STRENGTH & DURABILITY ANALYSIS OF NANO CLAY IN CONCRETE

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Abstract: Concrete is widely used in structural engineering with its high compressive strength, low cost and abundant raw material. But common concrete has some shortcomings, for example, low tensile and flexural strength, poor toughness, high brittleness, and so on that restrict its application. To overcome these deficiencies, additional materials are added to improve the performance of concrete. A Nano admixture is a composite material that has been developed in recent years. It has been successfully used in construction with its excellent flexural tensile strength, permeability and so on. An attempt has been made in this paper to provide the advantages and benefits of using nano admixtures in concrete for a variety of applications. The use of admixtures help in modifying properties of concrete both in plastic and hardened stage and thus results into a more durable concrete. The main purpose of this investigation is to study the effects of nano clay on the compressive, split tensile and flexural strength of concrete. Concrete specimens were casted with and without nano clay and tested after 7 and 28 days water curing. Experimental results show that addition of admixtures improves the performance of concrete.

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1. Introduction

The use of micro admixtures to reinforce concrete materials is a well–known concept. It has been practiced since ancient times, with admixtures mixed into micro size fine and coarse aggregate. However, in our modern day construction practices we have forgotten the ancient practices micro admixtures in concrete. Portland cement concrete is considered to be a relatively brittle material and is prone to crack in the plastic as well as the hardened stage. Plastic shrinkage occurs when the evaporation of water from the surface of concrete is greater than the rising bleed water. As concrete is very weak in tension in its plastic stage, a volume change causes the surface to crack. As it hardens, the water present in the pores of concrete begins to evaporate. This causes the concrete to shrink due to the volume change, which is restrained by addition of nano admixtures. This results in a tensile stress being developed in hardened concrete, again causing the concrete to crack. Cracks lead to negative perception of quality, durability and serviceability, however in most cases they become only aesthetic problems. Cracks also results in disputes between the owner, Architect, design Engineer and contractor which results in job delays and cost increases due to work stoppages and evaluation which is more severe than the actual consequences of cracking. One of the solutions to this problem is the additions of nano admixtures (nano size fine aggregate) to concrete.

An attempt has been made in this paper to provide the advantages and benefits of using nano admixtures concrete for a variety of applications. The use of nano admixtures help in modifying properties of concrete both in plastic and hardened stage and thus results into a more durable concrete, High early strength, Quick slump gain, Variable viscosity at same yield stress, etc.,

2. Definition of Nano-Concrete

For discussions presented in this paper, nano-concrete is defined as a concrete made with Portland cement particles that are less than 500 nano-meters as the cementing agent. Currently cement particle sizes range from a few nano-meters to a maximum of about100 micro meters. In the case of micro-cement the average particle size is reduced to 5 micro meters. An order of magnitude reduction is needed to produce nano-cement.

2.1 Main Objective:

The purpose of this study was to determine the effect of the use of nano materials (nC) in concrete and cement mortar. Specifically, the objective of the study was to determine if nano materials can increase strength, decrease permeability, and cause a denser cement matrix. The study was conducted with 4 batches of cement mortar, including, there Nano clay and without nano clay, that were made in the laboratory.

2.2 Concrete

Concrete is one of the most common and widely used construction materials. Its properties have been well studied at macro or structural level without fully understanding the properties of the cementitious materials at the micro level. The rapid development of new experimental techniques makes it possible to study the properties of cementitious materials at micro/nano-scale. Research has been conducted to study the hydration process, alkali-silicate reaction (ASR), and fly ash reactivity using nanotechnology.

The better understanding of the structure and behavior of concrete at micro/nano-scale could help to improve concrete properties and prevent the illness, such as ASR. Addition of nanoscale materials into cement could improve its performance.

The dispersion/slurry of amorphous nanosilica is used to improve segregation resistance for self-compacting concrete. It is also been reported that adding small amount of carbon nanotube (1%) by weight could increase both compressive and flexural strength.

2.3 Structural Composites

Steel is a major construction material. Its properties, such as strength, corrosion resistance, and weld ability, are very important for the design and construction. The new steel was developed with higher corrosion-resistance and weld ability by incorporating copper nanoparticles from at the steel grain boundaries. Sandvik NanoflexTM is new stainless steel with ultra-high strength, good formability, and a good surface finish developed by Sandvik Nanoflex Materials Technology. Due to its high performance, Sandvik NanoflexTM is suitable for application where requires lightweight and rigid designs.

