

Design of concrete mix requires complete knowledge of various properties of these constituent materials, the implications in case of change in these conditions at the site, the impact of the properties of plastic concrete on the hardened concrete and the complicated inter-relationship between the variables.

### Factors:

4 variable factors to be considered in connection with specifying a concrete mix are.

1. Water cement ratio.
2. Cement Content or cement aggregate ratio.
3. Gradation of the aggregate.
4. Consistency.

### Various Methods of proportioning:-

1. Arbitrary proportion.
2. Fineness modulus method
3. Maximum density method
4. Surface area method
5. Indian Road Congress, IRC 44 method
6. High strength concrete mix design
7. Mix design based on flexural strength
8. Road note No 4 (Grading curve method)
9. ACI committee 211 method
10. DOE method
11. Mix design of pumpable concrete (Imp)
12. Indian standard method (IS 4032:2009)

Commonly used.

## Statistical Quality Control of Concrete:

- It provides a scientific approach to the concrete designer to understand the realistic variability of the materials so as to lay down design specifications with proper tolerance to cater unavoidable variations.
- The basis of acceptance of a sample is that a reasonable control of concrete work can be provided by ensuring that the probability of test result falling below the design strength is not more than a specified tolerance level.
- The compressive strength test cubes from random sampling of a mix, results follow a normal distribution curve.
- Common terminologies which are used in statistical quality control of concrete are

### 1. Mean strength:-

It is defined as the average strength obtained by dividing the sum of strength of all the cubes by the number of cubes

$$\bar{x} = \frac{\sum x}{n}$$

Where,  $\bar{x}$  = Mean strength

$\sum x$  = Sum of the strength of cubes

n = Number of cubes.

### 2. Variance :-

It is defined as the measure of variability or difference between any single observed data from the mean strength.

### 3. Standard deviation:-

It is defined as the root mean square deviation of all the results

$$\sigma = \sqrt{\frac{\sum (x - \bar{x})^2}{n-1}}$$

Where,

$\sigma$  = Standard deviation.

$n$  = number of observations

$x$  = particular value of observations

$\bar{x}$  = arithmetic mean.

#### 4. Coefficient of Variation:

It is a non-dimensional measure of variation obtained by dividing standard deviation by arithmetic mean and is expressed as

$$V = \frac{s}{\bar{x}} \times 100; V = \text{Coefficient of variation.}$$

Do example (497-page) of M.S. Shetty (Construction technology).

#### American Concrete Institute (ACI) Method:-

##### 1. Assumptions of ACI method:

- Over a considerable range of practical proportions fresh concrete of given slump and containing a reasonably well graded aggregate of given maximum size will have practically a constant total water content regardless of variations in water/cement ratio and cement content, which are necessarily interrelated.
- It makes use of the relation that the optimum dry rounded volume of coarse agg. per unit volume of concrete depends on its maximum size and fineness modulus of fine aggregate.
- After complete compaction is done, a definite percentage of air remains which is inversely proportional to the maximum size of the agg.

##### Q. Design a concrete mix for construction of an elevated water tank.

The specified design strength of concrete (characteristic strength) is 30MPa at 28 days measured on standard cylinder. Standard deviation can be taken as 4MPa. Sp. gravity of FA and CA are 2.65 & 2.7. The dry rodded bulk density of c.A is  $1600 \text{ kg/m}^3$ . and fineness modulus of f.A is 2.80. Ordinary portland cement (type I) will be used. A slump of 50mm.

C.A is found to be absorptive to the extent of 1% and free surface moisture in sand is found to be 2%. Assume any other essential data.

(a) Assuming 5% of results are allowed to fall below specified design strength

The mean strength,  $f_m = f_{min} + ks$

$$= 30 + 1.64 \times 4 = 36.5 \text{ MPa.}$$

Here

$k$  = Timswoith constant = 1.64 or 1.65

$s$  = standard deviation,  $\text{N/mm}^2$

= For  $M_{10}, M_{15} = 3.5 \text{ N/mm}^2$

= For  $M_{20}, M_{25} = 4 \text{ N/mm}^2$

= For  $M_{30}, M_{35}, M_{40} = 5 \text{ N/mm}^2$

- For  $M_{45}, M_{50}, M_{55}, M_{60} = 5 \text{ N/mm}^2$

$f_{min}$  = design strength.

b) Since OPC is used, from table "N" estimated w/c ratio is 0.47. This w/c ratio (1:5) from strength points of view is to be checked against max w/c ratio given for special exposure condition given in table 11.6 and minimum of the two is to be adopted.

From exposure condition Table 11.6, the maximum w/c ratio is 0.50.

