Available Online at http://www.journalajst.com

ISSN: 0976-3376

ASIAN JOURNAL OF SCIENCE AND TECHNOLOGY

Asian Journal of Science and Technology
Vol. 10, Issue, 01, pp.9348-9352, January, 2019

RESEARCH ARTICLE

UTILISATION OF OLIVE MILL WASTE AND COAL ASHES IN NORMAL CONCRETE MIXES

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ARTICLE INFO

Article History:
Received 29th October, 2018
Received in revised form
15th November, 2018
Accepted 20th December, 2018
Published online 30th January, 2019

Key words:
Olive mill waste,
Normal coal ash waste,
Portland cement concrete,
Setting time,
Workability,
Compressive strength,
Non-structural use of concrete

ABSTRACT

The main objective of this research investigation is to study the effects of Olive Mill Waste (OMW) ash and Normal Coal (NC) ash on some engineering properties of normal strength concrete such as workability and compressive strength. This follows a worldwide desire for more sustainable concrete mixes utilising such wastes. A more environmentally-friendly approach would reduce the cement content in a concrete mix and replace it by wastes. Overall, there are numerous benefits associated with the recycling of such waste products for the provision of a substitute concrete mix. Firstly, replacing a certain amount of cement with OMW and NC ash would reduce the overall cost of the concrete mix. Additionally, recycling theses wastes would decrease the levels of pollution which would otherwise increase the spread of pests and negatively impact the health of the population. As well as aiding the achievement of a cleaner environment, regenerating these wastes for the purpose of creating a concrete mix would eliminate the costs of their disposal. In order to achieve this goal, different percentages e.g. 10, 20, 30 and 40% of both OMW ash and NC ash were used as an additive and/or replacement in the production of normal concrete strength mixes to obtain a concrete grade of 40 MPa. Four sets of concrete mixes were cast to test the workability and the compressive strength based on the changes of the percentage of OMW and NC ashes by weight of cement. The slump test results ranged from 58 to 110 mm with the addition and/or replacement of OMW and NC ashes. Moreover, the compressive strength is decreased as the percentage of adding and /or replacement of OMW and NC ashes is increased.

Citation: Osama Kamel Adwan and Faroq Riad Maraqa, 2019. "*Utilisation of olive mill waste and coal ashes in normal concrete mixes*", *Asian Journal of Science and Technology*, 10, (01), 9348-9352.

INTRODUCTION

More than 750 million olive trees are cultivated worldwide, with the greatest numbers being planted in the regions of the Mediterranean [Hytiris, 2004]. Around ¾ of the global olive oil production takes place in European with approximately 97% of European production coming from Spain, Italy and Greece [Armesto, 2001; Cuenca, 2013]. The history of olive oil dates back to centuries and even today, thousands of families are engaged in its production. Due to the extensive cultivation of olive trees in the Mediterranean, olive waste is a common form of agricultural waste in this region. The process of pressing the olive fruits results in the extraction of olive oil leaving a residue of solid waste. The solid wastes of olive fruits are dark colored wastes which consist of large amounts of organic matter. When dumped, the oil reacts to yield hazardous chemicals such as phenols and other aromatics [Bani Odi, 2007; Al-Akhras, 2010]. Additionally, the solid olive waste contributes to the pollution of the environment hence causing an environmental hazard [Esra, 2001].

