Partial Replacement Of Cement By Silica Fume

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Abstract - Portland cement is the most important ingredient of concrete and is a versatile and relatively high cost material. Large scale production of cement is causing environmental problems on one hand and depletion of natural resources on other hand. This threat to ecology has led to researchers to use industrial by products as supplementary cementations material in making concrete. The main parameter investigated in this study is M20 grade concrete with partial replacement of cement by silica fume by 0, 5, 10, 15 and by 20%. This paper presents a detailed experimental study on Compressive strength, split tensile strength, flexural strength at age of 7 and 28 day. Durability study on acid attack was also studied and percentage of weight loss is compared with normal concrete. Test results indicate that use of Silica fume in concrete has improved the performance of concrete in strength as well as in durability aspect.

Introduction

Portland cement is the most important ingredient of concrete and is a versatile and relatively high cost material. Large scale production of cement is causing environmental problems on one hand and depletion of natural resources on other hand. This threat to ecology has led to researchers to use industrial by products as supplementary cementations material in making concrete. This paper deals with the various tests conducted on the concrete materials used in this project work. To achieve the objectives of this study, an experimental programming was planned to investigate the effect of silica fume on compressive strength of concrete. The various tests have been conducted on cement, fine aggregate, coarse aggregate, water, silica fume and on the hardened concrete specimen (cubical) after suitable time period of curing 7 and 28 days with and without replacement of cement with silica fume.

Experimental Work: This work deals with the various tests conducted on the concrete materials used in this project work. To achieve the objectives of this study, an experimental programming was planned to investigate the effect of silica fume on compressive strength of concrete. The various tests have been conducted on cement, fine aggregate, coarse aggregate, water, silica fume and on the hardened concrete specimen (cubical) after suitable time period of curing 7 and 28 days with and without replacement of cement with silica fume.

Material: The required strength or target strength of concrete can be obtained by careful selection of ingredients, correct grading of ingredients, accurate water measurements and adopting a good workmanship in mixing, transporting, placing, compacting, finishing and curing of concrete in the construction work. When a binding material (cement), fine aggregate (sand), coarse aggregate (such as crushed stone, broken bricks etc.) and water are mixed together in suitable proportions, they form an easily workable mix known as plastic, wet or green concrete. When this plastic concrete becomes hard like a stone, this is termed as hardened concrete or simply as a concrete. The properties of material used for making the concrete mix are determined in laboratory as per relevant codes of practice. Different materials used in present study were cement, coarse aggregates, fine aggregates, water and silica fume. The aim of studying of various properties of materials is used to check the appearance with codal requirements and to enable an engineer to design a concrete mix for a particular strength. The description of various materials which were used in this study is given below:

Ordinary Portland cement: Although all materials that go into concrete mix are essential, cement is very often the most important because it is usually the delicate link in the chain. The function of cement is first of all to bind the sand and stone together and second to fill up the voids in between sand and stone particles to form a compact mass. It constitutes only about 20 percent of the total volume of concrete mix; it is the active portion of binding medium and is the only scientifically controlled ingredient of concrete. Portland cement referred as (Ordinary Portland Cement) is the most important type of cement and is a fine powder produced by grinding Portland cement clinker. The OPC is classified into three grades, namely 33 Grade, 43 Grade, 53 Grade depending upon the strength of 28 days. It has been possible to upgrade the qualities of cement by using high quality limestone, modern equipments, maintaining better particle size distribution, finer grinding and better packing. Although they are little costlier than low grade cement, they offer 10-20% saving in cement consumption and also they offer many hidden benefits. One of the most important benefits is the faster rate of development of strength.
The cement as determined from various tests conforming to Indian Standard IS: 8112:1989 are listed in Table 1. Cement was carefully stored to prevent deterioration in its properties due to contact with the moisture. The various tests conducted on cement are initial and final setting time, specific gravity, fineness and compressive strength.

