“Alternate for Silica fume for Normal Grade Concrete ”

By

AHMER HAYAT

A thesis submitted in partial fulfillment of the requirements for the Degree of M.E. [Structure]

R.No. - 3532

Department of Civil Engineering
Delhi College of Engineering
Bawana Road, Delhi
December, 2004

Certificate

This is to certify that thesis entitled **‘**Alternate for Silica fume for Normal Grade Concrete **’** being submitted by ***Mr. Ahmer Hayat*** to the ***Delhi College of Engineering***, Bawana Road, Delhi for award of M.E. [Structure] Degree in Civil Engineering is a record of bonafide research work carried out by him under our guidance and supervision.

To the best of our knowledge, the thesis has reached the requisite standard. The material presented in this thesis has not been submitted in part or full to any other university or institution for award of degree or diploma.

Dr. Rakesh Kumar
Scientist
Bridge & Instrumentation Engg.
Central Road Research Institute
Mathura Road,
New Delhi

Dr. D Goldar
Professor
Department of Civil Engineering
Delhi College of Engineering
Bawana Road,
Delhi

Acknowledgement

The author truly admires with all his hearts Dr. D Goldar, Professor & Head, Civil Engineering Department, Delhi College of Engineering, and Dr. Rakesh Kumar, Scientist, Bridges & Instrumentation Division, Central Road Research Institute [CRRI], New Delhi, for their perspective supervision, invaluable guidance and constant encouragement throughout the period of project/thesis work.

I pay my sincere thanks to the Director, CRRI New Delhi for allowing me to do my thesis work at this Institute of Repute.

I am thankful to Sh. Narender Kumar Technical Officer and other staff at CRRI, New Delhi for their cooperation in accomplishing my project / thesis work.

Thanks are also due to Mr. Azhar Hayat for assisting me in computerization of data. I also acknowledge my sincere thanks to my Parents without whose support it would have been impossible to accomplish this job.

Ahmer Hayat

ABSTRACT

In last few decades a lot of research was carried out throughout the world for how to improve the performance of concrete in terms of strength and durability qualities. Consequently a number of mineral admixture viz. silica fume, fly ash, rice husk ash etc. were used in concrete. Incorporation of mineral admixture in small amount in concrete significantly enhances strength and durability properties of concrete. Use of silica fume in last two decades has become a tradition for all high strength and high performance concrete. As silica fume is imported material, hence, it is costlier, therefore, in this study an attempt has been made to find a suitable alternate of silica fume. For this experiment work on concrete incorporating, rice husk ash, fly ash class C and class F in addition to control concrete and concrete incorporating silica fume were studied. Total of 13 concrete mixes were used for this study. Three replacement levels i.e. 5, 8, and 10% by mass of cement with silica fume, rice husk ash and fly ashes were used for this work. The relative performance of the mineral admixtured concrete were evaluated in terms of strength development and quality. Based on the results obtained, it is concluded that fly ash C type can be used as an alternate of silica fume for the concrete of strength used in this investigation.

List of Figures

Page No.

List of Tables

Page No.

Contents

CHAPTER 1

INTRODUCTION

1.1 THE BACKGROUND

Concrete is no longer made of aggregates, Portland cement and water only. Often, if not always it has to incorporate at least one of the additional ingredients such as admixtures, supplementary cementious material or fibers to enhance its strength and durability. During last few decades requirement of high performance and highly durable concrete has been on rise. The use of mineral admixture in combination with chemical admixture has allowed the concrete technologists to tailor the concrete for many specific requirements. Amongst the mineral admixture, silica fume, because of its finely divided state and very high percentage of amorphous silica, proved to be most useful, if not essential for the development of very high strength concretes and/or concrete of very high durability i.e. high performance concrete. Therefore it is being used on a worldwide scale in concrete, for the making of high performance concrete. In spite of its numerous advantages silica fume suffers from one major disadvantage that it is imported therefore, very costly. In this work an attempt has made to find a suitable alternate of silica fume.

1.2 OBJECTIVES OF THE STUDY

The major objectives of this experimental investigations are as given below:

- To find a suitable alternate, which performs in terms of strength development and quality of concrete at par with silica fume and is locally available.
- To develop a relationship between ultrasonic pulse velocity and compressive strength of mineral admixture concrete.

- To develop correlation between compressive strength and tensile strength of mineral admixture concrete.
- To develop correlation between compressive strength and flexural strength of mineral admixture concrete.

1.3 THE COMPOSITION

The thesis has been divided into five chapters. In chapter 1 a brief introduction, the major objective of the work is given. Chapter 2 deals with extensive literature review. Chapter 3 covers the properties of constituent materials and mix proportions of concrete, it also includes the details of various tests conducted both on fresh and hardened state. The results and discussions of various tests are presented in chapter 4.The major conclusions and need for future work is presented in chapter 5. Various tables and figures are presented for clear understanding of thesis work at appropriate places.

CHAPTER 2

LITERATURE REVIEW

2.0 General

This chapter deals with the basics of mineral admixtures, their need, and their types, which are generally used nowadays. It covers historical development of mineral admixture. This chapter also includes the recent research information's on the topic.

2.1 Admixtures

Admixtures are ingredients of concrete other than water, aggregate, hydraulic cement, and fibers. Admixtures are added to the concrete batch immediately before or during mixing. A proper use of admixtures offers certain beneficial effects to concrete, including improved quality, acceleration or retardation of setting time, control of strength development, improved workability and enhanced finishability. It is estimated that 80% of concrete produced in North America these days contains one or more types of admixtures. According to a survey by the National Ready Mix Concrete Association[18], 39% of all ready-mixed concrete producers use fly ash and 70% of produced concrete contains a water-reducer admixture. Admixtures vary widely in chemical composition and many perform more than one function.

2.1.1 Types of Admixtures

Admixtures can be broadly classified into two groups: Mineral and Chemical.

2.1.1.1 Mineral Admixtures

Mineral admixtures are usually added to concrete to enhance the workability of fresh concrete; to improve resistance of concrete to thermal cracking, alkali-aggregate expansion and sulfate attack; and to enable a reduction in cement content. Mineral admixture develops cementitious properties by reacting mainly with the calcium hydroxide liberated by the hydration of the silicates in cement. Of the several types of mineral admixture available, the most common are industrial by-products, such as silica fume, fly ash, and rice-husk ash etc. Other, however, are also in use, namely, zeolite, slags, water glass, and limestone powder [2].

2.1.1.1(a) Fly ash

Fly ash is finely divided by-product obtained from the combustion of pulverized coal of thermal power plant. It is collected by electrical or mechanical precipitators including cyclone precipitators. It is generally finer than cement and consist of mostly spherical glassy particles. During the combustion of coal, the by-products formed are fly ash, bottom ash and gasses and/or vapors. Fly ash is the fine part of the ash, which is entrained in the flue gases, whereas the bottom ash is the residue consisting of coarser discrete or fused particles heavy enough to drop out of the combustion zone onto the bottom of the furnace. It may be noted that depending on the type of precipitator used the majority of incombustible mineral present in coal, about 85 to 99.9% is retrieved in the form of fly and bottom ash while the remainder is discharged into the atmosphere. Fly ash makes up to 75 to 85 % of the total ash and the remaining is bottom ash or boiler slag. The properties of fly ash are extremely variable and depends upon several factors, such as the type and origin of coal (bituminous, sub bituminous and lignite coals), degree of coal pulverization, flame temperature, oxidation conditions, and method of collection of fly ash. Specifications for fly ash and raw or calcined natural pozzolan for their use as a mineral admixture in concrete are defined in ASTM C 618-89[24]. As per ASTM C 618-89, "pozzolan is defined as siliceous or siliceous and aluminous materials which in themselves posses little or no cementitious value but will in finely divided form and in the presence of moisture chemically react with calcium hydroxide at ordinary temperatures to form compounds possessing cementitious properties". ASTM C 618-89 categorizes the pozzolan into class N, F, C and S. Class N refers to raw or calcined natural pozzolans such as some diatomaceous earths derived from microscopic unicellular algae with siliceous wall cells, opaline shales or cherts, and volcanic ashes or pumicities. Class S refers to certain processed pumicites that are porous forms of volcanic glass and to certain calcined and ground diatomites, clays and shales. Class F and C pozzolans refers to fly ash derived from burning of different coals. Class F refers to fly ash derived from burning antharacite or bituminous coal. Its lime content is less than 10% and it possesses truly pozzolanic properties i.e., it needs an activator to undergo reactions and thus produce cementitious properties. Class C refers to ashes derived from burning lignite or sub-bituminous coal. Its lime content is more than 10% and it possesses some cementitious properties itself, in addition to pozzolanic properties. It contains less than 50% as oxides of silica, alumina and iron. Average particle size of fly ash varies from 1μm to 100μm. The value of specific surface area is reported to range from 2,00m^2/kg to 10,00m^2/kg. The specific gravity of fly ash varies significantly from 1.9 to 2.9. Colour of fly ash ranges from almost cream to dark-gray, essentially depending upon the proportion of un-burnt carbon present, as well as upon its iron content[1].

2.1.1.1(b) Silica fume

Silica fume is a by-product of the Ferro-silicon alloys and silicon metal industries. Silicon, Ferro-silicon, and other alloys of silicon are produced in electric arc furnaces where quartz is reduced by carbon at very high temperatures. In the process, SiO_2 vapors are produced which oxidize and condense in the form of very tiny spheres of non-crystalline silica, particles with an average size 0.1μm, which is about 100 times finer than the average cement particle. The product, which is highly pozzolanic, is recovered by passing the outgoing flue gas through a bag house filter. Silica fume containing more than 78% of silica can suitably be used in concrete. The specific gravity of silica fume is generally equal to that of amorphous silica, which is/are about 2.20. The specific surface of silica fume is around 200,00m^2/kg. Higher fineness, amorphous nature, and elevated content of silica makes silica fume a unique supplementary cementitious material. The small silica fume spheres acts as fillers since they occupy some of the space between coarser cement grains, which can be otherwise occupied by water. This results also in a denser matrix with a better gradation of fine particles. The filler effect of silica fume on improving the mechanical properties of concrete was shown by Detweiler and Mehta [20].

2.1.1.1(c) Rice husk ash

Rice husk constitute about 1/5th of the 300 million metric tons of rice produced annually in the world. Rice husk ash is obtained from agricultural waste rice husk. Controlled burning of rice husk between 500 and 600^{o} C for short duration of about 2hrs yields ash with low un-burnt carbon and anamorphous silica. When rice husk is burnt in an uncontrolled manner, the ash, which is essentially silica, is converted to crystalline forms and is less reactive[34]. Both the crystalline and amorphous rice husk ash is used to manufacture a lime- rice husk ash mix or a Portland rice husk ash cement or the rice husk ash can be used as a Portland cement replacement in concrete. Research in India and the United States has found that if the hulls or straw are burned at a controlled low temperature, the ash collected can be ground to produce a pozzolan very similar to (and in some ways superior to) silica fume and heat produced during burning can beneficially used in power production, by doing so not only crop waste can effectively disposed, but also can generate electricity for the area, and provide high quality cement. There are two well-known methods for producing rice husk ash, fluidized bed technology which is practiced in U.S and second method is torbed reactor which was developed recently developed in Egypt, it is found that the rice husk ash produced by the torbed technology is superior than fluidized bed technology. The characteristics of the typical rice husk produce in India has organic amorphous silica (made of rice husk ash) with silica content of above 85%, in very small particle size of less than 25 microns, which is used for making green concrete, high performance concrete, refectories, insulators, flame retardants etc. Mauro[19] observed that, when rice husk ash is added to concrete there was 38.7% decrease in water absorption and 25% of increment in compressive strength was obtained when 5% of rice husk ash was added to ordinary Portland cement. Dass[35] and other several investigators have examined the characteristics and properties of rice husk ash as; the Blaine air fineness is around 400 to 600 m^2/kg and its specific gravity is around 2.3.

2.1.1.2 Chemical Admixtures

Chemical admixtures are added to concrete in very small amounts mainly for the entrainment of air, reduction of water or cement content, plasticization of fresh concrete mixtures, or control of setting time. Various chemical admixtures frequently used these days are Air entraining agents, water reducers, set retarders, accelerators and superplasticizers. Among them superplasticizers is most commonly used chemical admixture in conjunction with mineral admixtures. Superplasticizer, procure a considerable increase in the workability of mortars and concrete at constant water-cement ratio[36]. The slump can be increased 2-3 times while maintaining the cohesiveness of the mix. Reduction of water can be up to 35%. The superplasticizers do not alter the structure of the cement paste and have not been reported to cause retrogression in the strength of concrete. Superplasticizer effectiveness is time dependent and cement specific. The nature of calcium sulphate, C_3A content and fineness of cement have a significant impact on the choice and dose of the superplasticizers[38]. Mortars and concretes of constant workability can be made with smaller amounts of water, saving more than 12% without undue retardation, excessive entrainment of air or detrimental bleeding[36].

2.2 Historical developments

Historically, natural pozzolana is the oldest among mineral admixtures. However, for obvious reasons it is preferable to use fly ash and granulated blast furnace slag whenever these are conveniently available for disposal. Condensed silica fume, rice husk ash and pulverized lime stone are also being used in relatively small quantities that are within 5 to 10% by weight of cement[1]. Romans were first to use pozzolana as lime-pozzolana mortar[2]. In the United States, the first major use of pozzolana was in construction of the Los Angeles aqueduct from 1910 to 1912. Since then natural pozzolana have been used in construction of number of dams, bridges and other large works, but mainly in western United States where pozzolana are found[3]. Use of fly ash in concrete started in the United States in the early 1930’s. The first comprehensive study was that described in 1937, by R. E. Davis at University of California. The major breakthrough in using fly ash in concrete was the construction of Hungary Horse Dam in 1948, utilizing 120,000 metric tons of fly ash. This decision by the U.S. Bureau of reclamation paved the way for using fly ash in concrete construction.

Although the use of silica fume in concrete has increased significantly in the past few years, its beneficial properties were not well realized until comprehensive research was undertaken in the late 70`s and early 80`s at the Norwegian institute of technology to study the influence of silica fume on concrete properties[4]. One of the first major structures to incorporate silica fume was in Sweden where silica fume concrete was used in the tower construction of the New Tjorn cable-stayed bridge that was completed in late 1981.The use of silica fume in concrete was first adopted by AASHTO in 1990. The AASHTO and ASTM C 1240[37] covers micro silica for use as a mineral admixture in Portland cement concrete and mortar to fill small voids in cases in which pozzolanic action is desired.

In 1972, Mehta[20], published the first of the several papers dealing with rice husk utilization, his work was significant because it was the first careful study of the pyroprocessing parameters and their influence on rice husk ash reactivity. A fluidized bed furnace was designed as a system utilizing rice husks to produce energy while also producing reactive ash. In 1979, the first workshop on rice husk ash cements was held in Peshawar, Pakistan. Some 15 papers were presented outlining the then state-of-the-art. Details of three methods for producing cement appropriate to developing countries were presented but only two had progressed to the pilot plant stage. The first involved controlled burning of the husks in incinerators and intergrinding the ash with lime or blending with Portland cement. The second simply ball-milled the ash to suitable reactivity after the husks had been used as a fuel source.

2.3 Recent Researches

Numerous studies[20-24] show the various advantages of using silica fume, fly ash, rice husk ash in concrete, the investigation of Mehta[20], Ronne[21], Austin[22] and especially the report of Roy[23] on the hydration of cement containing silica fume or fly ash prove that application of this material considerably improves the properties of blended cement and concrete.

