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Mechanical Properties of Cement Mortar Made with Black Tea Waste Ash as a Partial Replacement of Cement

Abstract- *Environmental pollution and the relatively high cost of waste disposal has been a major focus for scientists around the world, leading researchers to find a solution to reuse waste materials in different applications. Iraqi people consume hundreds of tons of black tea each year, which produce a large quantity of the used tea, leaves as waste. These large quantities go to landfills without any benefit or recycling. Additionally, landfills are considered one of the biggest crisis facing the Iraqi government. Therefore, this study aims to recycle the black tea waste ash (BTWA) by utilizing it as a partial replacement of cement. Cement mortar mixes containing five replacement levels of cement with BTWA (0%, 2.5%, 5%, 7.5% and 10% by weight) were carried out. The compressive strength and flexural strength tests were adopted to show the effect of BTWA on mechanical properties of cement mortar. The flow rate of fresh mortar was also measured. Results indicated that, up to 7.5% replacement, the compressive strength values were improved. For 10% replacement, the compressive strength values were equal to that for control specimens. In contrast, the BTWA had a negative impact on the flexure strength of mortar at replacement levels 5%, 7.5% and10%. For 2.5% substitution, however, the flexure strength was enhanced slightly (about 2%).*

Keywords- *Black tea waste ash, cement replacement, compressive strength, flexure strength.*

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1. Introduction

The presence of waste materials is harmful to the environment, so, the inclusion of these materials in building products, roads and other infrastructure is useful not only in reducing the quantities of disposed of materials in the landfills but also in reducing the impact of these substances on the environment [1].

Demand for green concrete production is constantly increasing as a result of the globally increasing use of concrete in the building industry. The negative use of concrete materials such as cement and aggregates is one of the main reasons for this demand [2,3]. The cement industry sector alone is responsible for approximately 7% of the total carbon dioxide emissions from human activities worldwide [2,4]. Environmental pollution and the relatively high cost of waste disposal has been a major focus for scientists around the world, leading researchers to find a solution to reuse the waste materials in different applications.

In Iraq, the black tea drink is a major beverage for most of the Iraqi people and this indicates the production of large quantities of tea leaves wastes every year. Yet, there is no local recycling of these residues, so they all go to landfills. Additionally, landfills are considered one of the biggest crisis facing the Iraqi government. It is therefore considered environmentally and economically beneficial to use these wastes as an alternative to cement in the construction industry.

Very limited studies were found in the literature concerned with the using of black tea waste as a cement replacement. Demirbas and Aslan [5] studied the effect of ground wood, hazelnut shell, spruce and black tea waste (supplied from a certain factory in Turkey) on the compressive and bending strength of cement. These materials were used as a cement replacement in the percentages 2%, 5%, 7.5% and 10%. It was demonstrated that the tea

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waste had a very negative impact on the mechanical properties of cement.

As described in the above study, the black tea waste was unburned and supplied from a certain factory. So, this study aims to explore the effect of the ash produced from burning the black tea waste (from domestic use) in a controlled oven on the mechanical properties of cement mortar. The effect of the black tea waste ash on the flow of the fresh mortar was also investigated.

2. Materials and Methods

The ingredients used in this study to prepare fresh mortar were cement, sand, black tea waste ash, superplasticizer and tap water. Lime cement Type CEM II/A-L 42.5R was used as a binder material. The chemical composition of cement was in compliance of the Iraqi specification IQS No.5/1984 [6], see Table 1. Natural sand with grading range 0.15-1.18 mm (as shown in Figure 1) was used as fine aggregate. The black tea waste ash (BTWA) was prepared by burning the used black tea leaves (wastes) in a controlled oven at 600 °C for two hours. The produced ash was left in the oven for about 24 hours to be cooled gradually to the room temperature then ground and passed through 150-micrometer sieve opening. The chemical composition of the BTWA is illustrated in Table 2. Glenium 54 superplasticizer (G54) purchased from BASF company was used as workability adjuster for the fresh mortar. The G54 is confirmed to ASTM C494 Type A and F [7]. The binder/sand (1:2.75), water/binder (0.485), the superplasticizer dosage (2.5% of the binder weight) was fixed for all mixtures. Five mixtures were executed for this study in which the BTWA was used in five proportions (0%, 2.5%, 5%, 7.5% and 10%) as a replacement for cement weight. The details of mortar mixes can be seen in Table 3. A planetary mixer with two-speed rates (140 rad/min and 285 rad/min) was used for mixing the mortar materials using the following procedure:

- The dry materials (cement, sand and BTWA if any) were fed into the mixer and they mixed at the low-speed rate (140 rad/min) for one minute.
- The mixer was stopped and the water (which was mixed with G54) was added. Then, the mixer was operated for one minute.
- Thereafter, the mixer was rested for 0.5 minutes.
- Finally, all the ingredients were mixed at the moderate-speed rate (285 rad/min) for one minute.