Therefore 0.47 value is adopted.

c) from table 11.8, for a slump of 50mm, 20mm maximum size of agg. for non-air entrained concrete, the maximum water content is  $185 \text{ kg/m}^3$  of concrete. Also the appropriate entrapped air content is 2%.

The required cement content =  $\frac{185}{0.47} = 394 \text{ kg/m}^3$ .

d) From table 11.4, for 20mm coarse aggregate for fineness modulus of 2.80 the dry rodded bulk volume of C.A is 0.62 per unit volume of concrete.

e) So weight of coarse aggregate =  $0.62 \times 1600 = 992 \text{ kg/m}^3$ .

f) From table 11.9, the first estimate of density of fresh concrete for 20mm maximum size of agg. and for non-air entrained concrete =  $23.55 \text{ kg/m}^3$

g) The weight of all the known ingredient of concrete:

$$\text{Weight of water} = 185 \text{ kg/m}^3$$

$$\text{Weight of cement} = 394 \text{ kg/m}^3$$

$$\text{Weight of C.A} = 992 \text{ kg/m}^3$$

$$\begin{aligned}\text{Weight of F.A} &= 2355 - (185 + 394 + 992) \\ &= 784 \text{ kg/m}^3.\end{aligned}$$

(OR)

The absolute volume of all known ingredients (most accurate)

$$\text{Cement} = \frac{394}{3.15} \times 10^3 = 125 \times 10^3 \text{ cm}^3$$

$$\text{Water} = \frac{185}{1} \times 10^3 = 185 \times 10^3 \text{ cm}^3$$

$$\text{C.A} = \frac{992}{2.7} \times 10^3 = 367 \times 10^3 \text{ cm}^3$$

$$\text{Air} = \frac{2}{100} \times 10^6 = 20 \times 10^3 \text{ cm}^3$$

$$\text{Total volume} = 697 \times 10^3 \text{ cm}^3$$

$$\therefore \text{Absolute volume of F.A} = (1000 - 697) \times 10^3 = 303 \times 10^3 \text{ cm}^3$$

$$\text{Weight of F.A} = 303 \times 2.65 = 803 \text{ kg/m}^3.$$

h) Estimated quantities of materials per cubic meter of concrete are

$$\text{Cement} = 394 \text{ kg}, \text{ F.A} = 803 \text{ kg}, \text{ C.A} = 992 \text{ kg}, \text{ water} = 185 \text{ kg.}$$

i. Proportions: C : F.A : C.A : Water

$$394 : 803 : 992 : 185$$

$$1 : 2.04 : 2.52 : 0.47.$$

j. The proportions are required to be adjusted for field conditions.

As F.A has 2% surface moisture.

Total free surface moisture in FA =  $\frac{g}{100} \times 803 = 16.06 \text{ kg/m}^3$ .

Weight of FA in field condition

$$= 803 + 16.06 = 819.06 \text{ kg/m}^3 \approx 819 \text{ kg/m}^3$$

CA absorbs 1% water

$$\begin{aligned}\text{Quantity of water absorbed by CA} &= \frac{1}{100} \times 992 \\ &= 9.92 \text{ kg/m}^3.\end{aligned}$$

Weight of CA in field condition =  $992 - 9.92$

$$= 982 \text{ kg/m}^3$$

With regard to water, 16.06 kg of water is contributed by FA and 9.92 kg of water absorbed by C.A.

So,  $16.06 - 9.92 = 6.14 \text{ kg}$  of extra water is contribute by agg. So,  
 $185 - 6.14 = 178.86 \text{ kg/m}^3 \approx 179 \text{ kg/m}^3$ .

K. Quantities of materials to be used in the field duly conducted for free surface moisture in FA and absorption characteristic of CA.

$$\text{Cement} = 394 \text{ kg/m}^3$$

$$\text{F.A} = 819 \text{ kg/m}^3$$

$$\text{Water} = 179 \text{ kg/m}^3$$

$$\text{Field density of fresh concrete} = 2374 \text{ kg/m}^3.$$

Acceptance Criteria:-

1. Compressive strength:-

The concrete is deemed to comply with the compressive strength requirement when both the following conditions are met.

a) The mean strength determined from any group of 4 consecutive test results complies with the appropriate limits in 2nd column of following table.

b) Any individual test result complies with the appropriate limits in 3<sup>rd</sup> column of following table.

