Experimental Investigation on Corrosion Damaged Concrete Column Added with Nano Silica

Prashanth. R, S. Senthil Selvan, G. Karthik, Divij Singh Bankal

ABSTRACT: This study examines behaviour of reinforced concrete subjected to corrosion. Concrete is the most extensively used building material in the world without a close alternative, due to this there have been major advancements in concrete technology and the need to reinforcing has been made indispensable. Traditionally the reinforcement has been carried out by steel, but the integrity of steel is greatly deteriorated by corrosion. This dictates the life of concrete in real condition. It has been observed that cement-based materials, on the addition of nanoparticles, develop distinctive properties at the molecular and nano level. In this paper, an experimental study on M30 grade conventional concrete columns and M30 grade concrete columns with 2% by weight of its cementitious materials replaced with nano-silica, subjected to varying degrees and different levels of corrosion are taken. The load is applied axially and the strength of the columns are compared. Concrete columns containing nano-silica shown an increase in strength by 20% compared to conventional concrete columns.

Index terms- reinforcement, corrosion, nano-silica.

INTRODUCTION

Over the last decade, a great deal of research has been conducted in the replacement of standard materials with alternative chemical components to achieve better workability of fresh concrete and durability in hardened concrete. Another critical factor that affects the strength of the structure is the corrosion of steel, and researchers have been investigating methods to control corrosion of steel in concrete structures. Minimizing the utilization of portland cement with minimal reduction in the strength of concrete is vital to the success of big projects in fiscal and environmental perspectives. To achieve this, it is imperative to explore the use of alternative building materials and naturally occurring compounds. It is estimated that the production of each tonne of cement results in a proportional amount of greenhouse gas emissions from clinker producing plants. This is bound to have an adverse effect on an already precarious environment. The addition of nanoparticles along with cement-based materials to concrete has been observed to modify the properties at the molecular level and has been shown to produce better results in terms of the compressive strength and durability, while simultaneously decreasing the cost and environmental impact, as compared to conventional concrete mixes. Additionally, the incorporation of nanoparticles to the concrete mix has also positively impacted the corrosion resistance of steel, owing to its ability to alter properties at the nano level.

EXPERIMENTAL

Materials

OPC 53 grade cement is used for this experimental study. Aggregates are coarse or fine-grained granular particles of various shapes and sizes, that are primarily sourced from quarries of bedrocks and naturally occurring gravels. Aggregates can, at times, even be sourced from reclaimed and recycled construction materials. These aggregates are classified according to their nominal sizes as coarse, if they are greater than or equal to 5mm in sizes, and fine aggregates if they are lesser than 5mm. Coarse aggregates are usually manufactured by blasting naturally - occurring bedrock, while fine aggregates are found in sand deposits, or are processed in the form of manufactured sand. For this experiment, we have used 12mm size coarse aggregate, and river sand passing through sieve size 4.75 mm as fine aggregate. Nano silica with particle size of 17 Nano, and having a specific gravity of 2.3 used for this experiment. Chemical admixture, CERAPLAST 300, a brown liquid with specific gravity 1.2 used as a superplasticizer for this experiment.

Fig. 1. 12mm Coarse aggregate

Revised Manuscript Received on April 05, 2019.

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Fig. 2. River sand

Fig. 3. Nano silica

Concrete Mix

Totally two concrete mixes were used for this experimental study. The first mix (CC) is M30 grade conventional concrete mix, the second mix (NS) is M30 grade concrete with 2% by weight of its cementitious materials replaced with nano-silica. For both the concrete mixes, chemical admixture, CERAPLAST-300 is added in quantity of 1% by the weight of cementitious material. The concrete mix prepared using hand-fed concrete drum mixer.

