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Research Paper

Production of eco-friendly self-compacting concrete with recycled concrete aggregate

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ABSTRACT

In recent years, recycled aggregate concrete (RAC) has become a major focus of research due to its positive environmental impact. The objective of this paper is to investigate the influence of dosage of recycled sand and gravel on the fresh properties of self compacting concrete (SCC). Experimental program was conducted on SCCs made with different rates of substitutions (25, 50, 75 and 100%) of natural sand and gravel (NS, NG) with recycled sand and gravel (RS, RG) by volume. All mixtures were obtained with a constant W/C ratio of 0.38, sand-to-mortar (S/M) ratio of 0.5 and a superplasticizer dosage of 1.5% of binder by weight. For fresh properties, tests were conducted for slump flow, V-funnel, L-box and resistance to segregation. Rheometer apparatus in the rheological testing of fresh SCC was used to determine the rheological parameters. The results indicated that an optimum replacement level of recycled sand and gravel of 50% can be achieved without adversely affecting key fresh concrete properties, including filling ability, passing ability, and segregation resistance. In addition, a clear correlation was established between the empirical and rheological parameters of the self-compacting recycled aggregates concrete.

1 Introduction

Construction and demolition waste (CDW) represents about 35% of global solid waste [1], with over 80% comprising concrete rubble, bricks, tiles, decorative materials, dust, and other construction materials [2]. The recycling and reuse of CDW is a key strategy for promoting sustainable development and has attracted significant research attention in recent years. The application of recycled concrete aggregate (RCA) in the concrete industry has gained increasing attention from both environmental and resource conservation perspectives [3]. The main difference between RCA and natural aggregate (NA) lies in the presence of adhered cement mortar and an interfacial transition zone (ITZ) formed between the original aggregate and the old mortar. Owing to the higher porosity of the attached mortar, RCA shows increased porosity and water absorption and reduced strength relative to NA [4]. Consequently, the combination of NA and RAC (by substituting NA with RAC) makes the cementitious matrix of the new concrete more complex due to the heterogeneity introduced by the presence of old hardened cement paste. The question arises as to whether the key characteristics defining self-compacting ability, specified

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by EFNARC recommendations [5], can be compromised if RCA are used as the only aggregates for the production of SCC. Khodair and Bommarreddy [6] reported that the use of RCA result in decrease in flowability and elevate rheological parameters, which requires either an increase in the Water-to-Cement ratio (W/C) or the use of an admixture to achieve flowability comparable to that of NA concrete. Kebaïli et al. [7] likewise indicate that self-compacting ability criteria were not satisfied for the concrete mixes investigated, irrespective of the replacement level of NCA with RCA. Conversely, Güneyisi et al. [8] reported that the self-compactibility characteristics of concrete are remarkably improved by the replacement of coarse and fine recycled concrete aggregate. Zhang et al. [9] found that the use of pre-saturated RCA increase the slump values with higher levels of RCA. As a result, the extensive of research work has focused on the valorization of recycled gravel (RG) in concrete, unlike the recycled sand (RS), which results in large quantities (50%) during crushing and is less studied due to its poor quality linked to the high content of attached mortar [10]. The novelty of this study lies in the simultaneous evaluation of the effect of replacing NS and NG with RS and RG from demolished concrete at different levels of 0%, 50%, 75%, and 100% on the rheology of fresh SCC. Very few studies have addressed this dual substitution in a combined manner, despite its importance for optimizing the formulation of eco-friendly SCCs that combine environmental sustainability with technical performance.

2 Materials and methods

2.1 Materials

The cement used in all SCC mixes complied with EN-197/1 and labeled as CEM I 42.5. Its specific surface area by Blaine and specific weight were 3200 cm²/g, and 3040 kg/m³, respectively. The chemical and physical property of cement used is given in Table 1. The natural and recycled sand with maximum size of 4 mm. The gravel aggregates used for both natural and recycled were two classes of either 8 mm or 16 mm maximum size. Sand and gravel recycled aggregates were obtained by crushing 1 m×1 m concrete slabs with a thickness of 10 cm. Slabs were manufactured in the laboratory and stored for 28 days in water curing. They were initially subjected to a preliminary manual crushing before a final processing using a mechanical crusher. The crushed material is passed through a sieve to obtain different fractions of recycled aggregates. The physical properties of natural and recycled aggregates are presented in Table 2. The grading sizes of coarse and fine aggregates are illustrated in Figure 1. A polyether-polycarboxylate based superplasticiser was used, which has a solid content of 30%.

Table 1 - Chemical analysis of cement and slag (%).

	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	MgO	SO ₃	Na ₂ O	K ₂ O	LI	TiO ₂	MnO	Cl
Cement	20.92	5.33	3.43	61.74	1.58	1.83	-	-	1.35	-	-	-
Slag	40.10	6.00	2.00	42.20	4.70	0.15	-	1.20		1.20	2.60	-

Table 2-Physical characteristics of the natural and recycled aggregates.

Properties	Sand aggregates			Gravel aggregates		
	NS	RS	NG 3/8	NG 8/15	RG 3/8	RG 8/15
Specific density (kg/m ³)	2530	2266	2730	2700	2386	2400
Bulk density (kg/m ³)	1640	1258	1475	1465	1172	1154
Water absorption (%)	1.7	8.87	0.5	0.5	7.39	3.21
Sand equivalent (%)	76.15	79.50	-	-	-	-
Fineness module (%)	2.8	3.82	-	-	-	-
Humidity (%)	1.7	6.3	0.13	0.13	3.73	2.64

NS: natural sand, RS: recycled sand, NG: natural gravel, RG: recycled gravel.

