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CIVIL AND ENVIRONMENTAL ENGINEERING REPORTS

E-ISSN 2450-8594

CEER 2019; 28 (2): 130-144
DOI: 10.2478/ceer-2020-0010
*Original Research Article*

# THE STUDY OF THE CHARACTERISTICS OF SAND CONCRETE BASED ON MARBLE WASTE SAND

Mohamed Ichem BENHALILOU[1], Mouloud BELACHIA[1,2], Hacène HOUARI[3], Assia ABDELOUAHED[1*]
[1]LMGHU Laboratory, University of 20 August 1955 - Skikda, Algeria
[2]Department of Civil Engineering, University of Guelma, Algeria
[3]Laboratory of Construction Materials and Durability, University of Constantine, Algeria

Abstract

The present study aims to valorize the waste and in particular the waste from the Fil-fila quarry. The main reason for choosing the waste from this quarry was the need to reduce the impact on the environment (by reducing stockpiling) and the raw material cost (economic reason). This study therefore consists in recovering this type of waste (discarded powder subject to weather changes) as sand in partial replacement of dune sand in the formulation of sand concrete with percentages of 5, 10, 15 and 20 %, by studying the behavior of these concretes in the fresh state (workability, density and occluded air) and the properties in the hardened state (compressive and tensile strength by bending, absorption by immersion, shrinkage and weight loss, chemical effect of HCl and $H_2SO_4$ solutions), and subsequently comparing the results obtained with reference samples (0%) based on ordinary sand. Based on the obtained results, it can be concluded that the substitution of ordinary (dune) sand with marble waste sand provides acceptable results from the point of view of workability, strength and durability.

These observations are likely to widen the field of applications of these sand concretes based on marble waste.

*Corresponding author: LMGHU Laboratory, University of 20 Août 1955 - Skikda, Algeria e-mail: a.abdelouahed@univ-skikda.dz,

Keywords: sand concrete, waste, marble, substitution, performance, durability

## 1. INTRODUCTION

Sand concrete is essentially composed of a mixture of sand (one or more types), fines, cement, water and other additions in suitable proportions. It can present a good alternative to replace the conventional concretes in the production of some construction elements [1]. This type of concrete, utilizing local natural resources in the absence of other aggregates, has interesting specific properties, such as strength, the absence of segregation, the good surface appearance and the small granularity, which favor its use in certain structures [2]. The reuse of different waste, which is an environmental nuisance, in this type of concrete was the subject of many studies [3]. Among these works, we can cite the introduction of plastic waste, demolition concrete waste, brick waste and marble waste as aggregates. The recovery of these types of waste has become a necessary solution to the economic problems of countries given the gradual depletion of aggregates and minimizing the environmental impact. In this context, the reflection opens on the development of sand concrete using abundant resources and in particular marble waste.

This work aims to study the possibility of using marble waste (discarded powder exposed to weather conditions) from the Fil-fila quarry (eastern Algeria) as a substitute to sand in the formulation of sand concrete. The waste from this quarry was recovered in several types of construction materials, as an addition in cement materials, as aggregates in concrete and mortar and as sand substitute in sand concrete.

Berdoudi et al., [4] developed a study on the use of marble waste fillers as an addition to cement. They found an improvement in the consistency of the cement paste, increase in the start and end times setting and improvement in the performance in compression and in bending tension in the case of mortars at a 5% substitution rate. Shrinkage increases with the increase in the substitution rate but remains within the standards. The introduction of marble waste sand into the composition of mortars was studied by Hebhoub et al. [5]; their work shows that this waste decreases workability and increases concrete density and strength at the young age. The same type of waste was introduced as an alternative to sand in the composition of ordinary concrete [6] and partially replaced sea sand at rates of 25, 50, 75 and 100%. In this study, the maximum density was obtained for the replacement rate of 25%. A decrease in workability and occluded air and the best mechanical performance were obtained by partially substituted concretes. The research carried out by Hebhoub et al. [7] on the use of marble waste aggregates in the concrete composition shows a significant improvement in mechanical performance for partially substituted mixtures and a

