International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 04 Issue: 05 | May -2020 ISSN: 2582-3930

EXPERIMENTAL STUDY ON CONCRETE BEAMS USING NANO MATERIALS AS ADMIXTURE

Rajamanikandhan.k (PGStudent)
Department of Civil Engineering
MNM Jain Engineering College
Thoraipakkam, Chennai 60097

Mr.S.ARUNBHARATHI(Guide
Department of Civil Engineering
MNM Jain Engineering College
Thoraipakkam, Chennai 60097

***Abstract*— This study aims to investigate the improvement in strength characteristics of Nano materials mixed reinforced concrete beam in a comparison to reinforced cement concrete beam. It is decided to carry out the experimental work with 2% of cementitious material of Nano silica, Nano aluminium oxide and Nano titanium dioxide, for the nano reinforced concrete beam with M25 mix propotion. The addition of supplementary cementations materials in the concrete will not only improve the mechanical properties of concrete, but also its workability, alteration in setting times and durability. The newer materials can also be obtained by intelligent and intermixing of existing materials at element level, with the advancement of Nano technology. Nano materials. The compressive strength and split tensile strength are to be carried out using tests on cube and cylinder specimens. The main purpose of this project is to study the flexural behavior and cracking pattern of RCC and Nano material mixed concrete beams.**

***Keywords*— Nano silica , Nanotitanium dioxide.**

I. INTRODUCTION

A. *General*

Micro silica is one of the world's most widely used products for concrete for over eighty years. Micro silica has lots of drawbacks and also induces silicosis when inhaled hence to avoid this Nano materials were used in concrete. Its properties allowed high compressive strength to concrete and chemical resistant concretes and they have better climatic resistance. This study aims to investigate the improvement in strength characteristics of Nano materials mixed reinforced concrete beam in a comparison to reinforced cement concrete beam. It is decided to carry out the experimental work with 2% of cementitious material of Nano silica, Nano aluminium oxide and Nano titanium dioxide, for the nano reinforced concrete beam with M25 mix propotion.

The addition of supplementary cementations materials in the concrete will not only improve the mechanical properties of concrete, but also its workability, alteration in setting times and durability. The newer materials can also be obtained by intelligent and intermixing of existing materials at element level, with the advancement of Nano technology. Nano materials. The compressive strength and split tensile strength are to be carried out using tests on cube and cylinder specimens.Concrete is a highly heterogeneous material produced by mixture of finely powdered cement, aggregates of various sizes and water with inherent physical, chemical and mechanical properties. A reaction between the cement and water yields calcium silicate hydrate, which gives concrete strength and other mechanical properties of concrete, as well as some by products including calcium hydroxide [CH], 'gel pores' etc. Despite the hydrated cement and their by-product materials are available everywhere in the concrete, the reactions within the concrete as it sets and strengthens are difficult to control and this is an on-going problem in the concrete industry. Apart from the above, permeability of gases through pores and micro- cracks in the concrete, which leads to corrosion problem in the reinforcement of concrete causes further deterioration. Moreover, the expansion and shrinkage in concrete, which are also cause for crack in concrete at later ages, are mainly due to the sulphate attack, which causes disintegration in concrete, chemical leaching and both the events are mainly due to the excess calcium hydroxide [CH], the by-product during cement hydration .It is learnt that the C-S-H is the strength phase, whereas the by- product, CH is not having any cementations properties, easily be leached out, prone to chemical attack. With the addition of suitable cementations materials, mostly siliceous or aluminous, with cement which will react with excess CH and produce additional C-S- H with the replacement of porous CH and refines the pore structure and reduces permeability of gases and water in concrete. The reduction of the CH content during cement hydration associated with the possibilities of sulphate attack and chemical leaching can be reduced further, which will tackle to remediate the concrete cracking to some extent.

The researchers worldwide have attempted to tackle the above problem with various methods such as pozzolanic reactions of cement using cementations materials, by means of chemical reactions of the by-product CH to get additional C-S-H materials or by pore filling mechanism by using cementations materials. The supplementary cementations materials such as pulverized fly ash, ground granulated blast furnace slag, condensed micro silica fume, rice husk ash, metakaoline etc. have been studied extensively in concrete as pozzolanic materials to enact the CH and get the additional C-S-H. The addition of supplementary cementations materials in the concrete will not only improve the mechanical properties of concrete, but also its workability, alteration in setting times and durability.