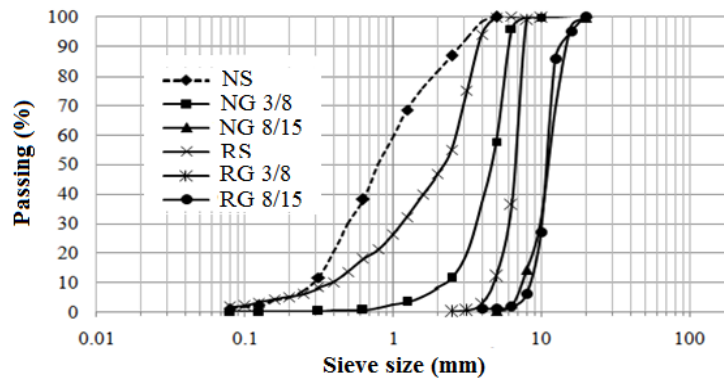


Fig. 1 – Particle size distribution of the materials used.

2.2 Mix proportions and mixing sequence of SCC

A total of five SCC mixes, including control mixes, where the natural aggregates (NS and NG) was partially replaced by recycled aggregates (RS and RG) at 0%, 25%, 50%, 75% and 100% by volume. The water/binder (W/B) ratio and superplasticizer dosage were kept constant at 0.38 and 1.5% of binder by weight, respectively. Further details of mixes proportions are shown in Table 3. The mixing procedure and time are very important to design SCC mixtures. In this study, the mixing sequence of the constituent materials of SCC mixes is based on the research work of Domone and Jim [11]. The batching sequence adopted for all SCC mixes produced consisted of homogenizing the binder and aggregates for 30 s in a rotary planetary mixer, then adding 70% of water and mixed for one minute. Afterward, remaining water (30%) with SP was introduced, and the concrete was mixed for five minutes, then the mixing was stopped for two minutes and again the concrete was further mixed for 30 s before it was removed discharged from the mixer.

Table 3 - Mix proportions of different SCC mixes (volume of concrete: 1 m³).

	Cement	Slag	NS	RS	NG 3/8	NG 8/15	RG 3/8	RG 8/15	Water	SP
SCCN (Reference)	507	0	910	0	245	490	0	0	193	7.61
SCCR25	507	0	682.5	203.75	183.75	367.5	54	107.75	193	7.61
SCCR50	507	0	455	407.5	122.5	245	108	215.5	193	7.61
SCCR75	507	0	277.5	611.25	61.25	122.5	162	323.25	193	7.61
SCCR100	507	0	0	815	0	0	216	431	193	7.61

2.3 Testing

In the present investigation, the filling ability was performed on SCC mixes using slump flow, V-funnel testes, conducted in accordance with EN 12350-8 [12] and EN 12350-8 [13], respectively. The passing ability is assessed using the L-box test method, performed in accordance with EN 12350-8 [14]. The resistance to segregation is determined by the sieve stability test in accordance with EN 12350-11 [15]. Rheological parameters are measured using a vane rheometer for fresh concrete, as illustrated in Figure 2(a). The rheometer consisted of an agitator, a cylindrical container (30 cm in height and 30 cm in diameter), and a steel vane (10 cm in height and 5 cm in diameter). The agitator is controlled by a computer equipped with dedicated software. Measurements are carried out using the rotational speed profile shown in Figure 2(b) [16]. In order to develop the rheological parameters from these measurements, the software records the torque (M) corresponding to the speed (Ω) imposed. The evolution of the shear stress (τ) is determined as a function of the shear rate ($\dot{\gamma}$) from the pair (M_i – Ω_i) by using formulas which were developed by several studies [17-18].

$$\dot{\gamma} = 2M \frac{d\Omega}{dM} \quad (1)$$

$$\dot{\gamma} = 2 \frac{M \frac{d\Omega}{dM}}{\left(1 - \frac{R_b^2}{R_c^2}\right)} - \frac{\Omega - M \frac{d\Omega}{dM}}{\ln\left(\frac{R_b}{R_c}\right)} \quad (2)$$

Where R_b and h denote the radius and height of the blade and R_c the radius of the container. Ω and M respectively represent the rotational speed and torque. The appropriated value of shear rate $\dot{\gamma}_i$ is one which maximizes the energy dissipation in the flowing sample. Then, the characteristic shear rate is defined as:

$$\dot{\gamma}_i = \max(\dot{\gamma}_{j[1]}; \dot{\gamma}_{j[2]}) \quad (3)$$

The derivative $d\Omega/dM$ in Equations 1 and 2 can be approximated by Equation 4:

$$\frac{d\Omega_j}{dM_j} \cong \frac{\Omega_{j+1} - \Omega_{j-1}}{M_{j+1} - M_{j-1}} ; i = j \text{ and } j = \overline{1, n} \quad (4)$$

The shear rate $\dot{\gamma}_i$ generated by a rotational speed Ω_i can be calculated by the Equation (5) below:

$$\dot{\gamma}_i = \max(\dot{\gamma}_{j[1]}; \dot{\gamma}_{j[2]}) \text{ with } i = j \text{ and } j = \overline{1, n} \quad (5)$$

Once the shear rate has been estimated by Equation 5, it is deemed to correspond to the following wall shear stress:

$$\tau_i = \frac{1}{2}(\tau_{j-1} + \tau_{j+1}) \text{ with } \tau_j(M) = \frac{M_j}{2\pi h R_b^2} \quad (6)$$

Equations (5) and (6) allow drawing the shear stress curves τ (Pa) according to the shear rate $\dot{\gamma}_i$ (1/s) and estimating then the rheological parameters.