Grade	Mean of Group of 4 Non-overlapping consecutive results in N/mm <sup>2</sup>	Individual Test Results in N/mm <sup>2</sup>
M <sub>15</sub>	$\geq f_{ck} + 0.825 \times$ established standard deviation $0.5 \text{ N/mm}^2$ (or) $(f_{ck} + 3) \text{ N/mm}^2$ , which ever is greater	$\geq f_{ck} - 3 \text{ (N/mm}^2)$
M <sub>20</sub> (or) above	$\geq f_{ck} + 0.825 \times$ established standard deviation $\leq 0.5$ (or) $f_{ck} + 3 \text{ N/mm}^2$ , which ever is greater	$\geq f_{ck} - 3 \text{ (N/mm}^2)$

## 2. Flexural strength:-

When both the following conditions are met,

- a) The mean strength determined from any group of 4 consecutive test results exceeds the specified characteristics strength by at least  $0.3 \text{ N/mm}^2$ .
- b) The strength determined from any test result is not less than the specified characteristic strength  $< 0.3 \text{ N/mm}^2$ .

## 3. Design a concrete mix for M<sub>45</sub> grade of concrete with the following data.

The type of cement is OPC 43 grades, maximum size of aggregate is 20mm. Exposure condition is severe (RCC), workability is 125mm slump, maximum cement content is 320 kg/m<sup>3</sup>, maximum w/c ratio is 0.45 method of placing concrete is pumping, Degree of supervision is good, type of aggregate is crushed angular agg. Sp.gr of CA & FA is 2.80, 2.70 respectively, water absorption of CA and FA is 0.5%, 1% resp.

Grading of CA conforming to Table 2 of IS 383<sup>3</sup>, Grading of FA conforming to grading zone II.

Target Mean Strength:

Characteristic strength,  $f_{ck} = 45$

Target mean strength,  $f_{ck} = f_{ck} + 1.65 \times 5$

$$= 45 + 1.65 \times 5 = 53.25 \text{ N/mm}^2$$

$s$  = Standard deviation

$$= 5 \text{ N/mm}^2$$

Water/Cement ratio:

w/c ratio mentioned in Table 5 of IS 456 is 0.45. w/c proposed is 0.42 (by the experience of the mix designer). This being lesser than 0.45, w/c ratio is taken as 0.42.

Selection of Water Content:

Maximum water content as per table 11.23 is 186 lt. This is for 50mm slump.

Estimated water content for 125mm slump =  $186 \times \frac{9}{100} + 186 = 203$  lt.

[3% increase for every 25mm slump over & above 50mm slump] = 203lt.

It is assumed that the efficiency of super plasticizer used as 25%.

Therefore actual water to be used =  $203 \times 0.75 = 152$  lt.

Calculation of Cement Content:

w/c ratio = 0.42

Water used = 152 lt

Cement content = w/c = 0.42

$$C = \frac{152}{0.42} = 362 \text{ kg/m}^3$$

## Calculation of CA and FA content:

From table 11.24 volume of CA corresponding to 20mm size agg and FA zone II for w/c ratio of 0.50 is found out to be 0.62

Here w/c = 0.42 ie; < 0.08.

The CA is increased at the rate of 0.01 for every decrease in w/c ratio of 0.05

$$\frac{0.01}{0.05} \times 0.08 = 0.016, \text{ volume of CA} = 0.62 \\ = \frac{0.016}{0.636}$$

∴ Connected proportion of 20% of CA = 0.636.

Since, it is angular agg. and the concrete is to be pumped, the CA can be reduced by 10%.

$$\therefore \text{final volume of CA} = 0.636 \times 0.9 = 0.572$$

$$\text{Vol. of fine aggregate} = 0.43.$$

## Calculation of Mix proportions:

$$\text{Volume of concrete} = 1m^3$$

$$\text{Absolute Vol. of cement} = \frac{362}{3.15} \times \frac{1}{1000} m^3 = 0.115 m^3$$

$$\text{Vol. of water} = 152L = 0.152 m^3$$

$$\text{Vol. of chemical admixture} = \frac{1.2 \times 362}{100 \times 1.1} \times \frac{1}{1000} = 0.004 m^3$$

(Assuming dosage of 1.2% by weight of cementitious material and assuming specific gravity of admixture as 1.1)

$$\text{Absolute vol. of all the materials except total agg} = 0.115 + 0.152$$

$$+ 0.004$$

$$= 0.271 m^3$$

$$\text{Absolute vol. of all the total agg} = 1 - 0.271 = 0.729 m^3$$

Weight of CA =  $0.729 \times 0.57 \times 2.80 \times 1000 = 1163 \text{ kg/m}^3$

Weight of FA =  $0.729 \times 0.43 \times 2.70 \times 1000 = 846 \text{ kg/m}^3$ .

