Mustansiriyah Journal of Materials Engineering and Sustainability
Volume 01, No. 01, 2025, Pages 07-12
https://mjmes.uomustansiriyah.edu.iq/
Research Article
DOI: https://doi.org/10.31272/8s7y8p06
ISSN: 3079-9899 (Print)
ISSN: 3079-9902 (Online)

Eco-Friendly Cement Mortar with Recycled Olive and Ceramic Waste

Dalia Adil Rasool[1*], Manolia Abed Al-Wahab Ali [1], Manal Hamed Jasem [1], Balsam Mahmood Shaker[2]

[1] Materials Engineering Department, College of Engineering, Mustansiriyah University, Baghdad, Iraq
[2] Department of Construction and Projects, Mustansiriyah University, Baghdad, Iraq
[*]Email: daliaadilalalali84@uomustansiriyah.edu.iq

Article Info
Received 20/04/2025
Revised 28/05/2025
Accepted 14/06/2025
Published 01/07/2025

Abstract

The disposal of ceramic tiles from demolished buildings and olive stone waste has contributed to significant environmental challenges. Enhancing their reuse and recycling potential is crucial for sustainable solid waste management. This study investigates the viability of partially substituting fine aggregates in cement mortar using a mixture of olive stone (a natural waste) along with ceramic powder derived from wall tiles (an industrial waste). Thermal and mechanical properties were analyzed to assess performance. In addition to promoting environmentally friendly materials that improve buildings' energy efficiency, recycling construction debris helps reduce landfill accumulation. To assess the effect on material qualities, specimens of cement mortar were made using a 1:3 mix ratio and a 0.5 W/C ratio, with the addition of 5% to 25% of these waste materials. The inclusion of a superplasticizer improved workability and compressive strength. Various ratios were tested for thermal conductivity, flexural strength, density, as well as compressive strength. According to the results, the best performance was achieved when ceramic powder and olive stone accounted for 20% of the fine aggregate, increasing compressive strength by 54% as well as flexural strength by 67%, while thermal insulation improved by 25% at 28 days. This study validates the practicality of integrating olive along with ceramic waste to improve the insulating characteristics along with the mechanical characteristics of cement mortar.

Keywords: Aggregates, Ceramic, Mortar, Olive Stone, Tile, Waste Materials, Compressive strength, Thermal conductivity.

1. Introduction

Cement mortar is a common construction material that is made by combining cement, sand, and water in specific proportions. Olive stone is an agricultural by-product generated from olive oil production and table olive processing. It is primarily composed of lignin, cellulose, and hemicellulose, which contribute to its relatively low density and porous texture. These properties make olive stone a lightweight material with good thermal insulation characteristics, as well as potential benefits for reducing the overall density of cement-based materials. Additionally, its availability as a renewable resource supports its consideration as an environmentally friendly alternative for partial replacement of natural aggregates in cement mortar.

The growing need for cement mortar as well as concrete has resulted in the depletion of natural resources, exacerbating the rising cost of building materials. A sustainable approach involves incorporating pozzolans and alternative materials to reduce cement content while maintaining mechanical strength, thereby lowering the energy-intensive production process. [1–4]

Ceramic and olive stone waste, derived from construction demolition and by-products, respectively, offer viable substitutes in mortar mixtures. Recycling these materials is crucial for sustainable construction. The increasing generation of olive stone waste from agricultural activities and ceramic waste from construction and demolition sites poses a growing environmental concern. Improper disposal of these wastes can lead to landfill overcrowding, resource depletion, and increased environmental impact. This situation highlights the urgent need for innovative strategies to manage such waste streams effectively. The present study addresses this challenge by exploring the use of olive stone and ceramic waste as partial substitutes for fine aggregates in cement mortar, aiming to develop sustainable construction materials that contribute to waste reduction and environmental protection.Ghazzawi et al. [5] found that replacing up to 10% of cement with olive waste ash (OWA) maximized strength, while higher percentages caused strength reduction. Vicente-Navarro et al. [6] demonstrated that replacing fine aggregates with 5–15% olive stones improved mortar performance and reduced thermal conductivity, enhancing energy efficiency. Al-Akhras [7] further emphasized that olive waste ash enhanced concrete's resistance to alkali-silica reactions.

