Comparison Between the Effect of Silica Fume and Wood Ash Used for the Production of High Performance Mortar

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Abstract

This paper presents a comparison between the use of silica fume and wood ash for High Performance Mortar (HPM). The different percentages used for each of the silica fume and wood ash are: 6, 8, 10, 12 and 16%. The experimental tests included density, compressive strength and flexural strength. The results illustrate that the use of silica fume increases the density, whereas the wood ash decreases the density of HPM. Besides, the inclusion of Silica fume (10 % as a partial replacement of cement) and wood ash at the same level of replacement gives the best properties of the HPM. In other words, the compressive strength and flexural strength have been enhanced by the inclusion of silica fume and wood ash.

Keywords: High performance mortar, silica fume, wood ash.

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1. Introduction

The use of silica fume in the production of high strength concrete has become a significant case, because of clear improvements attained on the interfacial zone of cement paste –aggregate. Silica fume consists of ultra fine (<1µm) particles and increases the bond strength between cement paste and aggregate by making the interfacial zone more dense. It also plays an important role in increasing the mechanical strength of concrete because of having a pozzolanic activity(Koksal et al , 2008, Ramli and Dawood, 2011). Another contributing factor is the fact that silica fume, because of its high fineness, reduces bleeding so that no bleed water is trapped beneath coarse aggregate particles. In consequence, the porosity at the interface zone is reduced, compared with a mix not containing silica fume. Subsequent chemical reaction of silica fume results in a lower porosity at the interface zone which, in consequence, is no longer particularly weak, either in terms of strength or permeability (Neville, 1995).

The development of High Performance Concrete (HPC) has brought forth the need for admixtures, both mineral and chemical, to improve the performance of concrete. Silica fume (SF) is one such material. Many investigations reflecting the performance of SF were conducted in the 1970s to 1980s. Promising results were shown by Malhotra and Carette (1983).

Wood ash is generated as a by-product of combustion in wood-fired power plants, paper mills, and other wood burning facilities. Since wood is a renewable source of energy and environmentally benign friendly material, there will be increased use of wood in energy production in the future. As a result, there will be increased amount of wood ash generation (Sashidhar and Rao, 2010).

The use of wood biomass as a source of renewable energy is gaining its popularity among the timber product industry and power production sector in several developed countries (Ban and Ramli, 2011).

In the absence of proper disposal technique, the fine and lightweight wood ash produced poses serious air pollution and health hazards to humans. Therefore, the reuse of wood ash as a supplementary binder material in concrete is perceived as a viable and sustainable method for disposal of the waste in mass amounts without side effects to the environment (Ban and Ramli, 2011).

Recent research (Udoeyo and Dashibil, 2002) was performed to investigate the feasibility of the use of wood waste ash as a partial replacement material for the energy intensive process of hydraulic cement for concrete production. The tests showed promising results in that wood waste ash can suitably be used as constituent material in the production of structural grade concrete with acceptable mechanical and durability properties.

These findings provide a solution for the waste management problems of wood waste ash and also contribute towards minimizing the consumption of energy intensive hydraulic cement production of greener concrete material supplying the ever growing demand of the construction industry. Hence, incorporation of wood waste ash as cement replacement material in blended cement and concrete will be beneficial not only in environmental terms for concrete material but also in production costs of the aforesaid materials.

The main objective of the present study is to investigate the effect of using different percentages of silica fume and also of wood ash as partial replacements of cement on the properties of high performance mortar.

2. Manufacture of Specimens

The cement used in the mortar mixtures was ordinary Portland cement a product of Iraqi cement produced by Badosh cement factory. The silica fume produced by Scancem materials Sdn. Bhd. was used as partial replacement of cement in different percentages to determine the optimum percentage of replacement. Besides, wood ash was used for the same purpose and the chemical composition of Ordinary Portland, silica fume and wood ash are given in Table 1.

The superplasticizer (SP.)(Conplast SP1000,Fosroc Sdn. Bhd.) was adjusted to give the properties of the required flowability for all mortar mixes. The flow design for all mixes was 140-160%. The fine aggregate used is natural sand, whose fineness modulus is 2.86 and the maximum size less than 5 mm.

The mortar mixes A0 to A6 are prepared using 0, 6, 8,10,12,14 and 16% of silica fume as partial replacement of cement, respectively. Whereas, the mixes A7-A12 are prepared using 6, 8,10,12,14 and 16% of the wood ash. The materials composition of Mortar mixtures are presented in Table 2. All batches were prepared by using a mechanical mixer conforming to the requirements of ASTM C305.

Each batch of mortar was produced in a pan mixer. Cement, sand, water and superplasticizer were first added to the mixer and mixed for 3 min. Then the silica fume or wood ash was added and the mixture was further mixed for 2 min.

The flow test for the mortar mixes was performed according to ASTM C230. Fresh mortar mixtures were cast into 50 mm cube molds and prismatic (40 × 40 × 160 mm) steel molds. The specimens were left in the molds for 24 hours at room temperature of 20 °C. After demolding, the specimens were kept in a curing room till the age of test (28 days). After the curing period, the mortar cube specimens were subjected to compressive load according to ASTM C109. The prismatic mortar specimens tested in flexural according to ASTM C348 where the specimens were loaded at mid span and over a span of 120 mm. The density test for all the mortar specimens was carried out according to BS 1881: Part 114, where the saturated densities have been determined.

