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Properties of Recycled Aggregate Concrete with Silica Fume

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Abstract: This study describes about the investigation undertaken to examine the suitability of recycled concrete as a substitute for fine aggregate. Recycled concrete (artificial sand) is used for 40% of fine aggregate and natural sand is retained for the remaining part. HPC of M 60 grade is attempted, with different replacement levels of cement with silica fume. Maximum 28 day compressive strength of 71.70 MPa with 15% replacement of cement with silica fume was observed for a water-binder ratio of 0.32 acid resistance and chloride impermeability increases with increase of silica fume content.

Key words: High performance concrete, silica fume, recycled aggregate, durability

INTRODUCTION

Increase in demand and decrease in supply of aggregates for the production of concrete result in the need to identify new sources of aggregates. Construction materials are increasingly judged by their ecological characteristics. Concrete recycling gains importance because it protects natural resources and eliminates the need for disposal by using the readily available concrete as an aggregate source for new concrete. Thus recycled aggregates, if used in making new concrete, will undoubtedly play a vital role in the conservation of our natural resources by Ravindrarajah (1987) and Ray (1991). Cycling if waste concrete as aggregate for new concrete attracted many researches and their finding have been reviewed by Forndistou *et al.* (1977) and Nixon (1976). Several investigations have been made to study the effects of recycled aggregate on the engineering properties of concrete.

Recycling of concrete is a relatively simple process. It involves breaking, removing and crushing existing concrete into a material with a specified size and quality. The quality of concrete with recycled concrete aggregates is very dependent on the quality of the recycled material used. Reinforcing steel and other embedded items, if any, must be removed and care must be taken to prevent contamination by other materials.

This study highlights the use of the recycled aggregate concrete both from strength and durability point of view.

SCOPE OF INVESTIGATION

The laboratory investigations were carried out with a water-cement ratio of 0.32. The effect of varying amounts of replacement of cement that is 10, 12.5, 15 and 17.5% with silica fume was studied. The quantity of recycled (40%) and natural (60%) fine aggregate was suitably adjusted for the different replacement levels with silica fume. The compressive strength, split tensile strength and flexural strength of the mixes were investigated as per IS specifications. Also, durability studies were carried out.

MIX proportions: There are no specific methods of mix design for HPC. The methods adopted for the design of conventional concrete mixes are not directly applicable to HPC. A simplified mix design procedure for HPC using silica fume and superplasticizer is formulated by combining BIS and ACI code methods of mix design and available literatures on HPC suggested by Sundarajan and Permual (2003) was used to determine the quantities of different ingredients. In calculating the mix proportions, air content for concrete was assumed as 1.5% in the present study. The chemical admixture used is Sulfonated naphthalene formaldehyde type superplasticizer at 1.5% by mass of binder. The mix CC, M1, M2, M3 and M4 were obtained by replacing 10, 12.5, 15 and 17.5% of the mass of cement by silica fume, respectively (Sarkhel, 2000; Allen, 1997). In the concrete mix CC, no mineral admixture was added and fully natural fine aggregate is used. But in

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Table 1: Mix proportioning details of condensed silica fume concrete

Mix designation	CC	M1	M2	M3	M4
Condensed silica fume (%)	0.00	10.00	12.50	15.00	17.50
w-b ratio	0.32	0.32	0.32	0.32	0.32
Cement content (kg m^{-3})	439.40	407.81	396.48	385.16	378.83
Condensed silica fume content (kg m^{-3})	0.00	45.31	56.41	67.97	79.30
Natural fine aggregate (kg m^{-3})	780.42	449.00	446.57	444.14	434.48
Recycled fine aggregate (kg m^{-3})	0.00	299.34	297.71	296.09	289.66
Coarse aggregate (kg m^{-3})	1075.00	1075.00	1075.00	1075.00	1075.00
Water (1 m^{-3})	140.64	150.98	150.90	150.83	150.54
Superplasticizer (1 m^{-3})	14.28	14.28	14.28	14.28	14.28

all other four mixes 40% of fine aggregate is replaced by artificial sand. Comparing with mix CC, all other mixes requires more water content due to high water absorption by recycled aggregates. The mix proportions of the concrete are given in Table 1.

