RMCMA

READY MIXED CONCRETE MANUFACTURERS' ASSOCIATION – (RMCMA)

(Bulletin No. 12)

Supplementary Cementitious Materials

PRESIDENT'S MESSAGE

Dear fellow RMCMA Members,

I hope this message finds you well. As we navigate an era defined by rapid technological advancements and a growing need for sustainable practices, it's crucial that we, the members of RMCMA India, remain at the forefront of innovation within our industry. This bulletin on Supplementary Cementitious Materials (SCMs) serves as a vital resource for us all, and I encourage you to delve into its contents with the utmost attention.

The bulletin provides a comprehensive overview of the different types of SCMs, their specific properties, and the profound impact they have on the performance of concrete in both fresh and hardened states. This knowledge is paramount for us as manufacturers, enabling us to optimize mix designs and consistently deliver high-quality concrete that meets the evolving demands of the construction sector.

The document underscores the critical role of SCMs in making concrete production more sustainable and environmentally responsible. By replacing a portion of OPC with SCMs, we actively contribute to the reduction of our carbon footprint. Remember, the production of OPC clinker releases significant amounts of CO_2 into the atmosphere. **By embracing SCMs, we can make a tangible difference in mitigating climate change.**

The bulletin emphasizes the importance of meticulous quality management, proper handling, storage, and accurate dosage of SCMs. These practices are non-negotiable if we are to ensure consistent and reliable performance in our concrete products.

I want to draw your attention to the exciting evolution of SCMs toward Ultrafine Supplementary Cementitious Materials. Building upon the established benefits of conventional SCMs, these advanced materials offer enhanced reactivity, leading to even greater improvements in concrete performance. **Ultrafine SCMs are poised to address persistent challenges in the construction world, including shrinkage, permeability, and durability concerns,** ushering in a new era of high-performance concrete.

I urge you to consider the following key takeaways:

- **Make the incorporation of SCMs a standard practice in your concrete production processes.**
- **Stay informed about the latest research and developments in the field of Ultrafine SCMs.**
- **Actively participate in knowledge sharing and collaborative initiatives within RMCMA to disseminate best practices and drive the widespread adoption of these sustainable materials.**

By embracing SCMs and pioneering the use of their Ultrafine SCMs, we not only elevate the quality and sustainability of our concrete but also demonstrate our unwavering commitment to a more responsible and environmentally conscious construction industry.

Er. Anil Banchhor
(President, RMCMA)

Published By: Ready Mixed Concrete Manufacturers' Association
Mobile No.: +91 93241 11122, Email: info@rmcmaindia.org, Website: http://rmcmaindia.org

Supplementary Cementitious Materials

1. Introduction

Supplementary Cementitious Materials (SCMs) have become an integral part of modern-day concrete. Use of SCMs in concrete provides numerous advantages in fresh and hardened state and they play equally important role in making a concrete sustainable and green construction material. SCMs are either industrial by-products like fly ash and GGBS or natural materials with low embodied energy component such as limestone powder, Calcined clay and Natural pozzolans.

Natural pozzolans and calcined clay with lime has been used as binding material from time immemorial in construction of forts, palaces and public works throughout the world. With the invention of Portland cement in 1824, a product easy and ready to use became available and the use of SCMs started declining. The harmful effects of use of excessive Portland cement on durability of structures, environment and sustainability have been widely discussed and realised across the world. The extensive research in different environment conditions on varieties of structures has firmly established that part replacement of OPC with SCMs not only enhances the durability but has very positive effect on environment and sustainability. SCMs have therefore become an important part of modern day concrete similar to cement, aggregates, water, and chemical admixtures.

The physical and chemical properties of SCMs determine their capacity to replace OPC and decide their performance. The quality management of SCMs and their proper use in concrete production is very important for achieving desired results. In this respect, various Codes have been formulated by different countries and different professional bodies on their specification and use in concrete. The quality parameters set out by different countries for SCMs have been touched upon in this Bulletin.