Table 1:- Properties of OPC 43 grade concrete:

S.no	Characteristics	Values obtained experimentally	Values specified by IS
1	Specific gravity	3.15	
2	Standard consistency (%)	33	
3	Initial setting time	105(minutes)	30(minutes)
4	Final setting time	430(minutes)	600(minutes)
5	Compressive strength 3 days 7 days 28 days	 25.2 N/mm^2 37.9 N/mm^2 47.8 N/mm^2	 23 N/mm^2(minimum) 33 N/mm^2(minimum) 43 N/mm2(minimum)

Aggregate: Aggregates constitute the bulk of a concrete mixture and give dimensional stability to concrete. To increase the density of resulting mix, the aggregates are frequently used in two or more sizes. The most important function of the fine aggregate is to assist in producing workability and uniformity in the mixture. The fine aggregate assist the cement paste to hold the coarse aggregate in suspension. This action promotes plasticity in the mixture and prevents the possible segregation of paste and coarse aggregate, particularly when it is necessary to transport the concrete some distance from the mixing plant to placement. The aggregates provide about 75% of the body of the concrete and hence its influence is extremely important. They should therefore meet certain requirements if the concrete is to be workable, strong, durable and economical. The aggregates must be proper shape, clean, hard, strong and well graded.

Coarse aggregate: The aggregate which is retained over IS Sieve 4.75 mm is termed as coarse aggregate. The coarse aggregates may be of following types:-
Crushed gravels or stone obtained by crushing of gravel or hard stone.
Uncrushed gravel or stone resulting from the natural disintegration of rock
Partially crushed gravel obtained as product of blending of above two types.

The normal maximum size is gradually 10-20 mm; however particle sizes up to 40 mm or more have been used in Self Compacting Concrete. Gap graded aggregates are frequently better than those continuously graded, which might expensive grader internal friction and give reduced flow. Regarding the characteristics of different types of aggregate, crushed aggregates tends to improve the strength because of interlocking of angular particles, while rounded aggregates improved the flow because of lower internal friction.

Locally available coarse aggregate having the maximum size of 20 mm was used in this work. The aggregates were washed to remove dust and dirt and were dried to surface dry condition. The aggregates were tested as per IS: 383-1970. Specific gravity and other properties of coarse aggregates are given in Table 2. The sieve analysis of coarse aggregate was done. Table 2 the result of sieve analysis. Proportioning of coarse aggregates was done and fineness modulus was obtained.

Table 2: Properties of coarse aggregate

Characteristics	Value
Colour	Grey
Size	20mm
Shape	Angular
Specific gravity	2.74

Fine aggregate: The aggregates most of which pass through 4.75 mm IS sieve are termed as fine aggregates. The fine aggregate may be of following types:
Natural sand, i.e. fine aggregate resulting from natural disintegration of rocks.
Crushed stone sand, i.e.fine aggregate produced by crushing hard stone.
Crushed gravel sand, i.e. fine aggregate produced by crushing natural gravel.

According to size, the fine aggregate may be described as coarse, medium and fine sands. Depending upon the particle size distribution IS: 383-1970 has divided the fine aggregate into four grading zones (Grade I to IV). The grading zones become progressively finer from grading zone I to IV. In this experimental program, fine aggregate was locally procured and conformed to Indian Standard Specifications IS: 383-1970. The sand was sieved through 4.75 mm sieve to remove any particles greater than 4.75 mm and conforming to grading zone II. It was coarse sand light brown in colour. Sieve analysis and physical properties of fine aggregate are tested as per IS:383-1970 and results are shown in Table 3.

