Experimental Study to Obtain Optimum Replacement Percentage of Flyash and Addition of Silica Fume in Blended Concrete

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Abstract:

The experimental work is carried out to investigate the optimum percentage of flyash and silicafume to replace cement effectively. An attempt is made to replace cement with flyash from 0 to 100% with an interval of 10% for minimum grade concrete i.e., M20 and is tested for fresh and hardened properties to identify the optimum percentage of flyash in concrete, on the other hand for the same optimum percentage of flyash, silica fume is incorporated into concrete at the levels of 2.5%, 5%, 7.5% & 10% by weight of cementicious material (flyash+cement) to enhance the properties of blended concrete. Compression , split tensile test are conducted to know the strength of the concrete at different replacement percentages, Galvano static weight loss method is done to find the corrosion resistance of the blended concrete, Acid Resistivity Test is done to find the resistance of blended concrete towards acid and SEM is conducted to know the pozzolonic reaction that takes place inside blended concrete.

Keywords:

Flyash, Silicafume, compressive strength, tensile strength, GSWLM, acid resistivity, SEM analysis

Introduction

Concrete plays a vital role in the development of infrastructure viz.., buildings, industrial structures, bridges and highways etc.., leading to utilization of large quantities of concrete. On the other side, cost of concrete is attributed to the cost of its ingredients, which is expensive and causes pollution. Now a days from small scale to large scale construction sector are giving more importance to life span of concrete than its cost, therefore this aspect enhanced the importance of Blended concrete.

Increasing the performance of concrete with the partial replacement of mineral admixture using flyash along with chemical admixture eliminates the drawbacks besides enhancing durability characteristics[8].

Flyash is the finely divided residue resulting from the combustion of ground or powered coal. Flyash as a siliceous or aluminous , it poses pozzolonic properties when used in concrete as a partial replacement of cement. Use of flyash has many advantages such as it improves the performance of concrete exposed to sulphate environment, deterioration caused by alkali aggregate interaction etc.[1]

Silicafume was first discovered in Norway in 1947 when the environment controls started the filtering of the exhaust gases from furnaces. Silicafume can be utilized as material for supplementary cementations to increase the strength and durability. Silica fume consists of fine particles with specific surface about six times of cement because its particles are very finer than cement particles. Therefore silica fume reduces pore space when mixed with concrete. Silica fume concrete may be appropriate in places where high abrasion resistance and low permeability are of utmost importance or where very high cohesive mixes are required to avoid segregation and bleeding

Materials and Methods

Ordinary Portland cement 53 grade was used throughout this experimental investigations. The cement satisfied the requirements of Indian Standard Specification IS: 12269-1987. The properties of Cement are tabulated in **Table 1.** The flyash used in the present investigation was taken from BELLARY THERMAL POWER STATION, kudatini, bellary district, Karnataka, India. The flyash satisfied the requirements of Indian Standard Specification IS: 3812-1981, the Properties of Flyash are tabulated in **Table 2.** Silicafume used in this investigation was taken from ORGANO SUBLIMO EXTRACTS, baikampady industrial area, Mangalore, Karnataka, India and it satisfied the requirements as per ASTM C 1240 and the properties are tabulated in **Table 3.**

characteristics	value	As per IS: 12269-1987
Specific gravity	3.15	≤3.15
Fineness (%)	2	< 10%
Standard consistency(%)	31	-
Initial setting time(min)	90	> 30
Final setting time (min)	395	<600

Table 1:Physical properties of cement

Characteristics	Value	As per IS:3812-1981
Colour	Grey	-
Specific gravity	2.27	1.6-3.1
Initial setting time (min)	125	-
Final setting time (min)	300	-

Table 2: Physical properties of Flyash

Characteristics	Value	As per ASTM C 1240
Colour	Baby pink	-
Specific gravity	2.3	2.2-2.3

Table 3: Physical Properties of Silicafume

PREPARATION AND CASTING OF TEST SPECIMENS

Concrete cubes of size 150 × 150 × 150mm were casted for all the concrete mixes for compressive strength, 150 × 300mm size cylinders were casted for tensile strength, for Galvano Static weight loss method(GSWLM) cylinders of size 150 × 300mm were casted and for acid resistivity test cubes of size 150 × 150 × 150mm were casted. After 24 hours of casting the specimens were demoulded and put into water curing tank until 7, 14 and 28 days of testing for compression and tensile strength, but for GSWLM the cylinders were demoulded after 24 hours and kept in salt water without any curing in normal water and for acid resistivity test the cubes were kept in normal water curing for 7 days and later placed in acid water bath for 28 days time.

