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A Replacement of Fine Aggregate in Concrete

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Abstract:

This project deals with the possibility of replacing the fine aggregate of concrete by sustainable materials. In this work M20 grade of concrete is taken for study and the fine aggregate is replaced by froth floated silica, a by-product of cement manufacturing plant by 20%, 40%, 60%, 80% and 100% weight of fine aggregate. The specimens are casted for testing compressive strength, split tensile strength, flexural strength and rapid chloride permeability test. The workability results shows that the replacement of fines by froth floated silica increases but in the presence of super plasticizer. The results indicate that when the fine aggregate is replaced by froth floated silica by 80% the compressive strength increased by 19.86%, split tensile strength by 16.29% and flexural strength increases by 28.14% than conventional concrete.

INTRODUCTION

GENERAL:-

Concrete can be simply termed as the synthesis of coarse aggregate and fine aggregate along with the adhesive material known as cement when mixed with water. In terms of volume a concrete mix is generally 10 % cement, 30% fine aggregate, 45% coarse aggregate and 15% water. The concrete ingredients in terms of percentage of volume of concrete are shown in the Figure 1.1.

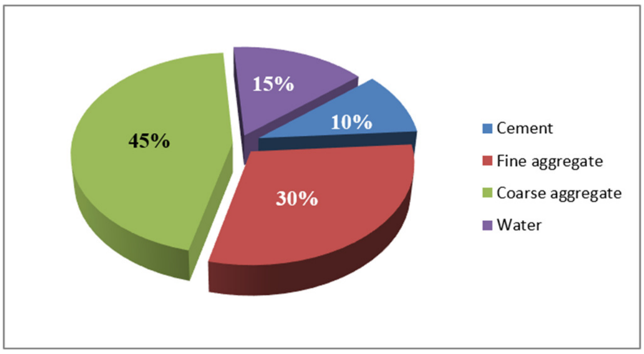

Figure 1.1 Concrete ingredients in terms of percentage of volume

From the Figure 1.1 large percentage of aggregate covered in concrete. Due to the fact that amount of aggregate in concrete is the more than any other ingredient; the need for aggregate is also more. In fact aggregates in concrete accounts for nearly 70% of the total volume of concrete [9].With the infrastructural development going around at a huge scale, the demand for aggregates is rising every single day due to which the aggregates are more utilized.

Reports suggests that the need for aggregate in India added up to 1.1 billion metric tons in 2006, making the nation the third greatest aggregate market in Asia/Pacific locale. Moreover India is the fourth biggest aggregate market on the planet after China, United States of America and Japan. The selling of aggregate in India have risen a normal of 7.7 % yearly for previously every 10 years, surpassing both local and worldwide midpoints. A quickly propelling economy and rising ways of life have helped in increment of foreign investment interest in India, animating a lot of industrialization and foundation related development movement. In any case, Indian item request (in respect to development spending and on a for every capita premise) is considerably underneath local and world midpoints [4].

When eco-friendly waste product and bi-product are used with concrete ingredients they make Green concrete. Today the word green concrete isn't simply constrained to shading, it speaks to the earth which is encompassing us. The other name of green concrete is resource saving material with diminished natural effect, for instance energy saving, CO_2outflows, squanders of solid fixings and so forth. This type of concrete material composed of waste products will enhance the sustainability of nature through eco friendly techniques [5].

In construction industry the availability of aggregates has reduced to a large extent. This is mainly in case of fine aggregate which are obtained from river bed. With continuous extraction of river sand and over utilization of this resource, the river bed is depleting. As a result of which the environmental problems are increasing. Moreover due to vast need of river sand the cost of the fine aggregate has increased which directly affects the cost of construction.

So there is an immediate need for an alternative which can replace the river sand without affecting the quality and strength of concrete. One such alternative can be froth floated silica which is the waste product of the cement industry obtained from the froth floatation process.

