International Information and Engineering Technology Association
Advancing the World of Information and Engineering

Revue des Composites et des Matériaux Avancés-Journal of Composite and Advanced Materials
Vol. 34, No. 3, June, 2024, pp. 295-303
Journal homepage: http://iieta.org/journals/rcma

Reuse of Hollow Concrete Blocks Waste in the Formulation of an Eco-Mortar Reinforced with Natural Fibers for Use in Filling Materials

Mohammed Ichem Benhalilou[1], Assia Abdelouahed[2*], Houria Hebhoub[2], Chiraz Kechkar[3], Alsayadi Hamid[2]

[1] TCT Batna 2, Department of Technology, University Batna 2, Batna 5000, Algeria
[2] LMGHU Laboratory, Department of Civil Engineering, University of 20 August 1955 Skikda, Skikda 21000, Algeria
[3] LGCH Laboratory, Department of Civil Engineering and Hydraulic, University of 8 May 1945 Guelma, Guelma 24000, Algeria

Corresponding Author Email: abdelouahedassia@yahoo.fr

https://doi.org/10.18280/rcma.340304

Received: 28 December 2023
Revised: 20 May 2024
Accepted: 31 May 2024
Available online: 22 June 2024

Keywords:
eco-mortar, hollow concrete blocks waste, Diss fibers, properties, mechanical resistance, durability

ABSTRACT

As a fact of matter, the aim of this paper is to produce a new ecological mortar based on recycled aggregates from hollow concrete blocks waste and reinforced with natural Diss fibers for use in manufacturing filling materials and masonry blocks, for the purpose of reducing the impact of such waste on the environment on the one hand, and making the most of the Diss plant, which is abundant in Algeria, on the other. In virtue of which, for achievement purpose of this work, we partially substituted the crushed-stones sand (CS) of a mortar reinforced with Diss fibers with recycled sand (RS) from hollow concrete blocks waste at rates of 15%, 30% and 50%. Besides, the produced mortars were subjected to density, consistency and air occlusion tests in their fresh state; moreover, they have alike been subject to compressive strength, flexural tensile strength, water absorption by immersion and capillary action, chemical resistance to acid and alkali, and chloride ion penetration tests in the hardened state. As consequence, the results illustrated improvements in consistency, mechanical strength and resistance to chemical attacks, with a slight increase in chloride ion penetration.

1. INTRODUCTION

Indeed, filling materials, mortar blocks, solid and hollow bricks and breeze-blocks are non-load bearing materials considered to be an older construction technique used in the construction of external walls or partitions in buildings. Further, solid infill panels prevent the framework from deforming freely, whilst masonry walls act as load-bearing walls that resist horizontal seismic forces in their plan, and they have shown to be characterized by their ease of use, low construction costs, low resistance to moisture and poor environmental credentials [1]. More to the point, reinforcing these materials with natural fibers, and Diss fibers in particular, makes it possible to exploit this local resource, reduce the environmental impact compared with other materials [2], increase ductility, reduce crack propagation and delay failure [3, 4], reduce the effect of seismic stress due to its lightness [4, 5], improve tensile strength and reduce conductivity, which increases thermal insulation capacity [6]. Furthermore, an improvement in durability in hydrochloric and acetic acid environments have alike been noticed [7].

Positively, the reuse of construction and demolition waste generated by the building sector (around 46 million tons of waste per year) or by concrete block manufacturing factories in civil engineering materials is the subject of a number of researchers [8, 9] because of the reduction in the consumption of natural aggregate resources together with the reduction in storage sites while preserving nature [10, 11]. In this respect, the use of recycled aggregates from construction and demolition waste in composite materials based on natural fibers has shown to be a new alternative, since the majority of researchers have worked either on natural fibers as reinforcement in composites or on the recycling of waste in composite materials, there is no previous work on the use of recycled aggregates in eco materials reinforced with fibers; in light of which, the aim of this paper is to use this waste as sand in the formulation of an eco-mortar based on Diss fibers intended for the manufacture of masonry materials.

Unquestionably, this work, which aims to partially substitute ordinary sand in a mortar reinforced with Diss fibers with recycled sand from cinder block (hollow concrete blocks) waste (Figure 1), stands for the continuation of the study in 2023 [7] by our research group.

Nonetheless, in the study carried out by Abdelouahed et al. [7], Diss fibers (1/3 of the formulation volume) were introduced instead of ordinary sand (2/3 of the formulation volume) for formulation purpose of a composite reinforced with natural Diss fibers used as filling materials. As consequence, the results of this study have without a doubt encouraged us to introduce recycled sand from hollow concrete blocks offcuts into the same formulation instead of ordinary sand at rates of 15, 30 and 50%, along with studying the modifications brought about by this sand on the fresh properties (density workability and Occluded air) and hardened states (compressive and flexural strength), as well as the durability parameters (Water absorption by immersion and capillary, chemical attack, and chloride penetration)

Figure 1. Hollow concrete blocks waste

2. USED MATERIALS

The different materials used in this study are:

-CPJ-CEM II 42.5 (S-L) cement from the Hdjar Soud cement plant in the Province of Skikda;

-Diss fibers F (Figure 2) obtained by cutting the Diss plant into fibers of 2.5 cm long, and then treated with boiling water for 20 min. Thus, the Diss plant comes from the mountains of the Province of Skikda, at the eastern part of Algeria;

Figure 2. Diss fibers

Figure 3. Sands used

-Quarry sand CS of class 0/4, from the quarry of Ben Brahim, Province of Constantine, East of Algeria;

- Hollow concrete blocks waste sand (recycled sand RS) is obtained by crushing and sieving hollow concrete blocks (cinder block) offcuts (Figure 3). Table 1 gives the properties of the two sands and these particle size curves are shown in Figure 4.