3 . Results and discussion

The flow test results for HPM mixes are shown in Table 2. It can be seen from this Table that the inclusion of wood ash gives better flow performance compared to silica fume. Thus, at the same level of replacement, the target flow of 140-160% was obtained with less amount of superplasticizer (Ban and Ramli, 2011).

Table 3 reports the mean test values of density, compressive strength and flexural strength for HPM mixes.

From these results, it can be noticed that the addition of silica fume to the mix gives a slight increase in density of the mortar. On the other hand, the inclusion of wood ash in the HPM mixes reduces the density considerably. This can be attributed to the specific gravity of wood ash which is less than the specific gravity of silica fume (Neville, 1995). Fig. 1 illustrates the relationship between silica fume with density of HPM, whereas Fig.2 shows the relationship between wood ash and density of HPM.

Regression analysis on the percentage of silica fume and density for HPM of mortar mixes reveals a strong correlation between them as shown for the following equation:

$y = -0.109x^3 + 2.124x^2 - 6.213x + 2349$, $R^2 = 0.906$ -------------------------------- (1)

On the other hand, Regression analysis on the percentage of wood ash and density for HPM of mortar mixes shows a strong correlation between them as shown for the following equation:

$y = 0.05x^3 - 1.908x^2 + 7.224x + 2349$, $R^2 = 0.991$ -------------------------------- (2)

The compressive strength results for HPM mixes (Table 3 and Fig.3) show that there are different increments of strengths by incorporation of silica fume. However, the highest increase was obtained by the inclusion of 10% of silica fume, which caused an increase in compressive strength of about 18%.

On the other hand, the use of wood ash up to 10% increased the compressive strength of HPM. The use of 10% wood ash increases the compressive strength of HPM by about 14%. This observation can be attributed to the increased calcium silicate hydrate (C-S-H) gel formation within the cement paste matrix microstructure of wood waste ash by pozzolanic activity (Udoeyo and Dashibil, 2002). However, the use of more than 10% of wood ash reduced the compressive strength considerably. Fig. 4 shows the relationship between wood ash and compressive strength of HPM.

Regression analysis on the percentage of silica fume and compressive strength for HPM of mortar mixes exhibits a significant correlation between them as shown for the following equation:

$y = 0.007x^3 - 0.539x^2 + 8.486x + 20.01$, $R^2 = 0.981$ --------------------------------- (3)

Whereas, Regression analysis on the percentage of wood ash and compressive strength for HPM of mortar mixes exhibits a strong correlation between them as shown for the following equation:

$y = 0.143x^3 - 5.118x^2 + 54.01x - 121.4,\ R^2 = 0.963$ ----------------------------------- (4).

The flexural strength results of HPM mixes are shown in Table 3. However, the use of silica fume increased the flexural strength considerably. The best increase of flexural strength for HPM was obtained by the inclusion of 10% silica fume. The relationship between silica fume and flexural strength is shown in Fig.5. On the other hand, the results of the flexural strength of HPM with wood ash (Fig.6) indicate that the use of 10% of wood ash as partial replacement of cement gives an increase of about 14%. However a reduction in flexural strength of HPM was obtained with the inclusion of 16% of wood ash in the mortar mix.

Regression analysis on the percentage of silica fume and flexural strength for HPM of mortar mixes reveals a strong correlation between them as shown for the following equation:

$y = 0.001x^3 - 0.091x^2 + 1.363x + 2.247,\ R^2 = 0.974$ --------------------------------- (5)

Regression analysis on the percentage of wood ash and flexural strength for HPM of mortar mixes reveals a considerable correlation between them as shown for the following equation:

$y = -0.001x^3 + 0.027x^2 - 0.005x + 6.452,\ R^2 = 0.890$ -------------------------------- (6)

4. Conclusion

This study was conducted to assess the properties of HPM produced by adjusting the percentage of superplasticizer with different percentages of silica fume and wood ash as partial replacements of cement (0, 6, 8, 10, 12, 14 and 16%). The following conclusions are drawn from the present study:

1. The inclusion of wood ash gives slightly better performance in term of flowability compared with silica fume.
2. The use of silica fume increases the density of the mortar slightly, whereas, the use of wood ash decreases the density significantly.
3. The use of 10% of silica fume enhances the compressive and flexural strengths of HPM by about 18 and 20%, respectively. Whereas, the use of 10% wood ash increases the compressive and flexural strengths of HPM by about 10 and 14%, respectively.

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المقارنة بين تاثير أبخرة السيلكا ورماد فحم الخشب المستخدمين لإنتاج مونة الاسمنت عالية الأداء

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المستخلص

هذه الدراسة تهدف إلى مقارنة بين استخدام أبخرة السيلكا ورماد فحم الخشب لإنتاج مونة الأسمنت عالية الأداء. تمت هذه الدراسة باستخدام نسب مختلفة من أبخرة السيلكا ورماد الفحم حيث كانت النسب كالأتي: 6%, 8%, 10%, 12%, 14%, 16% . تم فحص نماذج مونة الأسمنت لكل من الكثافة ومقاومة الانضغاط ومقاومة الانحناء. النتائج بينت ان استخدام ابخرة السيلكا سوف يزيد من كثافة مونة الاسمنت عالية الأداء في حين ان استخدام رماد الفحم يعمل على تقليل الكثافة. بالإضافة إلى ذلك فان استبدال 10% من أبخرة السيلكا أو رماد الفحم أعطت أفضل أداء لمونة الأسمنت وخاصة بالنسبة لمقاومتي الانضغاط الانحناء.

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