INFLUENCE OF NANO MATERIALS ON CONSISTENCY, SETTING TIME AND COMPRESSIVE STRENGTH OF CEMENT MORTAR

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Abstract— Nano Technology is one of the areas which is gaining prominence in the field of civil engineering. Application of the concepts of nano technology is steadily growing [(1)]. Materials at nano stage results in new materials which can change the entire property of the composites to which nano materials are added. Literature reveals that nano particles enhance the strength and durability of concrete [(3)]. Studies on nano particles added cement paste indicate that stronger and durable concrete can be made by adding particles at nano scale to concrete. At present, many investigations are being carried out to understand the hydration of nano sized cement particles and the use of nano-size ingredients such as alumina [(4)], fly ash and silica particles for production of concrete. During the present study, an attempt has been made to understand the influence of nano materials on the consistency, setting time and strength of cement mortar. Cement was replaced with nano-cement (NC), nano-flyash (NFA) and nano-silica fume (NSF). It is found that the consistency is not affected due to the presence of nano materials. The setting time and the compressive strength are influenced by the presence of nano materials to a greater extent. It is found that addition of nano-cement decreases the initial and final setting time of the cement mortar whereas addition of nano-flyash and nano-silica fume increases the initial and final setting time.

Keywords—: Nano Technology, cement mortar (NCM), nano-cement (NC), nano-Silica fume (NSF), nano- fly ash (NFA), consistency, setting time, compressive strength. .

1. INTRODUCTION

Nanotechnology is a very active research field and has applications in a number of areas. Nowadays nano materials are used in construction along with the traditional building materials. Incorporation of nano materials in concrete is a most promising concept for developing concrete having certain desirable properties. The extremely fine size of the particles can alter the specific surface area and hence the properties of concrete. Nano particles added cement composite can increase the workability, strength and durability characteristics [(5.6)]. Nano particles can also improve the bond between the aggregates and cement paste. Studies on cement paste with nano materials are absolutely necessary to understand the influence of nano materials. Currently this technology is being used for the creation of new materials, devices and systems at molecular, nano and micro-level. Nano materials show unique physical and chemical properties that can lead to the development of more effective materials than the ones which are currently available. The extremely fine size of nano-particles yields favorable characteristics. Because of their high surface area and excellent fire retardant properties, nano particles can be used in construction in many ways. Addition of nano-materials to cement and concrete can lead to significant improvements in the field of civil engineering.

The compressive strength of cement mortar mixed with nano-SiO_2 and Fe_2O_3 was studied by Hui Li et.al[(3)]. It was reported that the nano particles acted as a filler material and an improvement in the mechanical properties was observed. Byang-wan Jo.et.al,[(7)] studied the characteristics of nano SiO_2 particles. The result indicated that the heat of hydration increased with the addition of nano particles. The microstructure of cement mortar was experimentally studied by Hui Li[(8)]. Based on the mechanical properties of cement mortar with nano-Fe_2O_3 and nano-silica, a reduction in $CaOH_2$ compound among the hydrates was found. M. Collepardi et.al.,[(9,10)] reported that when nano-silica is

mixed with cement composite a reduction in bleeding and segregation occurred when super plasticizers are added. The concrete mixture was found to be cohesive and the compressive strength of concrete was not affected.

2. MATERIALS AND EXPERIMENTAL PROGRAMME

Nanotechnology is the use of very small particles in the scale of 1-100 nanometers [(1)]. A nanometer is 1/1000 of a micron, or 1 billionth of a meter which is about three atoms set side by side. The grain size is of the order of 10^{-9} m. It has extremely large specific surface area. It has favorable structural and non-structural properties [(11)]. The precise size at which the properties of materials are manifested varies between materials, but is usually in the order of 100 nm or less. During the present investigation, nano-cement, nano-fly ash and nano-silica fume were used as replacement for cement.

For making nano-cement, 53grade ordinary Portland cement was scaled down to nano level and was used as a replacement to cement. Similarly flyash and silica were scaled down to nano size and used as a replacement to cement. The nano particles were produced in a high intensity ball milling [(5)]. High impact collisions are used to reduce microcrystalline materials down to nano-crystalline structures without chemical change.

Scanning Electron Microscope (SEM) is used to determine the particle size of nano particles. Figure.1 shows the SEM picture of nano-cement, Figure.2 shows the SEM picture of nano-silica fume and Figure.3 shows the SEM picture of nano-Fly ash.

From the analysis of SEM picture, it is found that the size of nano-cement, nano-flyash, and nano-silica fume were in the range of 1-100 nm.

The primary objective of this paper is to determine the influence of nano materials on the consistency, setting time and the compressive strength of cement mortar.

The experimental investigation consisted of determination of consistency, setting time and compressive strength of cement mortar with nano materials.

