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EXPERIMENTAL STUDY ON FIBER REINFORCED CONCRETE FOR SELF-HEALING WITH NANO SILICA AND CRYSTALLINE ADMIXTURE

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Abstract: In this study the capability of Fiber reinforced concrete to self-heal against various environmental exposures namely Water Immersion (WI), Water Contact (WC), Wet Dry cycles (WD) & Air Exposure has been studied. A total of 8 mixes were cast and two of them for plain concrete with one containing crystalline admixture (CCA) and other not. Further mixes were also cast in the same manner i.e. with and without crystalline admixture but Nano silica was replaced at constant rate of 1%, 2% & 3%. At the end of 28 days curing cracks of size varying 0.10mm to 0.40mm were induced in the specimens and cured for respective exposures and tested for regained strength over a period of 7,14, 28 & 42 days. At last it was observed all the mixes containing crystalline admixture (CCA) has given exceptional recovery of healing and strength. However, mix containing 2% of Nano silica replacement and 1% of crystalline admixture (CCA) addition has given 100% efficiency over self-healing and strength restoration for the exposures Water immersion (WI) and Wet Dry cycles (WD).

IndexTerms **- Nano silica, crystalline admixture, Self-healing concrete.**

I. INTRODUCTION

Concrete is one of the popular and important sources for construction and always stands asthe choice of engineers. Even though it has the number of benefits like high strength, long life and susceptibility to over loads still the major drawback was the emission of carbon dioxide from the cement which was an ingredient of concrete. As to keep the environment safer, several mineraladmixtures like Fly ash, Silica fume, Metakaolin etc. were replaced in the concrete. Nano silica was the best suited for self-healing, although it costs more still it has the impeccable advantages which are as follows.

Role played by the Nano silica:

1. It acts as the filler for left over empty voids.
2. Well distributed Nano particles act as crystallization centers of hydrated products there byincreasing hydration rate.
3. Improve the structure of transition zone present in between the aggregate and paste.
4. Assist towards the formation of smaller $Ca(OH)_2$ crystals and homogeneous clusters of C-S-Hcomposition.
5. Reduce calcium leaching, enhancing strength which leads to increment in durability.

Even after attaining the greater strength with replacements of various mineral admixtures and yet the concrete was liable to the formation of cracks. With the age various chemicals and chlorides were penetrating in to the cracks and weakening the concrete. As one cannot keep money and time for continuous inspection, an alternative solution for the problem named Self-healing was introduced and started an era. Self-healing was categorized as autogenous and autonomous healing. Autogenous healing is a natural healing in which the process will takes place with the help of impurities present in the water, heat of hydration between the left over particles at the initial stages, calcium carbonate or calcium hydroxide formation and finally expansion of C-S-H gel. On the other side, Autonomous healing will require the human help and act as active modes and passive modes. There is no activation required for passive mode but the active mode will require it.

II. EXPERIMENTAL SCENARIO

The detailed information regarding the materials used and the process followed was listed below.

The materials which were used for this study are cement, sand, aggregate, water, crystalline admixture, steel fibers & super plasticizer. Cement used in the study was belongs to the OPC 53 grade. The individual properties of the cement were determined and they are satisfying the limits of IS: 12269-1987. Sand used was completely river sand but the aggregates were used in two proportions i.e. 12 mm aggregate at 30% and 20 mm aggregate at 70%. River sand used was belongs to the zone II and specific gravity of 20mm and 12 mm aggregates were obtained as 2.72 & 2.67 respectively.

2.1 NANO SILICA

When dimensions are shrunk from macro to Nano size, significant improvement will take place in the properties like optical absorption, chemical reactivity, and electronic conductivity and also for the mechanical properties which leads to allocation of more atoms on the surface. The specific properties of the Nano silica which has been provided by the Nano research lab have been listed below.

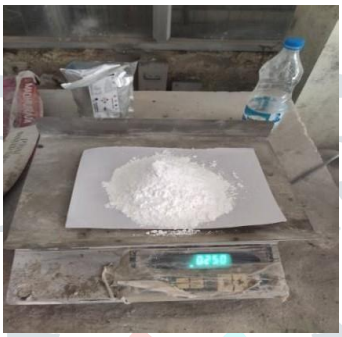


Fig.1. nano silica

table.1. individual properties of nano silica

S.no	Name of the property	Result obtained
1.	Actual particle size (APS)	30-50 nm
2.	Specific surface area (SSA)	200-600m^2/g
3.	Colour	White
4.	Form	Powder
5.	Morphology	Spherical
6.	Purity	99.9%
7.	True density	2.5 g/cm^3
8.	Bulk density	0.10 g/cm^3

2.2 Crystalline admixture

The crystalline admixture used in this study was Xypex C-2000NF. Based on the previous researchers 1% of the crystalline admixture has been used as additive in the study. It has shown the exceptional healing over the period of 42 days rather compared with the 28 days healing. With the increase in age the Xypex C-2000NF has shown an efficient healing on all the exposure conditions. Even for the Air exposure it has attained a better pozzolanic reaction with the moisture present in the air and there by leads to the C-S-H gel formation. So that C-S-H gel was the main required componentfor the healing.

