Improvement of the Durability of Blended Concrete using Nano-materials for Geotechnical Aspects

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Abstract

It is known that concrete foundations are chemically affected by harmful substances present in surrounding soil or groundwater. It is therefore important to take the necessary precautions to protect the foundations from any chemical activity between the concrete components and the surrounding medium. Although Nano-materials have been used to improve concrete durability, they have not received studiesas required.Most studies which interested in investigating the durability issue deal with cement paste and cement mortar and a few of them deal with concrete in some properties.From this point of view, this research come to compensate the shortage of this issue by studying the effect of using the Nano-silica and Nano-clay and hybrid from both of them on some durability properties of concrete produced with the three materials as a partial replacement of cement at three ratios for each one.

The experimental program of this study consists of nine blended concrete mixtures (three Nano-materialsand three ratios of replacement for each one) besides to the control mixture. Each mix had a number of specimens sufficient to study the following durability properties of the blended concrete:

- Resistance to exposure to aggressive mediaat 3, 6, 12 month.
- The water permeability.
- Resistance of the elevated temperature at 400 ^{o}C and 600 ^{o}C .
- The compressive strength at 7, 28,56 day.

The material characteristics, the procedures of specimen's preparation, the tests set up,thetest results and discussion are described in detail. Results of experimental work showed that; Nano-materials are efficient in improving the concrete durability in most of measured properties with different levels of improvement according to the type of the Nano-material and the ratio of replacement. Optimum replacement ratios are proposed for each type of the Nano-materials.Also, results yielded that Nano-clay is more effectivethan the Nano-silica and hybrid Nano-silica-Nano-clayin enhancing the durability properties of concrete.

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Key words: Concrete Durability ,Nano-materials , Nano-silica , Nano-clay, Aggressive media , Permeability, Fire resistance

1. Introduction

Until the late 1930s, there was no research on the durability of concrete. The first discussion for the concrete deterioration and durability was the second symposium at Stockholm in 1938. After this period, several conferences were held with many reports and papers being presented on durability and deterioration of concrete structures[1].Recently,many types of materials have been advanced to be used as concrete additives to improve concrete properties. One of these materials is using the traditional pozzolanic materials such as kaolin and silica at Nano-scale particles[2]. Many literature studies confirmed that, these Nano-materials have enhancing effect on cement mortar. A few of these studiestried to study the Nano-material effect on some durability properties of blended concrete, but it still insufficient[3]. Approximately, No studies inside Egypt focusing entirely on the impact of some Nano-materials (Nano-silica, Nano-clay and hybrid of them) on the most important properties of blended concrete durability such as permeability, fire resistance and resistance of aggressive media. So this study was conducted to the effect of these Nano-materials on these properties specifically.

According to American Concrete Institute (ACI) Committee 201, durability of Portland cement concrete is defined as its ability to resist weathering action, chemical attack, abrasion, or any other process of deterioration; i.e. durable concrete will retain its original form, quality, and serviceability when exposed to its environment[4]. But in fact, no material is inherently durable. Where, as a result of environmental interactions the microstructure and consequentlythe properties of materials change with time.The material is assumed to reach the end of service life when its properties under given conditions of use have deteriorated to an extent that the continuing use of the material is ruled either unsafe or uneconomical. There are many measurements that can be used to determine the efficiency of the concrete durability such as: mechanical strength (compressive, bond , indirect tension , flexure), aggressive media resistance , fire exposure resistance, permeability, shrinkage and creep.[1]

The permeability property in concrete is measured byD'Arcy coefficient.D'Arcy demonstrated in the late nineteenth century that for laminar flow conditions in saturated granular materials, the rate of flow is proportional to the pressure gradient. Coefficient of permeability (D'Arcy coefficient) is the constant of proportionality between volume flow and pressure gradient and can be interpreted as the average velocity of flow through the sample cross section.[5]

Fire resistance can be defined as the ability of concrete to enable the structural elements to withstand fire or to giveprotection from it. This includes the ability to confine a fire or to continue to perform a givenstructural function, or both[6]. Under most circumstances, the rise in temperature causes a decrease in the strength for the concrete. However, the rate at which the strength decreasedepends on the rate of increase in the temperature of the fire and the insulating properties ofconcrete. As known the fire test methods are used to determine the fire resistive properties of concrete. The most widely used and nationally accepted test procedure is that developed by ASTM-E119.[7]

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Deterioration of reinforced concrete structures subjected to aggressive media such as the regions near to the seas shores is a serious problem that challenges the structural engineers around the world. Concrete durability and performance are of great concern when concrete exposed to aggressive media especially sulfate attack. whereas, the aggressive effect of sulfate salts on concrete is more than on reinforcement steel and vise in case of the aggressive effect of chloride salts.The consequences of sulfate attack on concrete seems clear in loss of the strengths till complete disintegration or expansion of cracks, these the two common types of deterioration due to sulfate attack. The first type is eating away of cement matrix and gradually reducing it to a non-cohesive granular mass and leaving the aggregate proud and exposed. This type of attack occurs when the sulfate ions of magnesium or sodium react with calcium silicate hydrate of the hydrated cement paste. It takes place as a result of high solubility of magnesium sulfates.The second typeis working to expand the cracks in concrete, this occurs when the reactive aluminateswhich present in sufficient quantities in cement is attacked by sulfate ions of calcium, forming calcium sulfo-aluminate hydrate (ettringite), leading to disruptive expansion. So the type of cement is one of the most effective factors in resisting sulfate attack.[8].Examining the effect of Nano-materials on enhancing the concrete when exposure to an aggressive media, was considered the most important test for measuring the durability of concrete. Formation the aggressive media in laboratory needs using one salt or group of salts at certain concentration. Sulfate salts were preferred more than chloridesalts to represent the effect of aggressive media for the reasons mentioned above. The standard specification which estimated the percent of concentration of the sulfate to form a sulfate solution simulate the natural aggressive media is ASTM C 1012-04 [9] , But it could not determine a certain percent able to give a solution with a certain properties at a certain time. But the common concentration are estimated by "N" where N is the molecular weight of $MgSO_4$ and equal 120.7 gm/mol.

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2. The Materials

This part includes a detailed description of the materials used through this study, these materials are; cement, aggregates, Nano-silica (NS), Nano-clay (NC), hybrid Nano-silica-Nano-clay (NS+NC), water ,and admixtures. Also, the concrete mixproportions were designed. The processing techniques for mixing the materials to produce blended concrete with Nano scale materials are known to highly affect therefore, a comprehensive description of the employed techniques of mixing is presented.

2.1 Cement

Ordinary Portlandcementtype (CEM I 52.5 N) according to E.S.S. (4756-1-2006) manufactured by Bani-Suifcement company was used. The chemical analysis, physical and mechanical properties of the used cement were done as per the Egyptian Standard Specification ESS No.2421 part l, 2 and 7/2005.

2.2 Aggregates

The coarse aggregates that used in preparing the concrete specimens is natural gravel with, smoothly surface,spherical shapeand a maximum nominal size 9.5 mm. The fine aggregate is natural siliceous sand. The physical properties of coarse and fine aggregate including; specific weight, bulk density, percentage of clay and fine materials, sieve analysis for both coarse and fine aggregate were according to the Egyptian Code Practice (ECP 203-2007)

2.3 Nano-materials

2.3.1 Nano-silica

Amorphous Nano-silica (SiO2) with particle size ranged from 17-78 nm as shown in XRD diagram and TEM micrographs which illustrated in figure (1) was used in preparation the Nano-silica blended concrete specimens in this study. The material was obtained from national research center (NRC). The percentage of mass of the elements which constitute the nanomaterial chemical composition is shown in table (1).

