A Study of Acid Resistance of Concrete By Using Mineral Admixtures

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ABSTRACT

Concrete is a widely used construction material for various types of structures due to its structural stability and strength. The usage as well as the behavior of durability of concrete structures, built during the last first half of the century with Ordinary Portland Cement (OPC) and plain round bars of mild steel, the ease of procuring the constituent materials. . The Ordinary Portland Cement (OPC) is one of the most important ingredients used for the manufacture of concrete and has no alternative in the civil construction industry. Unfortunately, production of cement involves emission of large amounts of carbon-dioxide gas into the atmosphere, it causes greenhouse effect and the global warming, and hence it is replacement of some other material, like mineral admixtures (Silica fume and Fly ash and GGBS).Acidic attack is one of the world's wide problems that may cause gradual but severe damages to and by sulphuric acid produced from either sewage or sulpur dioxide present in the atmosphere of industrial cities. Most acid attacks concrete by a process of dissolution and leaching, converting the constituents of the cement paste into readily soluble salts. Acidic attack is one of the world's wide problems that may cause gradual but severe damages to and by sulphuric acid produced from either sewage or sulpur dioxide present in the atmosphere of industrial cities. Most acid attacks concrete by a process of dissolution and leaching, converting the constituents Acidic attack is one of the world's wide problems that may cause gradual but severe damages to and by sulphuric acid produced from either sewage or sulpur dioxide present in the atmosphere of industrial cities. Most acid attacks concrete by a process of dissolution and leaching, converting the constituents of the cement paste into readily soluble salts. The amount of attack depends on the of the cement paste into readily soluble salts.

Keywords:Acid Attack, Fly Ash, Global Warming, Replacement of Concrete.

INTRODUCTION

Every concrete structure should perform its intended function through the expected life time of the structure, irrespective of external exposure conditions. The ability of concrete to withstand any environmental condition that may result in premature failures or several damages is a major concern to the engineering professional.

In this study, the different admixtures were used to study their sole and combined effects on the resistance of concrete in addition to their effects on mechanical and durability properties by the replacement of admixtures by 5%, 10%, 15%& 20% by the weight of cement.

The weakening achieve of acid media on cement based constructions has become a distressing problem all more than the world. These media generally occur as acidic rains and mist, industrial and urban sewages and acidic ground water. The extent of attack depends not only on the type of concentration of attacking acid, but also on the properties of the material including the cement used. Acid attack is one of the phenomena that may disintegrate concrete structures depending on the type and concentration of acid. Certain acids such as oxalic acid are considered as harmless, while weak solutions of some acids have insignificant effects. Even though acids normally attack and leach away the calcium compounds of the paste, they may not willingly attack confident aggregates, such as siliceous aggregates calcareous aggregates often react willingly with acids.

Many researchers in the past decades covered the sulphates attacks from different aspects to improve the resistance of concrete to acid attacks, many researchers used mineral additives such as Fly ash and Silica fume. The use of these artificial pozzolanas can achieve not only economical and ecological benefits, but technical benefits as well. however, it is also well known that mineral additives may decrease the premature might of concrete.

REVIEW OF LITERATURE

A. General

In the last decades many experiments and researches have been done to investigate the effects of concrete influenced by the acidic attacks and the impact of chemicals on cementization. Literature relating to blended cements in concrete and the effect of curing regimes on this concrete are numerous. In this chapter, only literature concerning those aspects related to this particular research i. e. the mechanical and durability properties of hardened concrete incorporating metakaolin, fly ash, silica fume and slag as a mineral admixture added to concrete made with the Portland cement are discussed. This survey also includes the effect of curing conditions on the various properties of concrete.

N.I. Fattuhi and B.P Hughesexamined the effect of acid attack on concrete with differentadmixtures or protective coatings were used in an attempt to improve the chemical resistance of a standard concrete mix. The admixtures included pulverized fuel ash, styrene butadiene latex, water reducing, super plasticizing, retarding and water-proofing agents. Coatings, with PMMA and polymer emulsions, were brushed onto hardened concrete cubes. Forty I02 mm cubes containing the different admixtures or coatings were immersed in a channel with a solution of continuously flowing sulphuric acid. Twenty cubes contained centrally placed short mild steel bars. The changes in weight with time for each cube were determined continuously up to 172 days exposure, and the situation of the reinforcement was visually examined at termination. The effects of admixture additions on the workability and compressive strength of the concrete were also investigated.

