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An Overview on the Laboratory Investigation of Using Nano-Materials in Concrete

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Abstract: Nano-Concrete concrete is a new generation for special powerful concrete, its rich with many benefits. This study included the usage of Active Nano-clay and Nano-Silica with different percentages 3%, 5%, 7% / 1%, 2%, 3%, respectively as a replacement of cement content in concrete to get the optimum value to use. The methods of mixing (wet/dry) of these Nano-Materials are taken into consideration to deal with site/lab cases. Some properties of fresh and hardened concrete were measured. The absorption in case of thirty minutes up to twenty four hours are recorded to ensure durability. Elevated temperature also, had its share of attention in case of one hour, two hours and two hours with sudden water-cool to measure an indication for the loose of compressive strength during cool process. Ultrasonic wave pulses was used to evaluate the quality of internal contents of concrete (before and after) absorption and elevated temperature tests.

Key words: Nano-Concrete · Physical/ Mechanical Properties of Nano-Concrete · Mixing Technology of Nano-Concrete · Elevated Temperature Resistance · Active Nano-Clay · Nano-Silica · Absorption of Nano- Concrete

INTRODUCTION

Nanotechnology is a standout amongst the most dynamic research regions with both novel science and valuable applications that has step by step set up in the previous two decades. (Bhusan et al., 2015) investigated usage of Nano-Silica with recycled aggregates retrieved from demolition waste in concrete mixture. Experimental investigations are carried out to determine compressive and tensile strength of concrete mixes designed with recycled coarse aggregates and different percentages of Nano-Silica. Moreover, water absorption, density and volume voids of concrete mixes are also examined to ascertain the influence of Nano-Silica on behavior of recycled aggregate concrete. The outcomes of the research depict that properties of concrete mixes are significantly affected with the introduction of recycled coarse aggregates in place of the natural coarse aggregates. However, the study reveals that the depletion of behavior of recycled aggregate concrete could be restored with the incorporation of little amount (3%) of Nano-Silica.

(Khayati et al., 2015) reviewed the effects of oxide Nano-Particles (such as SiO2, TiO_2, Fe_2O_3, ZnO_2, Cr_2O_3 and Al_2O_3) on both of hardened concrete properties (i.e., compressive strength, split tensile strength and flexural strength, water permeability, Abrasion resistance and pore structure of concrete) and fresh concrete properties (workability and setting time). The studied results gave a good achievement in using Nano particle in concrete.

The influence of Nano-Particles on mechanical properties and durability of concrete has been investigated by (Shekari et al., 2011). Constant content of Nano-ZrO_2 (NZ), Nano-Fe_3O_4 (NF), Nano-TiO_2 (NT) and Nano-Al_2O_3 (NA) have been added to concrete mixtures. The compressive and indirect tensile strength and durability has been investigated through chloride penetration test and concrete permeability. Results of this study showed that Nano-Particles can be very effective in improvement of both mechanical properties and durability of concrete. Results of this study seem to indicate that the Nano-Al_2O_3 is most effective Nano-Particles of examined Nano materials in improvement of mechanical properties of high performance concrete.

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(El-Baky et al., 2013) studied the influence of adding Nano-Silica particles on the properties of fresh and hardened cement mortar through measurements of workability, compressive and flexural strengths. Nano-Silica particles (size 19 nm) have been used as a cement addition by 1, 3, 5, 7 and 10 % by weight of cement content. Results indicated that the cement mortar workability decrease with increasing Nano-Silica addition. On the other hand, the percentage of 7 % of Nano-Silica recorded as optimum percentage in compressive and flexure strength measured for cement mortar mixed with the Nano-Silica. In addition, the scanning electron microscope analysis of the microstructures showed that the Nano-Silica filled the cement paste pores, more homogeneity for cement paste and interfacial zone, by reacting with calcium hydroxide crystals forming more calcium silicate hydration also, concluded that using NS ratios from 1% to 7% gives a little increase in compressive strength value than NC for the same ratios by not more than 5% at 7 and 28 days. On the other hand, at 10% NC the compressive strength value is higher by 10% than that record for NS, this may be refer to the role of the activated NC as an amorphous materials and reacting with the calcium hydroxide at higher percentage. Finally from the analysis and results it is clear that 7% NS and 10% NC as replacement of the cement content are optimum percentage for increasing compressive strength value.

(Yang et al., 2012) studied the strength and shrinkage properties of Nano-Silica powder concrete and concluded that, Nano-Silica powder cannot improve the compressive strength of concrete significantly and when the content of Nano-Silica is 0.75%, leads to brittleness reducing and flexibleness enhancing. Also, (Zamani, 2012) studied the compressive strength, electrical resistance and water absorption of the concretes containing Nano-Silica and Micro-Silica in their mixture are investigated in the ages of 7, 14, 28 days. Observations indicate that the concretes produced with Micro-Silica and Nano-Silica show higher degrees of quality in their compressive strength than the concretes which only have Micro-Silica in their mixtures. Specimens with 2% Nano-Silica and 10% Micro-Silica have had less water absorption. (Brightson et al., 2011) studied the effect of Nano-Clay on the concrete compressive strength and indicated that the Nano-Clay concrete specimens gives higher compressive strength than control specimens.

Objective: A lot of researches are carried out on using Nano-Materials. These researches are recorded a good achievement in using these materials. Enhancing the fresh/hardened properties of Mortar (one of concrete ingredients) can control the properties of fresh and hardened concrete. This study will join Nano-Materials with concrete as a construction material and study producing enhanced concrete (wet/dry mixing) by using Nano-Materials (Active Nano-Clay and Nano-Silica) in addition to investigate the different properties (fresh and hardened) of the produced concrete and compare these results with the control mix.

The study divided into two phases, the first phase are includes the production of Nano-Concrete using ANC and NS powder. Second phase is related to test/investigate different properties of the produced concrete.

Experimental Work Program

Introduction: Concrete is most usable material in construction industry. It's been required to improve its behavior and quality. By using Nano-Materials, the improvement can affirm. Nano-Materials are added in mixes as replacement of cement content of ordinary cement. The ratio of replacement varies from 3% to 7% in Active Nano-Clay (size 60 to 100 nm) and with 1% to 3% for Nano- Silica (size 9 to 20 nm). Aggregate contents are constant in all mixes. w/c ratio is 0.475 and fixed at all mixes. The mixing process is taken as variable parameter to study the effect of wet or dry mixing on properties of final produced concrete. Table 1. Show the details of nine mixes including mix proportions for each mix according to (BS: 5328).