2. Types of SCMs

The following types of SCMs are covered in this Bulletin.

i) Fly ash obtained from Thermal Power Plants by burning coal,

   a) Silicious Fly ash (Type F)

   b) Calcareous Fly Ash (Type C)

ii) Ground Granulated Blast Furnace Slag (GGBS) obtained from integrated steel plants.

iii) Calcined clay

iv) Limestone Powder

3. Fly Ash

Fly ash is the by-product of combustion of pulverised coal in thermal power plants. The dust collection system removes the fly ash, as a residue from the combustion gases, before they are discharged into the atmosphere. Fly ash particles typically spherical, ranges in diameter from <1 micron to 150 micron. Fly ashes mainly exhibit pozzolanic activity, however, ASTM C 618 defines a pozzolan as "a silicious or calcareous and aluminous material which in itself possess little or no cementitious value, but which will, in finely divided form and in the presence of moisture, chemically react with calcium hydroxide at ordinary temperature to form compounds possessing cementing properties". Fly ash contain metastable alumino-silicates that will react with calcium ions, in the presence of moisture, to form calcium – silicate – hydrate.

The term fly ash was first used in electrical power industry in 1910. The first comprehensive data on its use in concrete was reported by Davis et al in 1937. The first major practical application was reported by US Bureau of Reclamation in construction of Hungry Horse Dam in 1948. Worldwide acceptance of fly ash as part replacement of cement slowly followed, but the interest has been increased since 1970s. it is estimated that in India nearly 280 million tons fly ash is generated by various TPPs every year. Due to the sustained efforts over the last 50 years, substantial portion (45% to 50%) of fly ash is now consumed by the cement and concrete industry in the country. The addition of fly ash in concrete is found to have positive effects in fresh as well as hardened condition. Fly ash can act both as a part replacement of fine aggregate and as a cementitious component. It influences the rheological properties of the fresh concrete and strength, porosity and durability of the hardened concrete as well as the cost, energy consumption and sustainability of limestone mines and other natural mineral resources.

3.1 Classification of Fly ashes

Canadian Standards Association (CAS) and ASTM C 618 recognise three general classes of fly ash.

a) Class N – Natural pozzolans like Volcano ash, diatomaceous earth, etc.

b) Class C, commonly produced from lignite or sub-bituminous coals.

c) Class F, normally produced from bituminous or anthracite coal.

Class C ashes differ from class F ashes particularly in percentage of calcium in their composition. In normal terminology, class C and Class F fly ash are called high calcium and low calcium respectively.

Table 1 Typical Composition of Class C and Class F Fly ash.

Sl. no	Composition	Class C Fly ash	Class F Fly Ash
		% Range	
1	Calcium oxide, CaO	15-30	2-6 (less than 10)
2	Silicon di-oxide ($Si0_2$)	20-50	45-60
3	Ferric oxide (Fe_2O_3)	2-10	15-20
4	Aluminium oxide (Al_2O_3)	20-25	15-25
5	Total alkalis (Na_2O+K_2O)	2-6	2-5
6	Magnesia (MgO)	3-6	0.5-2
7	Sulphates (SO_4)	0.1-1.0	0.2-1.5
8	Specific Gravity	1.9-2.2	2.1-2.3

In general, physical and chemical characteristics of fly ashes vary over a wide range depending upon their sources. In India predominantly class F fly ash is available, and class C fly ash is available only at few places by combusting lignite coal. Class N fly ash is generally neither available nor in use in India. Therefore it is not covered in this Bulletin.

3.2 Indian Codes for Fly Ash

In India use of fly ash in concrete and mortar is governed by following Codes;

a) IS:3812 (part-1) – 2013, Pulverised Fuel Ash specifications. For use as Pozzolana in cement, cement mortar and concrete.

b) IS: 3812 (part-2) Pulverised Fuel Ash Specifications. For use as Admixture in cement mortar and concrete.

Fly ash confirming to IS: 3812 (part-1) is only to be used as SCM. The specifications of Type F and Type C fly ash as covered in Indian code are compared with other International Codes in Table-2.

Table – 2 Comparison of Specifications of Fly ash in India with other International Codes.

