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A Brief Study on Properties of High Strength Concrete using Nano Silica and Micro Silica

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ABSTRACT

Concrete is the most versatile material. Due to the persistent and continuous demands made on concrete to meet the various difficult requirements, extensive and wide spread research work is being carried out in the area of concrete technology. Engineers are continually pushing the limits to improve its performance with the help of innovative chemical admixtures and supplementary cementitious materials like fly ash, silica fume, and granulated blast furnace slag, steel slag etc.

Keywords: Study on Properties of High Strength Concrete using Nano Silica and Micro Silica.

I. INTRODUCTION

Concrete will be stuff composed primarily of cement, combination and water. It is a wide used construction material for varied types of structures ascribable to its structural stability and strength. Increasing the event challenges in combos with the new innovations in materials and production techniques havegiven new basis for manufacturing high performance concrete structures. Presently concrete is obtaining used for wide styles of functions to make it applicable in varied conditions. In these conditions commonplace concrete could fail to exhibit the desired quality performance or strength. In such cases, pozzolanic or mineral admixtures are accustomed modify the properties of traditional concrete.

The word 'Pozzolana' was derived from pozzuolu, a city in Italy, some of miles from metropolis and mount vacuous.The materials are of volcanic region containing varied fragments of stone, obsidian, feldspars, and quartz etc. The name 'Pozzolana' was initial applied only to the current material. However the term has been extended later to earth, terribly chemical compound rocks and varied artificial merchandise.Thus, the pozzolanic materials are natural or artificial having nearly identical composition as that of volcanic tuffs or ash found at pozzuolu.

Pozzolanic materials are chemical compound or chemical compound and aluminous material, that in themselves possess very little or no whole price, but will, in finely divided kind and inside the presence of wet, with chemicals react with hydroxide liberated on association, at degree Centigrade, to make compounds, possessing artefact properties. On the association of tri-calcium salt and di-calcium salt, hydroxide is created joined of the merchandise of association. This compound has no whole price and it's soluble in water and will be leached out by the percolating water. The substance or aluminous compound throughout a finely dividedkind react with the hydroxide to make terribly stable whole substances of subtle composition involving water, range twenty and compound.

II. METHODS AND MATERIAL

The materials used in the present investigation are as fallows

1. Cement
2. Aggregates
3. Water
4. Super plasticizer
5. Silica Fume
6. Nano silica

1. Cement

In this gift investigation radical school cement of standard hydraulic cement (OPC) of fifty three Grades was used that satisfies the wants of IS: 12269-1987. The subsequent tests area unit conducted on cement.

Tests on Cement

Following tests area unit conducted to grasp the physical properties of cement

1. Fineness
2. Consistency
3. Initial and Final Setting Time
4. Soundness
5. Specific gravity
6. Compressive strength

2. Aggregate

Aggregates are the important ingredient materials in concrete. They impart bulk volume to the concrete and scale back the shrinkage result. They occupy seventy to eighty % of the overall volume of concrete.

Fine Aggregate : Domestically out there sand collected from watercourse Tungabhadra was used. The subsequent tests area unit conducted on fine mixture per IS: 383-1987

Test on fine Aggregate

- Sieve Analysis of Fine Aggregate
- Specific Gravity of Fine Aggregate

Sieve analysis of Fine Aggregate (FA): The sieve analysis of fine mixture is as found. And from this take a look at the sand utilized in gift study was conformed to zone-II Semi log graph premeditated for sieve analysis the fineness modulus of fine aggregate is 2.81

Coarse Aggregate: The crushed aggregate was used from the local quarry. In this experiment the aggregate was used of 20mm down and tested as per IS: 2386-1963(I, II, III) specification. The subsequent tests area unit conducted on coarse mixture**.**

Test on Coarse Aggregate

- Sieve Analysis of Coarse Aggregate
- Specific Gravity of Coarse Aggregate

Sieve analysis of Coarse Aggregate
The sieve analysis of coarse mixture is to be find and Semi log graph is premeditated for sieve analysis of coarse mixture.

3. Water

Water used for mix and natural action is pure domestic water, orthodox to IS: 3025 – 1964 half twenty two, half twenty three and IS: 456 – 2000.