The paper is alert on the study of chemical decomposition of concrete samples consequential in increased leakage due to sulphate environment. Sulphate aggressive atmosphere was represented by 0.5 % solution of H2SO4 (pH value of 0.99) and 0.5 % Al2 (SO4)3 solution (sulphate concentration of 3,000 mg/L). Distilled water used as orientation medium as proper escaperecreation environment. Concrete composites with/without coal fly ash cement substitution were used for the experiments. The laboratory experiments proceeded through the 60 days. No significant differences in chemical composition of concrete samples before and after the experiment were observed except for the iron, aluminium and silicon concentrations. abbreviation the results of chemical symphony of the liquid media previous to and after the experiments, the preliminary concentrations of Ca in leachates have been enlarged 2.0 to 3.5, 16.4 to 18.3 and 4.1 to 5.1 times for distilled water, sulphuric acid and aluminiumsulphate, respectively. In point of vision of calcium escape, the concrete examplewith fly ash was inclusive to be more disparate to sulphuric acid in correlation to the model without fly ash.

The primary concentrations of Si have been improved 1.9 to 1.91, 3.2 to 3.3 and 1.89 to 1.92 times for distilled water, sulphuric acid and aluminiumsulphate, respectively. In casing of all fluid media the growing character of pH values have been noticed. The most evident increase of pH value to the alkali expanse was experiential in case of distilled water (more than 1.8 times for both types of composites).

AliAllahvedi, Franti.EK, Kvaratested the performance on Mechanism of nitric acidattack on hardened paste of geopolymeric cements, in addition to the leaching process in which the soluble contents of the material (i.e. sodium and calcium) are depleted and replaced by H+ or H3O+ ions from solution along with an attack by acidic protons on polymeric Si-O-Al bonds resulting in the formation of a partially dealkalized and decalcified Si-, Al-rich residue, consists of an electrophilic attack by acid protons on polymeric Si-O-Al bonds resulting in the ejection of tetrahedral aluminium from the aluminosilicate framework. The structure vacancies are regularly re-occupied by silicon atoms consequential in the pattern of andamaged highly siliceous construction that is comparatively hard but weak. The ejected aluminium converted to octahedrally coordinated aluminium mostly accumulates in the intraframe work space.

MATERIALS AND METHODS

In this chapter, the materials and methods described together with their properties. In this the tests carried out on different concrete mixes, curing regimes, mix proportions and casting of specimens are discussed.

Ordinary Portland Cement (53 grade)

The cement used throughout the test programme was Ordinary Portland Cement (OPC) of 53 grade confirming to IS 4031:1988 was used in the present study. The specific gravity of cement is taken as 3.15.

Fine Aggregate

The most common ingredient of sand is silica, usually in the form of quartz, which is chemical inert and hard.
The sand is free from clayey matter, silt and organic impurities etc. therefore used as a fine aggregate in concrete.

Coarse Aggregate

Coarse aggregate is tested for specific gravity, in accordance with IS: 2386-1963. The maximum size of 20 mm is used as a coarse aggregate in concrete. For most of building constructions, the coarse aggregate consists of gravel or crushed stone up to 20mm size.

Fly ash (FA)

Fly ash is a by-product of the combustion of pulverized coal in power stations. It is a solid material extracted by electrostatic and mechanical means from the flue gases of furnaces fired with pulverized bituminous coal. During production of FA, the coal passes through the high temperature zone in the furnace and the carbon and volatile matter are burned off, whereas most of the mineral impurities, such as clays, quartz, and feldspar melt at high temperature. The fused matter is quickly transported to low-temperature zones, where it solidifies as spherical particles of glass. Some of the mineral substance agglomerates forming bottom ash, but most of it flies out with the flue gas stream and is called "fly ash". This ash is subsequently removed from the gas by mechanical separator, electrostatic precipitators. Its main constituents are SiO2, AL2O3 and Fe2O3 with smaller quantities of other metal oxides.

Due to its unique mineralogical and granulometric characteristics, fly ash generally does not need any processing before use as a mineral admixture. Bottom ash is much coarser, less reactive and therefore requires fine grinding to develop a pozzolanic property. Average worldwide utilization of fly ash is about 15%, whereas in India, its utilization is form 2 to 5% only. In the present study Fly ash is collected from RTPP. It is conformed to grade1 of IS: 3812-1981.

The physical properties of fly ash are shown in the following table 1

Table:1 Physical properties of fly ash

S.NO	DESCRIPTION	
1	Specific Gravity	2.5
2	Physical Form	Powder
3	Colour	Dark grey

Silica fume Silica fume is a by-product of silicon or Ferro-Silica industry and is 100 times finer than cement. A silica fume is also referred to as micro silica or strong silica fumes. It consists of amorphous silica and has high reactivity towards lime. Thesubstitute level of silica fume is generally lowatabout 10%. When SF is usedinconcrete mix, its beginning affects the physical understanding of the system, particularly near the aggregate surface where porosity exists. Silica fume starts reacting at the early stage of hydration procedure. The pozzolanic action of silica fume reduces considerably the quantity and size of “CH” crystals in hydrated cement paste. This phenomenon along with low W/C ratio reduces the thickness of conversion zones and thus the preferential orientation of CH crystals is significantly reduced. All these result in more uniform, stronger conversion zone potential of micro cracking.

