Bulletin No.3

# Developments in Ultrafine Cementitious Materials



## In Quest of Quality Concrete

## President's Message

Ready Mix Concrete Manufacturer's Association (RMCMA) is pleased to publish the new issue of its Bulletin "Developments in Ultrafine Cementitious Materials". The issue highlights that the results obtained from ultrafine materials such as UFFA, UFS, metakaolin and rice husk ash can be used as a viable substitute for silica fume. If the advantages of these materials are exploited in the concrete mix design, the initial rate of strength development may be the same or similar to those of silica fume mixes. At later stages, however, the pozzolanic activity of these materials leads to higher compressive strength values and enhanced durability. The use of UFFA and UFS, which are recent innovations, as an alternative to silica fume can be effective in enhancing the properties of concrete, both in its fresh and hardened state. The UFFA and UFS are also cost effective as compared to silica fume, metakaolin and RHA. UFFA and UFS offer exciting opportunities to the design of high performance concrete. With their unique properties, there are other additional applications that will certainly benefit the use of these materials, to name the few are: Specialist Grouts, Precast Concrete, Flooring made of Self-Compacting Concrete (SCC), etc. RMCMA is glad to inform that it's CTI Training Programs which were initiated to upgrade the knowledge of RMC professionals and their customers will also be playing a greater role in government departments including their contractors and quality professionals. Municipal Corporation of Greater Mumbai has agreed to hold training programs for their engineers and contractors under the aegis of RMCMA to upgrade their technical knowledge especially in the field of quality concrete. We welcome and thank this initiative of MCGM which will pave the way for knowledge sharing with other Government Departments in the field of Concrete and Construction practices. We hope this bulletin will be informative and useful for our readers.

Ramesh Joshi
(President, RMCMA)

## INTRODUCTION:

The ultrafine cementitious materials with particle size in the range of 3 to 5 micron and below have become indispensable part of high strength and high performance concrete. These materials in concrete improves durability to thermal cracking, durability to chemical attack, impermeability and in some cases workability and strength of concrete at early and later ages. Internationally silica fume, metakaolin and rice husk ash have been used as ultrafine materials but recently Indian innovation has added two more materials viz. ultrafine slag and ultrafine fly ash in this category. In this article the ultrafine materials are discussed with special emphasis on Ultrafine Slag (UFS) and Ultrafine Fly Ash (UFFA) with respect to their advantages in concrete production and performance.

## Choice of Ultrafine Materials:

The following Ultrafine materials are available in India for use in concrete.

a) Silica fume
b) Metakaolin
c) Rice husk ash
d) Ultrafine slag
e) Ultrafine fly ash

Each material is derived from different source but they are being used for the same purpose to improve impermeability, strength and performance of concrete. These materials are briefly described in the succeeding paragraphs.

## Silica Fume:

Silica fume, also referred to as microsilica or condensed silica fume, is another material that is used as an artificial pozzolanic admixture. Silica fume is very fine pozzolanic material composed of ultrafine, amorphous glassy sphere (average diameter, 0.10 to 0.15 micron) of silicon dioxide ($SiO_2$). In the production of silicon and ferro-silicon alloys by reducing of silica with carbon in an electric furnace, some SiO vapour is formed. This by-product oxidises in the vapour phase on contact with air and the resulting fume is condensed to fill a very fine silicon powder popularly called silica fume. Quality varies with source and better quality should have silica content 90% - 95%. It is further processed to remove impurities and to control particle size. Condensed silica fume is essentially silicon dioxide (more than 90%) in non-crystalline form. Since it is an airborne material like fly ash, it has spherical shape. It is extremely fine with particle size less than 1 micron and with an average diameter of about 0.1 micron, about 100 times smaller than average cement particles. Silica fume has specific surface area of about 20,000 $m^2$/kg, as against 280 to 300 $m^2$/kg in case of OPC. Silica fume is covered under IS 15388: 2003. ASTM C 1240-03, EN 132 63 and CAN/CSA-A 23.5-98. As per Indian Standard silica fume shall confirm to the chemical and physical characteristics as per Table-1 and Table-2.

