INNOVATIVE USE OF MICROFINES FOR SUSTAINABLE AND DURABLE CONCRETE

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Abstract: It's high time for the construction industry to adopt sustainable development initiatives for the wellbeing of our planet and development of society. Concrete is the most versatile product used as building material in world's construction industry, and it generates harmful gases like carbon dioxide to atmosphere which leads to global warming. A lot of work is going on in the area of environment friendly concrete which is sustainable and durable as well. This paper depicts the benefits of microfines in making of concrete to achieve sustainability. It also supports the use of durable concrete as a viable alternative to conventional concrete for structural applications. Current research needs and opportunities are also discussed.

***Index Terms* - Concrete, admixture, durable, high compressive strength.**

I. INTRODUCTION

Concrete is widely used as construction material around the world, and its properties have been undergoing changes through technological advancement. numerous types of concrete are developed to enhance the different properties of concrete. The earliest is that the traditional normal strength concrete which consists of only four constituent materials, which are cement, water, fine aggregates and coarse aggregates. With quick increment and better demand for housing and infrastructure, among recent developments in civil engineering, like high-rise buildings and long-span bridges, higher compressive strength concrete was required. in the beginning, reducing the water-cement ratio was the easiest way to attain high compressive strength. The fifth ingredient, a water reducing agent or super plasticizer was indispensable. However, sometimes the compressive strength was not as vital as some other properties, such as low permeability, durability and workability. Thus, high-performance concrete was proposed and widely studied at the end of the last century.

II. HIGH PERFORMANCE CONCRETE (HPC)

As a result of growth in advance technology in concrete, High Performance Concrete (HPC) has gained worldwide popularity in the construction industry since 1990. In practice, high performance concrete, are generally characterized by high cement content and very low w/c ratios. Such concrete suffer from two major weaknesses. It is extremely difficult to obtained proper workability, and to retain the workability for sufficiently long period of time with such concrete mixes. High dosage of High Range Water Reducing agents(HRWR) then become a necessity, and resulting cohesive and thixotropic, sticky mixes are equally difficult to place and compact fully and efficiently.

High performance concretes are used extensively throughout the world where oil, gas, nuclear and power industries are among the major users. The applications of such concretes are increasing day by day due to their superior structure performance, environmental friendliness, and energy conserving implications.

III. LITERATURE REVIEW

Darren T.Y. Lim et. al. stated improving the durability of concrete to sustain a longer life span and producing a greener concrete are becoming important criteria in obtaining quality concrete. Incorporating Ground Granulated Blast-furnace Slag (GGBS) as a mineral admixture improves the workability and pump-ability of fresh concrete. Blended cement concrete has reduced pore connections; thus, reducing the permeability and improving the resistance of the concrete against chloride penetration. With the use of GGBS, the amount of greenhouse gas produced in making the concrete and the energy required to produce the concrete are greatly reduced. Ultra-Fine GGBS (UFGGBS) with an average particle size less than 10μ and a Blaine surface area greater than 600 m^2/kg can greatly improve the properties of the concrete in terms of dispersion and chemical reactivity effects.

Nima Farzadnial, et. al. stated Numerous types of concrete have been developed to enhance the different properties of concrete. So far, this development can be divided into four stages. The earliest is the traditional normal strength concrete which is composed of only four constituent materials, which are cement, water, fine and coarse aggregates. With a fast population growth and a higher demand for housing and infrastructure, accompanied by recent developments in civil engineering, such as high-rise buildings and long-span bridges, higher compressive strength concrete was needed. At the beginning, reducing the water-cement ratio was the easiest way to achieve the high compressive strength. Thereafter, the fifth ingredient, a water reducing agent or super plasticizer, was indispensable. However, sometimes the compressive strength was not as important as some other properties, such as low permeability, durability and workability. Thus, high performance concrete was proposed and widely studied at the end of the last century. Currently, high-performance concrete is used in massive volumes due to its technical and economic advantages.

M.Frias, et. al. stated their experimental work, the influence of the pozzolanic activity of the Metakaolin (MK) on the hydration heat has been studied in comparison to the behaviors of other traditional pozzolanic materials such as flyash and silica fume. The results revealed that MK mortars produce a slight heating increase when compared to a 100% Portland cement mortar, due to the high pozzolanic activity of MK. With respect to the hydration heat, MK-blended mortar showed closer behaviors to silica fume than to fly ash.

