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

Annales de Chimie - Science des Matériaux
Vol. 47, No. 3, June, 2023, pp. 179-185
Journal homepage: http://iieta.org/journals/acsm

Characterization of Lightweight Mortars with Cork and Olive Stone Waste for Old Building Rehabilitation

Check for updates

Samia Boubakour[1*], Leila Kherraf[1], Houria Hebhoub[1], Karima Messaoudi[1], Ghania Boukhatem[2]

[1] LMGHU Laboratory, University 20 August 1955 Skikda, Skikda 21000, Algeria
[2] Civil engineering department, Badji Mokhtar Annaba University, Annaba 23000, Algeria

Corresponding Author Email: boubakour.samia@outlook.fr

https://doi.org/10.18280/acsm.470307

Received: 16 March 2023
Accepted: 25 May 2023

Keywords:
building rehabilitation, cork waste, lightweight aggregates, mortar properties, olive stone waste, sustainable materials

ABSTRACT

This paper investigates the potential of using cork and olive stone waste as lightweight aggregates in repointing mortars for the rehabilitation of old buildings. For this purpose, mortar blends were prepared like 1/3 mortar partly replacing ordinary sand with different percentages of cork or olive stones aggregates with a grain size of 0-4 mm. The partial substitution rates are: 5, 10, 15, 20, 25 and 30% respectively with a constant amount of binder (Portland cement CEM I 42.5R). All Specimens prepared were remolded after 24h then cured in potable water at 20±2°C until the date of the test. In course of this research, the mechanical and physical features were highlighted while taking into account certain parameters such as consistency, fresh density, mechanical performance (compressive strength, tensile strength), durability (absorption in immersion, capillary water absorption coefficient and chloride penetration). The results demonstrated that incorporating 30% olive stone waste as a sand replacement in the mortar resulted in improved durability and long-term performance compared to control blends. Additionally, all mortars containing lightweight aggregates were lighter than the control mortar.

1. INTRODUCTION

Biodegradable organic waste, of agricultural or forestry origin has always been a quality organic amendment for the soil. However, a large amount of waste is generated during the processing from the cork industries and rejected, mainly as cork dust. Also, residues from olive oil mills, mostly in the form of olive stones, pose an environmental problem due to their difficult disposal.

The bibliography shows that many researches affirm the possibility of reusing cork and olive stones residues as lightweight aggregates in the field of civil engineering, thus solving the problem of its disposal and producing a good construction material.

Obtaining a lightweight material was the main goal that stimulated the use of cork or olive stones in the preparation of the mortar to minimize the loads acting on the brick of the old building, and to improve the characteristics of mortars, two Materials wastes were chosen: cork and olive stones. Cork is a natural and ecological product [1] is a biological material with unique properties [2].

The chemical composition has made cork a material characterized by high compressibility, flexibility under compression, low permeability and chemical and biological inertness [2-4].

The main structural component of cork cell walls is suberin which accounts for approximately 40% of its composition. Hydrophobic lipids are at the origin of most of the principal properties of cork. Cork also contains lignin (>20%) and polysaccharides (20%), plus extracts (15%) [5]. The cork is also very resistant and durable [6].

Currently, Cork oak forests in Algeria account for more than 19% of its global area [7, 8].

Also, Olive stones consisting mainly of wooden planks represent the bulk of environmentally toxic solid waste from olive oil factories which without prior treatment create a major environmental problem [9, 10].

Recycling this waste into sustainable building materials provides a radical solution to pollution problems and is cost-effective for the design of environmentally friendly buildings [11].

Numerous papers, published in scientific journals showed the introduction of the cork in the construction materials also the development of mortars and concretes was the subject of several studies, replacing sand with cork reduce mortar density, compressive strength and thermal conductivity [6, 12, 13].

The low thermal conductivity of cork is due to its cellular structure which is characterized by low density and high gas content. The low density of cork and the interaction of its extracts during the moisturization of the cement influence the mechanical properties of the cement-cork mixtures [14].

The literature shows that the hydration of cement is less affected by the incorporation of cork particles larger than 2 to 3 mm, which is not the case for the compressive strength of cement-cork mixtures which tend to the decline. Karade et al. [15] Research has been conducted to create a lightweight mortar for coating structural concrete slabs by the use of granular expanding cork waste with cement-based mixtures [16].

Experimental results on mechanical and thermal properties have shown in the literature that substitution of sand by expanded cork particles in the screed reduces density, hardness, compressive strength and thermal conductivity. Due to their low compressive strength, screeds with very low cement contents are unsuitable for use as a final floor covering.