The Bingham model was used to describe the rheological behaviour of mortar [19], the rheological properties (yield stress and plastic viscosity) are described as follows:

$$\tau = \tau_0 + \mu \dot{\gamma} \quad (7)$$

Where τ (Pa) is the shear stress applied to the material, τ_0 (Pa) is the yield stress, μ (Pa.s) is the plastic viscosity and $\dot{\gamma}$ (1/s) is the shear rate.

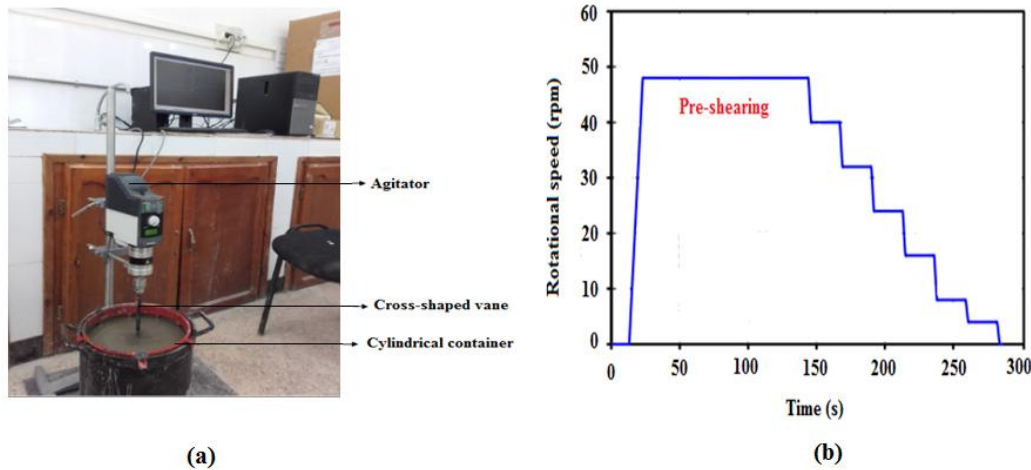


Fig. 2 – (a) Rheometer; (b) Rotational speed profile.

3 Results and discussion

3.1 Fresh density

Fresh density of the different SCC mixes is presented in Figure 3. The fresh density values varied in the range of 2395–2335 kg/m³. It can be seen from this figure that the fresh density of SCC mixes gradually decreases in terms of increasing RCA replacement levels. The use of RCA at 25%, 50%, 75% and 100% replacement levels resulted in a decrease in the fresh density compared to control SCC mixes by about 1.90%, 4%, 5.20% and 6.70%, respectively. This decrease was attributed to the porous old cement mortar adhered to RCA, specific gravity values of RCA mixes are lower than those for natural aggregates mixes. These findings are in agreement with those obtained by many researchers [20, 21].

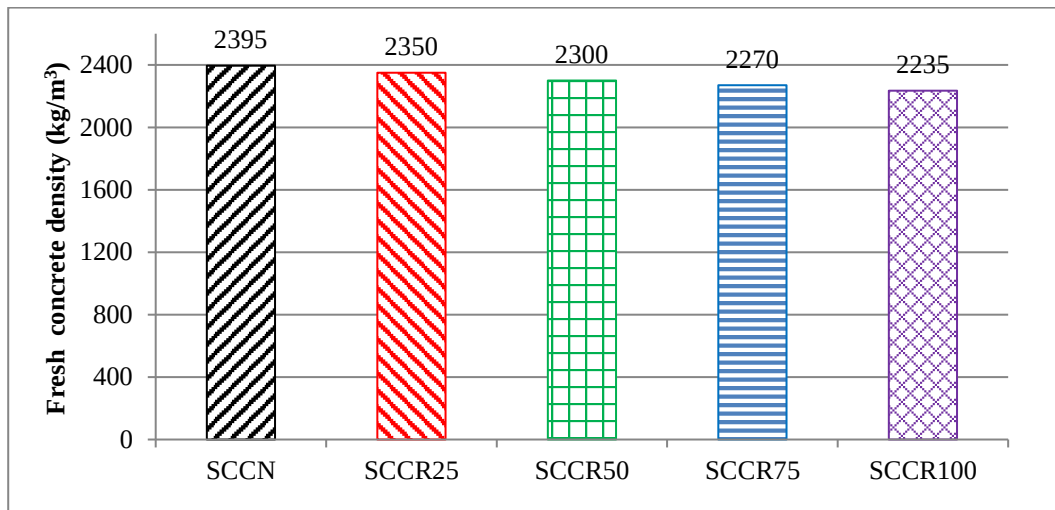


Fig. 3 – Fresh density of SSC mixes.

3.2 Empirical results

Slump flow spread results achieved for all SCC mixes are given in Figure 4. It can be seen that slump flow values for different SCC mixes groups were in the range of 713–750 mm and satisfy SCC fresh flow properties. According to EFNARC guidelines [5], all SCC mixes groups are within the category of slump flow classes SF2, which are generally suitable for applications, such as beams, columns and walls. It is clearly seen that the slump flow diameter increased as the percentage of replacement NA by RCA (RS and RG) increased up to 50%, followed by a reduction at higher substitution rates (75 and 100%). The observed initial improvement is likely due to the extra free water added to compensate for the high water absorption capacity of RCA, resulting in better flowability. According to Guo et al. [22], RA-SCC mixtures without SCMs exhibited slight improvements in slump flow, with increases of 2.03% and 4.24% for 70% and 100% RCA contents, respectively. A similar trend in workability has been reported by previous researchers [8].

