Effect of Fly Ash and Polymer on Compressive Strength of Concrete

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Abstract - *In this project work, an attempt has been made to study the effects of admixtures by partial replacement to cement in terms of improved performance in compressive strength concrete.*

Mix design of M20 grade concrete is made of different groups such as:-

1) *Mix design with Ordinary Portland Cement*
2) *Mix design with OPC + Fly Ash*
3) *Mix design with OPC + Polymer (SBR Latex)*

For these mix designs of concrete, cubes are caste in moulds and which will be further tested, analyzed for the said purpose.

In an effort to improve the performance of concrete, fly ash and polymer are introduced into concrete. It is well accepted that the interfacial bond between cement paste and aggregates can be improved and better pore structure of cementitious matrix can be obtained with minimized micro cracks using relative silica in the form of fly ash, granulated blast furnace slag, silica fume, etc. out of above fly ash has gained prominence due to growing awareness about benefits and easy availability of good quality fly ash.

It has been also reported that polymer-modified concrete (PMC) is more durable than conventional concrete due to high strength and low porosity. This research was carried out to establish the effects of fly ash and polymer addition on compressive strength using concrete with mix design of M20 grade of constant workability at local ambient temperature.

The mixes were prepared for M20 grade as a control mix, fly ash is replaced with 10%, 20%, and 30% by the weight of cement according to mix design by Indian Standard Method and polymer is replaced with 10%, 20% and 30% by weight of cement based on DOE (Department of Environment Method). Compressive strength was determined at the age of 7, 14 and 28 days from sample of size 150mm cubes. The addition of polymer in concrete resulting in reduction of W/C ratio for mixes. Mixes with 10% replacement of fly ash and polymer show higher compressive strength against 20% and 30% fly ash and polymer content.

Key Words: Mix Design as per Indian Standard, Fly Ash Concrete, Polymer Concrete, SBR Latex, Fly Ash

1. INTRODUCTION

Concrete is the most widely used construction material because of its flow ability in most complicated form i.e. its ability to take any shape while wet, and its strength development characteristics when it hardens. Generally concrete is used to build protective structures, which are subjected to several extreme stress conditions. Concrete is the most widely used construction material manufactured at the site. This composite material is obtained by mixing cement, water and aggregates. Its production involves a number of operations according to prevailing site conditions. The ingredients of widely varying characteristics can be used to produce concrete of acceptable quality. The strength, durability and other characteristics of concrete depend upon the properties of its ingredients, the proportions of the mix, the method of compaction and other controls. The popularity of concrete as a construction material is due to the fact that it is made from commonly available ingredients and can be tailored to functional requirements in a particular situation. Among the various properties of concrete, its compressive strength is considered to be the most important. However, workability of concrete plays an important role in the mix design. Other factors such as W/C ratio, Fineness modulus of aggregate and specific gravity of cement have their own importance in mix design.

Concrete mix design is the process of choosing suitable ingredients of concrete and determining their relative quantities with the objective of producing the most economical concrete while retaining the specified minimum properties such as strength, durability, and consistency. The selection of ingredient is normally done using data from tables and charts in the relevant mix design standard. While these data and numerical examples in the codes are sufficient to guide the mix designer, it is thought worthwhile to add more values to these data for convenience of the users.

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1.1 Introduction to Fly Ash

Fly ash is finely divided residue resulting from the combustion of powdered coal and transported by the flue gases and collected by electrostatic precipitator. In U.K. it is reffered as pulverized fuel ash (PFA). Fly ash is the most widely used material all over the world. In the recent time, the importance and use of fly ash in concrete has grown so much that it has almost become a common ingredient in concrete. Extensive research has been done all over the world on the benefits that could be occurred in the utilization of fly ash as a supplementary cementitious material. High volume fly ash concrete is a subject of current interest all over the world. The use of fly ash as concrete admixture not only extends technical advantages to the properties of the concrete but also contributes to the environmental pollution control.

1.2 Introduction of Master bond-SBR Latex

It is an emulsion of single component styrene butadiene co-polymer based latex specially developed to improve the properties of cementitious compositions. MASTERBOND-SBR LATEX when used in combination with standard quality of ordinary portland cement, it enhances the mechanical properties such as bonding (adhesion) with various building materials, flexurals, compression and impact strength. MASTERBOND-SBR LATEX improves the thin section fragility of cement when used as coating. It is resistant to hydrolysis hence can be used for external applications too.

