IS:- 10262-2019

# Concrete mix design

## Terminology

1) Water-cement Ratio (w/c)

- Ratio of mass of mixing water by the mass of cement.
- It refers to the ratio corresponding to the saturated surface dry condition of aggregates.

2) - Water-cementitious materials (w/cm)

- Ratio of mass of mixing water by the combined mass of the cement and flyash or other cementitious materials or combination

* Steps for mix design.

→ mix design means, determination of the proportion of the concrete ingredients i.e. cement, water, fine aggregate, coarse aggregate. which would produce concrete possessing specified properties such as workability, strength & durability..

methods for concrete mix design:-

(American concrete institute)

1) ACI method

2) British method

3) IS method

↳ These methods are based on two basic assumptions.

(i) Compressive strength of concrete is governed by w/c.

(ii) workability of concrete is governed by its water content.

M) 20 grade of mix design

(a) Design stipulations
(i) max^m size of agg - 20 mm
(ii) Degree of workability - 0.90.
(iii) Degree of quality of control - good
(iv) Type of exposure - mild.

(b) Test data for materials.
(i) sp. gravity of cement - 3.15
(ii) sp. of C.A - 2.60.
" " F.A - 2.60.
(iii) water absorption.
C.A - 0.50%.
F.A - 1.0%.
(iv) Free moisture.
C.A - Nil
F.A - 2.0%.

* Calculations :-

(i) Target mean strength of Concrete.

$$F_{ck} = f_{ck} + 1.65\ S.$$

where, strength
Fck = Target mean compressive
fck = characteristic compressive strength

S = standard deviation.
(grade of concrete)

= 20 + 1.65 X 4.
↓
Risk factor

= 26.6 Mpa ($N/mm^2$)

(2) Selection of water - cement ratio.

(from fig. 11.10) & 5
IS 456 : 2000, table-10 &
book table 9.18 pg. 415.

→ from fig w/c required for the target mean strength of 26.6 mpa is 0.50. This is lower than the $max^m$ value of 0.55 prescribed for "mild" Exposure. so. adopt w/c = 0.50

(3) Selection of water content.

for 20mm

From table 4., max size aggregate, water content = 186 kg. & Sand content as percentage of total aggregate by absolute vol = 35 percent.

Now, From table (11.26) book.

| Change in conditions | Water content | Sand in total aggregate |
|---|---|---|
| (1) for decrease in w-c ratio by (0.60-0.50) that is 0.10 | 0 | -2. |
| (2) For increase in compacting factor (0.9-0.8) that is 0.10. | +3. | 0. |
| (3) for sand Zone-III | 0 | -1.5. |
| Total = | +3 | -3.5 |

Therefore, required Sand content as percentage of total aggregate by absolute vol$^m$;

= 35 − 3.5 = 31.5%

Req$^d$ water content = 186 + 5.58

= 191.6 $l/m^3$

(4) determination of cement content.

W/C = 0.50

water = 191.6 litre

$$Cement = \frac{191.6}{0.50} = 383\ kg/m^3.$$

(5) determination of coarse & fine aggregate results.

$$V = \left[W + \frac{C}{S_c} + \frac{1}{P}\frac{f_a}{S_{fa}}\right]\frac{1}{1000}$$

$$C_a = \frac{1-P}{P} \times f_a \times \frac{S_{ca}}{S_{fa}}$$

$$0.98 = \left[191.6 + \frac{383}{3.15} + \frac{1}{0.315} + \frac{fa}{2.60}\right] \frac{1}{1000}$$

$fa = 546 \ kg/m^3$

$$Ca = \frac{1 - 0.315}{0.315} \times 546 \times \frac{2.6}{2.6}$$

$= 1188 \ kg/m^3$

Water = 191.6 kg/m³ (litre)
Cement = 383 kg
FA = 546 kg
C.A = 1188 kg

*. Mix design of M30 grade.

(1) grade designation = M30
Type of cement = Ultratech PPC
Cement Conforming to IS:1489
max nominal size of agg = 20mm
min Cement content = 320 kg/m³
max W/C = 0.50
workability = 50-75mm (slump)
Exposure = Moderate.
degree of supervision = good
Type of agg = Crushed angular
max Cement content = 450 kg/m3
chemical admixture = Recommended

(2) Test data for materials :-

(i) Cement used → Ultratech PPC
sp. gravity of cement - 3.05.
sp. gravity,
C.A = 2.68
F.A = 2.66.
water absorption
C.A = 0.85%.
F.A = 1.15%.

S.T

Step-1 Target mean strength of Concrete.

