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Production of Sustainable Concrete from Agro-Wastes ash

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ABSTRACT

There are various means of recycling agricultural wastes to maximize economic benefit from it. According to environmental statistics, agricultural wastes is one of the most dangerous types of wastes, especially in villages, because it is disposed of by burning. In this study, production of natural ash from agro wastes was carried out. Two types of agro waste ash were produced through burning and grinding process. waste date tree and waste reeds ash. The waste date ash (WDA) and waste reeds ash (WRA) were included in concrete by replacement of a specific portion of cement weight (5%, and 10%). Moreover, a blend of the two types of ashes were also considered. Furthermore, the natural ash was utilized in production of green concrete. Hardened density and compressive strengths at various ages (7, 28 and 56 days) were evaluated. The results in this research showed an excellent increase in compressive strength at ages (7,28 and 56) days. When measuring the compressive strength at the late age (56 days), DPA + WRA it was the best model used if it recorded the highest increase in it. Also, the use of WRA10% gave a good result, increasing its strength of the reference mixture and the rest of the mixtures also gave good and remarkable results in increasing the resistance, as the use of ash in these mixtures protects the environment from pollution and gives mixtures of higher resistance and can be used as a partial substitute for cement, except for DPA10%, so the usual mixture was better than it.

1. Introduction

The production of traditional cement leads to the emission of carbon dioxide in high quantities. It is estimating that huge quantities of greenhouse gases are emitted up to 800 kg and of carbon dioxide (CO2) when manufacturing one ton of cement (Khan,2012, Sojobi, 2017). Therefore, it's necessary to find alternative materials to use in cement production. On the other hand, burning of agro- wastes increases the environmental pollution. In this regard, researches on recycling of agro-wastes have been conducted. The aim of these researches, was to reduce the cost of concrete to a large extent and finding a solution to the problem of disposal of these wastes. However, due to various types of these agro-waters and their different properties, studies on evaluation of such type of concrete are still lacking. The common types of agro-waste that utilized in production of concrete and cement mortar were bagasse ash (SCBA)(Tripathy,2022, Shah 2022), rice husk ash (RHA)(Zaid,2021), palm oil fuel ash (POFA)(Santhosh,2022, Alani,2022), corn cob ash (CCA)(Ahmad,2023), coconut shell ash (CSA)(Herring,2022), wood ash (WA)(Natarajan,2023), peanut shell ash (Abd-Elrahman,2023), nutshells

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(Noaman,2023) wheat straw ash (WSA)(Zaid,2022), rice straw ash (RSA)(Amin,2022) , bamboo leaf ash (BLA)(Kolawole,2021) and many others.

In most of previous studies related to utilization of agro wastes ash in production of cement mortar or concrete, the ash resulted from agro waste burning were substituted in concrete or mortar as a cement replacement. Studies indicated that fly ash is relatively used as a supplementary cementations material (SCM) in concrete production. The quality of the produced concrete is mainly governed by chemical composition and physical properties of the residual burned ashes. A high amount of reactive SiO2 that react with Ca (OH)2 to produce calcium silicate hydrate (CSH) led to increased strength of this type of concrete (Charitha,2021). It was reported that the use of wheat straw ash this as a 10% replacement of the Portland cement resulted an increase of 12% in compressive strength compared to the reference mix which attributed to the filler ability and reaction with calcium hydroxide (Bheel,2021). In another study (Charitha,2021) it was observed that the optimum content of RHA and POFA was varied between 10% - 20% in which beyond this level a decrease in strengths occurred.

Reeds are locally available and occupied large areas all over the world especially in the southern part of Iraq, where it may be considered as an invasive plant (Heneberg,2022). Furthermore, the prescribed burning of this plant may lead to additional threat to the environment, in addition to the consumption of water. Based on above, a useful solution of this type of agro-waste can be obtained by recycling it in concrete to improve some properties or as a filler to reduce the amount of natural aggregate. One of these investigations on recycling of wild giant reed was presented by Zainab and Jaeel (Ismail,2014). They utilized giant reed ash (GRA) to partially replace sand in concrete mixes by 2.5%, 5.0%, 7.5%, 10.0%, and 12.5% (by weight). Concrete mixes were prepared and evaluated for workability, density, compressive strength, and flexural strength. The results showed at 28 days curing, the compressive strength increased up to 7.96% using GRA to replace sand by 7.5% by weight.

