Case Studies in Construction Materials 5 (2016) 19–25

Contents lists available at ScienceDirect

Case Studies in Construction Materials

journal homepage: www.elsevier.com/locate/cscm

Case study

Effect of olive waste (Husk) on behavior of cement paste

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ARTICLE INFO

Article history:
Received 15 February 2016
Received in revised form 24 April 2016
Accepted 17 May 2016
Available online 2 June 2016

Keywords:
Olive waste
Mechanical behavior
Cement paste
Environment

ABSTRACT

Jordan is a famous country in terms of olive trees agriculture that resulted in a mass production of olive oil products. The huge amounts of olive waste (husk) that resulted from olives processing to produce olive oil represent an environmental challenge in the country. The idea in this paper comes to use olive waste as a partial replacement for Portland cement in cement paste to conserve the environment, reduce cement consumption and increase cost efficiency. The wastes were burned properly in an oven and maintained for 6 h until it was fully transformed into ashes. Then, the oven was turned off and ashes were allowed to cool. After cooling, the material passed sieve #200 were used. The sieved ashes were used in the cement mix as a partial cement replacement for making the mortar and cement paste. Normal consistency and setting time were determined as well as soundness, compressive strength. Results indicated that normal consistency of the cement pastes containing different percentage of olive waste is somehow lower than that of the ordinary cement paste and slightly decreases with increasing the percentage. The results also indicated that the compressive strength of hardened blended cement paste containing different percentages of olive waste slightly decrease with olive waste content at 3, 7, and 28 days.

1. Introduction

Cement additives are common these days to enhance the engineering properties of cement paste and concrete. In literature, different additive materials were used such as silica fume, rice husk ash, fly ash, and electric-arc furnace dust. Priyanka et al. [15] investigated the replacement of natural sand by manufactured sand on cement mortar properties. Swaroop et al. [16] checked the durability of concrete when cement was replaced with Fly Ash and Ground Granulated Burnt Slag (GGBS). Essam et al. [9] studied the role of calcium chloride in the hydration properties of ground clay bricks cement pastes. Marthong and Agarwal [13] used fly ash as an additive for concrete. Isa et al. [12] replaced sand by Granulated Blast furnace Slag (GBS) and coal bottom ash to check the effect on concrete strength and durability.

However, few studies are related to the influence of Olive waste ash (OWA) on mortar and concrete properties. Olive waste is a by-product of Olive oil production industry. Large amounts of these wastes are produced that present an environmental threat in Olive oil producing countries such as in the case of Jordan. Therefore, there is an urgent need to treat these materials safely. This section explores the literature to highlight the research work conducted in terms of using industrial waste materials such as Olive waste ash in concrete production.

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http://dx.doi.org/10.1016/j.cscm.2016.05.001

Al-Akhras [1] investigated the effect of olive waste ash on the durability of concrete exposed to alkali-silica reaction. Results showed that Olive waste ash concrete is more resistant to alkali-silica reaction deterioration than plain concrete. The durability of Olive waste ash concrete with respect to alkali-silica reaction damage improved with the increase in Olive waste ash content. In the work of Al-Akhras and Abdulwahid [2], olive waste ash was used in mortar mixes to investigate workability, setting time, compressive strength, and flexural strength using different percentages of Olive waste ash. Setting time and workability of mortar decreased with olive waste. On the other hand, compressive and flexural strength decreased when more cement was replaced with olive waste ash. On a related work by Al-Akhras et al. [3], the effect of Olive waste ash on concrete behavior at high temperatures was investigated. Results showed that the performance of Olive waste ash concrete at high temperatures is higher than that of the control concrete.

The effect of tire rubber ash filler on mortar properties including air content, setting time, compressive and flexural strengths, freeze-thaw damage, and chloride ion penetration was studied by Al-Akhras and Smadi [4]. The test results showed that mortar workability increased with increasing the partial replacement of the tire rubber ash with sand. The air content of fresh mortar decreased with increasing the tire rubber ash content. The initial and final setting times of fresh paste are also increased. The tire rubber ash mortar showed higher compressive ad flexural strength strengths at various curing periods up to 90 days as compared to control mortar. Al-Akhras and Abu-Alfoul [5] investigated the effect of wheat straw ash on the compressive, tensile, and flexural strengths of mortar. The study showed that these properties increased with the increase in wheat straw ash replacement by sand.

