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Research Article

Influence of Incorporating Recycled Sand and Fines from Demolition Concrete Waste on the Physical Properties of Sand Concrete in Arid Zones

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Abstract Recycled aggregates contain a high percentage of fines with a diameter of less than 63 µm, resulting from the crushing and grinding of the source concrete. These fines contain a proportion of unhydrated cement likely to interact with the concrete in the presence of water. Portland cement was substituted with recycled fines (RF) with the following percentages: 5%, 10%, and 15%. The effect of these aggregates on alluvial sand (AS) and recycled sand (RS) concrete was studied, with two proportions: 85% AS + 15% RS and 75% AS + 25% RS. This study aimed to evaluate the impact of using recycled aggregates (RS and RF) from demolition waste on the physical properties of recycled sand concrete and alluvial sand concrete, including workability, weight loss, bulk density, and porosity. The results obtained show noticeable improvements in the studied properties; the sand concrete made with 85% AS + 15% RS and 10% RF gives the best results.

Keywords: recycled sand, valorization, recycled aggregates, recycled fine, sand concrete.

1. INTRODUCTION

Recycling is the act of processing used materials for reuse in the creation of a new product. In order to reduce dependence on natural aggregates, recycled aggregates can be used as substitute materials.

The applications of recycled aggregates in the construction sector are numerous and long-standing. Wilmot and Vorobieff [1] reported that recycled aggregates have been used in road construction for 100 years in Australia. Stones from old roads were reused in the reconstruction of their well-established road network. They also noted that since the end of the Second World War, the recycling industry has become well established in Europe. The global construction aggregates market is expected to grow by 5,2 %, and this trend is expected to continue, reaching up to 48,3 billion tonnes [2]. In the US, the Environmental Protection Agency [3] estimated that debris generation from the construction, demolition, and renovation of residential and non-residential buildings in 2003 was approximately 170 million tonnes. According to Eurostat [4], the total amount of waste generated in the EU in 2010 was more than 2.5 billion tonnes, of which almost 35% (860 million tonnes) came from construction and demolition activities, and 27% (672 million tonnes) came from mining and quarrying activities.

In Algeria, the amount of construction waste generated was estimated at more than 11 million tonnes in 2016.
Several barriers remain to the use of recycled aggregates (RA) in construction:
Lack of confidence among clients and entrepreneurs;
Lack of standards and specifications that concrete producers can comply with;
Poor quality of the final product, due to lack of knowledge and/or interest of construction and demolition waste (CDW) recycling plant owners;
Distance between construction and demolition sites and recycling plants;
In hope of stimulating and promoting the use of RA, government agencies around the world have often introduced taxes and laws to try to overcome these obstacles, with varying degrees of success. European Directive 2008/98/EC [5]. Encourages the reuse and recycling of waste.

In the same context, according to several studies, the cement industry is responsible for approximately 75% of global carbon dioxide emissions [6-9]; and solutions to reduce this problem have been proposed in several studies, such as: using materials that partially replace cement in their operation [10,11], which is a way to reduce carbon dioxide emissions from clinker and cement plants, or the use of recycled waste as an additive to cement[12-14]. The use of recycled materials in construction is a sustainable approach to the construction industry, especially in arid regions where building materials are difficult to access. Even when quarries are available, they are often located far from the affected regions, making transportation very expensive. This has many advantages, such as reducing the need for raw aggregates, energy consumption, landfilling waste, and emissions. Using recycled aggregate is not only an excellent environmental choice but also saves money.

Previous studies on the incorporation of recycled aggregates into concrete mixes have mainly focused on the potential for incorporating aggregates in the form of gravel and sand. Little research has been done on the substitution of cement with recycled aggregates. In a previous study, Kennouche et al. [11] investigated the impact of replacing recycled aggregates on the compressive and shrinkage strength of mortar. Regarding the use of recycled aggregates in arid zones, there is practically no research in this area. The purpose of this study is to assess the viability of recovering recycled concrete aggregates from construction and demolition waste, in the form of sand and fine particles for their integration into concrete suitable for arid zones. In particular, we examined the impact of these recycled aggregates on the physical properties of sand concrete.

2. MATERIALS USED

2.1. Sands

Two types of sand were used in this work. The recycled sand used as a corrector comes from waste from a concrete dump. This recycled sand (0/4 mm) is obtained by crushing and sieving concrete waste (Figure 1b). The natural alluvial sand was extracted from the Hassi Sayah quarry in the Ouargla region of Algeria (Figure 1a).

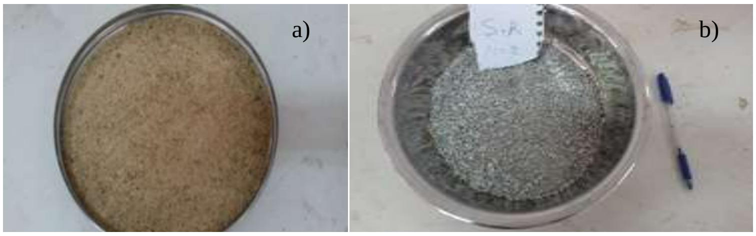


Figure 1.a) Alluvial sand and b) Recycled sand

2.2. Cement

The cement used in this study is CPJ - CEM II. It has a density of 3.10 g/cm^3 and a specific surface area of 3300 cm^2/g Tables 1, 2, and 3 provide respectively the chemical analysis and the physical, mechanical, and mineralogical characteristics of this cement, in accordance with standard NF P 15-301194.

