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Use of Super Absorbing Polymers (SAP) for Internal Curing of Conventional Concrete with Low W/C Ratio

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Abstract **- During the hydration process, the conventional concrete with low w/c ratio experiences a considerable amount autogenous shrinkage deformation lead to an early age cracks and these premature cracks severely reduce the durability of a concrete. External water curing is one of the most conventional and well known applied curing methods to mitigate the autogeneous shrinkage however once the capillary pores depercolate, it will be more difficult to provide adequate external water for curing. Internal curing has proved as an effective method for mitigating the early age chemical shrinkage for the reason that they gradually released the absorbed water and maximize the hydration process. The main objective of this study is to examine the effect of internal curing as a complement to traditional curing in conventional concrete. Internal curing was achieved by super absorbent polymer (SAP) and the experimental parameter was percentage of SAP substitution to regular sand. Experimental results revealed that internal curing water provide by the SAP, effectively reduce the early-age chemical shrinkage and significantly increase the compressive strength of concrete. It has been also found that incorporation of SAP beyond 45% lead to a decrease in the gain of compressive strength.**

Keywords: Autogeneous shrinkage, Concrete, Internal curing, SAP, Compressive strength

1. INTRODUCTION

The durability, strength and high performance during the life cycle of the concrete structure generally depends the curing of concrete and it is crucial from the initial setting hours. Therefore, an effective curing method is required in order to increase the hydration of cementitious material and minimize the cracking problems due to drying shrinkage. When the mixing water is contact with the cementitious materials, the hydration starts. During hydration some part of the mixing water becomes chemically bonded to the hydration products, some other adsorbed at the surface of the hydration products, and the rest remains in solution at the capillary pores formed during hydration. Cementitious materials get the water from the capillary pores to promote hydration, which generates surface tensions that result in volumetric reductions known as autogenous shrinkage. In case the free autogenous shrinkage of a concrete structure is not prevented, internal tensile stresses can be introduced at early ages, which can exceed the tensile strength of the concrete. As a result, premature cracks can be created, making the concrete more vulnerable to the ingress of potentially aggressive species and thus severely reducing the durability of the concrete (Bart Craeye et al). So that the autogenous shrinkage of hardening concrete becomes the core area of various research projects. One of the most conventional and well known applied curing methods is external water curing to mitigate the autogenous shrinkage of small size concrete elements. However, once the capillary pores depercolate, it will be more difficult to provide adequate external water curing. Therefore, internal water curing by means of pre-soaked or saturated light weight aggregate and Super Absorbent Polymer (SAP) is considered as the most effective method for reducing autogenous shrinkage. An internal water reservoir is created into the fresh concrete through inclusion of internal curing agent in to the concrete. Once the initial free water has been consumed, the water absorbed by the light weight aggregate/SAP will be gradually released to maximize the heat of hydration.

An extensive research has been carried out on SAP and light weight aggregate as a self curing agent in concrete production. One of the first well known studies in this topic is that, Daniel Cusson et al studied the effectiveness of internal curing (IC) to reduce autogenous shrinkage cracking in high-performance concrete (HPC) using different levels of internal curing. Internal curing was supplied by pre-soaked fine lightweight aggregate (LWA) as a partial replacement to regular sand. Experimental results revealed that pre-soaked LWAs effectively reduce the autogenous shrinkage of concrete and the quantities of pre-soaked LWA used in the concrete specimens up to 178 kg/m^3 did not adversely affect the strength and elastic modulus of concrete at 7 days. The experimental results of Masahiro Suzuki et al shown a high effectiveness of the porous ceramic coarse aggregates (PCCA) for internal curing purposes, to drastically reduce and even to completely eliminate autogenous shrinkage of HPC prepared with a very low water/binder ratio (w/b) of 0.15. in addition to that tt has been found that the incorporation of 40% of the PCCA leads to a non-shrinking HPC that result in an insignificant internal stress accompanied by a significant increase of the compressive strength.