Chai Jaturapitakkul[5] proposed that the coarse fly ash, having the average median diameter about 90-100μm, yields a very low pozzolanic reaction and should not be used in concrete. In order to improve its quality coarse fly ash was ground until the average particle size was reduced to 3.8μm. Then it was used to replace Portland cement by weights of 15%, 25%, 35% and 50% to produce high strength concrete. He found that concrete containing the ground coarse fly ash (FAG) replacement between 15% and 50% can produced high strength concrete and 25% cement replacement gave the highest compressive strength. In addition, the concrete containing FAG of 15-35% as cement replacement exhibited equal or higher compressive strength after 60 days than those of condensed silica fume concrete. His results, therefore suggests that FAG with high fineness is suitable to replace condensed silica fume in producing high strength concrete. Generally, high strength concrete is achieved by using superplasticizer to reduce the water- binder ratio and by using supplementary cementing materials such as silica fume, natural pozzolana, or fly ash in order to create extra strength by pozzolanic reaction. Furthermore, Shannag[8] used natural pozzolan and silica fume to produce high strength concrete in the range of 69 to 85 MP at 28 day, with medium workability. Many researchers[11, 25,26,27] concluded that classified fly ash with high degree of fineness was an important factor in producing high strength concrete. However, Berry[28] suggested that coarse fly ash exhibited low pozzolanic activity since it contained a high proportion of crystalline phases, and thus should not be used in concrete. It is shown that the classified fly ash is suitable for use in concrete, but the residue from the classifying process (coarse fly ash) has to be disposed of[11, 25]. Kittikomol et al.[29], Songpiriyakij and Jaturapitakkul[30] and Paya et al[31, 32] found that by grinding the coarse fly ash into a high degree of fineness the compressive strength of concrete could be improved. Cornelissen et al.[33] also investigated the micronised fly ash and found that the use of ground fly ash can produce concrete with excellent strength.

Nehdi.[34] developed a new technology for the production of rice husk ash (RHA) based on a torbed reactor allowed producing highly reactive RHA with much lower carbon content than that of RHA produced using fluidized beds. The technique was applied to rice husk from Egypt, and the performance of the resulting RHA was compared to those of silica fume and RHA produced in United States using fluidized bed technology. He concluded that at 56 days, using 7.5%, 10% and 12.5% cement replacement with Egyptian RHA increased the compressive strength of concrete by up to 20%, 27% and 40% respectively, depending on the type of RHA and the addition rate. Similar proportion of US-RHA and silica fume increased the compressive strength by up to 27%and 22% respectively. Based on strength results alone, his study shows that good quality RHA can match and even outperform strength enhancement in concrete achieve by silica fume, this is even more significant at early ages. The resistance to surface scaling of RHA concrete was better than that of concrete containing similar proportion of silica fume. While the chloride penetrability was substantially decreased by RHA, it remained slightly higher than that achieved by silica fume concrete. His study shows that economical technology can be used in rice-producing countries to produce a highly effective supplementary cementing material and reduce the environmental impact of uncontrolled burning of rice by-products.

Demirbas[39] emphasized on the particle size of cement admixture as it influences the hydration rate and therefore, strength development and setting behavior. The rate of hydration increases with the decrease of particle size. Typically, very fine particles increase the ability to react with water and plasticity. Smaller particles improve the mixing characteristics and strength development of the paste. The particle size is an important factors that influences compressive strength, with phase compositions becoming significant at later ages.

Bekir[6] determined that material passing through a sieve of the size under 0.149 mm called as mineral filler, when such material is added to concrete in range of 7-10% showed an improvement in compressive and flexural strength of concrete. A decrease in permeability, absorption and porosity of the concrete were also observed. The active mineral admixtures are extensively used as components of blended cements for various mortar and concrete. Stoitchkov[11] investigated on the physical and mechanical properties of concrete and cement mortar containing the active mineral pozzolit admixture and his study showed that the compressive strengths of silica fume and pozzolit containing concrete at the age of 28 and 180 days are practically the same and are higher than the corresponding strength of the reference plain concrete (without chemical and mineral admixture) by 50 and 40% respectively. The 28th day flexural strengths of concretes with mineral admixtures are merely the same and are by about 30% higher than the corresponding strengths of concretes without chemical and mineral admixtures. It is also noted that the effect of silica fume and pozzolit addition is greater in concrete than in mortar, which is possibly due to the formation of a more homogeneous and dense contact zone between the aggregate grains and the binding substance in concrete. The values of modulus of elasticity of mineral admixture containing concretes are almost equal. Water permeability exhibits also similar values.

Ferraris[9] concluded that among the following admixtures i.e. 1.coarse fly ash, 2.fly ash, and 3. Fine fly ash, 4.Ultra fine fly ash, 5. Metakaolin, and 6.silica fume, having the mean particle size of 18, 10.9, 5.7,3.1, 7.4 and 0.1 μm, the ultra fine fly ash was determined to give best results by reducing the yield stress and viscosity.

George[10] investigated the effectiveness of eight mineral admixtures in reducing the alkali silica reactivity of cement mortar. The admixture includes one class F fly ash, a condensed silica fume, a ground fiberglass, three glass containing waste materials and two inert fillers (carbon and calcium carbonate). He concluded that ground fiberglass is very effective in controlling the alkali-silica reaction, while inert filler have only a dilution effect.

Ganesh and Prakash[12] proposed that the 'overall efficiency factor' of silica fume can be assessed in two separate parts, and the 'general efficiency factor' – a constant at all the percentages of replacement and 'the percentage efficiency factor'- varying with the replacement percentage. A comparison of the efficiencies obtained from the earlier data with studies on a lower bound and it is possible to achieve even higher efficiencies with proper mix proportioning.

Results of Menon[13] indicates that concrete with 30% and 70% level of cement replacement exhibited better performance than normal Portland cement concrete in sea water exposed to tidal zone. Hence it is believed that both high strength concrete produced would withstand severe seawater exposure without serious deterioration.

The effect of silica fume, metakaolin, fly ash and ground granulated blast furnace slag (GGBS) on the setting time of high strength concrete has been investigated by Brooks[14]. He concluded that in general as replacement levels of mineral admixture were increased there was greater retardation in setting times. However, for concrete containing metakaolin this was only observed up to a replacement of 10%. Hassan[15], result showed that mineral admixture improved the properties of high strength concrete best at different rates depending on the binder type, while silica fume contributed to both short and long term properties of concrete. Fly ash required a relatively longer time to get its beneficial effect. In the long term, both mineral admixtures slightly increased compressive strength by about 10% but contributed more to the improvement of transport properties of concrete.

Zain and Radin[16] discuss two physical properties namely compressive strength and modulus of elasticity was produced by silica fume concrete under water and wrapped curing at temperature of 35^{o}C. They indicated that high pozzolanic reactivity and micro filler effect of silica fume at medium temperature has modified the open channels at the transition zone in silica fume concrete.

Tumidajski and Chan[17] concluded that mineral admixture in combination with a long initial curing, provided most durable concrete. Concrete with 65% slag had the best overall durability.

CHAPTER 3

EXPERIMENTAL STUDY

3.0 General

This chapter presents detail of materials used in the experimental work. It includes mix proportions and various tests conducted on both, fresh as well as hardened concrete. Total number of specimen cast for different mix is also given.

3.1 Material

The various material used in the experimental work were cement, fine aggregate, coarse aggregate, mineral admixtures, (namely; silica fume, rice husk ash, fly ash) superplasticizer and water.

3.1.1 Cement

The cement used in this research work was ordinary Portland cement of 43 grade. Cement was tested for its suitability according to IS 8112[44]. The various properties of the cement are shown in Table-1.

Table1: Properties of cement

Test Parameter	Value	Permissible Range As per I S: 8112
Specific Gravity	3.12	3.10-3.15
Blaine Fineness (m^2/kg)	309	225 min
Normal Consistency (%)	31.3	30-35
Initial Setting Time (min)	178	30 min
Final Setting Time (min)	340	600 max
Compressive Strength (MPa)		
7 days	33	33 min
28 days	46	43 min

All properties of the cement were within the permissible range, hence satisfied the codal requirement of Indian Standards.

3.1.2 Fine Aggregate

Sand used, as a fine aggregate in this experimental study was land quarried and locally known as Badarpur, generally used in and around Delhi. The sieve analysis of fine aggregate is shown in Table-2.

Table 2: Sieve analysis of fine aggregate

Sieve Size (mm)	Passing (%)	(%) Passing zones as per IS: 383-1970		
		1	2	3
10	100	100	100	100
4.75	98.5	90-100	90-100	90-100
2.36	95.5	60-95	75-100	85-100
1.18	87.5	30-70	55-90	75-100
0.600	68	15-34	35-59	60-79
0.300	7	5-20	8-30	12-40
0.150	3.75	0-10	0-10	0-10

The sand used in this experiment falls in between Grading zone 2 & 3, as per IS: 383-1970[41], which means that this sand was finer than the standard sand. The various other properties of sand are given in Table-3.

Table 3: Properties of fine aggregate

Properties	Values
Fineness Modulus	2.4
Specific Gravity	2.6
Water Absorption (%)	1.6
Bulk density (kg/m^3)	1614

The Fineness Modulus of sand is 2.4, which is well within limits 2.2 to 2.6.

3.1.3 Coarse Aggregate

Graded crushed stone aggregate with maximum nominal size of 20mm was used a coarse aggregate. Two types of coarse aggregate were used to have better gradation and higher density of the mix. The sieve analysis data for coarse aggregate is shown in Table-4.

Table 4: Sieve analysis of coarse aggregate

Sieve Size (mm)	Percent Passing (20 mm Nominal Size)	Percent Passing (12.5 mm Nominal Size)
40	100	100
20	100	100
12.5	N.A	96
10	10	84
4.75	3.5	18
2.36	N.A	4.5

The various properties of coarse aggregate are shown in Table-5.

Table 5: Properties of coarse aggregate

Parameters	Values
Specific Gravity	2.69
Bulk Density (kg/m^3)	1610
Water Absorption (%)	0.3
Fineness Modulus	6.7

The amount of coarse aggregate falling in the size of 12.5 mm and less was about 18%.

3.1.4 Mineral Admixtures

Four types of mineral admixtures were used in the experiment, viz. Silica fume, rice husk ash, Fly ash class F and Fly ash class C.

3.1.4 (a) Fly ash

Two types of Fly ashes were used in the experimental work, one of them was collected from Dadri thermal power plant (U.P), and it conforms to Class F fly ash as per ASTM C 618[24]. Bulk density of fly ash was found out 1143 kg/m^3. Other Fly ash used in the study obtained from a thermal power plant in Neyveli, Tamil Nadu that belongs to Fly ash C type according to ASTM C 618. Various physical and chemical properties of the fly ash are given in Table-6.

Table-6: Properties of Fly ash

Test	Fly ash F	ASTM C 618 Specifications		
		Class N	Class C	Class F
Retained on No. 325 sieve (%)	14	34 Max	34 Max	34 Max
Strength Activity Index with Cement at 28 days (%)	133	75 Min	75 Min	75 Min
Water Requirement (%)	98	115 Max	105 Max	105 Max
Autoclave Expansion (%)	N.A	+/- 0.8	+/- 0.8	+/- 0.8
Specific Gravity	2.14	-	-	-
Loss on Ignition (%)	0.6	10.0 Max	6.0 Max	6.0 Max
SiO_2	62.0	-	-	-
Al_2O_3	25.0	-	-	-
Fe_2O_3	4.1	-	-	-
SiO_2 + Al_2O_3 + Fe_2O_3 (%)	91.1	70 Min	50 Min	70 Min
CaO	1.4	-	-	-
MgO	0.8	-	-	-
SO_3	0.3	4 Max (%)	5 Max (%)	5 Max (%)

3.1.4 (b) Silica Fume

Silica fume used in the experimental work had specific gravity of 2.18 and Blaine specific surface is around 450 m^2/kg. It is supplied by Elkem materials under the name of Elkem Micro Silica grade 920. Some important properties of silica fume used, are shown in Table-7.

Table-7: Chemical properties of silica fume

Parameters	Analysis	Specification (%)
SiO_2	89.9	85 Min
Moisture Content	0.6	3.0 Max
Loss Of Ignition	1.5	6.0 Max
Carbon	0.9	2.5 Max
>45 Micron	0.3	10 Max
Bulk Density (kg/m^3)	380	500-700

Various above-mentioned properties of silica fume conform to the parameters of ASTM 1240-99[43].

3.1.4 (c) Rice husk ash

Rice husk ash is obtained from agricultural waste of rice husk. Rice husk used in the experimental study is obtained from a power plant in Jharsguda, Orissa and its specific gravity is 2.06. Bulk density of rice husk ash used was 718 kg/m^3. The particles of rice husk ash used were finer than 45µm. Various properties of Rice husk ash are given in Table 8.

Table 8: Properties of Rice husk ash

Parameter	Value
Silica	88.5
Carbon	5.1
Alumina	5
Mineralogy	Non crystalline
Average particle size	25μm
Shape	Irregular
Texture	Cellular

3.1.5 High Range Water Reducing Agent (HRWRA)

High Range Water Reducer (HRWR) commonly known as Superplasticizer is used in the experiment to increase the workability of concrete. Amount of superplasticizer used for various mixes are given under mix proportions heading. The mechanism of action of superplasticizer is mainly based on their ability to be adsorbed on the surface of cement particle and modify the rheological behavior of cement matrix. The rate of absorption of superplasticizer depends on the chemical and mineralogical composition of the cement, its fineness and in particular on the C_3A content. The superplasticizer used in this research was supplied by Master Builders Technology pvt. Ltd under the name of Glenium B 233.

3.1.6 Water

Potable water was used in the experiment, whose Ph value is greater than 6.

3.2 Mix Proportions

The proportions of various mixes are given in Table-9. Water/cementious material ratio is kept around 0.48 and dosages of superplasticizer is varied in range of 0.2% to 0.4% of binder's mass, to achieve the slump of about 75mm.

M30 grade concrete is used throughout the experimental study. A total of 13 concrete mixes were used for this study. Concrete mixes were made with 5%, 8%, and 10% replacement of cement with silica fume, rice husk ash, fly ash C type, and fly ash F type. The details of the mix proportions are given in Table-9.

TABLE-9: Mix proportions of concretes

Mix		Cement kg/m^3	Replacement kg/m^3	Fine Aggregate kg/m^3	Coarse Aggregate kg/m^3	Water ltr	Super Plasticizer ltr	w/c ratio
Control		386	Nil	590	1197	181	0.79	0.47
5%	S.F	366	19.3	590	1197	182	1.18	0.47
	R.H.A	369	19.5	595	1206	182	1.18	0.47
	F.A.F	366	19.3	590	1197	181	1.18	0.47
	F.A.C	369	19.4	595	1206	190.5	1.19	0.49
8%	S.F	352	30.5	586	1188	184	1.56	0.48
	R.H.A	355	31	590	1197	189	1.18	0.49
	F.A.F	355	31	589	1195	188	1.18	0.49
	F.A.C	364	31.5	605	1226	193.5	2.02	0.49
10%	S.F	345	38	586	1188	188	1.56	0.49
	R.H.A	345	38	586	1188	188	1.56	0.49
	F.A.F	347	38	590	1197	181	1.18	0.47
	F.A.C	346	38	590	1197	189	1.97	0.49

3.3 Specimen preparation

Concrete specimens are prepared by proper mixing of ingredient in proportions as mentioned in Table 9. First of all small amount of water is poured into tilting drum mixer then coarse aggregate, fine aggregate, cement and mineral admixture are fed, thereafter the ingredients are mixed dry in the mixer for about 30 seconds, then water was added and mixing was continued till the concrete attained the uniform colour and consistency, then mixer was stopped for about two minutes and finally superplasticizer was added and mixed for 2-3 minutes. Slump was measured and it was tried to maintain its value around 70mm by adding superplasticizer. Then compaction factor test was conducted. Specimens were compacted by placing them on the vibrating table. Density and temperature were measured subsequently. Total numbers and types of specimen cast for each mix are given in Table-10. The Compression Test and UPV Test had been carried out at different ages of 1, 3, 7, 14, and 28 days. Splitting Tensile Test had been carried out at ages of 7 and 28 days. Flexural strength Test and Modulus of Elasticity Test are conducted at age of 28 days.

Table-10: Number of Specimens

Specimen Type	Numbers
Cubes 150X150 X150 mm	18
Cylinders 150 X 300 mm	9
Beams 100 X100 X 500 mm	3

3.4 Curing conditions

After 24 hours of casting, specimens were demoulded and marked and immediately submerged in the curing tank of fresh water. They were cured continuously in water tank till testing.