Sl. no	Item	ASTM	European Standards		Indian	Indian
		C-618	EN-97-1	BS 3892-1	IS:3812 (Type-F)	IS:3812 (Type-C)
1	SiO_2 (min)	-	-	-	35%	25%
2	$SiO_2+Al_2O_3+Fe_2O_3$ (min)	70%	-	-	70%	50%
3	Reactive/Soluble SiO_2 (min)	-	25%	-	25%	20%
4	MgO_2 (max)	-	-	-	5%	5%
5	LOI (max)	6%	5.7%	7%	5%	5%
6	Total Alkalis (Max)	1.5%	-	-	1.5%	1.5%
7	SO_3 (max)	5%	-	2%	3%	3%
8	Free CaO (max)	-	1%	-	-	-
9	Total CaO (max)	-	10%	10%	>10%	<10%
10	Retention on 45-micron sieve	34%#	-	12%	34%	-
11	Blaines m^2/kg (min)	-	-	-	320	320
12	Cement reactivity 28 days (min)	75%+		80++	80%+++	80%+++
13	Lime reactivity	-	-	-	4.5 MPa	4.5
14	Autoclave % (max)	10 mm	10 mm	-	10 mm	10mm

permitted variation of ± 5% over average

+ 25% fly ash

++ 30% fly ash

+++ 20% fly ash

3.3 Replacement level of Fly Ash

Fly ash confirming to IS: 3812 (part-1)-2013 is permitted to replace OPC up to 35% by weight as cementitious material. If replaced beyond 35%, then such addition will not be considered while determining w/b ratio of the mix (IS:456 - amendment no.4). Additions beyond 35%, will not be considered as SCM, but will form part of replacement of fine aggregate.

3.4 Concrete Mix Design with Fly Ash

The efficiency of fly ash to replace OPC depends on its physical and chemical characteristics. However, it is observed that efficiency factor gradually decreases as percentage replacement increases. The factor may be as high as 75% to 80% at replacement level of about 15% to 16% and may come down to about 55% to 65% at a replacement level of 25% to 30%. While designing the fly ash mixes, following factors shall be kept in view.

i) The total cementitious content (OPC+ fly ash) shall be taken about 20% to 30% higher than pure OPC mix in trial mix and fine tuning shall be done through subsequent trials.

ii) As the cementitious content is increasing, the w/b ratio shall be kept lower than the control mix during trials.

iii) Compatibility of OPC plus fly ash with admixture shall be checked by Marsh Cone to arrive at correct dose of admixture.

iv) The mixing time of concrete shall be increased by 5 to 10 seconds to allow for proper dispersion of fly ash particles.

IS:10262-2019 provides one solved example of concrete mix design of M-40 grade concrete with fly ash is given as Annex ‘B”. It will be helpful to study it before understanding concrete mix designs in laboratory/construction sites.

3.5 Effects of use of Fly ash in concrete performance.

Fly ash has influence on performance of concrete in fresh as well as hardened state as described below;

3.5.1 Fresh state

i) Concrete mix has better workability and slump retention

ii) Fly ash particles being spherical help in ease of pumping of concrete even to greater heights.

iii) Rise in concrete temperature is slower as compared to control concrete due to lower rate of hydration.

iv) Density of fresh concrete is slightly lower than control concrete depending upon percentage replacement.

v) Mix is comparatively more cohesive having lesser bleeding.

3.5.2 Hardened state

i) The compressive strength at 3 and 7 days is lower than control concrete. 28 days strength may be comparable but 56 days and 90 days strengths are normally higher.

ii) Concrete becomes more dense and impermeable especially at 56 days and 90 days.

iii) Concrete is more prone to shrinkage and may require early as well as prolonged curing.

iv) Carbonation of cover zone will be faster and may require higher cover thickness.

v) Concrete will provide better resistance to chemical attack from sulphates, chlorides and other harmful elements due to its denser micro-structure.

4. Ground Granulated Blast Furnace Slag (GGBS)

Ground Granulated Blast Furnace Slag (GGBS) is obtained by rapidly quenching or cooling molten iron slag (a by-product of iron and steel industry) from a blast furnace by water or steam to produce a glassy, granular product that is then dried and ground into a fine powder. GGBS is a latent hydraulic binder forming calcium silicate hydrate (C-S-H) after contact with water. It is very useful compound, that enhances strength, refines micro-structure of concrete and makes it denser, thus reducing permeability and improving durability of concrete. GGBS as cementitious material has special advantage in mass and temperature-controlled concretes. The slow release of hydration heat allows to control the peak temperature in massive concrete structures. Use of GGBS is also very advantages in hot weather concreting and to enhance durability of concrete where chlorides and sulphates are found together.

