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Effect of Processed Fly Ash on Cement Mortar for Standard Fine and Normal Sand

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Abstract: **This paper investigates the effect of processed flyash, used as partial substitute for cement, on the performance of cement mortar with normal sand available locally and standard fine sand. This study involves the replacement levels of fly ash to cement at 5%, 10%, 20%, 30%, 40%, 50 % and 70% for 1:3 mix proportions. Mortar cubes are tested for compressive strength at 7, 14, 28, 56, 91 and 121 days. The tension tests on briquettes are conducted for 28 days. Surface morphology and EDX of hardened samples were studied under scanning electron microscope at 28 days of curing. The compressive strength and tensile strength increases up to 20 % replacement levels and marginal decrease in strength up to 50% when compared with the control mix for both types of sand. By reading the surface morphology of hardened specimens at 30%, 40% and 50% with reference mix it clearly indicates that surface texture is more uniform and pore diameter is less at higher replacement level. The EDX spectrum of hardened mixes shows that the silica content is less for lower replacement level and increasing more for higher replacement level. This trend was depicted in surface morphology as uniform texture.**

Keywords: **Flyash, standard sand, normal sand, compressive strength, tension, surface morphology and EDX.**

1. INTRODUCTION

Fly ash usually refers to ash produced during combustion of coal .Fly ash includes substantial amounts of silicon dioxide (SiO_2) and calcium oxide (CaO). In the past, fly ash was generally released into the atmosphere, but pollution control equipment mandated in recent decades now requires that it be captured prior to release. There are two classes of fly ash which are defined by (ASTM C618 2005); these are Class C flyash and Class F fly ash. The main difference between these two classes of fly ash is the amounts of calcium, silica, alumina and iron contents in the ash itself. Chemical content of the coal will influence the chemical properties of the fly ash [2]. .In this study we have used Class F flyash. The burning of harder, older anthracite and bituminous coal typically produces Class F fly ash. This fly ash is pozzolanic in nature, and contains less than 20% lime (CaO). Possessing pozzolanicproperties, the glassy silica and alumina of Class F fly ash requires a cementing agent, such as Portland cement, quicklime, or hydrated lime, with the presence of water in order to react and produce cementitious compounds. Alternatively, the additions of a chemical activator such as sodium silicate (water glass) to a Class F ash can lead to the formation of a geopolymer. Owing to its pozzolanic properties, fly ash is used as a replacement for some of the Portland cement content of mortar.

This paper reports the investigation conducted on the effect of fly ash on the properties of mortar. Cement mortar was made with cement, sand and various percentages of fly ashin place of cement. The mortar was then tested for Compressive strength, tensile strength, surface morphology of hardened specimens and the resultant chemical composition of the hardened mortar.

2. MATERIALS USED

The cement used in this research is ordinary Portland cement of grade 53.The chemical composition of Portland cement is given in Table 1. In case of sand, readily available river sand of fine variety and standard fine grade sand is used and for fly ash, class F, fine grade is used.

Table 1: Chemical composition of Cement [4]

Cement	CCN	Mass %
Calcium oxide, CaO	C	61–67%
Silicon dioxide, SiO_2	S	19–23%
Aluminum oxide, Al_2O_3	A	2.5–6%
Ferric oxide, Fe_2O_3	F	0–6%
Sulfate	S	1.5–4.5%

There are fourteen mixtures used in this investigation as indicated in Table. 2. The reference mix was made with a cement-to-sand ratio of 1:3 with no addition of fly ash. Cement was then replaced with processed fly ash at replacement levels of 5, 10, 20, 30, 40, 50 and 70 % byweight. The water-to-cement ratio was kept at 0.48 for all mixtures.

