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Experimental study of drying shrinkage mortar: partially replacement of cement with fly ash

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Abstract: - Portland cement production is a major contributor to the greenhouse gas emission. The use of fly ash as a cement replacement makes the mortar less permeable to harmful ions due to its finer particle size distribution and pozzolanic reactions. This results in an enhanced high performance and more durable mortar. Shrinkage is a reduction in volume, and in concrete, it is mainly caused by the loss of water. In most cases, shrinkage is measured by monitoring longitudinal strain. Drying shrinkage occurs due to the loss of moisture from hardened concrete. Among the different types of shrinkage, drying shrinkage usually results in the largest volume change. Moisture loss causes volume changes based on three mechanisms that result in changes in capillary stress, disjoining pressure, and surface free energy.
This study has examined the effect of fly ash used as replacement addition to the Ordinary Portland cement (OPC) on drying shrinkage of cement mortars of five hopper fly ashes at Khaperkheda Thermal Power Plant. This paper present the mix proportion 1:3 of cement mortar in which cement is partially replace with fly ash as 0%, 12.5%, 25% and 37.5% by the weight of cement.

Keywords: Fly ash, drying shrinkage

I. INTRODUCTION

Fly ash is an industrial waste and a material of puzzolanic characteristic occurring due to burning the pulverized coal in the thermal power plants. In India at present produces around 120 Million Ton of Ash per annum. Indian coal on an average has 35 % Ash and this is one of the prime factors which shall lead to increase in ash production and hence, Ash utilization becomes major problem for the country. Seventy percent of total utilization is covered in the cement industry, in which a large increase in utilization is not expected in the future because of limits to acceptable quantity. The classification of thermal plant fly ash is considered based on reactive calcium oxide content as class-F (less than 10 %) and class-C (more than 10 %). Indian fly ash belongs to class-F. The calcium bearing silica and silicate minerals of ash occur either in crystalline or non-crystalline structures and are hydraulic in nature.

Shrinkage is the common phenomenon generally encountered in almost every cementitious product due to contraction of total mass upon loss of moisture. Though it is multidimensional contraction, the drying shrinkage of mortar is normally measured in the largest dimension of the body. The total drying shrinkage of mortar can be contributed from various forms of shrinkage taking place in mortar. Drying shrinkage of mortar is the shrinkage caused by the evaporation of internal water in the mortar sample. Nevertheless, volume change in drying mortar is not equal to the volume of water removed. The change in volume of unstrained cement paste during hydration is approximately equal to the loss of water layer of one molecule thick from the surface of all gel particles.

The main objectives of this paper are:

- To Study the mechanism of drying shrinkage
- To study the drying shrinkage of mortar using fly ash of different fineness

The analysis of drying shrinkage was obtained from the experimental results obtained from the average of 3 samples in each batch. 3 batches of replacement of fly ash for cement mortar specimens and 5 hopper of thermal power plant specimens were used for this analysis. The influence of fly ash and its different specific gravity of five hopper of Khaperkheda power plant are considered for the drying shrinkage are investigated. Replacing fly ash with cement of an amount of 12.5%, 25% and 37.5% for the drying shrinkage measure from 7days to 35 days i.e. 28 days for same percentage of replacement.

II. CODAL PROVISION

IS 4031 (part 10)-1988 Methods of physical tests for Hydraulic cement (Part 10 Determination of Drying Shrinkage)

This standard covers the procedure for determining the drying shrinkage of hydraulic cement as obtained on rectangular specimens, prepared and tested under specified conditions.

Clause 5.1 The moulds shall be thinly covered with mineral oil. After this operation, the stainless steel or non corroding metal reference inserts with knurl heads shall be set to obtain an effective gauge length of 250 mm, cart being taken to keep them clean and free of oil.

Clause 6.1 Clean appliances shall be used for mixing and the temperature of the water and that of the test room at the time when the mixing operation is being performed shall be 27±2°C. Potable/ distilled water shall be used in preparing the mortar.

Clause 6.2 The materials for the standard test mortar shall be cement and standard sand in the proportion of 1: 3 by mass blended intimately.