RC Column design and detailing

The design and detailing of the reinforced concrete columns are as shown below:

Table 1. RC Column Detailing Specifications

Concrete grade	M30
Column height	1.2 m
Cross section	150 x 150 mm
Reinforcement (main bar)	4 nos. of 12 mm diameter bars
Reinforcement (stirrup)	6 nos. of 8 mm diameter bars @ 220 mm c/c

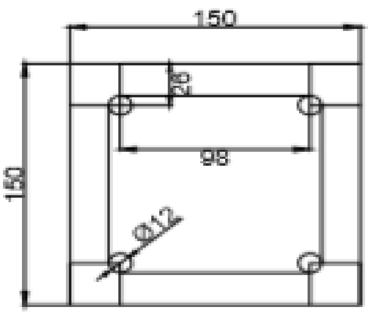

Fig. 4. Column cross-section

Concrete column specimens

A total number of 8 columns, each with dimensions 1200mm * 150mm * 150mm, were cast for the experiment. Out of these, 4 nos. of columns were cast with CC concrete mix and 4 nos. of columns with NS concrete mix. All columns are of the same size and contain the same reinforcement detailing, as specified in table 1. Along with the reinforcement, a strain gauge is fixed to the caging as shown in figure 6. The strain gauge aides in the measurement of the strain developed in the reinforcement cage when subjected to axial loads, which is applied on the specimen while testing.

Table 2. List of columns

Sn. No.	Concrete Mix	Columns			
1	CC	CC1	CC2	CC3	CC4
2	NS	NS1	NS2	NS3	NS4

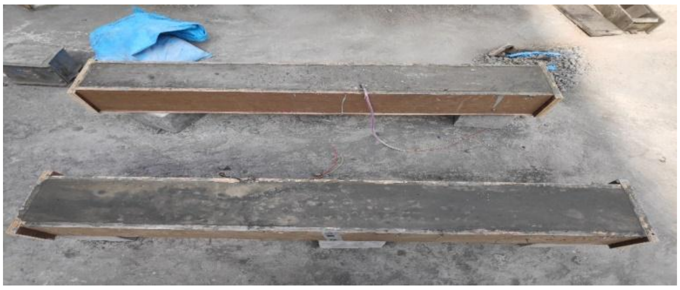

Fig. 5. Casting of concrete columns

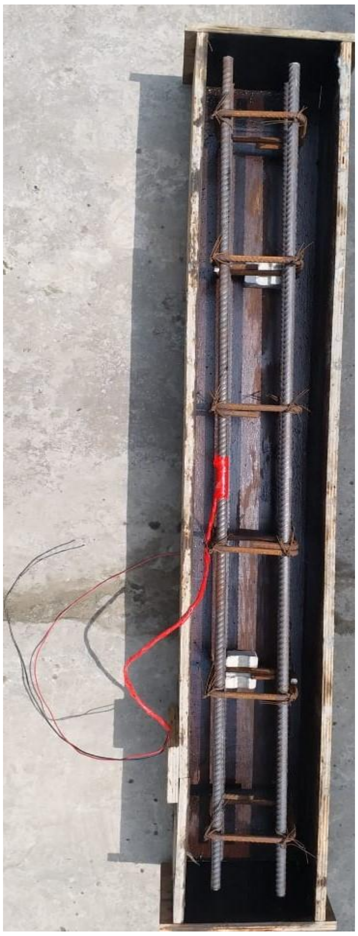

Fig. 6 Reinforcement with strain gauge.

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Fig. 7. Casting of columns

Curing

Curing is the process of controlling or aiding the maintenance of moisture content in the concrete mix during the process of cement hydration, so as to allow the concrete to develop the desirable strength. The procedure begins as soon as the concrete is placed and finished, so that the concrete attains the desired durability and strength. In this experiment, to attain various levels of corrosion, different curing done for concrete specimens by varying the salt content in the water used for curing. Columns, CC1 and NS1 are subjected to standard water curing. Columns, CC2 and NS2 are subjected to curing with water containing 20% salt content. Columns, CC3 and NS3 are subjected to curing with water containing 40% salt content. Columns, CC4 and NS4 are subjected to curing with water containing 60% salt content. All the columns are cured for 28days after they are cast.