### Table 1.
### Chemical Requirement as per IS 15388: 2003

| *Sr No. (1)* | *Characteristic (2)* | *Requirements (3)* | *Test Method (4)* |
|---|---|---|---|
| I. | $SiO_2$, percent by mass Min | 85.0 | IS 1727 |
| ii. | Moisture content percent by mass, Max | 3.0 | |
| iii. | Loss on ignition, percent by mass, Max | 4.0 | IS 1727 |
| iv. | Alkalies as $Na_2O$, percent Max | 1.5 | |

### Table 2.
### Physical Requirements as per 1S I5388: 2003

| *Sr No. (1)* | *Characteristic (2)* | *Requirements (3)* | *Test Method (4)* |
|---|---|---|---|
| I. | Specific surface, $m^2$ /g, Min | 15 | |
| ii. | Oversize percent retained on 45 micron IS sieve Max | 10 | 1727 |
| iii. | Oversize percent retained on 45 micron IS sieve, variation from average percent Max | 5 | 1727 |
| iv. | Compressive strength at 7 days as percent of control sample, Min | 85 | 1727 |

Silica fume as an admixture has opened up a new chapter in the advancement of concrete technology. The use of silica fume in conjunction with high range water reducing superplasticizers has been the backbone of modern High Strength and High Performance Concrete. It may be mentioned that silica fume in itself does not contribute to the strength dramatically though it does contribute to the strength property by being very fine pozzolanic material and also creating dense packing and pore filler of cement paste. However, the high strength of high performance concrete containing silica fume is attributable to large degree to the reduction in water content which has become possible with the high dose of superplasticizer. The dense packing of cement paste, refinement of pore structure and strong bond between aggregates and cement paste contribute together to the high strength of concrete.

Though silica fume is highly pozzolanic, but on the other hand it creates problems of handling and increases the water demand and consequent loss of workability. Therefore selection of compatible superplasticizer, its optimum dose and uniform dispersion of silica fume while mixing are critical in the use of silica fume based concretes. The mandatory chemical and physical requirements of silica fume as per ASTM, EN and CAN/CSA standards are given in Table – 3;

The high reactivity of silica fume leads to an increase in early heat of hydration, although as a replacement for Portland cement, silica fume progressively reduces total heat liberation as levels increase to about 10%. Incorporation of silica fume can increase concrete strength by a factor of around 2. But the principal practical benefit is reduced permeability and hence improved durability. The reduction in permeability is mainly due to acceleration in the early hydration of alite combined with the high Pozzolanic reactivity of silica which accelerates the consumption of Portlandite and the formation of C-S-H. Total porosity does not appear to be reduced significantly, but as observed with fly ash the pore size distribution is modified by an increase in the proportion of fine pores in the C-S-H gel. Some larger but unconnected pores are formed where Portlandite crystals have dissolved and reacted with the silica. The densification of the transition zone at the paste aggregate interface can contribute to the reduction of permeability of the concrete by a factor of 100.

