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Effect of Partial Replacement of Cement by Silica Fume and Sand by Quarry Dust on Strength and Durability of Concrete

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Abstract – In this paper we present an experimental investigation of effect of silica fume and quarry dust as partial replacements of cement and sand respectively on concrete. This effect has been studied on compressive strength, workability and durability of M25 concrete. Replacement levels of 8, 10 and 12% for silica fume and 20, 30 and 40% for quarry dust have adopted. The results of various tests conducted on control mix and other mixes with different proportions of silica fume an quarry dust have been compared. The mix with 10% silica fume and 30% quarry dust have shown better results than control concrete.

KeyWords: Compressive Strength, Workability, Durability, Silica Fume and Quarry Dust.

1. INTRODUCTION

Among all materials, concrete is the most widely used in construction industry. From a small house to the large infrastructure projects like dams, tunnels, multi story buildings etc. concrete is being used. Being a versatile material, it is difficult to replace concrete with other construction materials. The ingredients used for concrete production are cement, fine aggregates, coarse aggregates and water. Each and every material has its important role in overall performance of concrete. During the production of cement, our natural resources are consumed and CO_2 is emitted in the atmosphere. Heat of hydration also leads to increase in temperature of environment and this heat is also responsible for cracks in a structure after hardening of concrete. Thus there is a need to find some alternative material to reduce the production of cement and its use in concrete. In concrete fine aggregates also play an important role. Mostly natural river sand is used as fine aggregate in concrete which is becoming costly and scare, thus there is a need to find some alternative material satisfying economical as well as environmental needs. In this work we have used Silica Fume as partial replacement of cement and Quarry Dust as partial replacement of natural sand and studied their effect on the performance of M25 concrete.

1. Materials and Methodolgy

1.1 Cement

Cement: Ordinary Portland Cement 43 grade (OPC-43) confirming to IS 8112:1989. The cement used was of Ultratech Cement. Following table 1 gives the properties of cement tested.

Table 1 : Properties of Cement

S.no	Property	Unit	Value obtained	Values as per IS 8112:1989
1	Normal Consistancy	%	32	-
2	Initial Setting Time	Min.	50	Not less than 30 Min.
3	Final Setting Time	Min.	225	Not more than 600 Min.
4	Finess	%	92 (passed)	Not more than 10% residue
5	Specific Gravity	-	3.2	-

1.2 Fine Aggregates (FA)

Fine aggregate (natural sand) confirming to IS 383:1970 used in this study was locally procured. Physical properties of this sand are given in table 2 below.

Table 2 : Physical Properties of Sand

S.no	Property	Value
1	Type	Natural Sand
2	Sp. Gravity	2.6
3	Finess Modulus F.M.	2.57
4	Zone	III

1.3 Coarse Aggregates (CA)

Coarse aggregates of maximum size of 20mm were used in this study. The aggregates used were confirming to IS 383:1970. The properties of CA are given in table 3.

Table 3 : Properties of Coarse Aggregates

S.no	Property	Value
1	Shape	Angular
2	Finess Modulus FM	7.2
3	Sp. Gravity	2.63
4	Max. Size	20 mm
5	Water Absorption	0.5 %

1.4 Silica Fume (SF)

It is waste by product in the manufacturing of elemental silica. Also referred as micro silica or condensed silica it is a pozzolanic material. Having size less than 1µm and spherical shape, this is an ultrafine material. The specific surface is approximately 20,000 m^2/kg. It is of light to dark grey colour and generally acts as filler material in fine aggregates, thus improves the various properties of concrete. Due to its high surface area, high pozzolanic action and its chemical properties it has both engineering as well as economical benefits. The various physical properties of silica fume are given in table 4 below.

Table 4 : Properties of Silica Fume

S.no	Property	Value
1	Colour	Grey
2	Particle size	< 1 µm
3	Specific surface	20000 m^2/kg
4	Specific gravity	2.2

1.5 Quarry Dust (QD)

Quarry dust is a fine rock particle left in the crushing of boulders or stones. It is of grey colour. We have performed various tests on this quarry dust as per IS 383:1970 and IS 2386:1963 part III. All the physical properties of quarry dust are provided in table 5.

Table 5 : Properties of Quarry Dust

S.no	Property	Value
1	Sp. Gravity	2.6
2	Finess Modulus FM	3.1
3	Water Absorption	1.30%
4	Colour	Grey
5	Zone	III

1.6 Admixture

The admixture used in this study is Forsoc Auromix 200. This admixture compiles with IS 9103 and its properties are given in table 6.