Leiva et al. [11] substituted part of the Portland cement in mortar with Olive waste ash. Mortar compressive and flexural strengths were reduced by increasing the percentage of Olive waste ash due to the low siliceous content. Another study conducted by Khana et al. [10] tested the effect of using rice husk ash in mortar and concrete. Concrete achieves higher strength due to secondary binder compared to control specimens. Eisa [8] evaluated the performance of fresh and hardened concrete containing olive's seed ash in terms of workability and compressive strength. The results indicated that replacing the cement by olive's seed ash has a significant effect on fresh concrete workability. The compressive strength of mixtures containing olive's seed ash showed 45 and 75% decrease compared to the control mixtures.

Maslehuddin et al. [14] evaluated the effect of electric arc furnace dust on mechanical and durability properties of ordinary Portland cement and blended cement (silica fume and fly ash) concrete. The initial and final setting time and slump retention increased due to the incorporation of electric arc furnace dust in both ordinary Portland cement and blended cement concretes. Ordinary Portland cement concrete gained higher strength with electric arc furnace dust as compared to blended cement concretes. In a related study, Alexandre et al. [6] studied the use of electric-arc furnace dust in Pozzolan-modified Portland cement I pastes. Electric-arc furnace dust retarded the Portland cement's hydration reaction in its initial ages; however, at later stages significant gain of resistance in pastes containing electric-arc furnace dust was noted.

2. Olive waste processing

Olive waste is a waste material available in olive oil-producing countries such as in Jordan. Locally available olive wastes were used in the current study. The wastes were burned properly in an oven and maintained for 6 h until it was fully transformed into ashes. Then, the oven was turned off and ashes were allowed to cool. After cooling, the material passed sieve #200 were used. The sieved ashes were used in the cement mix as a partial cement replacement for making the mortar and cement paste. The XRD corresponding to the olive ash found that the major components are SiO2 (21%), CaO (30)% and K_2O (31.6%), Table 1. The surface area of olive waste and cement were 405 and 288 m^2/kg respectively.

3. Methodology

Different mix proportions were designed to study the effect of olive waste as filler on cement paste behavior in addition to the control mix that was prepared without olive waste. Olive wastes were added in different percentages ranging from 3 to 15% with 3% increments.

Table 1
Composition of the olive waste and cement.

Compound	Percentage (%)	
	Cement	Olive waste
K_2O	–	31.6
Fe_2O_3	4.3	2.5
Al_2O_3	5.4	3.1
CaO	65.5	30
SiO_2	19.5	21
Na_2O	–	0.4
P_2O_5	–	6.1
MgO	2.2	5.3
SO_3	3.1	–

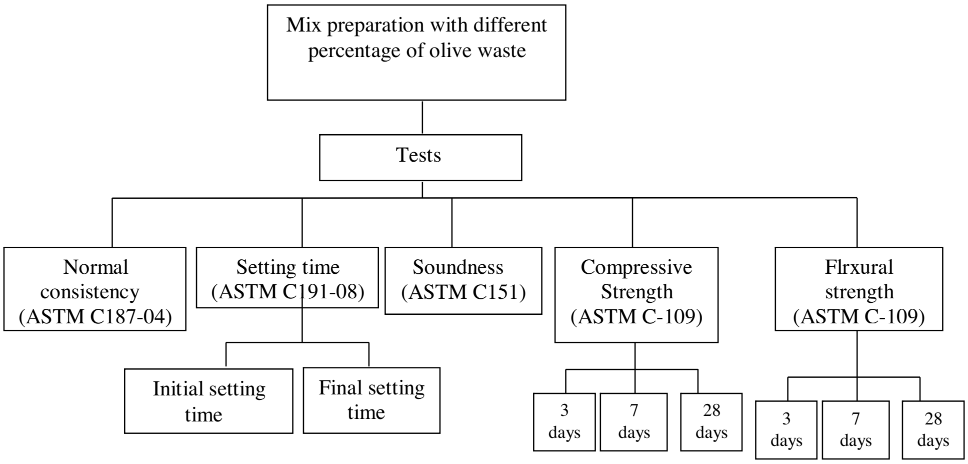

Fig. 1. Methodology flow chart.

Some mixes were prepared as a control mix in order to compare the physical and chemical properties of cement using 100% ordinary Portland cement with no olive waste filler addition. Olive waste filler additions were then added with a weight increment of 3% varying from 3% to 15%. For all mixes, the normal consistency, setting time (initial and final), bulk density, soundness, compressive and flexural strength using the standards of ASTM were determined. The normal consistency for the fresh control and blended cement pastes were determined using Vicat Apparatus according to ASTM: C187-04. Normal consistency is used to determine the amount of water required to penetrate the Vicat testing needle by 10 mm.