Table 2: Mix Composition

Mix	Cement(%)	Fly Ash(%)	Sand Used
1	100	0	Normal
2	95	5	Normal
3	90	10	Normal
4	80	20	Normal
5	70	30	Normal
6	60	40	Normal
7	50	50	Normal
8	30	70	Normal
9	100	0	Standard
10	95	5	Standard
11	90	10	Standard
12	80	20	Standard
13	70	30	Standard
14	60	40	Standard
15	50	50	Standard
16	30	70	Standard

3. TESTING

Mortar cubes were tested for strength up to 121 days. The Tensile strength, surface morphology and chemical compositionwere monitored at 28 days. Compressive strength test was carried out using a compression testing machine of 1000 kN capacity. Three cubes were tested and the average value was reported.Tension test was carried out in tension moulds, three moulds were casted and tension was tested on the 28th day and average of the value was reported. For surface morphology, 10mm cube of the mortar sample was taken for study in a scanning electron microscope and the images *for different accuracy* were*pictured*presented. After that, the cube was powdered using grinding machine and the powdered sample was studied for EDX to find the chemical proportion of different samples **[4].**

4. RESULTS AND DISCUSSION

4.1Compressive Strength

The relationship between strength and age of the samples is given in the Fig. 1. Strength increases with age for all mixtures. This is because of the hydration of cement and secondary reaction by fly ash [1]. The strength is more at 7 days for mix 1; whereas the strength is the lowest for mix 8. Mix 1 has no fly ash content is termed as reference mix and mix 8 has a maximum of 70% of fly ash. Hence, it is clear that the addition of fly ash reduces the strength at early ages. This is because the addition of fly ash reduces the amount of tri-calcium silicate C_3S in the mix which reduces the heat of hydration and hence reduces strength. It is also indicated from the graph that 7-day strength is lower when fly ash content is increased. The results of the test indicate that, the strength increases with a increase in fly ash content up to 20%. At 20% mix design, the attained strength is similar to the reference mix. There is a marginal difference between 30% mix when compared to 20% mix and it is in the reducing trend. And the steady state of strength sustains between 30% to 50% mix. So it can be concluded that fly ash can be added up to 50% in case of compressive strength of the mortar and is comparable with reference mix. The situation is similar for standard sand, the only difference is that, with increase in fineness of the sand the strength increases but this is not practically possible because the sieving of large quantity of sand is very expensive.

Table 3: Compressive strength of different mixes
Standard Sand ***Normal Sand***

Mix/days	7	14	28	56	91	121
1	12.4	14.8	16.6	20.6	23	30
2	10.8	11.6	12.4	14	16	20
3	9.4	11	14	16.6	18.6	25
4	7.2	8.8	12	15.6	22	30
5	5.8	6.6	7.8	9.5	10.5	18.6
6	5.8	9.8	12	13.6	15	16.6
7	7	8.4	11.4	12.6	13.6	15
8	3.4	4.4	5.8	5.8	6.5	10
9	21.8					
10	18.4					
11	20					
12	20.4					
13	14.4					
14	17					
15	16					
16	8.6					

