JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

Selection of Suitable Supplementary Cementing Materials (SCM) Based on Source and Availability for Concrete

Ashish A. Vilankar[1], Dr. (Mrs) Geetha K Jayaraj[2]

[1]PG Student, Department of Civil Engineering, Shivajirao S. Jondhle College of Engineering and Technology, Asangaon

[2]Principal, Shivajirao S. Jondhle College of Engineering and Technology, Asangaon

Abstract

Concrete is a material used in construction activities. It is a material which has a high compressive strength but a low tensile strength. Concrete is made by mixing materials such as cement, water, aggregate, admixtures, fibers, polymers, reinforcements etc. in various proportions so as to obtain different grades of concrete. Cement is most important material of the concrete which is produced by natural raw material like silica and lime. Over consumption of lime may lead to scarcity of lime required for production of cement. The focus of all researchers working is on construction related research work on cementitious waste material and use of it in high performance concrete. The rapid production of cement made impact on two big environmental problems for which civil engineering solutions need to be found out and they are as follows:

- The emission of Carbon dioxide (CO2) in the production process of the cement.
- Problem related to consumption of lime is the second environmental issue.

There arevariouswaste materialswhichare totally wastefor theindustries like groundgranulatedblast furnace slag which is obtained from iron industries and fly ash which is obtained from coal industries. As these products have cementitious properties which means that chemical composition of waste material resembles with the chemical composition of cement. Now a days there is a heavy load on the natural resources like lime for the production of cement. In the last decade, the use of these supplementary cementing materials has become an important part of high strength and high-performance concrete mix design. These can be natural materials, by-products or industrial wastes. Some of the commonly used supplementary cementing materials in addition to Flyash, Ground Granulated Blast Furnace Slag are Micro silica, Metakaolin, Rice Husk Ash, Ultrafine Flyash and Ultrafine slag. This paper presents an overview comparison of all the supplementary cementing materials(SCM) basedon their role and applicationin their respective categoriesfor various grades of concretethereby selectinga suitable SCM based on their source and availability.

Keywords: Flyash, Ground Granulated Blast Furnace Slag, Micro silica, Metakaolin, Rice Husk Ash, Ultrafine Flyash and Ultrafine slag (Alcofine).

Introduction

The most commonly used mineral admixture in the concrete industry is pozzolan. A "pozzolan is a siliceous and aluminousmaterial, which in itself possesses less or no cementingproperty, but will be in a finely divided form and in the presence of moisture it will chemically react with calcium hydroxide at ordinary temperature to form compounds possessing cementitious properties" [5]. Most common examples of pozzolanic materials are volcanic ash, pumice, burnt clay and fly ash [5]. The silica in a pozzolana has to be amorphous, or glassy, to be reactive. Fly ash (FA) from a coal-fired power station is a pozzolana that results in low- permeability concrete, which is more durable and able to resist the ingressof deleterious chemicals [3]. There are two types of pozzolan, namely natural pozzolan and man- made pozzolan [3]. Natural pozzolans are of volcanic origin such as pumicites, perlite, and Karoline. Man-made pozzolans generally include industrial by-products such as fly ash, blast furnace slag, and silica fume[3].

To further simplify the SCM's they have been classified into two categories namely:

Category 1: This category includes those SCM's which can be used all across the various types of concrete namely plain cement concrete (PCC), reinforced cement concrete (RCC) both low grade and high-performance concrete. These categories include SCM's such as Flyash (FA) and Ground Granulated Blast Furnace Slag (GGBFS).

Category 2: This category includes those SCM's which can be used only in high performance reinforced cement concrete. These category includes SCM's such as Silica Fume (SF) , Rice Husk Ash (RHA), Metakaolin (MK), Ultrafine Flyash (UFFA) and Ultrafine slag (UFS).

The above two categories are discussed in brief as follows.

SCM-Category 01: SCM's to be used for all grades concrete:

Fly Ash (FA) [3]:

Fly ash is a by-product of the combustion of coal in thermal power plants, which is capable of reacting with $Ca(OH)_2$ at room temperature. The pozzolanic reactivity of fly ash depends on the presence of SiO2 and $Al2O_3$ in the amorphous form. Fly ashes that comply with ASTM C618 for mineral admixtures in reinforced cement concrete come in two classes: Class C is produced from burning sub bituminous coal and has initial strengthgain, while Class F is produced from burning bituminous coal and has higher ultimate strength. In combination with portland cement, Class C fly ash can be used as a cement replacement, ranging from 25%-35% of the mass of cementitious material. In combinationwithportland cement, Class F fly ash can be used as a cement replacement ranging from 15%-25% of the mass of cementitious material. They can appear in shapes such as spherical, rounded, irregular and angular. Fly ash is generally half the cost of cement. In addition to its economical benefits, the use of fly ash reduces permeability, bleeding, water demand and the heat of hydration. It also improves the workability,despite slow gain in strength development.

