

Optimizing the Use of Sodium Polyacrylate in Plain Concrete

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ABSTRACT

This study focusses on the use of an optimum amount of Sodium Polyacrylate, SP, to be mixed in ordinary plain concrete. SP has two major effects on concrete. The first is to provide internal water source that helps in the hydration process, and curing and ultimately increases the concrete strength. The second effect is providing additional voids, due to drying process, in the concrete mass. These voids affect the concrete strength negatively; at the same time improve the concrete performance by improving the concrete workability and placeability, reducing the concrete susceptibility to freezing thawing cycles, reducing shrinkage, and improving the fresh concrete stability. The main focus of this study will be on the concrete strength. Several batches were prepared to determine the most effective amount of SP to use in the concrete mix.

Keywords- Concrete Durability, Hydration, Internal Curing, Sodium Polyacrylate

I. Introduction

Excess amount of SP will leave the concrete with large amounts of voids, which in turn reduces the concrete strength and durability. Small amount of SP, on the other hand, will have negligible effect on the concrete performance. The amount of water added to the fresh concrete is one of the most important key factors that affect the concrete properties, including durability and strength. The water is an essential ingredient needed for the hydration process in the fresh concrete and for the curing process in the hardened concrete at its early stages. Excessive amount of water added in the fresh concrete improves the concrete workability in general, reduces the concrete strength, and increases the drying shrinkage of the hardened concrete. Different admixtures were used to reduce the amount of water demand in the fresh concrete without jeopardizing the workability. Water reducer admixtures were used extensively in the ready mix plants. The most common admixture used nowadays is the high range water reducer, better known as superplasticizer which is water reducer and at the same time retarder.

Jensen (2013) used superabsorbent polymers in concrete. His study focused on the strength and shrinkage of concrete. He concluded that the shrinkage of concrete due to loss of water to the surroundings is the cause of cracking both in the

plastic and in the hardened stage. This type of cracking can effectively mitigated by slowing down the water loss. The superabsorbent polymers use in concrete has the potential to reduce concrete cracking. Jensen and Hensen (2001) studied the autogenous shrinkage phenomena in concrete. They concluded that the autogenous shrinkage may lead to cracking and affect concrete strength and durability, which is also, can be considered as technological challenge of high performance concrete. Addition of superabsorbent polymer in the ultra-high-performance concrete can be used to control the autogenous shrinkage. They also conducted tests that show that the shrinkage reduction due to superabsorbent polymer is related to a corresponding increase in the internal relative humidity of the cement paste. In addition, the use of superabsorbent polymer in concrete resulted in a reduction or elimination of stress buildup and related cracking during restrained hardening of these high-performance cementitious systems (Jensen and Hensen 2002).

The use of superabsorbent polymer in concrete is also useful in frequent freezing-thawing cycle environment, by providing the concrete frost protection. The superabsorbent polymers particles shrinks during the hydration process leaving voids in the concrete similar to the voids created by adding air entrainment agent to the concrete. The air bubbles left in the concrete are critical to absorb the hydraulic pressure caused by the freezing of water in the concrete mass. Water expands upon freezing about ten percent in volume generating hydraulic pressure in the concrete that has the potential to cause the concrete to crack. Providing voids in the concrete absorb the hydraulic pressure and provide additional space for the water to expand. The same can be said about the osmotic pressure in the concrete. The osmotic pressure is usually generated due to the difference in salt concentration in the water. This difference in salt concentration can be created by adding deicer to the concrete top surface, for the purpose of melting the ice on the concrete. Also these voids can be useful to absorb other kinds of internal pressures in concrete including alkali reactivity pressure.

Snoeck et al (2012) studied the use of superabsorbent polymers as a crack sealing and crack healing mechanism in cementitious materials. Their research focused on the use of the superabsorbent polymer to seal concrete cracks. As

concrete cracks due to its low tensile strength, harmful unfriendly chemicals may migrate into these cracks. The durability of concrete is endangered if no proper treatment or manual repair is applied. The first stage focused on hindering the fluid flow by swelling of superabsorbent polymers after they are exposed to a humid environment. The sealing capacity was measured by means of water permeability tests and through visualization of permeability tests by neutron radiography. They also concluded that the use of superabsorbent polymers is beneficiary to seal cracks and thus allowing a recovery in water-tightness as a decrease in permeability is noticed. The second stage focused on healing of small cracks in by the use of fiber reinforced cementitious materials that have the ability to restore the mechanical properties. These mechanical properties were analyzed by four-point-bending tests and the crack closure was microscopically monitored. Cracks close through the combination of further hydration of unhydrated cement particles, precipitation of calcium carbonate and activation of the pozzolanic reaction of fly ash. Also they concluded that the desorption of superabsorbent polymers triggers healing in the vicinity of crack faces and cracks up to 130 μm were able to close completely in wet/dry cycles due to the precipitation of calcium carbonate.

