THE EFFECT OF USING ASH RESIDUES OF OLIVE FRUITS ON THE PROPERTIES OF CEMENT MORTAR

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ABSTRACT

This research aims at studying the effect of the use of the burnt olive oil waste ash (OWA) resulting from olive plant wastes as a partial cement replacement (5%, 7% and 10%) on the properties of cement mortar. The ash burning temperature varies as 600, 700, 800 and 900˚C, and time as 6, 7, 8 hours. The mortar cured in air and water were prepared with 0.42 w/c ratio and sand to water ratio of 1.5 by mass.

The results showed that the 600˚C was efficient in terms of contribution to strength, specific gravity while 7% cement-OWA replacement mixture was found to favour flowability of the mortar compared to 5 and 10% substitution. Extending OWA burning time temperature to 900˚C and 8hrs increased its porosity and water absorption of the resulting mortar. The OWA slowed down the setting time which made it suitable in the hot weather concreting practice.

Keywords

cement; olive waste ash; mortar; curing; pozzolanic materials; compressive strength

1. Introduction

Large quantities of solid olive waste which contains organic minerals accumulate every year in the countries (Palestine. Tunisia and Libya) producing olive oil[1]. This causes great harm to the environment due to its interaction with heat and humidity thereby resulting in chemical hazards. For instance, the carbolic acid, and other strong life-threatening smell emanates from the decomposition[1]. There is increase in such waste accumulation at an alarming rate due to the lack of waste management techniques, such as recycling or re-use in a positive or productive environmental friendly manner with a view to reducing the environmental pollution risks and problems[1].

Concrete industry has seen significant development in the utilization of waste materials as partial replacement for ordinary Portland cement[1]. This research aims at exploring the performance of olive waste as alternative materials in concrete production for structures. Therefore, it is expected that such utilization could provide additional safety and longer service life to concrete structures.

Recently, a number of researchers focused on the use of agricultural material waste, as a partial replacement for cement mixtures so as to improve several properties of concrete and cement mortar. A significant breakthrough was recorded especially on palm oil fuel ash, rice husk ash and date palm ash as regards their performances in OPC based concrete and geopolvmer or alkaline activated binder[25]. In this study, the burnt out and ground waste of olive fruits will be used as a partial replacement for OPC cement to see the effect of different replacement ratios on the properties of cement mortar in terms of the workability grade, absorption and compressive strength, and setting time of cement paste.

2. Experimental program

2.1 Materials

2.1.1 Ordinary Portland Cement and sand

The ordinary Portland cement, of specific weight of 3.15 and surface area of 273 m^2/kg, in compliance with Libyan specifications No.340/1997m[2] was used in this study. The fine aggregate used was of specific weight 2.57, which is within the limit of fine aggregate in compliance with the British specifications (BS882-1992)[3].

2.1.2 Olive Oil waste treatment

The olive waste ash (OWA) was obtained through burning large quantities of olive fruit wastes at constant burning time of 6 hrs at temperatures of 600˚C, 700˚C, 800˚C and 900˚C, and in different burning times, 6 hrs and 8 hrs at the specific temperature of 900˚C. The rate of raising temperature inside the oven was 20˚C/Min. The ash was left for 24 hours in the air for cooling, and then ground in the grinding machine for 10 mins before sieving through sieve No. 200 (0.075mm). The surface area of the resultant ash was measured by Blaine device in accordance with the US standards (ASTM C204-92)[4].

2.2 Mix design and sample processing

The mixture of the samples was composed of cement of 0.42:1.5:1.0 by mass of cement, sand and water, respectively while OWA was used as a partial replacement for cement with 0wt.% (control), 5wt.%, 7wt.% and 10wt.% of cement. Mixing was done with an electric mixer for 5 mins while two-layer compaction was done in metal cube mould of dimension 50×50×50 mm in size with surface dressing and leveling using 16 tamping-rod blows, according to the approved US specifications steps (ASTM C109-92)[5]. Table 1 shows the details of percentages composition of materials in the prepared mortar. For each mix 21 cubes has been treated, as 9 cubes in the air at a temperature ranging from 20 to 24˚C, and 12 cubes in Jerry water according to US specifications (ASTM C109-92)[5] at a temperature ranging from 18 to 22˚C, and to maintain the purity of the water used, the treatment water was changed every 15 days.

