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Experimental study on effect of Colloidal Nano SiO_2 and Fly Ash addition on properties of cement mortar

V. R.RATHI, C.D. MODHERA
Department of Applied Mechanics, S.V.N.I.T. Surat - 395007, Gujarat, India
Email: vrrathiin@yahoo.com, cdmodhera@gmail.com

Abstract: The influence of Colloidal nano SiO_2 (CNS) addition along with P-100 grade of fly ash on hydration of cement paste and compressive strength of cement mortar were investigated. The result revealed that fly ash hydration is accelerated by CNS at early age thus enhancing the early age strength of materials also it was observed that standard consistency of cement paste does not vary much more but by addition of CNS along with fly ash Initial and final setting time get accelerated, also the compressive strength of cement mortar was improved significantly.

Keywords*: CNS, fly ash, IST, FST, Compressive strength*

Introduction:

Fly ash, a waste by product of power plant has been increasingly used in cement and concrete materials because of many advantages , such as reduced carbon foot prints, increased flow ability, decreased hydration heat, enhanced long term strength growth, reduced shrinkage, improved durability, and lower cost, undesirably delay in early age strength gain of fly ash cement based material is often considered to be major drawback , except for some special concrete applications such as mass concrete. To compensate for this short coming, many methods have been explored to accelerate the early –age hydration of fly –ash cement systems including mechanical grinding, chemical activation, mechano chemical treatment and hydrothermal treatment.

On the other hand Silica fume (SF) has been found to be very effective in accelerating cement hydration containing about 90% SiO_2, SF reacts calcium hydroxide (CH) and produces additional C-S-H gel in the cement hydration, improving the pozzolanic property as well as durability of hardened cementitious material.

More recently, a more pozzolanic – reactive material nano SiO_2 has been used to improve the properties of cementitious materials, and shown an excellent enhancing effect on early age properties. The improvement were observed due to three reasons,

1. The acceleration effect of CNS on cement hydration
2. Pozzolanic reaction of CNS
3. Improved particle packing of the matrix.

Although other nano particles were studied, nano silica has often been the first choice due to its high pozzolanic activity. The common characteristics of CNS and fly ash are that they are pozzolanic materials and absorb, react with, or consume, CH that is generated from cement hydration. Normally to get a considerable improvement of strength gain the dosage of CNS may be in the range of 1 to 6 % by mass of binder, since nano SiO_2 and FA compete in absorbing CH and nano SiO_2 is far more reactive than FA, it may be deduced that there may be shortage of CH in nano SiO_2 added fly ash cementitious materials system, thus Preventing fly ash hydration at later age, when FA content is high.

In present study it was tried to verify the effect of CNS on basic properties of cement paste like standard consistency, Initial and final setting time, soundness of cement with addition of FA (P-100 grade) in various proportions ranging from 10 to 30 % along with varying dosage of CNS from 1 to 6%, also the mechanical property such as compressive strength of cement mortar at 3, 7 and 28 days were studied.

Experimental work:

A] Standard consistency ;- The basic aim is to find out the water content required to produce the cement paste of standard consistency as specified by the I.S. 4031(Part-4)-1988 , the principle is that standard consistency of cement is that consistency at which Vicat Plunger penetrates to a point 5-7 mm from bottom of Vicat mould .

B] Initial and final setting time: - To calculate IST and FST as per I.S. 4031(Part-5)-1988 to do so use Vicat apparatus confirming to I.S 5513-1976.is used

C] Soundness test: - Soundness of cement is determined by Le-Chatelier's mould as per I.S. 4031(Part-3)-1988 and apparatus confirming to I.S 5514-1969 was used

D] Compressive strength of mortar cubes: - I.S Sand is used for determining compressive strength of cement mortar cubes of size 70.7 mm x 70.7 mm x 70.7 mm mortar with 1:3 proportions having one part of cement and three parts of standard sand, water content is taken as 0.85% of standard consistency required for each cement and cement replacing material used.

The three mortar cubes are filled with mortar material for each replacement for 3, 7, and 28 days of testing .The mortar cubes after casting are placed in humid atmosphere with 27± 2^oc atmospheric temperature about 65% humidity for 24 hrs and after that cured for specified period .

Properties of materials used:

A] Cement: Ultra-Tech 53 Grade OPC is used for the work with following physical properties

S.No	**Physical Requirements**	Ultra-Tech OPC 53 Grade	I.S 12269-1987
1	Specific Surface area m^2/kg	330	>225
2	Soundness by Le-Chatelier's mm	0.8	<10
3	Auto clave%	0.062	<0.8
4	Initial Setting time	150 min	>30min
5	Final Setting time	225 min	<600min
6	Compressive strength Mpa 3 days 7 days 28 days	38 47.6 63.6	>33 >43 >53
	Chemical Requirements		
7	Loss on Ignition %	2.78	< 5
8	Insoluble Residue %	1.80	< 3
9	Magnesium Oxide	1.00	< 6
10	Lime Saturation factor	0.90	0.8-1.02
11	Alumina Iron ratio	1.32	0.66-1.02
12	Sulphuric Anhydride	2.50	< 3
13	Chlorides	0.050	<0.1
14	C_3A	3.9	5.5