3.5 Testing

The various tests conducted on concrete specimen are described in two parts; (1) Tests on fresh concrete and (2) Tests on hardened concrete.

3.5.1 Test on fresh concrete

In order to study the behaviour of fresh concrete Slump test and Compaction factor test were conducted.

3.5.1(a) Slump Test

The mould for the slump test is a frustum of a cone, 300mm high. The base of 200mm diameter is placed on a smooth surface with the smaller opening of 100mm diameter at top, and the container is filled with concrete in three layers. Each layer is tamped 25 times with a standard 16mm diameter steel rod, rounded at the end, and the top surface is struck off by means of a Screeding and rolling motion of the tamping rod[40]. The mould was firmly held against its base during the entire operation. Immediately after filling, the cone is slowly lifted, which is shown in Fig-1 and the slump of unsupported concrete is noted for various mixes, which is shown in Table-7. Slump is measured to the nearest 5mm.

Fig: 1 Slump test

3.5.1(b) Compaction Factor Test

Mixes of stiff consistency have zero slumps and lean mixes shows widely different values of slump, these two limitations were overcome in compaction factor test. The function is same, to measure the workability, which is the amount of useful internal work necessary to produce full compaction. The apparatus consist essentially of two hoppers, each in the shape of a frustum of a cone, and one cylinder, the three being above one another. The hoppers have hinged doors at the bottom. All inside surface was oiled prior to concreting. Concrete is filled gently in the upper hopper. The bottom door of hopper is then released and the concrete falls into the lower hopper. This hopper is smaller than the upper one. Then bottom door of lower hopper is released and the concrete falls into the cylinder as shown in Fig-2. Excess concrete is cut off by rolling the tamping rod. Now the net mass of concrete is determined. Cylinder is again filled up with concrete in four layer each vibrated to obtain the weight of fully compacted concrete, then compaction factor is calculated as the ratio of weight of concrete by doing standard amount of work to the weight of fully compacted concrete[40].

Fig: 2 Compaction Factor test in progress

3.5.2 Test on hardened concrete

The various tests conducted on hardened concrete are given below.

3.5.2 (a) Compressive strength test

Compressive strength test is most important one, as concrete is primarily meant to withstand compressive stresses. Three cubes of 150mm size are cast for testing at each selected age i.e. 1day, 3day, 7day, and 28days. Direct compressive load is applied without shock and increased continuously at rate of 140 $kg/cm^2/min$ (31.5t/min) until the resistance of specimen to the increasing load breaks down and no greater load was sustained[45], as shown in Fig-3. The Failure load for each of the specimen was noted. Average of three specimens at each age of testing was taken as the representative compressive strength of the concrete. The result of the test is presented in Chapter-4.

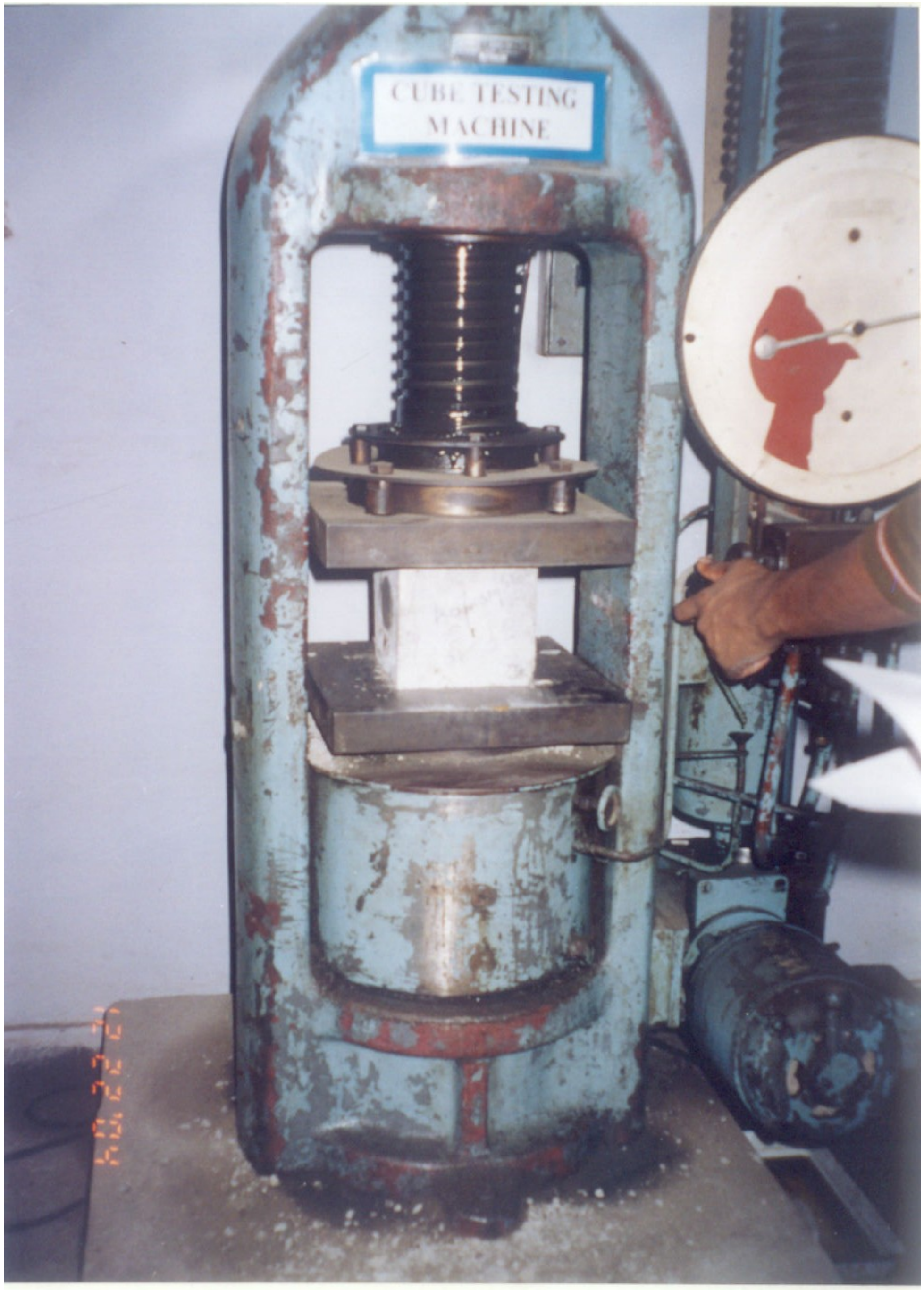

Fig: 3 Compressive strength test

3.5.2 (b) Splitting tensile strength test

Since it is very difficult to apply uniaxial tension to a concrete specimen because the ends have to be gripped and bending must be avoided, the tensile strength of concrete is determined by indirect method; the splitting test and the flexural test. In splitting test, a concrete cylinder of 150mmX300mm size is placed, with its axis horizontal, between platens of a testing machine, and the load is applied at constant rate of 2t/min and it is increased until failure takes place by splitting in the plane containing the vertical diameter of the specimen[45], as shown in Fig-4. The Failure load for each of the specimen was noted. The magnitude of tensile stress was calculated by $2P/\pi DL$, where P is the applied load, and D and L are the diameter and length of the cylinder, respectively. Average of three specimens was taken as the representative tensile strength of the specimen. Tensile strength test was conducted at the ages of 7 and 28 days.

Fig: 4 Splitting tensile strength

3.5.2 (c) Flexural strength test

The determination of flexural tensile strength or modulus of rupture is essential to estimate the load at which the concrete member may crack. Its knowledge is useful in the design of pavement slabs and airfield runway as flexural tension is critical in these cases. Specimen of standard dimension of 100mmX100mmX500mm over a span of 400mm, under symmetrical two-point loading is used to produce a constant bending moment between load points so that the span is subjected to the maximum stress, and therefore it is there that cracking is likely to take place. The specimen was placed in the Universal testing machine such that the load was applied to the upper most surface as cast in the mould, along two lines spaced 13.3cm apart. The load was applied without shock and increased continuously at rate of 180kg/min, until the specimen fails, as shown in Fig-5. The test was conducted at the age of 28 days and the average of three specimens was taken as the representative flexural strength of the concrete. The flexural strength of specimen is calculated by PL/bd^2, when ‘a’ is greater than 13.3cm. If ‘a’ is between 13.3 and 10 cm, it is calculated as 3Pa/bd. And if ‘a’ is less than 10cm the result of test is discarded[45].

Fig: 5 Flexural Strength test

3.5.2 (d) Ultrasonic pulse velocity

Ultrasonic pulse velocity method is used to evaluate the homogeneity of concrete, presence of crack, voids and other imperfections, it can also be used to determine modulus of elasticity of concrete if Poisson's ratio is known. The apparatus generates a pulse of vibrations at an ultrasonic frequency, which are transmitted by an electro-acoustic transducer held in contact with the surface of the concrete under the test. After passing through the concrete, the vibrations are received and converted to an electrical signal by a second electro-acoustic transducer, the signal being fed through an amplifier to a cathode-ray oscilloscope, as shown in Fig-6. The time taken by the pulse to travel through the concrete is measured by an electrical timing-unit with an accuracy of ± 0.1 microseconds and, knowing the length of the path traveled through the concrete, the pulse velocity is calculated. This test was conducted at age of 1, 3, 7, 14, and 28 days. Average of three specimens at each age of testing was taken as the representative UPV value. Direct transmission method is used, in which the leading edge of the longitudinal waves is detected by a receiving transducer located on the face of the concrete opposite to the emitting transducer. Because the velocity of the pulses is almost independent of the geometry of the material through which they pass and depends only on its elastic properties, pulse velocity method is convenient technique for investigating structural concrete. The underlining principle of assessing the quality of concrete is that comparatively higher velocities are obtained when the quality of concrete in terms of density, homogeneity and uniformity is good. In case of poorer quality, lower velocities are obtained. If there is a crack, void or flaw inside the concrete which comes in the way of transmission of the pulses, the pulse strength is attenuated and it passes around the discontinuity, thereby making the path longer. Consequently lower velocities are obtained. The actual pulse velocity obtained depends primarily upon the materials and mix proportions of concrete. Density and modulus of elasticity of aggregate also significantly affects the pulse velocity[46].

Fig: 6   Ultrasonic pulse velocity test

3.5.2 (e) Modulus of elasticity test

The specimen consists of concrete cylinder of 150mm diameter and 300mm long. The strain gauge is attached at one of the ends of the specimen and parallel to its axis, in such a way that the gauge points are symmetrical about the center of the specimen, and then the specimen was placed in the testing machine and accurately centered, as shown in Fig-7. The load was applied continuously and without shock at a rate of 140kg/cm^2/min until an average stress of (C+5) kg/cm^2 is reached, where C is One third of he average compressive strength of cubes calculated to the nearest 5kg/cm^2. The load was maintained at this stress for one minute and was then reduced gradually to an average compressive stress of 1.5 kg/cm^2 and the strain gauge reading is noted. The load was applied a second time at the same rate until an average stress of (C+1.5) kg/cm^2 is reached. The load was maintained at this figure while the strain gauge reading is noted. The load shall then be applied a third time and strain gauge reading was taken at ten approximately equal increments of stress up to an average stress of (C+1.5) kg/cm^2. If the overall strains observed on the second and third readings differ by more than 5%, the loading cycle was repeated until the difference in strain between consecutive readings at (C+1.5) kg/cm^2 did not exceed 5%. The stress-strain curve is plotted and the average slope of the curve is taken as modulus of elasticity of concrete[45]. The test was conducted at the age of 28 days and the average of three specimens was taken as the representative flexural strength of the concrete.

Fig: 7 Modulus of Elasticity test in progress

CHAPTER 4

RESULTS AND ANALYSIS

4.0 General

This chapter covers the results of various test conducted on both fresh as well as hardened concrete. Relationship developed between ultrasonic pulse velocity compressive strength, flexural strength and tensile strength of different mineral admixture mixes is also given in this chapter.

4.1 Effect of mineral admixture on setting time

The results of the test conducted for the study of effect of incorporation of mineral admixtures on setting time of cement is shown Fig. 8 & 9.

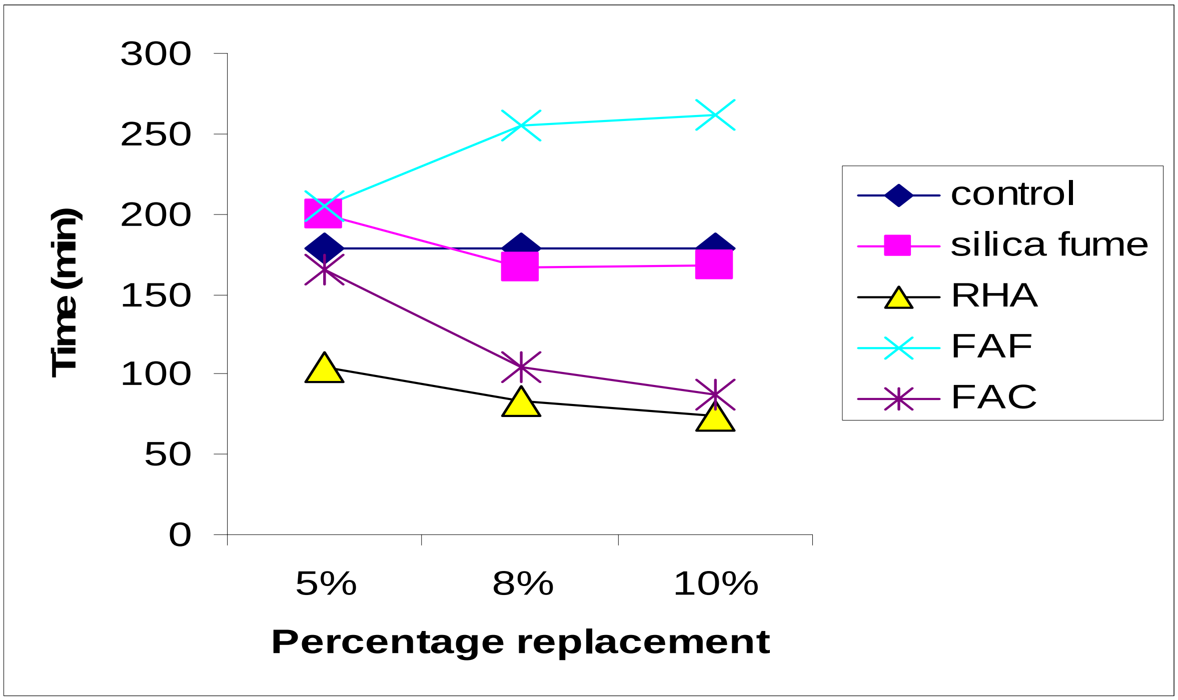

Fig: 8 Effect on Initial setting time using different mineral admixtures.

