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Advancements in High Performance Concrete as a Construction Material: A Review

Alpana Gupta[1], Sakshi Thakur[2] and Athar Hussain[3]

[1,2]UG Student, Ch.B. P. Govt. Engineering College, Jaffarpur New Delhi-73
[3]Civil Engineering Department, Ch. B. P. Govt. Engineering College Jaffarpur, New Delhi-73
E-mail: [1]anupamad29@Gmail.com, [2]sakshi246thakur@gmail.com, [3]athariitr@gmail.com

Abstract—*The construction industry demands for the improvement in the existing construction material which allows the technical advancement and making structures more reliable and economical too. Now a days high strength concrete has gained greater attention in the construction industry as its major use in buildings, bridges, highways etc. High strength concrete has special properties of having compressive strength greater then 6000psi after 28 days period as compared with the normal concrete. The high strength concrete consist of admixtures other than cement, water, fine and coarse aggregates. The main key attributes considered in high strength concrete are strength, ductility and durability. The need for high strength concrete arises as the concrete components must resist high compressive loads. At the beginning period of high strength concrete it can be applied for existing regulations for the design of seismic resistant structures and highway pavements. At later stage various research studies pertaining to the use of recycled materials for the production of high strength has been carried out worldwide. Therefore the use of high strength concrete is now a days has augmented drastically in tunnels, bridges and tall buildings for achieving greater strength and better performance. Also its use is very common used for other construction and repair works such as shotcrete repair, poles, parking garages etc. The paper explains various studies pertaining to the advancement in high strength concrete and its use for various construction applications. It also provides the general overview and effect of various chemicals and mineral admixtures used in the production of high strength concrete. Furthermore, it delivers requirements and properties of the high strength concrete over conventional concrete.*

Keywords*: high strength, high ductility, high durability, chemical admixture, mineral admixture.*

1. INTRODUCTION

High-performance concrete (HPC) exceeds the properties and constructability of conventional concrete. Traditionally and special materials are used to make these specially designed concretes that meets a standard combination of performance requirements. Special mixing, placing, and curing practices may be needed to produce and handle high-performance concrete High-performance concrete characteristics are developed for particular applications and environments; some of the properties that may be required include:

1. High strength
2. High early strength
3. High modulus of elasticity
4. High abrasion resistance
5. High durability and long life in severe environments
6. Low permeability and diffusion
7. Resistance to chemical attack
8. High resistance to frost and deicer scaling damage
9. Toughness and impact resistance
10. Volume stability
11. Ease of placement
12. Compaction without segregation
13. Inhibition of bacterial and mould growth

High performance concrete is a concrete mixture, which possess high durability and high strength when compared to (*Patil et al, 2016*) conventional concrete. High performance concrete contains one or more of cementious materials such as fly ash, Silica fume and usually a super plasticizer which enhances the strength, durability and workability of concrete.

Classification of high performance concrete related to strength

Table 1 Source: Choudhary And Bajaj, 2014)

Compressive strength	50	75	100	125	150
High performance class	I	II	III	IV	V

High-early-strength can be obtained by using one or a combination of the following, depending on the age at which the specified strength must be achieved and on job conditions:

- Type III or HE high-early-strength cement
- Low water-cementing materials ratio (0.20 to 0.45 by mass)
- Higher freshly mixed concrete temperature
- Higher curing temperature
- Chemical admixtures
- Silica fume (or other supplementary cementing materials)
- Steam or autoclave curing
- Insulation to retain heat of hydration
- Special rapid hardening cements

High-early-strength concrete is used for pre stressed concrete to allow for early stressing; precast concrete for rapid production of elements; high-speed cast-in-place construction; rapid form reuse; cold-weather construction; rapid repair of pavements to reduce traffic downtime; fast-track paving; and several other uses. In fast-track paving, use of high-early-strength mixtures allows traffic to open within a few hours after concrete is placed. An example of a fast-track concrete mixture used for a bonded concrete highway overlay consisted of 380 kg (640 lb) of Type III cement, 42 kg (70 lb) of Type C fly ash, 6.5% air, a water reducer, and a water-to-cementing materials ratio of 0.4.

Today about 90% of ready mixed concrete has a 28-day specified compressive strength ranging from 20 MPa (3000 psi) to 40 MPa (6000 psi), with most of it between 28 MPa (4000 psi) and 35 MPa (5000 psi). Therefore, HSC considered here has design strength of at least 70 MPa (10,000 psi).

Function of admixtures

Admixture plays an important role in the properties of high strength concrete. Chemical & mineral admixtures are used in the production of high strength concrete. The functions of both chemical and mineral admixture are summarised in table-2.

