

Influence of Nano-Silica on the Strength and Durability of Self Compacting Concrete

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Abstract - Self-compacting concrete (SCC) is also considered as a concrete which can be placed and compacted under its own weight with little or no vibration without segregation or bleeding. The use of SCC with its improving productions techniques is increasing every day in concrete production. Recently, nano particles have been gaining increasing attention and have been applied in many fields to fabricate new materials with novel functions due to their unique physical and chemical properties. In this work 40Mpa self-compacting concrete is developed using modified Nan-Su method of mix design. Slump flow, J-Ring, V-funnel tests are conducted to justify the fresh properties of SCC and are checked against EN12620 (2005) specifications. Specimens of dimensions 150x150x150mm were cast without nano silica and with two different grades of nano silica which is in colloidal state with 16% and 30% nano content are added in different percentages (1%, 1.5% and 2% by weight of cement) to SCC. To justify the compressive strength for 7 and 28 days, specimens are tested under axial compression. Durability properties were also studied by immersing the specimens in 5% HCl and 5% H₂SO₄. Sorptivity test has also been conducted. Test results indicate that use of Nano Silica in concrete has improved the performance of concrete in strength as well as in durability aspect.

Key Words: Nano Particles, Sorptivity test, J-Ring, and V-funnel tests etc...

1. Introduction of Self Compacting Concrete

From the foregoing discussion, it is clear that the main aim of the work is developing a SCC and understands the behavior of such a SCC under various loading action. In the early 1990's there was only a limited public knowledge about the use of self-compacting concrete, and if available that was mainly in Japanese. The first paper on self compaction concrete was presented by Ozawa at the second East-Asia and Pacific conference on structural engineering and construction in January 1989. After that

self compaction concrete became a point of interest for researchers and engineers around the world who are interested in the durability of concrete and in rational construction systems. In January 1997, RILEM's committee on self compaction concrete was formed and the first international workshop was held in Kochi, Japan in August 1998.

1.1 Self-Compacting Concrete (SCC)

Self-Compacting Concrete (SCC) is a new generation of concrete, which has generated tremendous interest since its initial development in Japan by Okamura in the late 1980's in order to reach durable concrete structures. SCC has gained wide use for placement in congested reinforced concrete structures with difficult casting conditions. For such applications, the fresh concrete must possess high fluidity and good cohesiveness. SCC is considered as a concrete which can be placed and compacted under its self-weight with little or no vibration effort, and which is at the same time, cohesive enough to be handled without segregation or bleeding. It is used to facilitate and ensure proper filling and good structural performance of heavily reinforced structural members

The other advantages of SCC are:

1. It eliminates noise due to vibration.
2. It provides high stability during transport and placement.
3. It provides uniform surface quality and homogenous.
4. It provides greater freedom for design.
5. It is useful for casting of underwater structures.

Eg1: A new type of concrete, which can be compacted into every corner of a formwork purely by means of its own weight, was proposed by Okamura in [1]

Mechanism for achieving SCC

The method for achieving SCC involves not only high deformability of paste or mortar, but also resistance to segregation between coarse aggregate and mortar when concrete flows through the confined zones of reinforcing bars. Okamura and Ozawa have employed the following methods to achieve self-compactability.

- (1) Limited aggregate content.

- (2) Low water-powder ratio.
- (3) Use of super plasticizer.

The frequency of collision and contact between aggregate particles can increase as the relative distance between the particles decreases and then internal stress can increase when concrete is deformed, particularly near obstacles.