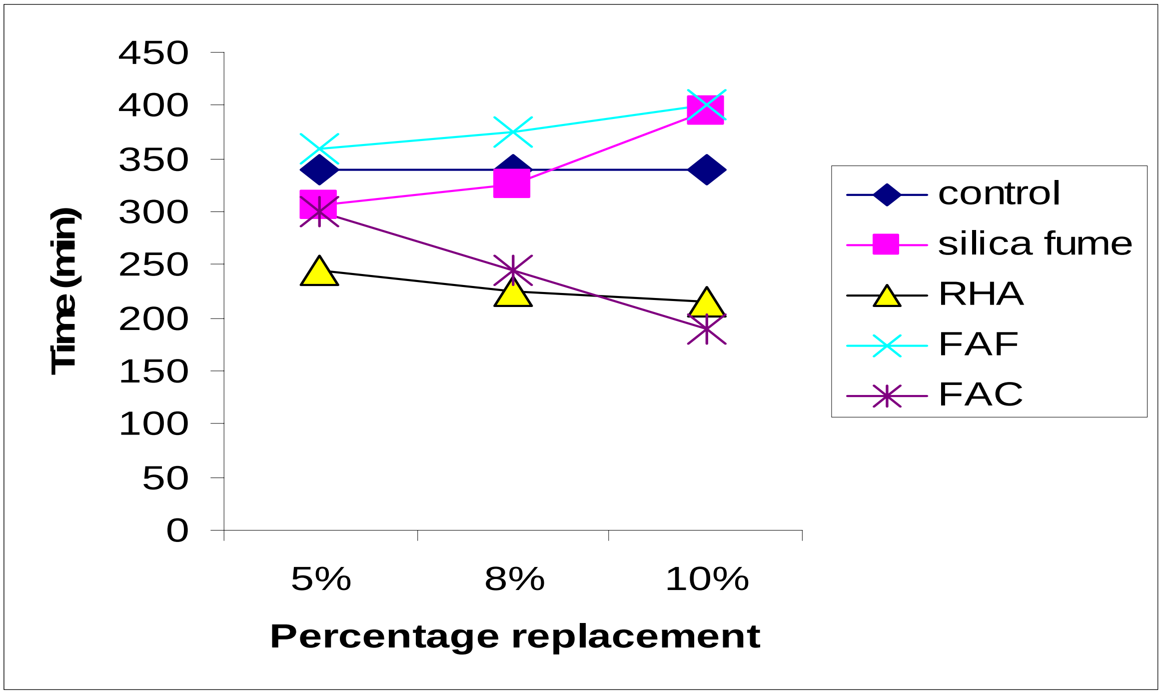

Fig: 9 Effect on Final setting time using different mineral admixtures

It is obvious from the given figures that

- At 5% replacement there was no appreciable change in initial and final setting times except RHA which sets earlier, its initial and final setting time is reduced by 45 & 90 minutes respectively.
- At 8% replacement there was no change in initial and final setting time of Silica fume but initial setting time of Fly ash F type was increased by 60 minutes.
- At 8% replacement initial and final setting time of RHA was decreased by 90 & 110 minutes respectively.
- At 8% replacement initial and final setting time of Fly ash C type was decreased by 75 minutes.

- At 10% replacement of Silica fume and Fly ash F type showed retarding effect on setting time, as there is an hour delay in their final setting times.
- At 10 % replacement of RHA and Fly ash C type showed accelerating effect on setting times, their initial and final setting time is decreased by more than 90 minutes.

4.2 Effect of mineral admixtures on properties of fresh concrete

The effect of mineral admixtures on properties of fresh concrete viz. slump, compaction factor, density and temperature are shown in Table-11.

Table: 11 Effect of mineral admixture on properties of fresh concrete

Mix		w/c ratio	Super Plasticizer (ltr)	Slump (mm)	Compaction factor	Density (kg/m^3)	Temperature	
							Room ^0C	Concrete ^0C
Control		0.47	0.79	70	*	2370	30	28
5%	S.F	0.47	1.18	70	*	2360	29	28
	R.H.A	0.47	1.18	70	*	2365	26	24
	F.A.F	0.47	1.18	65	*	2366	25	24
	F.A.C	0.49	1.19	65	0.89	2363	18	19
8%	S.F	0.48	1.56	70	0.93	2350	20	19
	R.H.A	0.49	1.18	70	0.95	2352	20	19
	F.A.F	0.49	1.18	100	0.96	2360	21	19
	F.A.C	0.49	2.02	90	0.95	2355	18	19
10%	S.F	0.49	1.56	65	0.89	2346	21	19
	R.H.A	0.49	1.56	60	0.90	2340	21	19
	F.A.F	0.49	1.18	75	0.94	2355	21	19
	F.A.C	0.49	1.97	60	0.91	2350	20	19

From the table above it is evident that,

- As the percentage of mineral admixtures was increased, the requirement of water and, or superplasticizer dose was also increased to maintain a constant slump.
- As the percentage of mineral admixture was increased, the density of the mix goes on decreasing.

4.3 Relative performance of hardened concrete using different mineral admixtures

Relative performance of hardened concrete was determined by the various tests, which are as given below

4.3.1 Compressive Strength

The development of compressive strength at different ages of various concretes understudy has been illustrated from Fig 10 – 16.

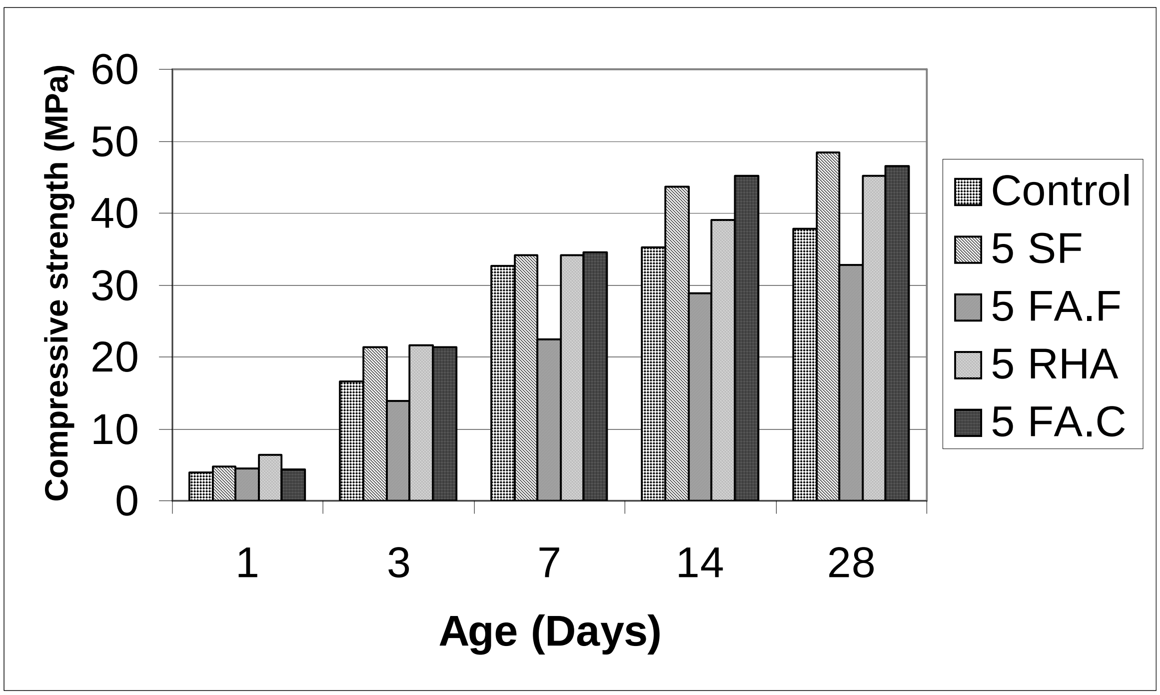

Fig: 10 Compressive strength development of concrete mixtures with age at 5% of mineral admixture

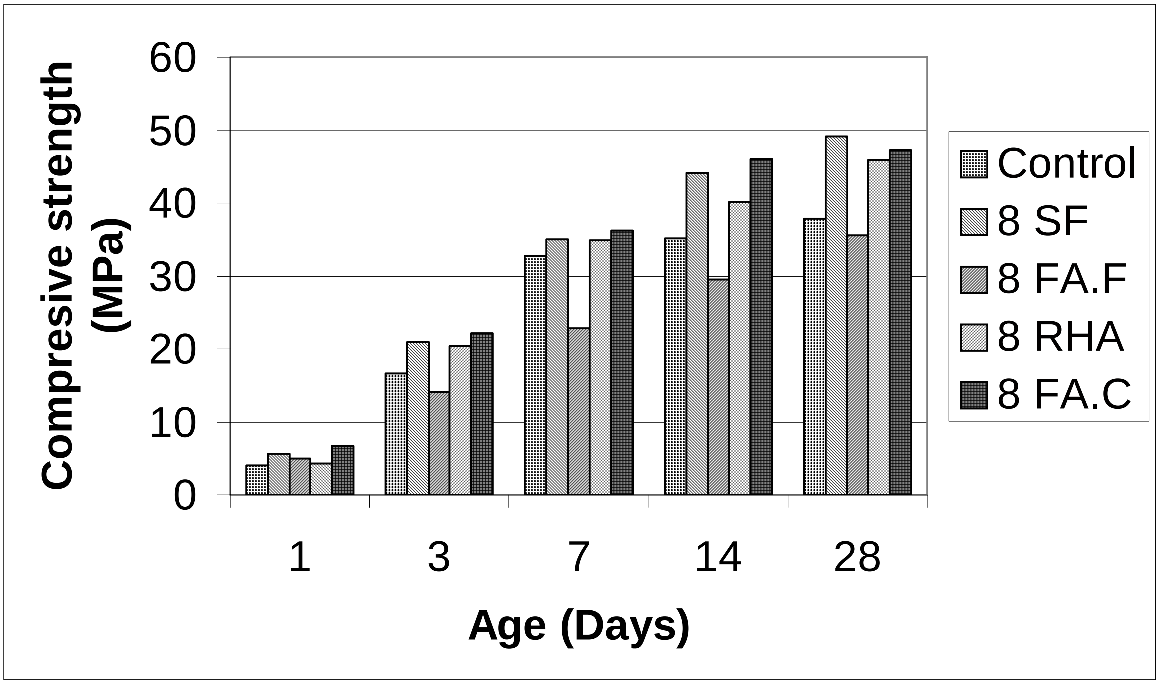

Fig: 11 Compressive strength development of concrete mixtures with age at 8% of mineral admixture

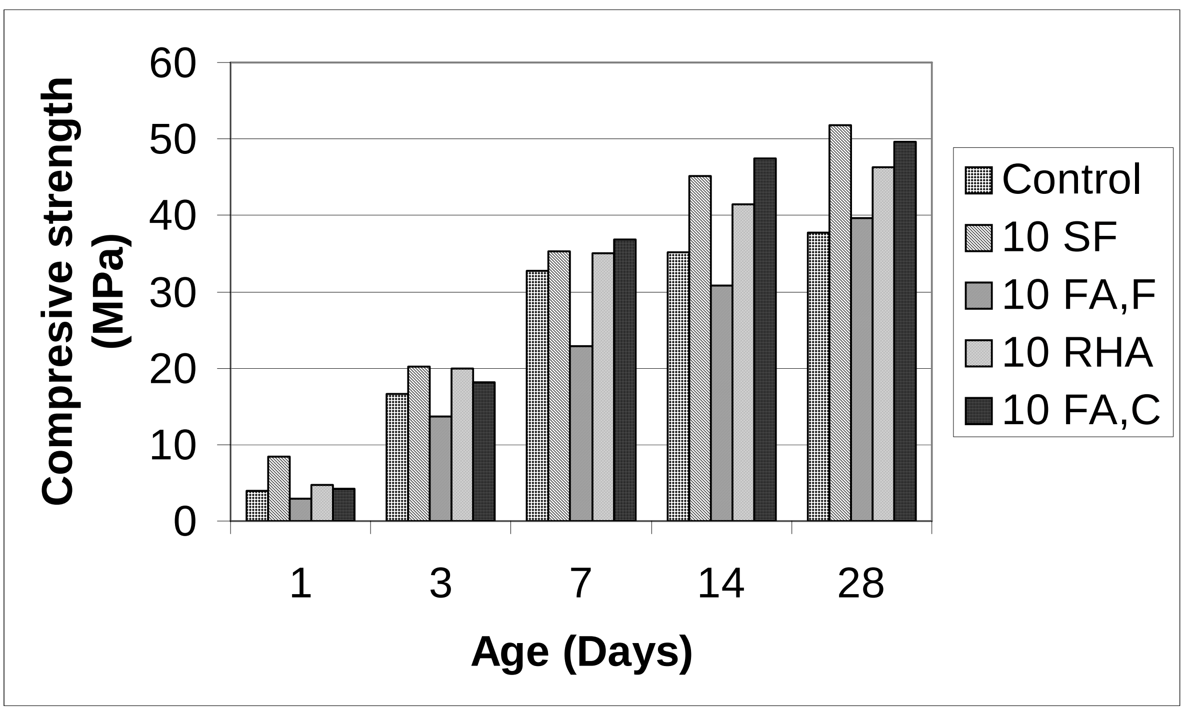

Fig: 12 Compressive strength development of concrete mixtures with age at 10% of mineral admixture

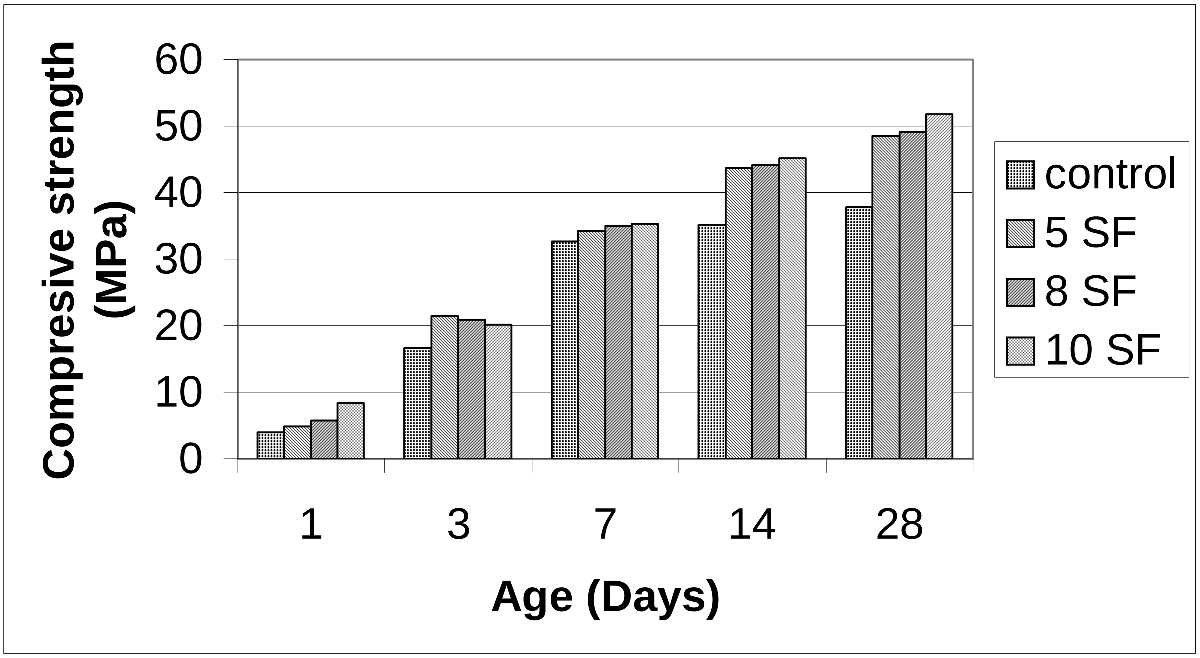

Fig 13 Compressive strength development of concrete mixture with age at different percentage of silica fume

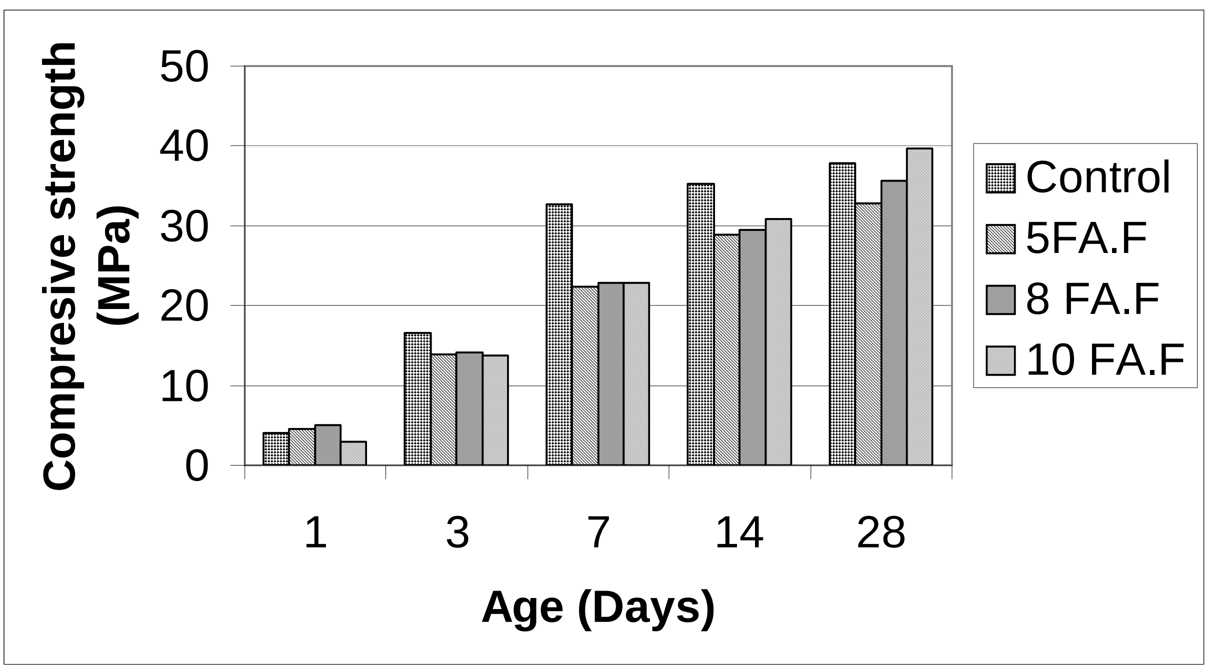

Fig 14 Compressive strength development of concrete mixture with age at different percentage of Fly ash F type.

