BUILDING MATERIALS AND CONCRETE TECHNOLOGY 18CV34

UNIT II

Cement: Manufacture of Portland cement, types of cement and its Chemical composition, hydration of cement.

Aggregates: Classification of aggregates according to the source, aggregate size and shape, properties of aggregate.

Introduction to Chemical and Mineral admixtures: Super-plasticizers, Retarders, accelerators, air entraining admixtures, GGBFS, Fly ash, silica fume, metakaolin.

Case Study:

1. Field Tests on cement to determine the quality
2. Case studies on the production of mineral admixtures
3. Case study on the operation of quarry

Self-Learning topics: Methods of storing the cement

CEMENT

DEFINITION

- The material that hardens under water.
- It’s the basic component of concrete.

COMPOSITION OF CEMENT

- ✓ Lime
- ✓ Silica
- ✓ Alumina
- ✓ Iron oxide
- ✓ Magnesium Oxide
- ✓ Soda Potash
- ✓ Sulphur Trioxide

TYPES OF CEMENT

- Ordinary Portland Cement (OPC)
- Portland Pozzolana Cement
- Rapid Hardening Portland Cement
- Sulphate Resisting Portland Cement
- Portland Blast Furnace Slag Cement
- White Cement
- Oil Well Cement
- Clinker Cement
- Quick setting cement

TYPES OF CEMENT

- Coloured cement
- Air entertaining cement
- Expanding cement
- Low heat cement
- High Alumina cement
- Concrete Sleeper Grade cement
- Very High Strength Cement
- Hydrophobic Cement
- Rediset Cement

ORDINARY PORTLAND CEMENT [OPC]

- The most commonly used cement.
- It is manufactured in the form of different grades, the most common in India being Grade-53, Grade-43, and Grade-33.
- OPC is manufactured by burning siliceous materials like limestone at 1400 degree Celsius and thereafter grinding it with gypsum.
- Tata Chemicals Limited is a major producer of OPC Grade 43 and 53.

Ordinary Portland Cement-Grade 43:

- Its certified with IS 8112:1989 standards.
- Grade 43 is in high demand in India and is largely used for residential, commercial, and other building construction purposes.
- Today OPC 43 is most widely available in Gujarat through an extensive distribution network.

Ordinary Portland Cement-Grade 53:

- Its certified with IS12269:1987 standards.
- Grade 53 is known for its rich quality and is highly durable. Hence it is used for constructing bigger structures like building foundations, bridges, tall buildings, and structures designed to withstand heavy pressure.

- Ordinary Portland Cement is used for quite a wide range of applications.
- Some of the Ordinary Portland applications are in pre-stressed concrete, dry-lean mixes, durable pre-cast concrete, and ready mixes for general purposes.
- Some of the big names involved in OPC manufacture are Tata Chemicals, Ultratech Cement, and ACC cement. Ordinary Portland Cement is in great demand in India and will continue to be used in Indian infrastructural upgradation and other constructions.

PORTLAND POZZOLANA CEMENT [PPC]

- Portland Pozzolana Cement is manufactured by blending pozzolanic materials, OPC clinker, and gypsum either grinding them together or separately.
- Portland Pozzolana Cement is widely in demand for industrial and residential buildings, roads, dams, and machine foundations.
- Pozzolana is an important ingredient in PPC which is commonly used in the form of:

1. Fly ash
2. Volcanic ash
3. Silica fumes
4. Calcined clay

CLINKERS

PORTLAND POZZOLANA CEMENT [PPC]

- PPC is resistant to harsh water attacks and prevents the formation of calcium hydroxide at the time of cement setting and hydration.
- It withstands aggressive gases, thermal cracks, wet cracking, etc.
- PPC is used in heavy load infrastructure and constructions such as marine structures, hydraulic structures, mass concreting works, plastering, masonry mortars, and all applications of ordinary Portland cement.

PORTLAND POZZOLANA CEMENT [PPC]

- One of the top Indian brands of Portland Pozzolana is 'Shudh Cement' manufactured by Tata Chemicals Limited.
- Shudh cement has 5 percent of the market share and is available abundantly in Gujarat, penetrating all 3 - primary, secondary, and tertiary markets.
- Some of the other big names in the Portland Pozzolana manufacture are Ultratech, Ambuja, ACC cements, Star Cement, and Birla group.

RAPID HARDENING PORTLAND CEMENT

- Rapid Hardening Portland Cement (RHPC) is a type of cement that is used for special purposes when a faster rate of early high strength is required.
- RHPC has a higher rate of strength development than the Normal Portland Cement (NPC).
- The Rapid Hardening Portland Cement's better strength performance is achieved by increasing the refinement of the product. This is the reason that its use is increasing in India.

- Rapid Hardening Portland Cement is manufactured by fusing together limestone (which has been finely grounded) and shale, at extremely high temperatures to produce cement clinker.
- To this cement clinker, gypsum is added in small quantities and then finely grounded to produce Rapid Hardening Portland Cement.
- It is usually manufactured using the dry process technology.
- Rapid Hardening Portland Cement is used in concrete masonry manufacture, repair work which is urgent, concreting in cold weather, and in pre-cast production of concrete. Quick repairs works such as airfield and highway pavements, marine structures, and bridge decks.

- The Rapid Hardening Portland Cement should be stored in a dry place, or else its quality deteriorates due to premature carbonation and hydration.
- As the Indian cement industry produces Rapid Hardening Portland Cement in large quantities, it is able to meet the domestic demand and also export to other countries.
- The cement industry in India exports cement mainly to the West Asian countries.

The raw materials required for the manufacture of Rapid Hardening Portland Cement are:

- Limestone
- Shale
- Gypsum
- Coke

The major companies producing Rapid Hardening Portland Cement in India are:

- ACC
- Ambuja
- J K Cement
- Grasim Industries
- Indian Cement Ltd.

SULPHATE RESISTING PORTLAND CEMENT

- This a type of Portland cement in which the quantity of tricalcium aluminate is less than 5%.
- It can be used for purposes wherever Portland Pozzolana Cement, Slag Cement, and Ordinary Portland Cement are used.
- The use of Portland Sulphate Resisting Cement has proved beneficial, particularly in conditions where there is a risk of damage to the concrete from sulphate attack.
- The use of Sulphate Resisting Portland Cement is recommended in places where the concrete is in contact with the soil, ground water, exposed to seacoast, and sea water.

- In conditions, where the concrete is exposed to attack from sulphates that are present in excessive amounts, which damage the structure.
- The Sulphate Resisting Portland Cement should be kept in a place which is dry otherwise through premature hydration and carbonation the quality of cement deteriorates.
- The cement industry in India manufactures Sulphate Resisting Portland Cement in large quantities so that it is able to meet the domestic demand and also export to other countries as well.
- The Indian cement industry exports cement chiefly to the West Asian countries.

The various uses of Sulphate Resisting Portland Cement are:

- ✓ Underground and basements structures
- ✓ Works in coastal areas
- ✓ Piles and foundations
- ✓ Water and sewage treatment plants
- ✓ Sugar, chemical, and fertilizers factories
- ✓ Petrochemical and food processing industries

The raw materials required for the production of Sulphate Resisting Portland Cement are:

Coke Limestone Iron Ore Iron Scrap

The major companies manufacturing Sulphate Resisting Portland Cement in India are:

- ACC
- J K Cement
- Indian Cement Ltd
- Grasim Industries
- Ambuja

PORTLAND BLAST FURNACE SLAG CEMENT

- The Slag Cement of the Portland Blast Furnace is a type of cement that is hydraulic and is manufactured in a blast furnace where iron ore is reduced to iron.
- The molten slag which is tapped is quickly drenched with water, dried, and then grounded to a fine powder.
- This fine powder that is produced is commonly known as the Portland Blast Furnace Slag Cement.
- The manufacture of Portland Blast Furnace Slag Cement requires 75% less energy than that needed for the production of the Portland cement.

- The low cost of production of Portland Blast Furnace Slag Cement makes it cheaper than Portland cement.
- It is for this reason that in recent years, the sales of Portland Blast Furnace Slag Cement have increased.
- Portland Blast Furnace Slag Cement has a typical light color and an easier 'finish' ability.
- Its concrete workability is better and it has a higher flexural and compressive strength.
- It is resistant to chemicals and also has more hardened consistency.
- Thus Portland Blast Furnace Slag Cement is used in the construction of dams, bridges, building complexes, and pipes.

The various raw materials required for the production of Portland Blast Furnace Slag Cement are:

- Limestone
- Iron Ore
- Iron Scrap
- Coke

The major companies producing Portland Blast Furnace Slag Cement in India are:

- J K Cement
- Grasim Industries and Ultra Tech
- ACC
- India Cement Ltd
- Ambuja Cement Ltd

The major countries where Portland Blast Furnace Slag Cement is exported from India are:

- South Africa
- UAE
- Sri Lanka
- Nepal
- Bangladesh
- Australia
- Doha-Qatar

WHITE CEMENT

- White Cement has registered growth in production and sale in India in the last few years.
- The White Cement sector has been growing at the rate of 11% per year.
- White Cement is much like the ordinary grey cement except that it is white in color.
- In order to get this color of the White Cement, its method of production is different from that of the ordinary cement.
- This modification in its production method makes White Cement far more expensive than the ordinary cement.

- The production of White Cement requires exact standards and so it is a product which is used for specialized purposes.
- White Cement is produced at temperatures around 1450-1500 degrees Celsius. This temperature is more than what is required by the ordinary grey cement.
- As more energy is required during the manufacture of White Cement, it goes to make it more expensive than the ordinary grey cement.
- White Cement is used in architectural projects the use of white cement has been specified.

- It is used in decorative works and also wherever vibrant colors are desired.
- White Cement is used to fill up the gaps between marble and ceramic tiles for a smoother and more beautiful finish.

The various raw materials required for the production of White Cement are:

- Limestone
- Sand
- Iron Ore
- Nickel
- Titanium
- Chromium
- Vanadium

The major companies producing White Cement in India are:

- ACC
- J K Cement
- Gujarat Ambuja Cement Ltd.
- India Cement Ltd.
- Grasim Industries and Ultra Tech

The major countries where White Cement is exported from India are:

- UAE
- Australia
- South Africa
- Sri Lanka
- Doha- Qatar
- Bangladesh
- Nepal

OIL WELL CEMENT

- Oil Well Cement as the name suggests, is used for the grouting of the oil wells, also known as the cementing of the oil wells.
- This is done for both, the off-shore and on-shore oil wells.
- As the number of oil wells in India is increasing steadily, the sales of Oil Well Cement have also increased.
- This has boosted the Indian cement industry to a large extent.

- Oil Well Cement is manufactured from the clinker of Portland cement and also from cements that have been hydraulically blended.
- Can resist high pressure as well as very high temperatures.
- Sets very slowly because it has organic 'retarders' which prevent it from setting too fast.
- It is due to all these characteristics that it is used in the building of the oil wells where the pressure and the temperature is around 500 degrees Fahrenheit.

- There are 3 grades of Oil Well Cements.
- Grades O is ordinary and is used commonly;
- HSR is high sulphate resistant
- MSR is moderate sulphate resistant.
- Each grade is used where it is applicable at a particular range of oil well sulphate environments, temperatures, pressures, and depths.
- This proved to be very beneficial for the petroleum industry due to its characteristics.
- It is due to the Oil Well Cement that the oil wells function properly.

The various raw materials required for the production of Oil Well Cement are:

- Limestone
- Iron Ore
- Coke
- Iron Scrap

The major companies manufacturing Oil Well Cement in India are:

- ACC
- Gujarat Ambuja
- India Cement Ltd.
- Grasim Industries and Ultra Tech
- J K Cement

CLINKER CEMENT

- The cement industry in India is highly technologically intensive and as a result, the quality of clinker cement that is produced in India is of a very high grade and is often considered among the best in the world.
- The production of Clinker Cement requires a lot of energy because it needs to be manufactured at the temperature of around 1400-1450 degree Celsius.
- Clinker Cement in India is produced in such large quantities that it is able to meet the domestic demand and is also exported.

- In 2001- 2002, 1.76 million tons of clinker cement were exported.
- In 2002- 2003, that figure stood at 3.45 million tons, and
- In 2003- 2004 5.64 million tons of clinker cement was exported from India.
- Clinker Cement is usually ground with calcium sulphate so that it it becomes Portland cement. It is also ground with other ingredients to produce Pozzolanic Cement, Blast Furnace Slag Cement, and Silica Fume Cement.
- If Clinker Cement is kept in a dry condition, it can be stored for a long period of time without any loss of its quality. It is for this reason that Clinker Cement is preferred.

