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Effect of Bio-Char of Santa Maria Feverfew Plant on Physical Properties of Fresh Mortar †

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Abstract: The present study concerns the application of nano-/micro-sized fibers (bio-char of Santa Maria feverfew) in cementitious mortars. The bio-char was added @ 0, 0.05 and 0.1% by mass of cement. The addition of bio-char did not affect the setting and consistency of the mortars. The fresh density was reduced by 11%, while the followability decreased by 50%. It is concluded that the bio-char results in a light-weight cementitious material, without affecting the setting time or consistency. Bio-char produces carbon-rich materials, the use of which as building materials adds to carbon sequestration in accordance with the Sustainable Development Goals of the UNO.

Keywords: bio-char; Santa Maria feverfew plant; cementitious mortar; fresh density; consistency; flowability; carbon sequestration; sustainable development goal

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1. Introduction

Pyrolysis is an endoergic method that encompasses the thermo-chemical breakdown of raw bio-mass in an inert atmosphere at high temperatures and pressures. This procedure yields different valuable products like bio-char, liquid bio-oil and fuel gases [1]. Bio-char is a light-weight, dark-colored carbon deposit. Scientists have used many different kinds of feedstock, including water hyacinth, oriental beech, corncob and many more [2–4]. In recent years, many researchers have added bio-char to cementitious products to enhance their performance. Gupta et al. added bio-char of sawdust at a rate 2% by mass of cement [5]. The results revealed that the addition enhanced the compressive strength and ductility of the end products. Tayyab et al. incorporated the bio-char of millet and maize in mortar [6]. The authors reported an enhancement of the fracture toughness and ductility of the specimens. This enhancement was attributed to crack bridging/branching due to the fibrous nature of the bio-char. Iftekhar et al. studied the effect of bio-chars of sugarcane bagasse and pine needles in cementitious mortars [7]. The authors reported enhanced interface shielding. Restuccia et al. used the bio-char of hazelnut shells in mortars. They reported an enhanced compressive strength, flexural strength, toughness and ductility. Ling et al. used bio-char @ 1–3% by mass of cement in mortar. Their findings revealed that a 3% bio-char content enhanced the degree of hydration [8]. Mensah et al. reported that bio-char has the capacity to enhance the mechanical and thermal properties of cementitious materials [9]. Most of the previous studies focused on the effects of bio-char on the hardened properties of the cementitious composites. Literature regarding the influence of bio-char addition on the fresh properties of cementitious materials is scarce.

The present study focusses on the addition of the bio-char of Santa Maria feverfew on the fresh characteristics of cementitious mortar. Santa Maria feverfew is a local plant known as gajjar boti. The use of the Santa Maria plant for producing bio-char and that of its bio-char as filler in mortar has not been studied previously. This study comprises of an evaluation of the cementitious mortar in terms of its fresh density, consistency, setting time and flowability.

2. Materials and Methods

Cementitious mortars containing both the control and the specimens with added bio-char were prepared. A C-53-grade local ordinary Portland cement was used (Table 1). River sand was used as a fine aggregate (Table 1). The transformation of the Santa Maria Feverfew plant from a raw product to pyroletic powder is shown in Figure 1. Three types of specimens were prepared: a control and those containing 0.05% and 0.1% bio-char as the mass of cement. The composition of the materials is presented in Table 2.

Table 1. Chemical and physical characteristics of the ingredients of the mortar.

Cement				Sand	
Compound	%Age	Property	Value	Property	Value
CaO	61	Specific gravity	3.1	Specific gravity	2.7
SiO_2	21	Soundness	2%	Fineness modulus	2.7
Fe_2O_3	3	Fineness	1%	Bulk density (Kg/m^3)	1480
Al_2O_3	6	Initial setting time	30 min	Dry-rodded bulk density(Kg/m^3)	1820
MgO	1.5	Final setting time	610 min	Water absorption(%)	3.9
Alkalis	0.5	Consistency	24%	Water Content (%)	1.98
Gypsum	4				

Figure 1. (**a**) Fresh Santa Maria Feverfew plant. (**b**) Dry plant. (**c**) Bio-char. (**d**) Powdered bio-char.