4. Super Plasticizers

Fosroc Aura combine four hundred was used for M40 and M50 Grade of concrete.

5. Silica Fume

The oxide fume was utilized in these experiments conforms to ASTM C 1240 and IS 15388:2003. The oxide fume is extraordinarily fine particle that exists in white color powder kind. Oxide fume has been procured from Astrra chemicals Ltd-Chennai.

6. Nano Silica

In this experimental study mixture nano oxide of **CemSyn®-XFX** is employed, it's a series of oxide based mostly binders /fillers obtained from Bee-chem.: Chemicals Ltd., Kanpur.

Test Programme

In this gift investigation it is aimed to study the strength characteristics of concrete such as compressive strength, split durability and flexural strengths of M40 and M50 grade concretes, by modifying standard concrete with totally different percentages of oxide fume (0%, 5%, 7.5%, 100 percent& 15%) and nano oxide (1%, 1.5%, 2%, & 2.5) by partial replacement of cement by weight. Various mix proportions of M40 and M50 grade concretes with nano silica, small oxide, combinations of nano silica and micro silica find out for for M40 and M50 grade concretes.

Mixing, Casting and Curing

The proportions of designed mixes for M40 (1:1.694:3.107) and M50 (1:1.501:2.827) grades alongside water cement quantitative relation zero.33 and 0.36 was utilized in the current study.

The different share replacement of cement with NS and SF for the each M40 and M50 grades concrete are found. these specimens were clean while not mud particles and were brushed with oil on all the inner faces to facilitate simple removal of specimens for demoulding.

The mixing of concrete is crucial for the assembly of uniform concrete. The blending ought to be confirming that the concrete becomes consistent, uniform and consistency.

Mixing of concrete is completed in line with IS: 516-1959. For every combine three cubes, three beams and three cylinders were forged. All the specimens were unbroken on the surface and therefore the freshly mixed concrete was poured in to the moulds in 3 layers every layer being compacted completely with a tamping rod to avoid voids. Finally all the specimens were vibrated on the moving table. The specimens are lined with bagging luggage to keep up close wetness content. When twenty four hours the specimens were demoulded and were unbroken immersed in an exceedingly clean cistern for set. When twenty eight days of set the specimens were tested for compressive strength, flexural strength and split durability.

TESTING OF CONCRETE

a.) Tests on Fresh concrete
b.) Tests on Hardened concrete

Testing of concrete plays a crucial role in dominant and conformist the standard of cement concrete works. Regular testing of raw materials of contemporary concrete and hardened concrete are plays a crucial half to manage the standard of the concrete that helps to attain higher performance of concrete with relevance each strength and sturdiness. The most purpose of testing hardened concrete is to substantiate that the concrete attains target mean strength.

a.) Tests on Fresh concrete

Fresh concrete or plastic concrete may be a freshly mixed concrete which may be moulded into any form. Strength of concrete primarily depends upon the strength of cement past.

The following take a look at is conducted to see the standard of concrete.

Compaction Factor Test

Compaction issue take a look at is adopted to work out the workability of concrete. The workability is that the property of the concrete that determines the quantity of labor needed to provide full compaction. To seek out the workability of freshly ready concrete, the take a look at is distributed as per specifications of IS: 1199-1959. It provides a concept of the capability of being worked, i.e., plan to manage the number of water in cement concrete combine to urge uniform strength.It was observed that increasing of silica fume and nano silica in the concrete shows the decreasing order of workability. The results of compaction factor for different mixes are found.

TESTS ON HARDENED CONCRETE

Introduction

Compressive strength of hardened concrete is that the most vital parameter and representative of just about overall quality of concrete. It chiefly depends on the water/cement quantitative relation of the combination, set and age when it's forged. Compressive strength of concrete is set by testing the cylinder and cube specimens of concrete employing a compression testing machine at numerous ages such as: three days, 7 days, 14 days, and 28 days respectively.

Compressive Strength of Concrete

The test is distributed to seek out the compressive strength of concrete for both M40 and M50 grade in an exceedingly Compressive Testing Machine (CTM) 2000 KN capacity as per IS: 516 1959.

$$\therefore \text{Compressive strength} = \frac{P}{A}\text{, in N/mm2}$$

Where,
P = most applied load in KN
A = space of Specimen over that load applied.

