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*Research Article*

# Impact of recycled concrete powders on the behavior of high-performance concrete in fresh and hardened states

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**Abstract**

The substantial volume of construction and demolition waste (CDW) generated annually poses a significant environmental challenge, necessitating innovative solutions for waste management and resource conservation. Recycled concrete powder (RCP) is a primary by-product of the reclamation process of CDW. This study investigates the potential of using RCP as a cement substitute in high-performance concrete (HPC), evaluating its effect on both fresh and hardened properties. Concrete mixtures were prepared by replacing cement with Concrete Demolition Powders (CDP) and Concrete Sample Scraps Powders (CSSP) at substitution rates of 10%, 15%, and 20%. The slump test was used to assess workability, while density, compressive strength, flexural strength, and porosity were measured at curing ages of 7, 28, and 90 days. The control mix was designed to achieve a targeted compressive strength of 80 MPa at 28 days. Results show that increasing the RCP substitution rate leads to a progressive reduction in workability. Both fresh and hardened density also decrease with the substitution rate, though this reduction remains relatively limited (< 2%), regardless of the type of powder or substitution rate. Compared to the control mix, compressive strength decreased by 3.85% to 11.5%, depending on the rate and type of powder used. The addition of RCP also reduced flexural strength and increased porosity. Despite these effects, concrete mixtures with RCP maintain the mechanical properties of HPC, supporting their potential as a cement substitute. This approach helps reduce cement consumption and promotes the valorization of construction waste.



## 1. Introduction

During The process of rapid urbanization is leading to a significant increase in the amount of construction and demolition (C&D) waste generated worldwide. This waste not only occupies valuable land resources but also contributes to the depletion of already limited landfill space. C&D waste amounts will be at a high level in the next decades [1]. Annual reports suggest that the total amount of C&D waste generated worldwide exceeds 10 billion tons, of which the United States produces about 700 million tons and the European Union more than 800 million tons [2]. In Algeria, the annual production of construction and demolition waste represented about 13 million ton in 2020 [3]. The construction sector is not only considered the main source of waste, but also the primary cause of environmental pollution [4]. The environmental impacts of C&D waste have become a worldwide issue [5]. This generation of waste has a significant impact on the environment, including the depletion of landfills, the emission of carbon and greenhouse gases, substantial waste of raw materials, and elevated project costs [6].

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Compared to recycling, landfilling remains the predominant method for managing construction and demolition (C&D) waste in many regions of the world, accounting for around 35% of such waste disposed of in landfills worldwide [7]. However, from a sustainability perspective, it is imperative to reduce, recycle and reuse this waste [8]. Recycling is increasingly seen as a viable option, particularly when it can significantly reduce the overall environmental impact throughout the life cycle of recycled products.

Numerous studies indicate that it is possible to use recycled concrete aggregates (RCA) in concrete, rather than just as road gravel, as an alternative approach. Recycled aggregates can be considered as another type of normal aggregate, suitable for construction in accordance with national and international specifications, when properly processed and classified [9]. On the other hand, the incorporation of recycled concrete aggregates could potentially exert adverse effects on the properties of concrete. Many studies have shown that the compressive strength of concrete incorporating recycled aggregates is often 5% to 40% lower than that of concrete made with natural aggregates [10], also a decrease in workability of fresh concert [11]. The presence of RCA significantly impacts the majority of durability indicators [12]. Numerous researchers have studied the incorporation of recycled concrete aggregates fine (RCAF) into mortars and concrete as a sand [13]. The results show a reduction in concrete properties when recycled sand is used, both in the fresh and hardened state [14,15]. In practice, the use of recycled sand in concrete mix design is strongly discouraged [10]. Nevertheless, given that recycled sand can make up as much as 50% of total recycled aggregates [16], it is essential to conduct research into other potential ways of optimizing the use of recycled sand. Instead of using fine RCA to replace natural sand, they will be considered as mineral additive to substitute cement after an additional crushing and screening process. The aim is to produce a powder with a maximum diameter of less than 80 µm, called RCP (Recycled Concrete Powders).

On the other hand, the production of Portland cement (PC) is responsible for around 7 to 8% of global greenhouse gas emissions [17,18] making it one of the most environmentally damaging materials in the construction industry [19]. Replacing Portland Cement (PC) with supplementary cementitious materials (SCMs) has emerged as a practical choice for several reasons. From an economic perspective, it offers advantages such as the availability of locally sourced materials and the possibility of large-scale production. Additionally, it offers significant environmental benefits, including the reuse of waste and substantial reductions in CO2 emissions. From a technical point of view, composite materials have been extensively studied for their long-term durability and suitability for use in construction, which contributes to their attractiveness as a substitute for PC [20]. From this point of view, PCR appears to be a viable option for use as SCM, as a waste product with wide local and global availability to encourage ecological recycling [21].