Table 1. Chemical analysis of the cement used showed the presence of elements that are present

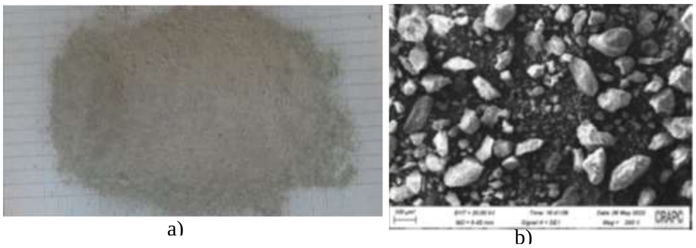
Loss of ignition (NA S0 4$_2$) (%)	Sulphate (SO_3) (%)	MgO magnesium oxide (%)	Chloride (NA S04$_2$) (%)
10,0 ± 2	2,5 ± 0,5	1,7 ± 0,5	0,02 – 0,05

Table 2. Physical and mechanical properties of the cement used

	Apparent density (g/cm^3)	Absolute density (g/cm^3)	Shrinkage at 28 days (µm/m)	Setting start time (hours)	End of setting time (hours)	Normal consistency	Cs_{28} (MPa)	Cs_2 (MPa)
CPJ-CEM II	1.22	3.10	< 1000	2h: 03	3h: 00	26.5 ± 2.0	≥ 42,5	≥ 10,0

Table 3. Mineralogical composition of clinker (Bogue) (%).

C3S	C3A
60±3	7.5±1



a) b)

Figure 2. a) Recycled Fine used (RF) and b) SEM image of RF

2.3. The Recycled Fine

As part of our approach, we introduced recycled fine (RF) as a replacement for part of the cement. This powder is obtained by crushing concrete, followed by sieving in the laboratory. This approach aims to explore the innovative concept presented in this study, as illustrated in Figure 2 (a and b).

3. EXPERIMENTAL METHODS

3.1. Process For Manufacturing Recycled Sand and Recycled Fine

A crushing-screening method was used to obtain fineness less than 80 µm. For concrete, the hardened concrete samples were first manually crushed with a hammer, reducing the size of the pieces to less than 10 cm. This measure was taken to facilitate their further processing in the crusher, thus saving time and money. The recycled aggregates (RA) were introduced directly into the crusher, following a method consisting of successively grinding the RA with a decreasing jaw opening. At the end of each crushing step, the material is sieved to 5 mm for recycled sand (RS), then to 80 µm for RF. The deliberate choice of 80 µm is motivated by the fact that this size is close to Dmax, the value traditionally used for mineral additions in this context.

3.2. Methods For Characterizing Recycled Sands and Fines

Tables 4 and 5 show the characterization tests of recycled sand and recycled fine.

Table 4. Sand characterization tests

Properties	Testing	Standards
Physical	Particle size analysis	FS 18-541
	Fineness module	FS 18-560.
	Apparent and absolute density	FS 18-555
	Sand equivalent	FS 18-598 (1991)
	Water absorption	FS 18-555
Chemical	EDX (chemical compositions by fluorescence X)	FS EN 196-2
Morphological	Scanning Electron Microscopy (SEM)	JSM 6700F
Mineralogical	Differential Scanning Calorimetry (DSC)	STA 449 F3

Table 5. Fine characterization tests

Properties	Testing	Standards
Physical	Specific surface area Blaine	[FS EN 196-6]
	Absolute density	FS EN 1097-7
Chemical	EDX (chemical compositions by fluorescence X)	FS EN 196-2
Morphological	Scanning Electron Microscopy (SEM)	JSM 6700F
Mineralogical	Differential Scanning Calorimetry (DSC)	STA 449 F3

3.3. Scanning Electron Microscopy (SEM)

Scanning electron microscopy (SEM) analysis was performed using a ZEISS EVO 15 field effect instrument (ESM/AWD). The applied voltage was 15 kV, and the maximum magnification reached 1,000,000X. The SEM was combined with the EDAX energy dispersive spectrometer (EDS). This combination offers the advantage of visualizing the grain structure on polished slices or pellets, performing specific chemical analyses for each mineral phase, and quantifying their proportions through image analysis.

These tests were conducted using the secondary and backscatter electronic modes.

3.4. Formulation and Preparation of Test Specimens

The method of preparing the test specimens is identical to that of ordinary mortar (standard EN 196-1). The different compositions were obtained from a reference composition (control) in which the volumetric fractions of sand and water are fixed. The control concrete is based on alluvial sand with a water/cement (W/C) ratio of 0.53.