Table: 2 Functions of mineral & chemical admixture (source-choudhary et. al., 2014)

Mineral admixture	Functions
Fly ash	Decrease permeability, Reduced heat of hydration & slump loss
Rice husk ash	High specific surface area, Rich in amorphous silica
Silica fume	Consolidated, textured, no waiting time for operation
Chemical admixture	**Functions**
Superplasticizer	Reduce water requirement by 20%
Accelerator	Reduce setting time of concrete
Retarder	Increase setting time of concrete

2. LITERATURE REVIEW

- Kumar et al (2010) studied the use of Slurry Infiltrated Fibrous concrete (SIFCON) as a substantial material in RC beams. It was investigated that SIFCON are used in places where structures need to be modeled to resist impact loads.
- Kilar et al (2003) discussed the criteria to use high performance concrete for the design of seismic resistant, economical and durable buildings. Building frames made up High Strength Light Weight Aggregate Fiber Reinforced Concrete (HPLWAFRC) were tested and analyzed under dynamic loads and the response of building in terms of force displacement relationship and rotation ductility factors were investigated.
- Yung Chih Wang (2007) explored reinforced concrete beam column junctions strengthened with Ultra high steel Fiber reinforced Concrete (UFC).
- Oh (1992) also indicated that the ductility and ultimate resistance of flexural members are increased remarkably by the addition of steel fibers.
- ACI committee 544(1998) also reported considerable improvement in strength, ductility and energy absorption capacity of buildings increases with an addition of steel fibers.

All the papers are summarised in the table 3

Table: 3 Research papers review

YEAR	STUDY/EXPERIMENTAL /ANALYTICAL	PARAMETERS	OUTCOMES	REMARKS
2004	Application of high strength concrete in design of seismically resistant structures	Experimental & analytical investigation on concrete strength, displacement on the basis of force applied	Use of HPC in seismically active region depends on relation between ductility & configuration of transverse reinforcements	Ensured sufficient ductility, effect of axial forces on hpc

2004	High strength concrete of M60 grade for highway parameters for heavy vehicles	Experimental investigation on compressive strength, flexural strength, modulus of elasticity & slump of HSC	Small size aggregate plays major role in development of hsc	Produced lean concrete mix & economical too
2012	Strength and durability properties of high performance concrete incorporating high reactivity Metakaolin	High performance concrete, high reactive metakaolin, mineral admixtures	Compressive strength, durability test	Compressive strength increases in HRM content up to 7.5%. Excess HRM reduces w/b ratio and delay pozzolanic activity.
2012	Experimental investigation on high performance concrete silica fume and super plasticizer	High performance concrete, super plasticizer and silica fume	Compression test, split tension, flexure and workability test	Reduce workability, less pH, low water absorption,7/28 days compressive strength ratio of HPC is 0.75-0.8
2013	A survey of hpc development in civil engineering field	Experimental investigation on application of admixture	Success of hpc depends on mix design, placing & curing	-
2014	Experimental studies on high strength concrete by using recycled coarse aggregate	Recycled aggregate, high strength concrete, mix design, durability test	Slump test results Compression test Indirect tensile test Modulus of elasticity Acid resistance results	Increased compressive strength, improved tensile strength and modulus of elasticity, compressive strength achieved for 30%-40% of RCA replacement
2014	Study of high performance concrete	Chemical and mineral admixtures used in HPC, behavior of SIFCON	Alternatives- Fiber reinforced concrete, autoclaved aerated concrete	Greater energy absorbing ability, dead load reduction, thermal conductivity
-	High performance concrete: fundamental & applications	Experimental investigation on strength, ductility & durability	-	Micro-structure & composition of HPC is important factor

3. OBJECTIVE

Globalisation demands for improvement in existing construction materials so as to making the structures more reliable & economical too. Development & application of high strength concrete in structural engineering to ensure seismically resistant structures.

Admixture can be effectively utilised in the production of high strength concrete in order to obtain the desirable properties. Requirement of function decides which type of admixture either mineral or chemical is used for concrete production.

4. MATERIALS AND METHODS

Materials Used in High-Performance Concrete:

Materials	Primary Contribution
Portland Cement	Durability
Blended Cement	Durability/High Strength
Fly ash	Durability /High Strength
Slag	Durability/ High Strength
Silica Flume	Durability/ High Strength
Calcined Shale	Durability/ High Strength
Super plasticizers	Flowability
High Range Water Reducers	Water Cement Ratio Reduces
Hydration Control Mixes	Control Settling
Retarders	Control Settling
Accelerators	Accelerate Settling
Corrosion Inhibitor	Control Steel Corrosion
Water Reducer	Water Cement Ratio Reduces
Shrinkage Reducer	Reduce Shrinkage
ASR Reducers	Control Alkali – Silica Reactivity
Polymer Inhibitors	Durability
Optimum Graded Aggregate	Improved Workability

5. METHODOLOGY

High strength concrete constitute of mix proportions greater then grade M60. A definite proportion of cement is replaced by the chemical and mineral admixtures.

The analytical results can be well compared with the experimental results to apply the high strength concrete for the development of the structures which are reliable & economical too.

Alternatives

New concrete products like light crete concrete, light weight concrete, fibre crete concrete, colour crete can also be experimentally verified & developed. Using recycled construction material for the development of high strength concrete & also to attain the same strength as by normal [7] concrete.

High reactivity metakaolin increases the strength of high strength concrete but only upto a [6] specified amount 7.5%.

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