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A Study on Use of Waste Material in High Strength Concrete

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Abstract: The amount of partial replacement of fine aggregates by blast furnace slag & cement by silica fume greatly influenced properties of cement concrete. It was observed from results that silica fume along with blast furnace slag could enhance properties of final concrete product if used at right level of replacement. Use of silica fume along with blast furnace slag in concrete could prove to be increases in early compressive strength, higher bond strength & also we know that silica fume is also Superior resistance to chemical attack from chlorides, acids, nitrates & sulphates & lifecycle cost efficiencies. Use of blast furnace slag along with silica fume in concrete would provide strength & eradicate disposal problem of construction & prove to be environment friendly thus paving way for greener & economical concrete.
Keywords: Blast Furnace slag, silica, compressive strength.

I. INTRODUCTION

Concrete is most widely used material on earth after water. Many aspects of our daily life depend directly or indirectly on concrete. Concrete is prepared by mixing various constituents like cement, aggregates, water, etc. which are economically available. Concrete is unique among major construction materials because it is designed specifically for particular civil engineering projects. Concrete is a composite material composed of granular materials like coarse aggregates embedded in a matrix & bound together with cement or binder which fills space between particles & glues them together.

A. Blast furnace slag

Slag is a by-product generated during manufacturing of pig iron & steel. It is produced by action of various fluxes upon gangue materials within iron ore during process of pig iron making in blast furnace & steel manufacturing in steel melting shop. Primarily, slag consists of calcium, magnesium, manganese & aluminium silicates in various combinations. Cooling process of slag is responsible mainly for generating different types of slag required for various end-use consumers. Although, chemical composition of slag might remain unchanged, physical properties vary widely with changing process of cooling.

II. LITERATURE REVIEW

A. Introduction

This part is all about the brief depiction about authors who researched on examination of mechanical properties of concrete utilizing impact heater slag and silica exhaust blending in various extents in concrete and published paper on it.

1) *Khajuria C and siddique R (2014) "Use of Iron Slag as partial replacement of sand to concrete",:* The states that sand is mostly supplanted by impact heater slag at 0%, 10%, 20%, and 30% out of a solid blend. Tests performed to impact heater slag solid quality included droop, new thickness, dry thickness, compressive quality, and split rigidity tests. This work is practical for 7, 28, and 56 days curing ages for concrete blends. Comes about demonstrates that solid blends made with impact heater slag had higher compressive qualities. compressive qualities of cement blends made of 30% iron slag increment by 44.4 %, 55.68% and 60.21 % for 7, 28 and 56 days curing periods. And split rigid qualities observed to be 2.04%, 2.85% and 3.13% for 7, 28 and 56 days curing periods. And he demonstrates that when sand is somewhat supplanted by impact heater slag, compressive quality expanding constantly up to 30%.
2) *Ramesh et al. (2013) "Use of furnace slag and welding slag as replacement for sand in concrete":* The reported that sand is in part supplanted by heater slag and welding slag at 0%, 10%, and 15% out of solid blends. In this task, an investigation was made to acquire minimal effort building materials utilizing modern squanders. Goal of study is to utilize these losses in minimal effort development with sufficient compressive quality. This work is useful for 7 and 28days curing ages for concrete blends. For test and different details, it could be presumed that welding and heater slag could expand quality of cement. Ideal compressive quality of cements following 28 days has been observed to be 41 N/mm2 for 5% welding slag and 39.7 N/mm2 for 10% heater slag substitutions. According to his outcome, compressive quality is most extreme when sand is halfway supplanted at 15% of welding slag and 10% of heater slag.
3) *Mohammed Nadeem, Arun D. Pofale (2012) "Experimental investigation of using slag as an alternative to normal aggregates in concrete":* In their research find that cement of M20, M30 and M40 grades were considered for a W/C

proportion of 0.55, 0.45 and 0.40 separately for substitutions of 0, 30, 50, 70 and 100% of totals (Coarse and Fine) by slag. The tests performed to impact heater slag solid quality included droop, crisp thickness, dry thickness, compressive quality, flexural quality, rigidity. This work is utilitarian for 7, 28, 56, 91 and 119 days curing ages for concrete blends. They come with the demonstration that compressive quality was higher by 2 to 4% in all blends at all ages when supplanted by coarse total and higher by 4 to 6% in all blends at all ages when supplanting is finished with fine total.

