Utilization of Hospital Waste Ash in Concrete

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ABSTRACT

Hospital waste management is a huge problem in Pakistan. The annual production of medical waste produced from health care facilities, in Pakistan, is around 250,000 tons. This research paper is intended to evaluate the feasibility of using of hospital waste ash obtained from Pakistan Institute of Medical Sciences, Rawalpindi, Pakistan, as partial replacement of cement.

The main variable in this research is the amount of hospital waste ash (2, 4, 6 and 8% by weight of cement) while the amount of cementitious material, water to cementitious material ratio, fine and coarse aggregate content were kept constant.

Test results substantiate that hospital waste ash can be used in concrete. XRD (X-Ray Diffraction) of hospital waste ash showed that it is rich in calcite while scanning electron micrographs indicated that the particles of hospital waste ash have highly irregular shape. The slump value, density of fresh concrete and water absorption decreased with the increase in the quantity of hospital waste ash in the mix. At 3 days of testing, the compressive strength of mixes with hospital waste ash was higher than the control mix while at 7 and 28 days the CM (Control Mix) showed higher strength than the hospital waste ash mixes except the mix containing 2% hospital waste ash by weight of cement.

Key Words: **Hospital Waste Ash, Compressive Strength, X-Ray Diffraction, Scanning Electron Microscopy.**

1. INTRODUCTION

At present lot of construction is taking place in earthquake-affected areas of Khyber Pukntoonkhwa Province of Pakistan and much more is anticipated in backdrop of recently announced construction of hydroelectric projects in the country. Furthermore, reconstruction phase in Afghanistan is already in progress. Demand of construction material in such scenario is liable to be enormous. Cement, is the most essential ingredient of the construction industry and directly affects the overall cost of any project. Therefore, economy in the prevailing environment will remain a key feature of all engineering activities.

Hospital waste management is a huge problem in Pakistan. The annual production of medical waste produced from health care facilities, in Pakistan, is around 250,000 tons [1].

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This research is intended to evaluate the feasibility of using HWA (Hospital Waste Ash) as partial replacement of cement in concrete. The successful utilization of HWA would not only lower the cost of construction, but would also substantially contribute to reduce the environmental hazards.

2. EXPERIMENTAL INVESTIGATION

For this research, five different mixes were prepared. These include one CM which was prepared without addition of HWA and remaining four mixes were prepared with different proportions of HWA as partial replacement of cement in concrete. HWA mixes include 2, 4, 6 and 8% of HWA in replacement mode by weight of cement. The mixes were designed for compressive strength of 30 MPa at 28 days. The mix design is illustrated in Table 1.

For each mix, normal consistency, setting time, strength activity index, water absorption and compressive strength were determined according to ASTM C187, ASTM C191-04, ASTM C618-03, ASTM C642-97 and ASTM C 39/C 39 M-03 [2-6]. The fresh concrete density was determined by procedure described in Properties of Concrete by Neville, [7]. X-ray Diffraction and Scanning Electron Microscopy test were carried out on selected samples of HWA.

TABLE 1. EXPERIMENTAL MATRIX

Mix	Cement (Kg/m^3) [C]	Hospital Waste Ash (Kg/m^3) [P]	[W/(C+P)]	Fine Aggregate (Kg/m^3)	Coarse Aggregate (Kg/m^3)
CM	340.0	0.0	0.55	850	975
2HC	333.2	6.8	0.55	850	975
4HC	326.4	13.6	0.55	850	975
6HC	319.6	20.4	0.55	850	975
8HC	312.8	27.2	0.55	850	975

2.1 Materials

The materials along with specifications, which were used for this experimental program, are summarized as:

2.1.1 Cement

OPC (Ordinary Portland Cement) from Cherat cement factory was used. The cement met the requirements of ASTM C150-04 Type I [8]. The properties of cement are tabulated in Table 2.

2.1.2 Fine Aggregate

Dry Lawrancepur sand was used as fine aggregate. The sieve analysis was carried out according to ASTM C136-01 [9]. The summary of results is given in Table 3.