Manufacturing Procedures of Nano-Concrete: Mixing is the basic process through which perfect dispersion of Nano-Particles in the base matrix can be achieved and ingredients are thoroughly blended in a uniform distribution. Mixing method is one of the most important parameters in this study because dry and wet mixing was used and a comparison between them is performed to obtain the effect of mixing techniques on the concrete properties. Dry mixing is a mixing technique where Nano-Particles are mixed with cement powder in a dry media using "Ball Mill Equipment" but mechanical mixer is used instead of it to mix Nano-Particles with cement powder to achieve proper dry mix. Wet mixing is the another type of mixing techniques where Nano-Particles are mixed with water and chemical admixture using "Magnetic Stirrer Equipment" but a driller connected with a steel bar as a drilling bit where its end has steel pieces formed X shape were used to enhance mixing process as shown in Figure 1. The alternative methods are used to try to achieve a Nano-Concrete without using special tools (as cast in site).

Table 1: Details of Proportions for Studied Mixes

Mix	Cement Content kg/m^3	ANC%	NS%	Sand kg/m^3	Dol. kg/m^3	Water Content kg/m^3	Superplasticizer %	Mixing Type
Control	400	-	-			190		-
M-1	388	3%	-			184.3		Dry
M-2	388	5%	-			184.3		
M-3	380	7%	-	613	1246	180.5	2%	
M-4	372	-	-			176.7		Wet
M-5	396	-	1%			188.1		
M-6	392	-	2%			186.2		
M-7	388	-	3%			184.3		
M-8	388	-	4%			184.3		Dry

Fig. 1: Wet Mixing Process

Fig. 2: Curing of Specimens

Curing begins immediately after casting of specimens so that the concrete may develop the desired strength and durability. Figure 2. Shows the final specimens in curing tank.

Results and Analysis

Introduction: The test results of the current experimental investigation are presented and discussed in two phases, the first one concerned with the fresh concrete properties (slump test results) and the effect of adopted parameters on results and the second phase concerned with the hardened concrete properties such as compressive strength, indirect tensile strength and flexural strength and the effect of adopted parameters on its results according to (BS: 12390). Absorption, elevated temperature effect and ultrasonic wave pulse tests were carried out to study the behavior of Nano- Concrete under selected tests.

Table 2: Slump Test Results for the different Mixtures

Mix	Mixing Type	Slump (mm)
Control	-	65
M-1, ANC (3%)	Dry	45
M-2, ANC (3%)	Wet	47
M-3, ANC (5%)		44
M-4, ANC (7%)		39
M-5, NS (1%)		48
M-6, NS (2%)		44
M-7, NS (3%)		42
M-8, NS (3%)	Dry	41

Fresh Properties: Firstly, fresh concrete were tested (slump test) to obtain results of fresh concrete slump and the effect of adopted parameters on results. Table 2. shows the results for different mixes of Nano- Concrete. Slump value for control mix is suitable for cast foundations (light steel reinforcement percentage less than 80kg/m^3) but all other mixes are suitable for mass concrete. This classification according to (ECP 203/2007). It's recommended from results that, superplasticizers percentage should be increase in Nano-Concrete mixture to increase slump values to achieve the ease of mixing, placing, compacting and finishing (when necessary).

The slump values reduced for different mixes when using ANC by 3%, 5% and 7% of used cement content comparing with the control by 28%, 33% and 40%, respectively, also the slump values reduced in case of using NS by 1%, 2% and 3% of used cement content comparing with the control by 27%, 33% and 36%, respectively. The reduction in slump at using ANC for mix M-2 (3%) is less than the reduction at using NS for mix M-7 (3%) so that Nano-Clay is better than Nano-Silica in consistency due to the particle size of NS is smaller than the particle size of ANC which lead to NS voracious absorption of water as seen in Figure 3. The effect of mixing technique of Nano-Materials on slump test results is as follow; wet mixing method gives slump value higher than dry mixing method where increased the slump values by 5% for ANC and by 3% for NS as represented at Figure 3.

Hardened Properties: This phase is focused on studying the hardened concrete properties for different mixtures comparing it with the control mix. Table 3. shows the compressive strength test results for control mix and mixes from M-1 to M-8 which tested at ages seven and twenty eight days. The ratio between Fcu at seven and twenty eight days are varies from 0.77 to 0.88 and this ratio is not matching with that mentioned in (ECP 203/2007), where the ratio stated in the code as a is 0.75. The obtained results shows a good achievement in comparison to previous researches like (Rajkumar et al., 2016).

Figure 4. shows that, there is an improvement in concrete compressive strength when using ANC by 3%, 5% and 7% as a replacement of used cement content comparing with the control, the compressive strength increased by 6%, 10% and 20% after seven days, respectively and by 15%, 20% and 35% after twenty eight days, respectively. The increases in concrete compressive strength are not constant with increasing the percentage of ANC and vary when tested at seven and twenty eight days. The increase in concrete compressive strength at twenty eight days is higher than the increase in concrete compressive strength at seven days, this may be refer to the hydration of cement and fulfill the pores. There is an improvement in concrete compressive strength when using NS by 1%, 2% and 3% of used cement content, the compressive strength increased comparing with the control by 18%, 19% and 23% after seven days respectively and by18%, 26% and 37 % after twenty eight days, respectively. The increases in concrete compressive strength are not constant with increasing the percentage of NS and vary when tested at seven and twenty eight days. The increase in concrete compressive strength at 28 days is higher than the increase in concrete compressive strength at seven days; this may be referring to the hydration of cement which fulfills the pores. The increasing in compressive strength of Nano-Concrete because it's have different reaction mechanism to develop strength with material called pozzolanic action which fulfill the pores.

From Figure 4 Using wet mixing method for ANC (3%) increased the compressive strength by 2% and 13% in comparison to dry mixing method at seven and twenty eight days, respectively. The compressive strength increased by 16% and 28% when using wet mixing method with respect to dry mixing method for NS at seven and twenty eight days, respectively. The compressive strength when using NS is higher than the compressive strength when using ANC. For the control mix, although ANC (3%)/NS (3%) mixed dry, the compressive strength increased by 3% and 2% / 6% and 7% at seven and twenty eight days, respectively. Also, the compressive strength in case of wet mixing method increased by 6% and 15% / 23% and 37% at seven and twenty eight days, respectively.

