J. Basic. Appl. Sci. Res., 1(9)1290-1294, 2011

ISSN 2090-424X
Journal of Basic and Applied Scientific Research
www.textroad.com

Investigating the Effects of Pozzolans in Improving Mechanical Properties of Concrete

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ABSTRACT

By ever-increasing of concrete structures, identifying pozzolans that improves mechanical properties of concrete is in high importance. Thus, performing wide investigational projects on different concrete constituents in recent years caused appearance of concretes which not only provides resistance, but other properties such as durability, impermeability, efficiency, and durability against factors like fire, has make basic changes on its role and application. In this paper, after a brief explanation of concrete, we have a description on history of pozzolanic materials, usage of overplus materials, such as microsilica, animal manure, etc, cause environmental pollutions. Also, chemical and physical characteristics of nanosilica and microsilica, and a definition on slag types and fly ash has been mentioned.
KEY WORDS: Pozzolans, concrete, microsilica, animal manure.

INTRODUCTION

Durability, stability, and economy, has changed the concrete to the most common construction material. Concrete is used in constructing high rise buildings, bridges, dams, roads, etc. So, recognition of concrete properties can help a lot in achieving expectable properties of concrete [2]. Durability of concrete can be defined as ability of concrete resistance against air setting, chemical attack, and abrasion, while keeping expected engineering properties by minimum mass fall in attacker environment. Ultimate durability and life expectation of concrete is affected by factors such as concrete constituents, ratio of these constituents, interaction between concrete constituents and method of concrete work and curing [2]. Generally, the more condensed concrete, the more desirable in properties. Although there is a vacant space among cement particles, these spaces would be filled and the concrete would be more condensed.

MATERIALS AND METHODS

2.1 The effect of pozzolans in concrete

One of the most important and influencing parts technicians and specialists of this major has been investing on is added materials to concrete, according to their properties and applications has been classified in large groups, such as sluices, mytics, covers, colors, etc [1, 2]. Considering the existence of corroding regions in southern parts of the country (coasts of Persian golf and Oman Sea) [3, 4] and similar conditions in northern parts of the country (edge of Caspian Sea), using of these products to prevent premature destroys and increase permanency of reinforced concrete structures can help a lot in enhancement of quality of concrete [5].

According to the regulation of executive standards of civil engineering projects, in framework of technical and executive system of civil engineering projects of country, which has obligated following standards BS 188 and ASTM 10202, using concrete complementary can be useful [6]. The first considered features in mind of constructors using concrete were efficiency and resistance of concrete. Mangat et al. [7] could increase its strength by reducing amount of mixed water, and could overcome reducing efficiency caused by lessening mixed water, by vibrating concrete by vibrator. Achieved successes of improvement of cement capabilities with help of other materials resulted in encouraging researchers and organizing researches, and testing hundreds of types of chemical and mineral materials. Gradually researchers [7, 8] recognized materials which have effect on characteristics of fresh concrete, and hardened concrete, today called "added materials". Today, in addition to expansion of using natural pozzolans and utilizing lateral products such as silica fume, fly ash, and the ash produced by burning animal manure, using minerals with less raising, such as kaolin as admixture , producing and supplying mixed cement containing added materials and types of metallic and nonmetallic fibers have been increased.

2.2 Types of pozzolan

Pozzolans are aluminosilicate materials, have acidic state, and great affinity to limestone. These materials alone do not have adhesion property but in normal temperature, their powder beside water composed with calcium hydroxide and produce calcium silicates (like cement) that have adhesion properties [8]. Natural pozzolans are produced by rapid cooling or quenching of thrown lava particles from inside the earth to the air, or flow lavas in water, and have considerable silica and non-crystals. Commercial or artificial pozzolans, some of their lateral products is known and used; not only their bothersome to origin industry have been reduced, but produce added values. Microsilica and fly ash are well-known artificial pozzolans

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(silica fume) [2, 3, 5, 8]. Blast furnace slag of iron melting is a material like cement, although they have less pozzolanic activity, they are not pozzolan.

2.3 Microsilica

Microsilica is a grey to white powder, classified as admixtures by cement properties, in practice is calculated by ratio of cement. Sometimes other names are used for microsilica, the most common one is silica fume, this name has been accepted by The American Concrete Institute (ACI) is a member-based technical organization with 20000 members worldwide. ACI as in our country it is known as microsilica, in this paper we use microsilica for this added. ACI describes microsilica as: "silica fume is a very delicate and non-crystal product, produced by silicone mooted or alley such as silicone."