$f'_{ck} = f_{ck} + 1.65 \times S$
$= 30 + 1.65 \times 5$
$= 38.25 \ N/mm^2$ / Mpa.

Step-2 Water Cement ratio.

From table 5, max^m water ~~content~~ (cement ratio)
= ~~186 liters~~ 0.50 (moderate).

So, 0.45 < 0.5 hence, ok

Step-3 Selection of water content.

From table 2,

max^m water content = 186 liters.
(For 25mm-50mm slump range)
Reduce water by about 20% as 0.75% SP is used
estimated water content = 152 liters.

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Step 4 Calculation of Cement Content.

W/C = 0.45

Cement Content = 152/0.45

= 337.7 ≈ 340 kg/m³

> 320 kg/m³

Hence, ok.

Step-5 Proportion of vol$^m$ of CA and FA Content.

From table 3,

vol$^m$ of C.A corresponding to 20 mm size agg. & fine aggregate (Zone II) for W/C of 0.50 = 0.62,

Modify this as W/C is 0.45.

The new value is 0.63.

vol$^m$ of F.A = 0.37.

Step-6 mix calculations:-

Volm of Concrete = $1 m^3$

Volm of cement = $\frac{\text{mass of cement}}{\text{sp.g. of cement}} \times \frac{1}{1000}$

$= \left[\frac{340}{3.05}\right] \times \left[\frac{1}{1000}\right]$

$= 0.112 m^3$.

Volm of water $= \left(\frac{152}{1}\right) \times \left(\frac{1}{1000}\right)$

$= 0.152 m^3$

Superplasticisers $= \left(\frac{152}{1}\right) \times \left(\frac{1}{1000}\right)$

$= 0.152 m^3$

Volm of all in agg $= a-[b+c+d]$

$= 1-[0.112+0.152+0.0022]$

$= 0.734 m^3$

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weight of C.A = e x vol$^m$ of C.A x Sp.g of C.A

= 0.734 x 0.63 x 2.68 x 1000

= 1239 kg.

weight of F.A = e x vol$^m$ of F.A x sp.g of F.A

= 0.734 x 0.37 x 2.66 x 1000

= 722 kg.

Cement = 340 kg/m$^3$
Water = 152 kg/m$^3$
F.A = 722 kg/m$^3$
C.A = 1239 kg/m$^3$
w/c = 0.45
S.P. = 2.55 lts
yield = 2456 kg/m$^3$.

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# Special Concrete

# General

- Special concretes are the concrete prepared for specific purpose like light weight, high density, fire protection, radiation shielding etc.
- concrete is a versatile material possessing good compressive strength. But it suffers from many drawbacks like low tensile strength, permeability to liquids, corrosion of reinforcement, susceptibility to chemical attack and low durability.
- Modification have been made from time to time to overcome the deficiencies of cement concrete. The recent developments in the material and construction technology have led to significant changes resulting in improved performance, wider and more economical use.
- Research work is going on in various concrete research laboratories to get improvement in the performance of concrete

# General

- Attempts are being made for improvements in the following areas. Improvement in mechanical properties like compressive strength, tensile strength, impact resistance.
- Improvement in durability in terms of increased chemical and freezing resistances.
- Improvements in impermeability, thermal insulation, abrasion, skid resistance etc.

# Different Types of Special Concrete

- Light Weight Concrete
- High Density Concrete
- Plum Concrete
- No Fines Concrete
- Aerated Concrete
- Fiber Reinforced Concrete (FRC)
- Polymer Concrete
- Ferro cement
- High Strength Concrete
- High Performance Concrete

