# INFLUENCE OF SELF HEALING CONCRTE IN RECENT THRENDS IN CONSTRUCTION ACTIVITIES

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**ABSTRACT**: - Concrete has become the most widely used material in the world after the invention of Ordinary Portland Cement. Concrete comprises of cement, fine aggregates, coarse aggregates and water. Though cement is responsible for providing strength and durability to the structures, for every tonne of cement produced, the same amount of carbon dioxide has been liberated into the atmosphere. For introducing sustainability in the field of concrete technology, cement can be replaced with certain eco friendly admixtures. Silica fume, fly ash, rice husk ash which are posing disposal problems due to very fine particle size can effectively be replaced for cement. In addition, construction and demolition wastes can also be used in the place of coarse and fine aggregates. A large number of innovations are going on in the field of concrete technology in order to provide strength and durability parameters to concrete structures.

In this research work, admixtures like silica fume, fly ash, recycled aggregates and rice husk ash has been used as healing agents and the healing efficiency of self healing concrete has been determined by mechanical and durability properties. The effects of self- healing on normal M30 concrete by replacing small amounts of silica fume, fly ash, rice husk ash for cement and recycled aggregates in partial replacement of coarse aggregates has been studied. For this purpose, 12.5% silica fume, 25% fly ash, 15% rice husk ash has been replaced for cement and based on the previous researches, recycled aggregates have been replaced 50% for coarse aggregates and the healing effect has been studied. The water cement ratio has been kept constant for all the mixes as 0.45. In order to provide workability, SNF based super plasticizer has been added to the concrete mix. Strength tests like compressive strength, split tensile strength, flexure strength, Ultrasonic Pulse Velocity Test has been carried out initially at 28 days for normal concrete, 12.5% silica fume replaced concrete, 25% fly ash replaced concrete, 50% recycled aggregate replaced concrete and 15% rice husk ash replaced concrete mixes. Then the specimens were subjected to 80% preloading in order to induce micro-cracks and the same tests have been carried out for checking the reduction in strength due to cracking. Then the preloaded specimens were kept for another 28 days in water so as to enable healing reaction and at the end of 56 days, the same tests have been carried out on the healed specimens to check whether due to healing reaction, the specimens were able to regain the original strength or not.

**Keywords:** Self-healing, admixtures, preloading, micro-cracks, sustained loading, mathematical modeling, portlandite, anorthite.

## I INTRODUCTION

Self-healing of concrete, a similar phenomenon like healing of injuries in a human body is gaining momentum in the field of concrete technology. Self-healing of concrete comprises complicated physical and chemical processes. Formation of calcium carbonate, hydration of un-reacted cementitious materials and swelling of CSH contributes for self-healing process. Cracks healed using admixtures in concrete are termed as autogenic healing. The use of mineral admixtures and expansive agents poses many advantages as well as has some disadvantages.

Self-repair of cracks made with the help of bacteria will be practiced for still 200 years because of its easy and potentiality to heal the cracks effectively. Cracks formed in structures pave the way for entry of moisture, which activates the bacteria for precipitating calcium carbonate. Formation of CaCO3 utilizes oxygen, which aids in preventing the corrosion of steel, thereby increasing the durability of structures. Bacteria to be used in concrete for self healing must meet certain criteria. Bacteria used in concrete must be able to withstand the high alkalinity nature of concrete. SEM images show the evidence of calcite precipitation in concrete.

Self-healing of concrete sometimes takes place naturally in the presence of rain water and carbon dioxide. Some other mechanisms contributing to self-healing are further hydration of cement or other binding particles and swelling of un-reacted particles. Crack width of 400µm can be sealed completely using suitable supplementary materials. The process of self-healing can be distinguished into two mechanisms. Self-tightening – small particles from crack faces or small particles present in water added to concrete block the

Cracks. Self-healing chemical reaction is like further hydration of cement or admixtures or precipitation of calcium carbonate. Crack healing is efficient for lower crack widths and at higher temperature self-healing can best be quantified by means of conducting elastic modulus test.