Burcu Akcay et al experimentally investigate the Effects of distribution of lightweight aggregates (LWA) on internal curing of concrete. Different sizes and amounts of natural pumice LWAs were used as water reservoirs to provide internal curing in mitigating autogenous deformation. Seven concretes were prepared using constant water to binder ratio of 0.28 and the light weight aggregate of three different volume fractions such as 10%, 20%, and 30% of the total aggregate volume of concrete added. Experimental results have shown that the use of pre-soaked LWAs as water reservoirs effectively mitigates the autogenous shrinkage of concrete. Experimental results of Bart Craeye et al (2011) revealed that addition SAP considerably reduce the autogenous shrinkage of the concrete and leads to a significant reduction in mechanical strength and modulus of elasticity.

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From the past research, research carried out so far boundless in the use of light weight aggregate as a internal curing agent in normal and HPC concrete besides inclusion of SAP as a self curing agent is not widespread. The main objective of this study is to experimentally investigate the inclusion of SAP as a self curing agent in normal concrete production to mitigate the autogeneous shrinkage. The experimental parameter was percentage of SAP substitution to regular sand. Concrete was prepared by 45%, 67.5%and 90% of natural sand is replaced by SAP. The effects of SAP on structural properties of concrete were evaluated through slump cone test, split tensile strength test, flexural strength test, and compressive strength test.

2. MATERIALS

2.1 Portland cement

The commercial Portland cement supplied by India cements was used in this study. The specific gravity of the cement was tested according to IS 455:1980 and the obtained value was about 3.14.

2.2 Aggregate

Natural sand passing through 4.75mm sieve and having a specific gravity of 2.48 was used in this study. The maximum size and the specific gravity of the coarse aggregate were 20mm and 2.67 respectively. According to IS 2386(1), grain size distribution analysis was carried out on both fine and coarse aggregate and the results are listed in Table 1.

2.3 Concrete

The concrete mix proportion was designed by IS method to achieve the strength of 30N/mm^2 and the designed mix proportion was 1:1.39:2.77 by weight. The designed water cement ratio was 0.35 and the formulations of various mixtures were listed in Table 2.

3. REQUIRED INTERNAL WATER

The improvement in internal curing of concrete mainly depends upon the amount of internal curing water added to the concrete and entrapped in the SAP. Furthermore the curing water by means of super absorbing polymers (SAP) is released at the right moment and the curing water should be available the whole time of hydration process. The required amount of internally curing water can be estimated theoretically by using Powers' model [1]:

$$\left(\frac{W}{C}\right)_{IC} = 0.18\left(\frac{W}{C}\right) for \left(\frac{W}{C}\right) \leq 0.36$$

Based on the previous research, the amount of SAP to be added to the concrete is estimated, aiming for an amount of internal curing water equal to 45 kg/m3 (SAP45), 67.5 kg/m3 (SAP67.5) and 90 kg/m3 (SAP90). This leads to a corresponding SAP amount of respectively 1.05 kg/m3, 1.50 kg/m3 and 2.00 kg/m3. The amount of curing water itself has to be added to the concrete during mixing. As compensation, the sand contentis reduced in order to obtain 1 m3 of concrete.

4. SPECIMEN PREPARATION

The concrete mixtures were prepared by Portland cement, natural sand, coarse aggregate (Blue metal) and SAP. Among the four series of mixtures, one was the control mixture and the remaining three mixtures were containing SAP substitution in various proportions such as SAP45, SAP67.5, and SAP90. Fig. 1 shows the super absorbent polymer (SAP) used in this study. For all the mixtures, aggregates were weighed in dry condition and the mixtures were mixed together for 4 to 5min in a laboratory counter current mixer. Workability of the fresh concrete was verified by slump test apparatus. Compressive and splitting tensile strength of the concrete measured using 150mmx150mmx150mm cubes and 150mmx300mm cylinders. In addition prisms/beams were prepared to determine the flexural strength of the concrete. After casting, specimens were kept in a room temperature for 24hrs, thereafter demoulded and transferred to the curing tank until their testing dates. Compressive strength of the cube was measured by compression testing machine (CTM) having a capacity of 2000kN at the age of 7, 8 and 90 days. The flexural and splitting tensile strength of the concrete was measured by flexure testing machine and by CTM respectively at the age of 7 and 28days. All the tests were carried out according to the relevant IS standards.