Other compositions were made by replacing a certain amount of cement with recycled fine (RF), maintaining the same volume as that of the replaced cement. Three percentages of RF replacement were used: 5%, 10% and 15%. The water/cement volume ratio of 0.53 remained constant for all compositions. The samples of all the prepared concrete had dimensions of 4 x 4 x 16 cm^3. The process began with a dry mixture of sand and cement for 60 seconds, followed by the introduction of water. The molds were then filled in two separate layers, each subjected to 30 seconds of vibration. After a 24-hour curing period, the specimens were demolded and fully immersed in water at 25±2°C for 14 days. They were then removed from the water and exposed to laboratory conditions (Figure 3) with a temperature of 30±5°C and a humidity of 25±2%.

The alluvial sand concretes that have been prepared and studied are designated as follows:

SCAL: Sand concrete based on alluvial sand (natural sand) and 0% fines (control).

SCALFx: Sand concrete based on alluvial sand (natural sand) and x% fines (control).
SCASRS1: Sand concrete with 85% alluvial sand and 15% recycled sand.
SCASRS1Fx: Sand concrete with 85% alluvial sand, 15% recycled sand, and x% fines.
SCASRS2: Sand concrete with 75% alluvial sand and 25% recycled sand.
SCASRS2Fx: Sand concrete with 75% alluvial sand, 25% recycled sand, and x% fines.
The mass substitution rate of recycled fines (RF) varied between 5%, 10%, and 15% for each sand concrete formulation.
Table 6 details the composition of the different formulations tested.
In this work, six specimens were used per test and per deadline.

Figure 3. Samples of prepared mixtures

Table 6. Mixing proportions for 1 m^3

Mixtures	Alluvial sand (kg)	Recycled sand (kg)	Cement (kg)	Recycled fine (kg)	Water (l)	W/C
SCAL	1404.00	0,00	468.00	0,00	248.10	0,53
SCALF5	1404.00	0,00	444.60	23.40	248.10	0.53
SCALF10	1404.00	0,00	421.20	46.80	248.10	0.53
SCALF15	1404.00	0,00	397.80	70.20	248.10	0.53
SCASRS1	1193.40	210.60	468.00	0,00	248.10	0,53
SCASRS1F5	1193.40	210.60	444.60	23.40	248.10	0.53
SCASRS1F10	1193.40	210.60	421.20	46.80	248.10	0.53
SCASRS1F15	1193.40	210.60	397.80	70.20	248.10	0.53
SCASRS2	1053.00	351.00	468.00	0,00	248.10	0,53
SCASRS2F5	1053.00	351.00	444.60	23.40	248.10	0.53
SCASRS2F10	1053.00	351.00	421.20	46.80	248.10	0.53
SCASRS2F15	1053.00	351.00	397.80	70.20	248.10	0.53

3.5. Characterization of Fresh Sand Concrete

3.5.1. Workability Test

In this work, the workability of concrete is measured using a maniabilimeter (figure 4), in accordance with FS 15-437. This test allows the fluidity of concrete to be estimated by measuring the flow time of fresh concrete or mortar subjected to vibrations.

Figure 4. Maniabilimeter

3.6. Characterization of Hardened Sand Concrete

3.6.1. Density and Porosity of Water Absorption of Concrete

The apparent densities of the concrete were measured using prismatic specimens measuring 4 cm x 4 cm x 16 cm, in accordance with standard EN 1015-10. These samples were then used to determine the porosity of the concrete by water absorption. These same samples were then used to determine weight loss over time by weighing them for 3, 7, 14, 28, and 90 days.

4. RESULTS AND DISCUSSION

4.1. Properties of Sands Used

4.1.1. Physical Properties of Sands Used

Figure 5 shows the particle size distribution of each type of sand used, including alluvial sand (AS), recycled sand (RS), 85% AS + 15% RS, and 75% AS + 25% RS. Table 7 presents the results of the physical properties of alluvial sand and recycled sand. These data show that alluvial sand has acceptable properties. Table 7 presents the results, indicating that the water absorption from recycled sand is higher than that of alluvial sand. This disparity is due to the increased porosity resulting from the presence of cement in the recycled sand, as well as fines from the crushing of concrete waste.

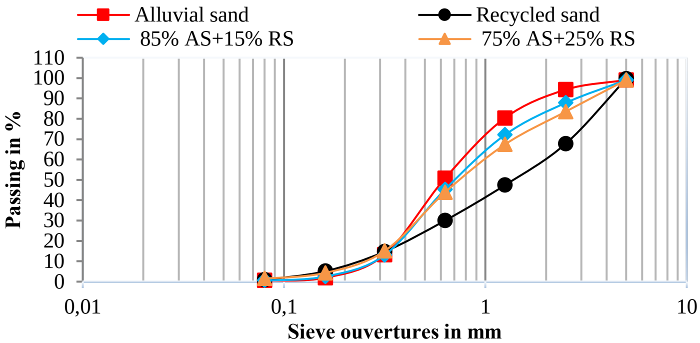


Figure 5. The granulometric distribution of the sands utilized [11]

Table 7. The physical characteristics of the sands used.

