INTERPRETATION OF HIGH STRENGTH MASONRY CEMENT EMBODYING INDUSTRIAL WASTES AND POZZOLANIC MATERIAL

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ABSTRACT

The main prospect of this research is to consume the peculiar industrial wastes (fly ash and phosphogypsum) and pozzolanic materials (hydrated lime and calcined clay) for better solution to tackle the waste generated and the growing need of cement and establish them as cementitious materials for partial replacement of cement. Chemical as well as physical properties of the cementitious materials were carried out to check the compatibility of materials with cement.All the four materials stated above are combined together in different proportions and used as partial replacement of cement in different mix batches. Total 7 batches of mix proportion involving M_0 with 0% of cement replacement whereas M_1, M_2, M_3, M_4, M_5 and M_6 representing 60%, 50%, 40%, 30%, 20% and 10% addition of cement replacement respectively. Through critical study of the test results it was found that 10% replacement of cementitious material in OPC 43 gives effective results of compressive strength test and tensile strength test.

Keywords: Fly ash, Phosphogypsum, Calcined clay, Hydrated lime, Fine aggregate.

1. INTRODUCTION

Million tonnes of industrial wastes are being produced per annum by chemical and agro industries in India and abroad. These materials pose dilemma of disposal as well as health hazards. The growth in infrastructure sector leading to increase in demand of cement thereby increasing the cost of cement.The cost of cement during 1995 was around Rs. 1.25/kg and in 2005 the price increased approximately three times and in recent times a bag of cement cost Rs. 14/kg. In order to combat the scarcity of cement and the increase in cost of concrete under these circumstances, the use of agro industrial wastes, and industrial by-products like fly ash, silica fume, phosphogypsum, etc. came into use. The use of above- mentioned waste products in concrete in partial amounts paved a role for modifying the properties of the concrete, controlling the concrete production cost and finally the judicious use of industrial wastes.

2. LITERATURE REVIEW

Research carried out by Solanki and Pitrodain the year 2013 found that the optimum compressive stress was obtained at 30% replacement of cement with flyash. At the place where strength is not of more importance or rather structure is for temporary basis then design mix proportion up to 40% replacement can also be utilized. Mohamed and Mohamed (2010)found through experimental work that fly ash mortars with 40% cement replacement shows around 14% higher compressive strength than OPC mortar after 90days of curing. The corresponding increase in tensile strength is reported to be around 8%. Bhadauriaand Thakare (2006) in their experimental work observed that cement can be replacedwith five percent raw phosphogypsum. Beyond this the consistency and strength of concrete will be affected.Phosphogypsum can be economically used up to five percent as an ingredient or admixture of cement-mortar mix, both for stone and brick masonry work.

3. MATERIALS USED AND ITS PROPERTIES

3.1 Cement

Ultratech43 grade ordinary portland cement was used for this study. The cement was fresh and without any lumps. The results of physical properties of cement are specific gravity is 3.0, normal consistency (% by weight of cement) is 27, initial setting time (minutes) is 80, Final setting time (minutes) is 215 and soundness is 1mm.

3.2 Fine Aggregate

Fine aggregate used was Badarpur sand without any organic impurities and confirming to grading zone II of Table 4 of IS: 383-2016. The results of physical properties of Fine aggregate are; fineness modulus is 2.99, specific gravity is 2.66, silt and clay content (%) is 5.3, Bulk Density (kg/m^3) is 1646. The results of sieve analysis and gradation are given in Table 1 and Figure1. The chemical composition given by the Manufacturer/ supplier is given in Table 2.

