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Research Article

Utilization of Textile Mill Sludge Waste in Concrete - An Experimental Study

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ABSTRACT

The sludge from the textile treatment plants is considered as perilous in nature as it contains heavy metals of chemicals and dyestuffs. After the treatment of textile water, the generated sludge is mostly disposed off in landfills. An attempt has been made to find an eco-friendly and cost effective solution for the sludge management as the processes related to transportation and disposals are very costly. All the tests were conducted as per Bureau of Indian Standard (BIS) codes by partial replacement of textile mill sludge with fine aggregates up to 55% in M20 grade of concrete adding 1% plasticizer by weight of cement. An experimental program was conducted to find out the compressive strength and durability of concrete. The replacement of textile mill sludge in concrete mix influences the properties of concrete as it has low values of specific gravity and density. After conducting the experiments on 252 specimens, recommendations have been made regarding optimum addition of percentage of textile mill sludge without compromising compressive strength of concrete.

Keywords: *Textile mill sludge, Concrete, Workability, Compressive strength, Sludge.*

INTRODUCTION

Textile industry plays an important role in economy of the country. It involves various processes and operations for converting the raw materials into a finished material. All these processes lead to consumption of large quantity of water and result in the production of extremely polluted waste water. This waste water known as the waste effluent contains inorganic and organic substances in various forms such as suspended, colloidal or dissolved and needs treatment for its safe disposal. The textile waste water is treated by using Lime, Ferric Chloride, Alum and polyelectrolytes. After the treatment of the wastewater, the separated waste in the form of settle-able solids from water (textile sludge) is then dried on sludge drying beds. The amount and the properties of textile sludge are mainly dependent on the chemical used for treatment and composition of wastewater.

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This sludge being chemical in nature containing some polymer solids, precipitated dye stuff, metal salts, inert solids etc. is a hazardous waste material. This sludge is then disposed into landfills which lead to various adverse effects on our environment. Disposal of this sludge waste in land filling and improper management of waste sludge causes various problems leading to contamination of the ground water and degradation of land. Many researchers have investigated the use of textile mill sludge for partial replacement of cement or fine aggregates in concrete and have reported the strength properties of concrete containing the textile mill sludge (Baskar et al., 2006), Dhinesh et al., (2014), BIS, (1987). In the present study, an attempt has been made to reuse this sludge waste in concrete and to produce a valuable product for the management of solid waste.

Experimental procedure

The effect of using textile mill sludge as partial replacement of fine aggregates on durability and mechanical properties of concrete was found.

MATERIALS AND METHODS

Textile Sludge: The textile mill sludge was collected in bags of 20 kg from textile industries located at Focal point, Ludhiana (Punjab) in plastic air tight bags. The textile mill sludge was collected only from those locations where the sludge was routinely removed from the treatment plants. At the time of collection of sludge, it contained nearly 30 to 35 % of moisture content. The whole quantity of sludge was dried in direct sunlight. The dried sludge was then ground using a grinder. The preliminary tests were conducted on textile mill sludge and are presented in Table 1.

Cement: Cement is one of the important ingredients of concrete and acts as a binding material for all type of works in building construction. The Ordinary Portland Cement (OPC) of 43 Grade, as per the guidelines of BIS 8112-2013 was used in this study. All the preliminary tests were performed to determine the physical parameters of cement and are presented in Table 2.

Fine aggregates: Locally available river sand was used in the study. Sieve analysis was done for the confirmation of grading zone and fineness modulus of fine aggregates. Table 3 gives the physical properties of fine aggregates evaluated as per BIS 383-2016.

Coarse aggregates: The coarse aggregates are chemically inactive or inert materials that form the bulk of cement concrete. The coarse aggregates of size 20 mm and 10 mm were used in same proportions for whole of the experimental work (50:50). The aggregates used in this study were free from all types of organic matter and fine dust. The fineness modulus and specific gravity was determined in the laboratory as 2.67 and 8.22 respectively.

Water: According to the recommendations given in BIS 456- 2000, the Potable water free from oils, acids, salts and organic substances was used for mixing and curing of concrete.