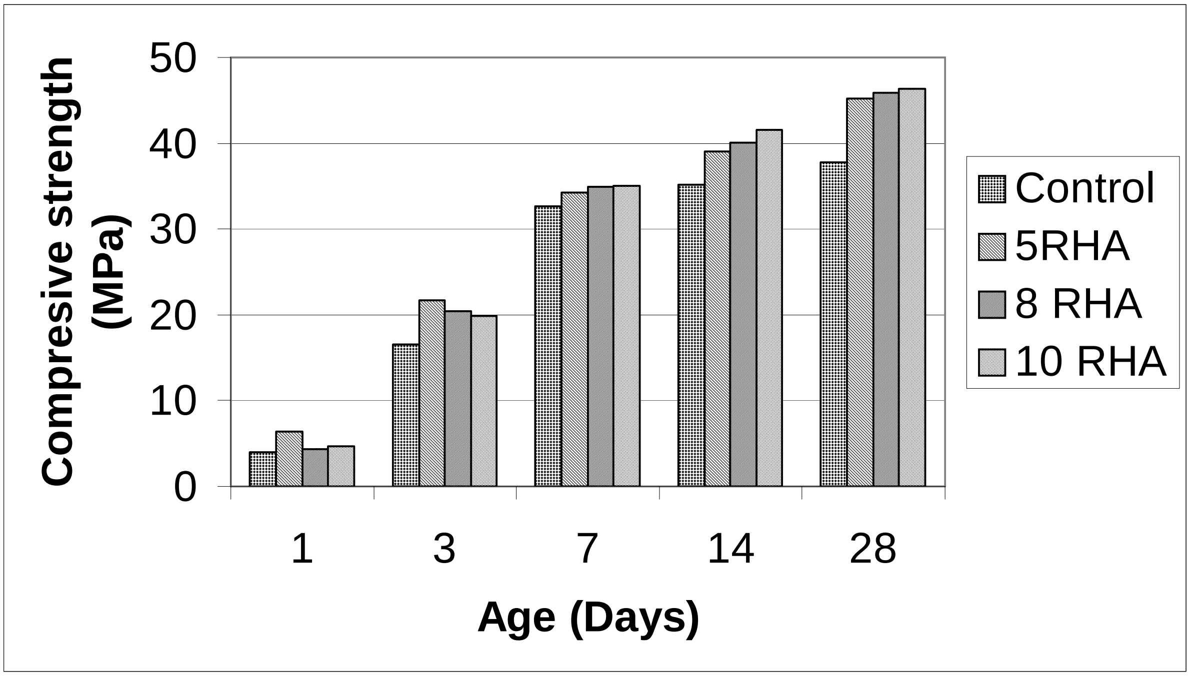

Fig 15 Compressive strength development of concrete mixture with age at different percentage of Rice husk ash

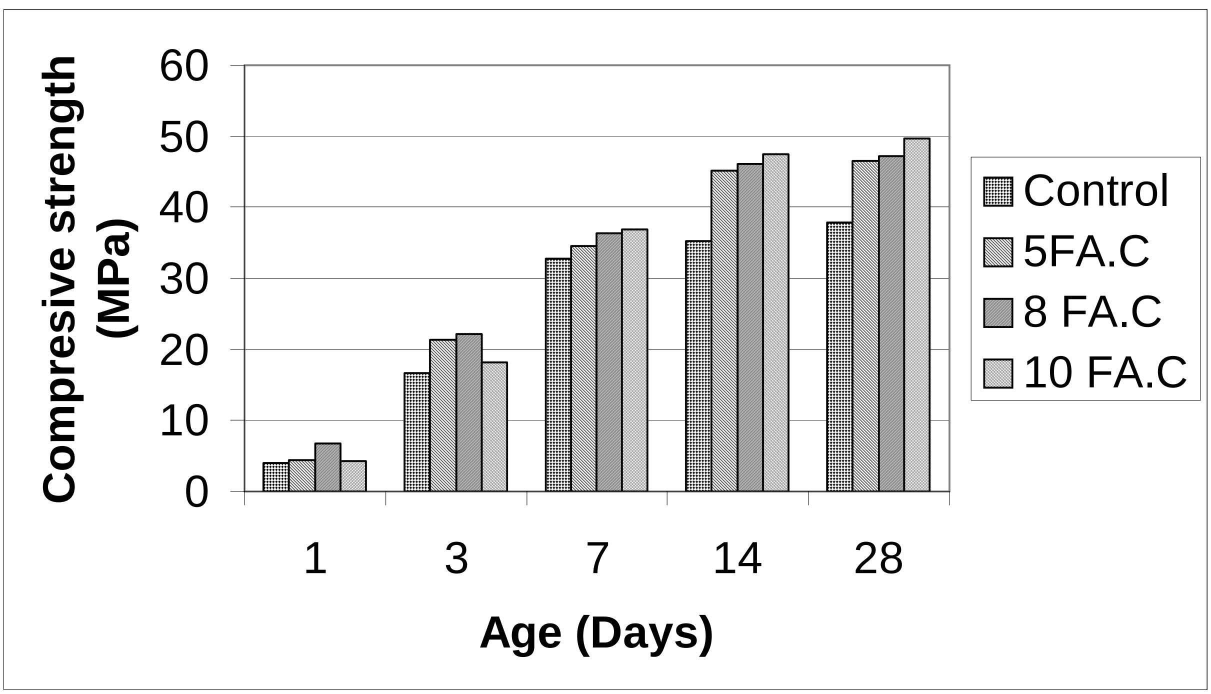

Fig 16 Compressive strength development of concrete mixture with age at different percentage of Fly ash C type

It is obvious from the above figures that,

- At the age of three days compressive strength of RHA mix was equal to silica fume mix and strength of Fly ash C type was even more than the compressive strength of silica fume mix at all replacement levels.
- At the age of 7, 14, and 28 days the compressive strength of RHA & Fly ash C type mix was almost equal to compressive strength of silica fume mix at all replacement levels.
- As the level was increased from 5 to 8 %, 1 day compressive strength was higher for all mineral admixture mixes than control mix, and 1 day compressive strength of RHA & Fly ash C was almost equal to silica fume.
- At 10 % replacement compressive strength of silica fume was better than RHA & Fly ash C type mix at the age of 28 days.
- As the replacement level increases from 5 to 10 %, the Compressive strength of all mineral admixtures mixes increases proportionally except Fly ash F type, whose strength gain is much slower.
- The gain in Compressive strength is, in general, directly proportional to the percentage of the mineral admixture used, except the RHA on which there is not much effect of level of replacement.

4.3.2 Splitting tensile Strength

The results of splitting tensile strength of various mixes are shown in Fig-17.

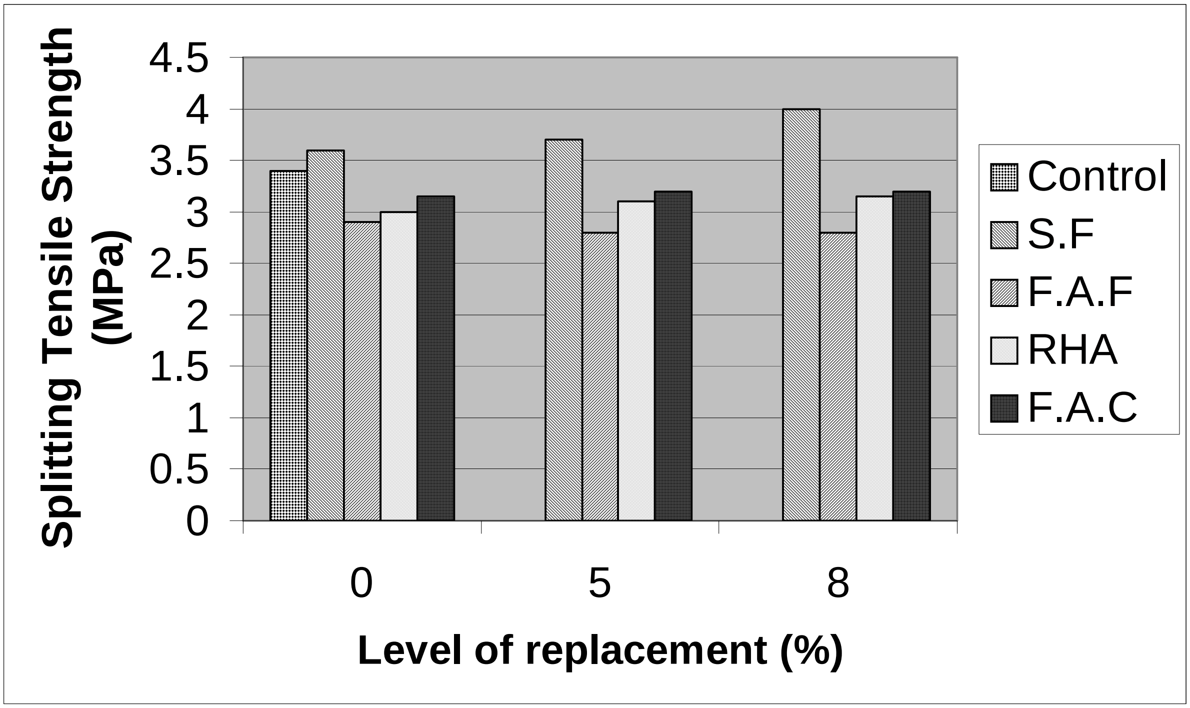

Fig: 17 Splitting tensile strength of different mineral admixture mixes at 5, 8 & 10%.

From the Fig-17, it is evident that,

- Splitting tensile strength of Silica fume was higher than control and other mineral admixture mixes.
- Splitting tensile strength of Fly ash C type was just less than the splitting tensile strength of Silica fume.
- Effect of level of replacement was insignificant on the spitting tensile strength on all mineral admixture mixes.
- Splitting tensile strength of all mineral admixture mixes was higher than control mix.

4.3.3 Ultrasonic pulse velocity

The overall quality of concrete was evaluated by ultrasonic pulse velocity. The result of UPV is given in Table-12. Quality grading of UPV given by IS: 13311, is shown in Table-13.

Table: 12 Ultrasonic pulse velocity

Age (days)		1	3	7	14	28
Control		3.27	4.08	4.44	4.54	4.58
5%	S.F	3.58	4.27	4.60	4.70	4.76
	R.H.A	3.26	4.09	4.49	4.60	4.67
	F.A.F	3.13	4.00	4.43	4.52	4.60
	F.A.C	3.29	4.17	4.44	4.60	4.62
8%	S.F	3.50	4.15	4.41	4.52	4.57
	R.H.A	3.45	4.12	4.48	4.58	4.64
	F.A.F	2.94	3.89	4.32	4.41	4.48
	F.A.C	3.07	4.09	4.46	4.64	4.67
10%	S.F	3.66	4.18	4.43	4.55	4.62
	R.H.A	3.45	4.13	4.47	4.59	4.65
	F.A.F	3.08	3.97	4.28	4.46	4.51
	F.A.C	3.36	4.20	4.54	4.71	4.75

Table: 13 Quality grading of ultrasonic pulse velocity given by IS 13311[46].

Velocity (km/s)	Quality grading
> 4.5	Excellent
3.5 to 4.5	Good
3 to 3.5	Medium
< 3	Doubtful

