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The Use Of Nanoclay As A Constructional Material

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ABSTRACT

This study evaluated the use of a type of nanomaterial i.e nanoclay in cement mortar compared with conventional cement mortar. Cement mortar specimens containing nanoclay were prepared in the laboratory and compared to those prepared without any nanoclay, Specimens were tested for compressive strength and permeability. The main objective of this research is to constitute a blended cement mortar with fractional increase in mechanical strength and a greater increase in water-tightness as compared to ordinary cement mortar. The nano-clay used in this investigation was nanometakaolin (NMK).The microstructure of this nanosilica cement is denser and more uniform than that of the conventional cement microstructure. The results of this study indicate that the nanoclay tested has tremendous potential in cement as well as concrete applications. However, further evaluation is required before nanoclay can be used in concrete in a full-fledged manner.

1. Introduction

Concretes containing various supplementary cementitious materials (SCMs) such as silica fume, fly ash, and slag have improved properties. Nanomaterials (a nanometer, nm, is 10-9 m), which are the new SCMs with possible applications in concrete, have the smallest particle size, that is less than 100 nm. Nanomaterials are very reactive because of the particles' small size and large surface area and have great potential in improving concrete & cement properties such as compressive strength and permeability. The potential benefits of using nanomaterials over other SCMs are their high reactivity, the need for smaller amounts, resulting in less cement replacement; and cost-effectiveness .They should be evaluated for improved dispersion to achieve uniformity, optimized amounts of ingredients, and cost effectiveness.

Why is there a need for Supplimentary cementitious materials in concrete ??

It is estimated that the present consumption of concrete in theworld is of the order of 10 billion tonnes (12 billion tons) every year.

The ability of concrete to withstand the action of water without serious deterioration makes it an ideal material for building structures to control, store, and transport water.

The ease with which structural concrete elements can be formed into a variety of shapes and sizes.

Concrete does not corrode, needs no surface treatment, and its strength increases with time; therefore, concrete structures requires essentially no maintenance.

Concrete durability is very important, especially when concretes are exposed to the outdoors. Therefore, many new ways to improve concrete properties to ensure longevity are being investigated. Nanotechnology is a relatively new technology that is being integrated into many applications including construction,electronics, telecommunications, and biomedicine. Manipulation at the nanoscale can change chemical reactions, temperature, electricity, and magnetism . Nanotechnology deals with particles having at least one dimension between approximately 1 and 100 nm. Recently ,nanotechnology has been applied in the production of concrete to reduce permeability, which is essential in extending service life. In addition, the nanomodification can result in improvements in strength, shrinkage, ductility, and impact resistance . When used as supplementary cementitious material (SCM) in concrete, various nanoparticles can improve and densify the cement matrix, leading to improved permeability and strength. The nanoparticles act as "nuclei" of hydration , possess pozzolanic behavior , and can fill the voids in the cement matrix .

Pozzolans chemically react with calcium hydroxide liberated during hydration to form cementitious compounds . The large surface area of nanoparticles and their abundance because of their small size can facilitate the chemical reactions necessary to produce a dense cement matrix with more calcium silicate hydrate (C-S-H) and less calcium hydroxide. This, in turn, will enhance the overall concrete performance. Nanoparticles are, in general, smaller than the commonly used SCMs, making them more reactive and effective. Different forms of nanosilica (NS) and nanoclays (NC) in cement paste have been shown to increase compressive strength, reduce permeability, and cause a denser microstructure. Nanoparticles can also strengthen the interfacial transition zone between the cement paste and the aggregate, which would lead to improved strength and permeability. For nanoparticles to be a substitute for other SCMs of larger particle size, equal or better performance at lower or equal cost is needed. This may be achieved by using lower dosages of nanoparticles.

Main Objective:

The purpose of this study was to determine the effect of the use of nanomaterials in concrete and cement mortar. Specifically, the objective of the study was to determine if nanomaterials can increase strength, decrease permeability, and cause a denser cement matrix.

The study was conducted with 4 batches of cement mortar, including, three Nano clay and without nanoclay, that were made in the laboratory

2. Theory

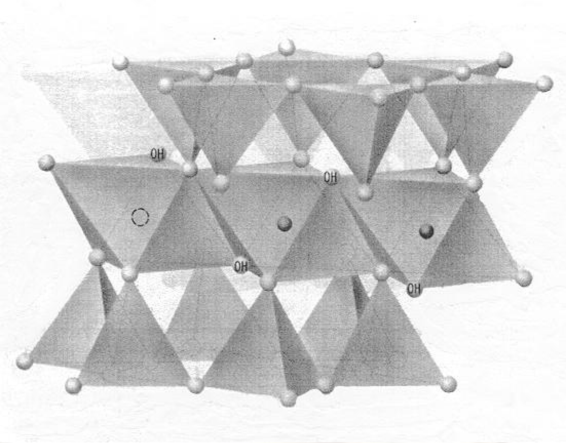
2.1 Nanoclays:

The essential nanoclay raw material is montmorillonite; a 2-to-1 layered smectite clay mineral with a platey structure. Individual platelet thicknesses are just one nanometer (one-billionth of a meter), but surface dimensions are generally 300 to more than 600 nanometers, resulting in an unusually high aspect ratio. Naturally occurring montmorillonite is hydrophilic. Since polymers are generally organophilic, unmodified nanoclay disperses in polymers with great difficulty. Through clay surface modification, montmorillonite can be made organophilic and, therefore, compatible with conventional organic polymers. Surface compatibilization is also known as “intercalation”. Compatibilized nanoclays disperse readily in polymers.