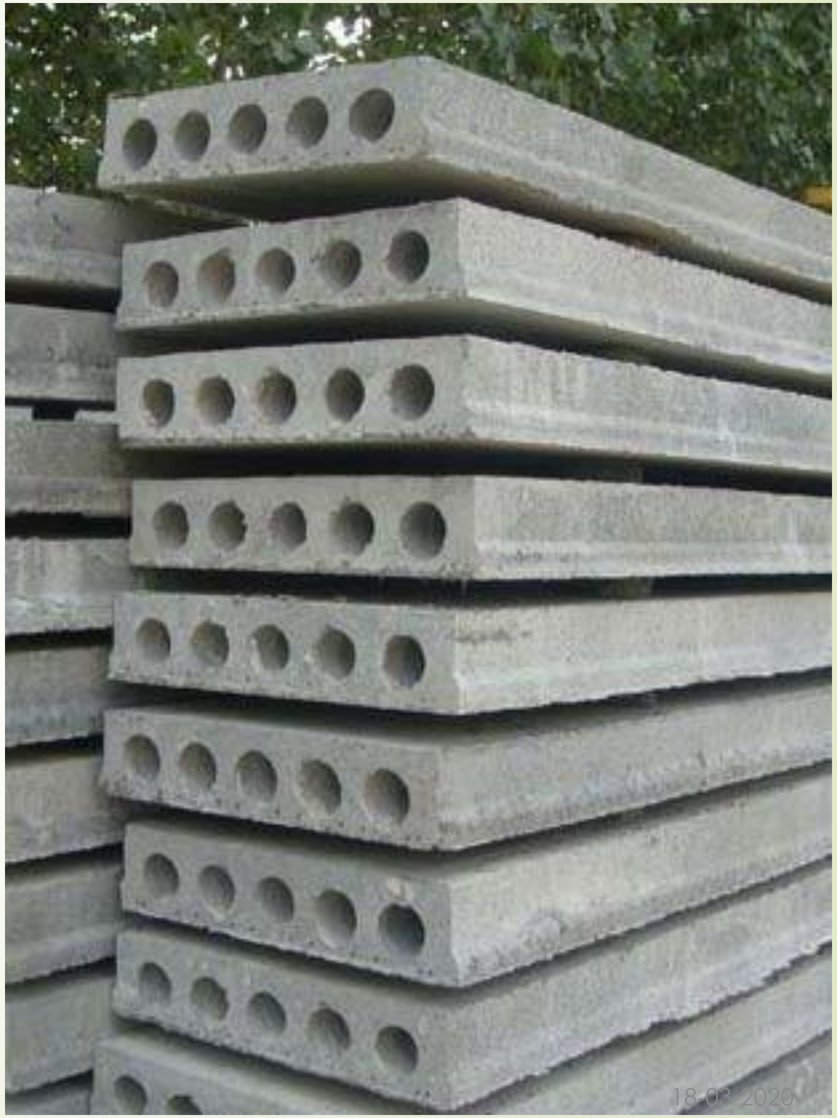
# Difference Between Ordinary and Special Concrete

| Ordinary Concrete | Special Concrete |
|---|---|
| Ordinary concrete is used for normal works like building, bridges, road etc. | This type of concrete is used for special type of structures like nuclear reactor, buildings with acoustic treatment, air conditioned buildings etc. |
| Ingredients of ordinary concrete are cement, sand, aggregate and water. | In case of light weight aggregate concrete, light weight aggregates are used. In polymer concrete, polymer binder is used instead of water. |
| Construction is carried out by conventional method. | Concreting is done by special techniques |
| Properties of Concrete like density, strength etc. are of normal range. | Properties of concrete like density strength are of higher range. For example, density of light weight concrete is about 500 to 2000 kg/m3 and that of heavy weight concrete is about 3000 to 5000 kg.m 3 |
| It is economical | It is costly |

# Light Weight Concrete

- The density of conventional concrete is in order of 2200 to 2600 kg/m 3.
- This heavy self weight will make it uneconomical structural material. The dead weight of the structure made up of this concrete is large compared to the imposed load to be carried.
- A small reduction in dead weight for structural members like slab, beam and column in high-rise buildings, results in considerable saving in money and manpower.
- Attempts have been made in the past to reduce the self weight of the concrete to increase the efficiency of concrete as a structural material. The light weight concrete with density in the range of 300 to 1900 kg/ m3 have been successfully developed.

# Light Weight Concrete



# Advantages of light weight concrete

- Reduction of Dead Load
- Smaller section of structural members can be adopted.
- Lower haulage and handling costs.
- Increase in the progress of work.
- Reduction of foundation costs, particularly in the case of weak soil and tall structures.
- Light weight concrete has a lower thermal conductivity. In case of buildings where air conditioning is to be installed, the use of light weight concrete will result in better thermal comforts and lower power consumption.

# Advantages of light weight concrete

- The use of light weight concrete gives an outlet for industrial wastes such as fly ash, clinkers, slag etc. which otherwise create problem for disposal.
- It offers great fire resistance.
- Light weight concrete gives overall economy.
- The lower modulus of elasticity and adequate ductility of light weight concrete may be advantageous in the seismic design of structures.

# The Light Weight Concrete Is Achieved By Three Different Ways

- By replacing the normal mineral aggregate, by cellular porous or light weight aggregate.
- By introducing air bubble in mortar this is known as ‘ aerated concrete’.
- By omitting sand fraction from the aggregate This is known as ‘ no fines concrete’.

