A SURVEY OF HIGH PERFORMANCE CONCRETE

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Abstract

The conventional concrete has lost its usage in modern days as it does not serve the present needs. Hence to improve the workability, durability and the ultimate strength of the concrete, high performance concrete (HPC) with super plasticizers and pozzolans are used. Concrete is probably the most extensively used construction material in the world. The addition of mineral admixture in cement has dramatically increased along with the development of concrete industry, due to the consideration of cost saving, energy saving, environmental protection and conservation of resources.

Keywords: Compressive strength, Durability, High Performance Concrete, High reactivity meta kaolin, Mineral Admixtures.

Introduction

Since 1990s, HPC has become very popular in construction works. At present, the use of HPC has spread throughout the world.

Concrete is the most widely used construction material in India with annual consumption exceeding 100 million cubic meters. In 1993, the American Concrete Institute (ACI) published a broad definition for HPC and is defined as the concrete which meets special performance and uniformity requirements that cannot always be achieved by using only the conventional materials and mixing, placing and curing practices. The performance requirements may involve enhancements of placement and compaction without segregation, long-term mechanical properties, early age strength, toughness, volume stability, or service life in severe environments. In the present day, world is witnessing the construction of very challenging and difficult civil engineering structures. Quite often, concrete being the most important and widely used material is called upon to possess very high strength and sufficient workability properties. Efforts are being made in the field of concrete technology to develop such concretes with special characteristics. Researches all over the world are attempting to develop high performance concrete by using silica fume and other admixtures in concrete up to certain proportions .

Definition of HPC

The performance requirements of concrete cannot be the same for different applications. Hence the specific definition of HPC required for each industrial application is likely to vary. The Strategic Highway Research Programme (SHRP) has defined HPC for highway application on the following strength, durability, and w/c ratio criteria.

(a) It should satisfy one of the following strength criteria:
4 hour strength ≥17.5 Mpa
24 hour strength ≥5.0 Mpa
28 days strength ≥ 70.0 Mpa
(b) It should have a durability factor greater than 80% after 300 cycles of freezing and thawing.
(c) It should have a water-cement ratio of 0.35 or less.

ACI defined high-performance concrete

As a concrete meeting special combinations of performance and uniformity requirements that cannot always be achieved routinely using conventional constituents and normal mixing, placing, and curing practice.

Typical Classification

Normal Strength	20-50 Mpa
High Strength	50-100 MPa
Ultra High Strength	100-150 MPa
Especial	> 150 MPa

Civil Engineering Research Foundation (CERP)

High performance construction materials and systems: An essential program for American and infrastructure. HPC is a concrete in which some or all of the following properties have been enhanced

(a) Ease of placement
(b) Long term mechanical properties
(c) Early age strength
(d) Toughness
(e) Volume stability
(f) Extended service life in severe environments

Requirements for High-performance Characteristics

Permeation is a major factor that causes premature deterioration of concrete structures. The provision of high-performance concrete must centre on minimizing permeation through proportioning methods and suitable construction procedures (curing) to ensure that the exposure conditions do not cause ingress of moisture and other agents responsible for deterioration.

Permeation can be divided into three distinct but connected stages of transportation of moisture, vapour, air, gases, or dissolved ions. These stages are schematically shown in Fig 2.

Concrete takes in water by capillary suction. The rate at which water enters is called ***sorptivity.***	The ease with which fluid passes through concrete usually under a pressure differential is referred to as ***permeation.***	Vapor or gas ions are sucked through concrete under the action of ion concentration differential known as ***diffusion.***

Fig: 1. Three stages of transportation of fluids and gases.

It is important to identify the dominant transport phenomenon and design the mix proportion with the aim of reducing that transport mechanism which is dominant to a predefined acceptable performance limit based on permeability. Like the requirement of permeation characteristics, there can be other performance characteristics which may become the specific need for which HPC is used. Table 1 gives a list of such desired characteristics for which HPC has been used.

Table: 1 salient high-performance requirements

1	Compressive strength > 70 Mpa
2	Very early strength (4 h) > 17.5 Mpa
3	Early strength (24 h) > 35 Mpa
4	degree of impermeability to prevent ingress of moisture/CO2/SO4/air/oxygen/chloride 5 High resistance to sulphate attack
5	High resistance to sulphate attack
6	Smooth fractured surface
7	Absence of micro-cracking
8	High level of corrosion resistance
9	High electrical resistivity
10	High chemical resistivity
11	High resistance to abrasion, erosion, and cavitation

The parameter to be controlled for achieving the required performance criteria could be any of the following.

