PARAMETRIC STUDY ON MECHANICAL PROPERTY OF CONCRETE USING SELF-SEALING MATERIAL

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Abstract :Researchers tried almost every feasible material to be mixed in concrete to vary some of its properties. To this end, the study proposes a model to predict changes in the amount of water runoff through cracks over time when spherical SAPs in superabsorbent material exhibit rapid swelling by absorbing the first water ingress after the occurrence of cracks. In this research superabsorbent polymer is going to be used as an admixture to improve its water tightness properties especially in aeration basins, concrete tank, and retaining structures. The concrete tries to seal the leak by blocking the water path by semi-solid gels. This gel is the product of the interaction of the superabsorbent polymer with water. Several samples were prepared to study the effect of the superabsorbent polymer on the concrete mechanical properties and on the concrete capability to block the water flow. In this study sodium polyacrylate were used as a super absorbent polymer (SAP). Concrete cubes, concrete beams, and concrete cylindrical samples were prepared to study the concrete strength of concrete mixed with superabsorbent polymer. Also concrete short cylindrical samples were prepared to study the concrete ability to block the water flow. These cylindrical samples are intentionally broken into two approximately equal pieces to create an induced crack. The artificially cracked samples were subjected to water pressure to study the concrete ability to stop the water flow though the induced concrete crack. Two kinds of water pressure are going to be consider in this research; the constant head and the falling head. And we were trying several proportion of superabsorbent polymer to find the optimum amount of doses require to seal the crack.

***IndexTerms* - Mechanical property, concrete, self-sealing, crack, superabsorbent polymer, sodium polyacrylate, cylindrical specimen**

I. INTRODUCTION

However, concrete is prone to cracking when exposed to structural loading or non-structural factors such as thermal effects, shrinkage and physiochemical reactions. So that, a fundamental principle of structural design is that concrete is cracked in the tension zone. Cracking causes leakage and affects water tightness, a critical serviceability requirement for many structures such as basements, retaining walls, reservoirs, dams, tunnels, pipelines and waste repositories. Cracks also act as pathways for aggressive agents, thereby accelerating deterioration mechanisms. Therefore, cracks not only affect water tightness, but also long-term durability and mechanical properties of concrete structures [9]. So that we have to identify the reason behind the crack development. Causes of crack in concrete due to Excess water in the mix that means, Settlement, Drying Shrinkage,Improper strength concrete poured on the job and incorrect selection of cementand other things is Crack most often occur due to lack of expansion and contraction joints. So on provide proper joint bonding and we have to take care about the control joints. And so we have to reduce the flow of water penetration in crack in concrete subjected to certain water pressure here we used superabsorbent polymer. Cracks may heal when exposed to water, but this is usually limited to narrow cracks (0.3mm) and dependent on many conditions such as mix composition, hydraulic pressure and temperature. However, special measures (e.g. external liners and pre-stressing) will be required if no leakage is permitted. Methods such as surface coating, resin injection and integral water resisting admixtures are also often used to prevent leakage, but are not always effective, for example where there is significant movement, e.g. ground subsidence. Coatings deteriorate and require maintenance or reapplication. For successful application in civil engineering structures, new materialsneed to satisfy many criteria including affordability, availability, robustness, durability, performance across a range of exposure environments, chemically inertness and low toxicology.

Superabsorbent polymer (SAP) is a promising class of materials that potentially meets these criteria and Application of SAP to improve frost resistance, SAP for mitigation of autogenous shrinkage and resist the deterioration [7]. Superabsorbent polymers, also known as hydrogels, are cross-linked polymers that have the ability to absorb a disproportionately large amount of liquid, expanding to form an insoluble gel. A unique characteristic of SAP is that its swelling rate and capacity can be altered depending on the polymer type and properties of the liquid including composition, temperature and pressure. For example, the swelling ratio of SAP in deionised water can be greater than 500 g/g, but it drops to about 10–20 g/g in typical concrete pore solution. The swollen gel forms a barrier to flow and it gradually releases absorbed water when the surrounding humidity drops [9].

II. SELF-SEALING AND MATERIAL

Self-Sealing is the ability to stop the flow of water by automatically closing cracks. If concrete can self-seal, blocking penetrations, the material becomes its own waterproofing barrier. This stands in contrast to more-conventional means of waterproofing, which usually involve adding waterproofing admixture to increase the swelling capacity to stop water flow.