NEED FOR RESEARCH

- ❖ To save the raw materials required in the cement production.
- ❖ To minimize the construction cost in production of concrete.

OBJECTIVES:-

- ❖ To study the compressive strength of concrete mixes with froth-floated silica as a fine aggregate replacement at different ages.
- ❖ To gain insights into how the micro-structure and physical properties of concrete change when froth-floated silica is used as a partial replacement.

SCOPE

- ❖ Fine aggregates will be replaced by froth floated silica at 20%, 40%, 60%, 80% and 100%.
- ❖ M20 grade of concrete will be prepared and tested for compressive strength, split tensile strength at 7, 14 and 28 days. Besides this the flexural strength will be tested for 28 days. The durability tests include RCPT which will be done for 90days and water absorption for 28 days.

LITERATURE REVIEW

Eldhose M Manjummekud et al. (2014),studied the properties of finely graded silica, crystalline rock sand and Granulated Blast Furnace Slag. Moreover the mechanical properties in concrete with replacement of finely graded silica and crystalline rock sand was studied in brief.By using finely graded silica concrete cubes were made and the highest value of compressive strength for cubes was obtained by replacing fine aggregate at 25% and 75%.Moreover when it comes to finely graded silica concrete, the cylinders which were made by interchanging fine aggregate with finely graded silica to test the split tensile strength, the values increased initially but as the replacement of fine aggregate went past 25% the values decreased gradually which indicated that up to 25% replacement the behavior of concrete is up to the optimum level and after that there is a loss in strength.

Dharshnadevi. D et al. (2017), analyzed the M30 grade of concrete by changing the river sand with eco sand at 5%, 10%, 15%, 20%, 22%, 25%, 27%, 30% and 35%. The compressive strength and flexural strength test was done and the results showed that eco sand replacement with fine aggregate at 25% gave optimum result but after that, the strength got slowly decreased. This meant that beyond 25% replacement of fine aggregate the behavior of concrete strength is not satisfactory and the replacement of this bi-product with fine aggregate is limited to 25% in concrete. For the M30 grade of concrete workability up to 25% can be increased with mixing of eco sand in concrete. Further the researchers found that while adding eco sand with 25%, the mass of fine aggregate reduced

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comparatively without reducing the split tensile strength, compressive strength, modulus of elasticity and ultimate strength of concrete which ultimately resulted in the reduction of the cost of fine aggregate in concrete without compromising the strength and durability.

M. Prabu et al. (2015),analyzed the chemical and physical properties of eco sand and Ground Granulated Blast Furnace Slag. The fine aggregate was partially replaced by eco sand at 10%, 20%, 30% and 40%. The researchers carried out tests on fresh concrete such as slump cone and compaction factor test. Further they also carried out tests on hardened concrete and studied the compressive strength, split tensile, flexural test for M20 grade of concrete. From the investigation the researchers concluded that eco sand replacement with fine aggregate at 20% gave optimum result but after that strength got reduced. This meant that beyond 20% replacement of fine aggregate the behavior of concrete strength is not satisfactory and the replacement of eco sand with fine aggregate is limited to 20% in concrete. It has shown if 20% replacement with eco sand for M20 grade, the workability will be increased. As a result the researchers concluded that for low grade of concrete like M20, fine aggregate can be replaced by the cement manufacturing bi-product like eco sand at a optimum level of 20% and is suitable for use with minimum cost.

A. Sudhahar et al. (2016),studied the replacement of fine aggregate with dolomite silica waste in cement concrete roads. In this research, the fresh concrete properties was analyzed using slump cone test and found that 100% replacement of eco sand gave better workability with increase in water cement ratio. Moreover they carried out tests on hardened concrete and also investigated the compressive strength and flexural strength test and observed that for low grade of concrete such as M20 and M30, the strength gain was increased compared to M40 grade of concrete. The researchers concluded that the utilization of dolomite silica as an alternative for fine aggregates gave optimum level results in strength and durability properties of M20 grade and M30 grade of concrete with diminished cost resultants while in case of higher grade of concrete such as M40 the replacement of fine aggregate with dolomite silica is not suitable as the concrete did not showed good behavior in strength and durability properties. As a result the replacement of the dolomite silica waste in concrete as a fine aggregate alternative should be limited to M20 and M30 grade of concrete only.

