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Experimental Study Report on Use of Fly Ash in Ready Mixed Concrete

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Abstract— Ready Mixed Concrete is defined as the concrete delivered in plastic condition and requiring no further treatment before being placed in position in which it is to set and harden. Instead of being batched and mixed on site, concrete is delivered for placing from central batching plant. Ever since the term high-performance concrete was introduced into the industry, it had widely used in large scale concrete construction that demands high strength, high flowability, and high durability.
A high-strength concrete is always a high-performance concrete, but a high-performance concrete is not always a high-strength concrete. Durable concrete Specifying a high-strength concrete does not ensure that a durable concrete will be achieved. It is very difficult to get a product which simultaneously fulfill all of the properties. So the pozzolanic material like Fly ash which can be used in concrete as partial replacement of cement, which are very essential ingredients to produce ready mixed concrete. So we have performed trials for high grade concrete for replacement of cement by 5 % ,10% ,15% ,20% ,25% and 30% fly ash in concrete. Also it is very important to maintain the fixed water cement ratio 0.39 , for that we have to use the water reducing admixture i.e superplasticizer, which plays an important role for the production of ready mixed concrete ,also at fixed dose of 1.2% .So, that of total weight of concrete and casting was done .
We prepared cubes, cylinder, beams of high grade concrete M50 and finally compressive test, splitting test, flexural test ,acid resistant test are conducted as per IS: 516 – 1959, IS: 5816 – 1999.
Also to obtain such performances that cannot be obtained from conventional concrete and by the current method, a large number of trial mixes are required to select the desired combination of materials that meets ready mixed concrete of better a)strength, b)workability, c)to enhance retention of ready mixed pumpable concrete for considered transportation time & casting time, it must be pumpable so that easily conveyed by pressure through hose pipes, d)durable , e)economical etc.

Index Terms—Compressive Strength, Durability, Fly Ash, Pumpability, RMC, Ready Mixed Design, Retention, Workability.

1 Introduction

AS PER Indian Standard code of practice (IS 4926) Ready Mixed Concrete (RMC) is defined as " The concrete delivered in plastic condition and requiring no further treatment before being placed in position in which it is to set and harden. Instead of being batched and mixed on site, concrete is delivered for placing from central batching plant."

RMC is a specialized material in which the cement aggregates and other ingredients are weigh-batched at a plant in a central mixer or truck mixer, before delivery to the construction site in a condition ready for placing by the builder. Thus, `fresh' concrete is manufactured in a plant away from the construction site and transported within the requisite journey time.

Sometimes Materials such as water and some varieties of admixtures can be transit-mixed(also known as Transit Mixture), that is they can be added to the concrete at the jobsite after it has been batched to ensure that the specified properties are attained before placement. Here materials are batched at a central plant and are completely mixed in the Batching Plant or partially mixed in transit.

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Transit-mixing keeps the water separate from the cement and aggregates and allows the concrete to be mixed immediately before placement at the construction site (Dry Concrete). This method avoids the problems of premature hardening and slump loss that result from potential delays in transportation or placement of central-mixed concrete.

Additionally, transit-mixing allows concrete to be hauled to construction sites further away from the plant. There are several types of RMC plants varying in type of mixing and capacity of concrete production.

These plants are generally available in capacities varying from 15 cum/hour to 200 cum/hour.

Secondly ,. Fly ash use can greatly improve pumpability while enhancing the quality of the concrete and controlling costs.

2 The Objectives and Scope of Present Study

2.1 Objectives

- To find the optimum mix design for ready mixed concrete with regards to the amount of water, Fly Ash, and cement ratio.
- To design mix to satisfy two services for the RMC, firstly one of processing the materials for making fresh concrete and secondly, of transporting a product within a short time before concrete get set below the required slump.

- To enhance retention time of the ready mixed concrete by considering transportation & casing time.
- To minimize cement use in concrete by introducing alternative material & its content.
- To investigate slump at different percentage of fly ash by replacing cement content to get pump-able ready mixed high grade concrete.
- To design RMC Pumped concrete so that it can be easily conveyed by pressure through a rigid pipe or flexible hose for discharge directly into the desired area.
- To find out fly ash percentage to replace cement in concrete ,so that ,it can greatly improve pumpability while enhancing the quality of the concrete.
- To investigate the physical properties of the FA,– strength (bending and compression)
- To design ready mixed pumped concrete more fluid, with enough fine material and water to fill internal voids.
- To study the relative strength development with age of FA + concrete M50 with control concrete M50.
- Use of industrial waste in a useful manner.
- To conduct compression test on Fly Ash concrete and control concrete on standard IS specimen size (150 x 150 x 150) mm.
- To conduct Flexural test on Fly Ash and control concrete on standard IS specimen size (100 x 100 x 500) mm.
- To conduct split tensile test on Fly Ash and control concrete on standard IS specimen size (150 mm ø x 300mm) mm.
- To conduct acid resistant test.
- To provide economical construction material.
- Provide safeguard to the environment by utilizing waste properly.