Micro silica is a lateral product of producing process of ferrosilicium in electric kiln. Produced materials have high reaction and by adding a few amount of it, capabilities of concrete increases desirably [5]. For saving environment, first by installing filter and strong duster separate silica fume from exhaust gases, and prevent diffusion of it in space. Materials collected in dusters should be transferred to a suitable place and buried there to not diffuse in space by wind blow, for this reason they usually blend collected fumes with water and transfer it to prepared place by pipe.

Benefits of microsilica includes increasing of pressure resistance and traction strength, increasing abrasion resistance, increasing connection resistance by steel, heating, pozzolanic behavior of microsilica, porosity reduction and adhesion increase, and less bleeding.

We can not to use microsilica for concretes with pressure resistance up to 98 Mp, but its' presence is necessary for higher resistances. Even in producing concretes with resistance between 63 to 98 Mp, using microsilica make reaching to that resistance easier, so if there is no economical problems, microsilica generally considers as a part of high resistance concrete. Today, microsilica is more condensed and its' weight is approximately double the last weight (400-500 kg/m^3).

Table 1. Presented characteristic by some of interior distributors of microsilica

Constituents	SiO_2	Fe_2O_3	Al_2O_3	MgO	Cao	Na_2O+K_2O	Particle size	Surface area
Ferrosilica participation	85-95	0.4-2	0.5-1.7	0.1-0.9	2-2.3	1-1.9	0.2-0.3 micron	$20M_2/g$
Chemical process	93.6	0.87	1.32	0.97	0.49	1.32		$20M_2/g$

2.3.1 Physical properties of microsilica

Particle size: less than 1 µm, Voluminal density: 130-430 kg/m^3, Specific mass: 2.2, Specific surface: 15-30 m^2/g.
Picture of Portland cement particle and microsilica particles is shown in figure 1 in left and right, respectively.

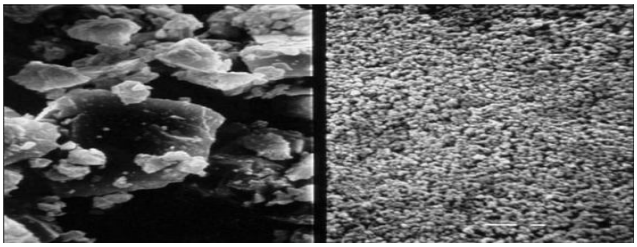

Figure 1. Portland cement particle and microsilica particles

2.4 Nanosilica

Nanoparticulars are materials which at least one of its dimensions (length, width, and thickness) is 100NM. In recent decays, because of their behavior, nanostructure materials have been considered in industrial part and in universities. Among industry, because of need for stability, strength, durability and high efficiency, construction industry is one of the important users of nanostructure materials. Non crystal nanosilica is more microlithic product than microsilica. It can be said that microsilica is a product in high range of gauge in nanometer measure; both of these materials are used in increasing function of cement material composite. It's important to mention that nanosilica particles have higher reactivity than microsilica.

At the present, the cost of microsilica in Iran is 2500-5500 Rial per kilogram, and its' cost in Europe is 0/25-0/5 Euro per kilogram, according to mentioned costs it can be said that the costs are similar in Iran and Europe, but as mentioned, in Iran nanosilica is not available, if necessary we must import it from other countries, but cost of nanosilica liquid in Europe is 0/45-0/9 Euro.

2.4.1 Physical properties of nanosilica

Nanosilica product is made of very non crystal colloid-silica particles, by less than 100 ml diameter, is available as dry powder particles or suspend in liquid solution, its' liquid is the most common kind of nanosilica solution. The other reason of high reactivity of nanosilica is fineness of nanosilica particles to microsilica.

2.5 Chemical properties of nanosilica and microsilica

Non crystal simply means microsilica and nanosilica are not crystal materials. Crystal material can not be solved in concrete and show reaction. Non crystality of microsilica particles is more than 90%, more than 99 percent of nanosilica particles are non crystal, and this difference is one of the reasons of high reactivity of nanosilica than microsilica. Presented characteristic by some of interior distributors of microsilica has shown in table 1.