David G. Snelson et al. investigated the effect of using Metakaolin and fly ash as partial replacements with cement on the rate of heat evolution during hydration. It was observed that adding fly ash to Portland cement enhanced the Portland cement hydration in the very early stages of hydration, but at extended periods an increase in fly ash replacement causes a systematic reduction in heat output. When combining Metakaolin and fly ash in ternary blending, the Metakaolin has a dominant influence on the heat output versus time profiles.

IV. RESEARCH METHODOLOGY

4.1.1 High Performance Concrete

In order to measure the effect of microfine, four sequences of concrete mixes were prepared. Following were the percentage of micro fines used.

OPC + 30%FA
OPC + 30%FA + 1.75%SF + 1.75%AL
OPC + 30%FA + 3.5%SF + 3.5%AL
OPC + 30%FA + 5.25%SF + 5.25%AL

Table 4.1 Parameters for mix design (M80 grade of concrete)

Grade	M80
Condition of exposure	Severe
Type of cement	OPC- 53grade
Brand of cement	AMBUJA cement
Mineral admixture	Fly Ash, micro silica, GGBS
Chemical admixture	Master Glenium
Fine aggregate Zone	Zone -1
Maximum size of aggregate	20mm

Steps of Mix design

Determination of target mean strength

$F_m = f_{ck} + (t)(s) = 80 + (1.65)(6) = 89.9 \approx 90$ MPa (refer table no.3.12, 3.13)

Where,

'f_{ck}' is the specified minimum or characteristic strength of concrete

's' is the standard deviation determined from table no. 3.4 for the above value of f_{ck} and degree of quality control expected at site.

't' is the constant depending on the probability of certain number of results likely to fall below f_{ck}.

Note: The above values correspond to the site control having proper storage of cement, weigh batching of all materials; controlled addition of water, regular checking of all materials, aggregates grading and moisture content; and periodical checking of workability and strength. **(Where there is deviation from the above the values given in the above table shall be increased by 1N/mm^2)**

Table no 4.2 Value of 't' (IS 10262 – 1982)

Accepted proportion of Low results	T
1 in 5	0.84
1 in 10	1.28
1 in 15	1.50
1 in 20	**1.65**

1 in 40	1.96
1 in 100	2.33

1. Selection of cement content

Maximum cement content specified by IS code is 450 kg/cum

Add 50% GGBS

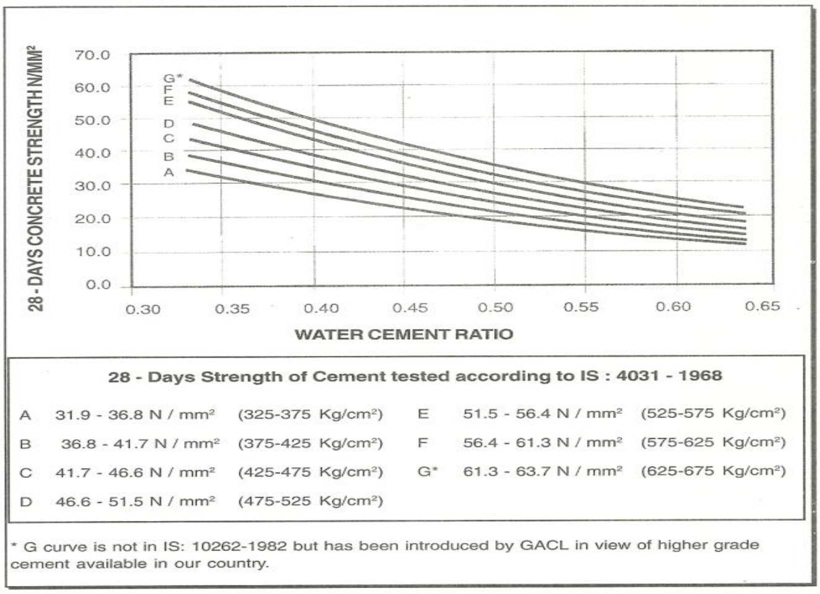
Total binder content = 710 kg/m^3

Table no 4.3 (cement content)