considerable increase in cohesion, the same results were confirmed by Belachia and Hebhoub [8].
Djebien et al. [9] incorporated marble waste sand into the formulation of self-placing concrete at rates of 25 to 100%, they concluded that marble waste sand increases cohesion and resistance to segregation of self-compacting concrete. Marble waste sand was introduced into the composition of sand concrete based on plant fibers in the work carried out by Rihia et al. [10]; the results indicate an improvement in workability, reduction in the content of entrained air, increase in the initial compressive strengths and in flexural tension. Capillary and immersion absorption are reduced to a rate of 10%. When Djebien et al. [11] used marble waste fines from the Fil-fila quarry which partially replaced limestone fines in sand concrete, they found an improvement in the properties in the fresh and hardened state as a function of the increase in the rate of fines.
This paper, presents an experimental study to evaluate the effect of marble waste on the properties of sand concretes in order to specify its fields of application and define the data necessary for the sizing criteria. Physical, mechanical and durability properties are examined, according to various compositions of sand concrete, for four substitution rates. (0%, 5%, 10% and 15%).

## 2. USED MATERIALS

The different materials used included:

- Dune sand DS of rolled nature with class 0/3 of Biskra origin, Algeria.
- Marble waste sand MWS from the Fil-fila quarry - Skikda, Eastern Algeria. Properties of different sands used are given in Table 1, and the grain size curves of the two types of sands are presented in Fig. 1.
- Cement CPA-CEM I 42.5N from the cement plant of Ain el Kebira-Sétif, with an absolute density of 3.22 g/cm3 and the Blaine specific surface of 3100 cm2/g. The chemical composition of cement is presented in Table 2.
- Limestone fines F from the quarry of Ben Azzouz - Eastern Algeria with an absolute density of 2.74 g/cm$^3$.
- Super plasticizer SP in a liquid form, in accordance with standard EN 934-2.
- Tap water for mixing.

Table 1. Properties of the different sands used

| Properties | DS | MWS |
|---|---|---|
| Apparent density g/cm$^3$ | 1.29 | 1.50 |
| Absolute density g/cm$^3$ | 2.580 | 2.750 |
| Value of blue methylene % | 1 | 0.35 |
| Sand equivalent % | 89 | 67 |
| Fineness modulus % | 1.36 | 1.66 |
| Fines content % | 2 | 8 |
| Absorption % | 1.37 | 2.40 |
| $CaCO_3$ | --1.69 | 98.67 |
| CaO | -- | 55.29 |
| $Al_2O_3$ | 0.50 | 0 .14 |
| $Fe_2O_3$ | 0.75 | 0.09 |
| $SiO_2$ | 95.11 | 0.53 |
| MgO | 0.15 | 0.2 |
| $Na_2O$ | 0.23 | 0.00 |
| $K_2O$ | 0.200 | 0.01 |
| Cl- | 0.00 | 0.025 |
| $SO_3$ | 0.01 | 0.04 |
| Loss on ignition | 4 | 43.40 |
| Insoluble residue | -- | 0.035 |

The particle size analyses of the two sands are presented in Figure 1.

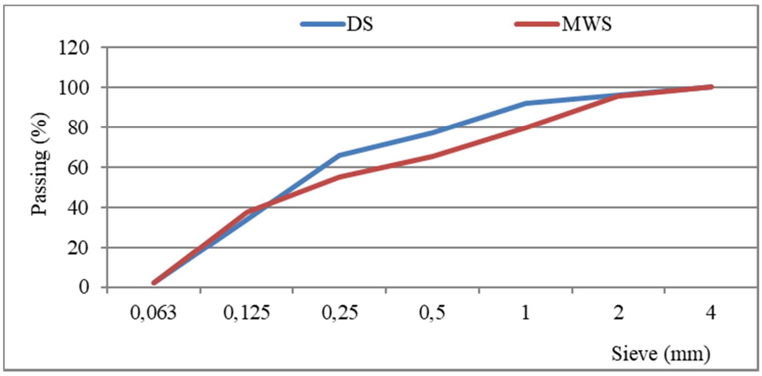


Fig. 1. Granulometric curves of sands

Table 2. The chemical composition of cement used

| Chemical characteristics | Cement |
|---|---|
| CaO | 63.69 |
| $Al_2O_3$ | 4.55 |
| $Fe_2O_3$ | 5.03 |
| $SiO_2$ | 20.90 |
| MgO | - |
| $Na_2O$ | 0.18 |
| $K_2O$ | 0.33 |
| $Cl^-$ | 0.001 |
| $SO_3$ | 2.08 |
| Loss on ignition | 0.70 |
| Insoluble residue | 0.75 |
| Free CaO | 0.75 |

## 3. EXPERIMENTAL PROGRAM

The objective of this work is to investigate the modifications to sand concrete by the partial volume replacement at rates of 5, 10, 15 and 20% of the ordinary sand of nature rolled by marble waste sand (discarded powder exposed to climate change). We approach the problem by analogy with numerous studies carried out on sand concrete.