2.2 Experimental Set up

Concrete mixes taken up for this study were proportioned with total cementitious content starting from 450 kg/cum in the incremental replacement of 22.50 kg/cum of fly ash.

For each cementitious content, 5 sets of concrete mixes were proportioned with 0%,5%,10%,15%,20%,25%,30% replacement of cementitious content by fly ash.

High range superplasticizer (CACN60)with fixed proportion of 1.2% of cementitious content was used in all the concrete mixes to achieve good workability. A slump of 180mm + or - 20mm was planned to ensure that these mixes could be pumped and placed even in the most congested areas. Unit water content was kept constant for all mixes. To check effect of partial replacement of cement by fly ash, the admixture dosage was kept constant & without changing the unit water content.

This ensured the identical W/C ratio with the effect of fly ash replacement can be directly studied is given in table -1. All the concrete mixes were produced in the concrete technology laboratory of YCCE college , Wanandongri, Nagpur & Ultra Tech RMC plant Nagpur. Mixing sequence and time was also standardized & material also used the same at both the places , in all the mixes to minimize the variations. The 2000 KN automatic compression testing machine was used to determine the strength properties of concrete mixes.

2.3 INGREDIENTS

2.3.1 Cement

The Ordinary Portland Cement of 43 grade conforming to IS: 8112-1989 was used. The 28 days compressive strength and the specific surface of cement used in this study was 60 N/sqmm and 275sqm/kg respectively. The specific gravity is 3.15.Initial and final setting time of cement was 190min and 275min respectively.

2.3.2 Coarse Aggregates

The Coarse Aggregates from crushed Basalt rock, conforming to IS: 383 were used.

The Flakiness and Elongation Index were maintained well below 15%.Specific gravity for 10mm and 20mm are 2.89 , 2.91 respectively.

2.3.3 Fine Aggregates

The river sand and crushed sand was used in combination as fine aggregate conforming to the requirements of IS:383. The river sand was washed and screened, to eliminate deleterious materials and over size particles. The specific gravity 2.63 .

2.3.4 Chemical Admixture

The high range water reducing and retarding superplasticizer conforming to IS9103 CAC-Superflow 60(NG9) , Concrete Additives & Chemical Pvt. Ltd.,was used. The base of admixture used in this study was sulphonated naphthalene formaldehyde and water reduction of admixture was around 20%.

2.3.5 Fly Ash

Fly ash for this study is taken from Koradi Thermal Power Station.There they have installed ESP for segregation and collection of fly ash into 6 different fields. As the field number increases the fineness of fly ash increases but the quantity decreases Since maximum availability of fly ash is from Field 6, same was used for our study. This fly ash conforms to the requirements of IS: 3812 Part 1.

Generally fly ash quality is assessed on the basis of some of the key parameters like pozzolanic activity, material retained on 45 micron sieve, loss on ignition and other chemical parameters. It is advisable that to qualify a source of fly ash all thetest as specified in IS shall be conducted initially and only key parameters can be tested for each batch to ensure a consistent quality of fly ash. Specific gravity is 2.22.

2.3.6 Ordinary Portland Cement

OPC 43 grade cement is used for this whole experimental study. The physical test results on OPC are as follows.

1) Normal consistency = 28%

2) Initial Setting time = 190 min.

3) Final Setting Time = 275 min.

4)Specific gravity =3.15

3.Factors affecting Compressive Strength of Ready Mixed Concrete

3.1 Effect of transit time on Ready Mixed Concrete:

1. Loss of workability:

As concrete stiffens with passage of time, delay in placement of concrete reduces workability of concrete. In addition, after sometime setting of concrete may also take place. Reduction in workability may lead to difficulty in placement or pumping of concrete . Thus, while planning for use of Ready Mixed Concrete, the aspect of loss of workability in the likely transit time involved. By measuring slump/compacting factor immediately after mixing at RMC plant & after a lapse of predetermined time (i.e. anticipated transit time), loss of workability may be estimated.

2 . Water Reducing Agent/ Admixtures

In order to reduce rate of loss of workability generally water reducing agent / superplasticizer is used. Dose of water reducing agent/ super plasticizer should be decided on trials. Excessive dose may lead to segregation. In addition, there may be retardation also.

3 Retempering in Ready Mixed Concrete

IS: 4926-2003, permits retempering i.e. addition of water in concrete at site to restore the workability, provided requirement for uniformity, as specified in IS: 4926-2003, are met with. Moreover, addition of water affects the strength and durability characteristic of concrete. Thus, it is advised that retempering should not be permitted at all either during transit or at the site of construction.