	Trail-1	Trail-2
GGBS (50%)	0.5 x 710	355kg/m^3
Cement	710-355	355kg/m^3

2. Determination of water to cement ratio

Graph no 4.1 Relation between water cement ration and concrete strength at 28 days for different cement strengths (IS 10262 – 1982)



Equation of curve G:

166.6 X2- 291.67X +140 = Target mean Strength

W, X= water to cement ratio

166.6 X2- 291.67X +140 = 90

X= 0.193

Adopt water to cement ratio as 0.22

3. Determination of aggregate proportions

There are usually 4 zones of sand according to its grading.

Table no 4.4 Various zones of sand

Zone 1	Preferred (not available)
Zone 2	Preferred
Zone 3	Not good
Zone 4	Worst

In this mix design we have used sand which belongs to Zone 2

Since our maximum size of aggregate is 20mm, according to IS:10262 : 2009 ,

For water cement ratio of 0.5, coarse aggregate is 0.62% - (Table 3)

Table no 4.5 Volume of coarse aggregate per unit volume of total aggregate for different zones of fine aggregate.

NOMINAL MAX SIZE OF AGGREGATE	ZONE IV	ZONE III	ZONE II	ZONE I
10	0.50	0.48	0.46	0.44
20	0.66	0.64	0.62	0.60
40	0.75	0.73	0.71	0.69

Since our water cement ratio is 0.22 we increase the volume of coarse aggregate.

Increase in volume = 0.63 + (0.01 x 5) = 0.68%.

For pump able concrete, this value can be reduced by 10%.

Volume of coarse aggregate = 0.68 x 0.9 = 0.612 %

Hence, final volume of coarse aggregate = 0.622%

Therefore fine aggregate = 1- 0.622 = 0.378%.

1. Volume of concrete 1m^3
2. Volume of cement = (355/ 3.15) x 0.001 = 0.112 m^3
3. Volume of GGBS = (355/ 2.19) x 0.001 = 0.122 m^3
4. Volume of water = (156/ 1) x 0.001 = 0.1562 m^3
5. Volume of admixture = 0.7% = 0.007 m^3
6. Volume of all in aggregate = 1- (0.112+ 0.122+ 0.156 +0.007) = 0.6028m^3
7. Mass of aggregate = Volume of all in aggregate x Volume of coarse aggregate x specific gravity of coarse aggregate x 100
   = 0.602 x 0.62x2.74 x 1000
   = 1028 kg.
8. Mass of aggregate = Volume of all in aggregate x Volume of coarse aggregate x specific gravity of coarse aggregate x 100
   = 0.628 x 0.378 x 1000
   = 556 kg

Since Specific gravity of coarse aggregate = 2.74

Specific gravity of fine aggregate = 2.44

Among coarse aggregate we assume 55% of 20 mm aggregate, and 45% of 10mm aggregate

Therefore, 20mm aggregate = 0.55 x 1028 = 565.4 kg ~ 570 kg

10mm aggregate = 1028 – 570 = 458 kg

Summary of Materials required per m^3 of concrete as per mix design

Table no 4.6 Materials per m^3 of concrete

Sr No.	Materials per m3 of concrete	Quantity(kg/m^3)
1	Cement	355
2	Total cementitious material	700
4	Coarse Aggregate (20mm)	570
5	Coarse Aggregate (10mm)	458
6	Chemical Admixture	0.7%

IV. RESULTS AND DISCUSSION

A. HIGH PERFORMANCE CONCRETE

Tabulations of Results

- **Mix I:-Trail mix OPC + 30%FA**

Table no 5.1 Material for Mix I

Material for Trial mix 1	
Ambuja Cement (OPC)	490Kg/m^3
Fly Ash	210Kg/m^3
Water	147kg/m^3
Admixture	0.7%

1. Assessment of Workability

Table 5.2 Workability Results Of Mix I

SLUMP (mm)	
Time in minutes	Trial mix
Initial	120

2. Assessment of Compressive Strength

Table 5.3 Compressive strength results of Mix 1

Compressive Strength (MPa)	
Time in days	Trial mix
3 Days	36.3
7 Days	70.4
28 Days	94.9