In Arabic lands, the presence of date palm tree is common. This tree is found in arid and tropical regions of the world. This type of tree produces a large number of wastes including stones and leaves especially after annual trimming operations (Riahi,2009). The aim of this study is the utilization of date palm ash in concrete production was considered by.

2. Experimental Program

2.1.1 Materials, mixing proportions and tests

Ordinary Portland cement (Type I) was used in this study as the main binding material. Coarse aggregate of maximum size 20 mm was used in addition to fine sand having maximum size of 4.75 mm. Two types of agro waste ash were produced in this study. Date palm ash (DPA) resulted by burning waste from date palm tree (leaves), and waste reed ash (WRA) produced through burning of waste reeds collected from river banks. The process of producing the ashes started by cutting the leaves into smaller pieces and burning it in an oven at a a temperature of 900 Cº in a time of 150 minutes (as shown in Fig. 1). After burning the ash, it was cooled and kept in a container. The second stage included grinded the ash by an automatic mill. Finally, all the grinded ashes were passed through a sieve 0.75 mm as shown in Fig. 2

Fig. 1 Burning of the wastes in the oven at 900 Cº.

(a) Date palm ash

(b) Waste reed ash

Fig. 2 Ash produced in the laboratory.

2.1.2 Mixing and casting

The concrete mixes were prepared as follows:
1-The required quantities of cement, aggregate, sand and water prepared.
2- A specific weight for each ingredient was selected as shown in Fig. 3

Fig.3 Materials used in this study

3-The dry ingredients coarse aggregate, sand and cement were blended together at first through the mixer, then gradually add water.
4-A 100mm cube molds were ready for casting.
5-When the fresh mix is ready, we pour it into molds, and then put the molds on an automatic vibrator for two minutes to make sure that bubbles come out.
6-The same steps above we repeat with the mixtures added to it DPA or WRA or both. Only with the difference in the percentage of cement, as it will decrease and compensate for it with the required additive.

Concrete specimens after casting and adding DPA or WRA or both are shown below in Fig.4

Fig.4 Specimens Of Concrete

Mixing Proportions are showing in Table1

Table 1 Mixing Proportions (kg/m3)

Mix	Cement	Gravel	Sand	DPA	WRA	Water
OPC	400	1050	850	-	-	200
DPA5%	380	1050	850	20	-	200
WRA5%	380	1050	850	-	20	200
DPA+WRA5%	380	1050	850	10	10	200
DPA10%	380	1050	850	40	-	200
WRA10%	380	1050	850	-	40	200
DPA+WRA10%	380	1050	850	20	20	200

The fresh concrete mixes were prepared by inclusion of all dry ingredients in a pan mixer in the lab. Cement, aggregate, sand was added and mixed for two minutes. Water was added gradually and the mixing continue for additional three minutes. For mixes containing DPA or WRA or blend of them, the ash was added together with the specific amount of cement. After mixing, the fresh concrete was poured into cubes having (100 mm side) and covered for 24 hours in the lab. After that, the cubes were cured in a water tank until date of test. Determination of hardened density at (7,28 and 56 days) was carried out according to EN 12390-7 (2009) - Testing hardened concrete - Part 7: Density of hardened concrete. British Standards Institution London, UK. The following equation used to calculate the hardened density:

$$\boldsymbol{Density\ (kg/m^3) = \frac{m}{v}} \quad (1)$$

Where:

m: Mass measured in the laboratory (kg).
v: The volume of the cube used (0.001 m^3).
For compressive strength at (7,28 and 56 days) it was determined as the measured load applied on the loaded are (cube face). The test was conducted according to BS EN 12390-3 (2009) Testing hardened concrete. Compressive strength of test specimens. British Standards Institution London, UK. using a hydraulic machine of 2000 kN capacity.

3. Results and discussion

3.1.1 Hardened density

As shown in Table 2, the density of the concrete has been slightly increased by including WRA or DPA with a content of 5% and 10%. However, this increase was slightly higher in WRA than that of DPA at 7- and 28-days age. However, a decrease in density with time was observed 56 days age for DPA5 % and WRA 10%. The decrease in density may be related to the flocculated and agglomerated cement and ash particles occupying larger spaces leading to a corresponding decrease in dry density (Zaid,2021).