	Alluvial sand (AS)	Recycled sand (RS)	Corrected sand formulations	
			85% AS + 15% RS	75% AS + 25% RS
Specific density (g/cm^3)	2,50	2,48	2,53	2,55
Apparent density (g/cm^3)	1.47	1,63	1,58	1,60
Water absorption (%)	2.00	8.00	3.00	3.60
Fineness modulus	2.56	3,30	2,76	2,78
Sand equivalency (%)	75.00	81.00	76.00	78.00

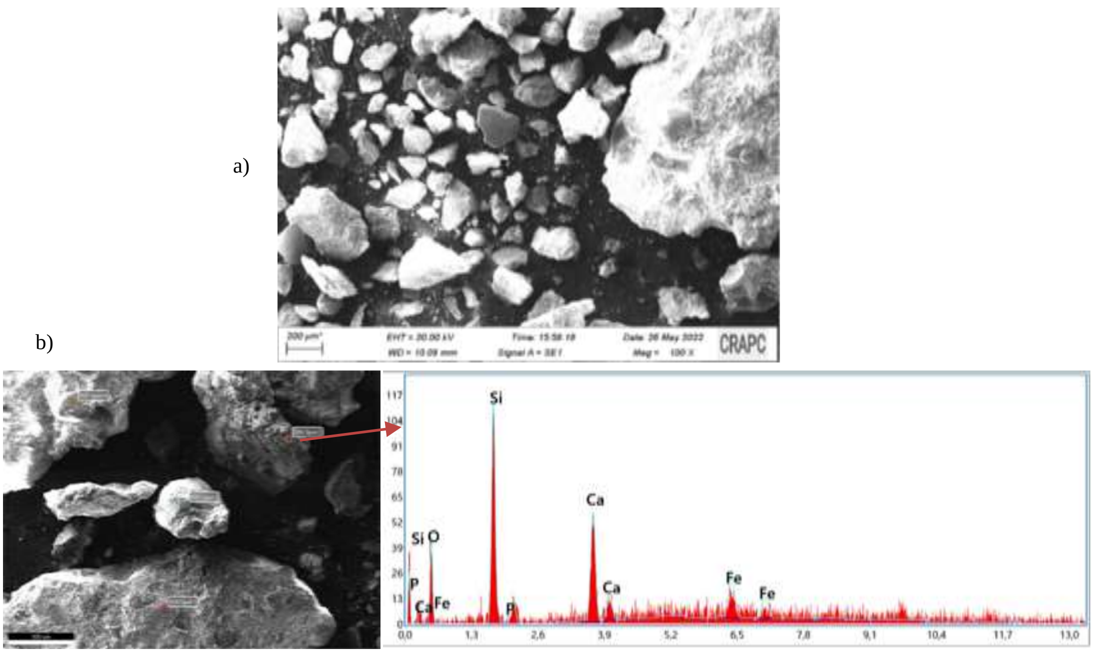


Figure 6. a) SEM images of RS and b) EDS of RS

4.1.2. Morphological and Chemical Properties

Figure 6 (a and b) shows scanning electronic micrographs (SEM) of recycled sand (RS). The shape of RS aggregates is irregular, with some particles being more angular, exhibiting well-defined edges and angles. This characteristic could be beneficial for filling the pores of the cement matrix. Figure 6(a) also shows that the surface texture of RS grains is extremely porous and rough. This texture can contribute to an increase in the surface area associated with the interface between the aggregates and the old mortar. An analysis of the surface of recycled sand (RS) by energy dispersive spectroscopy (EDS) (Figure 6(b)) revealed the presence of silicon (23.77%) and calcium (24.59%) (Table 8). These quantities may vary from one point to another, probably depending on the origin of the demolished base concrete. The presence of a layer of old mortar attached to RS particles could explain these differences. These results indicate that the RS contains a significant amount of cementitious material. These observations are consistent with previous studies [15-16].

Table 8. Smart quantitative results of RS

Element	OK	SiK	PK	CaK	Fek
% of mass	29.94	23.77	1.24	24.59	20.46

4.2. Properties of the Recycled Fines

4.2.1. Physical Properties

Table 9 presents the physical properties of the fines, including specific surfaces and absolute densities, compared to a reference material, CEM II cement. For the remainder of this study, especially when analyzing the concrete formulation, it is assumed that the fines do not have porosity. The Blaine surface area of fine particles (6500 cm^2/g) exceeds that of CPJ - CEM II (3300 cm^2/g) cement. Although the process is not optimized, combined crushing and grinding are still considered effective for producing very powdery materials. This is due to the progressive fracturing effect that occurs when raw materials, often rich in limestone and cement, repeatedly pass through the crusher jaws. This process does not appear to alter the representativeness of the fines compared to the original material, since the absolute density remains practically constant. Table 9 shows that waste particles, composed of hydrated cement and silica (sand), have a higher porosity (2.43 g/cm^3) than Portland cement (3.10 g/cm^3). Various studies suggest distinct values for the specific mass of different fractions of concrete waste. Corinaldesi et al [17] report values between 2.29 and 2.38 g/cm^3, Favaretto et al [18] cite 2.42 g/cm^3, and Evangelista et al [19] find values between 2.53 and 2.62 g/cm^3. These variations may result from the variability of waste and type of treatment. Evangelista et al [19] also reported that the adhesion of mortar particles is influenced by other constituents.