Previous studies have investigated the effect of thermal treatment on RCP and have shown that it has the potential to improve the characteristics of RCP. This improvement could allow higher levels of PC to RCP substitution. Xu et al found that thermal treatment of RCP has significant effect on material rehydration [22]. LV's results indicate that when the content of recycled concrete powder is less than 30%, its effect on cement strength is equivalent to that of fly ash. However, this influence becomes more significant after heat treatment [23]. However, heat treatment of these fines is difficult to achieve in ordinary building materials companies [24]. The active effect of RCF is therefore not investigated further in this study.

Florea et al. demonstrated in their study that recycled concrete fines, can be used as a substitute for up to 20% of the cement without a significant loss of strength, even without undergoing thermal treatment [25]. According to Ma and Wang, class C20 concrete can be prepared with the incorporation of 20% recycled concrete fines, as the results show little effect on rheological properties and mechanical strength [24]. Overall research shows a decrease in mechanical properties when using recycled concrete powder (RCP). The study by Zhao et al. demonstrated a progressive reduction in compressive strength with increasing cement replacement by RCP, decreasing from 65.96 MPa for the control mix to 45.64 MPa at a 40% replacement rate [26]. This trend continues as the percentage of RCP used to replace PC increases [27–31]. Also, the employed RP has a significant influence on the water transport and porosity. Huixia[32] reported that the porosity increases as RP incorporates. The majority of publications on PCR come from China, with 69.83% of studies, which is significantly higher than the second and third countries, Portugal 7.77% and Spain 6.80% [20]. In comparison, Algeria has had limited participation in scientific research in this field.

This study presents the results of laboratory studies on the properties of high-performance concrete (HPC) prepared with recycled concrete powders (RCP) of the same particle size as fillers (< 80 μm). These recycled concrete powders were obtained from two types of waste: the first from construction and demolition waste found in landfills, and the second from scraps concrete samples obtained in the laboratory. The aim of the study was to analyze the effect of replacing cement by varying proportions of recycled concrete powder, i.e., 10%, 15% and 20%, into high-performance concrete. Then, the experimental program was designed to evaluate both the rheological behavior and mechanical properties of the concrete by analyzing workability, density, compressive and flexural strength and porosity. This study contributes to the application of recycled concrete powders in the formulation of high-performance concrete, particularly in Algeria, where there is an immediate demand for sustainable construction practices and where scientific research in this field is still very limited.

## 2. Materials and methods

### 2.1 Materials

The studied fines were sourced from two distinct materials, both derived from concrete. The first source consists of mixed construction and demolition (C&D) waste aggregates, obtained by crushing waste from various construction sites and building materials. This C&D waste was collected from the technical landfill platform in Algiers (GECTAL) (Fig. 1). The second source comprises concrete sample scraps provided by the LCTP Algiers laboratory (Fig. 2). These scraps were obtained by fragmenting cylindrical concrete specimens (Ø16 × 32 cm) using a compression process. Both materials were processed using a ball mill to obtain fine particles below 80 μm (Fig. 3). The feasibility of using recycled concrete powder (RCP) from C&D waste is considered more practical than RCP derived from concrete sample scraps due to its greater availability.

The cement used in this study is a Portland cement of type CEM II 42.5N, produced by the GICA company at the Meftah factory in Algeria. The chemical and physical properties of the cement and both recycled powders, Concrete Demolition Powders (CDP) and Concrete Sample Scraps Powders (CSSP), are presented in Tables 1 and 2, respectively.

Fig. 1. Construction and demolition from GECTAL (Algiers)

Fig. 2. Scraps of concrete samples

(a) (b)

Fig. 3. (a) Concrete Demolition Powders, and (b) Concrete Sample Scraps Powders

The coarse aggregates used were crushed limestone gravels supplied by the GICA quarry in Algiers. Two fractions of gravel were used in this study: 3/8 gravel and 8/15 gravel. Additionally, two types of sand were used in this study: dune sand (rolled) sourced from the BOUSAÂDA region and crushed sand from the GICA quarry. The main characteristics and granulometric curve of these gravels are shown on Table 3 and Fig.4, respectively. The admixture used VISCOCRETE-775 FLOW, is a super plasticizer supplied by SIKA (Algiers - Algeria) company. Table 4 summarizes the main characteristics of the admixture. The mixing water used for concrete production was potable tap water.