Table 2: Results of Density at 7,28- and 56-days age

Type	Density (Kg/m^3) at 7 day	Density (Kg/m^3) at 28 day	Density (Kg/m^3) at 56 day
OPC	2355	2360	2376
WRA 5%	2442	2446	2459
DPA 5%	2438	2440	2376
WRA+DPA 5%	2431	2436	2435
DPA 10%	2424	2430	2478
WRA 10%	2466	2470	2451
DPA+WRA 10%	2425	2429	2430

Results of hardened density are shown in Fig. 5. 6 and7 respectively

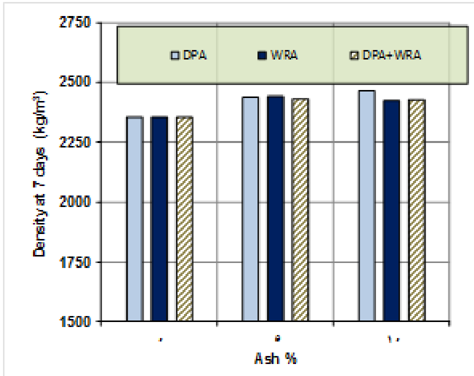

Fig. 5 Density at 7 days age

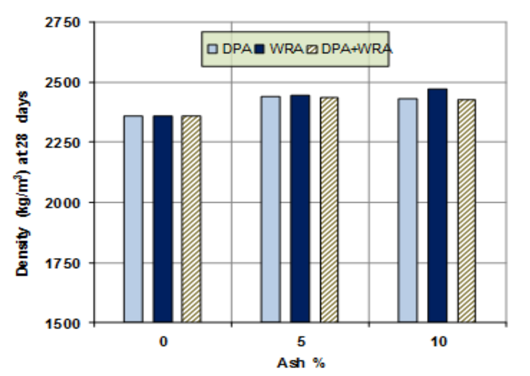

Fig. 6 Density at 28 days age

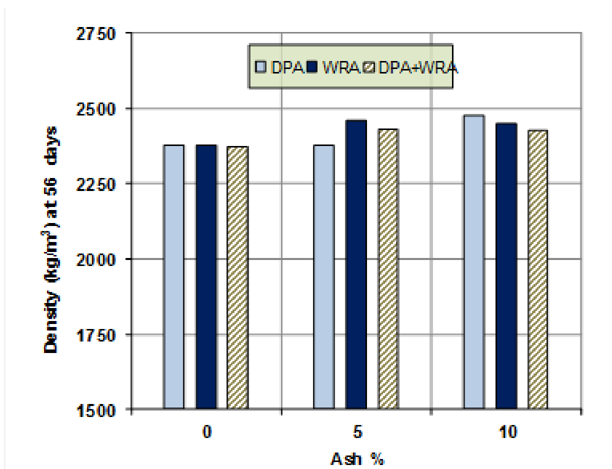

Fig. 7 Density at 56 days age

Density of mixes at various ages as shown in Fig.8

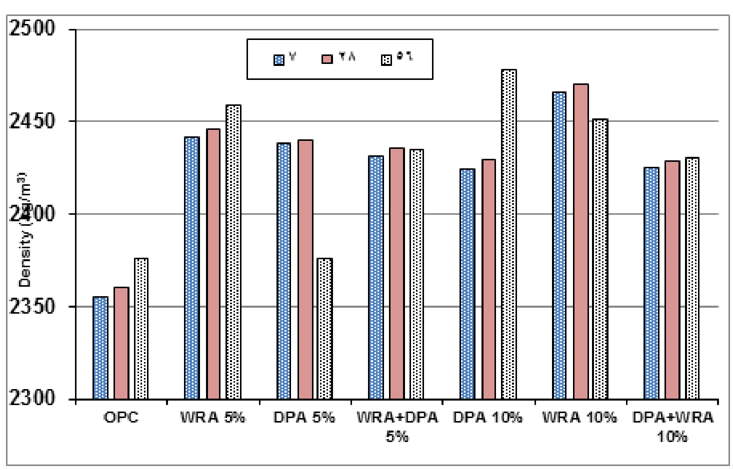

Fig.8 Density of mixes at various ages

3.1.2 compressive strength

Results of compressive strength test at 7 days age are presented in Table 3. As shown, an increase in compressive strength of WRA5% by 14.7% was obtained. For Mix DPA5% an increase of 20.8% was observed. For mix WRA+ DPA 5%, an increase of 29.4% was noticed. For mix with 10% WRA, an increase of 36.9% is shown. But, for mix DPA10% no significant increase was observed. However, a decrease in concrete strength at 7 days age was observed for DPA + WRA 10%.