Silica fume, also known by other names, such as condensed silica fume, volatilized silica, or simply as micro silica, is a by-product of the induction arc furnaces in the silicon metal and ferrosilicon alloy industries. Reduction of quartz to silicon at temperatures of up to 2000°C produces Compared to normal Portland cement and typical fly ashes, condensed silica fume samples show particle size distributions that are two orders of magnitude finer. This is why on the one hand the material is highly pozzolanic, but on the other it creates problems of handling and increases the water requirement in concrete appreciably unless water reducing admixtures are used. The by-product from the production of ferrosilicon alloy with 50 percent silicon contains much lower silica content and is less pozzolanic. The silica fume used in all concrete mixes was obtained from Elkem Materials Limited. The chemical composition information are given. It can be seen that the silica fume contains 85% silicon dioxide. The physical properties of Silica fume are shown in the following table2

Table: 2 Physical properties of Silica fume

S.NO	DESCRIPTION	
1	Specific Gravity	2.2
2	Physical Form	Powder
3	Colour	Grey

Water

Water is important ingredient of concrete as it actively participates in the chemical reaction with cement. Since it helps to structure the strength giving cement gel, the quantity and quality of water is essential to be looked into very carefully. The specific gravity of water is taken as 1.00.

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METHODS

The normal consistency of cement sample prepared with replacement of different mineral admixtures ranging from 5, 10, 15 and 20%. Both the initial and final setting time of cement sample prepared with replacement of different mineral admixtures ranging from 5, 10, 15 and 20% and are compared with ordinary cement. If the difference is less than 30 minutes, the change is considered to be insignificant and if it is more than 30 minutes, the change is considered to be significant.

The sieve analysis of fine and coarse aggregate which is used for the present experimental work.
The soundness of the cement with the partial replacements of mineral admixtures are determined.
The workability test of fresh concrete was measured by the partial replacements of mineral admixtures.

The average compressive strength of concrete of at least three cubes (150*150*150 mm) prepared with mineral admixture under consideration is compared with that of three cubes prepared with ordinary cement (for 3 days, 7 days, 28 days, 60 days and 90 days).

The average split tensile strength of concrete of at least three cylinders prepared with mineral admixture under consideration is compared with that of three cylinders prepared with ordinary cement (for 28,60 and 90 days). The water absorption test of concrete of at least three cubes prepared with mineral admixture under consideration is compared with that of three cubes prepared with ordinary cement. The acidic resistance test of concrete of at least three cubes prepared with mineral admixture under consideration is compared with that of three cubes prepared with ordinary cement (for 28 days).

Parameters tested in this study

- Normal consistency,
- Initial setting & Final setting time
- Soundness
- Workability
- Compressive strength
- Split tensile strength
- Water absorption
- Acid test.

RESULTS AND DISCUSSIONS

The use of cementitious and pozzolanic siliceous industrial by-products as mineral admixtures-in concrete can bring improvements in engineering properties of concrete (strength, impermeability and general durability). Normal pozzolana additives due to their low surface area and reactivity are not generally able to improve the early strength which is crucial to the strength and stability of structural concrete applications and durability of concrete. The problem, though, could be solved by using a mixture of normal (such as fly ash and silica fume) and a highly reactive pozzolana, to produce a durable concrete which does not suffer from low early strength.

Also the durability of concrete during its service life may be significantly affected by the environmental conditions to which it is exposed, and in order to produce a concrete of high quality, the placing of an appropriate mix must be followed by a planned curing system in a suitable environment during the early stages of hardening. This part presents and discusses the results of this investigation on the effect of curing conditions on the engineering properties such as of various concrete mixes made with cement replacement materials such as fly ash (FA) and silica fume (SF). The results obtained are used to analysis the effect of these cement replacement materials on the above engineering properties.

Normal consistency of cement with replacement of fly ash

The variation of normal consistency of cement paste with addition of fly ash is shown in the table 3. The normal consistency test shows a very slight increase with the partial replacement of cement by fly ash at different dosages of 5, 10, 15, and 20 % in ordinary Portland cement which are 2% respectively.

Table 3: Variation of Normal consistency with replacement of fly ash

S.NO	Details of Material	Normal Consistency (%)
1	100% cement + 0% FA	32

2	95% cement +5% FA	34
3	90% cement +10% FA	34
4	85% cement +15% FA	34
5	80% cement +20% FA	34

Normal consistency of cement with replacement of silica fume
The variation of normal consistency of cement paste with addition of silica fume is shown in the table 4. The normal consistency test shows a very slight increase with the partial replacement of cement by silica fume at different dosages of 5, 10, 15, and 20 % in ordinary Portland cement which are 2% and 4% respectively.