The various raw materials required for the production of Clinker Cement are:

- Iron Ore
- Bauxite
- Clay
- Limestone
- Quartz

The major companies producing Clinker Cement in India are:

- ACC
- Ambuja Cement Ltd.
- JK Cements
- Grasim Industries and Ultra Tech
- India Cements Ltd

QUICK SETTING CEMENT

- The cement sets very early.
- Gypsum is reduced at the time of clinker grinding.
- Used mostly for underwater construction as it reduces pumping time.

COLOURED CEMENT

- For manufacturing various colored cements, either white cement or grey Portland cement is used as a base.
- The use of white cement as a base is costly. With the use of grey cement, only red or brown cement can be produced.
- Coloured cement consists of Portland cement with 5-10% of pigment.
- The pigment cannot be satisfactorily distributed throughout the cement by mixing, and hence, it is usual to grind the cement & pigment together.
- Chromium oxide – green colour
- Cobalt – blue colour
- Iron oxide – brown colour

The raw materials used for white cement are:

- High purity limestone (96% $CaCO_3$ & less than 0.07% iron oxide)
- China clay (0.72-0.8% of iron oxide, silica sand, fluorspar as flux and selenite as retarder)
- Grey colour of OPC is due to the iron oxide present.

AIR ENTRAINING CEMENT

- **Air entrainment** is the intentional creation of tiny air bubbles in concrete.
- The bubbles are introduced into the concrete by the addition to the mix of an air entraining agent, a surfactant (surface-active substance, a type of chemical that includes detergents).
- The air bubbles are created during mixing of the plastic (flowable, not hardened) concrete, and most of them survive to be part of the hardened concrete.
- The primary purpose of air entrainment is to increase the durability of the hardened concrete, especially in climates subject to freeze-thaw.
- To increase workability of the concrete while in a plastic state.

EXPANSIVE CEMENT

- Expanding cement is cement to which an expansive component is added.
- It is a true expanding cement, since the expansion occurs after the cement has set.
- As expansion occurs, the cement is restrained by the formation and by the casing so that expansion produces a self-stress in the cement., and an expanded fit against the formation so that superior bonding is obtained.

LOW HEAT CEMENT

- It is well known that hydration of cement is an exothermic action which produces large quantity of heat during hydration.
- Formation of cracks in large body of concrete due to heat of hydration has focused the attention of the concrete technologists to produce a kind of cement which produces less heat or the same amount of heat, at a low rate during the hydration process.
- Cement having this property was developed in U.S.A. during 1930 for use in mass concrete construction, such as dams, where temperature rise by the heat of hydration can become excessively large.

- A low-heat evolution is achieved by reducing the contents of C_3S and C_3A which are the compounds evolving the maximum heat of hydration and increasing C_2S.
- A reduction of temperature will retard the chemical action of hardening and so further restrict the rate of evolution of heat. The rate of evolution of heat will, therefore, be less and evolution of heat will extend over a longer period.
- The specific surface of low heat cement as found out by air-permeability method is not less than 3200 sq. cm/gm.
- The 7 days strength of low heat cement is not less than 16 MPa in contrast to 22 MPa in the case of ordinary Portland cement.

HIGH ALUMINA CEMENT

- Calcium aluminate Cement is a rapid-hardening cement made by fusing at 1,500° to 1,600° C a mixture of bauxite and limestone in a reverberatory or electric furnace or in a rotary kiln.
- Suitable bauxites contain 50 to 60 percent alumina, up to 25 percent iron oxide, not more than 5 percent silica, and 10 to 30 percent water of hydration.

CONCRETE SLEEPER GRADE CEMENT

- It is manufactured as per IRC requirements.
- It is finely grounded with high tricalcium silicate content to develop high early strength required for manufacture of concrete sleepers for railway tracks.
- Can also be used for high strength structures.
- Its negligible chloride content protects against corrosion
- High fineness enhances workability with proper water cement ratio, ensuring water cement ratio, density, compactness, smooth, waterproofed and durable concrete.
- Lower percentage of C3A resulting in low heat of hydration, reduces cracks and hence leading to greater durability.

HYDROPHOBIC CEMENT

- Hydrophobic cement is obtained by grinding ordinary Portland cement clinker with water repellant film-forming substance such as oleic acid, and stearic acid.
- The water-repellant film formed around each grain of cement, reduces the rate of deterioration of the cement during long storage, transport, or under unfavourable conditions.
- The film is broken out when the cement and aggregate are mixed together at the mixer exposing the cement particles for normal hydration.
- The film forming water-repellant material will entrain certain amount of air in the body of the concrete which incidentally will improve the workability of concrete.

- Some places get plenty of rainfall in the rainy season and have high humidity in other seasons. The transportation and storage of cement in such places cause deterioration in the quality of cement. In such far off places with poor communication system, cement requires to be stored for long time.
- Ordinary cement gets deteriorated and loses some if its strength, whereas the hydrophobic cement which does not lose strength is an answer for such situations.
- The properties of hydrophobic cement is nearly the same as that ordinary Portland cement except that it entrains a small quantity of air bubbles.

- The hydrophobic cement is made actually from ordinary Portland cement clinker.
- The cement particle is sprayed in one direction and coated with a very fine film of water repellant material which protects them from the bad effect of moisture during storage and transportation.
- The cost of this cement is nominally higher than ordinary Portland cement

REDISET CEMENT

- Acclerating the setting and hardening of concrete by the use of admixtures is a common knowledge.
- Calcium chloride, lignosulfonates, and cellulose products form the base of some of admixtures.
- The limitations on the use of admixtures and the factors influencing the end properties are also fairly well known.
- High alumina cement, though good for early strengths, shows retrogression of strength when exposed to hot and humid conditions.
- A new product was needed for use in the precast concrete industry, for rapid repairs of concrete roads and pavements, and slip-forming.

PHYSICAL CHARACTERISTICS OF VARIOUS TYPES OF CEMENT

Sr. No	Type of Cement	Finess 3 2 / kg Min	Soundness By		Setting Time Min.		Compressve Strengt(Mp)			
			Lecchatelier (%) Max.	Autoclave (%) Max.	Initial (mts) Min.	Final (mts) Min	1 Days	3 Days	7 Days	28 Day
1	33 Grade OPC (IS 269-1989)	225	10	0.8	30	600	NS	16	22	33
2	43 Grade OPC (IS 8112-1989	225	10	0.8	30	600	NS	23	33	43
3	53 Grade OPC (IS 12269-1987)	225	10	0.8	30	600	16	27	37	53
4	Sulphate Resisting Cement (IS 12330-1988)	225	10	0.8	30	600	NS	10	16	33
5	Portland Pozzolana Cement-Part 1 (IS 1489-1991)	300	10	0.8	30	600	NS	16	22	33
6	Rapid Hardening Cement (IS 8041-1990)	325	10	0.8	30	600	NS	27	NS	NS
7	Portlanf Slag Cement (IS 455-1989)	225	10	0.8	30	600	NS	16	22	33
8	High Alumina Cement (IS 6452-1989)	225	5	NS	30	600	30	35	NS	NS
9	Super Sulphated Cement (IS 6909-1990)	400	5	NS	30	600	NS	15	22	30
10	Low Heat Portland Cement (IS 12600-1987)	325	10	0.8	60	600	NS	10	16	35
11	Masonry Cement (IS 3466-1987)	*	10	1.0	90	1440	NS	NS	2.50	5.0
12	53-S (IS 12269-1987)	370	5	0.8	60	600	NS	NS	37.5	NS

COMPOSITION OF CEMENT

- Lime
- Silica
- Alumina
- Iron oxide
- Magnesium Oxide
- Soda Potash
- Sulphur Trioxide

TYPICAL CONSTITUENTS OF PORTLAND CEMENT

Cement	Mass %
Calcium Oxide, CaO	60-67%
Silicon Dioxide, SiO_2	17-25%
Aluminum Oxide, Al_2O_3	3-8%
Ferric Oxide, Fe_2O_3	0.5-6%
Sulfate	1.3-3.0%

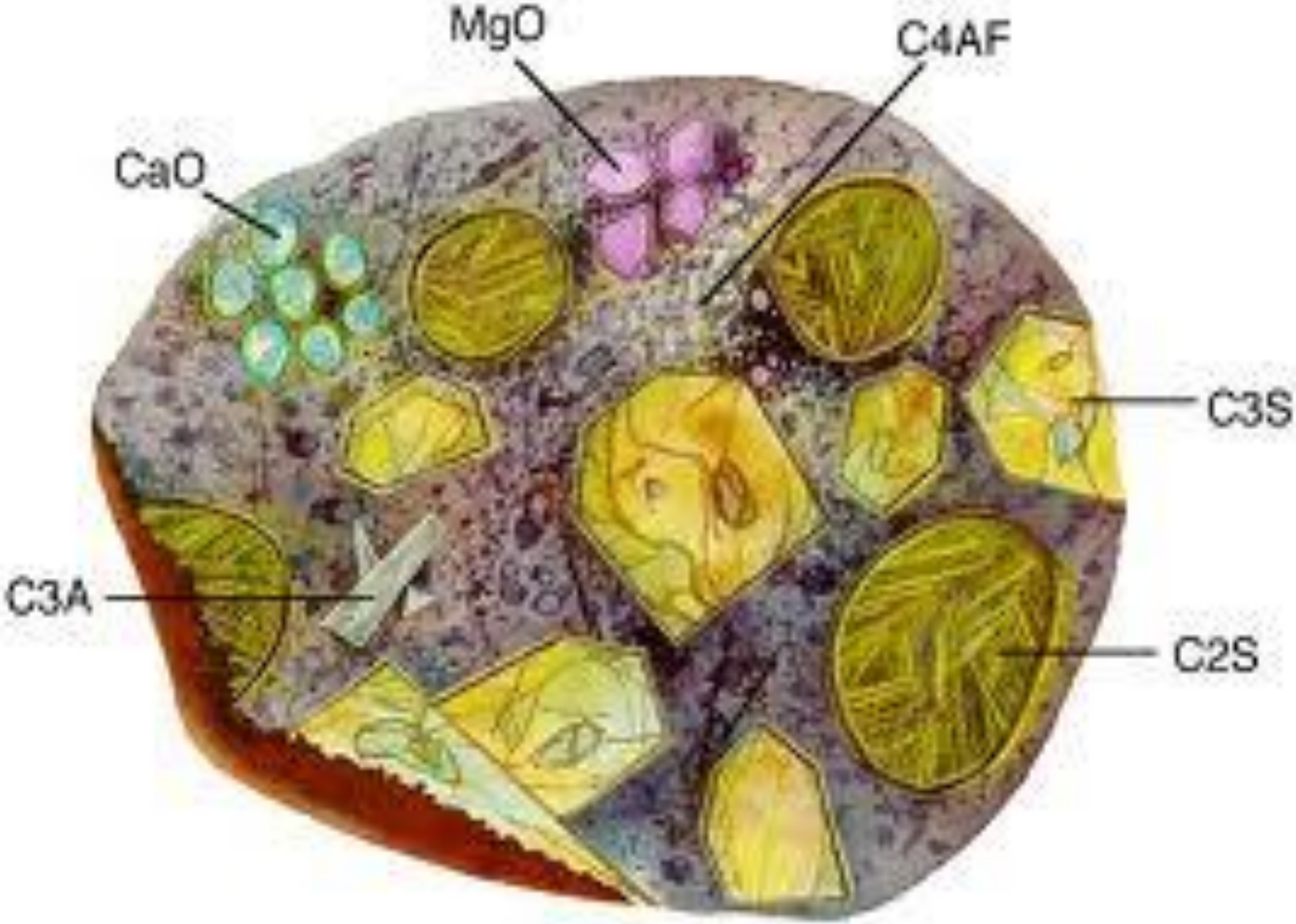
CHEMICAL COMPOSITION

Portland cement is made up of four main compounds:

- TriCalcium Silicate ($3CaO \cdot SiO_2$) – C_3S
- DiCalcium Silicate ($2CaO \cdot SiO_2$) - C_2S
- TriCalcium Aluminate ($3CaO \cdot Al_2O_3$) - C_3A and
- Tetra-Calcium AluminoFerrite ($4CaO \cdot Al_2O_3Fe_2O_3$) - C_4AF
- In an abbreviated notation differing from the normal atomic symbols, these compounds are designated as C_3S, C_2S, C_3A, and C_4AF, where C stands for calcium oxide (lime), S for silica, A for alumina, and F for iron oxide.
- Small amounts of uncombined lime and magnesia also are present, along with alkalies and minor amounts of other elements. The composition ranges of various kinds of Portland cement are shown in the table.

BOGUE'S COMPOUNDS

BOGUE'S COMPOUNDS	MASS IN %
TriCalcium Silicate $3CaO \cdot SiO_2$	54.1%
DiCalcium Silicate $2CaO \cdot SiO_2$	16.6%
TriCalcium Aluminate $3CaO \cdot Al_2O_3$	10.8%
TetraCalcium AluminoFerrite $4CaO \cdot Al_2O_3 . Fe_2O_3$	9.1%


MgO
C4AF
CaO
C3S
C3A
C2S

HYDRATION OF CEMENT

- When Portland cement is mixed with water its chemical compound constituents undergo a series of chemical reactions that cause it to harden. This chemical reaction with water is called "hydration".
- Each one of these reactions occurs at a different time and rate. Together, the results of these reactions determine how Portland cement hardens and gains strength.
- Hydration starts as soon as the cement and water are mixed.