Table (1) chemical composition of the Nano-silica (NS_1)

Element	SiO_2	Al_2O_3	CaO	MgO	Fe_2O_3	Na_2O	K_2O	SO_3	(LOI)
Nano-silica(mass %)	99.9	0.01	0.01	0.01	0.01	0.01	0.01	-	0.02

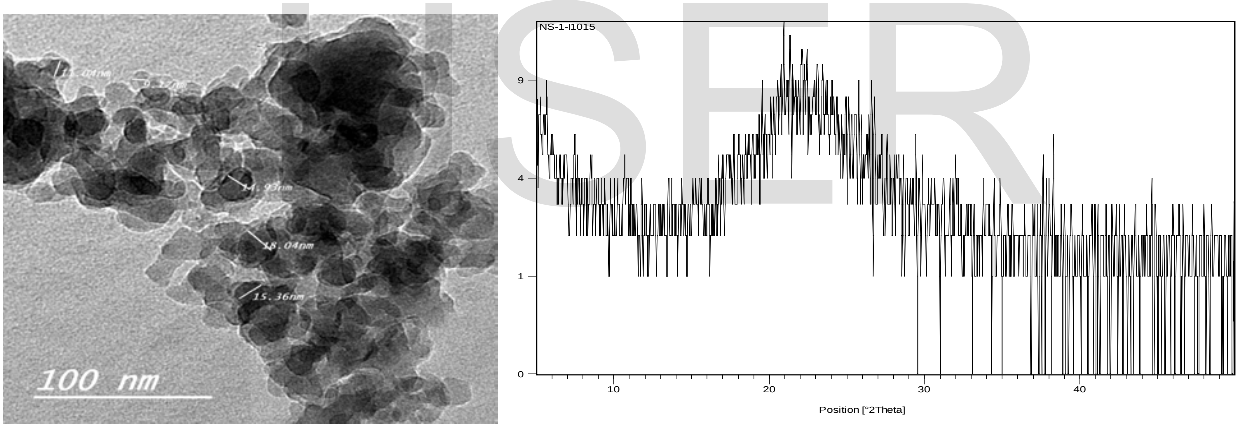

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Figure (1) TEM micrographs and XRD diagram for the Nano-silica

2.3.2 Nano-clay

Referring to table (2) find that the percentage of the mass of material elements almost unchanged in case of kaolin before burning and kaolin after burning (metakaolin) , this shows that the burning did not change the chemical composition of the material but impact on the particle size and the material crystallization (physical change). The size of Nano-clay particles and the diagram of XRD are shown in figure (2).

Table (2) chemical composition of the nanoclay (NC_3) (mass %)

Element	SiO_2	Al_2O_3	CaO	MgO	Fe_2O_3	Na_2O	K_2O	SO_3	(LOI)
Kaolin before burn	49.86	34.10	0.09	0.26	0.30	0.03	0.02	0.59	13.44
Kaolin after burn	57.53	38.63	0.11	0.30	0.35	0.01	0.03	0.56	0.93

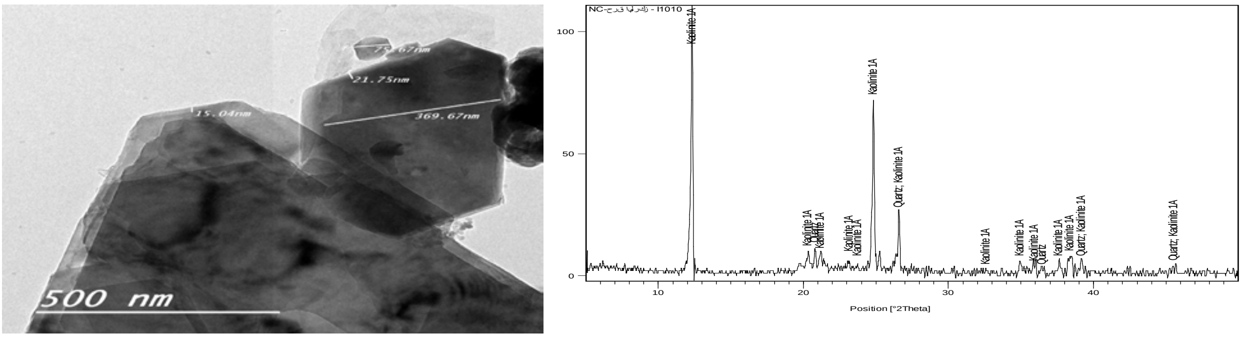

Figure (2).shows the XRD diagram and the TEM micrograph for nanoclay

2.3.3 Hybrid Nano-silica and Nano-clay

Hybrid Nano-silica – Nano-clay is a composition of mixing the two Nano-materials to obtain mixed characteristics related to the characteristics which distinctive each one individual. According to many of previous studies, the Nano-silica more amorphous than the Nano-clay so it has more contribution in increasing of the C-S-H gel during the hydration of cement. Also the studies showed that, the Nano-clay acted as filler more than the Nano-silica so it helps in decreasing the voids and produces a more density concrete. This two characteristics when together provides a more dense, a more strength and a less voids. So the mechanical and durability properties of the concrete increased when the hybrid is replaced partially by cement.

The technique of mixing based on two consideration;firstly the optimum ratio of Nano-clay as partial replacement of cement, it was 5 % as obtained from the experimental tests , secondly the Nano-clay is the main component and make a partially replacement with Nano-silica by certain ratios. The ratio of Nano-silica replacement was 10%, 20% and 30% as partial replacement of Nano-clay. Therefore, the used ratios of hybrid Nano-silica-Nano-clay was (0.5%NS + 4.5%NC), (1% NS + 4% NC) and (1.5% NS+3.5% NC) respectively as a partial replacement of cement.

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2.4 Water

The water used in the concrete mixtures was potable water from the laboratory tape**.** Ostensibly, the water was free from suspended solids and organic materials

2.5 Admixture

Polycarboxylic ether polymer super-plasticizer, (GLENIUM ACE 30) from BASF (chemical company) in Egypt, was used. GLENIUM ACE 30 is an innovative secondgeneration of polycarboxylic ether polymer superplasticizer. The particular molecularconfiguration of it, is acceleratesthe cement hydration. As compared to the traditionalsuper-plasticizers,GLENIUM ACE30 help the most finest cementitues materials to improve the most engineering properties of the concrete.

3. Specimens Preparing and Tests Set up

3.1 Mixing Technique and Specimens preparations

All nano-concrete mixes which used in manufacturing the specimens were prepared by using the wet mix techniqueaccording to the design mix proportions shown in table (3) as follows:

1- The quantities of traditional components of concrete (gravel, sand, cement) were prepared according to the design mixproportions and were mixed together.
2- The Nano-material powder was dispersion by adjusted drill in 80% of the estimated mixture's water quantityfor a suitable period time (2 minutes) in medium speed until the composite was converted to emulsion, then adding it gradually to the concrete mix.
3- The determined super plasticizer quantity was added and stirred to the remained 20 % of the mixture's water and adding gradually to the mixtures.
4- The pan mixer was used to mix all the components for2 - 5 minutes
5- The mix were molded in 10x10x10 cm and 15 x15x15cm cubes for 24 hours , then the specimens were demodulated to put in curing water for 28 day.

