Experimental Investigation On Self Curing High Performance Concrete

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Abstract- *Proper curing of concrete structures is important to ensure that they meet their intended performance and ductility requirements. Therefore, an effective in situ curing is necessary to maximize the degree of hydration and to minimize cracking problems due to drying shrinkage. Traditional external curing could not achieve the desired effect due to very low permeability and high chemical reaction in high-performance concrete. So, some research shifted their attention to self-curing, a new curing method that may greatly enhance the curing effect on high performance concrete. Super Absorbent Polymers (SAP) are used as self-curing agents. SAPs are a group of polymeric materials that could absorb and retain a significant amount of liquid from their surroundings and to retain the liquid within their structure without dissolving. In this study investigate experimentally and analytically the behavior of exterior beam-column joint and strength characteristics of Self Curing high performance Concrete (SCC) containing Super Absorbent Polymers (SAP) and Silica Fume. In this investigation SCHPC was made by replacement of cement by 10% of Silica fume and Super Absorbent Polymer (SAP) added at a various range of 0%, 0.2%, 0.3%, and 0.4% of cement. The experimental results were then compared with analytical results obtained from the FEM Analysis using ANSYS 14.0. Load Deflection characteristics, Stiffness, Ductility were studied, and it is found that the SCHPC has shown good improvement in load caring capacity. Mechanical characteristics like Compressive strength, Split-tensile strength, Flexural strength, and Modulus of Elasticity examined. A mathematical model was conducted using SPSS software for the mechanical characteristics of SCHPC.A comparative study between the results obtained from the laboratory and SPSS has been made. The predicted mathematical model for mechanical characteristics produced accurate results for the respective ages when compared with the experimental results. Also, the durability study for Self-cuing concrete after 28- and 56-days curing was done by conducting the tests such as saturated water absorption, porosity, Acid resistance, Sea water resistance, accelerated electrolytic corrosion and modified sportively.*

I. INTRODUCTION

Concrete is the most extensively used material in civil engineering construction so considerable attention is taken for improving the properties of concrete with respect to strength and durability.

Proper curing of concrete is important to ensure they meet their intended performance and durability requirements. In conventional construction, this is achieved through external curing, applied after mixing, placing, and finishing. Internal curing (IC) is a very promising technique that can provide additional moisture in concrete for a more effective hydration of the cement and reduced self-desiccation. Internal curing implies the introduction of a curing agent in to concrete that will provide this additional moisture.

Internal curing refers to the process by which the hydration of cement occurs because of the availability of additional internal water that is not part of the mixing water. The additional internal water is typically supplied by using relatively small amounts of saturated, light weight, fine aggregates, or super absorbent polymer particles in the concrete. Attentionally, curing concrete means creating conditions such that water is not lost from the surface i.e., curing is taken to happen ‘from the outside to inside’. In contrast, ‘internal curing’ allows for curing ‘from the inside to outside’ through the internal reservoirs Created. ‘Internal curing’ is often also referred as ‘Self–curing.’

1.1 CURING

Curing can be described as keeping the concrete moist and warm enough so that the hydration of cement can continue. More elaborately, it can be described as the process of maintaining satisfactory moisture content and a favorable temperature in concrete during the period immediately following placing, so that hydration of cement may continue until the desired properties are developed to a sufficient degree to meet the requirement of service. If the curing is neglected in the early period of hydration, the quality of concrete will experience a sort of irreparable loss. An efficient curing in the early period of hydration can be compared to a good and wholesome feeding given to a newborn baby. The pre-cast concrete items are normally in curing tanks for a certain duration. Pavement slabs, roof slabs etc. are covered under water by making small ponds. Vertical retaining walls or plastered surfaces or concrete columns etc. are cured by spraying water. In some cases, wet coverings such as wet gunny bags, Hessian cloth, jute matting, straw etc., are wrapped to vertical surface for keeping the concrete wet. For horizontal surfaces saw dust, earth or sand are used as wet covering to keep the concrete in wet condition for longer time so that the concrete is not unduly dried to prevent hydration. Conventional curing procedures of water ponding, as used for drying shrinkage are not effective in the case of autogenous shrinkage. They may eliminate the autogenous shrinkage in small cross sections only because the penetration of water from the external surface is limited. Moreover, external curing might be difficult to apply to some surfaces. In view of this limitation, different strategies have been developed in recent years, based on the use of internal water reservoirs; one strategy which has been investigated more extensively is based on the use of light weight aggregates, while the other is based on the use of water absorbing polymers. Both water saturated porous aggregates and water saturated polymers can act as internal reservoirs, providing a source of curing of curing water to the paste volume in their vicinity.

