PERFORMANCE OF SILICA FUME AND FLY ASH AS PARTIAL REPLACEMENT OF CEMENT IN CONCRETE WITH POLYPROPYLENE FIBER

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ABSTRACT

Concrete is the world's most versatile, durable and reliable construction material and because of its mould ability into any required structural form and shape due to its fluid behavior at early ages. Next to water, concrete is the most used material, which required large quantities of Portland cement. Ordinary Portland cement production is the second only to the automobile as the major generator of carbon dioxide, which polluted the atmosphere. In addition to that large amount energy was also consumed for the cement production. Hence, it is inevitable to find an alternative material to the existing most expensive, most resource consuming Portland cement. The objective of this research is to investigate the different properties of cement concrete containing fly ash and silica fume with polypropylene fiber. Content of fly ash will remain constant at 10% and silica fume will be differed by 10%,20%,30%,40% by replacement of equal weight of cement in concrete. Polypropylene fibers will be added by weight fraction of concrete. Analysis of concrete will be in fresh state as well in hardened state to evaluate different properties of concrete Compressive Strength and Split Tensile Strength by pond curing. Tests like Heat of Hydration and Durability of concrete is also to be carried out. In this research work the methodology of casting cubes of concrete will prepared and tested after 7 and 28 days (Durability 56 Days) will be adopted. The results will compare fly ash and silica fume with polypropylene fiber. Uses of such waste materials will not only depreciate the cost of construction but also contribute in safe disposal of waste materials.

Keyword: - *Concrete, Fly ash, Silica fume, Polypropylene fibers , Compressive strength, Split Tensile strength, Heat of Hydration, Durability*.

1. INTRODUCTION

As a by-product from thermal power stations, fly ash has been used in blended cements, and it has been used successfully to replace Portland cement without adversely affecting the strength and durability of concrete composite. Because fly ash causes environmental pollution and the cost of storage of fly ash is quite high, the utilization of fly ash in concrete technology, both in regard to environmental pollution and the positive effect on a country's economy, are beyond dispute. Different approaches have been used to accelerate the pozzolanic reaction of fly ash and, thereby, to increase the early strength of concrete containing fly ash. Today, silica fume is known as a by-product of silicon metal and ferrosilicon alloy industry instead of a waste product and its utilization in composite technology has increased recently. The first utilization of silica fume in concrete was reported in 1952 by a Norwegian researcher. It was only in the late 1970s that silica fume started to be used as a supplementary cementitious material in concrete in Scandinavia. . Now, there are numerous fiber types available for commercial use, the basic types being steel, glass, synthetic materials, and some natural fibers. Because polypropylene fiber is a kind of man-made synthetic fiber with the properties of low modulus of elasticity, high strength, excellent ductility,

excellent durability, and low price, many experimental works related to the use of polypropylene fibers in cement matrix composites have been published.

1.1 Fly-Ash

Coal is a dominant commercial fuel in India, where many mines are operated by Coal Indian and other subsidiaries production of hard coal was 358.4 mt, while utilization was 403.33 mt. India is 6th largest electricity generating and consuming country in the world. Fly ash can be considered as the world's 5th largest raw material resources. An estimated 25% of fly ash in India is used for cement production, construction of roads and brick manufacture. The fly ash utilization for these purposes is expected to increase to nearly 32 mt by 2009-10. Currently, the energy sector in India generates over 130 mt of FA annually and this amount will increase as annual coal consumption increases by 2.2%. The large scale storage of wet fly ash in ponds takes up much valuable agriculture land approximately (113 million m^2 and may result in severe environmental degradation in the near future, which would disastrous for India.

1.2 Silica fume

Silica fume is a byproduct of producing silicon metal or ferrosilicon alloys. One of the most beneficial uses for silica fume is in concrete. Because of its chemical and physical properties, it is a very reactive pozzolan. Concrete containing silica fume can have very high strength and can be very durable. Silica fume is available from suppliers of concrete admixtures and when specified, is simply added during concrete production. Placing, finishing, and curing silica fume concrete required special attention on the part of the concrete contractor. The raw materials are quartz, coal, and woodchips. The smoke that results from furnace operation is collected and sold as silica fume, rather than being landfilled. Perhaps the most imp use of this material is as a mineral admixture in concrete.