Table (3) the mixes design proportions

mix	**Symb.**	**Cement** (kg)	**Aggregate** (kg)		**Water** (lit.)	**S.P** (lit.)	**Nano materials** (kg)
			coarse	**fine**			
Control mix	**M0**	400	1109	597	160	6	-----
5%NC	**M_1**	380	1109	597	160	6	NC = 20
7%NC	**M2**	372	1109	597	160	6	NC = 28
10%NC	**M3**	360	1109	597	160	6	NC = 40
1%NS	**M4**	396	1109	597	160	6	NS = 4
2%NS	**M5**	392	1109	597	160	6	NS = 8
3%NS	**M6**	388	1109	597	160	6	NS = 12
0.5% NS + 4.5% NC	**M7**	380	1109	597	160	6	NS = 2 NC = 18
1% NS + 4% NC	**M8**	380	1109	597	160	6	NS = 4 NC = 16
1.5% NS + 3.5% NC	**M9**	380	1109	597	160	6	NS = 6 NC = 14

3.2 Compressive Strength Specimens

Concrete compressive strength testwas conducted at ages of7 days, 28 days and 56 days for all mixes as per EN 12390-3standards[10]andASTM C78. The specimenswere prepared for testing as shown in figure (3).

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Figure (3) the concrete specimens with dimension 10x10x10 cm

3.3 The Permeability

Durability of concrete depends mainly on its permeability, which is one of a major factors affecting on concrete resistance to sulfate and chloridediffusion, abrasion and other forms of chemical attack.

The permeability is measured by determining coefficient of water permeability "D'Arcy coefficient" for hardened concrete specimens. The test was conducted by using a permeability apparatus as shown in figure (4).Three cubes 15 x 15 x15 cm were prepared for each mix. Four lateral faces of the cube were painted with epoxy to prevent the flow of water through this faces. The other two opposite faces were left without painted. The specimens were placed in the permeability cells of the testing apparatus. The water is flow from the top face to the bottom face under a pressure of 30 bar for 24 hours. The penetratingwater is collected in graded flask. The permeability coefficient (Darcy's coefficient) is calculated by the following equation:

$$K = QL / tAh$$

Where:

k = D'Arcy Coefficient (Coefficient of Permeability) in (m/s)
Q = Volume of water in m^3
L= Length of the test sample in m
t = Elapsed time in seconds
h = Applied pressure head in m
A= Area of the test sample in m^2

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Figure (4) the permeability apparatus

3.4 The Fire Resistance

This part of the experimental work was allocated to investigate, if the used Nano-materials NS,NC,hyb. (NS+NC) have any significant effect on preventing the deterioration of the concrete durability after fire exposure, especially in terms of reduction of the compressive strength. A standard fire test is conducted by placing a 12 group of concrete specimens (each group contained 3 cubes 10 x10 x10 cm) in a furnace as shown in Figure (5). Specimens were heated in a temperature controlled furnace at a very slow heating rate up to the desired temperatures.The specimens were subjected to peak temperatures of 400, 600 ^{o}C for 2 hrs in the furnace. Thereafter, the specimens were cooled naturally in a closed furnace chamber. The purpose of using the slow heating rate was to minimize differential temperature gradient in the specimens [11].The compressive strengths were measured for thespecimens after exposure to the fire and compared with the strength of control specimens.

Figure (5) the concrete specimens inside the furans to exposure to the fire

3.5 The Aggressive Media Exposure

The aggressive media could be formed by using magnesium sulfate which known in the market as magnesium sulfate heptahydrate ($MgSO4.7H2O$).The used concentration in this process was 2N (247.5gm/mol) to increase the aggressive effect because of the short duration of exposure. Concrete specimens were submerged in the magnesium sulfate solution after 28 day of curing in tap water for a period of 3, 6 and 12 months as shown in figure (6). The tests included a visual inspection for the specimens as well as compressive strength test.

Figure (6) the specimens immersed in magnesium sulfate and the salt bottle

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4. Tests Results and Discussion

4.1 Compressive Strength Test

Although there are many measuresare used to assess the concrete durability, many of the standard specifications emphasize compressive strength as the primary means for assessing the concrete durability[12].Table (4**)** shows the test results of the compressive strength at age 7, 28, 56 day.

Table (4) the compressive strength test results

property	Age	Nanoclay (NC)%				Nanosilica (NS)%				Hyb. (NS + NC)%			
		0	5	7	10	0	1	2	3	0 + 0	0.5+4.5	1+4	1.5+3.5
Compressive	7	273	357	272	268	279	308	322	313	262	292	294	313
strength	28	352	409	357	343	342	394	373	368	339	392	405	399
(kg/cm^2)	56	359	433	403	368	363	403	413	393	367	408	422	417

In general, The 2 types of Nano-materials used and the hybrid of them enhanced the compressive strength of concrete. But the enhancement percentage vary according to the nano material type , the ratio of replacement and the curing age of specimensas shown in figures from (7) to (12). Some conclusions could be stated as follows:

1- The Nano-clay enhanced the compressive strength more than thehyb. NS + NC and Nano-silica respectively. The improvement percentage in compressive strength of concrete as a result of replacing 5% of cement by a Nano-clay was 20.6 % compared to the control mix and 15% , 13.8 % for hyb.(NS+NC) and Nano-silica respectively as shown in table (5).

2- The optimum ratio of replacement for the Nano-clay was 5% , 2% for Nano-silica and (1%NS+ 4% NC) for the hybrid .

3- The Nano-clay gave enhancement at early agesbut the rate is decrease with the increase of the age. Vice versa in case of Nano-silica where the rate is increase with the age .the hybrid is moderate case between the two Nano-materials.

Table (5) percentage of compressive strength enhancement due to effect of Nano-materials

Type of nanomaterial	Optimum percentage of replacement	Percentage of improvement in compressive strength(%)		
		7 days	28 day	56 day
Nanoclay (NC)	5%	30.8	16.2	20.6
Nanosilica (NS)	2%	15.4	15.2	13.8
Hyb. (NS+NC)	(1% + 4%)	12.2	19.5	15.0