Table 1: Details of cement mortar mixing quantities

Batch No.	Sample code	Cement weight (gm.)	Ash percentage (%)	Ash weight (gm.)	Fine aggregate weight (gm.)	Water weight (gm.)
S1	OPC	2500	0	0	3750	1050
S2	OWA60085	2375	5	125	3750	1050
S3	OWA60087	2325	7	175	3750	1050
S4	OWA600810	2250	10	250	3750	1050
S5	OWA70085	2375	5	125	3750	1050
S6	OWA70087	2325	7	175	3750	1050
S7	OWA700810	2250	10	250	3750	1050
S8	OWA80085	2375	5	125	3750	1050
S9	OWA80087	2325	7	175	3750	1050
S10	OWA800810	2250	10	250	3750	1050
S11	OWA90085	2375	5	125	3750	1050
S12	OWA90087	2325	7	175	3750	1050
S13	OWA900810	2250	10	250	3750	1050
S14	OWA90065	2375	5	125	3750	1050
S15	OWA90067	2325	7	175	3750	1050
S16	OWA900610	2250	10	250	3570	1050

3. Results and discussion

3.1 Physical analysis of olive waste ash

With increase in burning temperature and time of olives waste, the specific weight and the surface areas of ash resulting from the burning process decreases as shown in Table 2. The decreases could be due to volatility of the amorphous fine particles like carbon or other debris there by leading volume and surface area reduction as temperature or duration increases. The physical properties and chemical composition of OWA are shown in Table 2.

Table 2: Physical properties of olive waste ash samples

Sample code	Surface area (cm^2/gm)	Specific weight
OWA6008	7461	2.28
OWA7008	5779	2.18
OWA8008	4439	2.12
OWA9006	4751	2.21
OWA9008	3310	2.09

The surface area and specific gravity (Table 2) reduced by 40.5% and 7.1%, respectively as the temperature increased from 600-800˚C whereas at 900˚C increasing the burning duration from 6-8hrs caused the reduction of 30.3% and 5.4%, respectively from original values of 4751 cm^2/gm 2.21.

3.2 Oxide composition of olive wastes ash

Through the results of the chemical composition of olive wastes ash (OWA) samples by (XRF) device, shown in Table 3, it can be seen that temperature and burning hours have impact on the oxide composition of OWA. The sample burnt at 900˚C has more calcium and alumina contents while more burning duration favours the formation of silica at the same temperature. Besides, the increase in silica content from 18.22 to 31.98% (75.5% increment) as the temperature increases from 600 to 900˚C while potassium depleted significantly at that latter temperature.

Table 3: Oxide composition of olive waste ash samples

Chemical element	Sample code				
	OWA6008	OWA7008	OWA8008	OWA9006	OWA9008
(CaO%) Calcium	21.09	19.62	20.74	23.39	20.82
(SiO2%) Silica	18.39	23.6	22.94	18.22	31.98
(Al2O3%) Aluminum	1.23	1.27	1.26	1.21	1.44
(Fe2O3%) Iron	1.88	3.01	4.32	2.21	5.90
(K2O%) Potassium	44.96	42.24	40.99	42.2	31.25
(MgO%) Magnesium	0.64	0.75	0	0.79	0.53
(SO3%) Cobalt	5.45	3.88	3.95	4.93	2.78
(P2O5%) Phosphorus	6.19	5.46	5.6	6.87	4.99
(TiO2%) Titanium	0.18	0.17	0.2	0.17	0.26
(Cl%) Chlorides	1.42	2.15	1.81	1.03	0.55

3.3 Properties of fresh mortar and cement paste

3.3.1 Flowability and workability

From the results of the flow table for the workability values of the samples burnt at 600 deg C for 5, 7 and 10% shown in Figure 1. It is clear that 5% cement replacement percentage samples ($OWA_{60085}C$) and 10% ($OWA_{600810}C$) recorded a decline in workability values while $OWA_{60087}C$ (7%) were more homogeneous with high workability values, very close to the result of the reference sample (OWA_0C). This suggests that less the presence of CaO, SiO_2 and Al_2O_3 in the mortar with 10% OWA will definitely reduce the workability as seen in Figure 1. When the quantity of OWA was too low (5%) in concrete mixture, there could be excessive voids in the resultant mortar thereby increasing the interparticle sand grains friction which resulted in low workability as shown in the figure. The closeness of 7% OWA flowability to the control sample indicates that effective parking that ensured the control over voids distribution. The quantity of CaO, SiO_2 and Al_2O_3 is less than that of 10%OWA thereby causing the reduction in water demand in the mixture.