Table 1. Properties of sands used

Properties	Quarry Sand CS	Recycled sand RS
Apparent density (g/cm^3)	1.450	1.104
Absolute density (g/cm^3)	2.620	2.610
Absorption (%)	2.00	3.33
Methylene blue (%)	0.7	0.5
Sand equivalent (%)	61	67
Fineness modulus	2.93	3.47
CaO	55.55	47.49
Al_2O_3	0.18	1.28
Fe_2O_3	0.08	0.72
S_iO_2	0.13	2.20
MgO	0.25	1.83
Cl-	0.04	--

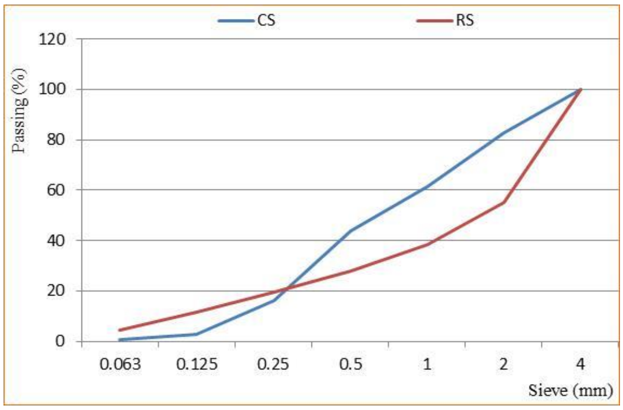

Figure 4. Grain size curve of sands

In the light of the results of the characterizations, we can conclude that:

-The apparent bulk density of recycled sand is lower than the one of ordinary sand and the absolute densities are almost identical;

-The recycled sand is cleaner and absorbs more water than ordinary sand; however, this high absorption is due to the presence and attachment of the old mortar to the aggregates [12].

-The recycled sand has an average regularity of granularity;

-The fineness modulus of both ordinary and recycled sand is 2.93 and 3.47 respectively, indicating a coarse sand, which gives high strength at the probable expense of workability;

-The recycled sand is slightly coarser than the ordinary sand;

-The fines content of recycled sand is high compared to the fines content of ordinary sand;

-The quarry sand has a higher CaO content than recycled sand, and a high CaO content increases the bond between the cement paste and the aggregates [10].

3. EXPERIMENTAL PROGRAM

3.1 Mix formulation

The objective of this work is to partially substitute with rates of 15%, 30% and 50% an ordinary sand of quarry by a sand of waste of hollow concrete blocks of a mortar reinforced by natural fibers of the Diss plant. Nonetheless, the reference formulation was fixed in a work published in 2023 [7], whereat we substituted 1/3 of the volume of the ordinary sand of this mortar by 1/3 of volume of Diss fibers. Hence, the fixed parameters of the different formulations are the cement content, the water content and the fiber content. In virtue of which, the used formulations are demonstrated in Table 2.

Table 2. Composition of mixtures

Mortar	M0%	M15%	M30%	M50%
Cement	1V	1V	1V	1V
SC	2/3V	85% two 2/3V	70% two 2/3V	50% two 2/3V
F	1/3V	1/3V	1/3V	1/3V
RS	0	15% two 2/3V	30% two 2/3V	50% two 2/3V
W	1V	1V	1V	1V

Notes: 1. V: Volume

3.2 Tests carried out

Three specimens were tested each test for the different formulations in the hardened state, these tests are:

-Consistency: Measured by spreading with a mini cone in accordance with standard NF EN 1015-3.

-Air content: Measured by a mortar hydrometer complying with the requirements of standard NF EN 1015-3.

-Density: The lower chamber of the hydrometer is used to measure the density of the fresh mixture in accordance with standard NF EN 1015-6. Thus, the Figure 5 demonstrates the different tests in the fresh state.

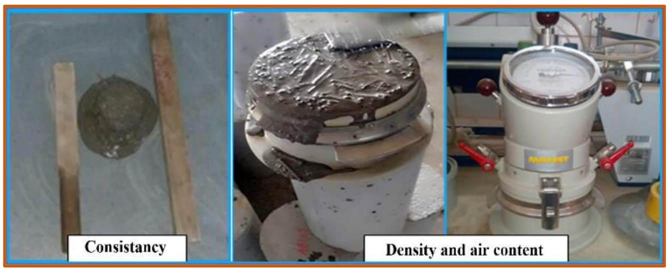

Figure 5. Tests on fresh mortar

Figure 6. Compression and flexural tensile strength test

The tests carried out on the different formulations in the hardened state are as follows:

-Three-point bending tensile strength measured on prismatic specimens measuring 4×4×16 cm^3 and compressive strength on specimens broken in bending tensile tests (Figure 6) are stored in water until the test days (7, 28 and 90 days) in accordance with the standards NF P18-406 and P18-407, respectively.

-On the other hand, water absorption by immersion (NF EN 12390-2) on the test pieces with dimensions (4×4×16 cm^3) kept for 28 days in water then brought to an oven at 105°C until a constant weight to measure their dry weight W1, then immerse them completely in water at 20°C for 24 hours to weigh their wet weight W2, the absorption coefficient (A) is given by Eq. (1):

$$A = \frac{\text{W2} - \text{W1}}{\text{W1}} \times 100 \quad (1)$$

- Capillary absorption (NF EN 480-5) measured on 4×4×16 cm^3 test specimens stored in water for 28 days then brought to the oven for 72 hours to have a constant weight, the side faces sealed before being subjected to unidirectional absorption of water from below for 257 minutes.