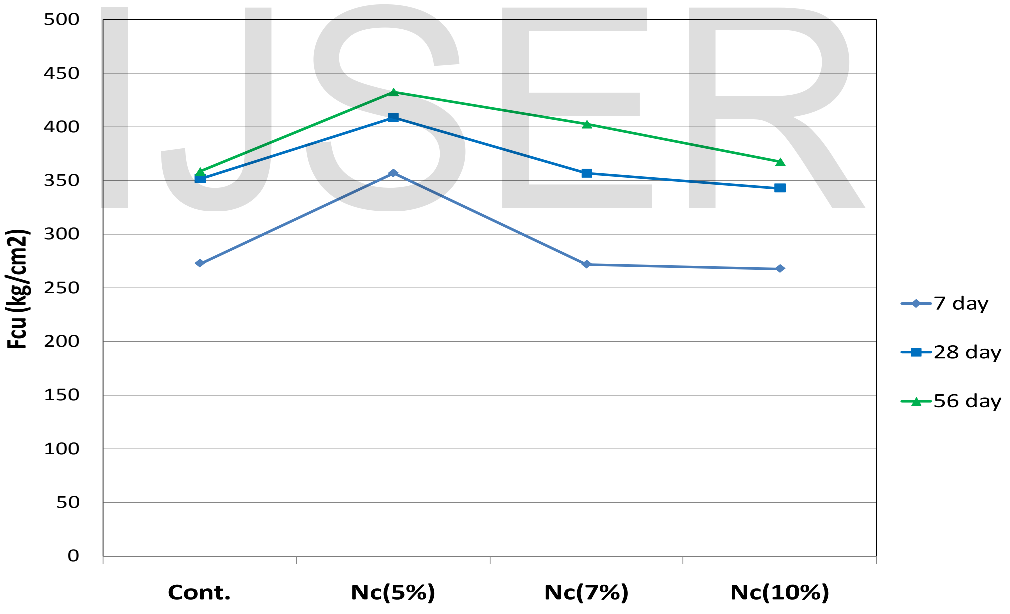

Figure (7) the Compressive Strength of NC at Different Ratios and Age

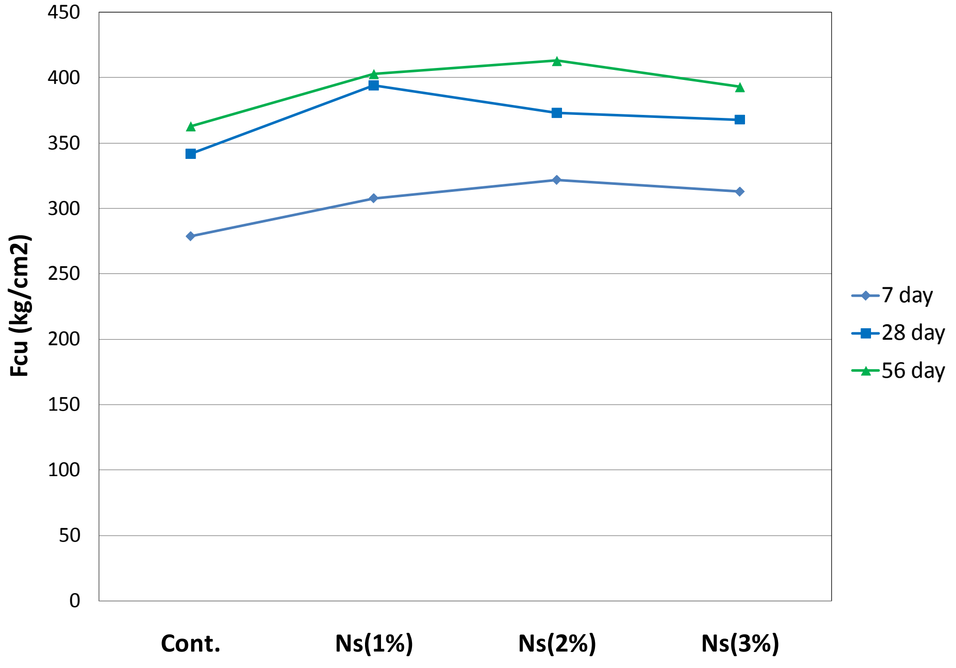

Figure (8) The Compressive Strength of NS at Different Ratios and Age

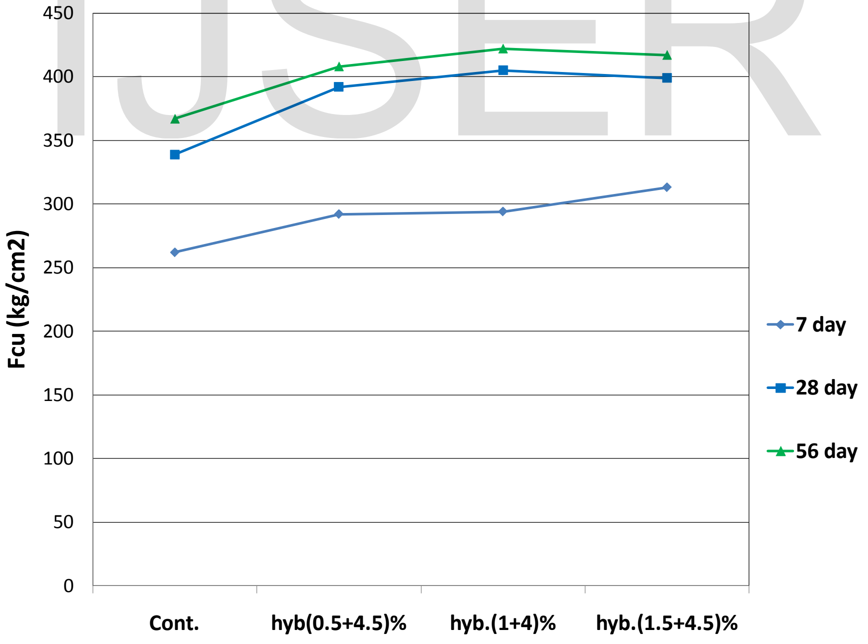

Figure (9) Compressive Strength of hybrid (NS+NC) at Different Ratios and Age

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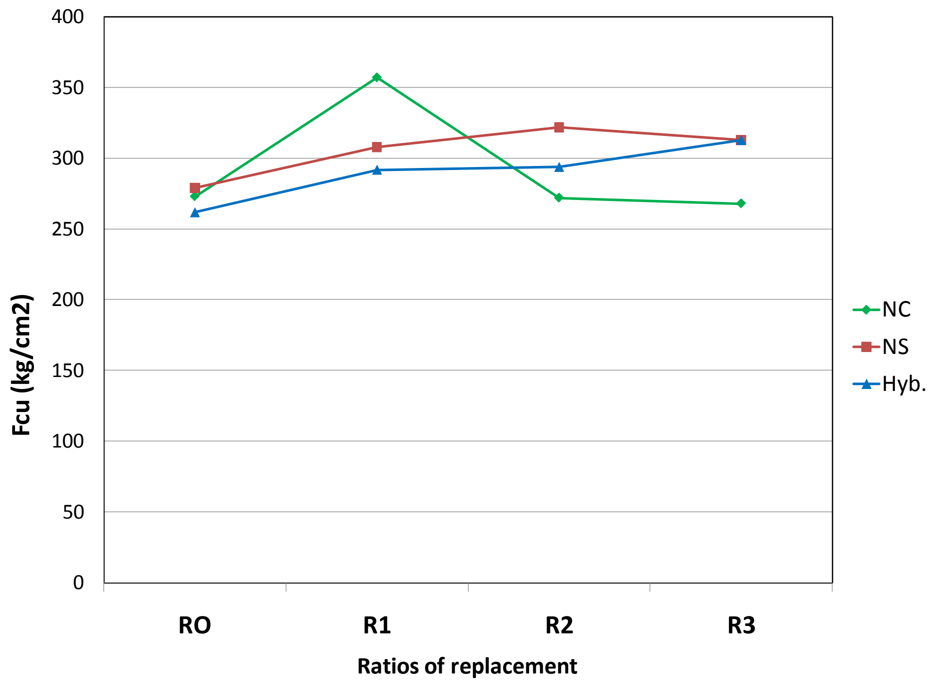