Experimental studies have shown the influence on the plastic, mechanical, transport, microstructure and thermal properties of cork mortars and concretes used as an alternative to olive stones [14].

Different varieties of the mix depend on the cork ratio and the size of the cork.

Experimental results show that with finer cork particles, it is more advantageous to obtain optimum mechanical properties and high permeability, which is on the contrary, can reduce durability.

On the other hand, many researches highlight the application of olive stones in construction for the improvement brought to the durability, the resistance to stripping, water, freezing and as an additive for resins [17, 18].

The study conducted by Arezki et al. [11] examines the influence of the addition of crushed olive stones on the significant increase in porosity and decrease of the water absorption coefficient in fired clay bricks [11].

In order to improve insulation, reduce density and increase water absorption of cement-lime mortar, Barreca and Fichera used olive stones as an addition [19].

An experimental design was developed by del Río Merino et al. [20], to evaluate the viability of substitution, the experimental test results show that substitution of expanded clay by waste of olive stones made possible to obtain mortars with lower density up to 30% and an improved compressive strength up to 20%.

This paper focuses on the same research point by highlighting the use of cork and olive stones as lightweight aggregate to develop mortars used in the rehabilitation of old buildings, the experimental testes program has investigated the beneficial effects on mechanical and physical properties of mortars containing cork and olive stone aggregates.

This examination evaluates the physical and mechanical properties of mortars mixed with different percentages of Cork or olive stone as sand replacement, the evolution of workability, density, compressive and Flexural tensile strength, Capillarity and immersion absorption, Chloride penetration were measured and compared in this study.

2. USED MATERIALS

2.1 Cement

Type CEM II (S-L) 42.5 Portland cement was used, produced at an industrial plant in Hadjar-Soud (Skikda, East of Algeria). With specific gravity 3.10g/cm^3 and Blaine specific surface of 3350cm^2/g.

2.2 Quarry sand

Table 1. Physical aggregates properties

Physical Properties	Quarries Sand	Cork	Olive Stones
Density (g/cm^3)	2.67	0.44	1.39
Apparent density (g/cm^3)	2.37	0.116	1.123
Sand equivalent	70	/	/
Value of blue methylene (%)	0.75	/	/
Absorption (%)	4.65	60	16.81

Quarry sand of class 0/4 was used. Physical properties of used aggregates are shown in Table 1.

2.3 Cork

Was taken from Qercus suber trees growing in the Algerian regions of Oum-toub/Skikda in July and August 2019 during the period of cork stripping. The cork was air dried than crushed by a crushing machine. The crushed cork aggregates were sieved and used.

2.4 Olive stones

Olive stones used in this research were collected in the area of Oum-toub/Skikda east of Algeria. Then washed in order to remove the remaining organic matter which could interfere in the results. They were air dried than in an oven than crushed with a crushing machine. The crushed olive stone aggregates were sieved and used.

Granulometric curves of the different aggregates are presented in Figure 1 and photos of the three types of used aggregates are presented in Figure 2.

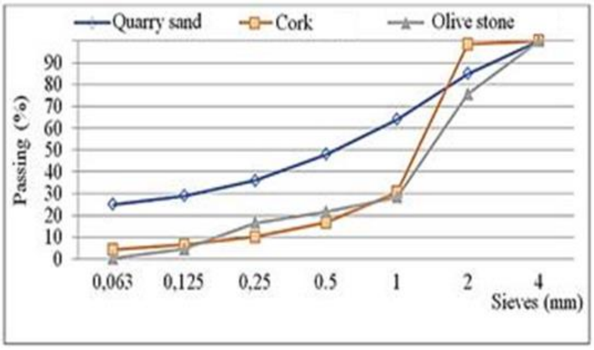


Figure 1. Granulometric curves of used aggregates

(a) Quarry sand (b) Cork (c) Olive stones

Figure 2. Three types of used aggregates

2.5 Water

Potable water was used in all blends.

From the properties we can draw the following observations:

Ordinary sand density is higher than those of cork and olive stones sand. And the cork registers the lower density.

Cork presents a high absorption coefficient with a big difference in comparison to olive stones and quarry sand.

3. EXPERIMENTAL PROGRAM

Elaborate an ecological mortar to investigate properties of the fresh and hardened mortars, we have introduced cork or olive stones waste as an ordinary sand replacement. All mortar mixtures were prepared as 1/3 mortars (i.e., 1 part cement to 3 parts sand by volume). Than compared to the control specimen 0% of substitution (Table 2).

For each mix design, variable percentages of cork and/or olive stones are introduced as an ordinary sand replacement (5%, 10%, 15%, 20%, 25% and 30%). And only cement and water dosage are fixed for all mortar mixtures. Water quantity is fixed by consistency tests, and that makes a total of seven different blends, including a control mortar.