Split Tensile Strength of Concrete

The durability is one in all the fundamental and necessary properties of the concrete. The concrete isn't usually expected to resist the direct tension attributable to its durability and brittle nature. However, the determination of durability of concrete is critical to work out the load at that the concrete member might crack. The cracking may be a type of tension failure.

The magnitude of this tensile stress σsp (acting in an exceedingly direction perpendicular to the road of applied loading) is given by the formula (IS: 516-1970)

$$\sigma_{sp} = \frac{2P}{\pi dl} = 0.637\,\frac{P}{dl}$$

Where P is the applied load; d and l are the diameter and the length of specimen, respectively.
Sample calculation of Split durability of concrete is found

Flexural Strength of Concrete

Flexural strength is one live of the durability of concrete. it's a live of Associate in Nursing unreinforced concrete beam or block to resist failure in bending. The flexural strength of concrete is completed within the universal testing machine (UTM).

Flexural strength of concrete

$$f_b = \frac{PL}{bd^2}\,\text{when a} \geq \frac{40}{3}\,\text{cm}$$

When 'a' is larger than 20.0cm for 15.0cm specimen or larger than 13.3 cm for a 10.0cm specimen,or

$$f_b = \frac{3Pa}{bd^2}\,\text{when}\,\frac{40}{3} \geq a \geq 11\text{cm}$$

When 'a' is a smaller amount than 20.0 cm however larger than 17.0 cm for 15.0 specimen, or but 13.3 cm however larger than 11.0 cm for a 10.0 cm specimen

Wherever
b = measured breadth in cm of the specimen.
d = measured depth in cm of the specimen at the purpose of the failure,
l = length of the span on that the specimen was supported, and
p = most load in weight unit applied to the specimen.

The compressive strength, split durability and flexural strength results of all mixes are found.

III. RESULTS AND DISCUSSION

Compressive Strength

Compressive strength of 2 mixes M40 and M50 at 28 days age, with replacement of SF was exaggerated bit by bit up to AN optimum replacement level of 7.5% and so remittent. The most twenty eight days cube strength of M40 grade with 7.5% of oxide fume was 61.24 N/mm2 and of M50 grade with 7.5% SF was 69.09 N/mm2.The compressive strength of M40 grade concrete with partial replacement of cement by 7.5% SF shows 23.56% improvement and of M50 grade with 7.5% replacement shows 22.53% improvement over plain mixes of M40 and M50 grades concrete. The compressive strength of M40 grade concrete with partial replacement of cement by two NS shows twenty 27.8% improvement and of M50 grade with two replacement shows twenty two.23% improvement compare to plain mixes of M40 and M50 grades concrete.

Split Tensile Strength

Split tensile strength of M40 and M50at 28 days age with replacement of NS was increased gradually up to an optimum replacement level of 2% and then decreased. The maximum 28 days Split tensile strength of M40 grade with 2% NS was 4 N/mm^2 and of M50 grade with 2% NS was 4.32 N/mm^2. Split tensile strength of M40 & M50grades were also studied with the combination of SF at 7.5% and NS at 2% which results in a marginal improvement in strengths over respective optimal replacement levels of SF (7.5%) and NS (2%).it clearly shows the variation of split tensile strength of M40 & M50grade with SF and NS replacement.

Flexural Strength

Flexural strength of two mixes M40 and M50at 28 days age, with replacement of SF was increased gradually up to an optimum replacement level of 7.5% and then decreased. The maximum 28 days flexural strength of M40 grade with 7.5% of silica fume was 4.160 N/mm^2 and of M50 grade with 7.5% SF was 4.560 N/mm^2. The Flexural strength of M40 grade concrete with partial replacement of cement by 7.5% SF shows 9.18% improvement and of M50 grade with 7.5% replacement shows 9.35% improvement over plain mixes of M40 and M50 grades concrete. The Flexural strength of M40 grade concrete with partial replacement of cement by 2% NS shows 16.80% improvement and of M50 grade with 2% replacement shows 12.94% improvement compare to plain mixes of M40 and M50 grades concrete.