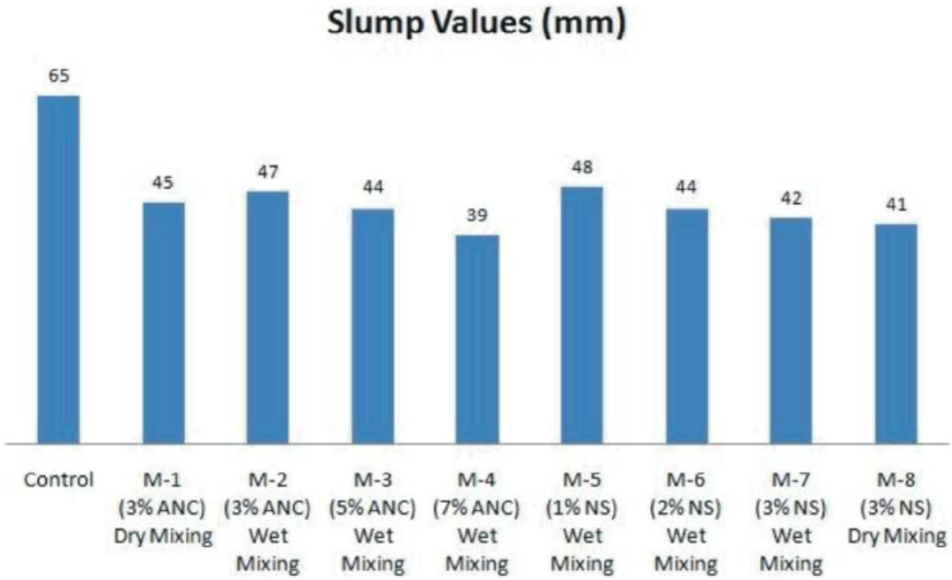

Fig. 3: The Effect of Nano-Materials on Slump Test Results

Table 3: Compressive, Indirect Tensile and Flexural Strengths for different Mixes tested at ages of 7 and 28 days

Mix	Mixing Type	Compressive Strength kg/cm^2 7 Days	Compressive Strength kg/cm^2 28 Days	Fcu7-Days/ Fcu28-Days	Indirect Tensile Strength kg/cm^2	Flexural Strength (kg/cm^2)
Control	-	312	358	0.87	33	53
M-1, ANC (3%)	Dry	322	366	0.88	37	57
M-2, ANC (3%)		330	413	0.80	40	65
M-3, ANC (5%)		344	428	0.80	43	69
M-4, ANC (7%)	Wet	372	484	0.77	47	76
M-5, NS (1%)		368	424	0.87	39	64
M-6, NS (2%)		370	449	0.82	49	70
M-7, NS (3%)		383	491	0.78	50	75
M-8, NS (3%)	Dry	330	383	0.86	39	58

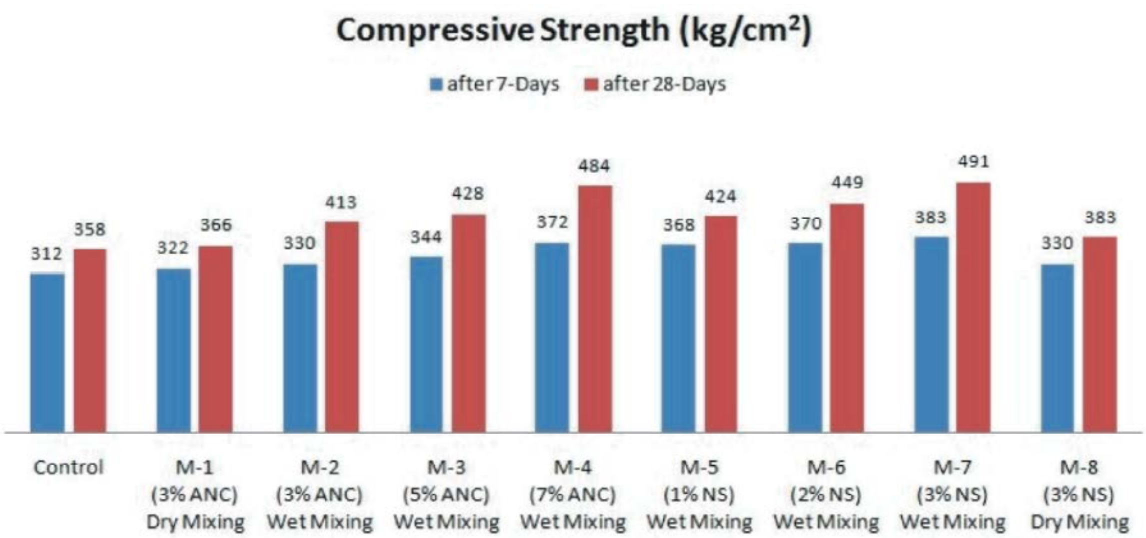

Fig. 4: Effect of ANC/NS as a Replacement on the Compressive Strength Comparing with the Control Mixing