1.3 Polypropylene Fiber

Various types of short, chopped polypropylene fibres are available. Typically they may be added to concrete at a rate of about 0.9 kg/m^3. Their primary role is to modify the properties of the fresh concrete. They increase the homogeneity of the mix, stabilising the movement of solid particles and blocking bleed water channels. This reduces the bleed capacity of the concrete and slows down the bleed rate, helping to reduce plastic settlement. The matrix of filements also helps reduce plastic shrinkage cracking which can occur when the concrete surface is allowed to dry out rapidly. Polypropylene fibres have a limited effect on the properties of the hardened concrete. They do not provide any significant post first crack ductility. Their ability to reduce bleed and segregation assists in maintaining the original water/cement ratio of the surface mortar, which can lead to improvements in the surface layer thereby increasing resistance to abrasion. Polypropylene fibres may be effective in distributing impact stresses and providing some enhancement to frost resistance. They have also been shown to reduce the spalling of concrete in a fire. Polypropylene fibres are also used in sprayed concrete, to improve the initial properties and to reduces loughing and rebound.

2. OBJECTIVE

- To evaluate the fresh properties of concrete (slump test) with use of partial replacement of silica fume by 10%, 20%, 30% , 40% and fly ash will remain constant at 10% replacement with cement and added 0.9 kg / m3 of concrete of polypropylene fiber.

- To achieve the harden properties (Compressive strength, Split tensile Strength) of Concrete with use of partial replacement of silica fume by 10%, 20%, 30% , 40% and fly ash will remain constant at 10% replacement with cement and added 0.9 kg / m3 of concrete of polypropylene fiber.

- To check the durability Properties, Acid attack (H_2SO_4) with use of partial replacement of silica fume by 10%, 20%, 30% , 40% and fly ash will remain constant at 10% replacement and added 0.9 kg / m3 of concrete of polypropylene fiber.

- To evaluate the optimum time of heat evolution of cement (heat of hydration) with use of partial replacement of silica fume by 10%, 20%, 30% , 40% and fly ash will remain constant at 10% replacement with cement.

3. MATERIAL USED IN CONCRETE

3.1. Cement

The Ordinary Portland Cement 53 grade was used for all concrete mixes. The properties of cement is fine, greenish, and grey powder. Cement is mixing with water, sand and aggregate to make standard concrete. The cement and water form a paste that binds the other materials together as the concrete harden state. A material having adhesive and cohesive properties which make it capable of bonding material fragment into compact mass. Cement is very important ingredient in concrete.

Table 1- Properties of OPC 53

TEST	Result Required as per IS 12269-2013	Result Obtain
Initial setting time	More than 30 min	105 min
Final setting time	Less than 600min	146min
Specific surface	More than 225m2/kg	315 m2/kg
Normal consistency	-	29.5
Soundness lechateller	Less than 10 mm	7min
Compressive strength 24 hr.	More than 20Mpa	22.5Mpa
Compressive strength 72 hr.	More than 27 Mpa	43.5Mpa

3.2 Water

Water used for mixing and curing shall be clean and free from injurious amount of salts, oils, acids, alkalis, organic materials or other deleterious materials.

3.3 Fine Aggregate

The fine aggregate (sand), which is used in the investigation is clean river sand and conforming to zone II as per IS: 383-2016. The sand was first sieved through 4.75 mm sieve to remove any particles greater than 4.75 m.

3.4 Coarse Aggregate

The coarse aggregate use as the crushed stone aggregate used which is passed through the 20 mm IS sieve and retained from the 4.75 mm IS sieve.

3.5 Silica Fume

Silica fume is also known as micro silica, condensed silica fume, volatized silica or silica dust. It can be used in concrete and refractory materials. Microsilica, when used in concrete, it can improve concrete's properties such as compressive strength, bond strength and abrasion resistance, reduces permeability.

It is usually a grey coloured powder, somewhat similar to Portland cement or some fly ashes. It can exhibit both pozzolanic and cementations properties.