2.3 Steel fibers

As concrete was weak in the tension zone the steel fibers incorporated in the concrete would nicely handle the tensile stresses. With reference to the previous researcher's study weight of steel fibers were chosen as 2% by weight of cement. Basic properties of the steel fibers were summarized below.

table 2. dimensions of the steel fibers

S.no	Name of the property	Obtained value
1.	Diameter	0.12mm
2.	Length	10mm

2.4 Super plasticizer

Conplast SP430 has been used as the super plasticizer and it has water reducing capability of 25%. In this study it was added at 1% by weight of cement.

2.5 Water

PH limits of the water has been completely followed as per the IS 456-2000.

III. MIX PROPORTIONS

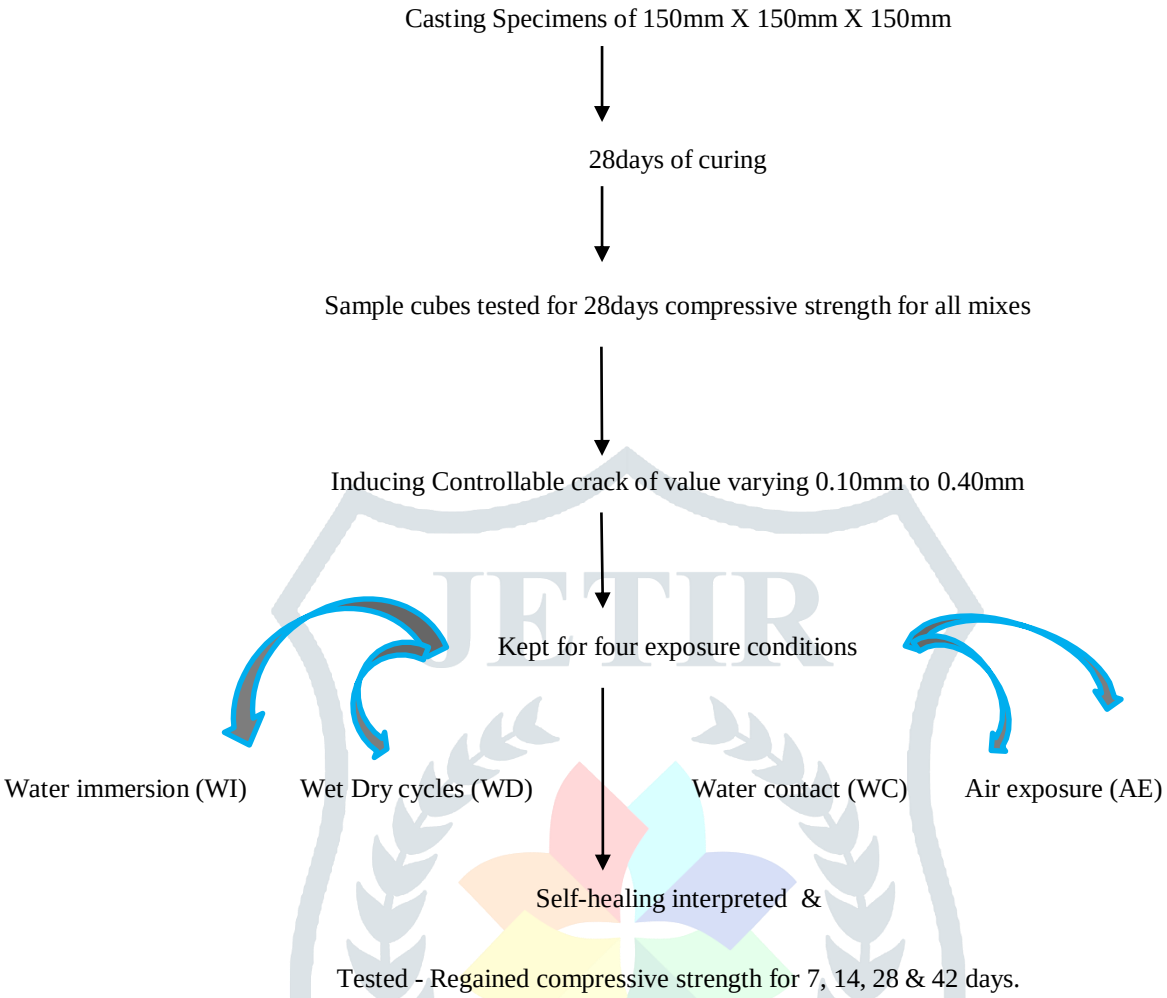
A total of 8 mixes were cast and two of them were plain concrete with one containing crystalline admixture and other not. Rest of the mixes were also cast in the same manner i.e. with and without crystalline admixture but the replacement of Nano silica was kept at constant at a rate of 1%, 2% & 3%. All the mixes were designed conforming to the IS 10262-2019 with a constant W/C ratio 0.35. The compositions of all the materials were listed in the table below.