The formulation of the control concrete mixture (BS0) was obtained using the SABLOCRETE method (SABLOCRETE- 1994) [12] with the fixed parameters of the W/C ratio, cement dosage, fines dosage and admixture dosage and the compositions of the mixtures (BS5, BS10, BS15 and BS20) were obtained by replacing ordinary sand with 5, 10, 15 and 20% of marble waste sand (Table 3).

Table 3. Compositions of mixtures

| Formulations | W/C | SP ($l/m^3$) | CEMI ($Kg/m^3$) | F ($Kg/m^3$) | DS ($Kg/m^3$) | MWS ($Kg/m^3$) |
|---|---|---|---|---|---|---|
| **BS0** | 0.68 | 5.556 | 400 | 98.64 | 1277.21 | 0 |
| **BS5** | 0.68 | 5.556 | 400 | 98.64 | 1213.35 | 68.07 |
| **BS10** | 0.68 | 5.556 | 400 | 98.64 | 1149.50 | 136.137 |
| **BS15** | 0.68 | 5.556 | 400 | 98.64 | 1085.628 | 204.205 |
| **BS20** | 0.68 | 5.556 | 400 | 98.64 | 1021.768 | 272.274 |

The tests carried out on the mixtures are:
- Density test in the fresh state according to standard NF EN 12350-6.
- Slump test at the Abrams cone (NF EN 12350-2).
- Occluded air measured by a concrete aerometer (NF EN 12350-7).
- Compressive and flexural tensile strength at the age of 2, 7, 28 and 90 days measured on prismatic test pieces with dimensions of 4x4x16 cm3 kept in water in accordance with standard NF EN 12390-5.
- Absorption by immersion measured on prismatic test pieces with dimensions of 4x4x16 cm3 according to Neville, 2000.
- Shrinkage and weight loss measured on prismatic test pieces with dimensions of 4x4x16 cm fitted with studs (NF P 18 - 433).
- Chemical effect tests with solutions of 5% HCl and 5% $H_2SO_4$ on cubic specimens with dimensions of 5x5x5 cm3 preserved for 28 days in water, then immersed in the solutions until the age of 90 days according to standard ASTM.

## 4. RESULTS AND DISCUSSIONS

### 4.1. Workability

The results of workability tests of different specimens are presented in Fig. 2

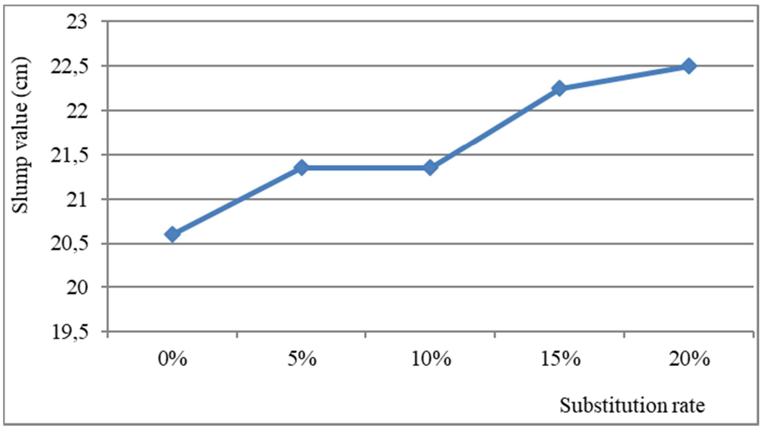


Fig. 2. Variation of workability as a function of substitution rate

The introduction of marble waste sand (Figure 2) leads to the increase in the workability of the control concrete, this can be explained by the presence of the fine elements in marble waste sand which positively affect the workability and marble waste sand facilitates the dispersion of the cement paste grains as a result of the effect of concrete void filling [10, 14].

