UNIT 4 CONCRETE

Structure

4.1 INTRODUCTION

Concretc and steel are the two most commonly used structural materials. Steel is manufactured under carefully controlled conditions. Its properties are determined in a laboratory and described in a manufacturer's certificate. Thus the designer needs only to specify the relevant standard and the site engineer's supervision is limited to the workmanship of the connections only.

In the case of concrete the situation is totally different. Properties of one of the ingredients of concrete, namely cement, is guaranteed by the manufacturer. The overall properties of concrete depend on workmanship of concrete making, placing etc. Hence to produce good concrete a thorough quality control, based on sound knowledge of concretc technology, is essential throughout the manufacturing from of concrete.

Sometimes an additional ingredient may be added to conventional concrete which may improve many of the designed properties of concrete. Fiber reinforced concrete, foamed concrete are some of the examples.

Curing is the last stage of the concrete manufacturing process. Curing ordinarily means either to prevent the evaporation loss of the capillary water or to supplement evaporated water by applying water from outside. The latter method of curing is most of the time tedious and in some cases impossible, Now a days various types of curing compounds are available in Indian market which when applied on fresh concrete surfaces prevents evaporation loss of the capillary water.

Objectives

After studying this chapter you should be able to

* identify the types, properties, manufacture, grades of the ordinary cement concrete,
* state the types, properties, manufacture and application areas of foam concrete,

* discuss about fiber reinforced concrete, how it is manufactured, types of fibers which can be used, various important properties and application areas, and
* evaluate curing compounds, their advantages, applications and
* evaluate the curing compounds available in the Indian market.

4.2 CEMENT CONCRETE

Concrete is the most widely used man made construction material. It is manufactured by mixing cement, water and aggregates (many times admixtures also) in .desired proportions. The mixture, when put in formwork and allowed to cure by application of water or by other means, becomes a substance like hardstone. The hardening is caused by a chemical process known as hydration of cement with water which continues for infinite time. This hydration process makes the concrete grow stronger with age. The hardened concrete may be compared with artificial stone in that the voids of larger particles (course aggregate) are filled by the smaller particles (fine aggregate) and the voids of fine aggregates are filled with cement. In a concrete mix there exists a two phase system – they are paste phase and aggregate phase. The cement and water form a paste called cement water paste which in addition to filling the voids of fine aggregates acts as binder on hardening, thereby cementing the particles of the aggregates, together in a compact mass. The cement and fine aggregate with water form the paste phase, while aggregate alone forms aggregate phase.

The strength, durability and other characteristics of concrete depend primarily upon :

1) the properties of its ingredients,
2) on the proportion of the mix,
3) the method of compaction, and
4) other controls during placing, compaction and curing.

The versatility and popularity of the concrete is due to the fact that it is manufactured out of the common ingredients and also it is possible to monitor the properties of concrete to meet the requirements of any particular situation. The advances in concrete technology have facilitated the way to make the best utilization of locally available materials by judicious mix proportioning and proper workmanship, so as to produce concrete which satisfies performancerequirements.

The concept of treating the concrete in its entity as a building material, like steel and other building materials has lead to introduction of **ready mixed concrete.** Everybody, in the construction field, eager to see that is such a system is implemented and functionalized as a routine. It should be possible to place order for concrete of a given grade, at a given location and time. With proper planning it should be possible to receive the product on the scheduled time, which then will be pumped to given location, placed and compacted. Concrete will be produced by weigh batching plant under complete quality control and delivered duly mixed to the site of placement by truck mounted agitators or dumpers.

Concrete has very high compressive strength while its tensile strength is very low. In places where it is subjected to tensile stresses, steel bars forming composite construction in conjunction with concrete is incorporated, which is called reinforced cement concrete. The concrete without reinforcement is called plain cement concrete. Sometimes the tensile stresses are neutralized by introducing coinpressive stresses in the concrete before it is placed under loading. Such construction is called prestressed cement concrete construction. The process of making concrete is called concreting. Figure 4.1 below shows a typical flow chart of concrete making.

