INVESTIGATION OF USING PAPER INDUSTRY WASTE (HYPO SLUDGE) IN CONCRETE MIX

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ABSTRACT

Cement industry is one of the major producers of carbon dioxide gas (a greenhouse gas) and ordinary concrete contains about 12% cement. The world's annual production of cement is 1.6 billion tons which accounts for about 7% emission of carbon dioxide gas in atmosphere. Concrete industry is consuming large amount of natural resources (gravel, sand, fine rock, water etc). In order to address such environmental issues related to cement manufacturing there is dire need of replacing cement with other binders to be used in concrete.

This study investigates the utilization of waste paper sludge ash (WPSA) in concrete. WPSA was partly replaced in the ratios of 5, 10, 15 and 20 percent of cement. Specimens were tested for initial setting time, final setting time, mechanical strengths (i.e. compressive and tensile strength) and dry density, and results are compared with ordinary concrete (without WPSA).The results showed that WPSA can be replaced up to 15% by weight of cement. Also the initial and final setting time of cement are gradually reduced by increasing the percentage of WPSA. The addition of WPSA results in a lighter concrete.

KEYWORDS: *waste paper sludge ash, compressive strength, tensile strength, dry density, initial setting time, final setting time.*

INTRODUCTION

Concrete is an important construction material. The reasons for its extensive use are its mechanical and durability properties and ease of molding into any shape[1]. This popularity comes with a huge price; its production causes adverse effects on environment. First, its production requires large amount of non-renewable resources e.g. coarse aggregates mainly come from river beds and fine aggregates are mined from earth. Second, production of cement requires large amount of limestone which also comes from earth. Third, concrete production requires large amount of water and might be critical in regions of earth having scarcity of fresh water[1-5].

Sustainability in concrete industry is achieved by reducing the production of cement. As 1 ton of cement production releases equal amount of CO_2 in atmosphere. Such adverse environmental effects demand means in which cement production can be reduced[1]. Over last several years, many researchers have tried to replace cement with waste material and by products from industries[6,7]. In the recent past, use of supplementary materials in concrete mix became very common[6]. Common supplementary materials which can give better results are ground granulated blast furnace slag (GGBS), fly ash, silica fume, marble waste and others[8-11].

Some other innovative materials as supplementary cementatious material in concrete have also been investigated. Use of sugar cane begasse ash as fractional replacement of cement in concrete was studied and results indicated improvement in durability and mechanical properties of concrete[12]. Studies on rice husk showed that it also gives better results when replaced with cement in concrete[13-16]. Another study used wood waste ash and densified silica fume as partial replacement of cement and resulting concrete indicated better compressive strength[17]. Shao et al. used ground waste glass as cement replacing material and found out that higher compressive strength was achieved at all ages[18].

A large amount of solid waste is produced from paper making. Recycling of paper fibers can only be done for a few times and the bad quality papers are removed as waste sludge. A large percentage of this sludge consumes the local landfill space. Burning this sludge may leads to other problems. It is therefore a dire need to make this material useful in other industries. Waste paper can be used as a building material[19]. With this aim, research efforts have been conducted to investigate the use of hypo sludge in different ratios of cements to produce

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cost effective concrete[20-26]. Some research efforts have been made on the use of waste paper sludge and waste paper sludge ash (WPSA) as supplementary cementitious material in concrete[27-31]. A concrete mix ratio of 1:2:4 is usually used in Pakistan. Therefore in this research, partial replacement of cement with WPSA in concrete mix ratio of 1:2:4 is investigated with a water/cement ratio of 0.6.

MATERIALS AND METHODS

Ordinary Portland cement (OPC) was used in this research. Margalla crush as coarse aggregates and Lawrencepur sand as fine aggregate were used. WPSA used in the study was collected from local paper industry. Four concrete mixes containing OPC, sand, coarse aggregate, WPSA and water were studied. Different proportions of WPSA were used with 0%, 5%, 10%, 15% and 20 % replacement of cement by weight. The mix proportions for all the mixes were based on weight proportion of 1:2:4 with a constant water/cement ratio of 0.6. A total of three samples were casted for each case and average of the results is reported.