Figure (10) The Nanomaterials Effect on Concrete Strength at Age 7 Days

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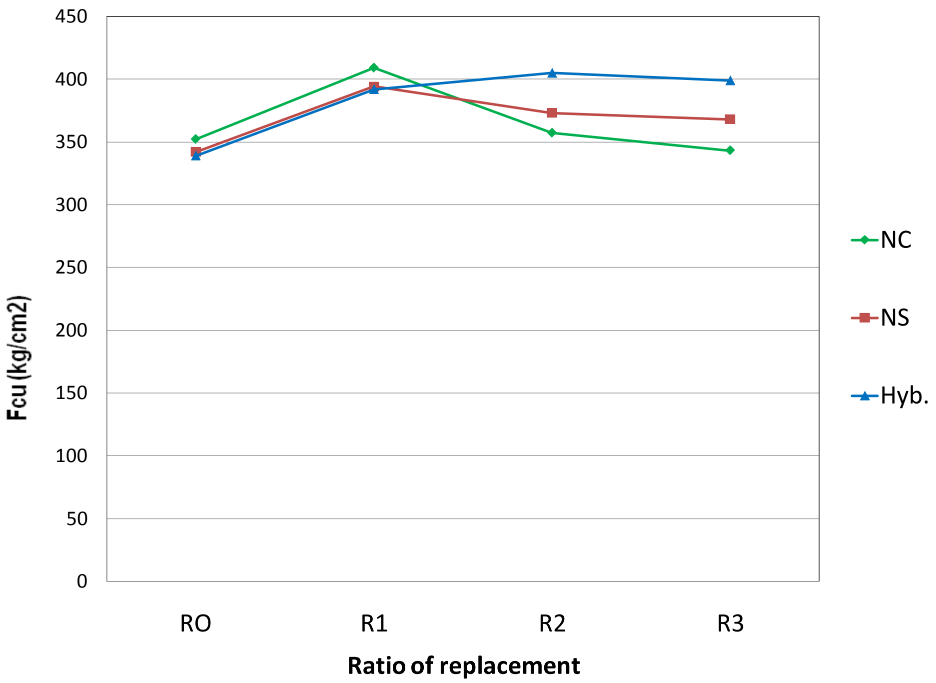

Figure (11) The Nanomaterials Effect on Concrete Strength at Age 28 Day

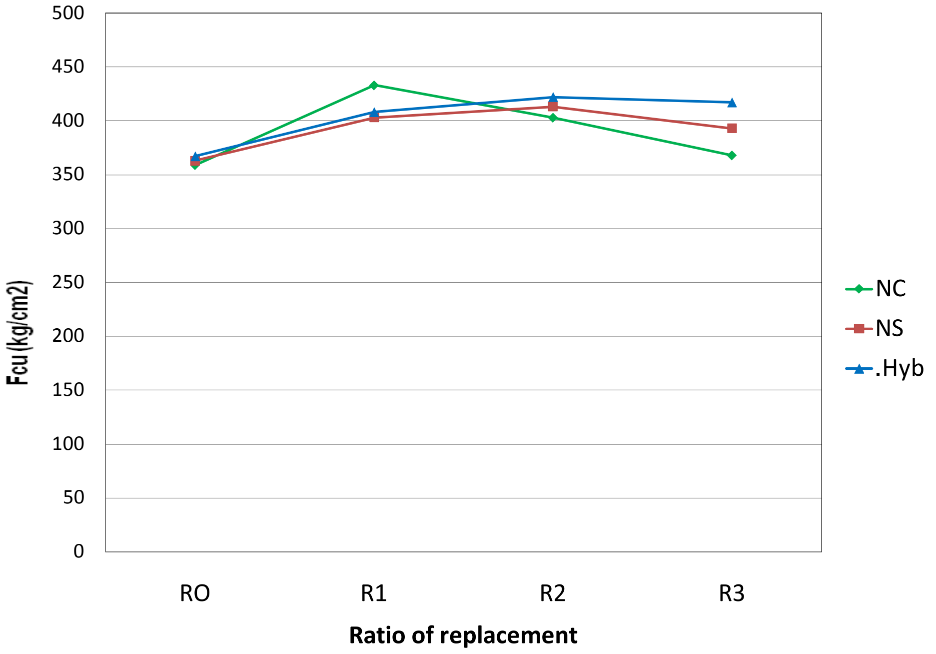

Figure (12) The Nanomaterials Effect on Concrete Strength at Age 56Day

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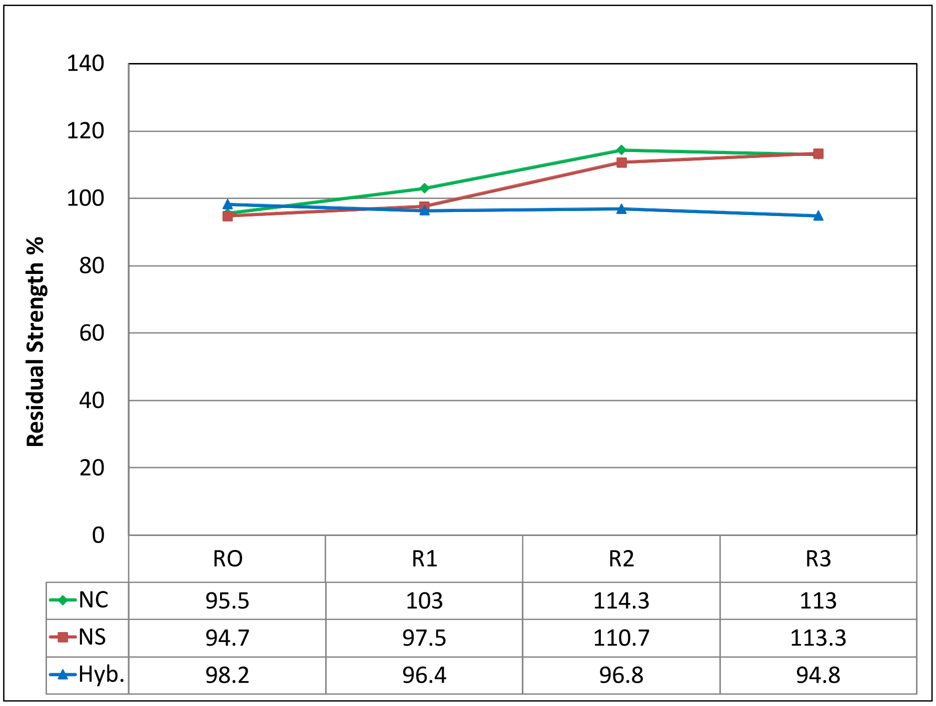
4.2 Elevated Heat Temperature

High elevated temperatures effects on a denser structure of blended concrete through the dehydration process. The dehydration of the formative hydrate is expelled free water and the residual part of water leads to formation of micro-cracks or/anddeveloped it. Therefore, the blended concrete compressive strengths of NC , NS and hyb. (NC+NS) display slow decrease than the control mixes[13]. The residual concrete strength vary from nanomaterial to another and from ratio of replacement to another as shown in table (6) and figure (13) , (14). The results correspond largely with the findings of Saleem et al.[14].

