







Among the tests used to assess the mobility of confined concrete test, V-funnel is the most widely used (Assié 2004). The V-funnel flow time gives an indication of the filling ability of SCC, its viscosity and indicates the blocking effect caused by segregation.

The passing ability, which is defined as the ability of SCC to flow in confined conditions and completely fill all spaces within the formwork under self weight and without vibration, is tested using the L-box and U-box tests when the concrete flowing through confined or reinforced areas. While the values of  $T_{20}$  and  $T_{40}$  represent the times for concrete to reach 20 and 40 cm flow, respectively. The L-box and U-box tests allow testing the filling ratio of the concrete by measuring the passing ability ratio ( $H_2/H_1$ ) through the reinforcement bars.

### 3. RESULTS AND DISCUSSION

The results of fresh properties of the six (06) self compacting concrete mixes are shown in Table 4.

Table 4. Fresh properties of self compacting concrete mixtures

Mixtures	Slump flow		$H_2/H_1$	L Box		V-funnel time	U Box ( $H_2/H_1$ )
	D (mm)	$T_{50}$ (s)		$T_{20}$ (s)	$T_{40}$ (s)		
SCC(N)	764	2.67	0.63	2.91	7.10	9.7	0.63
SCC(N)15Pz	711	3.35	0.60	1.42	2.12	12.8	0.60
SCC(R)	769	3.29	0.95	2.2	5.20	11.0	0.43
SCC(R)15Pz	736	6.2	0.97	2.7	5.9	14.4	0.98
SCC(NR)	744	3.23	0.98	1.67	3.94	9.7	0.31
SCC(NR)15Pz	715	5.2	0.83	2.01	8.25	38.6	0.53

#### 3.1. Slump flow test

Figure 1 shows the results of slump flow of the different SCC mixes with and without recycled aggregates and pozzolana. As can be seen in Fig. 1, the slump flow values for different concrete mixes were measured in the range of 711–769 mm. According to EFNARC (2002), all concrete mixtures under investigation can be categorized as slump flow class 2 (SF2) or class 3 (SF3). The diameters of SCC (N) and SCC (NR) are less than the diameter of SCC containing 100% recycled aggregates. Tu et al. (2006) obtained a cone slump for a high performance concrete (HPC) with 100% recycled aggregates higher than that of an HPC with natural fine and coarse recycled aggregates, with a rapid loss of workability. Moreover, Khatib (2005) found that increasing the amount of recycled concrete aggregates in ordinary concrete generates an increase in its cone slump.

On the other hand, Yong and Teo (2009) found that substitution of 50 and 100% natural aggregates by recycled aggregates leads to a reduction of the slump of ordinate concrete. Grdic et al. (2010) found that the values of flow diameters were comparable

for SCC with natural aggregates, 50 and 100% recycled aggregates. The substitution of cement by natural pozzolana decreases the workability of concrete with and without recycled aggregates. This reduction in slump flow may be attributed to the higher water demand of the pozzolana finer particles.

The incorporation of pozzolana as cement replacement in concrete increases the porosity of the paste and hence a higher water demand (SCC contains a higher paste volume) and hence the decrease of the workability of SCC mixtures containing natural pozzolana. It should be noted, the higher slump flow values are given by SCC mixtures made with 100% of recycled aggregates for both 0% and 15% Pz as cement replacement. Arya et al. (1990) reported that the incorporation of pozzolan improves workability of vibrated concrete.

The  $T_{50}$  flow time for the three concretes (Fig. 2) is less than the maximum limit of 5 seconds. We can also note that the SCC prepared with natural aggregates presents the smallest  $T_{50}$  of 2.67 seconds followed by SCC (NR) and SCC (R) with a  $T_{50}$  equal to 3.23 and 3.29 seconds respectively. These results indicate clearly that the incorporation of natural pozzolana increases  $T_{50}$  flow time of SCC. Grdic et al. (2010) found a  $T_{50}$  exceeding 5 seconds for the three types of concrete, but the values were very similar. SCC mixture made with 100% recycled aggregates with and without pozzolana gives the highest slump flow time  $T_{50}$  with 3.29 and 6.22 seconds, respectively compared to control mixtures, which indicates a more viscous SCC mixture. However, the lowest flow time value  $T_{50}$  is given by SCC (N) with and without pozzolana.