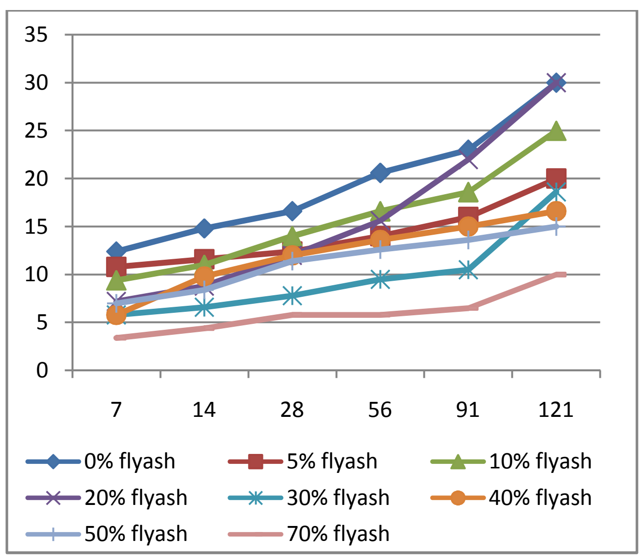


Figure1: Graphical representation of compressive strength

4.2 Tensile Strength

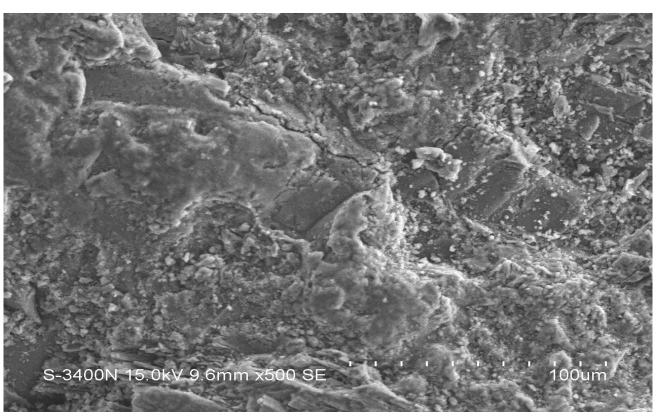
Tension was calculated using a specially designed butterfly shaped mould which is narrow in the middle and width increases on either side. As mentioned earlier, the tension was calculated at 28 days, a table is presented, the results were similar to compression, the tension strength increases with increase in fly ash content up to 20% mix design and then there is a marginal difference between 20% and 30% mix design, after with the tension bearing capacity sustained up to 50%. Table. 4 shows the trend of mortar.

Table 4 Tension strength of mortar

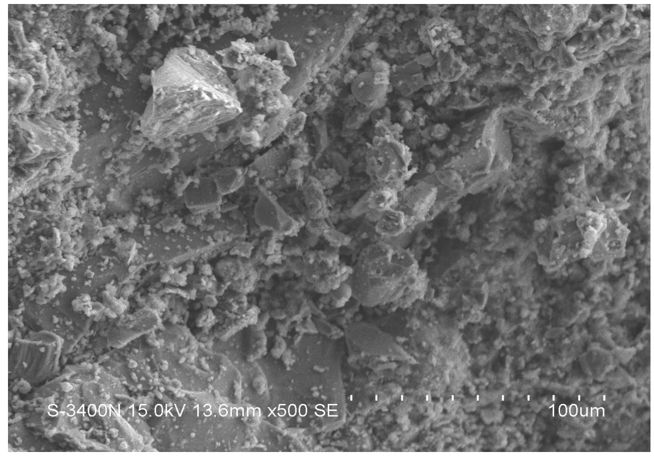
MIX	Tension at 28 days(kN/mm²)
1	2.8
2	2.1
3	2.4
4	2
5	1.4
6	2
7	1.8
8	1

4.3 Surface Morphology

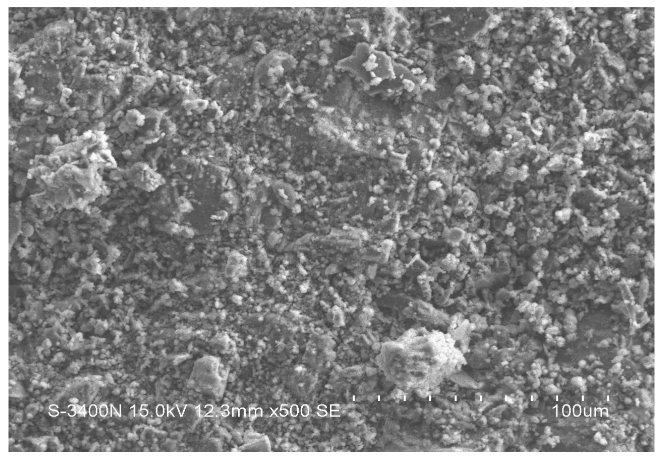
Surface morphology was done using Scanning electron microscope, a cube of 1cm was segmented down from cured samples of 28 days and is viewed in a SEM at 100µm accuracy. Images for standard mix (2.1), 30% (2.2), 40% (2.3), 50% (2.4) mix designs are shown below(fig-2). From the image, it can be inferred that the CSH gel formation increases with increase in fly ash content; this is proved through the white patch formed in the image. And from the image it can be seen that with increase in fly ash content, the sample is closely compacted. Thus it can be concluded that the increase in fly ash content, increases compaction, surface texture is uniform and reduces pore diameter.