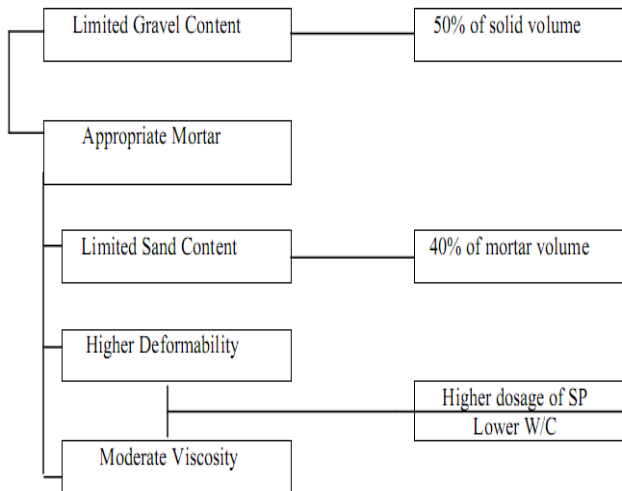


Chart -1: Methods for achieving self- compactability

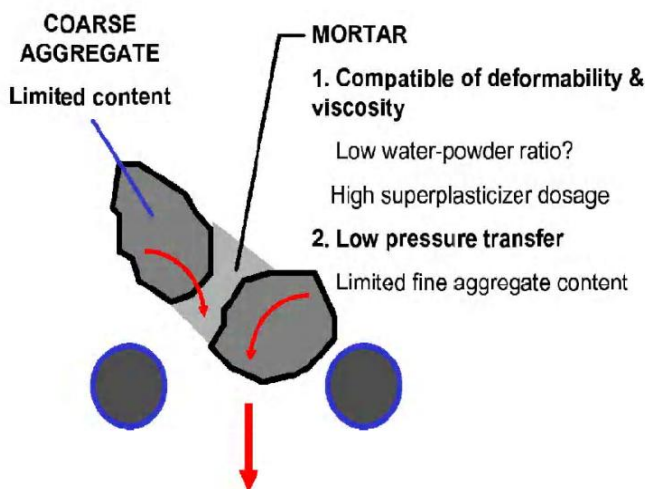


Fig -1: Mechanism for achieving self-compactability

1.2 Nano Technology

Nanotechnology is the art and science of manipulating matter at the nano scale.

Nanotechnology can be used for design and construction processes in many areas since nanotechnology generated products have many unique characteristics Lighter and stronger structural composites

Nano materials

The Nano materials can improve vital characteristics of construction materials such as strength, durability, and lightness, endow useful properties (e.g., heat-insulating, self-cleaning, and antifogging), and function as keysensing

components to monitor construction safety and structural health.

The particle packing in concrete can be improved by using Nano-silica which leads to densifying of the micro and nanostructure resulting in improved mechanical properties. Nano-silica addition to cement based materials can also control the degradation of the fundamental C-S-H (calcium-silicate-hydrate) reaction of concrete caused by calcium leaching in water as well as block water penetration and therefore lead to improvements in durability.

Carbon nanotubes (CNTs) when used as a proxy for polymeric chemical admixtures can remarkably improve mechanical durability by gluing concrete mixtures, that is, cementitious agents and concrete aggregates, and prevent crack propagation. Incorporation of CNTs as crack bridging agents into non-decorative ceramics can enhance their mechanical strength and reduce their fragility, as well as improve their thermal properties.

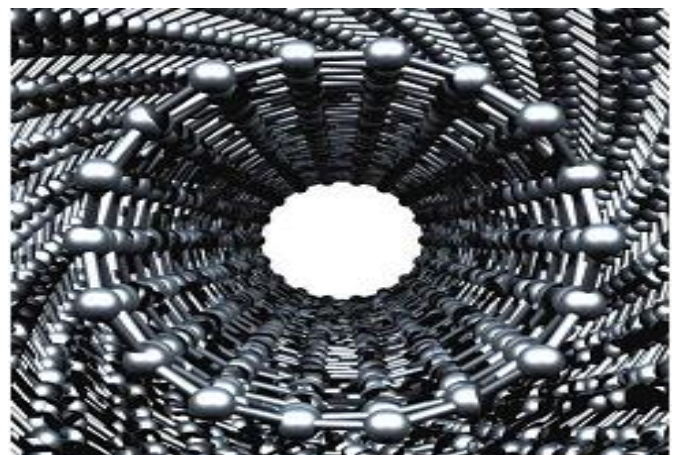


Fig -2: Nano tubes

SiO₂ and Fe₂O₃ nanoparticles (NPs) can be used as filling agents to pack the pores and reinforce concrete to prevent the penetration of CaCl₂ and MgCl₂ into nano- or micropores that concrete develops due to cement hydration, reacting with concrete constituents to weaken the structure.

Addition of magnetic nickel nano-particles during concrete formation increases the compressive strength by over 15% as the magnetic interaction enhances the mechanical properties of cement mortars.

Copper nano-particles mitigate the surface roughness of steel to promote the weldability and render the steel surface corrosion-resistant.

One of the principal structural units in nanotechnology is quantum dot or nanoparticle, which can be represented as a cluster of tens to thousands of atoms of 1-100 nm in

diameter. The key is the size of particles because the properties of materials are dramatically affected under a scale of the nanometer (nm), 10⁻⁹ meter (m).

