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Utilization of Silica Fume in Cement Concrete Paving Block

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Abstract: Silica fume is a by-product of electric arc furnace reduction of quartz into silicon and ferrosilicon alloy used in the electronics industry. This is composed mainly by silicon and this by-product can be used as a mineral admixture in mortar and concrete. This waste product is already causing serious environmental pollution which calls for urgent way of handling the waste. In this paper, silica fume has been chemically and physically characterized, in order to evaluate the possibility of their use in industry. Samples of varied amount of silica fume mix with cement at 0, 5, 10, 15, 20, 25&30 % respectively. Aging times were 28 days for compression strength.

Keywords: Interlocking concrete block pavement (ICBP), Silicon, SUDs

I. INTRODUCTION

Interlocking Concrete Block Pavement (ICBP) has been extensively used in many countries for quite some time as a specialized problem -solving technique for providing pavement in areas where conventional type of construction are less durable due to many operational and environmental constraints. ICBP technology have been introduced in India in construction, a decade ago for specific requirement namely footpaths, parking areas etc. but now being adopted extensively in different uses where the conventional construction of pavement using bituminous mix or cement concrete technology is not feasible or desirable .In this project , attempt has been made to reduce the proportion of cement and fine aggregate by adding the silica fume and crusher powder in various proportions.Silica fume is a by-product of ferro silica alloy are produced in electric furnace. Concrete containing silica fume can have very high strength and have high durability .Chukwudi Onyeakpa in this paper , a dual mould interlocking block machine with compaction effort was effectively constructed for interlocking block production. Silica fume is also known as micro silica, is an amorphous polymorph of silicon dioxide, silica. It is an ultrafine powder collected as an by- product of the silicon ferrosilicon alloy production and consists of spherical particles with an average particle diameter of 150 nm. These improvements stem from both the mechanical improvement resulting from addition of a very fine powder to the cement paste mix as well as from the pozzolanic reactions between the silica fume and free calcium hydroxide in the paste. Vireen Limbachiya has discussed that a study successfully reduced the cement content of concrete paving block by 40%. Sustainable urban drainage system (SUDs) is used for growing application of concrete paver block). K. Shyam Prakash had said, the mechanical properties and elastic modulus are improved by replacement of quarry dust. 100% replacement of sand with quarry dust gives better results in terms of compressive strength studies .The environmental effects and waste can be significantly reduced**.** M.Nishanth premhar The Effect of silica fume (SF) various strength properties of replacement of cement, coarse aggregate. 10% of cement weight replaced by silica fume. Result shows that 30% of silica fume in paver block attain its maximum compressive strength.

Effects of silica fume on different properties of fresh and hardened concrete include:

- **Workability**: With the addition of silica fume, the slump loss with time is directly proportional to increase in the silica fume content due to the introduction of large surface area in the concrete mix by its addition. Although the slump decreases, the mix remains highly cohesive.

- **Segregation and bleeding:** Silica fume reduces bleeding significantly because the free water is consumed in wetting of the large surface area of the silica fume and hence the free water left in the mix for bleeding also decreases. Silica fume also blocks the pores in the fresh concrete so water within the concrete is not allowed to come to the surface.

II. SILICA FUME

Silica fume is a by-product in the carbothermic reduction of high-purity quartz with carbonaceous materials like coal, coke, wood-chips, in electric arc furnaces in the production of silicon and ferrosilicon alloys.

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Fig 1. Silica Fume

Silica fume is an ultrafine material with spherical particles less than 1 μm in diameter, the average being about 0.15 μm. This makes it approximately 100 times smaller than the average cement particle. The bulk density of silica fume depends on the degree of densification in the silo and varies from 130 (undensified) to 600 kg/m^3. The specific gravity of silica fume is generally in the fume can be measured with the BET method or nitrogen adsorption method. It typically ranges from 15,000 to 30,000 m^2/kg. Addition of silica fume also reduces the permeability of concrete to chloride ions, which protects the reinforcing steel of concrete from corrosion, especially in chloride-rich environments such as coastal regions and those of humid continental roadways and runways (because of the use of deicing salts) and saltwater bridges.

III.CRUSHER DUST

Crusher dust is a common by-product of mining and quarrying. Rather than being discarded as a waste material however, recycled crusher dust has many practical applications around the home and in construction. Using crusher dust in lieu of other materials can have resounding environmental and economical benefits. With fine particles like soft sand, crusher dust can be used as a cost-effective filling and packing material around water tanks; blended with natural sands to improve concrete shrinkage and water demand; and as a material to back-fill trenches with.

Fig 2. M-Sand

Crusher dusts also have applications in horticulture as a natural fertiliser. Crusher dusts contain minerals that are insoluble to water, which makes it an ideal material to stop mineral leaching in soils; to reduce water logging; and to raise

3. STUDY ON PROPERTIES OF COLLECTED MATERIALS

The properties of materials such as cement, aggregate, silica fume and crusher stone powder have been studied and tested.

