Effect of Partial Replacement of Cement and Sand With Silica Fume and Copper Slag in Mortar

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Abstract- *The fast growth in industrialization has resulted in tons of byproducts and also increases the demand of infrastructure. The main objective is to increase the use of waste product in construction material. Present study evaluates the effect of Partial Replacement of Cement and Sand with Silica Fume and Copper Slag in Mortar. In cement mortar (1:3) cement is replaced by silica content varying from 0 to15% at an interval of 5% and sand is replaced by copper slag content varying from 0 to 50% at an interval of 10%. The use of silica fume and copper slag as replacement material improves mechanical properties of the mortar.*

Keywords- mortar, silica fume, copper slag, compressive strength, durability

I. INTRODUCTION

Mortar is one of the major building materials used in modern day construction. For a variety of reasons the mortar in construction industry is not sustainable. The sustainable development in construction involves use of waste materials and by-products to replace Portland cement & aggregates. Silica fume (SF) is a by-product of the smelting process in the silicon and ferrosilicon industry and copper slag is an industrial by-product material produced from the process of manufacturing copper.

OBJECTIVES:

1. To determine compressive strength of cement mortar with partial replacement of cement by silica fume
2. To determine compressive strength of cement mortar with partial replacement of sand by copper slag
3. To determine compressive strength of cement mortar with partial replacement of cement and sand by silica fume and copper slag
4. To obtain the suitable replacement level of silica fume and copper slag based on strength requirements.
5. To check durability of mortar.

II. MATERIALS AND METHODOLOGY

Cement: The cement used for the experiment is Ordinary Portland Cement of grade 53.

Sand: Natural river sand is used for the specimen preparation .The fineness modulus of sand is 2.79 and specific gravity is 2.63

Water: Water used is free from impurities. Neutral water which is of PH 7 is used For the specimen preparation.

Silica fume: Silica fume is the byproduct of producing silicon metal or ferrosilicon alloys in smelters using electric arc furnaces.

Mix Proportion:

All mixes were cast with cement: sand ratio of 1:3. Cement is replaced with silica fume for each mix with replacement percentages of 0, 5, 10, 15 and sand is replaced with copper slag with replacement percentage of 0, 10, 20, 30, 40, and 50.

III. RESULT & DISCUSSION

1. Compressive Strength test

This test is carried out on compressive testing machine (CTM).to measure the compressive strength of mortar. As per IS 2250 – 1981 .and loading rate 140 kg/cm2 are applied. Size of cube 71mm X 71mm X 71mm used for testing. And strength measure at 3, 7 and 28 days. Compressive test results for various proportions of silica fume, copper slag and combined silica fume and copper slag are as shown in table no 1, table no 2 and table no 3respectivly.

Table 1. Compressive Strength of Mortar in various proportion of Silica Fume

PROPORTION	3 DAY		7 DAY		28 DAY	
	COMP. STRESS IN (N/MM^2)	AVG. COMP. STRESS IN (N/MM^2)	COMP. STRESS IN (N/MM^2)	AVG. COMP. STRESS IN (N/MM^2)	COMP. STRESS IN (N/MM2)	AVG. COMP. STRESS IN (N/MM2)
SF 5% + CEMENT 95% + SAND	11.90	12.39	14.28	14.34	17.85	18.31
	12.89		13.88		18.25	
	12.29		14.87		18.84	
SF 10 % + CEMENT 90% + SAND	13.48	13.29	15.86	16.32	21.82	21.30
	12.89		16.86		19.88	
	13.29		16.26		22.21	
SF 15% + CEMENT 85% + SAND	13.88	14.67	17.85	18.64	22.81	23.3372
	14.87		18.84		23.80	
	15.27		19.24		23.40	
SF 20% + CEMENT 80% SAND	14.28	15.20	18.25	18.77	23.80	23.80
	15.47		19.24		24.20	
	15.86		18.84		23.40	
SF 25% + CEMENT 75% SAND	13.88	12.89	15.86	16.65	17.85	19.50
	11.90		16.86		18.84	
	12.89		17.25		21.82	