1. **nanoclay**

The nanoclay used in this experiment was Metakaolin. High-purity kaolinitic clays can be calcined at relatively low temperature 600-700o C to keep silica and alumina in amorphous state, then pulverized to particles smaller than 2 microns. The product is a highly reactive pozzolan of white color that is especially suitable for use in architectural concrete.

2.2 Properties of Nanoclay:



2. structure

Silica is the dominant constituent of clays, with Alumina being essential, as well. .Clays have a layered structure consisting of 2 types of sheets, the silica tetrahedral and alumina octahedral sheets. The silica tetrahedral sheet consists of SiO4 groups linked together to form a hexagonal network of the repeating units of composition Si4O10. The alumina sheet consists of two planes of close packed oxygens or hydroxyls between which octahedrally coordinated aluminum atoms are imbedded in such a position that they are equidistant from six oxygens or hydroxyls. The two tetrahedral sheets sandwich the octahedral, sharing their apex oxygens with the latter. These 3 sheets form one clay layer. If the octahedral positions were occupied by alumina, we would not be looking at clay at all, but the inert mineral pyrophyllite. So, extremely important to the structure of clays is the phenomena of isomorphous substitution. Replacement of trivalent aluminum by divalent magnesium or iron II results in a negative crystal charge. The excess negative charge is compensated on the clays’ surface by cations that are too large to be accommodated in the interior of the crystal. Further, in low pH environments, the edges of the clay crystal are positive, and compensated by anions. The result is a polyionic, supercharged nano-wafer that is unique in the world of minerals

3. Experimental Procedure

3.1 Mix Design used for 3 different batches

Ingridient	Proportion		
	1% nanoclay	2% nanoclay	Without nanoclay
Cement- gm	1700	1700	1700
Sand –gm	5100	5100	5100
Water –ml	680 (40%)	680 (40%)	680(40%)
Superplasticizer	17 ml	17 ml	17 ml
Nanoclay –gm	17	34	0

3. first batch of cube specimens casted

3.2 Number of specimens casted

Type of specimen	Number of specimens		
	1% NC	2% NC	W/O NC
CUBE (70mm)	6	6	6
CYLINDER(d=150mm ; h=50mm)	1	1	1
TOTAL	18 cubes & 3 cylinders		

3.3 Behaviour Tests:

3.3.1Compressive Strength

- The compressive strength tests were performed on 70 mm cube samples for 7 day & 28 day strength, using 3000KN compressive machine (Applied mechanics department, L.D.C.E) on according to IS. Three samples per batch were tested, and the average strength was reported. The loading rate on the cubes was 0.72 mm/min.

4. specimen tested for compressive strength

5. specimen after compressive failure

3.3.2 Permeability test :

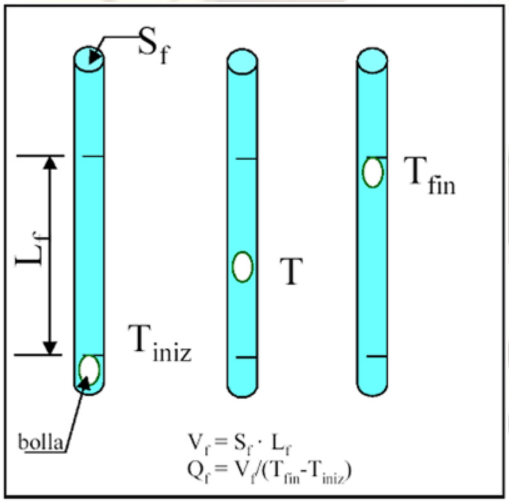
Testing Principle

- The concrete sample is subjected to the oxygen permeability test by applying a pressure ramp and measuring the flow and pressure of the input gas.
- The characteristics of oxygen permeability is calculated assuming that the conditions of flow stability required to meet the Hagen-Poiseuille relationship are met which governs the permeability of compressed fluids in a micro-porous body.

6. cylindrical specimen for permeability testing

7. permeability test apparatus

The gas flow f Q is then measured using the following relationships :



where:
Sf = net cross-section area of the flow meter
Lf = selected reference length
Vf = reference volume
Tfin – Tiniz = time need for bubble to travel from lower reference mark to upper reference mark (select a flow meter with a cross section such that this time is between 20 and 60 seconds).

