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Effect Of Small Percentage Additions Of Superabsorbent Polymer On Mechanical Properties Of Concrete

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Abstract— - *Internal Curing of Concrete has been a topic which has been gathering much more interest in the last couple of years coinciding with the growing demand of high strength concrete in construction. It is a method of countering a problem which unfortunately gets more severe in high strength concrete owing to a greater cement ratio and a correspondingly lower water cement ratio. To make matters worse the water which gets used up during the desiccation process leaves behind empty pores which lead to shrinkage stresses which prevents concrete from achieving its maximum achievable strength. Also in high strength concrete (HSC) the rate of absorption of water into the concrete microstructure is more than the rate at which water gets absorbed into the concrete matrix. This is a problem which prevents conventional methods of curing of water from being successfully implemented in HSC. Therefore we turn to alternate materials which can absorb, hold and supply water as required which also fulfils the role of aggregate such as lightweight aggregate or superabsorbent polymers. We could also use shrinkage reducing admixtures like polyethylene-glycol. The water molecules present in these materials are pulled out due to pressure created in the concrete matrix as water is used up during the curing process*. This is also a useful tool for areas where conventional curing is very difficult such as extreme climatic conditions which can lead to excessive evaporation and freezing. Also it will save water losses in sites which is a growing concern in the business as we move towards a more efficient use of our limited resources

Index Terms— Desiccation, Internal Curing, Shrinkage, Superabsorbent polymers, Compressive Strength, Flexural Strength, Split tensile Strength.

1 INTRODUCTION

When mineral admixtures fully react in a blended cement system, the curing water required (external or internal) is much higher than that which is needed in conventional ordinary Portland cement concrete. When this water is not easily available, due to depercolation of the capillary porosity, This leads to significant autogenous deformation and (early-age) cracking.

Due to the chemical shrinkage occurring during cement hydration, voids are created within the cement paste, inducing a decrease in its internal relative humidity as well as shrinkage which causes early-age cracking. This condition is increasingly severe in HPC due to its generally greater cement content, decreased water/cement (w/ c) ratio and the presence of pozzolanic mineral admixtures). The voids created during self-desiccation cause shrinkage stresses and influence the kinetics of cement hydration process, decreasing the final degree of hydration. The strength achieved by internal curing could be more than that possible under saturated curing conditions.

Generally. in High performance concrete,(HSC) it is nearly impossible to supply curing water from the outside or the top surface at the rate required to satisfy the ongoing chemical shrinkage, due to the extremely low permeability's isn't often achieved.

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 implies one achieves conditions such that water is not lost through the surface of concrete i.e., curing is understood to take place 'from the outside to inside'. Conversely, 'internal curing' which is also known as 'self curing' is facilitiating curing 'from the inside to outside' through the reservoirs present inside the system.Ti is for such a system material such as superabsorbent polymers, hydrogels and saturated fine lightweight aggregate are created.

ACI defines "High Strength Concrete is the one which have the compressive strength greater than 41 Mpa". Owing to lower water binder ratio, presence of mineral and chemical admixtures etc., the HSCs usually have many features which distinguish them from Conventional Concrete (CC)

Some of the advantages found in internal curing of concrete are that it reduces autogenous cracking, reduces permeability, largely eliminates autogenous shrinkage, protects reinforcing steel, increases mortar strength, increases early age strength sufficient to withstand strain, provides greater durability, higher early age (say 3 day) flexural strength higher early age (say 3 day) compressive strength, lower turnaround time, improved rheology greater utilization of cement, lower maintenance, use of higher levels of fly ash, higher modulus of elasticity, or through mixture designs, lower modulus sharper edges, greater curing predictability, higher performance, improves contact zone, does not adversely affect finishability, does not adversely affect pumpability, reduces effect of insufficient external curing.

2 PROPERTIES OF MATERIAL

2.1 Materials

2.1.1 Superabsorbent Polymer

Superabsorbent polymer(SAP) is a sodium salt of polyacrylic acids polymer which has applications in consumer applications. This material has the capacity of absorbing 200-300 times its own weight. It is an anionic polyelectrolyte with negatively charged carboxylic groups present in the main branch and positively charged acrylate compounds which attract water.