Table 2. Composition of the mortar.

Samples	OPC (g)	Sand (g)	Water (mL)	Bio-Char (g)	Admixture (mL)	W/C
C0	610	916	214	0	6	0.35
C0.05	610	916	214	0.305	6	0.35
C0.1	610	916	214	0.61	6	0.35

The materials were mixed as per the ASTM C305-20 standard method [10]. To avoid agglomeration, the bio-char was mixed in water via the UV–sonication technique. An admixture (super-plasticizer) was added (1% by mass of cement) to make the dispersion more effective. All the ingredients were mixed in a Hobart mixer. After mixing, the samples were cast in prisms (40 × 40 × 160 mm) according to the ASTM C1314 method [11]. After 24 h, the specimens were de-molded and immersed in water for curing. The flowability was measured through a flow table test (ASTM C1437) [12]. The consistency of the mix was determined using a Vicat apparatus (ASTM C187) [13]. The fresh density of the specimens was determined using the ASTM C138/138M method [14]. The mixing machine, molding and flowability test are shown in Figure 2.

Figure 2. (**a**) Mixing, (**b**) molding and (**c**) flowability test.

3. Results and Discussion

3.1. Setting Time

The initial setting times are presented in Table 3. The results show that there is a slight increase in the setting time, yet it is well within the limit, i.e., 30–45 min. The results show that the addition of 0.05–0.1% of the bio-char of Santa Maria Feverfew does not affect the initial setting time; the slight enhancement may be the result of the porous nature of the particles, which absorb water, thus delaying hydration. The final setting times are presented in Table 3. There is an almost negligible effect on the final setting time. Hence, the bio-char particles do not affect the setting time of the paste. The filler particles absorb water and, as such, may affect the hydration as well as the setting time, which is dependent on the water [15].

Table 3. Effects of bio-char on the setting time and consistency of cement paste.

Specimen	Initial Setting Time (min)	Final Setting Time (min)	Consistency (%)
C0	33.48	495	23.5
C0.05	35.32	485	23.7
C0.1	39.30	500	24.0

3.2. Consistency

The effect of the bio-char on the consistency of the cement paste is shown in Table 3. Consistency is an important measure, as it provides an indication of the amount of water for cement hydration. The slight enhancement may be the result of the porous nature of the bio-char. Since bio-chars are porous, they may absorb water and enhance the water requirements, but again, this enhancement is within the limits (25–30%).

3.3. Fresh Density

The fresh density of the mortar specimens is shown in Table 4. The results show that the density reduces with the addition of the bio-char.

Table 4. Effect of bio-char on fresh density.

Specimen	Density (kg/m^3)	% Difference
C0	2100	
C0.05	2000	4.8
C0.1	1880	10.5

The addition of bio-char enhances the volume of the mix. Since bio-chars are extremely light materials, the increase in mass is small as compared to the increase in volume. This, in turn, reduces the density. These results are in accordance with the previous literature [6,7].

3.4. Flowability

Flowability was assessed through a flow table test. The results are shown in Table 5.

Table 5. Effect of bio-char on flowability.

Specimen	D1 (mm)	D2 (mm)	D3 (mm)	Mean D (mm)	% Difference
C0	9.7	10.1	10.2	10	
C0.05	5.1	5.4	5.7	5.4	46
C0.1	4.9	4.8	4	4.6	54

The results show that the flowability drastically decreases with the addition of bio-char. The absorption of moisture by the bio-char particles reduces the flow. Bio-char particles are finer than cement. Finer particles enhance the specific area of the particles and, hence, lessen the amount of water for the lubrication of the mix. Therefore, there is a substantial reduction in flow. This situation demands the use of a larger amount of superplasticizer to maintain the flow. In the present study, the superplasticizer was mainly introduced for the dispersion of the bio-char particles. Owing to their nano-size, the particles become agglomerated.

The use of bio-char for the enhancement of the properties of cementitious products in a hardened form has been documented by many researchers. The present work explored the effects of bio-char on the fresh properties of cementitious materials. The results revealed that the bio-chars can be used as admixtures for reducing fresh density, with no effect on the setting time.

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