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Selecting Optimum Percentage of Fly Ash as a Replacement of PPC for M20 Grade of Concrete

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Abstract—*This paper focuses in finding means to put the percentage of fly ash as a replacement of PPC for casting of M20 grade of concrete. Here the fly ash (0.5-5.5µm) sample of Kolaghat Thermal Power Plant, West Bengal is used. The mix proportion as per Table-9 (Proportions for Nominal Mix Concrete) of IS 456:2000 is used for casting the cubes using different percentage of fly ash. The 28 days compressive strength of cubes are carried out and a curve is plotted between strength vs percentage of fly ash, from which the percentage of fly ash is obtained as 12% corresponding to desired target strength 26.6 MPa for M20. It revealed that 12% cement may be replaced by that fly ash to achieve the desired strength and also makes the concrete workable and economical as it saves approximately 9.92% of cost of cement per cubic meter of concrete casting.*

Keywords*: Fly ash, Kolaghat, PPC, Nominal.*

1. INTRODUCTION

Fly ash is a by-product of Thermal power plants. The fly ash generates 19.0883 million tone (Central Electricity Authority New Delhi, October, 2015) from 17 thermal power stations in West Bengal out of which 77.52% utilized for difference purposes. As it contains toxic elements like arsenic, lead, mercury, cadmium, chromium and selenium which adversely effects on environment as well as living organisms. So, to reduce the harmful effects and to produce economical concrete consumption of fly ash as a replacement of PPC is required without compromising the strength of concrete. Here the fly ash of Kolaghat thermal power plant is used for determining the optimum percentage of fly ash as a replacement of cement was studied for M20 grade of concrete. V.K. Singh, V. Srivastava, V.C. Agarwal, and A. Harison [1], shows cement can be replaced by 20% fly ash for M25 grade of concrete. They took the mix proportion 1: 1.5: 3 at w/c ratio 0.42. According to A. Harison, et al. [2], strength increased marginally (1.9% to 3.2%) at 28 and 56 days respectively for 20% replacement of PPC by fly ash and up to 30% replacement of PPC by fly ash strength is almost equal to referral concrete after 56 day. T. Madhavi, et al. [3], introduced an optimum replacement level of 40% to 60% fly ash, the concrete can be used in massive concrete structures and for using in footings, walls, columns and beams, a minimum of 7 days curing must be done. Fly ash contents of 40% to 50% are suitable for slabs with a mere broom finish and 25% to 50% with a trowel finishing avoiding unwanted delays in finishing. C.S. Poon, et al. worked for replacement of cement with fly ash containing low calcium for normal and high strength concrete and showed that more than 50% cement may be replaced for normal strength concrete while it is 15 ± 25% high strength concrete. M. Thomas concluded that up to 50% fly ash may be suitable provided adequate moist-curing; early-age strength should be fulfilled. Beside of that they have focused on the temperature during placing, the exposure conditions and the finishing & curing while selecting the optimum amount of fly ash replacement. The nominal mix proportion as per IS-456:2000 is taken. M20 grade has been chosen because people make two or three storied building or small structures using that nominal mix concrete. In this paper optimum percentage of fly ash replacement is find out and may be used for making low cost concrete by achieving desired strength and workability.

2. MATERIALS USE

The fly ash of Kolaghat thermal power plant, West Bengal was taken which is supplied by Marshall Corporation Limited, Kolkata, West Bengal. Here standard A type (according to Marshall Corporation Limited) fly ash is used and the physical & chemical properties of that are given below.

Table 1: Physical Test Findings

Sl. No.	Test Parameters	Unit	Results
1	Specific Gravity	..	2.84
2	Bulk Density	Gm/cc	0.89
3	Moisture Content	%	0.06

Table 2: Chemical Test Findings

Sl. No.	Test Parameters	Unit	Results
1	Silica (SiO_2)	%	64.68
2	Alumina ($Al2O_3$)	%	24.74
3	Oxide Of iron ($Fe2O_3$)	%	2.79
4	Titanium Oxide (TiO_2)	%	0.86
5	Lime (CaO)	%	1.95
6	Magnesia (MgO)	%	0.45
7	Potash (K_2O)	%	0.35
8	Soda (Na_2O)	%	0.61
9	Sulphur (SO_3)	%	0.05
10	Phosphorous (P_2O_5)	%	0.65
11	Loss On Ignition	%	2.65
12	Undetermined	%	0.22