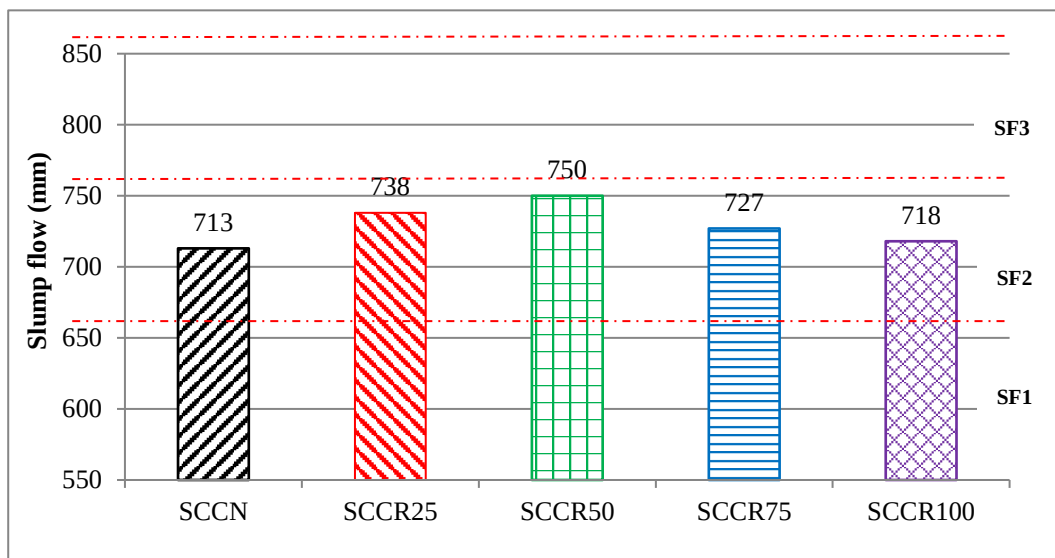


Fig. 4 – Slump flow diameter of SSC mixes.

To assess the viscosity of the SCC mixtures, the time required to reach a 500 mm slump flow (T_{500}) and V-Funnel flow time (T_{V-F}) were measured in this study. The values of the T_{500} and T_{V-F} time of SCCs with different percentages of replacement RCA was shown in Figure 5. The results presented in Figure 5 indicate that T_{500} follows the same trend as T_{V-F} , and the SCCR50 mixtures record the shortest flow times, suggesting superior filling ability and lower plastic viscosity. Based on the EFNARC guidelines [5], all mixtures satisfy the requirements of the VS2 viscosity class according to their T_{500} results;

likewise, the T_{v-f} measurements classify the SCC mixes within the VF2 viscosity class ($T_v > 9$ s). In the case of 100% RCA, the flow became intermittent with a longer flow time of concrete. This could be explained by the accumulation of coarse aggregates in the tapered outlet of the V-funnel due to the lack of cohesiveness and the low flowing ability.

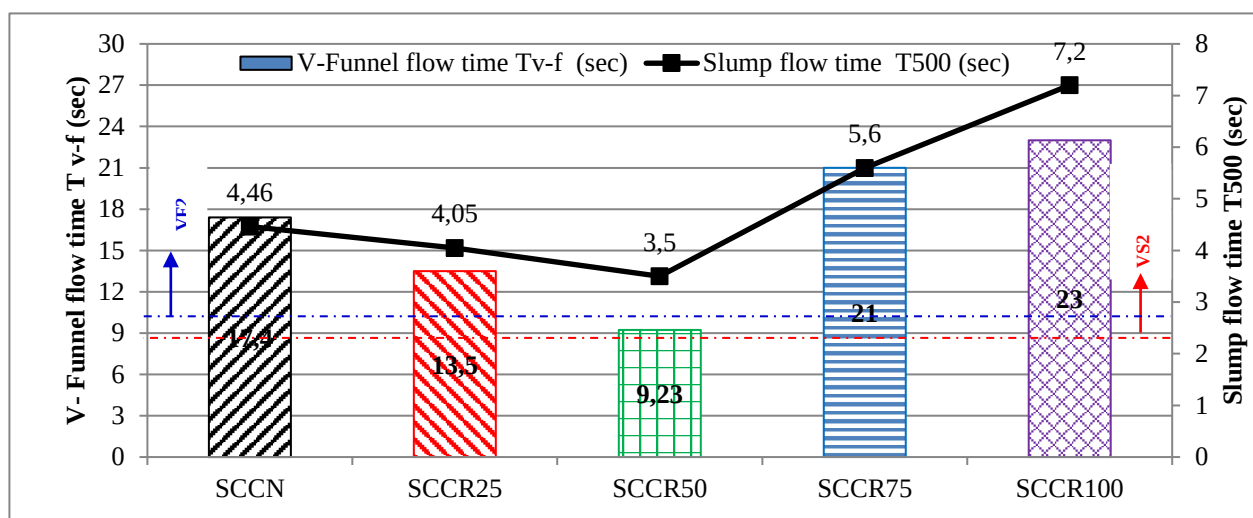


Fig. 5 – T_{500} and T_v of SCC mixes.