Table1. Chemical compositions of the utilized binders

| Binder | Composition (%) | | | | | | |
|---|---|---|---|---|---|---|---|
| | $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | CaO | MgO | $SO_3$ | $Na_2O$ |
| Cement | 14,37 | 4,28 | 3,67 | 70,61 | 1,6 | 3.47 | 1.2 |
| CDP | 10,2 | 1,83 | 1,81 | 82,65 | 1,7 | 0,66 | 0,39 |
| CSSP | 12,33 | 2,89 | 3,1 | 70,12 | 2,67 | 0,86 | 0,42 |

Table2. Physical properties of the utilized binders

| Procedure | EN 1097-6[33] | EN 196-6[34] |
|---|---|---|
| Binder | Density ($g/cm^3$) | Specific area ($cm^2/g$) |
| Cement | 3.19 | 4300 |
| CDP | 2.65 | 5440 |
| CSSP | 2.71 | 5430 |

Table3. Physical and mechanical properties of aggregates

| Material | gravels 3/8 | gravels 8/15 | Crushed sand | Dune sand | Procedure |
|---|---|---|---|---|---|
| Specific Gravity | 2.65 | 2.64 | 2.64 | 2.53 | EN 1097-6[33] |
| Water absorption(%) | 1.65 | 1.41 | 1.78 | 0.95 | EN 1097-6[33] |
| Los Angeles(%) | 22.5 | 22.3 | --- | --- | EN 1097-2[35] |
| Micro Deval(%) | 25.65 | 27.9 | --- | --- | EN 1097-1[36] |
| Sand equivalent (%) | --- | --- | 71.43 | 84.3 | EN 933-8[37] |
| Finesse module(%) | --- | --- | 3.36 | 0.66 | EN 933-1[38] |

Table 4. Properties of the chemical admixture

| | |
|---|---|
| Density | 1.1 ± 0.02 |
| pH Value | 4.7 ± 1.0 |
| Total Chloride Ion Content | ≤ 0.1% |
| Sodium Oxide Equivalent | ≤ 3,5% |
| Solid content | 31% |

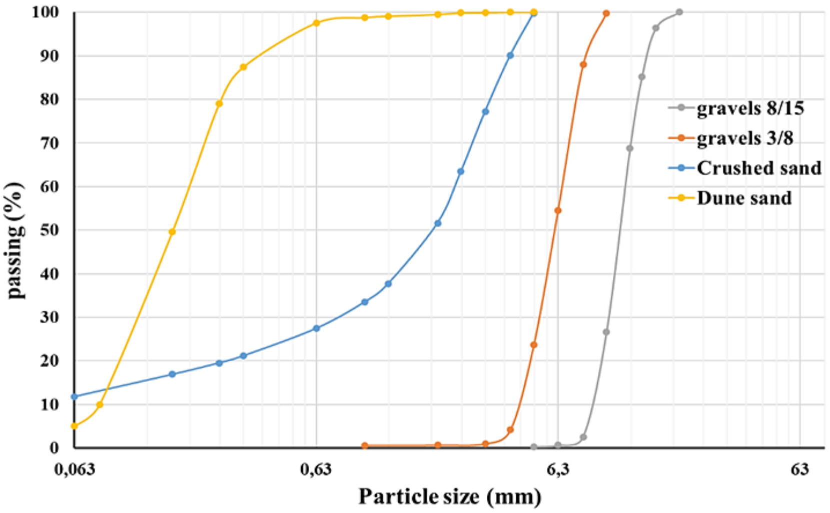



Fig. 4. The granulometric curve of gravels, crushed sand and Dune sand

## 2.2. Methods

### *2.2.1. Preparation Method*

Table 5 presents the mix proportions of concrete containing recycled powders at various substitution rates. The concrete mixtures were designed following the University of Sherbrooke method, developed by Pierre-Claude Aïtcin [39]. A total of seven concrete mixes were prepared, maintaining a constant binder content (cement + recycled powder) of 450 kg/m$^3$ while varying the replacement level of cement by recycled concrete powders. The mix designs are as follow:

- Reference mix (C.REF): A control concrete served as the baseline for comparison.
- Concrete with Concrete Demolition Powders (C.CDP): Cement replacement at 10%, 15%, and 20%.
- Concrete with Concrete Sample Scraps Powders (C.CSSP): Cement replacement at 10%, 15%, and 20%.