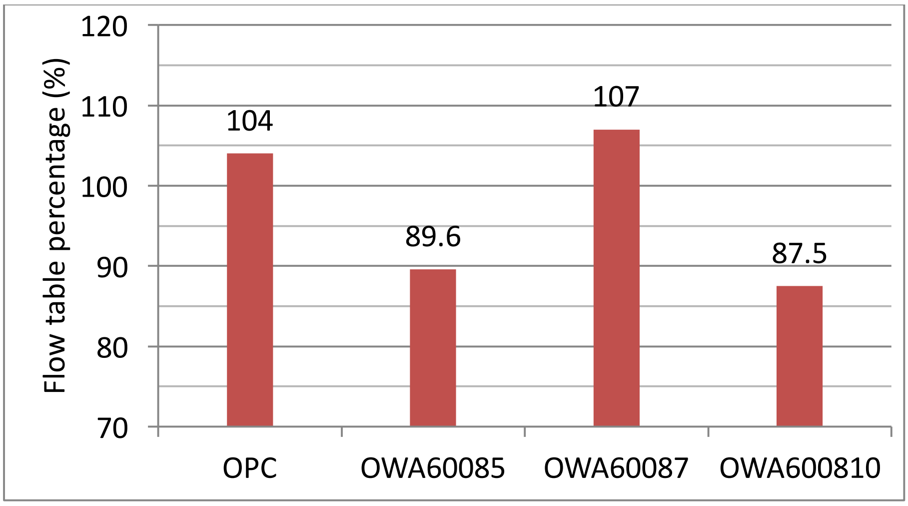

Figure 1: Effect of replacement percentage on flow

It was also observed in Figure 2 that the inclusion of OWA change the range of initial and final setting time which decreased from 135 mins of the control to 130.9 and 15 mins for 5.7 and 10% OWA additions, respectively as shown in Figure 2. This suggests that the more the quantity of OWA the more the delay of initial setting of the sample due to pozzolanic reaction and dilution of tricalcium aluminate portion of OPC that precede hydration reaction or the initial formation of forming calcium aluminium hydrate (CAH). The C_3A in the composition increases with OWA content and reacted with gypsum to from calcium-sulfo-aluminate hydrate (CSAH) – a retarding product. CSAH deposits and forms a protection film on the cement particles to hinder the hydration of C_3A and therefore delay the setting time of cement as noted in OWA 10% cement replacement. The hydration of alite and belite follows the initial setting spontaneously to form calcium silicate hydrate (C-S-H) in higher OWA content compared to low cement-OWA substitution.

