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Experimental Study of Using Organic Waste Ash (OWA) Instead of Cement in Concrete

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ABSTRACT:

In this experimental study, the mechanical strength properties of concrete using 5, 8 and 12% of organic waste ash (OWA) instead of cement are investigated. The results showed that the 28 days compressive and tensile strength and slump of the concrete made by OWA in compared with ordinary concrete were 0.99, 0.99, and 0.8, respectively, for 5% OWA instead of cement, 0.96, 0.9, and 0.69, respectively, for 8% OWA instead of cement, and 0.9, 0.9, and 0.09, respectively, for 12% OWA instead of cement.

Key words: Concrete, OWA, Mechanical strength, Cement.

1- Introduction

Based on the growing need for energy, "waste-to-energy" (WTE) programs seem to be a proper solution, which will use organic wastes as fuel to provide energy and at the same time help to control global warming by reducing the greenhouse gases produced due to improper landfilling of organic materials [1]. Remaining organic waste ash from this process could be used for other purposes such as producing compost or as construction materials. Due to the high price of cement, an eligible replacement for cement would seem a good solution to reduce the final costs of civil projects, in specific in third world countries where economic factors role the main part in the construction of industry. Wood ash (WA) is the residue generated due to combustion of wood and wood products (such as chips, sawdust, bark, etc.), it is organic and inorganic residue remaining after the combustion of wood or unbalanced wood fiber [2]. Wood ash can be used in controlled low strength materials, low and medium strength concrete, masonry products, materials for road base, and blended cement [3]. Experiments showed that bottom ashes from wood bio plan can be partly used as a replacement for limestone to produce Portland cement due to the high level of calcium carbonate in it without any harmful effects on cement [4]. Organic waste ash (OWA) used in this study is the residue generated due to combustion of about 80% waste wood (from oak, almond, milk vetch, etc.) and 20% animal waste with total density of 890 kg/m3 which is used in a common WTE program in rural regions of Iran for many years. The generated OWA in rural regions mostly is used as compost, the remaining is landfilled or used to reduce the PH of the soil. On the other hand, for WA, approximately 70% of it is land filled, 20% is applied on land as a soil supplement, and remaining 10% is used for miscellaneous applications [5, 6, 7, 8 and 9] including construction materials, and pollution control.

It should be noted that due to high carbon content in WA and OWA, their use criteria should be limited to low and medium strength concrete needs [2], therefore there are not many reports about the applications of WA or OWA as a construction material, in cement-based materials especially.

Several studies around the performance of concrete using fly ash, wood ash, and waste wood ash (WWA) have been done [2 to 15] but none of them investigated the effects of adding animal waste ash to WA on the mechanical properties of manufactured concrete. Naik et al. investigated on the economic benefits of using WA as a part of the total cementitious materials in concrete and concluded that only in Wisconsin city, approximately 120,000 to 500,000 US dollars annually could be saved by using only 5 to 12% wood ash [10]. Sashidhar investigated the influence of adding different percentages of wood ash (0 to 30%) to concrete on its resistance in acid attack with concentrated acids such as H_2SO_4 and HCL and concluded that 10% of wood ash is the optimum rate to confront acid threats [15]. Oye reported that wood bottom ashes have no components which would be harmful to cement [4]. Olokode et al. reported that the best ratio of WA to get the desired mechanical properties from concrete is about 5 to 10% [14].

2- Methods and materials

The cement used in this experiment is Portland type 2 with a specific gravity of 3500 kg/m^3. Saturation density of sand used as fine aggregate in this study is 2440 kg/m^3. Sand compliance with ASTM standards is shown in Figure 1. In this study scoria with the saturated density of 2550 kg/m^3 is used as coarse aggregate in accordance with ASTM standards. This compliance is shown in Figure 2. OWA used in this study is a mixture of milk vetch ash, oak and almond wood ash, and animal waste ash. The amount of OWA used in this study passing sieve #100 (150 µm) and sieve #200 (75 µm) was found to be 34.5% and 21.67% respectively. Based on the obtained results, the unit weight value of OWA determined to be 890 kg/m^3. To determine the chemical composition of the OWA used in this study a XRF test based on (ASTM E 1621, 2005) regulation has been used which the obtained results are shown in Table 1. Based on the obtained results 29.8 % of OWA is based on the oxides of aluminum, silicon, and calcium. Also, chemical analysis results (Table 1) showed that the major oxides in the OWA are silicon dioxide (SiO_2), lime (CaO), aluminum oxide (Al_2O_3), potassium oxide (K_2O) and iron oxide (Fe_2O_3) respectively.