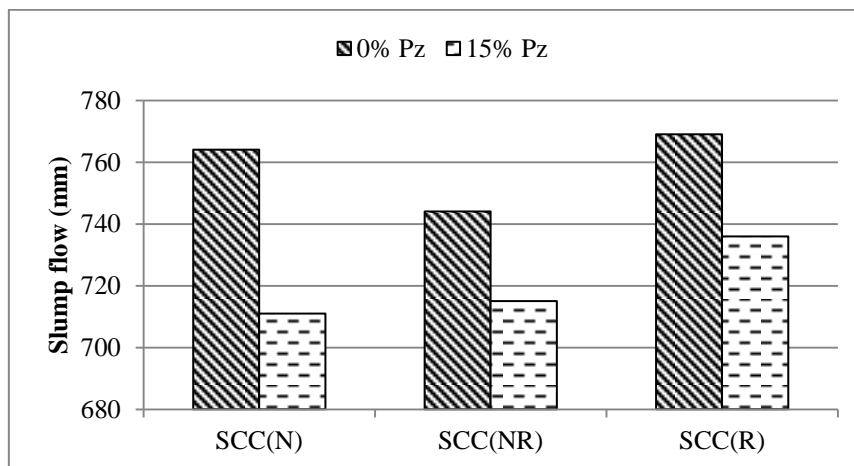


Figure 1. Slump flow test of SCC mixtures.

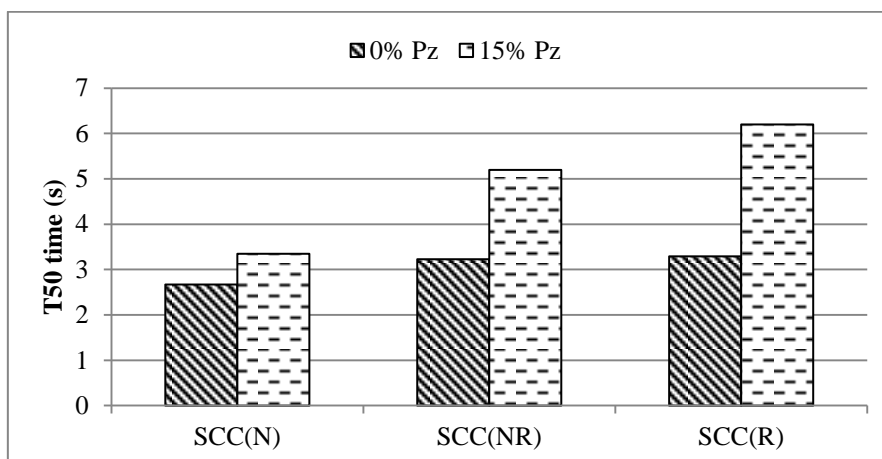


Fig 2. T<sub>50</sub> flow time of SCC mixtures.

### 3.2. L Box test

This test gives the passing ability of concrete through reinforcement bars, its filling capacity and its deformability. Figure 3 shows the measured ratio  $H_2/H_1$  from this test. It can be seen that the mixes made from 50 and 100% recycled concrete aggregates with and without pozzolana have better flow near the obstacles that the mix made from 100% natural aggregate with and without pozzolana.