-Chemical resistance to acids and alkalis in accordance with ASTM C- 267-96, obtained on 5×5×5 cm^3 cubic test tubes, these test tubes were kept in water for 28 days to measure the initial weight. Besides, W0 immersed in solutions of 5% HCL, 5% H_2SO_4, 5% CH_3COOH and 5% NaCL, weight measurements Wi are measured at 3, 7, 14, 21, 28, 56 and 90 days. Likewise, chemical resistance is assessed by weight loss W in (%) with Eq. (2):

$$W = \frac{\text{Wi} - \text{W0}}{\text{W0}} \times 100 \quad (2)$$

-Penetration of chloride ions at age 28 days on 4×4×16 cm^3 specimens preserved in water for 28 days, then in a 5% NaCL solution, the specimens were cut into half-prisms and treated with silver nitrate (Figure 7). The edge of each section changes color to a white color which represents the penetration depth of the chlorides. The penetration depth is the average of all the readings.

Figure 7. Measuring chloride penetration depth

4. RESULTS AND DISCUSSION

4.1 Density

The introduction of waste hollow concrete blocks sand into the mortar mix (Figure 8) results in an increase in density of up to 15%. This is due for the most part to the existence of a greater proportion of hardened cement paste in recycled sand [13] than in quarry sand, which increases the water content in the pores due to higher absorption [14]. In a consequence, these results agree with those found by Fernández-Ledesma et al. [15]. Above this rate, the effect reverses to reach a minimum value of 2.084g/cm^3 for a rate of 50%. This can be explained by the fact that the intrinsic densities of the two sands used are so close and the spatial arrangement of the grains in the mixture at high substitution rates and to some extent unfavorable.

In general, the densities marked by the different formulations have shown to be acceptable compared with the lower limit of 1.8g/cm^3 given by the standards [16].

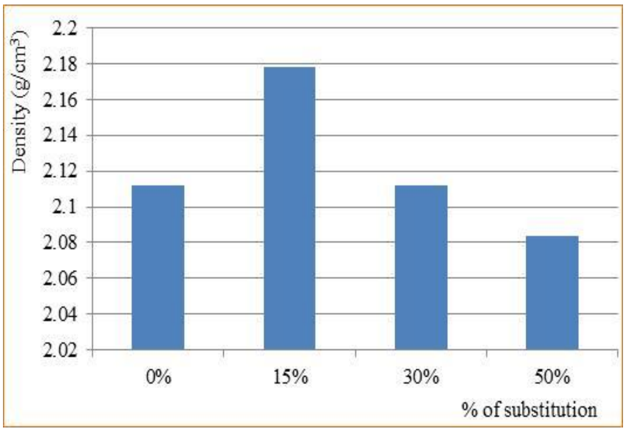

Figure 8. Variation in density as a function of substitution rate

4.2 Workability

The partial replacement of quarry sand by recycled sand (Figure 9) leads to an improvement in the consistency of the mortar compared with the reference mortar, with the maximum value recorded by the mortar being 15% of the substitution rate, which may be due to the arrangement of the grains in the mortar mix on the one hand, and to the presence of a large quantity of fines which favours the workability of the mortar, through facilitating the movement of the sand particles [12]. Improving workability makes it easier to place the material in the formwork and reduces the risk of segregation.

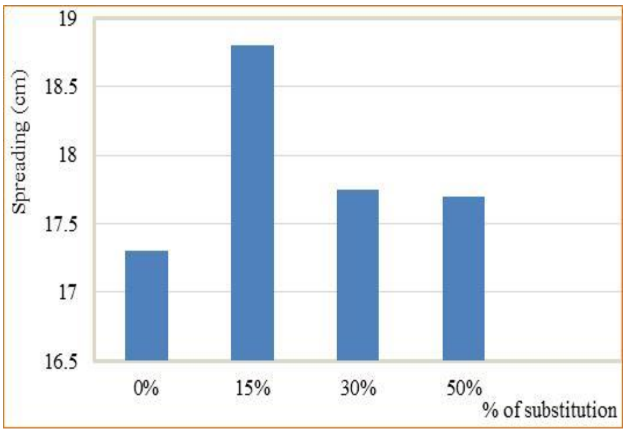

Figure 9. Variation in consistency as a function of substitution rate

4.3 Occluded air

The introduction of waste hollow concrete blocks sand for replacement purpose of ordinary sand (Figure 10) increases the air content in the prepared mortars compared with the control mortar. Thus, such increase reached a value of 6.4% in the mortar based on 50% recycled sand. Nonetheless, this result is expected because recycled sand is characterized by a heterogeneous structure that is more porous and that trap air bubbles [12]. However, during the vibration phase, the shape and roughness of the recycled sand prevents the air bubbles from degassing, which phenomenon can be accentuated in the event that there would be a large quantity of sand in the mortar.

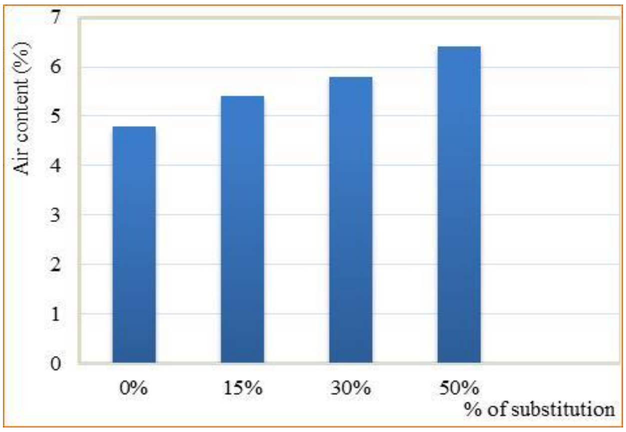

Figure 10. Variation in air content as a function of substitution rate

4.4 Compressive strength

At 7 days (Figure 11), the mortar based on 15% waste hollow concrete blocks sand shows the best compressive strength compared to the other formulations, the fact of which is due to the presence of a greater quantity of fine reactive particles in the recycled sand. Above and beyond, these fine particles act as fillers on the one hand and increase cohesion on the other [17].