4) *Dubey A, Dr .R. Chandak, Prof. R.K.Yadav (2012) "Effect of blast furnace slag powder on compressive strength of concrete",:* The detailed that bond is mostly supplanted by impact heater slag powder at 5 to 30% out of a solid blends. Tests performed to impact heater slag solid quality included droop, crisp thickness, dry thickness, compressive quality. This work is useful for 7, 14, and 28 days curing ages for concrete blends. Comes about demonstrates that solid blends made with impact heater slag somewhat diminishes compressive qualities up to 30%. The compressive qualities of cement blends made of 30% iron slag esteems are 15.40 %, 16.74% and 18.81 % for 7, 14 and 28 days curing periods. And he demonstrates that when concrete is mostly supplanted by impact heater slag compressive quality reductions ceaselessly up to 30%.

III. MATERIALS AND METHODOLOGY

A. *Methodology of research*

1) The methodology for present research consist of comparison of Specimens made of blast furnace slag & silica fume in different mixing in M25 grade concrete with reference M25 grade concrete made by Normal mixing approach on basis of fresh, hardened & durability properties.
2) The percentage of blast furnace slag & silica fume for partial replacement of natural sand & cement would be 0%, 10%, 20%, 30% & 0%, 8% & 16% respectively.
3) Testing of specimens in terms of strength & durability of concrete would be made.

B. *Material used*

In this section discussion is done on material used in work. Various tests performed on this material are also discussed.

1) Cement
2) Fine aggregate
3) Coarse aggregate
4) Water
5) Blast furnace slag
6) Silica fume

C. *Mix design of M25*

1) *Test data for materials*

a) Specific gravity of cement ---- 3.09
b) Specific gravity of silica fume ---- 2.27
c) Specific gravity of fine aggregates ----- 2.67
d) Specific gravity of coarse aggregates ----- 2.74
e) Water absorption of coarse aggregates(20mm down) ----- 0.40%
f) Water absorption of coarse aggregates(10mm down) ----- 0.50%
g) Water absorption of fine aggregates ----- 1.0%
h) Sieve analysis of aggregates is shown in table 3.5, 3.7(a) & 3.7(b)

2) *Target mean strength of Concrete:* The target mean strength for specified characteristic cube strength is

$\bar{f}ck = fck + tS$
$= 25 + 1.65 \times 4$
$= 31.6$ N/mm^2

3) *Water Cement ratio:* Adopting w/c ratio for target mean strength as 0.43.
4) *Selection of Water content:* For 20 mm nominal maximum size aggregate, water content per cubic meter of concrete = 186kg.

Estimated water content for 80mm slump = 186 + 3.6/100 X 186 = 192.696

Water content = 192.696 x 0.95 = 183.0612 litres.

5) *Cement:* w/c ratio = 0.43

Cement material = 192.696/0.43 = 448.13 kg/m^3

= (192.696x 0.95)/0.43= 425.72kg/m^3

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Water = 183.0612 litres.
Therefore, w/c ratio = 183.0612/425.72 = 0.43.
6) *Determination of coarse & fine Aggregate Contents:* From Table 3 of IS:10262-2009, volume of coarse aggregate to 20 mm size aggregate & fine aggregate ZONE 2 for water cement ratio of 0.50 = 0.62
Therefore, corrected proportion of volume of coarse aggregate for w/c of 0.43= 0.634
(Since proportion of volume of coarse aggregate is increased at rate of 0.01 for every 0.05 change in water cement ratio)
Volume of fine aggregate = 1.00-0.634 = 0.368
7) *Mix Calculations:* The mix calculation per unit volume of concrete shall be as follows:
a) Volume of concrete = $1m^3$
b) Volume of cement = (mass of cement /specific gravity of cement) x (1/1000) = 0.1377 m^3
c) Volume of water = (mass of water/ specific Gravity of water) x (1/1000) = 0.183 m^3
d) Volume of all aggregates = { a – (b + c) }
= 1 - 0.1377- 0.183 = 0.6793 m^3
e) Mass of coarse aggregate
= (e) x Volume x Specific gravity x 1000
= 0.6793 x 0.634 x 2.74 x 1000 = 1180.05 kg
f) Mass of fine aggregate (sand)
= 0.6793 x 0.366 x 2.67 x 1000
= 663.825 kg
8) *Mix Proportions*