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High amounts of waste require relatively high costs in processing for environmental protection. Owners of olive trees do not benefit from these wastes produced from olive oil, resulting in their disposal nearby water drainage networks in public spaces and residential areas. This generates bad odours, resulting in consequent environmental detriment which may subsequently lead on to affect human health via the spread of diseases [Cuenca, 2013]. Furthermore, it should be acknowledged that in Palestine, beside olive oil solid or liquid olive oil waste, many other types of wastes are also dumped in the common regions without any restrictions or limitations due to absence of an environmental law, leading to further exposure to pollution and problems of extinction. Nonetheless, olive oil waste is produced in large quantities due to the high dependency of the population on the agriculture of olive trees in particular, which are planted in many regions of Palestine [Bani Odi, 2007; Shaheen, 2004]. Such region include Wadi Zeimar in Nablus-Tulkarm region whereby OMW is discharged, flowing with municipal wastewater in the Alexander River, behind the green line (the 1967-cease fire border between Israel and Jordan) towards the Mediterranean. This has caused severe environmental problems which have led to the death of aquatic life in the river [Shaheen, 2004]. The effective use of olive oil burned wastes and replacing these waste materials with cement in order to produce concrete mixes for non-structural applications is an alternative method for producing cement mixes [Bakisgan, 2009; Naik, 2003]. This research investigation aims to contribute partially in reducing the environmental problems through the utilization of these wastes – olive waste ash- (OWA) as a replacement to Portland cement in concrete mixes and consequently reduce the water damping cost and/ or recycling costs of such wastes.

Experimental Programme: The concrete mixes were prepared in this investigation using the local materials available in Gaza Strip – Palestine. Aswan's block factory (Rafah region) supplied the fine and coarse aggregates. Obaied concrete plants in Gaza city provided Ordinary Portland cement (OPC). Additionally, Al-Amana olive press mill in Gaza supplied the olive oil wastes, and Al-samra bath for normal fly ash. Furthermore, the investigators obtained specific quantities of OMW ash from the University of Palestine.

The target compressive strength of all concrete mixes was 40 MPa which was used as a reference for all concrete mixes. All concrete mixes were prepared using OPC, natural sand and uncrushed coarse aggregates with a maximum nominal size of 20 mm and a wet relative density of 2.64. The water-cement (w/c) ratio was fixed at 0.48. The slump test for workability was measured for all concrete mixes. The water content of the concrete mixes varied between 195-220 litter/m^3 in order to obtain a slump within the region of 70-80 mm. Table 1 demonstrates the compositions of these reference concrete mixes. Overall, four sets of concrete mixes were made (total of 40 cubes of 100x100x100 mm were cast) –see Table 2. Figures 1-2 show some test procedures used to investigate the workability of all mixes based on the percentages changes of the OMW and NC ashes.

RESULTS AND DISCUSSION

Slump (consistency): It is known that the slump test depends on the workability of concrete. However, the behavior of adding and / or replacing material to concrete mixes limits the value of slump. OMW ash requires much more water to obtain high slump values. Overall, in concrete tests, it was found that slump values ranged from 58 to 80 mm for all percentages of OMW ash used in this investigation for both types of concrete mixes. Slump for concrete containing OMW ash as an additive and replacement: It has been established that the relationship between concrete slump and the percentage of adding and /or replacing of OMW ash depends on the proportion of the concrete mix. However, generally when OMW ash was added or replaced to concrete mixes the workability of concrete mixes was barely affected. This is essentially because OMW ash created more voids as the percentage increased. Therefore, more water was needed to get the desired slump. Figure 3 shows the slump test results for all concrete mixes (including adding and/or replacing). Results showed that as the percentage of adding and/or replacing increases the slump decreases slowly and linearly as shown in Figure 3. It appears that the values of slump consistency ranged from 58 to 80 mm. It is worth stating that there are no high values observed meaning that workability is not high. From Figure 3 slumps for concrete mixes were 80, 76, 70, 64 and 58 mm for adding 0, 10, 20, 30 and 40 % OMW ash respectively. Moreover, slumps for concrete mixes were 80, 80, 78, 75 and 70 mm for replacing 0, 10, 20, 30 and 40 % by weight of cement of OMW ash respectively.

Slump for concrete containing Normal Coal (NC) ash: The relationship between slumps for concrete mixes having NC ash depends on the amount of NC ash added and/or replaced to the concrete mix. Figure 4 shows that values of slump increases as adding and/or replacing of NC ash increases. The values of slump for NC ash as an additive were 80, 85, 89, 95 and110 mm ranging from (80 mm to 110 mm). Whereas, the values of slump for NC ash as a replacement were 80,90,100, 115 and 117 mm at 0, 10,20, 30 and 40 % respectively.