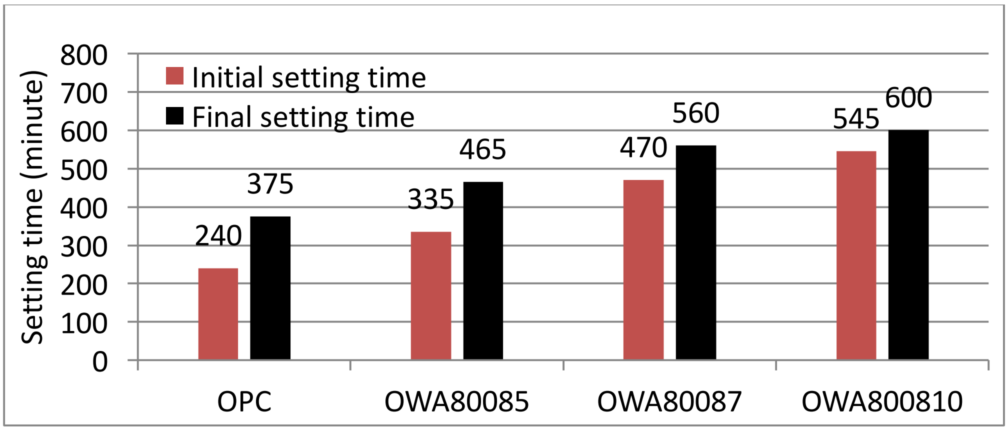

Figure 2: Effect of replacement percentage on setting time

Figure 3 shows the effect of burning time on setting time for the ash burned at temperature 900˚C and with replacement percentage 10%. The initial and final setting time of cement mortar decreased significantly, with increasing in burning time from 6 to 8 hours. The reason for this is due to increase in OWA particle surface area that resulted in more coating paste and enhanced particle reactivity as evidenced in earlier initial (485 mins) and final (540 mins) setting time in 8 hrs compared to 6 hrs of burning time of 555 and 675 mins, respectively.

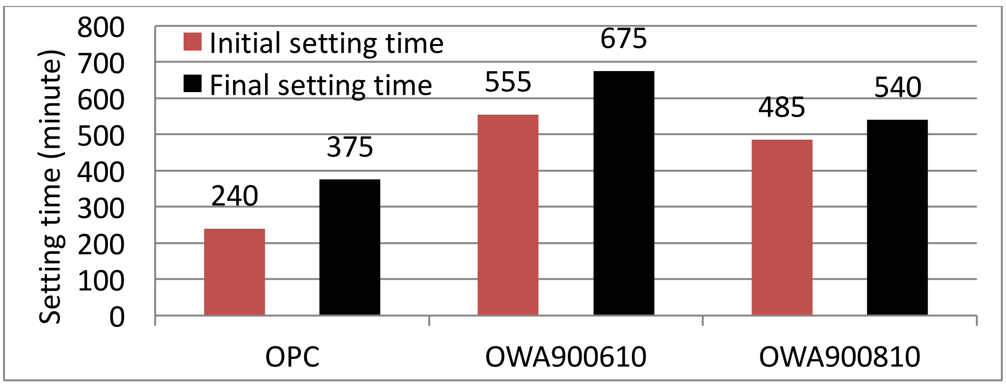

Figure 3: Effect of burning time on setting time for 10% replacement percentage

3.4 Compressive strength of mortar

Figure 4 shows the effect of burning temperature on the compressive strength for 5% cement replacement cured in the air. The OWA burnet at 600˚C appeared to perform better in compressive strength in comparison to those processed at higher temperatures. The rate of strength development was very close to the reference or control sample. However, the pozzolanic reactivity began to take effect at 28 days which indicates that about 20% of strength was gained as can be seen in Figure 4. However, there was no significant strength gained beyond 28 days in all the tested samples. This suggested that OWA underwent a limited pozzolanic reaction. This is more evident upon closely observing the OWA burnt at 700-900˚C for 8 hrs in Figure 4. Burning OWA beyond 600˚C appeared to have converted silica from amorphous phase to crystalline phase thereby affecting its reactivity.

With 100˚C margin from 600˚C, the 7, 28 and 90-day strengths were reduced by 40.1, 35.6 and 34.4%, respectively. The increment is closed to that observe at 900˚C when the difference becomes 38.5%, 26.1% and 35.1%. These values reduced to 13.9, 32 and 13.4% when the temperature margin is 200˚C that is at 800˚C, which signifies better performance compared to 700˚C and 900˚C. This suggests that the proportion of amorphous and crystalline silica at that temperature (800˚C) is at optimum and since the samples burnt at 600˚C contains more amorphous silica, the strength was noted to be the highest observed within the blended and the reference or control samples at 28 and 90 days. The burnt ash samples at 600˚C recorded 90-day compressive strength of 18.8 MPa, which was higher than the reference sample value by 27.8%.

From Table 2, the higher strength recorded in the 600˚C burnt sample could be attributed to its higher specific gravity compared to others samples whose specific gravity decreased with increasing burning temperature.

