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A Mix Design approach for High Performance Concrete

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Abstract— ***High Performance Concrete has gained more attention nowadays in construction industry across the world. This paper gives an approach or method to design high performance concrete based on different considerations. The correct proportions of ingredient of concrete along with admixtures ensure the desired results of mechanical and durability properties under different loading and aggressive conditions. The construction industry can save more amount of cement and reduce the environmental pollution by adopting such mix design method.***

Keywords— High Performance Concrete, Aggressive Condition, Durability Properties, Environmental Pollution, Mix Design

I. INTRODUCTION

There are no unified definitions for high performance concretes (HPC) and different institutions and experts define HPC differently. According to khadrinaikar (2012), HPC is a concrete in which certain characteristics are developed for a particular application and environment so that it will give excellent performance in the structure in which it will be placed, in the environment to which it will be exposed, and with the loads to which it will be subjected during its design life. As per Strategic Highway Research Programme (SHRP), concrete meeting one of the following requirements can be categorised as HPC (Holland, 1993):

1. Concrete with a maximum water-cementitious ratio (W/C) of 0.35
2. Concrete with a minimum durability factor of 80%, as determined by ASTM C 666
3. Concrete with a minimum strength criteria of either
    - 21 MPa within 4 hours after placement (VES)
    - 34 MPa within 24 hours (HES), or
    - 69 MPa within 28 days (VHS)

II. LITERATURE REVIEW

Several researchers designed HPC mixes by using mix design methods of normal strength concrete or by combining principles of one or more methods. In general, it was observed in literature that that all the methods of mix design did not give desired workability and compressive strength and needed some modifications for making HPC mixes (Bharatkumar, B. H. et al.,2001; Chang, P.,2004;Larrard, F. et al.,1997).

Kumbhar and Murnal (2012) suggested following modifications for existing mix design methods to achieve HPCs.

- IS code method gives a lesser proportion of fine aggregates so a proper coarse to fine aggregate ratio should be recommended for better workability of the mix. Further, IS code method incorporates the use of only one mineral admixture. There should be modification in method in terms of the addition of more than one mineral admixture with appropriate proportion of chemical admixture.
- DOE method suggests higher quantity of fine aggregate which increases water required and hence reduces the strength which is not acceptable for HPC. Therefore the proper dosage of SP should be recommended.
- The Modified ACI method gives usage of high dosage of SP to get high slump which reduces the strength therefore proper the content of SP should be recommended.

A Mix design procedure for HPC suggested by Laskar (2011) took rheological parameters into account to determine compressive strength, water cement ratio and aggregate volume to paste volume ratio. Instead of using water cement ratio and compressive strength relationship, relationship between compressive strength, paste volume-aggregate volume ratio; physical properties of aggregate and rheological parameters were used in the mix design. Correlation charts for rheological parameters and compressive strength was developed based on cube test results of several trial mixes whose rheological parameters have also been found by the rheometer. Muhammad Fauzi et al. (2005) developed a prototype expert system called HPCMIX according to the mix design method proposed by Aitcin that provides the proportion of trial mix of HPC and recommendations on mix adjustment. Mehta and Aitcin proposed a simplified mixture proportioning procedure that is applicable for normal weight concrete with compressive strength values between 60 and 120 MPa. The method is suitable for coarse aggregates having a maximum size of between 10 and 15mm and slump values of between 200 and 250mm.The optimum volume of aggregate is suggested to be 65% of the volume of the HPC.

III. MIX DESIGN METHOD

It must be admitted that up to the present time, progress in the field of high-performance concrete has been the fruit of an empirical approach rather than a fundamental and scientific one. As has often been the case in concrete technology, advances in practice have proceeded thorough scientific investigations. High-performance concrete is prepared through a careful selection of each of its ingredients. It is very difficult to gain the last MPa of compressive strength of a particular concrete mixture, or the 1 hour workability to place it safely and uniformly in the field, but it is so easy to lose them. The performance and quality of each ingredient become critical at a certain point as the targeted strength increases, but there are some issues that are more critical than others. Certain issues have a much stronger impact on the economics of high-performance concrete, and determine whether or not it will be competitive not only against steel but also against usual concrete. The Mix Design Method Proposed by by Mehta and Aitcin [54] is presented in flow chart shown in fig.1. The method follows the same approach as ACI 211-1 Standard practice for Normal, Heavy Weight and Mass Concrete. It is a combination of empirical results and mathematical calculations based on the absolute volume method. The water contributed by the super plasticizer is considered as part of the mixing water.