4.1 Composition

The chemical composition of a slag varies depending on the composition of the raw materials used in iron production. Silicate and aluminate impurities from the ore and coke are combined in the blast furnace with a flux, which lowers the viscosity of the slag. In the case of pig iron production, generally limestone and dolomite are used as flux. In the blast furnace the slag floats on top of iron and is decanted for separation. Slow cooling of slag melts results in an unreactive crystalline material, while to obtain good reactivity and hydraulicity, the slag melt should be rapidly cooled or quenched below 800°C in order to prevent re-crystallisation. To obtain a suitable reactivity, the dried fragments of granulated slag are ground to same or higher fineness of OPC cement.

The characteristics of Ground Granulated Blast Furnace Slag (GGBS) is governed by IS:16714-2018 are given in table 3. These are also compared with EN and ASTM Standards.

Table-3 Comparison of Chemical Characteristics of GGBS with IS, EN and ASTM standards.

Sl. no.	Item	EN 197-I	ASTM C-989	IS:12089
1	(C+M+1/3 A)/(S+2/3 A) Or (C+M+A)/S, min	-@	-	1.0
2	(C+M+S), min	67	-	-
3	(C+M)/S, min	1.0	-	-
4	MgO, % max	-	-	1.7
5	MnO, % max	-	-	5.5
6	Sulphide Sulphur, % max	-	2.5	2
7	Insoluble Residue, % max	-	-	5
8	Glass Content, % min	67	-	85

@ -denotes not specified.

(C=CaO, M=MgO, A=Al_2O_3, S=SiO_2)

ASTM C 989 does not provide requirement of minimum glass content in GGBS, EN 197-I provides it 67%, while IS Code provides minimum requirement of 85%. The chemical composition of slags obtained from different steel plants is found fairly uniform, having glass content in the range of 85% to 95%. IS:455-2015 for Portland Slag Cement permits slag content between 25% to 70%, while EN 197-I permits slag content up to 80% or even up to 95% for specific application.

The Physical requirements of GGBS are also provided in IS:16714-2018 and are given in Table - 4.

Table-4 Physical Requirements of GGBS as per IS: 16714-2018.

S. No.	Constituent	Requirement	Method of Test, Ref to
(1)	(2)	(3)	(4)
i)	Fineness, m^2/kg, Min	320	IS:4031 (Part-2) (see Note-1)
ii)	Slag activity index (see Note 2)		
	a) 7 days	Not less than 60 percent of control OPC 43 Grade cement mortar cube	
	b) 28 days	Not less than 75 percent of control OPC 43 Grade cement mortar cube	

NOTES:

1) For the purpose of testing GGBS as per IS:4031 (Part-2), wherever reference to cement has been made in IS:4031 (Part-2), it may be read as GGBS.

2) Slag activity index (SAI) shall be determined using blend of 50 percent GGBS and 50 percent control OPC 43 Grade confirming to IS:269, having total alkalis (Na_2O+0.658 K_2O) not more than 0.9 percent). The blend shall be tested in accordance with IS:4031 (Part-6), for determining compressive strength of mortar.

SAI shall be determined in accordance with I S:455-2015.