Water	Cement	Fine aggregates	Coarse aggregates
183.06 /m^3	425.72 kg/m^3	663.825 kg/m^3	1180.05 kg/m^3

D. Slump cone test
This method of test specifies procedure to be adopted, either in laboratory or during progress of work in field, for determining, by slump test, consistency of concrete where nominal maximum size of aggregate does not exceed 38 mm.

E. Compaction factor test
This method of test specifies procedure to be adopted in laboratory for determining compaction factor of freshly made concrete.
Theory**:** Work-ability of concrete is ability/ease with which concrete could be mixed, transported & placed. This is a major factor which contributes to other properties of concrete also. If concrete is workable enough then it could be compacted with less compacting effort. So there is a relation between amount of work required to compact a given fresh concrete & work-ability of concrete. This relation is well suited for concrete of low water cement ratio. Slump cone test is also used to find out work-ability of concrete but only recommended for concrete of higher work-ability. For less workable concrete (having less water cement ratio), compaction is standardized by various standards.

F. Compressive strength test
This test is performed on cube specimens (150mm x 150mm x 150mm) to determine compressive strength at various ages:-
Apparatus:-
Testing Machine :-The testing machine might be of any reliable type, of sufficient capacity for tests & capable of applying load at rate specified. permissible error shall be not greater than ± 2% of maximum load. testing machine shall be equipped with two steel bearing platens with hardened faces. One of platens shall be fitted with a ball seating in form of a portion of a sphere, centre of which coincides with central point of face of platen. other compression platen shall be plain rigid bearing block. bearing faces of both platens shall be at least as large as, & preferably larger than nominal size of specimen to which load is applied. Age at Test Tests shall be made at recognized ages of test specimens, most usual being 7 & 28 days. Test at age of 56 days could also be performed. Ages of 13 weeks & one year are recommended if tests at greater ages are required. Where it might be necessary to obtain early strengths, tests might be made at ages of 24 hours ± ½ hour & 72 hours ± 2 hours. ages shall be calculated from time of addition of water to dry ingredients..

G. Flexure strength test
This test is performed on beam specimen (100mm x 100mm x 500mm) to evaluate its flexure strength at various different ages.
Apparatus:-
Testing machine:-

The testing machine might be of any reliable type of sufficient capacity for tests & capable of applying load at specified rate. permissible errors shall not be greater than ± 0.5 % of applied load where a high degree of accuracy is required & not greater than ±1.5% of applied load for commercial type of use. bed of testing machine shall be provided with two steel rollers, 38 mm in diameter, on which specimen is to be supported, & these rollers shall be so mounted that distance from centre to centre is 60 cm for 15 cm specimens or 40 cm for 10cm specimens, load shall be applied through two similar roller, mounted at third points of supporting span, that is, spaced at 20 or 13·3 cm centre to centre. load shall be divided equally between two loading rollers, & all rollers shall be mounted in such a manner that load is applied axially & without subjecting specimen to any torsional stresses or restraints.

H. *Water Absorption test*

This property is very important in concrete as well as being important for durability. It could be used to predict concrete durability.

Apparatus: 150mm x 150mm x 150mm cube moulds, weighing machine, Oven to dry.

