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Study on Characteristic Compressive Strength of concrete with Fly ash as partial replacement of cement

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ABSTRACT

Experimental study is conducted on partial replacement of cement with Rosa Thermal Fly Ash in different grades of concrete. Cubes were casted with 15%, 20%, 25%, 30% and 35% flyash replacement in design mix concrete. It is observed that at 15% fly ash, rate of gain of strength is maximum in different grades of concrete (M20, M25, M30, M35). In M35 Grade Concrete, its strength decreases with increase in flyash quantity. After curing of concrete cube for 56 days, the rate of gain of strength is almost equal to that of 28 days curing strength.

I. INTRODUCTION

Fly ash is the notorious waste product of coal based electricity generating thermal power plants, known for its ill effects on agricultural land, surface and sub-surface water pollution, soil and air pollution and diseases to mankind. Fly ash particles are almost totally spherical in shape, allowing them to flow and blend freely in mixtures. That capability is one of the properties making fly ash a desirable admixture for concrete. These materials greatly improve the durability of concrete through control of high thermal gradients, , depletion of cement alkalis, resistance to chloride and sulphate penetration, and continued micro structural development through a long-term hydration and pozzolanic reaction

Fig: 1.1

II. OBJECTIVES

In this paper work, objective is to develop engineering database on the mechanical properties and to determine the necessary level of fluidity, generally termed as of fly ash concrete incorporating RTPS fly ash and Ordinary Portland Cement, and it is compared with controlled concrete.

Also four grades (M20, M25, M30 and M35) of concrete are targeted to select optimum percentage of cement replacement by Fly ash as cementitious material, for obtaining maximum possible 28 days compressive strength.

1. Preliminary laboratory test of fine aggregates, coarse aggregate for mix design.

2. Mix design and proportioning for ingredients.
3. Modification and correction in mix proportioning during concrete production to meet workability requirement.
4. Modification and correction in mix proportioning during concrete productions for moisture content of fine aggregates.
5. Water to binder (cement plus fly ash) ratio was kept 0.50, 0.46, 0.42 and 0.38 for M20, M25, M30 and M35 grade concrete respectively.
6. 150 mm size cubes were casted, cured in water tank and weighed for unit weight before compression testing for the determination of mechanical properties of concretes at 7 days and 28 days .
7. Super plasticizer dose was calculated for each grade of concrete for same W/C ratio to obtain slump value 80-120mm.
8. Test result interpretation for optimum selection of suitable part replacement of Fly ash as cementitious material.
9. Compressive strength test and analysis for the determination of mechanical properties of concrete at 7 days and 28 days from the date of casting of the test specimen.

III. CHARACTERISTICS OF FLY ASH

Table: 1.1

Characteristics	Value	Characteristics	Value
Moisture (%)	0.09	Total: SiO2 + AL2O3+ Fe2O3 (%)	87.73
Loss on Ignition (%)	7.03	Na_2O (%)	0.44
Fineness > 45mic	27.53	K_2O (%)	1.53
Fineness > 75mic	14.30	MgO (%)	1.45
Free CaO (%)	0.00	SO_3 (%)	0.25
Total CaO (%)	2.25	Chloride (%)	0.00
SiO_2 (%)	58.46	P_2O_5 (%)	0.16
AL_2O (%)	21.47	TiO_2 (%)	0.93
Fe_2O_3 (%)	7.81	Specific Gravity	2.36

Source: "Low cost high performance concrete using low quality fly ash" by Aires Camões, Patrício Rocha, J.C. Pereira, J.B. de Aguiar, Syed Jalali .

Table: 1.2 Loss on ignition of Fly ash

Fly Ash	L.O.I. (%)
Total 'as received'	7
Particles > 75µm	26.5
Particles < 75µm (enhanced fly ash)	3.5

Source: "Low cost high performance concrete using low quality fly ash" by Aires Camões, Patrício Rocha, J.C. Pereira, J.B. de Aguiar, Said Jalali.

IV. DESIGN OF CONCRETE MIX

As stated earlier Mix Designing Methods according to Indian Bureau of Standard **(IS456-2000)** is adopted as a general guideline to arrive at mix proportioning for four grade of concrete (M20, M25,M30 and M35) with super plasticizer**.**

Table: 1.3 Test of 53 grade OPC Cement

S.No	Test Conducted	Results	Requirement as per IS:12269-1987(RA1999)
1.	Brand of Cement	J P	
2.	Type of Cement	53 Grade-OPC	
3.	Normal Consistency	29.0%	Not Specified
4.	Initial Setting Time	140 Minutes	Shall not be less than 30 min.
5.	Final Setting Time	220 Minutes	Shall not be less than 600 min.
6.	Compressive Strength After		
	3 Days	44.6 Mpa	Shall not be less than 27.0 Mpa
	7 Days	55.0 Mpa	Shall not be less than 37.0 Mpa
	28 Days	59.0 Mpa	Shall not be less than 53.0 Mpa
7.	Fineness (by Blain's air permeability method)	326.0 m^2/Kg	Shall not be less than 225.0m2/Kg
8.	Soundness (by Le-Chatelier's method)	1.0mm	Shall not be more than 10mm
9.	Ratio of % of Alumina to that of Iron Oxide	1.22	Not less than 0.66
10.	Insoluble Residue	0.51	Not more than 3%
11.	Magnesia (%)	1.11	Not more than 6%
12.	Total loss of Ignition (%)	1.60	Not more than 4%