2. ANALYSIS OF CONCRETE MIX DESIGN

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	M-20 Concrete Mix Design	
	As Per IS 10262-2007	
I.	**Stipulations For Proportioning**	
1	**Grade Designation**	**M20**
2	Maximum Nominal Aggregate Size	20 mm
3	Type of Aggregate	Angular
4	Exposure Condition	Mild
5	Degree of Supervision	Good
6	Workability	75mm(slump)
7	Zone	I
9	**Type of Cement**	**OPC 53 Grade**
II.	**Test Data For Materials**	
1	**Specific Gravity**	
a.	Sp. Gravity of Cement	3.15
b.	Sp. Gravity of Water	1
c.	Sp. Gravity of Fine Aggregate	2.65
d.	Sp. Gravity of Coarse Aggregate	2.67
2	**Water Absorption**	
a.	Water Absorption of Fine Aggregate	1.40%
b.	Water Absorption of Coarse Aggregate	0.70%
3	**Free (Surface) Moisture Content**	
a.	Free (Surface) Moisture Content of Fine	2.20%
b.	Free (Surface) Moisture Content of Coarse	1.10%
III	**Target Strength For Mix Proportioning**	
1	Target Mean Strength [f_t = fck + (1.65×S)]	
	Where: f_t = target mean strength at 28 days, S = Standard	
	f_{ck} = characteristic compressive strength at 28 days.	
	From IS 10262:2007 for M20: S = 4 N/mm²	
	f_t = 20 + 1.65×4	26.6 N/mm²
IV.	**Water Cement Ratio**	
1	Water Cement Ratio	0.5
2	Maximum Water Cement Ratio	0.55
	From Table 5 of IS 456:2000, maximum water cement ratio =	
3	Adopted Water Cement Ratio	0.5
V.	**Selection Of Water Content**	
1	*Maximum Water Content (10262:2007-Table-2) for 20mm agg. =*	
	Estimated Water Content [186 + (3/100)	**191.58** liters
VI.	**Calculation Of Cement Content**	
1	Water Cement Ratio	0.5
2	Cement Content (191.58/0.5)	**383.16** kg/m³
VII.	**Proportion Of Volume Of Coarse Aggregate & Fine**	
1	Vol. of Coarse Aggregate	0.6
	As Per Table 3 Of IS 10262:2007 for agg. Size 20mm of Zone I	
2	Adopted Vol. of Fine Aggregate (1- 0.6)	0.4
VIII.	**Mix Calculations**	
a.	Volume of Concrete in m³	1
b.	Volume of Cement in m³	
	(mass of cement/specific gravity of	
	[383.16/3.15] × [1/1000]	0.122
c.	Volume of water in m³	
	(Mass of water/ specific gravity of water)	
	[191.58/1] × [1/1000]	0.192
d.	Volume of All in Aggregates in m³	
	a – (b + c) = 1 – (0.122 + 0.192)	0.686
e.	Volume And Weight of Coarse Aggregates in m³	
i.	Volume of Coarse Aggregates in m³	
	Volume = 0.686 × 0.6	0.412
ii.	Weight of Coarse Aggregates in kg	
	Weight = Vol. of CA × sp. gravity of	
	Weight =0.412 × 2.67×1000	**1100.04**
f.	Volume And Weight of Fine Aggregates	
i.	Volume of Fine Aggregates in m³	
	Volume = 0.686 × 0.4	0.274
ii.	Weight of Fine Aggregates in kg	
	Weight = Vol. of FA × sp. gravity of FA ×	
	Weight = 0.274×2.65	**726.1**
IX.	**Mix Proportions For One Cum Of Concrete (SSD Condition)**	
1	Mass of Water in litre	**191.58**
2	Mass of Cement in kg/m³	**383.16**
3	Mass of Fine Aggregate in kg/m³	**726.1**
4	Mass of Coarse Aggregate in kg/m³	**1100.04**
X.	**Mix Proportion**	

Water	Cement	F A	C A
191.58	383.16	726.1	1100.04
0.5	1	1.89	2.87

XI.	**Actual Quantity of Water, Sand, Aggregate**	
1	Water to be deducted for free moisture present	
	Fine aggregate (-2.2% × 726.1)	-15.97
	Course aggregate (-1.1% × 1100.04)	-12.1
2	Water to be added for absorption	
	Fine aggregate (1.4% × 726.1)	10.16
	Course aggregate (0.7% × 1100.04)	7.7

Water	**Cement**	**F A**	**C A**
181.37	383.16	742.07	1112.14
	1	1.9	2.9

XII	**Amount of Materials Required For One (15cm×15cm×15cm)**	
	Materials	Quantity
1	Cement	
	$383.16\times10^{-6}\times15\times15\times15$	1.29 kg/cm³
2	Fine aggregate	
	$742.07\times10^{-6}\times15\times15\times15$	2.5 kg/cm³
3	Coarse aggregate	
	$1112.14\times10^{-6}\times15\times15\times15$	3.75 kg/cm³
4	Water	
	$181.37\times10^{-6}\times15\times15\times15$	0.62 kg/cm³

Now with the reference to this mix design, cement is partially replaced with polymer and Fly Ash with different proportions respectively. Their cube test results are analyzed for most favorable combination of different ingredients for optimum compressive strength of concrete.