All mortar mixing was conducted in accordance with EN 196-1.

Three prismatic (4×4×16) cm^3 specimens per mix were prepared to measure flexural and compression strength at 7, 28 and 90 days respectively, capillary at 28 days and chloride penetration at 28, 56 and 90 days. Three (5×5×5) cm^3 cubes per mix were prepared for the measurements of immersion absorption.

Table 2. Mortar mix design

Mix %	Cement	Quarry Sand	Cork	Olive Stone	Water
M0	1v	3v	0	0	1v25
M5	1v	2.85v	0.15v	0.15v	1v25
M10	1v	2.7v	0.30v	0.30v	1v25
M15	1v	2.55v	0.45v	0.45v	1v25
M20	1v	2.4v	0.60v	0.60v	1v25
M25	1v	2.25v	0.75v	0.75v	1v25
M30	1v	2.1v	0.9v	0.9v	1v25

4. TESTING PROCEDURES

Consistency, measured by the mini slump test according to the standard NF EN 1015-3, for evaluating the workability of the fresh mortar mixtures for different substitution rates.

The fresh density of the mortar was measured using an adaptation of the procedure in NF EN 1015-6.

The bending and compressive strength tests were carried out on three prismatic specimens of 4×4×16 cm^3 in accordance with the EN196-1 standard for the periods (7, 28 and 90 days).

Absorption by capillary testing was undertaken on prismatic specimens 4×4×16 cm^3 generally following standard procedure NF EN 480-5, This characteristic reflects the amount of water that can be absorbed by the specimen when only one side of the element is in contact with water. It is expressed by the capillary coefficient C g/(m².s½).

The specimens are dried at 70°C to determine the dry mass. then brought into contact with 3mm of water by one of their faces. The side faces are waterproofed with a plastic film (an adhesive plastic tape) which forces the water to adopt a uniaxial path and avoid evaporation through these same faces. The mass of water absorbed is determined by successive weighing of the samples. The evolution of the mass follows a regular interval which is plotted on a graph as a function of time.

Absorption by immersion measured by Neville, 2000.

The resistance to chloride permeability was evaluated at 28, 56 and 90 days. According to UNI 7928 and JIS A 1171. On samples of 4×4×16 cm^3 kept in water at 20°C for 28 days before being placed in a 5% NaCl solution. The samples were cut into 4×4×8 cm^3 pieces for each test duration, and one of the newly split sections was sprayed with a silver nitrate solution.

5. RESULTS AND DISCUSSIONS

5.1 Consistency

The results of the mortar slump test are given in Figure 3. The addition of cork in the mortar has significantly decreased the slump measurements resulting is a less workable mixture compared to the control mortar.

The great cork's water absorption led all samples to display a dry consistency, which could hinder the mortar workability these results are consistent with those obtained by Panesar and Shindman [14].

A similar result is observed with the olive stones addition, earlier studies by Farag et al. [21] Observed that mortars that were made, replacing all the sand by olive stones, had a very dry consistency.

It should be noted that the mortars containing olive stones present a dry consistency in comparison to mortars made with cork.

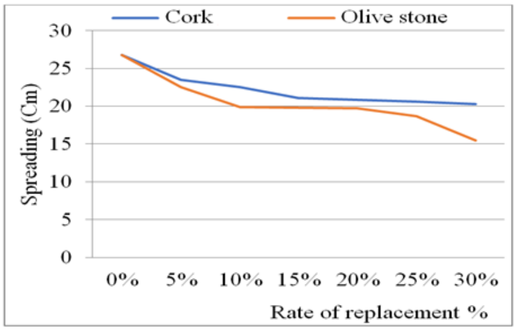


Figure 3. Correlation between consistency and substitution rate

5.2 Density

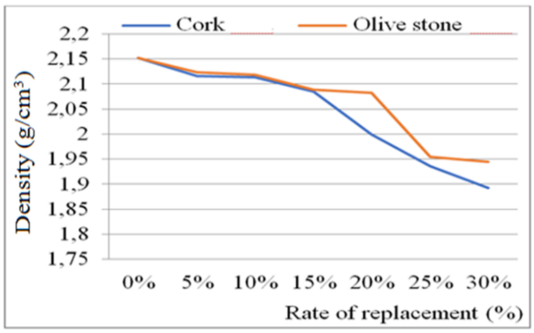


Figure 4. Correlation between fresh density and substitution

Depending on the content of cork, mortars are characterized by diversified fresh density and decreased with increasing percentage of cork (Figure 4).