### 4.2. Density

The results of density tests of different specimens are presented in Fig. 3

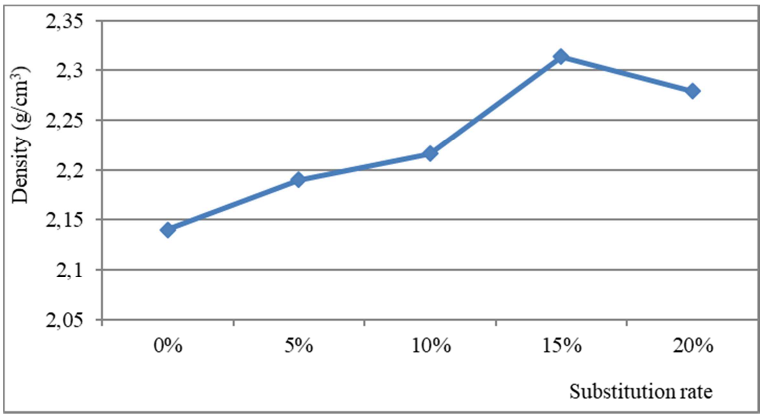


Fig. 3. Variation of density versus substitution rate

Fig.3 shows that the increase in the rate of substitution with marble waste sand leads to an increase in density up to a rate of 15%, beyond this rate the effect is reversed. The increase in density is explained by a higher density of waste sand [10,11,13].

### 4.3. Occluded air

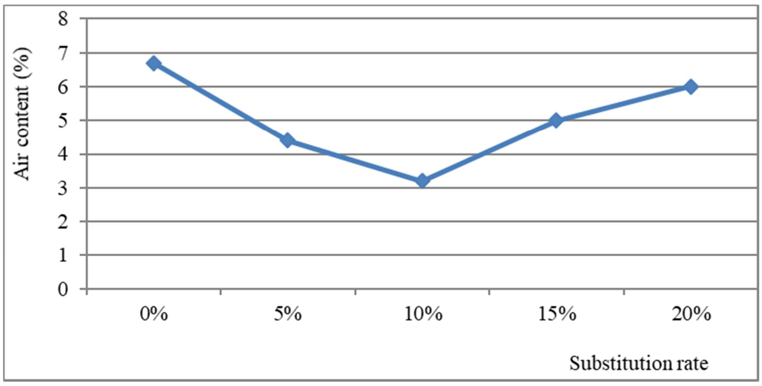


Fig. 4. Change in air content as a function of the substitution rate

The content of occluded air decreases along with the increase in the substitution rate up to 10% (Figure 4). This decrease occurs due to the increase in cohesion [7] on the one hand and the increase in the capacity of resistance to segregation on the other hand [15]. Above a 10% substitution rate, the effect is reversed and the content of occluded air remains lower than that of the control concrete.

### 4.4. Compressive strength

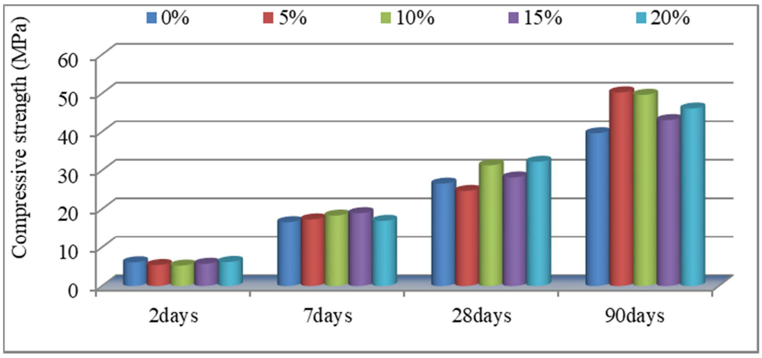


Fig. 5. The effect of substitution rate on compressive strength

At 2 days, the introduction of 5% of marble waste sand leads to a reduction in compressive strength (Figure 5), beyond 5%, the addition of marble waste sand leads to an increase in compressive strength to reach the maximum value of 6.20MPa at a 20% substitution rate. This increase can be explained by the presence of CaO in marble waste sand which offers a lot of $C_2S$ providing high initial resistances in accordance with those found by Hebhoub et al. [5].

At 7 days, the introduction of marble waste sand generates an increase in compressive strengths of the control concrete occurring due to a high content of CaO which increases the cohesion at a young age [5, 9]. The maximum value is given by the mixture of a 15% substitution rate.