Plasticizer: Plasticizer "Conplast SP430 G8" based on Sulphonated Napthalene Polymers complied with BIS: 9103:1999 and BS: 5075 Part 3 was used. It was in the form of liquid, brown in colour, dispersible in water and was used to produce good workable concrete with high quality. The plasticizer @1% by weight of cement was used for preparing these mixes.

Methodology

The compressive strength of concrete was determined besides durability characteristics of concrete. The fine aggregates were replaced with textile mill sludge. A total of six mixes were prepared with different percentages of textile mill sludge (0%, 5%, 15%, 25%, 35%, 45% and 55%) to replace the fine aggregates. After conducting various trials, it was found that binder ratio of 0.50 gives compressive strength close to target mean strength. Further, after conducting various trials, it was found that plasticizer to the tune of 1% by weight of cement improves the workability of concrete. Quantities of required raw materials like cement, sand, aggregates and water were estimated by concrete mix design according to the BIS 10262-2009. Finally a mix design was selected as shown in Table 4 and quantities (per cubic meter) were computed.

The estimated quantity of each ingredient was weighed separately. Firstly, the textile mill sludge was uniformly mixed with fine aggregates in dry state and for uniform distribution cement and coarse aggregates were mixed. After dry mixing, water with plasticizer was added to the dry mixed ingredients and all were mixed properly for 3 to 4 minutes. The workability of concrete was determined using compaction factor test on concrete. To determine the compressive strength and acid attack characteristics of concrete, the cubes of size 150 mm were prepared. For abrasion test of concrete, the cubes of 70.6 mm were prepared using 10 mm size coarse aggregates. Firstly the cube moulds were cleaned and then oiled. After the preparation of moulds, the concrete was filled and vibrated to ensure proper compaction. The finished specimens were left for 24 hours. The specimens were removed from the moulds after 24 hours of casting and were placed in the water tank, filled with potable water in the laboratory.

Compressive strength of concrete: The compressive strength of concrete was determined after 7, 14 and 28 days of curing in water on 150 mm cube size for different replacements of fine aggregates with textile mill sludge with plasticizer @1% by weight of cement.

Acid attack on concrete: The main aim of conducting this test on concrete was to obtain information regarding the damage that occurs due to acid attack on concrete. The acid attack on concrete occurred due to higher alkaline nature of Portland cement concrete. The acid attack test on concrete was performed after 28 days of curing in water and three specimens out of each mix were immersed in 5% of sulphuric acid solution for 28 days. All the specimens were kept in air tight containers to minimize the evaporation of solution. Again, three similar samples were kept in water for 56 days for computing compressive strength and weight loss in concrete.

Abrasion test on concrete: The abrasion test on concrete was performed on specimens after 28 days of curing as per BIS 1237-2012. Each specimen was weighed and thickness of each specimen was measured at five points. 20 g of good quality of sand was used as abrasive powder on grinding path of the disc. Specimen was fixed in holding device and load of 300 N was applied. Each specimen was abraded for 22 revolutions and after the machine had stopped, the specimen was turned to the vertical axis at an angle of 90^o in clockwise direction, total number of revolutions being 220. When test was over, each specimen was weighed and thickness was measured again. From the obtained results, the average loss in thickness of the specimens was determined using the following formula:

$$T = \frac{(W1-W2)\times V1}{W1 \times A}$$

Where

T = average loss in thickness in mm

W_1 = initial weight of the specimen in g

W_2= mass of the specimen after wear in g

V_1 = initial volume of the specimens in mm^3

A =surface area of the specimens in mm^2.

RESULTS AND DISCUSSION

Compressive strength: The compressive strength of concrete was determined after 7, 14 and 28 days of curing using Universal Testing Machine (UTM) on cubes of 150 mm for different replacements of fine aggregates with textile sludge and plasticizer @ 1% by weight of cement, as shown in Figure 1 and Figure 2.

For each day of curing, the average of three samples was taken as the final compressive strength of concrete mix (Fig.3) with textile mill sludge varying from 0 – 55%.

Durability Properties

Acid attack: The acid attack test was performed on concrete after 28 days of curing in sulphuric acid (H_2SO_4). After curing in acidic water, the specimens were washed and cleaned properly with water. All the specimens were weighed and tested for compressive strength. Percentage loss of weight and compressive strength of concrete as shown in Table 5 and Table 6 respectively.