For setting times (initial and final); Vicat apparatus according to the ASTM C191-08 testing standard was used. Blended cement pastes prepared using the required water according to the normal consistency was used to determine initial setting time. The initial setting time was measured to penetrate the Vicat testing needle of 1 mm diameter by 25 mm. When there was no penetration of the needle observed, the final setting time was determined.

The Soundness of the cement pastes was determined according to ASTM C151 method using an autoclave to investigate the olive waste influence on the length changes of the specimens. The Bulk Density was carried out in accordance to the European Norms (EN 1015). A sample of three prismatic specimens of $40 \times 40 \times 160$ mm was used for the different replacement percentages.

A set of three cubic specimens of mortar and curing time were used for the determination of compressive strength according to ASTM C-109. The specimens were cast in steel molds (50 mm $\times$ 50 mm $\times$ 50 mm). The mortar was placed into one cubic mold. After the top layer was compacted, the surface was smoothed. After molding, the specimens were first at room temperature 23 ± 1C for 24 h then the cube specimens were de-molded. Then, the specimens were cured up to 3, 7, and 28 days. Fig. 1 shows the methodology of this study.

4. Results and discussion

4.1. Normal consistency

Normal consistency of cement paste was conducted to determine the changes in water requirements of pastes due to olive waste. The normal consistency of the blended cement pastes with olive waste is shown in Table 2 and Fig. 2. The results show that, the normal consistency of the cement pastes containing different percentage of olive waste is somehow lower than that of the ordinary cement paste and slightly decreases with increasing the percentage. This is mainly due to low water absorption of the olive waste. This yield to decrease cement hydration and then higher porosity which reduces the material ability to take water.

Table 2
Relation between olive waste ash (OWA) ratio in the binder and the required water content (normal consistency).

Batch number	Cement content, (g)	OWA, (%)	OWA Content, (g)	Water Content, (g)	W/C ratio
1	600.0	0	0.0	165.0	27.50
2	582.0	3	18.0	161.2	26.87
3	564.0	6	36.0	159.1	26.52
4	546.0	9	54.0	156.3	26.05
5	528.0	12	72.0	152.2	25.37
6	510.0	15	90.0	148.6	24.77

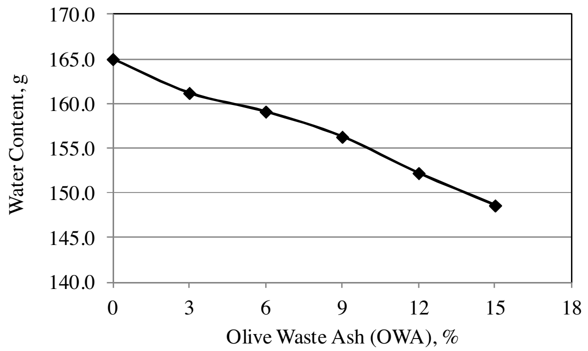

Fig. 2. Water content versus Olive Waste Ash (OWA) percent.

4.2. Setting times

As shown in Table 3 and Fig. 3, the initial setting time considerably increases with the partial replacement of cement by olive waste ash. This is due to the reduction in the amount of cement and low rate of hydration that decreases C3 S and C3A content in the cement paste. However, final setting time is slightly higher for blended cement paste as compared to the ordinary cement paste.

4.3. Soundness

Soundness test was conducted in this study. As shown in Table 4 and Fig. 4, it can be observed that the expansion considerably decreases with addition of olive waste into Portland cement as compared to the ordinary cement paste and it is less than the specification limit (0.8%).

This result indicates less chances of cracking. This effect can be attributed to the high content of MgO and free CaO. Slow hydration of MgO or CaO leads expansion of cement pastes.

Table 3
Initial and final setting time.