Present concrete structures are less susceptible to autogenous healing due to coarse particles as well as low availability of un-hydrated cement particles which is responsible for the formation of calcium hydroxide and calcium carbonate. Some researchers have already suggested adopting low water binder ratios in the mix design, thereby facilitating the availability of more un-hydrated particles for autogenous healing to take place. Though the use of admixtures like fly ash and blast furnace slag decreases the strength of concrete, their use as a self-healing material is highly appreciable. Their appreciable self-healing potential is because of slow hydration process. Research has shown that fly ash can be replaced up to 85% and in general, can be said, higher the replacement percentage of slag and fly ash, higher will be the self-healing capacity. It has also been found out that, the healing products form in the pores. When the pores no longer can be filled by the healing products, the hydration reaction stops.

In addition to considering durability and stability of structures, water tightness plays an important role to consider the functional life of structures. The aspect of water tightness can be achieved by introducing special membranes or by changing the composition of normal concrete. Reduction of water tightness in structures is due to the formation of tensile cracks. But in due course of time, due to the hydration process of un- hydrated cement particles or admixtures, if any, can help the cracks to heal automatically.

For a successful self-healing mechanism to take place in concrete structures, crack width plays a major factor. For self-healing, the crack width must be 50µm to 100µm, the optimum being 30µm according to research studies. If the crack width is still narrow, 100% possibility is there for intrinsic self-healing. To achieve controlled crack width for research purposes, addition of fibres come handy. Admixtures added in powder form poses workability issues whereas the healing efficiency improved when the admixtures are added in granular form. Even, engineered cement composites, a special type of high performance fibre reinforced cementitious can be used effectively.

From many research findings, it is obvious that additional water is required for self-healing which is not at all a problem for underground structures whereas for above ground structures, the additional water needed must be a very important criteria to be taken care of. If fly ash is used as an admixture in concrete, it produces CSH gel very easily due to its pozzolanic reaction without taking the aid of any additional water which in turn helps in achieving self-healing.

**Objectives:-**

- To discuss the effects of self-healing of concrete made with OPC and also by adding mineral admixtures like silica fume, fly ash, recycled aggregates and rice husk ash
- To study the effects of self-healing on normal concrete incorporating the mineral admixtures when subjected to continuous water exposure are to be studied
- To conduct experiment for assessing the healing effect using beam crack width and depth determination before and after healing in flexure prisms for all the admixtures used
- To investigate the effectiveness of utilizing the healing effect in concrete structures, a reinforced beam to be cast and the effect of sustained loading on self-healing capacity of RC beam with one admixture (Rice Husk Ash) is to be carried out for a sustained loading period of 10 months.

## II METHODOLOGY

The effects of self-healing has been studied on Normal Concrete (NC) with Ordinary Portland Cement (OPC) and also by replacing admixtures like Silica Fume (SF), Fly Ash (FA), Rice Husk Ash (RHA) for cement and by replacing Recycled Aggregates (RA) for coarse aggregates. For this purpose, silica fume was replaced at percentages of 0%, 2.5%, 5%, 7.5%, 10%, 12.5%, fly ash in replacement percentages of 0%, 5%, 10%, 15%, 20%, 25%, 30%, recycled aggregate replacement percentage of 50%, and rice husk ash with replacement percentages of 0%, 5%, 10% 15% and 20%. The adopted water cement ratio has been kept as 0.45 and SNF based super plasticizer was used to provide workability. 3 set of specimens were used for testing the healing effect. After finding the ultimate compressive load in the first set of specimens, 70% of ultimate load was applied on the second set of specimens to induce micro cracks. Then the specimens were kept under water for healing process to take place. Then the specimens were checked again for ensuring whether healing process has taken place or not.

The specimens were tested for mechanical properties like compressive strength at 28 days initially, after preloading and then after healing, split tensile strength and flexural strength at 28 days and Ultrasonic Pulse Velocity Test (UPVT) initially, after inducing micro cracks and after healing. For studying the durability aspects of self-healing concrete, water absorption test and Rapid Chloride Permeability Test (RCPT) has been conducted initially, 70% preloading and then after healing.