Ground Granulated Blast Furnace Slag (GGBFS) [5]:

Slags are residues from metallurgical processes, either from production of metals from ore or refinement of impure metals. The iron ore isput intothe furnacewith coke and limestone. The slag is formed at a temperature of 1300-1600^{0}C as a liquid layer floating on the top of liquid iron. It is then collected and cooled. The speed of coolingaffectsthe propertiesof the slag. If allowed to cool slowly, it crystallizes to give a material having virtually no cementing materials. If cooled sufficiently rapidly to below 800^{0}C, it forms a glass which is latent hydraulic cement. This substance is then ground into a very fine powder with a minimum of 80 percent less than 45 microns in size which is known as Ground Granulated Blast Furnace Slag (GGBFS). GGBFS has been used for many years as a supplementary cementitious material in reinforced cement concrete, either as a mineral admixture or as a component of blended cement.

SCM-Category 2: SCM's to be used from M50 and above grade of concrete:

Silica Fume (SF) [1]:

Silica fume is a by-product resulting from the reduction of high purity quartz along with coal and wood chips in an electric arc furnaceduring the productionof silicon metal or ferrosilicon alloys. The silica fume, which condenses from the gases escaping from the furnaces, has a very high content of amorphous silicon dioxide and consistsofveryfinespherical particles. Whenthesilicon content reaches 98%, the product is called silicon metal rather than ferrosilicon. As the silicon content increases in the alloy, the SiO_2 content will increase in the silica fume. Limited applications have been made using silica fume from production of 50% ferrosilicon alloys. Most silicafumes range from light to dark grey in colour. As SiO_2 is colorless, the color is determined by the non-silica components, which includes carbon and iron oxide. In general, the higher the carbon content, the darker is the colour of the silica fumes. The carbon content of silica fume is affected by many factors such as wood chip composition, wood chip use versus coal use, furnace temperature, furnaceexhaust temperature, and the type of metal alloy being produced. The degree of compaction may also affect the colour. The average diameter of silica fume particles are 0.1 μm and their specific surface area is about 20000 m^2/kg, as compared to 250 to 450 m^2/kg for an ordinary portland cement or a fly ash. Chemical composition of Silica Fume varies depending on the nature of the manufacturing process from which the SF is collected. The main constituent material in Silica Fume is silica (SiO_2) which is normally over 90%.

Metakaolin (MK) [7]:

The raw material used in the manufacturingof metakaoliniskaolin clay which is a fine white clay mineral that has been traditionallyused in the manufactureof porcelain. It is thought that the term kaolin is derived from the Chinese Kaolin, which translates loosely to white hill and has been related to the name of a mountain in China. Kaolinite is the mineralogical term that is applicable to kaolin clays. Metakaolin when used as a partial replacement for cement in concrete, it reacts with $Ca(OH)_2$ resulting in additional C-S-H gel which leads to increased strength. Metakaolin is produced by thermal activation of kaolin clay. To obtain an adequate thermal activation, the temperature range should be established between 600 to 750ºC. Chemical formula of Metakaolin is Al2O3·2SiO2·2H2O. The chemical reaction is given as Cement + Water = C-S-H gel + Ca $(OH)_2$ Ca $(OH)_2$ + Metakaolin = C-S-H gel.

Rice Husk Ash (RHA) [2]:

Rice husk ash is produced by burning the rice paddy husks. It is a by-product of rice milling industry. Controlled burning of rice husks between 500^0Cand 800^0C produces non-crystalline amorphous RHA. RHA is grey in color. The particles of RHA are generallycellular structure with a high surfacefineness. They have 90% to 95% amorphous silica. Due to high silica content, RHA possesses excellent pozzolanic activity. The physical properties of RHA largely depend on incinerating conditions. The partial burning of rice husks produces black RHA whereas the complete burning results in either white or grey RHA. The burning condition also affects the relative density of RHA. The relative density of grey RHA obtained from complete burning is generally 2.05 to 2.11. The RHA particles are mostly in the size range of 4 to 75 μm. The majority of the particles pass 45-μm (No. 325) sieve, which is larger than that of silica fume. However, unlike silica fume, the RHA particles are porous and possess a honeycomb microstructure. Therefore, the specificsurface area of RHA is extremely high. Then specific surface area of silica fume is typically 20 m^2/g whereas that of non-crystalline RHA can be in the range of 50 to 100 m^2/g.