Table 2. Compressive Strength of Mortar in various proportion of Copper Slag

PROPORTION	3 DAY		7 DAY		28 DAY	
	COMP. STRESS IN (N/MM2)	AVG. COMP. STRESS IN (N/MM2)	COMP. STRESS IN (N/MM2)	AVG. COMP. STRESS IN (N/MM2)	COMP. STRESS IN (N/MM2)	AVG. COMP. STRESS IN (N/MM2)
COOPER SLAG 10% SAND 90% CEMENT	17.85	17.52	19.837	18.51	21.82	23.80
	17.85		16.86		15.87	
	16.86		18.84		33.72	
COOPER SLAG 20% SAND 80 % CEMENT	10.91	14.21	15.86	18.51	24.79	26.44
	17.85		19.84		26.78	
	13.88		19.84		27.77	
COOPER SLAG 30% SAND 70% CEMENT	15.87	13.55	15.87	16.86	27.77	28.76
	12.89		17.85		29.75	
	11.90		16.86		28.76	
COOPER SLAG 40% SAND 60% CEMENT	17.85	19.17	20.83	20.76	37.69	37.02
	20.83		21.62		39.67	
	18.84		19.84		33.72	
COOPER SLAG 50% SAND 50% CEMENT	15.87	17.52	16.86	18.51	19.84	20.83
	17.85		19.84		21.82	
	18.84		18.84		20.83	

Table 3. Compressive Strength of Mortar in various proportions of Silica Fume and Copper Slag

PROPORTION	3 DAY		7 DAY		28 DAY	
	COMP. STRESS IN (N/MM2)	AVG. COMP. STRESS IN (N/MM2)	COMP. STRESS IN (N/MM2)	AVG. COMP. STRESS IN (N/MM2)	COMP. STRESS IN (N/MM2)	AVG. COMP. STRESS IN (N/MM2)
COOPER SLAG 10% SAND = 90% CEMENT = 95% SF = 5%	12.89	13.88	16.86	15.87	21.98	20.74
	14.87		15.87		18.11	
	13.88		14.87		22.13	
COOPER SLAG 20% SAND = 80 % CEMENT =90 SF = 10%	13.88	13.55	19.84	17.19	36.88	26.16
	13.88		16.86		25.35	
	12.89		14.87		23.60	
COOPER SLAG 30% SAND = 70% CEMENT = 85% SF = 15%	12.89	13.22	16.86	25.8	29.54	32.12
	14.87		15.87		30.68	
	11.90		18.84		28.82	
COOPER SLAG 40% SAND = 60% CEMENT = 80% SF = 20%	15.87	15.86	20.83	18.84	38.99	37.70
	14.87		15.87		41.57	
	16.86		19.84		32.55	
COOPER SLAG 50% SAND = 50% CEMENT = 75% SF =25 %	12.29	12.89	16.46	16.92	29.31	30.53
	14.48		15.67		33.72	
	11.90		18.64		28.56	

2. Durability test

Acid attack is determined by immersing specimen of size cube 71x71x71mm in 5%HCL solution respectively .deterioration of the specimen are measured in the form of percentage in reduction in weight of mortar specimen at 28 days. Durability test results for various proportions of silica fume, copper slag and combined silica fume and copper slag are as shown in table no 4, table no5 and table no 6respectivly.

Table 4. Acid Resistance of Mortar in various proportion of Silica Fume

Percentage of silica fume	Initial Weight		Final Weight		Percentage weight Loss %
	Weight	Average Wt.	Weight	Average Wt.	(W2 - W1)/ (W1) *100
SF 5 %	824	807.5	783.5	765.5	5.20 %
	791		747.5		
SF 10 %	833	823.5	780.5	769	6.61 %
	814		757.5		
SF 15 %	828	816.5	792.5	783.25	4.07 %
	805		774.0		
SF 20 %	839	826	797.0	787.25	4.69 %
	813		777.5		

Table 5. Acid Resistance of Mortar in various proportion of Copper Slag

Percentage of Copper slag	Initial Weight		Final Weight		Percentage weight Loss %
	Weight	Average Wt.	Weight	Average Wt.	(W2 - W1)/ (W1) *100
CS 10 %	796.5	804.75	753.5	762	5.31%
	813.0		770.5		
CS 20 %	838	854	789.5	805.25	5.70%
	870		821		
CS 30 %	865.5	876.5	819..0	828.75	5.44%
	887.5		838.5		
CS 40 %	884	894.5	832.0	841.25	5.95%
	905		850.5		