Using Powers model it is determined that the amount of water required theoretically is 0.18 times the w/c ratio when the water cement ratio is less than 0.36. However as these formulas tend not to take into account the dense microstructure in high strength concrete restricting mobility we will test at slightly higher value. Internally Cured water is added at 30kg/m^3, 50kg/m^3 and 70 kg/m^3.

2.1.2 Curing membrane (sealant)

The curing membrane used is Concure is added over the surface of the material to prevent loss of water to environment. After inital setting time the exposed surface of the samples are coated with the sealant to prevent evaporation loss. After 24 hours the samples are demoulded and the sealant is applied on all the remaining layers. Curing membrane used in this research is Concure WB. It is conforming to ASTM C309-90 standard. Concure WB is a white, low viscosity wax emulsion which uses a specific alkali reactive emulsion breaking system. This assures that the emulsion break down to form an impenetrating continuous film immediately upon contact with a cementitious surface. This impervious film prevents excessive water evaporation which in turn permits more efficient cement hydration, thus reducing shrinkage and increasing durability.

Once formed, the membrane will remain on the concrete surface until eventually broken down and eroded by natural weathering. Where it is required to apply a further treatment to such concrete surface, it may be necessary to remove the membrane remaining after curing by wire brushing or other mechanical means.

Fig 2 : Curing membrane

2.1.3 Super-plasticizer

The super plasticizer used initially was GLENIUM B233 which is a product of BASF. It is a reddish brown liquid with a relative density of 1.08 and a specific gravity of 1.09 which conforms to ATSM C494 and is used in high performance concrete and allowing for high workability without segregation or bleeding.

2.1.4 Aggregate

Sieved coarse aggregate of 20 mm down and 12 mm down at a ratio of 60:40 with a specific gravity of 2.65. The Sand used was river sand with a Fineness modulus of 2.664.

2.1.5. Cement

The cement used was ordinary Portland cement of grade 43 with a specific gravity of 3.006 which conforms to IS 8112 - 1939.

3 TESTING PROCEDURE

3.1 Mixing methodology

The mix designs of the reference cement was chosen so as to achieve a compressive strength of 60-70 MPa as its 28 day strength. The reference mix was cast with a water/ cement ratio of 0.36. Entrained water roughly equivalent to 0.06

For each of the mixes the cement and sand are first added and mixed for about 3minutes until it is thoroughly mixed. Next the aggregate is added and allowed to mix for another 2 minutes Mixing Water and allowed to mix before the addition of pre-wetted superabsorbent polymer. It is allowed to mix for another 2 minutes and placed into moulds.

The minimum additional water content determined to be sufficient theoretically according to Powers Model is said to be 0.18 times the w/c ratio which means an additional 0.06 to the w/c ratio. The predictive formulae's however do not account for water mobility inside the concrete mixture especially in

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HSC. Therefore we consider studying it at higher quantities of internal cured water namely 30kg/m³, 50 kg/m³ and 70 kg/m³.

After initial setting time the exposed surface of specimens are coated and after final setting time the samples are demoulded and the remaining surfaces are coated to prevent loss of water to surroundings

We cast 3 mixes of varying SAP content [0.1,0.15 and .2] with 3 variations in added water content [30kg/m³, 50 kg/m³ and 70 kg/m³]. For the purposes of simplicity we name the mixes with the percentage of superabsorbent polymer first followed by SAP with the additional water content following for E.g. : For superabsorbent polymer of .15% with added internal curing water of 50 kg/m³ we would use the notation 15SAP50.
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Mix Designation	Cement	Sand	Coarse aggregate	Water	Internal cured water	Super plasticizer	SAP
reference	436.36	156.232	791.03	876.75	-	1.19	-
0.10SAP30	436.36	156.232	791.03	876.75	30	1.19	0.654
0.10SAP50	436.36	156.232	791.03	876.75	50	1.19	0.654
0.10SAP70	436.36	156.232	791.03	876.75	70	1.19	0.654
0.15SAP30	436.36	156.232	791.03	876.75	30	1.19	0.873
0.15SAP50	436.36	156.232	791.03	876.75	50	1.19	0.873
0.15SAP70	436.36	156.232	791.03	876.75	70	1.19	0.875
0.20SAP30	436.36	156.232	791.03	876.75	30	1.19	1.091
0.20SAP50	436.36	156.232	791.03	876.75	50	1.19	1.091
0.20SAP70	436.36	156.232	791.03	876.75	70	1.19	1.091