3.2 Setting of in Ready Mixed Concrete

1. Excessive delay in transportation of concrete may lead to initial setting of concrete and may render it unusable. The suitability and dose of retarder is decided after conducting necessary trials. It may be noted that generally retarding effect of retarder is smaller at higher temperature and sometimes few retarders seem to be in-effective at extremely high temperature. Thus, it is desirable to keep the temperature of concrete as low as possible.

2. Doses of Admixture

It is necessary that suitability of retarding admixture is judged at the maximum ambient temperature likely to be achieved during concreting. In addition, it is also important that a dose of retarding admixture is tested by conducting trials. Large quantity of admixture/retarder may delay the setting of concrete adversely or may prevent the setting of concrete totally. Some time dosing of admixture is done in stages to ensure desired workability. In such cases, admixture should be mixed at delivery site only. Addition of admixture should not be permitted during transit.

3. Curing

Use of retarders also may increase the risk of plastic shrinkage. Good curing, soon after finished concrete surface shows sign of initial set, will reduce plastic shrinkage cracks. Protecting the concrete surface against hot and windy condition by covering the surface with wet hessian cloth also reduces shrinkage. Usually, Ready Mixed Concrete needs fast curing than normal concrete. The starting time of curing should be carefully decided and proper curing started once the concrete shows sign of initial set.

4. Time period for delivery of concrete

In order to control loss of workability and setting of concrete, IS: 4926, Cl. 6.3.1 specifies that concrete should be delivered completely to the site of work within one and half hours (when the atmospheric temperature is above 20o C) and within two hours (when the atmospheric temperature is at or below 20o C) of adding the mixing water to the dry mix of cement and aggregate or adding the cement to the aggregate whichever is earlier. Adequacy of the time period, required for delivery of concrete, required to check. In case, location of site of construction is such that this time

4 M 50 Grade of Ready Mix Concrete Design as per Indian Standards (As per SP 23)

4.1 Formula for Target mean strength

$$Fck = fck+t*S$$

Where; fck =Characterisic Compressive Strength at 28 days.

S =Standard Deviation

t = Statical value depending on expected proportion of low results

Target mean strength for M 50 grade concrete= 50+1.65*5=58.25N/mm2

Hence; Target mean strength for M 50 grade concrete=58.25 N/mm2

4.2 Quantity Calculations for Fine Aggregate and Coarse Aggregate

Per centage of fine aggregate (P) = 40% of total aggregate content in concrete

Per centage of coarse aggregate (1-P)= 60% of total aggregate content in concrete

Hence; P=0.400 , (1-P) = 0.600

V = [w+ (c/sc) + (1/p) * (fa/sfa)] * (1/1000)

1.0 = [177+(450/3.15)+(1/0.4)*(fa/2.63)]*(1/1000)

Hence, fa = 766 kg/m3

And V = [w+ (c/sc) + (1/1-p) * (ca/sca)] * (1/1000)

Hence, Ca = 1159 Kg/m3

Due to many advantages we mixed **fly ash 5%, 10%, 15%, 20%, 25%, 30%** in concrete mixes by partial replacement of cement **(1) Particle Size**: Fly ash meeting ASTM Specification 618 must have 66 percent passing the 325 (45-micron) sieve, and these fine particles are ideal for void filling. Just a small deficiency in the mix fines can often prevent successful pumping.**(2) Particle Shape**: Microscopic examination shows most fly ash particles are spherical and act like miniature ball bearings, aiding the movement of the concrete by reducing frictional losses in the pump and piping. Studies have shown that fly ash can be twice as effective as cement in improving workability ,i.e, pumpability of RMC. M50 grade concrete mix proportions with various % of fly ash are as below in Table 1

4.3 Factors influencing the Ready Mix Design

The fundamental requirement of a concrete mix is that should be satisfactory both in fresh as well as in the hardened state.

1. Compressive Strength

The usual primary requirement of good concrete is satisfactory compressive strength in its hardened state. For purpose of mix design, the strength of concrete can be considered to be solely dependent on water / cement ratio for low and medium concrete mixes. In the case of high strength concrete mixes, the aggregate / cement ratio, workability of the mix and the type and the maximum size of aggregate influence the selection of water / cement ratio for desired strength of concrete.

2. Workability

The workability of concrete mix is mainly determined to suit the type of construction, placing conditions and the means of compaction available at site.. The main factor affecting workability is the water content in the mix. Other parameter influencing workability is the maximum size of aggregate, its grading, texture and shape and the mix proportions.

3. Type, Size and Grading of Aggregate

Good concrete can be made by using different types of aggregates like rounded and irregular gravel and crushed rock mostly angular in shape. The grading of aggregate is a major factor, influencing the workability of concrete mix. The grading of aggregates should be such as to ensure that the voids between the large aggregates are filled with smaller fraction and mortar so as to achieve maximum density and strength.