- The rate of hydration and the heat liberated by the reaction of each compound is different.
- Each compound produces different products when it hydrates.
- TriCalcium Silicate (C_3S) Hydrates and hardens rapidly and is largely responsible for initial set and early strength. Portland cements with higher percentages of C_3S will exhibit higher early strength.

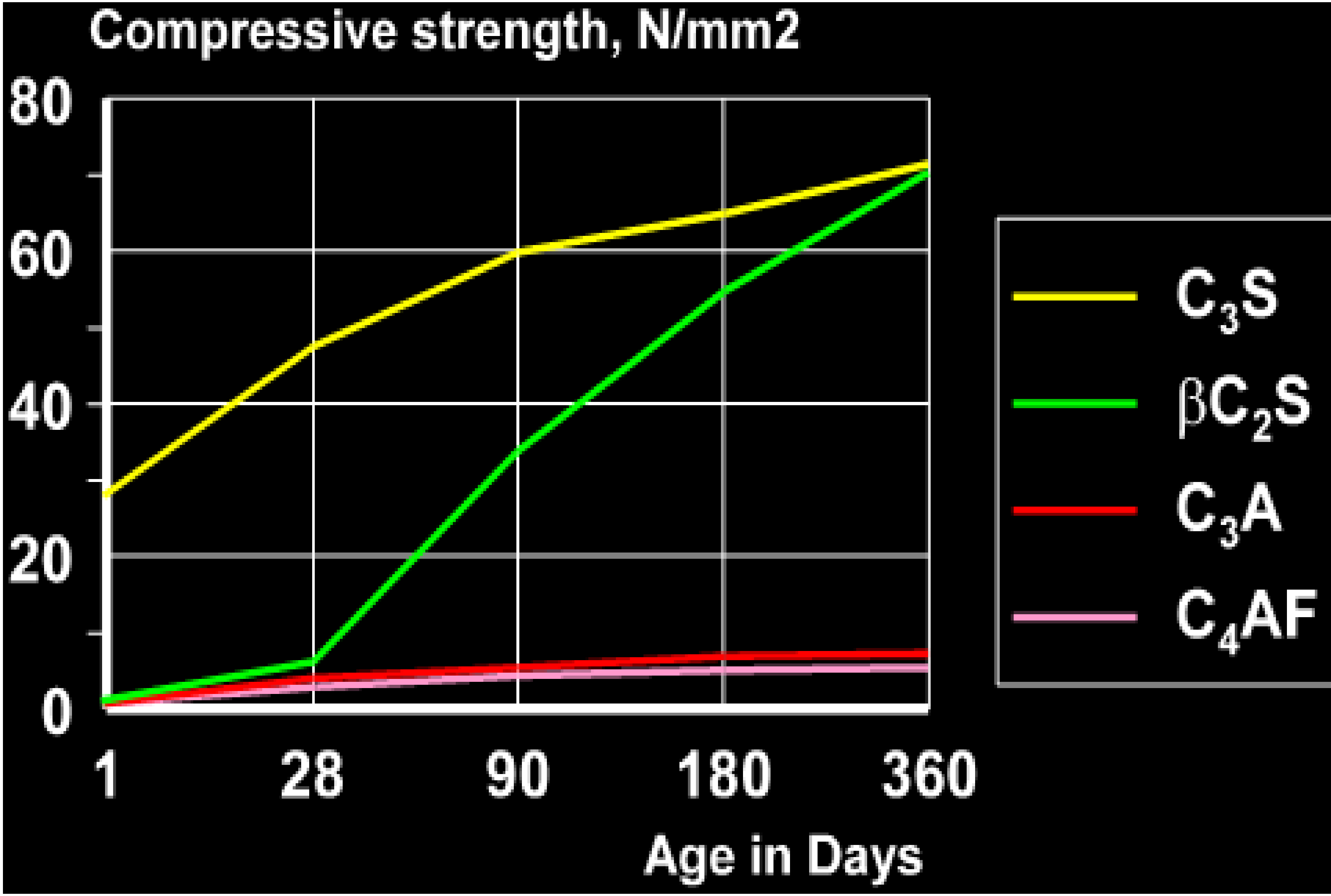
- Tricalcium aluminate (C_3A) Hydrates and hardens the quickest. Liberates a large amount of heat almost immediately and contributes somewhat to early strength.
- Gypsum is added to Portland cement to retard C_3A hydration. Without gypsum, C_3A hydration would cause Portland cement to set almost immediately after adding water.

- DiCalcium Silicate (C_2S) hydrates and hardens slowly and is largely responsible for strength increase beyond one week.
- TetraCalcium AluminoFerrite (C_4AF) hydrates rapidly but contributes very little to strength. Its use allows lower kiln temperatures in Portland cement manufacturing.
- Most Portland cement color effects are due to C_4AF

CHARACTERISTICS OF HYDRATION OF THE CEMENT COMPOUNDS

Compounds	Reaction Rate	Strength	Heat Liberation
C_3S	Moderate	High	High
C_2S	Slow	Low initially, high later	Low
C_3A	Fast	Low	Very high
C_4AF	Moderate	Low	Moderate

STRENGTH GAIN OF CEMENT PHASES



HEAT OF HYDRATION

- The heat of hydration is the heat generated when water and Portland cement react. Heat of hydration is most influenced by the proportion of C_3S and C_3A in the cement, but is also influenced by water-cement ratio, fineness and curing temperature. As each one of these factors is increased, heat of hydration increases.
- For usual range of Portland cements, about one-half of the total heat is liberated between 1 and 3 days, about three-quarters in 7 days, and nearly 90 percent in 6 months.
- The heat of hydration depends on the chemical composition of cement.

CHEMICAL COMPOSITION

The various tests are carried out to determine the chemical constituents of cement. Following are the chemical requirements of ordinary cement as per BIS 269-1975 :

(a) Ratio of percentage of alumina to that of iron oxide should not be less than 0.66.

(b) Ratio of percentage of lime to those of alumina, iron oxide and silica should not be less than 0.66 and it should not be greater than 1.02, when calculated by the following formula.

$$\frac{CaO - 0.7 \cdot SO_3}{2.8\ SiO_2 + 1.2\ Al_2O_3 + 0.65\ Fe_2O_3}$$

(c) The total loss on ignition should not be greater than 4 %.

(d) The total Sulphur content is calculated as SO_3 and it should not be greater than 2.75 %.

(e) The weight of insoluble residue should not be greater than 1.50 %.

(f) The weight of magnesia should not exceed 5 %.

TYPES OF CEMENT

There are two main types of cements:

- Portland cements
- Non Portland cements

NON PORTLAND CEMENTS

- The non Portland cement is a high resistance, sustainable cement with the addition of raw materials such as: Calcium SulfoAluminate, Alkali alumino silicates and certain Hydrocarbons.

GEOPOLYMER CEMENT

The Geopolymer cements are a mixture of water soluble alkali metal silicates and aluminosilicate mineral powders such as metakaolin and fly ash.

SLAG-LIME CEMENT

The slag lime cements contain blast furnace slag and is activated by the addition of alkalis. Lime is also used in their making.

MANUFACTURE PROCESS OF CEMENT

Main ingredients used are:

1.Limestone-calcium

2.Clay-Silica and alumina

3.Quarrying

Modern Day Portland Cement Ingredients

MANUFACTURE OF CEMENT

There are four stages in the manufacture of Portland Cement:

- Crushing and grinding the raw materials.
- Blending the materials in the correct proportions.
- Burning the prepared mix in a Rotary kiln and
- Grinding the burned product, known as “clinker,” together with some 5 percent of gypsum (to control the time of set of the cement).
- The three processes of manufacture are known as the wet, dry, and semidry processes.

CRUSHING AND GRINDING

- All except soft materials are first crushed, often in two stages, and then ground, usually in a rotating, cylindrical ball, or tube mills containing a charge of steel grinding balls.
- This grinding is done wet or dry, depending on the process in use, but for dry grinding the raw materials first may need to be dried in cylindrical, rotary dryers.
- Soft materials are broken down by vigorous stirring with water in wash mills, producing a fine slurry, which is passed through screens to remove oversize particles.

BLENDING

- In the dry process these mixes are stored in silos; slurry tanks are used in the wet process.
- Thorough mixing of the dry materials in the silos is ensured by agitation and vigorous circulation induced by compressed air.
- In the wet process the slurry tanks are stirred by mechanical means or compressed air or both.

BURNING

- The earliest kilns in which cement was burned in batches were bottle kilns, followed by chamber kilns and then by continuous shaft kilns, nowdays rotary kiln is used.
- These Rotary kilns—up to 200 metres (660 feet) long and six metres in diameter in wet process plants but shorter for the dry process—consist of a steel, cylindrical shell lined with refractory materials.
- The raw material feed, introduced at the upper end, moves slowly down the kiln to the lower or firing end.

- The fuel for firing may be pulverized coal, oil, or natural gas injected through a pipe.
- The temperature at the firing end ranges from about 1,350 to 1,550 °C (2,460 to 2,820 °F), depending on the raw materials being burned.
- The burned product emerges from the kiln as small nodules of clinker.
- These pass into coolers, where the heat is transferred to incoming air and the product cooled. The clinker may be immediately ground to cement or stored in stockpiles for later use.