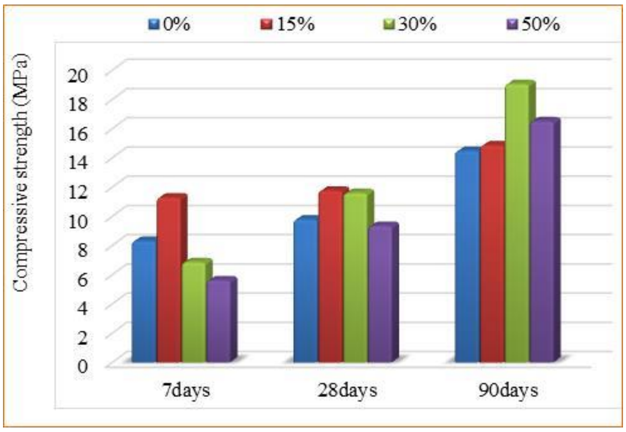

Figure 11. Influence of the substitution rate on compressive strength

Nevertheless, beyond 15%, the effect of the fineness of the recycled sand is more marked, which explains the lower strengths compared with the control. In addition, the recycled sand improves the compressive strength at 28 days of age of the control mortar for substitution rates of 15% and 30%. As consequence, these variations are assessed to 20.12% and 18.49%, respectively. Likewise, this improvement in strength is explained by the hydration of the anhydrous cement grains from the recycled sand [12], which have shown to be reactivated by the crushing process.

At 90 days, mortars containing recycled sand demonstrate the best compressive strengths compared with the reference mortar, and the maximum value is recorded in the mortar with a 30% substitution rate. In virtue of which, there are several reasons for these results:

-The high absorption of recycled sand due to the presence of a hardened cement paste adhered or not to the sand grain, which reduces the effective W/C ratio;

-The re-hydration of grains of anhydrous cement containing recycled sand [18];

-In addition, the new old mortar-cement paste interface is stronger [19] than the cement paste-quarry sand interface, the fact of which has a positive impact on compressive strength.

In light of the facts set out above, all the formulations demonstrate compressive strengths at 28 days of age that are acceptable for use as masonry materials in case we compare them with the minimum value of 5MPa given by the standard [16] and ASTM-C129 2017 [20] and can be used for the structural applications.

4.5 Flexural tensile strength

On the whole, the flexural tensile behaviour has shown to be the same as in compression, particularly at early age (7 days) and in the medium term (28days) (Figure 12). However, at 28 days conservation in water, the partial replacement of quarry sand by recycled sand gives a gain in flexural tensile strength to the order of 56%, 55% and 54% for mortars with 15%, 30% and 50% substitution rates.

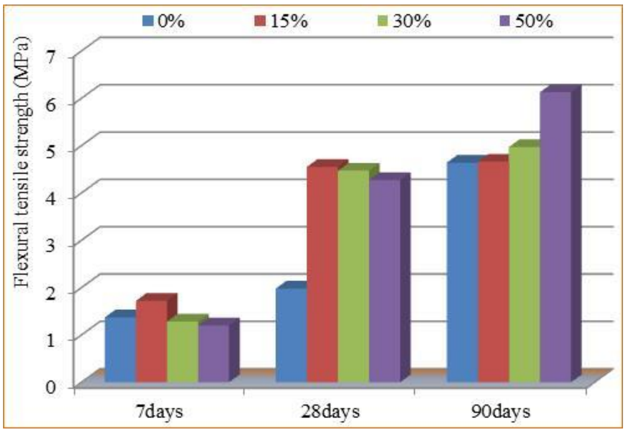

Figure 12. Influence of the substitution rate on flexural tensile strength

Above and beyond, these increases in strength can be explained on the one hand by the high fineness of the recycled sand and on the other hand by the reaction of the cement particles adhering to the recycled sand, which are activated during the crushing to obtain this kind of sand. In the long term, the same trends were not observed. The flexural strength of mortars made from the waste hollow concrete blocks sand increases with the increase of the substitution rate, whilst the mortar containing 50% recycled sand becomes of best performance, with a 32% increase in flexural strength. As a fact of matter, tensile strength increases when porosity decreases due to the re-hydration of the particles and grains of anhydrous cement present in the mixes. Likewise, it appears that the surface condition of the recycled sand plays an important role in the tensile strength and that the roughness of the recycled aggregate is very important, which improved the paste-sand adhesion [21].

4.6 Water absorption by immersion

In accordance with Figure 13, it can be noticed that the introduction of increasing rates of waste hollow concrete blocks sand in partial substitution of crushed quarry sand results in a decrease in water absorption values compared to the value illustrated by the control mortar. Besides, the 30% (RS) mix has the lowest absorption, which differs from that of the control by 31.11%. On the other hand, the 50% (RS) mix shows an absorption equivalent to the one of the reference compositions. In this respect, this indicates that although the fact that the absorption coefficient of waste hollow concrete blocks sand is 66% higher than that of quarry sand due to the presence of the porous residual mortar attached to the core of the initial aggregate, the quantity of fine particles contained in the recycled sand, which is greater than that existing in the quarry sand, has contributed to filling the available voids in a favourable manner and consequently reducing the porosity of the mortars [22], which results in mixes with better compactness. The absorption value equivalent to the one of the control recorded by the mortar based on 50% hollow concrete blocks sand indicates the presence of a high residual mortar content compared with the mixes containing 15 and 30% recycled sand, which has relatively increased the porosity of the mortar and absorption is therefore greater because the physical effect of the fines is not predominant. In fact, the water absorption by immersion is related to the porosity of the mortar [18].