Clause 6.2.1 The amount of water for gauging shall be equal to that required to give a flow between 100 and 115 percent with 25 drops in 15 second , as determined in clause 7.3 of IS : 4031 (Part 7) 1988.

Clause 6.3 The materials for moulding each batch of test specimens shall be mixed separately using the quantities of dry materials, conforming to the proportions given in 6.2 and the quantity of water as determined in accordance with the procedure given in 7.2.1 and 7.3 of IS: 4031 (Part 7) – 1988 to give a flow of 100 to 115 percent with 25 drops in 15 seconds. mixing shall be done mechanically as described in 7.3.1 of IS : 4031 (Part 7) - 1988.

Clause 7.1 Immediately following the completion of mixing, the test specimen shall be moulded in two layers, each layer being compacted with the thumbs and forefingers by pressing the mortar into the corners, around the reference inserts and along the surfaces of the moulds until a homogeneous specimen is obtained. After the top layer has been compacted, the mortar shall be levelled off flush with the top of the mould and the surface smoothed with a few strokes of the trowel. During the operations of mixing and moulding, the hands shall be protected by rubber gloves.

Clause 8.1 After filling the moulds, place them immediately in a moist room or moist closet for 24±2 h. Then remove the specimens from the moulds and immediately immerse in water at 27±2°C and allow them to remain there for six days.

Clause 8.2 Remove the specimens from the water and measure its length using a length comparator. Protect specimens against loss of moisture prior to reading for initial length. The temperature of the test specimens at the time of initial measurement shall be 27±2°C Store the specimens in a control cabinet maintained at 27±2°C and 50±5 percent relative humidity Measure the length of the specimens again 28 days after the initial measurement. Place the specimens in the comparator with the same end uppermost with respect to the position of the specimens as when the initial measurement was made. When making the measurements, the specimens, the comparator, and the reference bar shall be at a temperature of 27±2°C.

Clause 9.1 After the specimens are measured as in 8.2 at the age of 7 and 35 days, calculate the average difference in length of three specimens to the nearest 0.01 percent of the effective gauge length and report this difference as the drying shrinkage.

III. DRYING SHRINKAGE OF MORTAR

- The materials for the standard test mortar shall be cement and standard sand in the proportion of 1:3 by mass blended intimately.
- The amount of water for gauging shall be equal to that required to give a flow between 100 and 115 percent with 25 drops in 15 second, as deter- mined above in compressive strength of fly ash mortar.
- The materials for moulding each batch of test specimens shall be mixed separately using the quantities of dry materials, conforming to the proportions 1:3 and the quantity of water as determined in accordance to give a flow of 100 to 115 percent with 25 drops in 15 seconds. Mixing shall be done mechanically.
- Immediately following the completion of mixing, the test specimen shall be moulded in Beam mould of 25 x 25 mm size and 280 mm internal length in two layers, each layer being compacted with the thumbs and forefingers by pressing the mortar into the corners, around the reference inserts and along the surfaces of the moulds until a homogeneous specimen is obtained.

Figure 3.1 Drying Shrinkage Mould Specimen (Source: Google)

- After the top layer has been compacted, the mortar shall be leveled off flush with the top of the mould and the surface smoothed with a few strokes of the trowel. During the operations of mixing and moulding, the hands shall be protected by rubber gloves.

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- After filling the moulds, place them immediately in a moist room or moist closet for 24±2 hr. Then remove the specimens from the moulds and immediately immerse in water at 27±2°C and allow them to remain there for six days.