Table 3: Properties of fine aggregate

Characteristics	Value
Specific gravity	2.34
Bulk density (kg/m^3)	1.3
Fineness modulus	2.62
Water absorption	0.88

Cement: Cement is considered as the best binding material and is being commonly used as a binding material in the construction of various engineering structures these days. Since it sets quickly and provides sufficient strength to heavy and important structures, it is considered as one of the leading engineering material of modern times. Product obtained by burning and crushing in powder form, either stone containing 20 to 40% clay and remaining carbonate of lime or an intimate mixture of well proportioned calcareous and argillaceous materials is called natural cement. Natural cement is not as strong as artificial cement. Natural cement is rarely manufactured and used in Indian Portland cement is referred as ordinary Portland cement is the most important type of cement and is a fine powder produced by grinding Portland cement clinker. Concrete is made by Portland cement, water and aggregates. Cement constitutes about 20 % of the total volume of concrete. Portland cement is hydraulic cement that hardens in water to form a water-resistant compound. The hydration products act as binder to hold the aggregates together to form concrete. The name Portland cement comes from the fact that the colour and quality of the resulting concrete are similar to Portland stone, a kind of limestone found in England.

Classification of OPC: Depending upon the strength of the cement at 28 days when tested as per IS 4031-1988. Cement is classified as
a) 33 grade cement
b) 43 grade cement
c) 53 grade cement
If 28 days strength is not less than $33N/mm^2$, it is called 33 grade of cement, if the strength is not less than $43N/mm^2$, it is called 43 grade of cement, and if the strength is not less than $53N/mm^2$, it is called 53 grade of cement. But actual strength obtained by these cements at the factory is much higher than the BIS specifications.

Water: Generally, water that is suitable for drinking is satisfactory for use in concrete. The potable water is generally considered satisfactory for use in concrete. This was free from any detrimental contaminants and was good potable quality.

Test methods:-The methods used for testing cement, coarse aggregates, fine aggregate and concrete are given below:
Specific gravity: It is ratio of the weight of a given volume of a substance to the weight of an equal volume of some reference substance, or equivalently the ratio of the masses of equal volumes of two substances.
Compressive strength of concrete:- The compressive strength of concrete is one of the most important and useful properties of concrete. Test specimens of size 150mm×150mm×150mm were prepared for testing the compressive strength concrete. The concrete mixes of varying percentages (0%, 5%, 10%, 15%) of silica fume as partial replacement of cement were cast into cubes for subsequent testing. In this work, to make the concrete coarse aggregate of size 20mm, fine aggregates sand of zone II, Ordinary Portland cement (OPC), and Silica fume were mixed properly with appropriate proportions for dry mix followed by addition of water and then mixed efficiently to achieve uniform and high workable mix. Before placing concrete in the moulds the interior surface of the moulds and the base plates were oiled with lubricant before the concrete has been placed than the concrete has been placed in 150 mm ×150 mm×150 mm cube. The concrete is filled up to $1/3^{rd}$ height of the mould. Each layer is tamped at least 35 strokes of the tamping rod. After 24 hours the specimens were removed from the moulds and placed in clean fresh water at a temperature of 27 ± 2ºC. The specimen was cast were tested after 7, 14 and 28 days of curing measured from the time specimen placed for curing. For testing in compression, no cushioning material was placed between the specimen and the plates of the machine. The uniform applied loading of 4KN is given to sample in compression testing machine (CTM). The load was applied axially without shock till the specimen was crushed. Results of the compressive strength test on concrete with and without varying proportions (5%, 10%, 15% and 20%) of silica fume replacement at the age of 7days and 28 days were noted.

Concrete mixes:- Mix design for M20 grade of concrete was carried out using the guidelines prescribed by IS: 10262- 1982. The designed concrete mix for M20 served as basic control mix (CM). Silica fume concrete mixes were obtained by adding silica fume to basic control mix in percentages varying from 0 to 20% at an increment of 5% by weight of cement. (SFC0, SFC5, SFC10, SFC15, SFC20**)**.

Batching, mixing, and curing:- The concrete ingredients viz. cement, sand and coarse aggregate were weighed according to M_{30} and are dry mixed on a platform. To this the calculated quantity of silica fume was added and dry mixed thoroughly. The required quantity of water was added to the dry mix and homogenously mixed. The homogeneous concrete mix was placed layer by layer in moulds kept on the vibrating table. The specimens are given the required compaction both manually and through table vibrator. After through compaction the specimens were finished smooth. After 24 hours of casting, the specimen were demoulded and transferred to curing tank where in they were immersed in water for the desired period of curing.