Mix proportions for Trial number 1:

Cement	water	FA	CA	chemical admixture
↓	↓	↓	↓	↓
362 kg/m <sup>3</sup>	152 kg/m <sup>3</sup>	846	1163	4 kg/m <sup>3</sup>
		kg/m <sup>3</sup>	kg/m <sup>3</sup>	

Wet density of concrete =  $2597 \text{ kg/m}^3$

w/c ratio = 0.42

The above quantity are on saturated and surface dry condition.

Site Correction:

Absorption of fine agg. =  $1\% = \frac{1}{100} \times 846 = 8.46 \text{ lt}$

Absorption of coarse agg. =  $\frac{0.5}{100} \times 1163 = 5.82 \text{ lt}$

Total absorption =  $14.28 \text{ lt}$

Actual amount of water to be used =  $152 + 14.28$   
=  $166.28 \text{ lt}$

Actual wt. of FA to be used =  $846 - 8.46 = 837.5$

Actual wt. of CA to be used =  $1163 - 5.82 = 1157.20$

Proportion of material at the site

Cement	water	CA	FA	Admixture
↓	↓	↓	↓	↓
362 kg/m <sup>3</sup>	166.28 kg/m <sup>3</sup>	1157.2	837.5	4 kg/m <sup>3</sup>
		kg/m <sup>3</sup>	kg/m <sup>3</sup>	

Expression of proportion:

Cement : FA : CA : Water

362 : 846 : 1163 : 152

1 : 2.34 : 3.21 : 0.42

Proportion for one bag mix in the field/ site 50 : 116 : 160 : 23.

## Special Concrete

### 1. Light weight Aggregate:-

It is divided into two categories

1. Natural light weight aggregate
2. Artificial light-weight aggregate.

### 1. Natural Aggregate:-

→ These are not found in many places and they are also not of uniform quality.

Ex: Pumice (widely used)

Diatomite, scoria, Volcanic, Cinders, sawdust, Rice husk.

- (a) Pumice : Volcanic origin, light and strong enough.
- (b) Diatomite : It is a hydrated amorphous silica derived from the remains of microscopic aquatic plants called diatoms. also known as kieselghun.
- (c) Scoria : Volcanic origin  
It is slightly weaker than pumice.
- (d) Volcanic Cinders : Loose volcanic product.
- (e) Sawdust : Used in manufacture of precast conc. products, jointless flooring and roofing.
- (f) Rice Husk : For manufacture of light-weight conc. this is used limitedly.

### 2. Artificial Aggregates:

The examples of artificial aggregates are cinders, coke breeze, foamed slag, bloated clay expanded shales and slate, sintered flyash, expanded perlite, Thermoncole beads

### a) Cinder, Clinker and Breeze:-

These are used to cover the material partly fused or sintered particles arising from the combustion of coal. It is also used for making building blocks for partition walls, making screeding over flat roofs and plastering purposes.

### b) Foamed Slag:-

- It is made rapidly quenching blast furnace slag, a by-product produced in the manufacture of pig iron.
- Texture and strength depends upon chemical composition and method of production.
- It must be free from contamination of heavy impurities, free from volatile impurities such as coke or coal, free from excess of sulphate.

### c) Bloated clay:-

When certain glass and shales are heated to the point of incipient fusion, they expand or what is termed as bloat to many times their original volume on account of the formation of gas within the mass at the fusion temperature.

### d) Sintered flyash (Pulverised fuel ash):-

- Flyash is finely divided residue, comprising of spherical glassy particles, resulting from the combustion of powdered coal.
- It is mixed with limited amount of water and is first made into pellets and then sintered at a temperature of  $100^{\circ}\text{C}$  to  $1200^{\circ}\text{C}$ .

### e) Expanded perlite:-

It is one of the natural volcanic glasses like pumice.

### Light weight aggregate concrete :-

- It is used by the use of light weight aggregate.
- Most of the light -weight agg. with the exception of bloated clay and sintered flyash are angular in shape and rough in texture.
- It is comparatively porous, when used for reinforced concrete, reinforcement may become prone to corrosion.
- Most of the light, weight aggregates have a high and rapid absorption quality.
- Strength of this depends on the density of concrete.

### No fines Concrete :-

- It is a kind of concrete from which the fine aggregate fraction has been omitted.
- It is made up of only single sized coarse agg. (passing through 20mm, retained on 10mm), cement and water.
- It gives architecturally attractive look, which in addition to having large voids and hence light in weight.

### High Density Concrete :-

- The concrete is called as high density, when its unit weight ranging from about 3360 kg per cubic metre to 3840 kg per cubic meter, which is about 50% higher than the weight of conventional concrete.