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, deicer scaling resistance 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. Water may be ponded directly on the concrete surface or may use other methods like wet burlap bags or fogging near the surface of the concrete to prevent evaporation of water from the fresh concrete. Sealed curing is accomplished by applying some sort of sealant to the surface of concrete in order to prevent moisture loss. Internal curing can be divided into two categories. The first category is internal water curing in which an internal curing agent stores water during mixing which is gradually released as hydration processes. The second category is internal sealing which is very similar to external sealed curing in that its goal is to prevent the loss of moisture from the concrete (RILEM, 2007).

II. Sodium Polyacrylate

Sodium polyacrylate, also known as waterlock, is a sodium salt of polyacrylic acid with the chemical formula $[-\text{CH}_2-\text{CH}(\text{COONa})-]_n$ and broad application in consumer products. It has the

ability to absorb as much as 200 to 300 times its mass in water. Sodium polyacrylate is anionic polyelectrolytes with negatively charged carboxylic groups in the main chain. Figure 1, shows the chemical composition of the sodium polyacrylate.

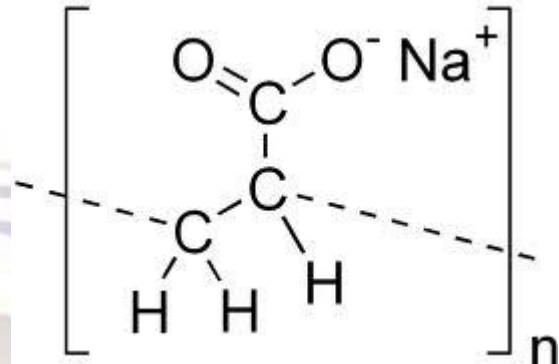


Figure 1: Sodium Polyacrylate chemical compound.

Sodium polyacrylate is a chemical polymer that is widely used in a variety of consumer products for its ability to absorb several hundred times its mass in water. Sodium polyacrylate is made up of multiple chains of acrylate compounds that possess a positive anionic charge, which attracts water-based molecules to combine with it, making sodium polyacrylate a super-absorbent compound. Sodium polyacrylate is used extensively in the agricultural industry and is infused in the soil of many potted plants to help them retain moisture, behaving as a type of water reservoir. Florists commonly use sodium polyacrylate to help keep flowers fresh. Figure 2 and Figure 3 show demonstration of the absorption capability of the sodium polyacrylate. For fast absorption a slight increase of sodium polyacrylate can be used for demonstration purposes.



Figure 2: 1.5 gram of sodium polyacrylate to be mixed with 200 ml of water



Figure 3: The mix turned into gel.

III. Flow Test

Mini slum cone is used to measure the workability of the cement past with sodium polyacrylates, SP. Figure 4 shows the mini slum cone used in this study. The height of the cone is 3 inches, the top diameter is 1.5 inches, and the bottom diameter is 3.5 inches. Mixing SP with water forms gel like material. This in turn kept the mix intact, and plastic. Visual comparisons between the mix without any admixture (control sample) and the one with SP, one can see smooth texture, easier to manage. Additional observation is that the mix with admixture showed better flow ability over surfaces, compared with the mix without admixture. This observation can be explored further, focusing of concrete place ability, especially using chutes or pumps. This property if proven to be the case, will improve the concrete resistance to segregation, and improves concrete pumping property. Figure 5 shows a typical measurement taken of cement paste with SP as admixture.