# Lightweight Aggregate Concrete



## Light weight Aggregates

- **Natural light weight aggregate**
  - Pumice
  - Scoria
  - Rice Husk
  - Diatomite
  - Volcanic tuff
  - Foamed lava
- **Artificial light weight aggregate**
  - Sintered fly ash
  - Foamed slag
  - Bloated Clay
  - Artificial Cinders
  - Expanded clay
  - Slate, shale
  - Coke breeze
  - Expanded perlite
  - Exfoliated vermiculite

# Light Weight Aggregates

## Natural light weight aggregate

- **Pumice:** These are rocks of volcanic origin. They are light coloured or nearly white and has a fairly even texture of interconnected voids. Its bulk density is 500 – 800 kg/ m3.
- **Scoria:** Scoria is light weight aggregate of volcanic origin, They are dark in colour It is slightly weaker than pumice.
- **Rice Husk:** Use of rice husk or groundnut husk has been reported as light weight aggregate.
- **Saw dust:** Saw dust is used as light weight aggregate in the flooring and in the manufacture of precast elements. But the presence of carbohydrates in the wood, adversely affect the setting and hardening of Portland cement.
- **Diatomite:** It is derived from the remains of microscopic aquatic plants called diatoms. It is also used as a pozzolanic material.

# Natural Light weight Aggregate



# Light Weight Aggregates

## Artificial Light Weight Aggregates

- **Sintered flash (Pulverized fuel ash):** The fly ash collected from modern thermal power plants burning pulverized fuel, is mixed with water and coal slurry in screw mixers and then fed on to rotating pans, known as pelletizers, to form spherical pellets.
- The pellets are then fed on to a sinster strand at a temperature of 1000 $^0$C to 1200 $^0$C. Due to sintering the fly ash particles coagulate to form hard brick like spherical particles.
- The produces material is screened and graded. In UK it is sold by the trade name ‘ Lytag’.

# Artificial Light weight concrete

## Foamed Slag

- Foamed slag is a by product produced in the manufacture of pig iron.
- It is a porous, honeycombed material which resembles pumice.

## Bloated Clay

- When special grade of clay and shales are heated to the point of incipient fusion, there will be expansion due to formation of gas within the mass.
- The expansion is known as bloating and the product so formed is used as light weight aggregate.

# Artificial Light Weight Aggregates

**Exfoliated vermiculite**

- The raw vermiculite material resembles mica in appearance and consists of thin flat flakes containing microscopic particles of water.
- On heating with certain percentage of water it expands by delamination in the same way as that of slate or shale.
- This type of expansion is known as exfoliation. The concrete made with vermiculate as aggregate will have very low density and very low strength.

**Cinders, clinkers, breeze**

- The partly fused or sintered particles arising from the combustion of coal, is termed as cinder or clinker or breeze.
- Cinder aggregate undergo high drying shrinkage and moisture movement. These are used for making building blocks for partition walls, for making screening over flat roofs and for plastering purposes

# Artificial Light Weight Aggregates

Exfoliated Vermiculate

Clinkers

# High Density Concrete



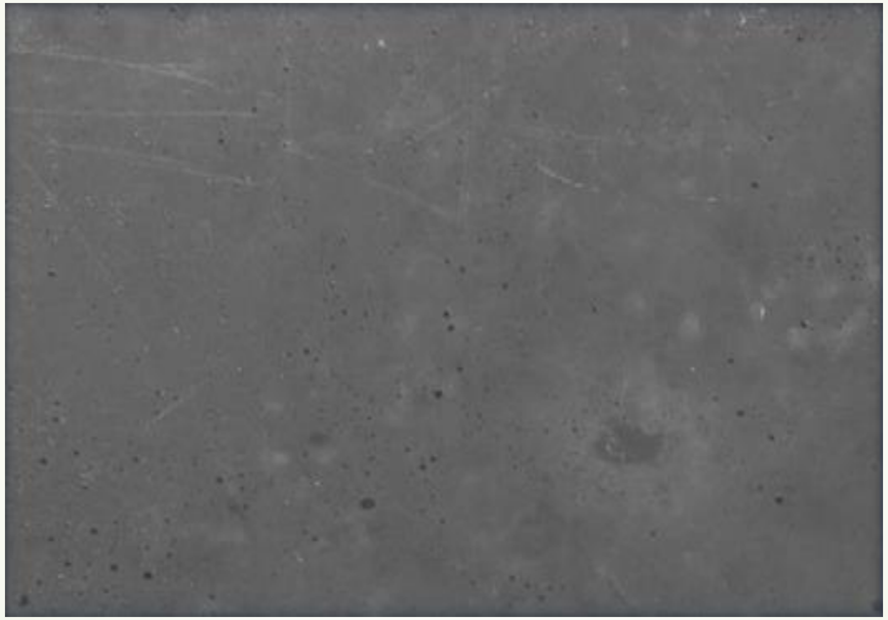
- High density concrete is also known as ‘ heavy weight concrete’.
- High density concrete is produced by replacing the ordinary aggregate by a material of very much higher specific gravity, usually over 4.0, compared with the specific gravity of ordinary aggregate of about 2.6.
- One of the more common natural aggregate is barium sulphate. It has a specific gravity of 4.1, and occurs as a natural rock with a purity of about 95 %.
- Barytes behaves rather like ordinary crushed aggregate and does not present any special problems as far as proportioning of mixes is concerned.
- The aggregate tends to break up and dust so that care must be taken in handling and processing and over mixing should be avoided. •
- Another type of natural heavy weight aggregate is iron: magnetite, limonite, hematite and geothite have been used.
- By using iron ore aggregate concrete concrete with densities of between 3000 to 3900 kg/ m 3 can be made.