Al-Akhras and Wahid [8] examined the effects of varying OWA proportions on concrete properties, revealing that increased OWA content decreased setting time and workability but also reduced compressive and flexural strength. Similarly, Leiva et al. [9] found that substituting Portland cement with OWA lowered strength due to its low siliceous content. Anderson et al. [10] studied the replacement of coarse aggregates with broken ceramics (20–100%), concluding that ceramic waste could serve as a feasible substitute with minimal impact on mechanical properties.

Wioletta et al. [11] investigated the use of sanitary ceramic waste as aggregate replacements in cement-based mortars, reporting enhanced flexural and compressive strength at a 20% substitution level while reducing shrinkage. Ravindra et al. [12] found that replacing 10% of natural sand with crushed ceramic improved strength properties. Similarly, F. Pacheco-Torgal and S. Jalali [13] discovered that using ceramic fragments in place of 20% of the cement, the durability, water absorption, compressive strength, and chloride diffusion resistance were all increased.

Cement mortar and concrete can benefit from the combined usage of fly ash and ceramic waste, according to Torkittikul and Chaipanich [14]. Based on their findings, a 50% substitution rate was optimal for enhancing compressive strength using ceramic waste. However, a 100% replacement in fly-ash-compressive concrete further improved strength. Additionally, Gonzalez-Corominas and Etxeberria [15] proved that high-performance concrete was achieved by replacing 15% fine ceramic aggregate (FCA) along with 30% coarse mixed aggregate (CMA). Compressive strength maintained at 100 MPa with 20% CMA, while mechanical and durability characteristics of concrete with 30% FCA were comparable to those of regular concrete. Concrete with a CMA content of up to fifty percent revealed a corrosion risk that was minimal after one hundred eighty days. San Vicente-Navarro et al. [16] conducted a sustainability assessment of mortar bricks incorporating ground olive stones. Their study developed a multi-criteria evaluation methodology and demonstrated that olive stone incorporation in facade mortar bricks not only reduced environmental impact but also supported circular economy practices in construction.

Al-Mattarneh et al. [17] evaluated the performance of concrete paving materials incorporating biomass olive oil waste ash and nano-silica. Their experimental results revealed significant improvements in compressive strength and durability, affirming the suitability of olive oil waste ash as a supplementary cementitious material in pavement applications. .

Similarly, Elemam et al. [18] examined the dual role of ceramic waste as fine aggregate and supplementary cementitious material. The study reported improved workability and mechanical strength of concrete, confirming the feasibility of utilizing ceramic waste in structural applications.This study aims to examine the effects of integrating natural waste (olive stones) as well as industrial waste (ceramic wall tiles) as partial replacements for fine aggregates in cement mortar, offering an environmentally friendly solution for improving mortar performance.

2. Experimental Work

2.1. Materials

Ordinary Portland Cement: Iraqi Cement was used for specimen preparation and maintained in a dry atmosphere to avert moisture-induced degradation. Tables 1 and 2 present its physical as well as chemical properties, conforming to IQS No.5/1984 [19].

Table 1. Fine-aggregate as well as Portland cement compositions.

The Composition	Cement %	Fine-Aggregates %
Iron (III) oxide	2.7	0.48
Calcium oxide	63.63	5.2
Magnesium oxide	4.02	0.78
Silicon dioxide	18.91	82.86
Aluminum oxide	4.52	0.60
Sulfur trioxide	0.78	2.77
Sodium oxide	-	-
LOI	4.02	5.65

Table 2. Physical Properties of the used cement.

Properties	Values
Specific surface area by (Blaine) (m2/kg)	340 m2/kg
Soundness by (Autoclave)	0.08%
The Compressive strength	
In 7- days	34.70 Mpa
In 3 - days	24.93 Mpa
The setting-time by (Vicat)	
The Final setting	3:08 hr:min
The Initial setting	1:15 hr:min

The Al Nabaey area was used as a source for the fine aggregates. According to Iraqi Specification No. 45/1984, Zone 3 criteria, their grading is given in Tables 1 and 3 [20].

Table 3. Characteristics of Fine aggregate.