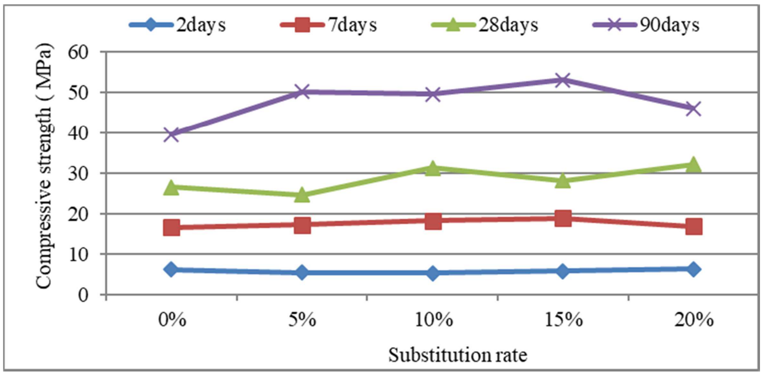


Fig. 6. The effect of age on the development of compressive strength.

At 28 and 90 days, concrete based on marble waste sand gives the best compression performance compared to the control concrete. These results can be explained by the calcareous nature of marble waste sand which offers good adhesion of the aggregates to the granular matrix [16], and capability of marble waste sand and cement to form more resistant products which contributes to an improvement in compressive strength [17].

From the obtained results (Figure 6), it can be noted that the development of the compressive strength of the studied concretes increases regularly with the age and does not fall until the age of 90 days, between 2, 7 and 28 days the curves are close together, they exhibit the same behavior as at 2 and 7 days. The variation between 28 and 90 days is very notable, the curves are distinct.

### 4.5. Flexural tensile strength

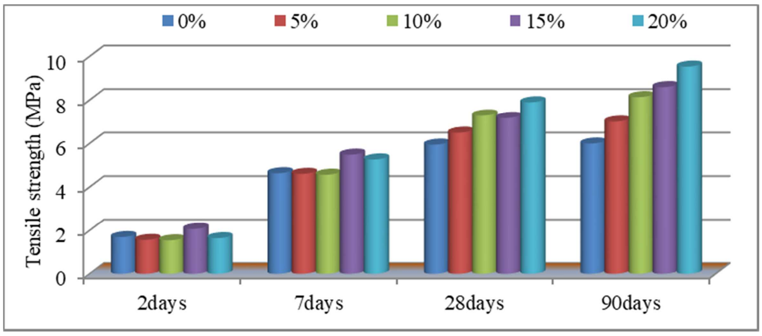


Fig. 7. The effect of the substitution rate on tensile strength

At a young age (2 days), there is a slight decrease in the strength of concrete based on marble waste sand compared to the control concrete except for the mixture with a 15% substitution rate (Figure 7). The tensile strength of concretes based on marble waste sand tripled their value at 7 days and the maximum value was obtained by concrete with a 15% substitution rate (the presence of CaO which increases the strength at a young age). The effect of the introduction of marble waste sand is more pronounced at 28 and 90 days, the maximum value of tensile strength is obtained by concrete with a 20% substitution rate. The increase in the substitution rate leads to an increase in the amount of CaO in the mixtures which increases cohesion and provides the good matrix / aggregate bonding [5,7,16].

The results of the flexural tensile strength test illustrated in Figure 8 show similar trends to compressive strength. There is a development of tensile strengths which increase regularly with age and do not fall until the age of 90 days. The variation between 2 and 7 days is more marked in comparison with 7 and 28 days. The curves are very close between 28 and 90 days in particular between 0% and 10%.

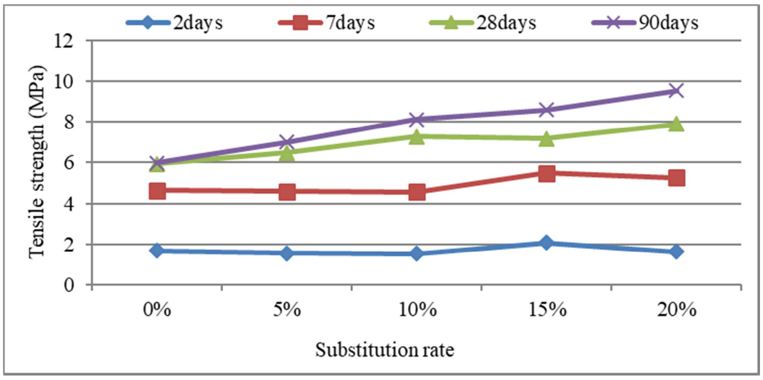


Fig. 8. The effect of age on the development of tensile strength

## 4.6. Absorption by immersion

The analysis of the results obtained in Figure 9 shows that concretes based on marble waste sand have high absorption coefficients compared to the control concrete. This increase is explained by the high absorption coefficient and the roughness of the grain of marble waste sand which affects the compactness [18]. The increase in the rate of marble waste sand causes an increase in porosity [13,19].