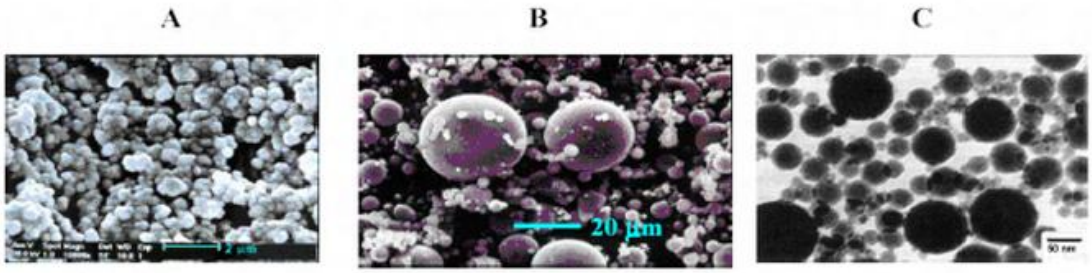

Figure 2. Microsilica (A), Fly ash (B), Nanosilica (C)

2.6 Microsilica and nanosilica reactions in concrete

Advantages gain from adding microsilica to concrete is made of two kinds of microscopic changes in concrete. One is caused by physical appearance of microsilica, the other from chemical changes in concrete made by microsilica. In this part we explain briefly these two changes.

Because reactions and function of microsilica and nanosilica in concrete by differences in their amount is similar, from this part on we pay attention to effects of microsilica in concrete, when come across a change in function of these two pozzolanic materials, in some parts of paper we mention it and investigate the changes.

2.6.1 Physical reactions

Adding microsilica or nanosilica to concrete, adds millions of tiny particles to mixture of concrete, and like microlithic fills vacant space between macrolithics. They also fill vacant space of cement particles. By creating this state, these microfillers could play an important role in improving characteristics of concrete even if microsilica and nanosilica don't show any chemical process. Size of nanosilica and microsilica particles beside other available particles in concrete is shown in table 3-2-3-1.

Table 2. Size of nanosilica and microsilica particles beside other available particles in concrete

Comparison of size of microsilica particles and other concrete constructing elements	
Nanosilica particles	1-50 nm
Microsilica particles	0.1-1 µm
Cement particle	45 µm
Sand particle	4.7 mm
Gravel particle	75 mm

2.6.2 Chemical reactions

C-S-H gel is produced in hydration process of Portland cement. This gel is the main product of cement, non-crystal calcium silicate hydrate, which have adhesion state and sticks gravels to each other. Beside this gel, about 20-25 percent of materials hydrate and produce calcium hydroxide $Ca(OH)_2$, weakest part of concrete, main damages of concrete structure is in this part. In contrast to C-S-H gel, crystals of calcium hydroxide are larger.

Due to reaction with calcium hydroxide, microsilica produces calcium silicate and aluminate hydrates, these changes help a lot to characteristics of concrete. It can be claim that 20 percent increase of microsilica is compound by pozzolanic materials. Tests show that reaction of nanosilica materials with calcium hydroxide is more rapid than microsilica. Less amount of this materials have the same pozzolanic effect of high amount of microsilica in primary ages.

2.7 Slag

Types of slag in steel and iron manufactories include: 1) blast furnace slag (BFS), 2) steel slag (includes: electric arc furnace slag (EAFS), oxygenic and basic furnace, flaming furnace)

Steel slags are used in constructing asphaltic superstructure, gravel in structuring base and subbase, gravel in producing concrete, rip rap and cabion, embankment and balasts. Because of proper density and strength, blast furnace slag can be used as gravel in concrete. Extra and damaging particles of blast furnace slag must be less than 1 percent. Properties of these gravels change according to their composition, and cooling speed. Using blast furnace slag in producing concrete improves following properties than normal concrete:

Efficiency, heat insulation, resistance against fire, alkaline environments, freezing conditions, freeze cycle and continuous melting, durability and solidity, adhesion of gravel to cement paste because of shape and tissue of slag, high handling loads capacity, suitable permanency, high rigidity, less energy to reach enough compression, proper drainage quality, less resistance in impact, high special weight, increasing use of bitumen.