5. DESCRIPTIONS OF MIXTURES

Among the four mixtures, three mixtures were prepared with natural sand substituted by SAP and the remaining one was control mixtures (CM). To identify the mixtures easily, the each mixture was designated with the names such as CM, SAP 45, SAP 67.5 and SAP 90. For example SAP 45 specifies that the concrete mixture made with natural sand is substituted by internal curing water equal to 45 kg/m^3.

6. RESULT AND DISCUSSION

6.1 Slump loss

The workability of the fresh concrete was measured by slump cone test, time ranged from immediate after mixing, 30min and 60min, it is the convenient method and useful to control the quality of the concrete. The slump loss of the SAP substituted fresh concrete are given in Table 3 and the Fig. 2 explain the effect of SAP on the workability of the fresh concrete. For all the mixtures there was a significant losses in slump was observed with time in addition to that the workability of the concrete decreases with the increases in the SAP substitution rate. The poor workability was observed for mixture of SAP 67.5 and SAP 90 when compared to the other mixture. This is a result of the fact that, the workability and the water demand of the concrete depends upon the particle shape, particle size distribution and surface texture. Compared to the natural sand, the SAP has a bonding and colloidal nature and the particle size are less than 50 microns i.e.) very fine powder. The bonding property of the SAP increase the friction between the coarse aggregate and paste and the increased specific surface area of the powder increasing the water demand by increased water absorption. As a result the workability of the concrete reduced further when increasing the substitution of the SAP.

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6.2 Compressive strength

In cement-based materials, the compressive strength is a considered as the most important mechanical properties. Substitution of SAP in concrete affected the compressive strength development process over time depending on their characteristics. Compressive strength value of all mixtures is listed in Table 4. The main objective of this research is to enhance the compressive strength of concrete by mitigate the autogeneous shrinkage of concrete with the use of SAP. As expected the substitution of SAP significantly mitigates the autogeneous shrinkage and the compressive strength of the concrete increased upon aging. Fig. 3 clearly shows that in early stage the compressive strength of the mixtures containing SAP content are neither close nor little lower than the control mixture and the contribution of SAP can be well identified at later ages. However, the compressive strength of the internally cured mixtures is competitively higher than reference mixture only later ages i.e. beyond 7 days. The minor reduction in compressive strength in early age may be due to the cement paste is relatively weak and it has not so far developed the sufficient resistance in addition the crushing strength of the SAP is significantly lower than the fine aggregate. Fig. 3 clearly shows that at later ages (at 28 and 90 days) the compressive strength of the all mixtures (SAP 45, SAP 67.5and SAP 90) is significantly higher than the control mixtures (CM). This is a result of the fact that the improvement of hydration processes by the internal water curing provided by the SAP content. Mixtures SAP 45, SAP 67.5 and SAP 90 enhanced their compressive strength by 36.10%, 22.74% and 19.02% when compared to the CM at the age of 28 days. From the Fig. 3 it was observed that the inclusion of SAP enhance the compressive strength of the concrete to some extent and the further increases in substitution rate leads to an decrease in the gain of the compressive strength. This is a result of the fact that the increases in SAP content decrease the workability of the concrete resulting poor compaction. The compactness of the concrete is inversely proportional to the porosity of the concrete. Thus increases in porosity can led to the reduction in compressive strength. In addition bulking of volume of the SAP was raising the demand of paste volume and produced the poor bonding between the aggregates in concrete. Mixtures SAP 67.5 and SAP 90 produced 10.34% and 14.37% respectively of drop off in strength compared to SAP 45.

6.3 Split Tensile Strength

Although the Compressive strength is the most important property of the hardened concrete, the tensile strength is critical properties for concrete subjected to tensile force which is induced by autogenous shrinkage. This might allow the evaluation of the ability of a concrete mixture to resist the tensile stresses that are induced during the hydration process. The split tensile strength of the concrete was measured at the age of 7 and 28days and the strength values are listed in Table 5. Fig. 4 clearly shows that substitution of SAP much not increase the tensile strength in early ages, and the strength values are significantly high in later age i.e. 28 days. The enhancement in strength may be attributed to by providing additional curing water by means of super absorbing polymers (SAP). An internal water reservoir is created into the fresh concrete serving as a curing agent by gradually releasing absorbed water during the hydration process. Mixtures SAP 45, SAP 67.5and SAP 90 showed 19.27%, 17.46% and 8.92% increases in strength when compared to the CM. However a keen observation of Fig. 4 exhibits that the increases in substitution rate SAP beyond 45% (SAP 67.5% and 90%) was affect the tensile strength. Compared to SAP 45, Mixture SAP 67.5and SAP 90 decreased their tensile strength by 1.50% and 9.51% respectively. The decreases in strength can be attributed to as said earlier the demand in cement paste volume which is contributed to the poor interlocking between the aggregate and cement paste.