B. NANO SILICA

Nano Silica (NS) is a mineral admixture, fine material with spherical particles size 60 µm in diameter.This makes it 50 times smaller than the average cement particle. Its properties, in particular its compressive strength, bond strength, and abrasion resistance. When pozzolanic materials are incorporated to concrete, the silica present in these materials react with the calcium hydroxide released during the hydration of cement and forms additional calcium silicate hydrate (C – S – H), which improve durability and the mechanical properties of concrete.

Fig1: nano silica

NANO ALUMINIUM OXIDE

Crystal Phase: 70:30 delta:gamma for 20nm & 40nm; Alpha for larger particles Morphology: Spherical for 20nm & 40nm; Irregular Platelets for larger particles Chemical Formula: Al_2O_3

Fig. 2. Nano aluminium oxide

II. LITERATURE REVIEW

Addition of nano materials to concrete increase various physical properties and some of those literature are listed below.

A. Overview Of The Literature

M.SHamidah (2016) This review paper discussed on the nano materials in concrete. Nowadays, the application of nano materials has received numerous attentions to enhance the conventional concrete properties. Eventually, the introduction of nano materials in concrete is to increase its strength and durability. Nano material isdefined as material that contains particle size which less than 200 nm. For the purpose of concrete study, the application of nano materials must be at least 500 nm in size. The addition of ultrafine nano material will help to reduce the cement content by partially replacing cement on weight basis to improve the binding effect. The ultrafine particles of nano material will also help reduce the formation of micro poresby acting as a filler agent, producing a very dense concrete and automatically reduce the growth of micro pores in the UHPC structures. Moreover, this paper presents on the advantages and benefits to enhance the concrete by utilizing nano materials.

Suhuan Du (2014) This study investigated the durability properties of concrete containing nano-silica at dosages of 0.3% and 0.9%, respectively. Due to the nano-filler effect and the pozzolanic reaction, the microstructure became more homogeneous and less porous, especially at the interfacial transition zone (ITZ), which led toreduced permeability. Tests on the durability properties verified the beneficial effects of nano-silica.The channels for harmful agents through the cement composites were partially filled and blocked.

Min-Hang Zhang et al, (2012) found that the incorporation of NS by about 2% weight of cement with 50% GGBS cement mixture, not only altered the setting time, but also increased the compressive strength by about 22% and 18% for 3rd and 7th days respectively compared to the reference slag concrete. They also reported that the large capillary porosity decreased and medium porosity increased in the slag cement pastes at 28 days. However, the incorporation of 2% NS by mass of cementious materials densify the pastes- aggregates interface compared with slag concrete without NS addition. Further reduction of size of NS appeared to be more effective in increasing the rate of cement hydration and reaction compared with SF. In another study, the same authors used NS to reduce setting times and increase early strength of concrete with high volumes of fly ash or slag. Based on the experimental results by using NS in pastes, mortars and concretes with about 50% of fly ash or slag, the incorporation of 2% NS by weight of cementations materials reduced initial and final setting times and increased 3- and 7- days compressive strengths of high volume fly ash by 30% and 25% respectively in comparison to the reference concrete with 50% fly ash and the similar trends were observed in high volume slag concrete too. . It was noted that later strength for NS with fly ash increased, but not in the case of slag cement. Similar action of chloride permeability of the NS with slag and fly ash concrete were reported compared with control concrete.

Stefanidou and Papayannis et al, (2012) The influence of NS with different dosages were studied by reported that the addition of NS tends to primarily increase the mechanical response and caused 20 -25% strength improvement . At the same time, with the addition of super plasticizers in 1% w/w of cement reduced the water demand and the strength increase varied from 30% to 35%. Impressive changes were also recorded in the structure of Nano-modified samples as the calcium silicate crystal size is larger in samples with high NS content and micro structure observation also recorded a denser structure in Nano-modified samples. In a similar line, the effect of NS addition with Portland cement pastes on the workability and compressive strength were studied by Berra, et al. They found that due to the instantaneous interactions between NS and the liquid phase of the cementations mixes (mainly dissolved alkalis), the formation of gels characterized by high water retention capacities produced a remarkable reduction of the mix workability, without changing water / binder ratio and /or addition of super plasticizers.

Kontoleontos et al, (2012) CNS behaved not only as a filler to improve cement micro- structure (decrement in porosity), but also a promoter of pozzolanic reaction by transforming CH in to C-S-H gel and reported that the optimized value of NS was 4%, which presented the higher compressive strength of 64% over control mix. They found that the enhancement of the compressive strength at later ages was due to the consumption of CH by NS. At the same time, the setting time and workability decreased, because of rapid agglomeration of the slurry from the suspending state and also NS improved the packing of particles, which contributes to the growth of paste viscosity. Also NS was proved as an agent that improved the micro-structure of the ultrafine cement pastes and showed the cement with NS presented a denser microstructure. The pore size refinement at later ages, as a result of pozzolanic reaction, also led to a significant enhancement of the compressive strength.