4. Aggregate / Cement Ratio

The various factors involved in selection the aggregate / cement ratio of the mix are, the desire workability, size, shape, texture and overall grading of the aggregates. The aggregate / cement ratio affects the strength of concretes in the high strength range to a significant degree and this is one of the reasons of considering the design of high strength concrete separately. It is important to note that mixes with very low water / cement and aggregate / cement ratios, having extremely high cement concrete of the order of 450 to 550 kg/m^3, exhibit retrogression of strength, especially when large size aggregate are used.

5. Durability

In such cases, the mix is designed by selecting the water/cement ratio on the basis of strength and workability rather than durability criterion. If the conditions of exposures are such that high durability is essential, the mix has to be designed by limiting the values of water/cement ratio depending upon the type of exposure.

6. Curing Conditions

It should be noted that the time - strength relations in concrete technology generally moist curing conditions and normal temperatures. At a given water / cement ratio, the longer the moist curing period the higher the strength assuming that the hydration of anhydrous cement is still going on. In thin concrete elements, if water is lost by evaporation from the capillaries, air - curing conditions prevail and strength will not increase with time. The curing age would not have any beneficial effect on the concrete strength unless curing is carried out in the presence of moisture.

A minimum period of 7 days of most curing is generally recommended for concrete containing normal Portland cement; obviously, the concretes containing fly ash with cement or a mineral admixture, a longer curing period would be desirable to ensure the strength contribution from the pozzolanic reaction.

7. Gain of Strength with age

Concrete develops strength with continued hydration. Rate of gain of strength is faster at start and reduces with age. Full strength of concrete is assumed to achieve at 28 days, however it develops strength after 28 days also. For the design purpose, increase in strength after 28 days is considered. It is necessary to predict the strength of concrete at an early age, hence efforts have been done to correlate strength of 3 ,7,28, 56 and 90 days. This depends on various factors like compound composition of cement, fineness of grinding and temperature of curing etc.

Mixes with low w / c ratio gain strength more rapidly than that of high w/c ratio. This strength is expressed as percentage of long-term strength. This possibly happens because cement particles are held more closely in concrete of high w/c ratio and hence form a continuous system of gel of high strength.

Strength of concrete is generally estimated at 28 days by crushing field test cubes or cylinders made from the representative concrete used for structure. It is necessary to ascertain the 28 days strength by which considerable amount of concrete is placed. It would be rather too late for remedial measures, if the result of the test cubes at 28 days were too low. On the other hand the structure will be uneconomical if the result of the test cube is too high. It is therefore of great advantage to be able to predict the strength of 28 days within few hours of casting the concrete, so that satisfactory remedial measures could be taken immediately before it is too late.

4.4 By Weighing Proportion of Ingredients

Weight batching was adopted in the experimentation and density was maintained in all the samples. In order to arrive at a practical range of quantities of the ingredients, a standard mix as given below was adopted as a starting point only. Weights of all the ingredients were varied simulating sensitivity analysis

Table No. 1 Concrete Mix Proportions with various % of Fly Ash

Table showing various Mix proportions for control mix to various % FA in concrete by replacing cement.

Mix Designation (X Fx)	Total Cementitious Content	Cement	Fly Ash	Coarse Aggregates		Fine Aggregates(Sand)	Admixture (CACN60) (1.2%)	Water	W/Cm	Density
	(Kg/Cum)	(Kg)	(Kg)	20MM IN(Kg)	10MM IN(Kg)	(Kg)	(Kg)	(Kg)		(Kg/Cum)
450 F 0	450	450	0	756	403	766	5.4	177	0.39	2557.40
450 F 5	450	427	23	756	403	765	5.4	177	0.39	2556.40
450 F 10	450	405	45	755	401	764	5.4	177	0.39	2552.40
450 F 15	450	383	67	751	400	758	5.4	177	0.39	2541.00
450 F 20	450	360	90	748	399	755	5.4	177	0.39	2534.10
450 F 25	450	338	112	754	402	753	5.4	177	0.39	2529.40
450 F 30	450	315	135	751	400	750	5.4	177	0.39	2521.40

Where; X = Cement Content for control Mix ; Fx =% of cement replace in concrete by fly ash.

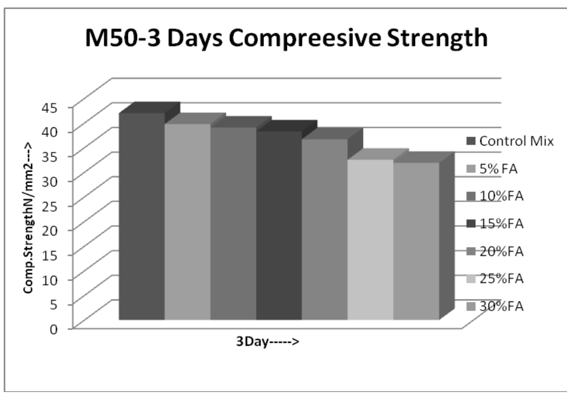
5 Testing Methods

Testing is done as per following IS code. The testing done for compressive strength of cubes were measured 3 , 7, 28,56 and 90 days as per IS : 516 – 1959 ,the testing done for flexural strength of beam were measured 28 days as per IS : 5816 - 1999 and the testing done for split tensile strength of cylinder were measured 28 days as per IS : 516 – 1959.Results for Compressive Strength Test on Cubes for 3, 7, 28, 56, 90 Days as in table.