D. L. Venkatesh Babu et al. (2015), studied the fly ash bricks with extracted dolomite silica fines.The conventional bricks were replaced by fly ash bricks and the fine aggregate for mortar was replaced by dolomite silica fines. The compressive strength and water absorption of bricks were studied and the researcher found that rough surface finish was obtained when the fly ash content was restricted to 50% and the crushed rock fines content was slightly higher than the extracted dolomite silica content. The durability test showed that the water absorption of bricks decreases with an increase of extracted dolomite silica content in the raw mix.

K. Chinnaraju et al. (2013), studied the concrete characteristics by replacing coarse aggregate with steel slag and fine aggregate with eco sand. M40 grade of concrete was prepared and tests were done on hardened concrete. Result analysis has shown that the compressive strength was increased after 7 days curing of M40 grade of concrete and with 40% replacement of eco sand, good compaction was achieved due to the smaller size of eco sand and when replacement of eco sand was increased, it was found that water absorption is reducing. So the researcher concluded that the optimum level was at 40% replacement of fine aggregate with eco sand.

MATERIALS AND METHODOLOGY GENERAL

Concrete is the most versatile material which is widely used in the construction industry due to its capability to withstand severe environment with sufficient strength and durability. Concrete can be simply termed as the synthesis of coarse aggregate and fine aggregate along with the adhesive material known as cement when mixed with water. Due to the recent trends of sustainable construction with environment friendly techniques, concrete ingredients are being replaced with innovative materials that help to build structures that are green and sustainable in environment.

The traditional concrete materials are fine aggregate, coarse aggregate, cement, water and sometimes admixtures. Now-a-days efforts are being made to partially or fully replace these conventional concrete ingredients with alternatives that are environment friendly, which will not only give sufficient structural strength but also provide efficient quality of structures than conventional concrete.

MATERIALS

A conventional concrete mix is composed of cement, coarse aggregates, fine aggregates, water and sometimes admixture. Almost three fourth of the concrete mix is occupied by aggregates which include fine aggregate and coarse aggregate. The availability of fine aggregate has reduced to large extent which are obtained from river bed due to the continuous use of river sand and over exploitation of the river bed. So an immediate need of alternative is required which can replace the river sand. In this project efforts are made to replace the river sand with froth floated silica as fine aggregate. The other concrete ingredients remain the same.

The properties and preliminary tests results that are conducted in the materials of concrete such as Cement, Froth Floated Silica, Coarse Aggregate, Water and Super Plasticizer are discussed in this chapter. The methodology adopted in doing this project is also discussed in this chapter.

Cement

Cement is the most essential and the fundamental constituent in the concrete mix because it is usually the delicate link in the chain of concrete mix process. The main purpose of cement is, first to tie the fine aggregate and coarse aggregate together, and second to fill the voids in the middle of fine aggregate and coarse aggregate particles to shape a smaller mass. In spite of the fact that cement constitutes just 10% of the volume of the concrete blend, it is the dynamic segment of the binding medium and just experimentally controlled element of concrete. Based on raw materials used in the cement manufacturing, the oxide composition of Ordinary Portland Cement are given in the Table 3.1

Table 3.1 Oxide composition of Ordinary Portland Cement

Oxide	Percentage	Average
Lime, CaO	60-65	63
Silica, SiO_2	17-25	20
Alumina, Al_2O_3	3.5-9	6.3
Iron oxide, Fe_2O_3	0.5-6	3.3
Magnesia, MgO	0.5-4	2.4
Sulphur trioxide, SO_3	1-2	1.5
Alkalis (Na_2O + K_2O)	0.5-1.3	1.0

