Journal of Civil Engineering and Environmental Technology
Print ISSN: 2349-8404; Online ISSN: 2349-879X; Volume 2, Number 5; April-June, 2015 pp. 469-473

http://www.krishisanskriti.org/jceet.html

Effect of Various Mineral Admixtures in the Properties of Concrete

Ramesh Kumar G B[1] and S. Andavan[2]

[1],[2]Saveetha School of Engineering Saveetha University, Chennai, India
E mail: [1]rameshkumargb@gmail.com, [2]andavancivil@gmail.com

Abstract—*Concrete is a composite mass made up of coarse and fine aggregates with cement as binder in presence of moisture. Although, 75% to 80% of concrete volume is made up of aggregates, the active constituent of concrete is cement properties. The performance and properties of concrete are also largely depend on the properties of cement paste. Many researchers have also reported that inclusion of mineral admixtures, particularly industrial waste by-products such as fly ash, silica fume, rice hush ash, and blast furnace slag improves properties of concrete considerably and favorably. Because of the spherical shape and small size of the glassy particles, these materials tend to fill the void space between relatively large cement grains which is otherwise occupied by water. As a result, better pore refinement and marked decrease in the volume of pores is reported. The extent of influence on concrete properties, however, depends on the type and amount of admixture used, concrete mix proportions, addition of chemical admixture and combined use of mineral admixtures, and many other factors. There is a need to Although good amount of works Therefore, to understand better about the behavior of concrete by incorporating various mineral admixtures In order to ascertain the performance of concrete in better behavior Hence, very few works have been taken up so far in respect of considering the existence of vast scope of research in this area, authors have reviewed the main purpose motive behind and marked decrease in the Despite of knowing the advantages o have some beneficial effects in conventional concrete due to inclusion of mineral admixtures. Inclusion of mineral admixtures like fly ash, silica fume, rice husk ash and ground granulated blast furnace slag etc. are reported to have better refinement of pore structure of concrete, decreased in permeability and increased chemical resistance of concrete due to their Pozzolanic action and higher packing efficiency of micro-fine mineral admixtures around the cement grains. Despite of extensive laboratory study in this regard, there improvement in durability of concrete. However, still today, there exists there is Hence, Durable concrete is one that performs satisfactorily in the working environment during its anticipated exposure conditions during service. The materials and mix proportions specified and used should be such as to maintain its integrity and, if applicable, to protect embedded metal from corrosion. One of the main characteristics influencing the durability of concrete is its permeability to the ingress of water, oxygen; carbon dioxide, chloride, sulphate and other potentially deleterious substances are discussed. Over the years, numerous studies have shown that admixtures containing silica in reactive form make them useful Pozzolanic material. The Pozzolanic materials like micro silica, fly ash, metakoline and slag etc. are often incorporated to modify the properties of concrete in its fresh and hardened states. They are viewed as replacements or substitutes for cement. Apart from these admixtures, inorganic fibrous mineral like wollastonite, which is normally occurring silicate mineral (β-CaO-SiO_2) has been used for development of high performance cement composites offering economic benefits over steel or carbo-fibres. Therefore, utilisation of mineral admixtures would lead to considerable saving in cost and energy consumption. Utilisation of increased volumes of mineral admixtures found in natural states & obtained from industrial by-products in cement and concrete will lead to conservation of energy and natural resources used in cement production.*

Keywords: *Mineral admixtures; silica fume; fly ash; properties; role in concrete.*