Increasing the amount of cork usually results in a reduction in density and generally mechanical properties, for decreasing of density it can be referred to the low density of cork aggregate and amounted to 0.440g/cm^3. The high rate of gas inside the small cells of consistency makes cork a material of relatively low density [6].

For the mortars with the olive stones, all specimens achieved densities below the reference because of the important porosity of the olive stones. And the weaker bond between the olive stones and the cement matrix, these results are consistent with those obtained by del Río Merino et al. [20].

It can be observed that the mortars containing cork as an ordinary sand replacement present a fresh density less than the mortars which were made by replacing ordinary sand with the olive stones.

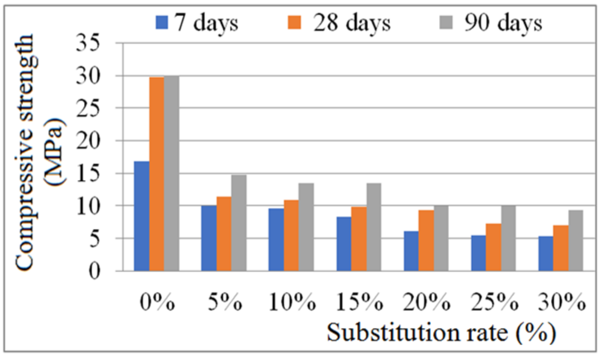
5.3 Compressive strength

After 7, 28 and 90 of water curing, the 4×4×16 cm^3 mortars samples were subjected to Compressive strength test.

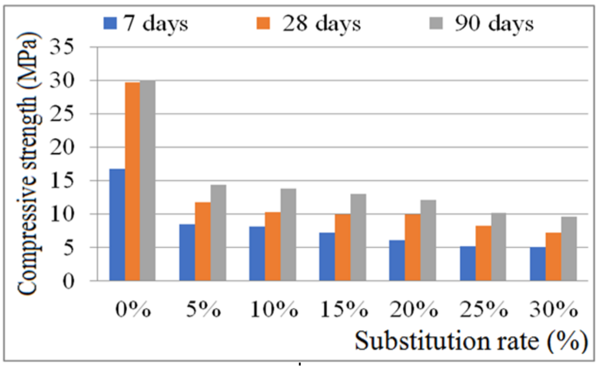
The results in Figure 5 show a steady increase in mortar compression resistance over 90 days. At 7 days, the substitution rate decreased the compressive strength of mortar containing cork relative to the check mortar.

The compressive strength decreases as density decreases.

A very rapid fall is observed when passing from the control mortar to the lightened mortars. This is due to the increase in voids and hence the porosity of the material increases [22].



(a) Cork



(b) Olive stone

Figure 5. Effect of substitution rate on the compressive strength

The introduction of 5% to 30% of Cork leads to a decrease in compressive strengths of the order of 40.77%, 42.91%, 50.54%, 63.75%, 67.82% and 68.35 % respectively.

During 28 days, the trends observed in 7 days are reproduced, we observe the reduction in resistance.

For 90 days, a decrease in compressive strength becomes more remarkable. There are compressive strengths losses of the order of 50.94%, 54.95%, 55.27%, 66.51%, 66. 89% and 68.85% in all mixes of 5% to 30% of cork successively.

The mechanical properties of cement-cork mixes are not only characterized by the low density of the cork, but also by the behavior of the cork extracts during the cement hydration process [15]. The studies of Panesar and Shindman [14] demonstrated that the larger amount of cork significantly reduces the hydration rate.

The compressive strength results obtained during the research conducted were consistent with those of Brás et al. [23].

The compressive strength of specimens with olive stones at the early curing age 7 days is low compared to that of the control mortar.

The introduction of 5% to 30% olive stones sand leads to a drop in compressive strengths of the order of 49.33%, 51.37%, 56.98%, 63.83%, 69.19% and 70.01% respectively to that of control mortar.

For 28 days, the trends observed in 7 days are reproduced; we observe the decrease in resistance compared to control mortar.

For an extended period of 90 days, decrease in resistance becomes more remarkable. There are resistance losses of around 52.05%, 53.73%, 56.61%, 59.63%, 65.84% and 67.86% in mortars containing olive stones from 5% to 30% successively.

Increasing the amount of olive stones, generally leads to a reduction in mechanical strength [11]. Because the increase in the amount of organic residues causes a reduction in density and an increase in porosity. Nothing that the control mortar has a compressive strength more than mixtures with both mortars with cork and olive stones.