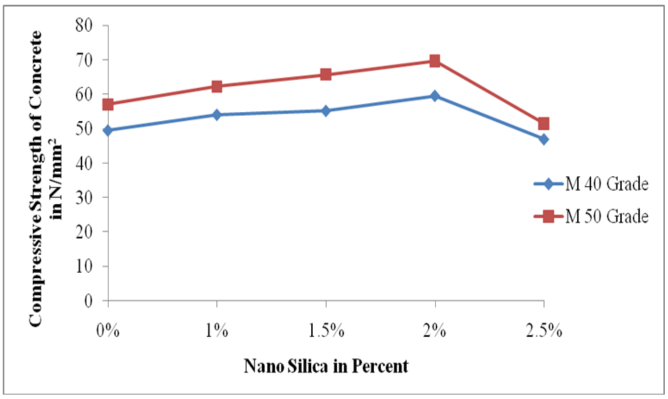

Figure 1. Compressive strength of concrete by using nano silica

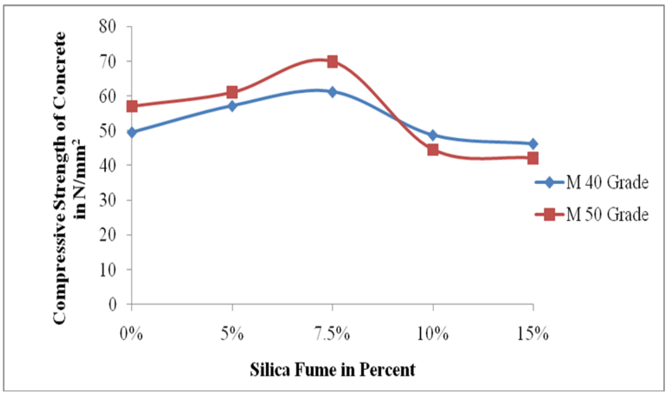

Figure 2. Compressive strength of concrete by using silica fume

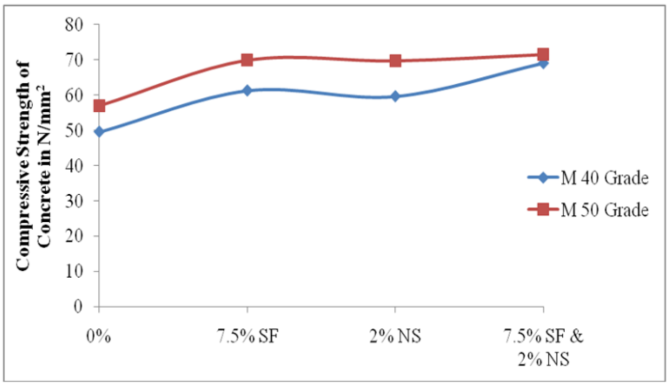

Figure 3. Compressive strength of concrete by using both nanosilica and silica fume

IV. CONCLUSION

Based on experimental results the following conlusions are drawn

1. Compressive strength, split tensile strength and flexural strength of both mixes M40 and M50 grades were increased gradually up to replacement level 7.5% SF and up to replacement level 2% NS and then decreased.
2. The workability of both M40 and M50 grade concretes were decreased with increase in replacement of SF and NS in concrete.
3. Maximum compressive strength, split tensile strength and flexural strength with replacement of cement by 7.5% SF for M40 grade concrete is 23.56%, 21.47% and 9.18% over conventional mix of M40 grades.
4. Maximum compressive strength, split tensile strength and flexural strength with replacement of cement by 2% NS for M40 grade concrete is 20.27%, 22.70% and 16.80% over conventional mix of M40 grades.
5. Maximum compressive strength, split tensile strength and flexural strength with replacement of cement by 7.5% SF for M50 grade concrete is 22.53%, 17.61% and 9.35% over conventional mix of M50 grades.
6. Maximum compressive strength, split tensile strength and flexural strength with replacement of cement by 2% NS for M50 grade concrete is 22.23%, 22.32% and 12.94% over conventional mix of M50 grades.
7. The percentage increase in compressive strength of concrete with combination of SF at 7.5% and NS at

2% is 25.80% for M40grade and 25.35% for M50 grade concrete more when compared to normal concrete of M40 and M50 grades respectively.