Fig. 8. Salt (for curing)

Fig. 9. Water added with salt

Fig. 10. CC columns under curing

Fig. 11. NS columns under curing

RESULTS AND DISCUSSION

All the 8 columns are tested by applying an axial load in the testing frame as shown in the figure 12. The resultant strain developed in the concrete and reinforcement due to the axial loading is determined using 120 Ω strain gauges, placed in the centre of main reinforcement and concrete surface respectively whose ends are connected to the strain indicator. The deflection values of the column specimen are recorded by a dial gauge that is fixed to the base of the column specimen, as shown in figure 13. The graph is plotted between load vs deflection values, and stress vs strain values as shown in figure 14, and figure 15.

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Fig. 12. Column loaded in testing frame

Fig. 13. Deflection meter attached to base plate.

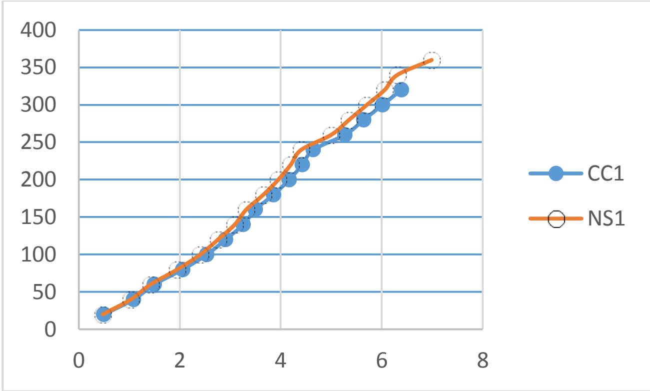

Fig. 14. Load vs deflection curve for CC1 and NS1

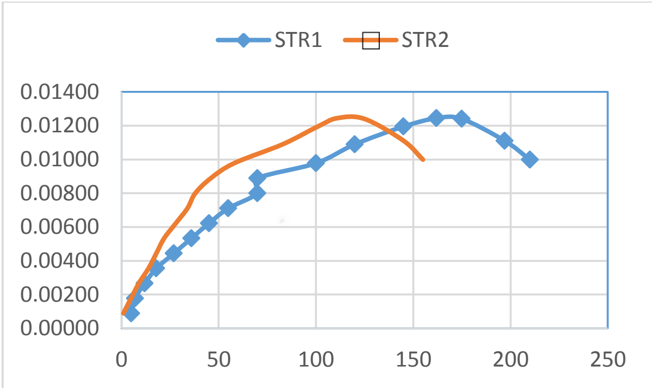

Fig. 15. Stress (N/mm^2) vs Strain curve of CC1 and NS1

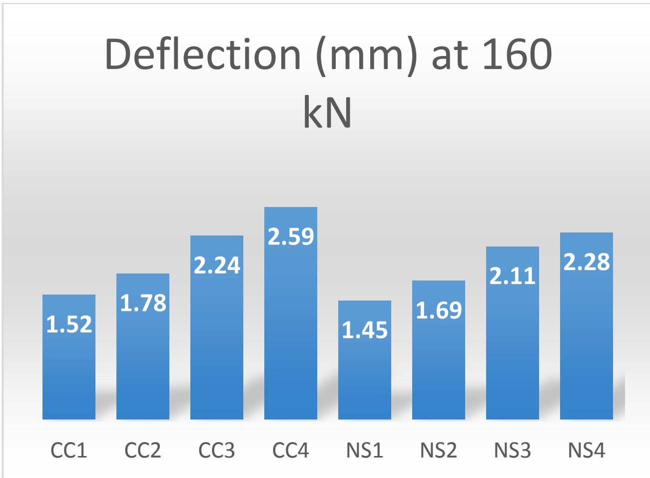

Fig. 16. Deflection of columns at 160 kN axial load

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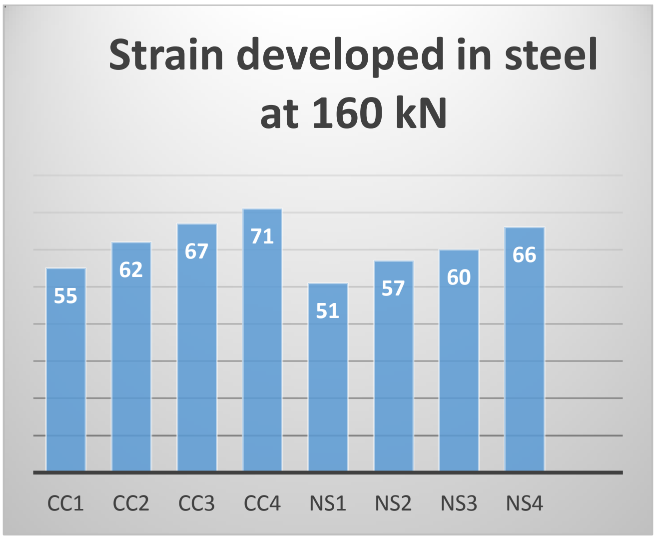

Fig. 17. Strain developed in reinforcement at 160 kN axial load.