TABLE 2. PHYSICAL AND CHEMICAL PROPERTIES OF CEMENTITIOUS MATERIALS

	OPC	Hospital Waste Ash
Specific Gravity	3.05	2.71
Silicon Dioxide (SiO_2) (%)	17.454	19.603
Aluminum Oxide (Al_2O_3) (%)	4.422	10.377
Ferric Oxide (Fe_2O_3) (%)	3.93	6.273
Calcium Oxide (CaO) (%)	65.844	36.636
Magnesium Oxide (MgO) (%)	2.346	2.136
Sulfur Trioxide (SO_3) (%)	3.979	5.598
Sodium Oxide (Na_2O) (%)	0.252	2.697
Potassium Oxide (K_2O) (%)	1.117	0.701
TiO_2 (%)	0.348	3.395
$P2O_5$ (%)	1.03	1.167
Cl (%)	0.012	5.370
SrO (%)	0.072	0.044
MnO (%)	0.064	0.123
ZnO (%)	-	3.883
CuO (%)	-	0.639
Cr_2O_3 (%)	-	0.412

2.1.3 Coarse Aggregate

Crushed stone from Margala with maximum nominal size of 19mm was used as coarse aggregate. The sieve analysis was carried out according to ASTM C136-01 [9]. The summary of results is given in Table 3.

2.1.4 Hospital Waste Ash

Hospital waste ash was obtained from PIMS, Rawalpindi. The ash obtained was a mixture of fine and coarse particles (broken glass bottles, metallic pieces including syringes and other surgical items) as shown in Fig. 1. This ash mixture was sieved through No. 50 sieve and retained material was discarded. The grinding of HWA was carried out in Los Angles Abrasion machine [10] with 9 balls in it. The weight of each ball was 450 ±5gm. To maintain uniform fineness each batch of 5 kg was given 4000 revolutions. The ash sample obtained after grinding is shown in Fig. 2. The properties of HWA are illustrated in Table 2.

TABLE 3. GRADING AND PHYSICAL PROPERTIES OF FINE AND COARSE AGGREGATE

	ASTM Sieve No.	Percentage Retained	Cumulative Percentage Retained	Cumulative Percentage Passing	ASTM Range (C 33) [15]
Grading of Fine Aggregate	4	0.57	0.57	99.43	95 to 100
	8	2.98	3.56	96.44	80 to 100
	16	12.16	15.71	84.29	50 to 85
	30	27.18	42.89	57.11	25 to 60
	50	44.15	87.04	12.96	5 to 30
	100	12.96	100.00	0.00	0 to 10
Grading of Coarse Aggregate	19	0.0	0.0	100	90 to 100
	12.5	12.5	12.5	87.53	-
	9.5	60.9	73.3	26.66	20 to 55
	4.75	26.3	99.7	0.33	0 to 10
	2.36	0.3	99.9	0.066	0 to 5
	Pan	0.1	100.0	0	-
Physical Properties	Unit Weight (kg/m^3)	Bulk Specific Gravity (SSD)	Absorption (%)	Fineness Modulus	Quarry
Fine Aggregate	1953.54	2.627	1.65	2.52	Lawrencepur, Pakistan
Coarse Aggregate	1529.28	2.678	1.07	-	Margala, Pakistan

2.1.5 Mixing Water

Potable water was used for the entire experimental program.

2.2 Specimen Designation

The mixes were abbreviated in two ways i.e. CM and XH. Specimen cast without addition of HWA were designated as CM, while XH represented the amount of cement, in per cent, that has been replaced with HWA. For instance, the specific designations, 2H, 4H and 8H indicated 2, 4 and 8% replacement of cement with HWA.

3. TEST RESULTS AND ANALYSIS

3.1 X-Ray Diffraction

Fig. 3 shows pattern of XRD of HWA. According to XRD data, HWA is rich in calcite. Calcite is composed of calcium carbonate ($CaCO_3$) and according to the literature [11]; it is major source of the world's quicklime and hydrated, or slaked, lime.

FIG. 1. HOSPITAL WASTE ASH OBTAINED FROM PIMS, RAWALPINDI

3.2 Scanning Electron Microscopy

The SEM (Scanning Electron Microscopy) was done to obtain the particle size and shape of HWA. The analysis of scanning electron micrographs (Fig. 4) indicated that HWA particles have highly irregular shape and the average size of the particle is less than 10 micron.