Table 1.4 Sieve Analysis of Fine Aggregate

Weight of sample: 2000gm

Sieve Size in mm	Weight Retained (gm)	% Weight Retained	Commulative % Weight Retained	%age Passing
40	0	0	0	100
20	0	0	0	100
10	0	0	0	100
4.75	32	1.6	1.6	98.4
2.36	152	7.6	9.2	90.8
1.18	564	28.2	37.4	62.6

600	468	23.4	60.8	39.2
300	553	27.6	88.4	11.6
150	206	10.3	98.7	1.3
L.P	25	1.3	100	0

Fineness modulus = Cumulative %weight retained/100 = 297.2/100 = 2.972

Water Absorption Test:

EXPERIMENT RESULT:

Weight of Saturated Surface Dry (SSD) sample (A) = 725.00 gm.

Weight of Oven dry Sample (B) = 705.00 gm.

Weight Absorption = (725-705) / 705 X 100 = 2.83 %

Sieve Analysis

Table: 1.5 Sieve Analysis of Coarse Aggregate (20mm)

Weight of sample =5000gm

Sieve Size in mm	Weight Retained (gm)	% Weight Retained	Commulative % Weight Retained	% Passing
40	0	0	0	100
20	315	6.3	6.3	93.7
12.5	4509	90.18	96.48	3.52
10	88	1.76	98.24	1.76
4.75	88	1.76	100	0
2.36	-	-	100	0
1.18	-	-	100	0
600	-	-	100	0
300	-	-	100	0
150	-	-	100	0

Fineness Modulus of Coarse Aggregate = 8.01

Table : 1.6 Sieve Analysis of Coarse Aggregate (12.5mm)

Weight of sample =5000gm

Sieve Size in mm	Weight Retained (gm)	% Weight Retained	Commulative % Weight Retained	% Passing
20	0	0	0	100
12.5	50	1.0	1.0	99.0
10	1125	22.5	23.5	76.50
4.75	-	-	100	0
2.36	-	-	100	0
1.18	-	-	100	0
600	-	-	100	0
300	-	-	100	0
150	-	-	100	0

Fineness Modulus of Coarse Aggregate = 6.245

Table 1.7 Combined Sieve Analysis Of 20mm And 12.5mmCoarse Aggregate

Cumulative Sieve size (mm)	Cumulative % Passing 20mm	Cumulative % Passing 20mm	Cumulative % Passing When 20mm and 12.5mm are mixed in 60:40 ratio	Requirements Of Cumulative % Passing for 20mm graded aggregates as per IS:383-1970(RA2002)
40	100	100	100	100
20	93.8	100	96.3	95-100
12.5	3.8	99.0	41.90	-
10	0.80	76.5	31.30	25-55
4.75	0	0	0	0-10

Specific Gravity Test

Experiment Result:

Saturated surface dry (SSD) sample weight (A) = 500.00 gm.

Pycnometer + water + SSD sample (B) =1847.00 gm.

Pycnometer + water (C) =1539.00 gm.

Oven dry Sample (D) = 498.00 gm.

Specific gravity = 2.65 gm/c

Aggregate Impact Value Test

This test is done to determine the aggregate impact value of coarse aggregates as per IS**: 2386 (Part IV) – 1963**. The apparatus used for determining aggregate impact value of coarse aggregates is Impact testing machine conforming to IS: 2386 (Part IV) - 1963, IS Sieves of sizes – 12.5mm, 10mm and 2.36mm, A cylindrical metal measure of 75mm dia. and 50mm depth, A tamping rod of 10mm circular cross section and 230mm length, rounded at one end and Oven.

Water Absorption Test

EXPERIMENT RESULT:

Coarse aggregate – 20mm:

Weight of Saturated Surface Dry (SSD) sample (A) = 705.00 gm.

Weight of Oven dry Sample (B) = 703.00 gm.

Weight Absorption = (705-703)/703 X 100 = 0.28 %

EXPERIMENT RESULT:

