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REDUCING THE WATER ABSORPTION OF MORTAR BY USING ECO-FRIENDLY WASTEPAPER SLUDGE ASH

[a] Ahsin Ihsan*, [b] Asad Shafique, [c] Muhammad Faisal Javed, [d] Sardar Kashif-ur-Rehman

a: Department of Civil Engineering, Comsats University Islamabad (Abbottabad Campus), 500ahsin@gmail.com
b: Department of Civil Engineering, Comsats University Islamabad (Abbottabad campus), asadshafiquekhan1@gmail.com
c: Department of Civil Engineering, Comsats University Islamabad (Abbottabad Campus), arbabfaisal@cuiatd.edu.pk
d: Department of Civil Engineering, Comsats University Islamabad (Abbottabad Campus), skashif@cuiatd.edu.pk
** Corresponding author: Email ID: 500ahsin@gmail.com*

Abstract- The aim of this research is to utilize the paper waste in mortar mixtures as a cement replacement in form of Wastepaper Sludge Ash (WPSA) to make them more efficient and enhance their required properties such as water resistance, permeability, sorptivity. Mixture was then investigated to understand its chemical, mechanical and physical properties. Depletion of natural resource can be reduced by using WPSA as cement replacement. Carbon dioxide (CO_2) and Sulphur dioxide (SO_2) emissions can be reduced as well because of less usage of cement proportions. The physical and chemical properties of WPSA was compared with the cement. As the result of testing, WPSA showed similar cementitious properties and at 25% cement replacement by weight with the WPSA, it showed favorable ultimate strength of 19.05 MPa. Also by using WPSA, water absorption was reduced approximately up to 60% hence it increases water resistivity and decreases permeability and sorptivity thus making the structure more durable.

Keywords- Ecofriendly, mortar, wastepaper sludge ash, water absorption.

1 Introduction

The Global Population massively increases with time which puts increased pressure on urban construction including residential, commercial, and industrial buildings. This led to increase in the need for cement use worldwide [1,2]. Cement is a basic construction material that has many applications [3,4]. Nevertheless, the cement industry is identified by a high energy consumption [5,6] and high greenhouse gases emissions [7–9]. Cement industries emits about 7% of Carbon dioxide (CO2) worldwide. [9,10]. Hence, there is an urgent need to explore a feasible replacement for cement to reduce this environmental impact [11]. The reutilization of waste products rather than disposal in landfills is an economical and viable solution to these issues [12,13]. A huge amount of paper waste is produced at daily basis in Pakistan. It is produced in every part of the country and it constitutes a huge proportion of total wastes produced. Waste paper sludge is produced in paper production industries and especially newspaper printing industries which is then incinerated and then disposed of to landfills which have harmful effects on soil properties. During the production of Paper and Pulp/Paper sludge, chlorine based bleaches are used. These are toxic materials or additives so when the paper waste is dumped in soil or released in the water (rivers, seas or oceans) it causes hazardous pollution. Also when the paper rots it emits methane gas which is 25 times more toxic than CO2 emission. These current disposal methods are not environmentally helpful rather causes more pollution. Increasing rate of population is increasing the rate of production of paper waste, it is also increasing because paper is taking place of plastic products worldwide such as paper bags and cardboards. Apart from all that use of cement is increasing day by day as well which is decreasing the natural resources for its production. Also it requires a huge portion of budget to treat these wastes that is ultimately effecting the economy of the country. In order to overcome all of these problems a proper solution is needed to reduce the depletion of natural resources and reutilizing the waste materials that will be beneficial for both

environment and economy. Therefore, a search for alternative methods to efficiently reuse WPSA is initiated and the most appropriate way to recycle the wastepaper sludge is in mortars, concrete or bricks manufacturing. This will alleviate the costs needed to dispose the WPSA and it will preserve the soil properties as well. Also by partially replacing WPSA with cement it will shrink the cement production rate and will eventually decrease the depletion of natural resources that will help the environment. By fulfilling the 3R concept, reuse, recycling and recovery of WPSA as an alternate method in construction, it is helping the environment and ecosystem in a positive manner. Replacement of cement with other ashes has been done and investigated by many researchers within last few decades. [14-16]. The research on WPSA is very limited. As per Scopus website data, only few documents were found related to WPSA in different fields like Veterinary, decision sciences, mathematics etc. however more research is carried out in engineering fields as given in Fig 1.