Table 3: The results of the compressive strength tests after 7 days (MPa)

Type	1	2	3	Average	Percentage of increase%
OPC	25.37	27.23	28.71	27.1	_
WRA 5%	31.71	30.96	30.56	31.1	14.76%
DPA 5%	32.49	31.46	34.29	32.74	20.8%
WRA+DPA 5%	37.36	34.82	32.75	34.97	29.04
DPA 10%	29.85	26.81	25.31	27.3	0.74%
WRA 10%	35.73	37.78	37.80	37.1	36.9%
DPA+WRA 10%	20.47	28.28	29.39	26.05	-3.87%

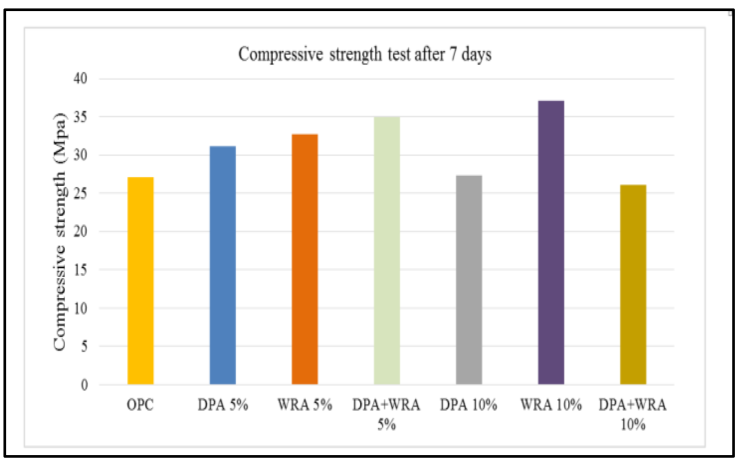

Fig.9 compressive strength test at 7 days age.

The results of the compressive strength test at 28 days of age are presented in Table 4. As shown, an increase in the compressive strength of WRA5% was obtained by 5.37%. For the DPA mixture, an increase of 3.96% was observed for the WRA + DPA mixture. An increase of 18.7% was observed. And if it was mixed with WRA10%, an increase of 24.9% was observed, but for a mixture of DPA 10%, no significant increase was recorded, however, a decrease in concrete strength was also observed at the age of 28 days for WPA + DPA 10%.

Table 4: The results of the compressive strength tests after 28 days (MPa)

Type	1	2	3	Average	Percentage of increase%
OPC	40.77	31.96	35.71	36.1	_
WRA 5%	39.75	33.03	41.34	38.04	5.37%
DPA 5%	38.79	39.05	34.75	37.53	3.96%
WRA+DPA 5%	41.48	45.53	41.55	42.85	18.7%
DPA 10%	33.95	32.88	32.24	33.02	-8.5%
WRA 10%	46.69	42.74	45.83	45.09	24.9%
DPA+WRA 10%	38.1	38	40	38.7	7.2

Results of the Compressive Strength Tests After 56 days as shown in Fig.10

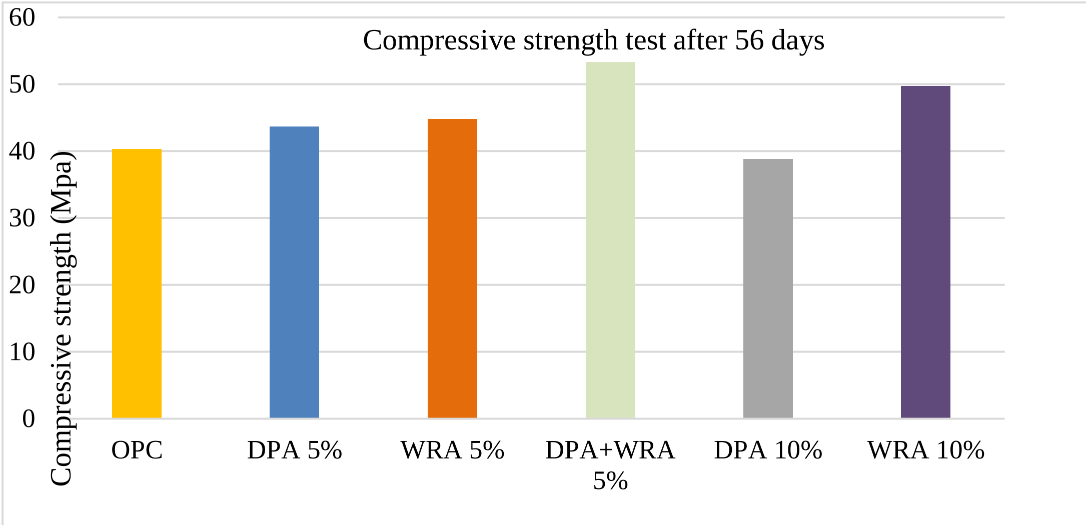

Fig.10 Results of the Compressive Strength Tests After 56 days (Mpa)