The fresh mortar for each mix was cast into three standard prism molds (40×40×160 mm). The fresh mortar was compacted using an electrical vibrator. The specimens remained in the molds for about 20-24 hours then lifted and immersed in water-tanks at room temperature until the test. The compressive and flexure strength tests were examined for the hardened mortar to explore the impact of the prepared BTWA on the mechanical properties of the cement mortar. The flow of the fresh mortar was also measured according to ASTM C1437 [8] immediately after mixing. The prism specimens were used for determining the flexure strength using the following equation (one point load method) [9]:

$$F = \frac{1.5\,P\,L}{b^3} \qquad (1)$$

Where; F is the flexure strength (MPa), P is the ultimate load (N), L is the distance between supports (mm) and b is the cross-section dimension of the prism.

The halves of the broken prisms under the flexure strength machine were used to determine the compressive strength of the hardened mortar by dividing the maximum failure load over the loading area (40×40 mm). Average of three readings for flexure strength test and an average of five readings for the compressive strength test were taking into account. The hardened tests were carried out at 28 days age only.

Table 1: The chemical composition of cement.

Oxides	Content, %
CaO	62.1
SiO_2	22.1
Al_2O_3	4.2
Fe_2O_3	3.9
MgO	3.3
SO_3	1.9
Free lime	0.7
L.O.I.	3.1
L.S.F.	0.86
I.R.	1.1

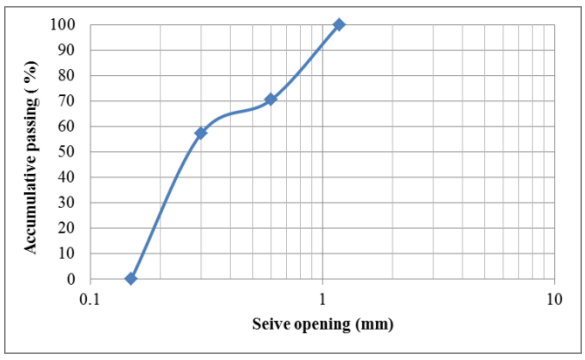

Figure 1: Grading of the natural sand

Table 2: The chemical composition of black tea waste ash (BTWA).

Oxides	Content, %
CaO	11.14
SiO_2	0.83
Al_2O_3	0.79
Fe_2O_3	0.37
MgO	2.15
P_2O_5	2.37
K_2O	4.21
MnO	0.44
SO_3	2.02
Cl	0.47
L.O.I.	75.02

3. Results and Discussions

I. Flow results

Figure 2 shows the results of the flow test for fresh mortar. In general, the flow values of mixtures incorporated BTWA were lesser than the corresponding value for the control mix. The higher the percentage of BTWA in the mix the lower the flow value. The reduction ratio of flow relating to the control mix (BTWA0) were, respectively, 6%, 9%, 13% and 19% for BTWA2.5, BTWA5, BTWA7.5 and BTWA10 mixtures. This indicated that the BTWA increased the water demand of the fresh mortar. Demir [10] used the processed waste tea in the production of clay brick. In that study, it was reported that processed waste tea increased the water requirements for plasticity.

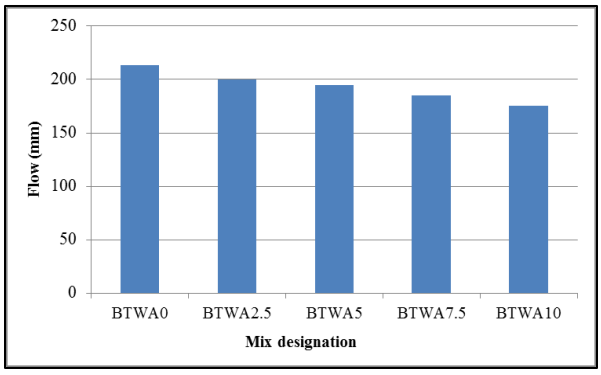

Figure 2: Flow results of black tea waste ash mixes.