5.4 Flexural tensile strength

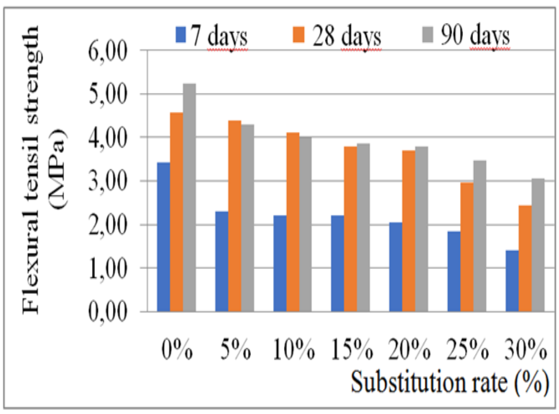
In general, the development of bending tensile strength in Figure 6 shows similar trends to the compressive strength. There is an evolution of flexural tensile strength which increases regularly for 90 days.

However, due to the absorption of water by the cork, the poor adhesion: cement paste-cork aggregate and the presence of pores in the structure of the cork, the tensile strengths of the mortars with the addition of cork aggregates became weak relative to the control mortar throughout the tests.

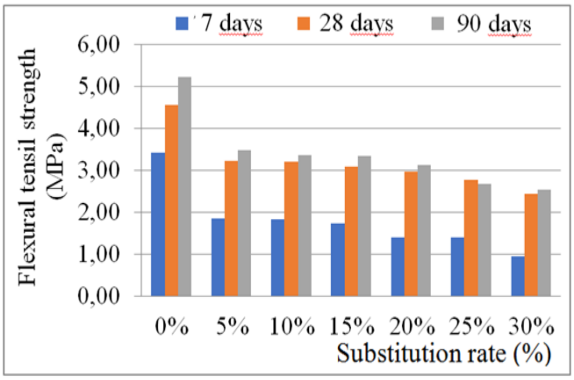
The results of flexural tensile strengths obtained in our study were comparable to the one found in the work of Brás et al. [23].

The flexural tensile strengths of mortars with the addition of olive stones, are low compared to those of the control mortar at all ages. It is noted that, the tensile strength decreases when the density of the mortar decreases, this is quite logical, because a positive relationship exists between the density of the mortar and its cube tensile strength, as for classics mortars.

We can conclude that the tensile strengths of the mortars with the addition of cork and/or olive stones are low compared to those of the control mortar at all ages.



(a) Cork



(b) Olive stone

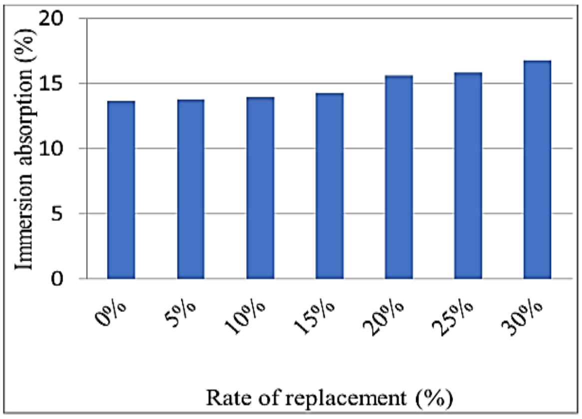
Figure 6. Effect of substitution rate on flexural tensile strength

5.5 Immersion absorption

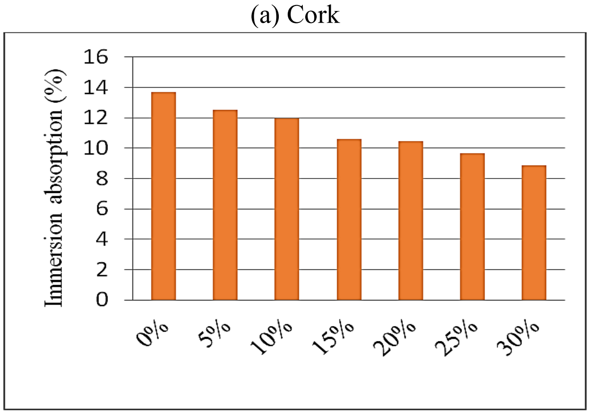
The absorption capacity of a mortar generally tells us about the presence and importance of voids in order to test the compactness of the mixture.

Analysis of the results Figure 7 obtained show that the control mortar absorption coefficient is equal to 13.71% lower than those with the addition of cork as an ordinary sand replacement for all mixtures rates (5 to 30%) of substitution.

Indeed, the absorption coefficient increases proportionally with the percentage of cork addition up to a substitution rate of 30% (maximum absorption coefficient=16.79%) and this is due to the porosity and to the open pore volume as mentioned previously by Rosa and Fortes [24].