4.2.1 Classification of Concrete

The main ingredients of concrete are cement, fine aggregate and course aggregate. Most popularly, concrete is specified by the proportion (either by volume or by weight) of these ingredients. Such classification are termed as prescriptive specifications. When specificationsspecify the requirements of the desirable properties of concrete such as strength, workability, durability etc. they are termed as performance oriented specification. Based on these considerations, the concrete can be classified into either controlled concrete or ordinary concrete, depending upon

a) the method of proportioning concrete mixes, and
b) the type of quality control exercised during the manufacturing process.

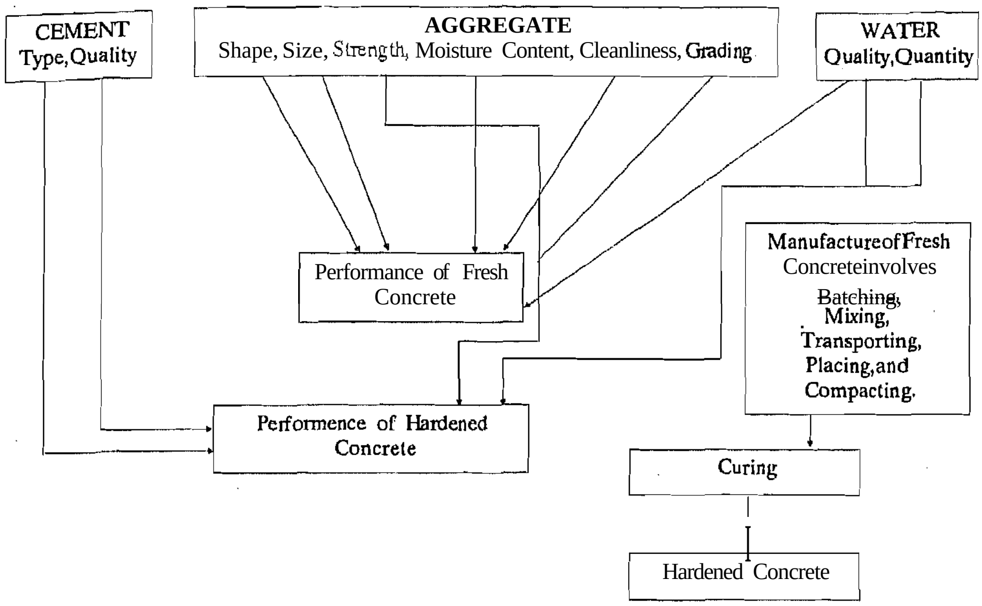

Fig. *4.1* : *Flow Chart of Cocrete* Making.

When the proportions of the ingredients are determined by designing the concrete **mix** with all necessary tests being carried out, it is called controlled concrete; the concrete mix when not so designed is called ordinary concrete. Present code does not mention about uncontrolled concrete; it only states varying degree of control. Besides mix designing with necessary tests, the quality control includes selection of the appropriate concrete materials by proper testing, proper batching and proper workmanship in mixing, transporting, placing, compacting and curing in conjunction with the testing of hardened concrete following acceptance criteria as laid down in IS:456-1978.

4.2.2 Properties of Concrete

Concrete making does not mean only mixing various ingredients to produce a plastic mass which is known as fresh concrete; quality concrete demands certain performance requirement to be satisfied in the plastic as also in the hardened stage. At plastic stage concrete should be workable and free from segregation and bleeding. Segregation means separation of aggregate phase from paste phase, while bleeding means separation of cement and water from remaining mass. Sometimes chemicals are added during manufacture of concrete to generate air which is uniformly and in minute quantities distributed over the concrete mass. This is known as air entrainment which improves certain properties of concrete such as reduction in thermal conductivity and self weight. ***Air*** entrainment also need is to be controlled during the manufacture of concrete.

