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Proceeding Paper

Improvement of Early-Age Mechanical Properties of Cement Mortar by Adding Biochar of the Santa Maria Feverfew Plant †

Ahmed Kamal Subhani, Mohib Nisar and Anwar Khitab *

Department of Civil Engineering, Mirpur University of Science and Technology (MUST), Mirpur 10250, AJ&K, Pakistan; ahmedksubhani@gmail.com (A.K.S.); mohibsardar11@gmail.com (M.N.)
* Correspondence: anwar.ce@must.edu.pk
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Abstract: This study focused on the application of nano-/micro-sized fibers obtained from pyrolysis of Santa Maria feverfew (biochar) in cement mortars. The biochar was added in amounts of 0, 0.05 and 0.1 percent by mass of cement. The mechanical characteristics were determined after 3 and 7 days and matched with those of the control samples. The compressive strength remained unchanged with the biochar addition, whereas the flexural strength increased. Biochar is a carbon-rich material, and its use in building materials leads to carbon sequestration, which is in accordance with the sustainable development goals of the UNO.

Keywords: cement mortars; biochar; Santa Maria feverfew plant; compressive strength; flexural strength; early age; carbon sequestration; sustainable development goals

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1. Introduction

Pyrolysis is an energy-intensive method that involves the thermochemical breakdown of raw biomass in an inert atmosphere at high temperatures and pressures. This procedure yields different valuable products, like biochar, liquid bio-oil and fuel gases [1]. Biochar is a low-density dark-color carbon deposit. Scientists have used many different kinds of feedstock, including water hyacinth, oriental beech, corncob and many more [2–4]. Many researchers in the recent past have added biochar to cementitious products to enhance performance. Gupta et al. added biochar of sawdust at the rate 2% by mass of cement [5]. The results reveal that the addition enhanced the compressive strength and ductility of the end products. Tayyab et al. incorporated the biochar of millet and maize in mortar [6]. The authors reported an enhanced fracture toughness and ductility of the specimens, which was attributed to crack bridging/branching due to the fibrous nature of biochar. Iftekhar et al. studied the effect of adding the biochars of sugarcane bagasse and pine needles into cementitious mortars [7]. The authors reported enhanced interface shielding due to the addition. Restuccia et al. used the biochar of hazelnut shells as an additive in mortar specimens. They stated it enhanced compressive strength, flexural strength, toughness and ductility. Most of the previous studies focused on the effect of biochar on the hardened properties of the cementitious composites. The literature as regards the influence of biochar additions on the early-age properties of cementitious materials is limited.

The present study focused on the addition of the biochar of Santa Maria feverfew on the mechanical characteristics of cementitious mortar at an early age. As a matter of fact, the effect of biochar on the hardened properties of cementitious materials is well known; however, research on its effect on early-age mortar's characteristics is limited. Santa Maria feverfew is a local plant also known as gajjar boti or gajjar ghass. This study involved the evaluation of cementitious mortar in terms of its compressive and flexural strengths.

2. Materials and Methods

Cementitious mortars containing both the control mix and specimens with added biochar were prepared. A C-53-grade local ordinary Portland cement was used; the physical and chemical properties are described in Table 1. Sand was acquired from Lawrencepur (a well-known quarry) and was used as a fine aggregate, and its physical characteristics are reported in Table 1. Unlike the control mix, the other two mixes were integrated with biochar of the Santa Maria feverfew plant, as shown in Figure 1. Three types of specimens were prepared: one control, and those containing 0.05% and 0.1% biochar by mass of cement. The composition of the materials is presented in Table 2. A 1:1.5 cement/sand mortar with a water-to-cement ratio of 0.35 was prepared. The admixture was added at the rate of 1% by mass of cement.

Table 1. Chemical and physical characteristics of the ingredients of 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				

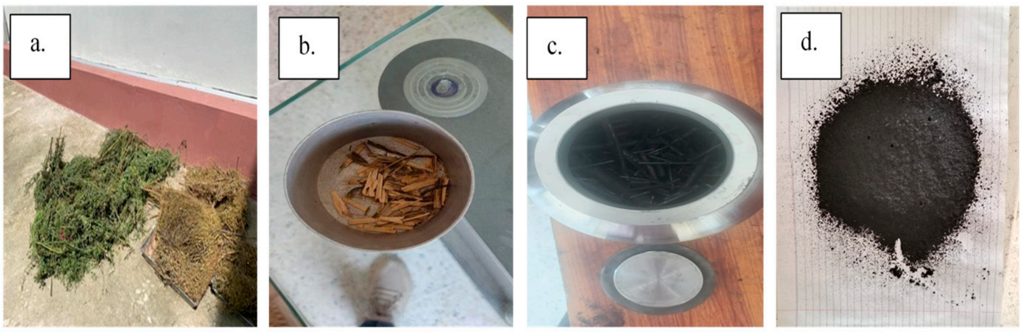

Figure 1. (**a**) Fresh Santa Maria feverfew plant, (**b**) dry plant, (**c**) biochar and (**d**) powdered biochar.