Table 6. Acid Resistance of Mortar in various proportions of Silica Fume and Copper Slag

Combination of Percentage of SF and CS	Initial Weight		Final Weight		Percentage weight Loss %
	Weight	Average Wt.	Weight	Average Wt.	(W2 - W1)/ (W1) *100
SF 5 % CS 10%	882.0	883.5	840.5	843	4.58%
	885.0		845.5		
SF 10 % CS 20%	803.0	816.5	779.85	782.85	4.12%
	830		785.0		
SF 15% CS 30%	902.0	892.5	865.5	855.25	4.17%
	883.0		845.0		
SF 20 % CS 40%	892.0	866	860	830	4.15%
	840.0		800.5		

3. Abrasion resistance test

In this abrasion test the mortar specimen are abraded on a revolving grinding table, or a wearometer or an abrasion testing machine, and the abrasion is measured, finding the loss of thickness of specimens after certain number of rotations. Mortar specimens of size 70.7 mm x 70.7 mm use for the testing. Abrasion test results for various proportions of silica fume, copper slag and combined silica fume and copper slag are as shown in table no 7, table no 8 and table no 9respectivly.

Table 7. Abrasion Resistance of Mortar in various proportion of Silica Fume

Mix proportion (%)	Initial t_1 mm	Final t_2 mm	Wear from thickness $t_w = t_1 - t_2$	Initial W_1 (g)	Final W_2 (g)	t_w mm
S-5	16.84	15.92	0.92	216	214.75	0.097
S-10	15.47	14.636	0.834	202	198..97	0.23
S-15	15.89	15.10	0.789	210	206.05	0.298
S-20	16.74	15.81	0.93	210	208.85	0.0916

Table 8. Abrasion Resistance of Mortar in various proportions of Copper Slag

Mix proportion (%)	Initial t_1 mm	Final t_2 mm	Wear from thickness $t_w = t_1 - t_2$	Initial W_1 (g)	Final W_2 (g)	t_w mm
C-10	23.644	22.261	1.383	309.5	304.65	0.3705
C-20	19.81	18.50	1.31	279.5	276.90	0.184
C-30	22.108	21.205	0.903	313	309.75	0.2296
C-40	24.308	23.403	0.905	321.5	319.20	0.179

Table 9. Abrasion Resistance of Mortar in various proportions of Silica Fume and Copper Slag

Mix proportion (%)	Initial t_1 mm	Final t_2 mm	Wear from thickness $t_w = t_1 - t_2$	Initial W_1 (g)	Final W_2 (g)	t_w mm
S-5 C-10	19.92	16.38	3.58	222.5	219.45	0.27
S-10 C-20	20.05	19.48	0.57	277	273.35	0.26
S-15 C-30	19.02	18.92	0.1	228	226.85	0.095
S-15 C-40	24.43	23.58	0.85	303.5	302.95	0.044

IV. CONCLUSION

- The use of silica fume and copper slag in cement mortar enhances the bonding between the fine aggregate and cement paste.
- Maximum compression strength was observed at a replacement level of 40% copper slag and 20% silica fume
- Highest compressive strength was achieved by 40% replacement of copper slag and 20% replacement with silica fume, which was found about 37.70 MPa. This means that there is an increase in the strength of almost 66% at 28 days. Beyond increasing level 40% and 20% of copper slag and silica fume in mortar it decrease in compressive strength was observed.
- By replacing 40% copper slag and 20% silica fume mortar becomes economical. The tested results demonstrate that the replacement of 20% of the Portland cement by silica fume and 40 % sand by copper slag used in the experimental investigation improved the resistance of the mortar to the acid solution attack.
- Density of mortar increased with increase in percentage of copper slag
- The use of silica fume and copper slag in cement mortar enhances the bonding between the fine aggregate and cement paste

V. FUTURE SCOPE OF WORK

This modified cement mortar mix is used in high cost infrastructure projects. Normal concrete/mortar is week in tension, has limited ductility and little resistance to cracking .Mortar modified with silica fume and copper slag can be perform in many different applications such as underwater mortar ,decrease permeability in mortars used for retaining wall construction, and increase the resistance to aggressive chemicals.

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