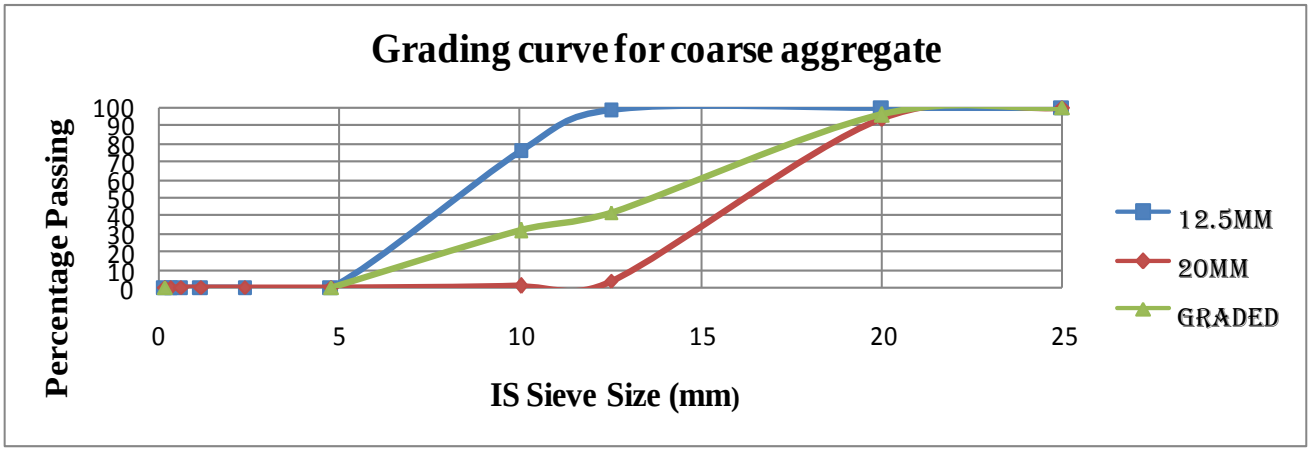
Total Weight of Sample passing on 12.5 mm sieve & retained on 10 mm sieve (A) =325gm.

Weight of the sample retained on 2.36 sieve (B) = 77 gm.

Impact value = 77/325 X 100 = 23.69%

Weight of Oven dry Sample (B) = 650.00 gm.

Weight Absorption = (653-650) X 100 = 0.54 %



V. EXPERIMENTAL WORK

Table:2.1 Nomenclature of Different types of mix compositions

Cube ID	Cementetious Material	Grade of concrete	W/(C + F)
MCM200	100 Percentage Cement	M20	0.5
MCF201	85 Percentage Cement + 15 Percentage Fly ash	M20	0.5
MCF202	80 Percentage Cement + 20 Percentage Fly ash	M20	0.5
MCF203	75 Percentage Cement + 25 Percentage Fly ash	M20	0.5
MCF204	70 Percentage Cement + 30 Percentage Fly ash	M20	0.5
MCF205	65 Percentage Cement + 35 Percentage Fly ash	M20	0.5
MCM250	100 Percentage Cement	M25	0.46
MCF251	85 Percentage Cement + 15 Percentage Fly ash	M25	0.46
MCF252	80 Percentage Cement + 20 Percentage Fly ash	M25	0.46
MCF253	75 Percentage Cement + 25 Percentage Fly ash	M25	0.46
MCF254	70 Percentage Cement + 30 Percentage Fly ash	M25	0.46
MCF255	65 Percentage Cement + 35 Percentage Fly ash	M25	0.46
MCM300	100 Percentage Cement	M30	0.42
MCF301	85 Percentage Cement + 15 Percentage Fly ash	M30	0.42
MCF302	80 % Cement + 20 Percentage Fly ash	M30	0.42
MCF303	75 Percentage Cement + 25 Percentage Fly ash	M30	0.42
MCF304	70 % Cement + 30 Percentage Fly ash	M30	0.42
MCF305	65 % Cement + 35 Percentage Fly ash	M30	0.42
MCM350	100 Percentage Cement	M35	0.38
MCF351	85 % Cement + 15 Percentage Fly ash	M35	0.38
MCF352	80 % Cement + 20 Percentage Fly ash	M35	0.38
MCF353	75 % Cement + 25 Percentage Fly ash	M35	0.38
MCF354	70 % Cement + 30 Percentage Fly ash	M35	0.38
MCF355	65 % Cement+35 Percentage Fly ash	M35	0.38

Table 2.2 Mixture Proportions for M20, M25 Grades of concrete

Cementitious Material	Mix No:	W/(C +F)	Quantities in Kg/m3				Water	S.PI
			Cement	Flyash	FA	CA		
100% Cement	MCM200	0.5	315.00	0.00	759	1152	157.5	2.20
85% Cement +15% Fly ash	MCF201	0.5	267.75	47.25	752	1141	157.5	2.00
80 % Cement + 20 % Fly ash	MCF202	0.5	252.00	63.00	750	1139	157.5	1.63
75 % Cement + 25 % Fly ash	MCF203	0.5	236.25	78.75	747	1135	157.5	1.63
70 % Cement + 30 % Fly ash	MCF204	0.5	220.50	94.50	745	1131	157.5	1.63
65 % Cement + 35 % Fly ash	MCF205	0.5	204.75	110.25	742	1127	157.5	1.63
100 % Cement	MCM250	0.46	340.00	0.00	750	1139	156.4	2.20
85 % Cement + 15 % Fly ash	MCF251	0.46	289.00	51.00	742	1127	156.4	2.20
80 % Cement + 20 % Fly ash	MCF252	0.46	272.00	68.00	739	1123	156.4	2.20
75 % Cement + 25 % Fly ash	MCF253	0.46	255.00	85.00	736	1118	156.4	2.20
70 % Cement + 30 % Fly ash	MCF254	0.46	238.00	102.00	734	1114	156.4	2.20
65 % Cement + 35 % Fly ash	MCF255	0.46	221.00	119.00	732	1111	156.4	2.10

Note: FA - Fine aggregates, CA – Coarse aggregates, Spl. – Super plasticizer (in Kg/m3)