This improvement in the compressive strength in by inclusion of WRA and DPA at 5% content can be ascribed to the extremely fine particles inclusion which filled the voids between concrete compositions, cement and fine aggregates, thereby improving the packing effect in the microstructural matrices. The heightening in SiO2 inclusion from ash reacted with the Ca(OH)2 created during the hydration process of cement to produce secondary C-S-H, which packed aggregates, improved the microstructural density and enhanced the compressive strength. As for the decrease when the DPA content is increased to 10% is due to the breaking of bonds between the components of the cement paste C-S-H network. which leads to weakness in the cement paste .AWAs (Agricultural Waste Ashes) have a different effect on compressive strength of blended concrete after 28 days of curing. The addition of AWAs in a certain proportion leads to an increase in the compressive strength, but if it exceeds the optimal alternative the level reduces the compressive strength of the concrete the system .The compressive strength of the ash was studied, as the study showed that the SCBA(Sugarcane bagasse ash) and RHA(Rice husk ash) mixed concrete had a better normalization. is found the range of (10–20%) .The optimum replacement level of RHA, as well as SCBA in concert. It was found that the natural higher than control concrete which is compressive strength of mixed concrete RHA and SCBA About 1.2 times that of controlled concrete, the amorphous silica content in SCBA and RHA primarily improved the pozzolanic performance and enhanced the properties of blended concrete. Additionally, the increase in pozzolan city and subsequent reinforcement of the interfacial region Among total and moisturizing products noted for RHA Mixed cement system .Previous studies have shown 10% alternative level while 20% as the optimal replacement level for POFA(Palm oil fuel ash). In addition, it was found that the optimum replacement level of POFA mixed concrete was in the range of 1.01 to 1.1 despite the difference It is minimal when comparing pressure.The strength of POFA mixed concrete and RHA mixed concrete is lower. At the highest replacement level (20% POFA) of Cement, although observed normal pressure Strength is drop, the strength is higher than that of concrete control. However, beyond the optimum replacement level, compressive strength tends to decrease as a result of less dense.

4. Discussions

The compressive strength of date palm ash (DPA) was increased with a content of 5% at the age of (7, 28 and 56) years, where the increase was respectively (20.8%, 3.96 and 11.03). However, it decreased slightly at the same ages when the DPA content was 10% at ages (7, 28 and 56) and according to the results, respectively (0.74, -8.5 and -4.1).

For the mixtures prepared from cane ash residues (WRA) with a content of 5%, the compressive strength showed an increase in all ages (7, 28 and 56) according to the results, respectively (14.67, 5.37 and 8.25). However, this increase was significant at a young age (7 days). For the mixture prepared from 10% WRA, a similar trend of increase but greater was observed at the same ages with results (36.9, 24.9 and 23.2).

For the mixtures prepared from the mixture of DPA and WRA, at a content of 5%, the largest increase in compressive strength was recorded at (7, 28, and 56) days, respectively (29.04, 18.7 and 32.1), but a slight decrease in this strength was determined at a content of 10 % of the mixture of DPA and WRA (-3.87, 7.2, and -19.1).

5. Conclusions

based on the experimental work. the main conclusions can be summarized as follows:

1.When measuring the compressive strength at the late age (56 days), in which silica (Si_2O_3) is responsible for the increase in the strength, we find that DPA + WRA increased its strength and it was the best model used if it recorded an increase in it by 32.10%.

2.Also, the use of WRA10% gave a good result, increasing its strength by 23.20% of The reference mixture and the rest of the mixtures also gave good and remarkable results in increasing the resistance, as the use of ash in these mixtures protects the environment from pollution and gives mixtures of higher resistance and can be used as a partial substitute for cement, except for DPA10%, so the usual mixture was better than it.

3.On the other hand, we note that the density of the mixtures was close to the reference mixture (OPC).

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