For certain applications, the components could be even thinner and lighter than that made from aluminium and titanium due to its ultra-high strength and modulus of elasticity. Its good corrosion and wear resistance can keep life-cycle costs low.

Attractive or wear resistant surfaces can be achieved by various treatments (Sandvik Nanoflex Materials Technology). MMFX2 is nanostructure-modified steel, produced by MMFX Steel Corp. Compared with the conventional steel; it has a fundamentally different microstructure- laminated lath structure resembling “plywood”.

3. Application of Nano Technology in Construction

Nanotechnology can be used for design and construction processes in many areas since nanotechnology generated products have many unique characteristics. These characteristics can, again, significantly fix current construction problems, and may change the requirement and organization of construction process.

These include products that are for:

i. Better properties of cementitious materials.
ii. Lighter and stronger structural composites
iii. Low maintenance coating
iv. Improving pipe joining materials and techniques.
v. Reducing the thermal transfer rate of fire retardant and insulation.
vi. Increasing the sound absorption of acoustic absorber increasing the reflectivity of glass.

The abbreviated list is not an exhaustive list of applications of nanotechnology in construction.

Table 1: Properties of Nano Clay:

Treatment	**Properties Cloisite-15A**	**Nanofill-15**
Organic Modifier	MT2ETOH (methyl, tallow, bis2-hydroxyethyl, quaternary ammonium)	nano disperse layered silicate, long chain hydrocarbon
Weight Loss on Ignition	43%	35%
Base Anion	Montmorillonite Chloride	Montmorillonite Ammonium Chloride
Particle – Sizes - 10% less than	2µm	5µm
50% less than	6µm	15µm
90% less than	13µm	25 µm
Loose Bulk, kg/m3	230	190
Packed Bulk, kg/m3	364	480
Density, g/cc	1.66	1.88
X Ray Results	d = 31.5Å	d = 28 Å
Plastic Index	88%	85%

4. Test Procedure & Results

Table 2: Workability

Sl.No	Type of materials	Percentage of nC	Workability Slump in mm
1	Conventional	-	140
2	Nano Clay	0.5	134
3		1.0	128
4		1.5	114

4.1 Testing of Hardened concrete

Testing of Hardened concrete plays an important role in controlling and confirming the

quality of cement concrete works. The test methods should be simple, direct and convenient to apply.
The following tests has been conducted are given below.

- Test for Compressive strength
- Test for Split tensile strength
- Test for Flexural strength

4.1.1 Compressive strength:

Concrete cubical moulds of size 15 cm x 15cm x 15 cm are commonly used. The concrete is poured in the mould and tempered properly so as not to have any voids. After 24 hours these moulds are removed and test specimens are put in water for curing. The top surface of these specimens should be made even and smooth. This is done by putting cement paste and spreading smoothly on whole area of specimen.

The specimens are tested by compression testing machine after 7 days curing or 28 days curing. Load should be applied gradually at the rate of 140 kg/cm^2 per minute till the Specimens fails. Load at the failure divided by area of specimen gives the compressive strength of concrete.

4.1.2 Split tensile strength:

The concrete is fill in the cylinder mould in four layers each of approximately 75 mm and ram each layer more than 35 times with evenly distributed strokes. Remove the specimens from the mould after 24 hours and immerse them in water for the final curing. The test is usually conducted at the age of 7-28 days. Apply the load without shock and increase it continuously at the rate to produce a split tensile stress of approximately 1.4 to 2.1 N/mm^2/min Compute the split tensile strength of the specimen to the nearest 0.25 N/mm^2.

4.1.3 Flexural strength:

Beams shall be fabricated in sets of three (3) beams for each test age. Before each use, apply a release agent such as a light coat of fresh oil to all inside surfaces of the mold. Place the concrete in the molds, Vibrate the concrete. The duration of vibration required will depend upon the workability of the concrete and the effectiveness of the vibrator. Cover the beams with an insulating blanket to hold the heat and moisture in the beams while they cure. Apply the load continuously at a rate that constantly increases the extreme fiber stress from 0.85 MPa to 1.2 N/mm^2/min, until rupture occurs. The average of these three Specimens is listed.