Table 4 Variation of Normal consistency with replacement of silica fume

S.No	Details of Material	Normal Consistency (%)
1	100% cement + 0% SF	32
2	95% cement +5% SF	34
3	90% cement +10% SF	34
4	85% cement +15% SF	36
5	80% cement +20% SF	36

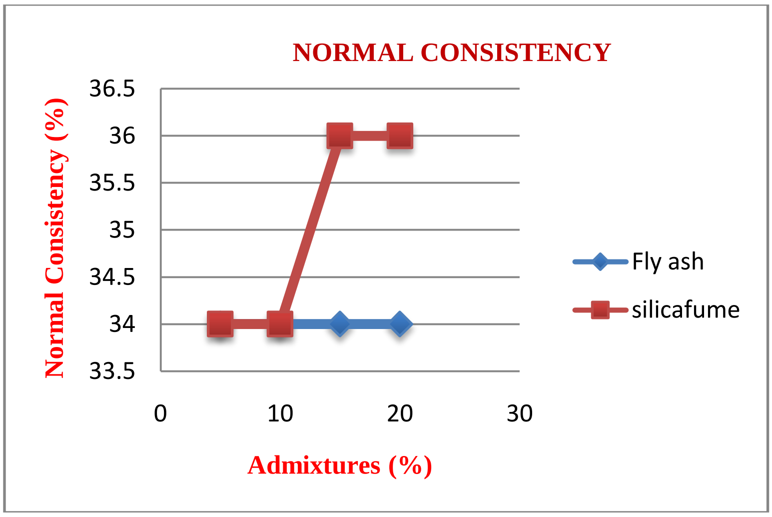

Figure 1: Effect on Normal Consistency for replacement of Cement with different admixtures

It can be seen that the percentage of water required for producing a cement paste of Standard Consistency is increasing with the increase in the amount of admixtures, when used as a partial replacement of cement.

RESULTS OF INITIAL AND FINAL SETTING TIME

Initial and final Setting time of cement with replacement of fly ash
The variations in the initial and final setting times of cement with addition of fly ash.From table 5 it is observed that both the initial and final setting times got retarded and accelerated by replacement of fly ash in the ordinary Portland cement.

Table :5 Initial and final Setting time of cement with replacement of silica fume

S.NO	Details of Material	Initial Setting Time (minutes)	Final Setting Time (minutes)
1	100% cement + 0% FA	45	300
2	95% cement +5% FA	50	300
3	90% cement +10% FA	60	290
4	85% cement +15% FA	70	280
5	80% cement +20% FA	70	260

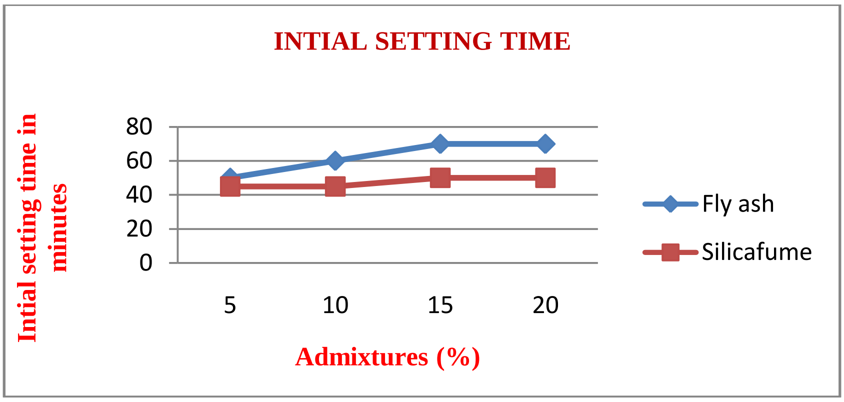

Fig: 2: Effect on initial setting time for replacement of cement with different Admixtures

Initial and Final setting time values cement with replacement of silica fume

From above results it can be known that the initial setting time of normal cement paste is 45 minutes. From figure .2 the initial setting time was found to increase as the replacement percentage increases after the replacement of 5%. As per the Indian standards, the initial setting time should not be less than 30 minutes. Here all the replacement percentages satisfy this requirement.

Table 6 Initial and Final setting time values cement with replacement of silica fume

S.NO	Details of Material	Initial Setting Time (minutes)	Final Setting Time (minutes)
1	100% cement + 0% SF	45	300
2	95% cement +5% SF	45	340
3	90% cement +10% SF	45	340
4	85% cement +15% SF	50	330
5	80% cement +20% SF	50	310