### Table 3. Mandatory Requirements of Silica Fume

| Mandatory Chemical And Physical Requirements | ASTM C1240 - 03 | | EN 13263 | | CAN/CSA A23.5 - 98 | |
|---|---|---|---|---|---|---|
| | Spec. | Frequency | Spec. | Frequency | Spec. | Frequency |
| $SiO_2$(%) | > 85.0 | 400 MT | > 85 | weekly | > 85 | 500 MT |
| $SO_3$(%) | | | < 2,0 | weekly | < 1, 0 | 1000 MT |
| Cl(%) | | | < 0,3 | weekly | | |
| FreeCaO(%) | | | < 1,0 | weekly | | |
| Free Si (%) | | | < 0,4 | monthly | | |
| Alkalies (as equivalent $Na_2O$, %) | Report | 400 MT | | | | |
| Moisture(%) | < 3,0 | 400 MT | | | | |
| Loss on ignition, LOI (%) | < 6,0 | 400 MT | < 4,0 | weekly | < 6,0 | 500 MT |
| Specific surface(BET - $m^2$/gram) | > 15 | 3200 MT/ 3months | >15 & < 35 | monthly | | |
| Bulk density (kg/$m^3$)- undensified | Report | 400 MT | | | | |
| Pozz. Activity Index (%)- 7 days accelerated curing | > 105 | 3200 MT/ 3months | | | | |
| Pozz. Activity Index (%)- 28 days normal curing | | | > 100 | monthly | | |
| Retained on 45 micronsieve (%) | < 10 | 400 MT | | | < 10 | 100 MT |
| Variation from avg. retained on 45 micron (%-points) | < 5 | avg. of last 10 tests | | | | |
| Density (kg/$m^3$) | Report | 400 MT | | | | |
| Autoclave expansion or contraction (%) | | | | | < 0,2 | 1000 MT |
| Foaming | | | | | No foam | 1000 MT |

## Metakaolin:

Metakaolin is not a by-product like silica fume but a manufactured product. It is obtained by the calcination of pure or refined Kaolinite clay between a temperature 700°C to 800°C. It is high quality pozzolanic material which is blended with cement mainly to improve the durability of concrete. When used with concrete, it will fill the void space between cement particles resulting in a more impermeable concrete.

Metakaolin is effective in increasing strength, reducing sulphate and chloride attack, and improving air-void network. Pozzolanic reactions change the microstructure of concrete and chemistry of hydration products by consuming the released calcium hydroxide (CH) and production of additional calcium silicate hydrate (C-S-H) resulting in an increased strength, reduced porosity and hence improved durability. Metakaolin looks to be a promising supplementary cementitious material for high performance concrete, possibly due to lower cost and easy availability. The substitution proportion of metakaolin ranges between 8% to 10% of the weight of cement. Metakaolin is basically a high reactive pozzolan and differs from cement in physical and chemical properties. A comparison of cement and metakaolin is provided in Table-4.

### Table 4. Comparison of Metakaolin and Cement

| Sr. No. (1) | Chemical Composition (2) | Cement % (3) | Metakaolin% (4) |
|---|---|---|---|
| 1 | Silica ($SiO_2$) | 34 | 54.3 |
| 2 | Alumina $Al_2O_3$ | 5.5 | 38.3 |
| 3 | Calcium oxide CaO | 63 | 0.39 |
| 4 | Ferric oxide Calcium oxide ($Fe_2O_3$) | 4.4 | 4.28 |
| 5 | Magnesium oxide (MgO) | 1.26 | 0.08 |
| 6 | Potassium oxide ($K_2O$) | 0.48 | 0.50 |
| 7 | Sulphuric anhydride ($SO_4$) | 1.92 | 0.22 |
| 8 | LOI | 1.3 | 0.68 |
| 9 | Specific gravity | 3.15 | 2.5 |
| 10 | Physical Form | Powder | Fine Powder |
| 11 | Colour | Grey | Off White |

Metakaolin offers better workability than silica fume. The increase in strength is similar to S.F modified concrete. The incorporation of metakaolin in concrete can reduce the drying shrinkage and restrained shrinkage cracking width. The silica fume concrete does better in chloride diffusion rate than metakaolin based concrete. The optimum replacement level of metakaolin as percentage of weight of cement is found between 7.5% to 10%. The inclusion of metakaolin results in faster early strength but later date strength may not differ much compared to control concrete.

The specifications of metakaolin have been issued by BIS under IS: 16354-2015. Chemical and Physical properties of Metakaolin are given in Table – 5 and Table – 6 respectively.

