Behaviour of Nano Silica in Tension Zone of High Performance Concrete Beams

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Abstract. High performance concrete (HPC) is similar to High strength concrete (HSC). It is because of lowering of water to cement ratio, which is needed to attain high strength and generally improves other properties. This concrete contains one or more cementitious materials such as fly ash, Silica fume or ground granulated blast furnace slag and usually a super plasticizer. The term ‘high performance’ is somewhat different because the essential feature of this concrete is that it’s ingredients and proportions are specifically chosen so as to have particularly appropriate properties for the expected use of the structure such as high strength and low permeability. Usage of nano scale properties such as Nano SiO₂ can result in dramatically improved properties from conventional grain size materials of same chemical composition. This project is more interested in evaluate the behaviour of nano silica in concrete for 5%, 10%, and 15% volume fraction of cement. Flexural test for beams were conducted with two point loads, at different percentage as mentioned above. From results interpolated, Nano silica with higher order replacement gives optimized results compared to control specimens.

1. Introduction
Utilization of nano scale measure particles can bring about drastically enhanced properties from regular grain estimate materials of same synthetic creation of materials. If nano particles are added with routine high rise building materials, will posses excellent properties for the construction of long span, high durable for civil engineering infrastructures development [1-3]. In late patterns utilization of nano materials in cement has expanded due to its improved properties, for such as sturdiness and mechanical properties and solidness. The mechanical conduct of concrete materials depends, as it were, of basic components that are successful utilizing on nano scale [4]. The size of calcium silicate hydrate (C-S-H) stage which goes about as an essential part assumes a noteworthy part for in charge of quality and different properties in nano run. The structure of C-S-H has affect on execution of cement in light of the fact that the structure is delicate to dampness condition [5-6]. From past research comes about, nano particles is important for enhancing mechanical and sturdiness properties and improving stop defrost toughness, scraped area resistance, and the bond strength with steel bar, the concoction assault resistance and erosion resistance of steel bar [8-11]. Failure of the structures sometimes identified with appearance of cracks. In concrete, strength is related to the stress required to cause fracture and is synonyms with degree of failure at which applied stress is maximum value. Since concrete already has cracks present in it the reason for using nano material is to fill these cracks which help in increase of durability and other strength parameters [12].
2. Experimental Investigation

2.1 Materials

Ordinary Portland Cement (OPC) with 53 grade which is satisfies the physical and chemical properties within the range of ASTM C150, Compressive strength of 54.5 MPa was used for complete experimentation process and density of the OPC is 3104 Kg/m³. Local river sand is added as Fine aggregate which specific gravity 2.65 and its fineness modulus 2.64. The properties of sand were determined by conducting tests as per IS: 2386 (Part-I). The results indicate that the sand conforms to Zone III of IS: 383-1970.

2.2 Nano SiO₂

Pure Nano-silica was brought and its properties are tested in manufacture company give by Table 1, SEM Figure as shown in 1.

| Test item                        | Standard Requirement | Test Result |
|----------------------------------|----------------------|-------------|
| Specific surface area (M²/G)     | 200-210              | 202         |
| pH value                         | 3.7-4.5              | 4.12        |
| Loss on drying @105⁰C (5)        | <1.5                 | 0.47        |
| Loss of ignition @1000⁰C (%)     | <2.0                 | 0.66        |
| Sieve Residue (5)                | <0.04                | 0.02        |
| SiO₂ content                     | >99.8                | 99.88       |
| Carbon content                   | <0.15                | 0.06        |

2.3 Specimen Preparation

The experimental program consists of preparation of reinforced high performance concrete. Beams specimens of size (100 x 150 x 1200) mm were prepared with reinforcement of 12 mm bars at tension side. Nano silica is replaced for the cement having different replacement levels ranging from 5%, 10%, and 15% for cement. These replacements are mainly concerned with the tension zone of the beam specimen and hence replaced in the bottom layer of beam. Two point loads was applied at 133.33mm from center of beam at either side. The beams were subjected to loading conditions under different replacement criteria.

2.4 Concrete Mix design

For this present study design of mix has been done based on ACI code. In order to meet high performance concrete that meet the strength requirement, careful selection of material is needed. After
designing the mix, various trails have been carried out by varying the ingredients to arrive at the optimum mix. The following procedure is adopted for mix proportioning of high strength concrete as per guidelines of ACI 211.4R-93

2.5 Casting Details
The casting specimen required amounts of the fixings were weighed and kept prepared for blending. For simple evacuation of the specimens, before throwing of specimen oil was connected to the inward surface of the molds and on the floor on which the specimen was threw. The measure of super plasticizer utilized for the mix were measured and kept prepared for mixing. Before mixing initiates super plasticizer was mixed a large portion of the amount of water. For blending, at first 50% of the considerable number of fixings were very much mixed in dry condition in a concrete blender half of computed measure of water was added to the dry mix and mixed altogether to get a uniform mix for around 2 minutes. After that the staying half fixings additionally added to the mix and the staying half of water blended with super plasticizer was poured into the mixer and very much mixed. The concrete set in beam, which was at that point kept prepared. Concrete was filled in the shape in three equivalent layers and compacted utilizing a needle vibrator. Subsequent to filling, best layer was done to show signs of improvement surface. Control specimen was likewise arranged by a similar mix.

2.6 Curing of Specimens
The specimens were covered using wet gunny bags one hour after casting to prevent the loss of moisture from concrete, which has low water cement ratio. After 24 hours of casting, specimens were removed from the mould and again moist cured for 28 days using wet gunny bags. After the curing period was over, the specimens were white washed and kept ready for testing. The control specimens were also cured under same environment.