Ultrafine Slag(UFS) [4]:

Ultrafine Slag is a new generation, micro fine material of particle size and is much finer than other hydraulic materials like cement, fly ash, silica etc. being manufactured in India under the brand name of Alcofine. Alcofine has unique characteristics to enhance "Performance of concrete" in fresh and hardened stages due to its optimized particle size distribution. There are two types of Alcofine: -

- **Alcofine 1203:** It is an alcofine with low calcium silicate. Alcofine 1200series is of 1201, 1202, 1203 which represents fine, micro fine, ultrafine particle size respectively. Alcofine 1203 is a slag based SCM having ultra-fineness with optimized particle size distribution. Alcofine 1203 can provide reduced water demand even up to 70% replacement level as per requirement of concrete performance.
- **Alcofine 1101:** It is an alcofine with high calcium silicate. It is a micro-finer cementitious grouting material for soil stabilization and rock anchoring. The performance of alcofine is superior to all other admixtures used in India.

Ultrafine Fly Ash(UFFA) [6]:

The Ultrafine Fly Ash is manufactured by a proprietary separation system that includes selective air classification. The commercially available product typically has a mean particle diameter of about 3 micrometers, with over 90% of the material (by volume) having a particle diameter less than 7 micrometers (as measure by a laser interferometer). This is significantly finer than typical FA demonstrated.

Category 01:

Fig 01: Flyash

Fig 02: Ground Granulated Blast Furnace Slag

Category 02:

Fig 03: Silica Fumes

Fig 04: Metakaolin

Fig 05: Rice Husk Ash

Fig 06: Ultrafine Slag

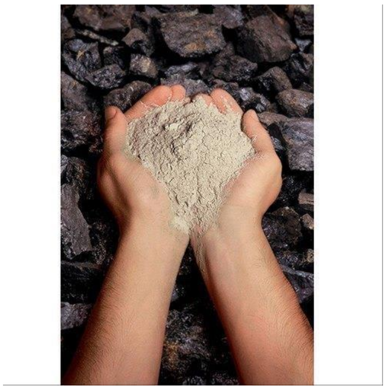

Fig 07: Ultrafine FlyAsh

Literature review

Ajibola Tijani et. al (2015) [1] discussed the results of an experimental research work on high performance concrete and determined the optimum addition of micro-silica required to achieve better strength and durability in high performance recycled aggregate concrete.

Alireza Naji Givi et. al (2010)[2] presented an overview of the work carried out on the use of RHA as partial replacement of cement in mortar and concrete.

American Concrete Institute (2002) [3] gave an overview of the origin and properties of Fly ash, its effect on the properties of portland-cement concrete, and the proper selection and use of fly ash in the production of portland-cement concrete and concrete products.

Ansari U.S et. al (2015) [4] carried out the study in which cement was partially replaced by alccofine and Fly ash for M70 grade of concrete. The compressive strength of concrete of OPC concrete and with alccofine and fly ash was compared.

Kalappa M Sutar et. al (2015) [5] carried out the work to investigate concrete mixes with GGBS substitution based on total cement weight in the range of 15% to 60% by weight.

Karthik H. Obla et. al (2003) [6] discussed the fresh and hardened properties of concrete made with an Ultra-Fine Fly Ash (UFFA) produced by air classification. Durability testing for chloride diffusivity, rapid chloride permeability, alkali-silica reaction (ASR), and sulfate attack was also conducted.

M. Narmatha et.al (2016) [7] reviewed the usage of Metakaolin as a supplementary cementitious material for high performance concrete.

P. Muralinathan et.al (2018) [8] has carried out the experiment on High Strength concrete (HSC) by replacing cement with Metakaolin for varying percentages. Metakaolin blended with concrete is exposed to elevated temperatures and its mechanical properties were evaluated.

Quaid Johar Bhattiwala and Kuldeep Dabhekar (2016) [9] studied the effect of concrete with various replacement of GGBS, and mainly focused on the compressive strength and flexural strength of concrete.

Sheikibrahim et.al (2018) [10] focused on the strength of the concrete by determining the compressive strength and tensile strength of the concrete by various replacement of Flyash and GGBS.

Comparison

It is very important to understand the various parameters of the SCM's which have been discussed, irrespective of their technical properties since all the SCM's more or less qualify on the basis of their technical properties, but lack in other parameters which most of us ignore which affect the concreting activity in most aspects, thereby having an impact on the overall progress of the construction project. In this, a comparison has been made among various SCM's irrespective of their categories based on the various parameters and is stated below:

- Grade of concretefor which the particular SCM has to be used.
- % Replacement by weight of Ordinary Portland Cement in concrete.
- Cost per kg. of that particular SCM
- Primary Sourcing of that particular SCM indicating exactly from which source where it is being generated.
- Availability of that particular SCM throughout theconcreting activity.
- Consistency in quality of the SCM throughout the concreting activity

Table 01: Comparison of SCM's based on various parameters.