- **Mix II:-** Trail mix OPC + 30%FA+1.75%SF+1.75%AL

Table 5.4 parameters of Mix II

Materials for Trial mix 2	
Ambuja Cement (OPC)	473 Kg/m^3
Alcco Fine	12.25 Kg/m^3
Silica Fumes	12.25 Kg/m^3
Fly Ash	202.65 Kg/m^3
Water	147 Kg/m^3
Admixture	0.65%

1. Assessment of Workability

Table 5.5 Slump test results of Mix II

SLUMP (mm)	
Time in minutes	Trial mix 2
Initial	120

2. Assessment Of Compressive Strength

Table 5.6 Compressive strength results of Mix 1I

Time in days	Trial mix

3 Days	39.0
7 Days	75.9
28 Days	98.1

- **Mix III:-** OPC + 30%FA+3.5%SF+3.5%AL

Table 5.7 Parameters of Mix III

Materials for Trial mix 3	
Ambuja Cement (OPC)	433.70 Kg/m^3
Fly Ash	195.30 Kg/m^3
Allco Fine	24.50Kg/m^3
Silica Fumes	24.50 Kg/m^3
Water	147 Kg/m^3
Admixture	0.7%

1. **Assessment of Workability**

Table 5.8 Slump test results of Mix III

SLUMP (mm)	
Time in minutes	Trial mix
Initial	125

2. **Assessment of Compressive Strength**

Table 5.9 Compressive strength results of Mix III

Time in days	Trial mix
3 Days	42.60
7 Days	79.1
28 Days	101.08

- **Mix IV:-** OPC + 30%FA+5.25%SF+5.25%AL

Table 5.10 Parameters of Mix IV

Materials for Trial mix 4	
Ambuja Cement (OPC)	438.55Kg/m^3
Fly ash	187.95Kg/m^3
Silica Fumes	36.75Kg/m^3
Allco Fines	36.75Kg/m^3
Water	147 Kg/m^3
Admixture	0.8 %

1. **Assessment of Workability**

Table 5.11 Slump test results of Mix IV

Time in minutes	Trial mix no 4
Initial	110

2. **Assessment Of Compressive Strength**

Table 5.12 Compressive strength results of Mix IV

Time in days	Trial mix
3 Days	46.26
7 Days	82.7
28 Days	112.2

5.4 Comparative study

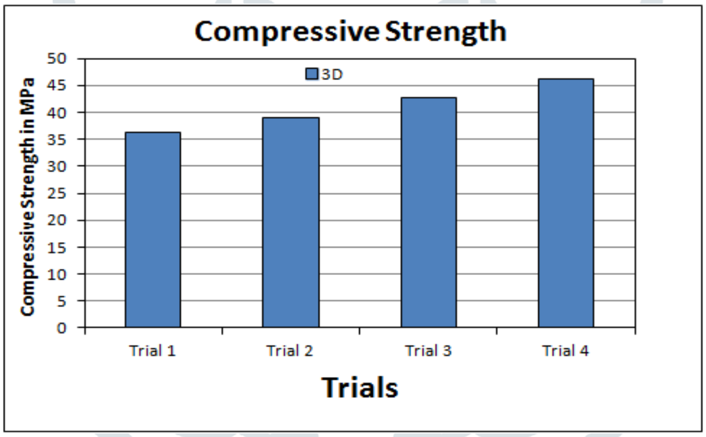
5.4.1Compressive test :-

We have done the compressive test on cube of size 15cmx 15cm x 15cm We have found the following results

Table 5.1 Comparision of Compressive strength test results

Trial mix	Strength in mpa		
	3days	7days	28days
OPC + 30%FA	36.30	70.4	94.9
OPC + 30%FA+1.75%SF+1.75%AL	39.0	75.9	98.1
OPC + 30%FA+3.5%SF+3.5%AL	42.60	79.1	101.08