The composition of Portland cement is rather complicated but it basically consists of tricalcium silicate (C_3S), dicalcium silicate (C_2S), tricalcium aluminate (C_3A) and tetracalcium alumino ferrite (C_4AF).The two silicates, namely C_3S and C_2S which together constitutes about 70-80% of cement control the most of the strength giving properties and C_3A is responsible for early setting. The compound composition of Ordinary Portland Cement is given in the Table 3.2

Table 3.2 Compound composition of Ordinary Portland Cement

Compund	Percentage by mass in cement
C_3S	25-50
C_2S	20-45
C_3A	5-12
C_4AF	6-12

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The Cement used in the experimental study is 53 grade Ordinary Portland Cement confirming to IS 12269-1987 of brand Chettinad Cement.Specific gravity of cement used in this project work was tested using density bottle of 100 ml and the specific gravity of the cement sample came 3.075. Preliminary test was also done to find out the fineness of cement where the fineness of cement sample came 7.74%. The physical properties of cement are given in the Table 3.3

Table 3.3 Physical properties of cement

Properties	Result
Specific gravity	3.075
Fineness	7.74%

Fine Sand

Those aggregate can pass through 4.75mm sieve is known as fine aggregate and contains only that much coarser material as is permitted by the specifications. Fine aggregate can be classified as coarser, medium and fine aggregate on basis of their particle size. According to IS 383-1970 particle size distribution, fine aggregate can be divided in to four grading zones. From grading zone I to IV finer properties of fine aggregate will be progressively.

For the concrete mix it has be surely analyzed there are no chemical contamination, clay, silt and chloride contamination, in fine aggregate. Fine aggregate must be properly homogenous graded and minimum void ratio. For the better results grading of fine aggregate should be very homogenous and does not increase water demand for mixing and should have also finer portion, in which finer materials can be placed and provide good bonding between ingredients. The specific gravity test of fine sand is done using pycnometer which is shown in the Figure 3.2 and the specific gravity of fine sand sample came as 2.501

Figure 3.2 Specific gravity test of fine sand using pycnometer

The fineness modulus of fine sand sample is also determined through sieve analysis and the fineness modulus of fine sand sample is 2.48. Since the fineness of sample of sand is between 2.2-2.6, so the sample sand is fine sand. The particle size distribution curve of fine sand sample is given in the Figure 3.3.

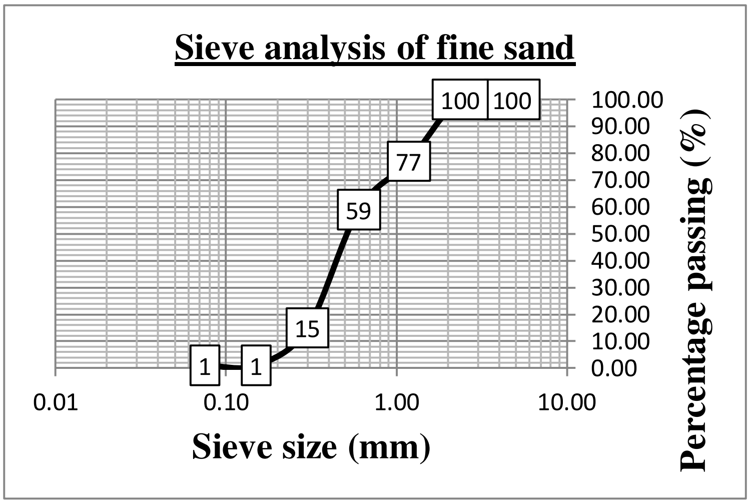

Figure 3.3 Particle size distribution curve of fine sand

Preliminary tests has been done on the physical properties of fine sand sample and the test results are given in the Table 3.5