- Low maintenance coating
- Improving pipe joining materials and techniques.
- Better properties of cementitious materials
- Reducing the thermal transfer rate of fire retardant and insulation
- Increasing the sound absorption of acoustic absorber

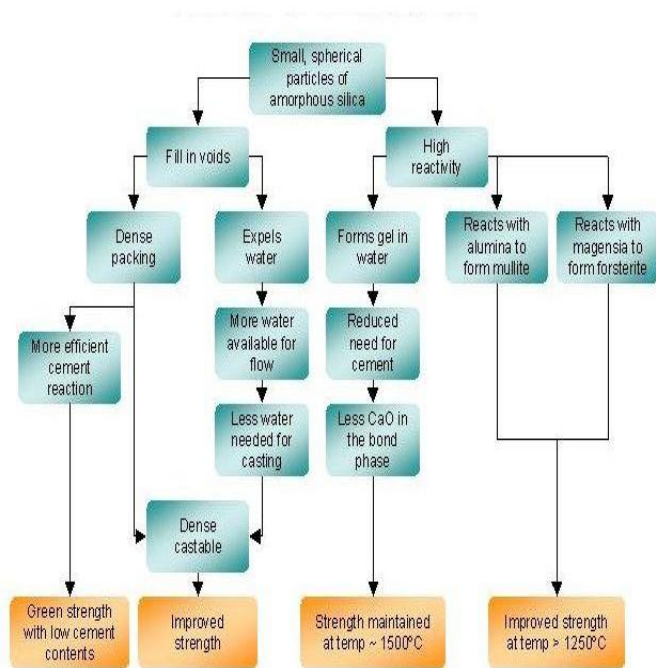


Chart -2: Nano Silica Properties

2. EXPERIMENTAL INVESTIGATION

2.1 Introduction

The experimental study consists of arriving at suitable mix proportions that satisfied the fresh properties of self compacting concrete as per EFNARC specifications. Standard cube moulds of 150mm x 150mm x 150mm made of cast iron were used for casting standard cubes. The standard moulds were fitted such that there are no gaps between the plates of the moulds. If there are any small gaps they were filled with plaster of paris. The moulds were then oiled and kept ready for casting. After 24hrs of casting, specimens were demoulded and transferred to curing tank where in they were immersed in water for the desired period of curing.

The program consists of casting and testing of 40Mpa Self Compacting Concrete with additions of nano silica and without nano silica. A total of 7 batches were made, out of which 1 batch is of normal SCC i.e., without nano silica, 3 batches of nanosilica (16% nano content) with additions of 1%, 1.5% and 2% bwoc and 3 batches of nano

silica (30% nano content) with additions of 1%, 1.5% and 2% bwoc. The mix proportion for 40Mpa Self compacting concrete was designed by using modified nan su method. Water reducing admixtures are added into mixes on requirement, till the desired properties are exhibited by them. 15 cubes were casted in each batch, out of which 6 cubes of each batch are tested for compressive strength for 7 days and 28 days, 3 cubes of each batch are tested for 5% H₂SO₄ (sulphuric acid), 5% HCl (Hydrochloric acid) and Sorptivity test for durability aspects.

The main objective of this project is to study the strength and durability effects of Nano silica inclusions in Self Compacting Concrete with various percentage additions.

The experimental study consists of arriving at suitable mix proportions that satisfied the fresh properties of self compacting concrete as per EFNARC specifications. Standard cube moulds of 150mm x 150mm x 150mm made of cast iron were used for casting standard cubes. The standard moulds were fitted such that there are no gaps between the plates of the moulds.

S. No	Grade of Concrete	Type of Concrete	% of Nanosilica added by BWOC added	No. of cubes cast 150x150x150mm
1.	40Mpa	SCC without Nano silica	-	15
		SCC with Nano silica (16% nano content)	1%	15
			1.5%	15
			2%	15
		SCC with Nano silica (30% nano content)	1%	15
			1.5%	15
			2%	15
Total Specimens				105

Table -1: Details of specimens cast

MATERIALS USED

The different materials used in this investigation are

- 53 Grade Ordinary Portland cement
- Fine Aggregate
- Coarse Aggregate
- Super Plasticizer (CONPLAST SP430)
- Fly ash.
- Water
- Nano Silica (16% and 30% nano content)