OWA, %	Initial setting time, min	Final setting time, min
0	160.8	378
3	181.9	380
6	210.3	383
9	221.6	387
12	227.4	389
15	231	391

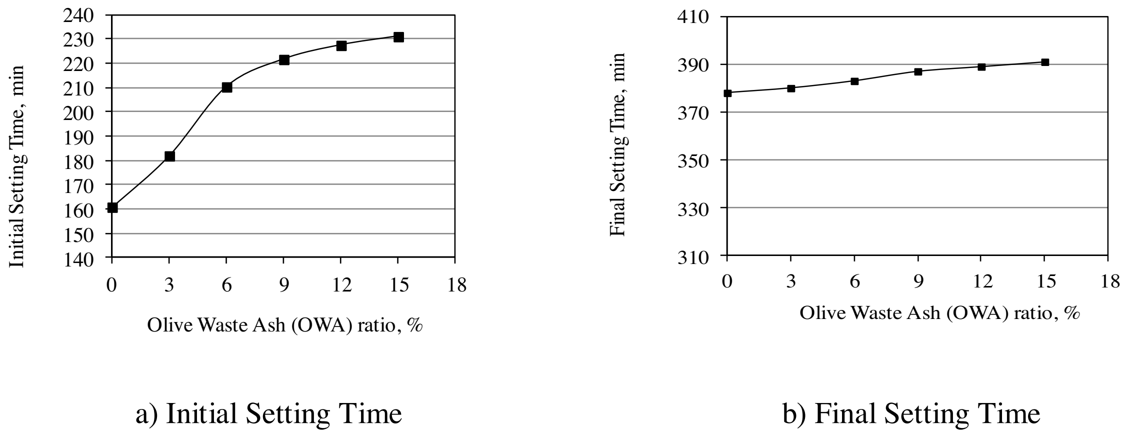

Fig. 3. Initial and Final Setting time versus Olive Waste Ash (OWA) percent.

Table 4
Autoclave Expansion for CEM-II Replacement of Olives residues.

Mix No.	OWA, %	After 24 h ± 30 min molding Initial Length mm	Final Length mm	Change in Length, mm	Expansion, %
1	0	3.210	2.865	−0.345	−0.138
2	3	2.723	2.245	−0.478	−0.191
3	6	2.830	2.245	−0.585	−0.234
4	9	2.721	2.032	−0.689	−0.276
5	12	2.531	1.689	−0.842	−0.337
6	15	1.987	1.125	−0.862	−0.345
Sample length (mm) 250					

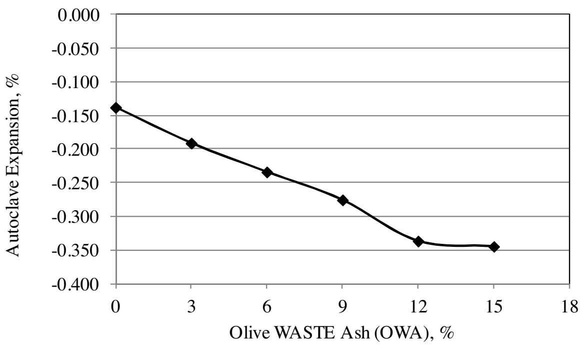

Fig. 4. Autoclave expansion versus Olive Waste Ash (OWA) percent.

4.4. Compressive strength

Cube specimens of mortar were prepared to conduct the compressive strength test according ASTM C-109. The test was made for determining 3, 7 and 28 days compressive strengths. The results obtained are shown in Fig. 5 and Table 5. The results indicated that the compressive strength of hardened blended cement paste containing different percentages,partial replacement of cement, of olive waste slightly decrease with olive waste content. This is mainly due to the decrease of

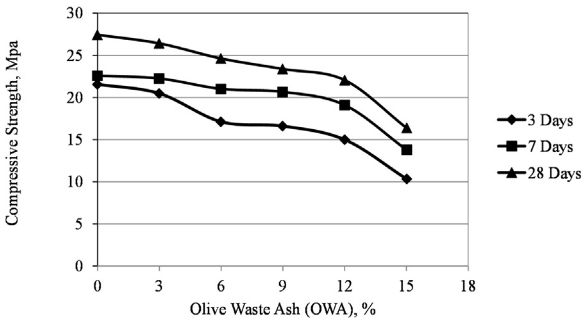

Fig. 5. Compression strength versus Olive Waste Ash (OWA) percent.

Table 5
Flexural and compressive strength for CEM-II mortar replacement of olives residues.

