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Influence of Pre-soaked Super Absorbed Polymers on Mechanical Properties of High Performance Concrete

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Abstract:
Super Absorbed Polymers (SAP) are multipurpose chemical admixtures. When Pre-soaked Super Absorbed Polymers are mixed with concrete, they control the rheological properties of fresh concrete and control the plastic shrinkage through internal curing. The major advantage of SAP is to improve the Durability, Stability of Hardened concrete. When the SAP is added to the mix, it absorbs the water and store more water than its own weight, within a short time. SAP absorbs 450 to 500 times water than its own weight and converts into the GEL. This absorption of water results in swelling up of SAP and thus an increase in its volume. The increase in volume fills the thin hair cracks in concrete and leads to control of cracks. In this study, 0.3% and 0.4% of Pre-soaked SAP was added to M40 concrete mix and compressive strength tests were conducted to standard cubes at 7,14&28 days. It is found that there is substantial increase in strength of concrete due to addition of Pre-soaked SAP.

Keywords: Concrete- Durability- Super Absorbent Polymers- Strength-Water Absorption-Workability.

I. INTRODUCTION

Super absorbent polymers (SAP) also known as slush powder. They effectively control the free water in the concrete mixture due to their significant water absorbent nature. In also control the rheological properties of fresh concrete and control the plastic shrinkage through internal curing. The SAP improves the Durability and Stability of concrete. Then, due to low ionic concentration, SAP eventually releases the previously absorbed water thus spreading itself in the cracks formed inside the concrete thus sealing them[1]. It means the SAP absorbs the water and convert into the GEL at the same time the volume increases proportionally. SAP can produced with water absorption of up to 400-500 times their own weight. The dosage of SAP varies from 0.1% to 0.7%. In this we can take 0.3% and 0.4% of SAP[2]. It has more compressive and tensile strength compared to the ordinary concrete. The main characteristic of the Super Absorbent Polymer (SAP) is its ability to absorb relatively large amount of water and converts it into gel, then releases it slowly with time. Its presence in hardened concrete influences strength and creep and it plays a central role in deterioration due to the frost action or alkali – silica reactions[3]. The advantages of adding superabsorbent polymers in conventional concrete mixes are

Shrinkage reduction: The changing of volume in concrete structures due to loss of moisture by evaporation is known as shrinkage. Today many concrete structures are failed due to early age of shrinkage. This is more common when high cement contents and low water-cement ratios are used to make the concrete, leading to autogenously shrinkage induced by self-desiccation. The SAP will reduce the early age of shrinkage and increase the strength and durability of concrete [4].

Controlled release: SAP may also be used to control the release of substances other than water that are dissolved in the SAP particles. Compared to other absorbent polymers, superabsorbent polymers have a special feature: the swelling capacity is more. The control of substances will lead to gain strength to the concrete.

Internal curing: The process of curing involves maintaining satisfactory moisture content and temperature after concrete is placed in order to hydrate the cement particles and produce the desired hardened concrete properties. Proper curing can improve strength, durability, abrasion resistance, resistance to freeze–thaw cycles, and reduce concrete shrinkage. Traditionally, concrete has been cured externally either through the use of water curing or sealed curing. Curing either supplies additional moisture from the original mixing water or minimizes moisture loss from the concrete.

Removal of concrete contaminants: A technique was described by which radioactive isotopes present in the pore solution of concrete and other porous materials can be removed. It was claimed that a single application of gel can remove up to 90% of the radioactive elements

Self sealing: The SAP is used for blocking cracks in concrete. When the water react with SAP, the chemical swells and form into gel, the gel fills the cracks and increase the strength and durability of structure. It has more self sealing capacity compared to ordinary concrete.

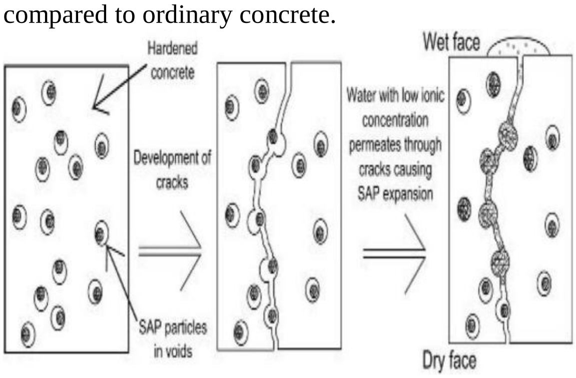

Figure.1. Self sealing of cracks

Relevant properties of SAP for concrete applications
For their application in concrete, the following properties of S AP are of particular relevance:

- Chemical stability in ionic solutions
- Distribution in particle size
- Behaviour of absorption and desorption on concrete.

