Experimental Study on Partial Replacement of Cement with Sewage Sludge Ash, Silica Fume and Marble Dust

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Abstract— In this project we use of incinerated sewage sludge ash (ISSA), marble dust and silica fume in the making of concrete structure with partial cement replacement. Sewage sludge was incinerated at 800ºC and collected from waste water treatment plant, marble dust was collected from construction building and silica fume was collected during silicon and ferrosilicon alloy production. In this project our main objective is to study the influence of partial replacement of cement with sewage sludge ash, marble dust and silica fume and to compare it with the compressive strength of M25 concrete. We are also trying to find the percentage of sewage sludge ash, marble powder, silica fume replaced in concrete that makes the strength of the concrete maximum. Now a day's sewage sludge, marble powder has become a pollutant. So, by partially replacing cement with sewage slude ash, marble powder, we are proposing a method that can be of great use in reducing pollution to a great extent. In this investigation a series of compression tests were conducted on 150mm, cube and 150mm x 300mm, cylindrical specimens using a modified test method that gave the complete compressive strength, using sewage sludge ash, silica fume and marble of 10%, 20%, 30% and 40% on Pozolana Portland cement concrete.
Keywords: Marble powder, Sewage sludge ash, Silica fume, Aspect ratio, Compressive strength, Tensile strength

I. INTRODUCTION

Cement plays the role of a binder, a substance that sets and hardens and might bind alternative materials along. Cement is widely used by human beings and it is second largest material after water used by human beings. Based on recent survey total amount of cement is used during the financial year of 2012 247 MT and it increases up to 550 MT for financial year 2020. India is second largest country after china based on uses of cement. During production of cement and hydration process of cement carbon dioxide is produced based on experimental investigation it has been proved that 1 tons of clinker produces around 1 tons of CO_2. This CO_2 production causes serious environmental damages and this can be prevented by two ways described as way-1 use another binding material instead of cement which is not possible right now for unavailability of such a binding material and another way is way-2 partial replacement of cement by appropriate material. Way -2 is quite simple because of lots of references are available as well as enough appropriate material is also available. We can save cement by partial replacement of cement with sewage sludge ash, silica fume and marble dust.

A. Sewage Sludge Ash (SSA):

Sewage sludge ash (SSA) is primarily a silty material with some sand-size particles. It is the by-product of the combustion of dewatered sewage sludge in an incinerator. The major components in SSA are SiO_2, CaO, Al_2O_3, and Fe_2O_3. Incinerated sewage sludge ash (ISSA) is a combustion residue and arises from the incineration of sewage sludge obtained from wastewater treatment plants. According to Petavratzi and Wilson (2007), about 22% of sewage sludge is incinerated. A typical incineration plant will dewater sewage sludge to 25% to 30% dry solids before combustion in a fluidised bed furnace at 800–900°C.

B. Silica Fume:

Silica fume, also known as micro silica is an amorphous (non-crystalline) polymorph of silicon dioxide. It is an ultrafine powder collected as a by-product of the silicon and ferrosilicon alloy production. It is extremely fine with particles size less than 1 micron and with an average diameter of about 0.1 microns, about 100 times smaller than average cement particles. Its behaviour is related to the high content of amorphous silica (> 90%).The reduction of high-purity quartz to silicon at temperatures up to 2,000ºC produces SiO_2 and condenses in the low temperature zone to tiny particles consisting of non-crystalline silica.

C. Marble Dust:

Marble powder or dust is mixed in the concrete as replacement material of Cement. It is the waste product of marble stone produces from surface finishing or stone in construction buildings or industries. n. The construction industry is the only area where the safe use of Marble powder or dust is possible.

II. LITERATURE REVIEW

1) F. Baeza et al. has done a research on Blending of industrial waste from different sources as partial substitution of Portland cement in pastes and mortars. He has done Binary and ternary combinations of sewage sludge ash (SSA) with marble dust (MD) as replacement in Portland cement pastes, were assessed.
2) Kumar & Dhaka (2016) write a Review paper on partial replacement of cement with silica fume and its effects on concrete properties. The main parameter investigated in this study M-35 concrete mix with partial replacement by silica fume with varying 0, 5, 9, 12 and 15% by weight of cement. The paper presents a detailed experimental study on compressive strength, flexural strength and split tensile strength for 7 days and 28 days respectively. The results of experimental investigation indicate that the use of silica fume in ordinary Portland cement.
3) Manju Pawar et.al (2014) A Study has been conducted on Periodic Research, The Significance of Partial replacement of cement with waste marble powder. They

found that the effect of using marble powder as constituents of fines in mortar or concrete by partially reducing quantities of cement has been studied in terms of the relative compressive, tensile as well as flexural strengths. Partial replacement of cement by varying percentage of marble powder reveals that increased waste marble powder (WMP) ratio result in increased strengths of the mortar and concrete .Leaving the waste materials to the environment directly can cause environmental problem. Hence the result, The Compressive strength of Concrete are increased with addition of waste marble Powder up to12.5 % replace by weight of cement and further any addition of WMP the compressive strength decreases.