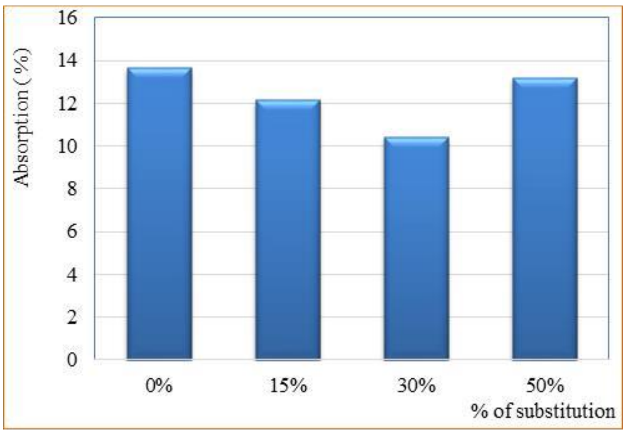

Figure 13. Change in absorption as a function of substitution rate

4.7 Water absorption by capillary

In general, the curves in Figure 14 demonstrate similar absorption trends for all the mortars containing the waste hollow concrete blocks sand. Furthermore, the capillary water absorption of the control mortar demonstrated higher results than the mortars based on recycled sand. In fact, replacing quarry sand with recycled sand reduces capillary water absorption by around 10% in mortars with 15 and 30% (RS), and by 11% in mortar containing 50% (RS). The presence of old mortar whose water porosity is higher than that of quarry sand results in a greater quantity of water being absorbed by the recycled sand. This in turn reduces the W/C ratio [23] and consequently the quantity of water penetrating the capillary pores. Similarly, this may alike be due to inadequate stacking of the aggregates, which has led to the interconnectivity of the pores [24].

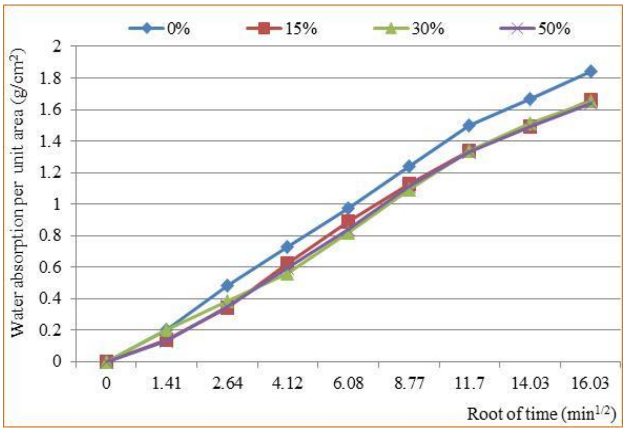

Figure 14. Variation in water absorption by capillarity as a function of substitution rate

4.8 Resistance to chemical attack

4.8.1 Attack by sulfuric acid (H_2SO_4)

From Figure 15, it can be observed that the weight loss is presented in all mortars immersed in sulfuric acid (H_2SO_4). The control mortar presents the highest loss in all ages because of the highest amount of calcium oxide (CaO), the fact of which increases the capacity of mortars to react with aggressions [25].

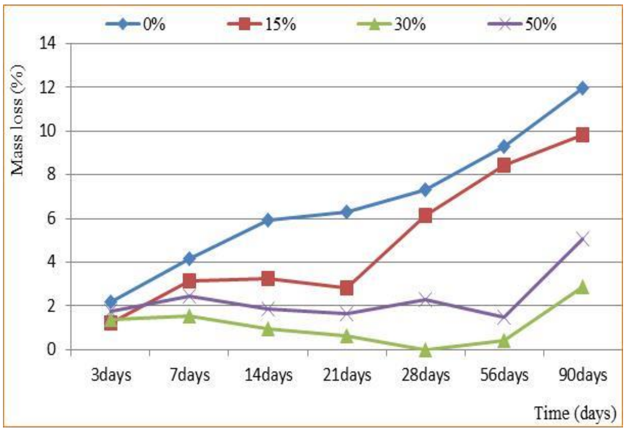

Figure 15. Loss of mass as a function of immersion period in 5% H_2SO_4

The weight loss results of specimens 0% and 15% increase as a function of time. On the other hand, the weight loss of specimens 30% and 50% decrease as a function of the time until 56 days, the fact of which has shown to be due to the amount of hollow concrete blocks waste being important in 30% and 50%, which contains a high silica content (S_iO_2), as it forms an additional C-S-H, by the effect of the pozzolanic reaction [12], according to the formula (Eq. (3)):

$$SiO_2 + Ca(OH)_2 + H_2O \rightarrow C - S - H \quad (3)$$

In H_2SO_4 medium, there was secondary precipitation of gypsum and ettringite, which was alike dependent on the composition of the binder, the chemical reactions are described (Eq. (4) and Eq. (5)):

$$H_2SO_4 + CaO(H)_2 \rightarrow CaSO_4 \cdot 2H_2O \text{ (gypsum)} \quad (4)$$

$$3CaSO_4 + 3CaO\ Al_2O_3 \cdot 6H_2O + 26H_2O \cdot 3CaO\ Al_2O_3 \cdot 3CaSO_2 \cdot 2H_2O \text{ (ettringite)} \quad (5)$$

4.8.2 Attack by hydrochloric acid (HCL)

In the light of the results of weight loss test (Figure 16), it can be noticed that the weight loss is illustrated in all mortars immersed in hydrochloric acid. Besides, the control mortar (0%) has an important loss in all ages compared to other specimens. The weight loss of the specimens (15%) and (30%) are identical, whereat mortar (50%) presents the best chemical resistance to hydrochloric acid. Calcium chloride ($CaCl_2$) causes dissolution of cement through the reaction between $Ca(OH)_2$ (Portlandite) and HCL medium, the reaction was expressed in Eq.(6).