Influence on strength: A SAP can ensure very efficient internal water curing, which is defined as "incorporation of a curing agent serving as an internal reservoir of water, gradually releasing it as the concrete dries out."7 Internal water curing has been used for decades to promote hydration of cement and to control the shrinkage of concrete during hardening. Saturated light weight aggregate was previously the only material used as an internal curing agent. But there are some major problems connected to the use of lightweight aggregates for internal water curing, including difficulties in controlling consistency and significant reductions in strength and elastic modulus. These difficulties are minimized with the use of SAPs[5].

Rheology modification: The addition of dry SAP during mixing results in a considerable change in the rheology of fresh concrete if extra water is not added to compensate for the SAP absorption. For example, with a water absorption of around 15 g/g dry SAP,5 the addition of just 0.4% SAP relative to the cement weight will lead to a lowering of the free w/c by 0.06. This change in w/c will cause the yield stress to triple and the plastic viscosity to increase by 25% for a concrete with an initial w/c of 0.4.17 In addition to this pure water binding effect, a further increase in the yield stress and plastic viscosity will be caused by the physical presence of the swollen SAP particles [1]. If the thickening effect caused by the SAP is unwanted, it may be mitigated by addition of plasticizing admixtures. Alternatively, the effect may be used to advantage. For example, the thickening effect associated with the absorption of water by the SAP may be particularly useful for wet-mix short-creting.

Frost resistance: The production of concrete that is resistant to freezing and thawing requires special attention to some specific material parameters, including the air-void system, of which effectiveness is controlled by the volumetric air content, spacing and size of the air voids. To this effect, SAP particles can be engineered to provide an adequate pore system, since SAP particles can de-swell during cement hydration and leave gas-filled voids, according to Jensen. The mixtures containing specific types of SAP were found to provide increased resistance to freezing and thawing in the presence of de-icing chemicals[6].

Water proofing: The volume increase of the gel of water-saturated swollen SAP can be used to form a barrier to water flow. Sealing composites made by blending modified SAP into rubber or a thermoplastic elastomer have been developed for sealing around the joints of various building materials[8].

II. LITERATURE REVIEW

Ole Mejlhede Jensen, et al. (2002): He Observed the mechanism of superabsorbent polymer and determined how it will affect long term shrinkage and reduces autogenous shrinkage. Also the authors outline the possible problems which are associated with the usage of superabsorbent polymer.

Mohammad J. Zohuriaan-Mehr, et al. (2008): Reviewed the SAP literature, background, types and chemical structures, physical and chemical properties, testing methods, uses, and applied research works. Also the original usage of SAP in agricultural and healthcare are reviewed.

Alexander Assmann, et al.(2010): Observed the mechanics behind the internal curing process for superabsorbent polymers and studied the changes it induces to the microstructure of the concrete. The author obtained the results of permeability testing, compressive strength and drying shrinkage

V. Mechtcherine (2011): He is the one of the editor in a report prepared by a technical committee on SAP compiled the reports of researchers from around the world who investigated the mechanism of SAP action in concrete materials and the limitations and advantages of SAP that could solve problems experienced by researchers in the area.

Marianne Tange Hasholt, et al. (2012): He studied the effect of SAP on the mechanical strength of concrete by optimizing the dosage and internal water added. The authors arrived at the conclusion that "Addition of SAP does not lead to decrease in mechanical strength and while one has to be very patient and careful, it is possible to not only retain the same strength but also to increase it while preventing self-desiccation.

Agnieszka Klemm, et al. (2012): In their study observed superabsorbent polymer in cementitious composites and studied the recent advances in the area of SAP modified concrete while providing an idea on what superabsorbent polymer is, how it functions and what are its benefits.

C. Chella Gifta, et al. (2013): Studied the effect of superabsorbent polymer on concrete and compared it to internally cured concrete which used superabsorbent polymer and lightweight aggregate. The researcher observed the advantages superabsorbent polymer has in durability against both lightweight aggregate and conventional concrete in this regard.

M. Manoj Kumar, et al. (2013): Studied the effects of addition of using different ratios of superabsorbent polymer on the various mechanical properties of concrete, like Compressive Strength, Splitting Tensile Strength and Flexural Strength and compared them to conventional concrete.

Bart Craeye, et al.(2013): Tested high performance concrete at various dosages of superabsorbent polymer to determine the optimum dosage of superabsorbent polymer which provides the maximum autogenous shrinkage reduction as well as the minimum strength reduction. They also studied thermal stress development due to heat of hydration and the chances of early age cracking are determined using finite element analysis and calculation.