Mastafa Jalal et al, (2012) Reported for the mechanical, rheological, durability and micro structural properties of high performance self-compacting concrete [HPSCC] containing silica of micro and Nano size and with blended NS and SF. The addition of NS alone up to 2% weight of cement enhanced both the compressive and split strengths by about 62% and 25% respectively, whereas 2% NS blended with 10% SF with control concrete, there was an additional strength improvement of 9% and 8% respectively. They described that the enhancement of strength was not only because of pore filling effect, but also by the accelerated cement hydration due to their higher reactivity of NS. Moreover, the water and capillary absorption results revealed significant decrease by the addition of blended NS and SF for the binder content. According to SEM microstructure studies, more refined microstructure and smaller pores were achieved by the addition of NS and SF, which can led to enhancement of mechanical, durability and micro structural properties of HPSCC.

Sololev et al, (2009) The role of Nano particles of silica act as fillers in the voids or empty spaces. The well dispersed NS act as a nucleation or crystallization centres of the hydrated products, thereby increasing the hydration rate, that is, NS assisted towards the formation of smaller size CH crystals and homogeneous clusters of C-S-H composition. Moreover, they found that NS improved the structure of the transition zone between aggregates and paste. The drawback in using NS in concrete is self - desiccation due to increased surface area and it will lead to autogenous shrinkage at high concentration and thereby produces cracks in concrete. However, it can be controlled by carefully adding superplasticisers and by appropriate curing methods.

J.J. Gaitero, W. Zhu (2008) Gaitero et al, revealed that the calcium leaching was a degradation process that consisted in the progressive dissolution of the cement paste as a consequence of the migration of Ca2+ ions to the aggressive solution. The results obtained showed that NS increases the strength of the cement paste by about 30% in the core samples and ultimately the observed results highlighted the introduction of NS particles modified the cement paste in three different ways viz. reduced porosity; transforming Portlandite (CH) into C-S-H gel by means of pozzolanic reaction; and modified the internal structure of the C-S-H gel increasing the average chain length of the silicate chains.

Lin et al, (2008) observed the effect of NS addition on permeability and compressive strength of fly ash cement mortar. From the pore analysis study, it was reported that the relative permeability and pore sizes of concrete were decreased, whereas the compressive strength increased by adding more NS. Li demonstrated the effect of addition of NS in high volume fly ash concrete (more of CaO content) and the results compared and reported that the pozzolanic activity of fly ash based concrete with NS were increased considerably and found that decrements in permeability of concrete gained high strength in the early and later stage. Lin et al described the improvements in the compressive strength on sludge / fly ash mortar in the presence of NS.

Ye Qing et al, (2007) found that the setting times and consistency for SF and NS incorporated concrete were different, but NS makes the cement paste thicker and accelerated cement hydration. Compare to SF concrete, NS showed improved compressive strength and bond strength too

Jo Byung-Wan et al, (2007) studied the properties of cement mortar with NS particles and reported the importance of NS addition towards strength characteristics, hydration progress and calorimetric investigations. Observations were also made from the heat of hydration values, which depicted the amount of CH formed by the addition of NS could increase the amount of heat evolved during setting and hardening of the cement.

Ji et al, (2005) studied the water permeability resistant behaviour and micro structure of concrete with NS. The water permeability tests showed that NS concrete has better water resistant permeability than control sample, and microstructure of the NS revealed that the uniform and more compaction of NS of concrete.

Bjornstrom J et al, (2004) investigated the hydration process of tricalcium silicate (C3S) cement and established the accelerating effects of colloidal silica and role of water during hydration. From their study, it was observed that CNS accelerate dissolution of C3S phase, thereby renders the rapid formation of C- S-H phase. If the Nano particles are integrated with cement based materials, the new materials might possess some outstanding properties. The pozzolanic activity of NS is more obvious than that of silica fume counterpart. NS can react with CH crystals, which are arrayed in the interfacial transition zone (ITZ decreased and the early age stre) between hardened cement paste and aggregates and produce C-S-H gel. Thus, the size and amount of CH crystals are significantly strength of hardened cement paste in increased.

III. METHODOLOGY

The methodology worked out to achieve the above mentioned abjectives is followed as shown in the flow chart below.

