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Effect of Silica Fume and Fly Ash as Partial Replacement of Cement and aggregate

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ABSTRACT:

The aim of this study is to determine the performance of concrete by adding the fly ash and silica fume in concrete by the partial replacement of cement and fine aggregate by some percentage and this will be done by different percentage at the gap of some percent and what will be effect on basic properties of concrete as from the other research paper it is noted silica fume and fly ash both are added separately in concrete by some partial replacement so result will be tremendous so here in this study by considering or reading all the previous data from the research paper the new work should also be positive fly ash is the waste product of coal combustion product also known as the fuel ash and silica fume is also known as the micro silica fume is non-metallic and non-hazardous material.

Key words: ***silica fume, fly ash, test on concrete.***

I. INTRODUCTION:

Concrete is a mix of the cement sand and aggregate and water in proper extent due to the use of concrete from previous decades the infrastructure and construction work is improving day by day by the modern techniques and by the lot of research done on concrete nowadays lot of research is done on concrete some time cement is replaced some time sand is replaced and also aggregate is replaced all these things are not completely replaced by anything just some percentage is replaced by any material in US one of the temple is made up of fly ash that is in that cement [1] is replaced by fly ash up to the 60% so this is the very good result and as well as good research on the replacement of cement by fly ash because manufacturing of cement in huge amount also affect the nature so research work on replacing these things is must because there are lot of other material that can be mix in concrete or replace fine aggregate and coarse aggregate [2] so in this work here the fly ash or silica fume both are replaced with cement to achieve good result because both these materials behave like cement when added to cement so by adding these the better strength is achieved both silica fume as well as are minx in concrete to improve its property the main benefits of adding silica fume it reduce the thermal cracking in concrete which cause by the cement hydration and fly ash is also SCM (supplementary cementitious material) [3].

II. Material and Methodology:

The fly ash and the silica fume both are mixed in terms of the comparison of their property with the simple casted concrete in terms of their property and the basic test which are done on concrete. It will be added in concrete by the replacement of cement and fine aggregate different percentage. It will be added in replacement of cement and fine aggregate. The fly ash and silica fume will be placed with same percentage if we have to mix 10 percent both then 5 percent silica fume and 5 percent fly ash will be replaced and the optimum percentage should be noted. That at which percentage we achieve the better result. The cubes will be casted for 7 days or 28 days and result will be noted. So main thing is enhance the property and reduce the amount of cement and fine aggregate in concrete.

III. Experimental Program and Approach

A. *Material of Specimen*

To obtain the best percentages of mix proportions in both cases (Fly Ash and Silica Fume) separate casting of the test specimens were conducted. Blending of Silica Fume (SF) and Fly Ash (FA) were avoided as the individual effects of SF and FA were observed in this study.

Concrete materials were mixed as per standard of ASTM C 192M-07. OPC was used and its physical and mechanical properties are tabulated in Table I. Graded river sand (Sylhet Sand) passing through 1.18mm sieve with fineness modulus of 3.0 was used which were free from organic chemicals and unwanted clay. Local crushed granite aggregate passing through 12.5 mm sieve and retained on 4.75mm sieve with fineness modulus 4.01 was used which satisfy both ASTM and Indian Standard. Fresh clean water, free from chlorine, suspended solids, acids and having pH value 7.0 was used for mixing purpose.

Silica fume was supplied by Rainbow Holdings Ltd., Dhaka, Bangladesh which satisfies the requirements of ASTM C 1240. The physical andchemical analysis constituents of SF are tabulated at Table I. High Calcium fly ash was obtained from Rainbow Holdings Ltd., Dhaka, Bangladesh which satisfies the requirement of ASTM class C. The chemical proportions of fly ash are tabulated at Table I.

Super-Plasticizers (SP) can affect the concrete strength even at constant water–cement ratio [4]. The strength of both cement paste and concrete can be affected by the dosage of SP [5].