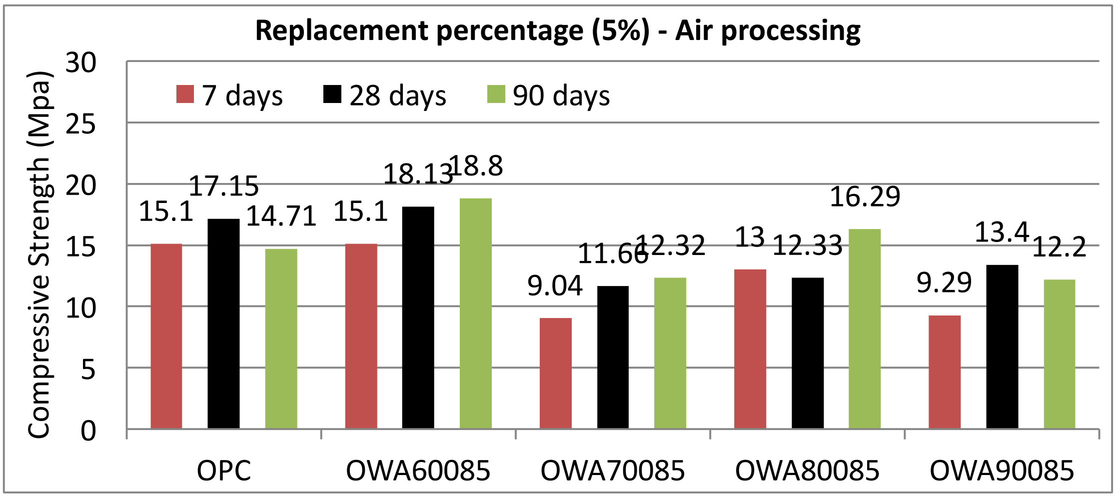

Figure 4: Effect of burning temperature on compressive strength

Figure 5 shows the effect of burning time on the absorption rate of replacement percentage of 7%. At 6 hrs duration at operating temperature of 900˚C, the absorption is found to be less than at 8 hrs by 15.4%. It implies that excessive exposure of the same leads to formation of more voids or pores with the interstices of the ash. The values recorded at 6 hrs is 4.5% higher than the control.

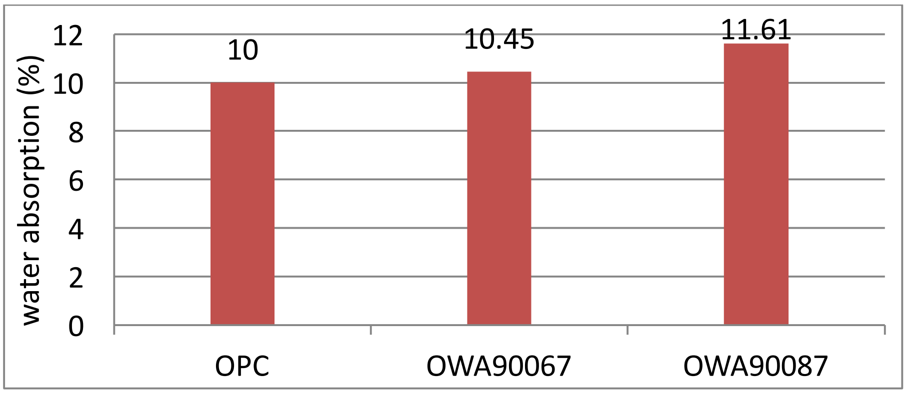

Figure 5: Effect of burning time on absorption at replacement percentage 7%

Figure 6 shows the effect of burning temperature on porosity at replacement of 10%. After 28 days of treatment in the water, it was noticed that the addition of burned ash at temperatures 600˚C, 700˚C and 800˚C led to decrease in porosity less than that of the reference sample, while adding the burnt ash at 900˚C led to increased porosity, that is increasing the proportion of air spaces inside the cement mortar, therefore leading to weakness in the compressive strength of the cement mortar.