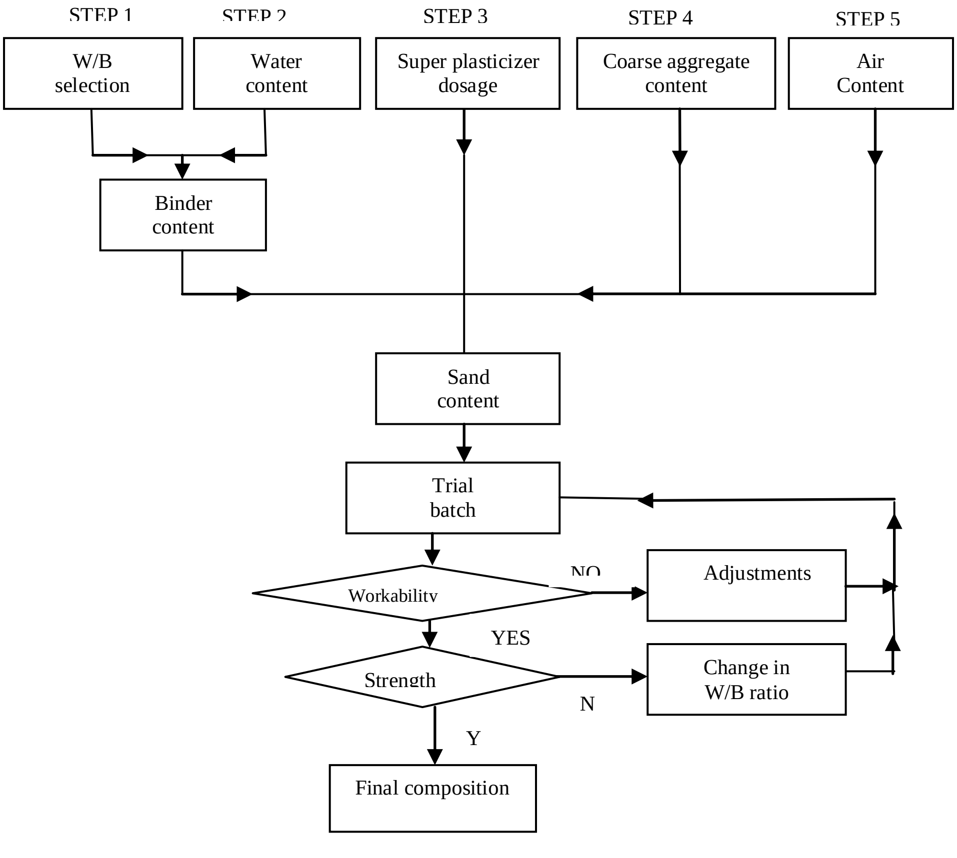

Fig.1 Flow Chart of Mix Design Method

1. Choice of strength: Arbitrarily divided into five grades, namely 65, 75,95and 120 Mpa.
2. Estimation of Mixing water: from a given strength grade, Table is used to estimate the maximum content of mixing water.
3. Volume fraction of cement paste components: From the total volume of 0.35 m^3 of cement paste, the water content and entrapped air is subtracted to get cementitious material.
4. Estimation of aggregate content: From the total aggregate volume 0.65 m^3 , assuming a 2:3 volumetric ratio between fine and coarse aggregate, individual volume fractions are calculated.
5. Calculation of batch weights: From the typical specific gravity values of ingredients the batch weights are determined.
6. Superplastizer dosage: If there is no prior experience with the superplasticizer, it is suggested to start with 1% and continue till the required workability is obtained.
7. Moisture correction: Depending on the moisture condition of batch aggregates, the appropriate moisture correction for fine and coarse aggregate must be made.
8. Trial batch adjustment: Several laboratory trials using the actual materials may be required before one arrives at the right combination of materials and mix proportions, which satisfy the given criteria of workability and strength.