Table 9. Absolute density and specific surface of the RF and CEM II used

Materials	CPJ - CEM II	Recycled fine
Absolute density ρabs (g/cm^3)	3.10	2.43
Blaine specific surface (cm^2/g)	3300	6500

4.2.2. Chemical Characteristics

Qualitative analyses were carried out by scanning electron microscopy, coupled with a specific chemical analysis by EDS, in order to characterize the recycled fines powder and assess its recovery potential. The results of the chemical composition by EDS of the recycled fine powder used in this study are shown in Figure 7 (a).

Figure 7 (a and b) shows the SEM image and the EDS analysis of the recycled fine powder (RF), respectively. The texture of RF shows a difference in grain size due to the effect of crushing and grinding of recycled concrete aggregates (RCA). RF contains cementing elements, thus forming hydrates. The presence of non-hydrated cement in the mass of recycled aggregate is responsible for these elements [20]. Studies have also shown that the fine fraction of recycled aggregates contains residual anhydrous clinker, which can be recovered by grinding. Residual anhydrous clinker represents about 24% [20]. Although calcium dioxide is also present, the intensity of the main calcite peak eclipses that of the other hydrated cementitious phases, which are a minority in this sample. The chemical composition reveals that the recycled fine powders (RF) are rich in elements such as calcium (45.80%) (Table 10), an amount almost equivalent to that present in Portland cement. There are also some minor oxides that can be considered impurities. The remarkable presence of residual anhydrous phases is an interesting aspect, suggesting that this material might not be inert in the presence of water after crushing. These results confirm and justify the choice of using RF as a substitute for cement in this study.

Table 10. Smart quantitative results of RF

Element	CK	OK	Nak	AlK	PK	SK	SiK	CaK	Fek
% of mass	5.19	42.03	1.11	0.80	0.87	0.63	1.86	45.80	2.36

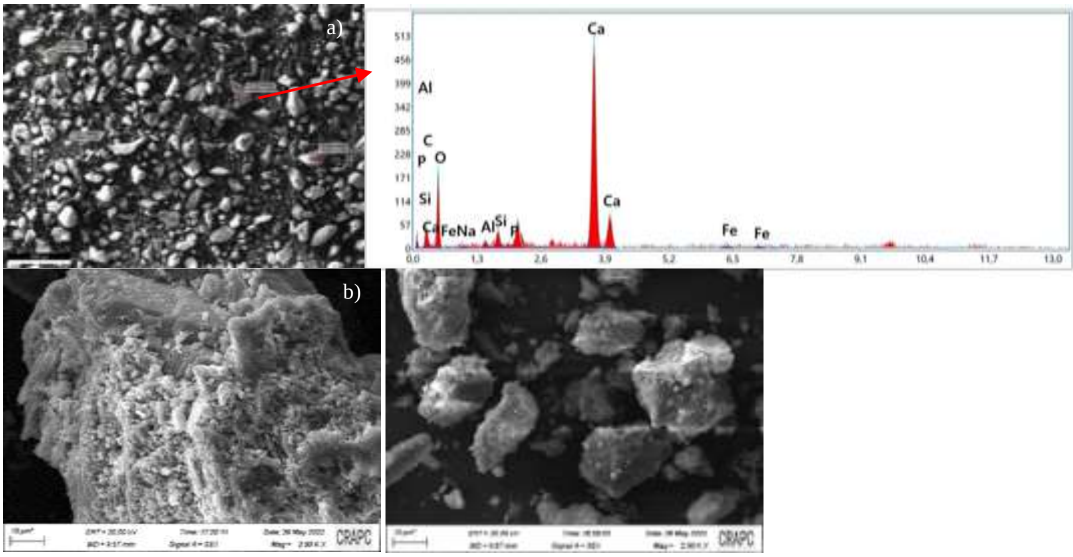


Figure 7. SEM images a) EDS of RF and b) the electron mode with reverse diffusion and EDS analyses of RF

4.3. Properties of Alluvial Sand Concretes with and Without Rs and Rf In Fresh State

4.3.1. Sand Concrete Consistency

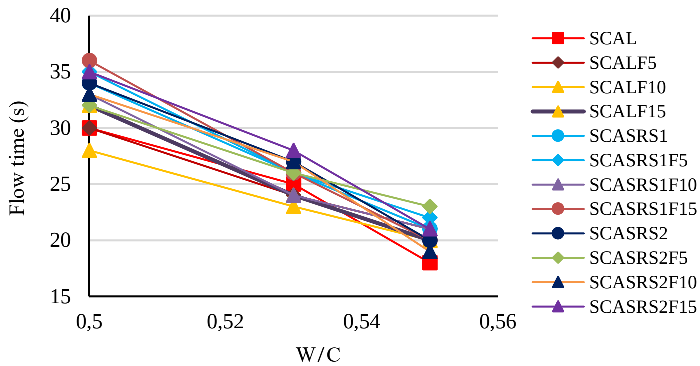


Figure 8. Flow time in (s) LCPC of sand concrete as a function of W / C

The test was carried out in accordance with FS 15-437, calibrating the water content to be added to the mixture. Figure 8 shows that with the increase in the percentage of incorporation of recycled aggregates in the proportions mentioned above, it appeared that less water was needed to obtain the desired consistency, since the voids previously filled with water were occupied by the very fine concrete particles (filler effect). A significant improvement in workability was observed during mixing as the incorporation rate increased, indicating that particle size, shape, and texture influence this property in the fresh state and justify a decrease in the water/cement ratio. Fine particles improve the internal cohesion of the mixture. The inverse relationship was observed by Bordy et al. [21], who concluded that the addition of different types of fines increased the mixing water requirements to obtain acceptable workability. It should be noted, however, that the percentage of incorporated fines mentioned in this reference is much higher (between 20 and 40%) than the maximum tested in this study.

