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Effect of Various Admixtures on Durability Properties of High Strength Concrete under Extreme Cold Climatic Conditions

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Abstract: Concrete is one of the most widely used construction materials for several structures such as buildings, homes, dams, roads, and bridges. Concrete performance is generally based on the mix design, material properties in the mixture, curing conditions, and environmental conditions during the service life of the structure. Cracking and spalling of concrete are the most common damage caused by expansion of the cement paste matrix under the effect of freeze-thaw cycles.The purpose of this paper is to explore the feasibility of use of high strength concrete in cold weather environments and assess its durability in that environment both with and without entrained air. The development and subsequent widespread use of high range water reducing admixtures or superplasticizers has ensured strength of concrete upto 100-120 MPa as a common occurrence in many parts of the country.In this study, targeting HSC in cold weather conditions, Super Absorbent Polymer(SAP) SHN 2120 have been experimentally compared with Polypropylene fibre (Recron 3S 12mm) and air entraining agent to gauge their relative performance under the parameters of mechanical properties like slump, compressive strength for a duration of 1/7/14/28 days for numbers of freeze thaw cycles as per BAW code of practice on freeze thaw of concrete.

Keywords: High Strength Concrete (HSC), Super absorbent Polymer (SAP), Freeze thaw, Polypropylene Fibre, Compressive Strength Test.

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I. INTRODUCTION

Concrete is one of the most widely used construction materials for several structures such as buildings, homes, dams, roads, and bridges. Concrete performance is generally based on the mix design, material properties in the mixture, curing conditions, and environmental conditions during the service life of the structure. The most important durability problem of concrete under cold climate is freeze-thaw effect. In particular, dams, bridge deck surfaces, and concrete road pavements with wide open surfaces are under risk of frost at cold climates. This condition can cause the freezing of water inside the capillary pore structure of concrete with 9% of volume expansion. Cracking and spalling of concrete are the most common damage caused by expansion of the cement paste matrix under the effect of freeze-thaw cycles.

High strength concrete is a concrete that having meets special qualities like performance and uniformity that cannot be achieved using conventional concrete making methods. Ever since the term high-performance concrete was introduced into the industry, it had widely used in largescale concrete construction that demands high strength, high flowability, and high durability. Durable concrete Specifying a high-strength concrete and does not ensure that a durable concrete will be achieved. It is very difficult to get a product which simultaneously fulfills all of the properties. Concrete is considered as durable and strong material. Reinforced concrete is the most popular material that used for construction.

Reinforced concrete is exposed to deterioration in some regions especially in coastal regions. There for researchers around the world are directing their efforts towards developing a new material to overcome this problem. Large construction plants now using more materials for construction. This scenario led to the use of additive materials to improve the quality of concrete HSC concretes are usually designed by using some admixtures to achieve these requirements, such as Fly Ash (from the coal burning process), Ground Blast Furnace Slag (from the steel making process), or Silica Fume (from the reduction of high quality quartz in an electric arc furnace). Different amounts of these materials are combined with Portland cement in varying percentages depending on the specific HSC requirements.

1.1 Definition of Cold Weather.

Cold weather is defined by ACI committee 306[3] as ―a period when for more than 3 successive days, the following conditions exist:

(a) the average daily air temperature is less than 5°C.

(b) the air temperature is not greater than 5°C for not more than one half of any 24-hour period.

1.2 Effect of Cold Weather.

Effects of cold weather on concrete Effects of cold weather on concrete, in the absence of special precautions, may be as follows:

a) Delayed Setting - When the temperature is falling to about 5°C or below, the development of concrete strength is retarded compared with the strength development at normal temperatures. The hardening period, necessary before the removal of forms is thus increased and the experience from concreting at normal temperature cannot be used directly.

b) Freezing of Concrete at Early Ages - When concrete is exposed to freezing temperature, there is the risk of concrete suffering irreparable loss of strength and other qualities, that is, permeability may increase and the durability may be impaired.

c) Repeated Freezing and Thawing of Concrete - If concrete is exposed to repeated freezing and -thawing after final set and during the hardening period, the final qualities of the concrete may also be impaired.

Figure1.2: Freeze Thaw Effect And Cracking In Concrete

d)

Stresses Due to Temperature Differential - It is a general experience that large temperature differentials within the concrete member may promote cracking and have a harmful effect on the durability. Such differentials are likely to occur in cold weather at the time of removal of form insulations.

1.3 Durability of Concrete.

Durability is defined as the capability of concrete to resist weathering action, chemical attack and abrasion while maintaining its desired engineering properties. It normally refers to the duration or life span of trouble-free performance. Different concretes require different degrees of durability depending on the exposure environment and properties desired. For example, concrete exposed to tidal seawater will have different requirements than indoor concrete.