Graph no. 5.2 Compressive strength test results

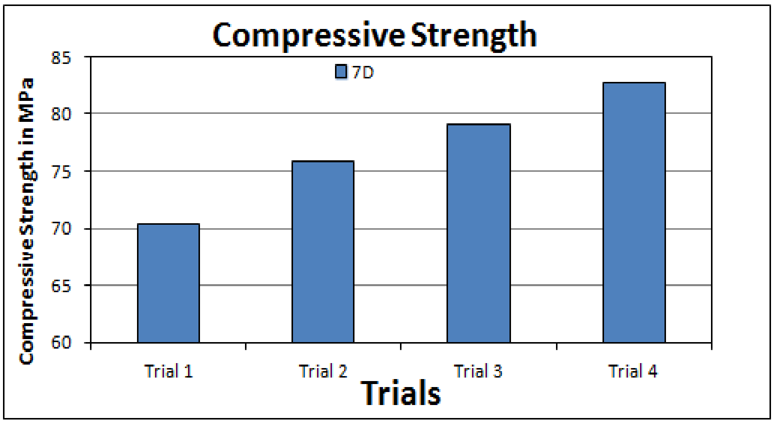


Discussion : Comparing the 3 days strength between the various micro fines, it can be observed the trial mix 4 which contains 50% of allco fine achieves the highest strength among the four.

Table 5.3 Compressive strength test results

OPC replacem	OPC	Flyash	Silica Fum	Alccofine	3D	
					Mpa	Avg
0.0%	70.00%	30.00%	0.00%	0.00%	35.2	
0.0%	70.00%	30.00%	0.00%	0.00%	36.7	36.3
0.0%	70.00%	30.00%	0.00%	0.00%	36.9	
5.00%	66.50%	30.00%	1.75%	1.75%	38.1	
5.00%	66.50%	30.00%	1.75%	1.75%	38.7	39.0
5.00%	66.50%	30.00%	1.75%	175%	40.3	
10.00%	63.00%	30.00%	3.50%	3.50%	42.0	
10.00%	63.00%	30.00%	3.50%	3.50%	42.5	42.6
10.00%	63.00%	30.00%	3.50%	3.50%	43.2	
15.00%	59.50%	30.00%	5.25%	5.25%	45.3	
15.00%	59.50%	30.00%	5.25%	5.25%	47.2	46.265
15.00%	59.50%	30.00%	5.25%	5.25%	46.4	

Graph no. 5.4 Compressive strength test results

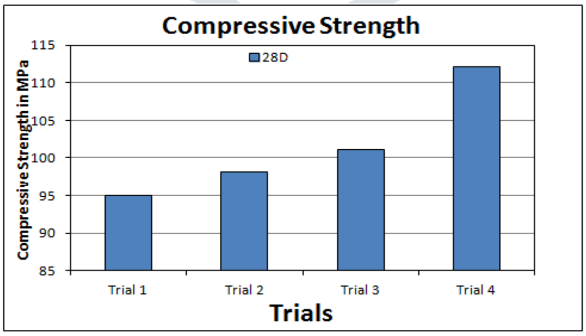


Discussion :- Comparing the 7 days strength between the various micro fines, it can be observed the trial mix 4 which contains 50% of all co fine achieves the highest strength among the four.

Table 5.5 Compressive strength test result

OPC replacem	OPC	Flyash	Silica Fum	Alccofine	7D Mpa	7D Avg
0.0%	70.00%	30.00%	0.00%	0.00%	64.5	70.4
0.0%	70.00%	30.00%	0.00%	0.00%	73.7	
0.0%	70.00%	30.00%	0.00%	0.00%	72.9	
5.00%	66.50%	30.00%	1.75%	1.75%	73.8	75.9
5.00%	66.50%	30.00%	1.75%	1.75%	76.0	
5.00%	66.50%	30.00%	1.75%	175%	77.9	
10.00%	63.00%	30.00%	3.50%	3.50%	79.9	79.1
10.00%	63.00%	30.00%	3.50%	3.50%	78.6	
10.00%	63.00%	30.00%	3.50%	3.50%	78.7	
15.00%	59.50%	30.00%	5.25%	5.25%	84.1	82.7
15.00%	59.50%	30.00%	5.25%	5.25%	82.0	
15.00%	59.50%	30.00%	5.25%	5.25%	81.9	