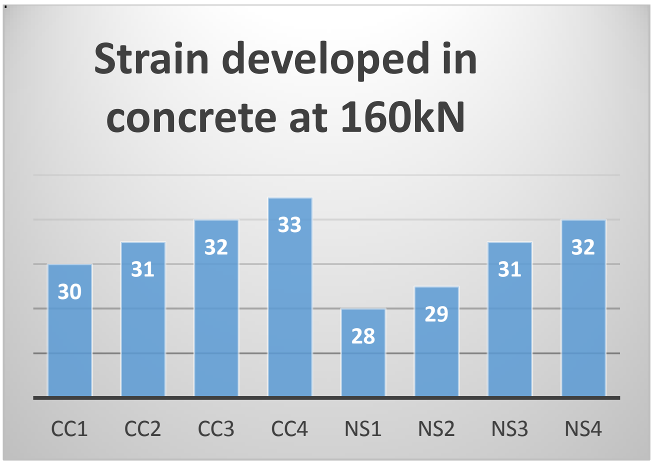

Fig. 18. Strain developed in concrete at 160 kN axial load.

Once, the ultimate load is reached, the concrete column fails. The load at which the concrete columns fail is as shown in the below figure 19.

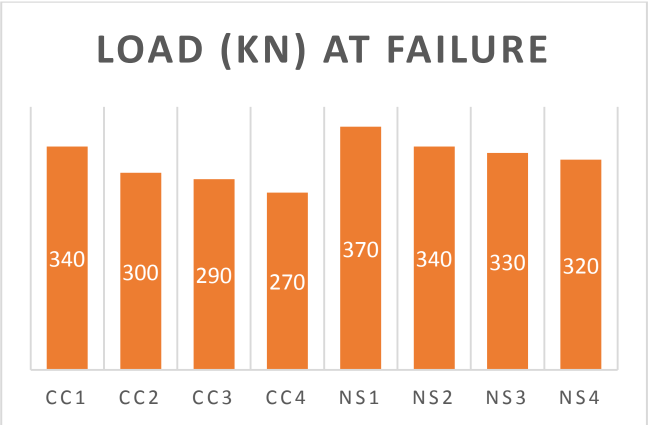

Fig. 19. Failure load of columns subjected to axial loading.

CONCLUSIONS

Based on the experimental study done, it is evident from the results that,

- Reinforced concrete columns added with nano-silica shows 5% less deflection when loaded axially, compared to the conventional concrete columns.
- The strain developed in the reinforcement of NS concrete column under axial load is 9% lesser when compared to CC concrete column.
- The strain developed in the reinforcement of NS concrete column under axial load is 7.8% lesser when compared to CC concrete column.
- The NS concrete columns have a 13% higher load of failure compared to CC concrete column when loaded axially.
- It is proven from the above-obtained test results that, adding nano silica to concrete mix improves the concrete strength and results in better durability.
- Also, adding nano-silica to the concrete mix provides better output in corroded condition, compared to the conventional concrete mix, and improves the lifetime of concrete structures.

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