Results and Discussion:- This chapter deals with the presentation of results obtained from various tests conducted on concrete specimens cast with and without silica fume are shown here. The main objective of the research program was to understand the strength and durability aspects of concrete obtained using silica fume as partial replacement for cement. In order to achieve the objectives of present study, an experimental program was planned to investigate the effect of silica fume on compressive strength and split tensile strength concrete. The experimental program consists of casting, curing and testing of controlled and silica fume concrete specimen at different ages.
The experimental program included the following:
Testing of properties of materials used for making concrete.
Design mix (M20).

Casting and curing of specimens.
Tests to determine the compressive strength and split tensile strength of concrete.

Compressive Strength:- In most structural applications, concrete is employed primarily to resist compressive stresses. When a plain concrete member is subjected to compression, the failure of the member takes place, in its vertical plane along the diagonal. The vertical crack occurs due to lateral tensile strains. A flow in the concrete, which is in the form of micro crack along the vertical axis of the member will take place on the application of axial compression load and propagate further due to the lateral tensile strains.

Test Procedure and Results:-
Test specimens of size 150 *150* 150 mm were prepared for testing the compressive strength concrete. The concrete mixes with varying percentages (0%, 5%, 10%, 15%and 20%) of silica fume as partial replacement of cement were cast into cubes for subsequent testing. In this study, to make concrete, cement and fine aggregate were first mixed dry to uniform colour and then coarse aggregate was added and mixed with the mixture of cement and fine aggregates. Water was then added and the whole mass mixed. The interior surface of the moulds and the base plate were oiled before concrete was placed. After 24 hours the specimens were removed from the moulds and placed in clean fresh water at a temperature of 270 C. The specimens so cast were tested after 7 and 28 days of curing measured from the time water is added to the dry mix. For testing in compression, no cushioning material was placed between the specimen and the plates of the machine. The load was applied axially without shock till the specimen was crushed. Results of the compressive strength test on concrete with varying proportions of silica fume replacement at the age of 7 and 28 days are given in the Table 4, and 5.

Table 4:- Compressive strength of cube for 7 days.

Mix(%)	Compressive strength (N/mm^2) after 7days		Average compressive strength after 7 days
	Specimen 1	Specimen 2	
0	14.10	13.90	14.00
5	15.80	15.88	15.84
10	16.08	16.00	16.04
15	16.45	16.05	16.25
20	15.00	14.60	14.80