2.7 Test Procedures
Specimens of size (100 x 150 x 1200) mm were tested in a Universal compression testing machine. In order to note down the applied load precisely, load cell of 25T capacity was used. Two Linear Variable Differential Transducer (LVDT) were for measuring the longitudinal strains at the top and bottom of the beam to find out the moment curvature relationship. The longitudinal deformation at the top and bottom were measured using LVDT with a range of 5mm and a resolution of 0.001mm. The beams were supported using two rollers having 30 mm diameter and one of which was fixed and other was capable of rotation. The effective span was kept as 1000 mm. The specimens were tested under two point loadings. Two rollers each of diameter 30 mm served as load points and was kept on the beams at a distance of 333.33 mm, kept in position by plaster of paris. A rolled steel joist was used to transmit the load from the machine to the two locations through the rollers. The load was applied in stages. For every stage of loadings, the following readings have been noted for deflection at mid span of the specimen.
3. Results and Discussion

3.1 Flexural Behaviour of beams

Table 2 below shows beams with different replacements of Nano Silica varying from 0%. 5%, 10%, 15% for cement, First crack, ultimate load, Failure load values for different specimens are studied and the values are shown in Table 3.

Table 2. Beam designation

| Beam designation | Volume fraction of NS replacement % for cement |
|------------------|-----------------------------------------------|
| B1               | 0                                             |
| B2               | 5                                             |
| B3               | 10                                            |
| B4               | 15                                            |

Table 3. Flexural Behaviour of Beams

| Beam designation | First Crack Load (kN) | Ultimate Load (kN) | Failure Load (kN) |
|------------------|-----------------------|--------------------|-------------------|
| B1               | 27                    | 50                 | 44                |
| B2               | 29.5                  | 55                 | 47                |
| B3               | 31                    | 58                 | 51                |
| B4               | 33                    | 62                 | 55                |
3.2 Stiffness
In Figure 4, the stiffness (k) is the resistance of the part against bending distortion. It is the capacity of elastic modulus (E), the area of moment of inertia (I) of the bar cross segment about the hub of intrigue, length of the beam and shaft limit conditions [9-11]. Bending stiffness in beam is also known as flexural rigidity. Typical Stiffness versus Deflection plots are shown below for the different replacement levels of nano silica.

3.3 Loads versus Deflection Behaviour
The load versus mid span deflection response of the beam specimens under monotonic loading is discussed in Figure 5. The recorded values of load and deflection have been used to obtain load versus deflection plot. From the above graph it is found that specimen with higher order replacement of NS is practically effective in bringing about the desired modification in the deformation characteristics from beginning to failure and contribute significantly to maintain the structural integrity of the beams.
4. Conclusions
The review of results above indicates the following general conclusions.

a. Addition of nano silica improves the consistency and workability of fresh and hardened concrete because an additional volume of fines is added to mixture.

b. Replacement of nano silica in concrete plays a major role because it acts as a key factor in modifying the micro structure of concrete consequently reducing the permeability thereby reducing the penetration of water which results in prevention of corrosion.

c. From load versus deflection graph plotted, Cement replaced with 15% of NS shows higher load carrying capacity 24 % higher comparing to control specimen also have lesser deflection comparing with other nominal replacements (5% and 10%).

d. From stiffness versus deflection graph plotted, comparing the results for various replacements, cement with 15% NS replacement shows increase in stiffness comparing other replacements.
This is mainly due to interlocking of nano particles with the concrete specimen which acts as pores filling agent.

References
[1] Jaishankar P and Saravana Raja Mohan K 2015 Influence of Nano particles in High Performance Concrete (HPC) *Int. J. ChemTech Res.* 8 278-84
[2] Nittaya Thuadaij and Apinon Nuntiya 2008 Synthesis and Characterization of Nano silica from Rice Husk Ash Prepared by Precipitation Method. *Cem. Concr. Res.* 7 55-9.
[3] Manoj Kumaar C, Mark U, Vivin Raj and Mahadevan D 2015 Effect of Titanium di-oxide in Pervious Concrete. *Int. J. ChemTech Res.* 8 183-7.
[4] Priya A K and Nithya M 2016 Experimental Investigation on Developing Low Cost Concrete by Partial Replacement of Waste Ildg. *Int. J. ChemTech Res.* 9 240-7.
[5] Madhavi T, Pavan Kumar P and Jothi lingam M 2015 Effect of Copper Slag on the Mechanical Strengths of Concrete. *Int. J. ChemTech Res.* 8 442-9.
[6] Praveen Kumar T, Sudheesh C and Sasi Kumar S 2015 Strength Characteristics of Saw Dust Ash Based Geo polymer Concrete. *Int. J. ChemTech Res.* 8 738-45.
[7] American Society for Testing and Materials (ASTM) Standard specification for Portland Cement ASTM C150/C150M ASTM International West Conshohocken PA 2015
[8] Shekari A and Razzaghi M 2011 Influence of Nano particles on Durability and Mechanical Properties of high performance concrete *Procedia Eng.* 14 3036-41.
[9] Sumathi A and Saravana Raja Mohan K 2015 Study on the Strength and Durability. Characteristics of High Strength Concrete with Steel Fibers. *Int. J. ChemTech Res.* 8 241-8.
[10] Jai Shankar P and Saravana Raja Mohan K 2015 Experimental investigation on nano particle In high performance concrete. *Int. J. ChemTech Res.* 8 1666-70.
[11] Jaishankar P and Muthu siva chandru B 2016 Effect of Nano silica additions on Mechanical and Micro structural analysis of High performance concrete. *Int. J. ChemTech Res.* 9 453-61.
[12] Ye Qing, Zhang Zenan, Kong Deyu and Chen Rongshen 2008 Influence of nano-SiO$_2$ addition on properties of hardened cement paste as compared with silica fume. *Mater. Des.* 21 539-45.