RESULTS AND DISCUSSION

Compressive strength: The compressive strength of HPC mixes at the ages of 3, 7, 28 and 56 days were given in Table 2. When silica fume is added as additional admixture, there is a significant improvement in the strength of concrete because of its high pozzolanic action to from more CSH gels (Chinnaswamy, 1989). It is observed that the compressive strength increases with increasing age of curing. The maximum cube compressive strength for the mix (M3) with 15 % of SF at 28 days 71.70 MPa and at 56 days is 79.85 MPa vide Table 2.

Split tensile strength: Tests were carried out according to IS 5816-1976 to obtain split tensile strength for various concrete mixes. The split tensile strength varies from 3.54 to 4.43 MPa at 28 days. It is observed that the split tensile strength is about 6 to 6.5 of compressive strength of concrete (Table 2).

Flexural strength: Tests were carried out according to IS 516-1959 to obtain flexural strength for various concrete mixes used. Three beams were cast for each mix and tested using two-point strength at the age of 28 days varies from 5.40 to 7.12 MPa. It is observed that the flexural strength is about 9 to 10% of compressive strength of concrete.

DURABILITY PROPERTY

Rapid chloride permeability test: Rapid chloride permeability test was conducted as per ASTM C1202 standards. The charge conducted by the specimens in coulomb was reduced to ASTM equivalent chloride ion

Table 2: Strength properties of high performance concrete

Properties	CC	M1	M2	M3	M4
Compressive strength, Mega Pascal					
3-day	29.48	20.44	22.67	33.63	30.96
7-day	45.33	37.33	41.19	53.19	48.30
28-day	67.56	61.78	62.22	71.70	64.89
56-day	73.33	64.15	65.19	79.85	69.19
Split tensile strength, Mega Pascal	4.24	3.54	3.82	4.43	4.20
Flexural strength, Mega Pascal 28 days	6.20	5.40	5.47	7.12	6.12
Modules of elasticity, Giga Pascal	38.52	37.67	38.46	39.57	38.42

Table 3: Acid resistance and chloride permeability test results

Mix designation	Silica fume (%)	Loss of weight in 3% H_2SO_4 solution (Immersed for 30 days)	Chloride permeability (ASTM Equivalent) Coulombs
CC	0.0	2.72	1890
M1	10.0	1.55	1620
M2	12.5	1.16	1350
M3	15.0	1.15	960
M4	17.5	0.96	840

CC-Controlled concrete with zero% silica fumes, M1-Concrete mix with 10% silica fume, M2-Concrete mix with 12.5% silica fume, M3-Concrete mix with 15% silica fume, M4-Concrete mix with 17.5% silica fume

permeability values. It is observed that the chloride ion permeability values fall in the range of low for mixes CC, M1, M2 and for mixes M3, M4 falls in the range of very low (Table 3). With increase in silica fume content chloride ion permeability gets reduced.

CONCLUSIONS

- Cement replacement level of 15% with silica fume in M60 grade of HPC (40% artificial sand and 60% natural sand) is found to be the optimum level to obtain higher values of compressive strength, split tensile strength and elastic modules Concrete mixes containing silica fume showed higher values of acid resistance and impermeability to chloride ions.
- The results of the strength and durability related tests have demonstrated superior strength and durability characteristics of the HPC mixes containing silica fume. This is due to the improvement in the microstructure due to pozzolanic action and filler effects of silica fume, resulting in fine and discontinuous pore structure.

- Even a partial replacement of cement with silica fume in concrete mixes would lead to considerable savings in consumption of cement and natural sand. Therefore, it can be concluded that replacement of cement with 15% of silica fume would render concrete (with 40% artificial sand) more strong and durable.

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