The Characteristics	Fine-Aggregate
Bulk-specific-Gravity	2.52
Present- water-absorption	0.581
Apparent specific Gravity	2.70
Percent-wear L.A	.....

i. Olive stones, derived as a byproduct from olive oil extraction and table olive processing, were first air-dried for several days, then soaked in water for 24 hours, followed by oven-drying. The dried stones were crushed and sieved, and only the particles passing through a 1.18 mm sieve were selected for use as a partial replacement for fine aggregates in the mortar.

ii. Ceramic waste, sourced from demolished buildings, was crushed and ground into a fine powder. Particles that passed through a 1.18 mm sieve were utilized as a partial substitute for sand to ensure a compatible particle size distribution. The chemical composition of the ceramic waste is provided in Table 4.Superplasticizer: A high-range water-reducing superplasticizer, Sikament FFN (manufactured by Sika, Germany), was used at a constant rate of 3% of cement weight in all mortar mixes to enhance workability and strength. Water: Each mixing and curing phase utilizes potable water.

Table 4. Olive stone and ceramic tile chemical composition.

Chemical compound	olive stone %	Ceramic tiles %
(Magnesium oxide) MgO	0.25	3.6
(Calcium oxide) CaO	0.43	3.64
(Iron (III) oxide) Fe2O3	0.28	1
(Aluminum oxide) Al2O3	0.19	31
(Silicon dioxide) SiO2	0.54	65
(Sulfur trioxide) SO3	0.15	-
(Sodium oxide) Na2O	0.02	1.41
LOI	1.6	-

2.2. Mixture Proportioning

Table 5 details the preparation, and the mixture percentages refer to the weight of sand of the specimens, which involved a water-to-cement (w/c) ratio of 0.5 and a ratio of 1:3 for the Portland cement and fine aggregates. Olive stone and ceramic debris made up 5–25% of the fine aggregates that were originally used. Three percent of the cement's weight was Sikament FFN superplasticizer (manufactured by Sika, Germany).

Table 5. The percentages of modified wastes that are mixed with mortar.

	%Mix Proportion OS%+CP% from sand	Cement in (gm)	Sand in (gm)	olive stone in (gm)	Ceramic Powder in (gm)	w/c
M0	0%	250	750	-	-	0.5
M1	2.5% + 2.5%	250	712.5	356.25	356.25	0.5
M2	5% + 5%	250	675	337.5	337.5	0.5
M3	7.5% + 7.5%	250	637.5	318.75	318.75	0.5
M4	10% + 10%	250	600	300	300	0.5
M5	12.5% + 12.5%	250	562.5	218.25	218.25	0.5

3. Testing Methodology and Sample Preparation

3.1. Compressive Strength

The compressive strength test followed ASTM C109M-02 guidelines and utilized 50 mm × 50 mm × 50 mm cubes [21]. After the 28-day period, a 200 kN capacity ELE-Auto digital compression machine was used for the tests.

3.2. Flexural Strength

Flexural strength was assessed using 40 mm × 40 mm × 160 mm prisms following ASTM C348-14 [22]. The modulus of rupture (σ) was recorded, demonstrating the material's bending and breaking properties.

3.3. Density

Density measurements followed ASTM C188-17 [23], using the formula:

$$\textbf{Density } (\rho) = \textbf{weight/volume.}$$

3.4. Thermal Conductivity

In order to find the K-values for the thermal conductivity of cubes of cement mortar, this work relied on ASTM C1058-03 and C177-10 as tests [24]. The methodology employed was the hot wire approach, which measures the rate of temperature growth of the metal wire before it reaches thermal equilibrium. Two separate scales were used for each wire to record the electric current temperature between the models. Internal cylinders measured (300 and 250 mm) and external cylinders measured (350 and 300 mm) made up the testing apparatus. Between the cylinders, we placed 5 cm thick layers of glass wool to act as heat insulation. Perched on top of the cylinder were brick cubes and a heating element. The cube's corners were sealed with thermal silicon to lessen heat loss. The device's top section, a high-precision multimeter (M890G), was utilized to monitor temperature, current, as well as voltage. The precise quantity of heat required to heat the sample could be introduced by regulating the heater's voltage. Eight hours were total for the duration of the experiment. The voltage and current fed into the heater were among the metrics gathered. K's value was determined by applying Fourier's Law. The manufacturer's recommendations were followed to progressively boost the temperatures to 50°C, the maximum midsummer temperature for concrete. Along with a voltage of 3 volts, the current increased to 0.6 amps.