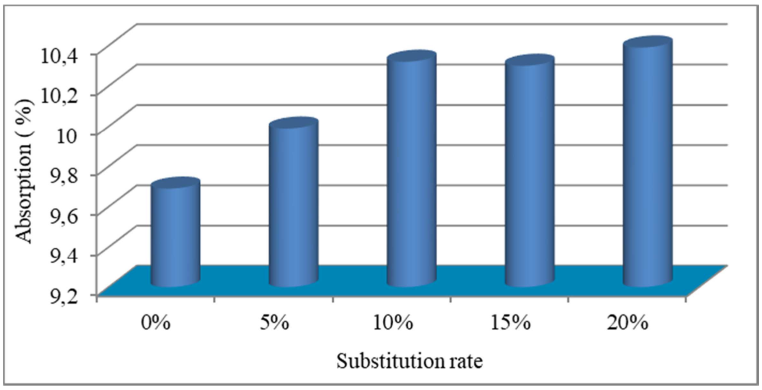


Fig. 9. Variation of absorption by immersion versus the substitution rate

### 4.7. Weight and dimensional variations

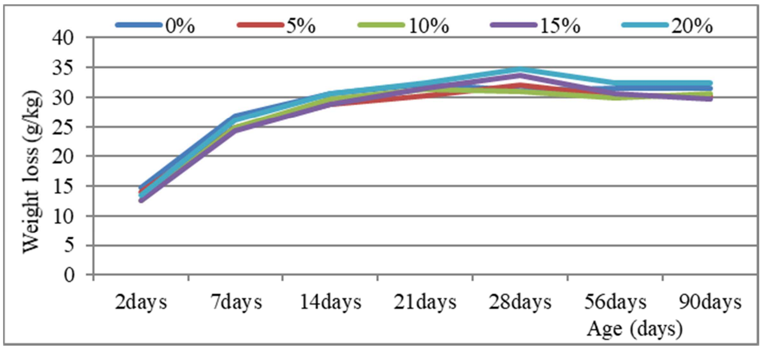


Fig. 10. The effect of the substitution rate on weight loss

During the first 14 days, there is a decrease in weight losses of concrete based on marble waste sands (Figure 10), after the 14th day the maximum weight loss is obtained by concrete with a 20% substitution rate. The weight variation curves show the same behavior and the maximum weight loss occurs at the age of 28 days for all the compositions.

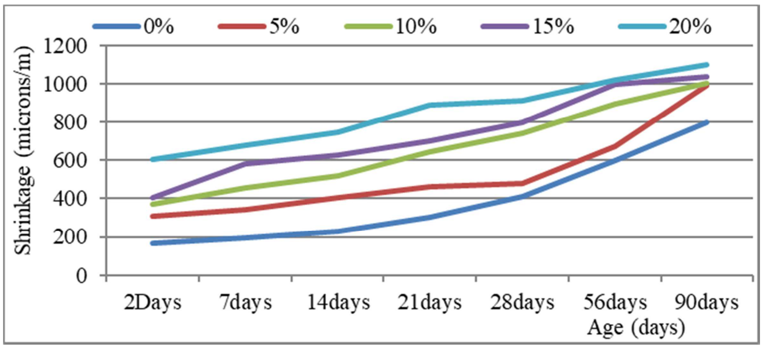


Fig. 11. The effect of the substitution rate on shrinkage

The analysis of the results of dimensional variations due to shrinkage (Figure 11) shows that concrete based on marble waste sand, exhibits a higher shrinkage than that recorded for the control concrete because of its high absorption and its strong fines content [20]. Shrinkage increases with the increase in the rate of marble waste sand but remains below 2000 um/m, the variation at 90 days is less significant in comparison with that of 2 days.