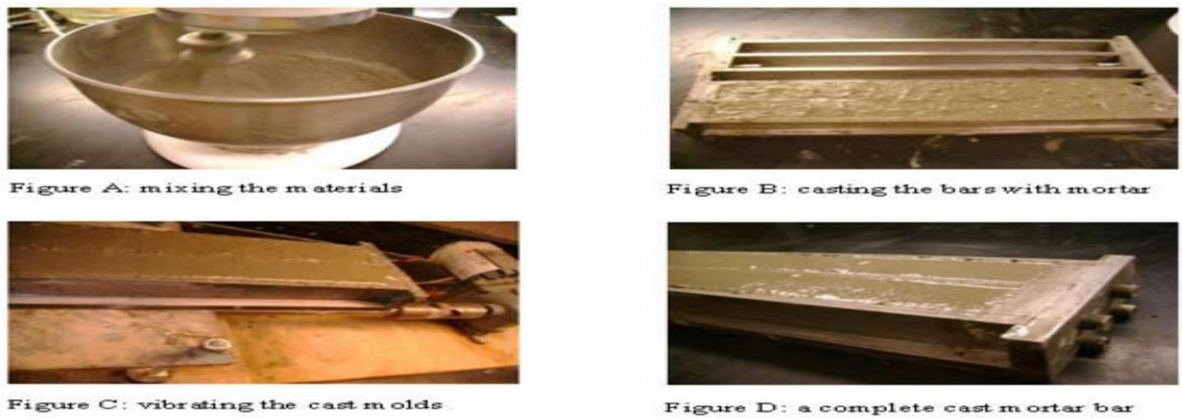

Figure 3.2 Procedure of Making Mortar Bar (Source: Google)

- Remove the specimens from the water and measure its length using a length comparator. Protect specimens against loss of moisture prior to reading for initial length. The temperature of the test specimens at the time of initial measurement shall be 27±2°C Store the specimens in a control cabinet maintained at 27±2°C and 50±5 percent relative humidity.
- Measure the length of the specimens again 28 days after the initial measurement. Place the specimens in the comparator with the same end uppermost with respect to the position of the specimens as when the initial measurement was made.
- When making the measurements, the specimens, the comparator, and the reference bar shall be at a temperature of 27±2°C.
- After the specimens at the age of 7 and 35 days, calculate the average difference in length of three specimens to the nearest 0.01 percent of the effective gauge length and report this difference as the drying shrinkage

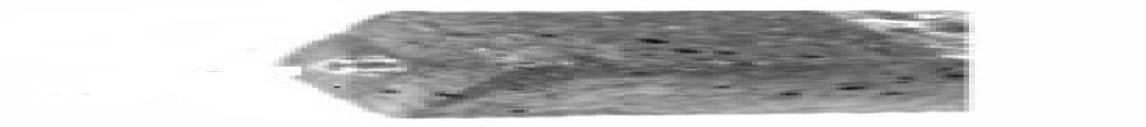

Figure 3.3 Specimen of Mortar Bar (Source: Google)

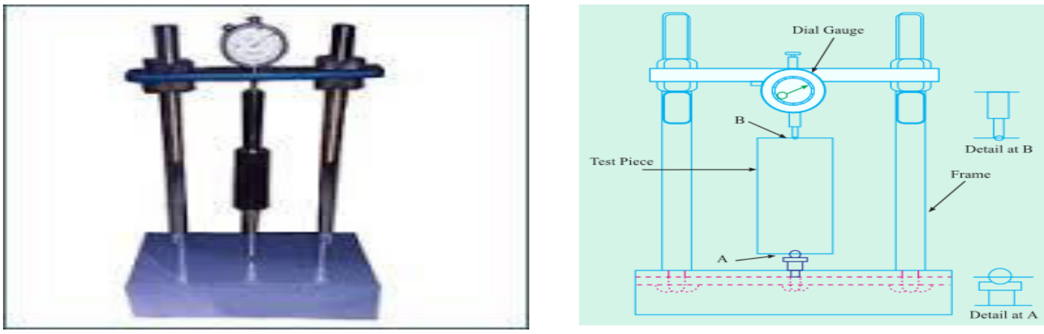

Figure 3.4 Length Comparator (Source: Google)