Table 1 : Mix designs of mixes

3.2 Tests Carried Out

The compressive test is carried out on 150 x 150 x 150 mm size cubes, as per IS: 516-1959.SImilarily flexure tests were conducted on 150 x 150 x 500 mm specimens while split tensile tests were conducted on.

The test specimens are marked and removed from the moulds within 24 hrs. The average of 3 samples are tested at 3,7, 28 days for compressive strength while the split tensile strength and the flexural strength are determined in 1 sample tested at age 28 days.

The split tensile test is conducted cylindrical specimens of 150 x 300mm. The Sample is place on its side and a plate is placed above and below it with a loading plate applied to the top Metal strips are used so that the load is applied uniformly along the length of the cylinder. The maximum load is divided by appropriate geometrical factors to obtain the splitting tensile strength. A diametric compressive load is then applied along the length of the cylinder until it fails.

The flexural test setup is shown below and is a 2 point loading setup. The bearing surfaces of the supporting and loading rollers are wiped clean, and any loose sand or other material removed from the surfaces of the specimen where they are to make contact with the rollers (38 mm dia.).The specimen is then placed in the machine in such a manner that the load is applied to the uppermost surface as cast in the mould along two lines spaced at 13.3 cm apart (Two Point Method). The load is increased until the specimen fails, and the maximum load applied to the specimen during the test is recorded. The flexural strength of the specimen shall be expressed as the

ISSN 2229-5518

modulus of rupture f_b, which, if '*a*' equals the distance between the line of fracture and the nearer support, measured on the center line of the tensile side of the specimen, in cm, shall be calculated to the nearest 0.5 kg/sq cm as follows:

Flexural strength, $f_b = \frac{P \times l}{bd^2}$

When '*a*' is greater than 20.0 cm for 15.0 cm specimen, or greater than13.3 cm for a 10.0 cm specimen

Flexural strength, $f_b = \frac{3P \times a}{bd^2}$

When '*a*' is less than 20.0 cm but greater than 17.0 cm for 15.0 cm specimen, or less than 13.3 cm but greater than 11.0 cm for a 10.0 cm specimen.

b= measured width in cm of the specimen,

d= measured depth in cm of the specimen at the point of failure,

l= length in cm of the span on which the specimen was supported,

P= maximum load in kg applied to the specimen.

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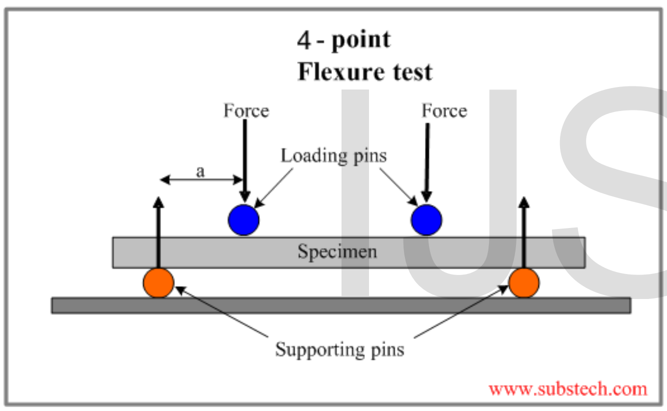

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Figure 3 : Split tensile test

Slump, Slump Flow and V-Funnel tests are carried out to check the workability and flowabilty of the mixs compared to the reference mix.

4. RESULTS

4.1 Compressive Strength

The compressive test is carried out at 3, 7 and 28 days with the average of three samples being taken at the above dates. It is found that the compressive strength of the sample with optimum dosage of SAP is found to be greater than that without SAP if only marginally.