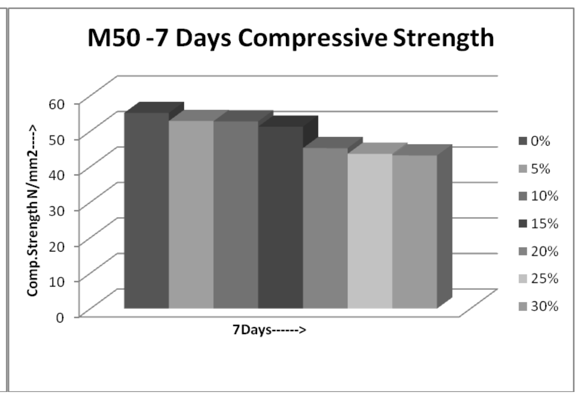
Table No. 2 Results of Compressive Strength Test on M 50 grd. Cubes for various % of Fly Ash .

Table showing Compressive Test Results for various Mix proportions for control mix to various % FA in concrete by replacing cement.

Mix Designation (X Fx)	Slump							Compressive Strength after curing				
	Initial	*30 Min*	*60 Min*	*90 Min*	*120 Min*	*150 Min*	*180 Min*	3 Days	7 Days	28 Days	56 Days	90 Days
	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	N/sqmm	N/sqmm	N/sqmm	N/sqmm	N/sqmm
450 F 0	Col-lapse	Col-lapse	Col-lapse	180 mm	160 mm	125 mm	80 mm	42	55.10	70.33	70.96	71.88
450 F 5	Col-lapse	Col-lapse	Col-lapse	170 mm	150 mm	120 mm	100 mm	39.78	52.83	67.19	67.81	69.89
450 F 10	Col-lapse	Col-lapse	Col-lapse	190 mm	160 mm	130 mm	110 mm	39.06	52.74	66.15	66.92	69.02
450 F 15	Col-lapse	Col-lapse	Col-lapse	180 mm	140 mm	120 mm	90 mm	38.28	51.24	66.45	61.34	63.24
450 F 20	Col-lapse	Col-lapse	Col-lapse	130 mm	70 mm			36.71	46.68	62.85	60.44	62.40
450 F 25	Col-lapse	Col-lapse	180mm	140 mm	80 mm			32.54	43.60	59.69	59.70	62.07
450 F 30	Col-lapse	Col-lapse	150 mm	60 mm				31.90	43.14	55.11	55.26	57.32

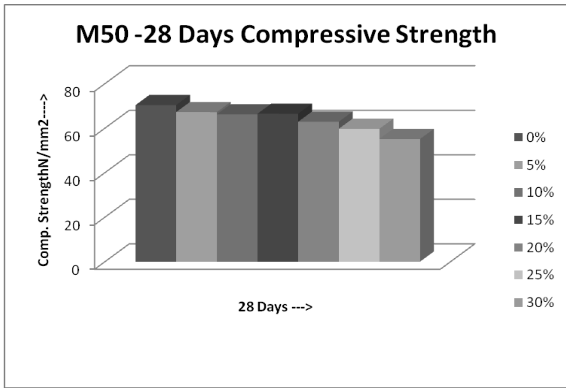


Graph 1

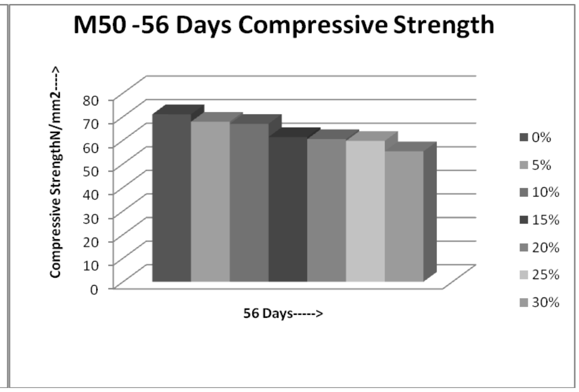


Graph 2

Graph 1 & 2 shows 3 & 7 Days Compressive Strength for M50 grd. Ready Mixed Concrete with various % of Fly Ash for Table No. 2