Table 5. Mix proportion of HPC incorporating RPs (kg/m$^3$).

| Material | C.REF | 10 CDP | 15 CDP | 20 CDP | 10 CSSP | 15 CSSP | 20 CSSP |
|---|---|---|---|---|---|---|---|
| Gravels 8/15 | 738.5 | 738.5 | 738.5 | 738.5 | 738.5 | 738.5 | 738.5 |
| Gravels 3/8 | 316.5 | 316.5 | 316.5 | 316.5 | 316.5 | 316.5 | 316.5 |
| Crushed sand | 566.72 | 566.72 | 566.72 | 566.72 | 566.72 | 566.72 | 566.72 |
| Dune sand | 242.88 | 242.88 | 242.88 | 242.88 | 242.88 | 242.88 | 242.88 |
| Cement | 450 | 405 | 382.5 | 360 | 405 | 382.5 | 360 |
| CDP | 0 | 45 | 67.5 | 90 | 0 | 0 | 0 |
| CSSP | 0 | 0 | 0 | 0 | 45 | 67.5 | 90 |
| Water | 144.3 | 144.3 | 144.3 | 144.3 | 144.3 | 144.3 | 144.3 |
| Superplasticizer | 9.24 | 9.24 | 9.24 | 9.24 | 9.24 | 9.24 | 9.24 |
| W/B | 0.32 | 0.32 | 0.32 | 0.32 | 0.32 | 0.32 | 0.32 |

For all mixtures, the water-to-binder (W/B) ratio was maintained at 0.32, and the superplasticizer dosage (VISCOCRETE-775 FLOW) was fixed at 0.7%. The mixing process was conducted using a laboratory mixer. Initially, aggregates, cement, and recycled powders were dry-mixed for one minute. Water and superplasticizer were then introduced and mixing continued for an additional five minutes. The fresh concrete was cast into standardized cube and prism molds and compacted using a vibrating table. After 24 hours, the specimens were demolded and cured in water at 23°C until the designated testing ages.

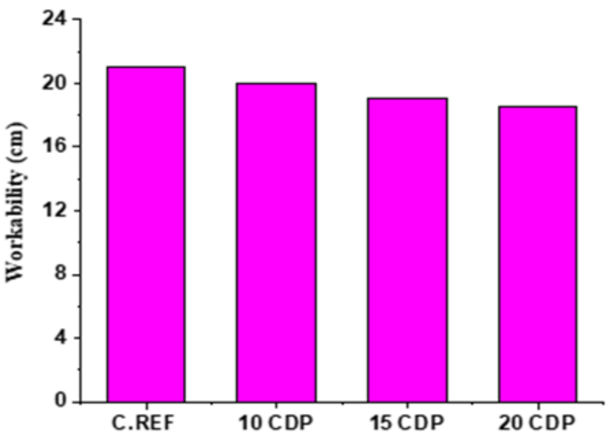
#### *2.2.2 Test Methods*

Each test used a set of three specimens to ensure the accuracy of the results. The workability was measured by the Abrams slump cone test according to EN 12350-2[40]. The measurement of the density is done on cubic specimens (150 × 150 × 150 mm) according to the standard EN 12350-6[41]. The compressive and flexural strengths tests were performed at the ages of 7, 28 and 90 days, the compressive tests were performed on three test cubes (150 × 150 × 150 mm) according to EN 12390-3[42] and the tensile–flexural tests on three prisms (70 × 70 × 280 mm) according to EN 12390-5[43]. The evaluation of the total porosity was based on the measurement of the water absorption and the determination of the dry density according to ASTM C 642[44]. To obtain the latter, the samples were dried at 105°C and then their dimensions and weights were measured.

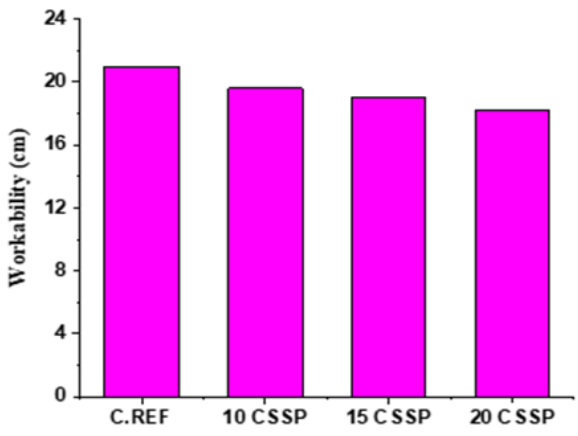
## 3. Results and Discussion

### 3.1. Workability

Fig. 5(a) and 5(b) present the workability of concretes with an increasing substitution rate. As shown, the incorporation of RCP led to a decrease in workability. The reference concrete is a plastic concrete with a workability of 21 cm. The workability of mixes containing CDP was approximately 5 to 12% lower than that of the reference concrete. For example, with a replacement rate of 10%, the workability becomes 20 cm, and 19 cm with a replacement rate of 15%. The same observation applies to the results obtained for the CSSP. A reduction of 6% was obtained at a substitution rate of 10%, while at 15% and 20% substitution, the reduction was 9.5% and 13%, respectively. The results indicate that concrete mixtures incorporating CDP and CSSP share similar trends in workability reduction, within the substitution range of up to 20%. When comparing concretes mixtures with CDP and CSSP, both exhibit a reduction in workability, though with slightly different variations. At a 10% substitution rate, the workability decreases by 5% for CDP and 6% for CSSP. At a 15% substitution rate, the reduction is approximately 9% for CDP and 9.5% for CSSP. These differences can be attributed to the porous microstructure and water absorption capacity of each powder.