Water resisting admixtures are generally divided into solid, crystalline and hydrophobic or water-repellent chemicals. solids and hydrophobic waterproofing admixtures are not considered effective in crack blocking. Some crystalline type admixture may seal very fine cracks, but only by reacting with unreacted cement and moisture to form crystalline products. Advance in materials science have led to the development of a range of smart adaptive materials that heal themselves when cracks develop and this is use for many purposes [7].

Superabsorbent polymer (Sodium Polyacrylate, Polyacrylate/Polyacrylamide Copolymer , Hydrogel, Expanded polymer balls and Others) a SAP may absorb 300 times its weight (from 30 to 60 times its own volume) and can become up to 99.9% liquid. In this research using sodium polyacrylate as a super absorbent polymer. It has high swelling rate. Sodium Polyacrylate is most effective superabsorbent polymer. Superabsorbent polymers, also known as hydrogels, are cross-linked polymers that have the ability to absorb a disproportionately large amount of liquid, expanding to form an insoluble gel [8,9,11]. A unique characteristic of SAP is that it's swelling rate and capacity can be altered depending.

Water-Swelling Rubber Particles is self-Sealing Cementitious Materials. In this, the application of water-swelling rubber particles for providing the cracked concrete a self-sealing function was developed [5].

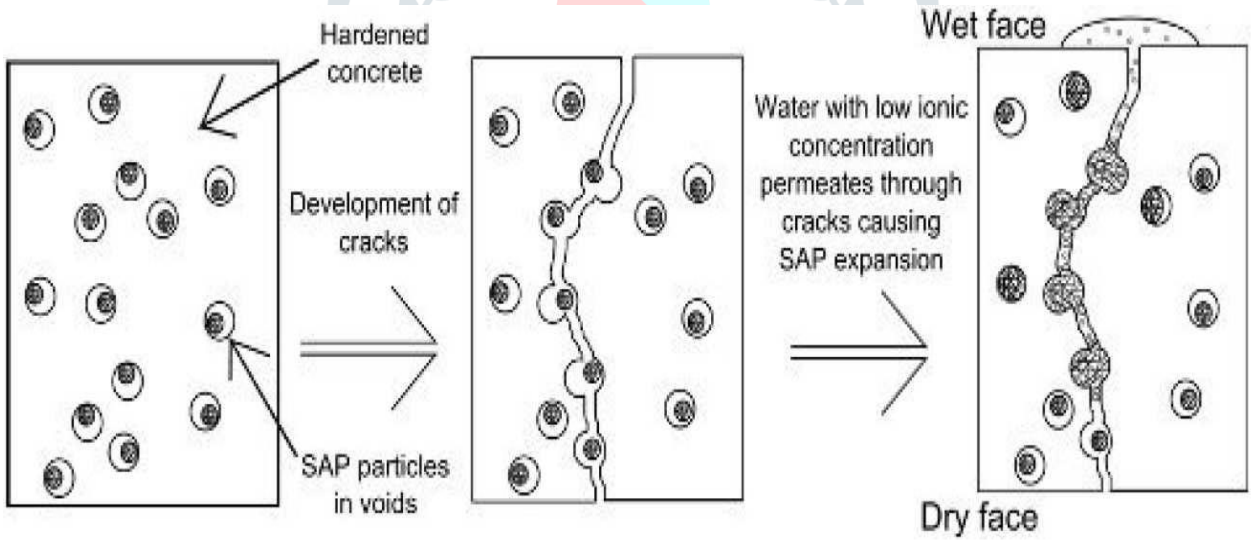
Carboxylic acid waterproofing Admixture for self-sealing watertight concretes. Fumaric acid-based waterproofing admixture improves concrete water tightness [2].

Brittle glass fibers or capsules containing adhesives which is used for self-healing in concrete.

Carbon fiber composite grout used in under flowing conditions to raise the sealing efficiency (SE) and dynamic flowing resistance of slurry, carbon fiber was added into the grout and a new grout for flowing water environmental was provided [3].