Graph no. 5.6 Compressive strength test results

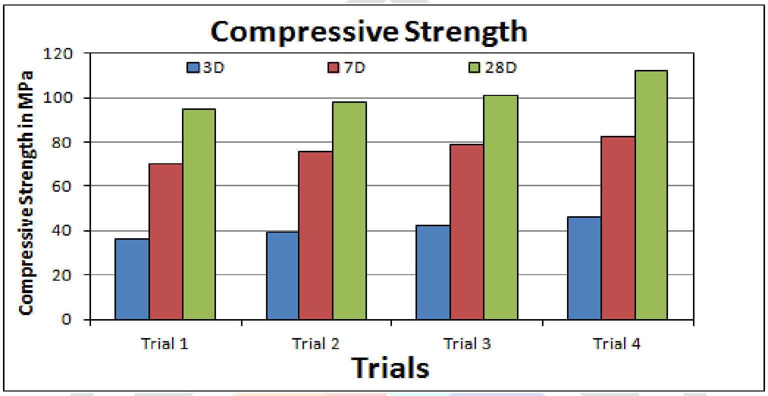


Discussion: - Comparing the 28 days strength between the various micro fines, it can be observed the trial mix which contains 50% of allco fine achieves the highest strength among the four.

Table 5.7 Compressive strength test results

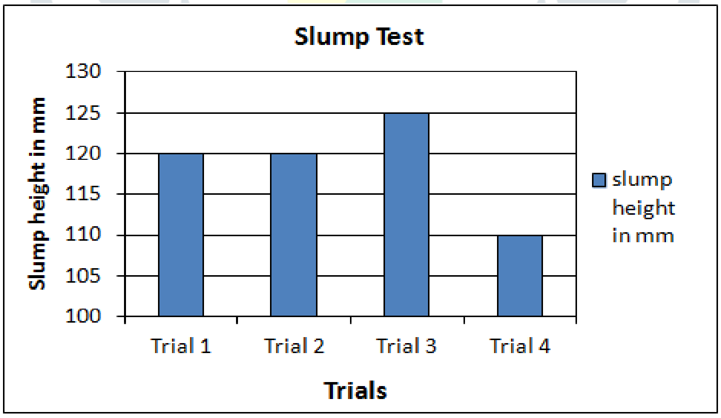
OPC replacem	OPC	Flyash	Silica Fum	Alccofine	28D Mpa	28D Avg
0.00%	70.00%	30.00%	0.00%	0.00%	94.6	94.9
0.00%	70.00%	30.00%	0.00%	0.00%	94.8	
0.00%	70.00%	30.00%	0.00%	0.00%	95.4	
5.00%	66.50%	30.00%	1.75%	1.75%	98.5	98.1
5.00%	66.50%	30.00%	1.75%	1.75%	98.1	
5.00%	66.50%	30.00%	1.75%	175%	97.8	
10.00%	63.00%	30.00%	3.50%	3.50%	100.1	101.08
10.00%	63.00%	30.00%	3.50%	3.50%	101.2	
10.00%	63.00%	30.00%	3.50%	3.50%	102.0	
15.00%	59.50%	30.00%	5.25%	5.25%	111.6	112.2
15.00%	59.50%	30.00%	5.25%	5.25%	111.6	
15.00%	59.50%	30.00%	5.25%	5.25%	113.0	

Graph no. 5.8 Compressive strength test results



Discussion :- Comparing the 3, 7, 28 days strength between the various micro fines, it can be observed the trial mix 4 which contains 50% of allco fines achieves the highest strength among the four.

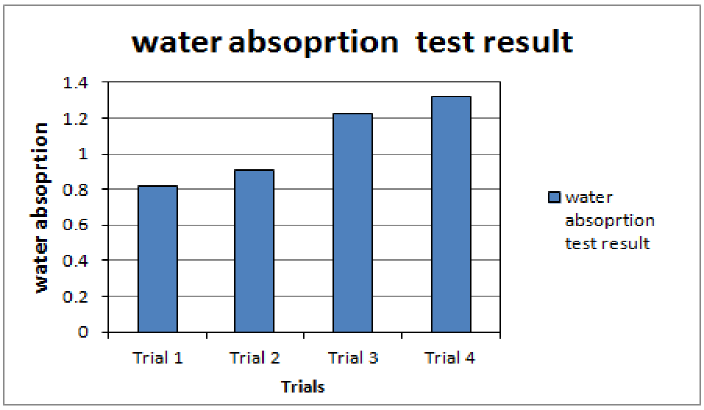
Graph no. 5.9 slump test results



Discussion

Since all the trial mix has the flow greater than120 mm, they are workable concrete and can be pumped for high rise buildings comparing the various between flows the various micro fines, it can be observed the flow is between the ranges of 120-130. High workability increases the compaction of concrete.