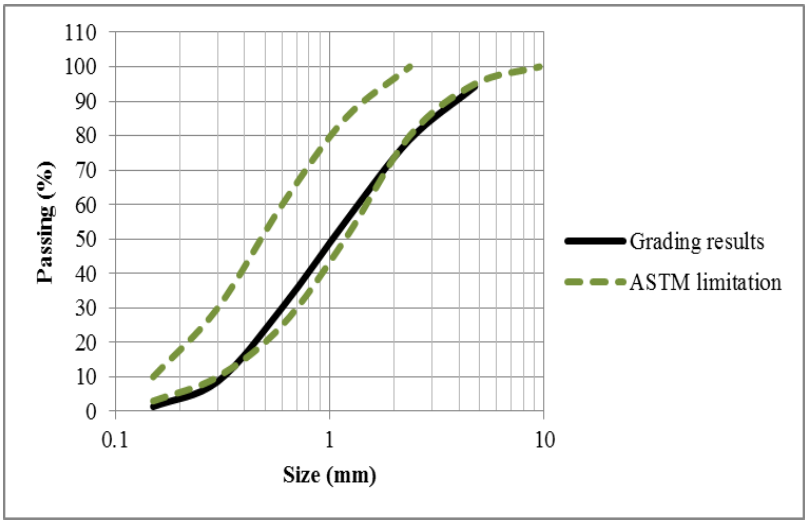

Fig.1. Fine aggregates compliance with ASTM standards.

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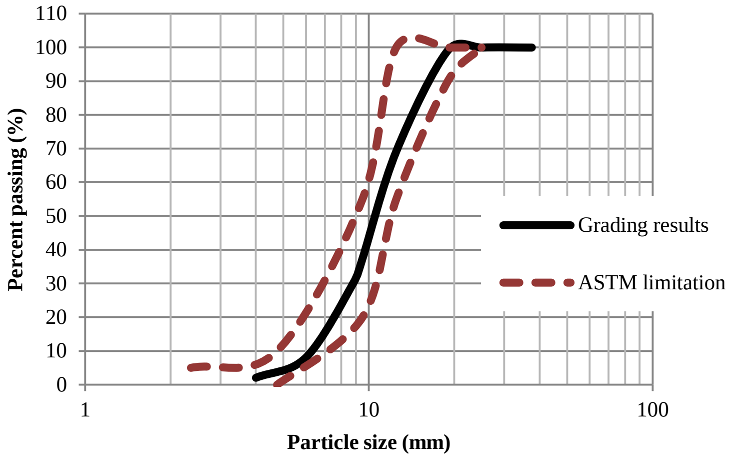

Fig.2. Coarse aggregates compliance with ASTM standards.

Table 1: Chemical analysis results on the OWA

Analysis Parameters	OWA
SiO_2 (%)	37.5
CaO (%)	16.7
Al_2O_3 (%)	7.8
K_2O (%)	6.7
Fe_2O_3 (%)	5.3
MgO (%)	4.1
Cl (%)	1.3
P_2O_5 (%)	1.2
SO_3 (%)	1.0
TiO_2 (%)	0.42
SrO (%)	0.13
Na2O, Available alkali (%)	1.1
L.O.I (at 1000 C) (%)	16.79
La&Lu (%)	<1.0

2.1. Properties of concrete including OWA

Slump test results of concrete containing different percentages (0, 5, 8, and 12% by weight of cement) of WOA are shown in Table 2, which indicates the inverse relationship between the workability and the percentage of used OWA.

Table 2: Slump of concrete with OWA as replacement for cement

OWA instead of cement (%)	0	5	8	12
Slump (mm)	42	35	29	4

Obtained results showed that by using 5, 8, and 12% by weight of cement of OWA, slump reduced respectively 16, 31, and 90%. It should be noted that by using 20% of OWA instead of cement, slump result was insensitive and all of the concrete samples manufactured by this rate of ash suffered from severe bleeding.

2.2. Compressive strength

In this experimental study the effect of using 5, 8 and 12% of OWA instead of cement on the compressive strength of produced concrete mixtures have been determined. Naik et al. evaluated the effect of using 5, 8 and 12% of the total cementitious materials of WA as a replacement on the compressive strength of concrete mixtures [13]. Figures 3, 4 and 5 indicate the attained compressive strength results using OWA and WA in concrete at the age of 7, 28 and 91 days, respectively.