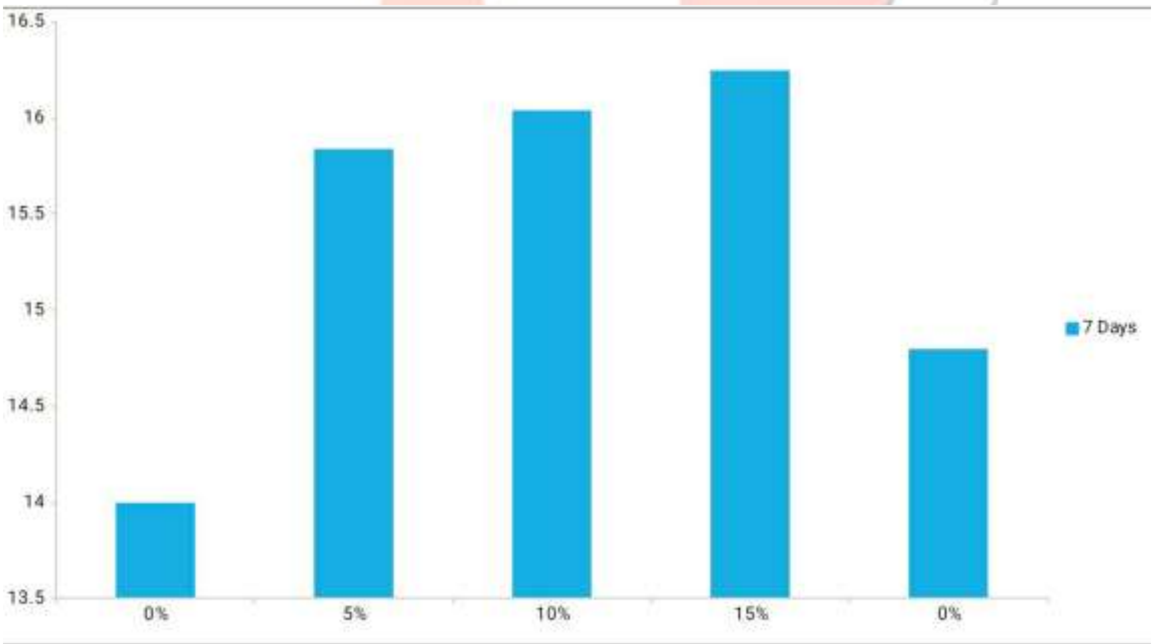

Fig 1:-Graphical representation of cube strength after 7 days

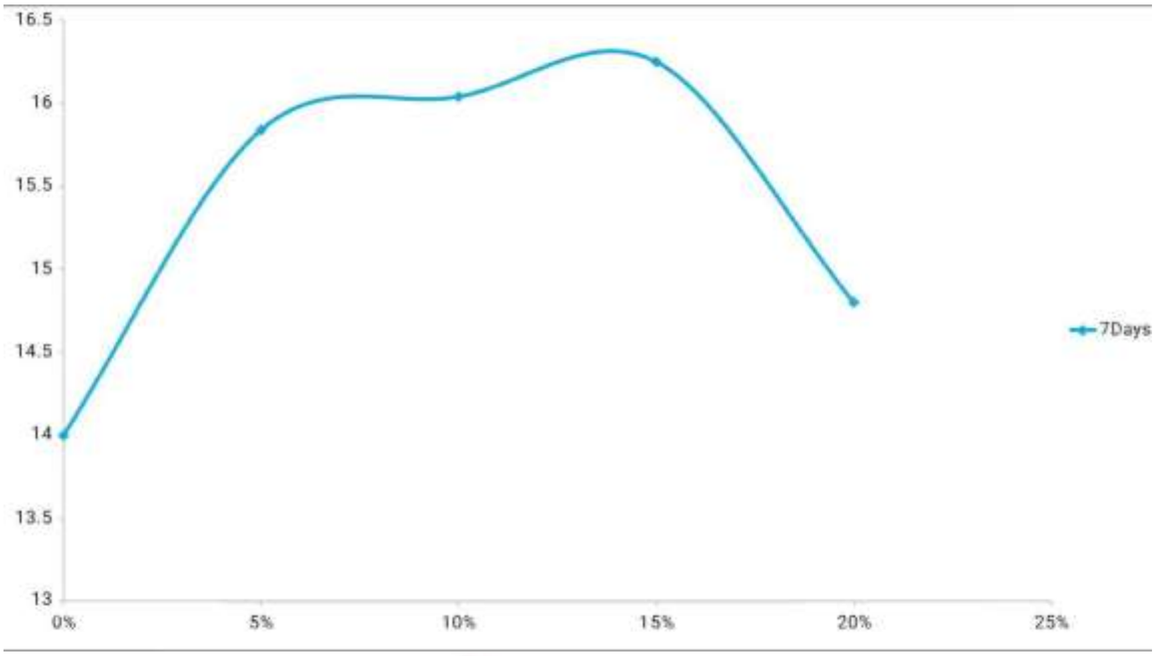

Fig:- Linear representation of cube strength after 7 days.

The cube strength results of concrete mix are also shown graphically in Figure 1. The compressive strength increases as compared to control mix as the percentage of silica fume is increased. As we increase the percentage of silica fume its compressive strength increases continuously from 5% to 10% respectively and after 10% its start decreasing. Figure 2. shows the variation of percentage increase in compressive strength with replacement percentage of silica fume. The results also indicate that early age strength gain i.e. at 7, 14 and 28 days, is higher when compared to the control mix if 10% of cement is replaced by silica fume.

