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# A REVIEW ON HIGH PERFORMANCE CONCRETE

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## ABSTRACT

High-performance concrete (HPC) is widely used in large scale concrete constructions that require high strength, high flow ability and high durability. Various studies are performed on high performance concrete with respect to workability, strength and durability. The effect of various mineral admixtures on HPC is studied. The incorporation of various mineral and chemical admixtures is found to increase the strength and durability of HPC. The deformability of concrete and fracture properties of HPC was investigated. The effect of temperature variation on HPC was also studied. HPC is a highly promising building material and has wide range of application due to its expectional properties.

**KEYWORDS:** High Performance Concrete, High Strength Concrete, Permeability, Drying Shrinkage

## INTRODUCTION

High-performance concretes are intended to be more durable and stronger than conventional concrete. It tends to exhibit lower ductility and provide more optimized performance characteristics and have high workability, very high fluidity and minimum permeability. It congregates particular combination of performance and uniformity requirements which cannot always accomplish by conventional constituents and normal mixing, placing and remedial practices. Special mixing, placing, and curing practices are the main factors which influences production of HPC. HPC mixtures are basically composed of the same materials as conventional concrete mixtures. But the proportions are engineered to provide the strength and durability needed for the structural and environmental requirements of the project. HPC is broadly using now for the manufacturing of precast pylons, piers, and girders of many long span bridges in the world. High-performance concretes are made with carefully selected high-quality components and optimized mixture designs; these are batched, mixed, placed, compacted and cured to the highest industry standards. Characteristically, such concretes will have a low water-cementing materials ratio of 0.20 to 0.45. Super Plasticizers are generally used to make these concretes fluid and workable. High-performance concrete can be designed in such a way that the blast resistance properties are excellent. HPC has a very good for resistance to carbonation because of its low permeability. The temperature plays an important role in the quality, strength, and durability of HPC

## HIGH PERFORMANCE CONCRETE (HPC)

### Types of HPC

- Very Early Strength (VES): Its minimum durability is 80%, water –cementitious ratio <0.4 and Minimum strength criteria is 2000psi/hrs.
- High Early Strength (HES): Its minimum durability is 80%, water-cementitious ratio <0.35 and minimum strength

criteria is 5000 psi/24hrs.

- Very high strength (VHS): Its minimum durability is 80%, water –cementitious ratio <0.35 and Minimum strength criteria is 10000 psi/28days.
- Fibre Reinforced : Its minimum durability is 80%, water –cementitious ratio <0.35 and minimum strength criteria is HES + (steel or poly)

**Properties of HPC**

**High-Early-Strength**

High-early-strength concrete or fast-track concrete, gets its specified strength earlier than the normal concrete. The time frame for a specific strength should be obtained from a few hours (or even minutes) to several days. High-early strength can be achieved by using traditional concrete constitutes and concreting methods, even though sometimes special materials or techniques are needed.

High-early-strength concrete is used for prestressed concrete to allow early stressing, precast concrete for rapid production of elements, rapid form reuse, cold-weather construction, rapid repair of pavements to reduce traffic downtime, fast-track paving, and many other uses. When making early-strength mixtures, strength development, durability, early stiffening, autogenous shrinkage, drying shrinkage, temperature rise, and other properties should be evaluated for the project compatibility. Fogging may need to control plastic shrinkage cracking.

**High-Strength Concrete**

Supplementary cementing materials are generally included into the concrete mixture. This produces extra benefits in the form of reduced heat generation throughout the process of hydration. Super plasticizing admixtures are consistently added to HPC mixtures to produce workable and flowable mixtures. Production of high-strength concrete sometimes require the purchase of special materials. The producer must know the factors affecting compressive strength and know how to get best results. Each variable should be analysed separately in developing a mix design. When an optimum mix design is developed means economic advantages of using locally available materials.

**Abrasion Resistance**

Abrasion resistance is mainly related to the strength of concrete. It creates high strength HPC model for all abrasive environments. The abrasion resistance of HPC involving silica fume is high. It makes silica fume concrete especially useful for spillways and stilling basins, and concrete pavements or concrete pavement overlays subjected to heavy or abrasive traffic. The best results achieved with a mix using slag cement, steel fibres, and silica fume. Because of better erosion resistance, less shrinkage drying, high freeze-thaw resistance, and good bond to the substrate were obtained.

**Permeability**

HPC has very low permeability to air, water, and chloride ions. The durability and service of concrete exposed to weather is related to the permeability of the cover concrete protecting the reinforcement. The dense pore structure of high-performance concrete, impermeable, suitable for uses where a high quality concrete would not require.