4) Chiang et al. (2000) examined the potential use of dried sludge from water treatment plant with agricultural waste and rice husk ash in production of novel light weight bricks. The results for the mechanical properties show that bricks with 40% by weight rice husk heated at 1100ºC exhibit a high strength required for lightweight bricks, use in future green building in accordance with Taiwan standards. Results of Toxic Characteristic Leaching Procedure (TCLP), shows that the concentrations of Cu, Zn, Cr, Cd and Pb in the products were lower than allowable level in the standard regulation.
5) Cusido et al. (2003) used sewage sludge and forest debris were used as raw materials in producing clay bricks, the product is lighter, more thermal and acoustic insulating when compared with conventional clay bricks. The bricks were dried at 100°C and then fired at 1000°C. The result shows significant increase in the level of greenhouse gas emission up to 20 times more as compare with conventional ceramic firing (though still within allowable level approved by environmental Protection Agency).

III. MATERIALS AND METHODS:

A. *Cement:*

Portland Pozzolona cement of ACC cement conforming to IS 269-1976 and IS 4031-1968 was adopted in this work. The cement used is 53 grade. The test conducted on cement is shown in Table No. 1.

Sr. no	Test	Result	IS requirement
1	Fineness of cement	6.54%	As per IS 269-1976 Max 10%
2	Consistency of cement	33.6%	-
3	Initial setting time	37min	As per IS 4031-1968 Min 30min
4	Final setting time	334min	As per IS 4031-1968 Max 600min
5	Compressive strength of cement	17.67N/mm² in 3days & 26.55N/mm² in 7days	As per IS 1489-1991 16N/mm² in 3days & As per IS 1489-1991 22N/mm² 17days

Table 1: Cement

B. *Coarse aggregate:*

The aggregate used in this project mainly of basalt rock which comes under normal weight category. The aggregates are locally available. 50% of the aggregate used are of 10-12 mm size and remaining 50% are of 20mm size. The coarse aggregate was also tested for various properties like impact value test, crushing value test, elongation and flakiness index test to check their suitability for the experiment. The test performed on aggregate is shown in Table No. 2.

Size of Aggregate	Crushing Value %	Impact Value %	Flakiness Index %	Elongation Index %
10-12 mm	23.60	7.74	21.58	58.98

Table 2: Aggregate

C. *Sand:*

Natural sand which is easily available and low in price was used in the work. It has cubical or rounded shape with smooth surface texture. Being cubical, rounded and smooth texture it give good workability. Particles of this sand have smooth texture and are clean. Sieve analysis was done to find out fineness modulus which comes out to be 3.14% which is under limit as per IS 383-1970. The test conducted on Sand is shown in Table No. 3.

Sr. no.	Test	Result	IS requirement
1	Fineness modulus	2.78	As per IS 383-1970 Max 3.2

Table 3: Sand

D. *Marble powder:*

Marble powder was collected from the dressing and processing unit in Jalgaon. It was initially in wet form (i.e. slurry); after that it is dried by exposing in the sun and finally sieved by IS-90 micron sieve before mixing in concrete.

Note: All the materials and equipments were provided by college itself, except Marble Dust Powder.

E. *Silica Fume:*

Also known as microsilica, (CAS number 69012-64-2, EINECS number 273-761-1)is an amorphous (non-crystalline) polymorph of silicon dioxide, silica. It is an ultrafine powder collected as a by-product of the silicon and ferrosilicon alloy production and consists of spherical particles with an average particle diameter of 150 nm. The main field of application is as pozzolanic material for high performance concrete.

Particle size	1μm
Bulk density	130 to 430 kg/m³
	480 to 720 kg/m³
Specific gravity	2.2
Specific surface	15000 to 30000 m²/kg

Table 4: Physical properties of silica fume

F. Sewage Sludge Ash:

The composition of the sewage sludge depends on the sewage type, treatment methods and utilization. Sewage sludge disposal practices include drying and incineration. SSA can be as a cement component in the amount of the up to 10% of the cement added to concrete. The important condition for the replacement of the portion of Portland clinker in the cement is pozzolanic activity dependent on the chemical and mineral composition. From the practical standpoint, the effect of the chemical composition is seen first of all in the delayed increase in strength. The long-term strength development, which may decide about the suitability of SSA for cement composition, has not been fully understood so far.

