USE OF SUPER ABSORBENT POLYMERS (SAPs) IN CONCRETE.

An overview of some aspects of superabsorbent polymers (SAPs) in concrete technology. The use of superabsorbent polymers as a crack sealing and crack healing mechanism in cementitious materials.

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Abstract:- The use of Super absorbent polymers (SAP) in concrete has many positive effects on various properties of concrete. Due to water entraining property of SAP, the concrete is cured internally as well as externally. Due to this type of curing, there is a significant influence on the strength on concrete. This is also achieved due to SAP's crack sealing mechanism which helps when cracks are developed inside the concrete due to hydration process. However, if too much quantity of SAP is added in the mix, it may lead to additional void formation in the concrete mass which in turn would have a negative effect on the hardened concrete. This effect of SAP on concrete leads to improvement in workability and placing on concrete. The main focus of this study would be to test various strengths of hardened SAP induced concrete and to compare them with ordinary M25 grade concrete.

***Keywords*:- Super absorbent polymer, Concrete, Strength, Concrete Curing, Voids.**

INTRODUCTION

Superabsorbent polymers (SAPs) are a new type of concrete admixture, which is used to supply the hardening concrete with additional water resources for the internal curing. When adding them dry to the mix, they absorb and store much more water than their own weight, within a short time. This absorption of water results in swelling up of SAP and thus an increase in its volume. 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. During the hydration process, the saturated SAPs supply the surrounding cement matrix with additional water. When dried out, the air filled pores of SAP (about 100 to 600 μm diameter) remain, acting similarly as pores generated by air-entraining agents. Besides a strong reduction of autogenous shrinkage and delayed drying shrinkage, the SAP addition can enhance the strength and durability of concrete.

EARLY INVESTIGATION

L. O. Ekebafe, D.E. Ogbeifun, F.E.Okieimen state that the use of polymer is gaining more and more popularity in the field of polymer chemistry and agriculture. Super absorbent polymers (SAP) help in minimizing various agricultural problems in today's life by maximizing land and water productivity without threatening the environment. This is done because SAP influences the soil structure, density, permeability etc. SAP helps in increases the efficiency of pesticides, allowing lower doses to be used due to its water entrainment property. This property of SAP made other researchers believe that incorporation of SAP in concrete would be advantageous in many ways.[3]

In 1997, the late Per Freiesleben Hansen and O. Mejlhede Jensen initiated a series of experiments involving a new curing technology concept. They called this technology "water entrainment" due to similarities with air entrainment. It was the culmination of a 10-year search for potential ways to mitigate autogenous shrinkage in high-performance concrete products. In 2013, Jensen again used superabsorbent polymers in concrete. He stated that water entrainment is a technique for incorporation of designed, water-filled cavities in concrete. Straightforward and free of significant drawbacks, water entrainment can be induced with fine SAP particles as a concrete admixture. At the same time, they also suggested a number of other potential uses of SAP in relation to concrete. These included frost protection, rheology modification, and controlled release of admixtures. [1]

Moayyad Al-Nasra and Mohammad Daoud in 2013 used super absorbents in concrete and their testing showed the same result as that of Jensen's. The use of superabsorbent polymer in concrete affects different properties of concrete in its fresh stage as well as hardened stage. Although the amount of SAP used in concrete varied for them, they were successful in duplicating the results of Jensen's research. They were also successful in performing the stability test on SAP induced fresh concrete and discovered that with SAP, concrete improves its plasticity and consistency. [2]