1.2 INTERNAL CURING

The ACI-308 code states that “internal curing refers to the process by which the hydration of cement occurs because of the availability of additional internal water that is not part of the mixing water.” Conventionally, curing concrete means curing conditions such that water is not lost from the surface i.e., curing is taken to happen ‘from the outside to inside’. In contrast, ‘internal curing’ allows for curing ‘from inside to outside’ through the internal reservoirs (in the form of saturated lightweight fine aggregates, super absorbent polymers, or saturated wood fibers) Created. Internal curing is often also referred to as ‘self-curing’.

Self-curing implies the introduction of a self-curing agent into the concrete that will provide this additional moisture. Currently there are two major methods available for self-curing concrete. The first method uses saturated porous lightweight aggregate (LWA) to supply internal source of water, which can replace the water consumed by chemical shrinkage during cement hydration. This internal curing water is naturally drawn during cement hydration from relatively large pores of lightweight aggregate into the smaller pores of cement paste. The second method uses super-absorbent polymers (SAP), as these particles can absorb a very large quantity of water during concrete mixing and form large inclusions containing free water, thus preventing self-desiccation during cement hydration. The disadvantages being Light weight aggregate can negatively impact strength and can variability in performance. SAP is more controllable but is relatively expensive compared to light weight aggregate.

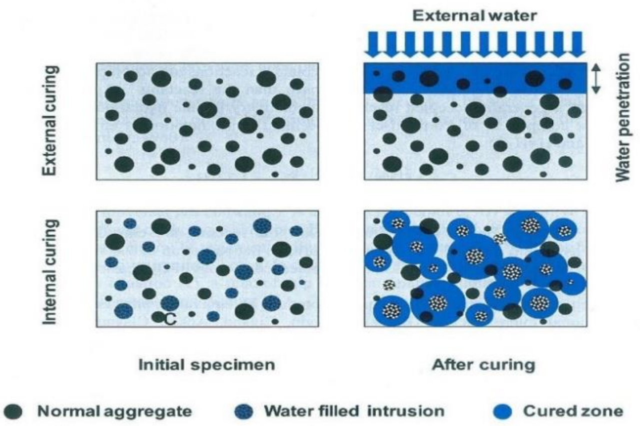


Figure 1.1 External and Internal Curing

The figure1.1 shows the differences between external and internal curing. While external curing water can penetrate just a few millimeters from the exposed surface due to depreciation (pores disconnection that normally occurs in low w/c mixtures), internal curing provides water throughout the matrix.

1.3 SUPER – ABSORBENT POLYMER(SAP) FOR IC

A super absorbent polymer, SAP, is a polymeric material which can absorb a significant amount of liquid from the surroundings and to retain the liquid within its structure without dissolving. SAPs are principally used for absorbing water and aqueous solutions. With the present polymer types the theoretical maximum water absorption is approx. 5,000 times their weight. However, the absorbency of commercially produced SAPs is around 50 g/g in dilute salt solutions such as urine, and in high ionic solutions such as cement paste pore fluid the absorbency may be below 20 g/g [13]. The absorption of water in the SAP is based on secondary chemical bonds, and the water is so loosely held that all of it essentially can be considered bulk water.

Most SAPs are cross-linked polyelectrolyte. Because of their ionic nature and interconnected structure, they absorb large quantities of water and other aqueous solutions without dissolving. Compared with lightweight aggregate SAP has some peculiarities. SAP can be used as a dry concrete admixture since it takes up water during the mixing process, and the use of SAP permits free design of the shape and the size of the formed inclusions.

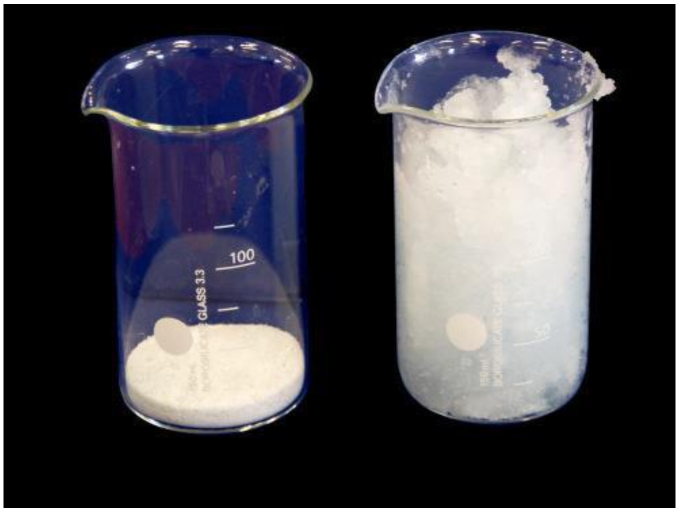


Figure 1.2 Super-Absorbent Polymer

The figure 1.2, the left side shows the SAP powder. The right cup shows the same amount of SAP after water absorption.