# High Density Concrete



- The high density concrete is used in the construction of radiation shielding i.e. in nuclear power plants.
- The questions of shielding resolves into protection against X- rays, Gamma rays and neutrons. The biological hazards of radiation arise from the fact that the radiation interacts with human tissues, losing some of their energy in the process.
- High density concrete is also suites for preparing counter- balance weights for lifting bridges and ballast blocks for ships, where the high density concrete reduces the volume of concrete required to produce the same dead weight, leading to economy.

# High Density Concrete



# Mass Concrete



- The concrete placed in massive structures like dams, canal locks, bridge, piers etc. can be termed mass concrete. This concrete is placed in large open forms. The mix is relatively harsh and dry and requires power vibrators of the immersion type for compaction.
- Because of the large mass of the concrete, the heat of hydration of cement may lead to a considerable rise of temperature In the concrete thus resulting in extensive and serious shrinkage cracks.
- These shrinkage cracks can be prevented by using low heat cements and continuous curing.
- Placing the concrete in small lifts and allowing several days before the placement of the next lift of concrete can help in the dissipation of heat.
- The concreting can be done preferable in winter season, such that the peak temperature in concrete can be lowered or as an alternative the aggregate may be cooled and then used. Circulation of cold water through pipes buried in the concrete mass may prove useful.
- The mass concrete develops high early age strength but the later age strength is lower than that of continuously cured concrete at normal temperature. There is negligible volume change in the case of mass concrete during setting and hardening but large creep may occur at later ages.

# Mass Concrete

# Fibre Reinforced Concrete

- In conventional concrete, micro-cracks develop even before loading because of drying shrinkage and other causes of volume change. When the structure is loaded, the micro cracks open up and propagate.
- The development of such micro-cracks is the main reason of inelastic deformation in concrete.
- The weakness can be removed by inclusion of small, closely spaced and uniformly dispersed fibers in concrete.
- The addition of fibers in concrete substantially improve its static and dynamic properties.
- These fibers offer increased resistance to crack growth, through a crack arresting mechanism and improve tensile strength and ductility of concrete.

# Fibre Reinforced Concrete

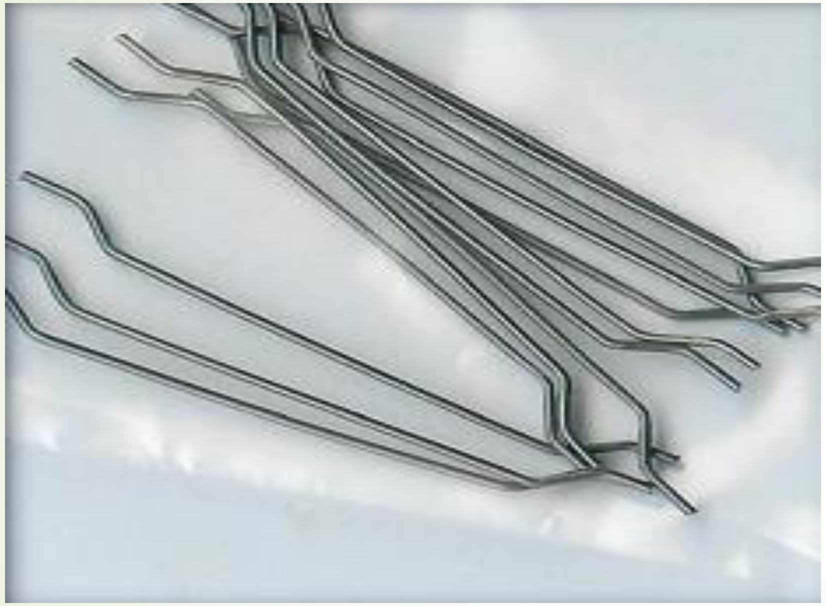
- Fiber reinforced concrete (FRC) can be defined as a composite material consisting of concrete and discontinuous, discrete, uniform dispersed fine fibers. The continuous meshes, woven fabrics and long wires or rods are not considered to be discrete fibers.
- The inclusion of fibers in concrete and shotcrete generally improves material properties like ductility, flexural strength, toughness impact resistance and fatigue strength.
- There is little improvement in compressive strength. The type and amount of improvement in compressive strength.
- The type and amount of improvement is dependent upon the fibre type, size, strength and configuration and amount of fibre