Table (6) the results of Nanomaterials effect on strength of concrete exposure to fire

property		Nanoclay (NC)%				Nanosilica (NS)%				Hyb. (NS + NC)%			
		0	5	7	10	0	1	2	3	0 + 0	0.5+4.5	1+4	1.5+3.5
Residual (F_{cu}) after exposure to fire (kg/cm^2)	25 ^{o}C	352	409	357	343	342	394	373	368	339	392	405	399
	400 ^{o}C	336	421	408	388	324	384	413	417	333	378	392	377
	600 ^{o}C	273	337	318	299	256	300	339	347	241	295	291	317



	RO	R1	R2	R3
NC	95.5	103	114.3	113
NS	94.7	97.5	110.7	113.3
Hyb.	98.2	96.4	96.8	94.8

Figure (13) Effect of Fire at 400 ºC on Blended Concrete Strength

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	RO	R1	R2	R3
NC	77.6	82.4	89	87.2
NS	74.8	86	80.4	94.3
Hyb.	71.1	75.3	71.8	79.4

Figure (14) Effect of Fire at 600 ºC on Blended Concrete Strength

4.3 Permeability

Table (7) shows the permeability test results. Nano powder could act as nano fillers, consequently it improve the blended concrete resistanceto water permeability . the test was conducted at ages 90 days (the curing was 28 days only, and 62 day at laboratory environment).The normal concretes has less permeability resistance than the nano-particles concrete. Because the microstructure of thenano-particles concrete is more uniform and denser than the control concrete mix. This results is agree with Mostafa. Khanzadi [15] who concludes the same result. Figure (15) introduces appropriate comparison between the effect of each nano material at its different replacement ratios on permeability resistance.

Table (7) Permeability coefficient ofblendedconcrete and the percentage of it

property		Nanoclay (NC)%				Nanosilica (NS)%				Hyb. (NS + NC)%			
		0	5	7	10	0	1	2	3	0 + 0	0.5+4.5	1+4	1.5+3.5
Permeability coefficient (k) (cm/sec)	(K) x 10^{-11}	8.62	2.46	5.54	7.08	7.7	4.0	4.0	3.1	6.78	5.54	4.3	2.77
	K %	100	28.5	64.3	82.1	100	51.9	51.9	40.3	100	81.7	63.4	40.9

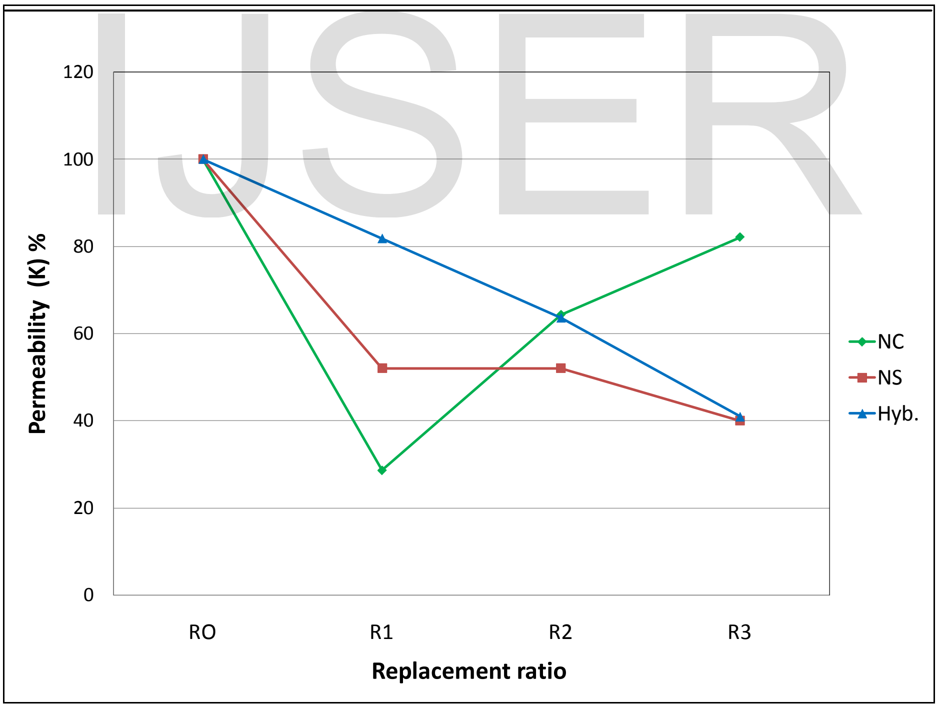

Figure (15) Effect of nanomaterials on concrete permeability resistance

4.4 Effect of Sulfate Attack

Two measures were used to investigate the sulfate attack effect; the compressive strength and the Visual inspection for specimens after exposure to sulfate.

4.4.1 The Compressive Strength Results

Compressive strength test results after submersing in the sulfate solution are shown in table (8). Figures from (16) to (21)illustrate the results in curves form to facilitate the comparison between the effect of different Nanomaterials and different ratios for each one on sulfate resistance of the blended concrete.

Table (8) The results of sulfate effect on blended concrete strength at ages ; 3, 6 , 12 month

property	Age (month)	Nanoclay (NC)%				Nanosilica (NS)%				Hyb. (NS + NC)%			
		0	5	7	10	0	1	2	3	0 + 0	0.5+4.5	1+4	1.5+3.5
compressive strength (kg/cm^2)	0	352	409	357	343	342	394	373	368	339	392	405	399
	3	319	399	329	312	294	330	327	343	296	345	369	352
	6	240	372	321	298	250	261	270	284	250	262	298	301
	12	164	234	180	184	219	253	258	272	209	218	271	244

