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Research Article

INVESTIGATION ON THE EFFECT OF NANOCILICE ON DECREASING THE ALKALI-SILICA PHENOMENON AND INCREASING DURABILITY OF CONCRETE

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ABSTRACT
In this research, the effect of Nano-silica on decreasing the alkali-silica phenomenon and increasing durability of concrete is studied. Firstly, a general review about this issue and prerequisites about the experiments are discussed and then the design experiment based on aggregates-the ability of them for reactions by the expedited prismatic mortar based on standards and industrial codes are mentioned. Finally, it is found that the application of Nano-silica has considerable results such as considerable decreasing of expansion of specimens and increasing the pressure strength.

Keywords: *Nano-Silica, Alkali-Silica Phenomenon, Increasing Strength*

INTRODUCTION
Being multi-purpose, durable and cost effective are the reasons that make concrete the most popular materials in construction. Concretecan be used in construction of roads, parking yards and stories, bridges, high rise buildings, dams, homes and so many other structures. In the previous researches, the applications of different materials like fly ashes (Atyayy, 2007), pozzolans (Atyayy, 2007), silica fumes (Ramazanian Pour, 2005; Maghsudi and Ahmadimoghadam, 2004), rice skin (Qurecaia and Brouwers, 2010) and micro silica (Atyayy, 2007; Maghsudi and Ahmadimoghadam, 2004; Qurecaia and Brouwers, 2010) as admixtures in concrete in order to increase durability and the age of concrete with different percent of mixtures are discussed. Moreover, the application of micro silica in oil storages is discussed in the previous researches as well. Other researches about the application of Nano silica in improvement of mechanical characteristics of concretes are done which show usefulness of these materials in special cases. Now, in this research we discuss the effect of Nano silica in decreasing the alkali-silica phenomenon and increasing the strength of concrete.

MATERIALS AND METHODS
In recent years, various experimental researches are done about the decreasing the alkali-silica reactions on aggregates, but each of them has its own limitation (Ramezanpoor *et al.,* 2005; Luke, 2006). In the majority of previous researches the trend of alkali-silica reactions in the concrete made out of ordinary Portland cements are without any admixtures are studied. However, the researches show that the admixtures have significantly leads to decreasing the effect of the alkali-silica reactions and their damages (Rangaraju *et al.,* 2006; Duchesne and Berube, 1994). It is shown in the researches of Thomas that using 20% of fly ashes in replacement of cements in the concrete specimens made out of reactive aggregates is highly effective and decreases the destructive effect of alkali-silica reactions in the experimental specimens (Thomas *et al.,* 1991). In another research, it is also shown that using a kind of fly ashes in concrete which has 4% of Na_2O can significantly mitigate ASR (Lukaschova *et al.,* 2008).

Provision of Aggregates from Mine and the Sever Experiment
It is necessary to consider a set of requirements about grading area of aggregates in the mixture design of concrete in order to carry out the standard prismatic mortar and investigation on the effect of alkali reactions on the plastic cement. In the table 1 the requirements of fine aggregates based on the standard of ISIRI 8573 (Iranian Standard and Industrial Researches Institute). Then, choosing the mine is based on the requirements of the table 1. It is worth saying that because of practical problems it is impossible to consider all of the requirements. Then, in this research- after experimental tests like grading and SE (sand

equivalent) on the sands and gravels from different mines of Tehran state-ultimately the Galumac mines of Tehran are selected.

Table 1: The Requirements of Grading Area of Fine Aggregates

Weight Percent	Sieve Gauge (mm)	
	Remained on the Sieve	Passed from Sieve
10	2/36	4/75
25	1/18	2/36
25	0/60	1/18
25	0/30	0/60
25	0/15	0/30

Firstly, a set of washed aggregate materials are put in the oven and then the sieve test on one kilogram of dry aggregates are done which its results are shown in table 2.

Table 2: The Grading Results of Fine Aggregates of Galumac Mine

Cumulative Remained Percent	Remained Percent	Weight Percent of Remained on the Sieve(gr)	The Sieve Number
4	4	40	4
24	20	200	8
46/5	22/5	225	16
83	20	200	50
96/5	13/5	135	100
	3/5	35	tray
317	100	1000	Sum

At the end of grading test, the fineness modulus of aggregates gets 3.17 which show the high percentage of coarse aggregates among sands. It is worth mentioning that this trait is seen in all other mineral specimens. Moreover the SE result is 78% which satisfies the minimum standards.