Table 1: Sieve analysis of fine aggregate

IS sieve size(mm)	Weight Retained in gm.	Cumulative weight retained in gm.	Cumulative % weight retained	Cumulative % weight Passing	Grading Zones as per IS 383-2016		
					Zone -II	Zone -III	Zone -IV
10	0	0	0	100	100	100	100
4.75	33.8	33.8	3.45	96.55	90-100	90-100	95-100
2.36	118.7	152.5	15.57	84.43	75-100	85-100	95-100
1.18	206.1	358.6	36.62	63.38	55-90	75-100	90-100
0.6	255.9	614.5	62.76	37.24	35-59	60-79	80-100
0.3	230.8	845.3	86.33	13.67	8-30	12-40	15-50
0.15	81.2	926.5	94.62	5.38	0-10	0-10	0-15
PAN	52.6	979.1	100	0			
	979.1		299.35	**F.M.=** $\frac{\text{Cumulative \% weight retained}}{100}$ Fineness modulus is **2.99**			

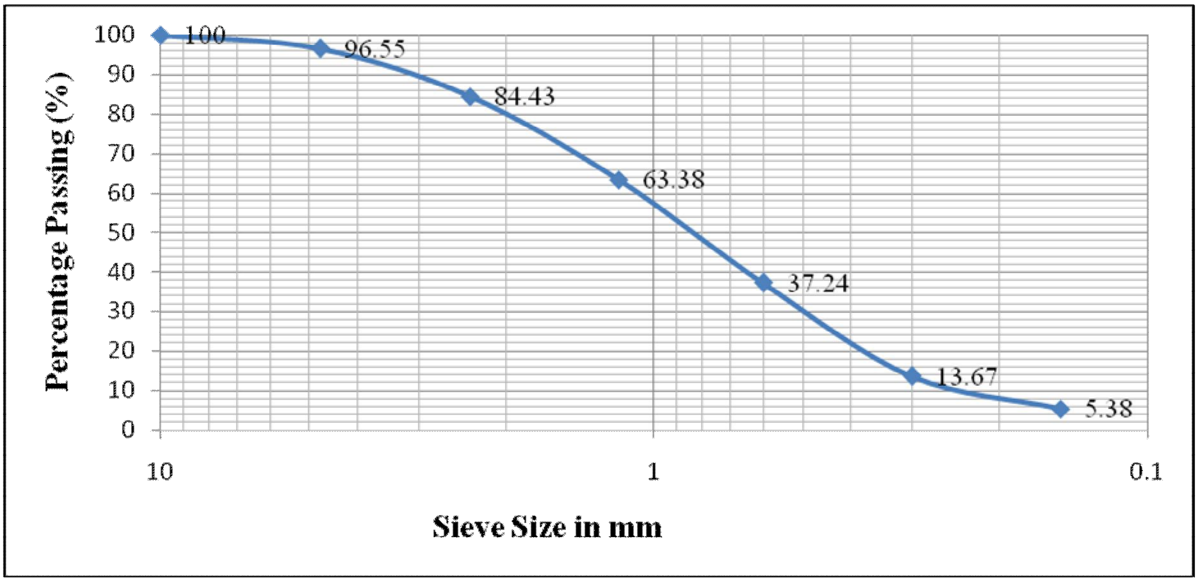

Figure 1: Fine aggregate particle size curve

3.3 Fly Ash

Fly ash used in this work was collected from NTPC Dadri. The chemical composition given by the Manufacturer/ supplier is given in Table 2.

3.4 Phosphogypsum

It is obtained as a by-product in the manufacture of phosphoric acid by wet process. It was collected from M.I.D.C., Pune. The chemical composition given by the Manufacturer/ supplier is given in Table 2.

3.5 Calcined Clay

Calcined clays are used in general purpose concrete construction. They can be used as a partial replacement for the cement, typically in the range of 15% to 35%, and to enhance resistance to sulphate attack, control alkali- silica reactivity, and reduce permeability.Calcined clay was borrowed from Central Soil and Materials Research Station, New Delhi. The chemical composition given by the Manufacturer/ supplier is given in Table 2.

3.6 Hydrated Lime

Hydrated lime is a type of dry powder made from limestone created by adding water to quicklime in order to turn oxides into hydroxides. Combined with water and sand or cement, hydrated lime is most often used to make mortars and plasters.Hydrated Lime was obtained from Central and Western India Chemical Bhosri M.I.D.C., Pune. The chemical composition given by the Manufacturer/ supplier is given in Table 2.