6.4 Flexural strength

The flexural test on prism specimens were performed at the age of 7 and 29 days and the test results are listed in Table 5. The keen observation of Fig. 5 shows that the effect of SAP on flexural strength is similar to the effect on tensile strength of the concrete. The 28 days flexural strength value of the mixtures SAP 45, SAP 67.5and SAP 90 was 5.40 N/mm^2, 4.91 N/mm^2 and 4.55 N/mm^2 respectively, which is 39.17%, 26.54% and 17.26% higher than the strength values of the CM. however flexural strength values of the concrete decreases with the increases in the SAP content.

7. CONCLUSION

This study demonstrated the effective approach for mitigating the autogeneous shrinkage by means of SAP as an internal curing agent. Compressive strength test, split tensile strength test and flexural strength test were conducted to evaluate the effect of internal curing as a complement to traditional curing in conventional concrete. Based on the test results following conclusions were drawn:

- The workability of the concrete was decrease with the increases in the SAP substitution rate and the poor workability was observed for mixture of SAP 67.5 and SAP 90 when compared to the other mixture.
- In early stage the compressive strength of the mixtures containing SAP content are neither close nor little lower than the control mixture and the contribution of SAP can be well identified at later ages.
- Substitution of SAP significantly mitigates the autogeneous shrinkage and the compressive strength of the concrete increased upon aging.
- Mixtures SAP 45, SAP 67.5 and SAP 90 enhanced their compressive strength by 36.10%, 22.74% and 19.02% when compared to the CM.
- Incorporation of SAP was enhanced the compressive strength of the concrete to some extent and the further increases in substitution rate leads to a decrease in the gain of the compressive strength.
- Substitution of SAP much not increase the tensile strength in early ages, and the strength values are significantly high in later age i.e. 28 days.

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8. REFERENCES

1. Bart Craeye, Matthew Geirnaert, and Geert De Schutter, (2011), "Super absorbing polymers as an internal curing agent for mitigation of early-age cracking of high-performance concrete bridge decks", *Construction and Building Materials*, Elsevier publication, Vol. 25, pp. 1-13.
2. Daniel Cusson, and Ted Hoogeveen, (2008), "Internal curing of high-performance concrete with pre-soaked fine lightweight aggregate for prevention of autogenous shrinkage cracking", *Cement and Concrete Research*, Elsevier publication, Vol. 38, pp. 757–765.
3. Masahiro Suzuki, Mohammed Seddik Meddah, and Ryoichi Sato, (2009), "Use of porous ceramicwaste aggregates for internal curing of high-performance concrete", *Cement and Concrete Research*, Vol. 39, pp. 373–381.
4. Burcu Akcay, and Mehmet Ali Tasdemir, (2010), "Effects of distribution of lightweight aggregates on internal curing of concrete", *Cement & Concrete Composites*, Elsevier publication, Vol. 32, pp. 611–616.

Table 1 Grading of fine and coarse aggregate

Fine Aggregate		Coarse Aggregate	
Sieve Size	% of Passing	Sieve Size	% of Passing
4.75mm	100	19mm	100
2.36mm	90	12.7mm	78
1.18mm	50	9.5mm	31
600 µ	25	4.75mm	0
300 µ	7		
150 µ	2		
Pan	0		
Specific Gravity	2.650	Specific Gravity	2.610

Table 2 Concrete mixture proportions

Mixture	Control Mixture	SAP 45	SAP 67.5	SAP 90
W/C ratio	0.35	0.35	0.35	0.35
Water (kg/m^3)	186	186	186	186
Cement (kg/m^3)	465	465	465	465
Sand (kg/m^3)	603	488.7	431.55	374.54
Coarse aggregate (kg/m^3)	1086	1086	1086	1086
Internal curing water (kg/m^3)	0	45	67.5	90
SAP (kg/m^3)	-	1.05	1.50	2.00