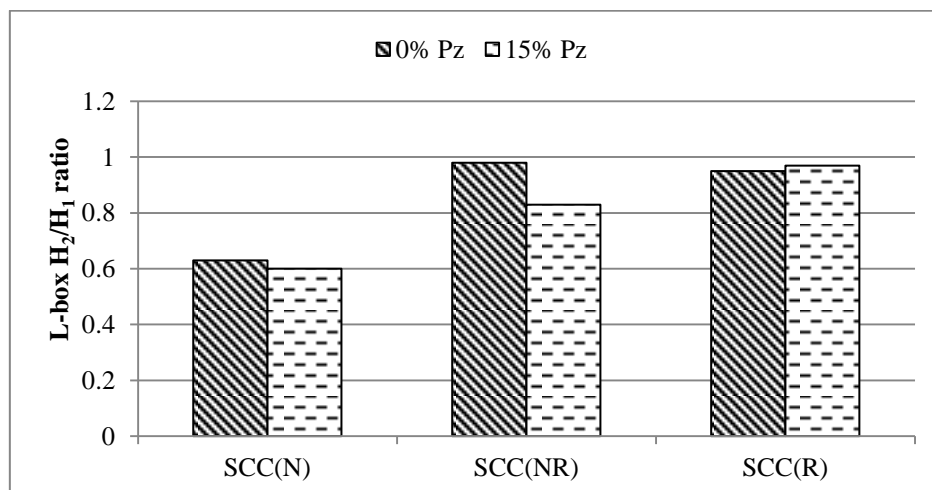


Fig 3. L-box ratio  $H_2/H_1$  of SCC mixtures.

A very high ratio was obtained for both SCC with 50 and 100 % recycled aggregates (98 % and 95 % respectively) and no blocking was noticed. This presents an improvement of the filling and passing ability relative to the SCC with natural aggregates where the  $H_2/H_1$  ratio did not exceed 63 %. Grdic et al. (2010) found

comparable results with a ratio of 95 % and 98 % for SCC with 50 and 100 % of recycled aggregates, respectively. This high passing ability of SCC with recycled aggregates may be due to the change in size and grading of the aggregates during mixing due to breakage of the adhering mortar. Corinaldesi et al. (2002) showed that the SCC containing recycled aggregates has a satisfactory behavior in L- Box test. However, the passing ability of SCC mixtures with 15% pozzolana and 0, 50 and 100% recycled aggregates are 60%, 83% and 97%, respectively.

It should be noted that the SCC mixtures made with natural aggregates with and without natural pozzolana present a slight blocking at the steel bars. The incorporation of natural pozzolana as a partial replacement by weight of cement led to an increase in  $T_{20}$  and  $T_{40}$  as compared with mixes without pozzolana. This is due to the high porosity of cement paste resulting from the use of pozzolana which leads to increased viscosity of mixes.

### 3.3. V-funnel test

This test evaluates the passing ability of concrete in confined space and provides an indication of segregation. Figure 4 gives the values of the flow time of the different SCC mixtures with and without 15% pozzolana. The V-funnel flow time is comparable for the three compositions of SCC without pozzolana, without segregation. So it can be said that the viscosity of the SCC is at least considered identical. The three values of  $T_v$  are below the upper limit which is equal to 12 seconds. However, the incorporation of 15% of pozzolana increases the V-funnel flow time, for all SCC mixtures with either natural or recycled aggregates, above the limits specified by EFNARC (2002).

The higher V-funnel flow time observed is for SCC containing 15% of pozzolana and 50% of recycled aggregates indicates a higher viscosity compared to SCC prepared with natural aggregates. Increasing natural aggregates substitution from 50% to 100% decreases the V-funnel flow time by 62%. Hence, it can be concluded that the plastic viscosity of SCC mixture decreases with increasing the substitution level of natural aggregates to 100% of recycled aggregates. From these results, it can be concluded also that the natural pozzolana increases the viscosity of all SCC mixtures and this increase is more important for SCC (NR).