III. CRACK SEALING MECHANISM

Illustrates the envisaged self-sealing mechanism. When concrete is batched, the mix water reaches a very high pH (~12.5–13) and ionic concentration (~150–700 mmol/L) within minutes in contact with cement because of rapid dissolution of the cement compounds releasing ions including Ca2+, K+, Na+, OH− and SO4 2−. As such,SAP that is added during batching will initially swell at a much reducedcapacity compared with SAP in freshwater. Calcium ions in the mix water forms a bidentate complex with the acrylates of the SAP, which further limits its swelling. The initial swelling is also confined by the mixing and compaction processes. As cement hydrates and concrete self-desiccates, the SAP gradually releases its absorbed water and shrinks, leaving behind voids of tens to hundreds of microns in size in the cement paste (Fig. a). These voids can be viewed as macro-defects, and so cracks that formduring the service life of the concrete structure are likely to propagate through them (Fig. b). The SAP lies dormant in the microstructure until a crack occurs through the SAP voids, exposing the polymer to the external environment. When the concrete is then subjected to wetting, ingress of water triggers the SAP to swell again. External fluids such as precipitation and groundwater havemuch lower ionic concentration compared to concrete pore solution and so the re-swelling of SAP will increase significantly. The reduced physical confinement will also increase the re-swelling capacity of the SAP. The swollen SAP forms a soft gel that expands beyond the void and into the crack, subsequently slowing down or preventing further flow (Fig. c) [9,12].



(a) SAP is added to concrete during Batching, initial swelling (S_1) is confined. As concrete hardens, the SAP shrinks and Lies dormant in the microstructure.
(b) Subsequent cracking propagates Through SAP voids, exposing the polymer.
(c) Ingress of water causes SAP to swell (S_2), expanding into crack and restriction further flow.

Fig. 1 Sealing mechanism of crack by using SAP

IV. THEORY AND METHODS OF CRACK SEALING

This section comprises some of the literatures used for various methods of inducing crack and various techniques of measuring flow through crack and check sealing capability of crack through superabsorbent polymer.

4.1Inducing Crack

H.X.D. Lee, H.S.Wong, 2015 [2] have proposed a new method for inducing crack was induced at the centre of each sample by tensile splitting using the loading device Pressure was applied through a metal bar placed at the tip of each sidegroove of the sample. The applied pressure was gradually increased until a single through crack was produced. This procedure was very effective because the shape of the sample lends itself to splitting between the grooves without producing visible broken pieces. The distance between the tips of each side groove i.e. the crack breadth was 30 mm. The cracked sample was then briefly taken apart and reassembled to ensure that a complete through crack was produced. A silicone rubber seal attached to a thin stainless-steel plate was fitted into the side grooves of the sample. A set of Perspex strips was then inserted into the side grooves and the assembled sample was held together using three stainless-steel hose clamps. The width of the crack was adjusted by adjusting the Perspex inserts and clamps. Tightening the Perspex strips widens the crack, while tightening the hose clamps reduces crackwidth. A stereomicroscope and image analysis were used tomeasure the crackwidth on six locations on the top and bottom flat surfaces of each sample, and the results were averaged. An angled light source was used to enhance the contrast of the crack and to increase the accuracy of the crack width measurement. In total, forty samples with average crack widths ranging from 0.1 mm to 0.4 mm were prepared in this manner for testing [9,13].

In order to evenly disperse the SAPs across the specimens, materials were mixed in accordance with the ISO 679 after dry mixing the cement and the SAP for 1 min. Disc-shaped mortar specimens with a diameter of 70 mm and height of 30 mm were fabricated to conduct the water flow test. A straight stainless steel wire with a diameter of 0.3 mm was installed in a direction perpendicular to the cracks in the specimen to prevent a specimen from being split apart while cracks were induced [1].

The samples of the water flow test are of cylindrical shape. Its height is 10 mm, and its diameter is 35 mm. The objective of the test is study the ability of the concrete to block the water flow through an induced artificial crack. Each water flow sample is broken into almost two equal parts, then these parts are put together again. The assembled sample represents a crack in the concrete of 10 mm depth, and width of 35 mm [4].

A concrete specimen used for indirect tension was considered. A custom jig was designed that produced cracks that were consistent, repeatable, and realistic.

The jig designed for the indirect tension crack testing produced a single crack from one side of the cylinder to the other, both longitudinally and across the cross section, as well as held the sample together after cracking. The jig incorporated two cutting edges that created a line of high-stress concentration on each side of the sample. The concentrated loads caused a single linear crack from point to point on the sample [12].