Table :2.3 Mixture Proportions for M30, M35 Grades of concrete

Cementitious Material	Mix No:	W/(C + F)	Quantities in Kg/m3				Water	S.PI
			Cement	Flyash	FA	CA		
100% Cement	MCM300	0.42	370.00	0.00	740	1124	155.4	2.88
85% Cement +15% Flyash	MCF301	0.42	314.00	55.50	731	1110	155.4	2.64
80 % Cement + 20 % Fly ash	MCF302	0.42	296.00	74.00	729	1106	155.4	2.64
75 % Cement + 25 % Fly ash	MCF303	0.42	277.50	92.50	726	1102	155.4	2.64
70 % Cement + 30	MCF304	0.42	259.00	111.00	723	1098	155.4	2.40

% Fly ash								
65 % Cement + 35 % Fly ash	MCF305	0.42	240.50	129.50	720	1094	155.4	2.40
100 % Cement	MCM350	0.38	400.00	0.00	730	1109	152	3.24
85 % Cement + 15 % Fly ash	MCF351	0.38	340.00	60.00	721	1095	152	3.24
80 % Cement + 20 % Fly ash	MCF352	0.38	320.00	80.00	718	1090	152	2.88
75 % Cement +25 % Fly ash	MCF353	0.38	300.00	100.00	715	1086	152	2.88
70 % Cement + 30 % Fly ash	MCF354	0.38	280.00	120.00	712	1081	152	2.64
65 % Cement + 35 % Fly ash	MCF355	0.38	260.00	140.00	709	1076	152	2.64

Note: FA- Fine aggregates, CA – Coarse aggregates, Spl. – Super plasticizer (in Liter/m3)

Fig. 2.1 Filling the cubes of size 150X150X150 (mm) with concrete

Table 2.4: Properties of hardened concrete M20, M25 grades:-

Cementitious Material	Mix No.	W/(C+F)	Compressive Strength	
			7 Days	28 Days
100% Cement	**MCM200**	**0.5**	**28.83**	**37.56**
85% Cement +15% Fly ash	**MCF201**	**0.5**	**25.84**	**36.98**
80 % Cement + 20 % Fly ash	**MCF202**	**0.5**	**23.35**	**35.11**
75 % Cement + 25 % Fly ash	**MCF203**	**0.5**	**20.28**	**33.28**
70 % Cement + 30 % Fly ash	**MCF204**	**0.5**	**19.58**	**32.23**
65 % Cement + 35 % Fly ash	**MCF205**	**0.5**	**17.94**	**29.07**
100 % Cement	**MCM250**	**0.46**	**28.23**	**51.61**
85 % Cement + 15 % Fly ash	**MCF251**	**0.46**	**26.46**	**50.27**

80 % Cement + 20 % Fly ash	**MCF252**	**0.46**	**25.41**	**47.09**
75 % Cement + 25 % Fly ash	**MCF253**	**0.46**	**23.92**	**46.54**
70 % Cement + 30 % Fly ash	**MCF254**	**0.46**	**21.86**	**43.67**
65 % Cement + 35 % Fly ash	**MCF255**	**0.46**	**21.41**	**38.89**

Note: 1. Test for compressive strength was carried out on 150x150x150mm cubes

2. Each value is average of three test results.

Table: 2.5 Properties of hardened concrete (M30, M35 grades):-

Cementitious Material	**Mix No.**	**W/(C+F)**	**Compressive Strength**	
			7 Days	**28 Days**
100% Cement	MCM300	0.42	30.22	54.68
85% Cement +15% Flyash	MCF301	0.42	27.56	52.89
80 % Cement + 20 % Flyash	MCF302	0.42	26.56	51.67
75 % Cement + 25 % Flyash	MCF303	0.42	25.98	47.91
70 % Cement + 30 % Flyash	MCF304	0.42	24.84	45.01
65 % Cement + 35 % Flyash	MCF305	0.42	24.62	42.85
100 % Cement	MCM350	0.38	36.78	57.87
85 % Cement + 15 % Flyash	MCF351	0.38	35.98	54.76
80 % Cement + 20 % Flyash	MCF352	0.38	34.12	53.34
75 % Cement + 25 % Flyash	MCF353	0.38	33.27	50.41
70 % Cement + 30 % Flyash	MCF354	0.38	29.94	48.45
65 % Cement + 35 % Flyash	MCF355	0.38	27.63	46.43