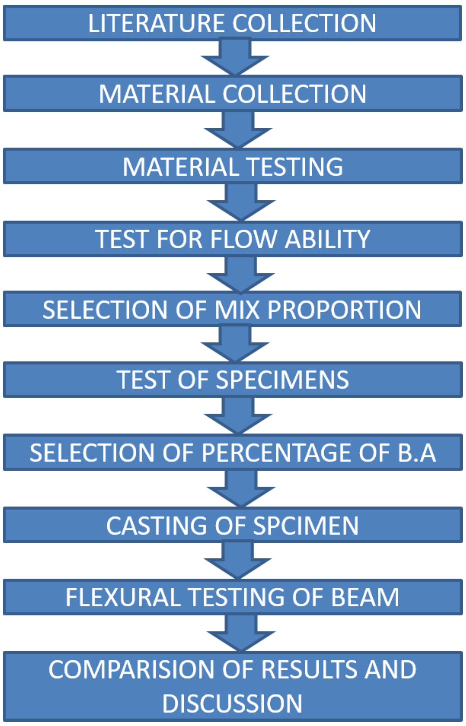

Fig.3.Methodology

IV. EXPERIMENTAL PROGRAM

A. *Mix Design*

TABLE I. MIX DESIGN

Cement (Kg/m^3)	Fine aggregate (Kg/m^3)	Coarse aggregate (Kg/m^3)	Water (Kg/m^3)	W/C	ADM IXTU RE
462.93	759.45	928.21	208.3	0.45	2%

TABLE II. MIX DESIGN RATIO

CEMENT	FINE AGGREGATE	COARSE AGGREGATE	WATER	PLASTICIZER
1	1.94	3.61	0.46	0.2% of nano materials

1. COMPRESSIVE STRENGTH TEST

The test was conducted as per IS516-1959. The specimens were kept in water. During testing surface dry conditions were obtained by wiping water on the surface. The load was applied without and increased continuously at a rate of approximately 140kg/cm^2/min until the resistance of the specimen to the increasing load breaks down and no greater load can be sustained. The maximum load applied to the specimen was then recorded and the Appearance of the concrete for any unusual features in the type of failure was noted. Average of three values was taken as the representative of the batch.

Fig. 4. Compressive Strength test

INDIRECT TENSILE STRENGTH TEST

The test was conducted as per IS 5816-1999. The tensile strength of concrete is one of the basic and important properties. Splitting tensile strength on concrete cylinder is a method to determine the Indirect tensile strength on concrete cylinder.

The concrete is very weak in tension due to the brittle nature and is not expected to resist the direct tension. The concrete develops cracks when subjected to tensile forces. Thus, it's necessary to determinate the tensile strength to determine the load at which the concrete members may crack.

Fig. 5. Indirect Tensile Strength test

3.FLEXURAL STRENGTH TEST

For determining the flexural strength of concrete a RC beam specimen of size 150mm x 150mm x 1000mm had casted. A structural loading frame had been used for the test. The testing machine may be set to any reliable type of sufficient capacity for the test. Permissible errors should be not greater than – 0.5%.

The flexural strength or modulus of rupture should be calculated using the formula given below

$$F_b = PL/(ad^2)$$

Where a is the distance between support and the crack (mm),

d is the measured depth (cm),

L is the length (mm) of the span on which the specimen is supported,

and P is the maximum total load (N) applied to the specimen.

V. RESULTS AND DISCUSSIONS

COMPRESSIVE TEST RESULT STRENGTH

Load at the failure divided by area of specimen gives the compressive strength of concrete. Compressive strength of nano silica concrete increases 28.4% at 7th day 12.9% at 28th day, compared to conventional concrete. The compressive strength resulsts are tabulated below.

DAY	CONTROLCONCRETE COMPRESSIVE STRENGTH	NANO MATERIAL MIXED COMPRESSIVE STRENGTH
7	22.90	29.27
28	30.69	34.84

SPLIT TENSILE STRENGTH TEST RESULT

Split tensile strength of nano concrete increases by 24.08% at the 7th day and increases by 13.6% at the 28th day compared to the conventional concrete. The spilit tensile strength results are tabulated below.

DAY	CONTROLCONCRETE SPLIT TENSILE STRENGTH	NANO MATERIAL MIXED SPLIT TENSILE STRENGTH
7	2.08	2.74
28	3.24	3.75

LOAD VS DEFLECTION RESULTS FOR RCC BEAM

RCC beams were cast for controlled concrete of M25 grade and nano concrete beam with Nano silica(2%) Nano titanium dioxide(2%) and Nano aluminium oxide(2%) were used additionally with cementations materials.