1.4 High Strength Concrete

High–strength concrete commonly refers to the increase in compressive strength of concrete, while high–performance concrete refers to the increase of all concrete's properties, with accent on mechanical properties, durability, workability, permeability etc. which is more than just increase of strength.

II. MATERIALS USED

2.1 Cement - Batch of OPC 53 grade Birla super cement used for the experiment. Details of Cement used in the experimental program: 53 Grade ordinary Portland Cement confirming to IS 12269-2013 with specific gravity = 3.14 . In the design mix cement is used in the proportion of 450 Kg/ CuM of concrete, the maximum quantity permitted as per IS 456:2000 and IS 10262: 2009.

2.2 Aggregates

The fine aggregate, crushed stone sand that passed through 4.75 mm sieve; and coarse aggregate, granite stone that passed through 12.5 mm IS sieve and retained on 10 mm sieve; will be used for the experiments.

2.3 Fine Aggregate

Options available for fine aggregates are river sand and or crushed stone sand. Both has their merits and demerits river sand gives a good quality but the availability throughout the year is a problem and crushed stone sand though is available throughout the year, but the quality control and fineness of particles is an issue with the problem of dust and presence of other deleterious material along with moisture content or absorption characteristics needs monitoring as quality of HSC will be sensitive to such changes.

2.4 Coarse Aggregate

Option of coarse aggregate is of size 20 mm or 10 mm or a combination of both. Aggregate of 20 mm or smaller size has been considered desirable for structures having congested reinforcement. Use of crushed angular aggregate of uniform quality with respect to shape and grading provides better strength characteristics. Various characteristics of aggregate are required to be ensured for the desired properties of concrete. Locally available 10 mm and 20 mm crushed angular aggregate is of basalt rock origin and the same is being used for the experiment in the proportion of 60:40.

2.5 Mineral Admixtures

There are various types of mineral admixture which includes pozzolanic materials like Fly ash (pulverized fuel ash), Silica fume, Rice husk ash and Metakaolin and Ground Granulated Blast Furnace Slag conforming to relevant Indian Standards may be used. Uniform blending with cement is required to be ensured. In the present study we intend to use fly ash in our mix composition with max permissible percentage of 25% of the cement quantity as specified in IS 3812 (part 2) 2013.

2.6 Fly ash

Fly ash is a by-product of the combustion of pulverized coal in thermal power plants. The dust-collection system removes the fly ash, as a fine particulate residue, from the combustion gases before they are discharged into the atmosphere. Fly ash particles are typically spherical, ranging in diameter from less than 1 µm up to 150 µm. The type of dust collection equipment used largely determines the range of particle sizes in any given fly ash. It was ensured that materials complied with respective material standards or properties.

2.7 Water

This is the least expensive but most important ingredient in concrete. The water, which is used for making concrete, should be clean and free from harmful impurities such alkali and acid etc. In general, the water fit for drinking, should be used for concrete. Confirming to IS 456-2000. Normal tap water was used for mixing the concrete throughout the experimental work.

2.8 Super-plasticizer

High range water reducers are called super-plasticizers. SP can cause a reduction of up to 40% of water in a mix. Modern Super-plasticizers are very efficient and keeps a concrete mix highly workable for more than an hour with much less water hence superplasticizer was used instead of normal plasticizer.

2.9 Polypropylene Fibre

Fibre-reinforced High Strength concrete is a composite material that has the advantages of the fibre addition to a brittle cementitious matrix. The greatest disadvantage of cementitious material is its vulnerability to cracking, which generally occurs at an early age in concrete structures or members. Cracking due to early age shrinkage may potentially reduce the lifetime of concrete structures and cause serious durability and serviceability problems. The most beneficial properties with the fibre addition to the concrete in the hardened state are the impact strength, the toughness, and the energy absorption capacity. Polypropylene fibres are available in three different Recron 3s 12 mm used, is a triangular shaped fibre providing more surface area for bonding.

III. SUPER ABSORBENT POLYMERS (SAP)

Super absorbent polymers (SAP) are made up of cross-linked networks of hydrophilic polymers which have the capacity to retain and absorb large amount of aqueous solutions or water. SAP has the capability to intake water in high concentrations and can be as high as many times its original weight (Zohuriaan & Kabiri, 2008[8])[8]. SAP actually comprises of a sodium polyacrylite material that enables water absorption, which is then transformed into gel form. Following which the wet/dry polymer is added into fresh concrete.

IV. EXPERIMENT PROGRAM.

4.1 **Design Mix**. The design mix is done as per IS Code method. The target strength is chosen as M50. The cement proportion is initially chosen as 450 KG/ CuM and fly ash as 25% of the cement quantity. Water binder ratio is chosen as 0.3 (with two mixes as +10% and -10%). The coarse aggregate is 60% of 10mm and 40% of 20 mm aggregate.