II. Compressive strength results

Results of the compressive strength of hardened mortars are illustrated in Figure 3. It was observed that, up to 7.5%, the compressive strength values were increased with the increasing of BTWA content in the mix. The enhancement percentages were 2%, 6% and 10% for BTWA2.5, BTWA5 and BTWA7.5 mixtures respectively. At the replacement level of 10%, the compressive strength tended to decrease, however, its value was approximately equal to that for control mix. This behavior may be due to the lack of plasticity of the fresh mixture as a result of increasing of BTWA percent that causes the air voids to be increased within the matrix (difficulties in compaction) and thus leads the compressive strength to be reduced.

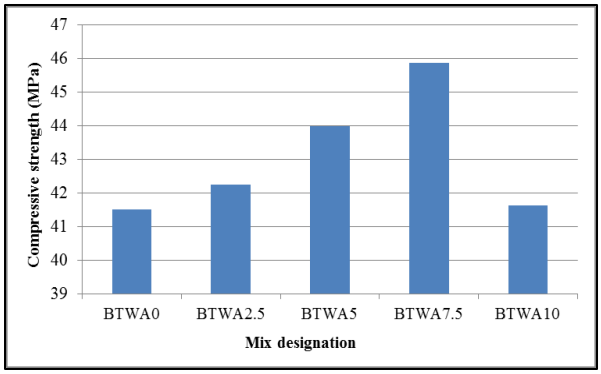

Figure 3: Compressive strength results of black tea waste ash mixes

III. Flexure strength results

Flexure strength results are illuminated in Figure 4. It was observed that replacing cement with 2.5% BTWA enhanced the flexure strength slightly (about 2%). Beyond that, the flexure strength values reduced considerably in comparison with corresponding values for the reference mix. The reduction rates were 26%, 29% and 26% for BTWA5, BTWA7.5 and BTWA10 mixtures respectively. This behavior may be attributed to the role of the BTWA in reducing the plasticity of fresh mortar, so, the escaping of air voids are restricted during compacting and consequently lead to weakness of the interfacial transition zone.

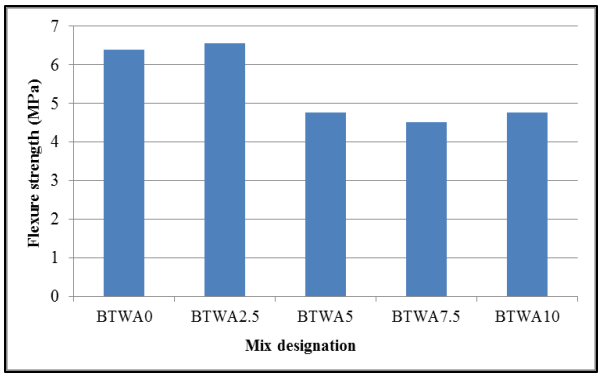

Figure 4: Flexure strength results of black tea waste ash mixes.

Table 3: Mortar mixes details for three prisms (40×40×160 mm).

Mix designation	Cement (gm)	Sand (gm)	BTWA (gm)	water/ binder	Superplasticizer (gm)
BTWA0	500	1375	0	0.485	12.5
BTWA2.5	487.5	1375	12.5	0.485	12.5
BTWA5	475	1375	25	0.485	12.5
BTWA7.5	450	1375	37.5	0.485	12.5
BTWA10	425	1375	50	0.485	12.5

4. Conclusions

1. Using of BTWA as a cement replacement reduces the flow rate of the cement mortar. The reduction rate increases with the increase of the replacement percentage.
2. The BTWA can improve the compressive strength of the hardened mortar. The best improvement is given by replacing the cement with 7.5% of BTWA, about 10% higher than conventional mortar.
3. The flexure strength of mortar affected negatively after using BTWA within the range (5%-10%). However, substitution the cement with 2.5% BTWA can enhance the flexure strength by about 2%.
4. Further studies should be executed to understand the influence of black tea waste ash on different mortar characteristics.

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