4.2 Techniques of Measuring Flow Through Cracks

The heart performances as a pump that regulates oxygen and blood around the body in order to keep it active. When the body is exercised the rate of heart beats in varied condition related to the volume of effort which is used. By noticing the effort applied by the beating of the heart, rate can be perceived.

The test specimens for the water flow test and the X-ray computed tomography (CT) analysis were completely wrapped to prevent water from flowing into other parts besides cracks. During the water flow test, the water pressure head of the water ingress provided for the specimens with a height of 30 mm was uniformly maintained at 20 mm. analyze the x-ray and CT image and also check for the swelling ratio [1,5].

The water flow sample is placed back in its mould, and then placed in a steel casing. The steel casing is then placed in the testing chamber in such way that the water has no path to flow but to flow though the concrete sample and in particular through the concrete crack. Water pressure is applied at the top side of the water flow sample. The samples were subjected to both constant water pressure (constant head) and decreasing water pressure (falling head). These two different types of pressure are used in this experiment to study the effect of the water pressure on the sealing capability of concrete [4,15].

The samples are subjected to average water pressure that varied from 175 cm. The time it takes for the water pressure to drop from 175 cm is measured and recorded. The amount of water that flows through the samples will be constant of about during the drop of the water pressure by 10 cm. The discharge though the sample can be calculated using the following equation (1):

$$Q=V/t \quad (1)$$

Where; Q= water flow rate in cm3/min
V= volume of water passing through the sample in cm3
t = the measured time that takes the pressure to drop from average 175 cm [10].
Several samples mixed with SAP were prepared to test the concrete samples in compression, tension and bending. Andexperiment to measure the concrete stability using SAP compared to plain concrete. And in this study one major observation one can make is that the concrete improves its plasticity and consistency with SAP [13].
One set-up was develop for the checking of water penetration rate and after that by using Scanning electron microscopy in the backscattered mode showed other microstructural changes due to the presence of SAP including the modified distribution of cement particles, large portlandite deposits and some microcracking at the SAP-paste interface [9,14].

4.3 Effect of SAP on Compressive Strength

Table. 1 Result of 0% SAP

0 % SAP (Mpa)				
Result (7 days)	Sample 1	Sample 2	Sample 3	Average
	16.12	13.07	14.00	14.39

Table. 2 Result of 0.1% SAP

0.1 % SAP (Mpa)				
Result (7 days)	Sample 1	Sample 2	Sample 3	Average
	17.42	12.72	15.81	15.31

Table. 3 Result of 0.2% SAP

0.2 % SAP (Mpa)				
Result	Sample 1	Sample 2	Sample 3	Average
(7 days)	11.94	15.95	14.61	14.16

Table. 4Result of 1% SAP

1 % SAP (Mpa)				
Result	Sample 1	Sample 2	Sample 3	Average
(7 days)	11.59	9.52	13.2	11.43

Table. 5Result of 2% SAP

2 % SAP (Mpa)				
Result	Sample 1	Sample 2	Sample 3	Average
(7 days)	6.95	9.28	8.26	8.16

Fig. 2 (A) Before compression test on specimen (B) After compression test on specimen

V. CONCLUSION

From above literature there are different test technique and method of analysis to perform the experimental work. In this the best technique to inducing crack is describe in paper 11. From different types of chemicals and minerals admixture like carbon fiber composite grout, superabsorbent polymer, carboxylic acid, kryton's crystalline chemical, water swelling rubber particles etc. use to check the effects on mechanical properties of concrete and after that the effective admixture is superabsorbent polymer.

In this research we conclude that get the maximum compressive strength on 0.1% SAP dosage. And if SAP dosage increase that time it is very effective on compressive strength and compressive strength decrease as increasing SAP dosage and it shown in above table in 2% SAP dosage.

Self-sealing effect in concrete depends on different conditions and sealing mechanism of crack. Most effective material is superabsorbent polymer like sodium polyacrylate absorb water up to 250-300 times of its own weight and make the concrete self-seal and it is effective and best suitable material comparatively others.

Optimum dose of superabsorbent polymer is 0.1% of Portland cement. Probably use of admixture compressive strength of concrete if improve but there is no effect on tensile strength and flexural strength of concrete.

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