# Fibre Reinforced Concrete

# Types of Fibers

- Fiber is a small discrete reinforcing material produced from steel, polypropylene, nylon, glass, asbestos, coir or carbon in various shape and size. They can be circular or flat.
- **Steel fibers:** Steel fibre is one of the most commonly used fibre. They are generally round. The diameter may vary from 0.25 mm to 0.75 mm.
- The steel fibre is likely to get rusted and lose some of its strength. Use of steel fibre makes significant improvements in flexural impact and fatigue strength of concrete.
- Steel fibers have been extensively used in overlays or roads, pavements, air fields, bridge decks, thin shells and floorings subjected to wear and tear and chemical attack.

# Steel Fibers



# Glass Fibers

- These are produced in three basic forms:

(a) Rovings

(b) Strands

(c) Woven or chopped strand mats.

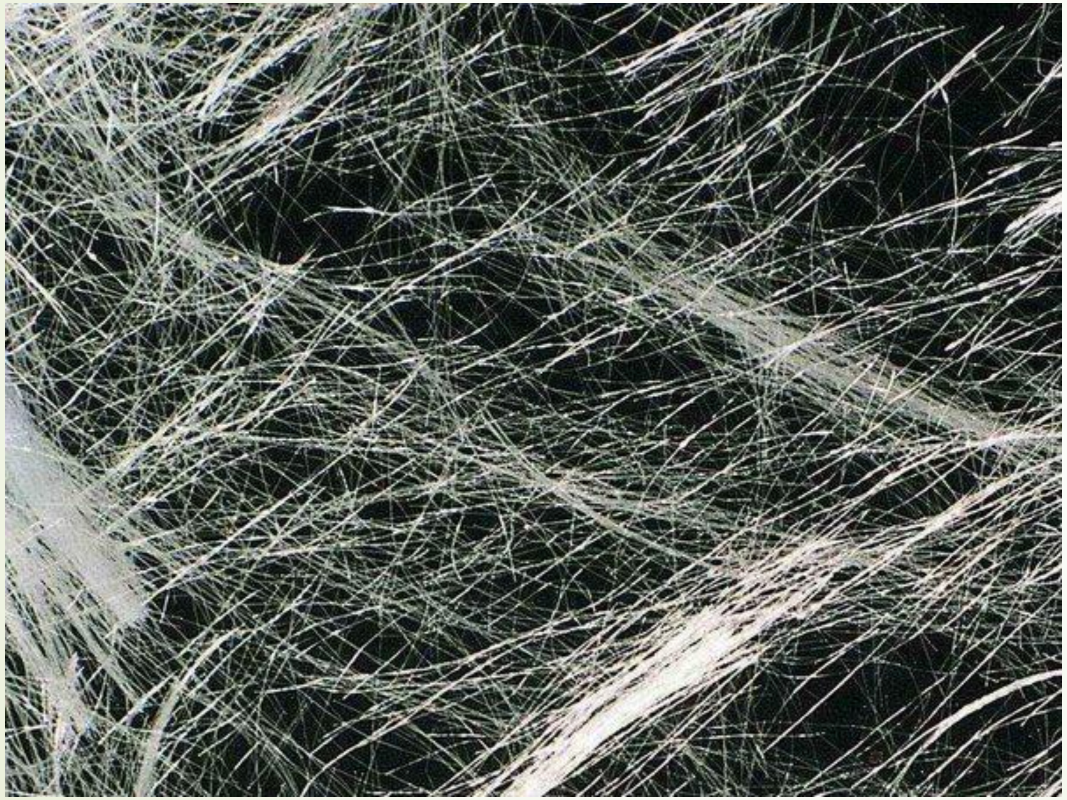
- Major problems in their use are breakage of fibre and the surface degradation of glass by high alkalinity of the hydrated cement paste. However, alkali resistant glass fibre have been developed now.
- Glass fibre reinforced concrete (GFRC) is mostly used for decorative application rather than structural purposes.
- With the addition of just 5 % glass fibers, an improvement in the impact strength of up to 1500 % can be obtained as compared to plain concrete. With the addition of 2 % fibers the flexural strength is almost doubled.