Table 5:- Compressive strength of cube for 28 days.

Mix(%)	Compressive strength(N/mm^2) after 28 days		Average compressive strength after 28 days
	Specimen 1	Specimen 2	
0	23.80	24.50	26.20
5	27.80	27.74	31.44
10	30.40	31.82	34.93
15	31.84	32.26	30.20
20	25.90	26.78	26.34

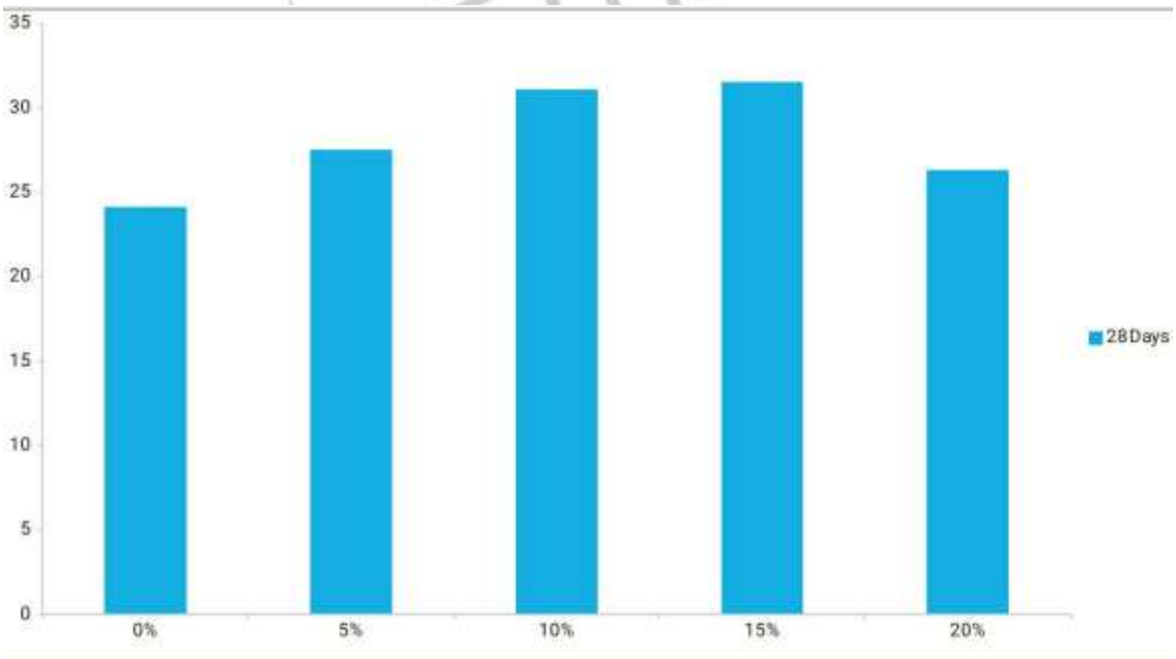

Fig 3:- Graph representation of cube for 28 days.

