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A Review on High-Performance Concrete

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Abstract - *Concrete is the most widely used building material. It has desirable Engineering properties, can be molded into any shape and more importantly is produced with cost-effective materials. Large number of mineral admixtures, which are waste products of other industries, are being beneficially used in making quality concrete. The increase the durability along with strength of concrete will lead to the use of high-performance concrete which will be more beneficial for environmental attacks on the structure. High-performance concrete involves variation of different parameters like water-cement ratio, use of mineral admixture, chemical admixture, temperature, curing regime, etc. The mechanical and environmental performance of concrete was observed to be depending on various types of material used in the concrete. The properties of concrete depends on packing of grains and type of curing regime.*

Key Words: High-Performance Concrete, Mineral admixture, chemical admixture.

1. INTRODUCTION

The increasing demand of infrastructure due to continuous rise in population and high rate of urban drift, concrete has more consumed because of industrialization and urbanization. Concrete is the most widely consumed resource in construction industry. The continuous global demand for concrete implies that, more aggregate and cement would be required in the production of concrete, thereby leading to more extraction and depletion of deposits of natural gravel, and increased CO_2 emission from quarrying activities. Also the continuous use of conventional concrete, (that is concrete produced with virgin aggregates and ordinary Portland cement) has proved to be very unfriendly to the environment.

The conventional concrete designed on the basis of compressive strength does not meet any functional requirements such as impermeability, resistance to frost, thermal cracking adequately. While high-strength concrete aims to enhance strength and consequent advantages owing to improved strength, the high-performance concrete (HPC) is used to refer concrete of required performance for the majority of construction applications. HPC is a concrete mixture which possess high workability, high strength, high modulus of elasticity, high density, high dimensional stability, low permeability and resistance to chemical attack. High-performance concrete is also a high-strength concrete but it has a few more attributes specially designed for high range of properties. Densification and strengthening of the transition zone, many desirable properties can be improved. A substantial reduction of quantity of mixing water is the fundamental step for making HPC. Reduction in water-cement ratio less than 0.3 will greatly improve the qualities of transition zone to give expected qualities in HPC. Adopting water-cement ratio in the range of 0.25 to 0.3 and getting a high slump is possible only with the use of PC based superplasticizer.

1.1 ADVANTAGES

- Reduction in member size as most on the compressive load will be beard by concrete.
- Increase in the usable floor space.
- Reduction in quantity of concrete and construction time.
- Reduction in self-weight of the structure and hence reduce the foundation cost
- Reduction in the area of formwork and time required for stripping forms
- Ability to withstand large column loads with reasonable sizes of columns,
- Reduction in floor thickness and beam height
- Superior durability and long-term performance
- Lower creep and shrinkage
- High resistance to crack propagation, chemical attack, etc.
- Reduction in maintenance costs.

1.2 DISADVANTAGES

- Requirement of cost.
- Combination of proper binding materials that will be designed for mix.
- No special Indian Standard code provisions are prescribed for design of concrete mix.

2. LITERATURE SURVEY

Ali Alsalman et. al., studied the effect of sand gradation, binder type and content, and curing regimes on concrete's compressive strength. The use of finer sand increases the compressive strength when compared to natural gradation sand. A fly ash content of more than 20% decreased the concrete's compressive strengths at early ages, but increased the strengths at later ages. The curing regimens influenced concrete's compressive strength. Curing regime C, which was 2 days at 60 °C followed by 3 days at 90 °C, resulted in the highest compressive strengths. The use of 3% by volume of steel fibers increased the compressive strength by 4% and 8% based on the test results of cylindrical and cube samples respectively [1].

N. A. Soliman et. al., a green ultra-high-performance glass concrete (UHPGC) with a compressive strength of up to 220 MPa was prepared and its fresh, mechanical and microstructural properties were studied. A Poly-carboxylate (PCE)-based high-range water-reducing admixture (HRWRA) with a specific gravity of 1.09 and solids content of 40% was used in all the concrete mixtures. The replacement of quartz powder and cement with glass powder can significantly reduce the cost of UHPC and decrease the carbon footprint of a typical UHPC [2].

Mohamadreza Shafieifar et. al., determined the tensile and compressive behavior of UHPC and a comparison is made with Normal Strength Concrete (NC) for the development of a numerical model to simulate the behavior of UHPC using the Finite Element (FE). Ductal is a commercial product, was the UHPC product used in this study, which is a product of Lafarge, Inc. composed of premix powder, water, superplasticizer, and metallic fibers. The compressive strength of commercial UHPC was three to four times greater than normal strength concrete. The strong mechanical interlocking force between steel fibers and concrete matrix cylinders and cubes remained intact even after failure loading, whereas the control sample of normal strength concrete after failure split into large concrete pieces [4].