Abrasion test: The abrasion resistance (expressed as depth of wear) of all the mixes was determined at the age of 28 days for the various replacement levels of textile mill sludge and plasticizer. Reduction in wear depth indicated increase in abrasion resistance and vice versa. The values of average depth of wear for different replacement levels of textile mill sludge (5%, 15%, 25%, 35%, 45% and 55%) using plasticizer (1% by weight of cement) at the end of 28 days curing period are given in Table 7.

Relationship between loss of weight and loss of compressive strength in concrete

The effect of acid attack in concrete was observed from the loss of weight and loss of compressive strength in concrete (containing textile mill sludge and plasticizer) specimens after immersion in acidic solution and graphical representation is shown in Figure 7. The value of correlation coefficient (R^2) was determined as 0.994 indicating strong correlation between these two parameters.

From Figure 4, it is seen that the loss of weight in concrete (containing textile mill sludge and plasticizer) increases with the loss of strength. Both weight loss and strength loss increase with increase in the percentage replacement of textile mill sludge.

Table 1: Physical properties of Textile Mill Sludge

S. No.	Characteristics	Value obtained experimentally
1.	Fineness Modulus	2.77
2.	pH Value	7.82
3.	Electrical Conductivity	0.37
4.	Specific Gravity	1.93
5.	Moisture Content	30-35%

Table 2: Properties of OPC 43 Grade

S. No.	Characteristics	Value obtained experimentally	Value specified by BIS: 8112-1989
1.	Specific Gravity	3.16	-
2.	Standard consistency	31%	-
3.	Initial Setting time	115 minutes	30 min. (minimum)
4.	Final Setting time	225 minutes	600 min. (maximum)
5.	Soundness	6 mm	Less than 10 mm
6.	Compressive Strength 3 days 7 days 28 days	 23.43 N/mm^2 34.51N/mm^2 46.61 N/mm^2	 23 N/mm^2 33 N/mm^2 43 N/mm^2

Table 3: Properties of fine aggregates

S. No.	Characteristics	Value obtained experimentally
1.	Fineness Modulus	2.73
2.	Specific Gravity	2.71
3.	Silt content (Using Nacl)	4.16%
4.	Water absorption	1.05%
5.	Grading Zone	II

Table 4: Quantities of ingredients of concrete

Water	**Cement**	**Fine aggregates**	**Coarse aggregates**
186 liters	372 kg	716.74 kg	1152.16 kg
0.50	1	2.00	3.10

Table 5: Percentage of weight loss of concrete due to acid attack

Mixes	Textile mill sludge (%)	Initial weight (g)	Final weight (g)	Wight loss (%)
S_0	0	8110	8075	0.43
S_1	5	8070.67	8036.67	0.42
S_2	15	8054.67	8019.33	0.44
S_3	25	7848.67	7809.33	0.5
S_4	35	7744.33	7694.33	0.65
S_5	45	7561.33	7499.67	0.82
S_6	55	7509.33	7435.67	0.98

Table 6: Percentage loss of compressive strength of concrete after acid attack

Mixes	Textile mill sludge (%)	Initial strength (N/mm^2)	Final strength (N/mm^2)	Strength Loss (%)
S_0	0	28.05	26.22	6.54
S_1	5	28.01	26.14	6.67
S_2	15	27.24	25.25	7.32
S_3	25	27.14	25.04	7.74
S_4	35	25.53	23.16	9.27
S_5	45	15.75	13.95	11.43
S_6	55	12.26	10.7	12.78

Table 7: Abrasion resistance in concrete

Mixes	Textile mill sludge (%)	Depth of wear (mm)
S_0	0	0.74
S_1	5	0.72
S_2	15	0.81
S_3	25	0.97
S_4	35	1.16
S_5	45	2.17
S_6	55	2.26