3.3 Setting Time and Consistency Test

The initial and final setting time was lowest for the CM and it increased with the increase in the amount of HWA (Fig. 5). The initial and final setting time was maximum for 8H mix i.e. 166 and 440 minutes respectively.

The results of consistencies of cement pastes having different HWA content are graphically shown in Fig. 6. It is clear that water requirement to make the paste of standard consistency increased with the increase in HWA content.

FIG. 2. HOSPITAL WASTE ASH SAMPLE AFTER GRINDING

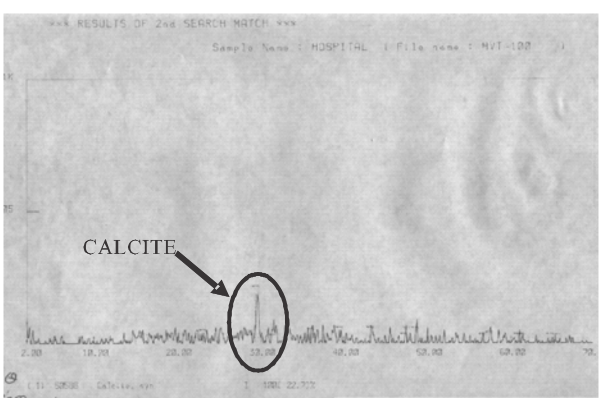

FIG. 3. X-RAY DIFFRACTION OF HOSPITAL WASTE ASH

3.4 Effect of HWA on Workability

The results of slump values of different mixes are graphically shown in Fig. 7. The slump values decreased

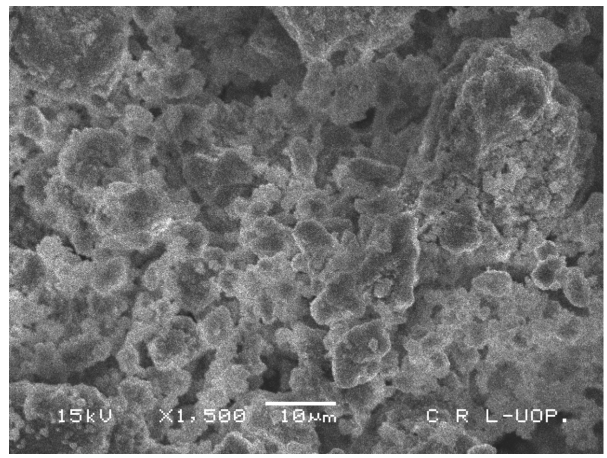

FIG. 4. SCANNING ELECTRON MICROSCOPY AT 1500X MAGNIFICATION

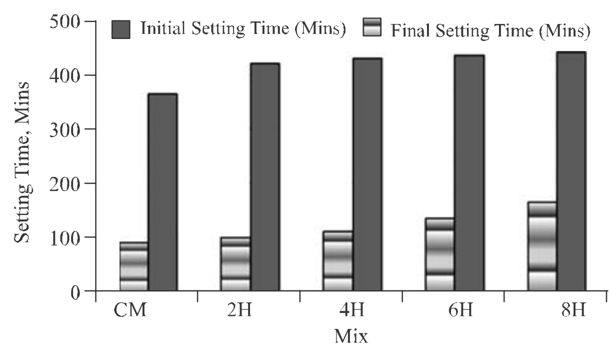

FIG. 5. INITIAL AND FINAL SETTING TIME OF DIFFERENT MIXES

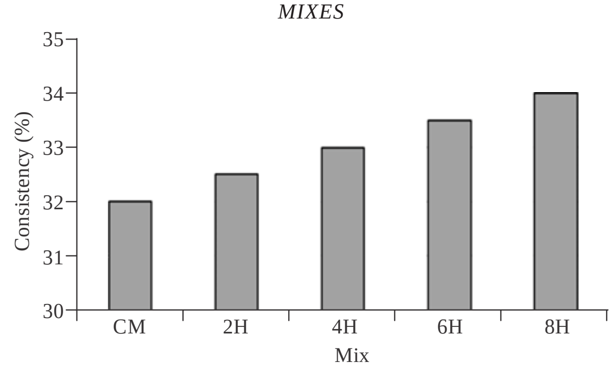

FIG. 6. CONSISTENCIES OF DIFFERENT MIXES

with the increase in the amount of HWA in the mix. This may be because of relatively high fineness and low density of the concrete mixtures [12].