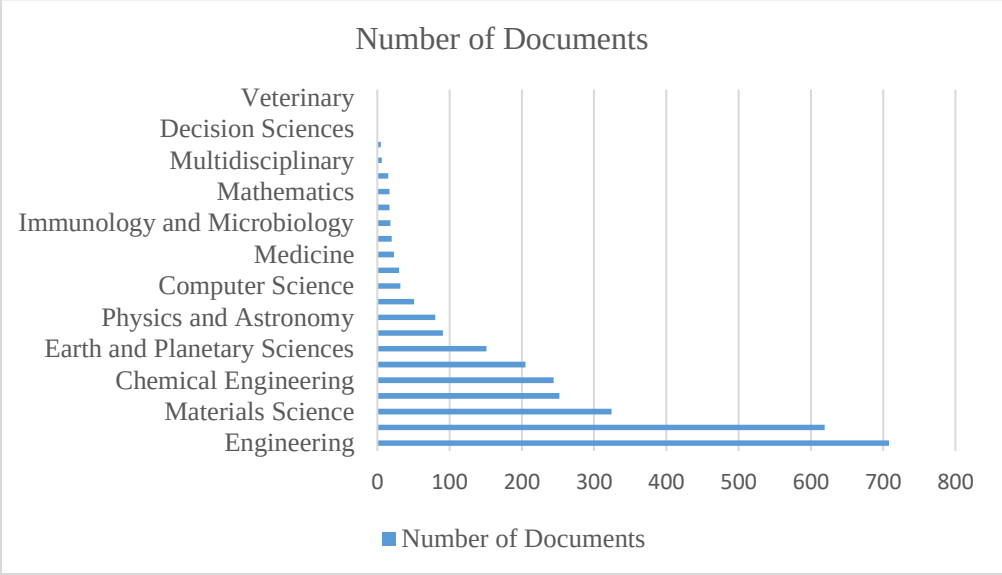

Figure 1: Publications of WPSA in different study fields.

In this research work WPSA is used as a partial replacement of Cement in the Mortar mix of 1:2.75 (binder/sand ratio). WPSA binds the Sand particles together similar to Cement. To produce waste paper sludge ash, paper sludge is combusted at 700-750 °C. As it contains a high proportion of organic matter, in form of cellulose and some inorganic compounds such as clays and calcium carbonate [17]. At 700 °C temperature, combustion of paper sludge transforms the clay minerals such as kaolinite into metakaolinite [17] and thus WPSA will behave as pozzolanic material [18,19]. Although composition of WPSA varies, it commonly contains a sufficient amount of Lime (CaO), Silica (SiO_2) and Alumina (Al_2O_3) and because of this reason it is being used as a supplementary cementitious material (SCM) [18,19]. The main objective of this research is to make green technology material. Also physical and chemical properties are not effected at a larger scale of material. Thus durability of a structure is not compromised. It also does not affect the compressive strength and water absorption is decreased. Researches have been done by replacing Cement with WPSA in concrete and bricks but our aim is to make mortar usage ecofriendly and efficient because it is a key material used for grey structure finishing and for other masonry purposes during the construction of projects. Mortar is also used to repair joints and cracks. By replacing 25% of cement by WPSA in mortar mix we can obtain such efficient mortar [17].

2 Materials and Methodology

2.1 Materials.

In this test Ordinary Portland cement (OPC) and waste paper sludge ash (WPSA) was used as a cementitious material. Waste paper sludge was collected from Private schools and universities of Abbottabad. It was then sun dried for 10 to 15 days and then burnt in electric furnace at 700°C for 2 hours. WPSA used in this test is shown in Fig 2.

Figure 2: Wastepaper sludge Ash (125g).

The Conventional chemical composition of OPC and WPSA is similar as given in the Table 1. [20,21]. Concentration of SiO_2, Al_2O_3 and CaO is greater in both of Cementitious materials. These oxides are present in similar quantities in both Cement and WPSA. Table 1 is showing detailed comparison of oxides present in Ordinary Portland Cement and WPSA. Sand used in this test was passed through 3.35mm IS sieve for better gradation as used in [9]. Ground water was used for mixing of materials.

Table 1 Chemical composition of OPC and WPSA

Empirical formula	OPC (% w/w)	WPSA (% w/w)
SiO2	21.3	23.3
Al2O3	5.6	5.3
Fe2O3	3.4	0.8
TiO2	0.1	0.5
MgO	2.1	2.5
CaO	64.6	62.4
Na2O	0.1	0.4
K2O	0.2	0.4
P2O	0.1	0.5
MnO	0.1	0.5
SO3	2.1	0.6

2.2 Mix Proportion.

Mortar samples were prepared with 25% replacement with WPSA. Mixing proportion details are given in the Table 2 where M0 denotes samples with zero percent WPSA and M25 is named for samples having 25 percent WPSA as a cement replacement. Sand to binder ratio was taken as 1:2.75 and water to cement ratio used for mixing was restricted to 0.48.