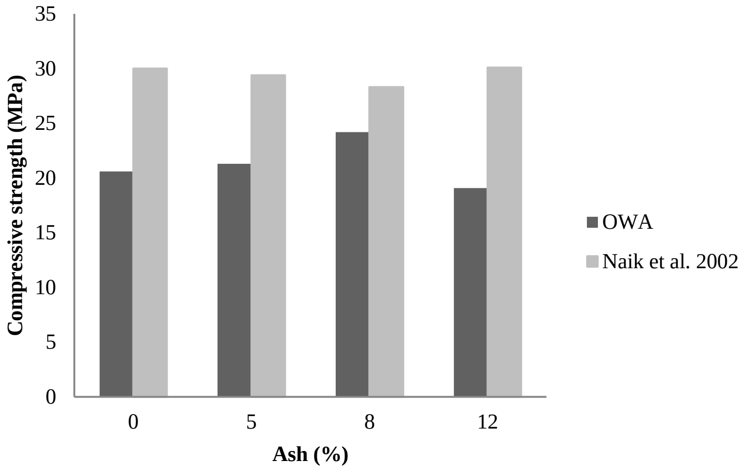

Fig.3. Compressive strength of concrete with OWA and WA at age of 7 days.

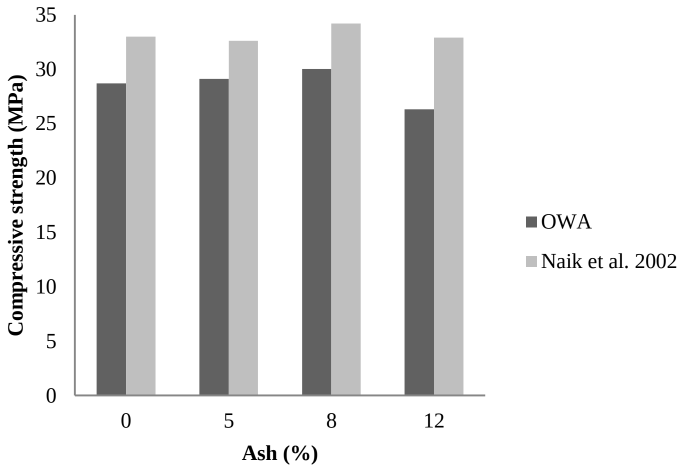

Fig.4. Compressive strength of concrete with OWA and WA at age of 28 days.

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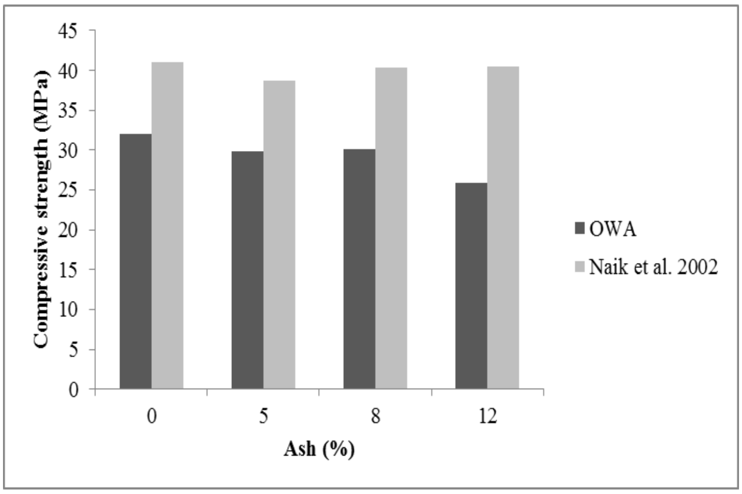

Fig.5. Compressive strength of concrete with OWA and WA at age of 91 days.

Compressive strength of concrete using 5, 8 and 12% of OWA to the normal mixture were respectively 0.97, 0.85, and 0.93 for the age of 7 days and 0.99, 0.96, and 0.92 for the age of 28 days. Based on the results of both experiments, the highest compressive strength at the age of 28.