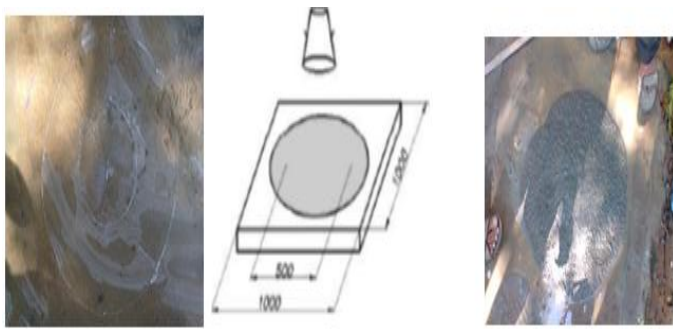


Fig -3: Abrams Slump flow Equipment

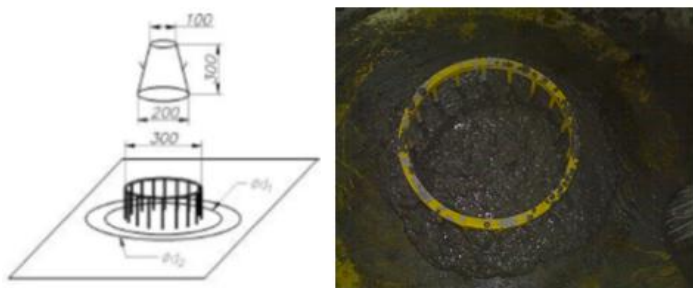


Fig -4: J-Ring equipment

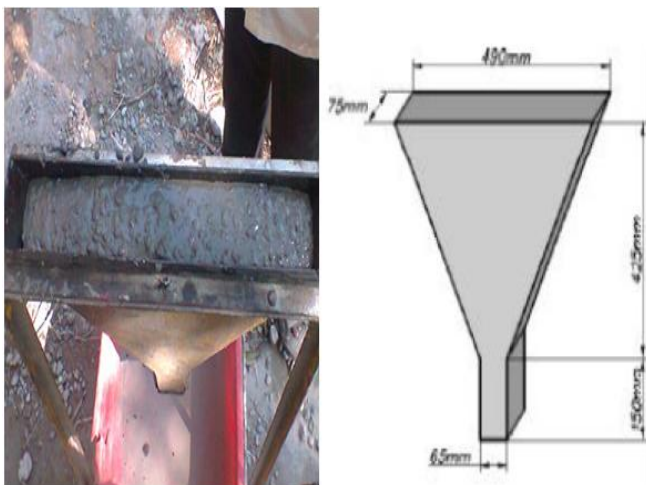


Fig -5: V-Funnel equipment

Grade	Compressive strength (Mpa)		%Increase in compressive strength(Mpa)	
	7 days	28days	7days	28days
Normal SCC				
NS.XLP (1%)	30.51	42.3	0	0
NS.XLP (1.5%)	41.19	51.86	34.99	22.60
NS.XLP (2%)	47.05	61.74	54.21	45.96
NS.XTX (1%)	39.93	52.98	30.88	25.25
NS.XTX(1.5%)	42.31	55.48	38.66	31.16
NS.XTX (2%)	47.11	59.7	54.40	41.13
NS.XTX (2%)	43.62	58.12	42.96	37.40