8. The percentage increase in split tensile strength of concrete with combination of SF at 7.5% and NS at 2% is 25.76% for M40grade and 25.03% for M50 grade concrete more when compared to normal concrete of M40 and M50 grades respectively.
9. The percentage increase in flexural strength of concrete with combination of SF at 7.5% and NS at 2% is 18.89% for M40grade 16.06% for M50 grade concrete more when compared to normal concrete of M40 and M50 grades respectively.

V. RECOMMENDATIONS FOR FUTURE WORK

1. Further studies can be carried out with the high grade concretes.
2. In this present study colloidal nano silica was used, the further study can be carried out by using nano silica powder.
3. Further studies can be carried out with suitable combinations of different nano materials like nanometakolin, nano iron, and nano titanium and carbon nano tubes.

V(a).MIX DESIGN FOR M40 GRADE

1. Stipulations For Proportioning:

Grade designation = 40Mpa
Type of cement = OPC
(Ultra Tech Cement53Grade)
Maximum size of aggregate = 20 mm
Minimum cement content = 320 kg
Maximum water cement ratio = 0.35
Workability = 50 mm
slump
Exposure condition Cement content = severe
Degree of supervision = Good
Type of aggregate = Crushed
Maximum cement content = 450 kg
Chemical Admixture Type = Aura Mix
SP-400 (Super plasticizer)

2. Test Data For Materials:

Cement used =OPC
(Ultra Tech Cement 53Grade)
Specific gravity of cement = 3.11
Specific gravity of coarse aggregate = 2.67
Specific gravity of fine aggregate = 2.68

Fine aggregate conforming to grade zone II of table-4 of IS- 383

Target Mean Strength For Mix Proportioning

$F^1_{ck} = f_{ck} + 1.65 \times s \quad (\therefore s = 5.0)$
$= 40 + 1.65 \times 5.0$
$f_{ck} = 48.25\ N/mm^2$

Where F^1_{ck} =Target average compressive strength at 28 days,
f_{ck}= Characteristic compressive strength at 28 days,
s = Standard deviation

Selection of Water Cement Ratio:

From table-5 of IS-456, maximum water cement ratio
= 0.45
Based on experience, adopted water cement ratio i= 0.36

Selection of Water Content:

Aggregate [for 25-50mm slump range] = 186 liter
From table 2, Maximum water content = 186 liter (for 25 To 50 mm slump range)

As Super Plasticizer is used, the water content can be reduced up to 20 percent and above. Based on trials with super plasticizer water content reduction of 22 percentages has been achieved. Hence, the arrived water content = 186 x 0.78

Calculation of Cement Content

Water cement ratio = 0.36
= 186 x 0.78 =145.08
= 145.08÷0.3
= 403 kg/m^3
From table-5 of IS-456, Maximum cement content
For sever exposure condition = 450 kg/m^3
403 $/m^3$< 450 kg/m^3
hence ok
404

Proportion of Volume of Coarse Aggregate and Fine Aggregate:

From table 3 volume of coarse aggregate corresponding to 20 mm size aggregate and fine aggregate (zone II) for water cement ratio of 0.50 = 0.62.

In the present case water cement ratio is 0.36. Therefore, volume of coarse aggregate is increased to decrease the fine aggregate content. As the water cement ratio is lower by 0.10, the proportion of volume of coarse aggregate increased by 0.03 (at the rate of -/+ 0.01 for every $\pm$ 0.05 change in water cement ratio). Therefore corrected proportion of volume of coarse aggregate for the water cement ratio of 0.36 = 0.648Volume of coarse aggregate= 0.648