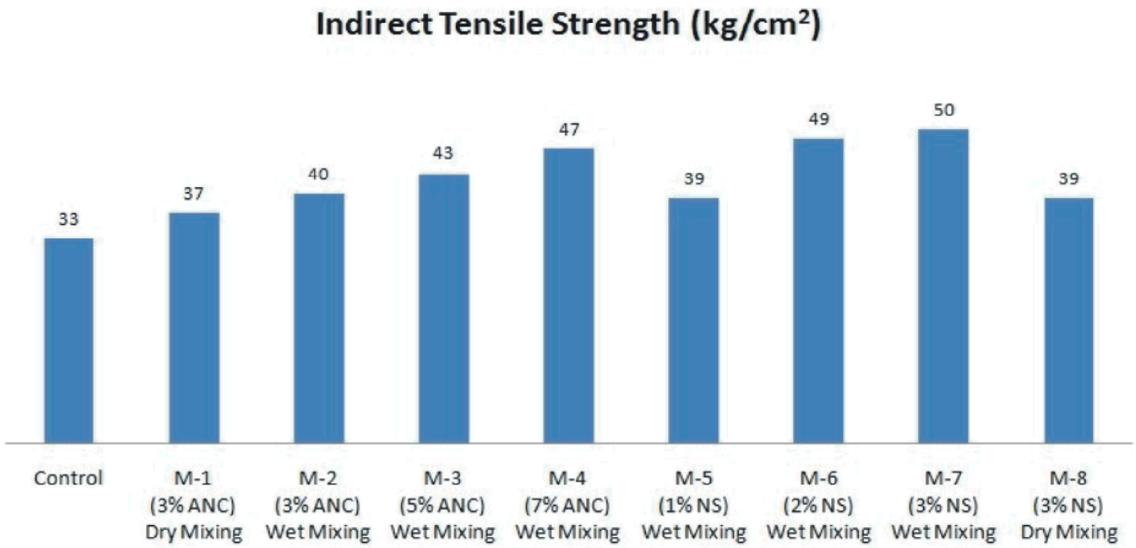

Fig. 5: Indirect Tensile Strength Results for Control Mix and ANC/NS Mixes

Table 3 shows the indirect tensile strength test results for control mix and mixes from M1 to M8 which tested at 28 days. Figure 5. represent an improvement in the indirect tensile strength when using ANC by 3%, 5% and 7% of used cement content comparing with the control, the indirect tensile strength increased by 21%, 30% and 42% after twenty eight days, respectively. The increases in the indirect tensile strength are not constant with increasing the percentage of ANC and vary when tested at twenty eight days. There is an improvement in the indirect tensile strength when using NS by 1%, 2% and 3% of used cement content comparing with the control, the indirect tensile strength increased by 18%, 48% and 51% after 28 days, respectively. The increases in the indirect tensile strength are not constant with increasing the percentage of NS and vary when tested at 28 days.

When using wet mixing method gives the indirect tensile strength higher than dry mixing method where increased the indirect tensile strength comparing with the control by 21% when using wet mixing method and increased by 12% when using dry mixing method for ANC at 28 days, respectively. The indirect tensile strength increased comparing with the control by 51% when using wet mixing method and increased by 18 % when using dry mixing method for NS 28 days, respectively. The indirect tensile strength when using NS is higher than the indirect tensile strength when using ANC as shown in Figure 5.

Table 3 shows the Flexural strength test for control mix and mixes from M1 to M8 which tested at 28 days. Figure 6. shows , there is an improvement in the flexural strength when using ANC by 3%, 5% and 7% of used cement content comparing with the control, the flexural strength increased by 23%, 30% and 43% after 28 days, respectively. The increases in the flexural strength are not constant with increasing the percentage of ANC and vary when tested at 28 days. There is an improvement in the flexural strength when using NS by 1%, 2% and 3% of used cement content comparing with the control, the flexural strength increased by 21%, 32% and 41% after 28 days, respectively. The increases in the flexural strength are not constant with increasing the percentage of NS and vary when tested at 28 days.

Figure 6 show that, when using wet mixing method gives the flexural strength higher than dry mixing method where increased the flexural strength comparing with the control by 32% when using wet mixing method and increased by 8% when using dry mixing method for ANC at 28 days, respectively. The flexural strength increased comparing with the control by 41% when using wet mixing method and increased by 9% when using dry mixing method for NS at 28 days, respectively. The flexural strength when using NS is higher than the flexural strength when using ANC.

Table 4 shows the direct tensile strength (0.85Fs and 0.6Ff) which obtained from results of the indirect tensile strength (Fs) and flexural strength (Ff) and the percentage of the direct tensile strength with respect to compressive strength (Fcu). The percentages of the direct tensile strength with respect to compressive strength ranged from 7.82% to 9.67% which is compatible with (ECP 203/2007) (5-10% Fcu).

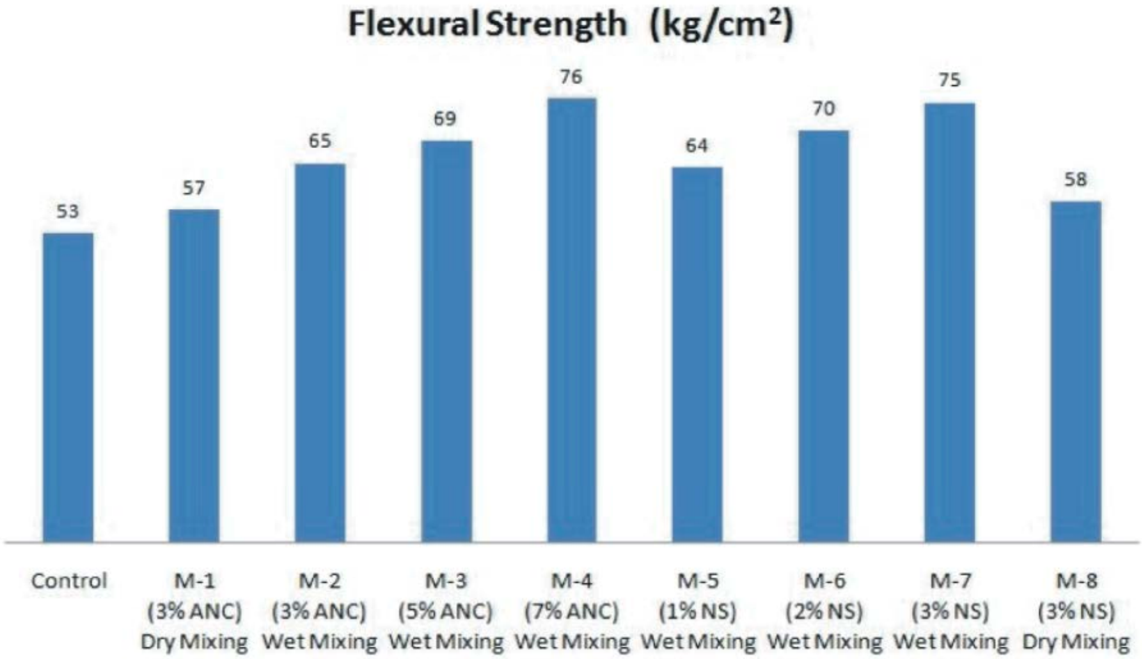

Fig. 6: Flexural Strength Results for Control Mix and ANC Mixes

Table 4: A Comparison between Indirect Tensile Strength and Flexural Strength with Fcu after 28 Days