4. Results and Discussion

4.1. The Compressive Strength

Ceramic powder exhibited a notable pozzolanic effect, contributing significantly to enhancing the compressive strength of mortar. As shown in Figure 1, replacing natural fine aggregates with a combination of olive stone and ceramic powder up to a 20% substitution ratio led to an approximate increase of 54.47% in compressive strength. This improvement is attributed to the formation of calcium silicate hydrate (C-S-H) gel, resulting from the reaction between reactive silica in the ceramic powder and calcium hydroxide produced during cement hydration. The presence of C-S-H gel enhances matrix densification and strengthens the mortar structure. However, at a 25% substitution level, a decline in compressive strength was observed. This reduction is likely due to increased porosity and weaker bonding at the aggregate–cement interface, which adversely affect the load-bearing capacity of the material.

These findings align with studies modifying mortar strength using ceramic and bone-based additives [25,9]. Figure 1 displays the Compressive Strength of the composite material.

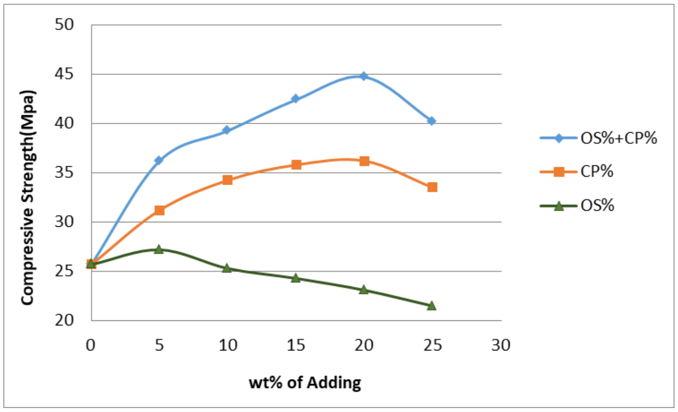

Figure 1. Fine aggregate substituted with olive stone compressive strength, ceramic powder, and an olive/ceramic blend at 28 days.

4.2. The Flexural Strength

According to Figure 2, flexural strength showed a general decline with higher olive stone content. Although a significant improvement of approximately 67% was recorded at the 20% substitution level, further increases resulted in a noticeable drop. This behavior can be explained by the initial benefits of pozzolanic reactions enhancing the cementitious matrix, followed by a reduction in plasticity and increased brittleness as the substitution level exceeded the optimal range. The weaker bonding and reduced cohesion between particles at higher replacement ratios contribute to the observed trend.

Similar findings have been reported by Wioletta et al. [11] and Ravindra R et al. [12].

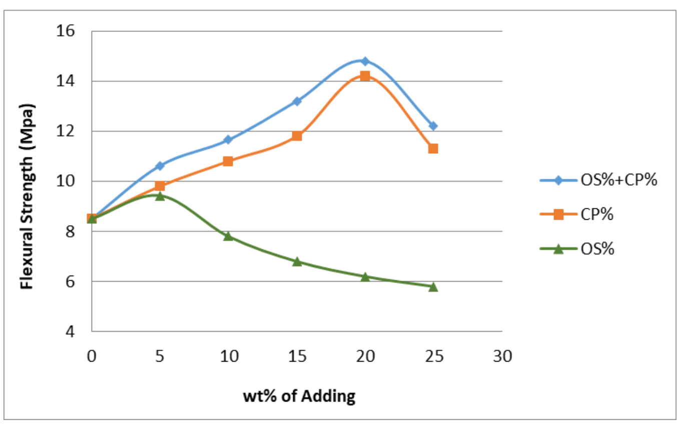

Figure 2. Flexural strength of fine aggregate substituted with olive stone, ceramic powder, and a mixture powder of olive and ceramic at (28) days.