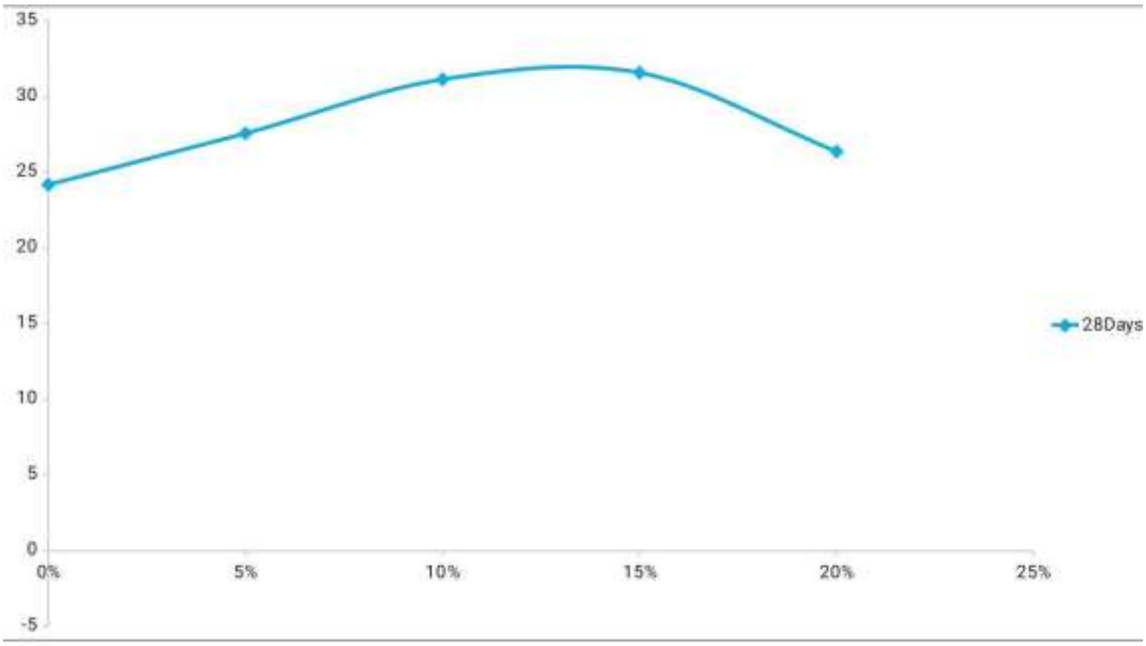

Fig 4:- Linear representation of cube for 28 days.

Comparison of strength of cube according to days:-

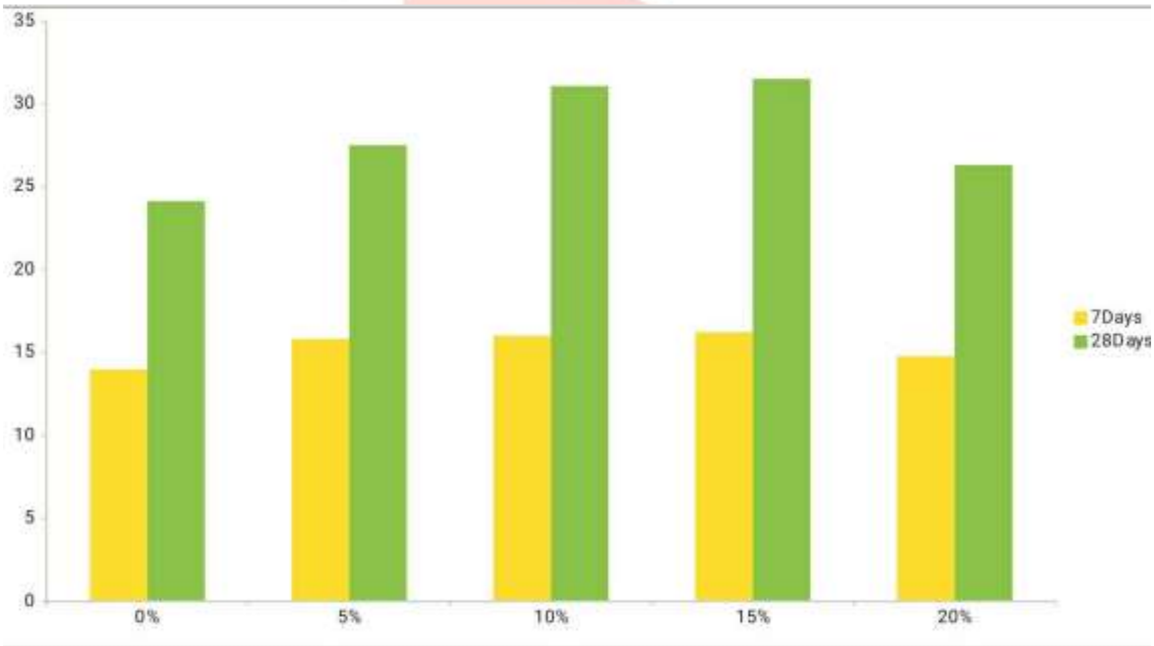

Fig 5:- Comparison of cubes according to days.