1.4 NEED FOR SELF–CURING

Benefits of internal curing include increased hydration and strength development, reduced autogenous shrinkage and cracking, reduced permeability, and increased durability. The impact of internal curing begins immediately with the initial hydration of the cement. With benefits that are observed at ages as early as 2 days. Internal curing is especially beneficial in low water cement ratio (w/c) concretes because of the chemical shrinkage that accompanies Portland cement hydration and the low permeability of the calcium silicate hydrates. In higher w/c concretes, this water can be and often is supplied by external curing, in low w/c concretes; the permeability of the concrete quickly becomes too low to allow the effective transfer of water from the external surface to the concrete interior. This is one of the justifications for internal curing. Additional water that can be distributed somewhat uniformly throughout the concrete will be more readily able to reach un-hydrated cement.

Internal Curing can provide several advantages, depending on the time (hours days- months) that it takes to provide the reaction with cement or pozzolans. To prevent micro cracking or autogenous shrinkage, the cement needs to be hydrated in the early hours after the water and cement are commingled. Early age (<3 days) is the crucial time for strength gains to be achieved to enable the concrete to be strong enough not to be cracked by the internal and external strains applied to it. This is the period that micro-cracking and autogenous cracking occur. The benefit of self-curing admixtures is more significant in desert areas where water is not adequately available. Also, the concrete works done at heights and in sloped roofs, (slope of roof is too steep) curing is very difficult. Where thickness of concrete is very larger, the percolation of water in the concrete, especially in high strength concrete is difficult. Self- curing methods used to overcome the current hurdles that exist to adopting concrete mixtures with higher volumes of fly ash (HVFA). The provision of self-curing may be beneficial in HVFA mixtures since it provides water for longer time periods so fly ash can further react.

1.5 REQUIREMENTS FOR SELF WATER CURING OF CONCRETE

Internal water curing of concrete requires some sort of water store that can supply water to the cement paste during the cementation’s reactions. In relation to concrete the water store may be formed either before or after the start of mixing. If encapsulated, liquid water is added to the concrete as particles, these particles must be strong enough to withstand the mixing process. If the formation of the water store is started after mixing, it must be finished before setting. Finally, after setting the stored water must be freely accessible for the cement hydration, which means the water must be thermodynamically and kinetically available for the cementation’s reactions. Kinetic availability refers to the transport of water from the water store to all parts of the self-desiccating, cementations material. First, this requires that the water is not confined but is readily released as the relative humidity in the surrounding cement paste drops. Secondly, the internal curing water should be properly spatially distributed. Despite these partly conflicting requirements, several techniques may, potentially, be used for internal water curing. Instinctively, water-absorbing materials may be thought of as the sole group of candidates for this purpose. For optimum performance, the internal curing agent should posses’ high water absorption capacity and high-water desorption rates.

1.6 HIGH PERFORMANCE CONCRETE

High-performance concrete is defined as a concrete meeting special combination of performance and uniformity requirements that cannot always be achieved routinely using conventional constituents and normal mixing, placing, and curing practices. High-performance concrete (HPC) exceeds the properties and constructability of normal concrete. Normal and special materials are used to make these specially designed concretes that must meet a combination of performance requirements. Special mixing, placing, and curing practices may be needed to produce and handle high-performance concrete.

High-performance concrete almost always has a higher strength than normal concrete. However, strength is not always the primary required property. For example, a normal strength concrete with very high durability and very low permeability is considered to have high performance properties. Bickley and Fung (2001) demonstrated that 40 MPa (6,000 psi) high performance concrete for bridges could be eco-nominally made while meeting durability factors for air-void system and resistance to chloride penetration.

By using of by-products such as silica fume with super plasticizer we can achieve high performance concrete, which possess high workability, high strength, and high modulus of elasticity, high density, high dimensional stability, low permeability, and resistance to chemical attack. HPC is often called “durable” concrete because its strength and impermeability to chloride penetration makes it last much longer than conventional concrete.

Super plasticizers are used in these concretes to achieve the required workability; moreover, different kinds of cement replacement materials are usually added because low porosity and permeability are desirable. Silica fume is the one of the most popular pozzolanas, whose addition to concrete mixtures results in lower porosity, permeability, and bleeding because their oxides (SiO2) react with and consume calcium hydroxides, which is produced by hydration of ordinary Portland cement. The main results of pozzolanic reactions are lower heat liberation and strength development; lime-consuming activity; smaller pore size distribution. Research shows that the optimum percentage of cement replaced by silica fume is 10% for achieving maximum compressive split tensile, flexural strength and elastic modulus.

1.7 IMPORTANCE OF SELF CURING IN HPC

The purpose of HPC is to obtain long term strength, early age strength, low permeability, density, and longer life in a severe environment. Internal curing is used for the same purposes and end-results including durability. It even improves the durability of higher fly-ash concretes. The two concepts have a synergistic effect, and internal curing enhances each of the desired characteristics of HPC and importantly durability.