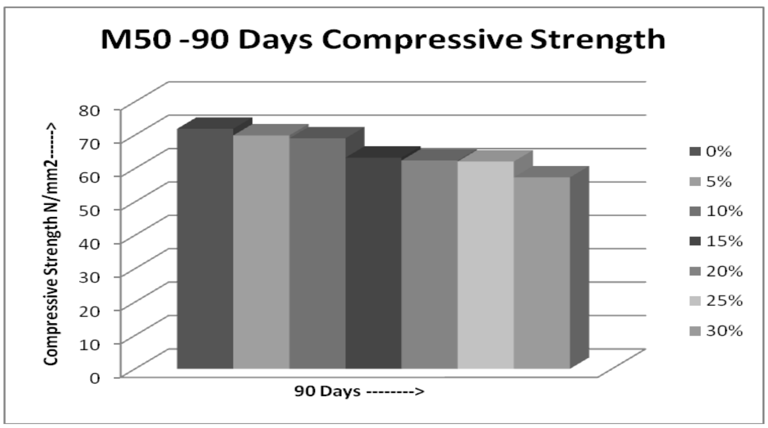


Graph 3



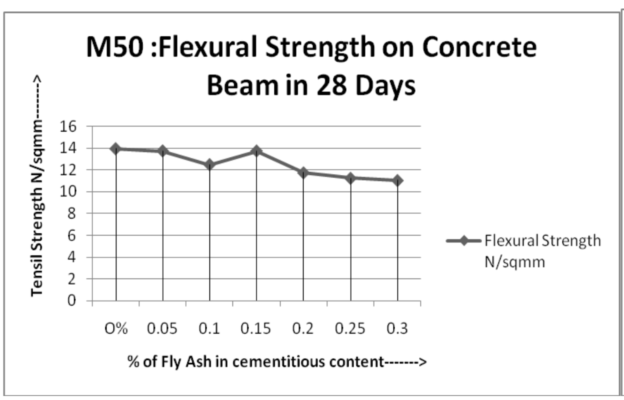
Graph 4

Graph 3 &4 shows 28 & 56 Days Compressive Strength for M50 grd. Ready Mixed Concrete with various % of Fly Ash for Table No. 2

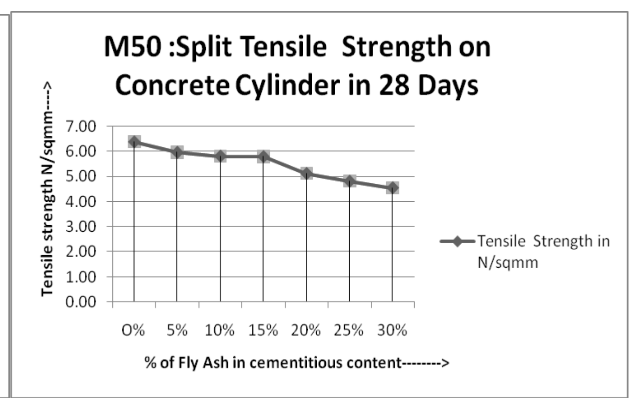


Graph 5

Graph 5 shows 90Days Compressive Strength for M50 grd. Ready Mixed Concrete with various % of Fly Ash for Table No. 2



Graph 6



Graph 7

Graph 6,7 Show Flexural & Split Tensile Strength on 28 Days Cylinders for 5%,10%,15%,20%,25% ,30% Fly Ash content, M50 grd. Concrete for Table No. 3

Table No. 3 Results Flexural Strength and Split Tensile Strength in N/mm² for 5%,10%,15%,20%,25% ,30% Fly Ash content

Results for Flexural Strength and Split Tensile Strength in N/mm²

Mix Designa -tion (X Fx)	Slump							Flexural strength	Split Tensile strength
	Initial	*30 Min*	*60 Min*	*90 Min*	*120 Min*	*150 Min*	*180 Min*		
	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	N/sqmm	N/sqmm
450 F 0	Collapse	Collapse	Collapse	180 mm	160 mm	125 mm	80 mm	13.95	6.38
450 F 5	Collapse	Collapse	Collapse	170 mm	150 mm	120 mm	100 mm	13.75	5.96
450 F 10	Collapse	Collapse	Collapse	190 mm	160 mm	130 mm	110 mm	12.50	5.81
450 F 15	Collapse	Collapse	Collapse	180 mm	140 mm	120 mm	90 mm	12.50	5.39
450 F 20	Collapse	Collapse	Collapse	130 mm	70 mm			11.50	5.11
450 F 25	Collapse	Collapse	180mm	140 mm	80 mm			11.00	4.80
450 F 30	Collapse	Collapse	150 mm	60 mm				11.25	4.54

Where , X=Cement F=Fly Ash x=% replacement of cement

6 Acid and Chloride Attack Test:-

When we enhancing on the durability aspects of concrete, by adding FA the chemical attack, which results in loss of weight, cracking of concrete and the consequent deterioration of concrete, becomes an important part of investigation

Ordinary Portland cement concrete usually does not have good resistance to acid and chloride attack. The addition of FA improves the micro structural properties of concrete like porosity, permeability. The reduction of porosity and permeability implies the improvement in chemical attack and corrosion.