Fig. 1: Fly Ash Sample Used for the Study

3. METHODOLOGY

The mix proportion for M20 grade of concrete is taken from Table-9 (Proportion for Nominal Mix Concrete) of IS 456: 2000. According to this table maximum quantity of water per 50 kg of cement is 30kg and maximum total quantity of dry aggregates by mass per 50 kg of cement, to be taken as the sum of the individual masses of fine and coarse aggregate is 250 kg with a mix proportion 1:2 by mass. Three cubes were casted following above which contains 0% fly ash. .Now PPC is being only replaced by 15%, 25%, 50%, 70% and 90% by fly ash and three cubes for each replacement of fly ash are casted. After 28 days compressive strengths are calculated and average strength are taken for each for the comparative study. A bar chart is represented showing the strength variation for each percentage of fly ash replacement at 28 days. The target strength for M20 is calculated using IS 10262: 2009. A curve is plotted between compressive strength vs. percentage of fly ash replacement from which the optimum percentage of fly ash replacement is identified against mean target strength (26.6 MPa) for M20 grade of concrete. The bar chart, curve and all necessary calculation are shown in "Result and Discussion" section.

Fig. 2: Casted Cubes with Different Percentage of Fly Ash

Fig. 3: Placing of Cubes at CTM

4. RESULT AND DISCUSSION

4.1. Calculation

As per Table-9 (Proportions for Nominal Mix Concrete) of IS 456: 2000, for M20 grade of concrete containing 0% fly ash. Cement (C) =50 kg, Water (W) =30 kg, Coarse Aggregate (C.A.) =166.67 kg & Fine Aggregate (F.A.) =83.33 kg. and the mix proportion is as follows

C: W: C. A.: F.A. =1: 0.6: 3.33:1.67. The weight of all individual ingredients for casting of three cubes are tabulated below,

Table 3: Calculation for Different Ingredient

% of Fly ash	Cement (kg)	Fly ash (kg)	Water (kg)	Fine Aggregate (kg)	Coarse Aggregate (kg)
0	5.67	0	3.33	9.12	18.33
15	4.82	0.85	3.33	9.12	18.33
25	4.25	1.42	3.33	9.12	18.33
50	2.84	2.83	3.33	9.12	18.33
70	1.7	3.97	3.33	9.12	18.33
90	0.57	5.1	3.33	9.12	18.33

The target strength for M20 grade of concrete as per clause 3.2 (Target strength for Mix Proportioning) of IS 10262: 2009,

$$f'_{ck} = f_{ck} + 1.65\ s$$

Where,

f'_{ck} =target mean compressive strength at 28 days in N/mm^2,

f_{ck} =characteristic compressive strength at 28 days in N/mm^2, and

s =standard deviation N/mm^2.

Again according to Table 1 (Assumed Standard Deviation) of IS 10262: 2009, standard deviation for M20 grade of concrete is 4 N/mm^2.

Now for M20 grade of concrete, target strength

$$f'_{ck} = 20 + 1.65X4 = 26.6\ N/mm^2.$$

4.2. Result

The 28 days and average compressive strength for each percentage of fly ash are given in tabular form and a curve is plotted. A bar chart is also shown to represent the variation of compressive strength for each percentage of fly ash.

Table 4: Average Compressive Strength with Different Percentage of Fly Ash

% Fly Ash used	Compressive Strength of Cubes(N/mm^2)			Average Strength (N/mm^2)	Slump Value (mm)
	1st cube	2nd cube	3rd cube		
0	30.22	28.89	31.56	30.22	50
15	25.22	24.21	26.13	25.19	50
25	23.58	22.86	23.12	23.19	50
50	13.33	14.22	13.78	13.78	50
70	6.67	6.66	6.68	6.67	50
90	1.79	1.78	1.81	1.79	50