Almeida [22], who tested the incorporation of fine stone grouts into concrete production, concluded that for incorporation percentages below 15%, there was less need to use water in the process, since the handling of the concrete was improved by the addition of very fine aggregates. Pan et al. [23] also showed that after replacing 20% of Portland cement with sewage sludge ash (a recycled material that can be used in cement mortar, such as pozzolan), the malleability of the mortar increased with fineness. In general, previous studies seem to indicate a trend towards improved workability with increasing incorporation of recycled concrete aggregate (RCA) fines, but this, of course, depends on the nature of the RCA. On the other hand, Angelim [24], it was necessary to increase the amount of water used during mixing to achieve the desired workability with fines incorporation rates between 20% and 40%. There is a trend towards improved workability with the incorporation of fines, but this trend is sensitive to their nature [25].

4.4. Properties of Alluvial Sand Concretes with and Without Rs and Rf in the Hardened State

4.4.1. Weight Loss

4.4.1.1. Weight Loss of the Control Sand Concrete

Figure 9 shows the mass loss of the control concrete. The mass loss of concrete decreases as the recycled sand content increases. This decrease is mainly due to changes in the water content in capillary voids. Recycled sand has a higher water absorption coefficient (8.3%) than alluvial sand (0.58%). Some of the water used for tempering will be absorbed by the sand, depending on the proportion of sand. A constant amount of water will be used for the hydration of cement, and the remaining variable amount will contribute to the formation of mixed capillary voids.

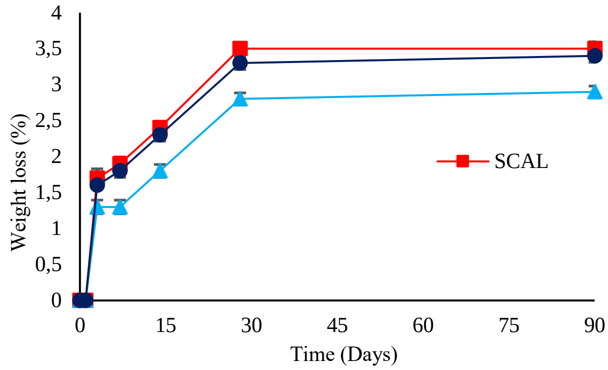


Figure 9. Age-related weight loss of sand concrete without addition of RF SCAL, SCASRS1 and SCASRS2.

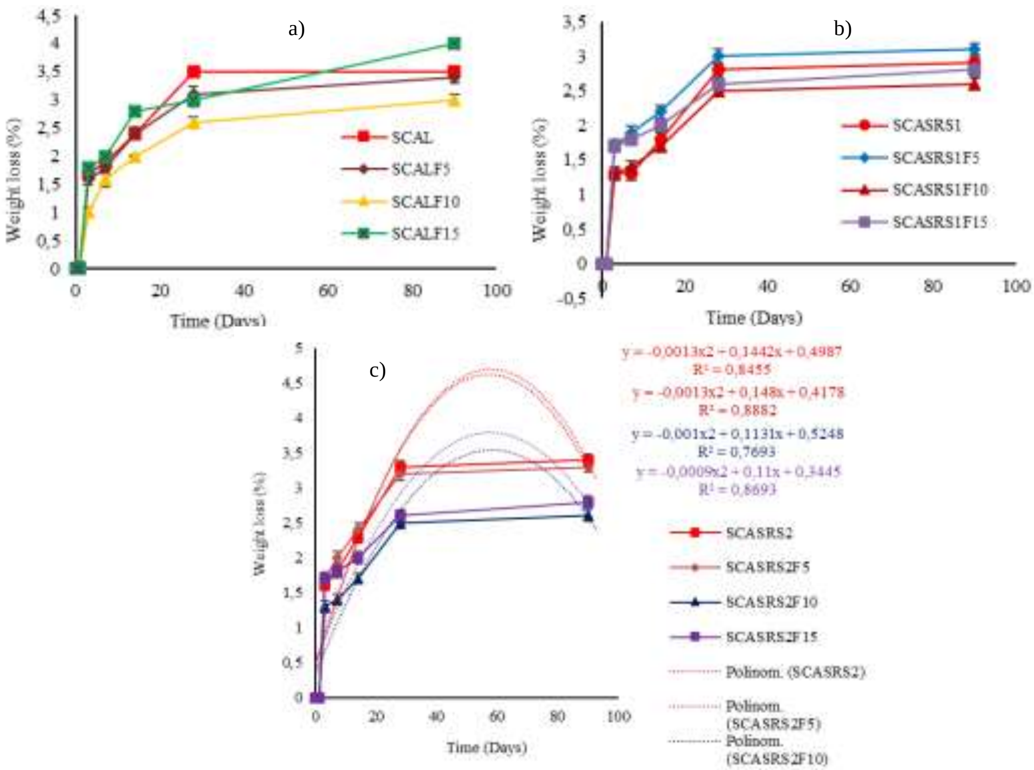


Figure 10. a) weight loss of SCAL, b) weight loss of SCASRS1with and without RF with and without RF, c) Weight loss of SCASRS2 with and without RF.