3.5 Fresh Concrete Density

The results of fresh concrete density of different mixes are graphically shown in Fig. 8. The fresh concrete density was maximum for the CM (2482 kg/m^3). The density decreased with the introduction of HWA as cement replacement, and higher the HWA contents lower is the density. This is due to the fact that the density being a function of specific gravity. Since the specific gravity of cement is more as compared to HWA, therefore, the density of the CM mix is highest.

3.6 Strength Activity Index

As prescribed in ASTM Standard C618-03 [4], the SAI (Strength Activity Index) is defined as:

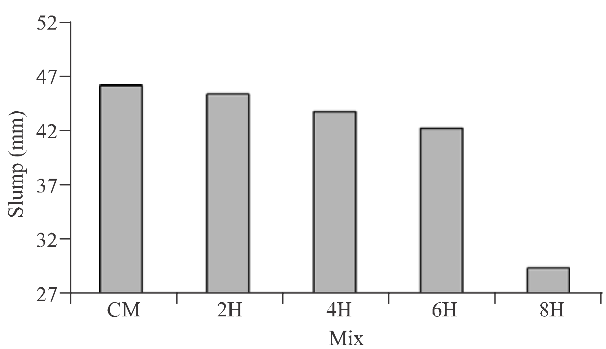

FIG. 7. SLUMP VALUES OF DIFFERENT MIXES

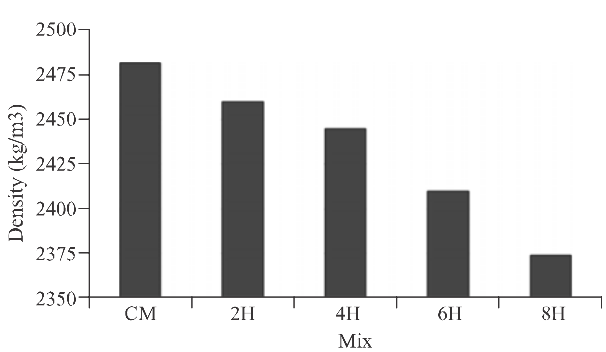

FIG. 8. DENSITY OF DIFFERENT MIXES

SAI = (A/B) x 100%

Where A is average compressive strength of the cement mortar cubes containing HWA, and, B is average compressive strength of cement mortar cubes without HWA.

As per the ASTM Standard C618-03, SAI should be a minimum of 75% of the control mixture at both 7 and 28 days. Test data showed that (Fig. 9).

- The mixes CM, 2H and 4H meet the requirements of ASTM C618-03 specifications.
- All the mixes showed higher rate of reactivity at 7 days in comparison to 28 days. This is because of the accelerating effect induced by calcite in HWA [13].

3.7 Compressive Strength

The results of compressive strengths of mixes are graphically shown in Fig. 10. Test data showed that:

- For all mixes, the compressive strength increased with the curing period i.e. from 3-28 days.
- At 3 days of testing, the mixes with HWA showed higher strength than CM. This is due to the presence of calcite in HWA.

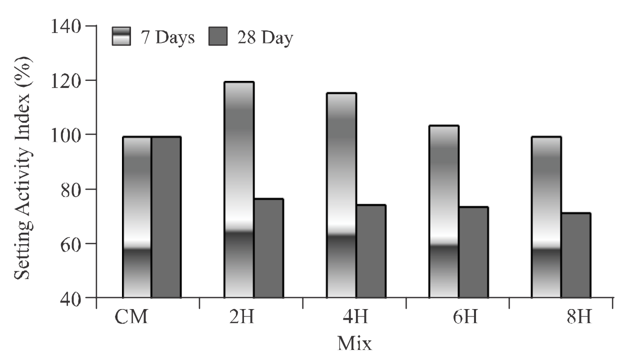

FIG. 9. STRENGTH ACTIVITY INDEX OF DIFFERENT MIXES

- ♦ The 7 and 28 days compressive strength of CM was higher than the mixes with HWA except the mix 2H. The increase in compressive strength of 2H mix may be due the micro filler effect. This needs to be endorsed through scientific investigation i.e. by studying SEM images of CM and 2H mixes at various ages. When the mix 4H is compared with the mix 8H, 4H showed higher strength at every stage of testing, which means that the amount of cementing material also plays an important role. This is because in the 8H mix the cement replacement is more as compared to 4H mix thus making later mix (4H) rich in cement content. Thus when the hydration of the portland cement commences the principal silicates namely tricalcium silicate, dicalcium silicate and tricalcium aluminate which are crystalline in nature decomposes rapidly in water to provide the desired silicate and aluminate ions for the formation of the cementitious hydrates. Therefore, for the mix containing higher amount of cement, higher compressive strength can be expected.