ROTARY KILN

ROTARY KILN & GRINDING MILL

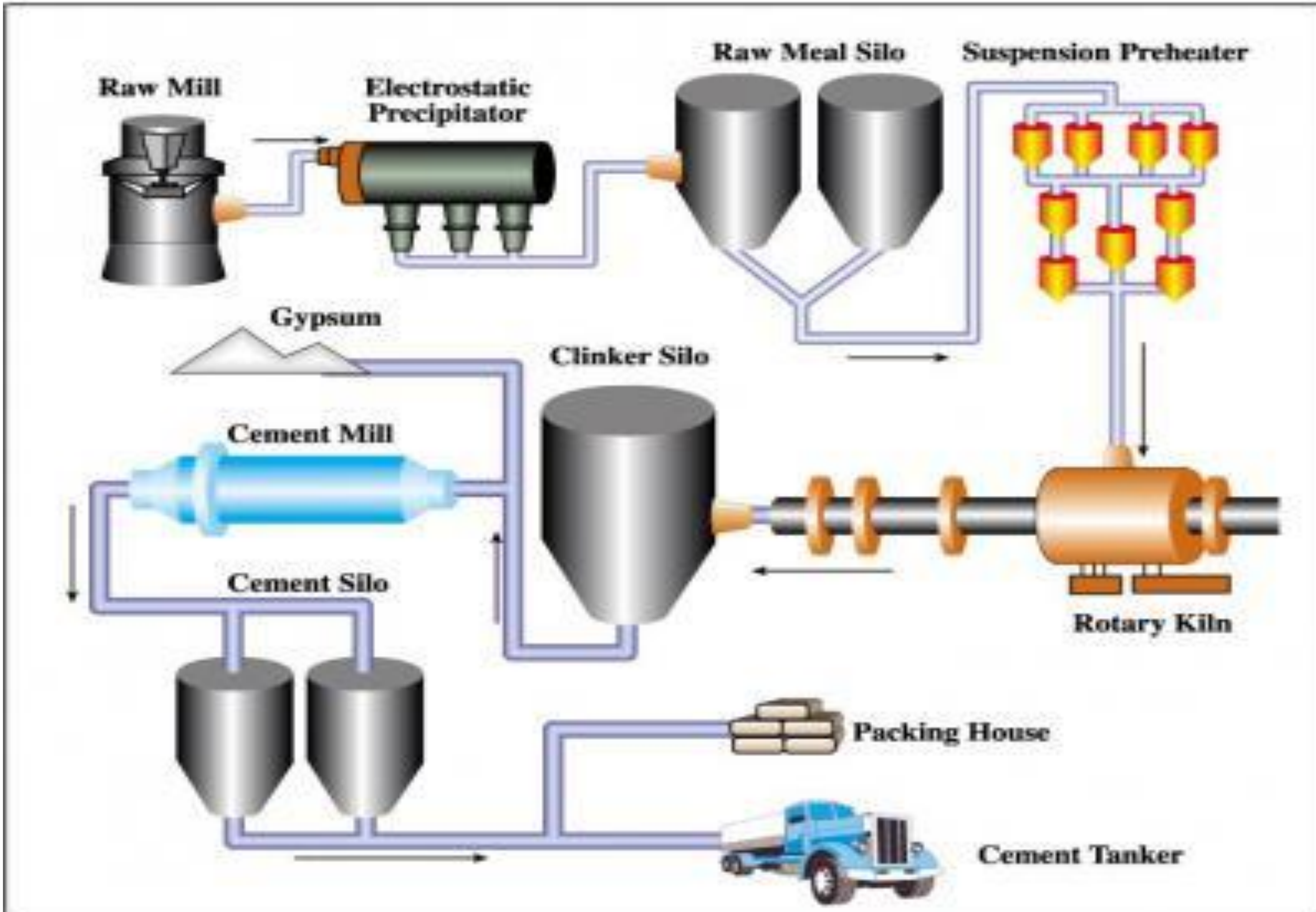
PORTLAND CEMENT CLINKER

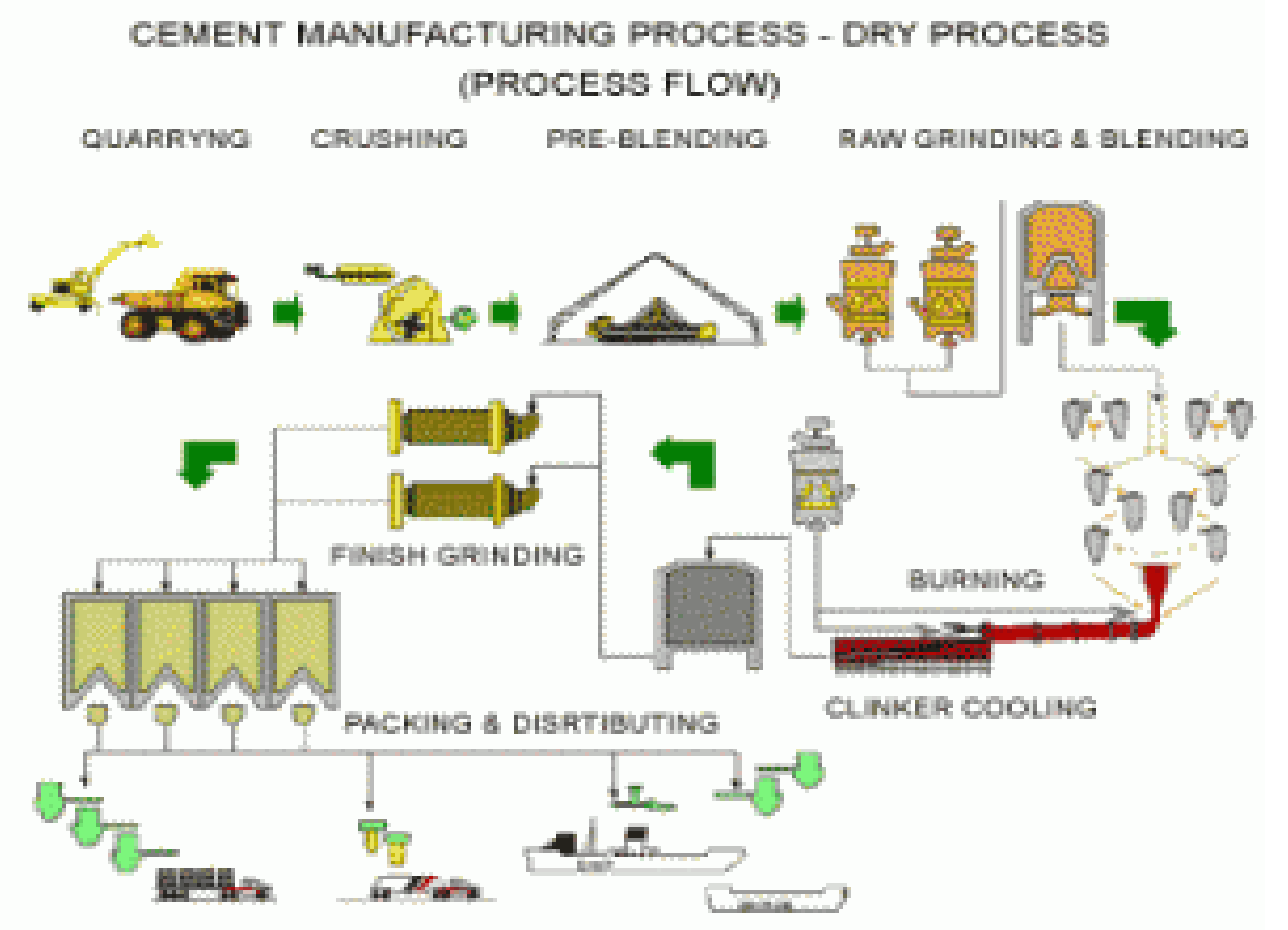
GRINDING

- The clinker and the required amount of gypsum are ground to a fine powder in horizontal mills similar to those used for grinding the raw materials.
- Finished cement is pumped pneumatically to storage silos from which it is drawn for packing in paper bags or for dispatch in bulk containers.

GYPSUM

Cement Production Process

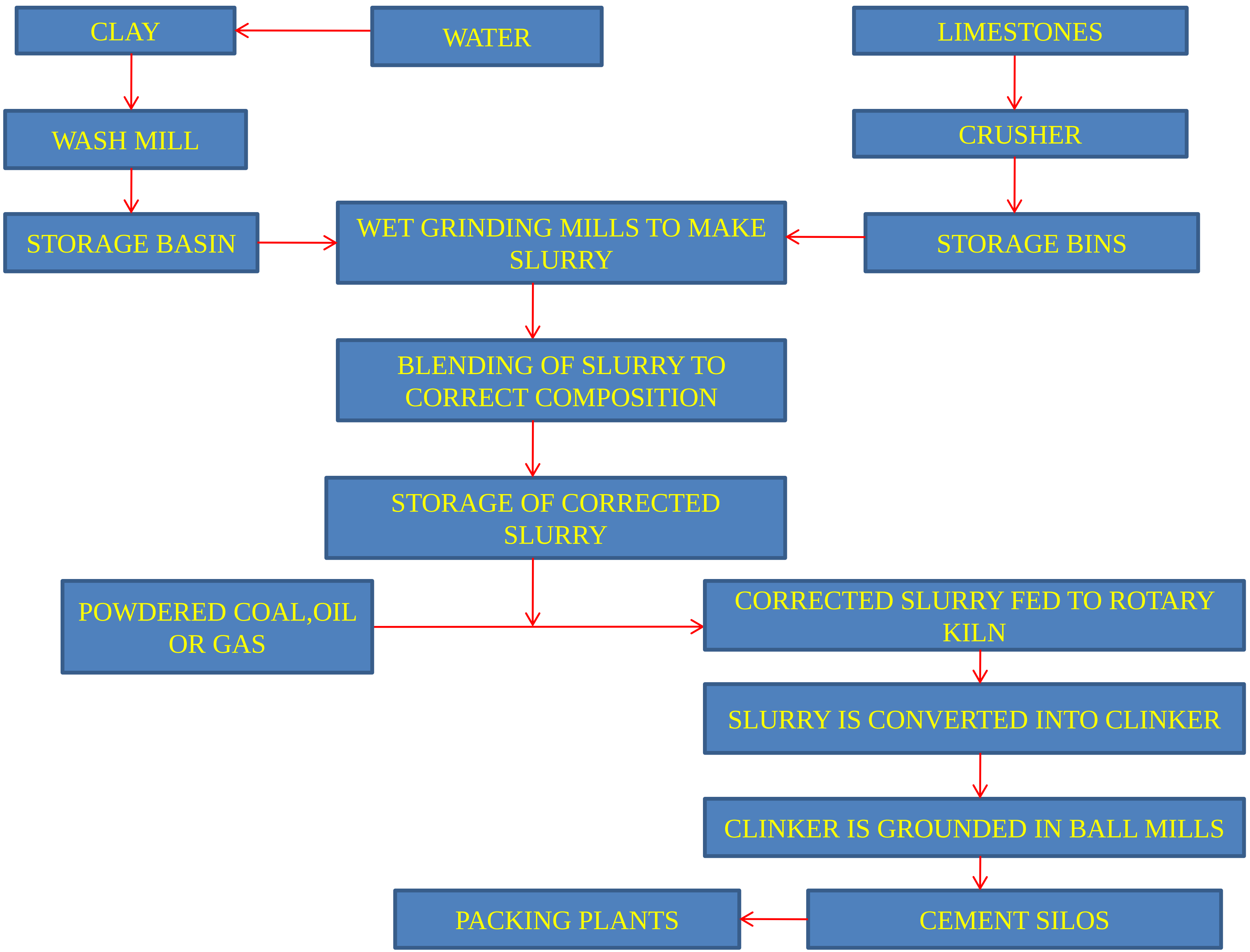



CEMENT MANUFACTURING PROCESS - DRY PROCESS
(PROCESS FLOW)
QUARRYNG
CRUSHING
PRE-BLENDING
RAW GRINDING & BLENDING
FINISH GRINDING
BURNING
CLINKER COOLING
PACKING & DISRTIBUTING

DRY PROCESS

- In dry process, the raw material are crushed dry and fed in correct proportion into a grinding mill where they are dried and reduced to fine powder.
- Dry powder called **RAW MEAL** is further blended and corrected to right composition and mixed by blended compressed air.
- The blended meal is further sieved and fed into rotating disc called granulator.
- A quantity of water about 2 percent by weight is added to make the blended meal into pellets.
- This is done to permit air flow for exchange of heat for further chemical reaction and conversion of the same into the clinker further to the grinding to obtain fine powder substance called cement powder.

WET PROCESS FOR MANUFACTURE OF OPC



WET PROCESS

- In wet process, the limestone is brought from quarry and then crushed to smaller fragment. Then it is taken to ball mill where it is mixed with clay and later grounded to form slurry when water is added.
- Slurry consist of water content of 35 to 50%.
- Slurry is pumped to slurry tank where it is kept in an agitated condition by providing compressed air at bottom to prevent setting of limestone and clay particles.
- Slurry is taken to rotary kiln. Rotary kiln is an important component in cement factory. It is thick steel cylinder of diameter 3m to 8m lined with refractory material. Slurry undergoes chemical reaction when heated at high temperature of about 1500^0C

- Some material gets fused. Lime, silica and alumina gets recombined. The fused mass turns into nodular form of size 3mm to 20mm known as clinker. The clinker is stored in bins or silos
- Later clinkers are cooled and again grounded in ball mill with addition of 3% to 5% of gypsum in order to control the setting of cement
- Ball mills have many compartments which have hardened steel balls
- Particles are crushed to required fineness and stored in storage bins

TESTING OF PORTLAND CEMENT

- To know the quality of a Portland cement, it should be tested before its use is recommended for any important engineering work. Care should be taken to collect the sample of cement.
- The properties of concrete mainly depend upon the quantity of cement used. To know the quality of Portland cement it should be tested before its use for any important engineering work.
- Testing of cement can be done by two ways.

(a) Field testing and

(b) Laboratory testing

FIELD TESTS

The following are the field tests on cement :

- ✓ The colour of the cement should be uniform. It should be grey colour with a light greenish shade.
- ✓ The cement should be free from any hard lumps. Such lumps are formed by the absorption of moisture from the atmosphere. Any bag of cement containing such lumps should be rejected.
- ✓ The cement should feel smooth when touched or rubbed in between fingers. If it is felt rough, it indicates adulteration with sand.

FIELD TESTS

- ✓ If hand is inserted in a bag of cement or heap of cement, it should feel cool and not warm.
- ✓ If a small quantity of cement is thrown in a bucket of water, the particles should float for sometime before it sink.
- ✓ A thick paste of cement with water is made on a piece of glass plate and it is kept under water for 24 hours. It should set and not crack.
- ✓ A block of cement 25 mm × 25 mm and 200 mm long is prepared and it is immersed for 7 days in water. It is then placed on supports 15cm apart and it is loaded with a weight of about 34 kg. The block should not show signs of failure.

LABORATORY TESTS

For examining the suitability of cement the following laboratory tests are usually performed:

1. Chemical composition
2. Fineness
3. Standard Consistency
4. Setting time
5. Soundness test
6. Compressive strength

AGGREGATES

AGGREGATE CLASSIFICATION

SIZE

Fine Aggregate and Coarse Aggregate

SPECIFIC GRAVITY

Light Weight, Normal Weight and Heavy Weight Aggregates.

AVAILABILITY

Natural Gravel and Crushed Aggregates.

SHAPE

Round, Cubical, Angular, Elongated and Flaky Aggregates.

TEXTURE

Smooth, Granular, Crystalline, honeycombed and Porous.

AGGREGATE CLASSIFICATION - SIZE

COARSE AGGREGATE

- Gravel and crushed stone
- >4.75 mm
- Typically between 9.5 and 37.5 mm.

FINE AGGREGATE

- Sand and/or crushed stone
- < 4.75 mm
- F.A. content usually 30% to 45% by mass or volume of total aggregate.