Table 2. Composition of mortar.

Samples	OPC (g)	Sand (g)	Water (mL)	Biochar (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

All the materials as described in Table 2 were mixed as per the ASTM C305-20 standard method [8]. To avoid agglomeration caused by the fine size of the biochar particles, the biochar was mixed in water using the UV-sonication technique. The admixture (superplasticizer) 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 cubes (50 mm size) and prisms (40 × 40 × 160 mm) according to the ASTM C1314 method [9]. After a one-day period, the specimens were de-molded and immersed in water for curing. The compressive strength was measured through ASTM C109 [10]. The flexural strength of the specimens was determined using the ASTM C348 method [11]. The mixing machine, molding process, strength test and sonicated mix of biochar and water are shown in Figure 2.

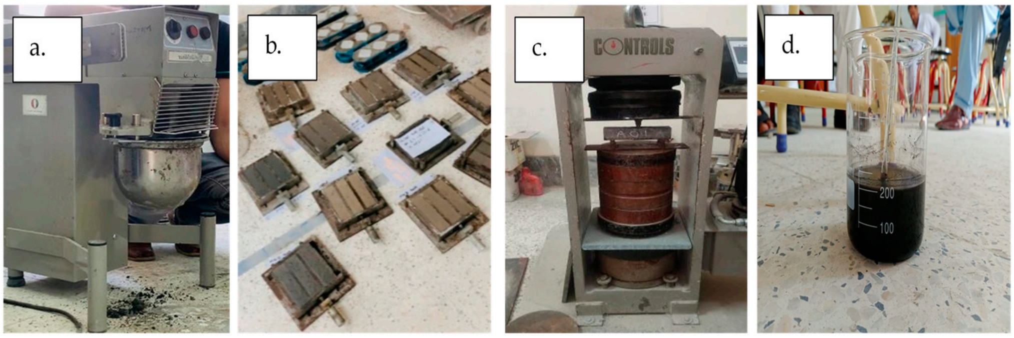

Figure 2. (**a**) Mixing, (**b**) molding, (**c**) flexural strength test and (**d**) UV-sonicated solution.

3. Results and Discussion

3.1. Compressive Strength

The strength results are presented in Table 3. The results show that there was a slight decrease in the compressive strength. The compressive strength of cementitious composites is closely related to their density [12]. Being porous and lightweight, biochar particles reduce density. A reduction in density might lead to a reduction in compressive strength [13,14]. In the hardened state, biochars are observed to enhance compressive strength [15,16].

Table 3. Effect of biochar on compressive strength of cementitious mortar.

Specimen	Compressive Strength (MPa)		
	3 Days	7 Days	% Difference
C0	13.2	16.7	
C0.05	12.3	15.3	−8
C0.1	12.5	15.8	−5

3.2. Flexural Strength

The influence of the biochar on the flexural strength of the cementitious mortar is shown in Table 4. The flexural strength was enhanced with the biochar addition. A previous study suggests that while the compressive strength mainly relies on the compactness of the material, the flexural strength is mainly dependent on the bond between the ingredients of cementitious materials [17]. As micro-/nano-fibers like those composing biochar enhance the cohesion between the particles, they may enhance the flexural strength [18].

Table 4. Effect of biochar on flexural strength of cementitious mortar.

Specimen	Flexural Strength (MPa)		
	3 Days	7 Days	% Difference
C0	1.3	1.9	
C0.05	1.7	2.4	26
C0.1	2.1	2.7	42

4. Conclusions

Based on the experimental outputs, the following conclusions are put forward. The biochar of the Santa Maria feverfew plant slightly reduces the compressive strength at an early age. The reduction in material density seems to be the cause of the reduction in compressive strength. The compressive strength is reduced by 8 and 5% with 0.05 and 0.1% additions of the biochar. Biochar enhances the flexural strength at an early age. Enhancement of material cohesion due to biochar's fibrous character seems to be the cause of the enhancement of flexural strength. The flexural strength is enhanced by 26 and 42% with 0.05 and 0.1% additions of the biochar at 7 days. Biochars are highly carbon-rich particles. As such, their addition to cementitious mixes is beneficial for carbon capture, a key sustainable development goal. Its addition results in high flexural strength of the end products at an early age, which is beneficial in many construction projects.

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