This is due to increased degree of hydration which leads to a dense microstructure. It is noted that the strength of the sample with SAP present at 3 days is lower than that of the reference mix but also that it attains strength at a faster rate than the reference mix at later ages almost catching upto reference mix by 28 days.

mix/AGE(in days)	3	7	28
Reference	30.9	43.4	62
0.10SAP30	23.1	40.4	57.2
0.10SAP50	21.9	38.3	57.43
0.10SAP70	13.7	24.9	39.87
0.15SAP30	27.38	48.97	65.18
0.15SAP50	20.94	40.69	54.85
0.15SAP70	8.58	28.69	41.93
0.20SAP30	25.45	45.85	62.6
0.20SAP50	13.57	33.69	51.01
0.20SAP70	8.76	26.89	40.7

Table 2 : Average Compressive strength at 3, 7 and 28 days

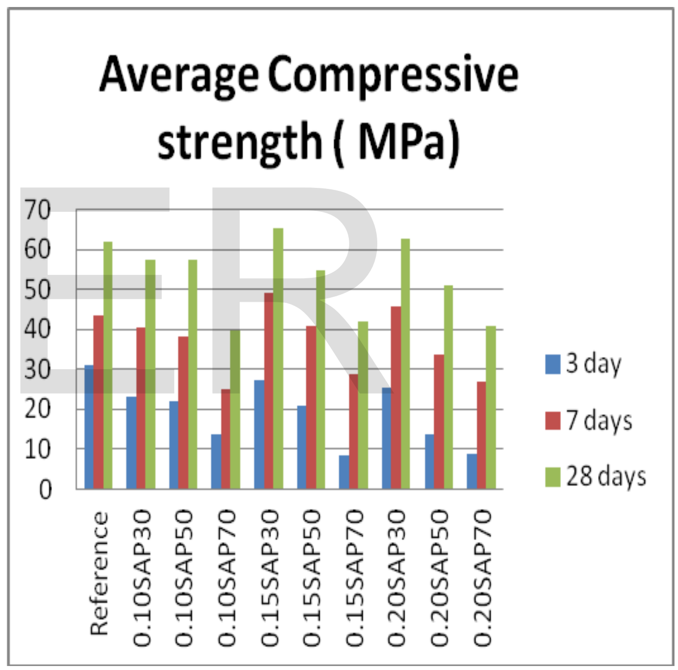

Chart 2 : trends in Compressive Strength vs SAP COntent

4.2 Flexural strength

The Flexural test is conducted at 28 days in a setup as shown above. It is determined that Flexural Strength increases at the optimum dosage of SAP. However the addition of additional curing water has a detrimental effect on the flexural strength in all cases. It is found that for water content of 30 kg/ m^3 the strength is found to increase

ISSN 2229-5518

mix/AGE(in days)	Flexural Strength(in MPa)
Reference	5.102
0.10SAP30	4.853
0.10SAP50	3.957
0.10SAP70	3.443
0.15SAP30	6.043
0.15SAP50	4.08
0.15SAP70	3.61
0.20SAP30	5.102
0.20SAP50	3.532
0.20SAP70	3.139

Table3: Flexural strength at 28 days

mix/age(in days)	Split Tensile Strength(in Mpa)
Reference	3.358
0.10SAP30	3.252
0.10SAP50	2.76
0.10SAP70	2.06
0.15SAP30	3.588
0.15SAP50	2.88
0.15SAP70	2.14
0.20SAP30	2.602
0.20SAP50	2.336
0.20SAP70	1.804