2.8 Fly ash

Fly ash has been used widely in concrete during long years. Unfortunately fly ash is more changeable in either chemical and or physical properties than microsilica. Any type of fly ash function well in normal concrete has proper function in concretes with high resistance. Concrete with pressure resistance up to 70 Mp is constructed by fly ash. There are few reports on reaching to resistance up to 98 Mp in concretes with fly ash. In order to reach higher resistances, microsilica should be used by fly ash, though this was not common in the past. Generally, amount of consumed fly ash in concretes with high

resistance is about 15 percent of cement, because even products of one fly ash manufactory have considerable changes. Quality control in factory is in high importance, this includes determining special surface of beeline and chemical compounds of this material (specially Al_2O_3, SiO_2, CaO, Fe_2O_3, alkaline, sulfate, and carbon), like microsilica it's necessary controlling its crystallization rate. The most glass tissues have the fly ash, the best.

RESULTS

3 Animal manure burn ashes

By ever-increasing of concrete structures, identifying pozzolans that improves mechanical properties of concrete is in high importance. Among these, using animal manure ash, found as pulverised in rural areas, cause reduction of environmental pollution, reduction of concrete producing cost, improving pressure resistance, permanency, durability, etc. in concrete. Because of unsuitable storage, animal manure ash, mostly produce in rural areas, cause environmental and air pollution.

3.1 The effect of animal manure ash on concrete

3.1.1 Efficiency of concrete

Easily pouring, condensing fresh concrete, and resistance against detaching are called efficiency. Due to its' spherical shape and increasing cementic materials, using animal manure ash cause increasing in efficiency. Using these pozzolans as a filter and stabilizer in self-condensed concretes for stability and resistance against detaching is important.

3.1.2 Time (hardening time)

Understanding speed of cement and water reaction is important for determining hardening of concrete. Primary reaction must be slow enough to have enough time to transport and pour concrete. There is no important effect on set time of produced concrete in using animal manure ash. However, in acquiring produced concrete's resistance speed, there isn't a noticeable change with normal concretes.

3.1.3 Bleeding

Bleeding is due to subsiding solid particle (cementic material and gravel) and simultaneous upward movement of water on water. Speed of bleeding and total subsiding volume increased due to primary height unit of concrete with primary water amount, concrete height, and pressure. Due to concrete bleeding, upper layer of concrete contains watery, by adding the next layer of concrete on it, capturing this extra water creates very weak, porous, and flimsy layers of concrete between both the layers. Concrete bleeding intensifies freezing risk, especially in thin slab and superstructures. Bleeding of concrete is not necessarily detrimental, if this action leave intact and water vaporize, water cement ratio of mixture will descend and strength will increase. Using animal manure ash increases volume of cementic materials and reduces bleeding of concrete.

3.1.4 Special weight of concrete

Special weight of concrete is almost fixed and makes no special changes by using animal manure ash.

3.1.5 Curing and pressure resistance of concrete

Optimal amount of using animal manure ash is 10 percent of cementic materials weight. Generally, we can reduce amount of consumable cement to reach similar resistance by using animal manure ash up to 10 percent. Animal manure ash also can be used as a complementary for silica fume and fly ash. It is important to distinguish the effect of these added materials to each other for using animal manure ash with other multiple materials.

3.1.6 Permeability and hermetic sealing

One of the important characteristic of concrete is impermeability. Impermeability has an important role in longevity of concrete as well as protecting environmental effects. From the view point of impermeability if the concrete is in good condition, it will not decompose in injurious condition in long term even if there is no other precaution used for it. By using animal manure ash, concrete will perform in better compression. High compression causes reduction of permeability and increase hermetic sealing of concrete.

3.2 Impact strength and friction strength

Impact strength and friction strength of concrete depends on pressure resistance and type of gravel. Complementary cementic materials usually don’t have ultra-effect on these characteristics than effect on strength.

3.3 Freezing resistance and heat resistance

Well condensed concrete and adequately hydrated before exposure to freezing or heat, shows desirable resistance against freezing and heat.

3.4 Other properties of using animal manure ash

Collection and risks caused by concrete with animal manure ash reduces, and concrete resistance against sulfate's attacks increases.

4 CONCLUSION

The main conclusion of this article is that increasing of pozzolans cause reduction of permeability of concrete and condensing of improving mechanical properties of concrete, but finding optimal percentage of these materials need repeated tests. Its necessary to say that pozzolanic properties for using concretes, which discarded as wastes, not only reduces costs of preserving, transporting or carrying, and removing pollutions caused by their diffusion, but strengthening concrete structures and optimizing blending plans.

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