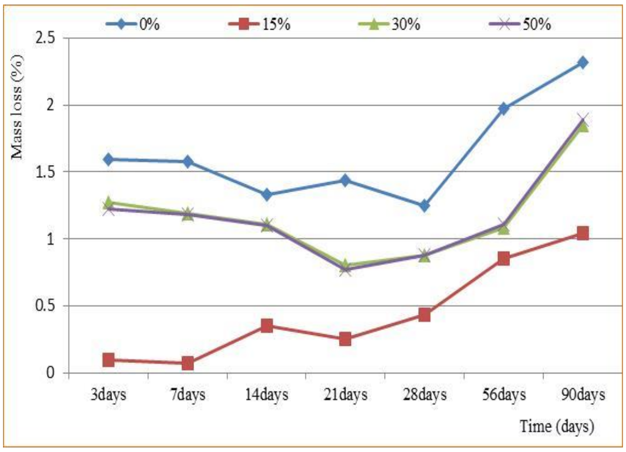

Figure 16. Loss of mass as a function of immersion period in 5% HCL

$$Ca(OH)_2 + 2HCl \rightarrow CaCl_2 + 2\ H_2O \quad (6)$$

By comparison between the results, it can be noticed that the weight loss in H_2SO_4 is very important to that in HCL.

4.8.3 Attack by acetic acid (CH_3COOH)

The partial replacement of quarry sand by recycled sand from hollow concrete blocks waste (Figure 17) leads to an improvement in the chemical resistance of mortars in the CH_3COOH medium; this resistance decreasing as a function of the immersion time of the samples to reach maximum losses at age 90 days. Besides, the reference mortar demonstrates the maximum loss, which can be explained by the dissolution of the hydrates formed, leading to more porous mortars [12]. Further, the positive effect of existing fines in the recycled sand is particularly visible in the mortar based on 15% hollow concrete blocks waste sand, which displays the maximum strength compared to the other mortars, these results agree with those found by Benamar et al. [26]. The good chemical resistance against chemical attack by acetic acid allows this material to be used in exterior facades exposed to bad weather.

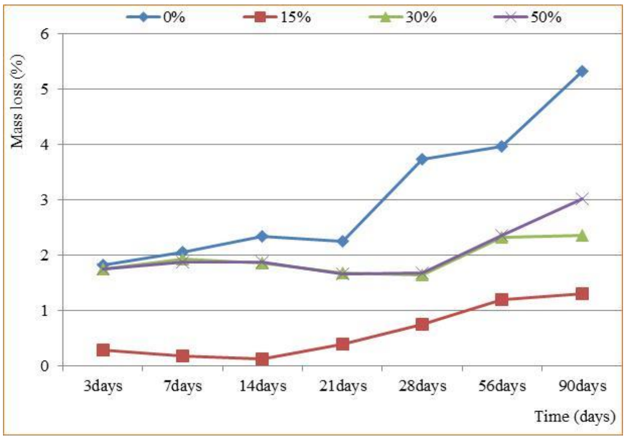

Figure 17. Loss of mass as a function of immersion period in 5% CH_3COOH

4.8.4 Attack by sodium chloride (NaCl)

All the mortars show gains in mass (Figure 18) with little variation as a function of age and the mortar with 15% substitution rate demonstrates the highest resistance to the saline environment. Besides, this resistance is due to the consumption of the fines existing in the sand recycled with $Ca(OH)_2$ to generate more C-S-H gels and C-A-S-H gels and improves resistance [27].

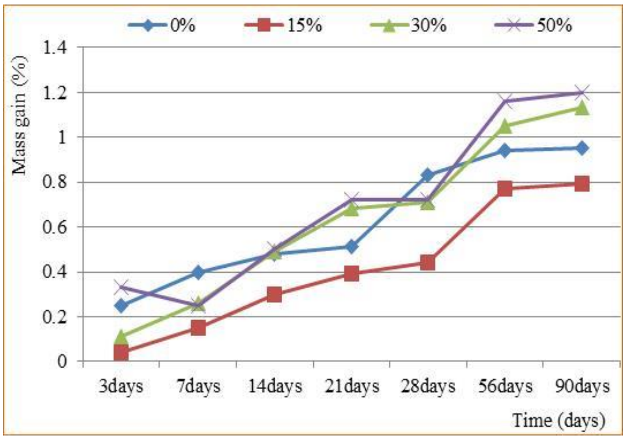

Figure 18. Gain of mass as a function of immersion period in 5% NaCl

4.9 Chloride penetration

It is clear from Figure 19 that the depth of penetration increases when quarry sand is substituted by recycled sand. However, there does not appear to be a significant difference in chlorine ion penetration for replacement rates of 15, 30 and 50%. Further, this increase in chlorine ion penetration is linked to the greater porosity of the cementitious matrix [28] containing recycled sand, the majority of which is composed of hardened old mortar. In addition, the new interfacial transition zone between the old hardened mortar and the new cementitious paste provides an easier path for chemical attack [29].

In matter of fact, whatever the percentage of replacement, resistance to chloride ion penetration tends to become similar and mortars based on recycled sand have revealed their low resistance to chloride ion diffusion.