**Diffusion**

Some aggressive ions like chloride, in contact with the surface of concrete will diffuse through the concrete until a state of equilibrium in ion concentration is obtained. If the concentration of ions at the surface is high, diffusion may result in corrosion-inducing concentrations at the level of the reinforcement.

### Chemical Attack

For resistance to chemical attack on most structures, HPC offers a much improved performance. Resistance to various sulfates is achieved primarily by the use of a dense, strong concrete of very low permeability and low water-to-cementing materials ratio; these are all characteristics of HPC.

### Importance of HPC

The first and the important use of high performance concrete is in high rise buildings. Advantages are decreased in dead loads and reduced sizes of the columns that allows more rentable space can be engaged. It can be used to increase the usable area and to avoid segregation. The main reason for using the high strength concrete in the area of high-rise buildings are to reduce the dead load, the deflection, the vibration and the noise, and the maintenance cost. High performance concrete is increasingly used for highway pavements due to its reduced permeability, abrasion resistance to steel studded fires and improved freeze-thaw durability. Different types of high performance concretes are considered for bridge deck overlays, floor slabs, pavements and pavement overlays, refractories, hydraulic structures, thin shells, rock slope stabilization, mine tunnel linings and special application of rehabilitation of structures and other developments.

## SUMMARY OF JOURNALS

### Principles Approached to HPC Application in Construction

It describes the existing practice of its application in modern construction. Standards of physical and mechanical properties of buildings and constructions mainly focus on their maintenance including safety issues and ecological matters to establish the increasing requirement of functional characteristics of construction materials. HPC is a principal material which can make serious change in attitude of approaches of our requirements. It has become a multifunctional material and attained high standards in making unique buildings and large scale constructions in terms of strength, safety, quality of life and less usage of resources at maintenance stage [1].

### The Deformability of a HPC

HPC has made a spectacular progress as it is easily measurable. So it was called initially as ‘concretes of high resistance’. HPC is most resistant to aggressive agents with the function of freezing thaw. In some applications, HPC is more economical, durable and more ecological than the usual concrete and also it provides less formwork, less concrete, less reinforcements and less aggregate. The life span is two or three times more than a usual concrete and also able to recycle two or three times before being transformed in to basic aggregate. It is necessary to lower the water/binder to the surroundings form 0, 20 to 0, 30 and to use one high quality super plastificant and must be very good quality concrete ingredients are important to achieve a level of raised resistance [2].

### Development of New in Situ Test Method to Measure the Air Permeability of HPC

It has an enhanced performance characteristic, resulting higher durability. But is not safe always as vital engineering concrete properties are not only related to material, mix properties and service environments, but also difficult factors to control on site, such as manufacturing and delivery process and construction practices. It leads a relationship between performance assumption and insitu construction quality should be considered. Site evaluation is important to make sure the ultimate delivery of high performance in practice. Assessment of concrete's near surface permeation characteristics is the reliable durability quality tool. RH testing is a reliable indicator in elimination of moisture influence on air permeability testing. RH value in the near surface region of HPC should be <60% to get a reliable air permeability value. No critical value can be suggested for a range of concrete mix types. Preconditioning specimen in an oven at 40$^{o}$C for more than 21days is advocated to defeat the misleading conclusions for HPC's air permeability measurements. Auto clam air permeability test is proposed in determining the air permeability of HPC's .LV test can be used to measure insitu air permeability of HPC's, but concrete should be in a moisture state equivalent of 21days of drying in an oven at 40 degree Celsius [3].

**High-Performance Concrete under Biaxial and Triaxial Loads**

Multiaxial strength tests were conducted on various high-performance concretes HPCs having uniaxial compressive strength from 58 to 94 MPa. Stress ratios of biaxial compression-tension, compression-compression and triaxial compression tests were noted. Servohydraulic jack with variable stress ratios were used to conduct experiments. The load was been transferred to the specimen by using steel brushes. Obtained normalized multiaxial strength decreases with increasing uniaxial strength. Uniaxial compressive and uniaxial tensile strengths was been calibrated with failure criteria and it can be used to estimate the multiaxial strength of HPC [4].