table.3. mix proportions for with and without CCA

Mix	Nano silica (%)	Nano Silica (kg/m^3)	Cement (kg/m^3)	FA (kg/m^3)	CA (kg/m^3)		Water (lit/m^3)	SP (Lit/m^3)	CCA (kg/m^3)	SF (kg/m^3)
					12mm	20mm				
PC	0	0	411	660	380	887	144	4.11	0	8.22
PC-WX	0	0	411	660	380	887	144	4.11	4.11	8.22
NS1	1	4.11	406.89	660	380	887	144	4.11	0	8.22
NS2	2	8.22	402.78	660	380	887	144	4.11	0	8.22
NS3	3	12.33	398.67	660	380	887	144	4.11	0	8.22
NS1-CCA	1	4.11	406.89	660	380	887	144	4.11	4.11	8.22
NS2-CCA	2	8.22	402.78	660	380	887	144	4.11	4.11	8.22
NS3-CCA	3	12.33	398.67	660	380	887	144	4.11	4.11	8.22

IV. TEST METHODOLOGY

Following flow chart will give you a clear description about the sequence of the variousprocesses.



V. INTERPRETATION OF RESULTS

The Regained compressive strength for 28 & 42 days were represented in the graphs below. It was found that the compressive strength obtained for the mix containing 2% of Nano silica replacement and 1% of crystalline admixture addition was higher among the all the mixes and found to be 61 N/mm^2. Optimum regained strength was also obtained for the same mix with the exposure water immersion (WI) and found to be71.65 N/mm^2.

Regained compressive strength was analyzed for both with and without Xypex conditions for all the exposure conditions over a time period of 7, 14, 28 & 42 days. The results obtained were plotted in the graphs for all the exposure conditions with respect to 28 & 42 days and represented below.

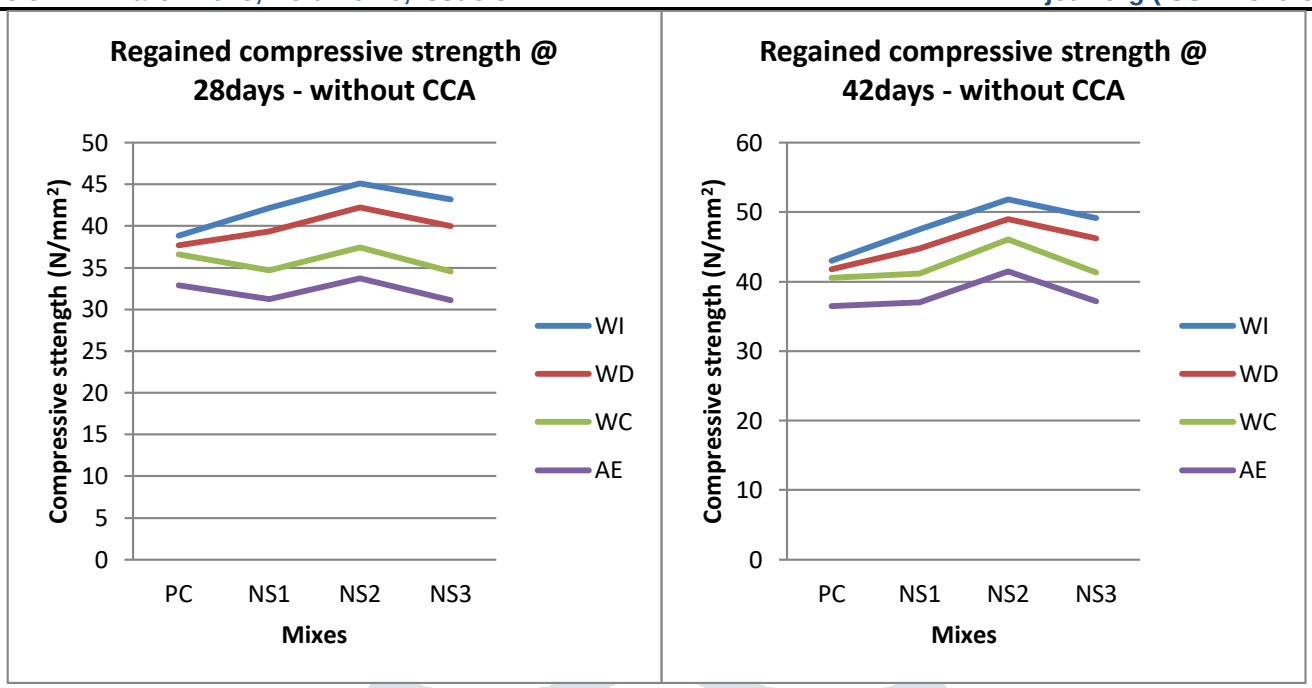


fig.2 & 3 variation of regained compressive strength for 28 and 42 days – without CCA

