the center; on the other hand, for the Slump-flow test, the smallest scattering diameter occurred, and, so, it is suitable for usage, since its density can damage at the time of concreting, leading to some pathologies in the structure. For the TE2, it could be observed a higher homogeneity in the scattering, as well as a higher workability and homogeneity, characterizing it as the ideal concrete to be used in construction works, as there will be better accommodation in forms and increased expected density. A higher scattering can be seen in TE3, with a more fluidity for the concrete, but a no-homogeneous mixture; its consolidation was not satisfactory since it splitted the coarse aggregate and fine aggregates, what shows a no-cohesive concrete [13], and also the concrete thickness, even presenting a more homogeneity, can not be classified as a concrete for usage.

The features in Table IV were analyzed for the L-box tests, with an assessing for the rheology and passing ability of the concrete for the three conditions under analysis: for the T1 feature, the concrete did not present a good fluidity, with difficulties for passing through the reinforcement affixed in the front part of the L-box. As the concrete was in a more cohesive form, it also presented difficulties for passing through, what led to an accumulation of part of it in the higher part of the box (the concrete could not flow within the box, which was expected, since its ability is to flow inside the box with no consolidation). Such difficulties for passing may cause poor compliance inside its form, with some pathologies and a decrease of its durability, leading to formation of drills and a no homogeneous fulfillment of the form. Similar to the Slump-flow test – Figure 3, an accumulation of the aggregate at the scattering center of 5 cm occurred, with a no uniformity, leading to a jeopardized workability.

TABLE V. CONCRETE THICKNESS AFTER SCATTERING (CM)

Feature	At the center	On the side	On the border
TE1	5	3	2
TE2	3.8	2.7	1.8
TE3	2	2	1

The T2 concrete flowed well with an expected workability within the limits; it showed no exudation nor aggregates retention in the test, associated with Figure 3b Slump-flow test with expected scattering, also presented fluidity and more uniform thickness according to Table V. The TE2 showed the ability to accommodate within the form, with great probabilities to be used in construction work, as long as care and precautions are taking into consideration.

A completely fluid concrete is presented for the T3: when placing the concrete in the form, the mortar was already escaping from the inside of it, even if the gate had not been opened. When it was opened, the concrete began flowing in large amounts, a spread of the slurry aggregates occurred, with a box entrance accumulation, and also without cohesion between the aggregates and the mortar. If it happens in a concreting process, an exudation and a non-compliance could occur, thus causing problems in the durability of the structure. The Slump-flow test; Figure 3c, clearly demonstrated the parting of the aggregates and the slurry, in which the concrete did not fit according to the expectations, even though it presented proper scattering homogeneity and cohesion.

The results of the compressive strength tests were performed in the EMIC press – Figure 4. After 14 days, the results were expected, since increasing the amount of water leads to a decrease in the concrete strength, Figure 5.

(a) (b) (c)

Figure 4. Test specimens ruptured, a, b and c.

It is important to highlight that a balance between the concrete strength and workability should be obtained, when it deals with the amount of water workability. Since it is a SCC, a high quality densification in the forms is needed, without causing pathologies such as drills, a no-completely densification and form homogeneity.

The Slump-flow and L-box tests helped to classify the concrete as a SCC with a T2, since its properties and resistance occurred as expected.

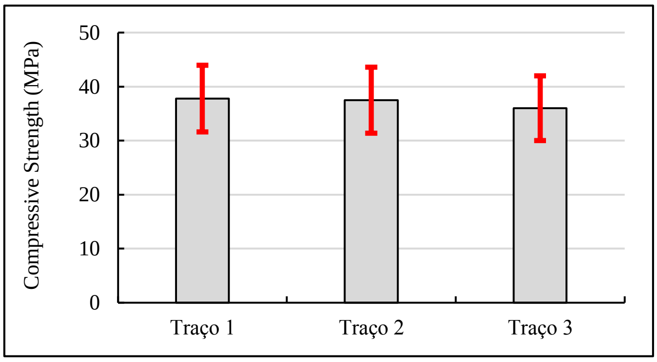

Figure 5. Compressive Strength Testing Results

IV. CONCLUSION

Among the characteristics of the self-compacting concrete, the passing ability and the fluidity are the ones that should be emphasized, once it is due to such characteristics that this type of concrete avoids the use of mechanical vibrators, increases the durability of forms, shortens the concreting period, and allows a higher compaction and consolidation in regions or parts with high reinforcement rates while maintaining its homogeneity.

The tests made for the passing ability could check the concrete's ability to overcome obstacles without flow obstruction or segregation. In order to verify such characteristic, there are three tests with this purpose: J ring, U-box and L-box. These testes use spaced steel bars so as to simulate the characteristics of the structural design of the construction work, accurately assessing in case the concrete fits the required specifications.

The scattering tests and concrete L-box made the assessment for the workability and passing ability of self-compacting concrete possible to occur. These tests showed results that demonstrated the fluidity and passing ability of the manufactured self-compacting concrete, reporting it as being suitable for use in structures with high density reinforcement and / or complex architectural form.

The L-box test can be considered as one more parameter to validate a concrete in its fresh state, its rheological compliance in density within the form, and also, even in a negative perspective, it is extremely important that it is performed very cautiously, preferably in a laboratory, and not in the construction site, so its performance can satisfactorily be evaluated.

The Slump-flow test, associated with the L-box, can be performed simultaneously because it is a simple test that can be performed in the construction place where the fluidity, the rheology segregation and the exudation of the concrete could be concurrently assessed, and also had its cohesion acknowledged.

Despite its strength in the hardened state, as shown in the compression tests, it could be slightly lower due to the a/c relation, once attention must be given to the workability and flowability in accordance within the form.

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