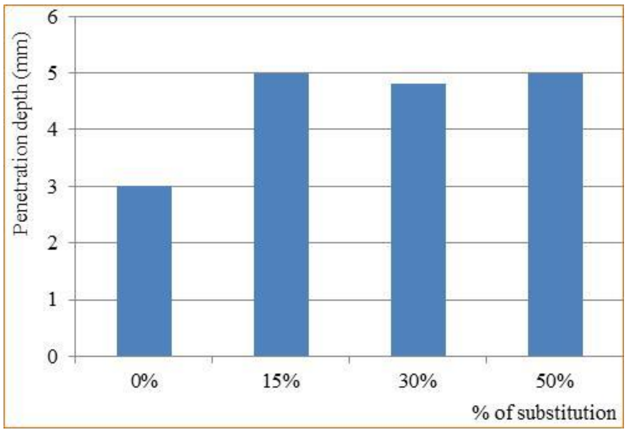

Figure 19. Variation in chloride penetration depth as a function of substitution rate

5. CONCLUSIONS

Taking into account the results obtained and their analyses, it was noted that the use of Dis fibers in the development of an eco-mortar; confirms the added value of this natural resource and the quality of inherited biodegradable material. A respect for nature through its non-polluting and non-waste characteristics on the one hand, the reuse of construction demolition waste and in particular concrete block scraps as sand in the formulation of an eco-mortar reinforced by this type of fiber makes it possible to produce an openable, resistant and environmentally friendly eco-material, the main conclusions drawn from this study are:

-The partial replacement of ordinary sand by recycled sand from waste hollow concrete blocks in the formulation of mortars reinforced with Diss fibers gives densities acceptable by the standards, an improvement in workability whatever the rate of replacement which is advantageous for the implementation; on the other hand, it generates an increase in the content of occluded air;

-The compressive strengths of the various mortars at 28 days are higher than the values recommended by the standard;

-The compressive strength increases with age, reaching a maximum value of 19.06MPa for mortar with a 30% substitution rate. The hydration of the cement fines in the old mortar plays a very important role in increasing strength with recycled sand, this material can be used as a filler material and for structural applications;

-The reaction of the cement particles adhered to the recycled sand, which are activated during the crushing process to obtain this sand, promotes an increase in flexural tensile strength over the medium and long term;

-The mortar made with 30% recycled sand gives the lowest absorption by immersion;

-The partial replacement of ordinary sand with recycled sand reduces water absorption by capillary action and makes the mortar more durable;

-The introduction of recycled sand as a substitute for ordinary sand in the formulation of mortar reinforced with Diss fiber increases the chemical resistance of this mortar to acid solutions, which allows this material to be used in aggressive environments;

-The mortar with 50% substitution rate gives the best resistance against alkaline solution;

-The mortars based on recycled sand demonstrate greater penetration depths for chloride ions compared with the reference mortar.

In the light of the facts set out in this study, we can conclude that the recycling waste hollow concrete blocks as sand to partially replace quarry sand in the composition of a Diss fiber-reinforced mortar, intended for filling materials and masonry blocks, and has shown to be beneficial and encourages research in this field through the development of in-depth studies such as:

- The study of dimensional variation,

-The study of long-term durability (more than 90 days),

-Go deeper into the behavior of this material from a sustainability point of view for the following parameters:

-Study of thermal characteristics,

-Study of durability with regard to corrosion,

-Study of resistance to freeze/thaw,

-Study of long-term durability (more than 90 days),

-Study of the characteristics of the microstructure,

-Extend the research theme to other types of fibers.

ACKNOWLEDGMENT

The authors would thank the staff of LMGHU and LHC laboratory, LTP-East laboratory and GICA company (Hdjar-soud) for their supervision and provision of equipment.

REFERENCES

[1] Berthon, E. Tout sur le béton- construire avec de la brique ou du parpaing? https://www.toutsurlebeton.fr Constr. Béton Direct 2017-2022.

[2] Bourgeois, M. Fibres agrosourcées. In Techniques de l'ingénieur. Techniques de l'ingénieur. https://www.techniques-ingenieur.fr. Accessed on 10 April, 2011.

[3] Merzoud, M. (2007). Elaboration et caractérisation d'un matériau composite à base de fibres de diss dans la fabrication de la maçonnerie. [Doctoral dissertation] Thèse de doctorat d'Etat, Université Badji Mokhtar.

[4] Fertikh, S., Merzoud, M., Habita, M.F., Benazzouk, A. (2011). Comportement mécanique et hydrique des composites à matrice cimentaire et argileuse à base de diss «Ampelodesma mauritanica». XXIXe Rencontres Universitaires de Génie Civil. Tlemcen, 188-196.

[5] Merzoud, M., Habita, M.F. (2008). Elaboration de composite cimentaire à base de diss «Ampelodesma Mauritanica». Afrique science: Revue Internationale des Sciences et Technologie, 4(2): 231-245. http://doi.org/10.4314/afsci.v4i2.61682

[6] Achour, A. (2017). Etude des performances des mortiers renforcés de fibres naturelles: Valorisation des plantes locales [Doctoral dissertation] Thèse de Doctorat, Université Aboubakr Belkaïd-Tlemcen, Algérie, p. 101.

[7] Abdelouahed, A., Kechkar, C., Hebhoub, H., Merzoud, M., Boukhatem, G. (2023). Enhancing the performance and durability of eco-friendly mortar with Diss fibers (Ampelodesmos mauritanicus). Revue des Composites et des Matériaux Avancés-Journal of Composite and Advanced Materials, 33(4): 219-226. https://doi.org/10.18280/rcma.330402

[8] Bourmatte, N., Houari, H. (2013). Caractérisation expérimentale des bétons et mortiers à base de granulats recycles: Béton de démolition et déchets de briques. Sciences & Technologie, B(38): 25-31.