MIX DESIGN

The experiment is conducted in 2 stages. In the first stage cement is replaced with flyash in steps of 10% till the strength decreases and the optimum value of the replaced percentage is noted down. In the second stage the optimum value of flyash is fixed and silicafume is varied in steps of 2.5% by replacing cement till 10%. Mix design used for the experimental work is

1:1.73:2.85:0.5

RESULTS AND DISCUSSION

A. Compressive Strength Test

Figure 1 : Cube specimen failure under compressive load

The compressive strength of concrete cubes replaced by flyash was determined at ages 7, 14 and 28 days and figure 2 shows the strength variation of the mix having flyash replaced with cement. The test is conducted as per IS:516-1999

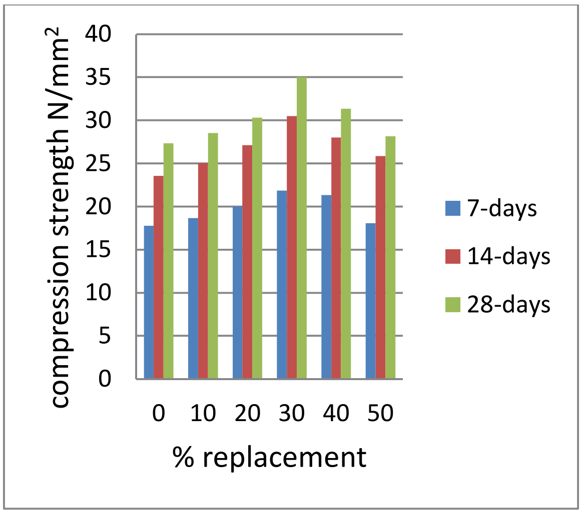

Figure 2: Compressive Strengths for 7, 14 and 28 days.

From the above graph it can be noted that 30% replacement of flyash with cement shows greater compressive strength as compared to any other percentages. In order to know if there is any increase in strength in between 30% replacement of flyash and 40% replacement of flyash **MATLAB** software was used. From the attempted replacement values an equation was generated from the software to find the intermediate strength values. The equation is as follows

$$Y = 18.001 + 0.01 \times X1 + 0.47 \times X2$$

Where Y is average compressive strengths
X1 is % of concrete (31%, 32%,...)
X2 is number of days (7, 14, 28)
Figure 3 shows the compressive strength for intermediate percentage

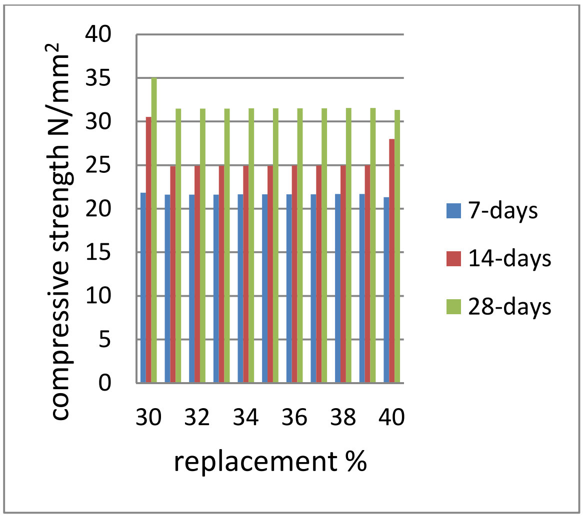

Figure 3: Compressive strength for intermediate percentage

From the above graph it can be noted that 30% replacement of flyash with cement shows higher compressive strength compared to other intermediate percentages. Therefore the optimum value of flyash that can be considered from the experimental work is 30% flyash. Now having optimum value fixed cement is replaced with silicafume in steps of 2.5% till 10% . Figure 4 indicates the compressive strength of concrete having mixture of cement + flyash + silicafume.