IV. DRYING SHRINKAGE RESULT

Table 4.2 Drying Shrinkage result

		7 DAYS			35 DAYS			DS	Avg. drying shrinka-ge
		bar reading	Refere-nce bar length	Initial Reading	bar reading	Refere-nce bar length	Final Reading		
Plane	0%	0.696	11.077	10.381	1.728	12.077	10.349	0.0114	0.0123
		0.896	11.077	10.181	1.923	12.077	10.154	0.0096	
		1.245	11.077	9.832	2.289	12.077	9.788	0.0157	
Hopper 1	12.5 %	0.957	11.077	10.12	1.974	12.077	10.103	0.0061	0.0103
		1.456	11.077	9.621	2.5	12.077	9.577	0.0157	
		1.486	11.077	9.591	2.511	12.077	9.566	0.0089	
	25%	2.201	12.367	10.166	1.984	12.077	10.093	0.0261	0.0125
		1.038	12.367	11.329	0.766	12.077	11.311	0.0064	
		2.431	12.367	9.936	2.155	12.077	9.922	0.005	
	37.5 %	1.318	11.077	9.759	2.351	12.077	9.726	0.0118	0.0213
		1.702	11.077	9.375	2.796	12.077	9.281	0.0336	
		1.564	11.077	9.531	2.598	12.077	9.479	0.0186	
Hopper 2	12.50 %	3.984	11.148	7.164	6.713	13.765	7.052	0.04	0.0269
		3.272	11.148	7.876	5.965	13.765	7.8	0.0271	
		3.074	11.148	8.074	5.729	13.765	8.036	0.0136	
	25%	2.887	11.148	8.261	5.613	13.765	8.152	0.0389	0.0263
		1.763	11.148	9.385	4.397	13.765	9.368	0.0061	
		2.563	11.148	8.585	5.275	13.765	8.49	0.0339	
	37.50 %	15.599	11.148	-4.451	18.29	13.765	-4.525	0.0264	0.0141
		16.351	11.148	-5.203	18.986	13.765	-5.221	0.0034	
		15.749	11.148	-4.601	18.401	13.765	-4.636	0.0125	

Hopper 3	12.50 %	3.609	12.003	8.394	5.419	13.765	8.346	-0.0171	0.0156
		4.683	12.003	7.32	6.519	13.765	7.246	0.0264	
		4.113	12.003	7.89	5.884	13.765	7.881	0.0032	
	25%	2.003	12.003	10	3.87	13.765	9.895	0.0375	0.0311
		3.146	12.003	8.857	5.022	13.765	8.743	0.0407	
		2.577	12.003	9.426	4.381	13.765	9.384	0.015	
	37.50 %	18.345	12.003	-6.342	20.128	13.765	-6.363	0.0075	0.0187
		20.1	12.003	-8.097	21.96	13.765	-8.195	0.035	
		19.156	12.003	-7.153	20.956	13.765	-7.191	0.0136	
Hopper 4	12.50 %	3.647	12.003	8.356	5.496	13.765	8.269	0.0311	0.0193
		2.587	12.003	9.416	4.385	13.765	9.38	0.0129	
		3.568	12.003	8.435	5.369	13.765	8.396	0.0139	
	25%	3.568	12.003	8.435	5.401	13.765	8.364	0.0254	0.0306
		3.672	12.003	8.331	5.518	13.765	8.247	0.03	
		3.359	12.003	8.644	5.223	13.765	8.542	0.0364	
	37.50 %	2.134	12.003	9.869	3.982	13.765	9.783	0.0307	0.0237
		2.154	12.003	9.849	3.988	13.765	9.777	0.0257	
		2.886	12.003	9.117	4.689	13.765	9.076	0.0146	
Hopper 5	12.50 %	2.145	12.003	9.858	3.968	13.765	9.797	0.0318	0.0186
		2.631	12.003	9.372	4.394	13.765	9.371	0.0004	
		2.185	12.003	9.818	4.013	13.765	9.752	0.0236	
	25%	2.26	12.003	9.743	4.099	13.765	9.666	0.0275	0.0281
		1.672	12.003	10.331	3.536	13.765	10.229	0.0364	
		3.169	12.003	8.834	4.988	13.765	8.777	0.0204	
	37.50 %	17.646	12.003	-5.643	19.412	13.765	-5.647	0.0014	0.0096
		15.027	12.003	-3.024	16.856	13.765	-3.091	0.0239	
		17.23	12.003	-5.227	19.002	13.765	-5.237	0.0036	

Above table shows the drying shrinkage of the 5 hoppers in which shrinkage is measure for the 0%, 12.5%, 25%, and 37.5% replacement of cement by the fly ash. For each replacement made 3 samples and calculate the drying shrinkage of it and at last I have to take mean of these three samples.