S.NO	LOAD	DEFLECTION
1	0	0
2	2	0.76
3	4	1.55
4	6	2.30
5	8	3.75
6	10	5.13
7	12	6.36

.LOAD VS DEFLECTION FOR NANO MATERIAL MIXED BEAM

S.No.	Load(kN)	Deflection(mm)
1	0	0
2	2	1
3	4	1.9
4	6	2.65
5	8	3.35
6	10	4.50
7	12	5.73
8	14	6.45
9	16	7.85
10	18	9.15
11	20	12.45

CONCLUSIONS

- Compressive strength of nano concrete increases 28.4% at 7th day and 12.9% at 28th day, compared to conventional concrete.
- Split tensile strength of nano concrete incresases by 24.08% at the 7th day and 13.6% at the 28th day compared to the conventional concrete.
- The flexural test shows that the deflection in nano silica concrete increases in a gradual manner until the ultimate load occurs whereas in conventional concrete the deflection is irregular due to lack of pore filling effect.
- While measuring the crack width it is found that the final crack width in conventional is
  83.1% more than the nano
  silica concrete. The load carrying capacity of Nano reinforced concrete beam increases by 12.5 % compared Concrete (RCC) beam. The load carrying capacity of Carbon Fibre reinforced Nano concrete beam increases by to Reinforced Cement
  17
  % compared to Reinforced Cement Concrete (RCC) beam
- The study concludes that the addition of nS in the concrete mixture behaves not only as a filler to improve the microstructure, but also as an activator to promote pozzolanic reaction thereby resulting in the enhancement of the durability and mechanical properties of the mix.
- It is very cost effective when considering the expenditure for the repair and renovation of conventional concrete structures.

REFERENCES

1. Sanchez F. and Sobolev K., Nano Technology in concrete - a review, Constr. Build Mater., 24, 2060-71 (2010).

2. Bjornstrom J., Martinelli A., Matic A., Borjesson L. and I. Panas, Accelerating effects of colloidal nano-silica for beneficial calcium–silicate– hydrate formation in cement, Chemical Physics Letters, 392, 242–248 (2004)

3. Ji T., Preliminary study on the water permeability and microstructure of concrete incorporating nano-SiO2, Cem. and Con. Res., 35, 1943–1947 (2005)

4. Ye Qing, Zenan Z., Deyu K. and Ch. Rongshen, Influence of nano-SiO2 addition on properties of hardened cement paste as compared with silica fume, Constr. Build Mater., 21, 539–545 (2007)

5. Jo Byung-Wan, Kim Chang-Hyun, Lim Jae- Hoon, Characteristics of cement mortar with nano- SiO2 particles, ACI Mat. Jl., 104(4), 404-407 (2007)

6. Gaitero J.J., Campillo I. and Guerrero A., Reduction of the calcium leaching rate of cement paste by addition of silica nano particles, Cem. and Con. Res., 38, 1112–1118 (2008)

7. Sololev K., Engineering of Silica nano particles for optimal performance in nano cement based materials: Nano Technology in Construction, Proceedings of the NICOM3, Prague, 139-148 (2009)

8. Senff L., Hotza D., Repette W.L., Ferreira V.M. and Labrincha J.A., Mortars with nano-SiO2 and micro-SiO2 investigated by experimental design", Constr. Build Mater, doi:10.1016/j.conbuildmat. 2010.01.012. (2010)

9. Senff L., Labrincha J.A., Ferreira V.M., Hotza D. and Repette W.L, Effect of nanosilica on rheology and fresh properties of cement pastes and mortars, Constr. Build Mater., 23, 2487–2491 (2009)

10. IS: 456 – 2000 (Fourth Revision) Indian Standard Plain and Reinforced Concrete Code of Practice.

11. IS: 2386 (Part III): 1963 Methods of test for aggregates for concrete: Specific gravity, density, voids, absorption and bulking.

12. IS: 2386 (Part IV): 1963 Methods of test for aggregates for concrete: mechanical properties.

13. Shetty. concrete technology**”**S.Chand and company Ltd, Delhi M.s,(2010) **“**

14. IS10262:2009 Concrete mix portio guidelines

15. Gambhir.M.L,“concrete technology” Tata McGraw-Hill Publishing company Ltd, New Delhi,2004.

16. Santhakumar.A.K.S, “concrete technology” Oxford Publication, New Delhi,2006.

17. IS 456 : 2000 code of practice for plain and reinforced concrete(third revision)

18. IS 516: 1959 method of test for strength of concrete (Jan-99)

19. IS 5816: 1999 methods of tests for splitting tensile strength of concrete (first revision)

20. IS: 8112-1989, Specifications for 43 grade Portland cement, Bureau of Indian Standards, New Delhi, India.