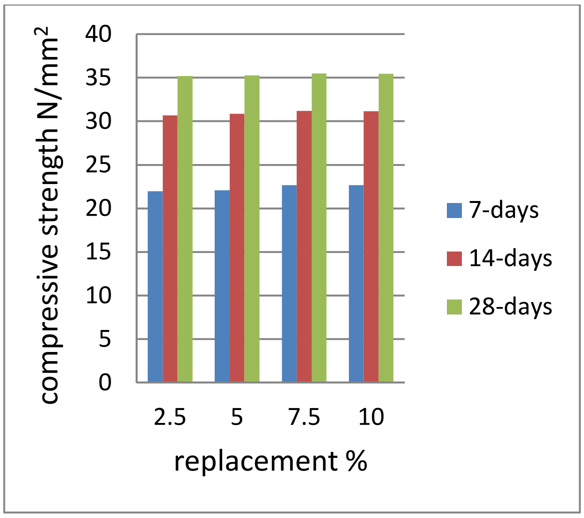

Figure 4: Compressive Strength for 7, 14 and 28 days

Silicafume with replacement percentage of 7.5% shows more strength as compared to other replacement percentages.

B. Tensile Test

The procedure of mix is as same as that of the compressive strength test . Figure 6 shows the tensile strength of cylinder specimen having cement replaced by flyash and figure 7 shows the tensile strength of cylinder specimen having the optimum value of flyash fixed and cement replaced with silicafume. The test is conducted as per IS:516-1999

Figure 5: cylinder failure under tensile loading

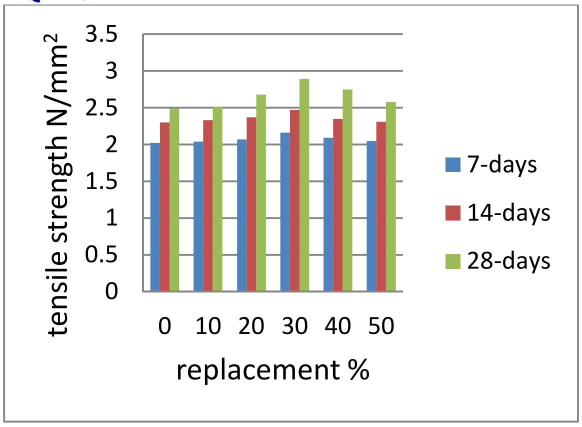

Figure 6: Tensile strength for 7, 14 and 28 days

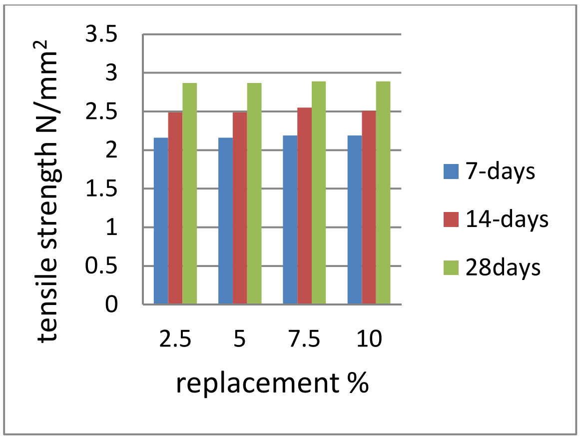

Figure 7: Tensile strength for 7, 14 and 28 days (cement + flyash + silicafume)

C. Galvano Static Weight Loss Method.

Figure 8: GSWLM setup

Test is done to find out the amount of corrosion that can be caused to the cylindrical specimen into which steel rods are embedded and that are immersed in the bath tub which contains 5% NaCL solution. 12v current is passed through the battery making the steel rods positive and the copper plate negative. The copper plate is connected to the negative terminal of the battery and is immersed inside the bath tub containing NaCL. The current is passed for 15 days and later the weight rods are noted down. Figure 9 represents the corrosion rate in mm/yr.

$$\text{Corrosion Rate} = \frac{K \times W}{A \times T \times D}\ (\text{mm/yr})$$

K = 87.6 in case of expressing corrosion rate in mm/yr.

T is the exposure time expressed in hours.

A is the surface area expressed in cm^2.

W is the mass loss in milli gram.

D is the density of the corroding metal (7.85 gm/cm^3).