Table 3: The Grading Results of Catenarycoarse Aggregates

Weight Percent of Remained on the Sieve(gr)	The Sieve Number
0	1
0	3/4
120	1/2
150	3/8
810	4
15	8
5	16 to 100 Tray
1000	Sum

Table 4: The Grading Results of Ovalcoarse Aggregates

Weight Percent of Remained on the Sieve(gr)	The Sieve Number
0	1
315	3/4
605	1/2
75	3/8
5	4
0	Tray
1000	Sum

In this research the specimens of coarse materials (gravels) were provided from the Deh e bala mines in the adjacent of Kerman state and are dried in oven and then they are graded which tables 3 and 4 show its results. Then the grading curve is drawn and the percentage of oval coarse aggregates is 65% and the percentage of catenary coarse aggregates is 35%. These percentages satisfy the standard of ASTMC33.

The Specifications of Nano Silica in Mixture Design

The Nano silica with the AEROSIL 200 commercial name which is the products of the Degussa Company with 12 Nano meter size, ±200 25 square meter on a gram special area, 99.8 purity degree, PH in between 3.7 and 4.7 and humidity percentage less than 1.5 percent.

The Specifications of Used Portland Cement

In this test the Portland cement type 2- product of Kerman factory is used. In comparison to hydraulic lime, Portland cements gets stiffer sooner and reaches to more significant strengths. Firstly, the amount of lime in materials shouldn't be more than the amount which is necessary for the combination of silica, alumina and oxidized iron. The reason of this phenomenon is production of free lime in cements which has different behavior from hydraulic lime. Hydraulic limes are not melted and its product is relatively soft and pervious for this reason the uncombined lime is slaked beside water instantly. Practically, the amount of calcium carbonate is controlled with the accuracy of ±.1 in the process of cement production. If the materials are not grinded enough, it is possible that by distribution of a mixture which is complete in terms of chemical view free lime is produced. Although there is a liquid phase, the reaction of getting clinker is done incompletely and then the uncombined lime is remained free. This process depends on the existence of high temperature in the process. Nowadays, defining the accurate allowable amount of saturated lime in cements is possible, because we know the essence of principle parts of Portland cement.
The necessary chemical characteristics of all five types of Portland cements should be in accordance with the contents of table 5. The arbitrary characteristics of them are shown in table 6.

Table 5: The Necessary Chemical Characteristics of Based on the Iranian 389 Standard

Test Method	Portland Cement Type					Chemical Characteristics	Row
	5	4	3	2	1		
Based on the National Iranian Standard, Number 1692	-	-	-	20/00	-	SiO_2(Minimum)	1
	-	-	-	6/00	-	Al_2O_2(Maximum)	2
	-	6/5	-	6/00	-	Fe_2O_3(Maximum)	3
	5	5	5	5	5	MgO(Maximum)	4
	2/30	2/30	3/5	3/00	3/00	SO_3 C_3A =8	5
	-	-	4/50	-	3/50	C_3A =8	
	3/00	2/50	3/00	3/00	3/00	The Weight Decrease under Burning	6
	0/75	0/75	0/75	0/75	0/75	The Remained None Solution Percent (Maximum)	7
	-	35/00	-	-	-	C_3S(Maximum)	8
	-	40/00	-	-	-	C_2S(Minimum)	9
	5/00(4)	7/00	15/00	8/00	-	C_3A (Maximum)	10
	25(2)	-	-	-	-	(C_4AF+C_2F) or ($2C_3A+C_2AF$) (Maximum)	11

Table 6: The Arbitrary Chemical Characteristics of Based on the Iranian 389 Standard

The Method Test Number Based on National Iranian Code	Portland Cement Type					Characteristics	Row
	5	4	3	2	1		
1692	-	-	8/00	-	-	Moderate -1-1 Sulphat Resistant (maximum) $2C_3A$	1
1692	-	-	5/00	-	-	High Sulphat -2-1 Resistant (Maximum)	
1692	-	-	-	58	-	(C_3A+C_3S) For Moderate Hydration Temperature (Maximum)	2
1695	0/60	0/60	0/60	0/60	0/60	(Na_2O+0/65$_8K_2O$) For Cements with Low Percents of Alkalis (Maximum)	3

Preparations for the Test

1) Preparation of the Specimens

Based on the instructions of the prismatic mortar test, three specimens for each combination of aggregates and cements should be produced.

2) Preparation of Molds

Based on the instructions of the prismatic mortar test, the internal areas of the molds should be covered by a kind of oils that not only does not have any effects on the concrete setting but also make separation of the specimens from the molds easier. It is not also detrimental to the water infiltration.

3) Moisture and the Temperature of the Laboratory

Based on the instructions of the prismatic mortar test, the temperature of the testing room (in which materials are kept and molded) shouldn't be less than 6 and more than 20 degree of Celsius. The temperature of the water should be about 23 degree of Celsius.