AGGREGATE CLASSIFICATION - SPECIFIC GRAVITY

LIGHTWEIGHT AGGREGATE

- Shale
- Clay
- Slate
- Slag

Produce structural lightweight concrete 1350 to 1850 kg/m3

- Pumice
- Scoria
- Perlite
- Vermiculite
- Diatomite

Produce lightweight insulating concrete— 250 to 1450 kg/m3

AGGREGATE CLASSIFICATION - SPECIFIC GRAVITY

NORMAL WEIGHT AGGREGATE

Most common aggregates

- Sand
- Gravel
- Crushed stone

Produce normal-weight concrete 2200 to 2400 kg/m3

AGGREGATE CLASSIFICATION - SPECIFIC GRAVITY

HEAVY WEIGHT AGGREGATES

- Barite
- Limonite
- Magnetite
- Ilmenite
- Hematite
- Iron
- Steel punchings or shot

Produce high-density concrete up to 6400 kg/m3

Used for Radiation Shielding

GRADING OF AGGREGATES

- Grading is the particle-size distribution of an aggregate as determined by a sieve analysis using wire mesh sieves with square openings. As per IS:2386(Part-1)
- Fine aggregate 6 standard sieves with openings from 150 µm to 4.75 mm.
- Coarse aggregates sieves with openings from 4.75mm to 80mm.

GRADATION (GRAIN SIZE ANALYSIS)

- Grain size distribution for concrete mixes that will provide a dense strong mixture.
- Ensure that the voids between the larger particles are filled with medium particles.
- The remaining voids are filled with still smaller particles until the smallest voids are filled with a small amount of fines.

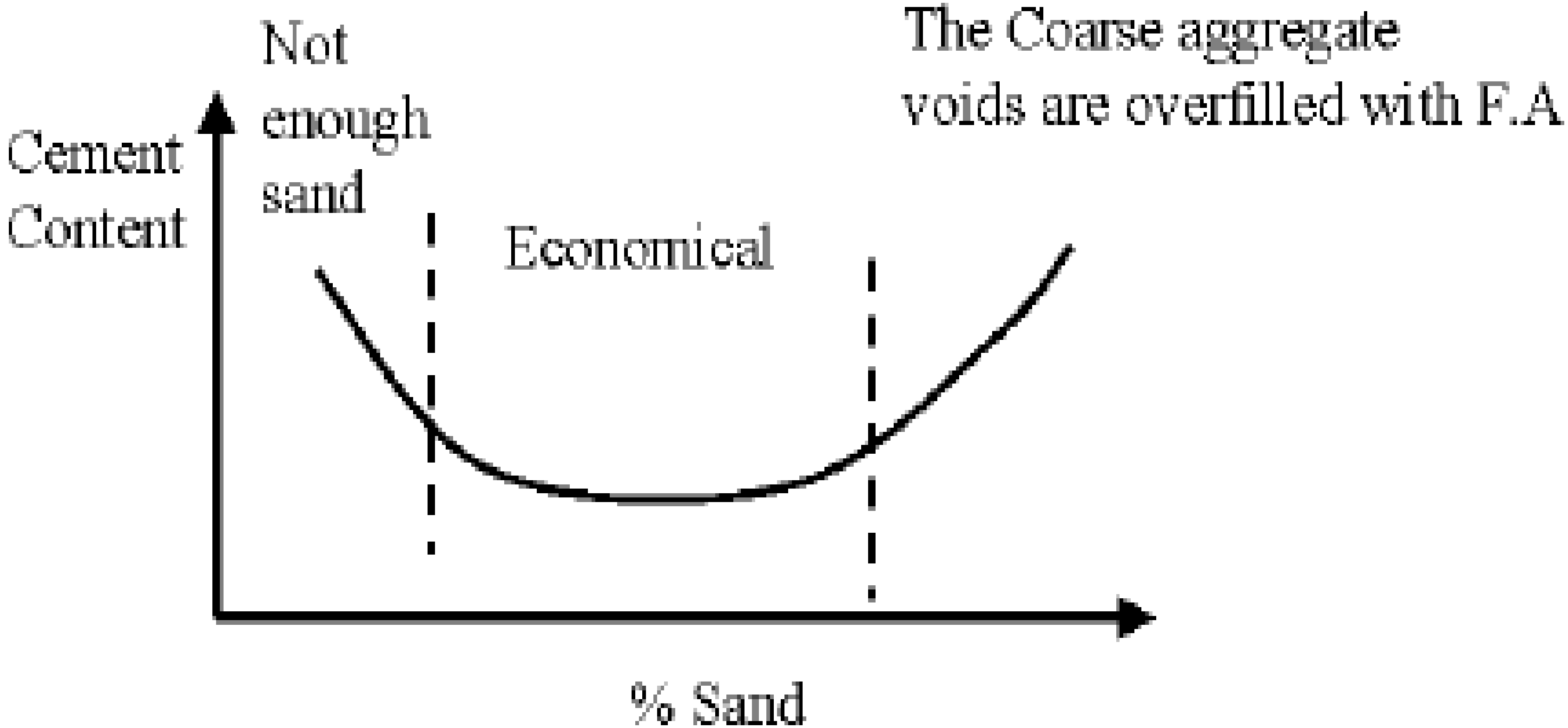
GOOD GRADATION

- Concrete with good gradation will have fewer voids to be filled with cement paste (economical mix)
- Concrete with good gradation will have fewer voids for water to permeate (durability)

Particle size distribution affects:

- Workability
- Mix proportioning
- Freeze-thaw resistance (durability)

Significance of Grading



Fine-Aggregate Grading Limits
IS -383

IS Sieve Designation	Percentage passing by weight Grading			
	Zone-I (Coarse Sand)	Zone-II Most Suitable/Desirable	Zone-III	Zone-IV (Fine Sand)
10mm	100	100	100	100
4.75mm	90-100	90-100	90-100	95-100
2.36mm	60-95	75-100	85-100	95-100
1.18mm	30-70	55-90	75-100	90-100
600µm	15-34	35-59	60-79	80-100
300µm	5-20	8-30	12-40	15-50
150µm	0-10	0-10	0-10	0-15
Fineness Modulus	4.0-2.71	3.37-2.10	2.78-1.71	2.25-1.35

- The percentage passing **600µm sieve will decide the zone of the sand.**
- Zone-I Coarse Sand
- Zone-II
- Zone-III
- Zone-IV Fine Sand

FINENESS MODULUS (FM)

- The results of aggregate sieve analysis is expressed by a number called Fineness Modulus.
- It is obtained by adding the sum of the cumulative percentages by mass of a sample aggregate retained on each of a specified series of sieves and dividing the sum by 100.

The specified sieves are

- 150 μm
- 300 μm
- 600 μm
- 1.18 mm
- 2.36 mm
- 4.75 mm
- 9.5 mm
- 19.0 mm
- 37.5 mm
- 75 mm
- 150 mm.

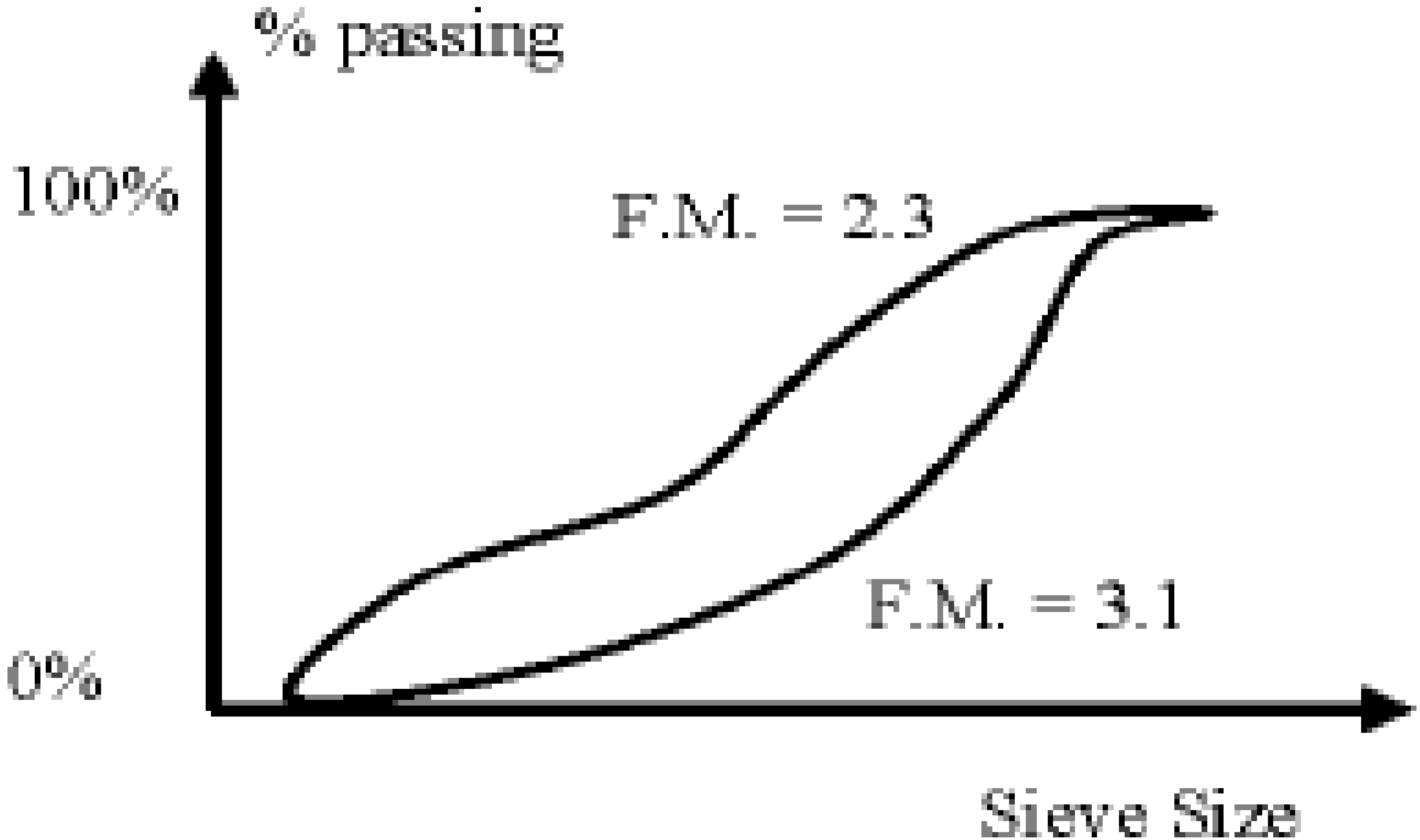
- Index of fineness of an aggregate.
- The fineness modulus of the fine aggregate is required for mix design since sand gradation has the largest effect on workability. A fine sand (low FM) has much higher effect paste requirements for good workability.
- The FM of the coarse aggregate is not required for mix design purposes.

Results of Sieve Analysis and calculation of FM of Sand

Sieve size	Percentage of individual fraction retained, by mass	Percentage passing, by mass	Cumulative percentage retained, by mass
10 mm	0	100	0
4.75 mm	2	98	2
2.36 mm	13	85	15
1.18 mm	20	65	35
600 µm	20	45	55
300 µm	24	21	79
150 µm	18	3	97
Pan	3	0	—
Total	100		283

Fineness modulus = 283 ÷ 100 = 2.83

- Note: The higher the FM, the coarser the aggregate.
- It is important to note that the fineness modulus is just one number which only characterizes the average size of the aggregate, and different grading may have the same fineness modulus.



For concrete sand, FM range is 2.3 to 3.1

FINE AGGREGATE EFFECTS ON CONCRETE

Oversanded (More than required sand)

- – Over cohesive mix.
- – Water reducers may be less effective.
- – Air entrainment may be more effective.

Undersanded (deficit of sand)

- – Prone to bleed and segregation.
- – May get high levels of water reduction.
- – Air entrainers may be less effective.

Sand grading

- – gap graded or single sized may enhance bleed and segregation. Air entrainment may help fill the gaps.

Coarse aggregate

- – Poor grading may give a harsh mix at low workabilities and segregation at high workabilities.
- – Effect on admixtures is small.
- – Elongated or flaky aggregates may cause workability difficulties .

NOMINAL MAXIMUM SIZE OF AGGREGATE

Size should not exceed

- 1/5 of the narrowest dimension between sides of forms.
- 3/4 clear spacing between rebars and between rebars and the form.
- 1/3 depth of slabs.
- Higher maximum aggregate size lowers paste requirements, increases strength and reduces w/c ratio.
- Excessively large aggregates reduce strength due to reduced surface area for bonding.