SUPER ABSORBENT POLYMER

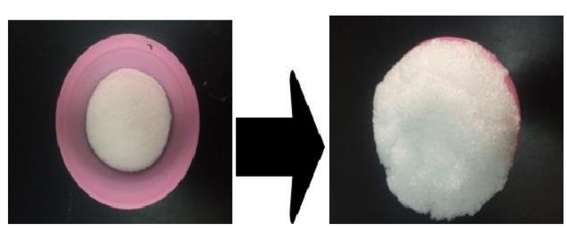
Super absorbent polymers (SAP) also known as slush powder are polymers which relative to their own mass, can absorb and hold extremely large amounts of liquid. Water absorbing polymers, through bonding between hydrogen and water molecules absorb aqueous solutions. A SAP may absorb 450-500 times its weight (from 40 to 60 times its own volume) and can become up to 99.99% liquid, but when put into a 0.9% saline solution, the absorbency drops to maybe 40-50 times its weight. The main use of SAP is found under agriculture. It is also used in disposable baby sanitary products due to its water retaining property. In powdered form, they appear to be white sugar like hygroscopic material. SAP is considered to be a smart material – It swells up when it is exposed to water and it reversibly shrinks and releases the entrained water, when subjected to drying. This article deals with the effects of SAP on different properties of concrete due its own water entraining property.

(Fig 1 - Powdered form of Super Absorbent Polymer – SAP)

SELF SEALING CRACKS WITH SAP

Cracking of concrete structures is a common problem due to the intrinsic brittleness of the material. This may lead to severe loss of durability and water tightness. Conventional methods for mitigating this problem such as providing additional reinforcement or movement joints in new structures and resin injection to seal cracks in existing structures may not always be appropriate or sufficient.

The aim is to investigate the potential of superabsorbent polymers (SAP) as an admixture for self-sealing cracks in concrete. SAP are unique cross-linked polymers that can absorb a vast amount of liquid and swell substantially to form a soft insoluble gel (Fig. 2 & 3). Common types of SAP are polyacrylate and polyacrylate-co-acrylamide that are widely used in personal care products such as nappies. Other applications of SAP include biomedical bandages, agricultural soil conditioning, waste solidification and meat packaging[1]. The swelling of SAP is highly dependent on pH, ionic content and concentration of the solution. This unique feature allows SAP to be exploited for self-sealing cracks.



(Fig 2: Dry SAP powder and Fig 3: Swollen SAP gel.)

INFLUENCE ON STRENGTH

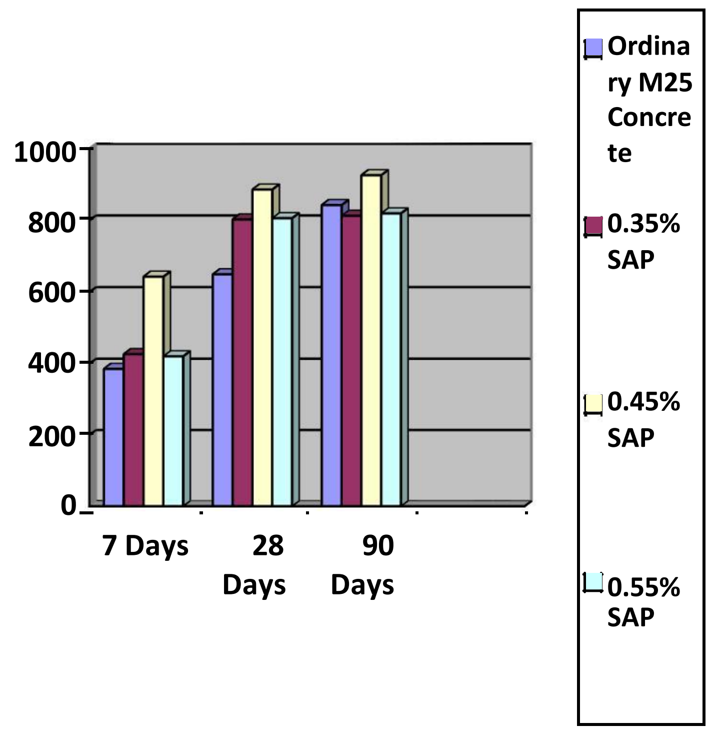
A SAP can ensure very efficient internal water curing, which is defined as said by O. Mejlhede Jensen "incorporation of a curing agent serving as an internal reservoir of water, gradually releasing it as the concrete dries out." Internal water curing has been used for decades to promote hydration of cement and to control the shrinkage of concrete during hardening. From a strength point of view, the addition of SAPs to concrete has two opposite effects: while the SAP generates voids in the concrete and thus reduces strength, the internal water curing provided by the SAP enhances the degree of hydration and thereby increases the strength. Which of these two effects is dominant depends on the water-cement ratio (w/c), the maturity of the concrete, and the amount of SAP addition. [1]