Mix	Compressive Strength (Fcu) kg/cm^2	Indirect Strength (Fs) kg/cm^2	Flexural Strength (Ff) kg/cm^2	Fs/Fcu (%)	Ff/Fcu (%)	0.85Fs kg/cm^2	0.6Ff kg/cm^2	0.85Fs/Fcu (%)	0.6Ff/Fcu (%)
Control	358	33	53	9.22	18.44	28.05	31.80	7.84	8.88
M-1, ANC(3%)	366	37	57	10.11	19.40	31.45	34.20	8.59	9.34
M-2, ANC(3%)	413	40	65	9.69	19.61	34.00	39.00	8.23	9.44
M-3, ANC(5%)	428	43	69	10.05	20.09	36.55	41.40	8.54	9.67
M-4, ANC(7%)	484	47	76	9.71	19.63	39.95	45.60	8.25	9.42
M-5, NS(1%)	424	39	64	9.20	18.87	33.15	38.40	7.82	9.06
M-6, NS(2%)	449	49	70	10.91	19.60	41.65	42.00	9.28	9.35
M-7, NS(3%)	491	50	75	10.18	19.14	42.50	45.00	8.66	9.16
M-8, NS(3%)	383	39	58	10.18	19.06	33.15	34.80	8.66	9.09

Absorption of Conventional and Nano-Concrete: Absorption test for conventional and Nano-Concrete are carried out to measure the ability of concrete to resist the water effect to achieve long term durability. The specimens were cured in oven to get dry weight then weighted after immersion in water as a wetted weight for predetermined duration of time (30, 60, 120 Minutes and 24 hours). Water absorption was then determined as the difference in the weight of the specimen before and after immersion in water relative to the weight of specimen before immersion in water, expressed in percentage. The following Equation 1. shows the relationship to calculate Absorption Percentage "A.P".

A.P (%) = [(Wwet - Wdry)/Wdry] x 100 Equation 1.

The results thus obtained are tabulated as shown in Table 5 and the comparison of the water absorption of the Nano-Concrete with conventional concrete is presented in Figure 7.

From Figure 7, it's seem that, control mix recorded the maximum value in all intervals in compared to Nano-Mixes due to pozzolanic activity and void filling of Nano-Materials which lead to decrease the permeability. By increasing Nano-Materials in mixes the absorption decreases but at certain percentages of ANC 5% and 7% the results achieved almost the same value in absorption due to fully occupy of Nano-Particles in space voids. NS 2% and 3% recorded a significant variations in absorption due to partially occupy of Nano-Particles in space voids. Although the percentages of ANC in concrete more than

Table 5: Results of Absorption Test from 30 Minutes up to 24 Hours

		Wwet (kg)				% of Absorption			
Mix	Wdry (kg)	30 Mins	60 Mins	120 Mins	24 Hrs	30 Mins	60 Mins	120 Mins	24 Hrs
Control	2.343	2.362	2.364	2.368	2.378	0.81	0.90	1.07	1.49
M-2, ANC (3%)	2.336	2.352	2.354	2.357	2.367	0.68	0.77	0.90	1.33
M-3, ANC (5%)	2.401	2.418	2.419	2.421	2.430	0.71	0.75	0.83	1.21
M-4, ANC (7%)	2.357	2.372	2.375	2.376	2.385	0.64	0.76	0.81	1.19
M-5, NS (1%)	2.344	2.361	2.363	2.365	2.374	0.73	0.81	0.90	1.28
M-6, NS (2%)	2.384	2.396	2.398	2.399	2.404	0.50	0.59	0.63	0.84
M-7, NS (3%)	2.408	2.420	2.421	2.422	2.426	0.50	0.54	0.58	0.75

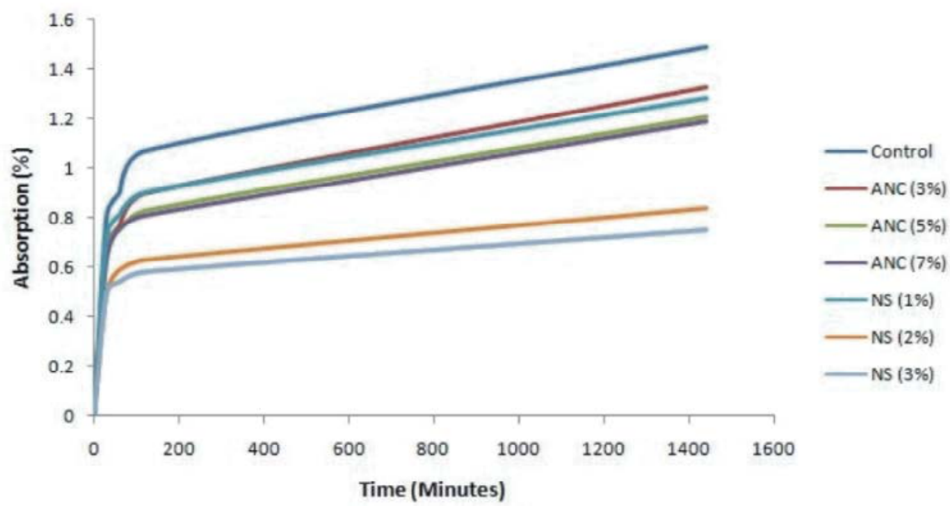

Fig. 7: Relationship between Absorption and Time for different Mixes

NS percentages but NS achieved less absorption and gives a promising result in durability. For the same percentage 3% of ANC and NS, the absorption reduced by 26% to 44% according to the period of water immersion in case of NS. The absorption of ANC 3%, 5% and 7% concrete less than conventional concrete by 11% to 16%, 12% to 19%, 20% to 21%, respectively according to the period of water immersion. The absorption of NS 1%, 2% and 3% concrete less than conventional concrete by 10% to 14%, 38% to 44%, 38% to 50%, respectively according to the period of water immersion. The following Figure 7. shows the relationship between absorption and time (minutes). The relationship confirm that by increasing time the absorption increase up to 1440 minutes (24 Hrs).

Resistance of Elevated Temperature: Effect of elevated temperature may reduce the compressive strength of concrete, in this section; specimens were subjected to elevated temperature up to (300°C) for one hour and two hours. The effect of sudden water cool (immersed in water for 5 mins) also, taken into consideration in case of two hours. Oven was used to effect on specimens with gradually increase in temperature with rate of increasing 10°C/min. Table 6. shows the details of recorded data. There was no significant visible changes appeared on specimens surface after heating and this also conducted by (Bastami *et al*., 2014).

Compressive strength of conventional concrete reduced by 15%, 17% and 25% after one hour, two hours and two hours/water cool, respectively. This mean, by increasing the period of elevated temperature effect, the compressive strength decreased due to propagation of internal cracks. The internal cracks appear significantly and propagate due to internal volume changes due to change in components which can affect internal structure and mechanical properties of concrete after exposing high temperature.