4.4.1.2. Weight Loss of Alluvial Sand Concretes with and Without Rf

When the proportion of recycled sand in the mixture increases, water absorption also increases, while the amount of water in capillary voids decreases. This results in a reduction in mass loss. The more recycled sand the mixture contains, the more the volume of the capillaries decreases. The evolution of mass loss of sand concretes, with and without the addition of RF, after drying and hardening is illustrated in Figures 10 (a, b, and c). The mass loss increases exponentially with drying time, which is rapid at first and tends to stabilize thereafter.

In addition, the addition of RF decreases the mass loss for most of the concretes studied in this section. Unlike several studies indicating that the incorporation of high levels of RCA increases the mass loss of concrete, this study does not show the same trend, as we do not exceed 25% of RS and 15% of RF. This improvement in recorded mass loss can be explained by the replacement of cement with high fineness RF, which plays a role in filling interstitial voids, hindering water evacuation and reducing evaporation, resulting in a reduction in mass loss compared to control concretes.

Figure 10 clearly shows that all sand concretes have lower mass loss values than the SCAL mix (control). The W/C ratio, a crucial factor affecting mass loss of sand concrete, indicates that concretes containing RS and RF have high W/C values compared to SCAL alluvial sand concrete (control). This difference is due to the high-water demand of recycled aggregates compared to natural aggregates. Therefore, the presence of RF rapidly consumes water from the mixture during curing, minimizing the amount of water remaining in the pores, which decreases water evaporation. With increasing fine/coarse aggregate ratio, air permeability and effective W/C ratio of RS and AS concretes decrease. The density of the mortar increases with age, while its water porosity and capillary water absorption decrease [26,27], thus indicating an improvement in the mass loss of these concretes.

4.4.2. Dry Bulk Density and Porosity of Sand Concrete

4.4.2.1. Dry Bulk Density and Porosity of Control Alluvial Sand Concrete

Figure 11 shows the results of concrete density and porosity at 28 days. An increase in bulk density was obtained for concretes with the incorporation of RS; this increase is of the order of 2.95% and 4.92%, respectively for the SCASRS1 and SCASRS2 mixtures compared to the alluvial sand concrete (control). According to these results, the presence of RS increases the dry bulk density of SCASRS1 and SCASRS2 mixtures compared to the SCAL mixture, which is due to a filling effect. Thus, the fineness < 0.063 mm contained in RS plays the role of filling the small pores, which results in an improvement in density and, of course, an improvement in porosity of alluvial sand concrete. Several authors, such as [28-31], found that the incorporation of concrete waste also reduces porosity. These authors found that the lowest capillary coefficient corresponded to the highest percentage of waste incorporation.

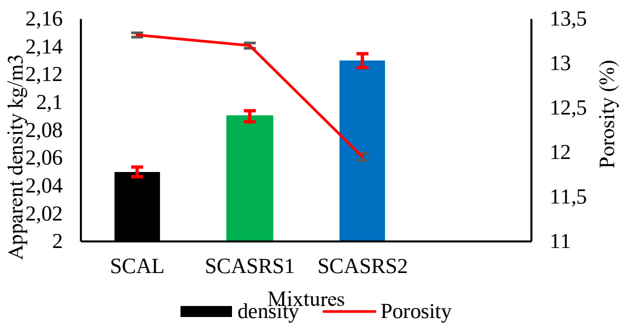


Figure 11. Density and porosity according to the age of sand concrete SCAL, SCASRS1 and SCASRS2

4.4.2.2. Dry Bulk Density and Porosity of Alluvial Sand Concrete with and Without Rf

The evolution of density and absorption of alluvial sand concrete with and without RF is illustrated in Figure 12(a). As for the incorporation of RS, an increase in bulk density and a decrease in porosity were detected in the hardened concrete as the RF is incorporated. In this case, the improvement of both properties studied can be explained by the fact that the part of the voids of the concrete not occupied by the sand is filled by the recycled fines, which are smaller.

Thus, as the replacement rate increases, there are fewer voids initially occupied by water, and concrete becomes more compact. In line with these results, Ishikawa [32] found that a higher content of particles passing through a 0.150 mm sieve contributes to lower air content, better packing of the mixture particles, and thus to an increase in bulk density. As with fresh concrete, the filler effect prevails over the effect of the lower apparent density of the concrete fines compared to sand for the range of incorporation rates tested.