IN GENERAL THE GRADING AND MAXIMUM SIZE OF AGGREGATE AFFECTS

- Relative aggregate proportions (i.e. FA/CA ratios)
- Cement and water requirements
- Workability and pumpability of fresh concrete: very coarse sands and coarse aggregate can produce harsh, unworkable mixes
- Uniformity of concrete from batch to batch
- Porosity, shrinkage, and durability of hardened concrete
- Economy in concrete production: very fine sands are often uneconomical

MOISTURE IN AGGREGATES

Aggregates have two types of moisture:

- Absorbed moisture – retained in pores
- Surface moisture – water attached to surface

Aggregates have four moisture states:

- Oven dry: all moisture removed
- Air dry: internal pores partially full & surface dry
- Saturated-surface dry: pores full & surface moisture removed
- Wet: pores full and surface film

Flaky Aggregates

ADMIXTURES

Fig. 6-1. Liquid admixtures, from left to right: antiwashout admixture, shrinkage reducer, water reducer, foaming agent, corrosion inhibitor, and air-entraining admixture. (69795)

DEFINITION

- Admixtures are chemical/mineral substances (other than fine and coarse aggregates, cement, or water), which are added in small amounts just before or during the mixing stage to concrete products.
- They can also be blended during the grinding stage of cement manufacturing.

Admixtures can be classified by function as follows:

- Air-entraining admixtures [Air Entrainers]
- Water-reducing admixtures [Water Reducers]
- Plasticizers
- Accelerating admixtures [Accelerators]
- Retarding admixtures [Retarders]
- Hydration-control admixtures

- Corrosion inhibitors
- Shrinkage reducers
- Alkali-silica reactivity inhibitors
- Colouring admixtures
- Miscellaneous admixtures such workability, bonding, damp proofing, permeability reducing, grouting, gas-forming, and pumping admixtures

Table 6-1. Concrete Admixtures by Classification

Type of admixture	Desired effect	Material
Accelerators (ASTM C 494 and AASHTO M 194, Type C)	Accelerate setting and early-strength development	Calcium chloride (ASTM D 98 and AASHTO M 144) Triethanolamine, sodium thiocyanate, calcium formate, calcium nitrite, calcium nitrate
Air detrainers	Decrease air content	Tributyl phosphate, dibutyl phthalate, octyl alcohol, water-insoluble esters of carbonic and boric acid, silicones
Air-entraining admixtures (ASTM C 260 and AASHTO M 154)	Improve durability in freeze-thaw, deicers, sulfate, and alkali-reactive environments Improve workability	Salts of wood resins (Vinsol resin), some synthetic detergents, salts of sulfonated lignin, salts of petroleum acids, salts of proteinaceous material, fatty and resinous acids and their salts, alkylbenzene sulfonates, salts of sulfonated hydrocarbons
Alkali-aggregate reactivity inhibitors	Reduce alkali-aggregate reactivity expansion	Barium salts, lithium nitrate, lithium carbonate, lithium hydroxide
Antiwashout admixtures	Cohesive concrete for underwater placements	Cellulose, acrylic polymer
Bonding admixtures	Increase bond strength	Polyvinyl chloride, polyvinyl acetate, acrylics, butadiene-styrene copolymers
Coloring admixtures (ASTM C 979)	Colored concrete	Modified carbon black, iron oxide, phthalocyanine, umber, chromium oxide, titanium oxide, cobalt blue
Corrosion inhibitors	Reduce steel corrosion activity in a chloride-laden environment	Calcium nitrite, sodium nitrite, sodium benzoate, certain phosphates or fluosilicates, fluoaluminates, ester amines
Dampproofing admixtures	Retard moisture penetration into dry concrete	Soaps of calcium or ammonium stearate or oleate Butyl stearate Petroleum products
Foaming agents	Produce lightweight, foamed concrete with low density	Cationic and anionic surfactants Hydrolized protein
Fungicides, germicides, and insecticides	Inhibit or control bacterial and fungal growth	Polyhalogenated phenols Dieldrin emulsions Copper compounds
Gas formers	Cause expansion before setting	Aluminum powder
Grouting admixtures	Adjust grout properties for specific applications	See Air-entraining admixtures, Accelerators, Retarders, and Water reducers
Hydration control admixtures	Suspend and reactivate cement hydration with stabilizer and activator	Carboxylic acids Phosphorus-containing organic acid salts
Permeability reducers	Decrease permeability	Latex Calcium stearate
Pumping aids	Improve pumpability	Organic and synthetic polymers Organic flocculents Organic emulsions of paraffin, coal tar, asphalt, acrylics Bentonite and pyrogenic silicas Hydrated lime (ASTM C 141)
Retarders (ASTM C 494 and AASHTO M 194, Type B)	Retard setting time	Lignin Borax Sugars Tartaric acid and salts
Shrinkage reducers	Reduce drying shrinkage	Polyoxyalkylene alkyl ether Propylene glycol
Superplasticizers* (ASTM C 1017, Type 1)	Increase flowability of concrete Reduce water-cement ratio	Sulfonated melamine formaldehyde condensates Sulfonated naphthalene formaldehyde condensates Lignosulfonates Polycarboxylates

Table 6-1. **Concrete Admixtures by Classification (Continued)**

Type of admixture	Desired effect	Material
Superplasticizer* and retarder (ASTM C 1017, Type 2)	Increase flowability with retarded set Reduce water–cement ratio	See superplasticizers and also water reducers
Water reducer (ASTM C 494 and AASHTO M 194, Type A)	Reduce water content at least 5%	Lignosulfonates Hydroxylated carboxylic acids Carbohydrates (Also tend to retard set so accelerator is often added)
Water reducer and accelerator (ASTM C 494 and AASHTO M 194, Type E)	Reduce water content (minimum 5%) and accelerate set	See water reducer, Type A (accelerator is added)
Water reducer and retarder (ASTM C 494 and AASHTO M 194, Type D)	Reduce water content (minimum 5%) and retard set	See water reducer, Type A (retarder is added)
Water reducer—high range (ASTM C 494 and AASHTO M 194, Type F)	Reduce water content (minimum 12%)	See superplasticizers
Water reducer—high range—and retarder (ASTM C 494 and AASHTO M 194, Type G)	Reduce water content (minimum 12%) and retard set	See superplasticizers and also water reducers
Water reducer—mid range	Reduce water content (between 6 and 12%) without retarding	Lignosulfonates Polycarboxylates

* Superplasticizers are also referred to as high-range water reducers or plasticizers. These admixtures often meet both ASTM C 494 (AASHTO M 194) and ASTM C 1017 specifications.

USES OF ADMIXTURES

- To reduce the cost of concrete construction
- To achieve certain properties in concrete more effectively than by other means
- To maintain the quality of concrete during the stages of mixing, transporting, placing, and curing in adverse weather conditions
- To overcome certain emergencies during concreting operations

AIR-ENTRAINING ADMIXTURES

- To purposely introduce and stabilize microscopic air bubbles in concrete.
- Air-entrainment will dramatically improve the durability of concrete exposed to cycles of freezing and thawing.
- Entrained air greatly improves concrete's resistance to surface scaling caused by chemicals.

Scaled concrete surface resulting from lack of air entrainment, and poor finishing and curing practices

- The primary ingredients used in air-entraining admixtures are salts of wood resin (Vinsol resin), synthetic detergents, salts of petroleum acids, etc.

WATER-REDUCING ADMIXTURES

- To reduce the quantity of mixing water required to produce concrete of a certain slump, reduce water-cementing materials ratio, reduce cement content.
- Typical water reducers reduce the water content by approximately 5% to 10%.
- Materials:
  - Lignosulfonates.
  - Carbohydrates.
  - Hydroxylated carboxylic acids.

WATER-REDUCING ADMIXTURES

The effectiveness of water reducers on concrete is a function of their chemical composition, concrete temperature, cement composition and fineness, cement content, and the presence of other admixtures.

SUPERPLASTICIZERS
(HIGH-RANGE WATER REDUCERS)

- These admixtures are added to concrete with a low-to-normal slump and water-cementing materials ratio to make high-slump flowing concrete.
- Flowing concrete is a highly fluid but workable concrete that can be placed with little or no vibration or compaction while still remaining essentially free of excessive bleeding or segregation.

SUPERPLASTICIZERS (HIGH-RANGE WATER REDUCERS)

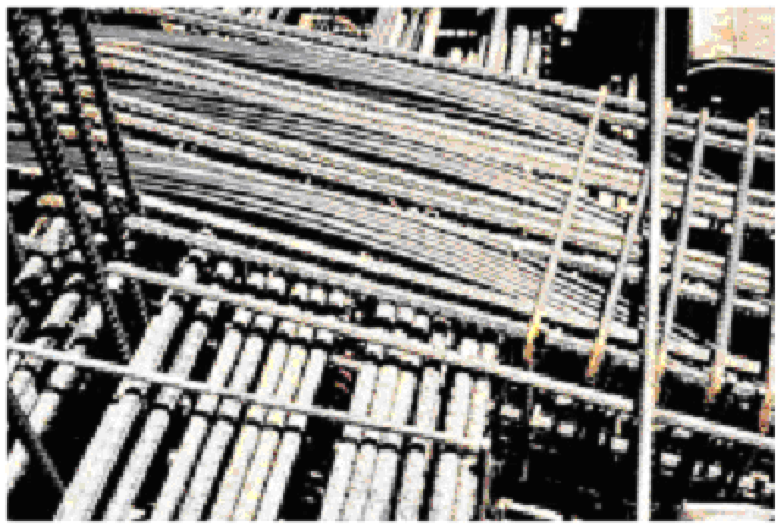
Applications where flowing concrete is used:

1. Thin-section placements
2. Areas of closely spaced and congested reinforcing steel
3. Pumped concrete to reduce pump pressure, thereby increasing lift and distance capacity
4. Areas where conventional consolidation methods are impractical or can not be used
5. To reduce handling costs.

FLOWABLE CONCRETE WITH HIGH SLUMP

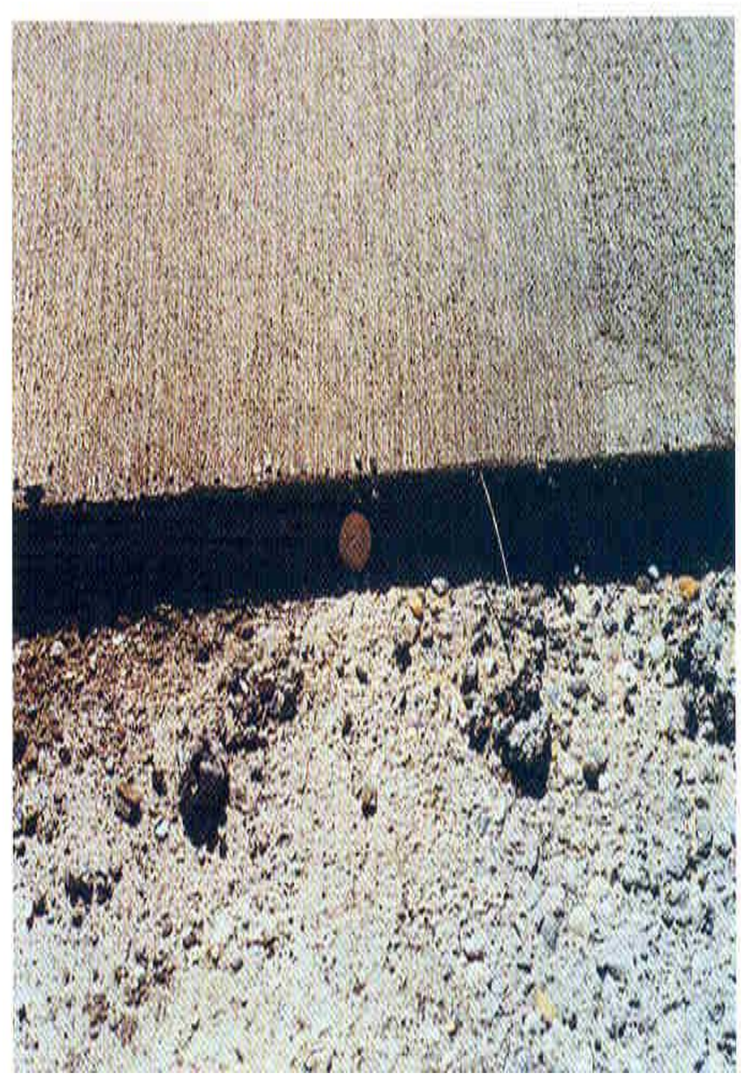
IS EASILY PLACED

EVEN IN AREAS OF HEAVY REINFORCING STEEL CONGESTION



- Low w/c ratio concrete with low chloride permeability easily made with high-range water reducers is ideal for bridge decks

- Plasticized, flowing concrete is easily placed in thin sections



SUPERPLASTICIZERS (HIGH-RANGE WATER REDUCERS)

Typical superplasticizers include:

- ✓ Sulfonated melamine formaldehyde condensates.
- ✓ Sulfonated naphthalene formaldehyde condensate.
- ✓ Lignosulfonates.
- ✓ Polycarboxylates.