1. INTRODUCTION

Admixtures have long been recognized as important components of concrete used to improve its performance. The original use of admixtures in cementitious mixtures is not well documented. It is known that cement mixed with organic matter was applied as a surface coat for water resistance or tinting purposes. It would be a logical step to use such materials, which imparted desired qualities to the surface, as integral parts of the mixture. The use of natural admixtures in concrete was a logical progression. Materials used as admixtures included milk and lard by the Romans; eggs during the middle ages in Europe; polished glutinous rice paste, lacquer, tung oil, blackstrap molasses, and extracts from elm soaked in water and boiled bananas by the Chinese; and in Mesoamerica and Peru, cactus juice and latex from rubber plants. The Mayans also used bark extracts and other substances as set retarders to keep stucco workable for a long period of time [1]. Admixture is defined as a material, other than cement, water and aggregates that is used as an ingredient of concrete and is added to the batch immediately before or during mixing (ASTM C125). Additive is a material which is added at the time of grinding cement clinker at the cement factory. Mineral admixtures are finely divided solids which are added to the concrete mix in comparatively large amounts (i.e. exceeding 15% by weight of cement) mainly in order to improve the workability of the fresh concrete and its durability, and sometimes also its strength, in the hardened state (defined by ASTM C125-S8). In fly ash, silica fume, and other mineral by-products in concrete (ACI Spec. Publ. SP-79, Vol I). "Mineral admixtures are used to enhance the properties of concrete and mortar in the plastic and hardened state. These properties may be modified to increase compressive and flexural strength at all ages, decrease permeability and improve durability, inhibit corrosion, reduce shrinkage, accelerate or retard initial set, increase slump and workability, improve pumpability and finishability, increase cement efficiency, and improve the economy of the mixture. An admixture or combination of admixtures may be the only feasible means of achieving the desired results. In certain instances, the desired objectives may be best achieved by mixture changes in addition to proper admixture usage.

Mineral admixtures Permitted by is 456: 2000

- Fly ash or pulverised fuel ash (IS 3812, grade I)
- GGBS or ground granulated blast furnace slag (IS 12089)
- SF or silica fume (IS 15388: 2003)
- Metakaolin (MK)
- Rice husk ash (RHA)
- Carry sufficient lab tests when there is no Standard

2. SIGNIFICANCE

Natural pozzolans in the raw state or after thermal activation are still being used in some parts of the world, due to economic and environmental considerations many industrial by-products have become the primary source of mineral admixtures in concrete. Power plants using coal as fuel, and metallurgical furnaces producing cast iron, silicon metal, and ferrosilicon alloys are the major sources of by-products being produced at the rate of millions of tonnes every year in many countries. Dumping of these by-products into landfills and streams amounts to a waste of the material and causes serious environmental pollution. Disposal as concrete aggregate or for roadbase construction is a low-value use that does not utilize the pozzolanic and cementitious potential of these materials. With proper quality control, large amounts of many industrial by-products can be incorporated into concrete, either in the form of blended Portland cement or as mineral admixtures. Whenever a pozzolanic and/or cementitious by-product can be used as a partial replacement for portland cement in concrete, it represents significant energy and cost savings. The mechanism by which the pozzolanic reaction exercises a beneficial effect on the properties of concrete is the same irrespective of whether a Pozzolanic material is added to concrete in the form of a mineral admixture or as component of a blended portland cement. From a description of the pozzolanic reaction and properties of blended cements it is clear that the engineering benefits likely to be derived from the use of mineral admixtures in concrete include improved resistance to thermal cracking due to low heat of hydration, enhancement of ultimate strength and impermeability due to pore refinement, strong interfacial transition zone, and very high durability to sulfate attack and alkali-aggregate expansion.

A. Advantages

- Improve resistance to attack by sulphate soils and sea water.
- Lower the heat of hydration and thermal shrinkage.
- Increase the water tightness.
- Reduce the alkali-aggregate reaction.
- Improve workability, strength and durability.
- Reduce the cost of construction.
- Lower susceptibility to dissolution and leaching.

3. CLASSIFICATION

Some mineral admixtures are pozzolanic (e.g., low-calcium fly ash), some are cementitious (e.g., granulated iron blast-furnace slag), whereas others are both cementitious and pozzolanic (e.g., high-calcium fly ash). A classification of mineral admixtures according to their pozzolanic and/or cementitious characteristics according to Mehta is shown in Table I. The table also contains a description of mineralogical composition and particle characteristics as these two properties rather than the chemical composition or the source of the material determine the effect of a mineral admixture on the behaviour of concrete containing the admixture.