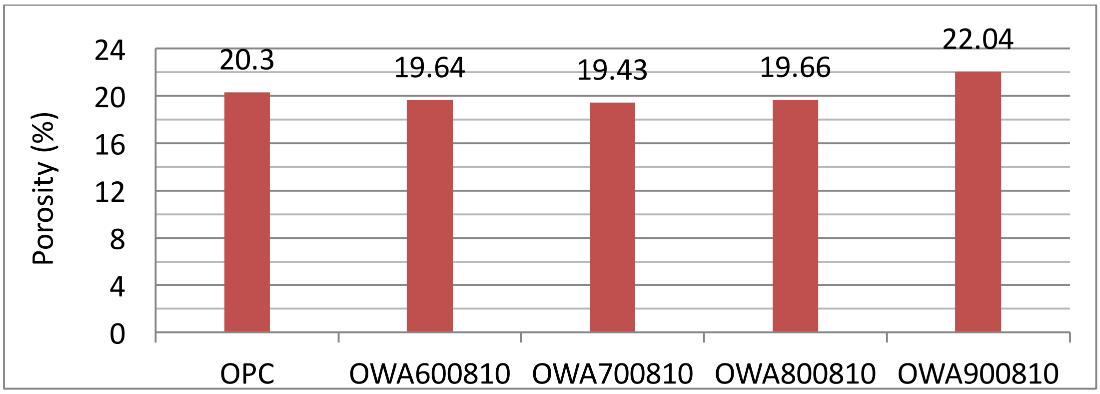

Figure 6: Effect of burning temperature on porosity at replacement percentage 10%

After 28 days of treatment in the water as shown in Figure 7, the effect of the burning temperature on the permeability at replacement percentage of 5%, was noticed to reduce at 600˚C (1.26×10^{-14}m/s) and it is 37% of the control sample (2.01×10^{-14}m/s). However, increment in permeability of the ash burnt at 700˚C ($2.83\text{x}10^{-14}$ m/s) increased by 41% compared to the control and 124% with reference to that of 600˚C. It appears the porosity of the sample treated at the temperatures of 800 and 900˚C are equally distributed.

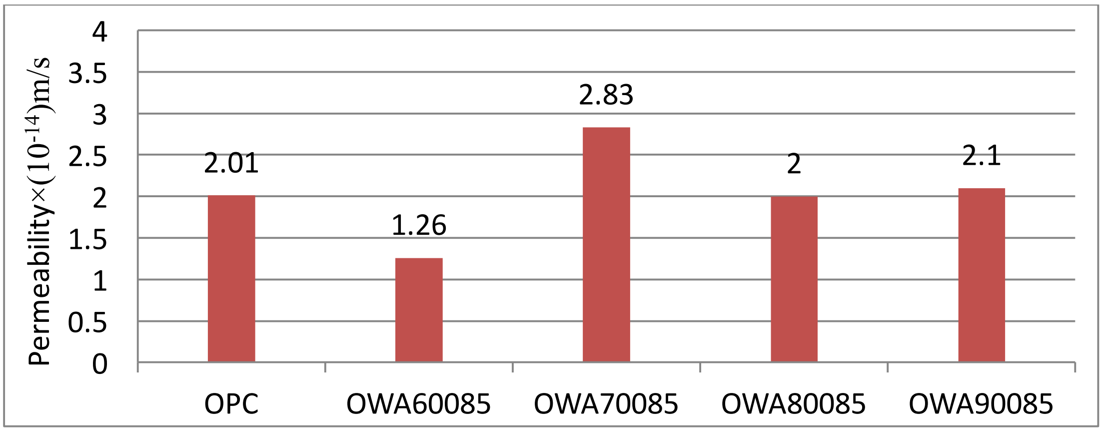

Figure 7: Effect of burning temperature on permeability coefficient at replacement percentage 5%

4. Conclusions

The following conclusions can be drawn from the results obtained from the treatment of olive waste ash (OWA) as partial cement replacement in blended mortar in terms of specific gravity, transport properties, workability and setting time:

- Burning temperature and burning time of OWA had an impact on the chemical composition and physical properties of the resulting ash most evidently, the specific gravity.
- With the increase in the replacement percentage of OWA, initial and final setting time of cement paste increased significantly due to prolonged or delayed pozzolanic reaction.
- Burning temperature had significant effect on the compressive strength of OWA blended cement mortar cured in the air. The ash was observed to perform better in terms of strength and permeability coefficient when it was treated at the 600˚C.
- Even at maximum treatment temperature of 900˚C, 6 hrs period of burning of OWA favored water absorption performance of OWA blended mortar than 8 hrs when the porosity was also noted to be worsened compared to lower treatment temperature and the control samples.

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