SUPERPLASTICIZERS (HIGH-RANGE WATER REDUCERS)

- Bleed significantly less that control concretes of equally high slump and higher water content.
- High-slump, low-water-content, plasticized concrete has less drying shrinkage than a high-slump, high-water-content conventional concrete.
- Has similar or higher drying shrinkage than conventional low-slump, low-water-content concrete.
- The effectiveness of the plasticizer is increased with an increase in amount of cement and fines in the concrete.

RETARDING ADMIXTURES

- To retard the rate of setting of concrete at high temperatures of fresh concrete (30°C or more).
- One of the most practical methods of counteracting this effect is to reduce the temperature of the concrete by cooling the mixing water or the aggregates.
- Retarders do not decrease the initial temperature of concrete.
- The bleeding rate and capacity of plastic concrete is increased with retarders.

The typical materials used as retarders are:

- Lignin
- Borax
- Sugars
- Tartaric acid and salts

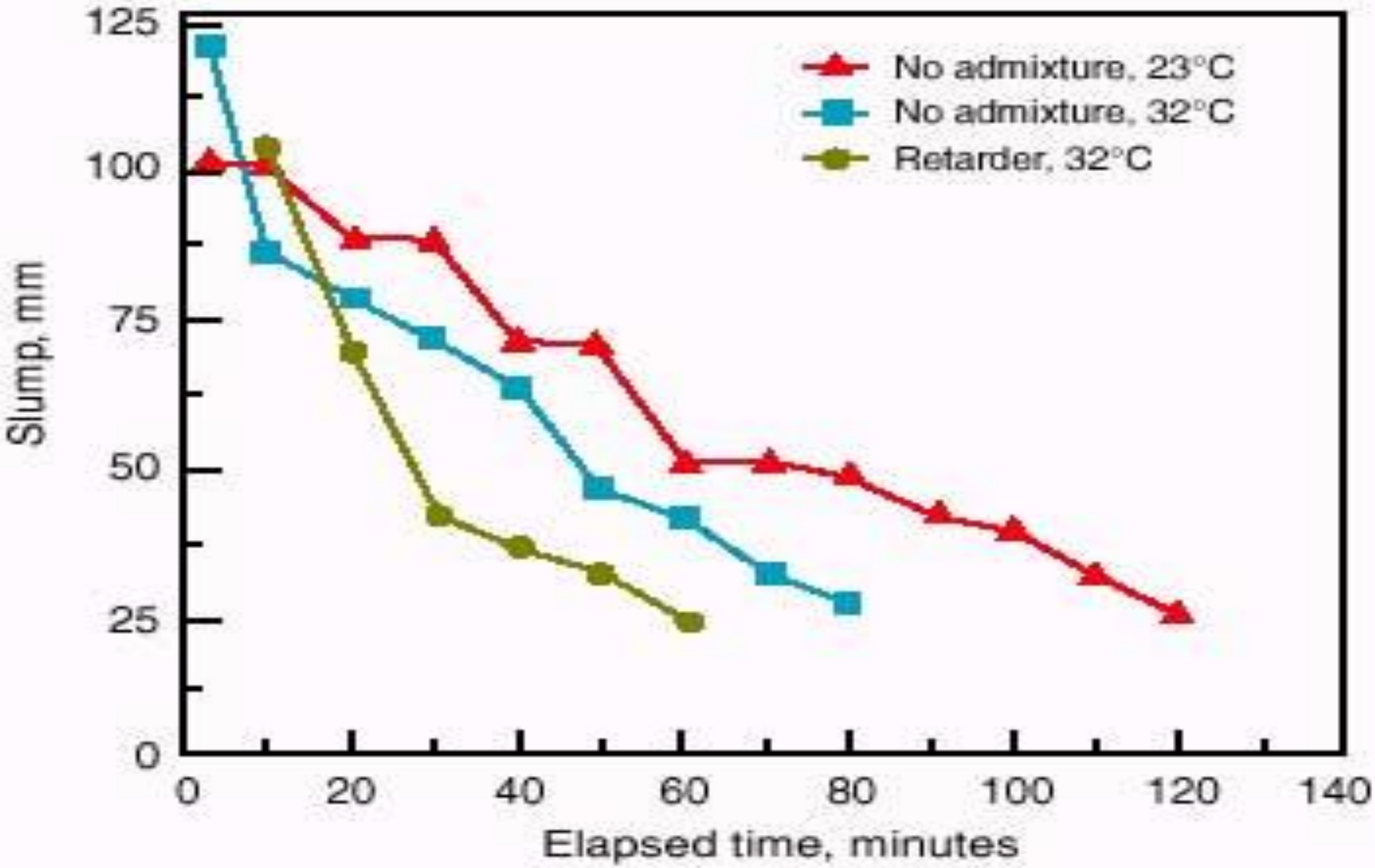


Fig. 6-15. Slump loss at various temperatures for conventional concretes prepared with and without set-retarding admixture (Whiting and Dziedzic 1992).

RETARDING ADMIXTURES

Retarders are used to:

- Offset the accelerating effect of hot weather on the setting of concrete
- Delay the initial set of concrete when difficult or unusual conditions of placement occur
- Delay the set for special finishing processes such as an exposed aggregate surface
- Some reduction in strength at early ages (one to three days) accompanies the use of retarders
- The effects of these materials on the other properties of concrete, such as shrinkage, may not be predictable.

ACCELERATING ADMIXTURES

To accelerate strength development of concrete at an early age.

Typical Materials are:

- ✓ Calcium chloride: most commonly used for plain concrete.
- ✓ Triethanolamine
- ✓ Calcium formate
- ✓ Calcium nitrate
- ✓ Calcium nitrite

CORROSION INHIBITORS

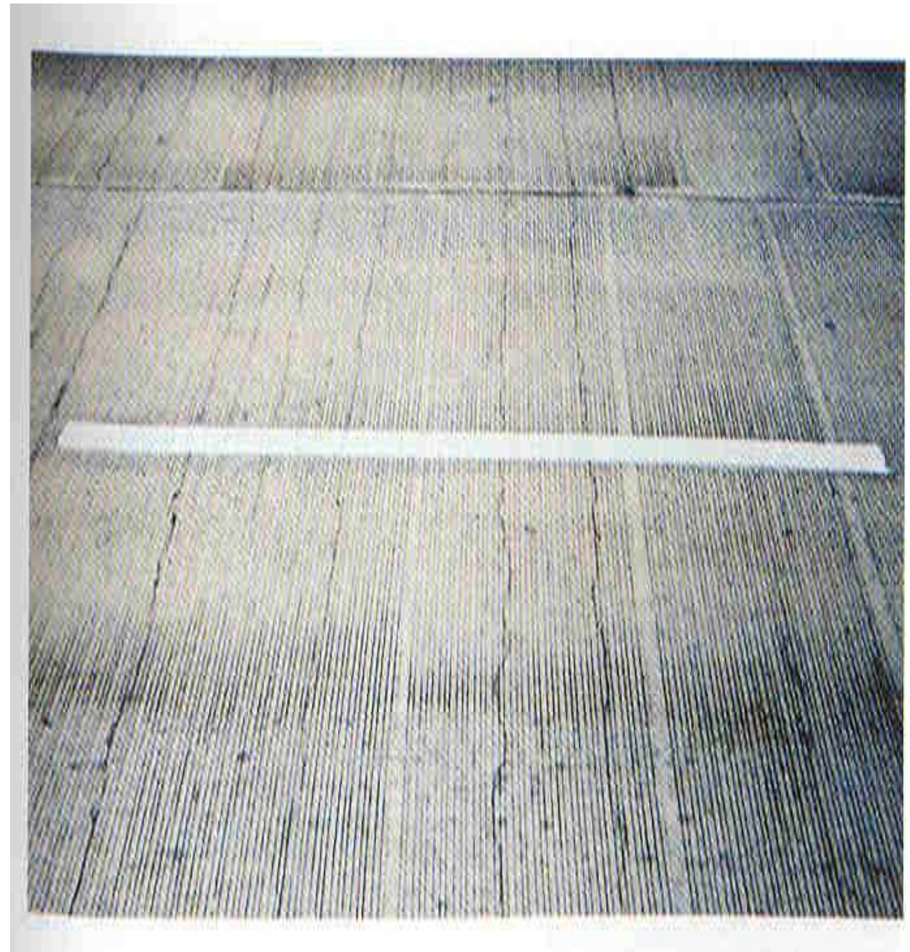
- The chlorides can cause corrosion of steel reinforcement in concrete.
- Ferrous oxide and ferric oxide are formed on the surface of reinforcing steel in concrete.
- Ferrous oxide reacts with chlorides to form complexes that move away from the steel to form **rust**. The chloride ions continue to attack the steel until the passivating oxide layer is destroyed.

CORROSION INHIBITORS

- Corrosion-inhibiting admixtures chemically arrest the corrosion reaction.
- Commercially available corrosion inhibitors include:
  - ✓ Calcium Nitrite
  - ✓ Sodium Nitrite
  - ✓ Dimethyl Ethanolamine
  - ✓ Amines
  - ✓ Phosphates
  - ✓ Ester Amines

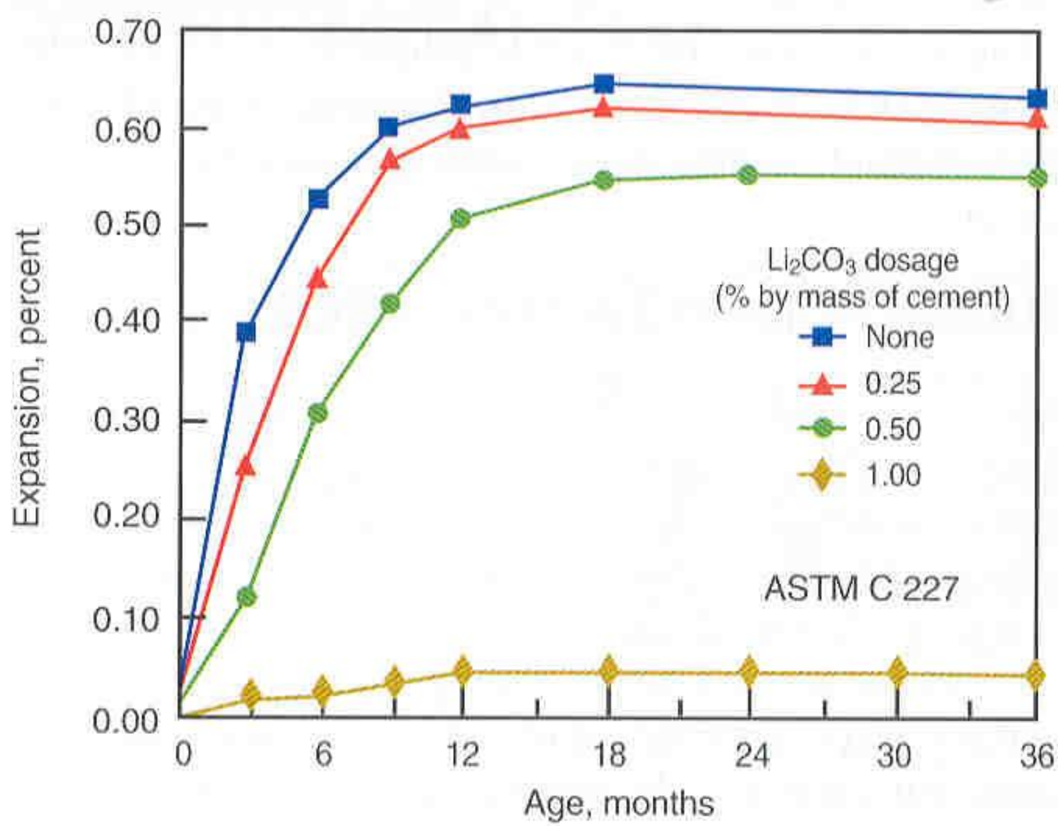
SHRINKAGE-REDUCING ADMIXTURES

- Shrinkage cracks, such as shown on this bridge deck, can be reduced with the use of good concreting practices and shrinkage reducing admixtures.



CHEMICAL ADMIXTURES TO REDUCE ALKALI-AGGREGATE REACTIVITY (ASR INHIBITORS)

- Expansion of specimens made with lithium carbonate admixture



COLORING ADMIXTURES (PIGMENTS)

- Red and blue pigments were used to color this floor

MINERAL ADMIXTURES

TIME

USE

- To modify the properties of either fresh or hardened concrete (or both) for particular reason when such a change cannot be effected by changes in the composition or properties of the normal mix.

MINERAL ADMIXTURES

- Fly ash or Pulverised Fuel Ash (PFA).
- Silica Fume or Micro silica.
- Rice Husk Ash.
- Ground Granulated Blast Furnace Slag (GGBFS).
- Metakaolin

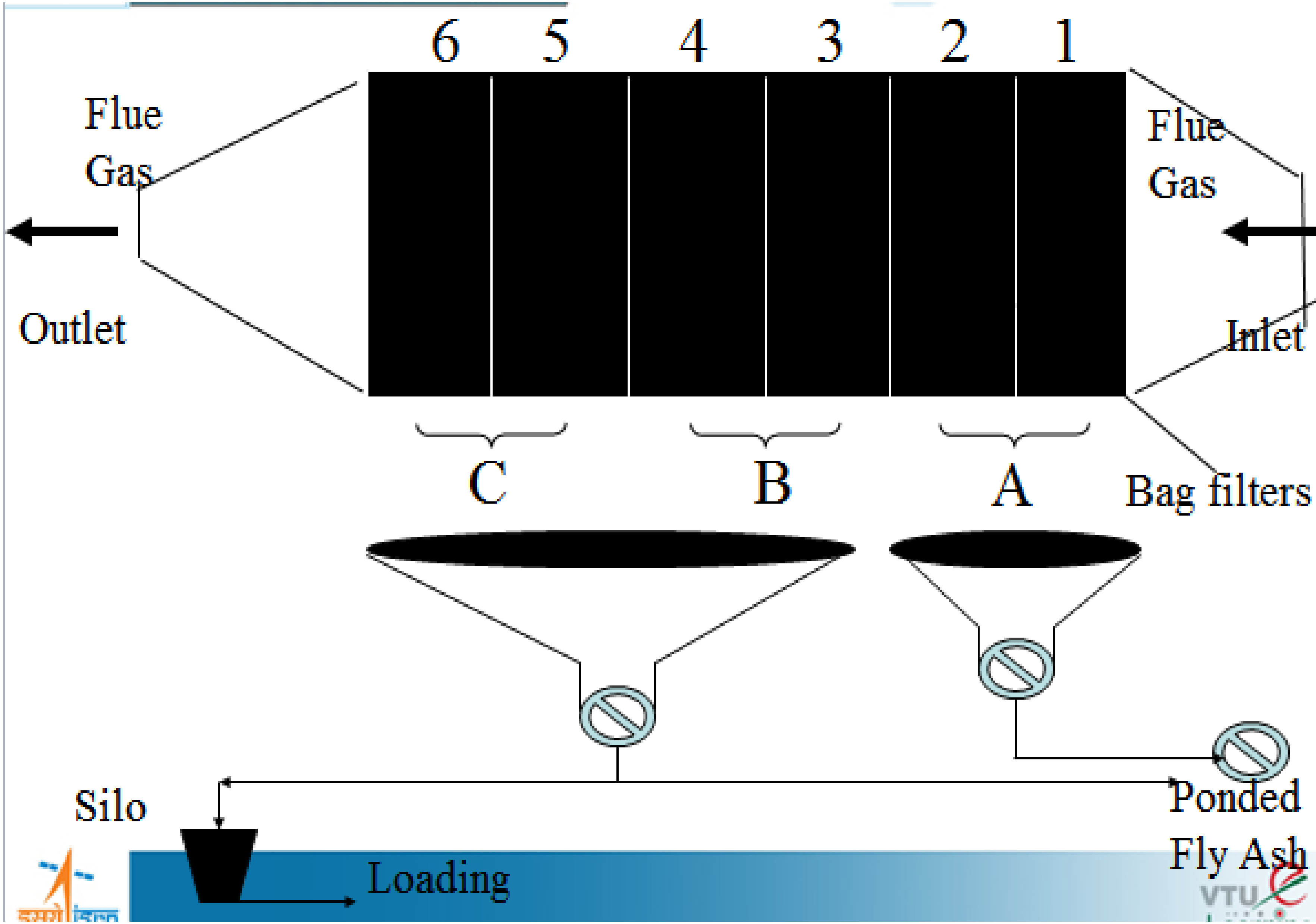
REASON: WHY FLY ASH?

- Fly ash is a solid, fine-grained material resulting from the combustion of pulverized coal in thermal plant/furnaces.
- Annually, more than 110 million tonnes of Fly Ash is being generated in India.
- Requires approximately 65,000 acres of land for disposal

COLLECTION OF FLY ASH

- Bottom ash: Collected from boiler bottom
- Ponded Fly ash: ESP Product Mixed with water
- Dry Fly ash : Separated from field B & C and stored in silo for loading in bunkers

COLLECTION OF FLY ASH



MORPHOLOGICAL CHARACTERISTICS

- The spherical particles in a flyash samples are its outstanding features specially in the context of its use as a pozzolana or admixture in concrete.
- Morphology of the particles – influenced by modes of collection
- Smooth, Glassy surface show higher reactivity.

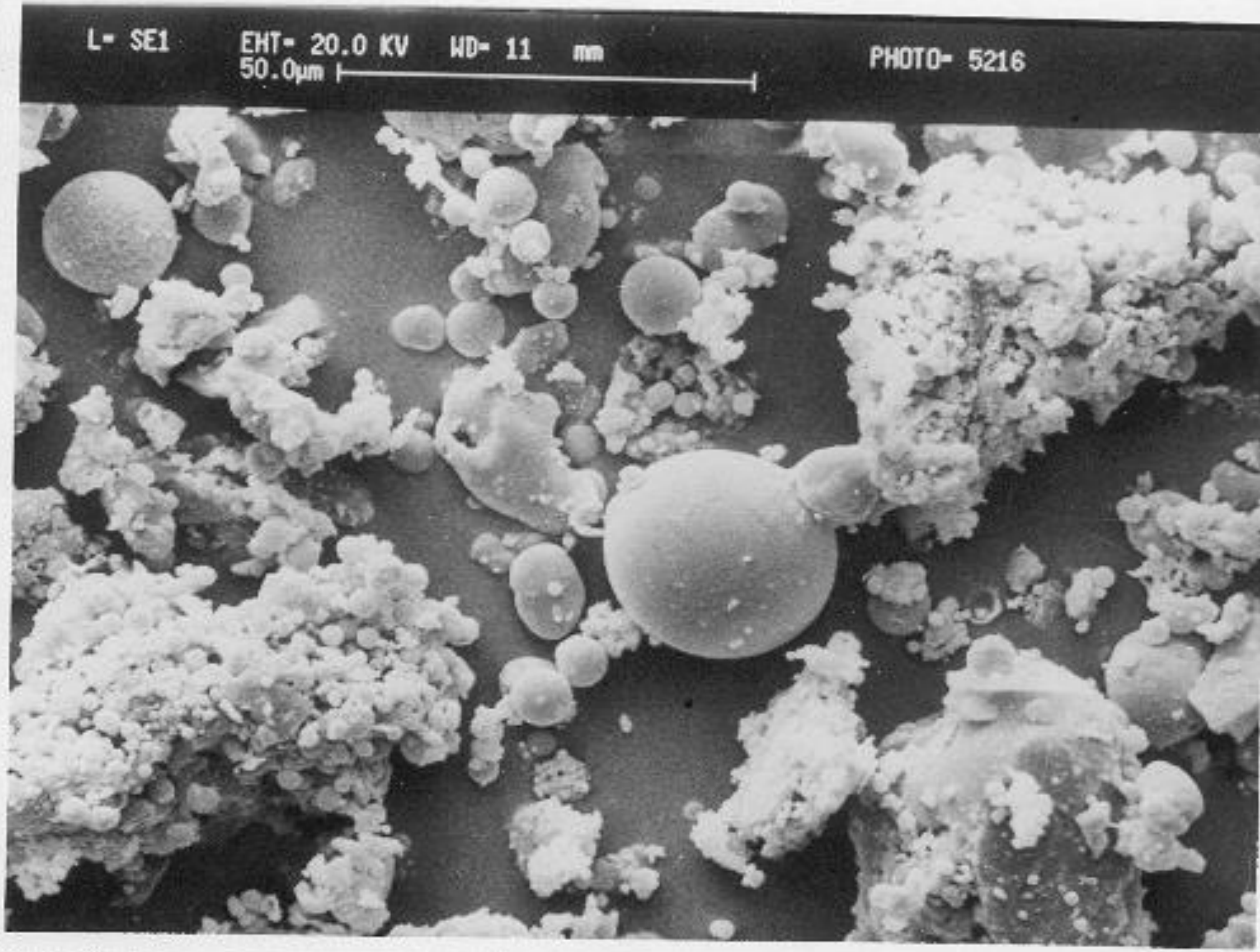


Plate 3.2

CHEMICAL COMPOSITION

Major constituents of most fly ashes are:

- SiO_2, Al_2O_3, Fe_2O_3, CaO and Loss on Ignition (LOI).
- Other elements are MgO, Na_2O, K_2O, SO_3, MnO, TiO_2.
- The early reaction is due to the presence of silica and alumina in the reactive form (amorphous).
- Long term strength is due to the crystalline form.

CHEMICAL COMPOSITION

Major constituents of most fly ashes are:

- Presence of alkalies may affect durability adversely although they may act as activators during the early stage reaction.
- Activity of the ash is influenced by the presence of important chemical constituent calcium.
- Unburnt Carbon Is the Most Important Component of LOI
- The higher the carbon content of a fly ash, the more water is needed to produce a paste of normal consistency.

GROUND GRANULATED BLAST FURNACE SLAG (GGBFS)

- **Ground-granulated blast-furnace slag** (**GGBS** or **GGBFS**) is obtained by quenching molten iron slag (a by-product of iron and steel-making) from a blast furnace in water or steam, to produce a glassy, granular product that is then dried and ground into a fine powder.
- Ground-granulated blast furnace slag is highly cementitious and high in CSH (calcium silicate hydrates) which is a strength enhancing compound which improves the strength, durability and appearance of the concrete.

GROUND GRANULATED BLAST FURNACE SLAG (GGBFS)

- The main components of blast furnace slag are CaO (30-50%), SiO_2 (28-38%), Al_2O_3 (8-24%), and MgO (1-18%).
- In general increasing the CaO content of the slag results in raised slag basicity and an increase in compressive strength.
- The MgO and Al_2O_3 content show the same trend up to respectively 10-12% and 14%, beyond which no further improvement can be obtained.
- Several compositional ratios or so-called hydraulic indices have been used to correlate slag composition with hydraulic activity; the latter being mostly expressed as the binder compressive strength.

GROUND GRANULATED BLAST FURNACE SLAG (GGBFS)

- The glass content of slags suitable for blending with Portland cement typically varies between 90-100% and depends on the cooling method and the temperature at which cooling is initiated.
- The glass structure of the quenched glass largely depends on the proportions of network-forming elements such as Si and Al over network-modifiers such as Ca, Mg and to a lesser extent Al.
- Increased amounts of network-modifiers lead to higher degrees of network depolymerization and reactivity.
- Common crystalline constituents of blast-furnace slags are merwinite and melilite.
- Other minor components which can form during progressive crystallization are belite, monticellite, rankinite, wollastonite and forsterite.
- Minor amounts of reduced sulphur are commonly encountered as oldhamite

APPLICATIONS

- GGBS is used to make durable concrete structures in combination with ordinary Portland cement and/or other pozzolanic materials.
- GGBS has been widely used in Europe, and increasingly in the United States and in Asia (particularly in Japan and Singapore) for its superiority in concrete durability, extending the lifespan of buildings from fifty years to a hundred years.
- Two major uses of GGBS are in the production of quality-improved slag cement, namely Portland Blastfurnace cement (PBFC) and high-slag blast-furnace cement (HSBFC), with GGBS content ranging typically from 30 to 70%; and in the production of ready-mixed or site-batched durable concrete.

APPLICATIONS

- Concrete made with GGBS cement sets more slowly than concrete made with ordinary Portland cement, depending on the amount of GGBS in the cementitious material, but also continues to gain strength over a longer period in production conditions.
- This results in lower heat of hydration and lower temperature rises, and makes avoiding cold joints easier, but may also affect construction schedules where quick setting is required.
- Use of GGBS significantly reduces the risk of damages caused by alkali–silica reaction (ASR), provides higher resistance to chloride ingress — reducing the risk of reinforcement corrosion — and provides higher resistance to attacks by sulfate and other chemicals.

- GGBFS possesses both cementitious and pozzolanic properties. An activator is needed to hydrate the slag.
- GGBFS increases the initial setting time of the concrete. But, it does not alter the workability of the concrete much because its fineness is almost same as that of the cement.
- The rate of strength gain of concrete is diminished by replacement of cement in the concrete with GGBFS.
- The ultimate strength gain is improved by slag replacement and also the durability of the concrete is increased.
- Concrete uses in marine purposes is highly prone to chemical attack and corrosion. GGBFS is a very good admixture in this regard, because it increases resistance to these attacks.
- However, concrete with GGBFS is reported to have higher carbonation rates than normal Portland cement concrete.