4.3. The Density

As illustrated in Figure 3, the density of mortar decreased steadily with increasing proportions of olive stone and ceramic powder. This trend is primarily due to the inherently lower specific gravity of the replacement materials compared to natural sand. Although the pozzolanic reaction leads to the formation of additional C-S-H gel, which can enhance matrix compactness, the lower mass and higher porosity introduced by the recycled materials result in an overall decrease in density.

This trend is consistent with studies by Silva et al. [26] and Vejmelková et al. [27].

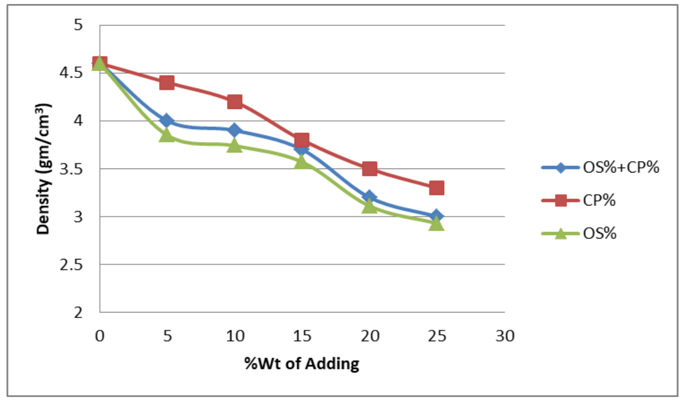

Figure 3. Density of fine aggregate substituted with olive stone, ceramic powder, and a mixture powder of olive and ceramic at (28) days.

4.4. The Thermal Conductivity Test

The results presented in Figure 4 reveal a nuanced relationship between thermal conductivity and the level of substitution. Despite the general reduction in density, samples containing higher percentages of olive stone and ceramic powder exhibited increased thermal conductivity. This can be attributed to the fine particle size of the additives, which may enhance the continuity of thermal pathways within the matrix. Furthermore, improved microstructural uniformity resulting from pozzolanic activity may facilitate better heat transfer. These findings suggest that thermal performance is influenced by multiple interconnected factors, including particle size distribution, material density, and the chemical reactivity of the components.This outcome supports the conclusions of Vejmelková et al. [24], which demonstrate a reduction in the heat conductivity of cement mortars.

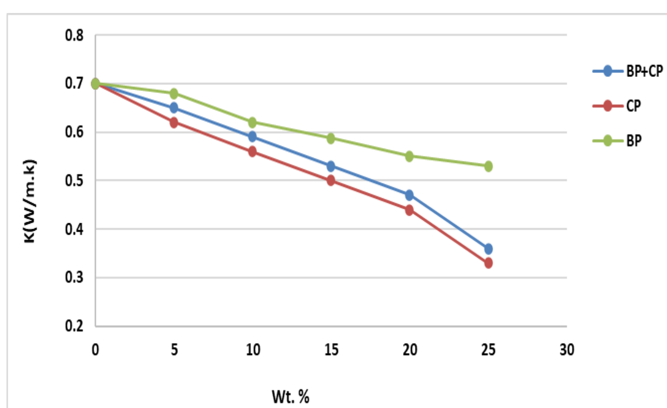

Figure 4. Examination of the thermal properties of fine aggregate replacement with bone powder, ceramic powder, as well as a combination of the two after (28) days.

5. Conclusions

This study demonstrated the potential of utilizing recycled ceramic waste and olive stone as partial replacements for natural fine aggregates in cement mortar. The integration of these materials led to significant improvements in both mechanical and thermal performance parameters. The findings revealed that a substitution ratio of 20% (10% ceramic powder + 10% olive stone) offers optimal performance, beyond which the benefits begin to decline.

The improved compressive strength, which increased by approximately 54.6%, is attributed to the pozzolanic activity of the ceramic material and the enhanced microstructure resulting from the interaction between the replacement materials and cement paste. Similarly, flexural strength improved by nearly 67% at the same substitution level, indicating a more resilient mortar matrix.

In addition to mechanical enhancements, the modified mortar showed reduced density due to the lower specific gravity of the waste materials, and varying effects on thermal conductivity depending on the replacement composition. Notably, the inclusion of ceramic and olive stone contributed to improved insulation properties, supporting their use in thermal-efficient construction applications.