From Figure 8 The results are show that, Compressive strength of ANC 3% and 5% concrete increased by 3%, 12% after one hour due to increasing the hydration rate and pozzolanic activity which lead to producing more strength by exposed up to certain temperature (Shah et al., 2013). The loss of compressive strength appeared after two hours, for ANC 3% and 5% compressive strength

Table 6: Results of Elevated Temperature Test

Mix	Fcu (kg/cm)	Fcu) ah 1hrs (kg/cm^2)	Fcu) ah 2hrs (kg/cm^2)	Fcu) ah 2hrs Water-Cool (kg/cm^2)
Control	358	305	298	269
M-2, ANC (3%)	413	427	400	494
M-3, ANC (5%)	428	479	424	441
M-4, ANC (7%)	484	422	350	472
M-5, NS (1%)	424	444	418	468
M-6, NS (2%)	449	596	511	466
M-7, NS (3%)	491	476	436	472

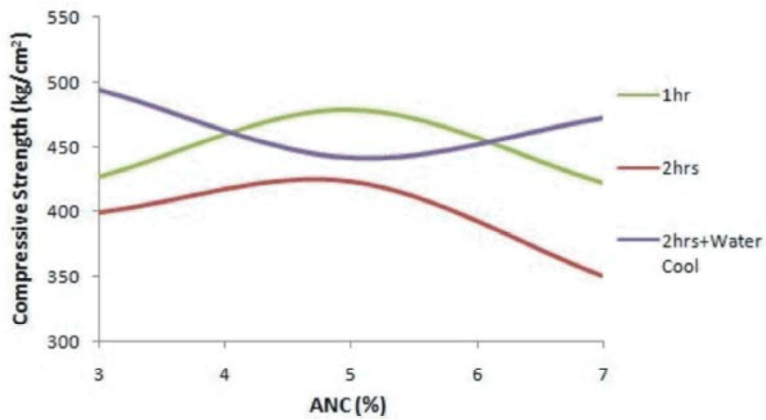

Fig. 8: Compressive Strength of ANC Concrete Mixes after Elevated Temperature Effect

decreased by 7%, 11% due to normal behavior of concrete like volume changes and propagation of internal cracks. Sudden water cool gives unexpected results, compressive strength increased by 23%, 4% for ANC 3% and 5% concrete, respectively. This because clay loss its strength and dispersed by heading due to swelling of clay particles (Hansen et al., 2012) (Sadek et al., 2013) and after decreasing the effect of heating (water cool) its regain more strength and particle transform to hardener behavior. ANC 7% concrete recorded the worst values in compressive strength reduction, the compressive strength reduced by 13%, 17% after one hour and two hours then regain strength by 35% after sudden water cool. It's worth to be noted that, the increasing in ANC percentages is not the best choice because the reduction increased. ANC 5% gives the optimum value to heat resistance but ANC 3% is the best value for water cool process (Wang et al., 2016).

From Figure 9 Compressive strength of NS 1% and 2% concrete are increased by 5%, 33% after one hour because Nano-Silica converts more of the calcium hydroxide to calcium silicate hydrate and this process gets accelerated for the concrete exposed up to such temperature (Shah, et al, 2013). However on further increasing the exposure temperature the specimens showed loss in compressive strength after two hours for NS 1% and 2% concrete by 6%, 14%. NS 3% concrete are reduced by 3%, 8% after one hour and two hours, respectively. Sudden water cool increased compressive strength by 12%, 8% for NS 1% and 3% concrete. This behavior due to reducing of temperature effect which lead to transform melted silica gel to hardener particles. NS 2% gives the optimum value in resisting heat but the worst in sudden cool (loss 9% of compressive strength). On the other hand, it's appear that, NS 1% capable of fighting heat in case of sudden water cool.

Ultra-Sonic Test: Ultrasonic test was carried out on the Nano-Concrete before and after the effect of elevated temperature in additional to measure of velocity after absorption test. The measurements were carried out and repeated five times in different locations on sample (four corners and central). The following Table 7. shows the average velocity obtained from testing. According to (IS 13311-1, 1992), Nano-Concrete can be classify as excellent quality (above 4.5 km/s). After 1hrs of heating, conventional/Nano-Concrete classified as good quality (between 3.5 to 4.5 km/s) except ANC 5% and NS 2% concrete still retains excellent quality. However, conventional/Nano-Concrete after 2hrs of heating still maintained its classification except ANC 7% and NS 2% classified as medium and excellent quality, respectively. After sudden water cool, Nano-Concrete maintained its durability and classified as good quality except ANC 3%

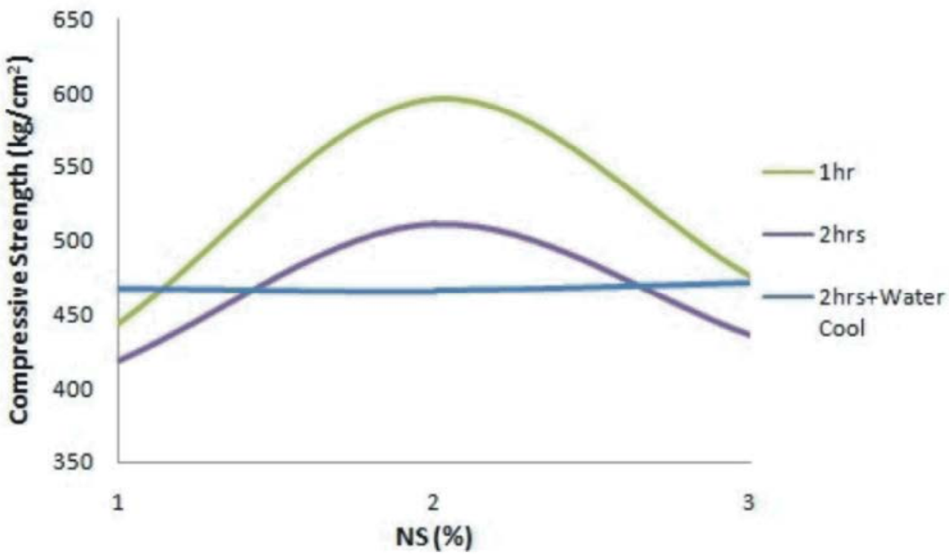

Fig. 9: Compressive Strength of NS Concrete Mixes after Elevated Temperature Effect

Table 7: Wave Velocity of Effected/Non-Effected Concrete with Elevated Temperature