Due to the chemical shrinkage occurring during cement hydration, empty pores are created within the cement paste, leading to a reduction in its internal relative humidity and to shrinkage which may cause early-age cracking. This situation is intensified in HPC (compared to conventional concrete) due to its generally higher cement content, reduced water/cement (w/ c) ratio and the pozzolanic mineral admixtures (fly ash, silica fume). The empty pores created during self-desiccation induce shrinkage stresses and influence the kinetics of cement hydration process, limiting the final degree of hydration. The strength achieved by IC could be more than possible under saturated curing conditions.

Autogenous shrinkage is the volume change in concrete occurring without moisture transfer from the environment into concrete. It is due to the internal and structural reactions of the concrete. Autogenous shrinkage is prominent in HPCs due to the reduced amount of water and increased number of various binders used. Self-curing eliminated the tensile stress due to restrained autogenous shrinkage without compromising the early-age strength and elastic modulus of HPC. It was shown that the risk of concrete cracking could be conservatively estimated from the extent of free shrinkage strain occurring after the peak expansion stain that may develop at early ages. Autogenous expansion, observed during the first day for high levels of internal curing, can significantly reduce the risk of cracking in concrete structures, as both the elastic and creep strains develop initially in compression, enabling the tensile strength to increase further before tensile stresses start to initiate later.

Often, especially in HPC, it is not easily possible to provide curing water from the top surface at the rate required to satisfy the on-going chemical shrinkage, due to the extremely low permeability often achieved.

1.8 SILICA FUME

Silica fume is one of the artificial pozzolans, commonly used as mineral admixture in HPC. Silica fume is very fine non-crystalline silica, produced in electric arc furnaces, as a byproduct of the production of elemental silicon or alloys containing silicon also known as condensed silica fume or micro silica. It is mainly amorphous silica with high SiO2 content, extremely small particle size and large surface area, highly reactive pozzolan used to improve mortar and concrete. It improves durability primarily by reducing permeability to water and chlorides.

Micro silica is produced during the high temperature reduction of quartz, to give silicon or ferrosilicon metal. As the quartz is heated to 20000 C and an electric arc is fired through the furnace, it releases silicon monoxide gas. This gas rises and reacts with oxygen in the upper parts of the furnace and condenses as it cools into the pure spherical particles of micro silica.

There are two reactions in the silica fume, Pozzolanic reactions are, Silica fume reacts with calcium hydroxide, which is liberated during process of hydration, about 22-24 percent and produces calcium-silicate-hydrate (C-S-H). The following are the chemical reactions that are taking place.

Portland cement reaction : C3+H = C-S-H+CH Portland reaction of silica fume : S+CH+H = C-S-H
Particle packing are,

The second function silica fume performs in cementitious compounds is a physical one. Because silica fumes are 100 to 150 times smaller than cement particles it can fill the voids created by free water in the matrix. This function, called particle packing, refines the microstructure of concrete, creating a much denser pore structure. Impermeability is dramatically increased, because silica fumes reduce the number and size of capillaries that would normally enable contaminants to infiltrate the concrete. Thus, silica fume modified concrete is not only stronger, it lasts longer, because it’s more resistant to aggressive environments. As a filler and pozzolan, silica fume’s dual actions in cementitious compounds are evident throughout the entire hydration process.

1.9 MATHEMATICAL MODELING

A mathematical model is a description of a system using mathematical concepts and language. The process of developing a mathematical model is termed mathematical modeling. Regression analysis is widely used for prediction and forecasting, where its use has substantial overlap with the field of machine learning. Regression analysis is also used to understand which among the independent variables are related to the dependent variable, and to explore the forms of these relationships. In restricted circumstances, regression analysis can be used to infer causal relationships between the independent and dependent variables.

The performance of regression analysis methods in practice depends on the form of the data generating process, and how it relates to the regression approach being used. Since the true form of the data-generating process is in general not known, regression analysis often depends to some extent on making assumptions about this process. These assumptions are sometimes (but not always) testable if a large amount of data is available. Regression models for prediction are often useful even when the assumptions are moderately violated, although they may not perform optimally. However, in many applications, especially with small effects or questions of causality based on observational data, regression methods give misleading results.

II. REVIEW OF LITERATURE

Gaston Espinoza-hijazin et al (2012) proven that Natural pozzolans (NP) have an effective supplementary cementitious material; however, the replacement of ordinary Portland cement (OPC) with NP might increase the autogenous and drying shrinkage of concrete. Internal curing (IC) might be of great help when using NP because it can promote the pozzolanic reactions and reduce shrinkage. The aim of this research is to assess the effect of IC in concrete containing NP. Results indicate that a 39% replacement of OPC with NP decreased compressive strength by 15%, decreased chloride ion permeability by 66%, and increased autogenous shrinkage by 40%.