Table 2- Chemical Properties of Silica Fume

Chemical Composition	Unit	Obtained Results
Silica as SiO2	%	92.80
Alumina as Al2O3	%	0.60
Iron as Fe2O3	%	0.30
Magnesium as MgO	%	0.60
Total Alkalis as (Na2O+0.658 K2O)	%	1.17
Sulphur Trioxide as SO3	%	Less Than 0.10
pH of 20% Soln.	-	8.83

Table 3- Physical Properties of Silica Fume

Properties	Unit	Results Obtained
Density	Mg/M3	1.89
Specific Surface Area (BET)	M2/gm	16.44
Bulk Density	Kg/M3	700
Moisture	%	1.17
Loss on Ignition	%	1.60
Accelerated Pozzolanic Strength Activity Index with Portland Cement at 7 Days	%	>106.3

3.6 Fly Ash

Fly ash is a fine powder byproduct from industrial plants using pulverized coal or lignite as fuel .It is the most widely used pozzolona siliceous or aluminosiliceous in nature in a finely divided form .They are spherical shaped "balls'' finer than cement particles.

Table-4 Physical Properties of Fly ash

Physical Properties	Test Results
Moisture as MOI %	0.5
Loss on ignition %	0.26
Residue greater than 45 micron sieve on wet basis %	14.66

Table-5 Chemical Properties of Fly ash

Chemical Composition	Test Results
Silica as SiO2 %	57.5
Alumina as Al2O3 %	23.22
Iron as Fe2O3 %	7.61
Titanium as TiO2 %	1.28
Magnesium as MgO %	2.92
Sodium as Na2O %	0.96
Potassium as k2O %	1.17
Sulphates as SO3 %	0.44
Phosphorous as P2O5 %	0.18

4 EXPERIMENTAL PLAN

4.1 Test procedure

a) Assessment of mix design methods
b) Selection of mixing procedures and test methods.
c) Selection of the target properties of normal concrete made with also fly ash and silica fume for the subsequent tests
d) Selection of constituent materials

4.2 Mix proportions

The cement is partially replaced with silica fume by 10%, 20%, 30% , 40% and fly ash will remain constant at 10% replacement with cement and added 0.9 kg / m3 of concrete of polypropylene fiber. Test was carried out for M 25, M 30, M 35.

5 RESULTS AND DICUSSIONS

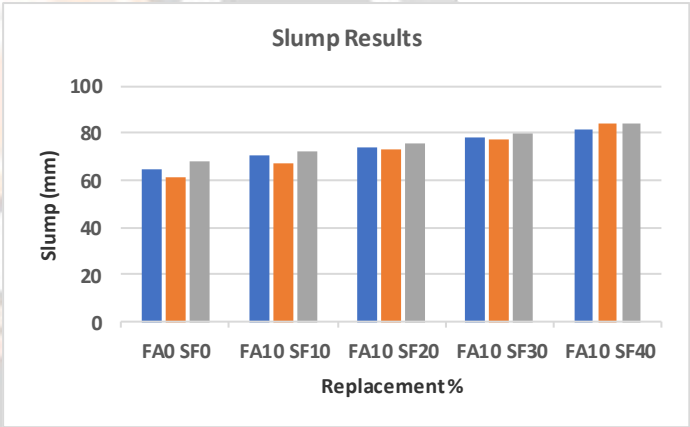
5.1.Fresh Concrete Result (Slump Test)

Workability of concrete is measured by slump test. In M-25 M-30 and M-35 grade concrete with the increment of fly ash and silica fume as partial replacement of cement there is increase in slump in the rate of percentage as 9.23, 13.85, 20, 26.15 in M-25, 9.84, 19.67, 26.23, 37.70 in M-30 and 5.88, 11.76, 17.65, 23.53 in M-35 grade of concrete.

Table-6 Results of fresh properties for concrete

Slump Value (mm)				
Sr. No.	Type of mix	M-25	M-30	M-35
1	FA0 SF0	65	61	68
2	FA10 SF10	71	67	72
3	FA10 SF20	74	73	76
4	FA10 SF30	78	77	80
5	FA10 SF40	82	84	84

Chart-1 Slump Flow Chart



5.2 Compressive Strength Test:

- Results of Compressive Strength of grades M-25, M-30, M-35 of partial replacement of cement with fly ash and silica fume with added popypropylene fiber as 0.9 kg / m3 of concrete are given below.
- In M-25 grade concrete the value of 10 % fly ash and 20 % of silica fume partial replacement gives maximum 34.07 MPa compressive strength. In M-30 grade concrete the value of 10 % fly ash and 10 % of silica fume partial replacement gives maximum 36.52 MPa compressive strength. In M-35 grade concrete the value of 10 % fly ash and 10 % of silica fume partial replacement gives maximum 41.86 MPa compressive strength.