(a) Cork



(b) Olive stone

Figure 7. Absorption of water by immersion as a function of substitution rate

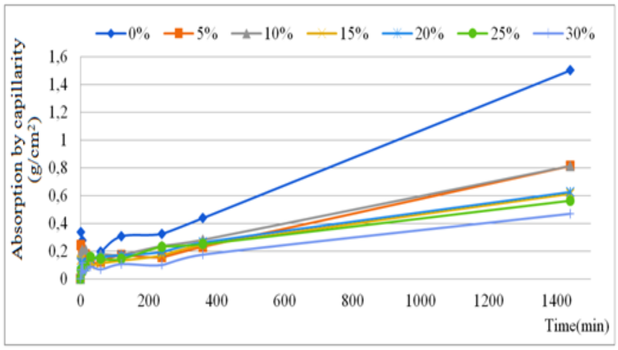
In contrast, results obtained with olive stone mortars indicate that the addition of olive stones decreases the immersion absorption coefficient relative to the reference.

The addition of 30% olive stone waste reduces the absorption coefficient by immersion, which means reduced porosity compared to the control mortar immersion absorption coefficient equal to 8.85%.

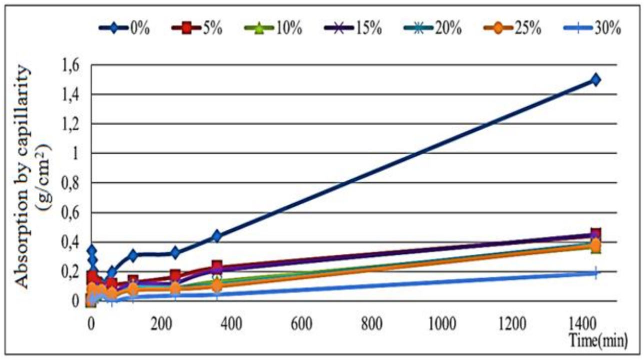
Permeability value obtained could be due to the voids between the olive stone particles since the olive stone particles were well covered with the polyester binder which reduces their permeability effect [21].

However, the results remain under that registered with mortar containing cork as sand replacement for all rates.

5.6 Capillarity absorption



(a) Cork



(b) Olive stone

Figure 8. Capillarity absorption of water as a function of time

Figure 8 shows the evolution of water absorption by capillary effects of mortar mixtures formulated over time.

Capillary absorption tests were undertaken on test specimens at 28 days of age.

The results show that water capillary absorption increased with time for all mixtures during 24 hours.

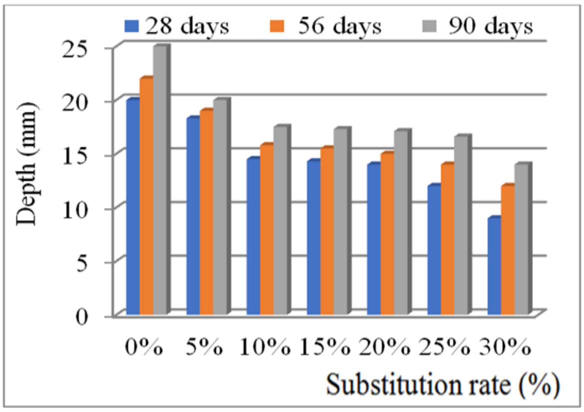
It is clearly apparent that the absorption of water by capillarity decreases as the dosage of cork waste increases. This decrease is probably due to the increase in the compactness of the mortar.

During the substitution of sand with 5-30% olive stones, different correlations describe the significant decrease in absorption values.

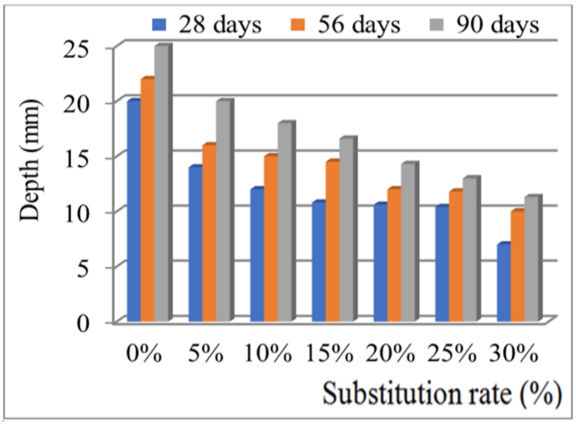
According to the research was performed by Farag et al. [21], that olive stone particles were well covered with the polyester binder which reduces the effect on the permeability of olive stones itself.