(a)




(b)

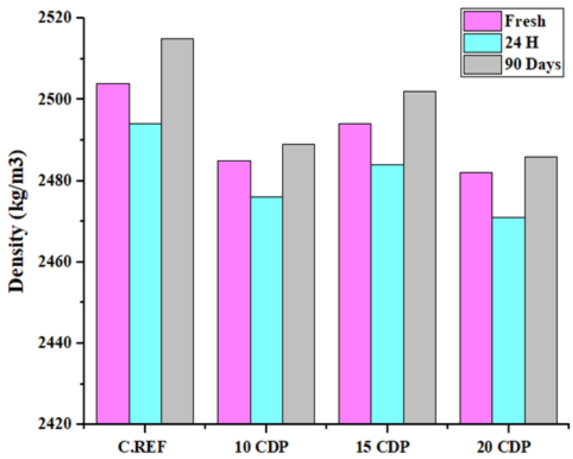
Fig. 5. Workability of concretes containing various RCPs (a)CDP and (b)CSSP

RCPs exhibit significant water absorption, as confirmed by the study of Zhenhua et al. [45], which found that all recycled powders (RPs) used in their research show irregular shapes and rough surfaces, with fine particles agglomerated on larger ones. This characteristic may be the main reason for the higher water demand of RPs compared to cement. Furthermore, these recycled powders, having undergone prior hydration, result in the formation of hydrated phases such as C-S-H gel and interconnected porous microstructures [27]. These interconnected pores increase the capacity of the powders to retain water and reduce the availability of free water in the mixture. Previous studies, notably that of Kim et al. [46], confirm that increasing the replacement rate of recycled powders systematically reduces the workability of mixtures due to their absorption and irregular microstructure. Furthermore, the results obtained in this study are consistent with the findings of [28, 47], which observed similar trends, particularly at higher replacement rates.

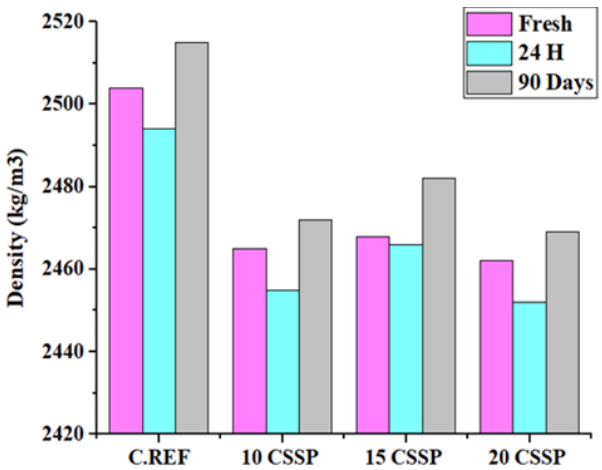
### 3.2 Density

The density in both fresh and hardened states for all studied mixes (Fig.6) decreased with increasing contents of recycled concrete powders.

In the fresh state, the density of the reference concrete (C.REF) is the highest, with a value of 2504 kg/m$^3$, indicating that without the addition of recycled concrete powders, the base mix is relatively dense. When concrete demolition powders (CDP) are introduced, the fresh density of the concrete gradually decreases as the substitution rate increases. For example, with a 10% substitution of CDP, the density is 2485 kg/m$^3$, and it drops to 2482 kg/m$^3$ at a 20% substitution rate, a reduction of 0.88% compared to C.REF. Similarly, mixes containing concrete sample scraps powders (CSSP) show a reduction in density. At 10 CSSP, the density reaches 2465 kg/m$^3$, a reduction of 1.56% compared to the reference concrete, and this decrease continues, reaching 2462 kg/m$^3$ at a 20% substitution rate. The decrease in fresh state density is explained by the intrinsically lower density of recycled powders compared to cement [48]. These powders, derived from the demolition or crushing of concrete, contain more porous and less dense particles, which affects the overall density of the mix. Furthermore, increasing the substitution rate amplifies this effect as the proportion of less dense material increases in the total mixture.