The final equation of the coefficient of permeability can be given by

: K=1.14*10-4*Qf*Pu/(P2-Pa2) ….(1)

where:

Q is the gas flow (m3.s-1)
p is the absolute input pressure (pascal)
pa and po according to the UNI standard are assumed to be
the same at the atmospheric pressure. Pa=1
Repeat the operations described at points b, c, d, e and f in
correspondence with each of the gas input pressures: 200;
250; 300; 350 Pa.

4.RESULTS AND OUTPUT ANALYSIS

4.1 COMPRESSION TEST RESULTS

7 day strength			
Percentage	**1% NC**	**2%NC**	**Without NC**
Compressive force endured before failure in KN	85	47.5	13.1
	28	33.5	13.5
	20	33.1	12.1
Average of force	44.3	38.03	12.9
Average Strength in N/mm^2	9.05	7.75	2.67

28 day strength			
Percentage	**1%**	**2%**	**Without NC**
Compressive force endured before failure in KN	**170**	**95**	**36.9**
	85	**65**	**33**
	80	**61**	**38**
Average	**111.7**	**73.7**	**35.9**
Average strength in N/mm^2	**22.7**	**15.04**	**7.32**

4.2 Permeability test results

Nanoclay %	Pressure in Kpa	Diameter in cm (d)	Length in cm (Lf)	TIME IN SEC(t)	AREA IN cm^2(Sf)	Reference velocity in cm^3(Vf) = Sf*Lf	Gas flow in cm^3/sec(Qf) = (Vf/(Tfinal-Tinitial))	Permeability(k)	mean of permeability
2%	**150**	**1.6**	**56**	**13.03**	**2.01**	**5017.6**	**385.0806**	**0.035119**	**0.016478 $*10^{-4}$**
	200	**1.6**	**49**	**8.13**	**2.01**	**3841.6**	**472.5215**	**0.017956**	
	250	**1.6**	**47**	**5.22**	**2.01**	**3534.4**	**677.0881**	**0.014702**	
	300	**1.6**	**39**	**4.02**	**2.01**	**2433.6**	**605.3731**	**0.008627**	
	350	**1.6**	**34**	**3.13**	**2.01**	**1849.6**	**590.9265**	**0.005988**	
1%	**150**	**1.6**	**48**	**8.43**	**2.01**	**3686.4**	**437.2954**	**0.039881**	**0.014782 $*10^{-4}$**
	200	**1.6**	**42**	**6.15**	**2.01**	**2822.4**	**458.9268**	**0.017439**	
	250	**1.6**	**35**	**5.34**	**2.01**	**1960**	**367.0412**	**0.00797**	
	300	**1.6**	**29**	**3.29**	**2.01**	**1345.6**	**408.997**	**0.005828**	
	350	**1.6**	**21**	**2.56**	**2.01**	**705.6**	**275.625**	**0.002793**	
0%	**150**	**1.6**	**20**	**2.14**	**2.01**	**640**	**299.0654**	**0.027275**	**0.009316 $*10^{-4}$**
	200	**1.6**	**16**	**1.56**	**2.01**	**409.6**	**262.5641**	**0.009977**	
	250	**1.6**	**13**	**1.3**	**2.01**	**270.4**	**208**	**0.004517**	
	300	**1.6**	**10**	**1.02**	**2.01**	**160**	**156.8627**	**0.002235**	
	350	**1.6**	**9**	**0.51**	**2.01**	**129.6**	**254.1176**	**0.002575**	

5. CONCLUSION OF THE TESTS PERFORMED

Based on the experimental studies presented in this paper, the following conclusions can be drawn:

Compressive and tensile strength of the cement mortars with Nanoclay is higher than that of the plain cement mortar with the same w/b ratio.

The enhancement of compressive strength was about 300% at 1% NC nanoclay Replacement and is about 290% at 2% NC for seven day testing. While for 28 day testing it was 310% for 1% NC and 200% for 2% NC.

The NMK in cement mortar acts as a nano-fiber due to its morphology.

The permeability coefficient of specimens with 1% Nanoclay was found to be around 150% more, while for specimens with 2% Nanoclay it was found to be 200 % more than that of specimens without Nanoclay.

5.1 Visual observations on specimens before and after the test

It was observed before testing of the specimens that the cubes with nanoclay were quick to dry , whereas those without any nanoclay took much longer to dry out under similar conditions of open atmosphere.

In accordance with this observation it was also noted after the specimens failed in shear that the mortar of the cubes with lesser strength was a bit wetfrom the inside, whereas the mortar for cubes with higher strength was dry and of the same colour as the exterior.

Hence, it may be concluded that nanoclay addition to cement mortar increases the speed of its drying capacity.

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LITERATURE REVIEW

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