(1) Water/ (cement + mineral admixture) ratio
(2) Strength
(3) Densification of cement paste
(4) Elimination of bleeding
(5) Homogeneity of the mix
(6) Particle size distribution
(7) Dispersion of cement in the fresh mix
(8) Stronger transition zone
(9) Low free lime content
(10) Very little free water in hardened concrete

Material Selection

The main ingredients of HPC are almost the same as that of conventional concrete.
These are

1) Cement
2) Fine aggregate
3) Coarse aggregate
4) Water
5) Mineral admixtures (fine filler and/or pozzolonic supplementary cementitious materials)
6) Chemical admixtures (plasticizers, superplasticizers, retarders, air-entraining agents)

Cement

There are two important requirements for any cement: (a) strength development with time and (b) facilitating appropriate rheological characteristics when fresh. Studies made by Perenchio (1973) and Hanna et al. (1989) have led to the following observations. **1)** High C3A content in cement generally leads to a rapid loss of flow in fresh concrete. Therefore, high C3A content should be avoided in cements used for HPC.

2) The total amount of soluble sulphate present in cement is a fundamental consideration for the suitability of cement for HPC.

3) The fineness of cement is the critical parameter. Increasing fineness increases early strength development, but may lead to rheological deficiency.

4) The super plasticizer used in HPC should have long molecular chain in which the sulphonate group occupies the beta position in the poly condensate of formaldehyde and melamine sulphonate or that of naphthalene sulphonate.

5) The compatibility of cement with retarders, if used, is an important requirement. Ronneburg and Sandrik (1990) suggested tailor-made cements with characteristics suitable for HPC (Table 2). Note that SP30 is ordinary Portland cement. SP30-4A and SP30- 4A (mod) are two varieties of tailor-made special cements. It is to be noted that the two special cements recommended to produce very high strength concrete have low C3A content, sulphate level, and heat of hydration apart from phase composition.

Table: 2 Composition of special cement for HPC

Particulars	**SP30**	**SP30-4A**	**SP30-4A(mod)**
C_2S (%)	18	28	28
C_3S (%)	55	50	50
C_3A (%)	8	5.5	5.5
C_4AF(%)	9	9	9
Mgo (%)	3	1.5-2.0	1.5-2.0
SO_3 (%)	3.3	2-3	2-3
Na_2O equivalent (%)	1.1	0.6	0.6
Blain fineness (m^2/kg)	300	310	400
Heat of hydration(kcal/kg)	71	56	70
Setting time critical(min)	120	140	120
Final	180	200	170

Coarse aggregate

The important parameters of coarse aggregate that influence the performance of concrete are its shape, texture and the maximum size. Since the aggregate is generally stronger than the paste, its strength is not a major factor for normal strength concrete, or for HES and VES concretes. However, the aggregate strength becomes important in the case of high performance concrete. Surface texture and mineralogy affect the bond between the aggregates and the paste as well as the stress level at which micro cracking begins. The surface texture, therefore, may also affect the modulus of elasticity, the shape of the stress-strain curve and to a lesser degree, the compressive strength of concrete. Since bond strength increases at a slower rate than compressive strength, these effects will be more pronounced in HES and VES concretes. Tensile strengths may be very sensitive to differences in aggregate surface texture and surface area per unit volume.

Effect of Aggregate Type

The intrinsic strength of coarse aggregate is not an important factor if water-cement ratio falls within the range of 0.50 to 0.70, primarily due to the fact that the cement-aggregate bond or the hydrated cement paste fails long before aggregates do. It is, however, not true for very high strength concretes with very low water-cement ratio of 0.20 to 0.30. For such concretes, aggregates can assume the weaker-link role and fail in the form of transgranular fractures on the failure surface. However, the aggregate minerals must be strong, unaltered, and fine grained in order to be suitable for very high strength concrete. Intra- and inter-granular fissures partially decomposed coarse-grained minerals, and the presence of cleavages and lamination planes tend to weaken the aggregate, and therefore the ultimate strength of the concrete. The compressive strength and elastic modulus of concrete are significantly influenced by the mineralogical characteristics of the aggregates. Crushed aggregates from fine-grained diabase and limestone give the best results. Concretes made from smooth river gravel and from crushed granite containing inclusions of a soft mineral are relatively weaker in strength. There exists a good correlation between the compressive strength of coarse aggregate and its soundness expressed in terms of weight loss. There exists a close correlation between the mean
compressive strengths of the aggregate and the compressive strength of the concrete, ranging
from 35 to 75 MPa, at both 7 days and 28 days of age.