Table 3.5 Physical properties of fine sand

Properties	Result
Specific gravity	2.501
Fineness modulus	2.48

3.2.4 Coarse Aggregate

After disintegration of rock and large stones particle in to smaller particles, those cannot pass through 4.75 mm sieve, known as Coarse aggregate. For the good impervious and toughness coarse material are used in the concrete. The chemical composition of coarse aggregate will not vary according to weather. By use of coarse aggregate the dimensional changes in structure and shrinkage will not produced when moisture will change. Coarse aggregate always provide water flow resistance in concrete and provided that the mix is suitably designed. Coarse aggregate can be simply classified as all-in-aggregate and single-size-aggregate. However other classifications are also there based on shape and unit weight.
According to shape coarse aggregate can be classified as:

- Rounded aggregate
- Irregular aggregate
- Angular aggregate
- Flaky and elongated aggregate

Based on unit weight coarse aggregate can be classified as:

- Normal weight aggregate
- Heavy weight or high density aggregate
- Light weight aggregate

The coarse aggregate generally posses the qualities of good building stone showing high crushing strength, low absorption and least porosity. The size of coarse aggregate adopted in this experimental study is 20 mm size aggregate. Preliminary tests has been done to determine the physical properties of coarse aggregate where the specific gravity of coarse aggregate was found to be 2.816 and the fineness modulus of coarse aggregate was 7.982. Fineness modulus of 7.982 means, the average size of the particle of given coarse aggregate sample is in between 7th and 8th sieves, that is between 10 mm to 20 mm. The particle size distribution curve of coarse aggregate is shown in the Figure 3.4

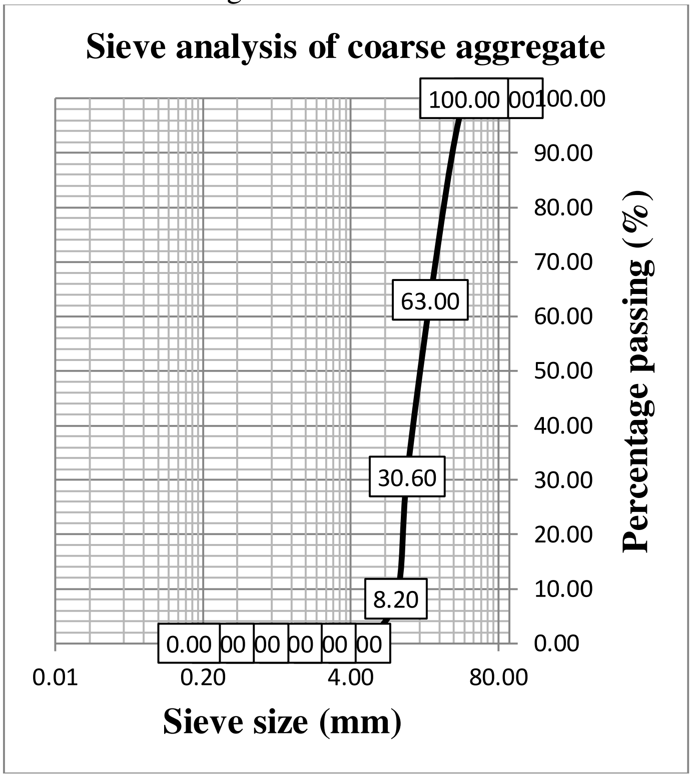

Figure 3.4 Particle size distribution of coarse aggregate

The preliminary test results of physical properties of coarse aggregate is shown in Table 3.6

Table 3.6 Physical properties of coarse aggregate

Properties	Result
Specific gravity	2.816
Fineness modulus	7.982

METHODOLOGY

In this project the process of doing the experimental investigation starts right from selecting the title of the project topic to the very end of publishing the paper. The methodology of doing this project work has been divided into different segments. At first title of the project topic was selected considering the necessity of doing

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innovative findings which will be helpful as environmental friendly techniques in the construction industry. The title of the project was chosen with the idea of doing sustainable construction techniques by the use of waste products which can be re-utilized in making green concrete. After the title was finalized literature review of different journals similar to this project work was studied and survey of all the literatures were done. The literature survey was followed by the collection of materials that constitute the basis of the project materials.