Ability of mixtures to flow through tight openings, such as spaces between steel reinforcing bars without segregation or blocking was measured by L-Box test. As shown in Figure 6, the L-box height ratio for all mixtures was greater than 0.8, indicating good filling ability according to EFNARC recommendations [5] and thus meeting the criteria for the PA2 class, except the SCCR100 mixture, where the blocking ratio is lower than the minimum required and did not show any tendency of blockage between the rebars of the L-box device. This supports the point of view reported earlier by Sethy et al. [23], which demonstrated that, even though the blocking ratio is greater than 0.65, SCC still has been accepted to achieve good passing ability. Figure 6 reveals an improvement in the filling ability of SCC mixes as the RCA content increases up to 50%; however, at higher replacement levels (75% and 100% RCA), the L-box filling ratio decreases, indicating a reduction in passing ability.

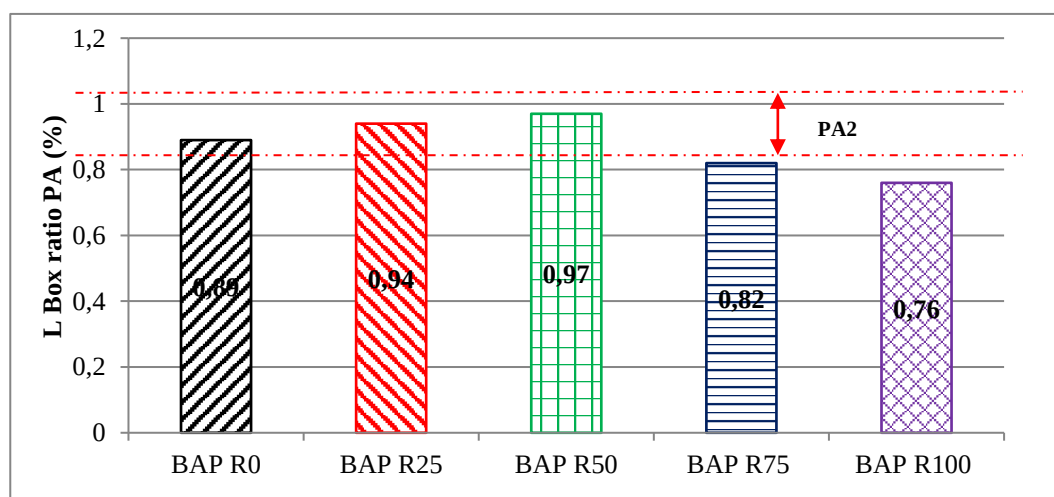


Fig. 6 – Blocking ratio (H_2/H_1) of SCC mixes.

The results of the sieve stability test used to measure ability to withstand the segregation of SCCs with different percentages of replacement RCA was shown in Figure 7. Sieve stability for all mixes ranged between 5.0 and 14.3%. Addition, the results show clearly that segregation index of the SCC mixes tend to increase with an increase of RCA content. The results also demonstrate that all SCC mixes in the present study were classified as SR2 class ($< 15\%$) in terms of segregation resistance classes according to EFNARC [5].

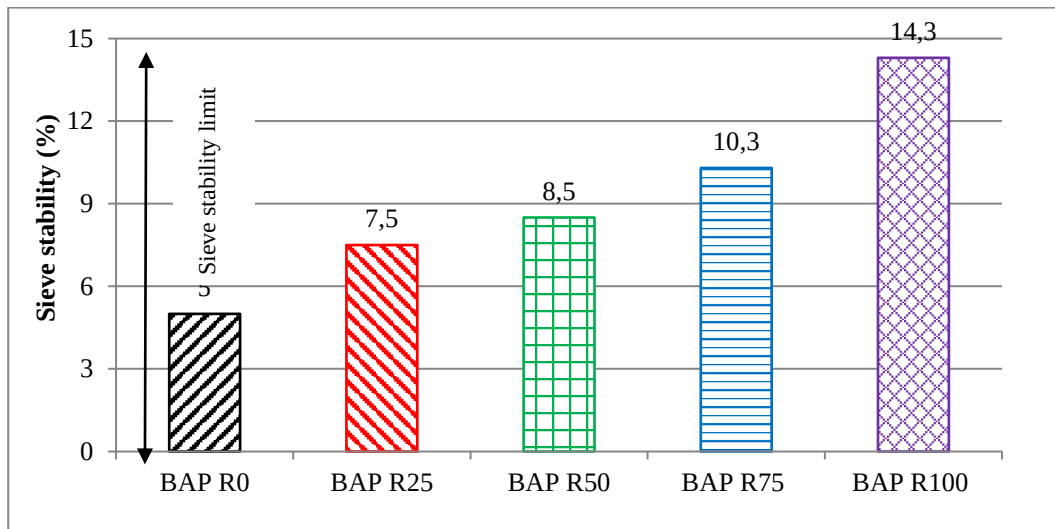


Fig. 7 – Segregation ratio of SCC mixes.

3.3 Rheological results

Figure 8 illustrates the variation of yield stress and plastic viscosity of SCC mixtures with increasing RCA replacement. Both rheological parameters decrease up to a 50% RCA content and subsequently increase at higher replacement ratios. This trend is consistent with the results reported by Güneyisi et al. [8], who observed lower yield stress in SCC incorporating RCA compared with the reference mix. Similarly, López et al. [24] observed that the inclusion of RS caused a significant increase in yield stress, reflecting a loss of filling ability in SCC, while plastic viscosity increased rapidly over time, leading to diminished passing ability after 45 min at higher RS replacement levels.