The relative moisture of the molding room shouldn't be less than 50 degree of Celsius. The water basin should be in accordance with the standards. The temperature of the water bath in which the specimens are kept should be in the range of 80±2. For this purpose we should use the Poly ethylene and warming elements.

4) The Normal Solution of Sodium Hydroxide

For the preparation of one liter of the solution, 40 grams of NaOH should be solved in 900 grams of water. Then, it should be diluted with pure water or a kind of water without any minerals to reach one liter volume. The volume ration of sodium hydroxide to the prismatic mortars in maintenance molds should be 4±0.5 volumes of solution to one volume of the prismatic mortar. The volume of each prismatic mortar is about 184 mille liters. The amount of the solution should be enough to inundate all of the prisms.

5) Preparation of the Aggregates

All of the aggregates that are tested by this method should be graded based on the requirements of the table 1. If there are not enough weight percentages of some of the aggregates, this can be compensated by grinding them.

6) Compression Mix Design

The mix design is carried out based on the standard of ACI-211-89 in a way that below ratios are considered for on cubic meter. (The unit of the materials is kilogram to cubic meter).

Table 7: The Mix Design of Cubic Specimens to Estimate the Compression Strength

Nano Silica	Super Plasticizer	W/C	Oval	Catenary	Sand	Cement	Design Name
0	7	0.47	450	500	900	350	Witness
5%	7	0.47	450	500	900	350	N5-f
10%	7	0.47	450	500	900	350	N10-f

Design mix of the prismatic specimens:

Table 8: The Mix Design of Prismatic Specimens to Estimate the Compression Strength

Nano Silica gr	Micro Silica gr	W/C	Aggregate gr	Cement gr	Design Name
0	0	0.47	990	440	Witness
5%	0	0.47	990	440	N5
10%	0	0.47	990	440	N10
20%	0	0.47	990	440	N20
30%		0.47	990	440	N30
40%	0	0.47	990	440	N40
0	10%	0.47	990	440	M10

7) Specimen Casting

The specimens are molded maximum 2 minutes and 15 seconds after mixing all of the materials. The molds are poured in 2 equal layers and each layer is compacted by bars which are compacted in corners, around pines and walls of the molds. After compaction of the last layer, the layer of the mortar with shear movement of the top part of the mold is leveled and smoothed by trowel.

Experiment Method

This test is carried out based on the "the aggregate-the ability of reaction of aggregates with alkalis by the expedited prismatic mortar method" which is produced by the ISIRI8753 (Hobbs, 1998).

Table 9: The Average Extension of Expedited Prismatic Mortar Specimens

14 days	7 days	1 day	Name of Specimens
0.204%	0.138%	0.115%	OC
0.153%	0.127%	0.110%	5N
0.102%	0.013%	0.010%	10N
0.227%	0.205%	0.186%	20N
0.330%	0.165%	0.109%	30N
0.383%	0.246%	0.150%	40N
0.092%	0.129%	0.133%	50N
0.182%	0.080%	0.028%	10M

Maintenance and Initial Reading

Each of the molds instantly after molding should get out of the molds after 24 hours and while their moisture is protected, the initial reading is done by digital caulis. It is worth saying that the initial reading and other readings should be recorded by the 0.002 accuracy. After opening the molds, should be put under water with 80±2 temperature and after basis reading, specimens that are constructed by the same aggregates should be saturated in the poly ethylene basin with the warming tool which has enough sodium hydroxide solution for 14 days. The basin is water proofed and has 80±2 temperature. Their level of solution should be constantly checked and if the length increscent percentage of specimens is less than 0.1, the reaction ability of materials is low. If the length increscent percentage of specimens is in between

0.1and 0.2, it is moderate. Ultimately, if this percentage is more than 0.2, it is high and maybe destructive.

Conclusion

By studying the results of this research it is found that:

1) The aggregate material of this study has the extension ability and accordingly they have the potential of damages caused by alkali-silica phenomenon.
2) Adding Nano silica to the mix design with the amount of 5 to 10 percents of cement weights can cause conspicuous extension of specimens.
3) The best result out of addition of Nano silica is observed at 10 percents of cement germs, because it decreases the destructive effect of alkali-silica phenomenon in prismatic specimens.
4) Addition of Nano silica with amount of 10 percents of cement weight to the mix design can decrease the length of specimens considerably.
5) With comparison of the results of the specimens which have Nano silica and micro silica with amount of 10 percents, it is shown that the Nano silica has better effect on alkali-silica reaction than micro silica.
6) The results of the compression strength in this research show that Nano silica can increase compression strengths, in a way that addition of 10 percent's of Nano silica can increase 2.7 % the compression strength of the specimens which is negligible.

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