Aggregates of essentially the same nominal maximum size, type and grading will produce concrete of satisfactory workability when a given volume of coarse aggregate per unit volume of total aggregate is used. Approximate values for this aggregate volume are given in the Table 3.9 conforming to Table 3 (Clauses 4.4, A-7 and B-7) of IS 10262 : 2009. These values for aggregate volume given the Table 3.9 are for water-cement ratio of 0.50, which may be suitably adjusted for other water cement ratios. For more workable concrete mixes which is sometimes required when placement is by pump or when the concrete is required to be worked around congested reinforcing steel,it maybe desirable to reduce the estimated coarse aggregate content by 10 percent.

CASTING AND TESTING DETAILS

For understanding the mechanical properties of concrete, samples are casted for compressive strength, flexural strength and tensile strength. The size of the specimen that were casted to know the compressive strength is 150×150×150mm³ cube, for flexural test the size of beams were 100mm breadth, 100mm thick and length 500mm and for split tensile strength, cylindrical specimens were casted of dia 300mm and 150mm height.

Moreover to know the durability characteristics of concrete water absorption and rapid chloride permeability test were conducted. For water absorption test 150×150×150 mm³ cubes were made and for RCPT small discs of dia100mm and thickness 50mm were cut out from cylinders that were casted previously.

4.3 TESTING DETAILS

Preliminary test like slump cone test was done to know the workability of conventional as well as replaced concrete with froth floated silica at different percentages. All things considered, concrete slump is utilized to know the workability, which gives the water-bond extent, yet there are typical components which comprises of material properties, mixing systems, measurements, admixtures, etc. which in like influences the slump value.

4.2.1 Slump Cone Test

The slump cone test is very straightforward workability test for concrete which incorporates very less effort and gives speedy results.The slump cone test was carried out by Abrams cone which is open at the top and at the bottom having height 30cm, lower dia of 20cm and upper dia of 10cm and is provided in the Figure 4.1. A tamping rod is used which is generally made of steel having 16mm dia and 60cm long and rounded at one end. The slump cone test is carried out as per procedures and stated in IS:1199-1959.

Figure 4.1 Slump Cone Test

Compressive Strength Test

Compressive strength of the specimen was found out in the UTM as per ASTM C109 code specifications. Cubes having 150×150×150mm³ size were made with different percentages of froth floated silica as fine aggregate replacement for a period of 7, 14 and 28 days.Bearing surface of the UTM was cleaned with the free sand and distinctive materials were ousted from the sample surface, that are made with the compression plates.Specimens were kept in compression testing machine as shown in the Figure 4.2. Specimens were set in the machine with load applied to the contrary sides of the samples as casted.

Figure 4.2 Compression Testing Machine

4.2.3 Split Tensile Strength Test

The cylinder that were used to test the tensile strength were of dia 150mm and of height 300mm. The specimens for the split tensile strength were casted and tested in universal testing machine as per ASTM C496 code specification. Cylindrical specimens were casted for a period of 7, 14 and 28 curing days. Bearing surface of the UTM was cleaned with the free sand and distinctive materials were ousted from the sample surface, that are made with the plates.The specimens were put on the universal testing machine and then load was applied continuously without shock. The breaking load P is noted. Using the flowing formula, split tensile strength is calculated :

$$T = \frac{2P}{\pi DL}$$

Where,

T = Split tensile strength in N/mm^2
P = Maximum load in N
D = Diameter of the specimen in mm
L = Length of the specimen in mm

4.2.4 Flexural Strength Test

Beams were casted of size 100×100×500 mm³and cured for a period of 7, 14 and 28 curing days. The specimens for the flexural strength were casted and tested in universal testing machine as per ASTM C496 code specification. The bed of UTM were furnished with a couple of steel rollers, 38 mm in width where the samples were upheld. The bearing surface of UTM was cleaned with the free sand and different materials were expelled from the surface of the samples.The specimens were put on the universal testing machine and then load was applied continuously without shock. The load is isolated similarly between the two stacking rollers and every one of the rollers were loaded such that the point that the load is connected pivotally and without making the sample to any stresses or restrains.