Fig. 1: Curing of Samples

Fig. 2: Testing of sample on UTM

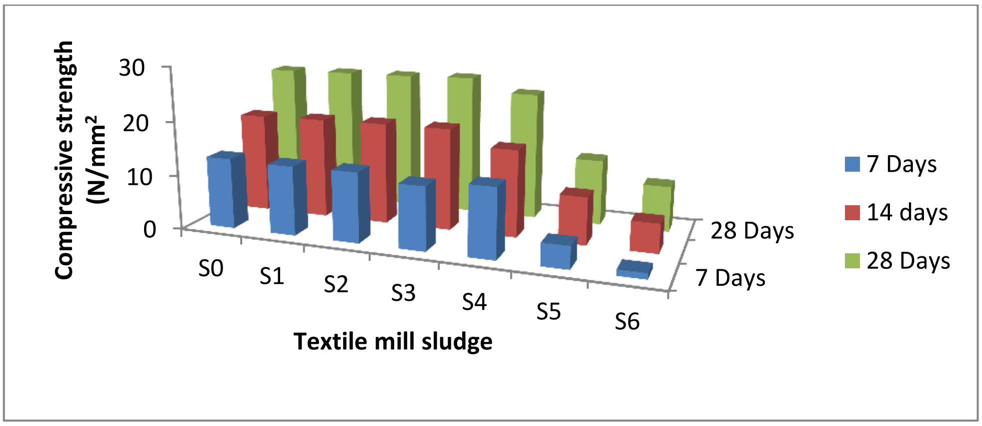

Fig. 3: Compressive strength of concrete with different percentage of textile mill sludge

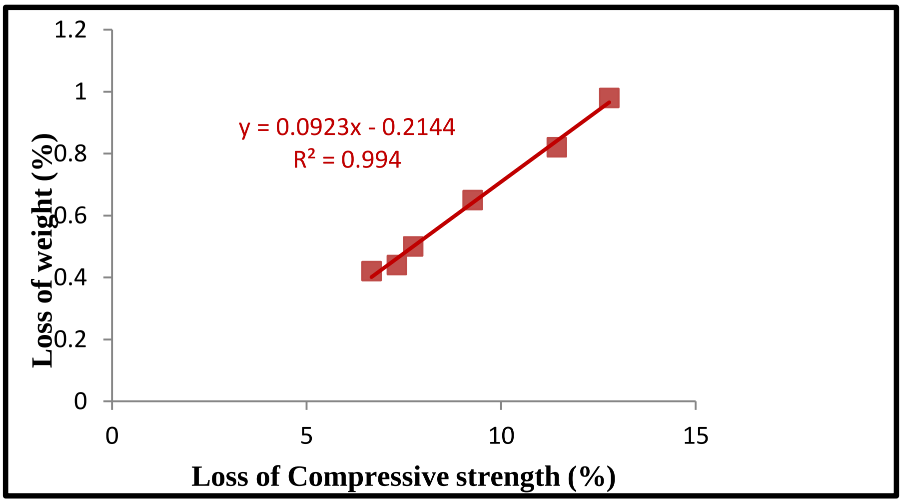

Fig. 4: Relation between Weight loss and Strength Loss

CONCLUSIONS

This study revealed the feasibility of using waste material generated from the textile industry in concrete as partial replacement with fine aggregates by evaluating the durability and strength properties of concrete. The following conclusions have been made based on the various tests conducted on concrete mixes:

(i). There is a slight increase in the compressive strength of concrete blended with 0% to 25% of textile mill sludge content for all curing ages. After that, the strength significantly reduced. The rapid reduction in strength is attributed due to the hydroscopic nature of textile mill sludge, as this sludge absorbs more water and strongly affects the water cement ratio in all mixes. It is recommended to use textile mill sludge up to 25% without compromising compressive strength of concrete.

(ii). The acid attack resistance on concrete was determined using sulphuric acid. The acid attack resistance was evaluated from loss of weight and loss of strength in concrete after immersion in acid. The loss of weight in concrete increased with increase in the percentage replacement of textile mill sludge. The loss of weight for 25% of textile mill sludge was 0.50% respectively. Whereas the loss of compressive strength was 7.73%. The higher content of textile mill sludge is not recommended as the higher dosage of textile mill sludge make the concrete permeable due to weak bonding in concrete. The voids increased with increase in the sludge content and acidic solution enters into concrete through the pores of the concrete. Moreover the acid solution deteriorates the concrete.

(iii). The correlation between loss of weight and loss of strength is 0.994 (close to 1.0).

(iv). The acidic solution enters into concrete through the pores and results in formation of gypsum layer on the outer surface of concrete specimens. The permeability of the specimen causes the reduction in strength of concrete.

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