Experimental Investigation on High Performance Concrete Using Silica Fume and Superplasticizer

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***Abstract*—This paper formulates a simplified mix design procedure for HPC by combining BIS and ACI code methods of mix design and available literature on HPC. Based on the above procedure M80 and M100 mixes are arrived at. These HPC mixes are tested experimentally for compression, split tension, flexure and workability. The performances of the design mixes are very good and the results are reported are in this paper. The durability characteristics of HPC are under progress.**

***Index Terms*—High performance concrete, superplasticizer and silica fume.**

I. Introduction

HPC is a construction material which is being used in increasing volumes in recent years due to its long term performance and better rheological, mechanical and durability properties than CC. HPC possess invariably high strength, reasonable workability and negligible permeability. Compared to CC, preparation of HPC requires lower water binder (w/b) ratio and higher cement content. The durability properties of concrete are given importance, which makes High Strength Concrete (HSC) into HPC. HSC refers to concretes of grade above M60. High strength and better durability properties become reality for CC by reducing porosity, in homogeneity, micro cracks in concrete and the transition zone. This is how HPC is evolved.

The HPC permits the use of reduced sizes of structural member, increased building height in congested areas and early removal of formwork. The use of HPC in prestressed concrete construction makes greater span-depth ratio, early transfer of prestress and application of service loads. Low permeability characteristics of HPC reduce the risk of corrosion of steel and attack of aggressive chemicals. This permits the use of HPC in marine/offshore structures, nuclear power plants, bridges and places of extreme and adverse climatic conditions. Eventually HPC reduces maintenance and repair cost.

II. Mechanism of HPC

According to nevillie “HPC is a concrete to fulfill specified purpose and no special mystery about it, no unusual ingredients or special equipments has to used. But to understand the behavior of concrete and will, to produce a concrete mix within closely controlled tolerances”.

Manuscript received March 12, 2012; revised May 4, 2012.

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III. Significance and Objectives

The objectives of the present investigation are to develop a simplified mix design procedure, specially for HPC by varying the percentage replacement of cement by SF(0-15%) at a constant dosage of super plastisizer, based on BIS and ACI code methods of mix design procedure and available literatures on HPC. Investigations were carried out on the above procedure to produce HPC in mixes for M80 and M100 grades using 12.5 mm maximum size of aggregates to ascertain workability and the mechanical properties of the designed mixes and to find an optimum cement replacement by SF.

Hence in the present investigation more emphasis is given to study the HPC using SF and superplasticizer so as to achieve better concrete composite and also to encourage the increased use of SF to maintain ecology.

IV. Experimental Program

Experimental investigations have been carried out on the HPC specimens to ascertain the workability and strength related properties such as compressive strength, split tensile strength, flexural strength and elastic modulus of the designed trial mixes and also non- destructive test(NDT)-ultrasonic pulse velocity(UPV) has been carried out to check the quality of concrete.

A. Materials Used

Silica fume as mineral admixture in dry densified form obtained from ELKEM INDIA (P) LTD, Mumbai conforming to ASTMC-1240.

Super plasticizer (chemical admixture) based on sulphonated naphthalene formaldehyde condensate-CONPLAST SP 430 conforming to BIS: 9103-1999 and ASTM C-494

B. Mix Design for HPC

Since there are no specific methods for mix design found suitable for HPC, a simplified mix design procedure, is formulated by combining the BIS method, ACI methods for concrete mix design and the available literatures on HPC using SF.

1) Calculation of binder contents

The binder or cementitious contents per m2 of concrete is calculated from the w/b ratio and the quantity of water content per m3 of concrete. Assuming the percentage replacement of cement by SF(0-15%), the SF content is obtained from the total binder contents. The remaining binder content is composed of cement. The cement content so calculated is checked against the minimum cement content for the requirements of durabilility as per table 5 and 6 of BIS: 456-2000 and the greater of the two values is adopted.

2) *Moisture adjustments*

The actual quantities of CA, FA and water content are calculated after allowing necessary corrections for water absorption and free (surface) moisture content of aggregates. The volume of water included in the liquid plasticizer is calculated and subtracted from the initial mixing water

3) *Unit mass of concrete*

The mass of concrete per unit volume is calculated by adding the masses of the concrete ingredients.

4) *Selection of water- binder (w/b) ratio*

The water binder ratio for the target mean compressive strength is chosen from figure BIS: 456- 2000

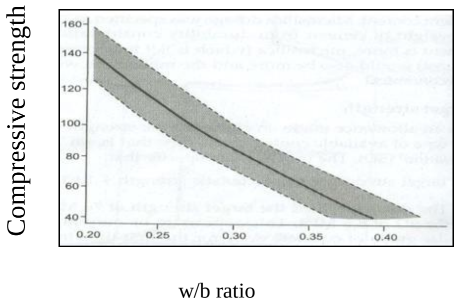

Fig. 1. Proposed w/b ratio Vs compressive strength relationship from BIS: 456- 2000

Figure 1 shows that the proposed w/b ratio vs compressive strength relationship. The w/b ratio so chosen is checked against the limiting w/c ratio for the requirements of durability as per table5 of BIS: 456- 2000, and the lower of the two values is adopted.