Table 3: Compressive strength of Concrete (7th day)

C/S Area of specimen (mm^2)	**Failure load (KN)**	**Compressive strength (N/mm^2)**	**Average Compressive Strength (N/mm^2)**
22500	495	22	
0%nC	490	21.77	21.70
Conventional Concrete	480	21.33	
22500	510	22.66	
0.5% nC	505	22.44	22.66
(nano clay)	515	22.88	
22500	520	23.11	
1.0% nC	530	23.55	23.12
(nano clay)	510	22.66	
22500	550	24.44	
1.5% nC	540	24.00	24.12
(nano clay)	538	23.91	

Table 4: Compressive strength of Concrete (28th day)

C/S Area of specimen (mm^2)	**Failure load (KN)**	**Compressive strength (N/mm^2)**	**Average Compressive Strength (N/mm^2))**
22500	720	32	
0%nC	750	33.33	32
Conventional Concrete	730	32.44	
22500	750	33.33	
0.5% nC	770	34.21	33.84
(nano clay)	765	33.99	
22500	760	33.77	
1.0% nC	770	34.22	34.12
(nano clay)	773	34.35	
22500	800	35.55	
1.5% nC	795	35.33	35.46
(nano clay)	798	35.46	

Table 5: Split tensile strength of Concrete (7th Day)

Length X Diameter (mm)	Failure load (KN)	Split tensile strength (2P/πLD)	Average (N/mm²)
300X1500%nC	230	3.25	
Conventional	220	3.11	3.25
Concrete	240	3.40	
22500	230	3.25	
0.5% nC	240	3.39	3.32
(nano clay)	235	3.32	
`22500	260	3.68	
1.0% nC	280	3.96	3.82
(nano clay)	270	3.82	
22500	345	4.88	
1.5% nC	350	4.95	4.91
(nano clay)	346	4.89	

Table 6: Split tensile strength of Concrete (28th Day)

Length X Diameter (mm)	Failure load (KN)	Split tensile strength (2P/πLD)	Average (N/mm²)
300X1500%nC	280	3.96	
Conventional	290	4.1	4.03
Concrete	285	4.05	
22500	300	4.24	
0.5% nC	290	4.10	4.08
(nano clay)	275	3.89	
22500	325	4.60	
1.0% nC	330	4.67	4.62
(nano clay)	322	4.55	
22500	395	5.59	
1.5% nC	400	5.66	5.56
(nano clay)	384	5.43	

Table 7: Flexural Strength of Concrete (7th Day)

% addition of nano Clay	Failure load (KN)	Flexural Strength (Pl/bd²)	Average Flexural Strength (N/mm²)
	6.2	3.1	
0% nC	6.3	3.15	3.10
Conventional Concrete	6.1	3.05	
0.5% nC	6.6	3.3	
(nano clay)	6.5	3.25	3.30
	6.7	3.35	
	9.3	3.72	
1.0% nC	9.5	3.80	3.76
(nano clay)	9.4	3.76	
1.5% nC	12.4	4.96	
(nano clay)	12.2	4.88	4.88
	12.6	5.04	

Table 8: Flexural Strength of Concrete (28th Day)

% addition of nano Clay	Failure load (KN)	Flexural Strength (Pl/bd²)	Average (N/mm²)
0% nC	8.0	4.00	
Conventional	7.8	3.90	3.916
Concrete	7.7	3.85	
	8.0	4.00	
0.5% nC **(nano clay)**	8.1	4.05	4.00
	7.9	3.95	
	11.3	4.52	
1.0% nC	11.1	4.44	4.48
(nano clay)	11.2	4.48	
	13.8	5.52	
1.5% nC **(nano clay)**	13.6	5.44	5.48
	13.7	5.48	

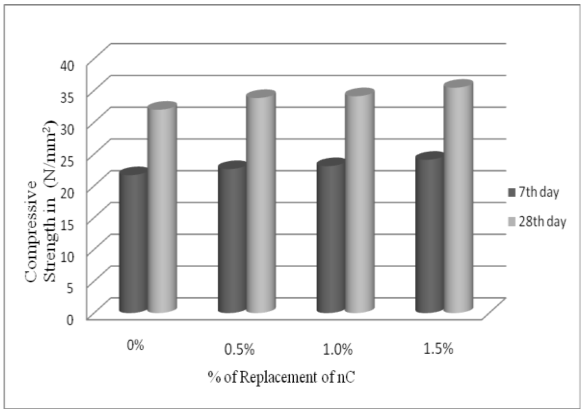

Chart-1: Compressive strength of Concrete with and without nC (0 - 1.5 %)