3.1 CEMENT

Ordinary Portland cement (OPC) 53 grade and M35 (1:0.5:1) is used for the project. Ordinary Portland cement) is manufactured by combination of pozzolanic materials. Pozzolana is an artificial or natural material which has silica in it in a reactive form. Along with pozzolanic materials in specific proportions, OPC contains clinker and gypsum.

Test Conducted	Results
Initial setting time	35min
Specific gravity of cement	3.12

The specific gravity, fineness test for the cement are given in table 4.1

3.2 AGGREGATE

Fine and coarse aggregate makes up the bulk density of a concrete mixture. Chips and crushed stone powder are used as fine and coarse aggregate respectively .Size of fine and coarse aggregate are less than 4.75 mm and 6 mm respectively.

3.3 FINE AGGREGATE

The sand passes through 2.36mm and retained on 900 micron sieve are used. The purpose of the fine aggregate is to fill the voids in the coarse aggregate and to act as a workability agent.

Test conducted	**Results**
Specific gravity of Coarse aggregate	2.8
Fineness modulus of fine aggregate	4.01

The specific gravity, fineness test for the silica fume are given in table 4.2

3.4 COARSE AGGREGATE

The Coarse aggregate used was broken crushed stone which of size pass through 40 mm sieve and retained in 6 mm sieve. It is well graded i.e, different particle size and cubical in shape.

Test conducted	**Results**
Specific gravity of Coarse aggregate	2.50
Fineness modulus of coarse aggregate	2.6

The specific gravity, fineness test for the silica fume are given in table 4.3

3.5 SILICA FUME

Silica fume is the industrial waste, which is generated during the production of electronic arc furnace reduction of quartz into silicon.

Test conducted	**Results**
Specific gravity of Coarse aggregate	2.1
Particle size	0.7µ

The specific gravity, fineness test for the silica fume are given in table 4.4.

IV.SPECIMEN PREPARATION

MIXING

Mix the fine aggregate and coarse aggregate on a water tight none-absorbent platform until the mixture is thoroughly blended and is of uniform colour. Add cement and silica fume with the line aggregate and crusher powder. Mix well until the coarse aggregate is uniformly distributed throughout the batch. Add water and mix it until the concrete appears to be homogeneous and of the desired consistency.

Fig. 3 Preparation of specimens.

The preparation of materials for making these test specimens are from the same concrete used in the field. The inner sides of moulds were coated with oil to prevent adhesion of concrete. Totally, interlocking concrete paver block specimens were cast.

3.6 SAMPLING

- Clean the mould and apply oil.
- Fill the concrete in the mould in layers approximately 5cm thick.
- Compact each layer with not less than 25 stokes per layer using a tamping rod (steel bar 16mm diameter and 60 cm long, bullet pointed at lower end).
- Level the top surface and smoothen I with a trowel.

3.7 PREPARATION OF MOULD

Before casting of the specimen, the mould was cleaned and fully tightened. The inner side of the mould was coated with oil to prevent

3.8 CASTING

With the mix ratio 18 paver blocks were casted by replacing the different percentage of silica fume for cement. The cement concrete were poured in the mould which was fitted in the machine (detachable). The machine is combined with a system which gave vibration for compaction of concrete in the blocks. The mould filled with concrete was pressed by a plate hammer nearly 25mm.Three blocks are manufactured each time. After initial set the blocks were placed in water vats for curing.

Concrete specimens of paver (230x175x60mm). Specimens were cured for 28 days.

3.9 COMPACTION

Vibrating compaction of concrete specimen is carried out.

Fig. 4. Compaction of specimens

3.10 DEMOULDING

The paver specimens should be demoulded in 24 hours after they have been made. When removing the concrete specimens from the mould, take the mould apart completely. Take care not to damage the specimens because, if any cracking is caused, the strengths may be reduced.

V.CURING OF TEST SPECIMENS

The specimens were allowed to remain in the rubber mould for the first 24 hours at ambient condition. Identification were marked on the exposed face of the specimen .The specimens were de – moulded and they were immersed in the water in the curing tank .The specimens were allowed to cure in water for periods of 7 and 28 days . The ambient temperature for curing was 27+2°C.

Fig. 5. Curing of specimens

VI .COMPRESSIVE STRENGTH

The main objective of this study is to find the compressive strength of hardened concrete after subjecting of curing at room temperature for duration of 7 and 28days. The specimens were taken out of the curing tank after the completion of the curing period. They were allowed to dry at the room temperature for about 3hours. The actual dimensions of the specimens were accurately measured.

Compressive Strength = Load /(Cross- sectional Area.)

