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

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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 than 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>
<thead>
<tr>
<th>Compressive strength</th>
<th>50</th>
<th>75</th>
<th>100</th>
<th>125</th>
<th>150</th>
</tr>
</thead>
<tbody>
<tr>
<td>High performance class</td>
<td>I</td>
<td>II</td>
<td>III</td>
<td>IV</td>
<td>V</td>
</tr>
</tbody>
</table>

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 prestressed 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)

<table>
<thead>
<tr>
<th>Mineral admixture</th>
<th>Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fly ash</td>
<td>Decrease permeability, Reduced heat of hydration &amp; slump loss</td>
</tr>
<tr>
<td>Rice husk ash</td>
<td>High specific surface area, Rich in amorphous silica</td>
</tr>
<tr>
<td>Silica fume</td>
<td>Consolidated, textured, no waiting time for operation</td>
</tr>
<tr>
<td>Chemical admixture</td>
<td>Functions</td>
</tr>
<tr>
<td>Superplasticizer</td>
<td>Reduce water requirement by 20%</td>
</tr>
<tr>
<td>Accelerator</td>
<td>Reduce setting time of concrete</td>
</tr>
<tr>
<td>Retarder</td>
<td>Increase setting time of concrete</td>
</tr>
</tbody>
</table>

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.
- 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

<table>
<thead>
<tr>
<th>YEAR</th>
<th>STUDY/EXPERIMENTAL/ANALYTICAL</th>
<th>PARAMETERS</th>
<th>OUTCOMES</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004</td>
<td>Application of high strength concrete in design of seismically resistant structures</td>
<td>Experimental &amp; analytical investigation on concrete strength, displacement on the basis of force applied</td>
<td>Use of HPC in seismically active region depends on relation between ductility &amp; configuration of transverse reinforcement</td>
<td>Ensured sufficient ductility, effect of axial forces on hpc</td>
</tr>
</tbody>
</table>
### 2004:
**High strength concrete of M60 grade for highway parameters for heavy vehicles**

- **Experimentation**
  - Investigation on compressive strength, flexural strength, modulus of elasticity & slump of HSC
- **Small size aggregate**
- **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 superplasticizer**

- **High performance concrete, superplasticizer and silica fume**
- **Compression test, split tension, flexure and workability test**
- **Reduce workability, less pH, low water absorptio, n7/28 days compressive strength ratio of HPC is 0.75-0.8**

### 2013:
**A survey of hpc development in civil engineering field**

- **Experimentation 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**
  - Compressive strength increases in HRM content up to 7.5%
  - Excess HRM reduces w/b ratio and delay pozzolanic activity.

### 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.**

### 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:

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

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%.

REFERENCES: