READY MIXED CONCRETE MANUFACTURERS' ASSOCIATION – (RMCMA)

(Bulletin No. 7)

Varieties of Concrete and Their Application




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

PRESIDENT'S MESSAGE

Concrete has been the most widely used man made commodity in the world for ages but in the last few years, the versatility of concrete has come to the forefront. The innovation in concrete technology is happening globally to drive enhanced performance, cost efficiencies, durability and sustainability. In industry parlance, the various kinds of concrete are broadly categorized as Normal Concrete and Specialty Concrete. Typically concrete grades of up to M60 are categorized as Normal while higher grade concrete and specific application based concrete are categorized as Specialty. There are about 25 varieties of specialty concrete currently prevalent in India some of which are deliberated upon in this bulletin.

Application of concrete is increasing in variety of structures. It's imperative that industry stakeholders including users and consultants are aware of various forms of concrete available and their applications which will help the construction industry to graduate to the next level. One such emerging variety is Ultra High Performance Concrete (UHPC) which is a very versatile material with a potential for vast range applications providing solutions like durability, aesthetics, sustainability and ductility.

There is a marked reversal in trend that's driving concrete innovation which is that the solutions are reimagined keeping in mind the requirement and needs of projects and customers rather than serving them what's cooked in the kitchen. Putting it differently, Industry is now gearing up to serve what the customer wants rather than providing the customers what they have. This is a welcome change and would go a long way in achieving the inclusive objective of overall efficiency, performance and most importantly sustainability of the planet.

Er. Ramesh Joshi
(President, RMCMA)

1.0 INTRODUCTION:

In modern times, concrete is the most widely used material for varieties of constructions. In order to achieve optimal results on performance, cost, durability and sustainability, varieties of concretes have been developed over the period and are being used. Concretes are broadly placed in two categories, 'Normal Concretes' for general construction and 'Special Concretes' for specific applications.

In view of availability of wide variety of mineral and chemical admixtures, fibers and other additives, it has been possible to develop varieties of concrete. American Concrete Institute (ACI) records more than 50 types of concrete, however nearly 15 to 20 types of concrete are now commonly used in different type of construction works in India.

In this bulletin, 15 types of concrete are briefly described with their properties and preferred application for the benefit of users, consultants, field engineers and spcifiers.

2.0 NORMAL CONCRETES:

2.1. The following type of concretes fall under the category of Normal Concretes;

- i Normal grades of concrete (M-10 to M-60)
- ii High strength concrete (M-65 to M-100)
- iii Pumpable concrete

3.0 SPECIAL CONCRETES:

3.1. The following varieties are described under this category.

- i. Self-compacting concrete
- ii. Pervious Concrete
- iii. High-volume fly ash concrete
- iv. Light weight concrete
- v. Heavy weight concrete
- vi. Fibre reinforced concrete
- vii. Stamped and coloured/decorative concrete
- viii. Temperature controlled concrete (with or without triple blends)
- ix. Roller Compacted Concrete
- x. Concrete for Prestressed Works
- xi. High performance concrete having special requirements in fresh or hardened state.
- xii. Ultra-high performance concrete

4.0 SELECTION CRITERIA:

Selection of any type of concretes shall be done based on project specific requirements. During selection of particular type of concrete for the project; various factors shall be considered such as contract and codal requirements, properties of locally available raw materials, workability, retention, weather and environment conditions of site such as wind speed and patterns, expected rainfall, temperatures during day and night, coastal areas, ground soil and water profile, pumping ability for long horizontal and vertical distances, durability requirements, ease of finish and compaction, reinforcement congestion, curing method to be adopted, minimum time cycle for producing, transporting and placing concrete, economy in overall process, etc.

5.0. NORMAL GRADES OF CONCRETE:

IS: 456 – 2000 classifies concretes into 3 category grades depending upon their strength grade (e.g. M-20 grade means a concrete which has compressive strength of 20 MPa or 200 kg/cm^2 at 28 days)

- a. Ordinary Concrete - (M-10 to M-20)
- b. Standard Concrete - (M-25 to M-60)
- c. High Strength Concrete - (M-65 to M-100)

For structural purpose, minimum grade of concrete shall be M-20, M-10 and M-15 are used for PCC (Plain Cement Concrete) for sub- base or base.

Common ingredients for concrete making, viz., cement, water, coarse and fine aggregate and superplasticizers are enough to design a normal concrete. The focus of normal concretes is generally to achieve strength with normal workability requirements. Durability of normal concretes is normally governed by minimum cement content, maximum w/c ratio and minimum grade of concrete for a given environment condition as specified in IS: 456 - 2000. The mineral admixtures like fly ash or granulated blast furnace slag (ggbs) can be used as part replacement of cement (OPC). The permissible limit for addition of fly ash is 35% of weight of total cementitious and ggbs upto 70% of weight of total cementitious. Normally the replacement level of fly ash ranges between 25% to 30% and that of ggbs between 40% to 50% in normal grade concretes.

Normal grade concretes (M-20 to M-40) are widely used in residential/commercial buildings, road works, bridges and general civil construction works. These concretes are normally compacted by needle and screed vibrators. The workability requirements at the time of placing generally varies between 50 to 80 mm. The w/b ratio in such concretes varies between 0.35 to 0.45. The mix proportioning of Normal Concretes is provided in IS: 10262 –2019.

6.0 HIGH STRENGTH CONCRETE:

Any concrete having strength higher than M-60 is categorised as high strength concrete as per IS:

456 - 2000. Under high strength concrete, IS:

456 – 2000 covers from M-65 to M-100 grades.

The main objective of using high strength concrete is to reduce the dead weight, have slender members and to provide special architectural features that demands elements to carry smaller loads as well as heavy loads with same slender member sizes. High strength concrete reduces the overall consumption of materials, high ratio of strength to volume, and creates more floor space due to reduction of column sizes. The use of HSC is increasing in multistorey buildings and long span bridges, etc.

The ingredients used for high strength concrete are virtually same as that of normal concrete, except that more emphasis is given on the uniformity and quality of raw materials to achieve higher strength. The concrete engineer knows exactly how to reduce the w/b ratio to achieve higher strength by making right choice of materials using right type of cement, mineral admixtures, fine and coarse aggregate and their proportions. Use of super plasticizers is mandatory in designing high strength concrete. Use of mineral admixtures becomes a must for grades higher than M60 to limit OPC component to 450kg/m^3 (max). Use of silica fume (SF) is very popular for achieving higher strength, though it is advisable to use a combination of OPC + Fly Ash/GGBS + Silica fume. Use of ultra-fine fly ash (UFFA) or ultra-fine slag (UFS) can also be made instead of silica fume. In high strength concrete, cementitious materials having high specific surface area is used so as to increase rate of hydration and thus to increase the rate of strength gain as well as bond between aggregates and cement paste. Mix proportioning of HSCs is not governed by IS: 10262 – 2019. Mainly these concretes have to be designed through lab trials.

Use of high strength concrete also improves the durability by virtue of lower w/b and use of mineral admixtures. But it must be noted that even normal concrete can be designed to have high durability. The w/b ratio of these concretes normally varies from 0.20 to 0.30.

7.0 PUMPABLE CONCRETE:

A concrete which can be easily passed through a pipeline under pressure without segregation and bleeding is called as Pumpable Concrete. Pumping may be done by static/mobile pumps and pipelines to the desired pouring locations. It enables the site team to place the concrete through very congested locations, at heights where direct placement of concrete is not possible by means of transit-mixers, chutes, wheel barrows/hand carts, etc.

Pumpable Concrete Placement at Site

The slump of pumpable concrete is kept at 100 mm or more to collapse range and the diameter of the pipeline shall be at least 3 – 4 times the maximum size of aggregate. Generally, 125 mm dia. pipeline is used for pumping concrete. Concretes with very low slump (stiff concrete) and with high slumps (collapse, with high water cement ratios) are not pumpable. For pumping ability, concretes shall contain fines passing through 300 micron sieve (including cement, cementitious materials, and fines in sand) in the range of 400 to 500 kg/m^3.

Concrete is pushed through the pipeline under pressure and hence it is resisted by drag resistance of the pipeline in the opposite direction by inner surface of the pipeline. For smooth pumping of the concrete, cement slurry is used for lubricating/priming of pump and pipeline. This helps for easy movement of concrete through pipeline by providing a thin lubricating layer between concrete and inner surface of the pipeline. Admixtures for lubrication/ priming are also available in lieu of cement slurry.

Water cement ratio, amount of cementitious material content, admixture type and dosages, aggregate shape, grading and fines content in the concrete mix plays important role in the pumpable concrete. It is important to maintain good grading and low void content, it is not always possible to design pumpable mix by getting ideal aggregates. Naturally occurring aggregate as well as crushed aggregates are also suitable for pumpable mix, but it is essential to be aware of grading, void content and uniformity.

To ensure smooth, uninterrupted concrete pour, it is important to choose a right pump and a system of pipeline. While choosing right pump some key factors shall be considered such as dia. of pipeline, length of horizontal and vertical pipe, number of bends, length of hose pipe, change in line diameter, slump of concrete, pumping distance, pump rate, line pressure, start-up pressure for pump, allowances for bends, couplings and safety factor, etc.

Some common causes of blockages in concrete pipeline and preventive measures are tabulated as mentioned in table No. 1.

Table 1: Common Causes of Blockages in Concrete Pipeline and Preventive Measures

Causes of blockages	Preventive measures
Pipeline not cleaned properly after previous concreting operation	Pipeline must be cleaned properly after each concreting as soon as possible
Improperly lubricated pipeline and hose	Proper priming shall be done with cement slurry or powder slurry primer
Wornout pipes, joints and hoses	Defect free pipes, joints and hoses shall be used
Tapered pipes, too many and too sharp bends	Try to avoid tapered pipelines, provide minimum possible sharp bends
Hot weather conditions, loss of moisture in a concrete mix	Pipelines shall be covered with wet hessian cloths during hot weather conditions to protect loss of moisture from concrete mix
Unsuitable concrete mix – lesser fines content, high cementitious material contents, poorly graded aggregates, expulsion of water / slurry from the mix, use of accelerating admixtures	Selection of suitable concrete cohesive mix with sufficient fines, optimum cementitious material content, well graded aggregates, optimum water content, controlling use of accelerating admixtures
Interrupted concreting operation	As far as possible concreting shall be done continuously
Improper handling of flexible end hose	Flexible end hose shall be handled properly

Nowadays, pumpable concrete is widely used due to ease of transportation and placement of concrete at any place including in high rise buildings. Also, it saves lot of manpower, lifts, etc and it enables speedy and timely completion of major pours.

8.0 SPECIAL CONCRETES:

Special concretes are different from normal concretes and these have some special/additional/different properties from normal concretes. These are used for specific applications and therefore their overall volume remains limited. It is necessary to create awareness about the application and advantages of special concretes amongst consumers/consultants for better durability, sustainability and aesthetics.

8.1 Self-Compacting Concrete (SCC):

Concrete that is able to flow and consolidate under its own weight, completely fills the formwork even in the presence of dense reinforcement, whilst maintaining homogeneity and without the need for any additional compaction is known as Self Compacting Concrete. It is used in high reinforcement congested areas, thin shells / structural members where compaction/ consolidation of concrete is difficult.

Self-compacting concrete is being widely used world over as well as in India since it was first developed during 1990s in Japan. In India, self-compacting concrete was first used in Nuclear Power Projects such as Kaiga, Kota and Tarapur. The use of self-compacting concrete in monolithic constructions using Mivan shuttering in buildings has become very common. Use of SCC provides very good surface finish and speeds up the construction. Use of SCC is increasing in different construction works due to many advantages it offers like, homogeneity, uniformity, low permeability, high durability, better surface finish and ease of placing without compaction thus reducing noise pollution.

SCC is produced, using same ingredients as that of normal concrete such as cement, mineral admixtures, fine and coarse aggregate, water and superplasticizers. To improve workability and to avoid segregation, use of Viscosity Modifying Agents (VMAs) and Air Entraining Admixtures is preferred. Also, shrinkage compensating compound may be used when used in repair works. The proportioning of SCC mix is much more scientific than that of conventional concrete mixes. SCC mix requires high powder content, lesser quantity of coarse aggregate, superplasticizers and VMA (Viscosity Modifying Agent) to give stability and fluidity to concrete mix without segregation. However, strict quality control is required during entire concrete production process and its testing for fresh as well as hardened properties. Nominal maximum size of aggregate depends on specific site conditions; usually it is limited to 20mm. Aggregate particles smaller than 0.125 mm contributes to the powder content. Water-Powder ratio shall be taken in between 0.80 to 1.10. Total Powder content may be taken as 240-350 litres (500-700 kg per cubic meter). Coarse aggregate content may be taken between 28-35 % by volume of the mix. Water content shall be kept below 180 litres/m^3. To avoid segregation limit vertical free fall of concrete to 0.5 m and horizontal flow from point of discharge to 10 m. Initial curing shall be started as soon as practically possible to avoid drying shrinkage of SCC.

Some important properties of SCC in fresh state are fluidity, deformability, filing ability and resistance to segregation. SCC mix shall maintain these properties for sufficient time period to allow transportation, placing and finishing. These properties are tested with different tests as compared with conventional concretes and these tests are mentioned in table no. 2.

Table 2: Tests to be carried out to ensure workability properties of SCC

(Reference: EFNARC Specifications and Guidelines for SCC)

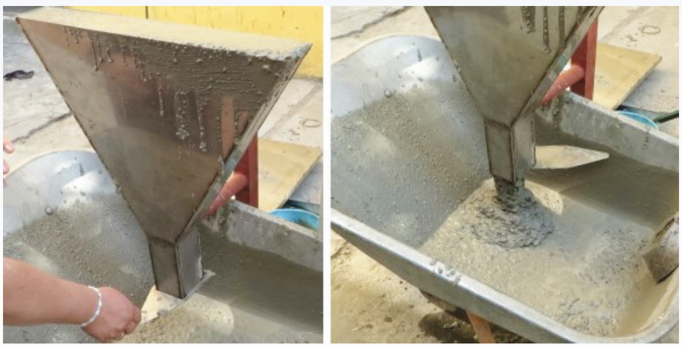
Property	Tests to be carried out
Filling (Flow) ability	Slump test, T_{500} Slump Flow time, V funnel, and Orimet
Passing ability	U Box , L Box, J Ring test and Fill Box
Resistance to segregation	V Funnel at $T_{5\ Minutes}$ and GTM Screen Stability test

For the initial mix design of SCC, all three workability parameters need to be assessed to ensure that all aspects are fulfilled. A full-scale test should be used to verify the self-compacting characteristics of the chosen design for a particular application.

When Self Compacting concretes are proposed to be used, special care needs to be taken to ensure leak proof formworks at site as this type of concrete is highly workable in nature and if due care is not taken then slurry may pass through the openings of the formwork and hence it may deteriorate the quality of concrete. Self-Compacting Concrete is costlier as compared with ordinary concrete due to high cementitious contents, superplasticizers, and use of Viscosity Modifying Agents (VMAs), leak proof formworks and requirement of skilled manpower etc., but SCC has many advantages over conventional concrete. The advantages of SCC outweigh its higher cost.

Slump flow test of SCC

T_{500} test of SCC (Time required to pass 500mm dia.)



V Funnel test of SCC

L Box test of SCC

Ring test of SCC

U Box test of SCC

8.2 Pervious Concrete:

Pervious concrete is also known as permeable or porous concrete. A concrete made up using cement, cementitious materials, coarse aggregates, water and plasticizers without fine aggregates (or with very less/negligible fraction of fine aggregates) is known as Pervious Concrete. This type of concrete allows water to pass through it and hence helps to drain off storm water through pavements/parking lots/walkways and also it helps to recharge ground water table. In Pervious concrete, frequent cleaning is required at intervals of every 6 months or 1 year as compared with normal concrete, as pores of the concrete may get choked due to entry of soil/mud during rainy season.

Pervious concrete is zero slump, open-graded material which has inter-connected pores ranging in size from 2 mm to 8 mm that allows water to pass easily. The void content can range from 18% to 35% with typical compressive strength of 2.8 MPa to 28 MPa. The drainage rate of pervious concrete will vary with aggregate size and density of the mixture. It can generally fall within the range of 80 to 130 l /min/m^2.

Pervious concrete is used for pervious pavements for parking lots, green-house floors, interior walls where better thermal insulation or acoustic absorption is required. Use of pervious concrete can be made in bridge embankment, swimming pool decks, sewage treatment plant, sludge beds and solar energy storage systems. Sufficient care is required in placing, curing and maintaining the pervious concrete in good condition.

Pervious concrete

8.3 High Volume Fly Ash Concrete (HVFAC):

A concrete made up using high volume of fly ash as a part replacement of cement is known as High Volume Fly Ash Concrete. In this type of concrete, fly ash is used in the range of 50% to 60% as part replacement of cement. The mix can be finalised after conducting trials with high volumes of fly ash and analysing the test reports for fresh and hardened properties of the concrete including durability requirements. Use of high volume of fly ash increases slump/flow of concrete, delayed setting time, and it reduces the rate gain of strength. High volume fly ash in concrete improves its compressive strength, flexural strength, split tensile strength and modulus of elasticity at a later date (56 to 90 days). Also, HVFAC requires longer curing than normal concrete. This type of concrete is most suitable in mass concrete in dams or where early strength requirement is very less and wherever we need to control heat of hydration of concrete. HVFAC has been used in India in various projects such as Bandra-Worli Sea Link, Nuclear Power Projects, Dam Projects, Highway projects, etc.

High volume fly ash concrete requires very low w/b ratio in the range of 0.26 to 0.30. To achieve workability at such low water binder ratio, high dose of superplasticizer is necessary. The quality of fly ash shall also conform to IS: 3812 Part – 1. HVFAC is very cost effective where source of fly ash is nearby, otherwise also its cost is generally lower than normal concrete of the same strength grade.

8.4 Light weight concrete:

Low density concretes are known as light weight concretes. It reduces the dead load of a structure, eases handling and placement of fresh and hardened concrete consequently accelerates the progress, having low thermal conductivity and good sound insulation properties.

Low weight concretes can be produced by using light weight aggregates (cellular, porous aggregates), by entraining air (using air entraining admixtures, gas or air bubbles) and by using no fines concrete (by omitting sand fraction from aggregates). Also, light weight concrete utilizes the industrial wastes such as fly ash, cinder slag, etc and hence helps in producing sustainable concrete.

The light weight aggregate concrete can be produced with dry density from 300 kg/m^3 upto 1840 kg/m^3. It can be divided into two types according to its application. One is partially compacted and the other is structural light weight concrete. The partially compacted light weight concrete is mainly used for precast concrete blocks or panels and for cast-in-situ, roofs and walls. The structural light weight concrete is fully compacted, similar to that of the normal reinforced concrete of conventional aggregate. It can be used with steel reinforcement and has a good bond between the steel and concrete. The shape and texture of the aggregate particles and coarse nature of the fine aggregate will produce harsh concrete mixes. The rounded and smooth surface aggregate produces good workable light weight concrete.

Light weight concrete

8.5 Heavy weight concrete:

High density concrete is known as Heavy weight concrete. It increases the dead load of the structure and helps in radiation shielding properties in Nuclear Power Plants, helps to build stable foundations for high rise buildings, retaining walls and heavy machines.

Heavy weight concretes can be produced by using heavy weight aggregates such as barite, magnetite, serpentinite, limonite, and hematite. Also density of concrete may be increased by addition of steel balls and steel fibers, etc. Density of concrete maybe increased from 3200 to 4200 kg/m^3.

The mix proportioning is an important aspect in case of heavy weight concrete because aggregate being heavy, the chances of segregation of particles are high. In order to maintain the cohesiveness of the mix and proper placeability of concrete, the paste content in the mix is maintained high by increasing the cementitious materials as well as fine aggregates. The mixing of heavy weight concrete also needs special precautions to avoid segregation by using proper dose of micro-silica and fly ash in the mix.

Heavy weight concrete

8.6 Fiber reinforced concrete:

A concrete made up with cement, fine aggregates, coarse aggregates, water and fibers is known as Fiber reinforced concrete. Various types of fibers are used such as steel fibers, polypropylene fibers, glass fibers, asbestos fibers, carbon fibers, organic fibers to improve/modify the properties of concrete to reduce the thermal and shrinkage cracks, water permeability, deflection, bleeding in concrete and to increase flexural rigidity, durability and tensile strength of the concrete. Flat/rounded shaped fibers may be used as per requirements. ISO 13270: 2013 Steel Fibers for concrete – Definitions and Specifications may be referred while using steel fibers and ASTM C1116/C1116M - Standard Specification for Fiber-Reinforced Concrete may be referred for fiber reinforced concretes.

Generally fibers are used in the ratio of 0.1 to 3% by unit volume of the concrete. Ratio of length to diameter is known as aspect ratio and usually fibers are available in the ratio of 30 to 150. The care shall be taken to ensure uniform distribution/ dispersion of fibers in the concrete mix and it should not be concentrated at one place. Fiber material shall be inert and shall not react chemically with other ingredients of the concrete. Even when steel fibers are used in the concrete, corrosion will not spread in concrete due to discontinuity of fibers in concrete mass. When fibers are used in concrete, workability reduces and skilled manpower is required to obtain good surface finish of concrete.

Fiber reinforced concrete is very useful where high abrasion of concrete surfaces is expected during the usage like, industrial floors, warehouses, railway platforms etc. The fiber reinforced concrete also helps in reducing plastic shrinkage cracks and to control the crack width in the hardened concrete. FRC increases the durability of concrete and generally recommended where constructions are required to be abrasion resistance and crack free.

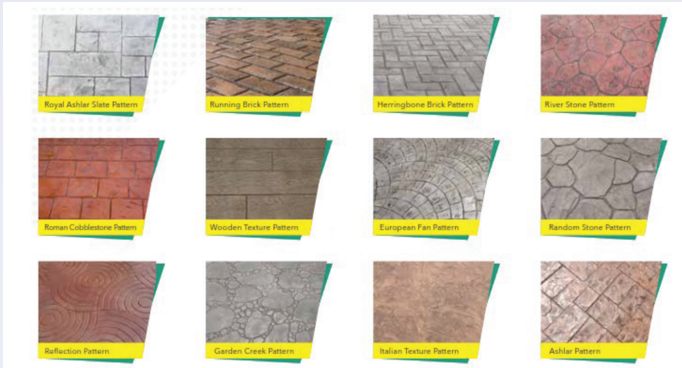
8.7 Stamped and Decorative Concrete:

Concretes are produced at RMC plants for aesthetic and decorative purposes also. Two types of concretes are very popular in this category, viz stamped concrete and coloured concrete. These concretes are used for flooring in parking lots, driveways, footpaths, around swimming pools, landscaping and similar applications.

(a) **Stamped Concrete:** Stamped concrete is decorative concrete used as alternative to tiles, granite, marble and pavers etc. Different and attractive designs and patterns and various colour combinations can be created in stamped concrete. The thickness of stamped concrete generally varies from 80 mm to 150 mm, concrete grade varies from M-25 to M-40. It is laid on well prepared sub-base and base. After laying the concrete, while it is still green (before final setting), the pigments and design/pattern are created by expert applicators/ masons on the concrete surface. The designs and patterns are cast-in-situ and have large flexibility to adopt or create any design of one's choice. Stamped concrete has following advantages.

- Customised design – Create your own or choose from existing designs.
- Strong, durable and low maintenance.
- Even and uniform surface, safe for pedestrian movement.
- Prevents growth of weeds and grass.

Some designs and patterns of stamped concrete are shown in Fig. below;



Designs / Patterns of Stamped Concrete

(b) **Coloured Concrete:** Coloured concrete having inorganic mineral pigments as colouring agents is another form of decorative concrete. It is also used for landscaping, walkways, footpaths, parking lot etc. The main difference between stamped and colour concrete is that while stamped concrete has designs/patterns, the coloured concrete has uniform coloured surface. Coloured concrete is also laid similar to stamped concrete and normally specifications are followed for different application as given below.

- Pedestrian movement, jogging and cycle track – Minimum grade M-25 and min thickness 75 mm.
- Light vehicle movement – Minimum grade M-30 and minimum thickness 100 mm.
- Heavy vehicular traffic – Minimum grade M-35/40 and minimum thickness M 150 mm.

Some figures of coloured concrete are given in Fig. below

Coloured Concrete

8.8 Temperature Controlled and Triple Blend Concrete:

Certain precautions in mass concrete (where member thickness exceeds 1 m) are necessary to avoid/control cracks through mix proportioning as well as its placing and curing to control its temperature and temperature gradient. Such concretes normally used in heavy/mass concrete works like raft foundations of tall buildings, bridge piers, abutments, retaining walls, etc. are called temperature controlled concretes.

Cement on hydration generates heat and due to this heat of hydration, the inside or core temperature in mass concrete can increase considerably. The high temperature inside and low ambient temperature outside of concrete surface will create temperature gradient. The differential temperature will cause tensile stresses and cause micro-cracks within the body of concrete and consequently affect its durability. The maximum differential temperature permissible by various codes is 20^0C The maximum temperature at core is generally limited to 70^0C to avoid delayed ettringite formation (DEF).

To control this differential temperature within 20^0C, normally following steps are taken in production of temperature controlled concrete.

- To minimize OPC content and to maximise use of supplementary cementitious materials like fly ash and ggbs, which have lesser heat of hydration.
- To cool coarse and fine aggregates (store in shaded areas and sprinkle cold water before use).
- Use triple blend mixes, i.e. OPC + Fly ash + ggbs. Such concrete mixes, when properly proportioned, produces low heat of hydration.
- Use ice flakes and chilled water to bring down the temperature of fresh concrete.
- Use insulated formwork to keep surface warm so that differential temperature between core and surface is minimised.

The use of temperature controlled and triple blend concretes is increasing due to construction of high rise buildings, long span bridges and heavy industrial structures. The use of fly ash and ggbs together to replace OPC content has been found very useful in proportioning mixes for temperature controlled concretes. Such concretes having three binding materials in the mix, viz OPC, fly ash and ggbs are called Triple Blend Concretes.

8.9 Roller Compacted Concrete:

Roller compacted concrete or RCC, is a zero slump concrete that is transported, spread and compacted using large earthmoving plants. As a consequence of application of high-capacity plant and equipment, RCC is most suited for large scale construction and mass concrete works. Since the 1980s, RCC has gained general acceptance as appropriate material for dam construction and sub-base of rigid pavements.

Roller compacted concrete is placed in layers thin enough to allow complete compaction. The optimum layer thickness ranges from 15 to 20 cm. To ensure adequate bonding between the new and old layer or at cold joint, segregation must be prevented and a high plasticity bedding mix must be used at the start of the placement. A compressive strength of about 10 MPa to 30 MPa have been obtained. The maximum size of aggregate is limited to 40 mm, shape and grading of aggregate is important to limit water requirement.

For effective consolidation, roller compacted concrete must be dry enough to support the mass of the vibrating roller, but wet enough to allow the cement paste to be evenly distributed throughout the mass during mixing and consolidation process.

The first RCC dam was taken up during 1978 and completed during 1980 in Japan. Construction of other dams using RCC quickly followed. By end of 1985, several RCC dams had been completed and by the year 2015, the number of RCC dam touched to 400 and even more.

In India Roller Compacted Concrete has been used as a base concrete in the construction of rigid pavements. RCC has been used as base course concrete in Pune - Mumbai express highway construction. In their projects the RCC was referred as "Dry Lean Concrete. The grade of concrete was M 10, thickness 15 cm. Such a concrete was thoroughly compacted by vibratory roller over which Pavement Quality Concrete (PQC) of grade M 40, 35 cm thick was laid.

Roller Compacted Concrete Dams in India

The first major application of RCC technology was adopted for the construction of Ghatghar dam in Maharashtra built by irrigation department. They built three RCC dams and it marks the first use of RCC in India. These three dams saddle, upper and lower dam design philosophy is chosen with high paste RCC using 220 kg/m^3 (88 kg Portland cement and 132 kg fly ash) cementitious material with 60% of fly ash. Details are given in the following table:

Table 3 - Features of Ghatgar RCC dam

Feature	Saddle dam	Upper dam	Lower dam
Height (m)	11.5	15.5	86
length (m)	250	451	415
Volume of RCC (m^3)	12,460	32,100	5,78,000

Encouraged by the experience and success of completing the above three dams, use of RCC will increase in India in dam and roads construction.

8.10 Concrete for Prestressed Works:

Concrete requirement of pre-stressing work is high early strength. Concrete shall attain compressive strength of 28-30 MPa within 3 days. Pre-stressing can be done only if concrete has attained this much strength. The grade of concrete for pre-stressing works shall be minimum M-35. Concrete is normally placed through pumping and compacted by needle/screed vibrators. Concrete for prestressing works require special care during cold weather as rate of gain of strength slows down. Proper care is required in mix proportioning of pre-stressed concrete to meet the site requirements under given environment and climatic conditions and of high early strength.

9.0 High Performance Concrete:

American Concrete Institute defines High Performance Concrete (HPC) as "Concrete that meets special performance and uniformity requirements that cannot always be obtained by using conventional ingredients, normal mixing procedure and typical curing practices." Some of the attributes of high performance concrete are:

- High strength
- High durability
- Long retention time
- Early strength gain
- Very high workability
- Long distance pumping
- Lower permeability
- Lower creep and shrinkage under loads and changing temperatures

HPC is designed with mineral admixtures, low w/b ratio, PC based superplasticizers, fibers and other additives.

Table 4 - Approach for Achieving Attributes of HPC

Attributes	Approach
High strength	Low w/b ratio Use of mineral admixtures, especially SF, UFS, UFFA, PCE based superplasticizers, well graded and strong aggregates.
High durability	Low w/b ratio Use of mineral admixtures Corrosion inhibitors, fibers Protective paints (ex. anti-carbonation paint)
Long retention time	Right choice of retarders and their optimum dosages High percentage of fly ash or GGBS or triple blends Agitation of concrete
Early strength gain	Right choice of admixtures (PCE based) Accelerators, only if required Higher OPC content Low w/b ratio Use of SF, UFFA, UFS
Very high workability	Right choice of admixtures (PCE based) and their optimum dosages Use of mineral admixtures, especially fly ash Use of river sand, if available Higher fines content (fine aggregates)

HPC – World record vertical pumping of 601 m with single pump (High workability)

HPC – Bandra-Worli Sea Link Project-
Highly flowable concrete with retention time of 5-6 hours
(High workability, high retention)

HPC - Hangzhou Bay Bridge, China - 36 km long bridge with predicted service life more than 100 years (High durability) (Constructed in 2007)

HPC – Achieving 25 MPa strength in 24 hours without steam curing (Very high early strength)

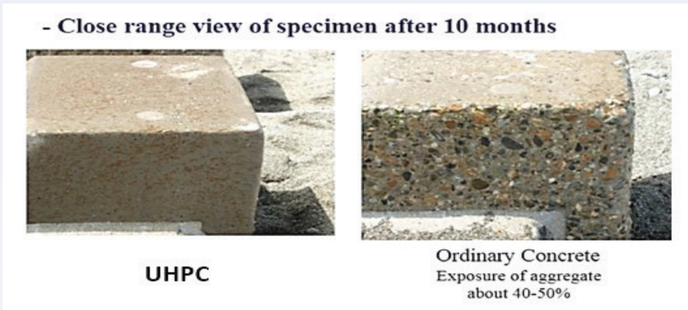
Though the initial cost of HPC is higher than that of conventional concrete but its use enhances the service life of the structure and the structures require very low maintenance that reduces service life cost.

10.0 ULTRA-HIGH PERFORMANCE CONCRETE:

Ultra-High Performance Concrete (UHPC) is a cementitious, concrete composite that has a minimum specified compressive strength of 150 MPa with maximum w/b ratio of 0.25 and specified durability, tensile ductility and toughness requirements; fibers are included in the mixture to achieve specified requirements.

Ultra-High Performance Concrete, is also known as reactive powder concrete (RPC). The material is typically formulated by combining Portland cement, mineral admixtures, reactive powders, limestone and or quartz flour, fine sand, high-range water reducers, fibers and water. The material can be formulated to provide compressive strengths in excess of 200 MPa. The use of fine materials for the matrix also provides a dense, smooth surface valued for its aesthetics and ability to closely transfer form details to the hardened surface. When combined with metal, synthetic or organic fibers it can achieve flexural strengths up to 48 MPa or greater. The mixing time of UHPC is more and to control temperature rise during mixing, chilled water is preferred.

Fiber types often used in UHPC include High Carbon Steel, PVA, Polypropylene, Nylon, Glass, Carbon, organic or a combination of these types or others. The ductile behaviour of this material is a first requirement for this concrete, with the capacity to deform and support flexural and tensile loads, even after initial cracking. The high compressive and tensile properties of UHPC also facilitate a high bond strength allowing shorter length of rebar embedment in applications such as closure pours between precast elements. Another distinguishable advantage of UHPC is its durability due to a finer, denser and discontinuous pore structure. Its dense structure reduces permeability and potential risk of corrosion of the reinforcement. Below is an image depicting two specimens, one of UHPC and one of conventional concrete, exposed to seawater in an abrasive environment for 10 months.



Durability of UHPC versus ordinary concrete

Gateway Pavilion, Washington DC, 122m x 18m, 45 mm

Due to the ultra-high strength of concrete, the overall cross section of concrete elements is much smaller and for the same bending moment capacity, the weight per metre of UHPC is very close to that of steel section. The reduction in cross section of the element reduces the overall weight of the structure making it sleek and aesthetically appealing and at the same time increasing the durability manifold.

11.0 APPLICATION OF DIFFERENT TYPES OF CONCRETE:

The various types of concrete discussed above and their preferred application are tabulated below. In addition, the composition of various types of concrete are also described in the table.

Table 4 - Types of Concrete and their Preferred Applications

Sl. No.	Types of concrete	Applications	Composition / constituent materials
Normal Grade Concrete			
i.	(M-10 to M-15)	PCC, sub-base and base of RCC works can be proportioned volumetrically	Cement + fine aggregate + coarse aggregate + water
ii.	(M-20 to M-60)	General civil construction (RCC) works in buildings, roads, bridges, water retaining structures etc.	Cement + Coarse and Fine Aggregates+ Mineral admixtures + Water + Superplasticizers
iii	High performance concrete	Bridges, industrial structures, power plants, marine structures, Nuclear plants, etc.	Cement + Fine aggregate + Coarse aggregate + Water + Corrosion inhibitor + Superplasticizers + Cementitious materials + Ultrafine Materials (All ingredients shall be of uniform consistent quality)
iv.	High strength concrete (M-65 to M-120)	High rise buildings, long span bridges, Industrial structures, power plants, pre-stressed concrete, foundations, etc.	Cement + fine aggregate + coarse aggregate + Water + Superplasticizers + Cementitious materials + Ultrafine Materials (SF/UFG/UFFA)
v.	Ultra high performance concrete	Special structures, bridges, industrial structures, marine structures, foundations, architectural and aesthetic works.	Cement + fine aggregate + water + Superplasticizers + Cementitious materials + reactive powders + Ultrafine materials + fibers
vi.	Pumpable concrete	Can be used in any type of structures	Cement + fine aggregate + coarse aggregate + water + Superplasticizers + Cementitious materials (particles finer than 300 micron shall be 450-500 kg/m^3)
Special Concrete			
i.	Self-compacting concrete	In high reinforcement congested areas/ members, thin members, inaccessible areas where consolidation/compaction of concrete cannot be done, Noise pollution is not required.	Cement + fine aggregate + coarse aggregate + water + Superplasticizers + Cementitious materials + Viscosity Modifying Admixtures (VMAs) + Air Entraining Admixtures (if required). Higher amount of fines in the range of 500-700 kg/m^3
ii.	Pervious concrete	Parking areas, Low traffic pavements, walkways, storm water management. Rain water harvesting works	Cement + fine aggregate (Negligible / Nil) + coarse aggregate + Water + Superplasticizers
iii.	High volume fly ash concrete	Sustainable concrete, Mass concrete, Lean concrete, Plum concrete, temperature controlled concrete	Cement + fine aggregate + coarse aggregate + water + Superplasticizers + High Volume Fly Ash. w/b ratio to be very low (0.25 to 0.3)
iv.	Light weight Concrete	Partition walls in high rise buildings, concrete blocks, temporary structures, situations where dead weight reduction is necessary	Cement + fine aggregate (Light weight) + coarse aggregate (Light weight / cellular / porous) + water + Superplasticizers + Inclusion of air / using air entraining admixtures / Fly ash / Cinder Slag
v.	Heavy weight Concrete	Radiation shielding in Nuclear Power Plants, Foundations, Retaining walls, machine foundations	Cement + fine aggregate (Heavy) + coarse aggregate (Heavy) + water + Superplasticizers + Steel shots + Cementitious materials

Sl. No.	Types of concrete	Applications	Composition / constituent materials
vi.	**Fiber reinforced Concrete**	Pavements, runways, shotcrete/sprayed concrete, special structures with specific requirements of flexural strength, spillways in dams, thin shell structural members, machine foundations, industrial floors, etc.	Cement + fine aggregate + coarse aggregate + water + Superplasticizers + Fibers (Steel/ Polypropylene/Glass/Asbe stos)
vii.	**Stamped and coloured concrete**	Landscaping, parking lots, footpaths, walkways, etc.	OPC + GGBS + Inorganic pigment + Admixtures + Coarse and fine aggregates + Water
viii.	**Temperature controlled concrete**	Raft foundations, pile caps, Retaining walls, bridge piers, abutments, etc. All places where mass concrete is used	OPC + Fly ash + GGBS + Admixtures + Coarse and fine aggregates + Chilled water + ice flakes
ix	**Rigid pavements and white topping**	Concrete Roads and wearing surface on flexible or rigid pavements (white topping)	OPC + Fly ash or GGBS + Admixtures + Coarse and fine aggregates + Fibers + Water
x	**Concrete for Prestressed Works**	Minimum M-35 grade and shall achieve compressive strength of 28-30 MPa within 3 days. Pre-stressing works at site or in precast yard.	OPC + Admixtures + Accelerators (if required) + Coarse and fine aggregates + Water

12.0 CONCLUSION:

Application of concrete is increasing in variety of structures. With the use of mineral and chemical admixtures, fibers and other additives, it has been possible to produce different types of concrete to meet specific requirements. It is essential that users as well consultants should be aware of the availability of different types of concrete at RMC plants in order to make best use of such concretes. The use of right type of concrete not only increases the life of the structure but it also saves effort and cost during its service life on maintenance. This bulletin is therefore published to create awareness about varieties of concrete that are easily available at RMC plants in our country.

There are many other varieties of concrete, which can be produced in RMC Plant, if so desired by the consumer. In this Bulletin, the concretes which are regularly produced by member companies of RMCMA in their plants are only covered. The new advancements in building materials and construction Technology across the world are enabling development of new varieties of concrete for sustainability, durability, aesthetics, life cycle cost and overall economy. The share of special concretes in total concrete production in India is lower as compared to other developed countries. Though variety of construction projects may be more in India as compared to other countries but due to lack of awareness the present situation exists. It is hoped that this Bulletin will help in bridging this gap and share of special concretes will increase in coming days.

ABOUT RMCMA

The Ready Mixed Concrete Manufacturer's Association (RMCMA), India is a nonprofit 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 programs for different officials working in RMC plants. RMCMA is conducting on regular basis following training programs.
   a) Concrete Technologist of India (CTI) for QC and engineering staff.
   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 officers.

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 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.
- M/s Sarvani Industries Pvt. Ltd.
- J K Lakshmi Cement Ltd.

RMCMA ASSOCIATE MEMBERS

- Sika India Pvt Ltd
- SCHWING Stetter (India) Pvt. Ltd

RMCMA

Editor - A. K. Jain, Principal Consultant - RMCMA

©RMCMA. No part of this entire publication shall be reproduced, copied and distributed in any form or by any means or stored in a data base or retrieval system without the prior written permission from RMCMA