4.2 Replacement Levels of GGBS

The replacement level of OPC by GGBS are governed by provisions of IS:456 – 2000 in structural grade concrete – The same are as under.

a) GGBS can replace OPC up to 50% when used alone as SCM with OPC (amendment no. 6 to IS:456-2000)

b) When GGBS is used in combination with Ultrafine materials, then total replacement can go up to 60% (amendment no. 6 to IS:456-2000)

c) If GGBS is used with any ultrafine material and w/b ration is below 0.4, then replacement level of OPC can go up to 65% (amendment no. 6 to IS:456-2000)

d) In Triple blend (OPC+GGBS+Fly ash), the combined quantity of GGBS and fly ash by mass shall not be more than 45% of total cementitious material (amendment no. 6) in which fly ash shall not be more than 25%.

e) If the w/b ratio of total Triple blend is below 0.4, then combined mass of GGBS and fly ash can go up to 50%.

f) Where chlorides and sulphates both are present either in ground water or soil, the GGBS permitted to replace OPC up to 50% (Note – Table 5 of IS:456-2000)

4.3 Mix Design with GGBS

The concrete mix design with GGBS is governed by IS:10262-2019. A solved example of M-40 grade concrete mix is also given in IS:10262-2019 for guidance. The following precautions are considered necessary while using GGBS in structural grade concrete.

i) GGBS is a finer material and its thorough blending with OPC in concrete mixer is necessary. The mixing time with GGBS shall be suitably increased as compared to OPC mix.

ii) The mixes with GGBS are more cohesive and difficult to pump especially at greater heights. The flow (slump) of GGBS mixes shall be kept higher than OPC mixes for ease of pumping.

iii) The mix being more dense and cohesive (having no or very little bleeding) is more prone to develop plastic shrinkage cracks. Early curing and protection of fresh concrete from environment elements (temperature, humidity and air velocity) is very critical for GGBS based mixes.

iv) GGBS based mixes need more water curing period as compared to OPC based mixes. Desirable wet curing period is from 10 days to 14 days depending upon climatic conditions.

v) If GGBS replacement level is high (50% and more), then cover concrete is likely to have higher rate of carbonation. The cover thickness in such cases shall be suitably increased and w/b ratio shall be kept lower for better durability.

vi) The compatibility of chemical admixtures with combined GGBS plus OPC shall be properly checked before making use of particular admixture.

vii) GGBS normally has higher alkali content in the range of 0.8% to 1% and even more. If aggregates are likely to have alkali-aggregate reaction, the use and percentage replacement shall be chosen carefully.

4.4 Effects of use of GGBS in Concrete Performance

GGBS generally has beneficial effects on performance of concrete in fresh as well as hardened state. However, certain precautions are necessary while using GGBS especially when percentage replacement is high.

a) Effects on Fresh Concrete.

i) Water demand will increase due to high quantity of finer ground material (cement & GGBS) in the mix. The flow of concrete will be lower and to increase it, higher dose of admixture will be required.

ii) Slump retention will be better especially with PC based admixtures in low w/b ratio mixes (below 0.3)

iii) Temperature rise of fresh concrete will be lower and placing temperature of concrete can be controlled better in GGBS based mixes.

iv) Concrete will be dense and cohesive and more prone to plastic shrinkage cracks.

v) Rate of gain of strength will be lower and it would be desirable not to keep concrete for long in plastic state, therefore use of retarders to be reduced and made judiciously to avoid early age cracks due to plastic shrinkage and plastic settlement.

b) Hardened Concrete

i) Concrete will require longer wet curing for strength and better durability.

ii) Concrete micro-structure will be denser having reduced permeability and better resistance to chlorides, sulphates and other harmful elements.

iii) The drying shrinkage and creep may be higher than OPC mixes depending upon other ingredients, size of structural element and time and rate of loading.

iv) Long term compressive strength of concrete may be better (90 days and beyond) as compared to OPC based, depending upon environment conditions and availability of moisture.

v) GGBS based concretes are more liable to carbonation and alkali-aggregate reaction (depending on aggregates), these factors shall be properly considered in structural design and testing of ingredients (especially aggregates beforehand.

5. Calcined Clay Pozzolana

Calcined clay pozzolana is a reactive pozzolanic material manufactured under controlled conditions of clay at suitable temperature and grinding the resulting product to the required fineness. This material can be used as part replacement of OPC in concrete. The specifications of Calcined Clay Pozzolana are covered under IS:1344-2008.

Calcined clay pozzolana has been used from time immemorial with lime mixture in mortar and concrete. It can be effectively used with present day OPC with part replacement in mortar and concrete. It is important to select suitable type of clay for calcination and past experience on use of such clays can be of invaluable help. The chemical composition of clays which can be considered for calcination are given in table 4.