Moayyad Al-Nasra, et al.(2013): Studied the effect on superabsorbent polymer on fresh and hardened concrete using sodium polyacrylate and conducted some tests on the strength and stability of internally cured concrete.

Vivek Hareendran, et al.(2014): Created five different mixes of self- curing concrete and tested them with conventional self cured concrete for mechanical properties of concrete like Compressive Strength, Splitting Tensile Strength and Flexural Strength.

D. Snoeck, et al.(2014): Observed the effect of high quantities of superabsorbent polymer in concrete with a high water-cement ratio as well as its effects and some precautions which should be taken when such high addition of the self curing agent are added.

III. METHODOLOGY

The methodology involves the adding of super absorbed polymer at different percentages of cement and study of compressive strength at different ages of concrete. The compressive strength will occur after analysing the results of strength tests. The super absorbed polymer is used an as admixture, for improving the properties of concrete. The excess of SAP leads to some additional problems. The proper and sufficient percent of SAP should be use. We took 0.3% and 0.4% of SAP.

Materials Used

Ordinary Portland Cement of 53 grade from a single batch was used for the entire work. Super absorbed polymer of 0.3% and 0.4% of cement. The percentage of SAP is based on the type of work and requirement.

Table.1. Properties of SAP

Form-dry	Crystalline white powder/granular
Form-wet	Transparent gel
Particle size	125 micron
Water absorbing with distilled water	450-500
pH of absorbing	Neutral
Density	1.08 (g/cm3)
Bulk density	0.85 (g/cm3)

River sand passing through 4.75mm sieve and crushed coarse aggregate of size 20mm. The aggregate was tested for its physical requirements such as gradation, fineness modulus specific gravity and bulk density etc. In accordance with IS: 2386-1963 and IS: 383-1970. Fresh water which is free from oil and organic matter. The workability was measured using the compaction factor apparatus.

Table.2. Design mix proportions

Grade	Proportion
M40	1:1.62:2.14
M40 with 0.3% and 0.4% of SAP	1:1.73:2.31

Concrete mix design

The tests are conducted to know the physical properties of materials, and from the properties the design mix is prepared. In this project M40 grade concrete is done according to BIS: 10262-2009. The concrete mix is design based on the IS: 10262-2009. The proportions are given below. The w/c ratio is 0.42

Figure.2. SAP in powder form

Figure.3. SAP in gel form

Figure.4. Concrete with SAP

IV. TESTING

The Compressive strength and Durability tests are conducted after the completion of different ages of concrete. The tests should be conducted on normal mix cubes and also 0.3% and 0.4% of SAP concrete.

Figure.5. Compressive strength testing of cubes casted with Pre-soaked SAP

V. RESULTS AND DISCUSSIONS

The SAP concrete has more strength compared to the ordinary concrete the following are the readings are

Table. 3. Compressive Strength values

Days	0% SAP	0.3% SAP	0.4% SAP
7	25.46 N/mm2	30.76 N/mm2	31.10 N/mm2
14	35.83 N/mm2	38.07 N/mm2	39.52 N/mm2
28	39.98 N/mm2	42.30 N/mm2	45.56 N/mm2

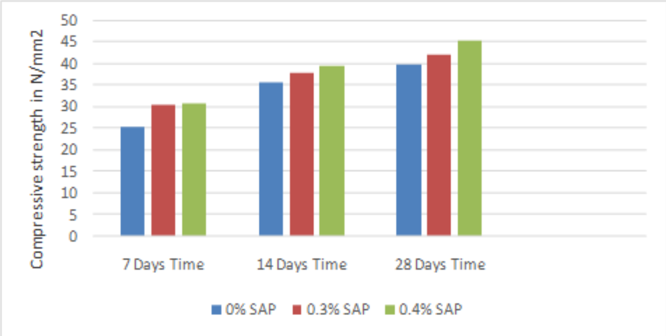

Figure.6. Compressive Strength values

VI. CONCLUSION

Concrete is used on a world-wide scale. However, there are issues regarding its possible cracking behavior due to shrinkage, freeze/thawing and/or structural stresses. This crack formation can be counteracted by using superabsorbent polymers (SAPs) for different applications in concrete. The autogenous shrinkage is reduced and even completely mitigated. This is due to internal curing. The freeze/thaw resistance is increased as the formed micro structural system of macro pores resembles the one of an air-entrained concrete. As the SAPs swell in cracks within hardened concrete, the SAPs decrease the water permeability and cause the so-called self-sealing effect. This is very interesting for constructions which need to be watertight. Another positive effect of SAPs is the promotion of autogenous healing. The compressive strength of concrete has increased substantially due to addition of Pre-Soaked Super Absorbent Polymers, owing to the internal curing effect.

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