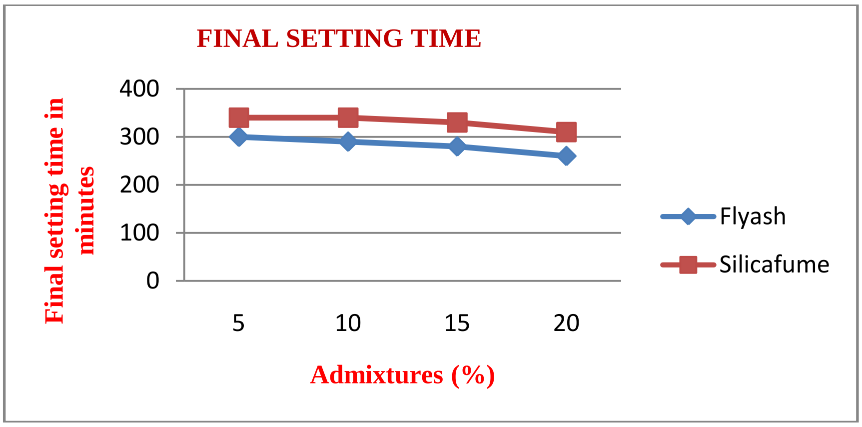

Figure 3: Effect on final setting time for replacement of cement

From above results it can be known that the final setting time of normal cement paste is 300 minutes. From figure 3 the final setting time was found to decrease as the replacement percentage increases after the replacement of 5%, As per the Indian standards, the final setting time should not be more than 600 minutes. Here all the replacement percentages satisfy this requirement.

Soundness of cement with replacement of fly ash

The Le-Chatelier soundness tests were performed on the paste to assess the possibility of deleterious expansion due to the hydration of uncombined calcium oxide and/or magnesium oxide. No evidence of significant possible late expansion was found. The mortar soundness (expansion) for fly ash composite cement indicates shrinkage increase. Increase in soundness with addition of fly ash and silica fume can be explained by the relative increase in volume of reaction products.

Soundness of cement with replacement of fly ash

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Soundness of cement with replacement of silica fume

The Le Chatelier soundness tests were performed on the paste to assess the possibility of deleterious expansion due to the hydration of uncombined calcium oxide and/or magnesium oxide. No evidence of significant possible late expansion was found. The mortar soundness (expansion) for silica fume composite cement indicates shrinkage increase. Increase in soundness with addition of silica fume can be explained by the relative increase in volume of reaction products.

Table 7, 8 Soundness of cement with replacement of fly ash& silica fume

S.NO	Details of Material	Expansion in mm
1	95% cement +5% FA	1
2	90% cement +10% FA	1.5
3	85% cement +15% FA	1.7
4	80% cement +20% FA	2

S.NO	Details of Material	Expansion in mm
1	95% cement +5% SF	1
2	90% cement +10% SF	1.5
3	85% cement +15% SF	1.7
4	80% cement +20% SF	2

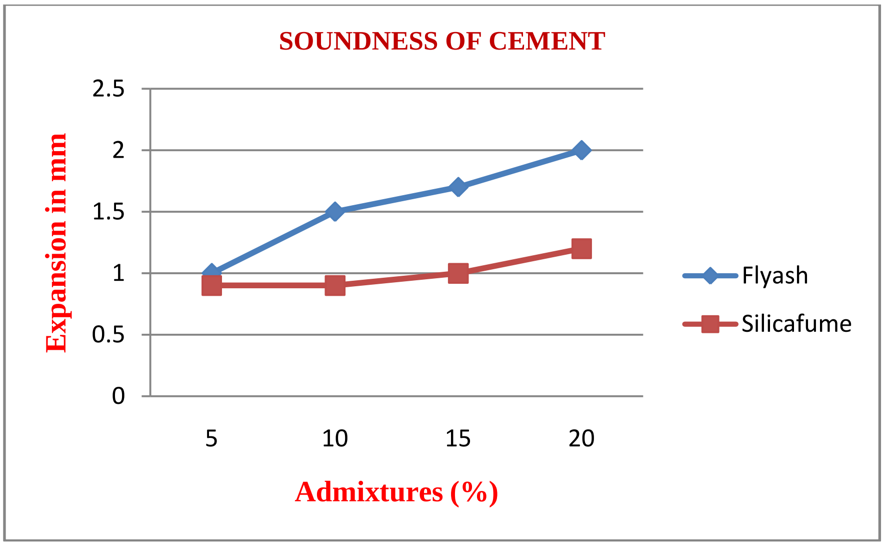

Figure 4: Soundness of Cement with replacement of different admixtures

WORKABILITY

Workability is related to the compatibility, mobility and stability of fresh concrete. Slump test is used to determine the workability of fresh concrete. Slump test as per IS: 1199 – 1959 is followed. In this test the vertical settlement, measured in mm and it is termed as slump.