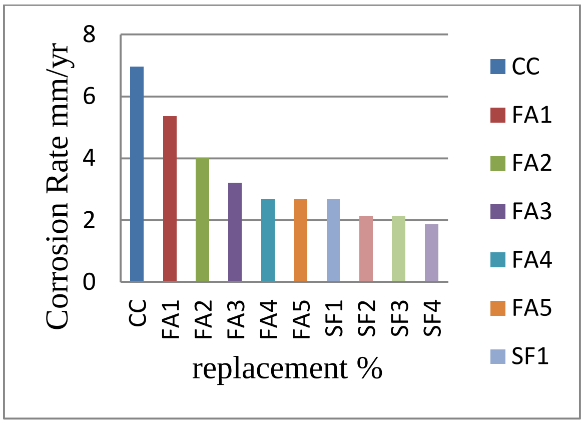

Figure 9: Corrosion Rate

When only cement is used in the concrete it can be seen from the graph that the corrosion is maximum at that point but with the replacement of fly ash into cement the corrosion decreases correspondingly as compared to cement mix. When silica fume is introduced into concrete having flyash constant and replacing cement (cement + flyash + silica fume) it can be seen from the graph that the corrosion is decreased still more as compared to the above combination (i.e cement + flyash). Therefore it can be concluded from the graph that with the use of cement + flyash + silica fume the corrosion can be decreased as compared to the conventional mix.(i.e 100% cement).

D. ACID RESISTIVITY TEST

This test is performed to know how much the concrete and the other replacement levels can resist the acid attack that can counter attack directly on the specimen. The cubes are casted and demoulded after 24 hours and are cured in normal water for 7 days and later taken out , dried in sun until they are properly dried. After drying is done the cubes are weighed and are placed in acid-water bath. P_H is maintained to 4. After 28 days the cubes are taken out from acid-water bath and dried and later weight is taken. Difference in weight signifies the ability of the concrete to resist acid attack. Figure 13 indicates the difference or loss in weight.

Figure 10: conventional concrete after submersed in acid-water bath

Figure 11: Cement + Flyash (70% + 30%)

Figure 12: Cement + Flyash + Silicafume (62.5%+30%+7.5%)

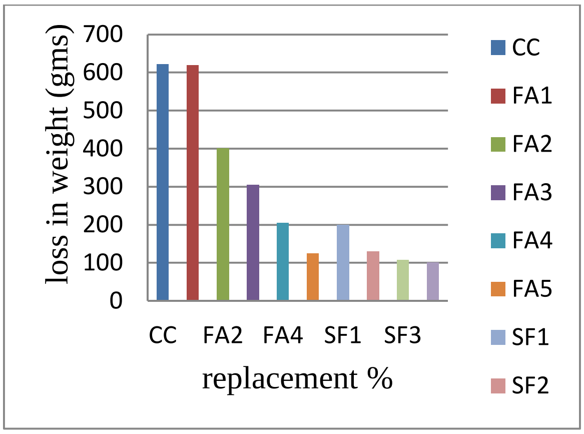

Figure 13: Acid Resistivity Results for 28 days

When only cement is used the rate of resistance to acid decreases but goes on increasing as the cement is replaced with flyash in higher percentages. The resistance ability to acid increases as the replacement percentage also increases. The resistance to acid increases vitally when silicafume is replaced with cement having flyash constant. The loss in weight decreases as the replacement percentage increases. The resistance to acid is gained because silicafume and flyash cover the pore space that are available so that they do not allow any water to pass through them.

E. Scanning Electron Microscope (SEM)

Samples are carbon coated and are analysed using SEM in the back scattered electron mode with acceleration voltage of 20Kev. The SEM analysis of conventional concrete, cement replaced with 30% flyash and cement replaced with 7.5% silicafume having flyash percentage constant. Figures 14, 17 and 20 shows the microstructure of the concrete. These 3 figures are analysed using **MATLAB** software. Textural segmentation using texture filters is done using Matlab software. Figures 15, 16, 18, 19, 21, 22 are the output that are gained using the software. The software is used to clearly find out the dense microstructure of specimen and this is can be identified from figures 15, 18 and 21(colours images). The size of the particle is indicated by mm micron.