Effect of Aggregate Size

The use of larger maximum nominal size of aggregate affects the strength in several ways. First, since larger aggregates have less specific surface area and the aggregate-paste bond strength is less, the compressive strength of concrete is reduced. Secondly, for a given volume of concrete, using larger aggregate results in a smaller volume of paste thereby providing more restraint to volume changes of the paste. This may induce additional stresses in the paste, resulting in micro cracks prior to application of load, which may be a critical factor in very high strength (VHS) concretes. Therefore, it is the general consensus that smaller size aggregate should be used to produce high performance concrete. It is generally suggested that 10 to 12 mm is the appropriate maximum size of aggregates for making high strength concrete. However, adequate performance and economy can also be achieved with 20 to 25 mm maximum size graded aggregates by proper
proportioning with a mid-range or high-range water reducer, high volume blended cements and coarse ground Portland cement. Change in emphasis from water-cementitious material ratio versus strength relation to water-content versus durability relation will provide the incentive for much closer control of aggregate grading than in the current practices. A substantial reduction in water requirement can be achieved by using a well-graded aggregate.

Mineral admixtures

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 (CO2) and chloride-ion penetration 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 product, and the water to fill voids with more calcium-silicate-hydrate (non-evaporable water) that binds the aggregate particles together. 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. Fly ash used as a partial replacement for cement in concrete, provides very good performance. Concrete is durable with continued increase in compressive strength beyond 28 days. There is little evidence of carbonation, it has low to average permeability and good resistance to chloride-ion penetration. Chloride-ion penetration rating of high volume fly ash (HVFA) concrete is less than 2000 coulombs, which indicate a very low permeability concrete. It continues to improve because many fly ash particles react very slowly, pushing the coulomb value lower and lower. Silica fume not only provides an extremely rapid pozzolanic reaction, but its very fine size also provides a beneficial contribution to concrete. Silica fume tends to improve both mechanical properties and durability. Silica fume concretes continue to gain strength under a variety of curing conditions, including unfavorable ones. Thus the concretes with silica fume appear to be more robust to early drying than similar concretes that do not contain silica fume. Silica fume is normally used in combination with high-range water reducers and increases achievable strength levels dramatically. Since no interaction between silica fume, ground granulated blast-furnace slag and fly ash occurs, and each component manifests its own cementitious properties as hydration proceeds, higher strength and better flowability can be achieved by adding a combination of SF, FA and GGBFS to OPC which provides, a system with wider particle-size distribution. HVFA concrete incorporating SF exceeds performance of concrete with only FA. The key to developing OPC-FA-SF and OPC-GBSF-SF concretes without reduction in strength is to incorporate within the mixture adequate amounts of OPC and water. Using both silica fume and fly ash, the strength at 12 hours has been found to improve suddenly over similar mixes with silica fume alone. This phenomenon has been attributed to the liberation of soluble alkalis from the surface of the fly ash. The contribution of silica fume to any property of hardened concrete may be expressed in terms of cementing efficiency factor, K. For compressive strength of concrete, K is in the range of 2 to 5, which means that in a given concrete, 1 kg of silica fume may replace 2 to 5 kg of cement without impairing the compressive strength. This applies provided that the water content is kept constant and the silica fume dosage is less than about 20 per cent by weight of cement.

CONCLUSIONS

1.High Performance Concrete can be prepared to give optimized performance characteristics for a given loading and exposure conditions along with the requirements of cost, service life and durability.
2.The applications of concrete will necessitate the use of High Performance Concrete incorporating new generation chemical admixtures (PCE based superplasticizers) and available mineral admixtures.
3.The success of High Performance Concrete requires more attention on proper Mix Design, Production, Placing and Curing of Concrete. For each of these operations controlling parameters should be achieved by concrete producer for an environment that a structure has to face.

REFERENCES

1) Kmita, "A New Generation of Concrete in Civil Engineering," *Journal of Materials Processing Technology*, Vol. 106, No. 1-3, 2000, pp.80-86. doi:10.1016/S0924-0136(00)00642-7

2) M. J. Shannag and H. A. Shaia, "Sulfate Resistance of High-Performance Concrete", *Cement & Concrete Com- posites*, Vol. 25, No. 3, 2003, pp. 363-369.