Bart Craeye et al (2010) search of an optimization of the internal curing process, an extensive experimental program was performed on HPC, using different degrees of internal curing, to assess the mechanical and thermal properties of the HPC, and to evaluate the effectiveness of the performed curing. By adding super absorbing polymers (SAP) into the HPC as an internal curing agent, and by adding additional curing water to the concrete mixture, the chemical shrinkage, and the self-desiccation during hydration of the concrete is counteracted and thus the autogenous shrinkage of the HPC can be significantly reduced.

El-DiebA (2006) investigated the water retention of concrete containing self-curing agents. Concrete weight loss and internal relative humidity measurements with time were carried out, to evaluate the water retention of self-curing concrete. Non-evaporable water at different ages was measured to evaluate the hydration. Water transport through concrete is evaluated by measuring absorption%, permeable voids%, water sportively, and water permeability. The water transport through self-curing concrete is evaluated with age. It is concluded that self-curing concrete

S. No.	Property Of Cement	Values
1	Fineness Of Cement	7.50%
2	Grade Of Cement	43
3	Specific Gravity	3.12
4	Initial Setting time	28 min
5	Final Setting Time	600 min

shows higher water retention, less self-desiccation, better hydration with time under drying condition, and lower Water transport.

Amen and AlRawi (2005) This paper is on statistical model for the prediction of the ultimate shrinkage of concrete has a function of the ration of moisture loss, volume of the paste and compressive strength and the time of starting of shrinkage. The model was designed using the lab test result of 500 empirical data points. During each test the shrinkage and weight loss of concrete prisms were measured at different drying times for different mix proportions and aggregate types. They compared the newly developed statistical model with practical test results. The model fits well to the test data recorded during the experiment.

Ravichandran and Antony Jeyasehar (2012) study eight full scale reinforced concrete exterior beam column joints, two control specimens and six specimens strengthened by the proposed method, were constructed, and tested under cyclic loading. The displacement is increased monotonically using a hydraulic push and pull jack. The hysteretic curves of the specimen have been plotted. The energy dissipation capacity of retrofitted beam column joints with various ferrocement configurations has been compared. In addition, comparisons were made between experimental and analytical (ANSYS) results of control specimen and ferro cement retrofitted specimen. The experimental result indicates that the proposed strengthening method is effective to enhance the ultimate loading capacity, stiffness, and energy dissipation.

III. MATERIALS AND DIMENTIONS

The materials that are used in the preparation of self-curing concrete are listed below with their corresponding properties. The concrete used in this study was proportioned to attain strength of 40MPa.

1. CEMENT

Ordinary Portland Cement, (43 Grade conforming to IS: 12269 – 1987) was used for casting all the specimens. To produce high performance concrete, the utilization of high strength cement is necessary. Different types of cement have different water requirements to produce pastes of standard consistency. Different types of cement also will produce concrete and have different rates of strength development. The choice of brand and type of cement is the most important to produce a good quality of concrete. This type of cement affects the rate of hydration, so that the strengths at early ages can be considerably influenced by the cement used. It is also important to ensure compatibility of the chemical and mineral admixtures with cement. The properties of cement are shown in Table 3.1.

Table 3.1 Properties of Cement

2. FINE AGGREGATE

Locally available river sand conforming to Grading zone II of IS: 383 –1970.Clean and dry river sand available locally will be used. Sand passing through IS 4.75mm Sieve will be used for casting all the specimens. The properties of fine aggregate are shown in Table 3.2

Table 3.2 Properties of Fine Aggregate

S. No.	Properties	Values
1	Specific Gravity	2.89
2	Fineness Modulus	2.25

3. COARSE AGGREGATE

Locally available crushed blue granite stones conforming to graded aggregate of nominal size 12.5 mm as per IS: 383 – 1970.Crushed granite aggregate with specific gravity of 2.77 and passing through 12.5 mm sieve and will be used for casting all specimens. Several investigations concluded that the maximum size of coarse aggregate should be restricted in the strength of the composite. In addition to cement paste – aggregate ratio, aggregate type has a great influence on concrete dimensional stability. The properties of coarse aggregate are shown in Table 3.3.

Table 3.3 Properties of Coarse Aggregate

S. No.	Properties	Values
1	Specific Gravity	2.69
2	Size Of Aggregates	Passing Through 12.5 mm Sieve
2	Fineness Modulus	5.96

For making SCC maximum size of aggregates is 12.5 mm. The aggregates used are sound; free from deleterious materials and hacking crushing strength, at least 1.5 times that of concrete. Crushed blue stone angular shaped aggregate is used.