Sieving of WPSA was done to get the particle size passing 90 µm sieve. Cubes and cylinders were casted using 1:2:4 concrete mix confirming to British and American standard respectively. Consistency of cement mortar was checked using Vicat apparatus confirming to AASHTO T 129. Slump test was performed on mortar confirming to ASTM C143M-05.

The concrete specimens were cured under water and compressive strength tests were carried out at the age of 7 days and 28 days. Subsequent to curing, compressive strength tests were conducted on cubes and splitting tensile strength tests were conducted on cylinders using a compression testing machine.

RESULTS AND DISCUSSION

Initial and final setting times of the concrete mix are reported in Table 1. From the values obtained, it has been found that initial and final setting times are gradually reduced by increasing the percentage of WPSA in mix. For 0% replacement initial and final setting times are 154 min and 255 min respectively while at 20 % replacement initial and final setting time get reduced to 106 min and 175 min respectively. Table 2 and Figure 1 states the slump values for all the samples. The slump values indicate that slump was reduced with increasing percentage of WPSA in the mix. A maximum slump value

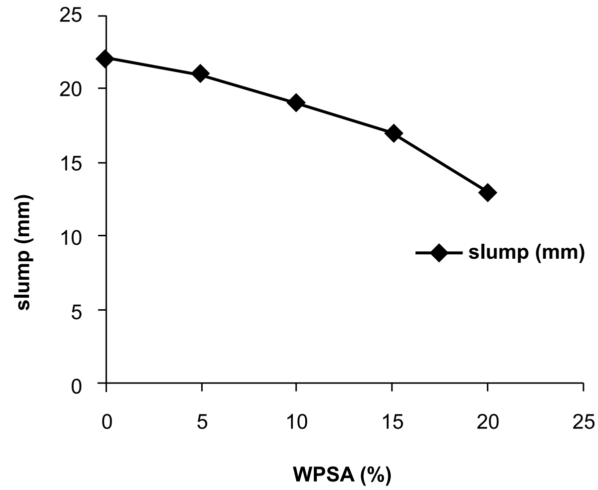

Figure 1. Slump variation of all mixes

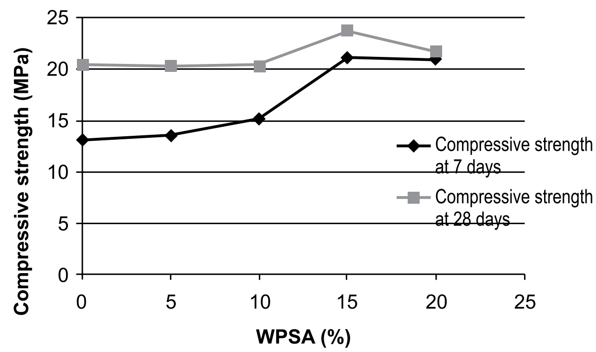

Figure 2. Compressive strength at 7 and 28 days age of concrete

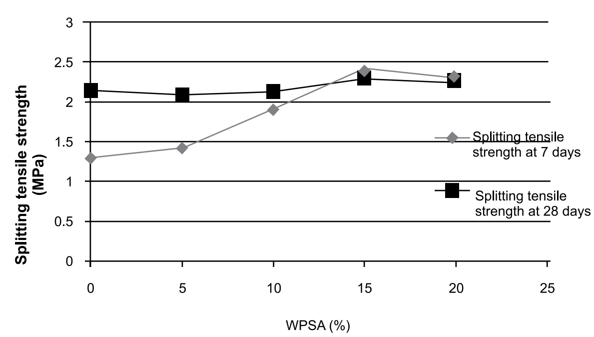

Figure 3. Splitting tensile strength at 7 and 28 days of age

Table 1. Initial and final setting times of cement

Sr. No.	WPSA (%)	Initial setting time (min.)	Final setting time (min.)
1	**0**	**154**	**255**
2	5	143	240
3	10	128	225
4	15	118	180
5	20	106	175