Result and Discussion

In this project titled "Experimental investigation on the effect of froth floated silica as a replacement of fine aggregate in concrete", initially the preliminary properties of the replaced concrete ingredients were investigated. The preliminary tests which were done to investigate the physical properties of these materials are specific gravity test and fineness modulus test.

Slump cone test was done to know the workability of conventional as well as replaced concrete with different percentages of froth floated silica. Concrete specimens were tested for their mechanical characteristics such as compressive strength, tensile test and flexural test. Moreover to understand the durability of the standard as well as replaced concrete water absorption and RCPT were done.

2 Fineness Modulus Test

Fineness modulus is an experimental factor acquired by including the total rates of aggregate totals held on every one of the standard sieve running from 80 mm to 150 micron and separating this entirety by 100.This test gives an idea about how fine the materials which we are using. Here in this experimental study fineness modulus of different concrete ingredients were found out and is provided in the Table 5.2

Table 5.2 Fineness modulus test results of concrete ingredients

Concrete ingredient	Fineness modulus
Cement	7.74
Froth floated silica	0.93
Fine aggregate	2.48
Coarse aggregate	7.98

5.2.3 Slump Cone Test

The slump cone test is very straightforward workability test for concrete which incorporates very less effort and gives speedy results. The slump cone test was carried out by Abrams cone which is open at the top and at the bottom having height 30 cm, lower dia of 20 cm and upper dia of 10 cm. A tamping rod is used which is generally made of steel having 16 mm dia and 60 cm long and rounded at one end. The slump cone test is carried out as per procedures and stated in IS:1199-1959. The slump cone test results are provided in the Table 5.3.

Table 5.3 Slump values of different percentages of froth floated silica concrete

Percentages of froth floated silica concrete	Slump value (mm)
0	76
20	72
40	58
60	52
80	36
100	24

The comparison of slump values of different percentages of froth floated silica in concrete is provided in the Figure 5.1 and the graph shows that with the increase in the percentage of froth floated silica in concrete, the slump value decreases.

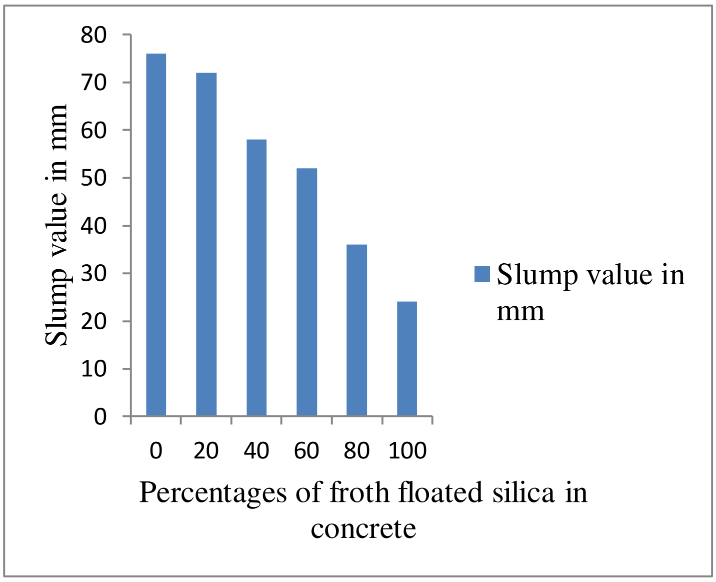

Figure 5.1 Comparison of Slump values of different percentages of froth floated silica in concrete.

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