Below graph shows compressive strength of various percent replacement of fly ash for five hopper of Khaparkheda thermal power plant.

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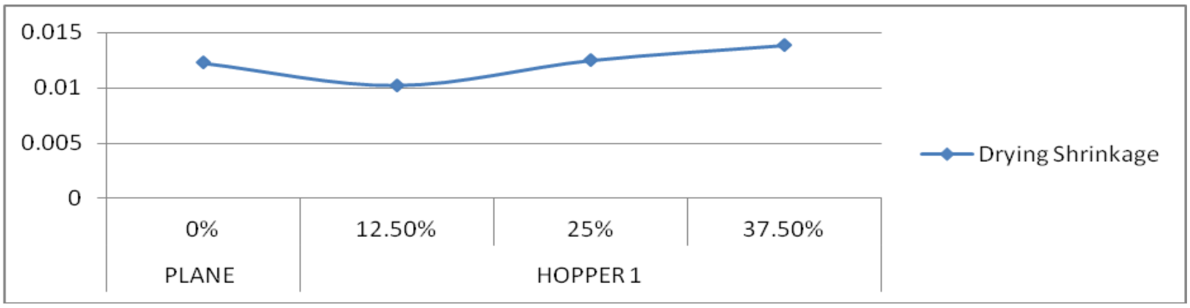

Figure 4.1 variation of drying shrinkage with percentage of fly ash for hopper 1.

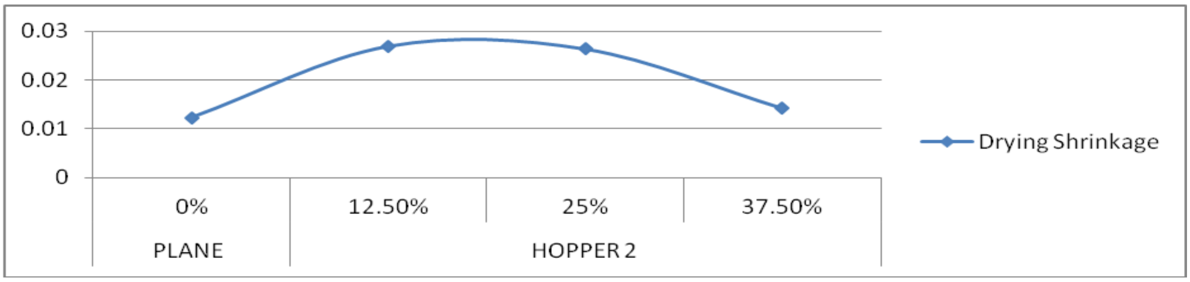

Figure 4.2 variation of drying shrinkage with percentage of fly ash for hopper 2.

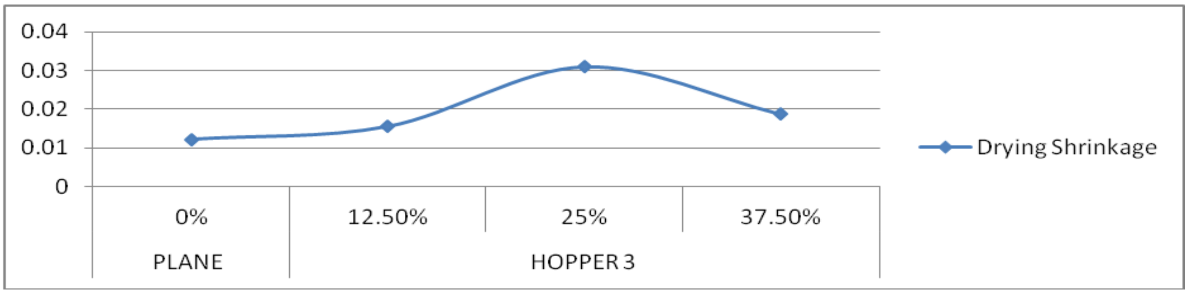

Figure 4.3 variation of drying shrinkage with percentage of fly ash for hopper 3.