### Table - 5.
### Chemical Requirements as per IS: 16354 – 2015

| Sr. No. (1) | Constituent / Characteristic (2) | Requirements (3) | Methods of Test, Ref to(4) |
|---|---|---|---|
| (I) | $SiO_2+Al_2O_3$, percent by mass, Min | 94.0 | IS: 1727 |
| (ii) | $SiO_2/AL_2O_3$, percent by mass, Min | 1.15 | IS: 1727 |
| (iii) | $Fe_2O_3$ + $T_iO_2$, percent by mass, Max | 3.0 | IS: 1727 |
| (iv) | $Al_2O_3$ percent by mass, Min | 40.0 | IS: 1727 |
| (v) | Moisture content, percent by mass, Max | 3.0 | |
| (vi) | Loss on ignition percent by mass, Max | 2.0 | IS: 1727 |
| (vii) | Alkalies as $Na_2O$ equivalent percent, Max | 1.5 | |
| (viii) | Pozzolanicity by modified Chapelle test, mg CaO pergmK, Min | 800 | Annex A of IS: 16354 - 2015 |

### Table - 6.
### Physical Requirements as per IS: 16354 – 2015

| Sr. No. (1) | Characteristic (2) | Requirements (3) | Methods of Test, Ref to(4) |
|---|---|---|---|
| (I) | Specific surface by BET method, $m^2/kg$, Min | 9000 | IS: 11578 |
| (ii) | Oversize percent retained on 45 micron IS sieve (wet sieving), Max | 1.5 | IS: 1727 |
| (iii) | Compressive strength at 7 days as percent of control sample, Min | 100.0 | IS: 1727 |

The high reactive metakaolin is having a potential to compete with silica fume giving early high strength and low permeability to concrete.

### Rice Husk Ash:

Rice husk are the shells produced during the de-husking operation of paddy rice. Each ton of paddy rice produces about 200kg of husks, which on combustion yield approximately 40kg of ash. The ash formed during open field burring or uncontrolled combustion in a furnace generally contains large proportion of non-reactive silica minerals which are insoluble. On the other hand a highly pozzolanic ash can be produced by controlled combustion at 550°C composition of RHA is given in Table-7.

### Table - 7:
### Chemical Composition of RHA

| Element | Requirements |
|---|---|
| SiO2 (Amorphous Silica) | 62.5 to 97.6% |
| $Fe_2O_3$ | 0.54% |
| $K_2O$ | 0.1 – 2.54% |
| CaO | 0.1 – 1.31% |
| MgO | 0.01 – 1.96% |
| $Na_2O$ | 0.01 – 1.58% |
| $P_2O_3$ | 0.01 – 2.69% |
| $SO_3$ | 0.1 – 1.23% |
| Carbon | 2.71 – 6.42% |

RHA essentially consists of amorphous silica (90% to 95%) carbon (4% to 5%) and $K_2O$ about 2%. The specific surface of RHA ranges between 40 to 60$m^2/g$ surface area by nitrogen adsorption. Effect of RHA on concrete is similar to micro silica. It gives high early strength and high impermeability to hardened concrete. It is also used in small doses of 6 to 12% as cement replacement.

India produces about 125 million tons of paddy annually. As noted earlier 40kg of RHA is obtained from 1 ton of paddy. If all paddy is burnt to produce RHA, we can get roughly 5 million tons of RHA annually. Even if 20% of paddy is utilized to produce RHA, around 1 million ton of RHA will be available for use annually. However, in India very small quantity of RHA is produced at present.

In USA, RHA is patented under trade name “agro silica”. However, in India no standard for RHA has been issued by BIS yet. The behaviour of RHA in concrete at replacement level 6% to 10% is almost similar to concretes modified with SF or metakaolin. In absence of any standard by BIS, the assurance of quality and consistency of RHA becomes difficult. The availability and sources of supply of RHA in India are limited at present. However, RHA is a potential cementitious material for use in concrete and especially high strength and high performance concrete.

## Ultra Fine Slag

The Ultrafine slag is an Indian innovation pioneered by some Indian companies. Ultrafine slag is a specially processed product based on slag of high glass content and low alumina with high reactivity obtained through the process of controlled granulation. The specific surface as computed by Blaine apparatus is about 12000 $cm^2/g$ and is truly ultrafine. The particle size ranges between 0.1 to 15 micron with average particle size of 4 micron. Ultrafine slag works in concrete as pozzolanic and cementitious material and being very fine also provides effective packing effect. Ultrafine slag reduces water demand due to amorphous nature of its particles and also helps in retaining slump. Ultrafine slag provides better workability to fresh concrete as compared to silica fume, rice husk ash or metakaolin. In enhancing impermeability and strength of concrete, it has same effect as other ultrafine materials like silica fume, rice husk ash and metakaolin.