VII. FLEXURAL STRENGTH

Flexural strength is one measure of the tensile strength of concrete. It is a measure of an reinforced concrete beam or slab to resist failure in bending.. Fig 6.3 shows the testing of prism specimen before and after failure. Cracking is due to diagonal tension but mostly due to restrained shrinkage and temperature gradients. Direct application of pure tension is difficult. The theoretical maximum tensile stress reached in the bottom of the test beam is as modulus of rupture.

$F=PL/(bd)^2$

Where,
F = Flexural strength of concrete (in MPa)
P= Failure load (in N)
L-Effective spin of the block
B-Breadth of the block

VIII .TEST AND DISCUSSION

The paving is in the curing stage, the test is to be conducted after the 7 and 28 days of curing. After testing the paving, the result is to be discussed and the graph is drawn for the compressive strength, of the paver block.

IX.RESULT AND DISCUSSION

9.1WATER ABSORPTION TEST RESULTS

This test method is used to determine the rate of absorption of water by hydraulic cement concrete by measuring the increase in the mass of a specimen resulting from absorption of water as a function of time when only one surface of the specimen is exposed to water .The specimen is conditioned in an environment at a standard relative humidity to induce a consistent moisture condition in the capillary pore system. The exposed surface of the specimen is immersed in water and water ingress of unsaturated concrete is dominated by capillary suction during initial contact with water .A brick is submerged in water for 24 hours .If its weight after 24hours exceeds its dry weight by 20% , the brick is not used for construction.

Table 9.1 Water absorption test result for 7days

Percentage of silica fume	Weight of block before curing (kg)	Weight of block after curing (kg)	Percentage change in weight (%)
5	6.080	6.120	0.65
10	5.995	6.065	1.16
15	5.875	5.900	0.42
20	5.960	6.205	4.11
25	6.025	6.070	0.68
30	5.945	5.980	0.58

Rate of water absorption of paver block after one day curing are shown in the table9.1

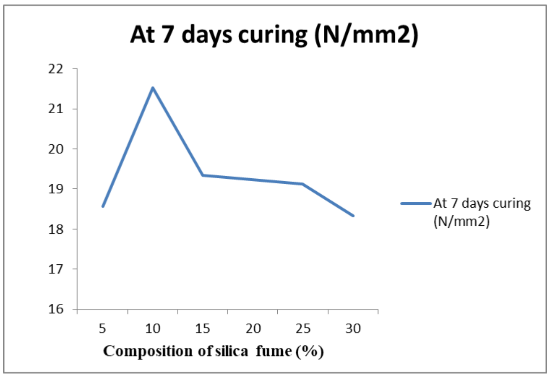
9.2COMPRESSION TEST RESULTS

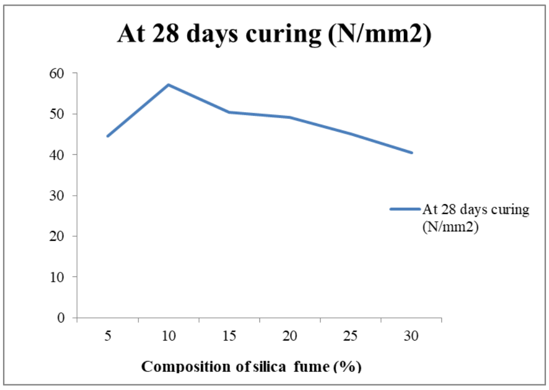
Out of many test applied to the concrete , this is the utmost important which gives an idea about all the characteristics of concrete .By this single test one judge that whether concreating has been done properly or not .Compressive strength of the concrete depends on many factors such as water - cement ratio , cement strength , quality of concrete material , quality control during production of concrete etc.. The compression test made on paver at varying curing stages such as 7 , 28 days are as follows.

Table 9.2 Compression strength test value

Composition of silica fume (%)	At 7 days curing (N/mm^2)	At 28 days curing (N/mm^2)
5	18.56	44.50
10	21.52	57.11
15	19.35	50.35
20	19.24	49.14
25	19.13	45.13
30	18.33	40.45

Compressive strength for the paver block after 7, 28 days are shown in the Table 9.2





X. CONCLUSION

- Preparation cost will be reduced.
- High strength can be attained at the optimum percentage of silica fume and crusher stone.
- Industrial waste will be reused and the pollution to be reduced.
- The use of industrial waste (silica fume, crusher stone powder) in place of conventional raw material will help to decrease the environmental pollution and also conserve our natural resources.
- To use silica fume and crusher powder by replacing it by cement and fine aggregate
- To identify various industrial waste suitable for utilization in cement manufacture.
- To increase the strength of the paver block by adding silica fume and crusher stone dust .
- Replacement of 20 % of silica fume gives the value of high strength during compression.

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