Table 2: Chemical Composition of various materials

Chemical constituents	OPC	fly ash	Phosphogypsum	calcined clay	hydrated lime
P_2O_5 (phosphorus pentoxide)	-	-	1.40	-	-
F (florine)	-	-	0.51	-	-
Organic matter	-	-	0.30	-	-
Cl (clorine)	-	-	0.10	-	-
$Na_2O + K_2O$ (sodium oxide + potassium oxide)	-	0.76	0.70	53.90	-
SiO_2 (silica oxide)	22.50	62.90	1.25	46.01	1.80
R_2O_3 (alumina + boric oxide)	9.60	32.10	0.70	0.29	0.50
CaO (calcium oxide)	61.50	1.50	32.20	0.60	0.60
MgO (magnesium oxide)	2.65	0.80	-	-	72.00
SO_3 (sulpher trioxide)	1.75	0.20	44.00	-	1.00
LOI(loss on ignition)	2.00	1.50	19.48	-	24.00
$CaSO_4.2H_2O$	-	-	94.60	-	2.50
Al_2O_3 (aluminium oxide)	-	-	-	-	0.50
Fe_2O_3 (ferric oxide)	-	-	-	-	0.60

4. EXPERIMENTAL PROGRAM

In this study,all the four materials viz. fly ash, Phosphogypsum, calcined clay and hydrated lime are combined together in different proportions and used as partial replacement of cement in different mix batches.M_0 represent the 0% of cement replacement whereas M_1, M_2, M_3, M_4, M_5 and M_6 represent 60%, 50%, 40%, 30%, 20% and 10% of cement replacement respectively.The strength parameters like compressive strength test and tensile test were assessed as a part of experimental programme. The different proportions used as partial replacement of cement in different mix batches are given in Table 3.

Table 3: Mix proportion for Masonry Cement

Mix Proportion	Cement %	Flyash %	Calcined clay %	Hydrated lime %	Phosphogypsum %
M_0	100	-	-	-	-
M_1	40	40	10	5	5
M_2	50	30	5	12	3
M_3	60	20	7	10	3
M_4	70	10	5	11	4
M_5	80	5	10	2.5	2.5
M_6	90	5	2	2	1

4.1 Compressive Strength

A set of 63 cubes of size 50mm×50mm×50mm were made for 7 different trial mixes. The details of different mortar mixes were given in Table 3. The Cubes were used for casting of specimen and tested for compression after 28days curing (Figure2) according to the test procedures given in the IS: 516-1959.

Figure2: Test specimens for compressive strength

4.2 Tensile Strength Test

The tensile test is required for estimating the tensile strength capacity of the cement mortar. Accordingly the briquette specimens were cast for obtaining tensile strength (Fig. 3). Standard procedure is obtained for the other activities such as mixing, placing, compaction, curing. Then the test was conducted to obtain 3, 7 days and 28 days tensile strength.

Figure3: Test specimens for tensile strength test

5. Results and Discussions

5.1 Compressive strength

The compressive strength varies from 35.5 N/mm^2 to 48.4 N/mm^2 for different mixes. The percent variation for different mixes with respect to control mix has been evaluated. The percentage variation in comparative strength is given in Figure 4.