(Fig 4:- Hardened concrete being tested for its compressive strength)

After the curing at desired intervals was done, we decided to test the various strengths of hardened concrete which includes compressive, tensile and flexural strengths. Suitable equipments and testing machines were used to test different strength for concrete. Cubes of dimension 15*15*15 centimeters were used to test the compressive strength and the average of which is displayed below at regular intervals.

Days	Ordinary M25 grade Concrete (KN)	0.35% SAP induced concrete (KN)	0.45% SAP induced concrete (KN)	0.55% SAP induced concrete (KN)
7	386	427	643.33	421
28	650	803.33	886.66	806.66
90	843.33	813.5	926.66	820

(Table I :- Compressive strength of ordinary M25 concrete and SAP induced concrete after curing at different intervals)



(Bar graph comparing compressive strength of normal concrete and SAP induced concrete with strength on Y axis at KN/m^2)

The total effect seems to be described well with existing models, such as the gel-space ratio concept. In particular, at a high w/c

(>0.45), SAP addition has very little effect on hydration and therefore generally reduces compressive strength. At a low w/c (<0.45), SAP addition may increase the compressive strength of concrete.[1] During the testing period of these results, the water/cement ratio was kept constant at 0.45 and then they were cured externally for a period of 7, 28 and 90 days respectively as shown in the table.

Along with the compressive strength, split tensile strength was also tested with the help of Cylinders of dimension 15*30 centimeters and the average tensile strength achieved are displayed below.

Days	Ordinary M25 grade Concrete (KN)	0.35% SAP induced concrete (KN)	0.45% SAP induced concrete (KN)	0.55% SAP induced concrete (KN)
7	110	140	145	155
28	120	220	230	260
90	200	240	235	240

(Table II :- Split tensile strength of ordinary M25 concrete and SAP induced concrete after curing at different intervals)

(Fig 5 :- Hardened concrete being tested for its flexural strength)

Simultaneously, flexural strength of hardened was also tested and compared with the help of flexural testing machine and beams of dimension 10*10*50 centimeters were used for this testing. The average strengths achieved throughout the 90 days for ordinary M25 concrete and SAP induced concrete are mentioned below.

Days	Ordinary M25 grade Concrete (KN)	0.35% SAP induced concrete (KN)	0.45% SAP induced concrete (KN)	0.55% SAP induced concrete (KN)
7	17.5	10.5	12.5	13.0
28	16.5	17.0	19.5	23.5
90	19.5	21.0	22.5	26.0

(Table III :- Flexural strength of ordinary M25 concrete and SAP induced concrete after curing at different intervals)

As it can be seen from the tables above, the effect of super absorbent polymer is more on the compressive strength of 0.45% SAP induced concrete in particular and overall, the effect of SAP is less tensile and flexural strength of hardened concrete as compared to the compressive strength, mainly during the initial testing period of around 7 and 28 days.

SHRINKAGE REDUCTION

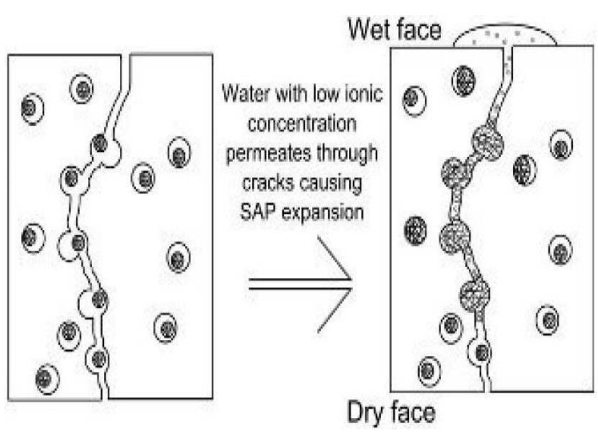
The shrinkage in concrete causes due to loss of water, this leads to crack formation in hardened as well as plastic state. This phenomenon can be reduced by preventing or slowing down the rate of water loss. As SAP acts as a water source, it can be used for the purpose. But cracks due to shrinkage occur on the surface hence it is difficult to know the action of SAP of this interface. Autogenous shrinkage may lead to cracking and also affect strength, durability and appearance of concrete. As autogenous shrinkage is closely connected to high performance concrete due to these the use of high performance concrete is limited.