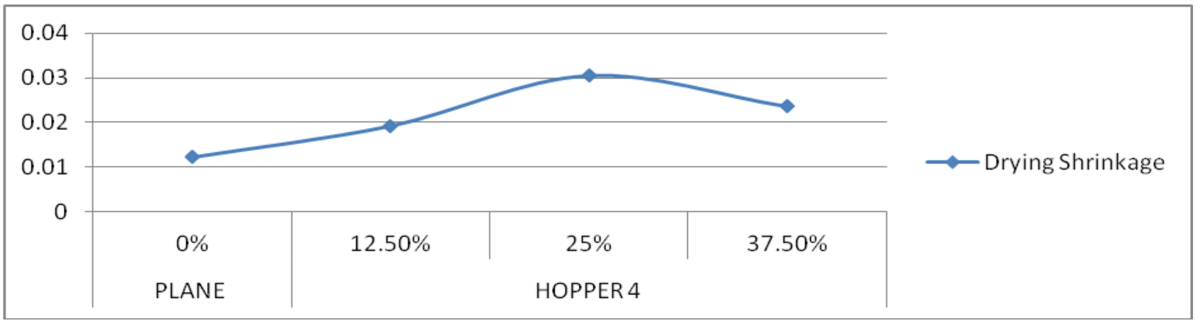

Figure 4.4 variation of drying shrinkage with percentage of fly ash for hopper 4.

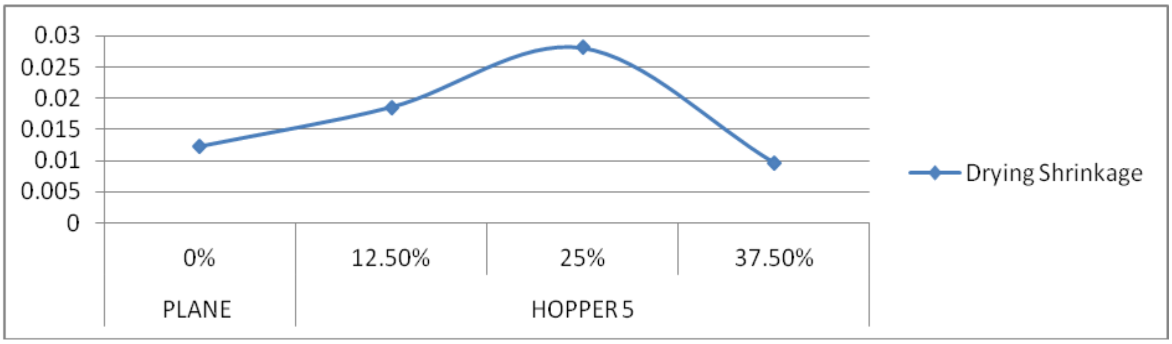

Figure 4.5 variation of drying shrinkage with percentage of fly ash for hopper 5.

From the above result it is seen that Hopper 1 drying shrinkage gives better result as related to plane sample. But for the hopper 2, hopper 3, hopper 4 and hopper 5 shrinkage will increase upto 25% and then it decreases to 37.5%.

V. CONCLUSION

A conclusion section must be included and should indicate clearly the advantages, limitations, and possible applications of the paper. Although a conclusion may review the main points of the paper, do not replicate the abstract as the conclusion. A conclusion might elaborate on the importance of the work or suggest applications and extensions. From the result it is seen that for very fine fly ash replacement gives better result than plain sample. And when the fly ash for hopper 2 to hopper 5 i.e. finer to courser fly ash which shows that shrinkage increases up-to 25% and then for 37.5% shrinkage will decreases.

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