### Fibre Reinforced Concrete :-

- It is defined as a composite material consisting of cement, mortar or concrete and discontinuous discrete uniformly dispersed suitable fibres.
- Continuous meshes, woven fabrics and long wires or rods are not considered to be discrete fibres.

→ As plain concrete posses a very low tensile strength, limited ductility and little resistance to cracking so, fibre reinforced concrete is used for improving the properties of concrete.

### Polymer Concrete:-

- The polymerisation of concrete is done to reduce the inherent porosity of the concrete to improve the strength and other properties of concrete.
- The porosity of concrete, due to air voids, water-voids. the strength of concrete naturally reduces.

### Types of polymer Concrete:-

Presently 4 types of polymer concreter materials are developed.

- a) Polymer Impregnated Concrete (PIC)
- b) Polymer cement concrete (PCC)
- c) Polymer Concrete (PC)
- d) Partially impregnated & surface coated polymer concrete.

#### a) PIC:-

- It is the precast conventional concrete, cured and dried in oven or by dielectric heating from which the air in the open cell is removed by chemical initiation.
- Mainly methyl methacrylate (MMA), styrene, Acrylonitrile are types of monomer used.

#### b) PCC:-

- It is made by mixing cement, aggregates, water and monomer. Such plastic mixture is cast in moulds, cured, dried and polymerised.
- The monomer that are used in PCC are furans polyster-styrene.

Epoxy - styrene, vinylidene chloride.

c) Polymer Concrete :- (PC)

- It is an aggregate bound with a polymer binder instead of portland cement as in conventional concrete.
- The main technique in producing 'pc' is to minimise void volume in the aggregate mass so as to reduce the quantity of polymer mass needed for binding the aggregates.

d) Partially Impregnated (Coated in depth CID) and surface coated (SC) concrete :-

- With partial impregnation, significant increase in the strength of original concrete has been obtained.
- It is produced by initially soaking the dried specimens in liquid monomer like methyl methacrylate then sealing them by keeping them under hot water at 70°C to prevent or minimise loss due to evaporation.
- It is found that the depth of monomer penetration is dependent upon pore structure of hardened and dried concrete, the duration of soaking and the viscosity of the monomer.



## Light Weight Concrete:

One of the disadvantages of conventional concrete is its high self weight is in the order of  $22 \text{ kN/m}^3$  to  $26 \text{ kN/m}^3$ . This heavy self weight will make an uneconomical structural material. If the density of concrete is reduced to  $3 \text{ kN/m}^3$  to  $18 \text{ kN/m}^3$ , the concrete is called as light weight concrete.

The advantages of light weight concrete are:

- i. Dead load reduces and hence deflections are reduced.
- ii. Lowers haulage and handling costs.
- iii. Increases the progress of the building.
- iv. Reduces the load on the foundation and hence advantageously used in-case of weak foundation soil.
- v. Improves thermal insulation.
- vi. It can be economically used for non-load bearing walls such as partition walls.
- vii. Industrial wastes such as clinker, fly-ash, slag, rice husk ash etc can be used to produce light weight concrete, which reduces the disposal problem of the waste.
- viii. Reduction in cost of construction.

Basically there is only one method for making concrete light ie; by the inclusion of air. in concrete. This is achieved in actual practice by the following three different ways.

- i. By replacing the usual mineral aggregate by cellular porous (or) light weight aggregate.

- i. By introducing gas or air bubbles in mortar. This is known as aerated concrete.
- ii. By omitting sand fraction from the aggregate. This is called as "no-fines" concrete.

Out of the three methods mentioned above, Light weight aggregate and aerated concrete are more than often used than the 'no-fines' concrete. A particular type of light weight concrete called structural light weight concrete is one which is comparatively lighter than conventional concrete but at the same time strong enough to be used for structural purposes. Perhaps this type of concrete will have great future in the years to come.

Light weight concrete, very often is made by using the light weight aggregates. Natural light weight aggregate normally used for producing light weight concrete are Pumice, diatomite, scoria, volcanic cinders. Saw dust, brick bats and rice husk. Artificial light weight aggregates such as brick bats, cinders, clinkers, foamed slag, bloated clay, sintered fly ash, expanded perlite etc are also used.

Aerated concrete is made by introducing air or gas into slurry composed of Portland cement (or) lime and finely crushed siliceous filler so that when the mix sets and hardens, a uniformly cellular structure is formed. Aerated concrete is produced by the following methods.

- i. By the formation of gas by chemicals reaction within the mass during liquid (or) plastic state.
- ii. By mixing performed stable foam with the slurry.
- iii. By using finely powdered metal (usually aluminium powder) with the

slurry and made to react with the calcium hydroxide liberated during the hydration process, to give out large quantity of hydrogen gas. This hydrogen gas when contained in the slurry mix, gives the cellular structure.