Procedure:

1) The cubes of 150mm x 150mm x 150mm are casted to carryout water absorption test.
2) cubes are then immersed in water for 28 days curing after casting.
3) The absorption capacity is determined by finding weight of wet sample after it has been soaked for 24 hours & is known as wet weight (W_1) of cube & again finding weight after sample has been dried in an oven at 110**°C** for 24 hours after 28 days curing & is known as dry weight of cube (W_2).
4) Percentage water absorption is taken as average of three cubes for each mix. Percentage water absorption could be calculated as given by following formula Water Absorption = $[(W_1-W_2)/W_1] \times 100$

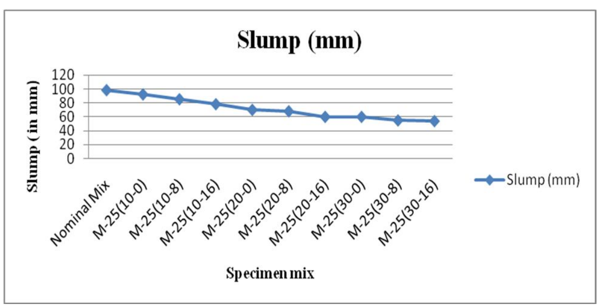
IV. RESULT AND DISCUSSION

A. *Slump cone test*

Slump tests were carried out to determine workability & consistency of fresh concrete. results of slump test is tabulated in table no. 1 & plotted in graph no.1.

Table 1 Slump value for different mixes

Mix	Slump (mm)
Nominal Mix	98
M-25(10-0)	92
M-25(10-8)	85
M-25(10-16)	78
M-25(20-0)	70
M-25(20-8)	68
M-25(20-16)	60
M-25(30-0)	60
M-25(30-8)	55
M-25(30-16)	54



Graph 1 Slump value for all mixes

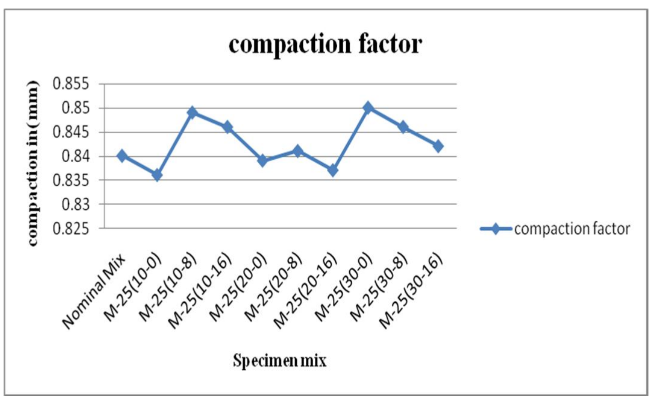
Graph 1 Slump test was performed on freshly mixed concrete. It was observed that maximum slump value was 98 mm which was for nominal mix of M-25 grade concrete. slump value was then observed as decreasing when blast furnace slag & silica fume content was increased from 0 to 30% & 0 to 16%.

B. Compaction factor test

The results of Compaction Factor test is tabulated in table no. 2 & plotted in graph no.2.

Table 2 Compaction Factor value for different mixes

Mix	Compaction Factor
Nominal Mix	0.840
M-25(10-0)	0.836
M-25(10-8)	0.849
M-25(10-16)	0.846
M-25(20-0)	0.839
M-25(20-8)	0.841
M-25(20-16)	0.837
M-25(30-0)	0.850
M-25(30-8)	0.846
M-25(30-16)	0.842



Graph 2 Compaction Factor value for all mixes

Graph 2 Compaction factor test was performed on freshly mixed concrete. It was observed that compaction factor of mix containing blast furnace slag with silica fume content almost same as corresponding to nominal mix & maximum value was observed as 0.850 which was of mix containing (30-0)% content.

C. Compressive strength test

To study effect of partial replacement of blast furnace slag with fine aggregates & silica fume as partial replacement of cement in different proportions with cement on compressive strength, cube specimens of dimensions 150 × 150 × 150 mm are prepared. replacement of blast furnace slag is 0%, 10%, 20%, 30% & silica fume replacement is 0%, 8%, & 1 6% in all cases of concrete mixes. specimens were cured in water & tested at ages of 7 & 28 days. Test results are given below in table 4.3 & are represented in figure 3.