B] P-100 Grade of fly ash (Given by Dirk India Pvt.Ltd Nasik)

S.No	Test	I.S. Specification	Pozzocrete-P-100
1	Fineness by Blain's Permeability m^2/kg	320	610
2	25 micron residue %	----	0.08
3	45 micron residue %	3.4	Traces
4	Lime reactivity N/mm^2	4.5	9.37
5	Moisture Content %	2.0	0.23
6	Auto clave expansion %	0.8	0.021
7	Comp. Strength at 28 days in Mpa A] P100+ Cement Mortar B] Plain Cement Mortar	33 32	103.13%
8	Loss on Ignition %	5.0	0.70
9	SiO_2 + Al_2O_3 +Fe_2O_3 %	70min by mass	93.26
10	SiO_2 %	35min by mass	60.35
11	MgO%	5max by mass	2.04
12	So_3 %	3max by mass	0.96
13	Na_2O%	1.5 max by mass	0.58
14	Total Chlorides%	0.05max by mass	.028

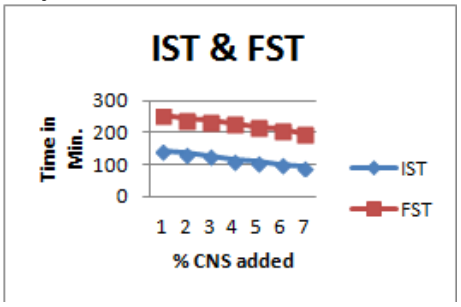
C] Colloidal Nano Silica (CNS) (Given by Bee-Chem. Pvt. Ltd Kanpur)

Parameter	Nano-Solids	Particle Size	Sp. gravity	Viscosity
Value	15-16%	5-8 nm	1.15	10-12 sec

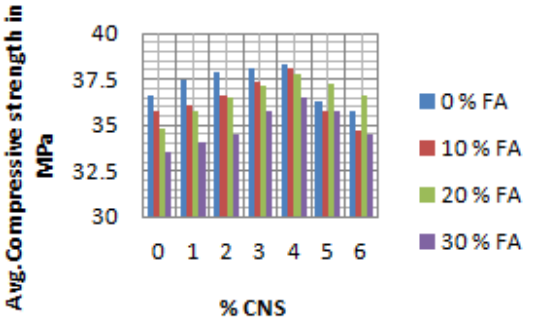
D] Standard sand:- for experimental work of cement mortar it is used as per specifications of I.S 650-1991 having following properties **.**

S.No	Type	Specifications	% Used
1	Grade-I	Smaller than 2mm and greater than 1mm	33.33
2	Grade-II	Smaller than 1mm and greater than 500 micron	33.33
3	Grade-III	Below 500 micron but greater than 90 micron	33.33

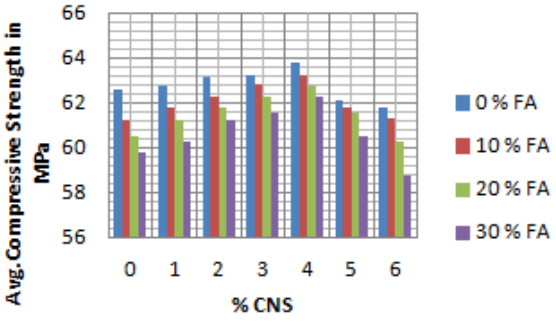
Experimental results: - As represented below graphically



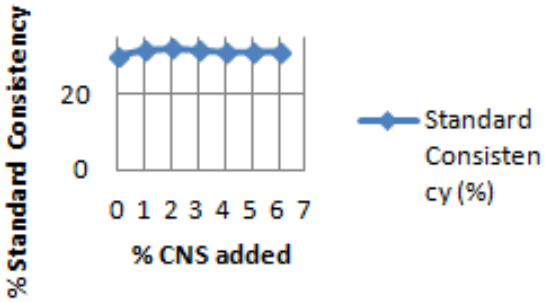
3 Days Comp. Strength



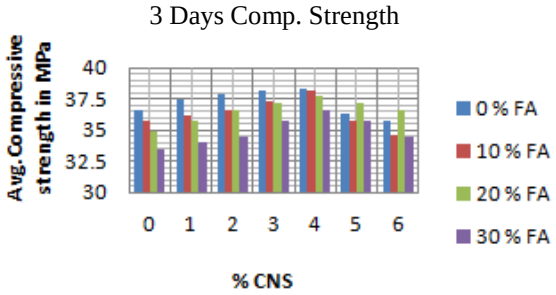
28 Days Comp. Strength



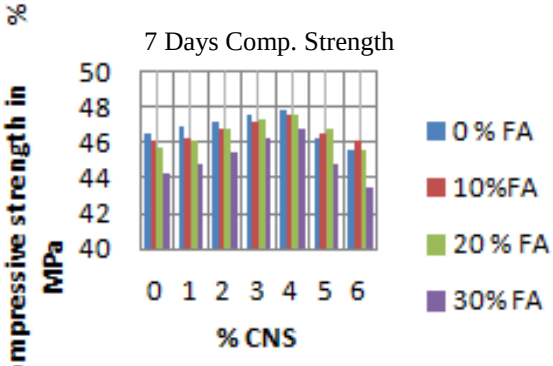
Standard Consistency (%)