### Fibre Reinforced Concrete : (FRC)

Plain concrete possesses a very low tensile strength, limited ductility and little resistance to cracking. Internal micro cracks are inherently present in the concrete and its poor tensile strength is due to the propagation of such micro cracks, eventually leading to brittle failure of the concrete.

It has been recognized that the addition of small, closely spaced and uniformly dispersed fibers to concrete would act as a crack arrester and would substantially improve its static and dynamic properties. This type of concrete is known as fibre reinforced concrete.

Fibre reinforced concrete can be defined as a composite material consisting of mixtures of concrete and discontinuous, discrete, uniformly dispersed suitable fibres. Continuous meshes, woven fabrics and long wires or rods are not considered to be discrete fibres. Fibre is a small piece of reinforcing material. They may be circular or flat. The fibres are often described by a parameter called 'aspect ratio'. The aspect ratio of the fibres is the ratio of its length to its diameter. Typical aspect ratio ranges from 30 to 150.

**Fibre used :** The following are the commonly used fibres

- a) Steel fibres
- b) Polypropylene fibres
- c) Nylons

- d) Asbestos.
- e) Coir
- f) Glass fibres
- g. Carbon fibres.

Steel fibre is one of the commonly used fibres. Generally round bars of diameter 0.25mm to 0.75mm are used. Use of steel fibres makes significant improvement in flexural, impact and fatigue strength of concrete. It has been extensively used in various types of structures, particularly for overlays of roads, air field pavements and bridge ducts.

Polypropylene and nylon fibres are found to be suitable to increase the impact strength.

Asbestos is a mineral fibre and has proved to be most successful of all the fibres as it can be mixed with portland cement. The composite product called as asbestos cement has considerably higher flexural strength than the portland cement paste.

Alkali-resistant glass fibres are recently used, which considerably increases the durability.

Carbon fibres possess very high tensile strength. The cement composite made with carbon as reinforcement will have very high modules of elasticity and flexural strength.

#### Factors affecting properties of fibre Reinforced Concrete:-

Fibre reinforced concrete is a composite material containing fibres in the cement matrix in an orderly manner or randomly distributed manner. Its properties would obviously, depend up on the efficient transfer.

of stress between matrix and the fibres, which largely depends up on the following factors.

- a) Type of fibre.
- b) Fibre geometry.
- c) Fibre content.
- d) Orientation and distribution of fibres.
- e) Mixing and compaction techniques of concrete.
- f) Size and shape of the aggregates.

Advantages of FRC :-

- Fibre reinforced concrete is increasingly used on account of the following advantages.
- i. Increases the static and dynamic tensile strength.
  - ii. Improves the energy absorbing characteristics.
  - iii. Better fatigue strength.
  - iv. Increases the modulus of elasticity.
  - v. Improves the durability.
  - vi. Provides isometric properties to concrete.

Fibre reinforced concrete has been extensively used on overlays of air field, road pavements, industrial floorings, bridge ducts, canal linings, explosive resistant structures, refractory linings etc. Fibre reinforced concrete can also be used for the fabrication of precast products like pipes, boats, beams, staircase steps, wall panels, roof panels, manhole covers etc.

## High density concrete :-

Density of normal concrete is in the order of  $24 \text{ kN/m}^3$ . To call the concrete as high density concrete, it must have unit weight ranging from  $34$  to  $38 \text{ kN/m}^3$ , which is about  $50\%$  higher than the unit weight of conventional concrete. They can, however be produced with densities with densities up to  $53 \text{ kN/m}^3$  using iron as both fine and coarse aggregate. The high strength concrete is used in the construction of radiation shields.

There are many aggregates whose specific gravity is more than  $3.5$  for making a heavy weight concrete. Out of these, commercially used aggregate are barite, magnetite, limonite, hematite etc. Steel and iron aggregate in the form of shots, punching scrap are also used as a heavy weight aggregate. The capacity of heavier aggregate to absorb gamma rays almost directly proportional to their density and also the heavier aggregate are more effective in absorbing fast neutrons by inelastic collision than the lighter one. Hence, as heavy aggregates as possible should be used for radiation shielding.

The effectiveness of radiation shielding quality of concrete can be increased by increasing the density. Another important requirement of shielding concrete is its structural even at high temperature. To produce high density and high strength concrete, it is necessary to control the water cement ratio very strictly. Use of appropriate admixture and vibrators for good compaction are required to be employed. Good quality control is to be followed.