**Developments in the Appilication of High Performance Concrete**

Over the last few decades there was a spectacular increase in the compressive strength of some of the concrete used. The technological development is the only reason for the increase in compressive strength. The dispersive action of super plasticizers plays a major role in the compressive strength of the concrete with which flowing concrete can be made with about same mixing water. The microstructure of the concrete become so dense and strong because of the action of super plasticizers and coarse aggregate become the weakest constituent. Silica fume, also known as microsilica, pozzolanic material enhaces paste/aggregate interface and minimizes debonding when final failure occurs. the usage of supplementary cementatious material also increases the property of te concrete. The application of HPC has been used widely not only because of the high strength but also their durability is valued [5].

**Effect of Hybrid Curing on Cracking Potential of High-Performance Concrete**

Autogenous shrinkage of high-performance concrete has been counteracted by using internal curing technology. There were not much change in the total shrinkage of internally cured concrete after exposure to drying. Drying shrinkage was been succesfully reduced by using shrinkage reducing admixtures. A hybrid curing technique was proposed that combines internal curing with shrinkage reducing admixture and thus total shrinkage and cracking potential of high performance concrete was reduced [6].

**Strength, Permeability and Carbonation of High-Performance Concrete**

Investigation on binary and ternary blended cementitious systems based on ordinary Portland cement (OPC), pulverised fuel ash (PFA) and silica fume (SF) was performed. Compressive strength, tensile strength, oxygen permeability and carbonation of concrete are tested. Concrete mixes containing 30% PFA and above with or without SF were not able to achieve the strength of OPC control. Optimum strength and permeability values were obtained for 8-12% SF as cement replacement. The incorporation of PFA reduces the oxygen permeability values, in comparison with that observed with SF, especially at later ages. SF inclusion slightly increased the depth of carbonationas compared to the OPC control [7].

**Physical Properties of High-Performance Concrete with Admixtures Exposed to a Medium Temperature Range $20^0$c to $50^0$c**

Compressive strength and modulus of elasticity of high - performance concrete made with four types of concrete mixes exposed to temperatures within the range $20^0$ Cto$50^0$ C under three types of curing methods was evaluated. The highest values of strength and modulus of elasticity were produced by silica fume (SF) concrete under water and wrapped curing at temperature of 35 $^0$C. The open channels at the transition zone in SF concrete were modified due to the high pozzolanic reactivity and microfiller effect of SF at medium temperature. Proper curing at medium temperature environment produce hardened concrete with higher strength and elasticity. The concrete specimens incorporated with mineral admixtures produced greater strengths from the age of 7 days. This indicated that the significant acceleration of pozzolanic reaction of those admixtures especially SF at medium temperature will increase strength. SF and FA concrete show higher dynamic modulus of elasticity values at the age of 56 and 91 days [8].

**Development of High Performance Concrete using Silica Fume at Relatively High Water Binder Ratios**

Development of high performance concrete (HPC) using silica fume (SF) at relatively high water ± binder ratios was studied. Water ± binder ratios of 0.45 and 0.50 were used. Test specimens were air and water cured and exposed to a medium temperature range of $20^0$Cto50 $^0$C. The compressive strength, modulus of elasticity and initial surface absorption (ISA) of hardened concrete were determined. It was observed that concrete under water curing offered the best result. The highest level of compressive strength and modulus of elasticity and the lowest level of ISA were produced by SF concrete under water curing and at temperature of $35^0$ C. Silica fume concrete produced the highest level of compressive strength and dynamic modulus of elasticity [9].

**An Approach to Optimizing Mix Design for Properties of High-Performance Concrete**

Densified mixture design algorithm (DMDA) was used to produce high-performance concrete (HPC) of good durability and high workability. The water-to-solid (W/S) weight ratio is known to have significant influence on the volume stability of concrete. The water-to-cement (W/C) ratio, water-to-binder (W/B) ratio and the W/S ratio also has significant effect on the performance of concrete. The utilization of fly ash and slag in HPC enhances its strength development and durability. The use of domestic pozzolanic materials and strong water-reducing agent also contributes to the high strength and workability of concrete [10].

**Fracture Parameters for High-Performance Concrete**

It involves the tests of 115 three-point bend specimens with different compression strengths to investigate the fracture properties of high-performance concrete. The parameters were obtained by the work-of-fracture method and by the size effect method. It was found that the ratio between the fracture energy measured by the work-of-fracture method (GF) and by the size effect method (Gf) matched the value estimated by other researchers. The ratio GF/Gf between the fracture energy measured by the work-of-fracture method and the SEM was found equal to 2.88 for the specimens cast with the same type of concrete, with a coefficient of variation equal to 38.1%.The results obtained from the standard compressive strength tests indicate that the concrete strength was limited by the type and size of the coarse aggregate [11].