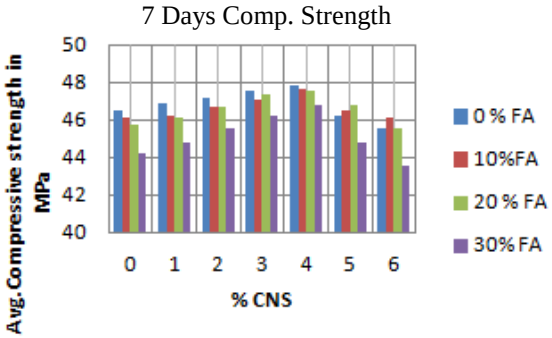
3 Days Comp. Strength

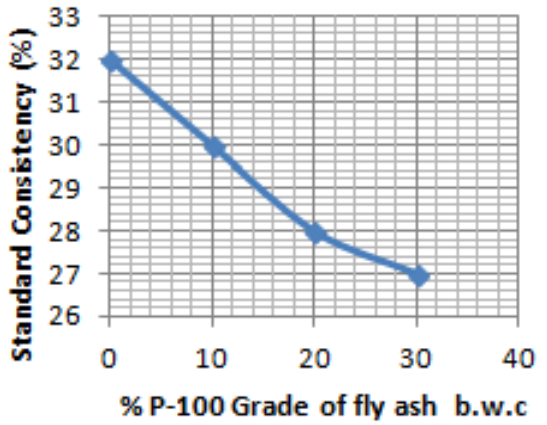


7 Days Comp. Strength

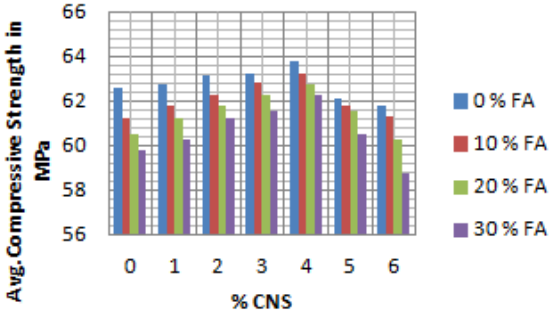


7 Days Comp. Strength

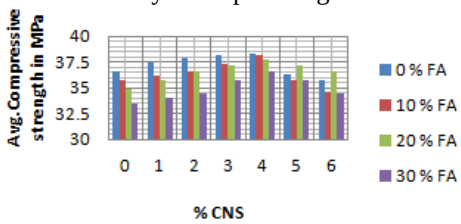


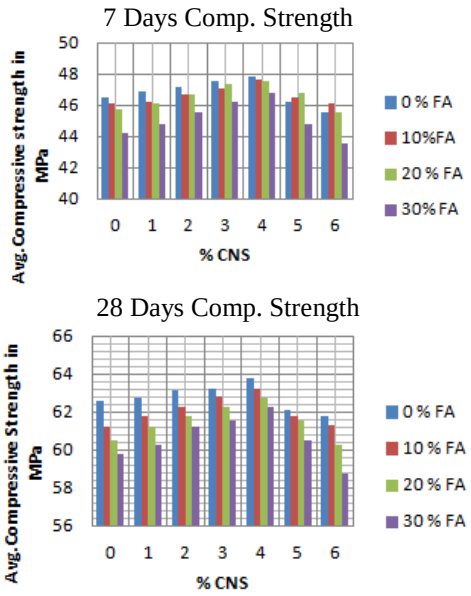


28 Days Comp. Strength



3 Days Comp. Strength





Conclusions:

1. It is concluded that initial and final setting time of cement paste goes on decreasing, which indicates the accelerating effect of CNS on cement hydration
2. It is concluded that CNS greatly shortened the IST and FST of all paste, when CNS Is added the IST and FST of cement + fly ash paste were significantly shortened although fly ash delays the hardening of paste the addition of CNS can greatly offset this effect
3. The standard consistency of fly ash based cement paste and after addition of CNS in various percentages in the same paste does not vary much more.
4. It is observed that average compressive strength of cement mortar at 3,7 and 28 days goes on increasing up to 4 % addition of CNS and there after goes on decreasing.
5. It is concluded that when 0 % fly ash is added the strength of fly ash based cement mortar is less as compare to 10 % , 20%, 30% replacement of cement by P-100 grade of fly ash.
6. It is concluded that standard consistency decreases as % of P-100 grade of fly ash is increases

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