Table 3 Fresh concrete properties

Mixture Designation	Immediate After mixing	After 30 minutes	After 60 minutes
CM	121	85	55
SAP 45	92	55	11
SAP 67.5	54	21	0
SAP 90	35	0	0

Table 4 Compressive strength of all mixtures

Mixture designation	Compressive Strength ((N/mm^2)		
	7 Days	28 Days	90 Days
CM	30.14	40.23	41.56
SAP 45	35.33	54.75	57.12
SAP 67.5	32.41	49.38	50.12
SAP 90	31.25	47.88	48.69

Table 5 Split and flexural strength of all mixtures

Mixture designation	Split tensile strength (N/mm^2)		Flexural strength (N/mm^2)	
	7 Days	28 Days	7 Days	28 Days
CM	3.32	4.48	2.60	3.88
SAP 45	4.05	5.34	3.49	5.40
SAP 67.5	3.90	5.26	3.22	4.91
SAP 90	3.59	4.88	3.08	4.55

Fig. 1 super absorbent polymer

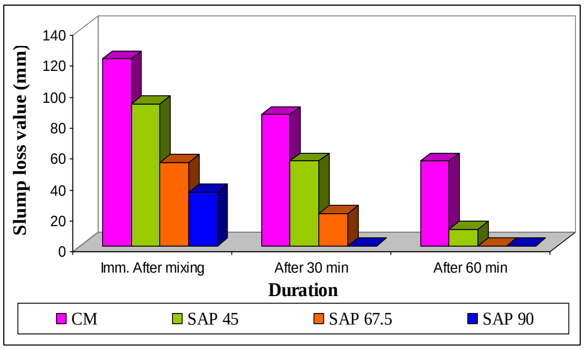

Fig. 2 Slump loss value of concrete for all mixtures

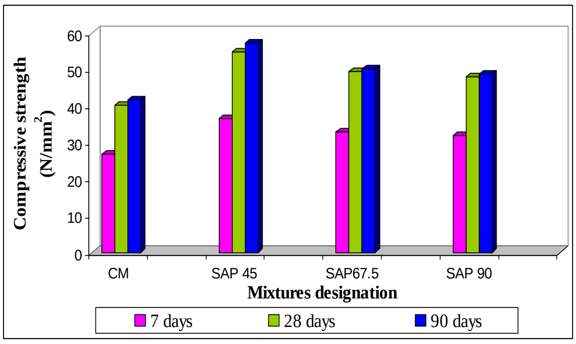

Fig.s 3 Compressive strength of all mixtures

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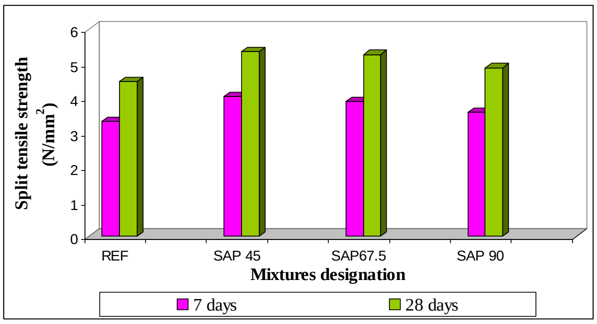

Fig. 4 Split tensile strength of all mixtures

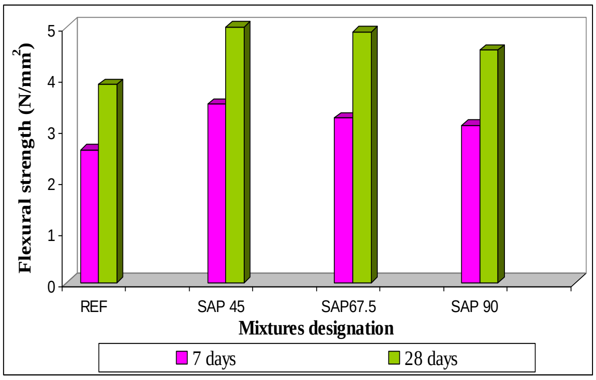

Fig. 5 Flexural strength of all mixtures

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