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Table 3 Compressive strength of concrete mixes with blast furnace slag & silica fume

Mix	Compressive strength (N/mm^2)			Average Compressive Strength (N/mm^2)		
	7 days	14 days	28 days	7 days	14 days	28 days
Nominal mix M-25(0-0)	17.55	25.12	31.44	17.51	26.08	31.03
	19.77	26.22	30.66			
	15.22	26.90	31.00			
M-25(10-0)	18.55	27.21	36.66	18.47	27.65	35.77
	18.22	27.80	38.44			
	18.66	27.96	32.22			
M-25(10-8)	21.00	27.56	37.77	19.55	27.70	36.55
	20.77	28.34	36.66			
	16.88	27.21	35.22			
M-25(10-16)	18.55	27.83	38.44	18.15	27.72	34.88
	19.70	28.40	34.44			
	16.22	26.87	31.77			
M-25(20-0)	20.11	25.81	37.00	20.10	25.95	37.33
	20.33	26.96	36.88			
	19.88	25.10	38.11			
M-25(20-8)	20.45	26.92	39.44	21.37	27.38	38.18
	22.55	28.10	38.00			
	21.11	27.12	37.11			
M-25(20-16)	23.27	29.12	39.88	19.42	27.39	36.26
	18.11	27.64	35.22			
	16.88	25.42	33.68			
M-25(30-0)	23.15	28.42	42.10	22.15	27.21	40.80
	22.60	27.37	40.50			
	20.70	25.85	39.80			
M-25(30-8)	23.70	28.47	42.60	22.50	27.19	41.21
	22.20	27.21	41.15			
	21.60	25.90	39.90			
M-25(30-16)	21.20	24.86	39.90	20.84	24.55	37.05
	21.70	25.17	36.15			
	19.60	23.64	35.10			

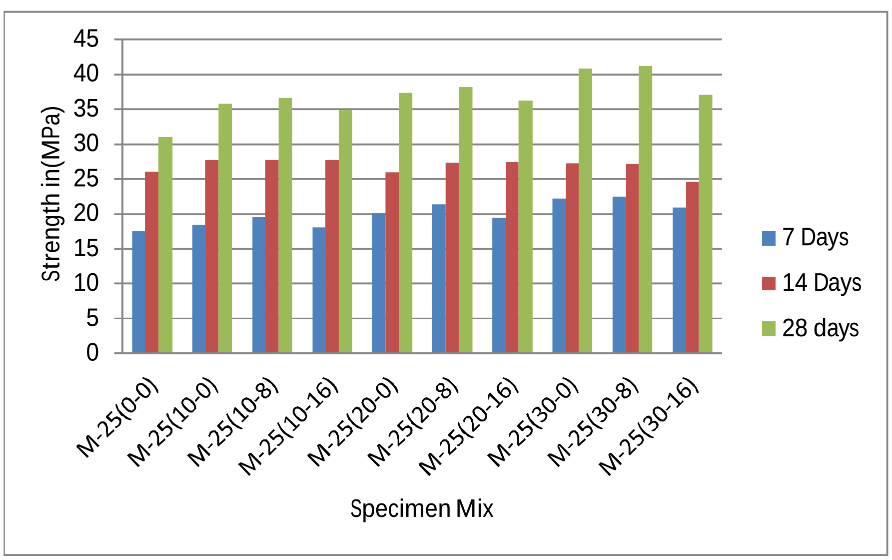

Chart 1compressive strength of blast furnace slag & silica fume concrete.