Based on these outcomes, the incorporation of recycled ceramic and olive stone materials can be considered a sustainable and effective solution for producing eco-friendly mortar with enhanced structural and thermal performance. Such mortars are especially suitable for applications in non-structural walls, façade systems, and thermally insulated building components, contributing to waste reduction and improved energy efficiency in the construction sector.

Acknowledgements

The authors acknowledge Mustansiriyah University (www.uomustansiriyah.edu.iq) in Baghdad, Iraq, for its support in this research.

Conflict of interest

"The authors declare that there are no conflicts of interest regarding the publication of this manuscript".

Author Contribution Statement

This work was carried out in collaboration between all authors. Manolia Abed Al-Wahab organized and verified the data.
Balsam Mahmood Shaker analyzed the data.
Dalia Adil wrote the manuscript.
Manal Hamed read and approved the final manuscript.

AI Declaration Statement

The author confirm that the manuscript has been written without the assistance of generative AI or AI-based writing tools.

References

[1] O. P. Jaggi, ''History of science and technology in India, In some was in the construction of the bath'', first edition, 1969.
[2] D.A. Rasool, M.A. Abdulkarem, and M.A. Abdulrehman, ''The Effect of Adding Recycled Waste on the Mechanical Properties of Concrete''. *Defect and Diffusion Forum*, vol. 398, pp. 83-89, 2020. **DOI:** 10.4028/www.scientific.net/DDF.398
[3] M.A. Abdulkarem, DA Rasool, and BJ Nabhan, ''Utilization of Olive and Pumice Stones to Improve the Thermal Properties of Cement Mortar.'' *International Journal of Nanoelectronics and Materials*, vol. 13, No.1, pp.181-188, 2020.
[4] D.A. Rasool, M. A. Abdulkarem and M. A. Abdulrehman, ''Sustainability of the Concrete by using Recycled Waste Materials'', *journal of engineering and sustainable development*, vol.22, No.2, pp.55-65, 2018. **DOI:** 10.31272/jeasd.2018.2.67
[5] S. Ghazzawi, Ghanem, H., Khatib, J., El-Zahab, S., and Elkordi, A. ''Effect of Olive Waste Ash as a Partial Replacement of Cement on the Volume Stability of Cement Paste''. *Infrastructures*, vol. 9No. 11, pp. 193, 2024. **DOI:** 10.3390/infrastructures9110193.
[6] S. V.Navarro, A., Mendívil-Giro, M., Los Santos-Ortega, J., Fraile-Garcia, E., and Ferreiro-Cabello, J.. ''Alternative Use of the Waste from Ground Olive Stones in Doping Mortar Bricks for Sustainable Façades''. *Buildings*, 2023. **DOI:** 10.3390/buildings13122992 7.
[7] N. M. Al-Akhras, "Performance of olive waste ash concrete exposed to alkali-Silica reaction", *Struct. Concr. J.* vol. 13, No. 4, pp. 221–226, 2012. **DOI:** 10.1002/suco.201100058.
[8] N. M. Al Akhras, M. Y. Abdul Wahid, "Utilization of olive waste ash in mortar mixes", *Struct. Concr. J.* vol.11, No. 4, pp. 221–228, 2010. **DOI:** 10.1680/stco.2010.11.4.221
[9] C. Leiva, L. F. Vilches, J. Vale, C. Fernández-Pereira, "Influence of the type of ash on the fire resistance characteristics of ash-enriched mortars", *Fuel*, vol. 84, pp. 1433–1439, 2005. **DOI:** 10.1016/j.fuel.2004.08.031
[10] D. J. Anderson, S. T. Smith, Francis T.K. Au, ''Mechanical properties of concrete utilizing waste ceramic as coarse Aggregate'', *Construction and Building Materials*, vol. 117, pp.20–28, 2016. **DOI:** 10.1016/j.conbuildmat.2016.04.153
[11] W. Jackiewicz-Rek, K. Załęgowski, A. Garbacz, B. Bissonnette, ''Properties of cement mortars modified with ceramic waste fillers'', *Procedia Engineering*, vol.108, pp.681 – 687, 2015. **DOI:** 10.1016/j.proeng.2015.06.199
[12] R. R, Anand Kumar BG, P. Rooparchana, ''Suitability of Crushed Ceramic Tiles as Fine Aggregates in Cement Mortar'', *Recent Trends in Civil Engineering & Technology*, vol.4, No.1, pp. 33-37, 2014.
[13] F. Pacheco-Torgal, S. Jalali, ''Reusing ceramic wastes in concrete'', *Construction and Building Materials*, vol. 24, pp.832–838, 2010. **DOI:** 10.1016/j.conbuildmat.2009.10.023
[14] P. Torkittikul, and A. Chaipanich, ''Utilization of ceramic waste as fine aggregate within Portland cement and fly ash concretes'', *Cement & Concrete Composites*, vol. 32, pp.440-449, 2010. **DOI:** 10.1016/j.cemconcomp.2010.02.004
[15] A. Gonzalez-Corominas and M. Etxeberria, ''Properties of high-performance concrete made with recycled fine ceramic and coarse mixed aggregates'', *Construction and Building Materials*, vol. 68, pp. 618-626, 2014. **DOI:** 10.1016/j.conbuildmat.2014.07.016.
[16] A. San Vicente-Navarro, J. Los Santos-Ortega, E. Fraile-García, and J. Ferreiro-Cabello, "Methodology for Sustainability Assessment for the Use of Ground Olive Stones in Mortar Bricks for Facades," Applied Sciences, vol. 14, no. 8, p. 3388, 2024. DOI: 10.3390/app14083388.