Note: 1. Test for compressive strength was carried out on 150x150x150mm cubes

2. Each value is average of three test results

VI. TEST RESULTS AND DISCUSSIONS

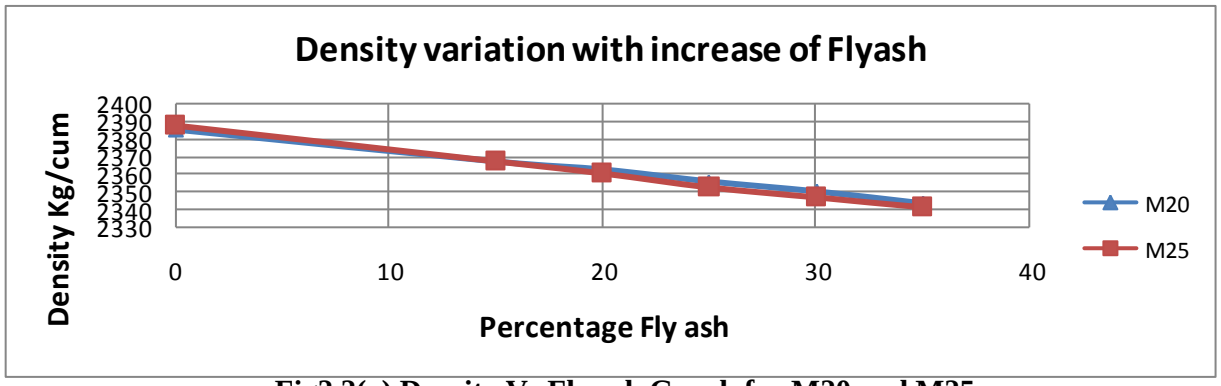


Fig2.2(a) Density Vs Fly ash Graph for M20 and M25

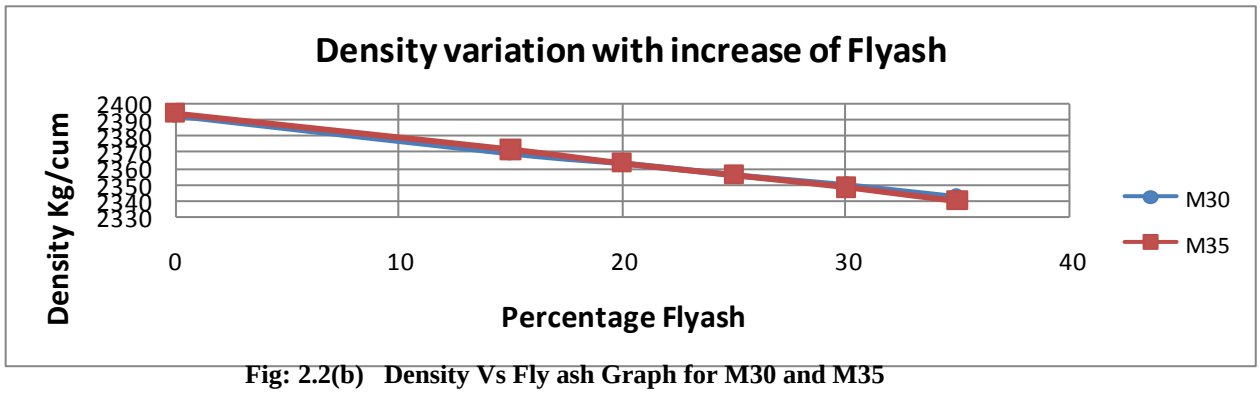


Fig: 2.2(b) Density Vs Fly ash Graph for M30 and M35

Slump of different grades of concrete:

The replacement of cement (by mass) with five percentage of fly ash (0%, 15%, 20%, 25%, 30%, 35%) increased the workability. For the economical consideration the SPL dosage will be reduced due to increment of Flyash Percentage to maintain the slump between 80 – 120 mm. This is due to the ―ball Bearing‖ action of the spherical particles of fly ash. Results are shown in Figures