3) N. V. Ramana, K. Gnaneswar, C. Sashidhar and T. Na- resh Kumar, "Behavior of High Performance Concrete Two Way Slabs in Punching Shear", *International Jour- nal of Science and Advanced Technology*, Vol. 2, No. 3, 2012, pp. 122-126.

4) P. Muthupriya, K. Subramanian and B. G. Vishnuram, "Experimental Investigation on High Performance Rein- forced Concrete Column with Silica Fume and Fly Ash as Admixtures", *Asian Journal of Civil Engineering* (*Buil- ding and Housing*), Vol. 12, No. 5, 2011, pp. 597-618.

5) S. A. Al-Mishhadani, W. A. Al-Qaisi and S. F. Al-Kha- faji, "Predicting Mechanical Properties of High Perfor- mance Concrete by Using Non-Destructive Tests," *Jour- nal of Engineering & Technology*, Vol. 27, No. 3, 2009, pp. 425-444.

6) B. B. Patil and P. D. Kumbhar, “Strength and Durability Properties of High Performance Concrete Incorporating High Reactivity Metakaolin,” *International Journal of Modern Engineering Research*, Vol. 2, No. 3, 2012, pp. 1099-1104.

7) V. G. Ghorpade and H. S. Rao, **“**Chloride Ion Perme- ability Studies of Metakaolin Based High Performance Concrete,” *International Journal of Engineering Science and Technology* ,Vol. 3, No. 2, 2011, pp. 1617-1623.

8) S. Bhanja and B. Sengupta, “Influence of Silica Fume on the Tensile Strength of Concrete,” *Cement and Concrete Research*, Vol. 35, No. 4, 2005, pp. 743-747. doi:10.1016/j.cemconres.2004.05.024

9) K. Yildiz and L. O. Ugur, **“**Examinatıon of Durablity of High Performance Concrete (hpc) That Has Been Sub- jected to MgSO4 and NaCl Corrosıon against Freezing and Thawing,” *Scientific Research and Essay*, Vol. 4, No. 9, 2009, pp. 929-935.

10) H. Memon, S. S. Radin, M. F. M. Zain and J. F. Trot- tier, “Effects of Mineral and Chemical Admixtures on High-Strength Concrete in Seawater,” *Cement and Con- crete Research*, Vol. 32, No. 3, 2002, pp. 373-377. doi:10.1016/S0008-8846(01)00687-1

11) R. F. Martins and J. L. Akasaki, “Study of Compressive Strength of High Performance Concrete Added with Tire Rubber”, *Materials Compuestos*, 2005, pp. 1-8.

12) V. Malagavelli and P. N. Rao, “High Performance Con- crete with Ggbs and Robo Sand,” *International Journal of Engineering Science and Technology*, Vol. 2, No. 10, 2010, pp. 5107-5113.

13) Pazhani and R. Jeyaraj, “Study on Durability of High Performance Concrete with Industrial Wastes,” *Applied Technologies & Innovations*, Vol. 2, No. 2, 2011, pp. 19- 28.

14) Camoes, B. Aguiar and S. Jalali, “Durability of Low Cost High Performance Fly Ash Concrete,” International Ash Utilization Symposium, Center for Applied Energy Research, University of Kentucky, Paper 43, 2003.

15) H. H. Nassif , H. Najm and N. Suksawang, “Effect of Pozzolanic Materials and Curing Methods on the Elastic Modulus of HPC,” Cement & Concrete Composites, Vol. 27, No. 6, 2005, pp. 661-670. doi:10.1016/j.cemconcomp.2004.12.005

16) E. Vejmelkova, M. Keppert , P. Rovnanikova, M. Ondra- cek, Z. Kersner and R. Cerny, “Properties of High Performance Concrete Containing Fine-Ground Ceramics as Supplementary Cementitious Material,” Cement & Con- crete Composites, Vol. 34, No. 1, 2012, pp. 55-61. doi:10.1016/j.cemconcomp.2011.09.018

17) K. E. Hassan, J. G. Cabrera and R. S. Maliehe, “The Ef-fect of Mineral Admixtures on the Properties of High Performance Concrete,” Cement & Concrete Composites, Vol. 22, No. 4, 2000, pp. 267-271. doi:10.1016/S0958-9465(00)00031-7

18) G. Li and X. Zhao, “Properties of Concrete Incorporating Fly Ash and Ground Granulated Blast-Furnace Slag,” Cement & Concrete Composites, Vol. 25, No. 3, 2003, pp. 293-299. doi:10.1016/S0958-9465(02)00058-6