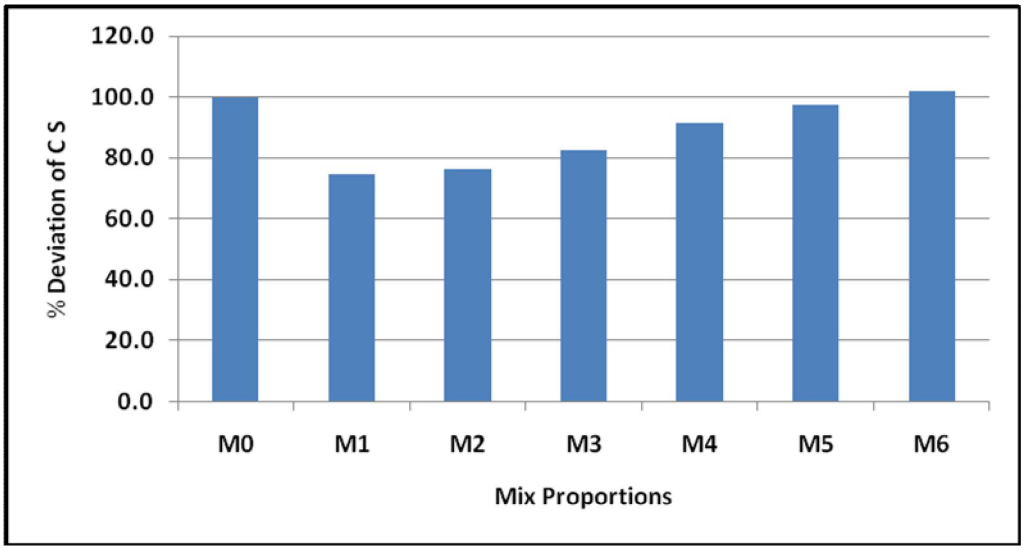

Figure4: Percent variation in Compressive Strengths of Different Mixes

From Figure4, when the values of compressive strength are compared with controlled mix M0 and replacement content from M1 to M6,it is observed that strength reduced by 25.4% for M1, 23.7% for M2, 17.6% for M3, 8.8% for M4 and 2.7% for M5. However, the strength increases in M6 by 1.8%. Therefore, it is concluded that as the percent replacement increases the strength decreases. The strength is higher than controlled mix in case of ten percent replacement of cement with mixture of four materials.

5.2 Tensile Strength

The tensile strength varies from 3.2 N/mm^2 to 4.8 N/mm^2 for different mixes. The percent variation in tensile strength for different mixes with respect to control mix has been evaluated. The percentage variation in comparative strength is given in Figure5.

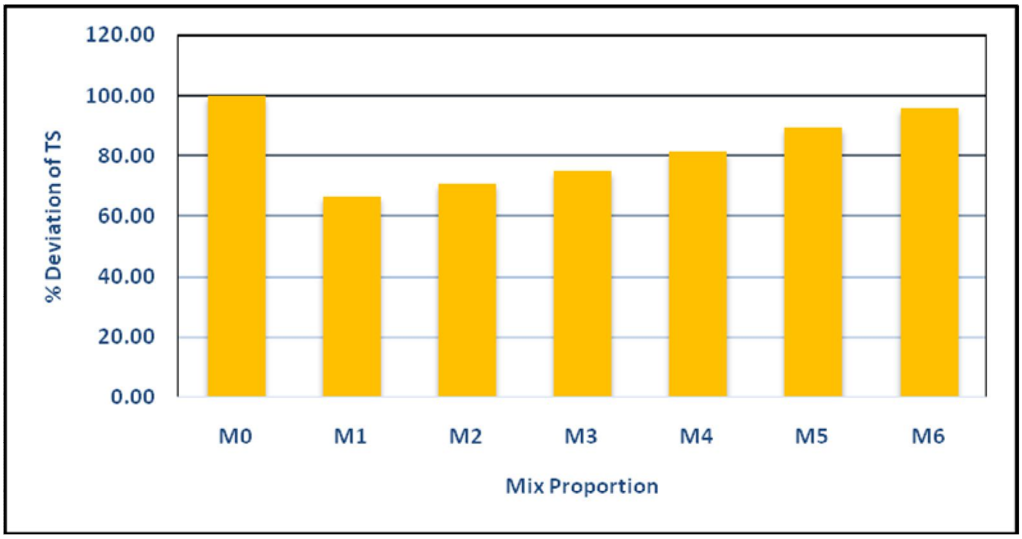

Figure 5: Percent variation in Tensile Strength of Different Mixes

The graphical representation shows that by comparing results obtained with the control mix M0and replacement content from M1 to M6, it is observed that tensile strength reduced by 33.33% for M1, 29.17% for M2, 25% for M3, 18.75% for M4, 10.42% for M5 and 4.17 for M6.Therefore, it is concluded that as the percent replacement of cement with mixture of four materials increases the tensile strength decreases. The decrease in tensile strength is observed in all the mixes for replacement of cement with mixture of four materials.