The Bureau of Indian Standards (BIS) has recently issued standard under IS: 16715 for Ultrafine granulated blast furnace slag. The particle size distribution as determined by any suitable PSD analyser as per standard is given below;

$d_{50} < 5$ micron
$d_{95} < 15$ micron

$d_{95}$ indicates that 95 percent of the particles on a mass basis are below a given size (diameter) while $d_{50}$ indicates that 50 percent of the particles on mass basis are below a given diameter. The chemical composition of Ultrafine slag shall conform to IS: 16714, Ground Granulated Blast Furnace Slag for use in Cement, Mortar and Concrete – Specifications. The chemical requirements of Ultrafine slag are given in Table – 8.

### Table – 8.
### Chemical Requirements of Ultra Fine Slag 16714 -2018

| Sr. No. (1) | Constituent / Characteristic (2) | % by Mass (3) | Methods of Test, Ref to(4) |
|---|---|---|---|
| (I) | Manganese oxide (MnO), Max | 5.5 | IS 4032 |
| (ii) | Manganese oxide (MgO), Max | 17.0 | IS 4032 |
| (iii) | Sulphide sulphur (S), Max | 2.0 | IS 4032 |
| (iv) | Sulphide (as $SO_3$), Max | 3.0 | IS 4032 |
| (v) | Insoluble residue, Max | 3.0 | IS 4032 |
| (vi) | Chloride content, Max | 0.1 | IS 4032 |
| (vii) | Loss on ignition, Max | 3.0 | IS 4032 |
| (viii) | $\frac{CaO+MgO+{}^{1}/_{3}Al_2O_3}{SiO_2+{}^{2}/_{3}Al_2O_3}$, Min | 1.0 | IS 4032 |
| (ix) | $\frac{CaO+MgO+Al_2O_3}{SiO_2}$, Min | 1.0 | IS 4032 |
| (x) | $\frac{CaO+CaS+{}^{1}/_{2}MgO+Al_2O_3}{SiO_2+MnO}$, Min (For granulated slag with > 2.5 percent MnO) | 1.5 | IS 4032 |

**Note:**

**Slag Activity Index** – As per IS: 16715 the activity index of Ultrafine slag shall be;

7 days – Not less than 60 percent of control OPC
28 days – Not less than 75 percent of control OPC

Slag activity index is determined by using blend of 50 percent of ultrafine slag and 50 percent of OPC (43 grade conforming to IS: 269) having total alkalies ($Na_2O+0.658K_2O$) not less than 0.6 percent and not more than 0.9 percent. The blend is tested for compressive strength by casting and testing prisms in accordance with IS: 4031 (Part-8). The mortar mix proportions are kept, one part of the cement blend under test, 3 parts of standard sand conforming to IS: 650 and ½ part of water (w/c 0.5). The slag activity index is determined as;

$$\frac{\text{Compressive strength of ultrafine slag plus OPC blend}}{\text{Compressive strength of OPC}} \times 100$$

The high activity index of ultrafine slag allows fast development of initial strength of concrete and continued hydration increases long term strength as compared to OPC concretes. Ultrafine slag performs equally well or better than other ultrafine materials like silica fume, rice husk ash and metakaolin in production of high strength and high performance concrete.

Improvement in properties of concrete such as strength permeability, heat of hydration, cohesiveness and workability with the addition of GGBS have been well documented by various researchers across the globe. Addition of ultrafine slag further enhances the performance of concrete. Ultrafine slag strength on hydration by its both cementitious and pozzolanic reactions. This leads to generation of more hydrated products and enhances strength, performance and durability of concrete.