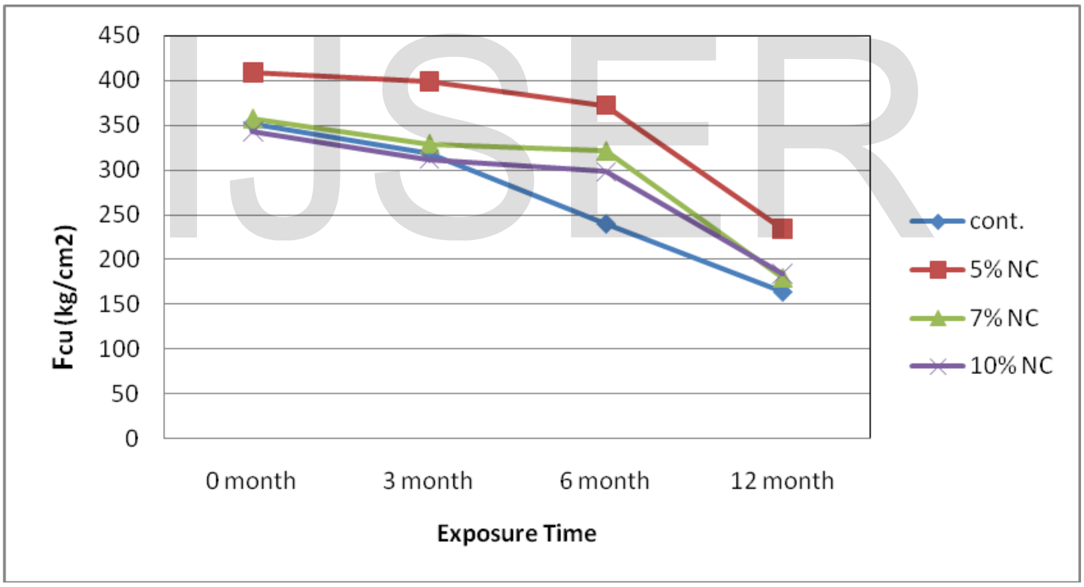

Figure (16) the effect of nanoclay on sulfate resistance of blended concrete

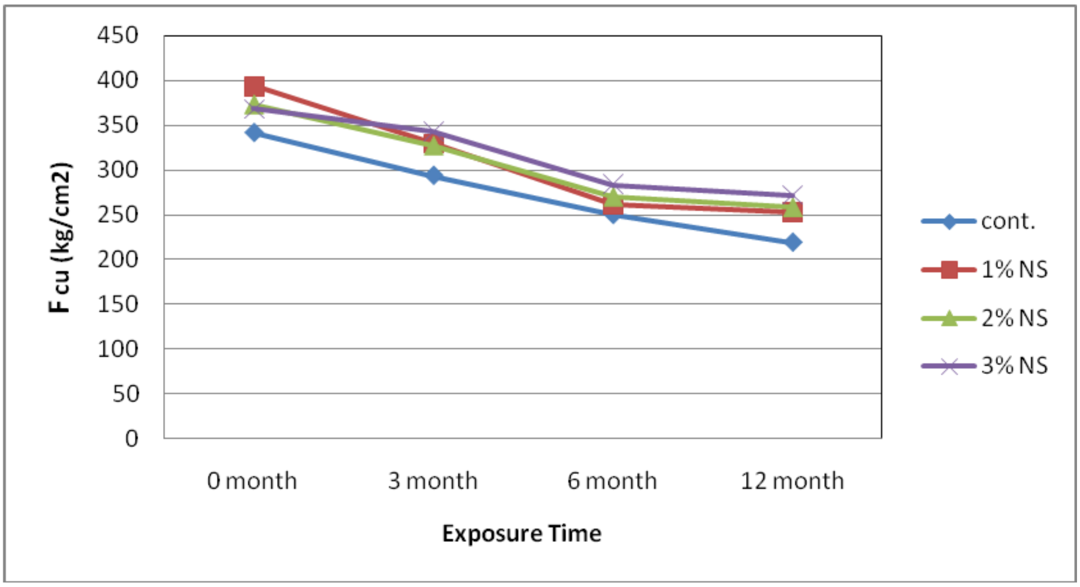

Figure (17) the effect of nanosilica on sulfate resistance of blended concrete

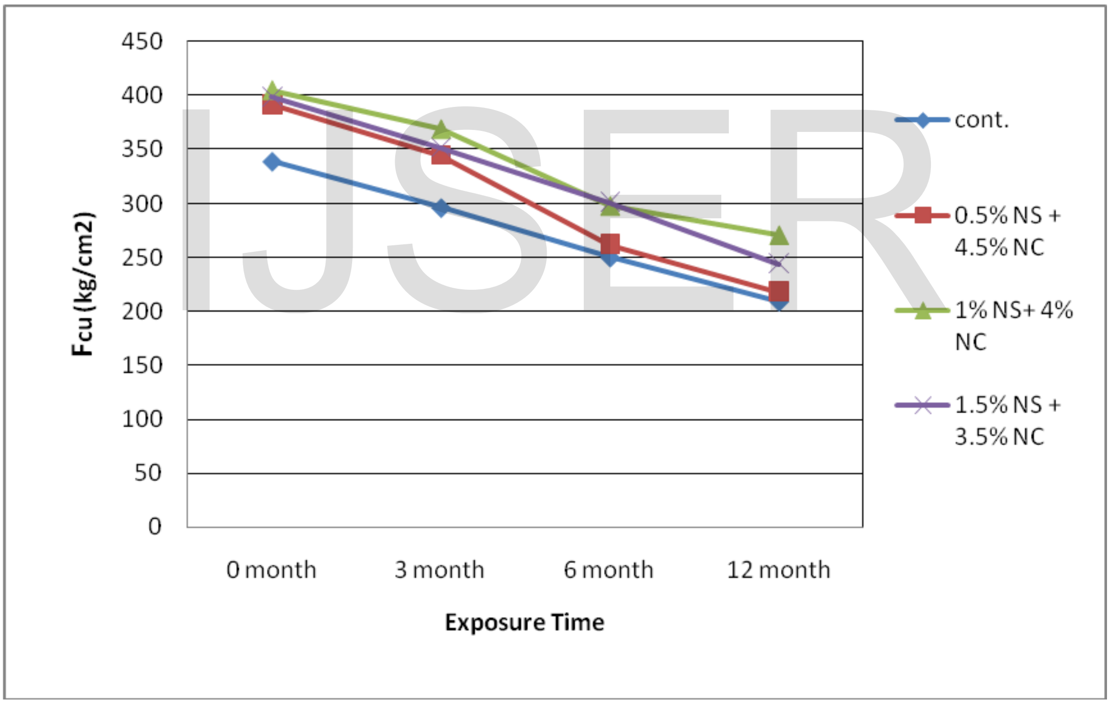

Figure (18) the effect of hyb.(NS+NC) on sulfate resistance of blended concrete

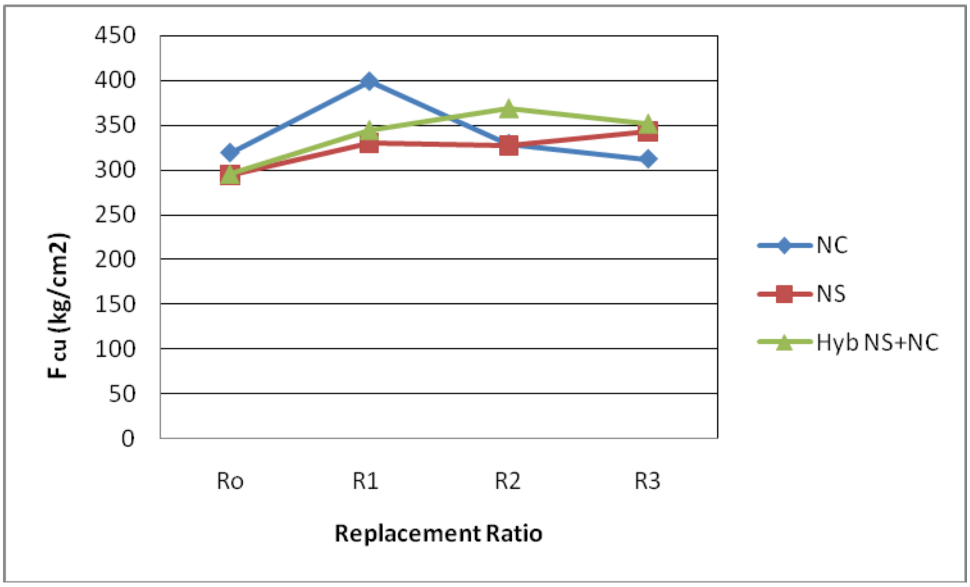

Figure (19) The aggressive media effect on blended concrete strength for 3 months