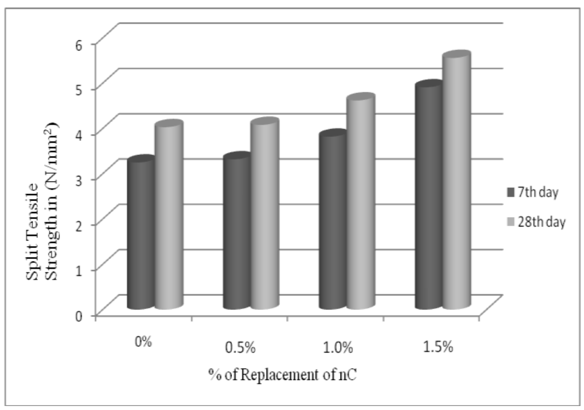

Chart-2: Split tensile strength of Concrete with and without nC (0 – 1.5 %)

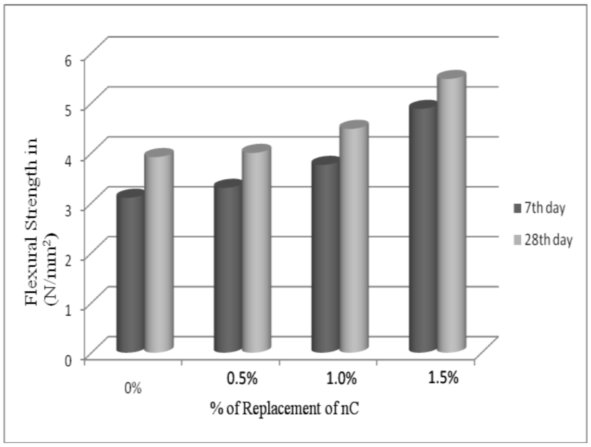

Chart-3: Flexural Strength of Concrete with and without nC (0 – 1.5 %)

5. Immediate Benefits For the Users

i. High impermeability.
ii. Cessation of super plasticizing utilization.
iii. Cessation of silicosis risk.
iv. Cessation of contamination caused by micro clay solid particles.
v. Lower cost per building site.
vi. Concrete with high initial and final compressive and tensile strengths.
vii. Concrete with good workability.
viii. Reduction of cement using Core concrete Nanoclay.
ix. Core concrete nano clay on itself produces nano cement.
x. During the moisturizing reaction of the cement, the clay produces CSH particles, the “glue” of the concrete ensuring the cohesion of all the particles.
xi. Core concrete has a specific surface near to 1,000 m^2/gr (micro silica has only 20 m^2/gr) and a particle size of 5nm to 250 nm.

6. Conclusion

The nano Clay based concrete structure fill all micro holes, because its thousand times smaller than in the case of traditional concrete materials. This allows the reduction of the cement used and gives the compression needed to reduce over 90 % of the additives used in the production of concrete. Core concrete allows saving some percentage of the used cement.

The use of nano Clay help in modifying properties of concrete both in plastic and hardened stage and thus results into a more durable concrete. It has been recognized that the addition of small, closely spaced and uniformly dispersed nano Clay to concrete would act as crack arrester and would substantially improve its static and dynamic properties. Addition of nano Clay enhances the ductility performance, post-crack tensile strength, fatigue strength and impact strength of concrete structures. The main purpose of this investigation is to study the effects of nano Clay on the workability, compressive strength, split tensile and flexural strength of M20 grade concrete. For comparison, reference specimens were tested. Experimental results show that the workability of concrete reduces with the addition of nano Clay in concrete and also the results show that the nano Clay concrete specimen’s gives higher compressive, split tensile and flexural strength.

7. Future Challenge and Direction

While nanotechnology based construction products provide many advantages to the design and construction process, the production of these products, however, require a lot of energy.

Also, the nano tubes might cause a lung problem to construction workers. In other words, it creates an environmental challenge to the construction industry as well. Sustainability and environmental issues caused by growing economic development has gained intensive statewide and worldwide attention. Since the construction industry is heavily involved in the economic development and consumes great amount of resources and energy, its impact on environment is significant. Therefore, it is necessary and urgent to regulate the construction and its related performance to sustainable manners.

The nano technology becomes a double-edge sword to the construction industry. More research and practice efforts are needed with smart design and planning, construction projects can be made sustainable and therefore save energy, reduce resource usage, and avoid damages to environment. It is necessary to establish a system to identify the environmentally friendly and sustainable of construction nano materials and to avoid the use of harmful materials in the future.

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