Table 4 : Split tensile strengths

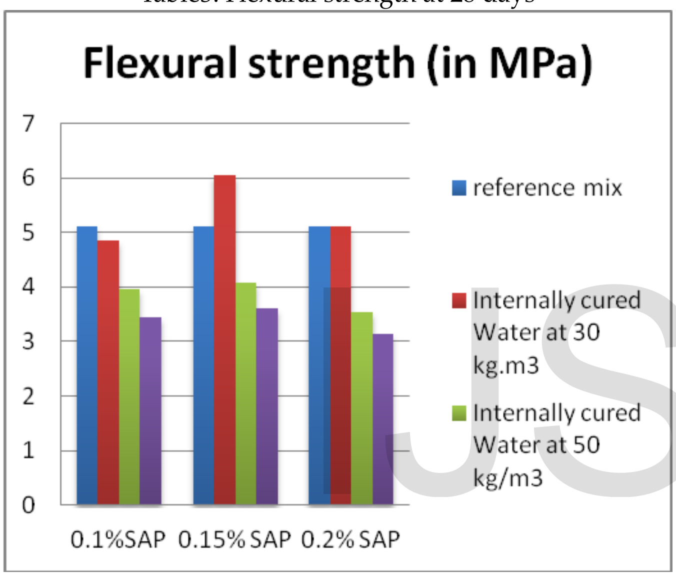

Chart 3 : Indicating trends in Flexural Strength vs SAP content

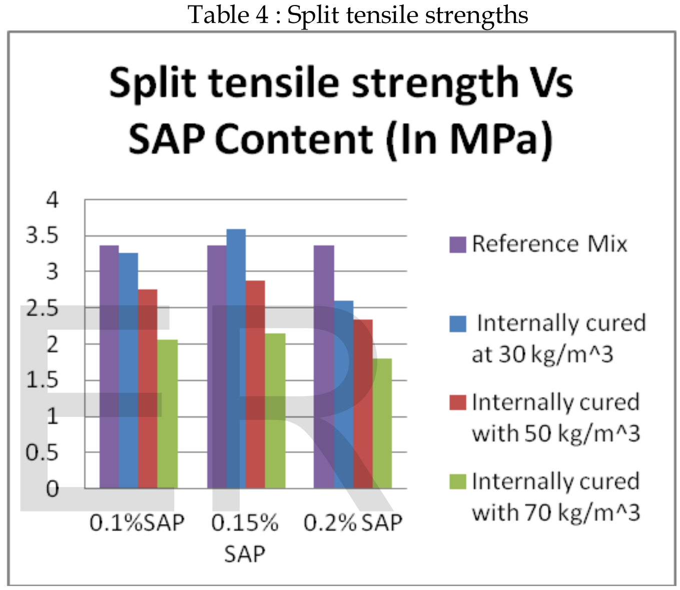

Chart 4 : Graph indicating trends in Split tensile strength vs SAP Content

4.3. Split tensile strength

The split tensile strength is found to decrease with the increase of Superabsorbent polymer generally . However at 0.15 % SAP there is a slight increase over reference mix . This can be attributed to a better degree of hydration as . compared to reference mix which offsets the voids formed by the SAP particles However too much of SAP Particles result in a larger number of voids which result in lower splitting strength as seen in the graph.

5. CONCLUSIONS AND DISCUSSIONS

It is found that

1. The compressive strength of material with SAP is lesser than that of reference mix in general. However at the optimum dosage of 0.15% by weight of cement and 30 kg /m^3 of internally cured water it has a slightly higher value of compressive strength. With the addition of greater amounts of internally cured water this value is found to decrease
2. The flexural strength of SAP infused concrete is greater than that of the reference mixture at .15% by weight of cement. With the addition of greater amounts of internally cured water this value is found to decrease.

ISSN 2229-5518

3. The split tensile strength is found to decrease with the increase of internal cured water as well as the introduction of more superabsorbent polymer.
4. It is noted that most of the samples experience brittle failure .Therefore the usage of fibers to help bridge micro-cracks can be thought of as a possible means of increasing the strength as well.

This type of curing will be highly advantageous in regions of extreme climates where the curing water is inevitably lost due to evaporation or freezing.

However, it should always be noted that this is an ad-mixture which is used primarily to reduce shrinkage most prominently autogenous shrinkage and can results in major losses in strength if higher percentages of SAP are used indiscriminately.

In today's age where material and services are getting more expensive and the focus is on saving resources we can cut a lot of the wastage of water down as well as free up the manpower which is used to constantly curing the concrete.

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