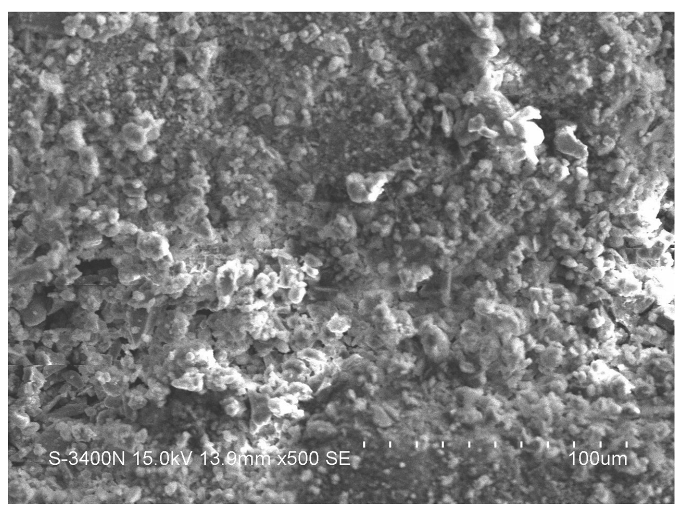
Mix 1 (2.1)



Mix 4(2.2)



Mix 5(2.3)



Mix 6 (2.4)

Figure 2 Surface Morphology for different mixes

4.4 Chemical Composition

Table 5 Chemical composition of different mixes

Element Line	*Weight %*	*Atom %*	*Formula*
O K	36.51	54.30	O
Al K	9.10	8.02	Al
Si K	21.38	18.11	Si
Ca K	32.57	19.34	Ca
Ca L	---	---	
Sc K	0.44	0.23	Sc
Sc L	---	---	
Total	100.00	100.00	
Mix 1 (5.1)			
O K	43.22	61.05	O
Na K	1.28	1.26	Na
Mg K	0.71	0.66	Mg
Al K	6.27	5.25	Al
Si K	17.70	14.24	Si
S K	1.16	0.82	S
S L	---	---	
Ca K	29.65	16.72	Ca
Ca L	---	---	
Total	100.00	100.00	
Mix 4 (5.2)			
O K	40.03	55.71	O
Na K	1.68	1.63	Na
Al K	8.26	6.82	Al
Si K	33.30	26.40	Si
K K	10.63	6.05	K
K L	---	---	
Ca K	6.10	3.39	Ca
Ca L	---	---	
Total	100.00	100.00	
Mix 5 (5.3)			
O K	40.04	59.48	O
Mg K	0.68	0.66	Mg
Al K	3.55	3.13	Al
Si K	14.16	11.98	Si
S K	0.58	0.43	S
S L	---	---	
Ca K	40.99	24.31	Ca
Ca L	---	---	
Total	100.00	100.00	
Mix 6 (5.4)			

The powered sample is taken at 28 days and is tested for EDX in a Scanning electron microscope. The chemical composition for standard mix design (5.1), 30% (5.2), 40%(5.3) and 50%(5.4) are viewed and tabulated below. From the results it can be inferred that the silica content increases with increase in fly ash content and the calcium content decreases at a marginal rate.

5. CONCLUSION

The compressive strength and tensile strength increases up to 20 % replacement levels and marginal decrease in strength up to 50% when compared with the control mix for both types of sand. By reading the surface morphology of hardened specimens at 30%, 40% and 50% with reference mix it clearly indicates that surface texture is more uniform and pore diameter is less at higher replacement level. The EDX spectrum of hardened mixes shows that the silica content is less for lower replacement level and increasing more for higher replacement level. This trend was depicted in surface morphology as uniform texture.

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