(a)




(b)

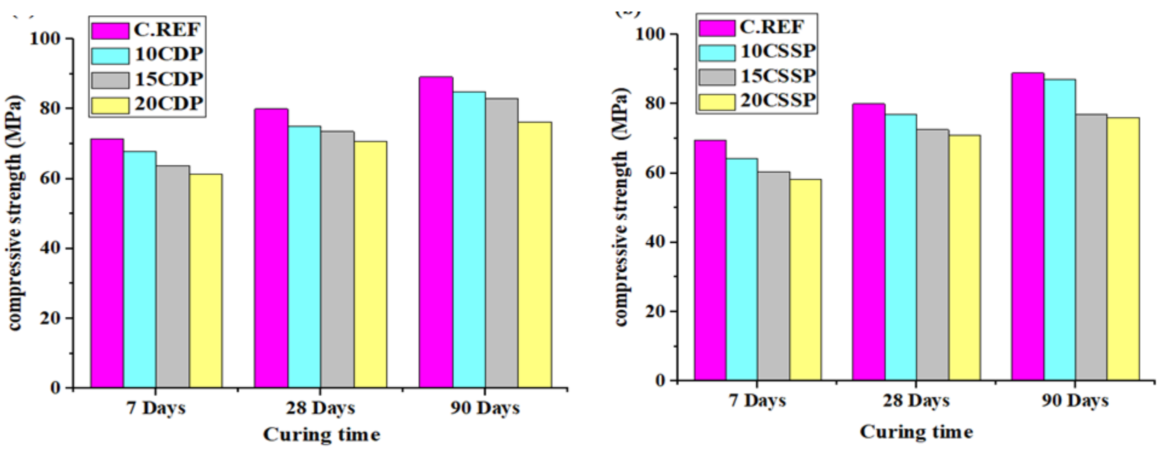
Fig. 6. Density of concretes containing various RCPs (a)CDP and (b)CSSP

In the hardened state (after 90 days), the reference concrete shows a density of 2515 kg/m$^3$, slightly higher than in the fresh state due to the ongoing process of hydration, which gradually densifies the material. In contrast, for mixtures containing CDP, the hardened density remains lower than that of the reference concrete. For example, with 10CDP, the density represents a decrease of about 1.04%, while at 20% substitution, it shows a reduction of approximately 1.15%. This decrease is attributable to the porous microstructure of the recycled powders, which limits densification through hydration. Mixtures containing CSSP also show a reduced density after curing, with a 1.7% decrease at a 10% substitution rate and a density of 2469 kg/m$^3$ at a 20% rate. The observed reduction is primarily attributed to the porous structure of the recycled powders, which hinders the densification of the material. Since the powders derived from recycled concrete have already undergone a hydration reaction during their initial life cycle, their potential to produce new hydration products is significantly reduced. Furthermore, these porous particles lead to the formation of low-density zones within the cementitious matrix, compromising the microstructural compactness of the concrete after setting and hardening. These results indicate that the use of recycled powders leads to a predictable decrease in density due to their porous microstructure and low reactivity. However, this reduction remains relatively limited (< 2%), regardless of the type of powder or the substitution rate, indicating that these materials can be incorporated without significant impact in applications where a slightly reduced density is acceptable.

### 3.3 Compressive and Flexural Strength

The results of compressive strength and flexural strength are presented in Fig.7 and Fig.8 respectively. The evaluation was carried out after 7, 28, and 90 days of curing. The results indicate that both compressive and flexural strength decrease with increasing substitution rates of recycled concrete powders, whether using concrete demolition powders (CDP) or concrete sample scraps powders (CSSP). After 28 days, the highest compressive and flexural strengths were recorded for the reference concrete at 80 MPa and 15 MPa, respectively, while the compressive and flexural strengths of mixtures with RCP ranged from 75 MPa to 70 MPa and from 14 MPa to 13 MPa depending on the substitution rate and the type of recycled concrete powder.

At 28 days, for mixtures containing CDPs, compressive strength decreased by 6.14% and 11.5% compared to the reference concrete for mixtures with 10CDP and 20CDP, respectively. This trend continued at 90 days, although the overall compressive strength increased with curing time. For instance, with a 10 CDP substitution, compressive strength at 90 days was 4.75% lower than that of the reference concrete, while at 20%, the reduction reached 14.5%. For mixes with concrete sample scraps powders (CSSP), a similar trend was observed. At 28 days, incorporating 10 CSSP reduced compressive strength by 3.85%, and with 20 CSSP, the decrease reached 11.2%. At 90 days, the mixture with 10 CSSP displayed only a 2.23% reduction in strength compared to the reference concrete, while the 20% substitution rate led to a 14.5% decrease.