**HPC under Elevated Temperature**

Changes in the composition of concrete mixes can cause insufficiency of HPC at high temperature. Moisture gradients and free water influence the characteristics of the concrete at high temperature and it may be the reason of spalling. Air entrainment and PP Fibres are effective in decreasing the spalling risk. If HPC exposed to high temperature, safety measures should be taken for lessen the damages [12].

**Durability Assessment of HPC with SRA's and FLWA's**

Shrinkage reducing admixtures (SRA's) and pre-wetted fine light weight aggregates (FLWA's) are the two methods effective in reducing concrete shrinkage. Durability performance of concrete was studied. Freeze-thaw resistance, permeability and retrained drying shrinkage of high-performance concrete was determined. The addition of SRA's and FLWA's reduces the permeability of HPC by 23%. Combining SRA and pre-wetted shale FLWA resulted resulted in the lowest stress rate [13].

**Predicting the Strength Properties of High Performance Concrete using Mineral and Chemical Admixtures**

The study displays that by mixture-optimized HPC usage, major reductions in $CO_2$ contributions can be recognized for concrete construction-in conventional buildings, and all other major tasks. There is a increasing consciousness all over the world about the widespread damages being caused to the atmosphere due to waste material accumulation in the form of pounded fuel ash from thermal power plants, silica fume, blast furnace slag etc. Universal efforts are being made to utilize these industrial wastes as different material for both in building industry and for road construction. The experimental studies showed on HPC mix of M70 grade using mineral and chemical admixtures in numerous quantities. The chief resolution of this analysis is to develop confidence among users to use mineral and chemical admixtures in a required quantity in most of the construction works. This study emphasizes the usage of admixtures to attain high strength concrete mixes and from the experimental investigation, it is obvious that mineral admixtures contribute efficiently for achieving high strength and durability [14].

**Experimental Study on High Performance Concrete**

It specifies the outcomes of study on silica fume centred HPC. The attempt has been made to compare, the 7 days and 28 days compressive strength, breaking up the tensile strength and flexural strength of concrete by using silica fume with the normal concrete of M60 grade with maintaining the water cement ratio 0.3. The objective of this study is to develop concrete with good strength, less porous, less capillarity, thus the durability will be achieved. There search has been carried out on M60 grade of concrete, using silica fume in different percentage 0%, 5%, 10%, 15% to the cement weight for this purpose [15].

## CONCLUSIONS

- High performance concrete is a very promising building material that achieve various goals set by high standards of modern customers to unique buildings and constructions.
- The development in the application of HPC is mainly due to its exceptional properties and durability possibilities and they can provide economical, safe and attractive solutions to the problems they face.
- Inorder to raise the level of resistance in HPC, all the ingredients of the concrete must be of very good quality and the water-binder ratio have to be lowered. Incorporation of mineral admixtures effect the module of elasticity of concrete. Concrete containing an addition presents a module higher than the pilot concrete.

- A new in situ method was developed to measure the air permeability of HPC. The LV test exhibits strong potential to become an established method for assessing in situ HPC permeability.
- Multiaxial loading tests have shown that known results about normal strength concrete cannot be transferred to more brittle materials such as HPC. The increase in multiaxial strength is dependent on uniaxial strength and stress ratio.
- A hybrid curing technique that combines internal curing with shrinkage reducing admixture is observed to be a promising approach for reduction of total shrinkage and cracking potential of HPC.
- Optimization of blended cementitious system for the development of HPC was done and the strength, permeability and carbonation of concrete is studied.
- Medium temperature environment associated with proper curing has played an important role in the hydration process and thereby increase the strength and durability of hardened concrete. It was observed that incorporation of mineral admixtures in concrete specimen produced greater strength from the age of 7 days.
- Silica fume concrete produced the highest level of compressive strength and dynamic modulus of elasticity and the lowest level of initial surface absorption under water curing.
- Densified mixture design algorithm (DMDA) can be used to produce HPC of good quality and workability.
- Fracture parameters of HPC was studied and it was observed that the fracture energy increases as the compressive strength of concrete increases.
- HPC exposed to high temperature can lead to severe damage. PP fibres and air entraining admixture can together decrease the effect of this damage.
- The use of shrinkage reducing admixtures and pre-wetted light weight aggregate can reduce the shrinkage of concrete and permeability of HPC.
- Desirable proportions of mineral and chemical admixtures are incorporated in HPC. The use of these admixtures helps to achieve high strength in concrete mixes. Mineral admixtures contribute to durability as well as high strength of HPC.

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