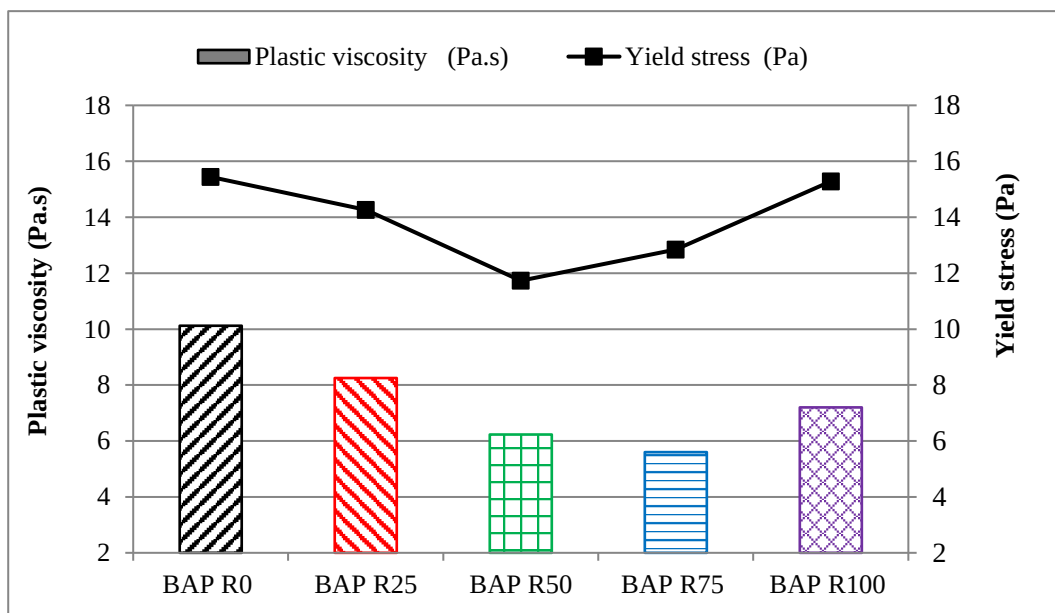


Fig. 8 – Effect of RCA content on the yield stress and plastic viscosity of SCC.

3.4 Relationship between empirical and rheological results

The slump flow test has become an insufficient measurement to characterize the workability of new concretes such as SCC, high performance concrete (HPC) and environmental friendly concretes. The measurement of the rheological parameters becomes necessary to better understand the flow of SCC mixtures. However, the rheological measurements are expensive and time consuming and there is a need to develop the relationships between these parameters. In this context,

plastic viscosity was correlated with both T500 and Tv, as illustrated in Figure 9. The results revealed a strong relationship between the plastic viscosity and T500 as well as between plastic viscosity and Tv, with correlation coefficients of 0.935 and 0.848, respectively. These findings indicate that plastic viscosity can be accurately estimated from T500 and Tv measurements for SCC mixtures incorporating different RCA contents. Furthermore, Figure 10 presents the relationship between slump flow and yield stress, demonstrating a good linear correlation between filling ability and yield stress ($R^2 = 0.693$). The presented results align well with the observations of Iris et al. [25]. In summary, the established correlations demonstrate that rheological parameters are effective indicators for predicting the essential fresh properties of SCC.

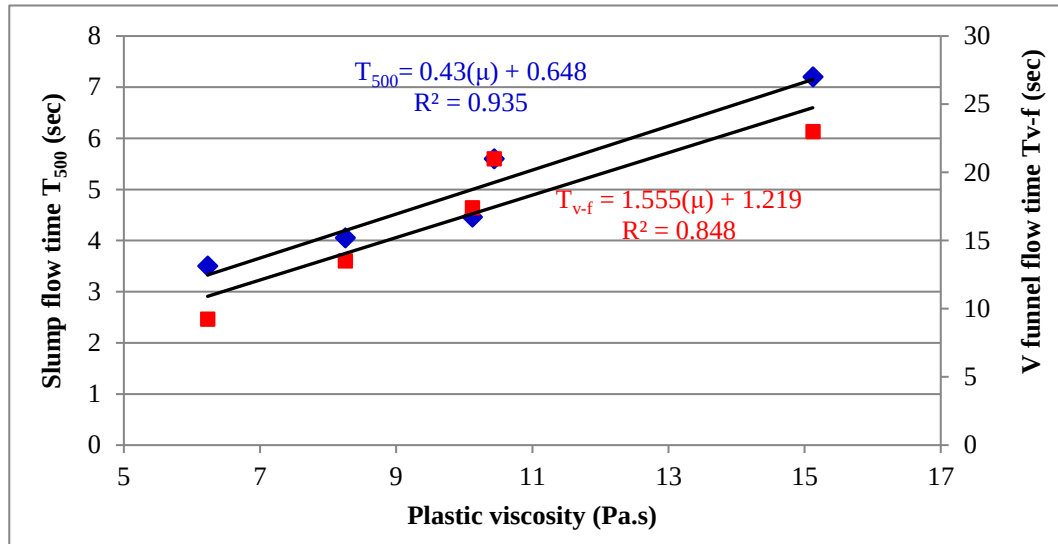


Fig. 8 – Relationship between T_{500} , T_v and plastic viscosity.