### 4.8. Chemical effect tests with hydrochloric acid and sulfuric acid

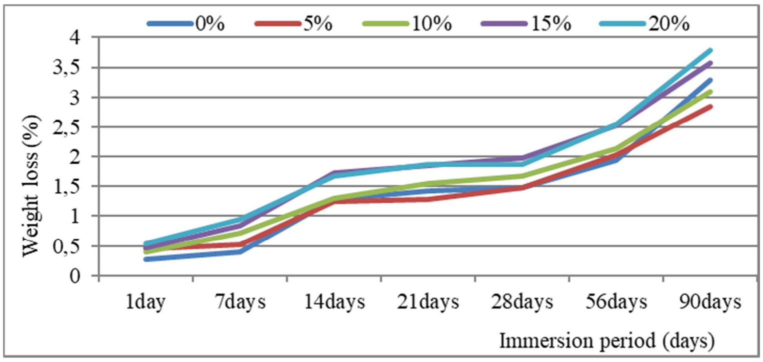


Fig. 12. Variation of weight loss versus the immersion period in HCl

At the end of the first week (Figure 12), there generally is a reduction in mass loss for all the investigated mixtures. On the other hand, after the 7th day of storage, an increase in mass loss was observed for the said compositions. The chemical resistance of the control concrete is better than that of concretes containing marble waste sand at the early age; this is explained by the high content of $CaCO_3$ in marble waste sand.

Concrete with a 5% substitution rate of sand from marble waste, is more resistant to the effect of hydrochloric acid compared to other concretes.

Poor resistance to the chemical effect is demonstrated by concrete with a 15 and 20% substitution rate. The variation is very close between 0 and 10% in comparison with a 10 and 20% substitution rate.

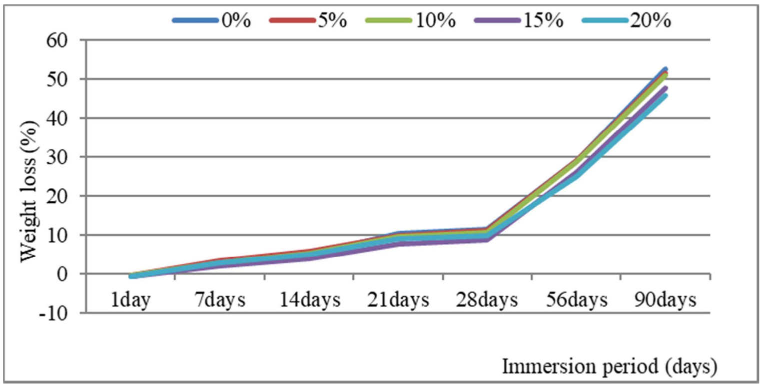


Fig. 13. Variation of weight loss versus the immersion period in $H_2SO_4$

The curves in Figure 13 have the same appearance irrespective of the substitution rate and the age. The best resistance to the effect of sulfuric acid is demonstrated by concrete with a 15% substitution rate between 1 and 28 days, concrete with a 20% substitution rate older than 28 days has the best chemical resistance. The inclusion of marble waste sand made the mixtures relatively inert to any change in compressive strength [17].

## 5. CONCLUSIONS

On the basis of the obtained results, it can be concluded that:

- Marble waste sand increases the density and decreases the content of occluded air.
- The partial replacement of ordinary (dune) sand with marble waste sand improves the workability
- The maximum compressive strength is obtained by concrete with a 20% substitution rate at the age of 28 days
- The best performances in compressive and flexural tensile strength are obtained by concretes based of marble waste sand at 28 and 90 days.
- Marble waste sand increases cohesion.
- Concretes partially substituted by sand marble waste absorb more water than ordinary sand.
- Shrinkage increases with the increase in the rate of marble waste sand but remains within the standards.
- Concrete containing 5% of marble waste sand demonstrates a better resistance to hydrochloric acid.
- The best resistance to the effect of sulfuric acid is obtained by concrete at a 15% substitution rate.

It can be currently noted that the introduction of marble waste into the sand concrete improves the rheological characteristics of the matrix. We have shown the difficulties in quantifying these improvements. Due to the fact this study is part of a limited framework, its purpose was to specify the main_properties (in particular the increase in cohesion). The obtained results are likely to widen the field of applications of these sand concretes based on marble waste.

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*Editor received the manuscript: 01.02.2020*