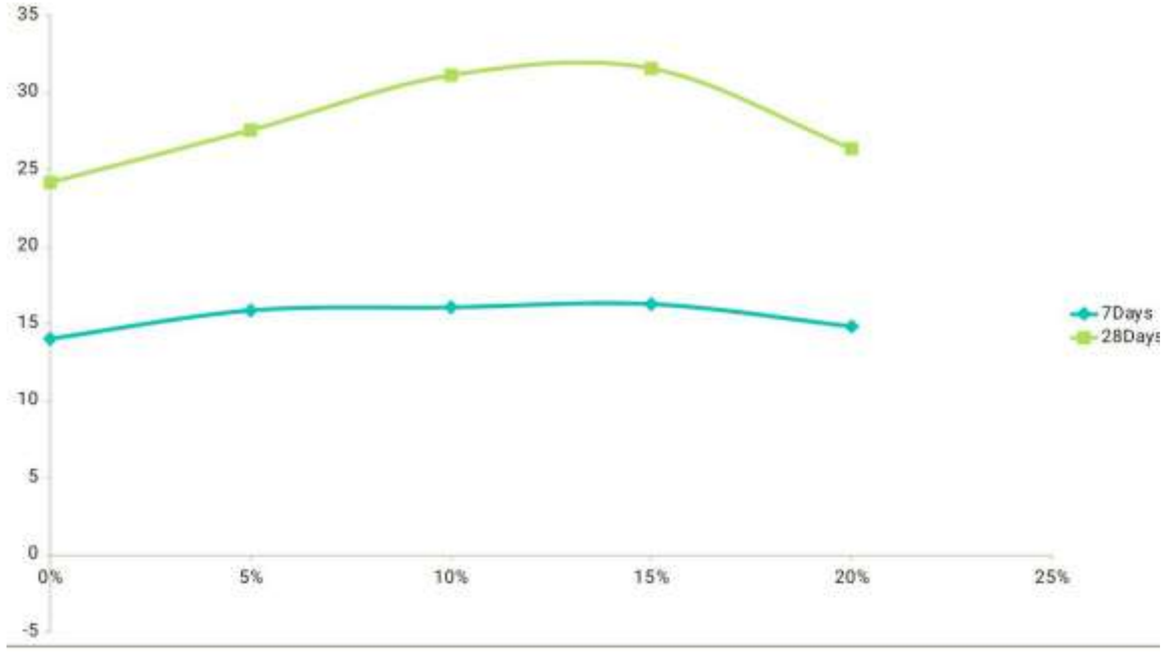

Fig 6:- Linear comparison of cubes according to days.

Conclusion

The strength and durability characteristics of concrete mixtures have been computed in the present work by replacing 5%, 10%, 15% and 20% silica fume with the cement. On the basis of present study, following conclusions are drawn:

Compressive strength:- After adding 5% silica fume in the mix, there is an increase in the strength of cube after 7 days as compared to concrete without replacement. And after 28 days there is enormous increase in strength as compared to the control mix.

By adding 10% silica fume, there is large amount of increase in strength after 7, 14 and 28 days respectively. The Compressive strength tends to increase with increase percentages of silica fume in the mix .

By adding 15%S.F , there is more amount of increase in strength after 7 and 28 days resp. The compressive strength tends to increase with increase in %age of S.F. and decrease after 15% replacement.

The optimum strength of cube is gain at 15% replacement for all 7, and 28 days respectively.

Scope for further work

In the present study only upto 20% replacement of cement by silica fume has been considered The other %ages i.e. 25% and 30% need investigation. In the present study only 0.50 w/c ratio has been considered. The other ratios are 0.45 and 0.55

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