4. SUPER PLASTICIZER

A commercially available sulphonated naphthalene formaldehyde based super plasticizer (CONPLAST SP430) was used as chemical admixture to enhance the workability of the concrete. Obtained from BASF-The Chemical Company, PeelameduPudur, Coimbatore. Conplast SP430 is based on Sulphonated Naphthalene Polymers and is supplied as a brown liquid instantly dispersible in water. Conplast SP430 has been specially formulated to give high water reductions up to 25% without loss of workability or to produce high quality concrete of reduced permeability.

Figure 3.1 Super Plasticizer

Table 3.4 Properties of Super Plasticizer

S. No.	Properties	Values
1	Specific gravity	1.265 - 1.280 at 270C
2	Chloride content	Less than 0.05%
2	Air entrainment	Less than 1% over control

Compatibility: Can be used with all types of cement except high alumina cement. ConplastSP430A2 is compatible with other types of Fosroc admixtures when added separately to the mix. Site trials should be carried out to optimize dosages.

Workability: Can be used to produce flowing concrete that requires no compaction. Some minor adjustments may be required to produce high workable mix without segregation.

Cohesion: Cohesion is improved due to dispersion of cement particles thus minimizing segregation and improving surface finish.

Compressive strength: Early strength is increased up to 40%if water reduction is taken advantage of. Generally, there is improvement in strength up to 20% depending upon W/C ratio and other mixed parameters.

Durability: Reduction in W/C ratio enables increase in density and impermeability thus enhancing durability of concrete.

5. SUPASORB MPS-65

Obtained from ELKEM India (P) Ltd., Navi Mumbai conforming to ASTM C 1240 as mineral admixture in dry densified form. A super absorbent polymer (Supasorb MPS-65) is used as the self-curing agent. Obtained from Alchemy Substances-Chemical Company, Basaveshwar Nagar, Bangalore. Super Absorbent Polymers are prepared from acrylic acid and a crosslinker by solution or suspension polymerization. The type and quantity of crosslinker controls both the swelling capacity and gel modulus. It is one kind of functionality macromolecule polymer which is non- toxic, non-irritating and non-corrosive. It cannot conflagrate and blast. Supasorb can be used to solidify slurries into a more manageable consistency for disposal. Supasorb can be used as a Lost Circulation Material where very heavy losses are expected. Once the slurry has been solidified, disposal can be carried out without the risk of slurry spill/escape into the watercourse.

Dosage: For tunneling applications pre-mix 1-2kg per 1000litres of slurry, allow time for the water to absorb into the polymer and agitate where necessary. For HDD applications add between 2-7kg per 1000litresFor LCM, add between 150-350g per 1000 liters of fluid. With good expansion properties, sealing features, and resistance to the changes of weather and age and the existence of chemical erosion, Supasorb can be used for filling, plugging, and leak-proof additives to make a new type of cement-based, self-conservative admixture building materials. It also can be used as fire extinguishing material, desiccant, anti-fog agent, adhesives, and heat storage agent in buildings. Supasorb containing flood bags are used to embank rivers, lakes; to prevent flood damage; to keep water out of subways, underground parking; to quickly absorb water for roads, highways, bridges, construction areas, grounds, oil fields, coal mines, trenches, playing fields, golf courses; to control plumbing incidents of burst pipes, bath overflow, washing machine/dishwasher leaks, etc.

Figure 3.2 Supasorb MPS - 65

6. SILICA FUME

The silica fume is another type of pozzolana and its merit being the 'Silica Fume Concrete' produced using this to attain compressive strength of 96 MPa which is 2 to 3 times the strength of Portland Cement Concrete (PCC). This results in a reduction in weight and size of structure, lower its permeability and makes it a very durable material. SF used as an admixture, improves the properties of fresh and hardened concrete. Due to the high surface area of SF, SFC requires more water for obtaining the given slump. The fresh SFC mix is cohesive and there is no risk of segregation during handling of concrete and desired finish can be achieved. SF increases the electrical resistivity of concrete because it reduces the rate of carbonation of concrete. For instance, PCC has an electrical resistivity of 4200 ohms-cm and SFC produced with 20% SF in cements has 110,000 ohms cm.

Figure 3.3 Silica Fume

Table 3.5 Chemical Properties of Silica Fume

Chemical parameter	Silica fume (%)
SiO2	97.1
Al2O3	0.4
Fe2O3	0.3
CaO	0.3
MgO	0
SO3	0.2
Total alkalies (Na2O)	0
LOI	1.7

7. WATER

Casting and curing of specimens were done with the potable water that is available on the college premises. The water used for both mixing and curing shall be clean and the amounts of deleterious materials such as Viz oils, acids, alkalis, salts, sugar, organic materials, or other substances that may be deleterious to concrete or steel. Potable waters are generally satisfactory for mixing and curing concrete. In cause of doubt, the suitability of water for making concrete shall be ascertained by the compressive strength and initial setting time test specified in I.S. 456 – 2000.