## III RESULTS

Table 1 Marsh cone test results

| Dosage | Initial flow | Flow after 1 Hour |
|---|---|---|
| 0.50 | 37 | 53 |
| 0.60 | 28 | 35 |
| 0.70 | 24 | 31 |
| **0.80** | **22** | **22** |
| 0.90 | 22 | 22 |
| 1.00 | 22 | 22 |
| 1.10 | 22 | 23 |

From the Marsh cone test, it has been evident that 0.80% dosage is the optimum dosage of super plasticizer to be added to the mix.

Table 2 Compressive strength results for M30 mix

| Specimen details | Compressive strength test results (MPa) | | |
|---|---|---|---|
| | 7 days | 14 days | 28 days |
| NC 1 | 25 | 35 | 39 |
| NC 2 | 26 | 36 | 40 |
| NC 3 | 26 | 36 | 40 |
| NC 4 | 26 | 36 | 40 |
| NC 5 | 26 | 38 | 42 |
| NC 6 | 24 | 41 | 46 |
| NC 7 | 24 | 39 | 44 |
| NC 8 | 25 | 34 | 38 |
| NC 9 | 27 | 36 | 40 |
| NC 10 | 26 | 39 | 44 |
| **Average** | **25** | **37** | **41** |

Table 3 Compressive strength values for silica fume mix, 12.5% as optimum

| Specimen details | 7 days strength | 14 days strength | 28 days strength |
|---|---|---|---|
| SF 1 | 26 | 36 | 40 |
| SF 2 | 26 | 36 | 40 |
| SF 3 | 28 | 39 | 44 |
| SF 4 | 29 | 40 | 45 |
| SF 5 | 27 | 37 | 41 |
| SF 6 | 26 | 37 | 41 |
| SF 7 | 28 | 38 | 42 |
| SF 8 | 25 | 35 | 39 |
| SF 9 | 29 | 40 | 44 |
| SF 10 | 28 | 39 | 43 |
| **Average** | **27** | **38** | **42** |

Table 4 Compressive strength values for fly ash mix, 25% as optimum

| Specimen details | 7 days compressive strength | 14 days compressiv e strength | 28 days compressive strength |
|---|---|---|---|
| FA 1 | 31 | 42 | 47 |
| FA 2 | 32 | 44 | 49 |
| FA 3 | 31 | 43 | 48 |
| FA 4 | 32 | 44 | 49 |
| FA 5 | 32 | 44 | 49 |
| FA 6 | 32 | 45 | 50 |
| FA 7 | 33 | 45 | 50 |
| FA 8 | 32 | 44 | 49 |
| FA 9 | 32 | 45 | 50 |
| FA 10 | 32 | 44 | 49 |
| **Average** | **32** | **44** | **49** |

Table 5 Compressive strength values for recycled aggregate mix, 50% replacement

| Specimen details | Compressive strength test results (MPa) | | |
|---|---|---|---|
| | 7 days | 14 days | 28 days |
| RA 1 | 25 | 35 | 39 |
| RA 2 | 25 | 35 | 38 |
| RA 3 | 27 | 37 | 41 |
| RA 4 | 29 | 40 | 45 |
| RA 5 | 28 | 38 | 43 |
| RA 6 | 28 | 39 | 44 |
| RA 7 | 26 | 36 | 40 |
| RA 8 | 26 | 36 | 40 |
| RA 9 | 25 | 35 | 39 |
| RA 10 | 28 | 38 | 42 |
| **Average** | **26** | **36** | **41** |