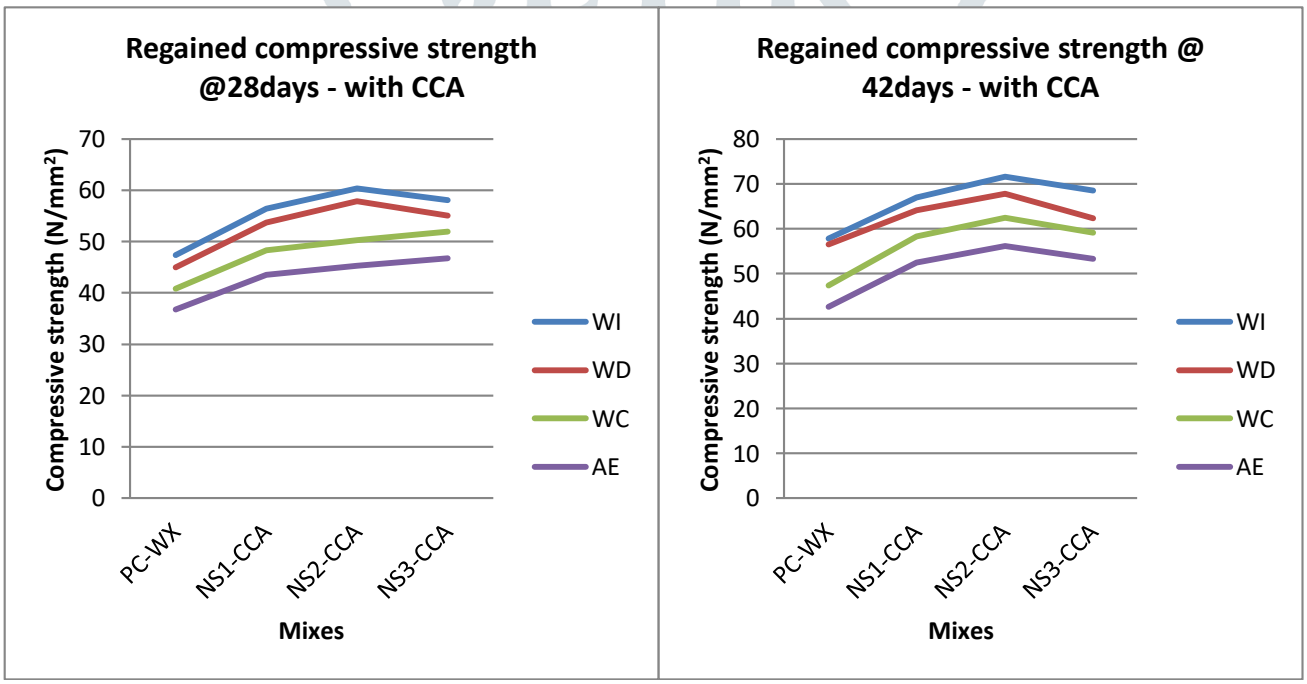


fig.4 & 5 variation of regained compressive strength for 28 and 42 days – with CCA

VI. CONCLUSIONS

After analyzing the regained compressive strength and crack closure capabilities over the curing period with respect to different environmental exposures several conclusions were made and summarized below.

- The optimum compressive strength for 28 days curing was obtained for the mix containing 2% of Nano silica replacement and 1% of crystalline admixture addition and itwas found to be 61 N/mm^2.
- From the crack closures and regained compressive strength values obtained for the mixes with absence of crystalline admixture and presence of Nano silica it was proved that Nanosilica has contributed partial amount of healing.
- The mixes which contains both the crystalline admixture and Nano silica has given a veryexceptional results for all the exposure conditions.
- Environmental exposures named Water immersion (WI) and Wet dry cycles (WD) has the complete crack closure ability and the maximum Regained compressive strength obtained for Water immersion (WI) was efficient and found to be 71.65 N/mm^2.
- The healing rate was in the order of WI > WD > WC > AE.

- Even the specimens kept for open air has given the better results by undergoing a good heat of hydration with the moisture present in the air.

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