5) *Trial mix proportion*

Because of many assumptions underlying the forgoing theoretical calculations, the trial mix proportions must be checked, if necessary the mix proportion should be modified to meet the desired workability and strength criteria, by adjusting the % replacement of cement by SF, % dosage of super plasticizer solid content of binder, air content and unit weight by means of laboratory trial batches to optimize the mix proportion. Fresh concrete should be tested for workability, unit weight and air content. Specimens of hardened concrete should be tested at the specified age.

C. *Mixer Proportions and Casting of Specimens*

Mix proportions are arrived for M80 and M100 grades of concrete based on the above formulated mix design procedure by replacing 0, 2.5, 5, 7.5, 10, 12.5 and 15% of the mass of cement by SF and the material requirements per m^3 of concrete are given in table 6 and 7. The ingredients for the various mixes are weighed and mixing was carried out using a drum type mixer and casting were done in steel moulds for concrete cubes 150mm size, cylinders 150mmx300mmand beams 100mmx100mmx500mm. Curing was done under water for various desired periods.

V. Tests on Fresh and Hardened Concrete

Workability tests such as slump test, compaction factor test and Vee- bee consistometer test were carried out for fresh concrete as per BIS specifications, keeping the dosage of super plasticizer as constant at 3% by weight of binder. For hardened concrete cube compression strength test on 150mm size cubes at the age of one day, 3 days, 7 days, 14 days, 28 days and 56 days curing were carried out using 3000kN capacity compression testing machine as per BIS 516- 1959. Also compression strengthtest and split tensile strength on 150mmx300mm cylinders and flexure tests on 100mmx100mx500mm beams were carried out on 28 days cured specimens as per BIS specifications. The stress- strain graph for HPC is obtained using compressometer fitted to cylinders during cylinder compressive strength test. UPV measurements were taken using NDT method on 150mm size cubes for assessing the quality of concrete as per BIS 13311 (part 1)1992.

VI. Results and Discussions

A. *Tests on Fresh Concrete*

The test results of workability are listed in shown in figures 2, 3 and 4. It was observed that the workability of concrete decreased as the percentage of SF content was increased.

B. *Tests on Hardened Concrete*

The results of cube compression strength, cylinder compression strength, split tensile strength, flexural strength, and modulus of elasticity and water-binder materials are shown Figure 5, & 6. The optimum percentage of cement replacement by SF is 10% for the above test for M80 & m100 grades of concrete. This may be due to the fact that the decrease of strength characteristics is due to pozzolonic reaction and filler effects of SF. The ratio of cylinder to cube compressive strength was found to be 0.81. The flexural strength obtained experimentally are higher than the value calculated by the expression 0.7fck^0.5 as per BIS:456-2000. The variation of modulus of elasticity values with respect to percentage of SF for 28 days for M20 and M100 grades of concrete are shown in figure 6. For 10% SF content this is found to be optimum for modulus of elasticity also. The modulus of elasticity achieved was 3.97 GPa and 4.15 GPa for M80 and M100 grades of concrete respectively at the age of 28 days of concrete the values are comparatively lower than the values calculated by the expression 5000fck^0.5 as per BIS:456-2000. The velocities prove that the quality of concrete is excellent.

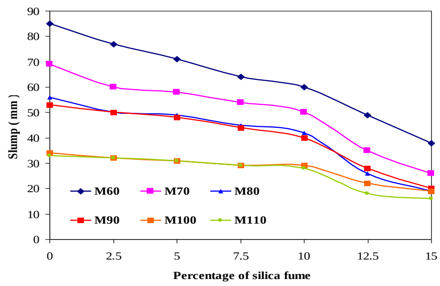

Fig. 2. Workability through slump values

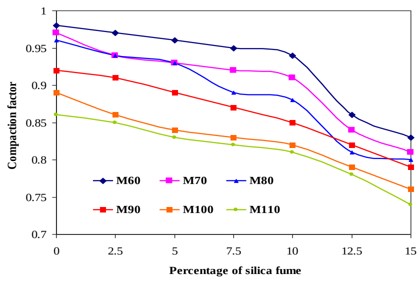

Fig. 3. Workability through compaction factor values

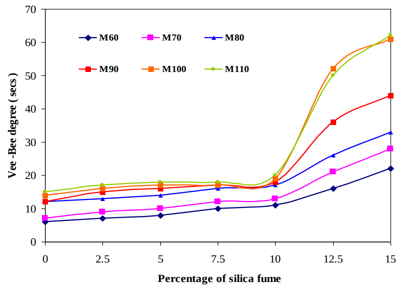

Fig. 4. Workability through Vee-bee values

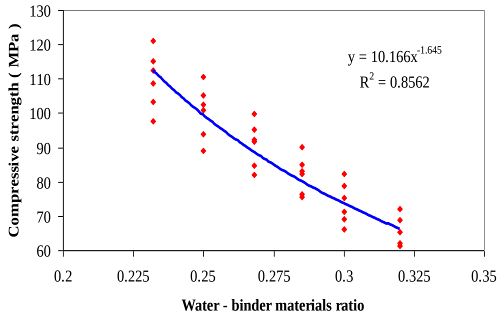

Fig. 5. Relationship between compressive strength and water-binder ratio of silica fume-based concrete