Acid and Chloride attack is one of the most important aspects to be considered while dealing with the durability of concrete. Because it preliminary causes corrosion of reinforcement. Concrete cube with replacement of FA are immersed in solution of 1% of sulphuric acid & 3% sodium chloride by weight of water for 30 days. Than the cubes are taken out and weighted and the percentage loss in weight and percentage reduction of compressive strength are calculated, it is seen that replacement of cement by FA improves the resistance of concrete against acid & chloride attack, thereby reducing the deterioration over years.

i) Reduction in Weight

FA when added in the concrete reduces the weight of the concrete, It is observed that after 28 days curing of specimen, reduced the weight of specimen up to 4% for control mix and upto 1 % for FA mix concrete. Also there is high reduction in compressive strength in control mix as compared to FA mix concrete.

For reduction in weight and reduction strength after immersion of cubes in H2SO4 & NaCl kindly find …..

Table No. 4 & 5 below

Table 4 shows Reduction in weight and compressive strength of cubes

- **Concrete Cubes immersed in 1% Sulphuric Acid solution.**

Sr. No.	Mix Particulars	Average weight of cubes before immersion in kg W1	Average weight of cubes after immersion in kg W2	Reduction in weight % (W1-W2) *100/ W1	Average compressive strength before immersion, N/mm^2	Average compressive strength after immersion, N/mm^2	Reduction in compressive strength %
1	Control mix	8.935	8.696	2.67	70.33	64.78	7.89%
4	15%FA by weight of cement	8.630	8.587	0.49	66.45	64.16	3.45%
7	30%FA by weight of cement	8.520	8.485	0.42	55.11	54	2.01%

Table 5 shows Reduction in weight and compressive strength of cubes

- **Concrete Cubes immersed in 3% Sodium Chloride Solution.**

Sr. No.	Mix Particulars	Average weight of cubes before immersion in kg	Average weight of cubes after immersion in kg	Reduction in weight %	Avg. comp. strength before immersion, N/sqmm	Avg. comp. strength after immersion, N/sqmm	Reduction in compressive strength %
1	Control mix	8.900	8.569	3.72	70.33	65.42	6.98%
4	15%FA by weight of cement	8.650	8.573	0.89	66.45	64.95	2.25%
7	30%FA by weight of cement	8.485	8.461	0.28	55.11	54.45	1.19%

7 Results and Discussion

Test results of properties of fresh and hardened concrete are given in Table -5.8 and 5.9. The main observations are follows.

1. **Workability**

   As it has been considered that the spherical shaped particles of fly ash act as miniature ball bearing within the concrete mix and this leads to the improvement of workability of concrete or reduction of unit water content. In the present study I have kept the same unit water content & the admixture dosage are also kept constant as the fly ash content is increased from 0% to 30%. But as it is high grade concrete (M50 grade) it has observed that replacement of cement up to 15% fly ash providing very good pumpable concrete , but to maintain workability , replacement of cement above 15% fly ash, admixture dose or W/C ratio required to increase to get pumpable concrete for two hours after mix.

2. **Density**

   As fly ash has lower specific gravity as compared to cement, at higher level of cement replacement, there is a slight reduction in the density of concrete.

3. **Bleeding and Surface Finish**

   Use of fly ash in concrete mixes reduces bleeding by providing greater fines volume, which blocks bleed water channels. Use of fly ash also improves the cohesiveness of the concrete mix resulting in reduction of pumping pressure and better surface finish.

4. **Compressive Strength at Various Ages**

   Compressive strength of all the mixes has been determined at 3 , 7, 28, 56 and 90 days. For each set of cementitious content the development of compressive strength at various ages with respect to different fly ash percentages are shown in Table 5.8 & Graph 1to5.

The observations indicate that:

a) As the fly ash content increases there is reduction in the strength of concrete.

This reduction is more at earlier ages as compared to later ages.

5. Durability of Concrete

One of the major advantages of use of fly ash in concrete mixes is to improve the durability of concrete. The existence of large pores and large crystalline products in the transition zone in OPC concrete are greatly reduced by the introduction of fine particles of fly ash. The decrease in the water content combined with the pore interconnectivity of concrete thus decreases the permeability of fly ash concrete.

The reduced permeability results in improved long term durability and resistance to various forms of deterioration of concrete structures.

Based on the various trials it is proved that fly ash can be used in making for high grade concrete with improved characteristics at fresh and hardened stage, durable, eco friendly and economical without any reservation.

Concrete mix proportioning with fly ash as a cementitious ingredient is slightly tricky as compared to the OPC concrete. It depends on various parameters like type of fly ash, percentage of replacement, age at which desired strength is required, and durability criteria. From this study it is clear that simple replacement of cement by fly ash reduces the strength of concrete at early ages and the development of strength at various ages is related to total cementitious content or W/C and the percentage replacement of cement by fly ash.