For the purposes of a detailed description of the important mineral admixtures given below, the materials are divided into two groups:

(i). Natural materials: Those materials that have been processed for the sole purpose of producing a pozzolan. Processing usually involves crushing, grinding, and size separation; in some cases it may also involve thermal activation.

(ii). By-product materials: Those materials that are not the primary products of the industry producing them. Industrial by-products may or may not require any processing (e.g., drying and pulverization) before use as mineral admixtures.

A. Natural pozzolanic materials

Except diatomaceous earth, all natural pozzolans are derived from volcanic rocks and minerals. During explosive volcanic eruption, quick cooling of the magma that is composed mainly of aluminosilicates results in the formation of glass or vitreous phases with a disordered structure. Due to the simultaneous evolution of dissolved gases when magma is solidifying, the solidified matter often acquires the solidified matter often acquires a porous texture and high surface area which enhances its chemical reactivity. Aluminosilicates with disordered structure are not stable on exposure to alkaline solutions. This is why volcanic glasses exhibit Pozzolanic activity with lime or Portland cement in an aqueous environment.

Example: Volcanic tuffs, Calcined clays or shales and and Diatomaceous earth.

B. By-product materials

Ashes from the combustion of coal and some crop residues such as rice hull and rice straw, silica fume from certain metallurgical operations, and granulated slag from both ferrous and nonferrous metal industries are among the industrial by-products that are suitable for use as mineral admixtures in Portland cement concrete. Countries like China, India, the United States, Russia, Germany, South Africa, and the United Kingdom, are among the biggest producers of coal fly ash which, at the current rate of production, some 500 million tonnes a year, constitutes the largest industrial waste product in the world. Norway is the principal producer of silica fume, while granulated blast-furnace slag is available in many countries. In addition to these materials, China, India, and other Asian countries have the potential for producing large amounts of rice husk ash. Example: Fly ash, blast-furnace slag, Silica fume, Rice husk ash, metakaolin and wollastonite micro fibres.

Table I: Classification, Composition, and Particle Characteristics of Mineral Admixtures for Concrete

Chemical classification	Mineralogical composition	Particle characteristics
Cementitious and pozzolanic Granulated blast-furnace slag (cementitious) High-calcium fly ash (cementitious and pozzolanic)	Mostly silicate glass containing mainly calcium, magnesium, aluminium, and silica. Crystalline compounds of melilite group may be present in small quantity. Mostly silicate glass containing mainly calcium, magnesium, aluminium, and alkalies. The small quantity of crystalline matter present generally consists of quartz and C3A; free lime and periclase may be present; CS- and C4A3S- may be present in the case of high-sulfur coals. Unburnt carbon is usually less than 2%.	Unprocessed material is of sand size and contains 10–15% moisture. Before use it is dried and ground to particles less than 45 µm (usually about 500 m2/kg Blaine). Particles have rough texture. Powder corresponding to 10–15% particles larger than 45 µm (usually 300–400 m2/kg Blaine). Most particles are solid spheres less than 20 µm in diameter. Particle surface is generally smooth but not as clean as low-calcium fly ashes.
Highly active pozzolans Condensed silica fume Rice husk ash	Consist essentially of pure silica in noncrystalline form. Consist essentially of pure silica in noncrystalline form.	Extremely fine powder consisting of solid spheres of 0.1 µm average diameter (about 20 m2/g surface area by nitrogen adsorption). Particles are generally less than 45 µm but they are highly cellular (40–60 m2/g Surface area by nitrogen adsorption).
Normal pozzolans Low-calcium fly ash Natural materials	Mostly silicate glass containing aluminium, iron, and alkalies. The small quantity of crystalline matter present generally consists of quartz, mullite, sillimanite, hematite, and magnetite. Besides aluminosilicate glass, natural pozzolans contain quartz, feldspar, and mica.	Powder corresponding to 15–30% particles larger than 45 µm (usually 200–300 m2/kg Blaine). Most particles are solid spheres with average diameter 20 µm. Cenospheres and plerospheres may be present. Particles are ground to mostly under 45 µm and have rough texture.
Weak pozzolans Slowly cooled blast- furnace slag, bottom ash, boiler slag, field burnt rice husk ash	Consist essentially of crystalline silicate materials, and only a small amount of noncrystalline matter.	The materials must be pulverized to very fine particle size in order to develop some pozzolanic activity. Ground particles are rough in texture.