2.1 Preparation of Materials For Mix

Materials used for this study were cement, coarse aggregates, fine aggregates, water, fly ash and polymer. The concrete mix uses a single batch of cement supply to minimize variation of results. Aggregates of well graded type and free from impurities were checked and certain standards were complied in the course of this study.

2.2 Mixing Of Polymer

The polymer modifier used in this study was in an emulsion-based polymer. Thus, it was used without further treatment or addition of chemicals. The total solid content was determined by drying the polymer until a constant weight can be obtained as described.

2.2.1 Determination of Solid and Water Content in Polymer Latex

Latex emulsion contains about 50% of water. It is important to determine the percentage of latex solid and water in the emulsion to maintain the water-cement ratio and polymer-cement ratio. The procedures of determining the solid content in polymer latex consists of weighing an empty porcelain crucible followed by weighing latex polymer in the porcelain crucible. The latex polymer was dried in an oven for 24 hours at a temperature of 100°C. Average weight of cooled samples was taken and total solids content is expressed as a percentage of the original weight. To calculate the percentage of latex solid and water in the emulsion, the following rule is observed:

Mass of empty aluminium can =a
Mass of polymer + aluminium can =b
Mass of dried polymer + aluminium can =c
Mass of water contain in the sample, x =b - c
Percentage of water, y =[x\ (b-a)] × 100%
Percentage of latex solid =100% - y
Result of latex solid-water percentage of latex polymer

Sample	Readings	
	1	2
Mass of empty container (g)	97	130.8
Mass of polymer + container (g)	197	280
Mass of dried polymer + container (g)	146	231.3
Mass of water content in the sample (g)	51	48.7
Total water content (%)	51	48.7
Total solid content (%)	49	51.3

The average value of the analysis is taken as:
Total solid content = 49.85%
Total water content = 50.15%

2.2.2 Calculation For Quantities Of Fly Ash And Polymer

The cement is replaced by 10%, 20% and 30% with fly ash and polymer.
Quantities of materials for cube of 15 cm, with constant W/C ratio of 0.5, are:
Cement = 1.29 kg, Water
Coarse Aggregate = 3.75 kg, Fine
Aggregate = 2.5 kg

I. For 10% replacements of cement with fly ash, calculation as follows:

Fly ash 10% replacement of cement = (10/100) × 1.29
=0.129kg
Quantity of cement required = 1.29-0.129 =1.16 kg
Total quantity of cement required for 9 cube = 9 × 1.16
=10.44 kg

II. For 10% replacement of cement with polymer, calculations are as follows:

Total Solid Content of Latex Polymer = 50%
Polymer Solid/Cement = 10%
Polymer Solid = 0.1 × 1.29
Total Latex Polymer = (0.129/50%)
Total Water Content in Latex Polymer = 0.129 kg
Therefore Free Water needed = 0.62 - 0.129
For 9 cubes
a) Total polymer = 9 × 0.258= 2.32lit
b) Total water required = 9 × 0.49 = 4.41lit
Similarly, calculation will be done for 20% and 30% with replacement of fly ash and polymer.

2.3 Preparation of Moulds

Moulds were checked for the cleanliness and proper assembling of joints. The interior surface of the moulds was coated with a thin layer of diesel oil to ease in removing.

2.4 Mixing

Prior to mixing, all materials were precisely weighed. Hand mixing was done in iron sheet tray. All dry materials were added in the following sequence of coarse aggregates, fine aggregates and cement to get a homogeneous mix. A small portion of the total free water was poured into the mix. Same mix was followed by fly ash to get fly ash concrete. But for polymer concrete first of all polymer was mix with the cement and further both properly mix to coarse aggregate and fine aggregate. The remaining free water was added subsequently to achieve the calculated water-cement ratio.