Volume of fine aggregate= 0.352

Mix Calculations

The mix calculations per unit volume of concrete shall be follows

a) Volume of concrete = 1 m^3

b) Volume of cement

$$= \frac{\text{Mass of cement}}{\text{Specific gravity of cement}} \times \frac{1}{1000} = (403 \div 3.11) \times \frac{1}{1000} = 0.1296\ m^3$$

c) Volume of water

d) $$\frac{\text{Mass of water}}{\text{Specific gravity of water}} \times \frac{1}{1000} = \frac{145.08}{1} \times \frac{1}{1000}$$

$$= 0.14508\ m^3$$

Volume of Chemical Admixture @ 0.5% by mass of Cementitious Materials

$$= \frac{\text{Mass of chemical admixture}}{\text{Specific gravity of admixture}} \times \frac{1}{1000}$$

$$= \frac{2.0151}{1.2} \times \frac{1}{1000} = 0.00167917\ m^3$$

Volume of coarse aggregate = [a-(b + c +d)]

= 1-(0.1296 +0.14508 + 0.00167917)= 0.724 m^3

Mass of coarse aggregate =e x volume of coarse Aggregate x Specific Gravity of Coarse Aggregate x 1000 = 0.724 x 0.648 x 2.67 x1000 = 1252.04 kg/m^3

e) Mass of fine aggregate = e x volume of coarse aggregate x Specific Gravity of fine aggregate x 1000 = 0.724 x0.352 x2.68 x1000= 682.67 kg/m^3

3. Mix Proportions

Cement = 403kg/m^3
Water = 145.08 kg/m^3
Fine aggregate = 682.67 kg/m^3
Coarse aggregate = 1252.04 kg/m^3
$\frac{\text{Water}}{\text{Cement}}$ Ratio = 0.36

Cement	Water	Fine aggregate	Coarse aggregate
403	145.08	682.67	1252.04
1	0.36	1.69	3.10

V(b).Mix Design For M50 Grade

1. Stipulations For Proportioning

Grade designation = 50Mpa
Type of cement = OPC (Ultra Tech Cement53Grade)
Maximum size of aggregate = 20 mm
Minimum cement content = 320 kg
Maximum water cement ratio = 0.35
Workability = 50 mm slump
Exposure condition = severe
Degree of supervision = Good
Type of aggregate = Crushed
Maximum cement content = 450 kg
Chemical Admixture Type = Aura Mix SP-400 (Super Plasticizer)

2. Test Data For Materials:

Cement used = OPC (Ultra Tech Cement 53Grade)
Specific gravity of cement = 3.11
Specific gravity of coarse aggregate = 2.67
Specific gravity of fine aggregate = 2.68

Fine aggregate conforming to grade zone II of table-4 of IS- 383

3. Target Mean Strength For Mix Proportioning

F^1_{ck} = f_{ck}+ 1.65 x s (∴ s = 5.0)
= 50 + 1.65 x 5.0
= 58.25 N/mm^2

Where F^1_{ck}=Target average compressive strength at 28 days,
f_{ck}= Characteristic compressive strength at 28 days,
s = Standard deviation

Selection of Water Cement Ratio:
From table-5 of IS-456, maximum water cement ratio = 0.40
Based on experience, adopted water cement ratio is = 0.33

4. Selection Of Water Content:

From Table-2 of IS: 10262-2009 the m maximum water content for 20mm Aggregate [for 25-50mm slump range] = 186 literFrom table 2, Maximum water content = 186 liter (for 25 to 50 mm slump range)

As Super Plasticizer is used, the water content can be reduced up 20 percent and above. Based on trials with super plasticizer water content reduction of 22 percentages has been achieved. Hence, the arrived water content = 186 x 0.78

5. Calculation Of Cement Content:

Water cement ratio = 0.33

Cement content = 186 x 0.78

= 145.08
= 145.08÷0.33
= 439.64 kg/m^3

From table-5 of IS-456, Maximum cement content for sever exposure condition 450 kg/m^3.439.64 kg/m^3< 450 kg/m^3 hence ok.

6. Proportion Of Volume Of Coarse Aggregate And Fine Aggregate:

From table 3 volume of coarse aggregate corresponding to 20 mm size aggregate and fine aggregate (zone II) for water cement ratio of 0.50 = 0.62.