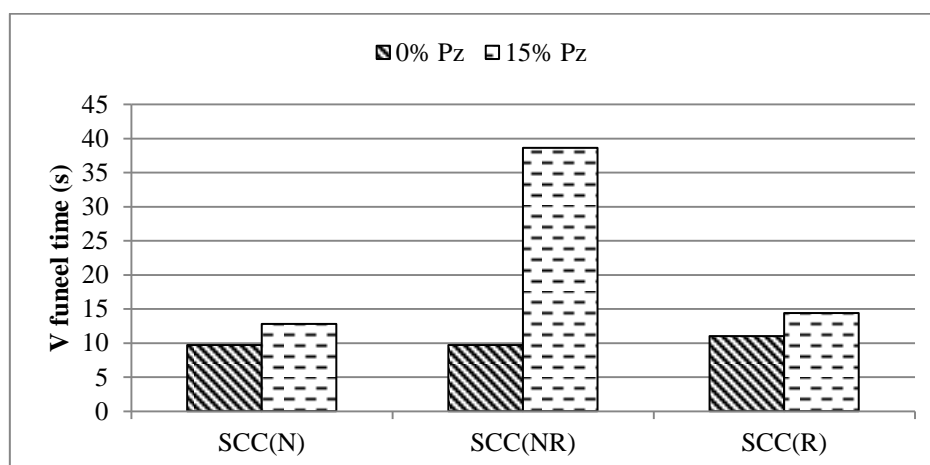


Fig 4. V-funnel time of SCC mixtures.

### 3.4. U Box test

Figure 5 shows the results obtained for the six SCC mixes. This test is used to measure the filling ability of SCC. In this test, the degree of compactability can be indicated by the height that the concrete reaches after passing through obstacles. The results obtained show that the SCC with 50 and 100% recycled aggregates has a less important filling rate than SCC with natural aggregates. However, a remarkable improvement was obtained for concrete with 100% recycled aggregates and 15% pozzolana where it showed excellent deformability without segregation.

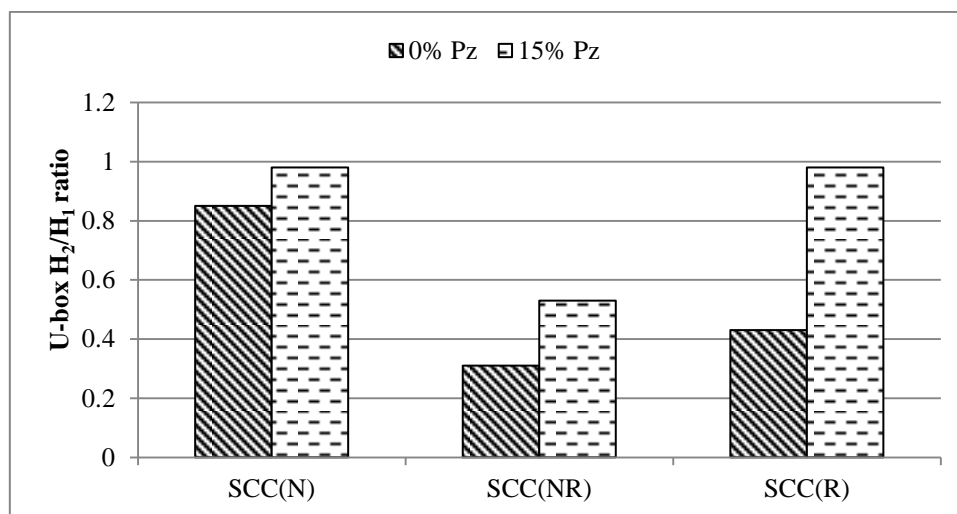


Fig 5. U-box ratio  $H_2/H_1$  of SCC mixtures.

## 4. CONCLUSIONS

The analysis of experimental results presented in this paper could lead to the following conclusions:

- The total or partial substitution of natural aggregates by recycled aggregates gives SCC with comparable fresh properties and characteristics compared to those of SCC with natural aggregates.
- The effect of the natural pozzolana on both SCC with natural or recycled aggregates is similar. Substituting 15% of cement by the pozzolana causes a decrease in workability. However, the addition of pozzolana in SCC with recycled aggregates (50 and 100%) gives a more homogeneous concrete.
- The plastic viscosity of SCC mixture decreases with increasing the substitution level of natural aggregates to 100% of recycled aggregates.
- The passing ability through L-box test is better for recycled aggregates concrete than that for natural aggregates.
- Pozzolana improves water retention and gives a good homogeneity coupled with a reduction in bleeding tendency.



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