Table-7 Compressive Strength of Concrete

Compressive Strength (Mpa)							
Sr. No.	Type of mix	M-25		M-30		M-35	
		TMS = 31.6		TMS = 34.12		TMS = 38.15	
		7 days	28 days	7 days	28 days	7 days	28 days
1	FA0 SF0	21.79	32.42	25.16	35.86	27.46	40.42
2	FA10 SF10	22.56	33.3	25.92	36.52	29.54	41.86
3	FA10 SF20	23.39	34.07	24.81	34.95	26.37	39.49
4	FA10 SF30	20.15	32.16	23.61	33.66	24.61	36.72
5	FA10 SF40	18.96	30.96	20.46	29.5	22.76	35.95

Chart-2 Compressive Strength @ 7 days

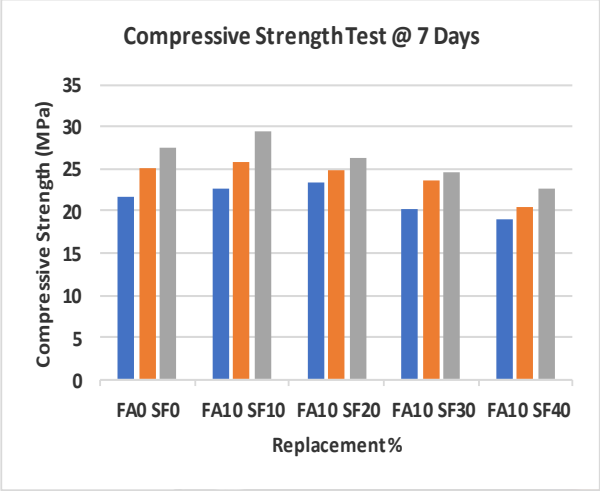
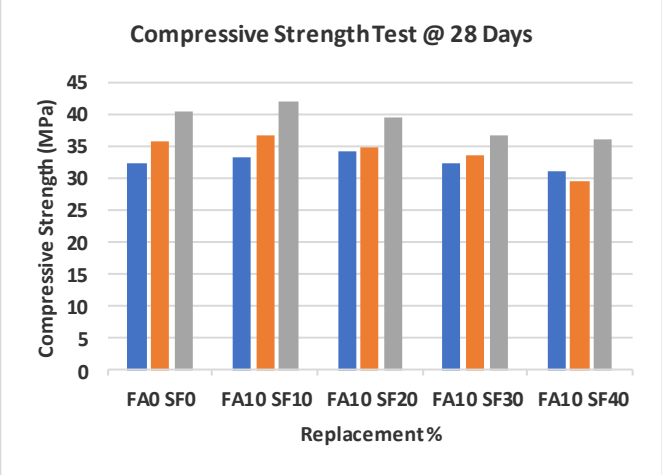


Chart-3 Compressive Strength @ 28 days



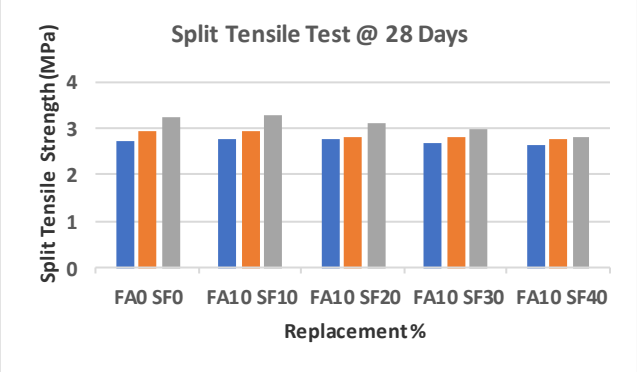
5.3 Split Tensile Strength Test:

- In M-25 grade concrete the value of 10 % fly ash and 20 % of silica fume partial replacement gives maximum 2.72 MPa Split Tensile strength. In M-30 grade concrete the value of 10 % fly ash and 10 % of silica fume partial replacement gives maximum 2.94 MPa Split Tensile strength. In M-35 grade concrete the value of 10 % fly ash and 10 % of silica fume partial replacement gives maximum 3.29 MPa Split Tensile strength.