Compressive Strength: This paragraph aims to analyse the test results to show how concrete behavior in particular compressive strength will change as a result of the volumetric replacement and/or adding of OM ash and NC ash with cement when compared with a standard concrete mix made of ordinary Portland cement (OPC) at a target compressive strength of 40 MPa.

Effect of using OMW ash on compressive strength: The relationship between compressive strength as a percentage of adding and/or replacement depends on the quality and specification of material use, particularly when OM ash is used in concrete mixes with different percentages. Figure 5 shows compressive versus the percentage of OMW ash as an additive. It is clear that there is a decrease in a compressive strength as the percentage of additive increases. The compressive strength as an additive is 44.61, 42.1, 38.24, 32.51 and 24.23 MPa at 28 days for 0, 10, 20, 30 and 40% respectively. The percentage drop reflecting those percentages 5.63, 14.28, 27.12 and 45.68% respectively when OMW ash used in concrete mix as a replacement with different percentage. Figure 6 shows compressive strength versus percentage of OMW ash as a replacement. Again, the same trend was observed as before. The compressive strength for each percentage as a replacement is 44.61, 35.2, 30.4, 22.4 and 18.3 MPa at 28 days for 0, 10,20,30 and 40% respectively. The compressive strength percentage dropped reflecting the following 21.1, 31.9, 49.8 and 59% respectively. It has been noticed when the percentage replacement increases the concrete becomes brittle.

Effect of using normal coal ash on compressive strength: The trend between compressive strength and NC ash when added and/or replaced to the concrete mix is decreased as the percentage increases. From Figures 7 and 8 for the reference concrete mix- 40 MPa, the compressive strength where NC ash are used as an additive are 44.61, 30.2, 25.60, 23.40 and 19.5 MPa for 0, 10,20,30 and 40% respectively. This showed a decrease in compressive strength of 32.30, 42.61, 47.60 and 56.30% respectively from the original reference concrete mix value. Furthermore, when comparing concrete mixes using NC ash as a replacement, it is noticed that at 10, 20, 30 and 40% a decrease in compressive strength of 44.40, 58.1, 63.70 and 70% is shown respectively. This means that using NC ash as an additive in concrete mixes gives slightly better results when comparing to concrete mixes made by NC ash as a replacement.

Comparison between compressive strength for concrete mixes containing OMW ash and other containing NC ash: Figures 9 and 10 give the basic trend of the percentage of adding and replacing by OMW ash and NC ash versus compressive strength at 28 days.

Table 1. Concrete mix proportions for the reference one

C	S	CA	W	W/C
Kg/m^3	Kg/m^3	Kg/m^3	L/m^3	
406.75	572.4	1216.35	195-220	0.48

C= cement; S=sand; CA=coarse aggregate; W=water; W/C= water-cement ratio

Table 2. Compositions of all concrete mixes of OMW ash and coal ash

C	S	CA	OMW ash	Coal ash	% Replacement	% Adding
Kg/m^3	Kg/m^3	Kg/m^3	Kg/m^3	Kg/m^3	by Wt.	by Wt.
406.00	572	1216	0	0	0	0
365.40	572	1216	40.60	40.60	10	10
324.80	572	1216	81.20	81.20	20	20
284.20	572	1216	121.80	121.80	30	30
243.60	572	1216	162.40	162.40	40	40