# Glass Fibre

# Plastic Fibers

- Fibers such as polypropylene, nylon, acrylic, aramid and polyethylene have high tensile strength thus inhibiting reinforcing effect.
- Polypropylene and nylon fibers are found to be suitable to increase the impact strength.
- Their addition to concrete has shown better distribute cracking and reduced crack size.

# Plastic Fibers



# Types of Fibers

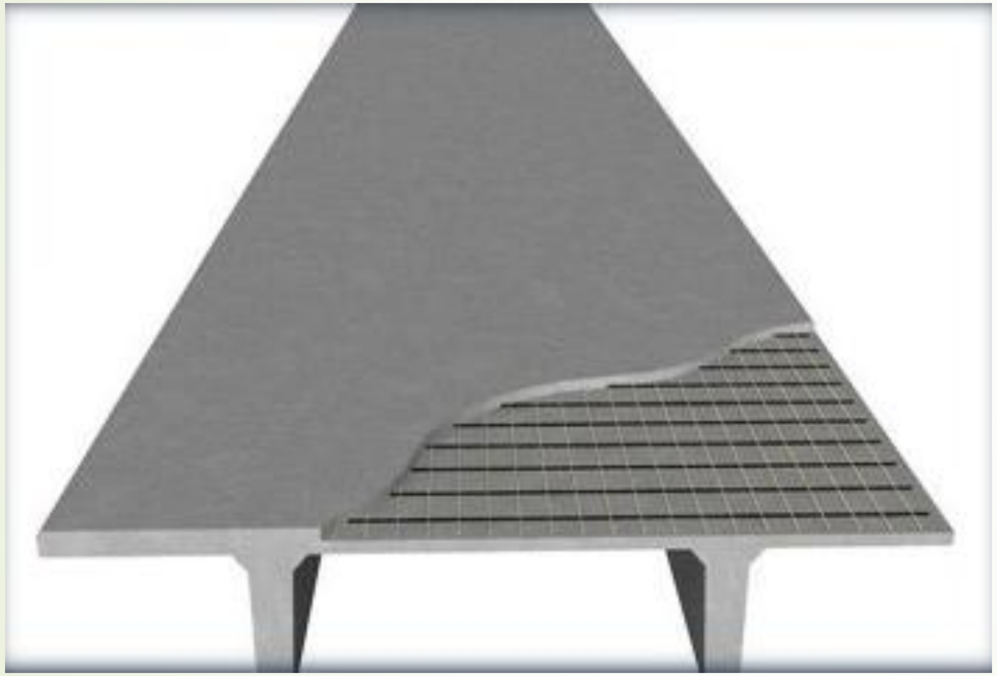
**Carbon Fibers**

- Carbon fibers possess high tensile strength and high young's modulus. The use of carbon fibre in concrete is promising but is costly and availability of carbon fibre in India is limited.

**Asbestos fibers**

- Asbestos is a mineral fibre and has proved to be most successful fibre, which can be mixed with OPC. The maximum length of asbestos fibre is 10 mm but generally fibers are shorter than this. The composite has high flexural strength.

# Carbon Fibers



# Asbestos Fibers

# Factors Affecting Properties Of Fiber Reinforced Concrete

- Volume of fibers
- Aspect ratio of fibers
- Orientation of fibers
- Size of coarse aggregate
- Workability and compaction of Concrete
- Mixing

# High Strength Concrete

- Based on the compressive strength; concrete is normally classified as normal strength concrete, high strength concrete and ultra strength concrete.
- Indian standard recommended methods of mix design denotes the boundary at 35 Mpa between normal strength and high strength concrete.
- The advent of prestressed concrete techniques has given impetus for making concrete of higher strength.
- High strength concrete is necessary for the construction of high rise building and long span bridges.
- To achieve high strength, it necessary to use high cement content with the lowest possible W/C ratio which invariable affect the workability of the mix.
- It should be remembered that high cement content may liberate large heat of hydration causing rise in temperature which may affect setting and may result in excessive shrinkage.

# Various methods of producing high strength concrete

**(i) Seeding**

**(ii) Revibration**

**(iii) Inhibiting Cracks**

**(iv) Using admixtures**

**(v) Sulphur impregnation**

- Seeding is a process of adding a small quantity of finely ground Portland cement to the fresh concrete mix.
- Revibration of plastic concrete also improves the strength of concrete.
- Concrete undergoes plastic shrinkage. Mixing water creates continuous capillary channels and bleeding, reducing strength of concrete.
- Revibration removes all these defects and increases the strength of concrete.