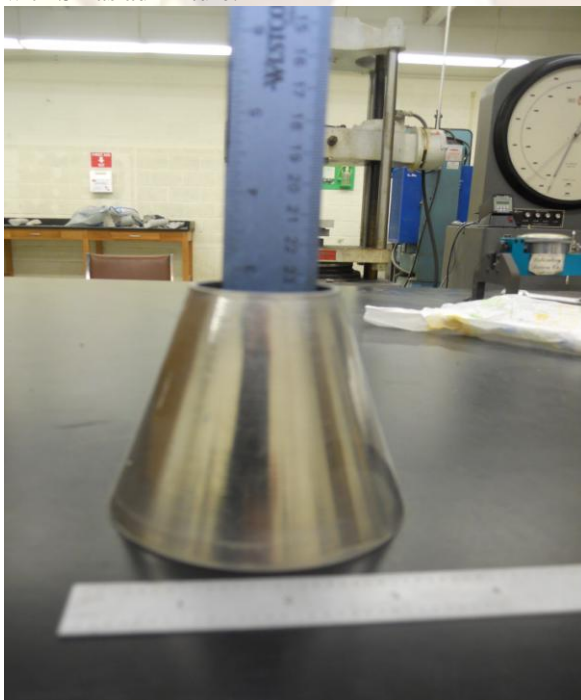


Figure 4: Mini slum cone used to measure cement paste flow ability.

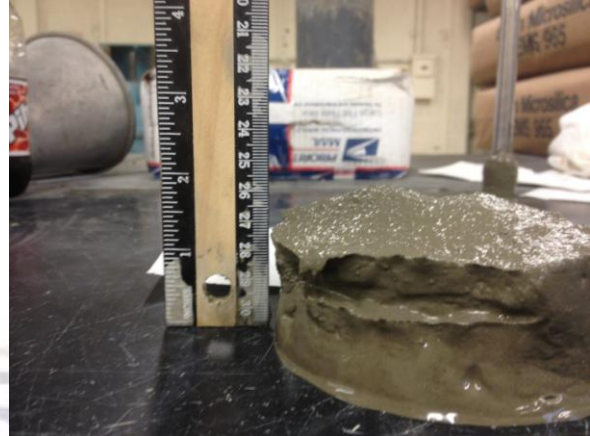


Figure 5: Typical flow ability measurement of sodium polyacrylate cement paste.

Table 1 shows the results of cement paste flow ability test. The measurement in this table shows the amount of slum in inches. The table shows a comparison between a control sample, cement paste without any admixture, and a sample of cement paste with SP used as admixture. The water cement ratio is kept constant though out the entire test of a value of 0.5. One can observe from the data collected in Table 1 that the slump readings of the sample with admixture are higher at the beginning, and then reduced with time. The two sets of reading seem to converge with time, especially after the initial setting of the cement.

Table 1: Mini-slump test results

Test No.	Time Min.	Plain Cement Paste (in)	SP Cement paste (in)
1	5	1.57	2.25
2	20	1.72	1.48
3	35	1.38	1.38
4	50	1.25	1.25
5	65	1.12	1.15

IV. Concrete Strength Tests

Several samples were prepared to determine the most appropriate amount of SP that can be added to the mix design in order to maximize the concrete compressive strength. The original control mix design was not changed, where the water cement ratio, W/C, is kept 0.5, and the mix proportion is taken as 1:1.6:3, cement to sand to gravel. After several trials, a ratio of SP to cement of 0.11 percent is found to be the most effective ratio as far as the concrete compressive strength is concern. Twelve 6 inch X 12 inch cylinders were prepared for each set to be tested by compression. Six cylinders were tested, three of each set, at 7 days, 14 days, 21 days and 28 days. Figure 6 shows the results of these tests. It can be observed from Figure 6 that there is a slight increase in the concrete

compressive strength of the mix with SP, compared to the plain concrete. This increase is not substantial and can fall within the standard deviation of the test. Even though the compressive strength improvement is not quite noticeable, but other properties of concrete can be improved by using this type of admixture. Figure 7 shows the different texture of concrete with and without SP. The concrete with SP is slightly lighter in color and shows small uniformly distributed voids in the concrete mass. These voids used to be filled by gel, and acted as internal curing tool.

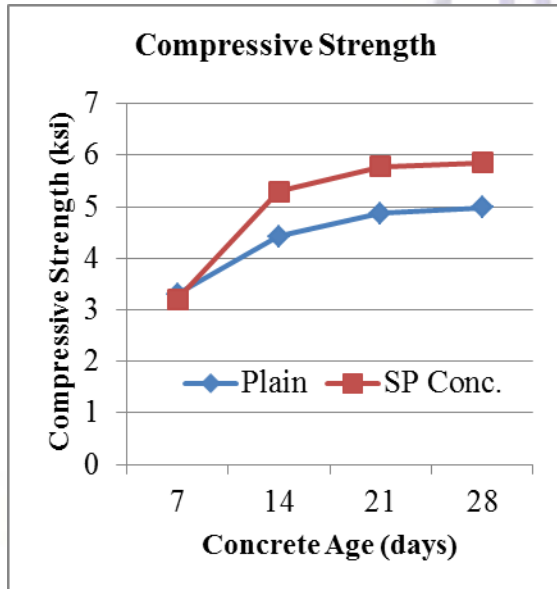


Figure 7: Compressive strength of concrete, with and without SP.