Table 6 Compressive strength values for rice husk ash mix, 15% as optimum

| Compressive strength test results (MPa) | | | |
|---|---|---|---|
| **Specimen details** | **7 days strength** | **14 days strength** | **28 days strength** |
| RHA 1 | 29 | 41 | 45 |
| RHA 2 | 28 | 39 | 44 |
| RHA 3 | 30 | 41 | 46 |
| RHA 4 | 29 | 40 | 45 |
| RHA 5 | 30 | 41 | 46 |
| RHA 6 | 30 | 42 | 46 |
| RHA 7 | 30 | 41 | 46 |
| RHA 8 | 29 | 40 | 44 |
| RHA 9 | 30 | 42 | 47 |
| RHA 10 | 29 | 40 | 44 |
| **Average** | **29** | **41** | **45** |

Table 7 Split tensile test results of OPC mix

| Specimen details | 28 days split tensile strength (MPa) |
|---|---|
| NC 1 | 2.12 |
| NC 2 | 2.32 |
| NC 3 | 2.25 |
| NC 4 | 2.19 |
| NC 5 | 2.53 |
| NC 6 | 2.04 |
| NC 7 | 2.93 |
| NC 8 | 1.76 |
| NC 9 | 2.76 |
| NC 10 | 2.86 |
| **Average** | **2.38** |

Table 8 Split tensile test results of fly ash mix

| Specimen name | 28 days split tensile strength (MPa) |
|---|---|
| FA 1 | 2.30 |
| FA 2 | 2.29 |
| FA 3 | 2.32 |
| FA 4 | 2.34 |
| FA 5 | 2.28 |
| FA 6 | 2.32 |
| FA 7 | 2.37 |
| FA 8 | 2.30 |
| FA 9 | 2.37 |
| FA 10 | 2.34 |
| **Average** | **2.32** |

Table 9 Split tensile test results of silica fume mix

| Specimen details | 28 days split tensile strength (MPa) |
|---|---|
| SF 1 | 1.96 |
| SF 2 | 2.15 |
| SF 3 | 2.17 |
| SF 4 | 2.28 |
| SF 5 | 2.36 |
| SF 6 | 2.23 |
| SF 7 | 2.43 |
| SF 8 | 2.19 |
| SF 9 | 2.29 |
| SF 10 | 2.15 |
| **Average** | 2.22 |

Table 10 Split tensile test results of all mixes

| Specimen details | 28 days split tensile strength results (MPa) |
|---|---|
| Conventional M30 mix | 2.38 |
| 12.5% silica fume replaced mix | 2.22 |
| 25% fly ash replaced mix | 2.32 |
| 50% recycled aggregate replaced mix | 2.24 |
| 15% rice husk ash replaced mix | 2.29 |

## IV Conclusions

The following conclusions can be made from the research work carried out:

1. Based on the strength tests like compressive test, split tensile test and flexural test, the admixture added mixes gave good results like that of conventional M30 mix. Recycled aggregate added mix gave similar values like that of conventional mix, while silica fume, fly ash and rice husk ash added mixes gave higher strength values compared to nominal mix
2. Based on UPVT, compressive strength after healing values, water absorption test and RCPT values, it has been evident that, among the admixtures used in this research work, silica fume and rice husk ash proved to be good healing agents because of their fine particle size and good packing effect
3. Comparing the crack width and depth closure abilities, silica fume and rice husk ash mixes gave a satisfactory healing effect
4. Based on the test conducted on reinforced beam under sustained loading, rice husk ash proved to be a remarkable healing agent which can very well be adopted practically for crack healing
5. Based on the chemical tests carried out, in all the admixture added mixes, presence of healing compounds was noticed and to be specific, the silica content in the admixture played a vital role in effecting self healing ability in the concrete mixes. Silica fume and rice husk ash being high in silica content gave good quantity of healing products and in the specimens containing these two admixtures, crack closure ability was a bit faster and even good efficiency being obtained with regard to crack closure
6. From mathematical modelling, it has been evident that for the future years, if the same type and quantity of admixtures are used for self healing, the strength can be predicted. From the strength prediction values of fly ash mix shown as an example, when the pores no longer can be filled by the healing products, the hydration reaction stops. Once the reaction stops, the strength gain will not be possible and the same strength will be maintained till the structure is subjected to any disturbance or deterioration.

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