C= cement; S=sand; CA=coarse aggregate; W=water; W/C= water-cement ratio

Figure 1. Preparing the concrete mix components by hand

Figure 2. Slump test of concrete mix of 30% of OMW ash by weight of cement

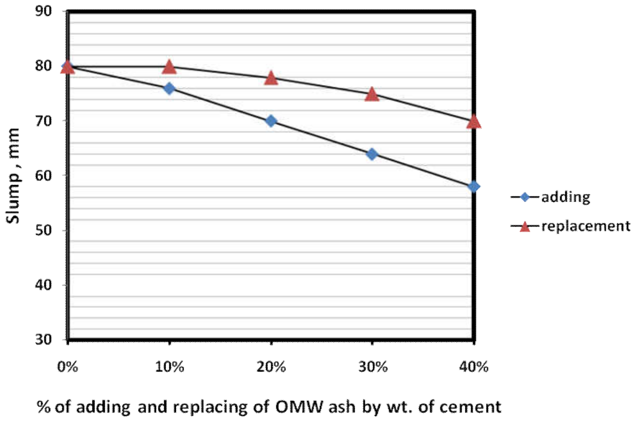

Figure 4. Percentage of adding and replacing of OMW ash versus slump

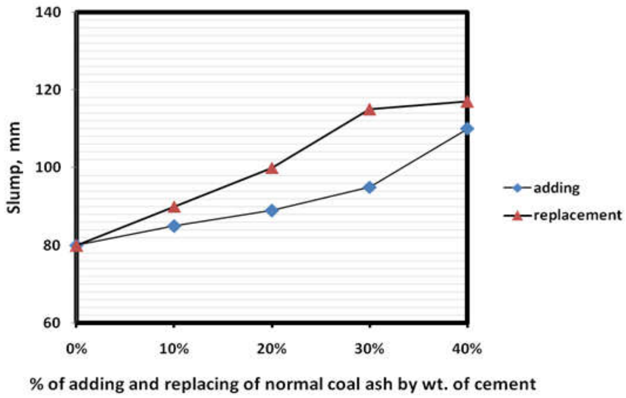

Figure 5. Percentage of adding and replacing of NC ash versus slump

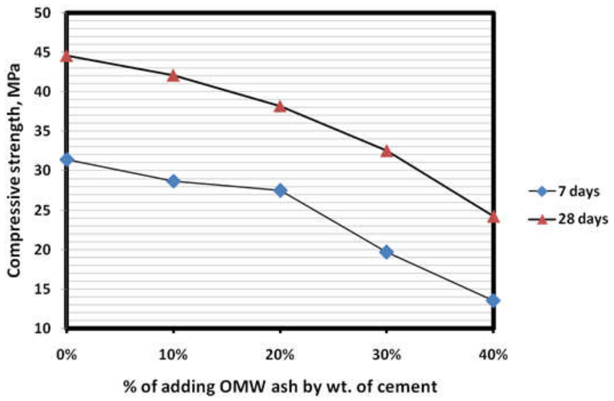

Figure 6. Compressive strength of concrete for various % of adding OMW ash

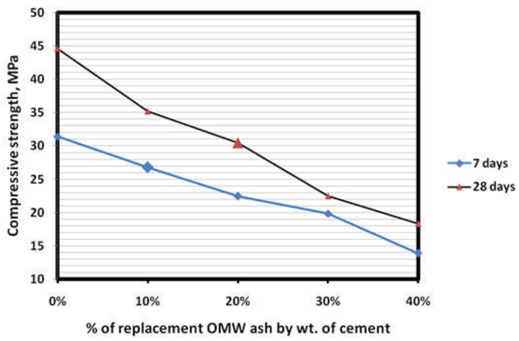

Figure 7. Compressive strength of concrete for various % of replacement OMW ash

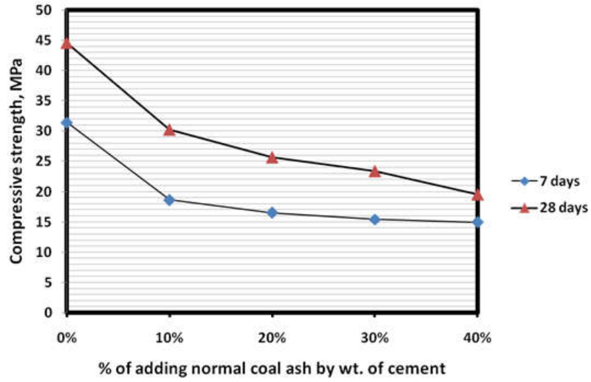

Figure 8- Compressive strength of concrete for various % of adding NC ash

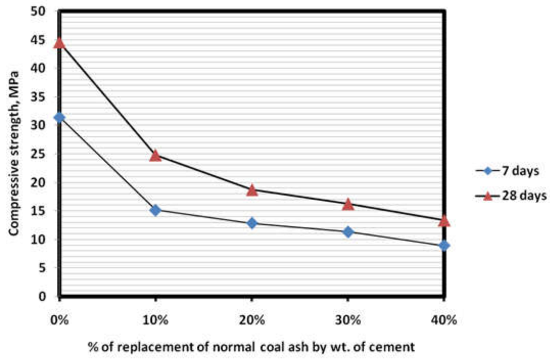

Figure 9. Compressive strength of concrete for various % of adding NC ash

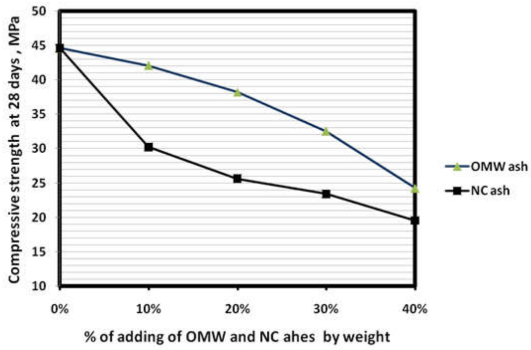

Figure 10. Compressive strength of concrete for various % of adding ashes

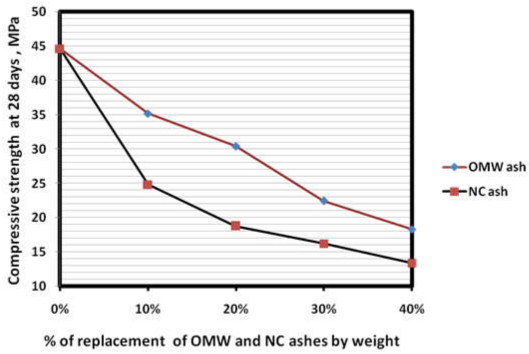

Figure 11. Compressive strength of concrete for various % of replacing ashes

As a result of a volumetric adding of both materials to the concrete mixes; compressive strength decreases as the percentage of both additive increases as shown in Figure 9. At zero adding, the compressive strength was 44.60 MPa whilst at 10% adding by OMW ash or NC ash; the compressive strength was 42.1 MPa and 30.22 MPa which is a decrease by 5.63% , and 32.26% respectively. At 20% adding, compressive strength was 38.24 MPa which is decrease of 14.28% from the original value of OMW ash, but compressive strength for NC ash was 25.64 MPa accounting for a 42.52% decrease. For 30 % and 40% adding; the compressive strength dropped to 47.52% and 56.2% respectively when adding NC ash as a percentage of cement by weight. On the other hand, the same relationship was obtained when replacing