2.3. Tensile splitting strength

In this experimental study the effect of using 5, 8 and 12% of OWA instead of cement on the tensile splitting strength of produced concrete mixtures have been determined. Naik et al. evaluated the effect of using 5, 8 and 12% of the total cementitious materials of WA as a replacement on the tensile splitting strength of concrete mixtures [13]. Figure 6 indicates the attained tensile splitting strength results using OWA and WA instead of cement at the age of 28 days.

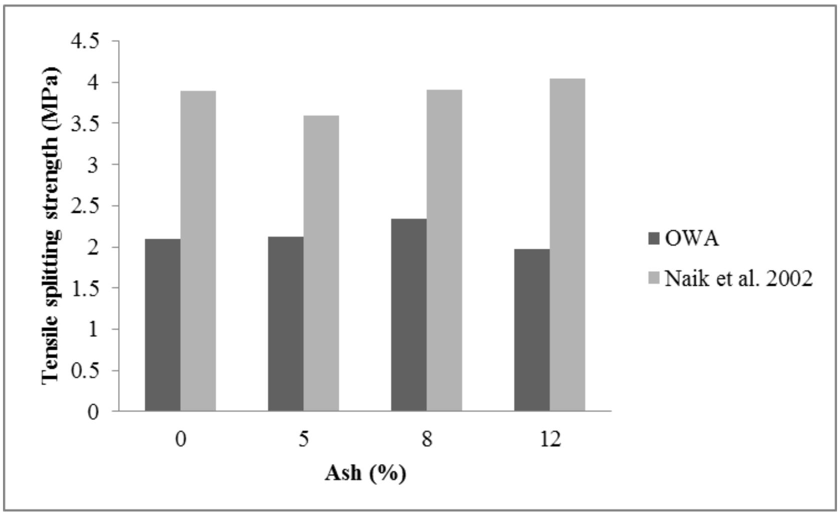

Fig.6. Tensile splitting strength of concrete with OWA and WA at age of 28 days.

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Tensile splitting strength of concrete using 5, 8 and 12% of OWA to the normal concrete mixture were respectively 0.99, 0.9, and 0.94. Based on the results, by using 8% of OWA compressive strength and tensile splitting strength in 28 days would increase respectively 17 and 11%, which makes it the optimum among the rest.

2.4. Relationship between compressive strength and tensile splitting strength

To determine the relationship between compressive and tensile splitting strength of concrete, results of following mixtures have been used:

Water/Cement ratio = 0.35: mixtures with 5 and 8% of OWA by weight of cement

Water/Cement ratio = 0.45: mixtures with 5, 8 and 12% of OWA by weight of cement

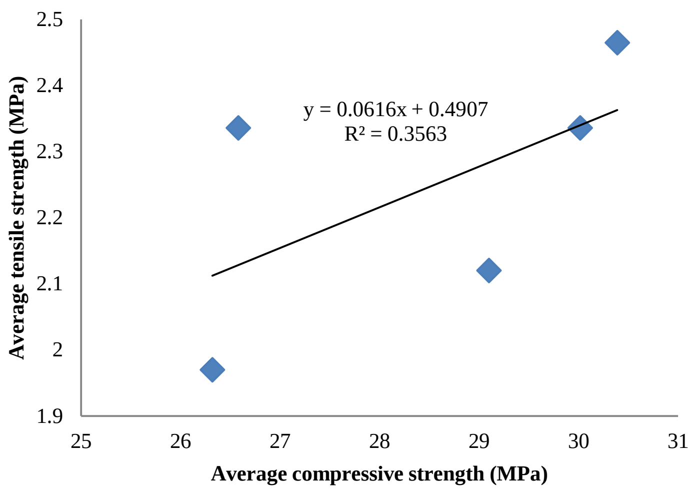

Fig.8. Relationship between tensile and compressive strength with OWA.

3- Conclusion

Results of this study can be explained in follow:

1-The optimum ratio of OWA to be used in concrete mixtures as a replacement for cement is 5 to 8 percent by weight of cement which is in compliance with results on the WA from other experimental studies.

2-Slump test results decreased by increasing the ratio of OWA in concrete mixtures.

Concrete mixtures containing 20 percent of OWA by weight (with constant water to cement ratio) suffered from severe bleeding and lack of workability.

3-Compressive strength results at 91 days proved that organic waste would cause no severe hazard or threat on the mechanical properties of concrete.

4- By increasing the OWA ratio from 0 to 8 percent instead of cement by weight, the ductility of concrete would be increased respectively.

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