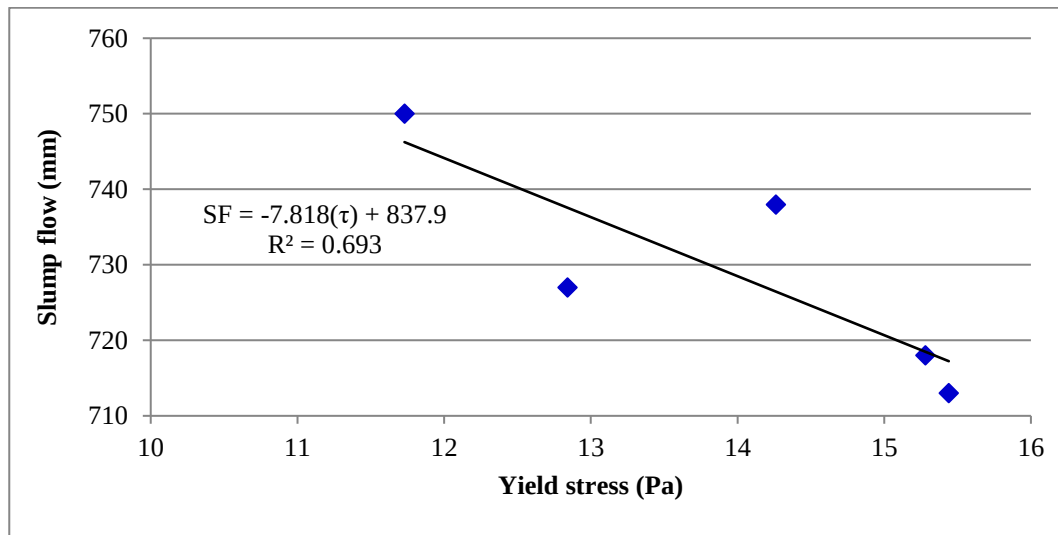


Fig. 9 – Relationship between SF and yield stress.

4 Conclusion

The study of fresh concrete rheology, particularly that of self-compacting concrete, is fundamental for ensuring reliable rheological testing and for tracking the evolution of flow properties using appropriate models. Nevertheless, research in this field remains incomplete, as the fresh-state behavior of concrete varies significantly with mixture composition and mixing procedures. The experimental investigation to assess the fresh properties of SCC with partial replacement of NA with RCA was carried out. From the fresh concrete test results the following conclusions can be drawn:

- The lower specific gravity of RCAs, attributed to the porous old cement mortar attached to their surfaces, results in a gradual reduction in the fresh density of SCC mixtures with increasing RS and RG contents.
- The lower specific gravity of RCAs, mainly due to the porous old cement mortar adhered to their surfaces, leads to a gradual decrease in the fresh density of SCC mixtures as the RS and RG contents increase.
- The fluidity of SCC increases with the substitution of NA by RCAs, reaching an optimum at a 50% replacement level.
- The incorporation of higher contents of RCA leads to an increase in mixture viscosity. Nevertheless, all mixtures satisfy the allowable ranges and fall within the VS2 and VF2 classes specified by EFNARC.
- Using 100% RCA markedly decreases the passing ability, and the resulting mixture fails to meet the fresh-state requirements of self-compacting concrete.
- Addition of RCA until 100% does not affect the concrete stability and the obtained values are lower than 15%, synonymous to proper stability. However the homogeneity of the concrete decrease with the presence of RCA.
- The comparison between empirical and rheological tests parameters shows a strong relationship between T_{500} , T_v and plastic viscosity value and a reasonably good relationship between yield stress and slump flow.
- In summary, comparing the results of this experimental investigation, the recycled sand and gravel can be used up to 50% in SCC mixes as an environmentally friendly alternative to natural aggregates, without affecting the fresh properties of concrete.

REFERENCES

- [1]- J. Liu, Y. Yi, X. Wang, Exploring factors influencing construction waste reduction: A structural equation modeling approach. *J. Clean. Prod.*, 276 (2020) 123185. <https://doi.org/10.1016/j.jclepro.2020.123185>
- [2]- L. Kong, B. Ma, Evaluation of environmental impact of construction waste disposal based on fuzzy set analysis. *Environ. Technol. Innov.*, 19 (2020) 100877. <https://doi.org/10.1016/j.eti.2020.100877>
- [3]- A. Gil, Current insights into lignocellulose related waste valorization. *Chem. Eng. J. Adv.*, 8 (2021) 100186. <https://doi.org/10.1016/j.cej.2021.100186>
- [4]- M. Faisal, H. Mohamed, A. Almotaseembillah, K. Nasir, R.K. Hammad, H. Asad, Influence of bonded mortar on recycled aggregate concrete properties: A review. *Constr. Build. Mater.*, 432 (2024) 136564. <https://doi.org/10.1016/j.conbuildmat.2024.136564>
- [5]- EFNARC, Specification Guidelines for self-compacting concrete. European Federation for Specialist Construction Chemicals and Concrete Systems. Norfolk, UK. 2005.
- [6]- Y. Khodair, B. Bommareddy, Self-consolidating concrete using recycled concrete aggregate and high volume of fly ash, and slag. *Constr. Build. Mater.*, 153 (2017) 307–316. <https://doi.org/10.1016/j.conbuildmat.2017.07.063>
- [7]- O. Kebaïli, M. Mouret, N. Arabi, F. Cassagnabere, Adverse effect of the mass substitution of natural aggregates by air-dried recycled concrete aggregates on the self-compacting ability of concrete: Evidence and analysis through an example. *J. Clean. Prod.*, 87 (2015) 752–761. <https://doi.org/10.1016/j.jclepro.2014.10.077>
- [8]- E. Güneyisi, M. Gesoglu, Z. Algin, H. Yazici, Rheological and fresh properties of self-compacting concretes containing coarse and fine recycled concrete aggregates. *Constr. Build. Mater.*, 113 (2016) 622–630. <https://doi.org/10.1016/j.conbuildmat.2016.03.073>
- [9]- H. Zhang, X. Xu, W. Liu, B. Zhao, Q. Wang, Influence of the moisture states of aggregate recycled from waste concrete on the performance of the prepared recycled aggregate concrete (RAC) – A review. *Constr. Build. Mater.*, 326 (2022) 126891. <https://doi.org/10.1016/j.conbuildmat.2022.126891>
- [10]- C. Ulsen, H. Kahn, G. Hawlitschek, E.A. Masini, S.C. Angulo, V.M. John, Production of recycled sand from construction and demolition waste. *Constr. Build. Mater.*, 40 (2013) 1168–1173. <https://doi.org/10.1016/j.conbuildmat.2012.02.004>
- [11]- P.L.J. Domone, J. Jin, Properties of mortar for self-compacting concrete. In: *Proceedings of the RILEM International Symposium on Self-Compacting Concrete*, Stockholm, Sweden, RILEM Publications, Paris, France, 1999, pp. 109–120.
- [12]- EN 12350-8:2010, Testing fresh concrete. Part 8: Self-compacting concrete. Slump-flow test. European Committee