In the present case water cement ratio is 0.35. Therefore, volume of coarse aggregate is increased to decrease the fine aggregate content. As the water cement ratio is lower by 0.10, the proportion of volume of coarse aggregate increased by 0.03 (at the rate of -/+ 0.01 for every $\pm$ 0.05 change in water cement ratio). Therefore corrected proportion of volume of coarse aggregate for the water cement ratio of 0.33 = 0.654

Volume of coarse aggregate = 0.654
Volume of fine aggregate = 0.346

7. Mix Calculations:

The mix calculations per unit volume of concrete shall be follows

a) Volume of concrete = 1 m^3
b) Volume of cement =
$$\frac{\text{Mass of cement}}{\text{Specific gravity of cement}} \text{ x } \frac{1}{1000}$$
$$=(439.64 \div 3.11) \text{ x } \frac{1}{1000} = 0.1414 \text{ m}^3$$
c) Volume of water =
$$\frac{\text{Mass of water}}{\text{Specific gravity of water}} \text{ x } \frac{1}{1000}$$
$$= \frac{145.08}{1} \text{ x } \frac{1}{1000} = 0.14508 \text{ m}^3$$
d) Volume of Chemical Admixture @ 0.7% by mass of Cementitious
$$\text{Materials} = \frac{\text{Mass of chemical admixture}}{\text{Specific gravity of admixture}} \text{ x } \frac{1}{1000}$$
$$= \frac{2.198}{1.2} \text{ x } \frac{1}{1000} = 0.00183182$$
e) Volume of coarse aggregate = [a-(b + c +d)]
= 1-(0.1414 +0.14508 + 0.00183182)
= 0.712 m^3
f) Mass of coarse aggregate = e x volume of coarse Aggregate x Specific Gravity of Coarse Aggregate x 1000 = 0.712 x 0.654 x 2.67 x1000= 1242.80 kg/m^3

g) Mass of fine aggregate = e x volume of coarse aggregate x Specific Gravity of Fine Aggregate x 1000 = 0.712 x0.346 x2.68 x1000= 659.96 kg/m^3

8. Mix Proportions

Cement = 439.64 kg/m^3
Water = 145.08 kg/m^3
Fine aggregate = 659.96 kg/m^3
Coarse aggregate = 1242.80 kg/m^3

$$\frac{\text{Water}}{\text{Cement}} \text{ Ratio } = 0.33$$

Cement	**Water**	**Fine aggregate**	**Coarse aggregate**
439.64	145.08	659.96	1242.80
1	0.33	1.50	2.82

VI. REFERENCES

[1]. ACI Committee 234, (1995), "Guide for the use of Silica Fume in Concrete", ACI Materials Journal, pp 437 – 440.
[2]. Shannag M.J, "High strength concrete containing natural Pozzolana and silica fume", Cement & Concrete Composites, vol 22, 2000, pp. 399-406.
[3]. Joshi, N. G. Bandra – Worli Sea Link: "Evolution of HPC mixes containing Silica Fume", Indian Concrete Journal, (Oct. 2001), pp. 627-633.
[4]. Basu, P. C.: "NPP containment structures Indian experience in Silica Fume –based HPC", Indian Concrete Journal, (Oct. 2001), pp. 656-664.
[5]. Verma Ajay, Chandak Rajeec and Yadav R.K. "Effect of micro silica on the strength of concrete with ordinary Portland cement" Research journal of Engineering Science ISSN 2278-9472 vol.1(3), 1-4, sept (2012).
[6]. Thomas, M D. A. "Using Silica Fume to Combat ASR in Concrete", Indian Concrete Journal, (Oct. 2001), pp 656-664.
[7]. Lewis, R. C., Hasbi, S. A.: "Use of Silica Fume concrete: Selective case studies", Indian Concrete Journal, (Oct. 2001), pp. 645-652.
[8]. IS: 10262-2009 Recommended guide lines for concrete mix design.
[9]. IS: 383-1970 Specification for coarse and fine aggregates from natural resources.
[10]. IS: 516-1959 Methods of tests for strength of concrete.
[11]. IS: 5816 Method of test for splitting tensile strength.
[12]. IS: 4031-1996 (Part-1) Determination of Fineness by dry sieving.
[13]. IS: 4031-1988(Part-3) Determination of soundness.
[14]. IS: 4031-1988(Part-4) Determination of Standard consistency of Cement paste.
[15]. IS: 4031-1988(Part-5) Determination of Initial and Final Setting Times.