K. E. Hassan et. al., paper presents a laboratory study on the influence of two mineral admixtures, silica fume (SF) and fly ash (FA), on the properties of superplasticised high-performance concrete. The concrete mixes were assessed based on short-term and long-term testing techniques used for the purpose of designing and controlling the quality of high-performance concrete. SF enhances the early ages as well as the long-term properties of concrete. It reduces the permeability when compared to OPC concrete. FA concrete has relatively poorer characteristics at early ages, but achieves similar strength and transport characteristics to SF concrete in the long term [5].

Tiefeng Chen et. al., studied compressive strength, flexural strength and fracture toughness of ultra-high performance concretes (UHPC) containing silica fume and different dosage of fly ash (0%, 10%, 20% and 30%) after exposure to different autoclave curing conditions with pressure of 0.5 MPa, 1.0 MPa and 1.5 MPa and duration time of 6 h, 8 h, 10 h and 12 h. The microstructure of UHPC samples was measured by using MIP, XRD and SEM. The incorporation of fly ash increases compressive strength and different fly ash dosage can lead to different effect. . The autoclave curing effectively improves the compressive and flexural strength of UHPC, with the maximum increase of 37.5% and 30.3% respectively. The incorporation of fly ash and the increasing autoclave duration reduce the porosity of UHPC samples [8].

Sukhoon Pyo et. al., studied mechanical properties and shrinkage of ultra-high performance concrete (UHPC) by adding coarser fine aggregates with maximum particle size of 5 mm. UHPC mixes with dolomite and more than 1.0% volume fractions of steel fiber resulted in strength values of more than 150 MPa at the age of 56 days. The replacement of silica powder with coal bottom ash powder resulted in comparable compressive strength and cracking patterns compared to the UHPC with silica powder, the replacement was not effective at improving the tensile capacities. It was found that the usage of basalt as a coarser fine aggregate in UHPC was not favorable for achieving exceptional mechanical properties [9].

Josef Fladr et. al., investigated resistance of UHPC to permeable chemical agents and freeze-thaw cycles. Different tests were undertaken to compare the behavior of UHPC and fibre-reinforced concrete. Fibres made from waste products are metal strips from the production of steel plates were used. The proposed UHPC mix is competitive also from the economical point of view as the costs were decreased by 30% by the use of fibres made from waste steel strips. No relation between the flexural strength and the number of freeze-thaw cycles was observed for any of the two materials, reduction in the strength would probably occur after much higher number of the cycles. Tensile strength is affected by geometry, strength and amount of the fibres and type of the anchorage. The dense structure of UHPC did not allow the brine to penetrate the internal part of the samples [10].

Kay Wille et. al., investigated the material efficiency in the design of ultra-high performance concrete which is influenced by the flowability, mechanical performance, durability and cost. A reduction in the amount of the most expensive material and an increase in the amount of the least expensive material might lead to an improvement in performance versus cost [12].

Jedadiah F. Burroughs et. al., finely ground limestone powder was hypothesized as a potential filler to help minimize these negative aspects when used as either a partial or full mass replacement of similarly sized cement and silica powder. Potential health concerns can arise due to repeated inhalation of crystalline silica powder during production. Limestone powder had a positive effect on fresh properties of the composite including mixing time and workability. The limestone powder used as a partial replacement of cement and partial or full replacement of silica powder slightly decreased the mixing time required to produce UHPC. Partial replacement of cement has a strong positive effect on the workability of the composite. Replacement of silica powder has less effect on the workability [13].

3. CONCLUSIONS

Based on the literature, the following conclusions were drawn:-

[1] Curing regime greatly effect on early gain in compressive strength of concrete leading to strength more than 100 MPa.

[2] Curing regime and use of admixture were useful to increase mechanical and environmental performance of concrete.

[3] Use of different fine materials can make a better compact mix for high-performance of conventional concrete.

[4] The maximum compressive strength can be obtained more than 200 MPa by controlling various parameters like water-cement ratio, admixtures, etc. along with different curing methods as per requirement.

[5] The use of fine materials decreased voids in concrete which resulted in high resistance to ingress of water, moisture, CO_2, etc.

[6] Mineral admixtures like silica fume, ground granulated blast furnace slag (GGBS), fly ash of various types, etc. are sometimes used as fine materials to decrease the voids in concrete and increase compaction.

[7] Use of 5% Silica Fume and 30 % Fly Ash contributed more to short and long-term properties of concrete.

[8] Use of admixture increases density of concrete, which in turns increase the compaction to avoid ingress of any foreign agents inside concrete.

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