Chart 1 shows that specimen mix M-25(10-0) shows an increase of 5.5% in 7 day compressive strength & 15.3% in 28 day strength, however, specimen mix M-25(10-8) shows an increase of 11.6% in 7 day compressive strength & 17.8% in 28 day strength & specimen mix M-25(10-16) shows an increase of 3.7% in 7 day compressive strength & 12.41% in 28 day strength with respect to nominal mix specimen. specimen mix M-25(20-0) shows an increase of 14.8% in 7 day compressive strength & 20.3% in 28 day strength, however, specimen mix M-25(20-8) shows increase of 22.01% in 7 day compressive strength & 23.05% in 28 day strength & specimen mix M-25(20-16) shows an increase of 10.9% in 7 day compressive strength & 16.85% in 28 day strength with respect to nominal mix specimen. specimen mix M-25(30-0) shows an increase of 26.5% in 7 day compressive strength & 31.55% in 28 day strength, however, specimen mix M-25(30-8) shows increase of 28.5% in 7 day compressive strength & 32.76% in 28 day strength & specimen mix M-25(30-16) shows an increase of 19.0% in 7 day compressive strength & 19.45% in 28 day strength with respect to nominal mix specimen. Maximum increment of compressive strength is observed by 32.76 % for mixM-25(30-8) at 28 days with respect to reference mix.

D. Water Absorption Test

Water absorption studies were carried out at age of 28 days. Cubes of 150x150x150mm are casted to carryout water absorption test. Test results are given below in table 4. As seen in table, test results indicated that these results are represented graphically below in Fig. 4

Table 4 Water absorption of concrete mixes with blast furnace slag & silica fume

Mix Description	Wet weight (kg) W_2	Dry weight (kg) W_1	% Water absorption	Average % Water Absorption
Nominal mix M-25(0-0)	8.600	8.320	3.25	2.82
	8.345	8.140	2.39	
	8.500	8.260	2.82	
M-25(10-0)	8.400	8.140	3.09	3.01
	8.400	8.140	3.09	
	8.380	8.140	2.86	
M-25(10-8)	8.350	8.060	3.44	3.26
	8.370	8.070	3.58	
	8.320	8.090	2.76	
M-25(10-16)	8.360	8.040	3.82	3.41
	8.240	7.960	3.39	
	8.520	8.260	3.03	
M-25(20-0)	8.340	7.990	4.19	3.47
	8.345	8.060	3.41	
	8.335	8.100	2.81	
M-25(20-8)	8.325	7.980	4.14	3.93
	8.320	8.990	3.96	
	8.350	8.040	3.71	
M-25(20-16)	8.360	7.980	4.54	3.89
	8.440	8.100	4.02	
	8.360	8.100	3.11	
M-25(30-0)	8.400	7.990	4.88	4.03
	8.323	7.880	4.12	
	8.323	8.150	3.09	
M-25(30-8)	8.310	7.900	4.92	4.43
	8.330	7.950	4.56	
	8.360	8.040	3.82	
M-25(30-16)	8.320	7.860	4.85	4.58
	8.440	8.060	4.50	
	8.160	7.800	4.41	

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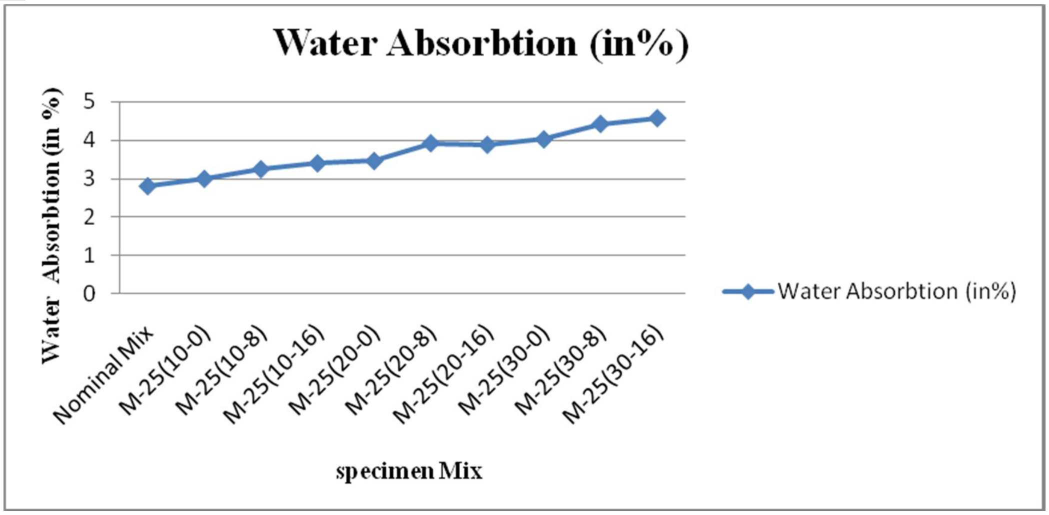

Graph 4 Water absorption of blast furnace slag & silica fume concrete.