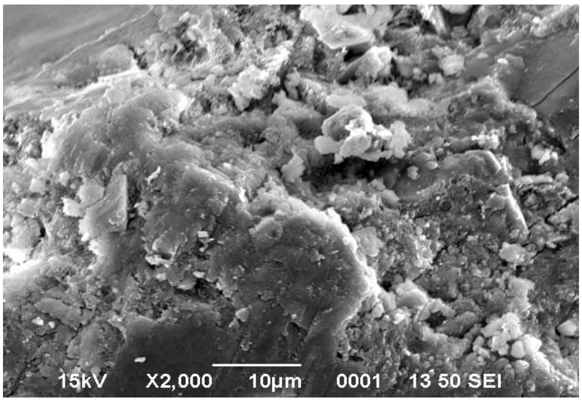

Figure 14: Cement + Flyash + Silica fume (62.5% + 30% + 7.5%)

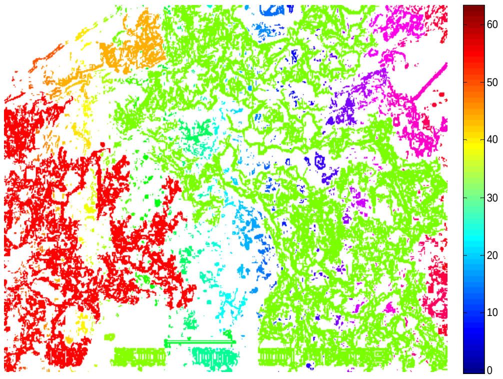

Figure 15: Coloured Image showing particular texture

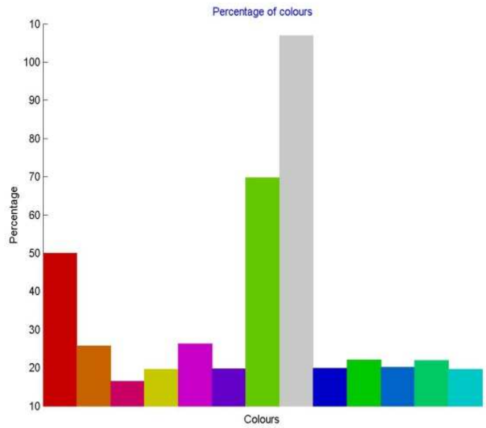

Figure 16: Percentage of colours

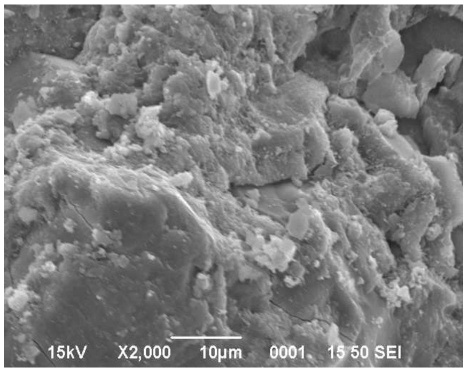

Figure 17: Cement + Flyash (70% + 30%)