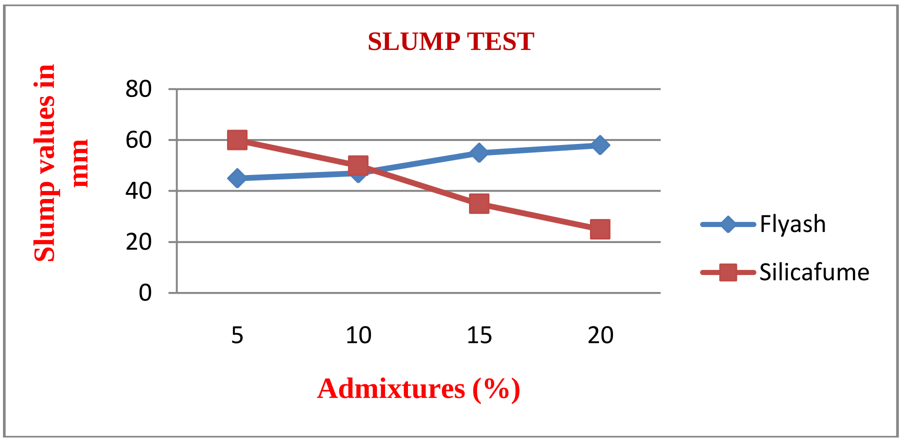

Figure 5: Workability of concrete with replacement of different admixtures

From the figure 5 it shows that the values of slump test of concrete specimens containing various percentages of different admixtures. It is found that slump values increases with the increase in the percentage replacement of fly ash, beyond that it also found that slump values decreases with the increase in the percentage replacement of silica fume. As per the Indian standards1199 – 1959, here all the replacement percentages satisfy this requirement.

COMPRESSIVE STRENGTH:

Table 9: Compressive strength of concrete containing fly ash

Material Used	Test day	Compressive strength of concrete containing fly ash N/mm^2				
		0%	5%	10%	15%	20%
	3	15.82	14.7	14.81	15.03	15.78
	7	18.74	20.30	21.83	22.66	22.78

Fly ash	28	29.25	30.50	31.15	36.80	37.40
	60	35.47	35.63	37.77	40.19	42.26
	90	37.54	38.84	41.05	44.02	45.30

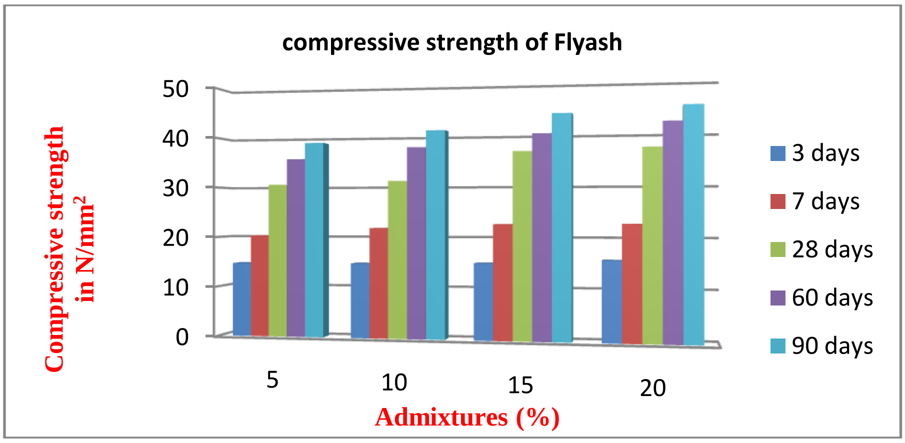

Figure 6: Compressive strength of concrete with replacement of fly ash

From figure 6, it can be seen that the replacement percentage of fly ash is between 5% to 20%, maximum strength is obtained at 20 %. It is found that compressive strength also increases with the increase in the percentage replacement of fly ash.

Compressive strength of concrete containing silica fume

Table 10 Compressive strength of concrete containing silica fume

Material Used	**Test day**	**Compressive strength of concrete containing silica fume N/mm^2**				
		0%	**5%**	**10%**	**15%**	**20%**
	3	15.82	15.62	19.64	17.33	16.85
	7	18.74	18.21	22.43	19.07	17.7
Silica	28	29.25	25.33	30.30	24.66	22.43
fume	60	35.47	32.73	34.43	29.07	27.50
	90	37.54	33.33	37.88	31.26	30.30