Thus, the dosage of SP was keptconstant for all the specimen mixes to identify the sharp effects of silica fume and fly ash. If the dosage of SPis varied with the silica fume and fly ash replacement percentage, thenthe variations in the concrete strength will occur not only dueto variations in the silica fume or fly ash contents but also due to change in dosage of SP [6]. Since the SPcontent of all the mixes was kept constant, to minimizevariations in workability,the compaction energywas variedfor obtaining proper compaction[7]. Toensure good

Table I: Physical and chemical properties of opc, silica fume and fly ash

Properties	Ordinary Portland Cement	Silica Fume	Fly Ash
Physical pr operties			
Specific Gravity	3.15	2.21	3.1
Initial Setting Time (Min)	115	-	-
Final Setting Time (Min)	229	-	-
Fineness as Surface Area (m^2/kg)	370	20,000	420
Chemical P roperties			
Silicon Dioxide (SiO_2)	21.02%	91.4%	53.92%
Aluminium Oxide (Al_2O_3)	5.68%	1.1%	21%

Ferric Oxide (Fe_2O_3)	3.53%	0.3% - 0.5%	3.9% - 4.3%
Magnesium Oxide (MgO)	1.1%	1.3%	2.2%
Calcium Oxide (CaO)	62.25%	0.7%	4%
Sulphur Trioxide (SO_3)	3.0%	0.4%	0.6%
Sodium Oxide (Na_2O)	0.15%	0.8%	0.4% - 0.6%
Potassium Oxide (K_2O)	0.35%	0.5%	0.2%
Loss of Ignition	1.05%	2.4%	1.9%

Dispersion of the silica fume at such variable dosages, highbinder content and an optimum dosage of SP were used with constant mixing times. As the SP dosage was kept constant, while adjusting the binder content, it was considered that the mix should not segregate at higher water–binder ratios, nor it should be unworkable at lower water–binder ratios. The mixing procedure and time were kept constant for all the concrete mixes investigated [7]. According to I. B. Muhit (2013), the maximum strength for concrete is obtained from a fixed dosage percentage of super-plasticizer and it is exactly 1.0% by weight of cement and the effective dosage ranges between 0.6% and 1.0% [8].Sikament® R2002 was used as SP because it is not only a high range water reducing admixture for promoting high early and ultimate strengths but also is non-hazardous and nontoxic under relevant safety and health issue [8]. It is a highly effective super-plasticizer with a set retarding effect for producing free flowing concrete in hot climates. It complies with ASTM C 494 Type G and B.S. 5075 Part 3[9, 10].

B. *Mix Proportions of Specimen*

The mixture proportions of all specimens for replacement of Silica Fume and Fly Ash are tabulated respectively at Table 2 and Table 3. The replacement levels of cement by SF were selected as 0% (control mix), 2.5%, 5%, 7.5%, 10%, 15% and 20%. And the replacement levels of percentages of cement by FA were selected as 0% (control mix), 5%, 10%, 15%, 20%, 25% and 30%. For all specimens, water/binder (w/b) ratio was kept constant and it was 0.42where the total amount ofbinder content was 480 Kg/m^3 for every specimen. Here binder refers the mixture of Cement and Silica Fume for SF study group and mixture of Cement and Fly Ash for FA study group. The mixture proportions of Binder: Fine Aggregate: Coarse Aggregate was taken as 1: 1.28: 2.2.

C. *Casting of Specimen and Curing*

Four types of specimens were casted to conduct all sort of test regarding strength and water permeability. Standard Sample (dimension 120mm x 200mm x 200mm) for water permeability test, Standard Cube specimen (dimension 150mm x 150mm x 150mm) for compressive strength test, Cylinder specimen (dimension 150mm diameter with 300mm height) for split tensile strength test and beam specimen (100mm x 100mm x 500mm) for flexural tensile strength test were casted. During curing period, thesamples were stored in a place free from vibration and in relatively moist air at a temperature ranges from 25ºC to 27ºC[11]. After 2 days, them old was removed and marked with symbol to identify later and finally cured under clean fresh water.

D. *Testing of Specimen*

To measure the workability of concrete, Slump Test [12, 13, 14, 15] and Compacting Factor Test (Derived by Road Research Laboratory U.K) were conducted. Through DIN 1048 (Part 5), thepermeability of concrete specimen was determined. The resistance of concrete against the penetration of water exerting pressure is an indication of permeability. More than 28 days and less than 35 days aged concrete were exposed either from above or below to a water pressure of 5 bars acting normal to the mold-filling direction for a period of three days. The pressure was kept constant throughout the test. Compressive strength of cube specimen as per ASTM standard was conducted by compression machine for 7, 14, and 28 days. Split tensile strength was measured by cylinder specimen and flexural tensile strength measured by beam specimen for 7, 14 and 28 days.