Table 6 : Properties of Admixture

S.no	Property	Value
1	Sp. Gravity	1.03-1.07
2	Chloride content	Nil
3	Alkali Content	< 1 g
4	Appearance	Yellowish

1.7 Water

Water is also a very important element in concrete as it is responsible for the hydration of cement in concrete. Water quality and quantity should be carefully observed as it helps in producing strength giving cement gel. Normal consumable water is generally suitable for concrete. In present study we have used water for mixing as well as for curing.

1.8 Mix Design

Mix design of M 25 concrete has been prepared as per the provisions of IS 10262:2009. This mix is prepared by keeping water cement ratio constant.

Table 7 : Mix Design (M25)

Units	Cement (kg)	Water (kg)	FA (kg)	CA (kg)	Admi-xture (kg)	W/C
m^3	375.25	157.6	806	1078	4	0.42
Ratio	1	0.42	2.14	2.87	0.01	

2. Tests Performed on Specimen

2.1 Compressive Strength

Compressive strength of a material is its strength to resist deformation caused by external compressive forces and is calculated as per IS standards. For calculating compressive strength we have casted cubes of 150 mm size. The compressive strength of cubes after the curing of 7 and 28 days was examined. The average of three cubes is considered as the compressive strength for that mix for that particular period. Samples were tested in a compression testing machine of 3000KN and the load at which failure has appeared was noted (P) and divided by surface area (A = 150 x 150 mm^2). The compressive strength in N / mm^2 of a specimen is taken as:

Compressive strength f_{ck} = Load / Area = P / A

Where, f_{ck} = Compressive strength in N / mm^2, P = Maximum load in N and A = Cross sectional area of cube in mm^2

2.2 Workability

Workability is defined as the ease with which concrete can be mixed, transported, casted and finished and it is done on the fresh concrete. We have conducted compaction factor test in lab to check the workability of different samples.

Compaction factor (CF) = Weight of partially compacted concrete / weight of fully compacted concrete

2.3 Rapid Chloride Penetration Test

RCPT test is used to determine the durability of concrete which is harmed by the movement of chloride ions through it. These chloride ions are responsible for the corrosion of reinforcement in concrete. The test was conducted in lab as per the standards of ASTM C 1202. First of all we have maintained vacuum in the desiccator for 3 hrs and for another 1 hr after allowing de aerated water to enter into it. Then we left our samples in it for 18 hrs to soak, after which samples were made dry and placed in a gasket. The solutions used for this testing were (a) 3% NaCl (b) 0.3 M NaOH

These solutions were filled in the two cells in the apparatus at room temperature and a 60 V supply was made. Then readings were recorded after each hour. The formula used for calculating average charge (coloumbs) passing through each specimen is:

Q = I x t

Where Q = Charge passing (coloumbs), I = Average current (amperes) and t = time (seconds)

The standards for RCPT as per ASTM C are given in table 8 below.

Table 8 : RCPT Standards as Per ASTM C 1202

Coloumbs Passed	Chloride ions Permeability
>4000	High
2000-4000	Moderate
1000-2000	Low
100-1000	Very Low
<100	Negligible

3. Results and Discussion

3.1 Compressive Strength

The compressive strength after 7 and 28 days on conventional concrete as well as on concrete with silica fume and quarry dust. Silica fume @ 8, 10 and 12% and quarry dust @ 20, 30 and 40% were used as partial replacements of cement and sand respectively. The test results are given in table 9.

Table 9 : Compressive Strength Results

Replacements	Average Compressive Strength MPa (7 days)	Average Compressive Strength MPa (28 days)
SF 0% + QD 0%	24.33	34.61
SF 8% + QD 0%	25.15	37.53
SF 10% + QD 0%	27.51	40.30
SF 12% + QD 0%	22.70	32.13
SF 10% + QD 20%	25.89	38.63
SF 10% + QD 30%	28.84	42.45
SF 10% + QD 40%	23.57	33.56

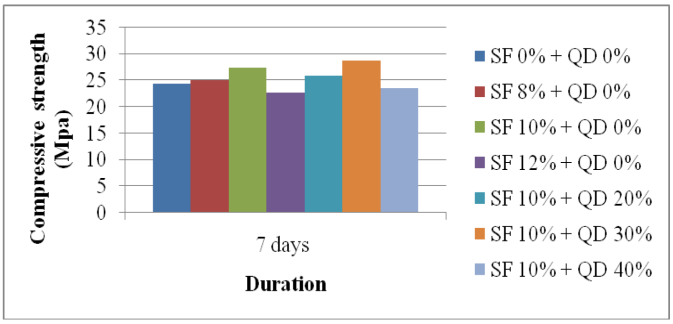

Fig. 1 : Variation of 7 days compressive strength with variation of %age of silica fume and quarry dust