4. MIX DESIGN AND CASTING

Mix Design is the process of selecting suitable ingredients of the concrete and determining their relative proportion with object of producing concrete possessing certain minimum desirable properties like workability in fresh state minimum desirable strength and durability in hardened state. To obtain the required strength properties of concrete in SCC, a higher proportion of ultra fine materials and the incorporation of chemical admixtures are necessary. The control mix was proportioned by IS 10262: 2009 to obtain compressive strength of 40 MPa.

The various data required for concrete mix design were summarized below:

Grade Designation : M40

Type of cement : PPC 43 Grade

Workability : 100mm (slump)

Specific Gravity of Cement : 3.15

Specific Gravity of Fine Aggregate : 2.89

Specific Gravity of Coarse Aggregate : 2.69

Maximum Size of Coarse Aggregate : 20 mm

Fineness Modulus of Fine Aggregate : 2.25

Fine Modulus of Coarse Aggregate : 5.96

Quality Control : Good

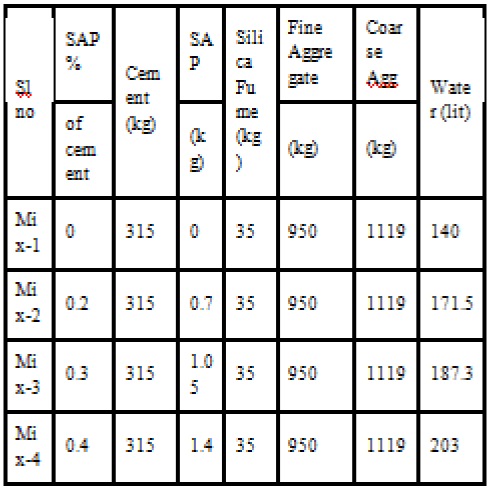
Exposure Condition : Mild

Chemical admixture type : Super Plasticizer

Mix proportions:

The control mix was proportioned by IS 10262: 2009 to obtain compressive strength of 40 MPa. The identification, mix proportion and quantity of material taken for one meter cube of self-curing concrete mixes are given in Table 3.6. The mixes 1, 2,3 and 4 were obtained by adding SAP content 0%,0.2%,0.3%, and 0.4% of weight of cement. Additional water added to the mix depends upon the amount of SAP added (for 1 kg SAP add 45-liter water). Super plasticizer CONPLAST SP430 is added 2% to the weight of binder

Table 3.6 Mix Proportions Per m3



Sl no	SAP %	Cement (kg)	SAP	Silica Fume (kg)	Fine Aggregate	Coarse Agg	Water (lit)
	of cement		(kg)		(kg)	(kg)	
Mix-1	0	315	0	35	950	1119	140
Mix-2	0.2	315	0.7	35	950	1119	171.5
Mix-3	0.3	315	1.05	35	950	1119	187.3
Mix-4	0.4	315	1.4	35	950	1119	203

Casting of Specimens for beams:

All the reinforced beam-column specimens were cast at the structural laboratory. Wood moulds were used for casting the specimens. The mould is arranged properly and placed over a smooth surface. The sides of the mould exposed to concrete were oiled well to prevent the side. walls of the mould from absorbing water from concrete and to facilitate easy removal of the specimen. The reinforcement bars were cut to the required lengths. The longitudinal bars and stirrups were secured to each other at correct spacing by means of binding wires. The reinforcement cages were placed in the moulds and the cover between cage and form provided was 25 mm. Cement mortar block pieces were used as cover blocks. Required quantities of cement, sand and coarse aggregate were mixed thoroughly in a concrete mixer machine, and 50% of water was added to the dry mix. The remaining 50% water, mixed with the super plasticizer, was added later along with the mineral admixture silica fume. Required quantities of Super absorbent polymer added in the mix in dry form. Mixing was done till a uniform mix was obtained. The concrete was placed into the mould immediately after mixing and well compacted. After 24 hours, specimens were demolded and only control mix concrete cured under wet gunny bags for 28 days. After curing period, the beams were kept for 24 hours in a dry state. After drying they were cleaned with sandpaper to remove all grit and dirt. Then all the specimens were prepared by white washing from all sides. White washing was done to facilitate easy detection of crack propagation.

Figure 4.1 Wood Cum Reinforcement

V. RESULTS AND DISCUSSIONS

5.1 Ultimate Load

For each mix two specimens were tested. As the difference between the two test results was found to be less than 15%, the average values of the test results are taken and are given in Table 5.1. The first crack loads are 12 kN, 14 kN, 16 kN and 15 kN and the ultimate loads ,31 kN, 33 kN, 35 kN and 32 kN for specimens M1, M2, M3 andM4 respectively. Results show an increase of about 33% in the first crack load and 13% in the ultimate load from the control mix for the self-curing concrete specimens with SAP content 0.3% of cement. The increase in ultimate load may be due to the following reasons. The increase in cement hydration, promoted by an effective curing, has been shown to increase mechanical properties such as strength and elastic modulus. However, an effective curing can also reduce shrinkage, and specifically cracking caused by shrinkage, which can also increase strength and elastic modulus. This in turn increases the ultimate load.