SiO_2 [%]	Al_2O_3 [%]	Fe_2O_3 [%]	CaO [%]	MgO [%]	SO_3 [%]	Cl^- [%]	P_2O_5 [%]	Na_2O [%]	K_2O [%]
16.50	5.10	9.11	13.10	3.81	2.10	0.01	15.10	3.50	2.81

Table 5: Chemical composition of SSA.

G. Water:

The water used for experiments was portable water conforming as per IS 456-2000.

IV. EXPERIMENTAL PROCEDURE

M25 grade concrete mixes of different materials such as marble dust and Sewage sludge ash (0% to 40% replacement of cement) and silica fume of 10% with w/c ratio of 0.50 were prepared. The mixes were designated in accordance with IS: 456-2000. A total of 20 concrete cubes were casted for the different percentages of replacement of cement. The specimens were demoulded after 24 hours and curing was done for different age of testing. They were tested for their strength properties on 7th and 28th days.

Sr. No.	cement replacement [%]	Cement [gm]	Coarse aggregate [gm]	Fine Aggregate [gm]	Cement replacement by SSA [gm]	Cement replacement by silica fume	Cement replacement by marble dust
1.	0	533.15	1599.45	799.73	0	0	0
2.	10	421.20	1599.45	799.73	53.32	5.33	53.32
3.	20	309.20	1599.45	799.73	106.63	10.70	106.63
4.	30	197.25	1599.45	799.73	159.95	15.99	159.95
5.	40	85.30	1599.45	799.73	213.26	21.33	213.26

Table 6: Details of Mix Proportions of Concrete.

% Replacement of SSA, Silica fume & Marble dust	Compressive strength in N/mm²	
	7 days	28 days
0	13.63	21.24
10	14.30	23.41
20	15.83	24.33
30	16.50	25.81
40	12.31	19.76

Table 7: Compressive strength of cubes on 7 and 28 days.

% Replacement of SSA, Silica fume & Marble dust	Split tensile strength in N/mm²	
	7 days	28 days
0	7.84	15.83
10	7.10	13.15
20	6.47	10.69
30	5.42	9.87
40	2.10	6.23

Table 8: Split tensile strength of cylinders on 7 and 28 days.

V. RESULTS

When the SSA, Silica fume and Marble dust replaced by cement with varying percentage from 10% to 40% the following results were drawn.

1) 1. With 10% of SSA, Silica fume and Marble dust the compressive strength at the end of 7 and 28 days 14.30 and 23.41 N/mm² respectively.

2) 2. A similar increase in the compressive strength was observed when the fly ash is increase till 30% (25.81N/mm² at the end of 28 days).
3) 3. The compressive strength at the end of 28 days decreases when the SSA, silica fume and marble dust percentage is increased beyond 30%. However the compressive strength of M25 concrete at the end of 28 days for 50% replacement of fly ash is 25.81N/mm² as shown in Table 5.
4) 4. The compressive strength showed a steep decrease when the fly ash percentage is increased beyond 30%.
5) 5. With10% of fly ash the split tensile strength at the end of 7 and 28 days is 7.10 and 15.83 N/mm² respectively.
6) 6. A similar increase in the split tensile strength was observed when the fly ash is increase till 30% (9.87 N/mm² at the end of 28 days).
7) 7. The split tensile strength at the end of 28 days decreases when the SSA, silica fume and marble dust percentage is increased beyond 30%. However the split tensile strength of M25 concrete at the end of 28 days for 50% replacement of SSA, silica fume and marble dust is 9.87 N/mm2 as shown in Table 6.

VI. CONCLUSIONS:

Based on the experimental investigation the following conclusions were drawn on the strength characteristics.

1) Compressive and split tensile strength showed an increased value with the SSA, silica fume and marble dust is replaced up to 30% at the end of 28 days.
2) Compressive and split tensile strength reduces when cement replaced by SSA, silica fume and marble dust percentage is increased beyond 30% at the end of 28 days.
3) The results indicate that replacing cement with SSA, silica fume and marble dust up to 30% is possible to be used in structural concrete.
4) From the above study, it is concluded that the SSA, silica fume and marble dust be used as a replacement material for cement.
5) It can be concluded that replacement of cement with silica fume up to 10 % and 30% of SSA, silica fume and marble dust replacement would render the concrete more strong and durable.

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