5.3 Comparison of percent variation in compressive strength and tensile strength

The results of compressive strength and tensile strength were compared for all the mixes. The graphical representation is given in Figure 6.

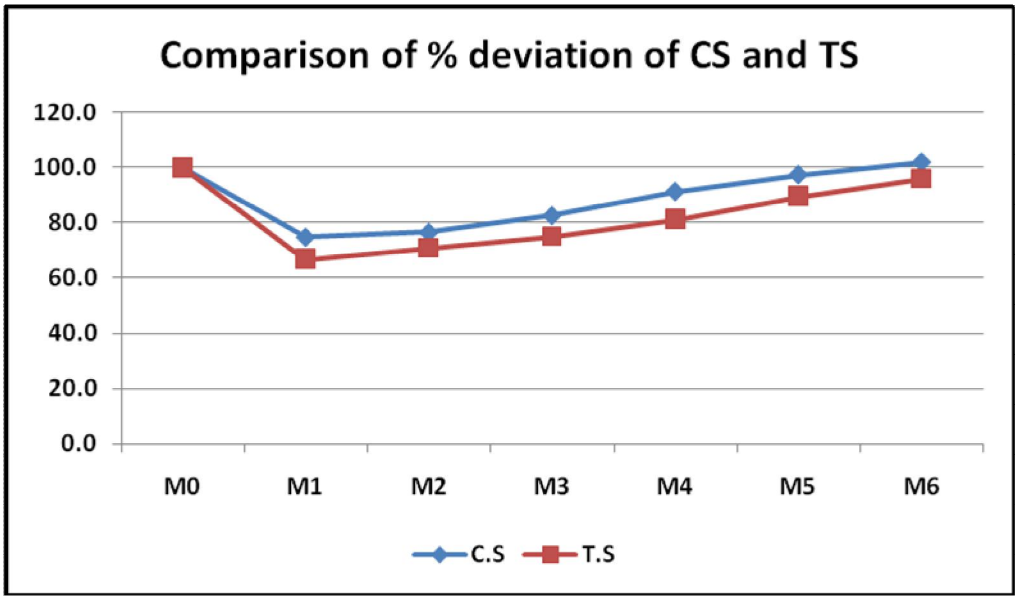

Figure6: Percentage deviation of Different Mixes

From the graph it is observed that both compressive strength and tensile strength decreases with increase in the percent replacement of cement with mixture of four materials. The decrease in tensile strength is proportionate to the decrease in compressive strength. However in case of mix M6, the compressive strength is more than the controlled mix M0.

6. CONCLUSIONS

The following conclusions can be drawn from the experimental study:

- The mix proportion with 10% replacement showed the most optimum consistency i.e. 28%.
- The sand on getting wet gets bulked and then becomes quite troublesome in batching thus it is advised to use dry sand in batching.
- A specimen with 10% replacement showed positive results with 1.8% increase in compressive strength.
- A specimen with 10% replacement showed appreciable/ acceptabledecrease in tensile strength.
- Masonry cement suitable for use in masonry mortar can be produce by mixing fly ash (5%), phosphogypsum (1%), calcined clay (2%) and hydrated lime (2%) with OPC (90%) by weight.
- Cementitious materials in OPC mix considerably retard setting time but do not contribute to produce unsound cement paste.
- Calcined clay has little effect on water demand than normal doses.
- M_6 specimen turned out to be the most optimum in terms of strength saving around 9.14% over the cost of OPC 43 grade cement.

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