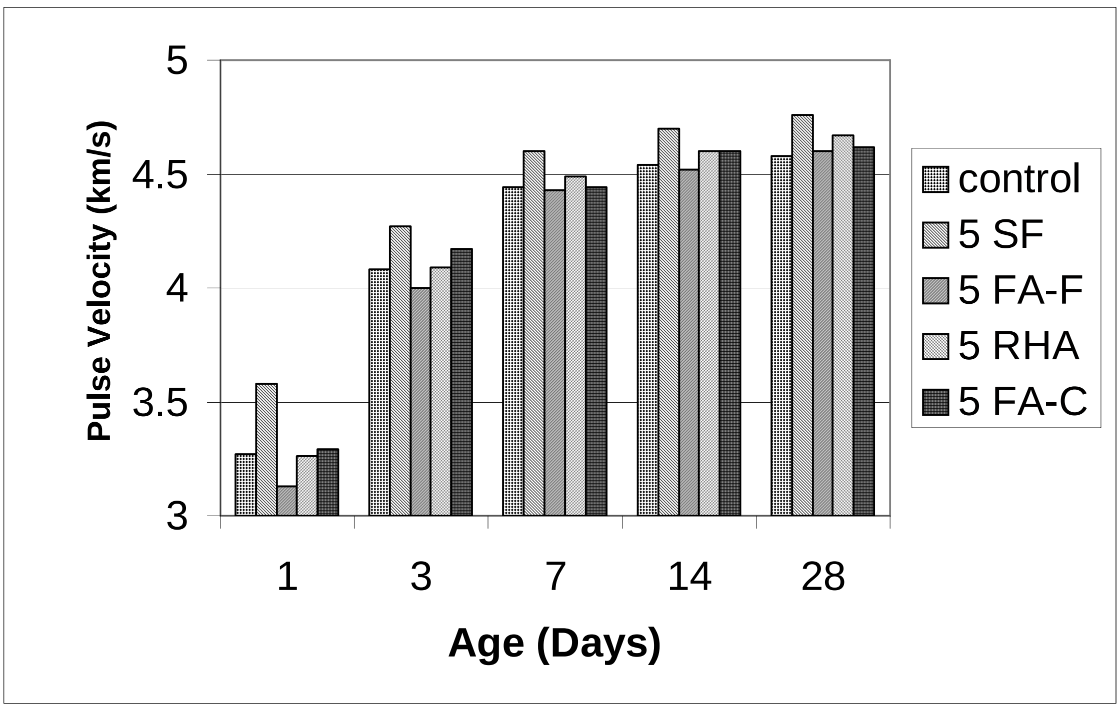

Fig: 18 Ultrasonic pulse velocity with age at 5% of mineral admixture

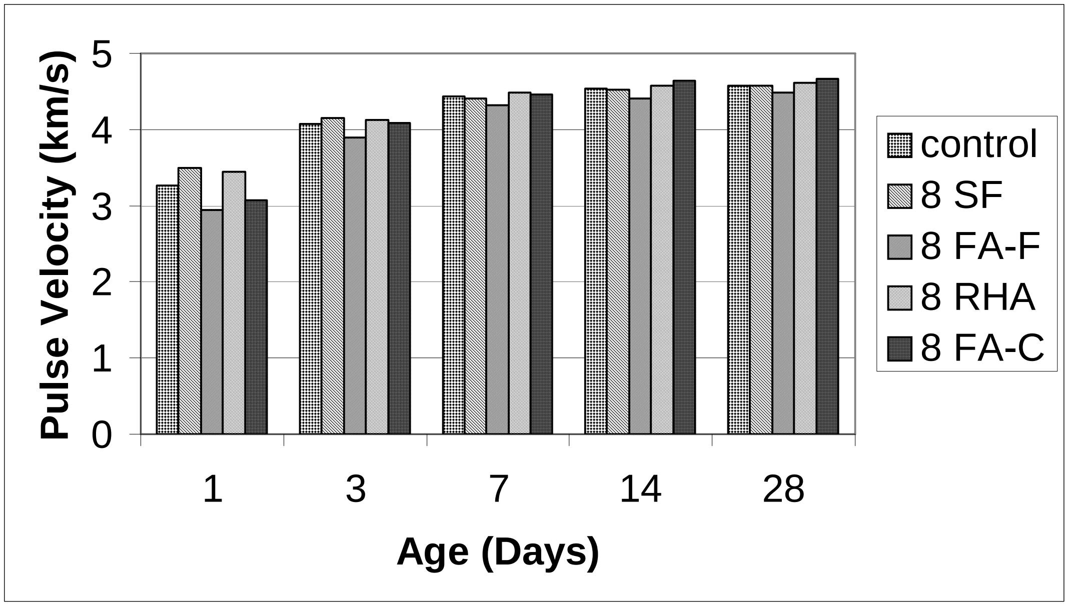

Fig: 19 Ultrasonic pulse velocity with age at 8% of mineral admixture

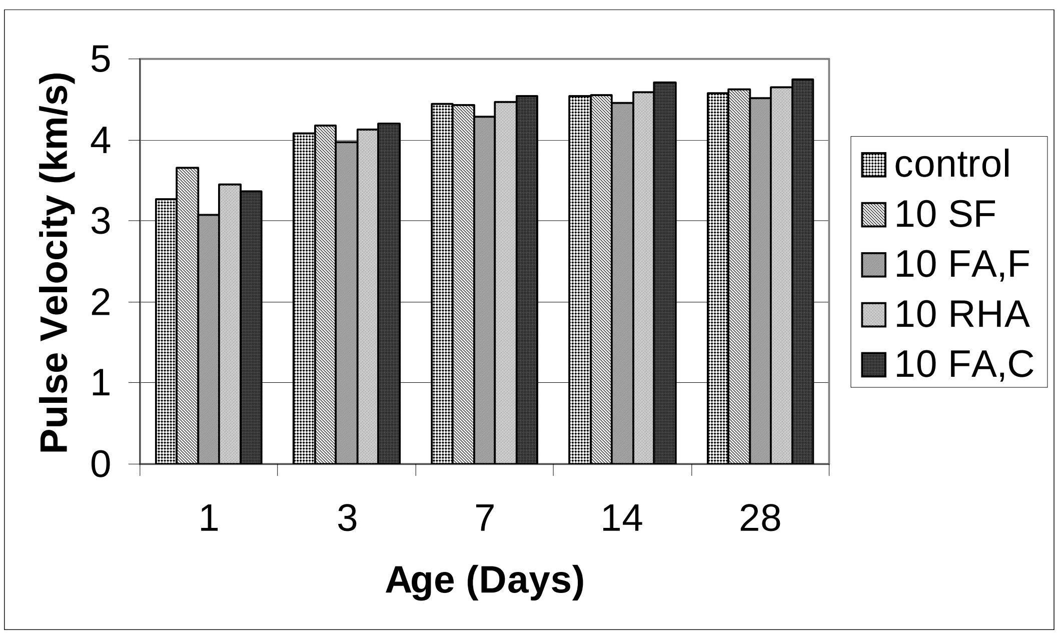

Fig: 20 Ultrasonic pulse velocity with age at 10% of mineral admixture.

From the Table-12, 13 and Fig 18,19,20, it is observed that,

- At the age of 3 days UPV values for all mineral admixture mixes was greater than 4 km/s, which signifies that grading quality was good.
- At the age of 14 days UPV values for all mineral admixture mixes was greater than 4.5 km/s, which signifies that grading quality was excellent.
- At 5% replacement the UPV values of RHA mix was next higher to the UPV values of Silica fume mix.
- At 8% replacement RHA mix performs even better than Silica fume mix.
- At 10% replacement all mineral admixture mixes had almost similar UPV values at the age of 28 days.
- At all level of replacements the increase in UPV values after the age of 14 days is insignificant for all mixes.

4.3.4 Young's Modulus of elasticity

In order to investigate the effect of addition of mineral admixture on Modulus of elasticity (E) value of concrete, the E value at 28 days was determined which is presented in Table-14.

Table: 14 Modulus of elasticity

Mix	Control	Silica Fume			Rice Husk Ash			Fly Ash F			Fly Ash C		
		5%	8%	10%	5%	8%	10%	5%	8%	10%	5%	8%	10%
Modulus of Elasticity (GPa)	32.33	32.4	32.45	32.62	32.23	32.3	32.42	30.3	29.23	29.1	32.6	33.1	33.4

From the Table 14, it can observed that,

- Fly ash F type mix showed slight lower values of Young's modulus of elasticity than control mix, and Fly ash C type mix showed higher values of Young's modulus of elasticity than control mix.
- In general, there appears to be no significant difference in the values of Young's modulus of elasticity of different mineral admixture mixes.

4.3.5 Flexural strength

The flexural strength of various mixes is shown in Table 15

Table: 15 Flexural strength

Mix	Control	Silica Fume			Rice Husk Ash			Fly Ash F			Fly Ash C		
		5%	8%	10%	5%	8%	10%	5%	8%	10%	5%	8%	10%
Flexural Strength (N/mm^2)	3.9	5.4	6.0	6.4	5.0	5.9	6.1	3.9	4.8	5.1	5.0	5.6	5.8

From the above table it can be concluded that,

- At all level of replacements Silica fume had higher flexural strength than other mineral admixture mixes
- RHA and Fly ash C type mixes performs just behind Silica fume mixes in flexural strength values.

4.4 Relationship between UPV and compressive strength of mineral admixture concrete

Relationship between UPV and compressive strength of various mineral admixtures are given in Fig 21 to 24. The Relationship between UPV and compressive strength for silica fume, rice husk ash, fly ash F type and C type developed are valid for 5 to 10 % of replacement level.

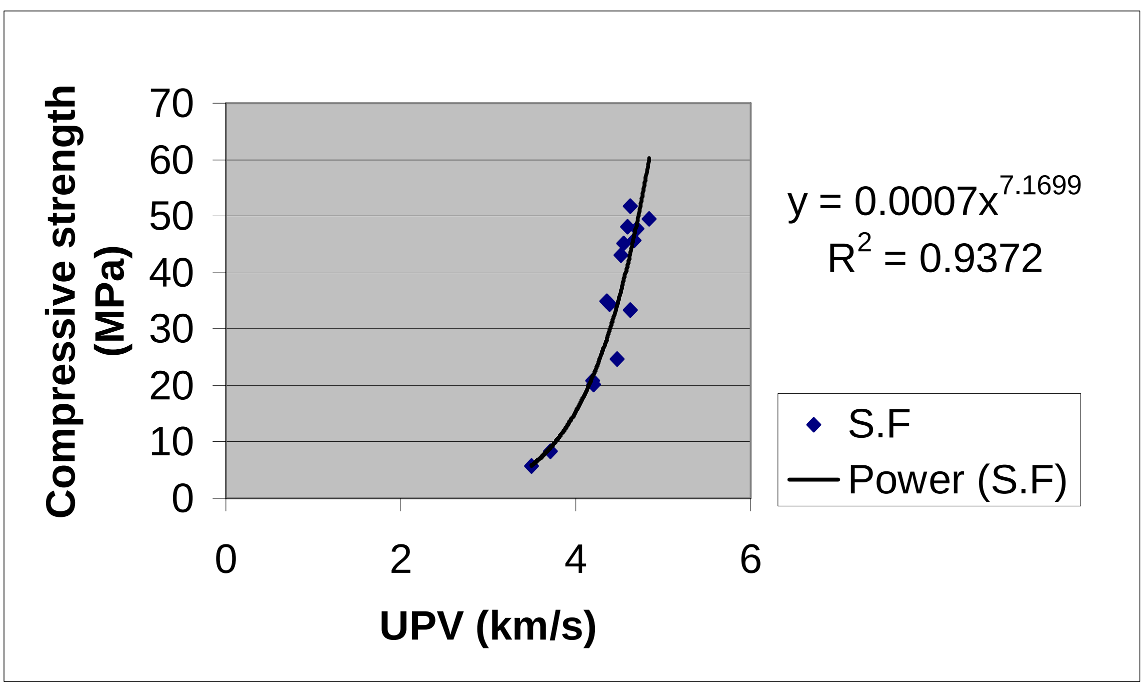

Fig: 21 Relationship between compressive strength and UPV for silica fume

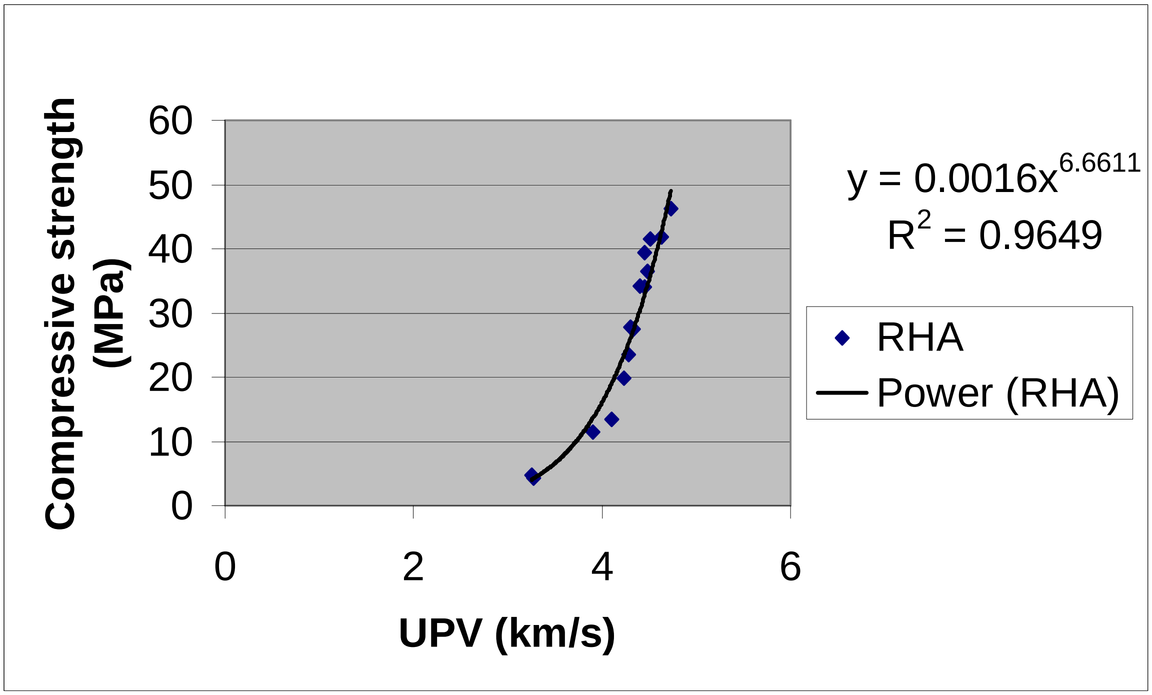

Fig: 22 Relationship between compressive strength and UPV for rice husk ash

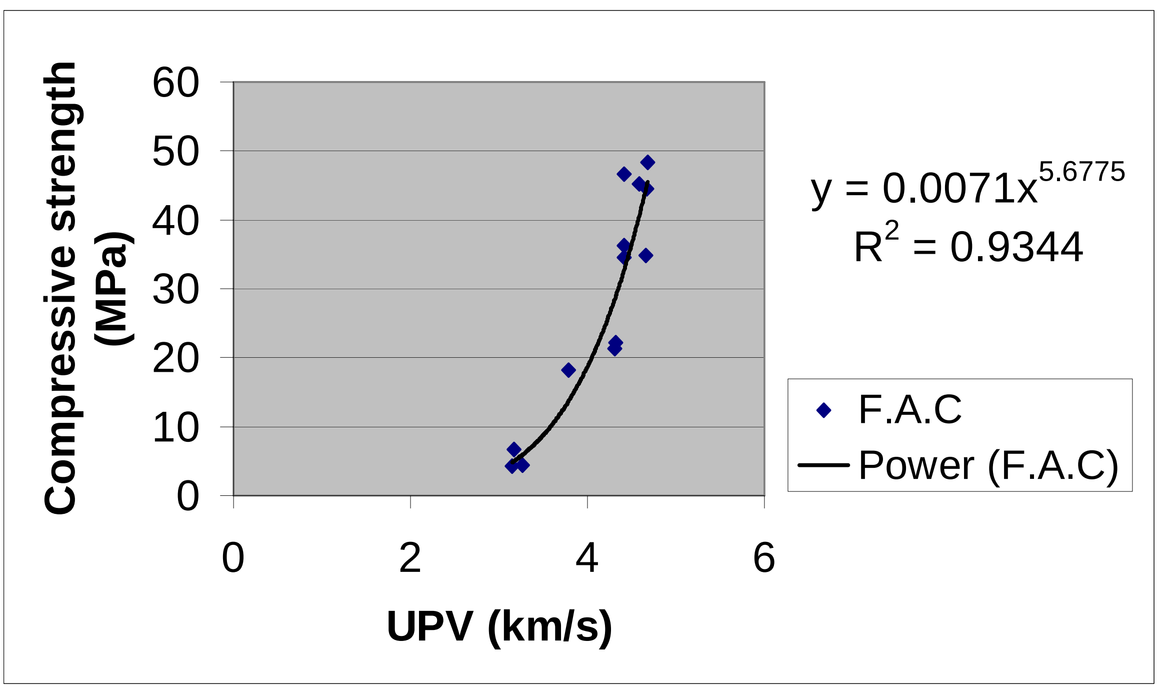

Fig: 23 Relationship between compressive strength and UPV for fly ash C type

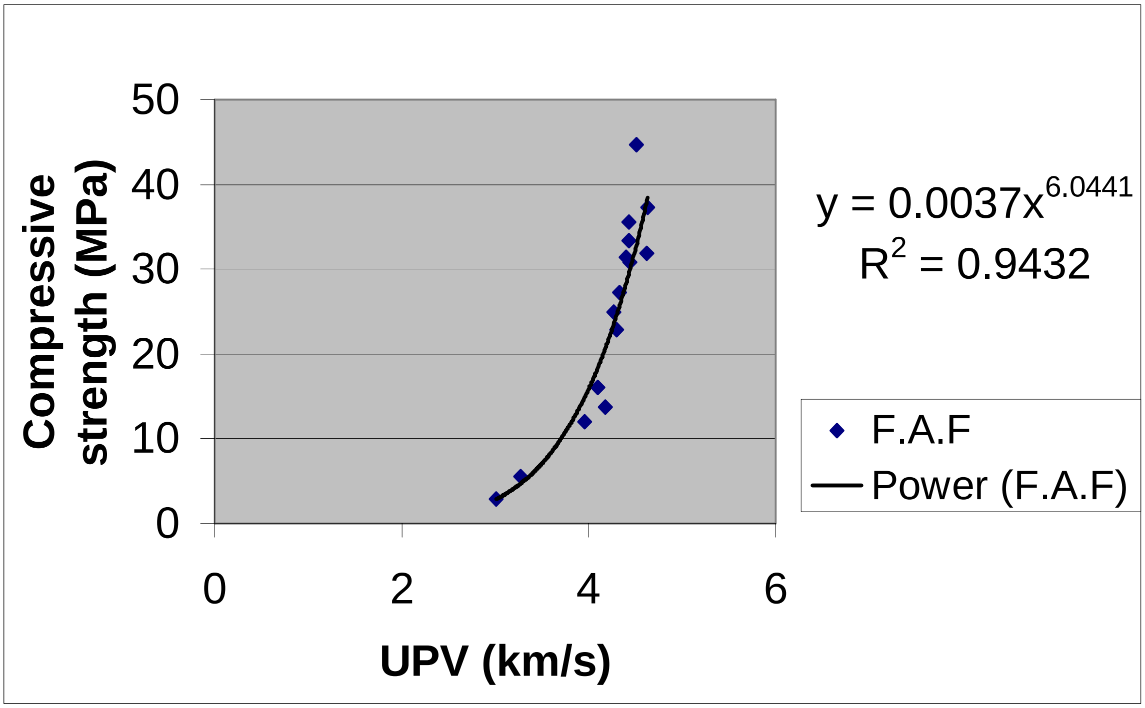

Fig: 24 Relationship between compressive strength and UPV for fly ash F type

4.5 Relationship between compressive strength and splitting tensile strength of mineral admixture concrete

Relationship between compressive strength and splitting tensile strength of various mineral admixtures are given in Fig 25 to 28. The Relationship between compressive strength and splitting strength for silica fume, rice husk ash, fly ash F type and C type developed are valid for 5 to 10 % of replacement level.