= 0.62 kg

Fig. No. 2.1 Mixing of polymer with cement

2.5 Preparation of Samples

The size of the samples was 150mm × 150mm × 150 mm for each set of mix type. Each sample was filled into the mould in two layers with each layer being compacted by tampering 35

times using a standard 25 mm square steel rod to remove the entrapped air. The surface of the samples was trowel and left to bleed for a while after the full compaction was achieved. A final smoothing of the surface was done prior to curing.
Curing was done under 2 conditions i.e. wet condition and dry condition, both at ambient temperature. In this study, the samples of plain concrete and fly ash concrete were left to cure under dry condition for the first day and wet condition for the subsequent days. The polymer concrete samples were left to cure under wet condition for first 3 days and dry condition for subsequent days. Wet curing allows the hydration process of cement to take place while dry curing provides an environment for the polymer film to form. Subsequent wet curing is not necessary due to polymer film blocking the pores and sealing in moisture. After casting, samples were covered with plastic sheet for 24 hours to preserve the moisture. The then demould specimens were marked for identification purpose and place in the curing tank to further enhance the wet curing process and later, samples were cured in dry condition.

2.6 Tests on Hardened Concrete

Cubes were tested at the age of 7, 14, and 28 days. Only one type of test is done for hardened concrete, namely compressive strength. Compressive strength is described below.

2.6.1 Compressive Strength

Sample:
At the material laboratory of Civil Engineering Faculty, the compressive strength test was done using compressive machine. Samples were taken randomly from shelf at the specified age and were checked for cleanliness.

Procedure:
At the age of 7 days, 3 cubes were removed from the shelf. Each cube was then positioned in the compressive machine with the cast faces in contact with the platens. The maximum load was recorded. These procedures were applied onto the remaining 2 samples and the average reading was taken as the compressive strength at the age of 7 days. This test was performed again at the concrete age of 14 and 28 days and also for fly ash and polymer concrete cubes.
Compressive Strength = P/A
Where,
P = Ultimate compressive load of concrete (KN)
A = Surface area in contact with the platens (mm^2) (i.e. 150mm×150 mm)

Fig. No. 2.2 Compressive Strength Testing Machine

3. TEST RESULT & DISCUSSION

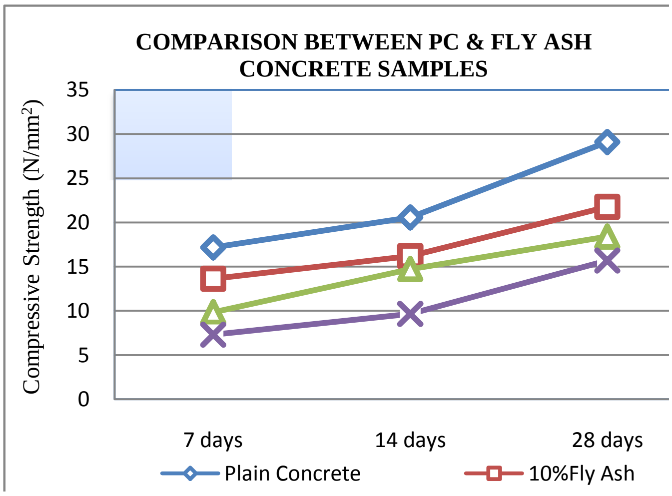
Analysis was done according to parameters used in controlling the effects of fly ash and polymer addition on concrete under wet and dry curing condition at the room temperature.
The casting of cubes were done by replacing cement in the amount 10%, 20%, 30% of fly ash for fly ash concrete and 10%, 20%, 30% of polymer for polymer concrete with constant water cement ratio.
For the appropriate test result 3 cubes were casted for 7, 14, and 28 days curing of 10%, 20%, & 30% addition of fly ash and polymer.
After the testing of cubes, the obtained results were shown below in charts and graph. The results focused on compressive strength development of concrete with optimization fly ash and polymer addition compared to plain concrete.

3.1 Observations

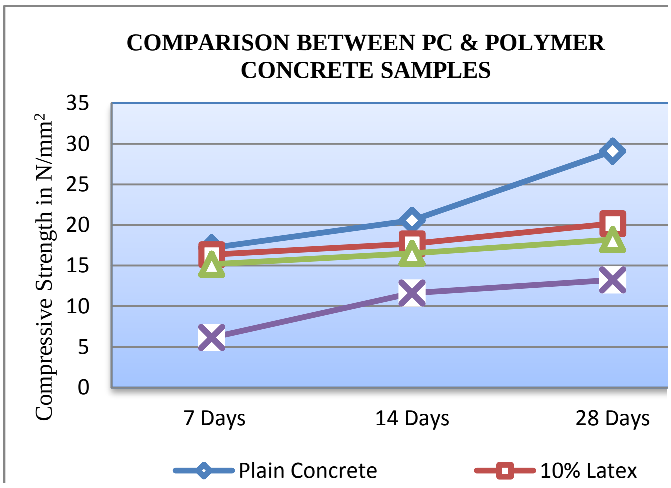
Sr. No.	Type of Concrete Mix Design	Compressive Strength in (N/mm²)		
		7 days	14 days	28 days
Analysis For Plain Concrete (PC) Cubes				
1	Plain Concrete Cubes	16.44	20.33	29.3
2		16.89	21.5	28.78
3		18.22	19.9	29.18
	Avg. Compressive Strength	**17.18**	**20.57**	**29.09**
Analysis For Fly Ash Concrete Cubes				