4. ENHANCEMENT OF DURABILITY WITH MINERAL ADMIXTURES

Recent use of fly ash in Delhi Metro rail project has been mainly for attaining a design life of 120 years of the structure [2]. The comparative properties of hardened concrete of non-fly ash concrete and fly ash concrete reported for the project is shown in below Table2.

Krishnamoorthy has rightly pointed out that fly ash should be regarded more as a durability enhancer and void blocker than as a cement economiser (provided, it is a low calcium dry fly ash obtained from ESP hoppers and with a minimum fineness of 320 m^2/kg) [3]. The Delhi Metro project data shown in Table 2 amply illustrates the reduced permeability, water absorption and drying shrinkage in fly ash concrete [2].

Table 2: The comparative properties of hardened concrete of non-fly ash concrete and fly ash concrete

Properties	Non fly ash concrete	Fly ash concrete
Compressive strength (28d), MPa	52.09	52.15
Flexural strength (28d), MPa	5.98	7.45
Indirect tensile strength, (28d), MPa	4.20	4.60
Drying shrinkage, percent	0.042	0.040
Permeability (As per DIN-1048), mm	11.65	6.19
Water absorption, percent	1.43	1.0

The increase in flexural strength (of the order of about 25 percent), and tensile strength (of the order of about 10 percent) in fly ash concrete mix of the similar 28 days compressive strength as that of nonfly ash concrete is worth noting in Table

2. This advantage makes the fly ash concrete a worthwhile option for nuclear containment structures, which has not been tapped so far in the country. In nuclear power plants of RAPP 3 and 4 units and Kaiga, the split tensile strengths achieved were 4.08 MPa and 3.94 MPa, with even higher compressive strengths, that is, 73.5 MPa and 69.5 MPa respectively. With fly ash concretes of similar compressive strengths, higher tensile and flexural strengths can possibly be attained. The primary reason for using ground granulated blast furnace slag (GGBFS) in large quantities, in the Mumbai Sewage disposal project, was again to make concrete dense, impervious and to have an ability to resist any deterioration on account of the hazardous elements in the sewage [4].

Micro-silica concrete of different grades has been used for durability aspects in various projects in the country, which includes:

(i) Deepak Fertilisers plant to achieve high chemical resistance in the concrete used for the storage silos [5].

(ii) Construction of piers and pier caps of the second bridge across river Narmada in Baruch, Gujarat (M60 grade) [5].

(iii) 5.6 km Bandra-Worli Sea Link project in Mumbai (2, 00, 000 m^3).

(iv) For abrasion resistant M50 grade concrete (20,000 m^3 in Baglihar hydro-electric project: Exterior 1.0 m thickness on upstream of spillways crest above elevation 805 m and downstream glacis of spillway except the portion covered by the steel lining, exterior 1.0 m thickness on upstream waterside faces of piers upto 11 m height from the spillway surface in the portion not covered by steel lining and top 1.0 m thickness in the plunge pool floor [6].

(v) The rapid chloride ion permeability test (RCPT) and initial surface absorption test (ISAT) values were less than 300 coulombs and of the order of 0.016 $ml/m^2/s$ respectively, implying a fairly impermeable concrete with the use of 10 percent micro-silica in J.J. Flyover, Mumbai [7] .

