# PROPERTIES OF CONCRETE MADE WITH RECYCLED COARSE AND FINE AGGREGATES

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**Abstract -** *The advancement of concrete technology, as well as the development of new materials and components has resulted in increased performance and strength needs, which are not adequately satisfied any longer. Maintenance, repair, and rehabilitation of existing cement concrete structures also involve a lot of problems causing significant expenditures. Here recycled concrete aggregate is used as a substitute for fine aggregate. Recycled concrete aggregate is used for 40% of fine aggregate and natural sand is retained for the remaining part. High Performance concrete (HPC) of M60 Grade is attempted here with two types of admixtures i.e. silica fume and fumed silica. Investigations are being carried out in order to make a quantitative assessment of different natural fine aggregates replacement levels with recycled concrete aggregate on the strength and durability properties of M60 grade of HPC mixes and also to arrive at the optimum level of replacement of cement with silica fume and fumed silica at different water binder ratios.*

*There are several attempts to develop a method for the proportioning of mixes with cement replacement material, which could be classified as addition, replacement or rational methods. Existing methods of mix proportioning are not adequate for the optimization of many factors that must be considered for HPC. Therefore, a simplified and modified mix design procedure based on the BIS and ACI methods of concrete mix design has been formulated in this thesis. The HPC mix M60 grade was designed using the above formulated mix design procedure and experimental investigations were carried out to verify the proposed mix proportioning method at different w/b ratios.*

*In this thesis, investigations were carried out on mechanical properties such as compressive strength, splitting tensile strength, flexural strength. The results of these investigations demonstrates the superior mechanical and durability characteristics of silica fume and fumed silica based concrete mixes. Based on the results obtained, the replacement of cement with 15% of silica fume and 1% of fumed silica which yields superior mechanical and durability characteristics was arrived at. The details of the investigations along with the results are presented in this thesis.*

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

## 1. 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. These 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 Fomdistou 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 UPC. 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 super plasticizer at 1.5% by mass of binder. The mix CC, Ml, 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 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 scope of the present work includes the following:

1. To determine the suitability of recycled concrete aggregate with respect to strength and durability.
2. To determine the optimum level of replacement of natural sand with recycled concrete aggregate.
3. To determine the strength of high performance concrete containing mineral admixtures.

**INGREDIENTS USED:-**

The ingredients used in this present investigation are:

- Ordinary Portland Cement, 53 Grade conforming to BIS: 12269-1987.
- Silica fume in dry densified form obtained from ELKEM INDIA (P) LTD., MUMBAI conforming to ASTM C 1240.
- Fumed silica in dry densified form obtained from CABOT SANMAR LIMITED.
- Superplasticizer (chemical admixture) based on sulphonated naphthalene formaldehyde condensate - CONPLAST SP 430 complies with BIS: 9103-1999 and ASTM C 494 (1992).
- Locally available quarry and crushed blue granite stones conforming to graded aggregate of nominal size 12.5 mm as per Table 2 of BIS: 383- 1970 with specific gravity 2.80 and fineness modulus 6.70 as coarse aggregates. The aggregates were tested as per the procedure given in BIS: 2386-1963.
- Locally available river sand conforming to Grading Zone II of Table 4 of BIS: 383-1970 with specific gravity 2.40 and fineness modulus 2.95 as fine aggregates.
- Recycled concrete aggregate obtained from laboratory cast concrete with specific gravity 2.50 and fineness modulus 6.45.
- Locally available drinking water is used for concreting and curing.

Table1: Mix proportioning details

| Mix Designation | Proportions of RCA & NFA |
|---|---|
| M1 | 75% RCA & 25% NFA |
| M2 | 70% RCA & 30% NFA |
| M3 | 65% RCA & 35% NFA |
| M4 | 60% RCA & 40% NFA |
| M5 | 55% RCA & 45% NFA |
| M6 | 50% RCA & 50% NFA |
| M7 | 45% RCA & 55% NFA |
| M8 | 40% RCA & 60% NFA |
| M1 | 75% RCA & 25% NFA |

Mix proportions were arrived at for M60 grade of HPC trial mix based on the above formulated mix design procedure by replacing 0, 10, 12.5, 15, 17.5 and 20 percent of the mass of the cement with silica fume and 0, 0.5, 0.75 1.00, 1.25 and 1.50 percent of the mass of the cement with fumed silica at a w/b ratio of 0.32, 0.30 and 0.28. A total of 6 trial mixes were arrived at. In all the trial mixes, a super plasticizer namely, CONPLAST SP 430 was used at 1.5% by weight of binders for obtaining workable concrete.

**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.

**Table 2: Strength properties of high performance concrete**

| **Properties** | CC | Ml | M2 | M3 | M4 |
|---|---|---|---|---|---|
| 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-thy | 73.33 | 64.15 | 65.19 | 79.85 | 69.19 |
| Split tensile strength | 4.24 | 3.54 | 3.82 | 4.43 | 4.20 |
| Flexural strength | 6.20 | 5.40 | 5.47 | 7.12 | 6.12 |
| Modules of elasticity | 38.52 | 37.67 | 38.46 | 39.57 | 38.42 |

**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 permeability values. It is observed that the chloride ion permeability values fall in the range of low for mixes CC, MI, 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.

**Table 3: Acid resistance and chloride permeability test results**

| Mix designatio | Silica fume | Lass of weight in 11,S0., solution (Immersed for 30 days) | Chloride (ASTM 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, MI-Concrete mix with 10% silica fume, M2-Concrete mix with 12.5% silica Same, M3-Concrete mix with 15% silica fume, M4-Concrete mix with 17.5% silica fume

**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.

- The workability of concrete as measured from slump and compaction factor decreases as percentage of silica fume and fumed silica in concrete increases, whereas for Vee-bee degree increases for all w/b ratios. This is not only due to the fact that as the percentage of silica fume and fumed silica increases the water available in the system decreases, thus affecting the workability, but also due to the presence of high pozzolanic reactive nature of silica fume and fumed silica with liberated calcium hydroxide.

- The compression failure pattern of concrete is due to crushing of coarse aggregate and not due to bond failure.
- The silica fume and fumed silica used in this investigation exhibits good pozzolanic properties. Therefore, it is strongly recommended for the production of HPC.
- The optimum replacement of cement by silica fume and fumed silica for HPC mixes was found to be 15 and 1 percent respectively for achieving maximum cylinder compressive strength at the age of 28 days at all w/b ratios.
- The ratio between cylinder and cube compressive strength was found to be 0.89 at the age of 28 days.
- The optimum replacement of cement by silica fume and fumed silica for HPC was found to be 15 and 1 percent respectively for achieving maximum value of flexural strength at the age of 28 days at all w/b ratios.
- The flexural strength increases along with increase in compressive strength. The flexural strength of HPC is 9 to10 percent of cube compressive strength.
- The flexural strength of concrete at the age of 28 days was higher than the value calculated by the expression 0.7 ck as specified in BIS:456- 2000 The code BIS:456-2000 underestimates the value of flexural strength of silica fume and fumed silica -based HPC.

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