Ser No	Constituents	Quantity / Cum of Concrete		
		W/C Ratio 0.3	W/C Ratio 0.25	W/C Ratio 0.35
1	Cement (BIRLA SUPER 53 GRADE OPC)	450 KG	450 KG	450 KG
2	Flyash (25% of Cement) (POZZOCRETE 60)	112.5 KG	112.5 KG	112.5 KG
3	Fine Aggregate (FA) Stone Dust	635.68 KG	642.53 KG	630 KG
4	Course Aggregate (CA) 10 MM Agg	679 KG	718 KG	642.5 KG
5	Course Aggregate (CA) 20 MM Agg	452.6 KG	474.5 KG	428.08 KG
6	Water	152 Litre	126.5 Litre	177 Litre
7	Super Plasticizer (MASTER GLENIUM ACE 30) (2 % by mass)	10.465 Litre	10.465 Litre	10.465 Litre

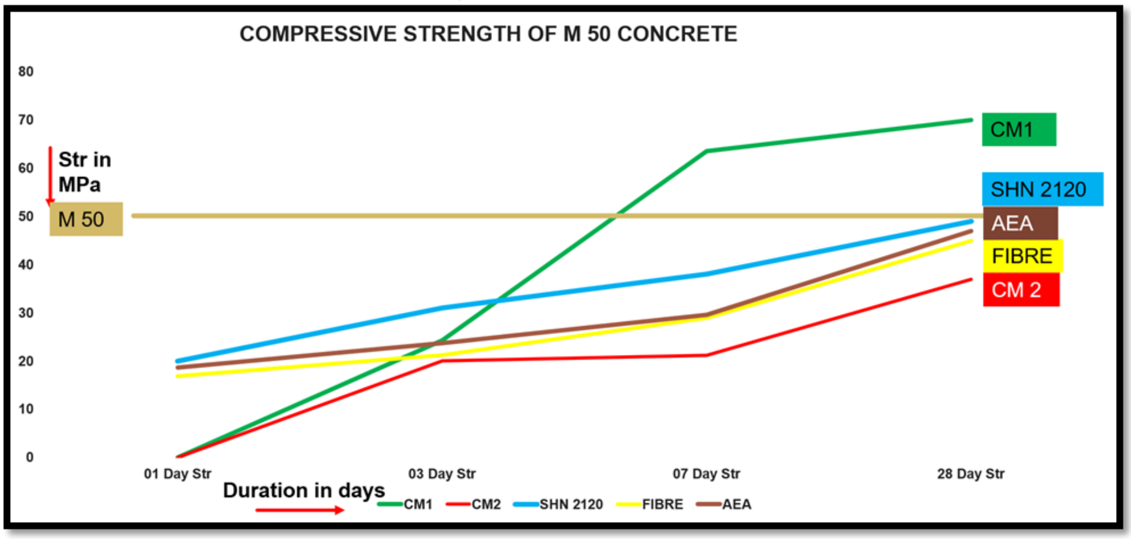
Fig 1 . Mix design of High Strength Concrete M-50 grade

4.2 Mix Combinations. On completion of the mix design, four combinations are developed as under-

- Combination 1 – Control Mix (OPC + FlyAsh +Accelerator Superplasticizer)
- Combination 2 – Control Mix + Polypropylene Fibre
- Combination 3 – Control Mix + SAP SHN2120
- Combination 4 – Control Mix + Air entraining agent

All the four combinations are tested for the compressive strength for restricted curing (01/07/14/28 days)

4.3 Results - The result obtained after testing the cube samples of various combinations are as under -



V. RESULTS AND DISCUSSION

5.1 Testing

(a) Slump test -Slump test is the most commonly used test as indicator of consistency and workability of concrete. It can be employed either in laboratory or at site of work. It is used conveniently as a control test and gives an indication of the uniformity of concrete from batch to batch. It does not measure all the factors contributing to workability. Because of simplicity it is widely employed all over the world.

(b) **Compressive Strength Test** - Compressive strength is an important property of concrete mix which is required to be tested to determine some of its important characteristics such as shrinkage and maintenance of high strength criteria (M50+) (Neville, 2012)[9]. The design and material proportioning for concrete (be it normal, high strength or high performance) is mostly governed by this unique property. This unique property of concrete mix is tested as per IS:516-1959 on 7th and 40th day of curing. The test concrete is made into cube (or cylinder specimen) which is stored for 24 ½ h under damp sack followed by clean water (270C) until required for testing.