	Before Elevated Temperature Effect	After Elevated Temperature Effect (1hr)	After Elevated Temperature Effect (2hrs)	After Elevated Temperature Effect (2hrs) (Water-Cool)	
	Velocity (km/s)	Velocity (km/s)	Velocity (km/s)	Velocity (km/s)	
Mix	Dry	Wet	Dry	Dry	Dry
Control	4.35	4.64	3.61	3.52	3.18
M-2, ANC (3%)	4.56	4.81	4.21	3.92	4.91
M-3, ANC (5%)	4.69	4.93	4.67	4.15	4.31
M-4, ANC (7%)	4.83	4.95	3.75	3.17	4.26
M-5, NS (1%)	4.65	4.74	4.41	4.21	4.67
M-6, NS (2%)	4.73	4.76	5.67	4.83	4.37
M-7, NS (3%)	4.85	4.93	4.25	3.88	4.21

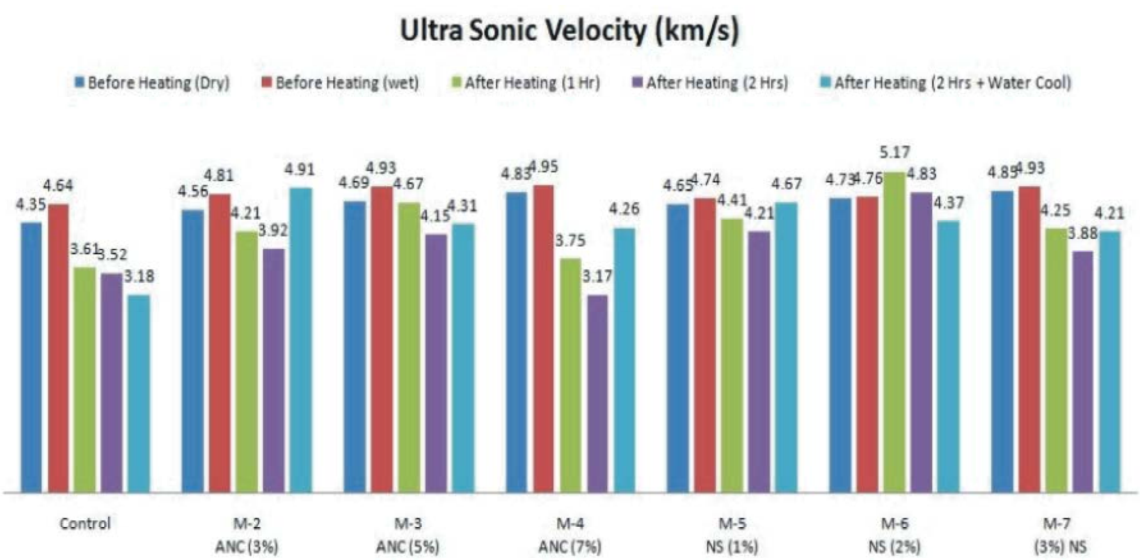

Fig. 10: Ultrasonic Wave Velocity of Concrete Mixes

and NS 1% concrete classified as excellent but Conventional concrete was classified as good quality (between 3.0 to 3.5 km/s). This values confirms the relationship between compressive strength and Nano-Material percentages (R. Hamid, et al., 2010).

Many researchers represented the relationship between compressive strength and pulse velocity of ultrasonic wave by exponential or power equation (Nik et al., 2013) and (Musmar et al., 2008). By linking the results of ultrasonic velocity test with compressive strength on samples, the following approximate conservative (because samples are little) mathematical equation (power) can be deduced in case of ANC Equation 2 and NS Equation 3, respectively. Regression coefficient (R2) for all ANC and NS specimens are 0.915 and 0.999, respectively.

$$Fcu = 6.098\ Vd^{2.768} \quad \text{(Equation 2)}$$

$$Fcu = 1.983\ Vd^{3.490} \quad \text{(Equation 3)}$$

where:

Fcu: Compressive Strength of Concrete after 28 Days (Standard Cube 15x15x15 in cm). Vd: Pulse Velocity of Ultrasonic Wave in Km/s.

From Figure 10 It's noted that, the trend of ultrasonic velocity in all mixes are the same. Wave velocity of ultrasonic gives the maximum values in case of wet specimens (24 hrs immersed in water) but in case of elevated temperature effect gives the lowest values. By increasing time of heating, the velocity decreased due to internal cracks and drying behavior which generate voids between particles. The results showed that, the behavior of Nano-Concrete is more resistant to elevated temperature than conventional concrete. Also, the optimum results obtained for NS 3% and confirmed by ultrasonic test. However, ultrasonic wave velocity give indication for quality of concrete and conservative results.

CONCLUSIONS

The study concludes that the addition of ANC/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. Nano-Powder even in a small quantity could enhance the compressive strength of concrete. This is a result of increasing the bond strength of cement paste-aggregate interface.

- For fresh Nano-Concrete, By increasing replacement percentage of Nano-Powder in mixes, the slump decreased. Dry mixing method gives the lower value in contrast to wet mixing method. At the constant percentage 3%, the workability and consistency of ANC mixes more than NS mixes.
- ANC and NS wet mixes are gives the optimum mechanical properties of hardened concrete by using percentage of 7% and 3% as a replacement of cement content, respectively. The compressive strength increased by 20% at 7 days and increased by 35% at 28 days for ANC 7% mixes as a replacement of used cement content comparing with the control mix, on the other hand, the compressive strength when using NS by 3% as a replacement of used cement content comparing with the control mix increased by 23% at 7 days and increased by 37% at 28 days, so that, the compressive strength for NS mixes are higher than ANC mixes.
- The indirect tensile strength recorded the maximum values in case of NS 3% mixes as a replacement of used cement content comparing with the control mix increased by 51% at 28 days but ANC by 7% as a replacement of used cement content comparing with the control mix increased by 42% at 28 days, hence, the indirect tensile strength when using NS is higher than the indirect tensile strength when using ANC.
- The flexural strength for ANC 7% mixes as a replacement of used cement content comparing with the control mix increased by 41% at 28 days and by using NS 3% as a replacement of used cement content comparing with the control mix increased by 43% at 28 days, so that, the flexural strength when using NS is higher than the flexural strength when using ANC.
- The ratio between Fcu at 7 and 28 days is ranged from 77% to 88% and 78% to 87% for ANC 7%, NS 3% as a replacement of cement content, respectively. The ratio between indirect tensile strength and compressive strength at 28 days is ranged from 9.60% to 10.08% and 9.10% to 10.90% for ANC 7%, NS 3% as a replacement of cement content, respectively. The ratio between flexural strength and compressive strength is ranged from 15.50% to 16.10% and 15.00% to 15.50% for ANC 7%, NS 3% as a replacement of cement content, respectively.
- The absorption of ANC 3%, 5% and 7% concrete less than conventional concrete by 11% to 16%, 12% to 19%, 20% to 21%, respectively according to the period of water immersion, also, the absorption of NS