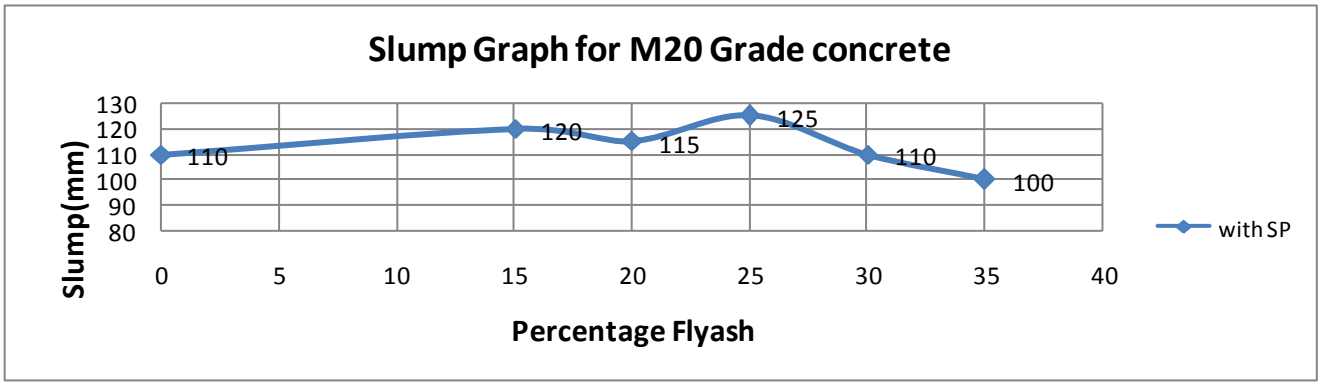


Fig2.3(a): Fly ash Vs Slump Graph for M20

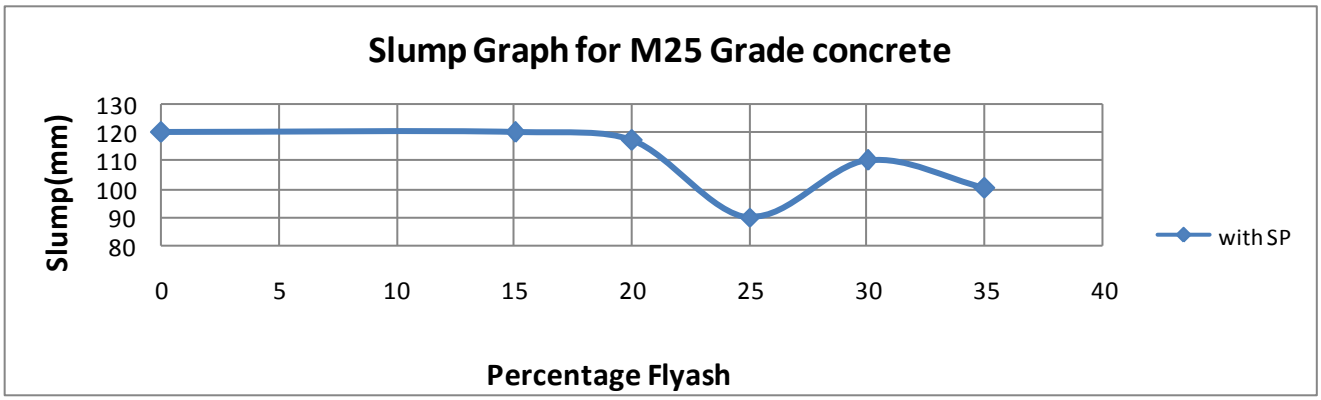


Fig.2.3 (b): Fly ash Vs Slump Graph for M25

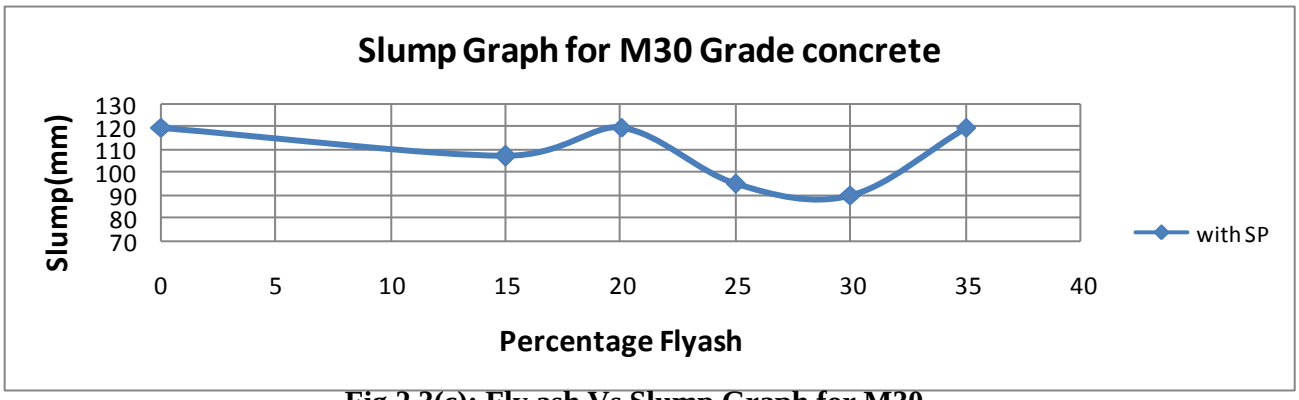


Fig.2.3(c): Fly ash Vs Slump Graph for M30

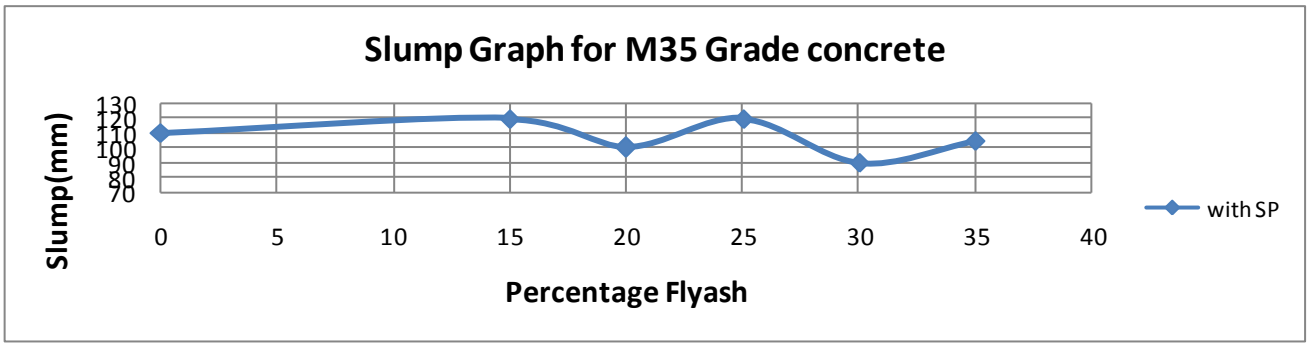


Fig.2.3 (d): Fly ash Vs Slump Graph for M35

PROPERTIES OF HARDENED CONCRETE:

7 Days compressive strength:

The replacement of cement (by mass) with five percentage of fly ash (15%, 20%, 25%, 30%, 35%) content reduced the compressive strength of concrete (for M35 Grade) 3.14%, 7.77% ,9.55%, 18.98%, 25.23% respectively. This is probably due to non-contribution in compressive strength of fly ash at early age. Results are shown in Fig. 5.3.