To simplify the mix proportioning process, based on the above study, strength vs different percentages of fly ash Graph 1 , 2 , 3 and 4 at 3 , 7, 28 days and 56 days age respectively. For a given type of concrete ingredients these graphs can be used to quickly design the concrete mix proportions of the M50 grade.

It is also observed from the study that there is a considerable increase in the compressive strength of concrete with fly ash beyond 28 days. Therefore structures like raft, footing and column etc. where design load is not expected to come on 28 day, the acceptance criteria for fly ash concrete can be based on 56 days compressive strength. This practice of accepting the concrete mix at 56 days will help in utilizing the development of strength of fly ash concrete beyond 28 days, reduction in total cementitious content and overall economy of the concrete mix without compromising the quality of concrete.

8 CONCLUSIONS

Based on the experimental studies conducted following conclusions are drawn on the fly ash high grade concrete (M50).

1. Retention time extended for Ready mixed concrete for say two hours after mix by using of fly ash at fixed W/C ratio & fixed dose of admixture.

2. Compressive strength, Tensile and Flexural strength

3. results, for partial replacement of cement by up to 15% fly ash, are desirable for M50 grade concrete.

4. Ready mixed high grade concrete make pump-able up to two hours after mix, as shown the slump results for partial replacement of cement by up to 15% fly ash.

5. Increment in fly ash content up to 15% given best result in terms of compressive strength & slump. From 20% and above it can be increase the per-centage for up to 30% but high precautions required during mixing to get required results.

6. Density of concrete mix is generally not much affected with the use of fly ash. Reduced slightly in the range of 0.04 % to 1.5% on increasing replacement of cement by fly ash.

7. Bleeding in fly ash concrete is significantly reduced and other properties like cohesiveness, pumping characteristics and surface finish is improved.

8. As the fly ash content increases there is reduction in the strength of concrete. This reduction is more at earlier ages 3 , 7 & 28 days as compared to later ages 56 , 90 days.

9. At mixes above 15% we get good strength results on 56, 90 days, but workability get to start reduce after15% replacement of cement by FA for M50, at fix admixture and water content.

10. This is expected, as the secondary hydration due to pozzolanic action is slower at initial stage for fly ash concrete.

11. Rate of strength development at various ages is related to the W/C , Admixture content and percentages of fly ash in the concrete mix.

12. Lower permeability due to superior microstructure (smaller particle size) of fly ash, results in improved long term durability.

13. Better performance in aggressive environment (Sulphates, Chlorides etc.) and no significant loss in concrete cube weight have been observed.

14. Fly ash concrete is economical as compare with controlled concrete. This has been proved that fly ash can be used in making concrete strong, durable, Eco-friendly and economical.

15. The 90 days compressive strength was obtained with cement replacement of 5% to 25 % by fly ash mix give good results. But only 15% fly ash results with slump & compressive strength for high grade concrete are desirable .For 15% FA the slump value was 90mm at three hours after mix & compressive strength was 63.24 N/mm^2 .
16. The maximum 28 days split tensile strength was obtained with 15% fly ash mix was 5.39 N/mm^2.
17. The maximum 28 days flexural strength was obtained again with 15% fly ash mix was 12.5 N/mm^2.
18. The transition zone gets improved and densified with the use of fly ash mix concretes even for high grade concrete.
19. The mechanical properties in terms of flexural and tensile strength have been found no significant loss with the addition of FA.
20. Rate analysis shows that as the percentage of FA added on the concrete the cost goes decrease up to 22%.

9 RECOMMENDATIOS

- Development of strength of fly ash concrete beyond 28 days, so the practice of accepting the concrete mix strength at 56 days required to follow in design of concrete (at least for foundation concrete) , to enhance use of fly ash in concretes.
- In mass fly ash ready mixed high grade concrete works , micro cracks may observed , can be controlled by using steel fibers. For content of steel fibers further study required, to make economical & durable concrete.
- Upto 15% replacement of cement by fly ash gives better strength and workability (slump value) in higher grade concrete like M50.
- Above 15% replacement of cement by fly ash can also give better strength and low workability (slump value) in higher grade concrete like M50, but required high precautions while making such mixes.

10 FUTURE SCOPE

- According to the experts, there is lot of scope for the development and growth of RMC in India. It can grow to consume40-45 percent of cement by 2015 through setting up of RMC plants.
- As RMC plants increases as per demand, it is sure that in future production of cement, may not get or get at very lower rate and costly in compare with demand production of cement.
- Now for engineers new researches, for substitute of cement and increase % of partial replacement of cement by various waste products like fly ash, Rice Husk, Silica, Alcofine (Ambuja Product) etc by using admixtures.
- Further increase of retardation of concrete for Ready Mixed pumpable concrete.
  So, that bad practices like addition of water after retaining period of concrete will not get encourage on site.
- Use Industrial Waste in concrete,so helps in reducing the environment pollution.

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