TABLE. II. MIX PROPORTIONS FOR SF (SILICA FUME) STUDY GROUP

Specimen ID	w/b Ratio	Cement (Kg/m^3)	Silica Fume		Aggregates (Kg/m^3)		Water (Kg/m^3)	SP (%)
			%	Kg/m^3	Fine	Coarse		
SF-I	0.42	480	0	0	616	1058	201.6	1.0
SF-II	0.42	468	2.5	12	616	1058	201.6	1.0
SF-III	0.42	456	5.0	24	616	1058	201.6	1.0
SF-IV	0.42	444	7.5	36	616	1058	201.6	1.0
SF-V	0.42	432	10	48	616	1058	201.6	1.0
SF-VI	0.42	408	15	72	616	1058	201.6	1.0
SF-VII	0.42	384	20	96	616	1058	201.6	1.0

TABLE. III. MIX PROPORTIONS FOR FA (FLY ASH) STUDY GROUP

Specimen ID	w/b Ratio	Cement (Kg/m^3)	Fly Ash		Aggregates (Kg/m^3)		Water (Kg/m^3)	SP (%)
			%	Kg/m^3	Fine	Coarse		
FA-I	0.42	480	0	0	616	1058	201.6	1.0
FA-II	0.42	456	5	24	616	1058	201.6	1.0
FA-III	0.42	432	10	48	616	1058	201.6	1.0
FA-IV	0.42	408	15	72	616	1058	201.6	1.0
FA-V	0.42	384	20	96	616	1058	201.6	1.0
FA-VI	0.42	360	25	120	616	1058	201.6	1.0
FA-VII	0.42	336	30	144	616	1058	201.6	1.0

IV. RESULTS AND DISCUSSIONS

A. *Effects on Water Permeability of High Performance Concrete*

The water permeability (maximum penetrated water depth) of concrete for SF study group (for different replacement levels of OPC with silica fume) and for FA study group (for different replacement levels of OPC with fly ash) is represented at Fig. 1 and 2 respectively. From Fig. 1 it is very clear that very low penetration of water is allowed in SF-V type specimen where 10% OPC was replaced with silica fume. Without any silica fume, the penetration depth was 28mm and with 10% silica fume it was 11mm, which shows that, more than 60% reduction of water penetration can be achieved by mixing 10% silica fume. Silica fume contains fine size particles which fill the little spaces between the cement particles and it results denser concrete than the concrete without silica fume. Consequently, optimum dosage of silica fume decreases the permeability significantly but excessive silica fume can't.

From Fig. 2 it is evident that, very low penetration of water is allowed in FA-V type specimen where 20% OPC was replaced with fly ash. Without any fly ash the penetration depth was 28mm and with 20% fly ash it was 15mm, that means more than 46% reduction of water penetration can be achieved by mixing 20% fly ash.

B. Effects on Compressive Strength of High Performance Concrete

For replacement of OPC by Silica Fume:

Silica fume has strong effects in compressive strength of concrete for 7, 14 and 28 days of age. The variation of compressive strength for different replacement levels of OPC by silica fume for 7, 14 and 28 days is shown in Fig.3. For 7 days concrete it was observed that maximum compressive strength (42 N/mm^2) was exhibited by SF-IV type specimen, which contains 7.5% silica fume with 92.5% OPC. The compressive strength increases almost 17% for SF-IVtype specimen compared to the control mix (SF-I) for 7 days. For 14 and 28days the maximum compressive strengths were obtained 53 N/mm^2 for SF-IV type specimen and 65 N/mm^2 for SF-IV type specimen respectively. So, it is clear that maximum compressive strength can be obtained by replacing 7.5% OPC with silica fume.