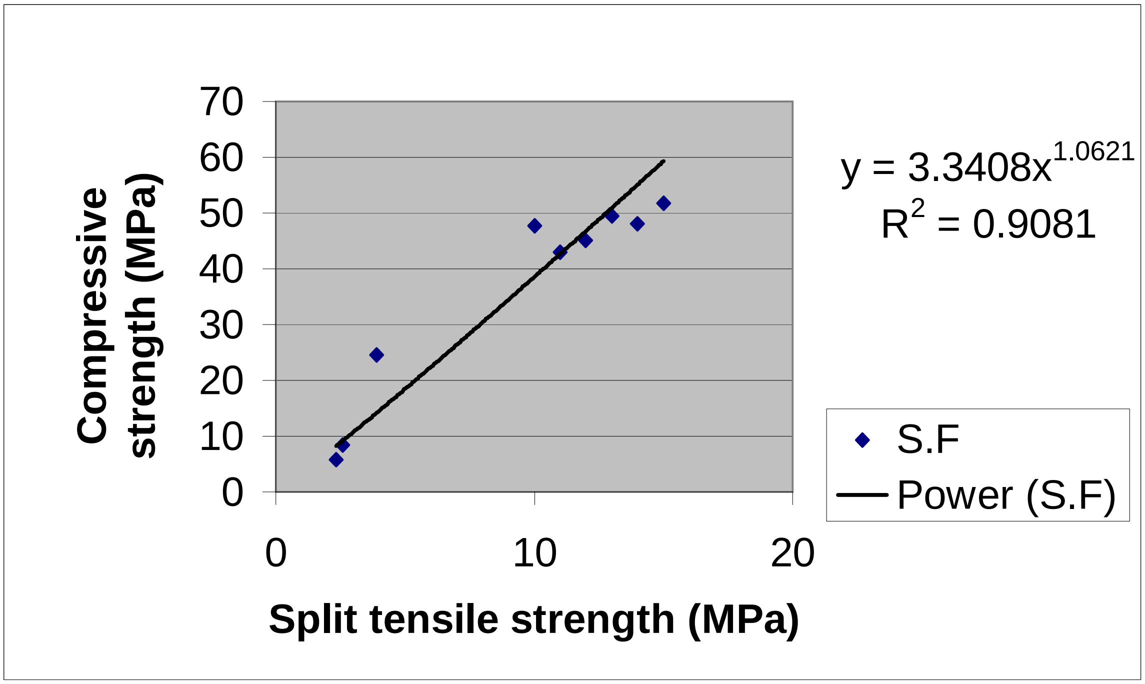

Fig: 25 Relationship between compressive strength and splitting tensile strength for silica fume.

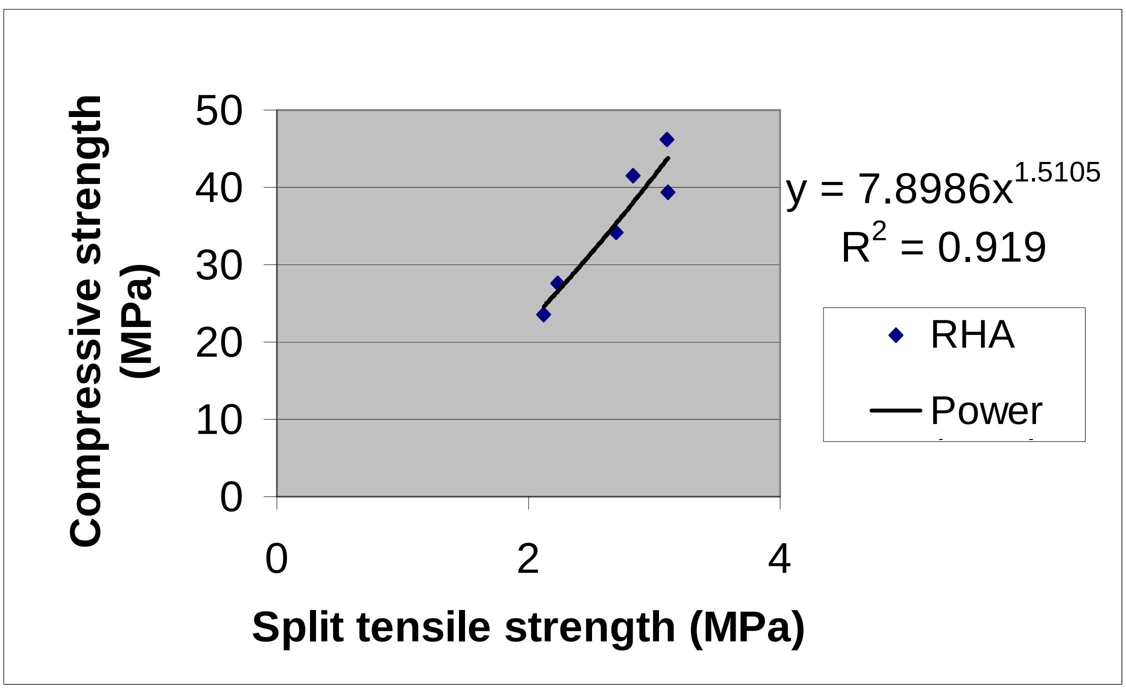

Fig: 26 Relationship between compressive strength and splitting tensile strength for rice husk ash

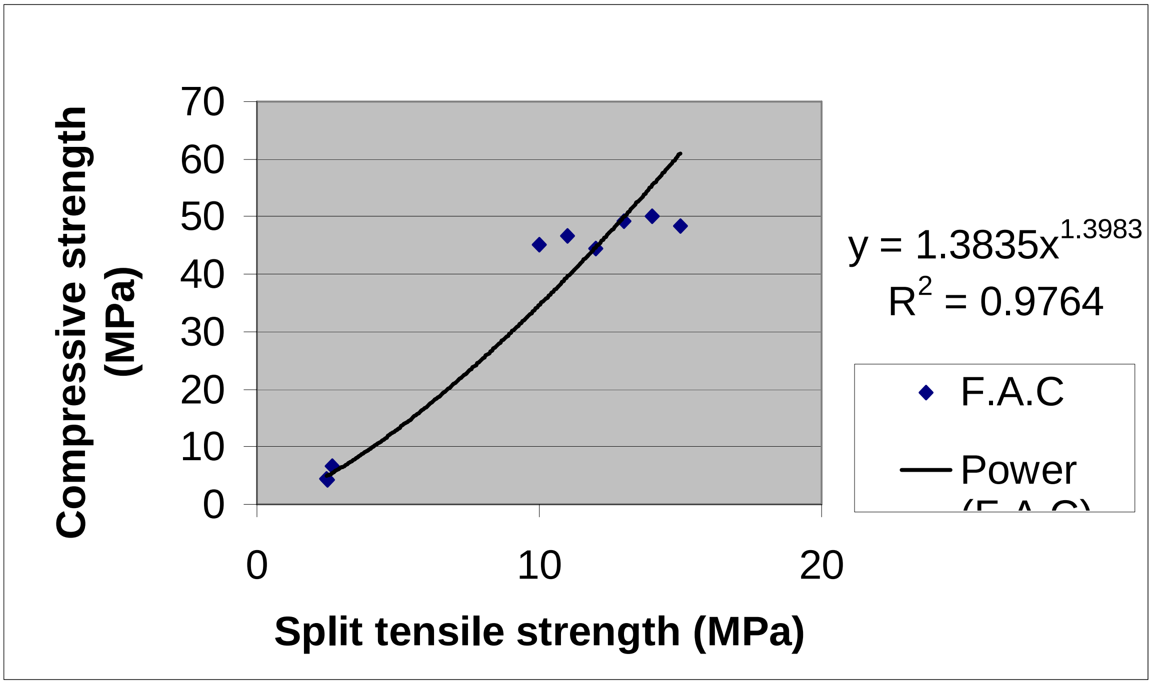

Fig: 27 Relationship between compressive strength and splitting tensile strength for fly ash C type

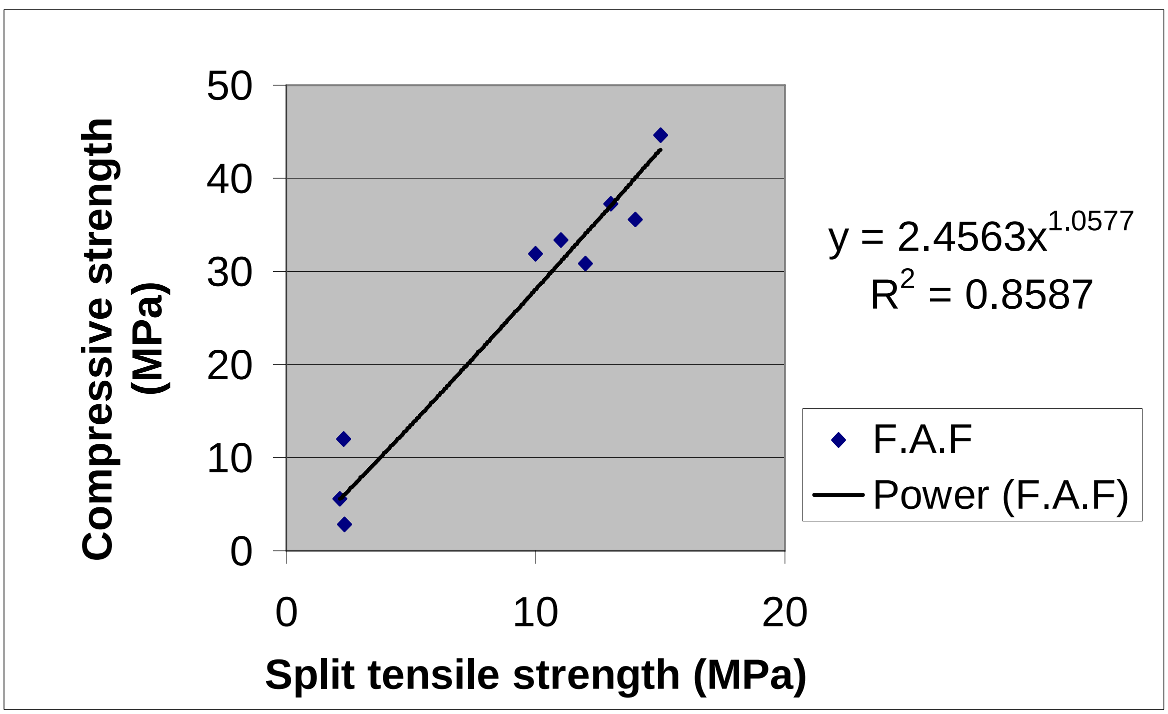

Fig: 28 Relationship between compressive strength and splitting tensile strength for Fly ash F type.

4.6 Relationship between compressive strength and Flexural strength of mineral admixture concrete

Relationship between compressive strength and flexural strength of various mineral admixtures are given in Fig 25 to 28. The Relationship between compressive strength and flexural for silica fume, rice husk ash, fly ash F type and C type developed are valid for 5 to 10 % of replacement level.

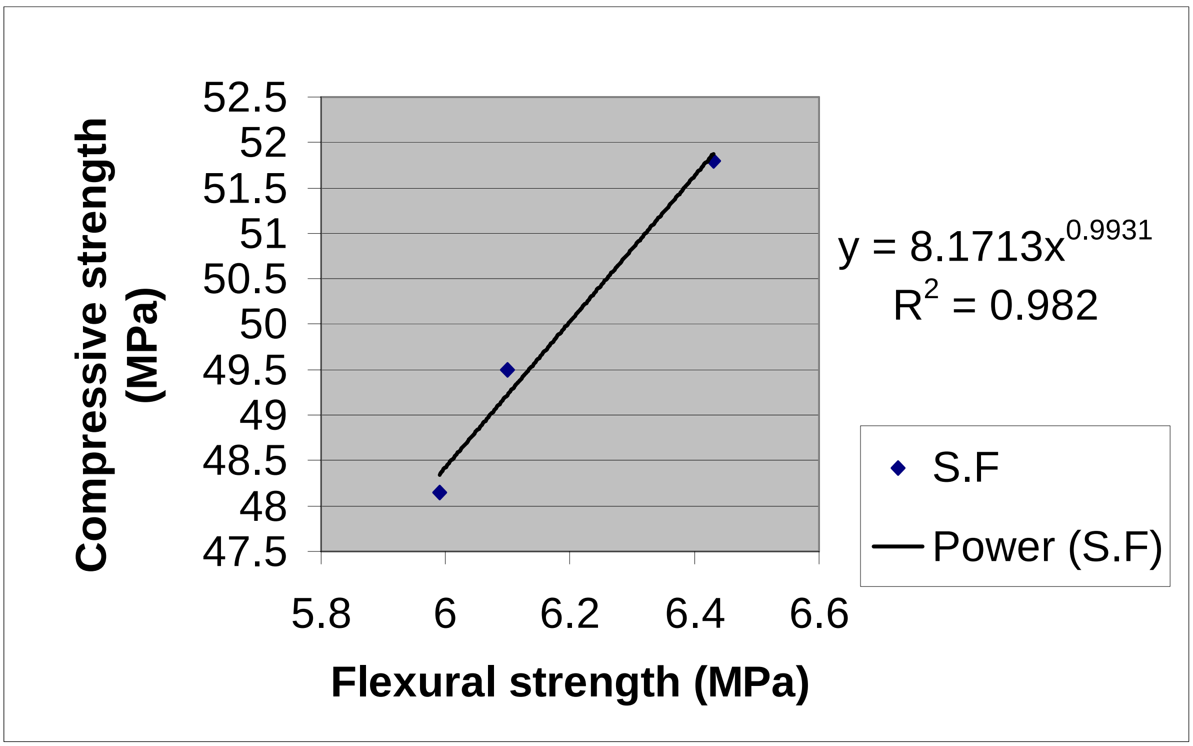

Fig: 29 Relationship between compressive strength and flexural strength for silica fume.

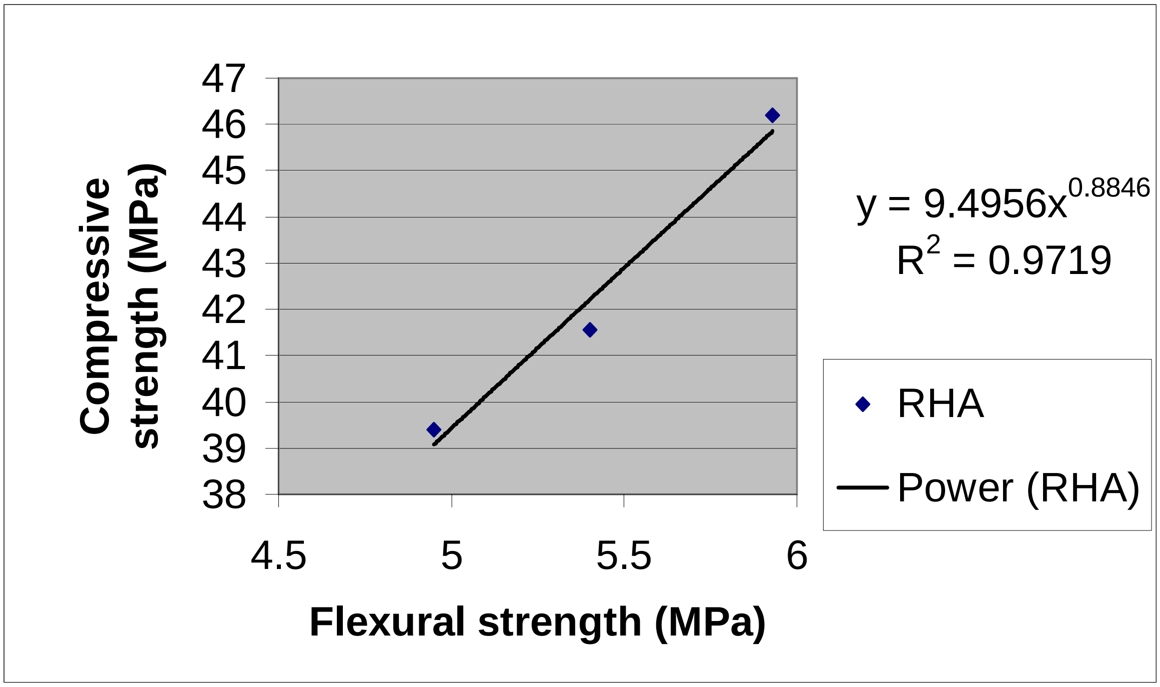

Fig: 30 Relationship between compressive strength and flexural strength for rice husk ash.