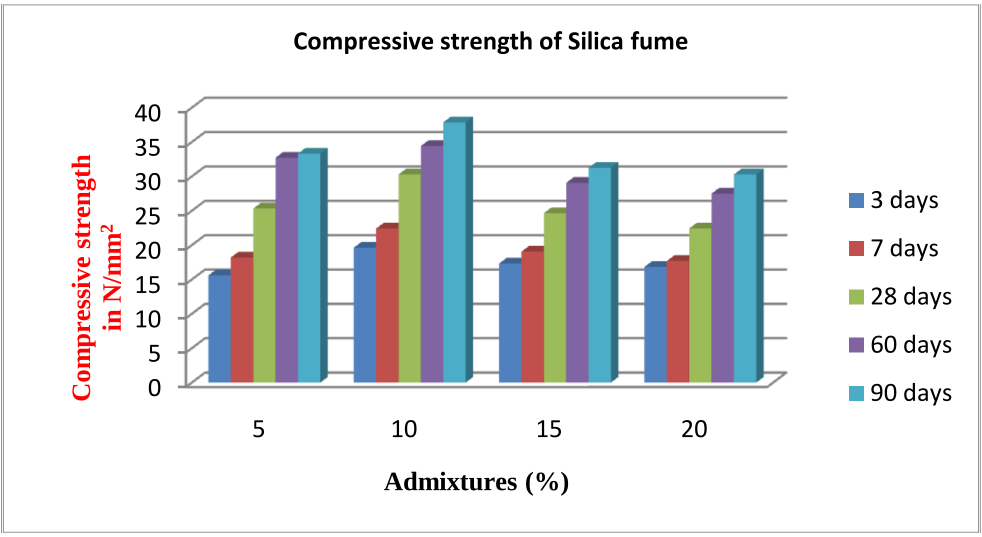

Figure 7: Compressive strength of concrete with replacement of silica fume

From figure 7, it can be seen that the replacement percentage of silica fume is between 5% to 20%, maximum strength is obtained at 5 and 10 %.It is found that compressive strength also increases with the increase in the percentage replacement up to a 10 percentage and beyond that it is found to be decrease.

Split tensile test

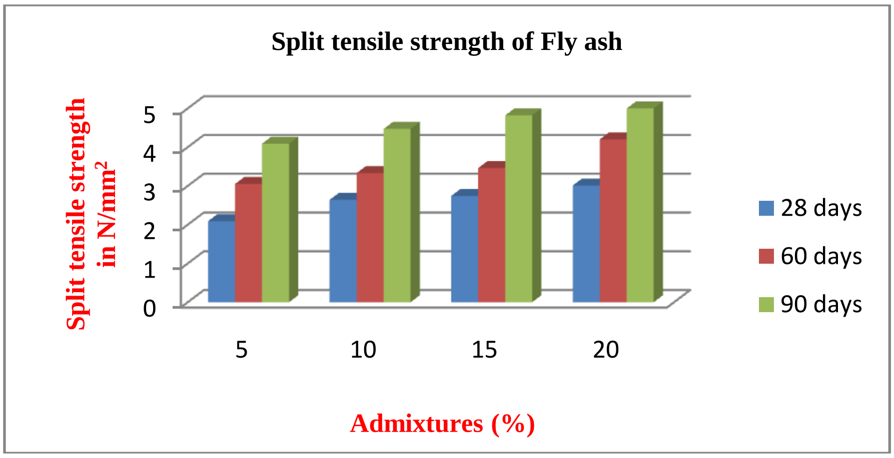

Figure 8: Split tensile strength of concrete with replacement of fly ash

From figure 8, it can be seen that the replacement percentage of fly ash is between 5% to 20%, maximum strength is obtained at 20 %. It is found that split tensile strength also increases with the increase in the percentage replacement of fly ash.

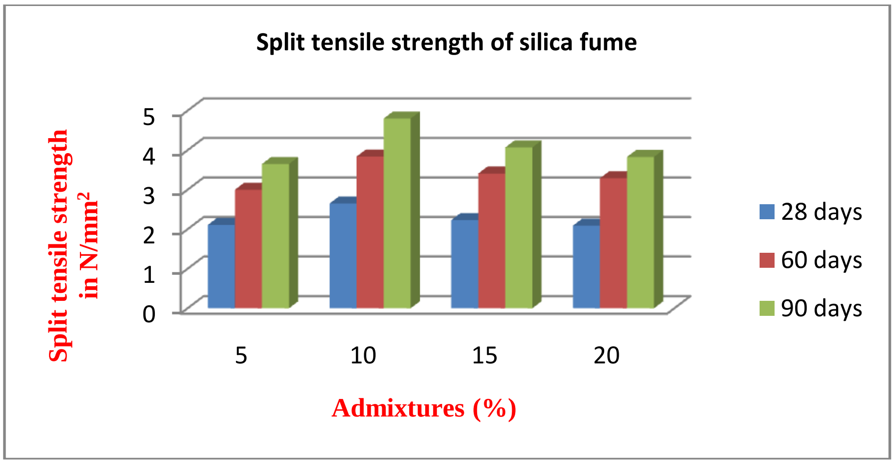

Figure 9: Split tensile strength of concrete with replacement of silica fume

From figure 9 it can be seen that the replacement percentage of silica fume is between 5% to 20%, maximum strength is obtained at 5 and 10 %.It is found that split tensile strength also increases with the increase in the percentage replacement up to a 10 percentage and beyond that it is found to be decrease.