## Ultrafine Fly Ash (UFFA):

Ultrafine Fly Ash is also Indian innovation pioneered by some Indian companies. It is processed fly ash obtained through multiple classification of fly ash conforming to IS 3812 (Part-1). In Ultrafine fly ash, the spherical shape of the particles is retained as it is produced through air classifier and not through grinding operation. The ultrafine fly ash is really very fine material having fineness of about 10,000-

13,000 $cm^2/g$ when tested by Blaine's apparatus. The average particle size of ultrafine fly ash ranges between 3 to 5 micron. UFFA performs in concrete similar to other ultrafine materials like silica fume, rice husk ash, metakaolin and ultrafine slag. The very small size and glassy texture of spherical particles of ultrafine fly ash make it possible to reduce the amount of water required for a given consistency. The finely divided particles of UFFA generally improves workability of concrete by reducing the size and volume of voids. Ultrafine fly ash provides better workability to fresh concrete as compared to other ultrafine materials.

BIS had recently circulated a draft standard for Ultrafine fly ash for public comments. As per the draft standard, the chemical and physical requirements of Ultrafine Fly Ash are given in Table – 9 and Table – 10.

### Table – 9
### Chemical Requirements

| Sr. No. (1) | Characteristic (2) | Requirements (3) | Test Method (4) |
|---|---|---|---|
| a) | Silicon dioxide ($SiO_2$) plus aluminium oxides ($Al_2O_3$) plus iron oxide ($Fe_2O_3$) in percent by mass, Min | 70 | IS: 1727 |
| b) | $SiO_2$, percent by mass, Min | 35 | IS: 1727 |
| c) | Reactive silica in percent by mass, Min | 25 | IS: 1727 |
| d) | Magnesium Oxide in percent by mass, Max | 5 | |
| e) | Total sulphur as sulphur anhydride ($SO_3$), Max | 3 | IS: 1727 |
| f) | Total chlorides in percent by mass, Max | 0.05 | As per Annex B of IS 3812 (Part I). |
| g) | Loss on ignition by percent by mass, Max | 4 | |
| h) | Moisture content, percent by mass, Max | 2 | |
| j) | Total alkalies equivalent to sodium oxide ( $Na_2O$) in percent by mass, Max | 1.5 | |

### Table – 10
### Physical Requirements

| Sr. No. (1) | Characteristic (2) | Requirements (3) | Test Method (4) Ref to |
|---|---|---|---|
| a) | Specific surface $m^2/kg$, Min | 1000 | |
| b) | Oversize percent retained on 45 micron IS sieve, Max | 15 | IS: 1727 |
| c) | Oversize percent retained on 45 micron IS sieve, variation from average percent, Max | 5 | IS: 1727 |
| d) | Compressive strength at 7 days as percent of control sample, Min | 85 | IS: 1727 |

## Mix Design Criteria with UFFA:

The foregoing vividly illustrates the importance of understanding the factors that influence the rate of strength development in concrete mixes containing UFFA. In order to maximise the benefits of fineness, sphericity and pozzolanic activity of UFFA, particular attention must be given to mix design criteria.

In the first instance, using the same amount of water and superplasticiser in concrete mixes containing the UFFA, as used in comparable concrete with silica fume, results in large increase in slump. This is mainly due to the sphericity of the UFFA, which facilitates flow. As can be expected, the concrete with higher slumps exhibit a slower initial rate of strength development. At later ages (90 days) the compressive strength of concrete with UFFA is similar to those containing silica fume.

If, however the amount of water or superplasticiser used in the mix is adjusted and the concretes are designed to have similar slumps, the picture changes entirely. Not only are the rates of strength development comparable but also due to its latent pozzolanic activity, the compressive strength of the mixes containing UFFA exceeds those with silica fume.

The long-term pozzolanic activity of the UFFA can be seen as a function of its particle size distribution. Silica fume is much finer than the UFFA. As a result of the higher surface area the pozzolanic reaction proceeds rapidly and strength is quickly developed. The downside of this is that as the surface of the silica fume becomes covered with the reaction products, the $Ca(OH)_2$ can no longer reach and the pozzolanic reaction slows down. UFFA on the other hand has a wider range of particles sizes. As the finer particles are covered and thus prevent from participation in further reaction, the larger particles still remain available. The pozzolanic reaction can thus still proceed at later ages.