In an ultra performance concrete the autogenous shrinkage can be controlled by adding small amount of SAP. It is seen that there is increase in the relative humidity of cement paste due to addition of SAP. It has been analyzed that due to addition of SAP there is reduction in cracking and stresses developed. [1]

SAP added to a concrete mixture during mixing permits an active control of geometric and thermodynamic properties of the water phase. The water in the formed SAP inclusions is essentially free water, and the size and shape of the inclusions are governed by the initially added SAP particles. Water entrainment can thus be considered “Engineered water phase distribution”. [1]

SELF-SEALING MECHANISM

As concrete hardens, due to the heat of hydration, the water which was previously absorbed by SAP is released and SAP shrinks (Fig. 4). Due to this, there are pores formed with sizes ranging between tens to hundreds of microns. Until the cracking inside the concrete occurs, SAP lies there in dormant position. After this, when the concrete is subjected to external curing, the extra water being soaked inside the concrete causes the SAP to swell again which increases its volume and the SAP spreads into the previously formed cracks in the concrete, thus sealing them and reducing the flow.



(Fig 6 : Schematic showing the mechanism of self-sealing using SAP.)

CONCLUSION

The use of sodium polyacrylate as super absorbent polymer in concrete has promising potential to improve several properties of concrete including the concrete strength. This can be explained by providing internal curing source that releases moisture slowly over days and may be weeks. This increase in strength is relatively small even at the optimum amount of sodium polyacrylate used in the concrete. This may become advantageous in the absence of concrete curing. However, Excessive amount of sodium polyacrylate used in concrete has a substantial negative effect on the concrete strength. The compressive strength of normal concrete after 90 days averaged at 843.33 Kilonewton/Meter^2 while the 0.45% SAP induced concrete sustained a load of 926.66 Kilonewton/Meter^2 We believe that SAP being comparatively cheap at INR 500/KG, this smart material could be used in the construction of a structure which require high strength performance and which would also help us to maintain the balance between economy and assured high strength which is very important to a in today’s construction industry.

REFERENCES

[1] Jensen, M, “Use of superabsorbent Polymer in concrete”, Concrete International, Vol 35, No. 1, January 1, 2013, pages 48-52.

[2] Al-Nasra, Moayyad, and Daoud, Mohammad, “Investigating the use of Super Absorbent Polymer in plain concrete”, IJETAE, Vol 3, Issue No. 8, August 2013, pages 598-603.

[3] Ekebafe, L. O., Ogbeifun, D.E., and Okieimen, F.E. “Polymer Applications in Agriculture”, Biokemistri, Vol 23, No. 2, June 30, 2011, pages 81-89.

[4] Jensen, O, and Hensen, “Autogeneous deformation and RH-Change in prospective,” Cement and Concrete Research, Vol. 31, No. 12, Dec 2001, pages 1859-1865

[5] Al-Nasra, Moayyad, “Optimzing the use of Sodium Polyacrylate in Plain Concrete” International Journal of Engineering Research and Applications (IJERA), Vol. 3, Issue 3, May-June 2013, pages 1058-1062

[6] RILEM, Internal Curing of Concrete – State-of-the-art Report of RILEM Technical Committee 196-ICC. State of the Art Report, RILEM Publications SARL, 2007.

[7] Mechtcherine, Viktor, and Dudziak, Lukasz, and Schulze, Joachim “Internal curing by super absorbent polymers (SAP) – effects on material properties of self-compacting fibre-reinforced high performance concrete” RILEM Publications SARL, ISBN : 2-35158-004-4, Year 2006, pages 87-96.