Table-8 Split Tensile Strength of Concrete

Split Tensile Strength (MPa) @ 28 Days				
Sr. No.	Type of mix	M-25	M-30	M-35
1	FA0 SF0	2.72	2.92	3.24
2	FA10 SF10	2.76	2.94	3.29
3	FA10 SF20	2.77	2.83	3.11
4	FA10 SF30	2.68	2.8	2.97
5	FA10 SF40	2.63	2.78	2.82

Chart-4 Split Tensile Strength @ 28 days



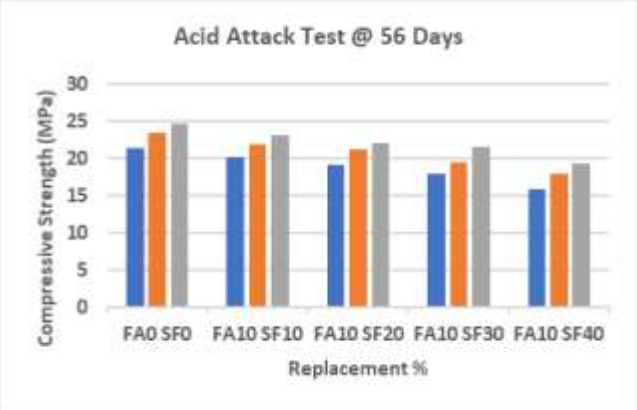
5.4 Acid Attack Test Results:

- In the acid attack test the compressive strength of concrete is measured after 56 days of curing 28days of normal water curing and 28days of curing in 5% H_2SO_4 .the all value of partial replacement of fly ash and silica fume to be decrease compare to the 0% replacement of fly ash and silica fume. Hence from that we say that this result was weaker in acid attack compare to normal concrete i.e M-25, M-30, M-35.

Table-9 Compressive Strength of Concrete

Compressive Strength (MPa) @ 56 days				
Sr. No.	Type of mix	M-25	M-30	M-35
1	FA0 SF0	21.38	23.51	24.68
2	FA10 SF10	20.12	21.96	23.1
3	FA10 SF20	19.07	21.16	22.12
4	FA10 SF30	17.94	19.45	21.49
5	FA10 SF40	15.86	17.94	19.26

Chart-5 Compressive Strength @ 28 days



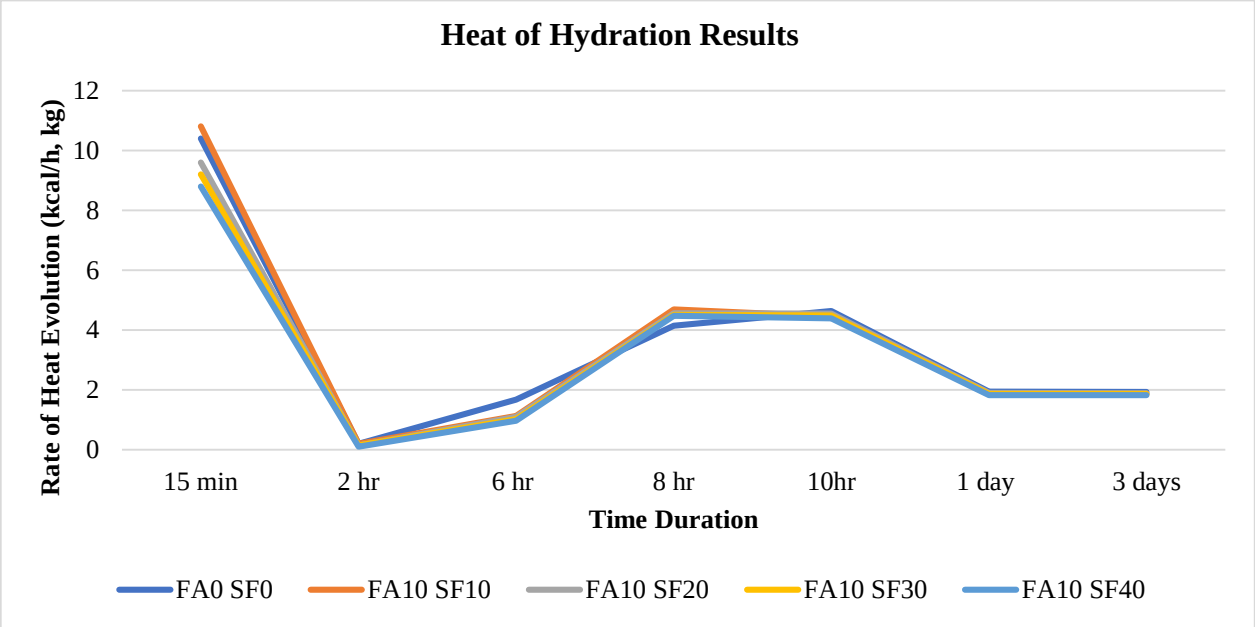
5.5 Heat of Hydration Results

- In this lab test, using calorimeter, the result came is rate of evolution of hydration of cement with partial replacement of silica fume and fly ash of time duration of 3 days. Here maximum rate of heat evolution measured between 8 to 10 hrs of reading.