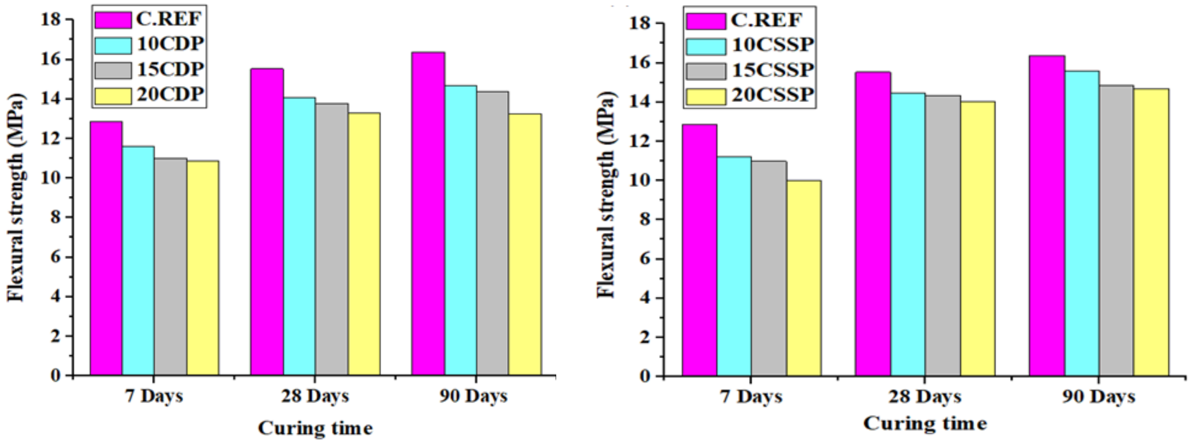



(a) (b)

Fig. 7. Compressive strength of concretes containing various RCPs (a)CDP and (b)CSSP

The incorporation of recycled concrete powders also reduced flexural strength. This finding has been confirmed by various studies demonstrating that the substitution of cement with recycled concrete powders decreases flexural strength [49, 50]. The results show a similar trend to that observed in compressive strength. For example, at 28 days, mixtures containing 10 CDP and 20CDP had a flexural strength 9.27% and 14.3% lower than the reference concrete, respectively. At 90 days, the decrease on the flexural strength was 10.26% and 19% for mixtures with 10CDP and 20CDP, respectively. For mixtures containing CSSP, flexural strength reductions were also observed. At 90 days, flexural strength losses reached 4.6% for 10CSSP and 10.3% for 20 CSSP.

Overall, compressive and flexural strengths of concretes containing CDP and CSSP showed a linear decrease as the substitution rate of recycled concrete powder increased. However, at lower substitution rates (≤10%), the negative impact of CSSP on strength is less pronounced than that of CDP. However, at higher substitution rates (≥15%), the beneficial effect of CSSP becomes insufficient to compensate for the reduction in reactive phases, leading to a strength decrease similar to that observed with CDP.




(a) (b)

Fig. 8. Flexural strength of concretes containing various RCPs (a)CDP and (b)CSSP

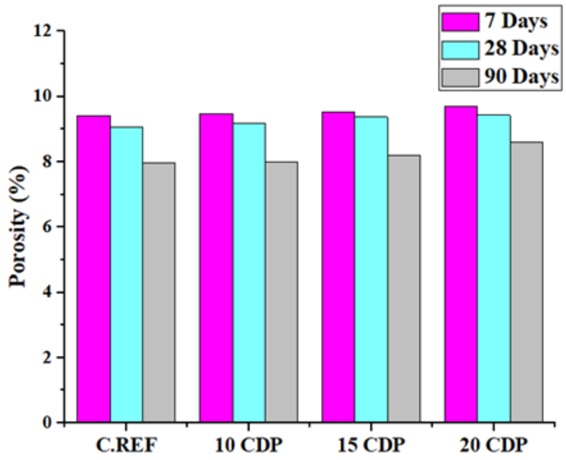
The compressive and flexural strength of concrete prepared with powders is always lower than that of the reference concrete, decreasing with increasing substitution rate, regardless of the curing time. This decrease in mechanical strength (compressive and flexural strength) is due to the reduction in the main reactive phases, C2S and C3S, as well as the low reactivity of fine particles compared to cement, which has reduced the content of new hydration products in the mixture [20] which are responsible for binding and developing mechanical strength. Moon et al. [51] also explained that the decrease in strength is due to the inert components present in the recycled powders, leading to a decrease in the formation of new hydration products and strength as the recycled powders are incorporated. These results are consistent with previous studies [52, 53].