Table-5 Chemical Requirements of Clays.

Sl. no	Constituents	Contents	Remarks
1	Silica+Alumina+Iron Oxide ($SiO_2+Al_2O_3+Fe_2O_3$)	Not less than 70%	For chemical analysis of clays, reference shall be made to IS:1727-1967. Methods of Test for pozzolanic Materials
2	Silica (SiO_2)	Not less than 40%	
3	Calcium Oxide (CaO)	Not more than 10%	
4	Magnesium Oxide (MgO)	Not more than 3%	
5	Sulphuric Anhydride (SO_3)	Not more than 3%	
6	Soda Ash & Potash (Na_2O+K_2O)	Not more than 3%	
7	Water soluble alkali	Not more than 0.1%	
8	Water soluble material	Not more than 1%	
9	Loss on ignition	Not more than 10%	

5.1 Manufacture of Calcined Clay Pozzolana

The clay is prepared by addition of suitable amount of water into a plastic mass, weeding out gritty material, pebbles, sticks, etc. The prepared clay is calcined at suitable temperature varying between 600⁰C to 1000⁰C depending upon the nature and quality of clay. The calcined material is subsequently pulverised to the required fineness. In India, the method is normally practised by calcining clay into bricks, tiles or balls and the calcined material is later pulverised. The calcined clay pozzolana shall be protected from rain and ingress of moisture.

5.2 Physical Requirements

The physical requirements of Calcined clay pozzolana are given in IS:1344-2008 as given below;

Characteristics	Requirement	Remarks
Fineness (min)	320 m^2/kg	Test shall be conducted in accordance with IS:1727-1967
Lime reactivity (min)	4.0 MPa	
Drying Shrinkage (max)	0.15%	
Compressive Strength at 28 days	80% of corresponding plain cement cube	

5.3 Replacement level and Mix design

Calcined play pozzolana is permitted to be replaced up to 35% of OPC in concrete. It is similar to fly ash in performance and other characteristics. The mix design of concrete as provided in IS:10262-2019 for fly ash is also applicable to calcined clay pozzolana. The effects on fresh and hardened concrete are also similar to that of fly ash, therefore these are not discussed separately in this Bulletin.

5.4 Present Use

The use of calcined clay decreased after fly ash from TPPs became available as an alternate material. However, on concerns of Carbon footprints and sustainability, BIS has recently prepared Code for "Calcined Clay Lime stone cement" (LC3) under IS:18189-2023. As per this Code, low percentage of clicker (45%), gypsum (5%), limestone (25%) and calcined clay (25%) can be used to produce LC3 cement, meeting the requirements of 43 grade cement. The availability of fly ash in certain geographical areas is also decreasing and, in this context, the use of calcined clay pozzolana as part replacement of OPC is likely to increase. It is also expected that production units of calcined clay pozzolana will be set up in near future by cement plants and others and this material of requisite quality confirming to IS:1344-2008 will be available to the end consumers.

6. Limestone Powder

Limestone is also used as supplementary cementitious material as well as part replacement of sand in concrete and mortar. European Union Code EN 197-1 on cements, provides blending of limestone powder from 6% to 20% in CEM II/A-LL and 21% to 31% in CM2 II/B-LL types of cements. There is yet no Indian Code issued by BIS on Limestone Cement. However, a proposal to prepare Code on Limestone Cement is under consideration of BIS. The proposal includes replacement of OPC clinker with limestone up to 25% and the limestone shall have total carbonates not less than 75% in its composition and fineness not less than 400m^2/kg.