Grade of Concrete	SCM's	% Replacement of OPC	Cost Rs./kg	Source	Availability and Quality consistency
All grades from M5	Flyash	15-40	@1.20/- to 2.50/-	Thermal power stations	Available and consistent in quality
All grades from M5	Ground Granulated Blast Furnace Slag	25-70	@3.25/- to 4.00/-	Steel manufacturing industries	Not available everywhere but consistent in quality
From M50 and above	Silica Fume	5-10	@18.00/ - to 28.00/-	Silicon and ferro-silicon production industries	Available and consistent in quality
From M50 and above	Metakaolin	5-10	@18.00/ - to 21.00/-	Sources containing clay mineral kaolinite such as paper sludge waste, kaolinite deposits, etc.	Available and varies in consistency
From M50 and above	Rice Husk Ash	5-10	@8.00/- to 10.00/-	Rice milling industries	Not available everywhere and varies in consistency
From M50 and above	Ultrafine Flyash	5-10	@11.00/ - to 13.00/-	Thermal power stations	Not available everywhere but consistent in quality with certain limitations
From M50 and above	Ultrafine Slag	5-10	@15.00/ - to 21.00/-	Steel manufacturing industries	Not available everywhere but consistent in quality with certain limitations

Conclusion

In this paper, SCM's namely Fly Ash (FA), Ground Granulated Blast Furnace Slag (GGBFS), Micro silica (SF), Metakaolin (MK), Rice Husk Ash (RHA), Ultrafine Flyash (UFFA) and Ultrafine Slag (UFS) have been discussed in detail based on their role in concrete in addition to their percentage replacement in concrete, cost per kg, sourcing, availabilityand consistency in quality.

From the above discussions, 3 factors namely sourcing, availability and consistency in quality have been emphasized for the following reasons in order to checking the most suitable SCM's in concrete:

- Sourcing: Every region shouldhave multiple sources to cater with their concrete requirement.
- Availability: Particular SCM should be available at any point of time to execute the concrete activity in order to save time and money.
- Consistency in quality: SCM selected from the approved source and quality should remain consistent throughout without anyvariations.

It is concluded that as on date Fly Ash (Category1) and Silica Fumes (Category 2) being the preferred SCM's followed by Ground Granulated Blast Furnace Slag (Category 1) are the most suitable SCM's based on their sourcing, availabilityand consistency in quality.

References

1 Ajibola Tijani et. al (2015), “Optimum use of microsilica in high performance concrete”, International Journal of Civil and Structural Engineering – IJCSE Volume 2 : Issue 2 , [ISSN : 2372-3971], University of Birmingham United Kingdom.

2 Alireza Naji Givi, Suraya Abdul Rashid et. al (2010), “Contribution of Rice Husk Ash to the Properties of Mortar and Concrete:A Review”, Journal of American Science 2010;6(3), Institute of Advanced Technology, Universiti Putra Malaysia, Malaysia.

3 American Concrete Institute (2002), “Use of Fly Ash in Concrete”, ACI 232.2R-96- Reapproved 2002.

4 Ansari U.S et. al (2015), “High Performance Concrete with Partial Replacement of Cement by ALCCOFINE & Fly Ash”, Indian Research Transaction Vol. 5, No.2 , EISSN: 2250-0804., SND College of Engineering and Research Centre,Yaola Dist-Nashik, Maharashtra, India.

5 Kalappa M Sutar et. al (2015), “Experimental Studies on Pozzolanic Action of GGBS and Strength Properties of GGBS Concrete”, IJIRST –International Journal for Innovative Research in Science & Technology| Volume 1 | Issue 12 | May 2015 ISSN (online): 2349- 6010, Shetty Institute of Technology,Kalaburgi.

6 Karthik H. Obla et. al (2003), “Properties of Concrete Containing Ultra-Fine Fly Ash”, ACI Materials Journal, V. 100, No.5.

7 M.Narmatha et. al (2016), “Metakaolin –The Best Material for Replacement of Cement in Concrete”, IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 13, Issue 4 Ver. I (Jul. - Aug. 2016), PP 66-71¸Dr.Mgr Educational Research Institute University, Chennai.

8 P.Muralinathan1 et.al(2018),“Study Of High Strength Concrete Using Metakaolin At Elevated Temperatures”, International Journal of Pure and Applied Mathematics Volume 119 No. 14 2018, 1267-1273, ISSN: 1314-3395,SRMIST, Chennai, TN, India.

9 Quaid Johar Bhattiwala and Kuldeep Dabhekar (2016), “Effect of Cementitious Waste Material (GGBS) on concrete as a Replacement in Cement”, IJSTE - International Journal of Science Technology & Engineering | Volume 2 | Issue 11 | ISSN: 2349-784X, G. H. Raisoni College of Engg, Nagpur.

10 Sheikibrahim k1 et.al(2018), “Ground Granulated Blast Furnace Slag (GGBS or GGBFS) And Flyash In Concrete”, International Research Journal of Engineeringand Technology (IRJET) e-ISSN: 2395-0056 Volume: 05 Issue: 04