Table 2 Mix proportion of WPSA and OPC.

Mix ID	Ordinary Portland cement (OPC)	Waste paper sludge Ash (WPSA)	Sand	Water
M0	500 g	0 g	1375 g	242 g
M25	375 g	125 g	1375 g	242 g

2.3 Preparation of Samples.

Specimens were prepared according to ASTM C109/C109M. Materials (OPC, PSA and sand) in dry form were firstly mixed in an Automatic Programmable Mortar mixer UTCM-0085 for 2 min. Water is added to the mixture and then blended for 5 more min in a mixture machine. Then wet mix was casted in (50x50x50) mm cube moulds shown in Fig 3. Samples were taken out of moulds after 24h and then placed in water container for curing at room temperature (20°C to 25°C). Samples were ready for testing after ultimate strength was achieved as shown in Fig 4.

Figure 3: Mortar mix Casted in Moulds.

Figure 4: WPSA (25%) Mortar Samples.

2.4 Water Absorption.

Mixes with 0% and 25% WPSA were tested for water absorption using ASTM C642-97. Samples were firstly dried in oven for 24h at 100°C to 110°C temperature and then allowed to cool down in air at room temperature. Saturated mass was then determined after immersion of samples for 48h in a water container. Specimens were then boiled for 5h and after boiling, their saturated mass was determined. After that immersed apparent weights of specimens were examined. Water absorption percentage was then calculated using these weights.

3 Results and Discussion

3.1 Compressive strength.

The impact of curing period and replacement of Ordinary Portland Cement (OPC) with 25% Waste Paper Sludge Ash (WPSA) is tested. Increase in curing time increased the compressive strength of mortar mix while an addition of WPSA has decreased the compressive strength. At early ages of curing both samples were having same compressive strength. Similar results were obtained by other researchers [9,22]. Mortar cubes with 0% WPSA showed Compressive strength of 16.47 and 24.17 MPa after 7 and 28 days of curing and cubes with 25% WPSA gave compressive strength of 14.9 and 19.05 MPa as mentioned in Table 3. Therefore, at 25% cement replacement by weight with WPSA showed favourable ultimate strength of 19.05 MPa, thus it can be adopted for environmental friendly and economical construction.

Table 3 Compressive strength at 7, 14, 21, 28 days.

Curing days	Compressive strength (MPa)	
	0 % WPSA	25% WPSA
7	16.47	14.9
14	21.73	17.21
21	23.1	18.95
28	24.173	19.05

3.2 Water Absorption.

Addition of 25% WPSA reduced water absorption up to 55%, 57%, 60% after 7, 14 and 28 days of curing respectively as given in Table 4. Mortar samples with 0% WPSA has water absorption of 10.49 and 9.79 percent after 7 and 28 days of curing while samples having 25% WPSA has water absorption of 4.8 and 3.9 percent as shown in Table 4. Replacement of 100% cement with WPSA increases water absorption as mentioned in [23]. However, using 25% WPSA with cement increased water resistivity, reduced pores, decreased permeability and water absorption. Hence using WPSA can make structure more durable.

Table 4 Water Absorption at 7, 14, 28 days.

Curing days	Water Absorption (%)	
	0 % WPSA	25% WPSA
7	10.49	4.8
14	10.20	4.4
28	9.79	3.9

As waste paper sludge ash is lighter in weight as compared to cement particles, it occupies more volume when we replace 25% of it by weight. By excessive volume it decreases internal voids that decreases the water absorption. And also WPSA provides an adequate amount of compressive strength by binding the aggregate.

4 Conclusion

By obtaining all the favourable results we can conclude many significances and can predict the usages of WPSA mortar. From experimental data following conclusions are made:

1. Chemical and physical properties of WPSA showed similar behaviour as that of cement.
2. WPSA reduces the emission of CO_2 and SO_2 causing less environmental damages and is ecofriendly.
3. Replacement of 25% WPSA with cement showed favourable ultimate compressive strength of 19.05 MPa.
4. By usage of WPSA, water absorption reduced to approximately 60% which indicated less permeability.
5. The technique developed in this study can be used in runoff structures, sewage pipes, canal surfaces and wall plastering.

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