6.1 Preparation of Limestone Powder

The quality of limestone and its fineness are of critical importance in determining its capacity to replace OPC in cement or concrete. In general, the limestone shall have following chemical and physical characteristics. These are based on EN 197/1 and our past experience;

Table 6 – Properties of Limestone

Sl. no.	Constituents	Contents	Remarks
1	Silica+Alumina+Iron Oxide ($SiO_2+Al_2O_3+Fe_2O_3$)	Not less than 70%	For chemical analysis of clays, reference shall be made to IS:1727-1967. Methods of Test for pozzolanic Materials
2	Silica (SiO_2)	Not less than 40%	
3	Calcium Oxide (CaO)	Not more than 10%	
4	Magnesium Oxide (MgO)	Not more than 3%	
5	Sulphuric Anhydride (SO_3)	Not more than 3%	
6	Soda Ash & Potash (Na_2O+K_2O)	Not more than 3%	
7	Water soluble alkali	Not more than 0.1%	
8	Water soluble material	Not more than 1%	
9	Loss on ignition	Not more than 10%	

6.2 Hydration process and Effects of Limestone Powder

Limestone powder in concrete has four distinctive effects, Filler effect, Nucleation effect, Dilution effect and Chemical effect. Filler effect has negligible effect on hydration process; however, it improves the micro-structure by filling the pores between hydration products. The nucleation effect of LS powder could improve the hydration degree of cement and generate more hydration products at early ages. The dilution effect of LS can decrease the reactive cement portion and could reduce the total amount of hydration products. The chemical effect of addition of LS powder resulted in additional formation of hemi or mono carbonates instead of mono sulphates. In addition, it is reported that more ettringite was formed when LS powder was in the system. The influence of addition of LS powder on concrete can be summarised as under;

i) Addition of fine LS powder accelerates the hydration of C_3S and it also increases the hydration peak of C_3S.

ii) The micro-structure of concrete is densified due to filler effect of LS powder in between the hydration products.

iii) Hemi-mono carbonates are formed instead of mono-sulphates. The effect on compressive strength of concrete is marginally positive due to LS powder addition.

iv) The dilution effect may become significant at higher replacement levels of LS powder. The optimum percentage of replacement will depend upon quality of clinker, quality of LS, fineness, w/b ratio, etc. However, in general replacement is limited between 15% to 25%.

v) The slump/flow and its retention in concrete is reported to be better than control concrete, if the replacement level is 15% percent and above.

7. Conclusions

SCMs have become integral part of modern-day concrete. SCMs have numerous advantages, which can be briefly mentioned as under.

i) SCMs improves pore structure of concrete, makes it more denser, reduces its permeability and enhances its durability and provides much higher resistance to ingress to chlorides, sulphates and other harmful elements.

ii) In general, SCMs improves properties of fresh concrete in respect of slump/flow and its retention. The initial and pouring temperature of concrete are decreased which are very helpful in mass concrete works.

iii) The cohesiveness of concrete improves with addition of SCMs, making it easier to pump, especially at long distances and greater heights.

iv) The properties of hardened concrete are improved due to prolonged hydration resulting in better strength over a period of time (56 days and beyond).

v) Most of the SCMs are industrial by-products and their utilisation leads to conservation of natural minerals and energy saving, thus provides better sustainability.

vi) Use of SCMs greatly helps in reducing carbon footprints by reducing the use of OPC clinker, which is responsible for releasing nearly 0.9t of CO_2 to atmosphere in production of one tone of clinker.

vii) SCMs based concretes require longer period of wet curing and proper care of concrete at initial period to derive desirable beneficial effects.

viii) SCMs based concrete are in general more cost effective as compared to pure OPC based concretes.

ix) Thorough mixing or blending of SCMs with OPC is essential and it may require better quality of mixer and more mixing time. It shall be ensured and uniformity of mix shall be periodically checked.

x) Proper quality, storage, handling and accurate dosage of SCMs shall be ensured at RMC plants to achieve requisite properties of fresh and hardened concrete.

References

1. IS: 269-2015 - Specifications of Ordinary Portland cement

2. IS:3812-(part-I)-2013 - Pulverised Fly Ash – Specification

3. IS:16714-2018 - Ground Granulated Blast Furnace Slag for use in Cement, mortar and concrete specifications.

4. IS:1344-2208 - Specifications for calcined clay pozzolana

5. (EN 197(part-I) Composition, specification and conformity criteria for common cements.

6. ASTM C 618 - Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for use in Concrete.

7. Wendimu Gudissa, et, al – department of Civil Engg, University of Adis Ababa – The use of Limestone Powder as an Alternative Cement Replacement Material – An Experimental Study, published in Journal of EEA, Vol 27, 2010.