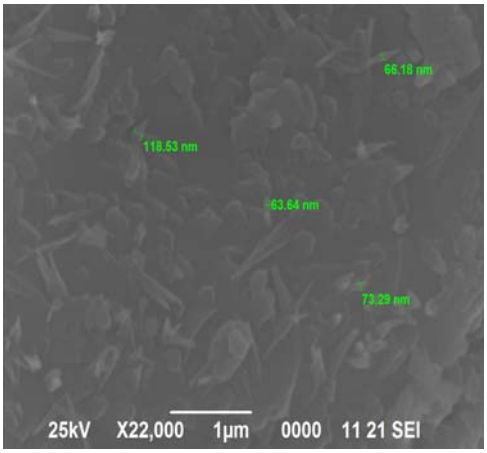

Figure 1.SEM picture of nano-cement

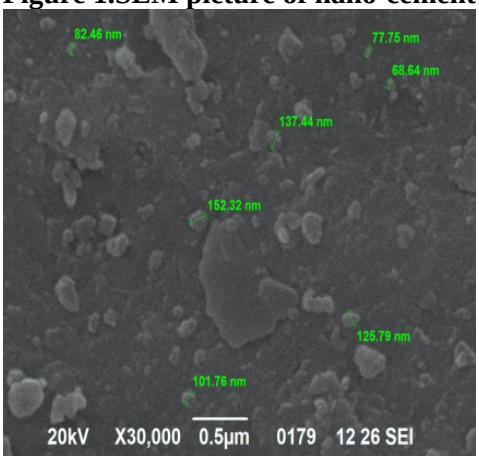

Figure 2.SEM picture of nano-silica fume

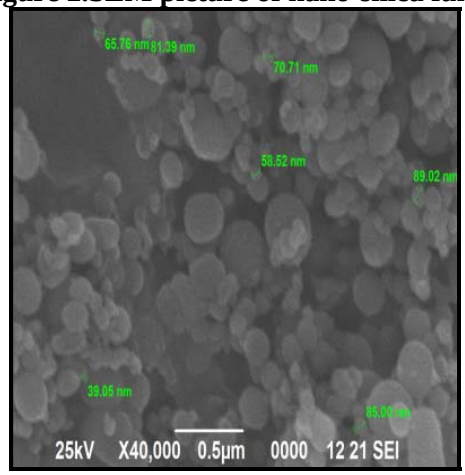

Figure 3.SEM picture of nano-fly ash

Nano cement mortar was made by replacing 10%, 20%, 30%, 40% and 50% of cement with nano materials. The nano particles used in this experimental investigation are nano-cement, nano-fly ash and nano-silica fume. Eighteen mixes were made and the tests were carried out.

3. TESTS ON CEMENT MORTAR

The consistency test[12] and setting time test[13] on cement mortar with nano particles were carried out using the Vicat apparatus conforming to IS: 5513 – 1996[14]. The compressive strength of hardened cement mortar with nano particles were found using mortar cubes of size 70.6 mm x 70.6 mm x 70.6 mm. Compression testing machine of capacity 2000 kN was used to find the strength. The compressive strength of cement mortar was carried with a uniform rate of 14N/mm^2/min after the specimen had been centered in the testing machine.

4. RESULTS AND DISCUSSION

The consistency, initial setting time and final setting time of the cement paste with and without nano particles are given in the Table.1.

From Table.1, it is seen that the consistency values are not significantly altered when cement is replaced with nano materials However, it can be seen that the presence of nano materials significantly alters the values of the initial and final setting time. The compressive strengths of cement mortar with and without nano particles are given in Table.2.

Table.1. Values of Consistency, Initial and Final Setting Time of Cement Mortar

% replacement of nano particles	Normal Consistency of mortar with			Initial Setting Time of mortar with			Final Setting Time of mortar with		
	Nano cement	Nano Flyash	Nano Silica fume	Nano cement (Mins)	Nano Flyash (Mins)	Nano Silica fume (Mins)	Nano cement (Mins)	Nano Flyash (Mins)	Nano Silica fume (Mins)
0	34	34	34	70	70	70	510	510	510
10%	33	33	35	40	95	85	465	550	560
20%	33	33	33	35	110	95	395	620	615
30%	34	35	34	35	120	110	335	663	695
40%	35	35	33	35	135	135	295	785	835
50%	33	33	33	30	155	150	245	920	910

Table.2. Compressive Strength of Cement Mortar with and without nano particles

% replacement of nano particles	Compressive strength of mortar with								
	Nano cement (N/mm^2)			Nano Flyash (N/mm^2)			Nano Silica fume (N/mm^2)		
	3days	7days	21 days	3days	7days	21 days	3days	7days	21 days
0	52.50	67.00	73.00	52.50	67.00	73.00	52.50	67.00	73.00
10%	52.60	70.65	79.50	56.99	72.98	80.02	58.98	74.48	83.23
20%	52.70	70.89	80.52	57.98	74.48	82.76	62.98	79.50	88.42
30%	52.80	72.57	81.24	58.98	75.99	83.48	65.50	81.20	90.96
40%	52.90	76.26	86.5	59.98	74.00	79.48	62.49	77.37	85.50
50%	53.00	77.66	86.97	57.50	72.48	79.98	60.00	75.53	83.42

The 7th day and 21st day compressive strengths of mortar with nano materials are shown in Figure.4 and Figure.5 respectively.