1%, 2% and 3% concrete less than conventional concrete by 10% to 14%, 38% to 44%, 38% to 50%, respectively according to the period of water immersion, hence, Nano-Mixes gives the minimum value of absorption due to pozzolanic activity and void filling of Nano-Materials which lead to decrease the permeability. At percentage 3% of ANC and NS, the absorption reduced by 26% to 44% according to the period of water immersion in case of NS, so that, NS achieved the best values in less absorption and this indication put NS in the enhanced durability.

- Elevated temperature effect reduced compressive strength of conventional concrete by 15%, 17% and 25% after one hour, two hours and two hours/water cool, respectively. ANC 5% and NS 2% concrete gives the optimum value for resisting elevated temperature because compressive strength increased due to rise of temperature. By increasing percentage of Nano-powder the resistance to elevated temperature decreased especially in ANC. Sudden water cool gives unbelievable values because compressive strength increased especially in case of ANC 3% and NS 1% concrete. There are no significant changes appeared on surface of samples due to temperature effect up to 300°c. It's recommended to heat up Nano-Concrete with one hour (up to 300°c) and this will help to gain more strength.
- Wave velocity of ultrasonic gives the maximum values in case of wet specimens (24 hrs immersed in water) but in case of elevated temperature effect gives the lowest values and generally the test confirmed obtained data from compressive strength.

REFERENCES

1. Shah, A.H., U.K. Sharma, Danie A.B. Roy and P. Bhargava, 2013. "Spalling behaviour of nano SiO_2 high strength concrete at elevated temperatures", MATEC Web of Conferences 6, 01009 (2013), published by EDP Sciences. DOI: 10.1051/matecconf/20130601009
2. Aref Nik, Omid Omran, 2013. Estimation of compressive strength of self-compacted concrete with fibers consisting nano-SiO2 using ultrasonic pulse velocity, Construction and Building Materials, Elsevir, 44: 654-662.
3. Bibhuti Bhusan, Mukharjee and Sudhirkumar V. Barai, 2015. "Characteristics of sustainable concrete incorporating recycled coarse aggregates and colloidal nano-silica", Advances in Concrete Construction, 3(3): 187-202. DOI: http://dx.doi.org/10.12989/acc.2015.3.3.187
4. BS: 5328, British Standard for Concrete Mix Design.
5. BS: 12390, British Standard for Testing Hardened Concrete. ECP: 203/2007, Egyptian Code of Practice.
6. ES: 1109/2002, Egyptian Standards. ES: 2421/2005, Egyptian Standards.
7. Hansen, E.L., H. Hemmen, D.M. Fonseca, C. Coutant, K.D. Knudsen, T.S. Plivelic and J.O. Fossum, 2012. "Swelling transition of a clay induced by heating". Scientific Reports, pp: 1-4. https://doi.org/10.1038/srep00618.
8. Gholam Reza Khayati, Hojat Mirzaei Ghasabe and Masoud Karfarma, 2015. "A survey on the application of oxide nanoparticles for improving concrete processing", Advances in Concrete Construction, 3(2): 145-159. DOI: http://dx.doi.org/10.12989/acc.2015.3.2.145
9. Hongxia Yang, 2012. Strength and Shrinkage Property of Nano-Silica Powder Concrete, 2nd International Conference on Electronic & Mechanical Engineering and Information Technology, Singapore.
10. IS 13311-1 (1992), Indian Specifications, Method of Non-destructive testing of concrete, Part 1: Ultrasonic pulse velocity [CED 2: Cement and Concrete]
11. Mazen A. Musmar and Nafeth Abed Alhadi, 2008. "Relationship between Ultrasonic Pulse Velocity and Standard Concrete Cube Crushing Strength", Journal of Engineering Sciences, Assiut University, 36(1): 51-59, January 2008.
12. Mohammed Reza Zamani, 2012. The effect of Nano-Silica on the properties of concrete, Construction and Building Materials, Japan.
13. Brightson, P., G. Baskar and S. Basil Gnanappa, 2011. "Strength & durability analysis of nano clay in concrete" Durability of Concrete, Sydney, Australia, 1: 331-347.
14. Rajkumar R., Akkineni Surya Teja and Ramya Sajeevan, 2016. Experimental Study on the Strength and Durability of Nano Concrete, International Journal of Applied Engineering Research ISSN 0973-4562, 11(4): 2854-2858.
15. Hamid, R., K.M. Yusof and M.F.M. Zain, 2010. A combined ultrasound method applied to high performance concrete with silica fume. Constr. Build. Mater., 24(1): 94-98.
16. Sadek, O., S. Reda and R. Al-Bilali, 2013. "Preparation and Characterization of Silica and Clay- Silica Core-

Shell Nanoparticles Using Sol-Gel Method". Advances in Nanoparticles, 2, 165-175. doi: 10.4236/anp.2013.22025.

17. Sayed Abd El-Baky, Sameh Yehia, Enas A. Khattab and Ibrahim S. Khalil, 2013. “Effect of Nano-Clay on The Mechanical Properties of Fresh and Hardened Cement Mortar Comparing with Nano-Silica”, The Second International Conference on Materials, Energy and Environments (ICMEE), August 08-09, 2013, Yokohama, Japan.
18. Sayed Abd El-Baky, Sameh Yehia and Ibrahim S. Khalil, 2013. Influence of Nano-Silica addition on properties of fresh and hardened cement mortar, October 16th-18th 2013, Brno, Czech Republic, EU.
19. Shekari, A.H. and M.S. Razzaghi, 2011. "Influence of nano particles on durability and mechanical properties of high performance concrete, Procedia Engineering, 14: 3036-3041.
20. Wang, W., S. Wang and C. Lin, 2016. Effect of Hot Environment on Strength and Heat Transfer Coefficient of Nano-Clay Concrete. Journal of Materials Science and Chemical Engineering, 4: 45-52. doi: 10.4236/msce.2016.47007.