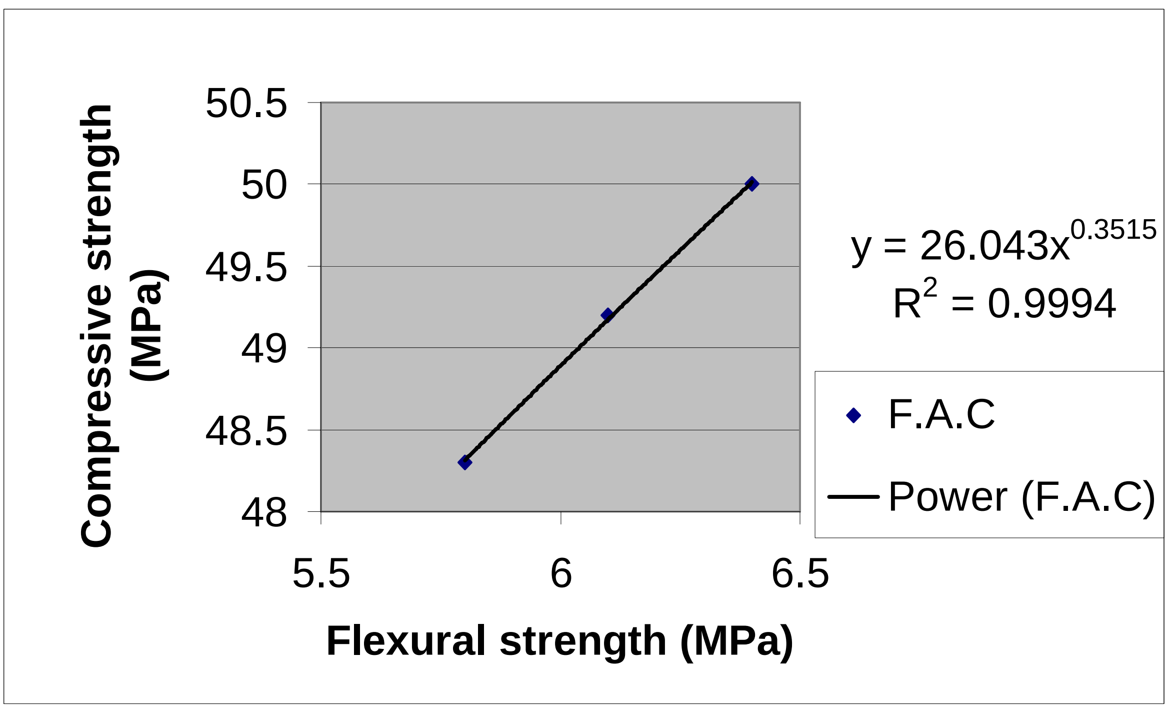

Fig: 31 Relationship between compressive strength and flexural strength for Fly ash C type.

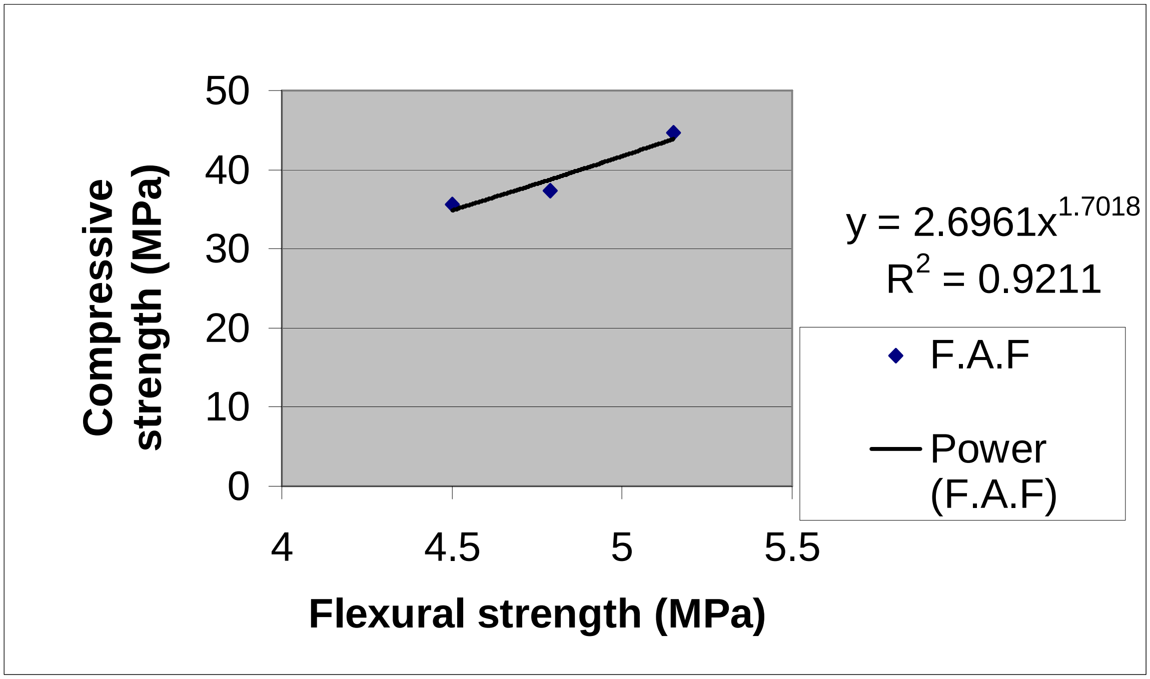

Fig: 32 Relationship between compressive strength and flexural strength for Fly ash F type.

CHAPTER 5

CONCLUSIONS

5.0 General

This chapter covers the conclusions of the present study and the Scope for further work.

5.1 Conclusions

Based upon the result shown in relevant chapter, it can be concluded that silica fume can be suitably replaced by fly ash C type. Various other conclusions of the experiment are as follows

- Early age compressive strength of Fly ash C type mix was higher than Silica fume.
- 28 days compressive strength of RHA and Fly ash C type was at par with Silica fume.
- Splitting tensile strength of RHA mix was just less than the splitting tensile strength of Silica fume.
- Silica fume can be replaced by RHA where flexural strength is main criteria of design.
- Fly ash F type prolongs the setting time of the, thereby it can be used as a retarder in the mixes.
- Fly ash C type and RHA decreases the setting time thus they can be used as an accelerator.
- Modulus of elasticity of all mineral admixture mixes is almost same.
- Density of all mineral admixture mixes is slightly lower than the control mix.
- Relationship was developed between UPV, compressive strength, Splitting tensile strength and flexural strength concrete for different mineral admixture concrete.

5.2 Scope for further work

Further research is needed to establish the long-term durability of concrete containing mineral admixtures. The microstructure properties of concrete are needed to be further researched. Other innovative low cost locally available materials that can be used, as mineral admixtures are required to be developed. Other levels of replacement of cement can be researched. Some tests relating to durability aspect such as water permeability, resistance to the penetration of Chloride ions, corrosion of steel reinforcement, resistance to Sulphate attack, durability in marine environment etc. needs investigation.

REFERENCES

1. Biagini Shondeep, L. Sarkar and Ghosh, S. N, Progress in Cement and Concrete, “Mineral admixtures in cement concrete”, vol. 4, 1993.
2. Swamy, R. N, Concrete Technology and Design,“Cement Replacement Materials”, Vol. 3, 1986.
3. Davis, R. E. “Historical account of mass concrete”, Symp. On Mass Concreting SP-6 American Concrete Institute.
4. Gjorv, O. E. and Loland, K. E. condensed silica fume in concrete, Proc. Nordic Res. Semi.1989.
5. Chai, J., Kiattikomol, K., Sata. V., Leekeeratikul, T., “Use of ground coarse fly ash as a replacement of condensed silica fume in producing high-strength concrete”, Cement and Concrete Research, Vol.34, 2004.
6. Topcu, I. B., and Ali, U., “Effect of the use of mineral filler on the properties of concrete”, Cement and Concrete Research, Vol.33, 2003.
7. Demirboga, R., Turkmen, I.,and Mehmet, B. K., “Relationship between ultrasonic velocity and compressive strength for mineral-admixtured concrete”, Cement and Concrete Research, Vol.20, 2004.
8. M. J. Shannag, “High strength concrete containing natural pozolana and silica fume”, Cem. Concr. Compos.Vol. 22, 2002.
9. Chiara, F. Ferraris, Karthik, H, and Russell, “The influence of mineral admixtures on the rheology of cement paste and concrete”, Cement and Concrete Research, Vol. 31, 2001.
10. George, J. Z. Xu, Daniel, F. Watt, and Peter, P. Hudec, “Effectiveness of mineral admixtures in reducing ASR expansion”, Cement and Concrete Research, Vol. 46, 2000.

11. Stoitchkov, V., Abadijiev. P., Lilkov, V., and Vasileva, V., "Effect of the pozzolit active mineral admixture on the properties of cement mortars and concretes", Cement Concrete Research, Vol. 26, 1996.

12. Babu, Ganesh. K., Prakash, Surya. P .V., "Efficiency of silica fume in concrete", Cement Concrete Research, Vol. 25, 1995.

13. Mennon, A. H., Radin, S. S, Zain, M. F. M., "Effect of mineral and chemical admixtures on high strength concrete" Cement Concrete Research, Vol. 32, 2002.

14. Brooks, J. J, Johari, M. M, and Mazloom, M., "Effect of admixtures on the setting times of high-strength concrete", Cement Concrete Research, Vol. 22, 2000.

15. Hassan, K. E, Cabrera, J. G, and Maliehe, R. S., "The effect of mineral admixtures on the properties of high performance concrete", Cement Concrete Research, Vol. 22, 2000.

16. Zain, M. F, and Radin, S. S, "Physical properties of high performance concrete with admixtures exposed to a medium temperature range 20^{o}C to 50^{o}C", Cement Concrete Research, Vol. 30, 2000.

17. Tumidajski, P. J, and Chan, G. W, "Durability of high performance concrete in magnesium brine", Cement Concrete Research, Vol. 26, 1996.

18. www.fhwa.com (United States Department Of Transportation Federal Authority Administration.)

19. Mauro, M. Tashima, Carlos, A. R. Da Silva, Jorge, L. Akasaki, and Michele Beniti Barbosa, "Possibility of adding rice husk to the concrete", Conference, FEIS/UNESP, Brazil,2001.

20. Malhotra, V. M, and Mehta, P. K, Advances in Concrete Technology, "Pozzolanic and Cementitious Materials", Vol.1, 1996.

21. Ronne, M, "Effect of condensed silica fume and fly ash on compressive strength development of concrete", proc. of third Int. conf. On fly ash, silica fume, slag and natural pozzolan in concrete, Vol. 1, 1989.
22. Austin, S. A, and Robins, P. J, "Development of a mix design method for Portland cement concrete containing a blend of fly ash and silica fume", proc. Of third Int. conf. On fly ash, silica fume, slag and natural pozzolan in concrete, Vol. 1, 1989.
23. Roy, D. M, " Fly ash and silica chemistry and hydration", proc. of third int. conf. on fly ash, silica fume, slag and natural pozzolan in concrete, Vol. 1, 1989.
24. ASTM C 618-93 Specification for Fly Ash and Raw or Calcined Natural Pozzolana for Use as a Mineral Admixture in Concrete
25. E. Angsuwattana, C. Jaturapitakkul, K. Kiattikomol, A. Siripanichgorn, T.Ketratanabovorn, "Use of classified Mae Moh fly ash in high strength concrete", paper of the sixth CANMET/ACI International conference on fly ash, silica fume, slag and natural pozzolans in concrete, 1998.
26. S. Slanicka, "The influence of fly ash fineness on the strength of concrete", Cement Concrete Research, Vol. 21, 1991.
27. M. N. Haque, O. Kayali, "Properties of high strength concrete using a fly ash", Cement Concrete Research, Vol. 28, 1998.
28. E. E. Berry, R. T. Hemmings, W. S. Langley, G. G. Carrette, "Beneficiated fly ash: hydration, microstructure, and strength development in Portland cement", proceeding of the first international conference on fly ash, silica fume, slag, and natural pozzolana in concrete, SP-114, 1989.

29. K. Kiattikomol, C. Jaturapitakkul, “A study of ground coarse fly ashes with different fineness from various sources as pozzolanic materials”, Cement Concrete composites, Vol. 23, 2001.

30. S. Songpiriyakij, C. Jaturapitakkul, “A study on ground Mae Moh fly ash as a pozzolan for increasing concrete strength”, KMITT research division journal 18. 1995.

31. J. Paya, J. Monzo, M. V. Borrachero, E. Peris-Mora, “Mechanical treatment of fly ashes”, Cement Concrete Research, Vol. 25, 1995.

32. J. Paya, J. Monzo, M. V. Borrachero, E. Peris, E. Glonzalez-lopez, “Mechanical treatment of fly ashes: part 3, studies on strength development of ground fly ashes-cement mortar”, Cement Concrete Research, Vol. 27, 1997.

33. H. A. W. Cornlissen, R. E Hellewaard, J. L. J. Vissers, “Processed fly ash for high performance concrete”, proceeding of fly ash, silica fume, slag, and natural pozzolana in concrete, SP 153-4, American Concrete Institute. 1995.

34. Ganeshan, K., Rasagopal, K., Thangavel, K., Sarawathi. V. And Selvaraj, R. “Rice Husk Ash”, Journal, Indian Cement Review, May-04.

35. Dass, A., and Mohan, R. (1979). “ Prospects and problems in the production of cementitious materials from rice husk”, Proc. UNIDO/ESCAP/RCTT Workshop on RHA cements.

36. Paillere, A. M., and, S., “Application of admixture in concrete”. 1985.

37. ASTM C 1240-98 Specification for Silica Fume for Use as a Mineral Admixture in Hydraulic Cement Concrete, Mortar and Grout.

38. Kumar, Rakesh., Kumar, Ram. , And Rao, B. "Innovative non-conventional material for cement concrete roads", National conference on modern cement concrete and bituminous roads, Dec18-20, 2003.

39. Demirbas, A., "A discussion of the paper 'Performance of rice husk ash produced using a new technology as a mineral admixture in concrete' by M. Nehdi, J. Duquette, and A. EL Damatty", Cement Concrete Research, Vol. 34, 2004.

40. Neville, A. M., and Brooks, J. J, Concrete Technology, low price edition, Pearson education Ltd. Third reprint 2003.

41. I S: 383-1970(second revision), Specification for Coarse and Fine Aggregate from Natural Sources for Concrete.

42. I S Handbook on concrete mixes SP: 23-1982.

43. ASTM C 1240-99Specification for Silica Fume for Use as a Mineral Admixture in Hydraulic Cement Concrete, Mortar and Grout.

44. I S: 8112-1989 Specifications for 43 Grade Ordinary Portland Cement

45. I S: 516-1959 Methods of Tests for Strength of Concrete.

46. I S: 13311 Part 1: 1992 Non Destructive Testing of Concrete Method of Test, Ultrasonic Pulse Velocity.