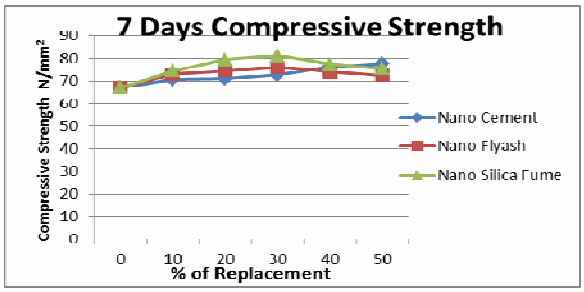

Figure 4. 7 days Compressive Strength

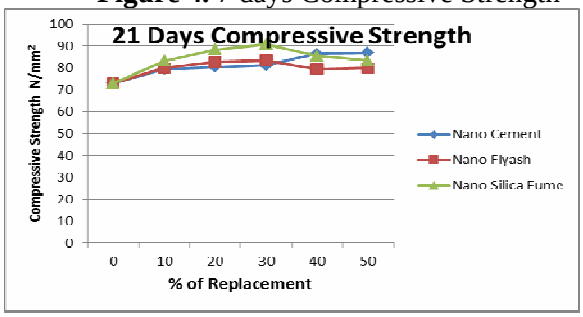

Figure 5. 21 days Compressive Strength

From Figure.4 and Figure.5, it can be seen that the strength of mortar containing nano-cement increases as the percentage replacement of cement with nano cement increases. However in case of mortar with nano-fly ash and nano-silica fume, the strength increases with the percentage replacement, reaches a maximum value and then decreases. The optimal replacement is found to be 30%. The increase in compressive strength indicates that the nano materials not only acts filler materials but also acts as a binder and takes part in the process of hydration. Figure 6. and Figure 7. show the variation of initial and final setting time with respect to the percentage replacement of cement with nano materials.

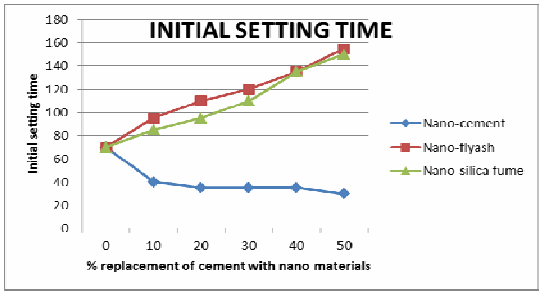

Figure 6. Variation of Initial Setting Time with respect to % Replacement.

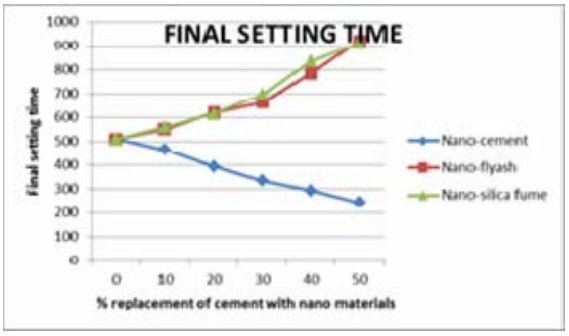

Figure 7. Variation of Final Setting Time with respect to % Replacement.

From figure 6 and figure 7 it can be seen that both initial and final setting time of cement mortar with nano materials are significantly altered by the pressure of nano materials. In case of replacement of cement with nano-cement, the initial and final setting time of cement decreases as the percentage replacement increases. The initial setting time reduces from 70 minutes to 40 minutes when 10% of cement was replaced with nano-cement. Thereafter, the reduction in the setting time is gradual. The reduction in the final setting time is almost linear with respect to percentage replacement. The final setting time decreases from 510 minutes when the replacement is 0 % to 245 minutes when the replacement is 50%. In case of replacement of cement with nano-flyash or nano-silica fume, the initial setting time and final setting time increased with addition of nano particles. Replacement of cement with nano-flyash was found to increase the initial setting time from 70 minutes to 155 minutes when its percentage replacement was varied from 0 to 50. The final setting time increased from 510 minutes to 920 minutes. Almost similar trend was noticed for the replacement of cement with nano-silica fume.

5. CONCLUSIONS

An experimental investigation has been carried at to find out at the effect of replacing cement with nano-cement, nano-flyash and nano-silica fume on the strength, consistency, initial and final setting times of cement mortar. It was found that replacement had insignificant effect on the consistency of cement paste. The initial and final setting times of cement mortar containing nano-cement was found to decrease with increase in the replacement percentage. Increase of replacement of cement with nano-flyash and nano-silica fume, the initial and final setting times were found to increase as the percentage replacement increases. From the strength point of view the optimal

replacement percentage of nano-flyash and nano-silica fume is around 30%. However since the final setting time shall not be more than 600 minutes, the percentage replacement of cement with nano flyash and nano silica fume should not exceed 20%.

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