## Polymer Concrete :-

Conventional concrete is porous, which is due to air voids, water voids or due to the inherent porosity of gel structure itself. The presence of pores reduces the strength and durability of concrete. The addition of monomer and subsequent polymerization is the latest technique adopted to reduce the porosity of the concrete, to improve the strength and other properties of concrete. Polymer concrete posses high compressive strength, fatigue, resistance, impact resistance, toughness and durability.

The following four types of polymer concrete materials are being developed presently.

- i, Polymer impregnated concrete (PIC)
- ii, Polymer cement concrete
- iii, Polymer concrete.
- iv, Partially impregnated and surface coated polymer concrete.

## Polymer Impregnated Concrete :-

It is a hardened cement concrete that has been impregnated with a monomer (low viscosity liquid organic material) and subsequently polymerised. In this case, the cement concrete is cast and cured in the conventional manner. After the concrete gets hardened and dried, air from the voids is removed under partial vacum or by dielectric heating and a low viscosity monomer (vinyl chloride, styrene, acrylonitrile etc) is diffused through the pores of the concrete. The concrete is then finally subject to polymerization by radiation or by heat treatment or by chemical initiation, thereby converting the monomer filled in the voids into solid plastic. Polymer impregnated concrete due to its high resistance to wear and tear impact

etc., is widely used for kerb stones, pre-cast slabs for bridge decks, roads in marine structures, food processing buildings etc.

Partial impregnation may be sufficient in situations where surface resistance against chemical and mechanical attack is required.

### Polymer Cement Concrete (PCC):

This type of concrete is produced by incorporating an emulsion of polymer or a monomer in ordinary cement concrete. The ingredient comprising of cement, aggregate and a monomer are mixed with water and the monomer in the concrete mix is polymerized after placing concrete in position. The resultant concrete has improved work ability, strength, adhesion, chemical resistance, impact resistance, abrasion resistance and low permeability and absorption.

### Polymer Concrete (PC):

In this type of concrete, polymer/monomer is used to act as a binder in place of cement. The monomer and the aggregate are mixed together and the monomer is polymerized after placement of concrete in position. It is however, necessary to pre-heat the coarse and the fine aggregate while mixing the monomer. Polymer concrete serves as a very good dielectric material. It can be advantageously used for the construction of irrigation works.

### Advantages of Polymer Composites:

- (i) Increases the Compressive strength.
- (ii) Increases resistance to wear and tear.
- (iii) Improves Fatigue resistance.
- (iv) Improves Impact resistance.
- (v) Impermeability.
- (vi) Increases the Durability.

## Self-Compacting Concrete:

Self-compacting concrete (SCC) is defined as "Concrete that is able to flow and consolidate under its own weight, completely fill the formwork or bore hole even in the presence of dense reinforcement, whilst maintaining homogeneity and without the need for additional compaction."

The purpose of good compaction for conventional is to ensure satisfactory strength, sound impermeable, concrete with satisfactory detail at corners, good bond with the steel reinforcement, good finish and appearance and impermeable protective cover to the steel reinforcement. SCC on the other hand does not require any mechanical effort such as the use of immersion vibrators or external formwork vibrators, to achieve full compaction.

The basic constituent materials used in SCC are essentially the same as those of conventional concrete, although additional admixtures, or fine materials may be necessary to achieve the required rheological properties. However, the biggest difference between the two concretes is the actual proportioning of these materials. In order to achieve its defined purpose, SCC mixes contain lower coarse aggregate contents, higher amounts of sand, higher amounts of cementitious materials including portland cement, lower water/cementitious materials ratio, higher superplasticiser doses and sometimes viscosity modifying admixtures.

The reduction in the amount of coarse aggregate is done in order to reduce the friction between them and therefore enhance the overall concrete fluidity. The increase in paste contents (i.e. sand, cementitious materials, admixtures etc) is also further increase fluidity as well as enhance its cohesiveness

and resistance to segregation and viscosity. Control of the viscosity and the cohesiveness of the paste ensures the flow of the SCC through obstacles such as steel reinforcement without any aggregate blockages.

The three essential fresh properties required by SCC are:

#### \* Filling Ability:

The concrete must have the ability to flow and completely fill all parts within the formwork under its own weight without leaving voids.

#### \* Passing Ability:

The concrete containing the required aggregate size must have the ability to flow through and around restricted spaces between steel reinforcing bars and other embedded objects under its own weight and without blocking or segregation.

#### \* Segregation Resistance

The concrete must be able to satisfy both the filling ability and passing ability requirements while it still remains homogeneous both during transport and placing and after placing.