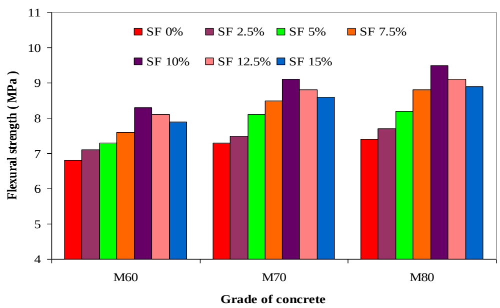

Fig. 6. Influence of SF on the flexural strength of M60, M70 & M90 grades of HPC trial mixes at 28 days

VII. Conclusions

Based on the investigations carried out on HPC mixes the following conclusions are drawn.

1) A simplified mix design procedure for HPC using SF and super plasticizer is formulated by combining BIS and ACI methods of mix design and available literatures on HPC.
2) The optimum percentage of cement replacement by SF is 10% for achieving maximum compressive, split tensile and flexural strength and elastic modulus.
3) The 7 days to 28 days compressive strength ratio of HPC is 0.75 -0.8.
4) The BIS 456-2000 code underestimates the flexural strength and over estimates the modulus of elasticity for HPC.
5) The use of SF in concrete reduces the workability.
6) The compression failure pattern of concrete is due to crushing of coarse aggregate and not due to bond failure.
7) The concrete mixes containing silica fume showed less value of pH as compared to concrete mix without silica fume.
8) From the test results, it is observed that the percentage of saturated water absorption of the HPC mixes containing silica fume was lower when compared with that of HPC mixes without silica fume.

References

[1] Neville, “Properties of Concrete,” 4th and final edition , pearson education Asia Pte. Ltd, England, 2000.

[2] Metha and Monterio, “Concrete:micro structure, properties and materials,” Indian edition, Indian concrete institute, Chennai, 1999.

[3] Nawy, “Fundamentals of high performance concrete,” Second edition, john wiley and sons inc., Newyork, 2001.

[4] Shah and Ahmad, *High performance concretes and applications*, Edward Arnold, London, 1994.

[5] Joshi, “Evolution of HPC mixes containing silica fumes,” *The Indian concrete journal*, vol. 75, no. 10, pp 627-633, 2001.

[6] Rixom and M. Vaganam, *Chemical admixtures for concrete*, second edition, E& F.N spon, London, 1996.

[7] Basu, “NPP Containment structures: Indian experience in silica fumes based HPC,” *The Indian concrete journal*, vol.75, no.10, pp. 656-664, October 2001.

[8] A. Mittal and Basu, "Development of HPC for PC dome of NPP, kaiga," *The Indian Concrete Journal*, vol. 73, no. 9, pp. 561-568, September 1999.

[9] A. Mittal and Kamath, "Properties of HPC for PC dome of NPP, Kaiga," *The Indian Concrete Journal*, vol. 73, no. 9, pp. 561-568, September 1999.

[10] Chinnappa, "HPC," *proceedings of the advanced in concrete technology with emphasis on HPC*, held at Pondicherry, pp. 185-194.

[11] Rajamane, "HPC mix proportioning," Advanced course on HP materials and methodologies for construction and rehabilitation of concrete structures, SERC, Chennai, 2000.

[12] Jagadish, "HPC," in *Proceedings of national seminar on Waver of the future, civil engg in 21st century*,15-16 june 2001, Assosciation of consulting civil engineers, (India), Banglore, pp. 72-90, 2001.

[13] Shigihlli and M. Ath, "High strength concrete containing silica fume, national," *Seminar on Advances in concrete and concrete structures* The Institution of Engineers, Belgaum, India, 2002.

[14] Wang and Read, "Trials of grade 100 high-strength concrete," *Magazine of concrete research*, vol. 51, no 6, pp. 409- 414, December 1999.

[15] Basu, "High Performance Concrete: Mechanism and Application," *ICI Journal*, April-June 2001, pp. 15- 26

[16] ASTM C 494, "Standard Specification for Chemical Admixtures for Concrete," *Annual Book of American Society for Testing Materials Standards*, 1992

[17] L. V. A. Seshasayi and M. Sudhaker, "Relationship of Water-Cementitious Materials Ratio and Compressive Strength of Silica Fume Concrete," *ICI Journal*, vol. 5, no.1, June 2004, pp. 11 - 14.