[17] H. Al-Mattarneh, M. Abuaddous, R. Ismail, A. B. Malkawi, Y. Jaradat, H. Nimer, and M. Khodier, "Performance of concrete paving materials incorporating biomass olive oil waste ash and nano-silica," AIMS Materials Science, vol. 11, no. 5, pp. 1035–1055, 2024. DOI: 10.3934/matersci.2024049.

[18] W. E. Elemam, I. S. Agwa, and A. M. Tahwia, "Reusing Ceramic Waste as a Fine Aggregate and Supplemental Cementitious Material in the Manufacture of Sustainable Concrete," Buildings, vol. 13, no. 11, p. 2726, 2023. DOI: 10.3390/buildings13112726.

[19] Iraqi Standard No. (5). Portland Cement. Central Organization for Standardization and Quality Control, Baghdad, 1984.

[20] Iraqi Standard No. 45. Rubble of Natural Resources Used in Concrete Construction Central Agency for Standardization and Quality Control, Baghdad, 1984.

[21] ASTM C109M-02, Standard Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens. ASTM International, West Conshohocken, PA, USA, 2019.

[22] ASTM C348-14, Standard test methods for flexural strength of Hydraulic-Cement Mortar, American Society for Testing and Material International, 2019.

[23] ASTM C188-17, Standard test methods for Density of Hydraulic Cement, ASTM International, West Conshohocken, PA, 2017.

[24] ASTM C1058-03, standard practice for selecting temperatures for evaluating and reporting thermal properties of thermal insulation "and C177-10" standard test method for steady-state heat flux measurements and thermal transmission properties by mean of the guarded hot plate apparatus," ASTM International, West Conshohocken, PA, USA, 2010.

[25] M. Balaha, M. H. Seleem, M. H. A. Kotb, H. E. M. Sallam, H. Abd El-Rahman, ''Fracture, Behavior of Concretes Incorporating olive stone'', *MEJ. Mansoura Engineering Journal*, vol.33, pp.66-77, 2008. **DOI:** 10.21608/bfemu.2020.127077

[26] J. Silva, J. de Brito, R. Veiga, ''Fine ceramics replacing cement in mortars Partial replacement of cement with fine ceramics in rendering mortars'', *Materials and Structures*, vol.41, pp.1333-1344, 2008. **DOI:** 10.1617/s11527-007-9332-z

[27] E. Vejmelková, D. Koňáková, T. Kulovaná, R. Černý, ''Mechanical and Thermal Properties of Moderate-Strength Concrete with Ceramic Powder Used as Supplementary Cementitious Material'', *Advanced Materials Research*, vol. 1054, pp.194-198, 2014. **DOI: 10.4028/www.scientific.net/AMR.1054.194**