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Efficiency and Sustainability: Enhancing Mortar Mixtures with Wastepaper Sludge Ash †

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Abstract: The study aims to increase the efficiency of mortar mixes and improve their necessary qualities such as strength, density, and durability by using wastepaper as a cement substitute in the form of wastepaper sludge ash (WPSA). Mortars with 20, 25, and 30% cement replacement were tested. Due to less use of cement and greater usage of WPSA, CO_2 and SO_2 emissions can be reduced. The chemical properties of WPSA were compared to those of Ordinary Portland Cement (OPC). Testing showed that WPSA had similar cementitious properties. Results demonstrate the potential applications of this mortar in a variety of settings where increased toughness and equivalent characteristics are needed while still preserving the environment.

Keywords: wastepaper sludge ash; mortar; density; water absorption; acid attack

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1. Introduction

The global population rapidly increases with time, which puts increased pressure on urban construction including residential, commercial, and industrial buildings. This has led to an increase in the need for cement use worldwide [1,2]. One of the most versatile fundamental construction materials is cement [3,4]. However, the cement sector is characterized by significant levels of energy consumption [5,6] and greenhouse gas emissions [7,8]. Around the globe, the cement industry emits roughly 7% of carbon dioxide (CO_2) [8,9]. Therefore, in order to lessen this influence on the environment, it is necessary to investigate a viable cement substitute [10]. Reusing waste materials rather than disposing of them in landfills is a practical and affordable solution to these problems [11,12]. Paper recycling industries produce wastes called wastepaper sludge and wastepaper sludge ash (WPSA). The chemical composition of WPSA varies; it usually includes lime (CaO), silica (SiO_2), and alumina (Al_2O_3) and can be used as a supplemental cementitious material (SCM) [13]. The primary objective of this research is to develop a green technology material. WPSA has been used in concrete, bricks, and in studies instead of mortar. Our goal is to develop an eco-friendly and effective mortar for construction purposes. Mortar is also used to repair joints and cracks. By replacing 25% of cement with WPSA in mortar mixes we can obtain such efficient mortar.

2. Materials and Methods

2.1. Materials

A proportional mixture of Ordinary Portland cement (OPC) and wastepaper sludge ash (WPSA) was used as a cementitious material. Wastepaper sludge was collected from private schools and universities of Abbottabad. It was dried in the sun for 12 to 15 days and then burnt in an electric furnace at 750 °C for 2 h to make ash. The composition of the WPSA, analyzed via X-Ray Fluorescence (XRF), is presented in Table 1. It consists primarily of calcium and can serve as a binding material.

Table 1. Chemical/elemental composition of WPSA.

Empirical Formula	WPSA (%)
Ca	75.37
Si	17.096
S	4.397
Fe	1.994
K	0.428
Ti	0.263
Sr	0.184
Zn	0.114
Cu	0.072
Mn	0.049
Zr	0.027
V	0.007

2.2. Methods

Mortar mix ratios for 'MC' samples for each ratio were prepared according to ASTM-C109 by partially replacing 0, 20, 25, and 30% of cement with WPSA by weight. The sand-to-binder ratio was taken as 1:2.75 and the water-to-cement ratio used for mixing was restricted to 0.48. Weights and proportioning data are shown in Table 2.

Table 2. Mix proportion of WPSA, cement, sand, and water.

Name	Cement	Sand	WPSA	Water
MC-0	500 g	1375 g	0 g	242 g
MC-20	400 g	1375 g	100 g	242 g
MC-25	375 g	1375 g	125 g	242 g
MC-30	350 g	1375 g	150 g	242 g

3. Results

3.1. Flowability

The study conducted showed that when the percentage of WPSA increased, the workability of the mortar decreased. Figure 1 displays the results of this research.

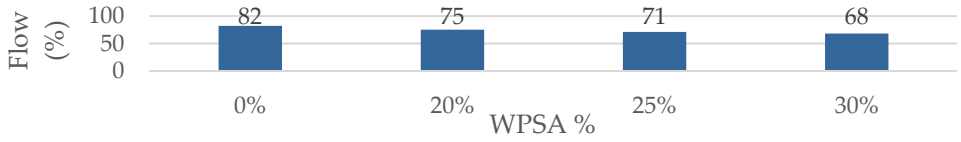

Figure 1. Flow/workability of 0, 20, 25, 30% WPSA mortar mix.