5.7 Chloride penetration

Results resumed in Figure 9 show that the reference mortar achieves the highest depth of chloride penetration in 90 days with a slight decreasement in depth in comparison to the others ages 28 and 56 days. Also, the results show that the lowest depth of chloride penetration was registered by mix 30% of cork as sand replacement for all ages with 9, 12 and 14 mm corresponding to 28, 56 and 90 days respectively this values represent 55, 45.45 and 44% under that of the reference.



(a) Cork



(b) Olive stone

Figure 9. Depth of chloride penetration

Generally, the results describe a different correlation between the depth of chloride penetration and the substitution rates.

The presence of cork in mortar reduces the absorption during the Immersion in NaCl solution. The kinetics of absorption are rather slow at long times, density becomes significantly higher than of water, which drags the cork to the bottom [25]. The ability of cork to resist water absorption is closely linked to the presence of suberin [25]. All these factors lead to a decrease in chloride ion migration.

The same behavior is recorded by mortars containing olive stones as sand replacement a remarkable decrease in penetration depth was recorded as a function of the olive stones substitution rates from 5% to 30% relative to the control mortar for all ages.

It should be noted that there is a slight decrease in depth of chloride penetration in mortars containing olive stones in comparison to that of mortars containing cork as sand replacement. It was clear from previous results in our study that olive stones present a more resistance to water absorption than cork. This refers to the functional properties of the olive stones against water and its aggregate structure. The polyester binder that covers the olive stones, its porosity and the volume of the open pores. Therefore, the distribution, the pore size and the porosity of the mortars are determining parameters of chloride penetration depth. Moreover, the difference in the latter may be due to the mobility of the chlorides within the pores and their distribution in mortar.

6. CONCLUSIONS

The use of cork and olive stone can be a sustainable economic and ecological solution, since their reuse in the form of lightweight aggregates would solve the problem of its disposal and develop a good construction material used in the rehabilitation of old buildings, and to improve certain functional, physical and mechanical properties, this was the objective and motivation behind our study, for this purpose cork and olive stones wastes are introduced as aggregates in mortar admixtures, partly replacing the ordinary sand with different percentages.

The work carried out is a physical and mechanical characterization of the mortars based on cork and olive stones lightweight aggregate properties. The following findings can be made:

• Cork and olive stones lightweight aggregates lower the strength parameters, mortar density and reduce workability.

• The results obtained show that olive stones used reduce water absorption.

• Mechanical properties are systematically decreasing with the increasing substitution of ordinary sand by cork or olive stones lightweight aggregates. Indeed, a significant drop in Compressive and flexural strength at all ages.

However, the penetration of chlorides from mortars made from cork or olive stones is favorable, which indicates its adaptation to deterioration linked to durability and external exposure and these characteristics are advantageous for our case study because the buildings are located in a tidal zone and exposed to salts and aggressive agents. For that purpose the study of durability parameters are recommended for this kind of constructions materials.

As future work to understand more comprehensively the performance of cork and olive stones wastes as lightweight aggregates in a mortar and its performance against such environmental conditions and their adaptation to durability related to degradation, more tests must be carried out to assess chemical properties of these mortars. These tests and their results will be the subject of the next articles.

REFERENCES

[1] Branco, F.G., Tadeu, A. (2007). Can cork be used as a concrete aggregate? International Journal for Housing and Its Applications, 31(1): 1-11.

[2] Pereira, H. (2007). Cork: Biology, production and uses. Engineering.

[3] Pereira, H. (2015). The rationale behind cork properties: A review of structure and chemistry. BioResources, 10(3): 6207-6229.

[4] Leite, C., Oliveira, V., Miranda, I., Pereira, H. (2020). Cork oak and climate change: Disentangling drought effects on cork chemical composition. Scientific Reports,