#### Advantages of SCC

The principal benefits of SCC are advantages derived from the properties of fresh mix itself, namely:

1. Ability to completely fill complex formwork and encapsulate areas of congested steel reinforcement without any compaction and yet with reduced risks of voids and honeycombing.

2. Ability to develop higher early and ultimate strengths and enhanced durability properties compared with conventional vibrated concretes.

3. Potential for improved surface finishes with reduced making good costs related to poorly compacted surfaces.
4. Lower surface absorption and therefore better durability.
5. Reduced construction time and labour costs.
6. Reduced man power for placing and compacting.
7. Lower equipment costs and less noise since vibrators are not required.
8. Improved OH&S in the workplace environment through the elimination of vibrating associated health and safety risks. Reduced noise levels, reduced trip and fall hazards, less manual handling.

The following precautions should be taken into account when working with SCC:

1. Due to high fines content and viscosity SCC concrete tends to dry faster than conventional concrete which leads to plastic shrinkage cracking. As such it is important that evaporative retarders are used between initial screeding and finishing and curing is implemented in a timely manner as per specification requirements.
2. SCC must be supplied on a continuous basis and sufficient manpower and equipment must be on site to avoid any delays.
3. In order to minimise the risk of segregation of SCC the vertical free-fall should be limited to 3m and the horizontal flow point of discharge to 6m.
4. As SCC concretes are more susceptible to quality and material fluctuations than conventional vibrated concrete, a stricter quality control regime, production control, construction control and training regime must be put in place.

## Sho~~it~~creting of Concrete:-

In this system, fine concrete or mortar is deposited by jetting it pneumatically through nozzles with a considerable velocity on to a prepared surface. It is used for construction of lightly reinforced thin overhead, vertical or horizontal surfaces particularly curved or folded sections, canal linings, prestressed tanks, encasement of steel girders, repairing of damaged or defective refractory linings and fire proofing of steel sections. The mix can range from 1:3 to 1:4 (Cement to sand of maximum size 10mm) with water cement ratio 0.35 to 0.50 depending on the strength and impermeability required.

The advantages are that shuttering is required only on one side and concreting possible even where access is difficult. High strength is achieved due to low water cement ratio and high compaction. Wastage through rebound can be 5 to 50% depending up on the location of the surface.

## The disadvantages of this system are:

- i. Skilled labour is required for the job.
- ii. The work results in a porous structure.
- iii. The work is dusty.
- iv. It results in large shrinkage cracks.
- v. The surface is rough.
- vi. Wastage of concrete through rebound will be more.  
→ reinforced concrete beam can be repaired by gunniting with a wire mesh fabric 7.5x7.5cm of 5mm dia. To reduce initial shrinkage located 10mm away from the original concrete surface. Gunning acts as a part of

(25)

the structure and can be considered as a monolithic beam of increased dimensions for all design purposes. This technique is used extensively in the repair of dams, spill ways, water mains, beams and column where concrete has spalled off due to corrosion of reinforcement or exposure to fire and water proofing of swimming pools, reservoirs and tunnels.

### Concreting in high-rise buildings:

Modern high-rise concrete buildings are models of design skill in the use of materials. It is common to specify high strength concrete, for compression members in the lower stories of multi-story buildings concentration of reinforcing bars in these members is very high. The trend toward buildings other than rectilinear in shape is producing some unusual structural members. All of these factors tend to placing problems unless a mix design is formulated that produces concrete of considerable flowability and high quality.

The problem of obtaining uniform, high-quality concrete in this work depends mainly on two basic considerations:

1. Mix design; and
2. Placing and curing procedures.

The narrow, high forms often used for columns and shear walls aggravate the tendency of mixes to bleed and produce laitance.

These problems are quite common in tall building construction field, but they can be prevented by close attention to two aspects of the mix design.

1. Cement paste consistency and physical composition; and
  2. Characteristic of aggregate. Air entrainment and minimum water content can also play an important role in halting bleeding, formation of laitance and segregation.
- Without proper placing procedures, however, even the best designed concrete will segregate and bleed, resulting in honeycombing, poor bond to steel and other problems. Because column and wall forms are usually rather high and reinforcing bars are often spaced quite closely, workmen must be careful in depositing and vibrating concrete in this work. Concrete should be dropped in a true vertical plane and have a free fall of not more than four feet. Vibration can be a great help in concreting high - rise buildings. because it permits use of lower water contents. However vibration can be misused if it is employed with wet mixes or continued for important bearing on the quality of concrete flatwork. These desirable proportioning and placing practices will also largely hold true for lightweight concrete. However, uniform workability of the mix is more difficult to maintain with lightweight aggregates. This can be improved with air entraining and water reducing agents.