Table -2: Average Compressive Strength of SCC with and without nano silica

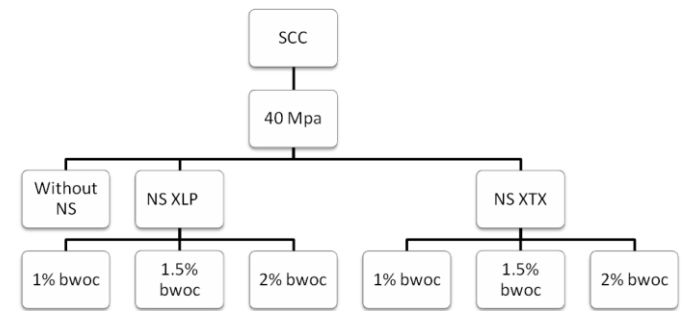


Chart -3: Flow Chart showing the details of Experimental program

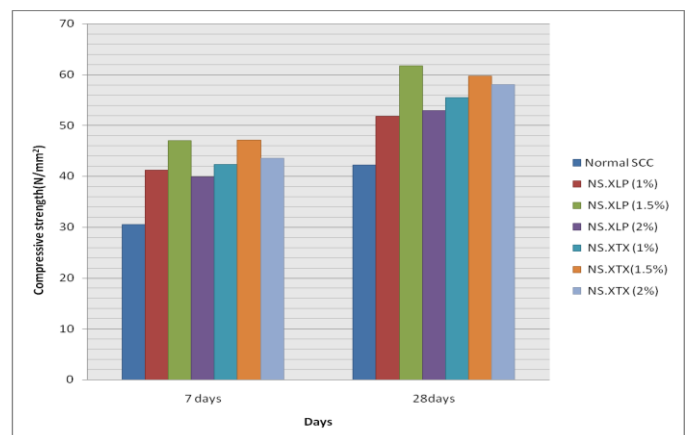


Chart -4: Average compressive strength of SCC without and with nano silica

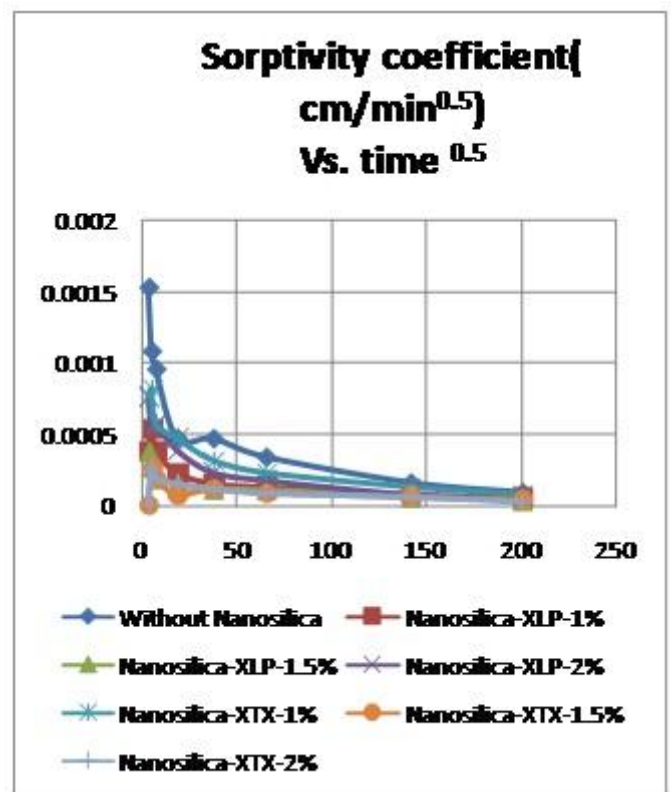


Chart -5: Graph between Sorptivity Coefficient and time

From the graphs it is observed that

- Initially there is little bit increase in water absorption in all the batches but after 14 days it is observed that there is decrease.
- Out of three specimens in all the batches only one or two specimens are showing a marginal increase in weight.
- Nano additions in SCC are almost impermeable, as there is no capillary suction. This is might be due to fill of nano materials into the pores.
- There is no much comparison of coefficient of sorptivity between the various nano additons, but 2% Nano XTX addition has less coefficient of sorptivity when compared to the other types.

3. CONCLUSIONS

The present work deals with understanding the effect of nano silica inclusion on strength and durability properties of self compacting concrete.

Effect of Nano Silica on Compressive Strength:

1. In the present study 40Mpa SCC was developed based on modified nan su method and nano silica additions are made in that.
2. There is a steep increase in the compressive strength at 28days of about 45.2% and 41.13% with the addition of 1.5% Nano silica of XLP grade and XTX grade respectively. Hence 1.5% addition of nano silica is said to optimum.
3. The addition of nano silica improves the hydrated structure of concrete.

Effect of Nano Silica on Durability:

1. The surface of the specimens was badly damaged and cement mortar was completely eaten up in 5% H₂SO₄ and it was not found in 5% HCl.
2. The percentage mass loss with 5% H₂SO₄ and 5% HCl revealed that nano additions have less percentage of mass loss than normal SCC.
3. After 28 days, the percentage mass loss for Nano Silica XLP with 1.5% addition is 1.06% in 5% sulphuric acid, which is said to less when compared to other percentage of nano silica.
4. After 28 days, the percentage mass loss for Nano Silica XTX with 2% addition is 1.81% in 5% hydrochloric acid, which is said to less when compared to other percentage of nano silica.
5. The percentage loss of both compressive strength and weight are increasing with the time of exposure to acid attack.
6. The percentage compressive strength loss is more for 1.5% Nano Silica-XLP and is about 56.02 % and 18.74% with 5% H₂SO₄ and 5% HCl respectively after 28 days of immersion. This may be due to higher pozzalonic content.