OWM and NC ashes by weight of cement as a percentage- See Figure 10. It is worth stating that OMW ash results gave higher compressive strength at all percentages added and/or replaced. This is may refer to the high carbon content in OMW concrete mixes when compared with the other concrete mixes, which had led to an increase in concrete hardening and hence caused the concrete samples to become more brittle as confirmed by Armesto *et al.* [2] in his investigation.

Conclusion

Based on the results obtained and analysis discussed herein the followings are concluded:

Conclusion on OMW waste ash

- When OMW waste ash is used in concrete mix it requires along duration to cure i.e. setting is too long.
- Slump results of concrete mix samples in replacement are better than results of adding OMW ash. This is basically due to the less water content of the later one.
- Portland cement concrete having OMW ash up to 20% of adding by weight of cement can give the target required compressive strength. However, for concrete mixes having an additive of more than 20% the compressive strength is reduced significantly and thus such mixes can be used to produce concrete hollow blocks.
- As the percentage of adding and/or replacement of OMW ash increases, compressive strength for all decreases by particularly high percentages.

Conclusion on NC waste ash

- Slump test results in replacement are as same as values of adding NC ash in concrete mixes.
- Using NC ash as an additive in concrete mixes gave better results when comparing results of concrete made by NC ash as a replacement i.e., 10% of adding process can give values near the target compressive strength.

Acknowledgments

The authors wish to acknowledge the support provided for this research investigation by the University of Palestine-Gaza-Palestinian Authority as part of this study has been conducted there.

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