1	**10% Fly Ash + 90% Cement**	14.22	17.5	21.61
2		13.77	14.3	26.4
3		12.86	16.7	17.28
	Avg. Compressive Strength	**13.61**	**16.2**	**21.76**
1	**20% Fly Ash + 80% Cement**	10.22	15.2	19.13
2		10.17	14.4	18.26
3		9.13	14.6	17.83
	Avg. Compressive Strength	**9.84**	**14.7**	**18.4**
1	**30% Fly Ash + 70% Cement**	7.11	12	17.11
2		6.44	7.2	15.16
3		8.34	9.72	14.81
	Avg. Compressive Strength	**7.29**	**9.65**	**15.69**
Analysis For Latex Polymer Concrete Cubes				
1	**10% Latex + 90% Cement**	16.44	17.11	21.11
2		16.89	18.44	19.24
3		15.78	17.56	20.22
	Avg. Compressive Strength	**16.37**	**17.7**	**20.19**
1	**20% Latex + 80% Cement**	15.33	16	18.67
2		14.67	17.33	17.78
3		15.56	16.22	18.67
	Avg. Compressive Strength	**15.19**	**16.52**	**18.23**
1	**30% Latex + 70% Cement**	5.56	11.78	12.67
2		6	12.67	13.33
3		6.89	10.44	13.78
	Avg. Compressive Strength	**6.15**	**11.63**	**13.26**

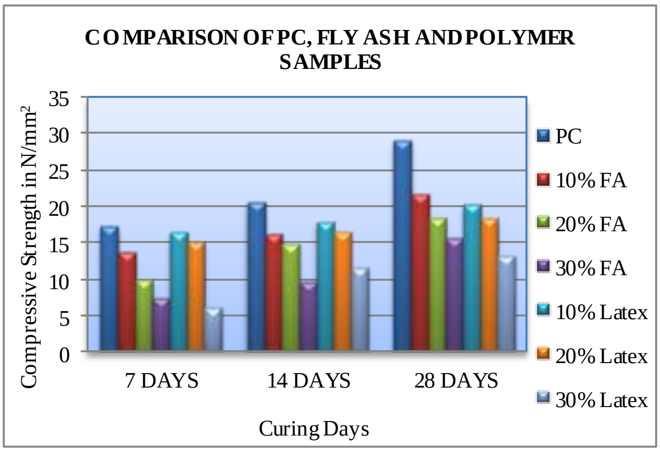
3.2 Comparative Graphs



Graph No. 3.1 Test results comparison of Plain and fly ash concrete samples



Graph No. 3.2 Test Rest Results Comparison Of Plain And Latex Polymer Concrete Samples



Graph No. 3.3 Test Rest Results Comparison of Plain, Fly Ash and Polymer Concrete Samples

4. CONCLUSION

1. It is obtained from results that with more replacement of fly ash and polymer have the lowest compressive strength when compared to concrete samples with less fly ash and polymer for the ages 7,14,and 28 days of curing.

2. Compressive strength of 10% replacement by polymer met the strength of Plain concrete. Hence up to 10% cement can be replaced with polymer in construction.

3. The curing period of polymer modified concrete is found to be less from results.

4. Polymer concrete also cost significantly more than conventional concrete.

5. From the results 10% replacement of cement by fly ash can be used in concrete in construction as fly ash is economical and easily available.

6. Fly ash utilization especially in concrete is significant as it increase the life of concrete roads and structures by improving concrete durable.

7. As curing period for polymer concrete is less, it is very useful material. Polymer concrete finds application in runway construction and runway repairs, rehabilitation of hydro technical constructions, wear and corrosion resistant floors in chemical plants, etc. Overlays on existing road way using polymer concrete results in durable and highly skid resistant road surface.

8. So polymer concrete is a good material for construction, in decorative, sporty applications.

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