3.2. Compressive Strength

Mortar cubes with 25% WPSA exhibited favourable compressive strengths of 19.1 (CTM) and 18 MPa (RH). In comparison, the cubes with 20% and 30% WPSA replacements showed lower compressive strengths as shown in Figure 2. Therefore, replacing 25% of cement with WPSA results in a mixture that can be used for environmentally friendly construction purposes.

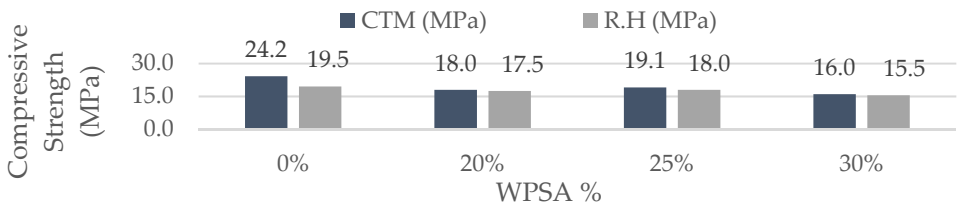

Figure 2. Compressive strength results (CTM and RH).

3.3. Ultrasonic Pulse Velocity

The test was conducted according to ASTM C597-02. The UPV results for WPSA replaced samples are shown in Figure 3. These results suggest that the 25% WPSA sample had higher velocity, indicating the most uniform mass, and similar quality.

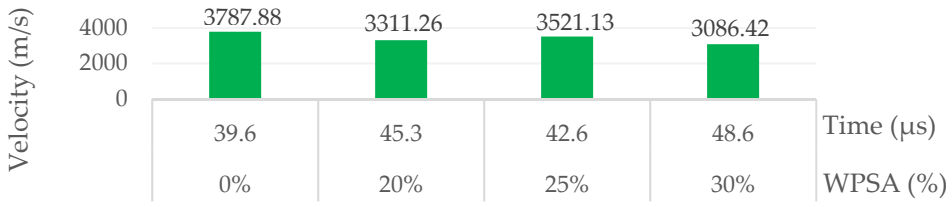

Figure 3. Ultrasonic pulse velocity results for 150 mm long samples.

3.4. Water Absorption

The test was conducted according to ASTM C642-9. It was found that the addition of 25% WPSA to mortar mixtures resulted a significantly lower water absorption rate compared to other replacements, as depicted in Figure 4.

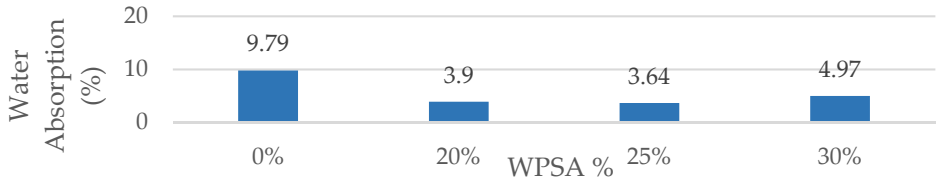

Figure 4. Water absorption results for 0, 20, 25, 30% WPSA mortar samples.

When 25% of the cement was replaced with WPSA, it increased the volume of the mixture and reduced internal voids, resulting in a denser mixture as given in Table 3.

Table 3. Bulk density values for WPSA mortar samples.

WPSA (%)	Density (g/cm^3)
0%	2.174
20%	2.18
25%	2.204
30%	2.065

3.5. Acid Attack (HCL)

In this study, HCL with a pH value of 3.01 was used to test the durability of the mortar samples. The results of the acid durability test showed that the acid resistance of the WPSA samples slightly decreased as the WPSA content increased. The results are shown in Figure 5.

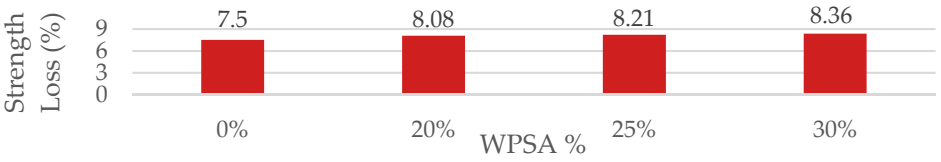

Figure 5. Loss of strength (%) in WPSA mortar samples.

4. Conclusions

1. The chemical properties of WPSA showed similar behaviour to that of cement. A high calcium content in the WPSA results in good quality and characteristics of the mortar.
2. Replacement of 25% WPSA with cement showed favourable ultimate compressive strength and reduced water absorption by approximately 60%.

3. The technique developed in this study can be used in runoff structures, sewage pipes, canal surfaces, and wall plastering.

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