The load capacity of the Compression Testing machine, should be increased steadily on the cube, at a rate of 140kg/cm2/min until the specimen breakdown. The maximum load applied and any unusual features noted should be recorded for further analysis. The formula for calculating compressive strength of concrete is given below (IS:516-1959.);

Compressive strength (kg/cm2) **= Wf / Ap**

Where

Wf = Maximum applied load just before failure, (kg)

Ap = Plan area of cube mould, (mm^2)

(c) FREEZE THAW CYCLE:

The BAW's Code of Practice "Frost Resistance Tests for Concrete"[4] describes methods of testing the freeze-thaw resistance and freeze-thaw and de-icing agent resistance of concrete, sprayed mortar and sprayed concrete.

Freeze-thaw testing: Freeze-thaw testing is a cyclic attack in which the specimens are subjected to a temperature cycle in accordance with Section 4 (Figure 4) in a temperature-controlled chest. Generally speaking, 28 freeze thaw cycles are required for both the freeze-thaw resistance test and the freeze-thaw and de-icing agent resistance test.

A freeze-thaw cycle of 12 hours is applied. Starting at +20 °C, the temperature is lowered at a constant cooling rate of 10 K/h over 4 hours. It is then maintained at a constant -20 °C for 3 hours before being raised to +20 °C at a heating rate of 10 K/h over 4 hours. The temperature is maintained at a constant +20 °C for 1 hour. The temperature cycle is monitored at the reference point. The temperature measured at the reference point may not deviate from the minimum temperature by more than ± 0.5 K or more than ± 1 K from all other temperatures. A constant time shift between the test containers is acceptable. The tolerance on the temperature may be exceeded for a maximum of 10 minutes immediately after the first ice formation.

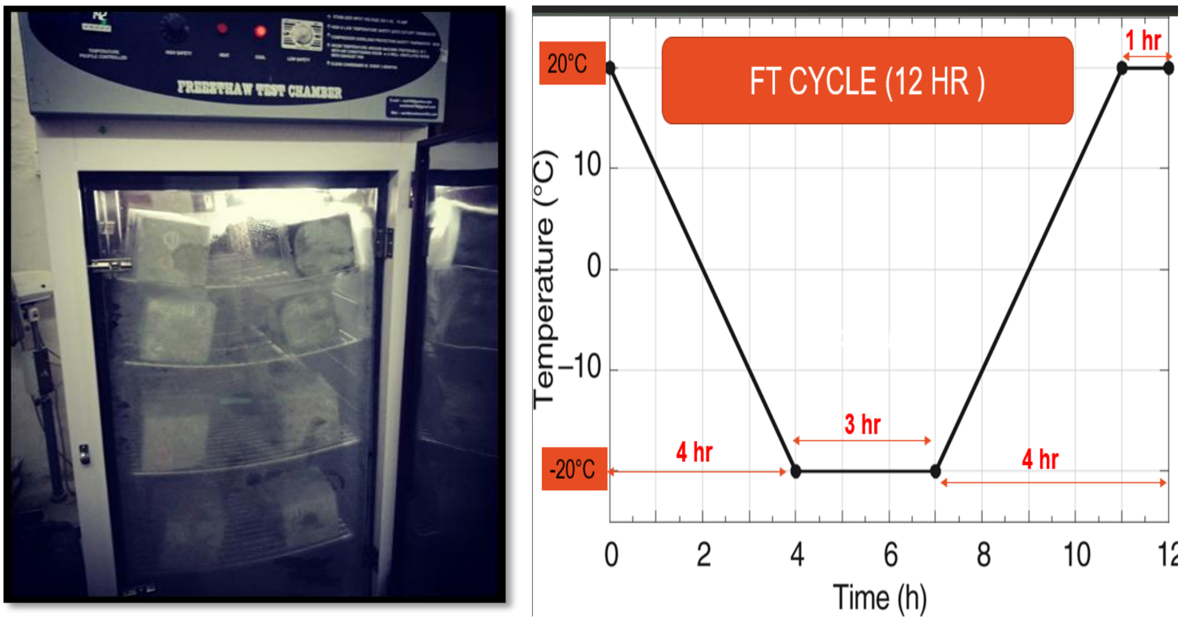


Figure 3. 18: Freeze Thaw Chamber and Freeze Thaw cycle

VI. CONCLUSION

This project work is primarily focused on the properties of materials used, mix proportion of High Performance Concrete, making of concrete specimen, curing and testing of harden concrete. On performing the various tests the physical properties of the specimens are studied and the following conclusions are arrived. On comparing the result high strength concrete having 10% Fly ash gives a maximum compressive strength value. The important deductions are as under -

(a) Samples without freeze thawing (water curing) gain adequate str upto 80-90 MPa in 40 days

(b) Samples with freeze thawing initally gain low strength but with increased curing and setting time gain adequate strength upto 75-80 MPa

(c) Use of admixtures shows encouraging improvement in compressive strength wrt Control Mix strength.
(d) The dosage and type of admixtures can be varied as per conditions of site for achieving desired results.

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