10(1): 7800. https://doi.org/10.1038/s41598-020-64650-9
[5] Pereira, H. (1988). Chemical composition and variability of cork from Quercus suber L. Wood Science and Technology, 22(3): 211-218. https://doi.org/10.1007/BF00386015
[6] Barnat-Hunek, D., Widomski, M.K., Szafraniec, M., Łagód, G. (2018). Impact of different binders on the roughness, adhesion strength, and other properties of mortars with expanded cork. Materials, 11(3): 364. https://doi.org/10.3390/ma11030364
[7] Silva, J.S., Catry, F. (2006). Forest fires in cork oak (Quercus suber L.) stands in Portugal. International Journal of Environmental Studies, 63(3): 235-257. https://doi.org/10.1080/00207230600720829
[8] Touati, R., Santos, S.A., Rocha, S.M., Belhamel, K., Silvestre, A.J. (2015). The potential of cork from Quercus suber L. grown in Algeria as a source of bioactive lipophilic and phenolic compounds. Industrial Crops and Products, 76: 936-945. https://doi.org/10.1016/j.indcrop.2015.07.074
[9] Lesage-Meessen, L., Navarro, D., Maunier, S., Sigoillot, J.C., Lorquin, J., Delattre, M., Simon, J.L., Asther, M., Labat, M. (2001). Simple phenolic content in olive oil residues as a function of extraction systems. Food Chemistry, 75(4): 501-507. https://doi.org/10.1016/S0308-8146(01)00227-8
[10] Naghmouchi, I., Mutjé, P., Boufi, S. (2014). Polyvinyl chloride composites filled with olive stone flour: Mechanical, thermal, and water absorption properties. Journal of Applied Polymer Science, 131(22). https://doi.org/10.1002/app.41083
[11] Arezki, S., Chelouah, N., Tahakourt, A. (2016). The effect of the addition of ground olive stones on the physical and mechanical properties of clay bricks. Materiales de Construcción, 66(322): e082-e082.
[12] Demertzi, M., Silva, R.P., Neto, B., Dias, A.C., Arroja, L. (2016). Cork stoppers supply chain: Potential scenarios for environmental impact reduction. Journal of Cleaner Production, 112: 1985-1994. https://doi.org/10.1016/j.jclepro.2015.02.072
[13] Barnat-Hunek, D., Siddique, R., Łagód, G. (2017). Properties of hydrophobised lightweight mortars with expanded cork. Construction and Building Materials, 155: 15-25. https://doi.org/10.1016/j.conbuildmat.2017.08.052
[14] Panesar, D.K., Shindman, B. (2012). The mechanical, transport and thermal properties of mortar and concrete containing waste cork. Cement and Concrete Composites, 34(9): 982-992. https://doi.org/10.1016/j.cemconcomp.2012.06.003
[15] Karade, S.R., Irle, M., Maher, K. (2006). Influence of granule properties and concentration on cork-cement compatibility. Holz Als Roh-Und Werkstoff, 64(4): 281-286. https://doi.org/10.1007/s00107-006-0103-2
[16] Moreira, A., António, J., Tadeu, A. (2014). Lightweight screed containing cork granules: Mechanical and hygrothermal characterization. Cement and Concrete Composites, 49: 1-8. https://doi.org/10.1016/j.cemconcomp.2014.01.012
[17] Al-Masaeid, H.R., Hamed, M.M., Khedaywi, T.S. (1994). Empirical evaluation of olive husk in asphalt cement binder and bituminous concrete. Transportation Research Record, 1436: 124-132.
[18] Siracusa, G., La Rosa, A.D., Siracusa, V., Trovato, M. (2001). Eco-compatible use of olive husk as filler in thermoplastic composites. Journal of Polymers and the Environment, 9: 157-161. https://doi.org/10.1023/A:1020465305193
[19] Barreca, F., Fichera, C.R. (2013). Use of olive stone as an additive in cement lime mortar to improve thermal insulation. Energy and Buildings, 62: 507-513. https://doi.org/10.1016/j.enbuild.2013.03.040
[20] del Río Merino, M., Rodríguez, J.G., Martínez, F.F., Astorqui, J.S.C. (2017). Viabi[ity of using olive stones as lightweight aggregate in construction mortars. Revista de la Construcción, 16(3): 431-438.
[21] Farag, E., Alshebani, M., Elhrari, W., Klash, A., Shebani, A. (2020). Production of particleboard using olive stone waste for interior design. Journal of Building Engineering, 29: 101119. https://doi.org/10.1016/j.jobe.2019.101119
[22] Ahmed, Z., Ahmida, F., Marie, D.R., Michelle, Q. L'effet de taille des granulats de liège sur les caractéristiques physico-mécaniques et thermiques d'un béton léger à base de sable calcaire. Séminaire International de Génie Civil sur les Matériaux cimentaires, SIGC, Oran, Algeria: Conference Paper.
[23] Brás, A., Leal, M., Faria, P. (2013). Cement-cork mortars for thermal bridges correction. Comparison with Cement-EPS Mortars Performance. Construction and Building Materials, 49: 315-327. https://doi.org/10.1016/j.conbuildmat.2013.08.006
[24] Rosa, M.E., Fortes, M.A. (1993). Water absorption by cork. Wood and Fiber Science, 339-348.
[25] Gil, A.M., Lopes, M.H., Pascoal Neto, C., Callaghan, P.T. (2000). An NMR microscopy study of water absorption in cork. Journal of Materials Science, 35: 1891-1900. https://doi.org/10.1023/A:1004749932170