for Standardization (CEN), Brussels.

- [13]- EN 12350-9:2010, Testing fresh concrete. Part 9: Self-compacting concrete. V-funnel test. European Committee for Standardization (CEN), Brussels.
- [14]- EN 12350-10:2010, Testing fresh concrete. Part 10: Self-compacting concrete. L-box test. European Committee for Standardization (CEN), Brussels.
- [15]- EN 12350-11:2010, Testing fresh concrete. Part 11: Self-compacting concrete. Sieve segregation test. European Committee for Standardization (CEN), Brussels.
- [16]- H. Soualhi, E.H. Kadri, T.T. Ngo, A. Bouvet, F. Cussigh, Z.E.A. Tahar, Design of portable rheometer with new vane geometry to estimate concrete rheological parameters. *J. Civ. Eng. Manag.*, 23(3) (2017) 347–355. <https://doi.org/10.3846/13923730.2015.1128481>
- [17]- P. Estellé, C. Lanos, A. Perrot, S. Amziane, Processing the vane shear flow data from Couette analogy. *Appl. Rheol.*, 18(3) (2008) 34037. <https://doi.org/10.3933/ApplRheol-18-34037>
- [18]- H. Dada, H. Soualhi, A.S.E. Belaidi, E.H. Kadri, B. Benabed, A study of the rheological behaviour of ecofriendly mortar made with metakaolin and marble powder at various ambient temperatures. *Eur. J. Environ. Civ. Eng.*, 27(3) (2023) 1088–1103. <https://doi.org/10.1080/19648189.2022.2072404>
- [19]- A. Yahia, M. Tanimura, Rheology of belite-cement – Effect of w/c and high-range water-reducer type. *Constr. Build. Mater.*, 88 (2015) 169–174. <https://doi.org/10.1016/j.conbuildmat.2015.03.029>
- [20]- S. Ahmed, A. El-Zohairy, A.S. Eisa, M.A.B. Mohamed, A. Abdo, Experimental investigation of self-compacting concrete with recycled concrete aggregate. *Buildings*, 13 (2023) 856. <https://doi.org/10.3390/buildings13040856>
- [21]- I. Bouldoum, T. Boubekeur, K. Ezziane, T.T. Ngo, E.H. Kadri, J.C. Lacouture, Effects of recycled concrete sand on the physical, mechanical properties, and hydration heat of mortar. *J. Sci. Ind. Res.*, 84(8) (2025) 839–851. <https://doi.org/10.56042/jsir.v84i8.14070>
- [22]- Z. Guo, J. Zhang, T. Jiang, T. Jiang, C. Chen, R. Bo, Y. Sun, Development of sustainable self-compacting concrete using recycled concrete aggregate and fly ash, slag, silica fume. *Eur. J. Environ. Civ. Eng.*, 26(4) (2022) 1453–1474. <https://doi.org/10.1080/19648189.2020.1715847>
- [23]- K.P. Sethy, D. Pasla, U.K. Sahoo, Utilization of high volume of industrial slag in self-compacting concrete. *J. Clean. Prod.*, 112 (2016) 581–588. <https://doi.org/10.1016/j.jclepro.2015.08.039>
- [24]- C.D. López, G.B. Fonteboa, D.J. de Brito, M.F. Abella, G.I. Taboada, P. Silva, Study of the rheology of self-compacting concrete with fine recycled concrete aggregates. *Constr. Build. Mater.*, 96 (2015) 491–501. <https://doi.org/10.1016/j.conbuildmat.2015.08.091>
- [25]- G.I. Iris, G.F. Belén, M.A. Fernando, C.L. Diego, Self-compacting recycled concrete: Relationships between empirical and rheological parameters and proposal of a workability box. *Constr. Build. Mater.*, 143 (2017) 537–546. <https://doi.org/10.1016/j.conbuildmat.2017.03.156>