Mix No.	w/c	OWA, %	3 days		7 days		28 days	
			Compressive Strength, MPa	Flexural Strength, MPa	Compressive Strength, MPa	Flexural Strength, MPa	Compressive Strength, MPa	Flexural Strength, MPa
1	0.60	0	21.58	7.24	22.59	8.02	27.44	8.89
2	0.60	3	20.49	6.01	22.26	7.03	26.42	7.80
3	0.60	6	17.13	4.77	21.03	5.49	24.63	6.72
4	0.60	9	16.61	4.59	20.67	4.92	23.39	6.06
5	0.60	12	15.01	4.04	19.11	4.33	22.07	5.82
6	0.60	15	10.34	3.17	13.80	3.91	16.41	4.81

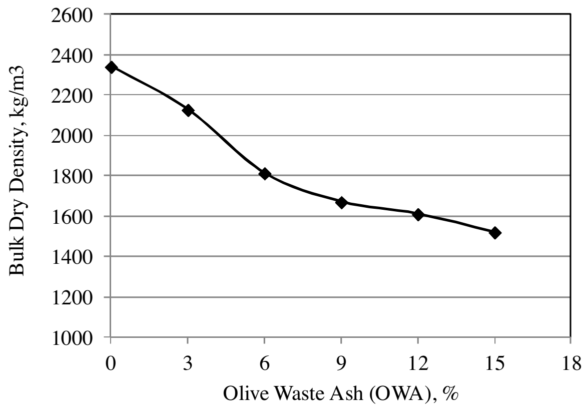

Fig. 6. Bulk density versus Olive Waste Ash (OWA) percent.

Table 6
Dry bulk density for CEM-II mortar replacement of olives residues.

Mix No.	OWA, %	Dry Mass, kg	Sat. Mass, kg	Mass in Water, kg	Volume, m^3	Bulk Dry density, kg/m^3
1	0	0.4823	0.4871	0.2810	0.00021	2340
2	3	0.2410	0.2471	0.1338	0.00011	2127
3	6	0.2191	0.2453	0.1244	0.00012	1812
4	9	0.2226	0.259	0.1257	0.00013	1670
5	12	0.2019	0.2354	0.11	0.00013	1610
6	15	0.1835	0.2218	0.1011	0.0001	1520

amount of cement in blended cement paste. This leads to a decrease in the amount of hydration products such as C3S and C2S which are responsible for strength development as well as increase of porosity (decrease of bulk density as shown in Fig. 6 and Table 6) of the blended paste. Fig. 5 shows also that when the olive waste percentage increases up to 12% the compressive strength considerably decreases. This is due to the increase in the amount of olive waste that leads to significant retard of hydration.

4.5. Flexural strength

The flexural strength of mortar for all partial replacement levels after 3, 7 and 28 days curing is plotted as shown in Fig. 7 and Table 5. Flexural strength values for olive waste partial replacement mortar in comparison with ordinary mortar are observed to decrease in a 6% to 15% value. This is attributed to the decrease in the amount of cement content as this leads to less hydration and so porosity of mortar is more pronounced. More porosity shows lower flexural strength. On other hand it believed that such reduction is due to the decrease in bond between the surface of olive waste and the cement paste.

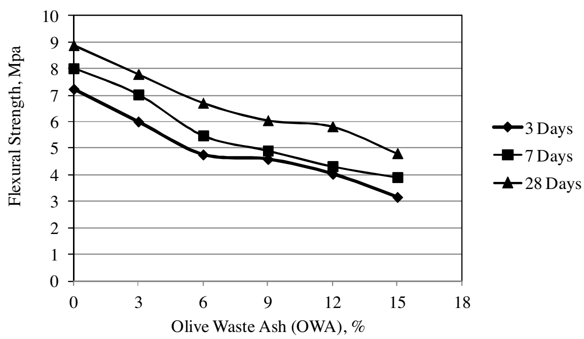

Fig. 7. Flexural strength versus Olive Waste Ash (OWA) percent.

5. Conclusions

The use of olive waste as a partial replacement of cement, especially at low percentages of replacement, is promising. This study investigated the behavior of cement paste and mortar after using olive waste. The results show that, the normal consistency of the cement pastes containing different percentages of olive waste is somehow lower than that of the ordinary cement paste and slightly decreases with increasing in replacement percentages. Furthermore, the initial setting times considerably increases with the addition of olive waste into Portland cement compared to ordinary cement paste. However, the final setting is slightly higher for blended cement paste as compared to the ordinary cement paste. Soundness test results show that the expansion considerably decreases with the percentage of olive waste. The results related to compressive and flexural strength of hardened blended cement paste containing different percentages of olive waste indicated slight decrease with olive waste content.

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