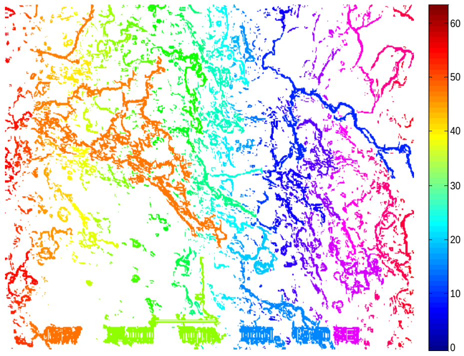

Figure 18: Coloured Image showing particular texture

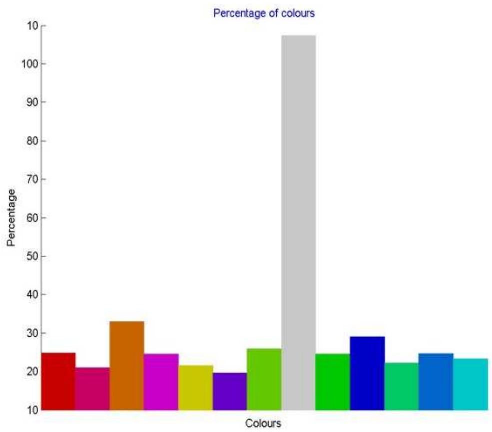

Figure 19: Percentage of colours

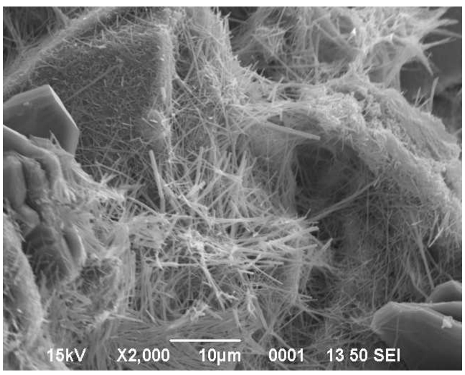

Figure 20: Conventional Concrete

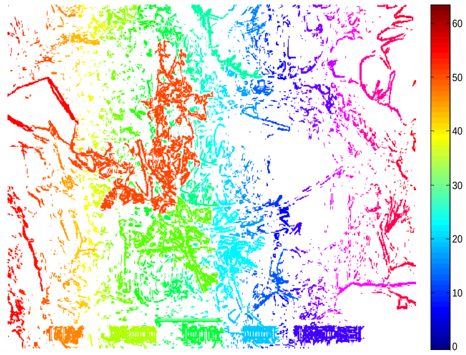

Figure 21: Coloured Image showing particular texture

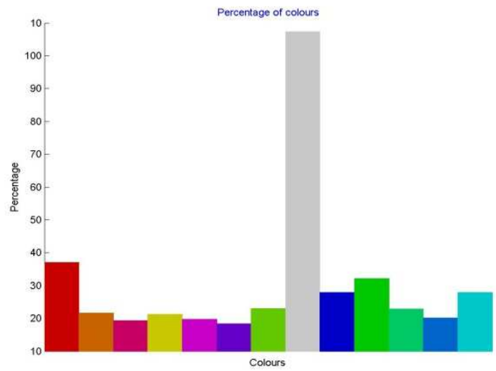

Fig 22: Percentage of colours

The above figures 16, 19 and 22 represents the percentage of colours of the coloured images in the form of histogram. The scale denotes the size of the materials in micron. From the figure 15, 18 and 21 it can be approximately judged that the materials varying from 0 to 20 microns are un-hydrated (un-reacted) or partially hydrated and materials varying from 20 to 40 microns are partially un-hydrated or hydrated and materials varying from 40 to 60 microns are hydrated. Figure 16 shows 51% variation from 40-60 microns, 63.66% variation from 20 to 40 microns and 8% variation from 0-20 microns. Figure 19 shows 43% variation from 40-60 microns, 36.11% variation from 20-40 microns and 28.95% variation from 0-20 microns. Figure 22 shows 35.66%

variation from 40-60 microns, 25.82% variation from 20-40 microns and 24.32% variation from 0-20 microns. From this it can be concluded that figure 16 shows more dense structure as compared to figures 19 and 22. Due to the dense microstructure of the concrete, there is a good bonding between the materials due to which strength increases and the permeability resistance increases. Due to the increase in the permeability resistance of the concrete the corrosion effect on the re-inforcement can be controlled and the resistance to acid is also achieved.

CONCLUSION

- It is observed from compressive and tensile test that as the Flyash content increases the strength also increases but after a certain increase in the percentage of Flyash the strength decreases. Upto 30% replacement of Flyash the strength increases and after 30% replacement of Flyash the strength decreases. In the next stage the optimum found from the 1st stage is fixed i.e percentage of Flyash is fixed and silicafume is varied w.r.t cement. From the results it can be concluded that till 7.5% replacement of silicafume w.r.t cement the strength increases but with more increase in the percentage of silicafume the strength decreases. Therefore the mix containing 30% Flyash & 7.5% Silicafume w.r.t cement can be used.
- From GSWLM test the durability of the concrete decreases when only cement is used but with the use of higher replacement percentage of Flyash the durability of the concrete increases. With the replacement of Silicafume further having Flyash constant the durability of the blended concrete increases more than that of concrete having just Flyash replaced.
- The resistance ability of the concrete to acid decreases when cement is used, but increases when higher percentage of Flyash is replaced with cement. With the replacement of Silicafume w.r.t cement having Flyash constant the resistance ability to acid increases more than that of mix having Flyash alone. The resistance ability increases as the percentage of Silicafume increases.
- The mix containing Cement + Flyash + Silicafume shows dense microstructure than mix containing Cement + Flyash and conventional mix. Due to the dense microstructure the permeability resistance of the concrete increases due to which the strength also increases.
- It can be concluded from the investigations that Cement with replacement of 30% Flyash and 7.5% Silicafume can be used.

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