For replacement of OPC by Fly Ash:

As well as silica fume, fly ash has strong effects in compressive strength of concrete for 7, 14 and 28 days of age. The variation of compressive strength for different replacement levels of OPC by Fly Ash for 7, 14 and 28 days are shown in Fig. 4. For 7 days concrete it was observed that maximum compressive strength (49.5 N/mm^2) was exhibited by FA-IIItype specimen, which contains 10% fly ash with 90% OPC. The increase in compressive strength is 37.5% for theFA-IIItype specimen compared to the control mix (FA-I) for 7 days. For 14 and 28days the maximum compressive*D. Effects on Flexural Tensile Strength of High Performance Concrete*

For replacement of OPC by Silica Fume:

Silica fume has strong effects in flexural tensile strength of concrete for 7, 14 and 28 days. The variation of flexural tensile strength for different replacement levels of OPC by silica fume for 7, 14 and 28 days are shown in Fig. 7. For 7 days concrete it was observed that maximum flexural tensile strength (6.8 N/mm^2) was exhibited by SF-IV type specimen which contains 7.5% silica fume with 92.5% OPC. For 14 and 28days the maximum flexural tensile strength were obtained 8.15 N/mm^2 for SF-IV type specimen and 10.2 N/mm^2 for SF-IV type specimen respectively. So, eventually it can be decided that the partial replacement of 7.5% silica fume was found to be optimum and more than 39%flexural tensile strength was increased from control mix (0% fly ash) at 28 days.

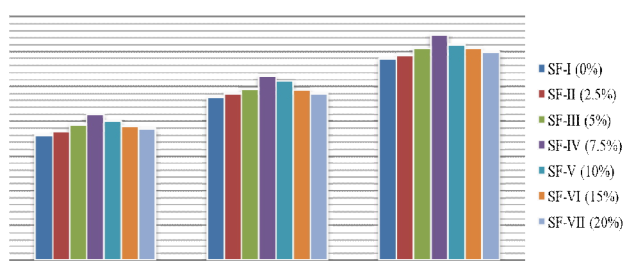

Figure 3.Compressive Strength fluctuation for different levels of Silica Fume for 7, 14 and 28 days

- Pozzolanic materials have significant influence on water permeability and mechanical properties of concrete.
- 10% by weight silica fume exhibited lowest penetration of water (11mm), where

lowest water permeability (15mm) for fly ash was obtained at 20% by weight.

- 65 N/mm^2 was the maximum compressive strength which was obtained for 7.5% by weight silica fume. 10% by weight fly ash showed maximum compressive strength and it was 66 N/mm^2.
- 5.2 N/mm^2 was the maximum split tensile strength which was obtained for 7.5% by weight silica fume. 10% by weight fly ash showed maximum split tensile strength and it was 5 N/mm^2.
- In case of flexural tensile strength, 7.5% by weight of silica fume and 10% by weight of fly ash proved to be optimum for maximum strength 10.2 N/mm^2 and 10.1 N/mm^2 respectively.
- The water permeability and strength characteristics of high performance concrete can be improved considerably by replacing the Ordinary Portland Cement with either silica fume or fly ash.

From literature review and from this investigation it can be recommended that blending of silica fume and fly ash is not essential to increase the water permeability and strength characteristics of concrete. Either silica fume or fly ash alone is enough to enhance the quality.

V. CONCLUSION

From the whole investigations and research, the following conclusions can be drawn:

Pozzolanic materials have significant influence on mechanical properties of concrete.

The maximum compressive strength increased by 1.43% after 7 days and 4.42% after 28 days at 10% replacement of cement by weight with silica fume. However when silica fume was blended with fly ash in different percentages, a continuous decrease in compressive strength was recorded.

The maximum split tensile strength increased by 3.83% after 28 days at 10% replacement of cement by weight with silica fume. However when silica fume was blended with fly ash in different percentages, a continuous decrease in splitting tensile strength was recorded.

The maximum flexural strength increased by 1.79% after 28 days at 10% replacement of cement by weight with silica fume. However when silica fume was blended with fly ash in different percentages, a continuous decrease in flexural strength was recorded.

The strength characteristics of high performance concrete can be improved considerably by replacing the Ordinary Portland Cement with silica fume. However blending of silica fume with fly ash results in a decrease in strength of concrete.

In terms of economy, replacement of cement with silica fume results in cost reduction considerably for large projects. About 3 – 3.5 % of the total concreting cost could be saved. The replacement of cement with silica fume is environment friendly in nature. One of the biggest benefits of using silica fume is reduction in CO_2 emissions, which is the main cause of Green – house effect.

From the complete investigation and the results of this work, it may be recommended that blending of silica fume and fly ash should not be done to increase the strength characteristics of concrete. Silica fume alone is enough to enhance the quality. Use of silica fume is economical and also eco – friendly in nature.

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