Graph no 5.10 water absorption result



Discussion

Comparing the water absorption readings, we come to know that water absorption from the prepared trial mixes of concrete is low and hence it will be more durable and can be used for under water concreting.

Table 5.11 (Cost comparison)

Trial mix 1			
Item	**Rs/kg**	**Quantity required in Kg. /Cum of concrete**	**Cost**
Coarse Aggregate – I	1.75	434.7	760.73
Coarse Aggregate – II	1.75	531.30	929.78
Fine Aggregate	2.75	644	1771
Water	0.75	147	73.50
Cement	7.5	490	3430
Flyash	4	210	840
GGBS	20	0	0
Silica Fumes	21	0	0
Admixture	125	4.97	621.25
Total			8426.26

Table 5.12 Cost of materials

Trial mix 2			
Item	**Rs/kg**	**Quantity required in Kg. /Cum of concrete**	**Cost**
Coarse Aggregate – I	1.75	434.7	760.73
Coarse Aggregate – II	1.75	531.30	929.78
Fine Aggregate	2.75	644	1771
Water	0.75	147	110.25
Cement	7.5	473	3547.5
Flyash	4	202.65	810.6
GGBS	20	12.25	245
Silica Fumes	21	12.25	294
Admixture	125	4.38	547.5
Total			9016.36

Table 5.13 Cost of materials

Trial mix 3			
Item	**Rs/kg**	**Quantity required in Kg. /Cum of concrete**	**Cost**
Coarse Aggregate – I	1.75	434.70	760.73
Coarse Aggregate – II	1.75	531.30	929.72
Fine Aggregate	2.75	644	1771
Water	0.75	147	110.25
Cement	7.5	433.70	3252.75
Flyash	4	195.30	781.2
GGBS	20	24.50	490
Silica Fumes	21	24.50	514.5
Admixture	125	4.9	612.5
Total			9222.7

Table 5.14 Cost of materials

Trial mix 4			
Item	**Rs/kg**	**Quantity required in Kg. /Cum of concrete**	**Cost Rs**
Coarse Aggregate – I	1.75	433.70	760.73
Coarse Aggregate – II	1.75	531.30	929.72
Fine Aggregate	2.75	644	1771
Water	0.75	147	110.25
Cement	7.5	438.55	3289.13
Flyash	4	187.95	751.8
GGBS	20	36.75	735
Silica Fumes	21	36.75	771.75
Admixture	125	5.95	734.75
Total			9854.12/-

Cost of Concrete / Cum

Table 5.15 Cost comparision of materials

Trial no	**Trail no 1**	**Trial no2**	**Trial no 3**	**Trial no 4**
Cost/cum	**8426**	**9016**	**9223**	**9854**

Discussion

Comparing the cost between various trials, it can be observed trial no 3 is more economical as compared to others.

CONCLUSION

By analyzing the above graphs and results, we conclude that:

1. Trial 4 can be readily used in high performance concrete to increase the strength and overall performance of concrete.
2. Since micro fines are being used in the concrete, high durability can be achieved.
3. Ground Granulated Blast Furnace Slag can be used in concrete to lower the pH value of concrete and reduce permeability of concrete.

4. Thus by using micro fines we develop environment friendly concrete having high durability and sustainability as well .
5. It is observerd that trial 3 gives high workability than other trials. Not much difference is observed between trail 1 and trial 3, where as replacement in trial 4 leads to less workability.
6. Alccofine is good dispersing agent.
7. Silica fumes gives high early strength while Alccofine gives high later on strength.
8. It is environmental friendly.

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