Table 2. Slump values for all mixes

Sr. No.	WPSA %	Slump (mm)
1	**0**	**22**
2	5	21
3	10	19
4	15	17
5	20	13

Table 3. Compressive strength at 7 and 28 days age of concrete

Sr.No	WPSA %	Compressive strength @ 7 days (MPa)	Compressive strength @ 28 days (MPa)
1	**0**	**13.11**	**20.35**
2	5	13.55	20.22
3	10	15.10	20.28
4	15	21.10	23.77
5	20	20.98	21.66

Table 4. Splitting tensile strength of concrete at 7 and 28 days of age

Sr.No	WPSA %	Compressive strength @ 7 days (MPa)	Compressive strength @ 28 days (MPa)
1	**0**	**13.11**	**20.35**
2	5	13.55	20.22
3	10	15.10	20.28
4	15	21.10	23.77
5	20	20.98	21.66

of 22 mm was obtained at 0% replacement of cement with WPSA and 13 mm for 20% replacement. From the graph, a decreasing trend of slump with increasing percentage of WPSA is observed. 150 mm x 150 mm x 150 mm sized cubes were casted for compressive strength. Curing was done under normal conditions and strengths were determined at 7 days and 28 days. Compressive strength at 7 and 28 days are reported in Table 3 and Figure 2. The compressive strength values indicate an improvement in the compressive strength with the

Table 5. Average dry weight values at different replacement ratios for cubes

Sr. No.	WPSA%	Dry weight of cube with 0% replacement (gm)	Dry weight of cube after partial replacement (gm)	Dry density of cube (kN/m^3)	Weight reduced (gm)	Change in weight (%)
1	**0**	**8382**	**8382**	**24.83**	**0**	**0%**
2	5%	8382	8352	24.75	30	- 0.358%
3	10%	8382	8225	24.37	157	- 1.870%
4	15%	8382	8115	24.04	267	- 3.185%
5	20%	8382	7998	23.70	384	- 4.580%

increase in WPSA content up to 15% replacement. For concrete of 7 days age, compressive strength gradually increased up to 15% replacement ratio, beyond which the compressive strength was decreased. Similarly for 28 days of age, compressive strength showed not much change up to 10% replacement (in fact a small decrease in value) and an increase in strength at 15% replacement ratio. The compressive strength was however decreased at 20% replacement ratio. It has also been found that the increase in compressive strength values is observed for 28 days as compared to 7 days for replacement up to 15%. However, there is not much improvement in the strength at 28 days with respect to 7 days for 20 % replacement of cement. It can be concluded that a maximum of 15 % replacement with WPSA can be effectively applied with corresponding decrease in the cement content. Cylinders of size 6" x 12" were casted for splitting tensile strength and its results are given in Table 4 and Figure 3. A similar trend was obtained for splitting tensile strength as compared to compressive strength test for 7 and 28 days. Generally, with the increase in the cement replacement with WPSA, tensile strength was increased up to 15 % replacement ratio. Afterwards the strength decreased at 20 % replacement. Maximum tensile strength was obtained at 15 % replacement ratio. It was also noted that there is not much improvement in the strength at 28 days with respect to 7 days beyond 10% replacement of cement. The cube specimens were also investigated for the average dry weight and results were compared with normal concrete cubes. The results of these weights are reported in Table 5. From the table, it has been observed that average dry weight of cube was reduced on addition of WPSA. Lightest concrete cube was obtained at 20% replacement ratio where the average dry weight was reduced by 4.58 %.

CONCLUSIONS

On the basis of this research related to cement replacement of concrete with WPSA, the following are the conclusions:

- Compressive and splitting tensile strength generally increases as the percentage of WPSA is increased from 0 % up to 15%. As WPSA content is increased beyond 15%, both the strengths decrease.

- The WPSA addition results in lighter concrete material. The weight of the concrete with 20 % WPSA replacement decreases by 4.58%.

- With increase in WPSA content, slump value decreases.

- Therefore, it can be concluded that hypo sludge ash could be used as an innovative material in concrete industry.

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