WATER ABSORPTION TEST

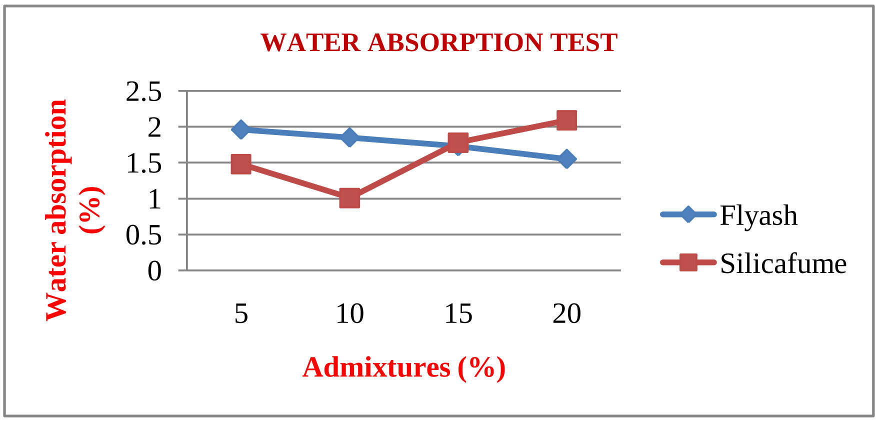

Figure 10: Water absorption of concrete with replacement of different admixtures

From the figure 10it shows that the values of water absorption of concrete specimens containing various percentages of different admixtures. It is found that water absorption values increases with the increase in the percentage replacement of fly ash, beyond that it also found that water absorption values decreases with the increase in the percentage replacement of silica fume.

Effect of acid attack on concrete containing fly ash & silica fume

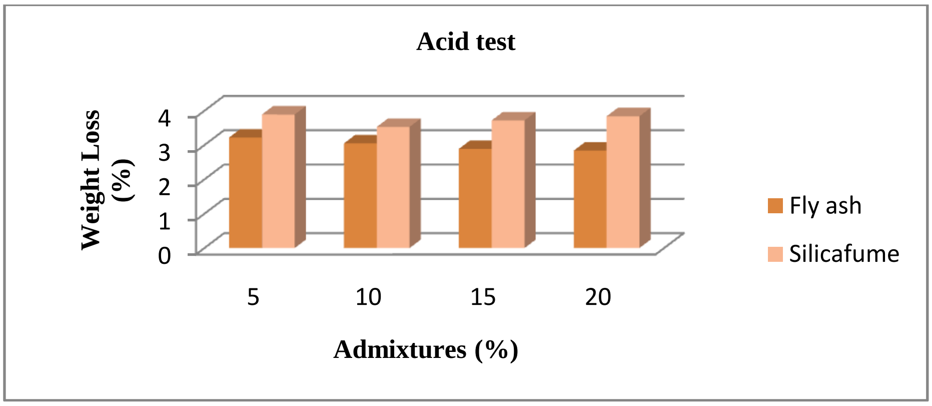

Figure 11: Acidic test of concrete with replacement of different admixtures

From the figure 11it shows that the values of acid test of concrete specimens containing various percentages of different admixtures. It is found that acid test values increases with the increase in the percentage replacement of fly ash, beyond that it also found that acid test values decreases with the increase in the percentage replacement of silica fume.

CONCLUSION

Based on the test data and analysis of results presented in this thesis, the following conclusions can be drawn.

- With regard to normal consistency and setting time of OPC with mineral admixtures, increases when the addition of mineral admixture.
- Although the soundness of cement was found to be increase, after the replacement percentage of mineral admixtures increases.
- It was noticed that the slump values increases with the increase in the percentage replacement of fly ash, beyond that it also found that slump values decreases with the increase in the percentage replacement of silica fume.
- It can be seen that the replacement percentage of fly ash is between 5% to 20%, maximum strength is obtained at 20 %. It is found that compressive strength also increases with the increase in the percentage replacement of fly ash.

- It can be seen that the replacement percentage of silica fume is between 5% to 20%, maximum strength is obtained at 5 and 10 %. It is found that compressive strength also increases with the increase in the percentage replacement up to a 10 percentage and beyond that it is found to be decrease.
- For split tensile test the maximum strength of fly ash maximum strength is obtained at 20 %. And similarly for silica fume maximum strength is obtained at 5 and 10 %.
- From the results it was found that the optimum replacement of silica fume and fly ash are 10%, 10% 20% and 20 % respectively.
- All mineral admixtures were very effective in improving the strength of concrete.
- It appears that the water absorption values increases with the increase in the percentage replacement of fly ash beyond that it also found that water absorption values decreases with the increase in the percentage replacement of silica fume.
- This indicates the acid test values increases with the increase in the percentage replacement of fly ash, beyond that it also found that acid test values decreases with the increase in the percentage replacement of and silica fume.

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