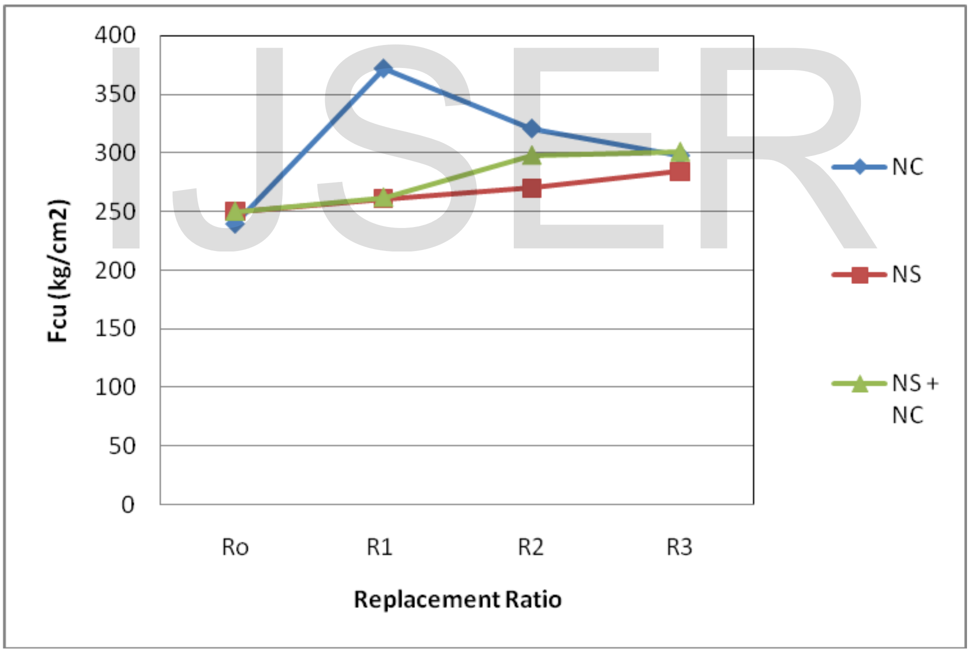

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Figure (20) The aggressive media effect on blended concrete strength for 6 months

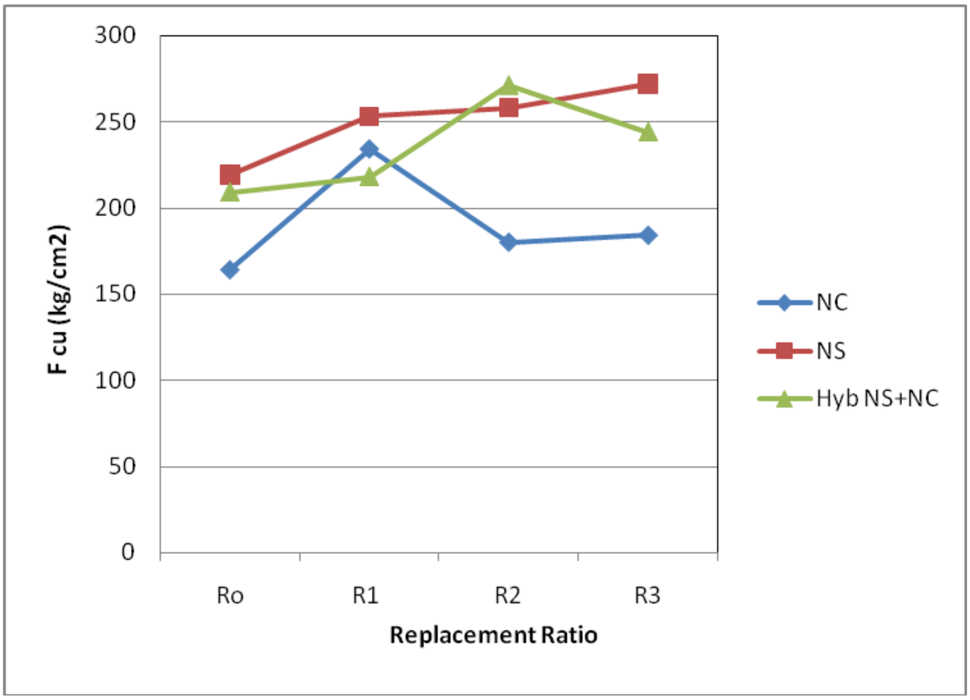

Figure (21) The aggressive media effect on blended concrete strength for 12 months

4.4.2 Visual Observation

The visual inspection indicates that the specimens have surface deterioration but the deterioration different from sample to another as shown in the Figures from (22) to (25) . The higher deterioration occurred in the control specimens. Also the initial mass of specimens were measured before immersed them in magnesium sulfate solution andwere measured againafter 3,6 and 12 month of immersion, change in mass, is also observed at 6 , 12 month, but there is no change in at 3 month , only Efflorescence was observed on the surface of the specimens at this age. There was change in dimensions increased with increase in the immersion time, it can be observed clearly at age 6 , 12 month.

Figure (22) the surface deterioration of specimens after immersion in magnesium sulfate for 3, 6 , 12 month

Figure (23) the surface case of blended concrete with nanoclay immersion in sulfate for 12 month

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Figure (24) the surface case of blended concrete with nanosilica immersion in sulfate for 12 month

Figure (25) the surface case of blended concrete withhyb. (NS +NC) immersion in sulfate for 12 month

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5. The Conclusions

After analysis of the results the following conclusions could be listed as following::

1- Utilizing of byproduct /natural materials which have pozzolanic activity as SCMs can introduce environmental benefits by minimizing the production of cement which is one of the main sources of carbon dioxide emission.

2- The 5 % nanoclay , hybrid (1% nanosilica + 4% nanoclay) , and 2% nanosilica as a partial replacement of cement increase the concrete compressive strength at 28 day more than concrete without Nanomaterials (control mix) with 20.6 % ,15 % and 13.7 % respectively.

3- . But the nanoclay is more effective in case of concrete and increase the concrete strength more than Nanosilica with 3.8 %.

4- 11- There is no one ratio of replacing cement by Nanomaterials can be considered the optimum ratio for enhancing all properties of concrete where the optimum ratio changing from property to another.

5- The influence of high rise temperature on the blended concrete mixes showed a loss in the strengths with variety range. These losses in strengths increased after temperature level of 600 ^{o}C.

6- The concrete specimens of different replacement ratios of nanosilica , nanoclay and hybrid of them by cement which exposure to elevated temperature recorded a higher compressive strengths of concrete specimens at 400 ^{o}C compared with the same mixes at ambient temperature (25 ^oC) . But at 600 ^oC, the compressive strength of hardened specimens of these mixes were degraded. The less degradation occurred at 7% NC , 3 % NS and (1% NS + 4% NC) hybrid with 11% , 6 % and 3.3% respectively, while the control mix degraded with 22.5 %.

7- concrete mix with replaced partially by 5% NC and 3% NS and (1.5% NS+ 3.5% NC) hybrid showed the best performance in permeability investigation . This could be noticed the largest reduction in permeability coefficient for these mixes with ratios 71.4% , 60% and 59% respectively compared to the control .

8- As a result of exposure of blended concrete specimens to aggressive media of concentrated solution of magnesium sulfate (MgSO4) for 3 months , approximately equal losses in concrete strength were occurred for all mixes , while at 6 months exposure, the control mix loss 33.4 % , 5.5%, 2.3 % more than NC, NS and hybrid mixes respectively.

9- For one year exposure to sulfate attack the blended NC-concrete specimens have a loss in strength equal to 46.5 % while the control mix specimens have 60 %.

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