3.8 Water Absorption

Results of water absorption test are graphically shown in Fig. 11. Test data showed that the water absorption

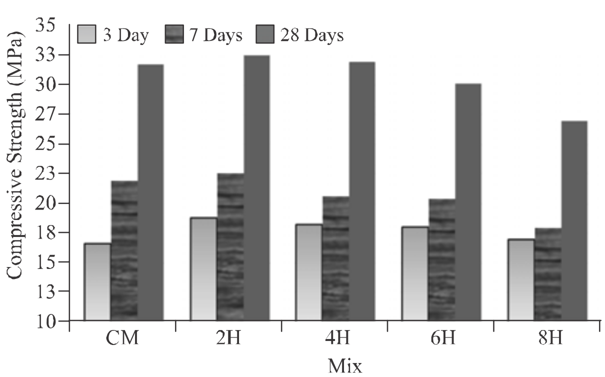

FIG. 10.COMPRESSIVE STRENGTH OF DIFFERENT MIXES

decreased with the increase in the quantity of HWA as cement replacement. This decrease was due to the micro filler effect which improves the durability of the mixture by altering the framework of the matrix [14].

4. COST COMPARISON

The control mix and other mix selected for cost comparison were those, which fulfilled the requirement of ASTM standards for SAI (ASTM C618-03) i.e. (CM and 4H) and had almost similar compressive strength. The results are summarized in Table 4. Based on cost analysis, mix design of 4H was found to be approximately 3% cheaper than CM.

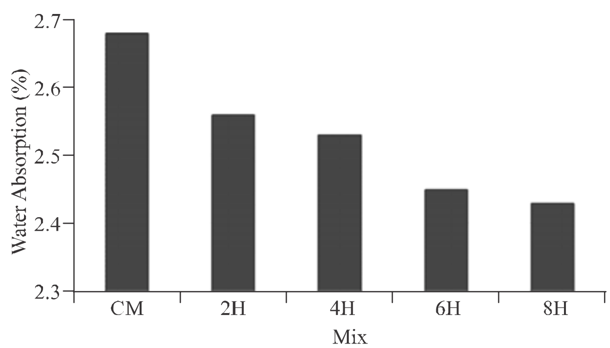

FIG. 11. WATER ABSORPTION OF DIFFERENT MIXES

TABLE 4. COST COMPARISON

Material	Unit Price (PKR)*	Control Concrete (CM)		Mix with Hospital Waste Ash (4H)	
		Quantity (Per m^3)	Amount (Rs.)	Quantity (Per m^3)	Amount (Rs.)
Cement (kg)	6	340.0	2040	326.4	1958.4
Coarse Aggregate (kg)	0.274	975	267.15	975	267.15
Sand (kg)	0.125	850	106.25	850	106.25
Hospital Waste Ash** (kg)	0.75	-	-	13.6	10.2
Total	-	-	2413.4	-	2342
Percent Reduction in Cost = 3 Approximately *PKR Stands for Pakistani Rupee, **HWA Hauling Cost= Rs. 400/metric Tonne (Assuming 10 km haul), and Grinding Cost= Rs. 350/ Metric Tonne					

5. CONCLUSIONS

Based on the experimental results, following conclusions can be drawn.

(i) Low cost concrete can be made by utilizing HWA as partial replacement of cement in concrete without compromising the strength parameters.

(ii) The setting time increased while the density and water absorption of mixes decreased with the increase in the percentage of HWA in the mix.

(iii) The utilization of HWA as partial replacement of cement in concrete solves the problem of it's the disposal thus keeping the environment free from pollution.

(iv) In future research, further scientific investigation should be carried out to endorse the results.

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