# Various methods of producing high strength concrete

- In conventional concrete, micro-cracks develop even before loading because of drying shrinkage and other volume change.
- When the structure is loaded the micro cracks open up and propagate. The weakness can be removed by inclusion of small, closely spaced and uniformly dispersed fibers in concrete.
- Use of water reducing agents are known to produce increased compressive strength.

# High Performance Concrete

- The development of high performance concrete (HPC) is a giant step in making concrete a high-tech material with enhanced characteristics and durability.
- High performance concrete is an engineered concrete obtained through a careful selection and proportioning of its constituents.
- The concrete is with the same basic ingredients but has a totally different microstructure than ordinary concrete.

# High Performance Concrete

# High Performance Concrete

- The low water cement ratio of HPC results in a very dense microstructure having a very fine and more or less well connected capillary system.
- The dense microstructure of HPC, makes the migration of aggressive ions more difficult, consequently HPC is more durable when exposed to aggregate environment conditions.
- High performance concrete can hence be defined as an engineered concrete with low water/ binder ratio to control its dimensional stability and when receive an adequate curing.
- The cementitious component of high or any combination of cementitious material such as slag, flyash, silica fume, metakaolin and filler such as, limestones

# High Performance Concrete

- Concrete compressive strength is closely related to the density of hardened matrix. High performance concrete has also taught us that the coarse aggregate can be the weakest link in concrete when the strength of hydrated cement paste is drastically increased by lowering the water/binder ratio.
- In such case concrete failure can start to develop within the coarse aggregate itself. As a consequence, there can be exceptions to the water/binder ratio law when dealing with HPC.
- When the concrete's compressive strength is limited by the coarse aggregate, the only way to get higher strength is to use a stronger aggregate.
- If water curing is essential to develop the potential strength of cement in plain concrete, early water curing is crucial for high-performance concrete in order to avoid the rapid development of autogenous shrinkage and to control concrete dimensional stability, as explained below.

# High Performance Concrete

- The hydration of cement paste is accompanied by an absolute volume contraction that creates a very fine pore network within the hydrated cement paste.
- This network drains water from coarse capillaries, which start to dry out if no external water is supplied.
- Therefore, if no drying is occurring and no external water is added during curing, the coarse capillaries will be empty of water as hydration progresses.
- This phenomenon is called self desiccation. The difference between drying and self-deesiccation is that, when concrete dries water evaporates to the atmosphere, while during-self desiccation water stay within the concrete i.e.
- It only migrates towards the very fine pores created by the volumetric contraction of the cement paste.

# High Performance Concrete

- HPC must be cured quite differently from ordinary concrete because of the difference in shrinkage behavior.
- The ordinary concrete exhibits no autogeneous shrinkage whether it is water cured or not, where as HPC can experience significant autogenous shrinkage if it is not water cured during the hydration process.
- While curing membranes provide adequate protection for ordinary concrete, they can only help prevent the development of plastic shrinkage in HPC. They have no value in inhibiting autogenous shrinkage.
- Therefore, the most critical period for any HPC runs from placement or finishing upto 2 to 3 days later. During this time the most critical period is usually from 12 to 36 hours.
- In fact, the short time during which efficient water curing must be applied to HPC can be considered a significant advantage over ordinary concrete.

- Water ponding, whenever possible or fogging are the best ways to cure HPC.
- The water curing can be stopped after 7 days because most of the cement at the surface of concrete will have hydrated
- A specially designed high performance, self-leveling, non shrink, pre-blended concrete was formulated and was put into use against the aggressive chemical environment at fertilizer plant in Gujarat- Gujarat Narmada valley Fertilizers Ltd. (GNFC)- Bharuch. The system has been applied in 1997 and there are no signs of deterioration observed since then.

# Precast Concrete

- When mass concrete work is required for huge and speedy construction work, precast concrete is used. Precast concrete elements are manufactured in industries and transported to site.
- They are casted in separate forms and placed in the structure on site.
- Hollow and solids concrete blocks of desired shape and size are prepared and cured in water tanks at industrial sheds and then placed on site.

# Precast Concrete

# Application of Precast Concrete

- Beam
- Columns
- Slabs
- Water Tanks
- Bridge girders
- Bridge Piers
- Concrete Piles
- Cassions
- Compound wall poles
- Electricity Poles
- Ornamental Structures
- Concrete lintels
- Water supply RCC Pipes
- Sewer Pipes