7. At 28 days, the loss of compressive strength is less for XLP- Nano-Silica of 1% addition which is about 41.23% and has more Acid Durability factor of about 58.77, hence it is said to be more durable when compared to others.
8. The deterioration effect of 5% sulphuric acid is more severe when compared to 5% Hydrochloric acid.
9. Acid durability factor for cubes immersed in 5% Hydrochloric acid are almost same but after 28 days ADF is more for 2% Nano silica SCC of XTX grade, and also for 1% Nano silica SCC of two grades. This implies that 2% Nano silica SCC of XTX grade, 1% addition is more durable in hydrochloric acid when compared to other in terms of Acid durability factor.
10. Nano silica additions are less attacked and said to be more durable when compared with normal SCC in terms of Acid attack factor.
11. At 28days 1% and 1.5% Nano silica- XLP has an acid attack factor of about 0.344 when immersed in 5% sulphuric acid, hence it is said to be less attacked in terms of Acid Attack Factor.
12. Acid Attack Factor values are almost same for the cubes immersed in 5% HCl after 28 days.

Effect of Nano Silica on Sorptivity:

- Initially there is little bit increase in water absorption in all the batches but after 14 days it is observed that there is decrease.
- Out of three specimens in all the batches only one or two specimens are showing a marginal increase in weight.
- There is no much comparison of coefficient of sorptivity between the various nano additons, but 2% Nano XTX addition has less coefficient of sorptivity when compared to the other types.
- Nano additions in SCC are almost impermeable, as there is no capillary suction. This is might be due to fill of nano materials into the pores.

The present work deals with understanding the effect of nano silica inclusion on strength and durability properties of self compacting concrete.

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The addition of nano silica improves the hydrated structure of concrete. The percentage compressive strength loss is more for 1.5% Nano Silica-XLP and is about 56.02 % and 18.74% with 5% H₂SO₄ and 5% HCl respectively after 28 days of immersion. This may be due to higher pozzalonic content.

REFERENCES

- [1]. Hajime Okamura and Masahiro Ouchi (2003), "Self-Compacting Concrete", *Journal of Advanced Concrete Technology* Vol.1, No.1, 5-15, April 2003.
- [2]. Ozawa K., Kunishima, M., Maekawa, K. and Ozawa, K, "Development of High Performance Concrete Based on the Durability Design of Concrete Structures". *Proceedings of the second East-Asia and Pacific Conference on Structural Engineering and Construction (EASEC-2)*, Vol. 1, pp. 445-450, January 1989.
- [3]. Nan Su, Kung-Chung Hsu, His-Wen Chai, "A simple mix design method for self-compacting concrete", *Cement and Concrete Research*, 6 June 2001, pp1799-1807.
- [4]. S. Venkateswara Rao, M.V. Seshagiri Rao, P. Rathish Kumar "Effect of Size of Aggregate and Fines on Standard And High Strength Self compacting Concrete", *Journal of Applied Sciences Research*, 6(5): 433-442, 2010.
- [5]. M.R.Arefi, M.R. Jahaveri, E. Mollaahmadi,(2011) Silica nanoparticle size effect on mechanical properties and microstructure of cement mortar, *Journal of American science*.
- [6]. **A.A. Magsoudi, M.Magsoudi, and M. Noori**, "Effect of Nanoparticles on SCC", *second international conference on sustainable construction materials and technologies*. June 28, 2010.
- [7]. Ashwani K. Rana, Shashi B Rana, Anjna Kumari and **Vaishnav Kiran**, "Significance Of Nanotechnology in Construction Engineering. *International journal of recent trends in engineering*", Vol 1, No. , May 2009.
- [8]. **G.Quercia & H.J.H. Brouwers** ; "Application of Nano-Silica (nS) in Concrete Mixes", 8th fib OhD symposium in Kgs. Lyngby, Denmark June 20-23, 2010.
- [9]. IS : 12269 -1987 "Indian Standard Specification for 53 Grade Ordinary Port land Cement", First Reprint September 1993.
- [10]. IS : 383-1970 "Indian Standard Specification for Coarse and Fine Aggregates from Natural Sources for Concrete (Second Revision)", Ninth Reprint September 1993.
- [11]. ASTM C94, "American Society for Testing and Materials - C94".
- [12]. IS : 2386 (Part IV) - 1963 "Indian Standard Methods of Test for Aggregates for Concrete (Part IV) Mechanical Properties", Tenth Reprint March 1997.
- [13]. IS : 456-2000 "Indian Standard Plain and Reinforced Concrete - Code Of Practice" (Fourth Revision).