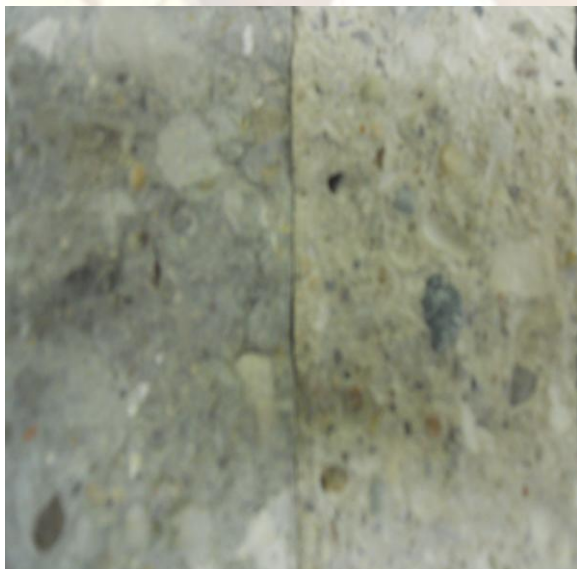


Figure 7: Concrete cylinders side by side after failure. The one on the left is the control concrete sample, and the one on the right is with SP admixture.

Flexural strength of concrete is also explored by preparing a total of eight 4 inch x 4 inch

beams. The beams were tested at 7, 14, 21, and 28 days also. Figure 8 shows a typical mode of failure of a tested concrete beam. The behavior of the beams under test was almost identical. All fail with the same failure mechanism. Figure 9 shows the effect of the use of SP as admixture on the concrete beams modulus of rupture. There is a slight and insignificant increase in modulus of rupture by using SP-admixture in concrete. This increase is almost negligible and falls within the standard of deviation.



Figure 8: Typical beam failure, by flexure.

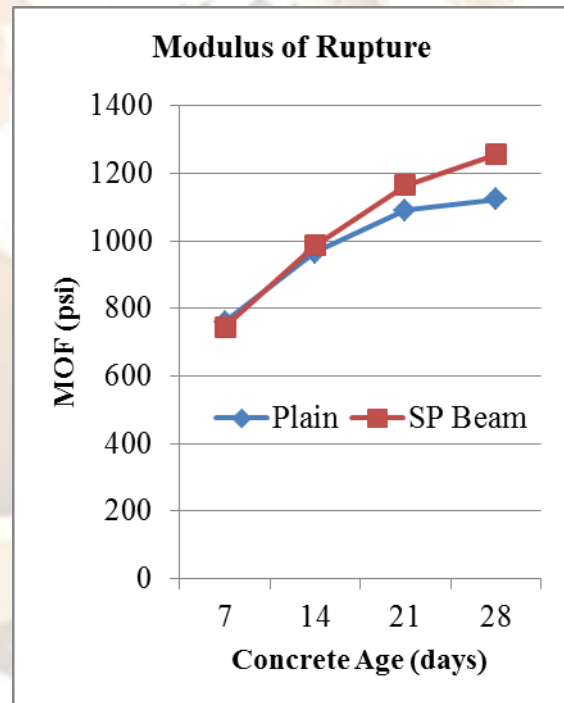


Figure 9: Effect of SP on the modulus of rupture of concrete beams

V. Conclusion

The use of sodium polyacrylate in concrete may increase the concrete strength due to internal curing process. This increase 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. Excessive amount of

sodium polyacrylate used in concrete has a substantial negative effect on the concrete strength. Other important properties can be improved using this type of admixture especially concrete stability, where the gel provides cushioning to the large aggregates which in turn reduces the possibilities of concrete segregation. Frost resistance is the other important property that can be improved by using this admixture, by absorbing the hydraulic pressure generated by water expansion. Other internal pressures can also be absorbed by these voids including the osmotic pressure and the alkali reactivity pressure. These voids seem to be very well distributed in the concrete mass.

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