Table-10 Heat of hydration of cement

Heat Evolution of Cement Hydration (kcal/h, kg)							
Sr. No.	Replacement %	Cement	100	80	70	60	50
		Fly ash	0	10	10	10	10
		Silica fume	0	10	20	30	40
1	Time Duration	15 min	**2.6**	**2.7**	**2.4**	**2.3**	**2.2**
2		2 hr	**0.4**	**0.4**	**0.3**	**0.3**	**0.2**
3		6 hr	**10.1**	**6.8**	**6.6**	**6.1**	**5.8**
4		8 hr	**33.2**	**37.5**	**36.5**	**36.1**	**35.8**
5		10hr	**43.2**	**40.9**	**42.4**	**41.7**	**40.5**
6		1 day	**46.4**	**44.6**	**45.5**	**44.9**	**43.9**
7		3 days	**46.4**	**44.7**	**45.4**	**44.8**	**43.8**

Chart-6 Rate of Heat Evolution in cement



6. CONCLUSIONS

Based on experimental investigation, following observations are made on the fresh property, hardened properties and durability of M-25, M-30 and M-35 grade of concrete:

- Workability of concrete is measured by slump test. In M-25 M-30 and M-35 grade concrete with the increment of fly ash and silica fume as partial replacement of cement there is increase in slump in the rate of percentage as 9.23, 13.85, 20, 26.15 in M-25, 9.84, 19.67, 26.23, 37.70 in M-30 and 5.88, 11.76, 17.65, 23.53 in M-35 grade of concrete.

- In M-25 grade concrete the value of 10 % fly ash and 20 % of silica fume partial replacement gives maximum 34.07 MPa compressive strength. In M-30 grade concrete the value of 10 % fly ash and 10 % of silica fume partial replacement gives maximum 36.52 MPa compressive strength. In M-35

grade concrete the value of 10 % fly ash and 10 % of silica fume partial replacement gives maximum 41.86 MPa compressive strength.

- In M-25 grade concrete the value of 10 % fly ash and 20 % of silica fume partial replacement gives maximum 2.72 MPa Split Tensile strength. In M-30 grade concrete the value of 10 % fly ash and 10 % of silica fume partial replacement gives maximum 2.94 MPa Split Tensile strength. In M-35 grade concrete the value of 10 % fly ash and 10 % of silica fume partial replacement gives maximum 3.29 MPa Split Tensile strength.

- The study shows that in M-25 grade, partial replacement of 10% fly ash and 20 % silica fume attains maximum strength while in M-30 and M-35 grade, partial replacement of 10% fly ash and 10 % silica fume attains maximum strength in some case.

- In a acid attack test (5% H2SO4) of Durability all replacements shows lower value than the normal mix (0% fly ash and silica fume).

- Using calorimeter, the result came is rate of evolution of hydration of cement with partial replacement of silica fume and fly ash of time duration of 3 days. Here maximum rate of heat evolution measured between 8 to 10 hrs of reading.

8. REFRENCES

- Text book "Concrete Technology" – by M.S.SHETTY

- Combined Effect Of Fly Ash And Fiber On Properties Of Cement Concrete (Marinela Barbuta, Roxana Bucur, Sorin Scutarasu, Elsevier-2016)

- Effect Of Fly Ash And Silica Fume On Compressive Strength Of Self Compacting Concrete Under Different Curing Conditions (Heba A. Mohamed, Elsevier-2011)

- Effect of polypropylene fiber on durability of concrete composite containing fly ash and silica fume. (Elsevier-2012)

- Effect of fly ash and silica fume on heat of hydration of Portland cement. (Pergamon-
Cement and concrete research 32-2002 1045-4051).

- IS 516 (1959): Method of Tests for Strength of Concrete

- IS 456-2000: - "Plain And Reinforced Concrete"

- IS 10262: Guidelines for concrete mix design proportioning