The influence of RF on the density and porosity of AS and RS mixed sand-based concretes is slightly different from that of standard (control) concrete, as an increase in density of about 1.91% and 2.39%, respectively, is observed for the mixes SCASRSF5 and SCASRSF10 incorporation of fines, and a 0.47% decrease in density with 15% fines in Figure 12(b). It is found that above 10% fines, there is a negative effect on the density and thus on the porosity of the mortar. This may be explained by the extra amount of fine sand that creates gaps between the large grains, resulting in increased porosity and decreased density. For the SCASRS2 mixture, the results shown in Figure 12 (c) show that incorporation of fines decreases density and increases porosity of the mixture for all replacement rates. The decrease is of the order of 0.93%, 20.18%, and 24.88%, respectively, for the incorporation of 5%, 10%, and an increase in porosity of the order of 1.93%, 3.47%, and 5%, respectively. It is found that the presence of fines in high quantity leads to a decrease in density and an increase in porosity, since the M2-SASR mortar contains more fine elements than other concretes.

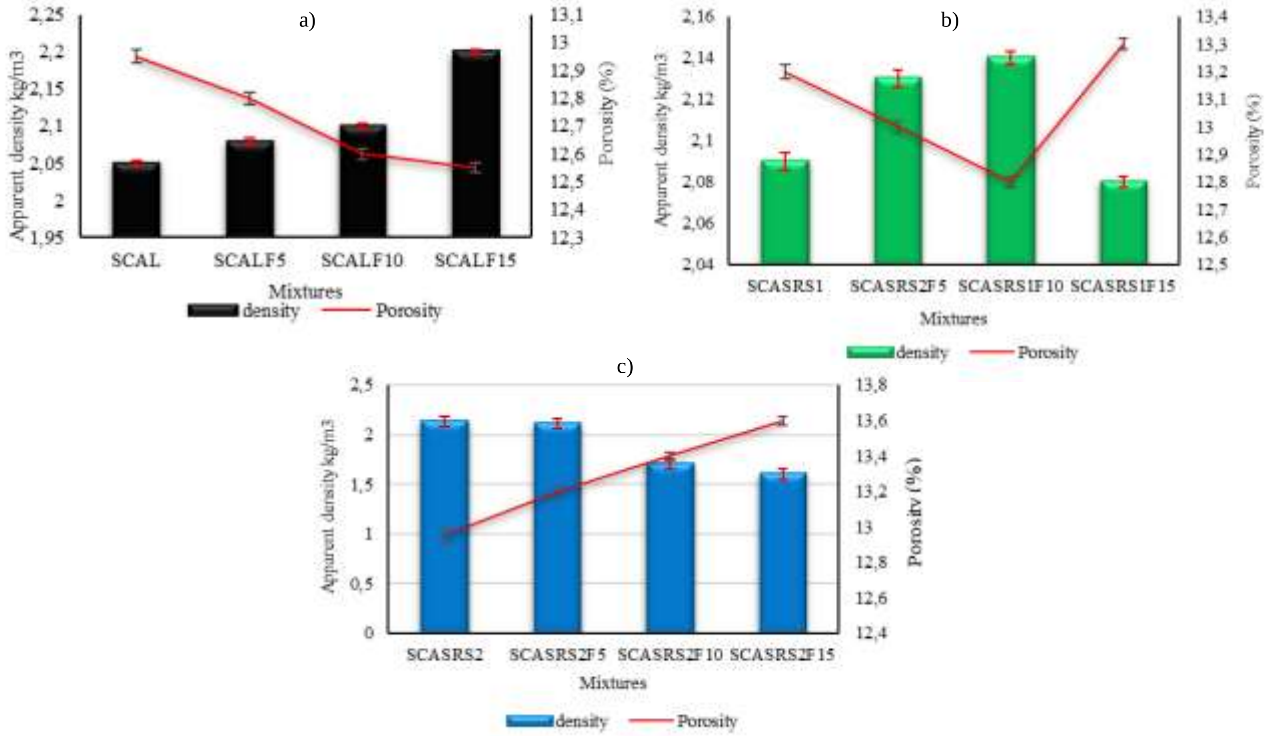


Figure 12. Density and porosity of mixtures; a) SCAL with and without RF, b) SCASRS1 with and without RF and c) SCASRS2 with and without RF

5. CONCLUSION

The study and analysis of the results regarding the physical characteristics of the tested sand concretes yielded the following main conclusions:

- The granulometric correction of recycled sand by alluvial sand had a positive effect on improving physical characteristics (fineness modulus);
- The incorporation of recycled sand with percentages of 15% and 25% in alluvial sand concrete showed an improvement in all the physical properties studied compared to concrete made with 100% alluvial sand;
- The incorporation of recycled fines at percentages of 5% and 10% in alluvial sand concrete showed an improvement in density;
- Mixtures containing SCASRS1F5 and SCASRS1F10 are better than other mixtures;

The study suggests that the integration of recycled aggregates and fines into the formulation of cementitious materials can contribute to more sustainable constructive practices, reducing the environmental footprint while preserving the quality of structures. These results offer promising prospects for the construction sector, encouraging further research and development in recycled materials for more sustainable and environmentally friendly construction.

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