5.2 Load-Deflection Behaviors

The loads and the corresponding deflections for M1, M2, M3 and M4 specimens were plotted on graphs. These results were obtained by conducting load tests on the corresponding specimens. Referring to Figure 5.1, it can be seen that HPC specimens with SAP showed no strength degradation for the descending portion of the load-deflection plot and that the load carrying capacity of the joints increased with increasing SAP content. The area under the load-deflection curve represents the energy absorption capacity of the specimen. It is observed that the average ultimate load carrying capacity of the specimens M1, M2, M3 and M4 are 31.00kN, 33.00Kn, 35.00and 32.00kN with the corresponding lateral displacement of 7.60mm, 8.06mm, 8.42mm and 7.68mm respectively. Among these M4 exhibits the maximum load carrying capacity. The results also show an increase of about 11% in deflection at the ultimate load for the specimens with SAP content 0.3% of cement.

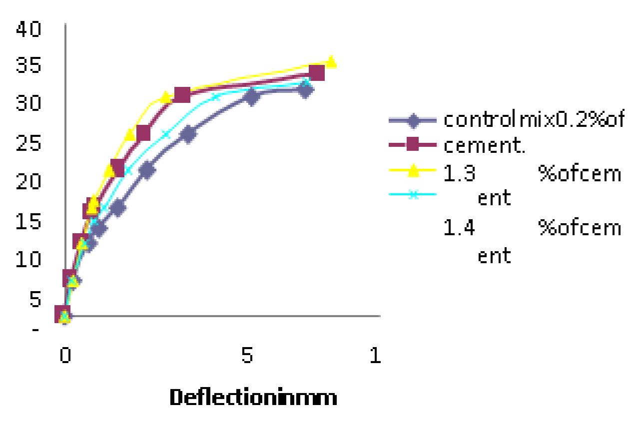


Figure 5.1 Load Vs Deflection Graph

5.3 Stiffness behavior

In the case of reinforced concrete beam-column joints, stiffness of the joint gets degraded when the joint is subjected to static loading. The joints initially develop micro cracks inside and it leads to the lowering of energy limit of the materials, and thereby results in the increase of deformation inside the joints. This may consequently cause a reduction in stiffness. Therefore, it becomes essential to assess the degradation of stiffness in the beam column joints subjected to static loading. The stiffness (K) is calculated $K= (P/\delta)$, P-is the average load and δ-is the average displacement values (δ). The values of the stiffness obtained for each load increment are plotted for all the specimens, it has been observed that stiffness of self-curing specimens was greater than the control mix. The result also shows that specimen M3 has the higher stiffness value.

5.4 Ductility Behavior

Ductility is generally measured in terms of displacement ductility, which is the ratio of the maximum deformation that a structure or an element can undergo without significant loss of initial yielding resistance to the initial yield deformation. It is essential that an earthquake resistant structure should be capable of deforming in a ductile manner when subject to several cycles of lateral loads in the inelastic range. Ductility is the property which allows the structure to undergo large deformation beyond the initial yield deformation without losing its strength abruptly. Ductility (μ) can be defined as the ratio of ultimate deflections (δu) to initial yielding deflection (δy). $\mu= (\delta u/\delta y)$. it is observed that specimens M2, M3 and M4 exhibit higher ductility than control mix M1 by 65%, 105% and 25 % respectively. Among these specimens M3 exhibits better performance.

VI. CONCLUSION

STRENGTH PROPERTIES:

Addition of SAP leads to a significant increase of mechanical strength (Compressive, split tensile and flexural) Maximum compressive stress, split tensile and Flexural strength and modulus of elasticity develop in M-40 grade self-curing concrete by adding SAP 0.3% of cement. Performance of the self-curing agent will be affected by the mix proportions, mainly the cement content and the w/c ratio. The mathematical model predicted accurate results when compared with experimental results. In stepwise and forward regression models the parameters influenced the equation were the same. In the case of backward regression model a greater number of parameters involved in all strength characteristics. Hence backward regression is the best method which gives accurate results.

DURABILITY PROPERTIES:

The water absorption percentage and the porosity percentage were found to be slightly higher for self-curing concrete than those for continuously moist cured conventional concrete. Acid resistance and Sea water resistance capacity increases in self-curing concrete and maximum in SAP content of 0.3% of cement. Self-curing concrete mix were more electrolytic corrosion resistant than conventional concrete mix due to the higher rate of hydration. Water sportively values for self-curing concrete decreased with age indicating lower permeable pores percentage because of continuation of cement hydration.

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