28 Days compressive strength :

The replacement of cement (by mass) with five percentage of fly ash 15%, 20%, 25%,30%,35%) content improves the strength gain but still reduced(for M35 Grade) by 5.22%,7.66%,12.83%,15.68%, and 19.73% respectively with super plasticizer. Fly ash starts reaction with Ca (OH)2 after 14 days. Results are listed in Fig. 5.3 (a).

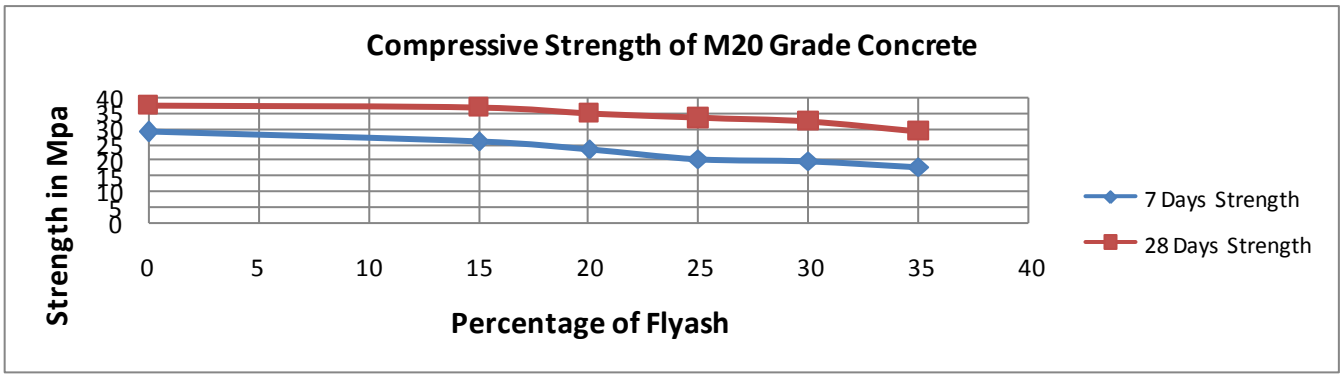


Fig.3.3 (a): Variation in Compressive Strength with Fly ash Increase for M20

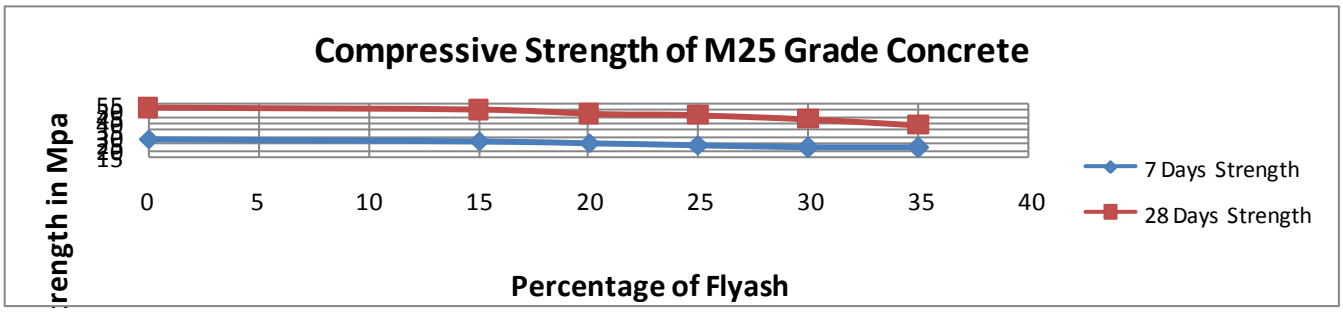


Fig. 3.3 (b): Variation in Compressive Strength with Fly ash Increase for M25

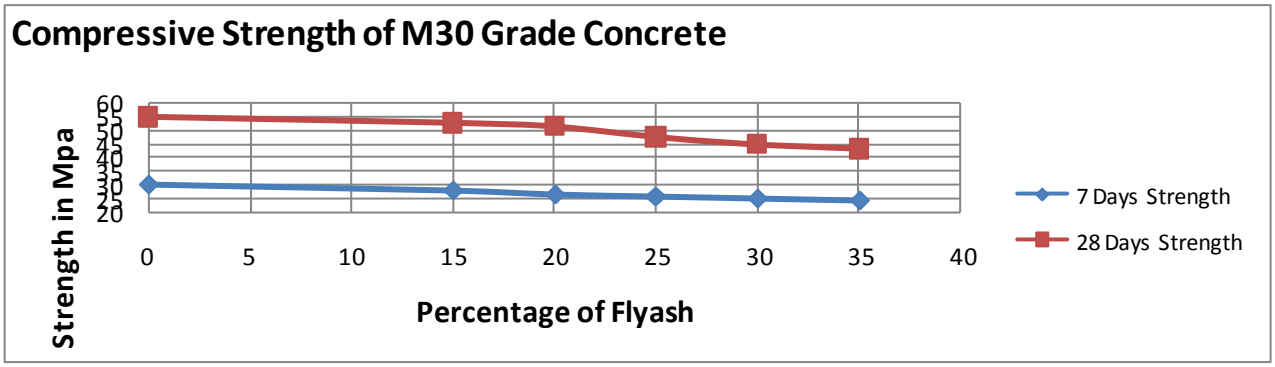


Fig. 3.3(c): Variation in Compressive Strength with Fly ash Increase for M30

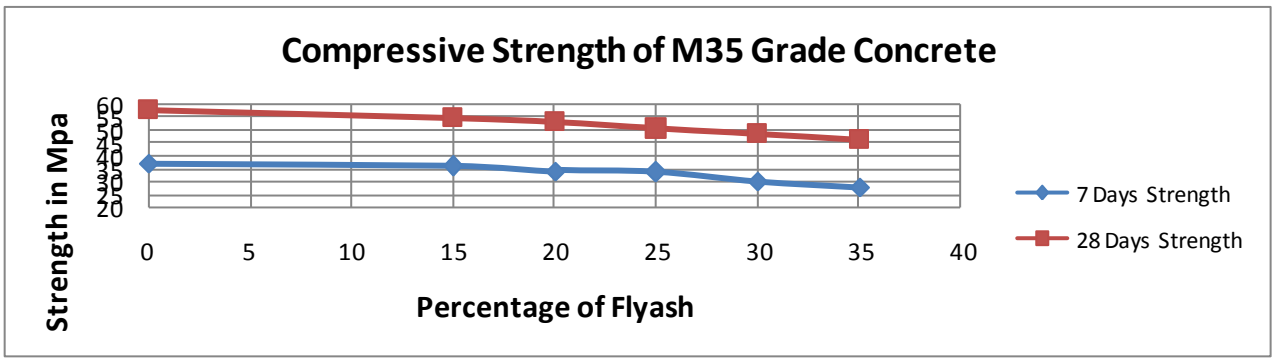


Fig. 3.3(d): Variation in Compressive Strength with Fly ash Increase for M35

56 days compressive strength:

The replacement of cement (by mass) with five percentage of fly ash (15%, 20%, 25%, 30%, 35%) content of (ex: for M35 grade) concrete given strength almost equal to control mix. This shows that fly ash reaction continues for longer time up to 90 days or more. Results are listed in Fig.

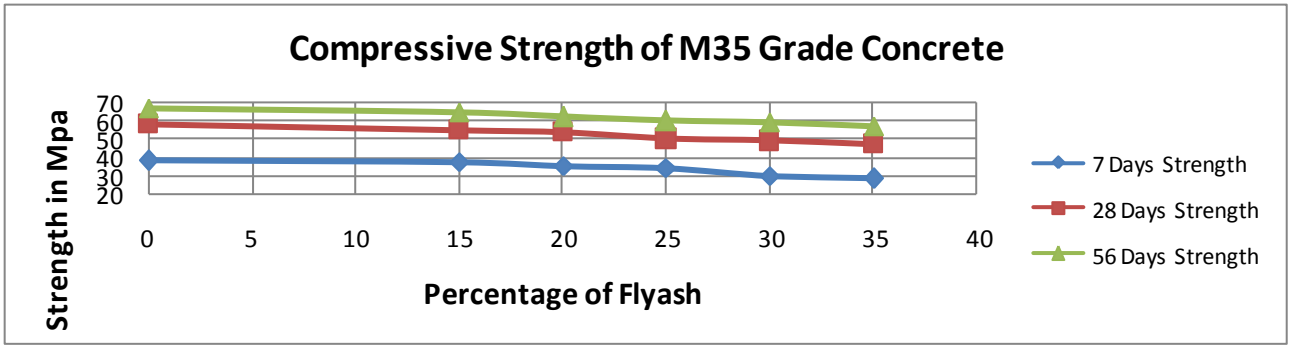


Fig. 5.3(e): Variation in Compressive Strength with Fly ash Increase for M35 at 56th day Compressive Strength

VII. CONCLUSIONS

In this chapter conclusions of the so far done study/Experimental work of this project are given. Following conclusions are given from the present study:

- RTPS Fly ash (class F) incorporation in the mix ingredient enhances performance of concrete by improving workability, flow-ability, finishibility and compactibility in fresh state of concrete in both plasticizerised as well as unplasticizeried concrete.
- Increasing fly ash content decreases the strength. Although the strength of High Fly ash Concrete (HFC) is very poor at early curing age, it develops rapidly with longer curing age, resulting in long-term strength almost equal to that of control mix (with no fly ash).
- By the analysis fly ash effect in HFC becomes positive after 7 days of curing age, and it develops rapidly. The contribution of fly ash in HFC with 56-day curing age to strength is equal or approaches 80%, and is more remarkable compressive strength.
- Finally, cement contribution to strength of HFC can be divided into two aspects. The first is through the hydrated products produced in the hydration of itself, and the second is the fly ash effect activated by it. At early curing age, the former is the dominant factor, while the latter is more significant afterward. After 56 days, the contribution of fly ash effect to strength of HFC approaches 80%.

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