The above is certainly not the definitive explanation since the glass content of the pozzolan as well as the composition and concentration of both alkaline and alkali hydroxides influence the rate and extent of the pozzolanic reaction. Nevertheless, the higher rate of strength development exhibited at later ages by the UFFA must necessarily take the difference of particle size distribution into account.

## Summary and Conclusions:

Results obtained show that ultrafine materials such as UFFA, UFS, metakaolin and rice husk ash can be used as a viable substitute for silica fume. If the advantages of these materials are exploited in the concrete mix design, the initial rate of strength development may be the same or similar to those of silica fume mixes. At later ages, however, the pozzolanic activity of these materials leads to higher compressive strength values.

Durability test measuring the water permeability and absorption as well as chloride permeability have comparable values for both silica fume and these materials.

The use of UFFA and UFS, which are Indian innovations, as an alternative to silica fume can be effective in enhancing the properties of concrete, both in its fresh and hardened state. The UFFA and UFS are also cost effective as compared to silica fume, metakaolin and RHA. Due to the lower water demand required, UFFA and UFS can be ideally used to:

- Lower the water/binder ratio.
- Lower the amount of HRWR required; or
- A combination of the above.

UFFA and UFS are not only a new-generation cement extender offering exciting opportunities to the design of high performance concrete. With their unique properties, there are other additional applications that will certainly benefit the use of UFFA and UFS. Some that spring to mind are:

- Specialist Grouts.
- Ready Mix Concrete.
- Precast Concrete.
- Self-levelling Flooring.
- Self-Compacting Concrete (SCC).
- Cement Modified Pre-Mix Bagged Materials.

Future developments could possibly see the co-utilisation of UFFA and silica fume and UFS and silica fume, as this will provide civil engineers with the opportunity to simultaneously exploit the best properties of both products.

## References:


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6. IS 16354-2015 : Metakaolin for Use in Cement, Cement Mortar and Concrete - Specification

7. Draft Code issued by BIS under their document no. CED 2(01220) WD – June 2018 on specifications of ultrafine fly ash.

8. IS 15388 – 2003, Specification of silica fume.

9. IS 16714 – 2018 : Ground Granulated Blast Furnace Slag for Use in Cement, Mortar and Concrete – Specification.

10. IS 16715-2018 Ultrafine Ground Granulated Blast Furnace Slag – specifications.

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## About RMCMA

The Ready Mixed Concrete Manufacturer's Association (RMCMA), India is a non-profit industry organisation of leading ready mixed concrete producers from India established in March 2002. The vision of RMCMA is to make Ready-Mixed concrete the preferred building material of choice as the best environment-friendly material of construction. The RMCMA is committed to provide leadership to the Ready Mixed Concrete industry in India. It promotes the interests of the entire Ready Mixed Concrete industry in India, without sacrificing the interest of end users, designers, specifiers, owners and other stake holders.

RMCMA strongly supports the Quality Scheme for RMC Plants as spearheaded by Quality Council of India (QCI) and BIS. RMCMA through its efforts have already brought about 350 RMC plants throughout the country under certification scheme. RMCMA is endeavouring that all RMC plants in India shall be brought under the umbrella of 3rd party certification. RMCMA is focused on following activities

1) Organising Training Program for "Concrete Technologist of India" at different cities.
2) Creating Awareness about advantage of quality concrete in construction.
3) Certification of RMC Plants through QCI and BIS
4) Participation at National and International level to promote RMC
5) Formulation and revision of Codes pertaining to concrete and RMC
6) Safety, Health and Environment requirements at RMC Plants.
7) Dissemination of Knowledge amongst Civil Engineers and QC professionals.
8) Participation in Seminars/ Conferences and Exhibitions for promotion of RMC.

RMCMA

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