### 3.4 Porosity

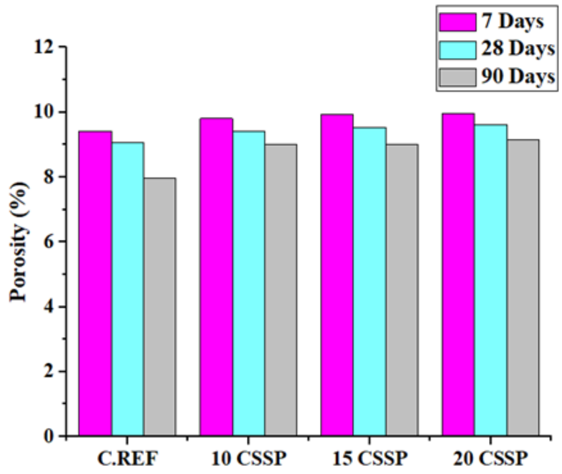
Fig.9 compares the results of porosity levels in concrete mixes under different conditions of substitution ratio and curing time. For the reference concrete (C.REF), porosity decreases significantly with curing time, dropping from 9.07% at 7 days to 7.97% at 90 days. This reduction can be attributed to the continuous hydration process, which densifies the cement matrix by gradually filling the pores. For mixtures containing CDP, the porosity is higher than that of the reference concrete and increases with the substitution rate. At 28 days, the porosity of REF is 9.07%, while mixtures with 10%, 15%, and 20% CDP show porosity levels of 9.17%, 9.37%, and 9.43%, respectively. At 90 days, although there is a slight reduction in porosity due to ongoing hydration, mixtures containing CDP maintain higher porosity levels than the reference concrete.

For CSSP, porosity follows a similar trend. For example, at 28 days, a mix with 10CSSP exhibits a porosity of 9.41%. At 90 days, porosity also decreases in mixes with CSSP, reaching, for instance, 9% for 10 CSSP and 9.14% for 20 CSSP, which remains higher than the porosity of the reference concrete. At the same substitution rates, both types of recycled powders increase the porosity compared to the reference concrete. For example, at 28 days, a mixture with 10% CSSP shows a porosity of 9.41%, while a mixture with 10% CDP shows a porosity of 9.17%. This slight difference indicates that CSSP have a slightly more pronounced influence on increasing porosity than CDP.

For both types of recycled powders, increasing the substitution rate leads to an increase in porosity. This is explained by the use of recycled concrete powders, which reduce the amount of new hydration products in cementitious composites. Additionally, as recycled powders are incorporated, the pore size of cementitious materials increases, resulting in a porous structure [54]. Regardless of the substitution rate, prolonged curing leads to a reduction in porosity in all mixtures. This observation is explained by the continuous hydration process of the recycled concrete in the mixture. Consequently, even if the substitution rate of recycled concrete powder remains constant, porosity decreases as curing time increases due to the continuous hydration phenomenon.




(a)




(b)

Fig. 9. Porosity of concretes containing various RCPs (a)CDP and (b)CSSP

## 4. Conclusion

This research represents an experimental approach aimed at substituting cement with recycled concrete powders in high-performance concrete mixtures. This study contributes to the research and application of recycled powders while supporting environmental preservation and sustainable development in Algeria. The main conclusions can be drawn as follows:

- The use of powder reduces workability by 5%–12% in mixes with demolition concrete powder and by 6%–13% in mixes containing concrete sample scraps powder, both relative to reference concrete. This reduction is due to the high absorption and irregular microstructure of the recycled powders. Furthermore, as the rate of substitution increases, the reduction in workability becomes more pronounced, showing a direct correlation between the proportion of recycled powders added and the reduced workability of the concrete mixtures.
- Recycled powder decreases the density, especially when the substitution rate of the powder is 20%. The decrease in density is primarily caused by the lower density of recycled powders compared to cement and the reduced formation of hydration products due to the lower cement content. However, the variation remains minimal, with changes of less than 2% compared to the reference concrete, regardless of the type of powders or the substitution rate.
- At 28 days, the compressive strength of the mixture containing 10% concrete demolition powders (CDP) decreased by 6.14%, while the mixture containing 20CDP showed an 11% reduction compared to the reference concrete. As the substitution rate increased, the strength loss became more significant. Similar results were observed in mixes incorporating concrete sample scraps powders (CSSP). This decrease is due to the decrease in the formation of new hydration products in cementitious materials, which affects overall strength development of the concrete.
- The incorporation of recycled concrete powders also resulted in a decrease in flexural strength, with trends similar to those observed for compressive strength. For example, at 28 days, the flexural strength of mixes containing 10% CDP and 20% CDP was 9.27% and 14.3% lower, respectively, then that of the reference concrete.
- The study of the porosity of concrete mixtures shows that the incorporation of recycled concrete powders increases this effect in newly prepared concretes. This increase in porosity is linked to the reduced formation of new hydration products in the mixture, which results in a more porous structure.

The results indicate that although there are slight reductions in some mechanical properties and rheological behavior, these changes remain within acceptable limits and do not significantly affect the overall performance of the concrete. This suggests that recycled concrete powders could be used as a substitute for traditional cement, helping to reduce the environmental impact of cement production and promoting the principles of the circular economy in the construction industry.

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