5. PAVEMENT QUALITY CONCRETE WITH FLY ASH/GGBFS

A roller compacted concrete wearing course of 100 mm thickness has been constructed with zero slump concrete in a demonstration project of rural road construction on Salarpur-Dadupur road in district Gautam Budh Nagar, Uttar Pradesh [8]. Nearly 220 kg of cement and an equal amount of fly ash per cubic metre of concrete were used in the construction. Other demonstration road projects include construction of concrete roads at Chandigarh on Morinda byepass Ludhiana by PWD Punjab, in Haryana by PWD Haryana with HUDA and NCCBM support, at Raichur by Karnataka PWD with support from fly ash mission and one in Mumbai with CANMET/CIDA support [8-9]. Satander et al and Malhotra have advocated the use of blended cements in general and high volume fly ash concrete respectively in road construction [9-10]. Tiwari and Bandopadhyay have reported a laboratory study on development of pavement quality concrete with blended cements [11]. Portland slag cement (PSC) with 48 percent slag absorption and portland pozzolona cement (PPC) with about 23 percent fly ash absorption were used in development of PQC of grades M30 and M40.

6. CONCLUSIONS

The following conclusions are drawn from the above review paper:

- The utilization of by-product mineral admixtures is the best alternative for nowadays since it not only makes the concrete accomplish the proper performance but also reduce the concrete cost and environmental problems.
- The use of by-product mineral in large amount such as cement factory or ready mix concrete should be the main principal consuming by-product materials.
- Use of supplementary cementitious materials particularly, fly ash, blast furnace slag and microsilica have been adopted in prestigious projects in the country, with an aim to achieve higher strengths and better durability.
- The road sector in the country is likely to use cement concrete in a big way in coming years. Demonstration projects and laboratory studies have indicated good performance.

REFERENCES

[1] Chemical admixtures for concrete; ACI Education bulletin E4-03, pp. E4-2.

[2] Agarwal, R., Gupta, A.K. and Garg, R. High performance fly ash mixed concrete in underground construction of Delhi Metro, Proceedings of the third International conference on Fly ash utilisation and disposal, February 19-21, 2003, CBIP, New Delhi, pp. IV-1- IV-15.

[3] Krishnamoorthy, S. Some basic truths of concrete, ICI Journal, January-March 2002, p. 10.

[4] Haridas, G.R. Mumbai sewage disposal project-A new experiment, The Indian Concrete Journal, June 1999, Vol 73, No 6, pp. 354- 362.

[5] Lewis, Robert and Hasbi, S.A. Use of silica fume concrete: selective case studies, The IndianConcrete Journal, October 2001, Vol 75, No 10, pp. 645-652.

[6] Lazaric, Boris and Pandita, N.K. Silica fume based high performance concrete for hydraulic structures in Baglihar hydroelectric project, Proceedings of the workshop on use of silica fume based high performance concrete in hydraulic structures, ISCMS, CSMRS, New Delhi, pp. 4-8.

[7] Saini, Sunil, Dhuri, S.S., Kanhere, D.K. and Momin, S.S. High performance concrete for an urban viaduct in Mumbai, The Indian Concrete Journal, October 2001, Vol 75, No 10, pp 634-640.

[8] Vittal, Guru, U.K., Mathur, S., Sengupta, J.B. and Swami, R.K. A case study on rural road construction using fly ash, Proceedings of the 3rd international conference-fly ash utilisation & disposal, February 19-21, 2003, New Delhi, pp. VI- 47-51.

[9] Kumar, Satander, Sikdar, P. K. and Sood, V. K. Choice of blended cements and fly ash for costeffective and durable concrete roads, Proceedings of the 3rd international conference on fly ash utilisation and disposal, February19-21, 2003, New Delhi, pp. VI-103-VI-111.

[10] Malhotra, V.M. High performance HVFA concrete : A solution to the infrastructural needs of India, The Indian Concrete Journal, February 2002, pp. 103-107.

[11] Tiwari, A. K. and Bandopadhyay, P. Pavement quality concrete using blended cements, The Indian Concrete Journal, February 2002, Vol 76, No 2, pp. 117-120.