[9] Bourmatte, N. (2017). Granulats recycles de substitution pour bétons hydrauliques. [Ph.D.] Génie civil, Université des Frères Mentouri Constantine, Constantine, Algérie. http://archives.umc.edu.dz/bitstream/handle/123456789/6173/BOU7014.pdf?sequence=1

[10] Rihia, C., Hebhoub, H., Kherraf, L., Djebien, R., Abdelouahed, A. (2019). Valorization of waste in sand concrete based on plant fibres. Civil and Environmental Engineering Reports, 29(4): 41-61. http://doi.org/10.2478/ceer-2019-0043

[11] Hebhoub, H. Kherraf, L., Mouats, W., Abdelouehed, A., Boughamsa, W. (2020). Effects of the 15% substitution rate of sand of ceramic waste on the properties of a hydraulic concrete. Algérie Equipement, 62: 18-23. http://enstp.edu.dz/revue/files/article_hebhoub__publier_confirm.pdf

[12] Kherraf, L., Hebhoub, H., Abdelouahed, A., Boughamssa, W. (2022). Comparative study on the performance of sand-based mortars from marble, floor tile and cinder block waste. Journal of Building Engineering, 45: 103433. https://doi.org/10.1016/j.jobe.2021.103433

[13] Bonifazi, G., Palmieri, R., Serranti, S. (2018). Evaluation of attached mortar on recycled concrete aggregates by hyperspectral imaging. Construction and Building Materials, 169: 835-842. http://doi.org/10.1016/j.conbuildmat.2018.03.048

[14] Evangelista, L., Guedes, M., De Brito, J., Ferro, A.C., Pereira, M.F. (2015). Physical, chemical and mineralogical properties of fine recycled aggregates made from concrete waste. Construction and Building Materials, 86: 178-188. https://doi.org/10.1016/j.conbuildmat.2015.03.112

[15] Fernández-Ledesma, E., Jiménez, J.R., Ayuso, J., Corinaldesi, V., Iglesias-Godino, F.J. (2016). A proposal for the maximum use of recycled concrete sand in masonry mortar design. Materiales de Construcción, 66(321): 1-15. http://doi.org/10.3989/mc.2016.08414

[16] Q Green Techcon Pvt.Ltd. Things you need to know before using concrete block as a building material, https://qgreentech.com

[17] Hebhoub, H., Belachia, M., Djebien, R. (2014). Introduction of sand marble wastes in the composition of mortar. Structural Engineering and Mechanics, 49(4): 491-498. https://doi.org/10.12989/sem.2014.49.4.491

[18] Torres-Gómez, A.I., Fernández-Ledesma, E., Otero, R., Fernández, J.M., Jiménez, J.R., de Brito, J. (2016). Combined effects of non-conforming fly ash and recycled masonry aggregates on mortar properties. Materials, 9(9): 729. https://doi.org/10.3390/ma9090729

[19] Mefteh, H., Kebaìli, O., Oucief, H., Berredjem, L., Arabi, N. (2013). Influence of moisture conditioning of recycled aggregates on the properties of fresh and hardened concrete. Journal of Cleaner Production, 54: 282-288. https://doi.org/10.1016/j.jclepro.2013.05.009

[20] ASTM C129-17. Standard specification for nonloadbearing concrete masonry units. West Conshohocken, PA, ASTM International. accessed on, 2017. https://webstore.ansi.org/standards/astm/astmc12917

[21] Silva, R.V., de Brito, J., Dhir, R.K. (2014). Properties

and composition of recycled aggregates from construction and demolition waste suitable for concrete production. Construction and Building Materials, 65: 201-217. https://doi.org/10.1016/j.conbuildmat.2014.04.117
[22] Elat, E., Pliya, P., Pierre, A., Mbessa, M., Noumowé, A. (2020). Microstructure and mechanical behavior of concrete based on crushed sand combined with alluvial sand. CivilEng, 1(3): 181-197. https://doi.org/10.3390/civileng1030011
[23] Berredjem, L., Arabi, N., Molez, L. (2020). Mechanical and durability properties of concrete based on recycled coarse and fine aggregates produced from demolished concrete. Construction and Building Materials, 246: 118424. https://doi.org/10.1016/j.conbuildmat.2020.118421
[24] Chawla, A., Syed Ahmed Kabeer, K.I., Vyas, A.K. (2018). Evaluation of strength and durability of lean concrete mixes containing marble waste as fine aggregate. European Journal of Environmental and Civil Engineering, 24(9): 1398-1413. https://doi.org/10.1080/19648189.2018.1471009
[25] Abdelouahed, A., Belachia, M., Sebbagh, T. (2016). Effect of SCMs on mechanical, chemical and microstructural properties of SRC in acidic medium. European Journal of Environmental and Civil Engineering, 22(2): 212-225. https://doi.org/10.1080/19648189.2016.1185971
[26] Benamar, S., Kameche, Z.L.A., Houmadi, Y. Mamoune Sidi Mohammed, A. (2022). Etude de comportement physique et mécanique des mortiers à base de déchet de brique. Communication Science et Technologie, 20(2): 9-22. https://www.asjp.cerist.dz
[27] Liu, X., Liu, R., Xie, X., Zuo, J., Lyu, K., Shah, S. P. (2023). Chloride corrosion resistance of cement mortar with recycled concrete powder modified by nano-silica, Construction and Building Materials, 364: 129907. https://doi.org/10.1016/j.conbuildmat.2022.129907
[28] Silva, R.V., de Brito, J., Neves, R., Dhir, R. (2015). Prediction of chloride ion penetration of recycled aggregate concrete. Materials Research, 18(2): 427-440. https://doi.org/10.1590/1516-1439.000214
[29] Chiker, T. (2017). Durabilité des varietés de bétons-Carbonatation- Perméabilité- Milieu Agressif. [Ph.D.] Génie civil, Université Mentouri Constantine, Constantine, Algérie. http://archives.umc.edu.dz/bitstream/handle/123456789/6172/CHI7031.pdf?sequence=1&isAllowed=y.