In its hardened state concrete should be strong, durable and impermeable and it should have minimum dimensional changes so that it develops **minimum** cracks.

Among the various properties of concrete, the compressive strength is considered to be the single most important property which if not quantitatively, but certainly qualitatively speaks of the other properties of concrete and hence is taken as an index of its overall quality. In fact many a times compressive strength test becomes the only quality control measure because of the intrinsic importance of compressive strength in concrete construction and as it is an easy test to perform.

4.2.3 Grades of Concrete

Grading of concrete is done based on 28 days characteristic compressive strength, while characteristic strength is defied as the strength of material below which not more than 5 percent of the test result are expected to fall. The various grades of concrete as stipulated in IS:456-1978 are given in Table 1.

In the designation of a concrete mix, letter M refers to the **mix** and the number to the specified characteristic compressive strength of 15 cm^3 at 28 days expressed in N/mm^2. M 5 and M 7.5 grades of concrete may be used for lean concrete bases **and** simple foundations for masonry wall construction. These mixes need not be designed. Grades lower than M 15 shall not be used in reinforced concrete, and grades lower than M 25 are generally not used for prestressed concrete.

Table 1 : Grades of Concrete

Grade **designation**	Specified characteristic compressive **strength** at **28 days (N/mm²)**
M 10	10
M 15	15
M 20	20
M 25	25
M 30	30
M 35	35
M 40	40

4.2.4 Do You Know ?

The quantity of water to be mixed to manufacture concrete is expressed as a ratio with . cement by weight which is known as water-cement ratio. If excess water is used in a mix, the space occupied by this water may not gel ultimately filled by the hydrated product of cement, which has about 2.1 times volume of the volume of cement and water which has taken part in hydration. As a result, in hardened concrete voids are left which are known as capillary pores. These pores cause reduction in strength, increase permeability of concrete when they form a continuous channel throughout the section of the structure and also allows undesirable elements to penetrate into the core of the structure, making concrete less durable. Theoretically optimum water cement ratio should be 0.38, but it is also to be seen that with this water cement ratio, it is possible to compact concrete properly. Poorly compacted concrete will have entrapped air which will invite all the problems which otherwise would have been caused due to existence of capillary pores.

Hydration of cement is an exothermic process. Ordinary portland cement liberates about 120 calories of hear per gram of cement. In cold weather concreting this heat can be preserved to raise the temperature of concrete as rate of hydration retards with fall of temperature and at about – 11° C, the hydration almost stops. In mass concreting, the heat of hydration may create problems, because the heat developed at core of the structure will be preserved, as surrounding concrete is insulating in nature. At the periphery, concrete gives away the heat generated to the ambient atmosphere, leading large temperature stresses causing concrete to crack. The solution in this case will be to use special cement which produces low heat of hydration over a longer period of time. One such cement is known as low heat cement.

Maximum size of aggregate used for concrete making influences the properties of fresh and hardened concrete considerably. By increasing the maximum size of aggregate, within limit workability can be improved, i.e. ease with which concrete can be compacted after placement. Increase in maximum size of aggregate, within limits also improves strength of hardened concrete. However, maximum size of aggregate also depend on the

i) thickness of section,

ii) spacing of reinforcement,

iii) clear cover of concrete over reinforcement, and

iv) handling of mixing and placing technique.

¤ Aggregates below the size of 4.75 mm are known as f i e aggregate (F.A) while larger than 4.75 mm are known as course aggregate (C.A). Normally in reinforced concrete and high strength concrete (M 35 and above) maximum size of aggregate does not go beyond 20 mm. In pre-packed concrete or in plum concrete the same may go upto 80 mm or even more.

¤ Shape of aggregate also influences concrete properties. Rounded aggregates improve workability Angular aggregates (produced by stone crusher) exhibit a better interlocking effect in concrete. This makes superior concrete which is used for roads and pavement or where it is subjected to impact, abrasive or fatigue loading.

¤ Particle size distribution of aggregate, which is also known as grading should follow the ideal grading prescribed in IS:383-70.