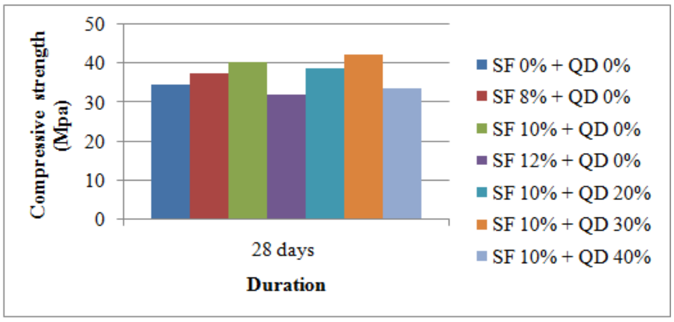

Fig. 2 : Variation of 28 days compressive strength with variation of %age of silica fume and quarry dust

The 7 days compressive strength of conventional concrete was 24.33 MPa which goes on increasing with addition of silica fume up to 10% after which again strength decreased. This strength again increased with addition of quarry dust in combination with silica fume @ 10%. The maximum increase of 18.5% was achieved in a sample with silica fume @10% and Quarry dust @ 30%. Similarly 28 days strength also goes on increasing with increasing percentage of silica fume and quarry dust. The maximum 28 days strength of 42.45 MPa was also achieved at SF 10% + QD 30%.

3.2 Workability

The compaction factor goes on decreasing as we add silica fume and quarry dust in concrete, thus giving maximum workability in case of conventional mix. The values obtained in test are given in table 10.

Table 10 : Compaction Factor Results

Replacements	CF
SF 0% + QD 0%	0.96
SF 8% + QD 0%	0.91
SF 10% + QD 0%	0.84
SF 12% + QD 0%	0.79
SF 10% + QD 20%	0.70
SF 10% + QD 30%	0.61
SF 10% + QD 40%	0.52

3.3 Durability

Rapid Chloride Penetration Test (RCPT) has been performed as per ASTM C 1202 on cylindrical samples. Conventional mix has shown the maximum porosity because of voids in its microstructure which has been improved with different combinations of silica fume and quarry dust. The results obtained are given in table 11.

Table 11 : RCPT Results

Replacements	Coloumbs Passed
SF 0% + QD 0%	1347
SF 8% + QD 0%	983
SF 10% + QD 0%	634
SF 12% + QD 0%	561
SF 10% + QD 20%	413
SF 10% + QD 30%	324
SF 10% + QD 40%	454

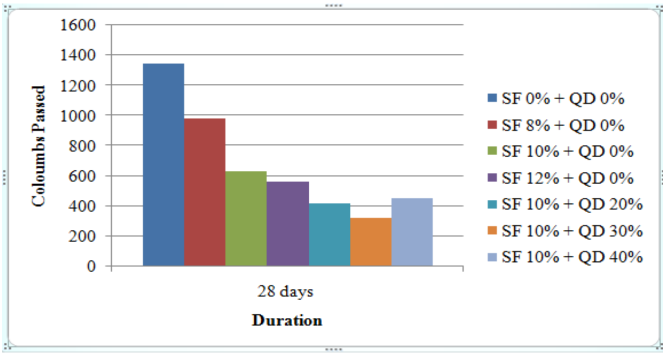

Fig. 3 : Variation of coloumbs passed with %age variation of silica fume and quarry dust

The durability of concrete has been increased with an increase in content of silica fume and quarry dust. The sample with SF 10% + QD 30% has given maximum durability with least no of coloumbs passing through it.

4. Conclusions

The compressive strength has increased with increase in silica fume content, his increase is due to the pozzolanic action and binder formation of silica fume with cement. The decrease in strength beyond 10% silica fume may be due brittle behavior of concrete due to presence of extra binder. With further addition of quarry dust in addition to silica fume has increased its strength due to good bond formation due to rocky structure of quarry dust. The optimum replacement level was SF 10% + QD 30%

The workability of concrete has reduced considerably as we go on adding silica fume and quarry dust in it. This decrease is due to the presence of higher surface are of particles and more water absorption by silica fume and quarry dust.

RCPT values show that the permeability of ions through go on decreasing with addition of silica fume as it acts as a void filler in concrete. Thus durability increased due to improvement of microstructure with addition of silica fume. This increase in durability continues as we add quarry dust with 10% silica fume, but this increase in durability is only upto SF 10% + QD 30% after wich durability again falls.

Thus we can conclude that to reduce the environmental pollution and heat we can replace cement by industrial wastes like silica fume. Similarly natural sand can also be replaced with quarry dust.

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