RMCMA IS ORGANIZING FOLLOWING TRAINING PROGRAMS ON REGULAR BASIS.

1) **Concrete Technologist of India (CTI)**

This Program was conceived in association with National Ready Mixed Concrete Association of USA (NRMCA) in 2013. Since then, 728 candidates have been trained under this program.

The program is conducted online for 4 days by well-known faculty and online exam is held on 5th day. All aspects of Concrete Technology are covered.

Preferably candidate shall be B E (civil) or Diploma (civil) with 4–5-year experience either of RMC plant or construction site.

Based on exam results, a certificate is issued by RMCMA to each candidate, which is valid for 5 years. Nearly 500 pages Training Manual (hard copy) is provided to each candidate.

2) **Training for Newly joined and Marketing Officers in RMC Industry**

RMCMA is conducting this program on regular basis since 2022. As on date 430 candidates have been trained.

This program is conducted online of 3 days by well-known faculty covering all aspects of Concrete Technology.

This program is aimed at newly joined candidates in QC function and Marketing officer.

Based on the exam, conducted on 4th day, RMCMA issues certificate to each candidate, which is valid for 5 years. Nearly 200 pages Training Manual (hard copy) and other reading material is provided to each candidate.

3) **Safety, Health/Hygiene and Environment Training**

This Training Program is held in association with National Safety Council of India. The training schedule is prepared keeping in view the requirements of RMC plant and construction sites in placing and pumping of concrete.

This program is aimed for the candidates who are responsible for Safety, Health/Hygiene and Environment at RMC Plant. It is two-day online program without any exam.

On successful completion of program, a certificate is given to each candidate by RMCMA/NSC, which is valid for 5 years. The suitable reading and Training material is shared with each candidate.

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 for construction as the best environment-friendly sustainable material. 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 interests of end users, designers, specifiers, owners and other stakeholders. 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 Programs for different officials working in RMC Industry. RMCMA is conducting on regular basis following training programs.
    a) Concrete Technologist of India (CTI) for QC and Technical support service staff of Cement and Concrete industries.
    b) RMC business overall view for Marketing and New QC staff.
    c) Safety, Hygiene and Environment Training Program in association with National Safety Council of India for safety in RMC operations.
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) Participating in formulation and revision of Codes with BIS pertaining to concrete and RMC.
6) Safety, Health and Environment requirements at RMC Plants.
7) Dissemination of Knowledge amongst Civil Engineers and QC Professionals on Concrete Technology through publishing Bulletins and holding Round Table Conferences.
8) Participation in Seminars/ Conferences and Exhibitions for promotion of RMC.
9) Focusing on use of Special Concretes or niche applications.
10) Organizing lectures in engineering colleges to expose students on RMC Technology.

RMCMA

RMCMA MEMBERS

- UltraTech Cement Ltd.
- Prism Johnson Ltd
- RDC Concrete India Pvt. Ltd.
- ACC Ltd.
- Nuvoco Vistas Corp. Ltd.
- Godrej & Boyce Mfg Co Ltd.
- Skyway Rmc Plants Pvt. Ltd.
- IJM Concrete Products Pvt. Ltd.
- The India Cements Ltd.
- Sarvani Industries Pvt. Ltd.
- S. V. Concrete
- J K Lakshmi Cement Ltd.
- N S Arcus

RMCMA ASSOCIATE MEMBERS

- Schwing Stetter (India) Pvt. Ltd.
- Ecomix Concrete LLP
- Ajax Engineering Pvt. Ltd.
- I S Infra Conmix
- Ammann India Pvt. Ltd.
- Macons Equipments Pvt. Ltd.
- Aquarius Engineers Pvt. Ltd.
- SIMEM India Pvt. Ltd.
- Concrete Additives & Chemicals Pvt. Ltd.
- Putzmeister Concrete Machines Pvt. Ltd.
- Cosben Engineering Pvt. Ltd.
- KYB Conmat Pvt. Ltd.
- M/s Janyu Technologies Pvt. Ltd.
- IDS Technologies India Pvt Ltd

This Bulletin has been written and edited by Shri A K Jain, Principal Consultant, RMCMA