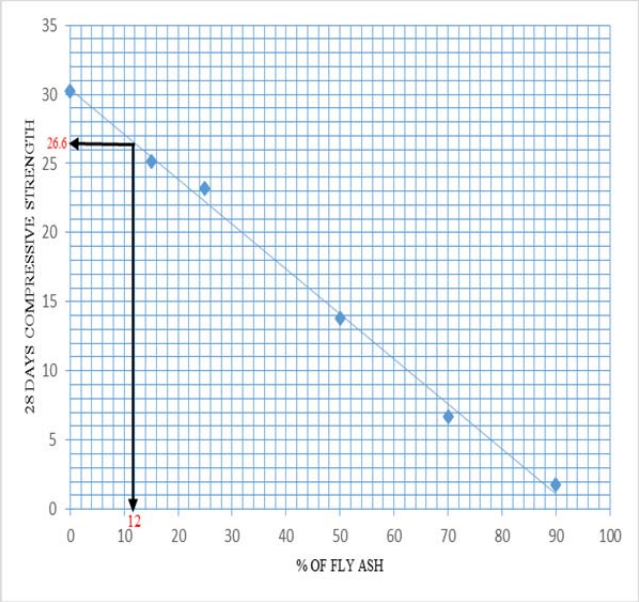

Fig. 4: 28 Days Compressive Strength vs % of Fly Ash curve

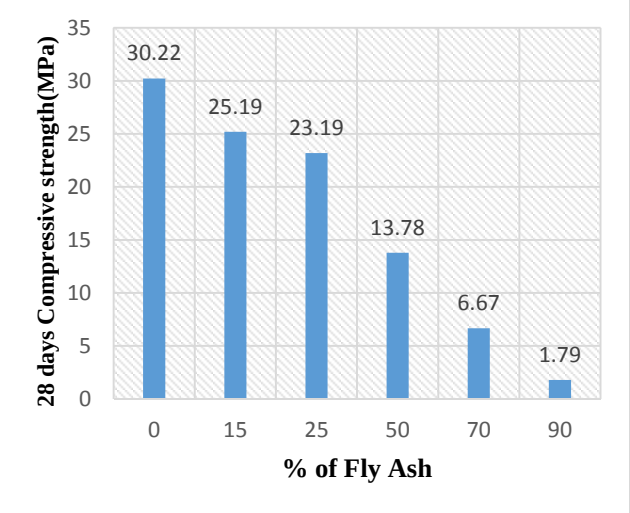

Fig. 4: Bar Chart of 28 Days Compressive Strength vs % of Fly Ash

4.3. Discussion

It has been observed that average strength continuously decreasing corresponding to increasing of percentage of fly ash replacement for a fixed workability i.e. 50 mm slump. From the graph it has been stated that the mean target strength for M20 grade of concrete i.e. 26.6 MPa may be achieved for 12% fly ash replacement using same mix proportion i.e. Cement: Fly Ash: Water: Coarse Aggregate: Fine Aggregate =1: 0.14: 0.68: 3.79: 1.89. Calculation of required materials per cubic meter of concrete as follows,

Fine Aggregate= $\frac{0.031}{0.137}$X1 =0.23 m^3

Coarse Aggregate= $\frac{0.058}{0.137}$X1 =0.42 m^3

Cement= $\frac{0.017}{0.137}$X1 = 0.13 m^3

Water= $\frac{0.030}{0.137}$X1 =0.22 m^3

To convert the compacted wet materials to dry volume, it has to multiply 1.5 with the wet volume of each ingredient. So, dry weight of cement require for 1 m3 concrete =1.5X 0.13X3X1000 =585 kg. The amount of cement can be reduced by fly ash = 585X0.12=70.2 kg. As per market price the cost of 50 kg cement is 350 rupees i.e. 7 rupees per kg. So, cost of 585 kg and 70.2 kg cement is 4095 rupees and 491 rupees respectively. The cost of fly ash is approximately 1200 rupees per ton. The cost of 70.2 kg fly ash is approximately 84 rupees.Net save amount for using fly ash is (491-84) or 407 rupees. Total amount may be saved for casting 1 m3 of concrete with 12% fly ash replacement is $\frac{407}{4095}$X100 or 9.92%.

5. CONCLUSION

(1) 12% cement may be replaced by Kolaghat fly ash to achieve the desired strength of M20 grade of concrete.

(2) The concrete should be workable and economical as it saves approximately 9.92% of cost of cement per cubic meter of concrete casting.

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