IV. METHODS FOR ACHIEVING HIGH PERFORMANCE CONCRETE

In general, better durability performance has been achieved by using high-strength, low w/c ratio concrete. Though in this approach the design is based on strength and the result is better durability, it is desirable that the high performance, namely, the durability, is addressed directly by optimizing critical parameters such as the practical size of the required materials. Two approaches to achieve durability through different techniques are as follows.
(1) Reducing the capillary pore system such that no fluid movement can occur is the first approach. This is very difficult to realize and all concrete will have some interconnected pores.
(2) Creating chemically active binding sites which prevent transport of aggressive ions such as chlorides is the second more effective method. There are two approaches are shown in fig.2.

Mineral admixtures form an essential part of the high-performance concrete mix. These are used for various purposes, depending upon their properties. More than the chemical composition, mineralogical and granulometric characteristics determine the influence of mineral admixture's role in enhancing properties of concrete. The fly ash (FA), the ground granulated blast furnace slag (GGBS) and the silica fume (SF) has been used widely as supplementary cementitious materials in high performance concrete. These mineral admixtures, typically fly ash and silica fume (also called condensed silica or micro silica), reduce the permeability of concrete to carbon dioxide $(CO)_2$ and chloride-ion enetration

without much change in the total porosity. These pozzolanas react with OPC in two ways-by altering hydration process through alkali activated reaction kinetics of a pozzolanas called pozzolanic reaction and by micro filler effect. In pozzolanic reaction the pozzolanas react with calcium hydroxide, $Ca(OH)_2$, (free lime) liberated during hydration of cement, which comprises up to 25 per cent of the hydration.

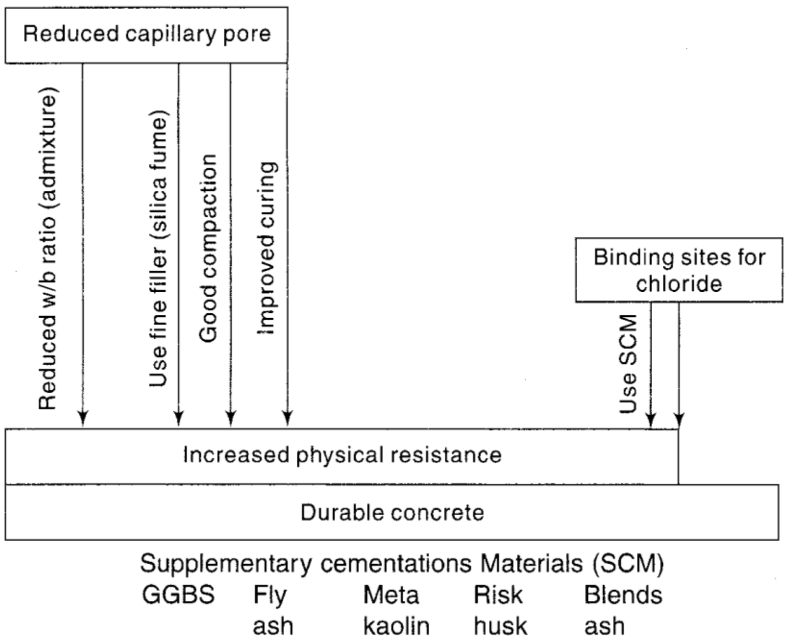

Fig. 2 Techniques of production of HPC

The pozzolanas may also react with other alkalis such as sodium and potassium hydroxides present in the cement paste. These reactions reduce permeability, decrease the amounts of otherwise harmful free lime and other alkalis in the paste, decrease free water content, thus increase the strength and improve the durability.

There is no a prior way of determining the required superplasticizer dosage; it must be determined by trial and error procedure. Basically, if strength is the primary criterion, then one should work with the lowest w/c ratio possible, and thus the highest superplasticizer dosage. However, if the rheological properties of the HPC are very important, then the highest w/c ratio possible consistent with the required strength should be used, with the superplasticizers dosage then adjusted to get the desired workability. In general, of course, some intermediate positions must be found, so that the combination of strength and rheological properties are optimized.

V. CONCLUSIONS

The methods discussed will provide the platform for engineers to design HPC by optimized proportioning of different ingredients and using conceptual approach. Dense and impermeable concrete can be achieved without compromising service life of structure.

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