Graph 4 shows variation of water absorption in concrete with change of amount of blast furnace slag & silica fume. specimen mix M-25(10-0) shows an increase in water absorption by 6.8%, whereas, specimen mix M-25(10-8) shows an increase in water absorption by 15.7% & specimen mix M-25(10-16) shows an increase in water absorption by 21.0%.with respect to nominal mix specimen. specimen mix M-25(20-0) shows an increase in water absorption by 23.1%, whereas, specimen mix M-25(20-8) shows an increase in water absorption by 39.4% & specimen mix M-25(20-16) shows an increase in water absorption by 36.0%.with respect to nominal mix specimen. The specimen mix M-25(30-0) shows an increase in water absorption by 43.0%, whereas, specimen mix M-25(30-8) shows an increase in water absorption by 57.1% & specimen mix M-25(30-16) shows an increase in water absorption by 62.5%.with respect to nominal mix specimen. Maximum increment in water absorption is observed by 62.5% for mixM-25(30-16)with respect to reference mix.

V. CONCLUSIONS

1) The properties of cement concrete are greatly influenced by use of blast furnace as fine aggregate and silica fume as cement. It was observed from results that silica fume along with blast furnace slag could enhance properties of final concrete product if used at right level of replacement.
2) Use of silica fume along with blast furnace slag in concrete could prove to be increases in early compressive strength, higher bond strength & also we know that silica fume is alsoSuperior resistance to chemical attack from chlorides, acids, nitrates & sulphates & lifecycle cost efficiencies.
3) Use of blast furnace slag along with silica fume in concrete would provide strength & eradicate disposal problem of construction & prove to be environment friendly thus paving way for greener & economical concrete.

On thebasis of experiments performed, following conclusions could be drawn:-

A. *Slump Test*

1) Slump value of concrete mix decreases with increase in blast furnace slag & silica fume content but stays in workable range.
2) Slump of concrete mix decreases from 98 mm for reference mix to 54 mm for mixM-25(30-16) which is a workable value.

B. *Compaction Factor Test*

1) The compaction factor shows a non-uniform trend as it increases at lower percentages & attains maximum value atmixM-25(30-0) & then decreases on further increasing percentage of blast furnace slag & silica fume.
2) Compaction factor test did not followed same trend as shown by slump test.

C. *Compressive Strength Test*

1) Fine aggregates could be replaced by blast furnace slag up to 30% by weight showing increase in compressive strength at 7 & 28 days both.
2) Cement could be replaced by silica fume up to 16% by weight showing increase in compressive strength at 7 & 28 days both.

3) At M-25(10-16) replacement, % increase in compressive strength at 7 days was about 3.7% & % increase at 28 days was about 12.41% respectively.
4) At M-25(20-16) replacement, increase in strength is measured to be 10.9% & 16.85% as compared to reference mix at age of 7 & 28 days respectively.
5) At M-25(20-16) replacement, increase in strength is measured to be 19.0% & 19.45% as compared to reference mix at age of 7 & 28 days respectively.
6) Maximum increment of compressive strength is observed by 32.76 % for mixM-25(30-8) at 28 days with respect to reference mix.

D. Water Absorption Test

1) With increase in blast furnace slag & silica fume content, water absorption of concrete increases but still is in permissible range.
2) AtM-25(10-16), M-25(20-16),M-25(30-16), replacement of fine aggregates by blast furnace slag & cement replaced by silica fume, increase in water absorption is about 21.0%, 36.0% & 62.5% respectively with respect to water absorption of nominal mix specimen.
3) AtM-25(10-0), replacement of fine aggregates by blast furnace slag & silica fume is optimum value for replacement considering minimum increase in water absorption.

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