¤ Water mixed during manufacture of concrete has to be maintained within concrete till such time hydration has progressed considerably. However, in practice as concrete is open to atmosphere, the mixed water gets evaporated and thus the water available in the concrete will not be sufficient for effective hydration to take place, particularly in the top layer. Curing is a process by which concrete is kept moist enough to make good the loss of water due to evaporation as also to take away the heat developed due to heat of hydration. Curing is being given a place of increasing importance as the demand for high quality concrete increases. Curing has to be started just after final setting time and should be continued at least for 7 days, 5 days and 21 days for OPC, RNC and LHC respectively.

Tensile strength of concrete is much lower than its compressive strength. The tensile strength is about one tenth of compressive strength.

SAQ 1 :

1) Name various ingredients required to manufacture concrete.

2) Describe the various stages in the manufacture of concrete.

3) Wow is Concrete classified ?

4) What do you understand by the **Grades of Concrete** ?

5) What is **Hydration of Cement** ? What is **Heat of Hydration** ?

4.3 FOAM AND AERATED CONCRETE

One of the disadvantages of conventional concrete is its high density. High density involves large dead weight, more haulage and handling costs. One of the methods of reduction of density is by introducing gas bubbles into the plastic cement mix in order to produce a material with a cellular structure resembling sponge rubber. The resulting concrete is known as aerated concrcte or cellular concrete. This concrete has much lower density than conventional concrete but has lower strength than conventional concrete. In many cases structuralstrength does nat form any requirement and in some cases where it even forms a requirement much lower strength than conventional concrete can serve the purpose. Hence, in those cases aerated concrete is the most economical alternative. Also, aerated concrete induces certain special properties like thermal and sound insulation.

4.3.1 Types of Foam/Aerated Concrete

Depending on the method of gas production in concrete, the end product can be named as

i) Gas concrete, and

ii) Foamed concrete.

Gas concrcte may be obtained by adding an admixture of fresh mortar thus making a chemical reaction with one of the minor compounds of cement (generally alkali) or calcium hydroxide liberated by process of hydration of cement forming gas bubbles. When mortar . sets it contains a large number of such gas bubbles. The speed of gas evolution, consistency of mortar and setting time of mortar should be matched in such a way that required amount of gas bubbles arc formed which expand without escaping from the mix. Some of the commonly employed admixtures that produce gas concrete are aluminum powder, zinc powder and hydrogen peroxide.

Foamed concrete is produced by adding a foaming agent, usually some form of hydrolyzed protein or resin soap, to the mix while mixing it at a high speed. After required time of mixing, stable, uniformly distributed air bubbles are formed throughout the mass of plastic *mix.* In some processes a stable pre-formed foam is added to the mortar during mixing in an ordinary mixer.

4.3.2 Properties of Foam/Aerated Concrete

Aerated concrete may or may not contain course aggregate depending on whether the same is to be used for structural use or not. When aggregates are not used the density varies between 200 to 800 kg/m^3. However when ground sand is used in lieu of naturally occurring sand the density can go upto 1100 kg/m^3 which can be used for structural purposes. It may be mentioned that with increase in density, both strength and thermal conductivity increases. For example concrete with density 500 kg/m^3 has strength in the region of 3 to 4 N/mm^2 and thermal conductivity of about 0.1 Jm/m^2.S.°C while concrete with density of 1400 kg/m^3 the corresponding values are 12 to 14 N/mm^2 and 0.4 Jm/m^2.S.°C.

4.3.3 Application of Aerated/Foamed Concrete

Aerated concrete is mostly used in partitions for heat insulation purposes because of its low thermal conductivity(about one tenth of ordinary concrete) and for fireproofing as it offers better fire resistance than ordinary concrete. Structurally, it is used mostly in the form of high-pressure steam-cured block or precast members but it can also be used for floor construction instead of hollow tile floor. Aerated concrete can be sawn and nailed.

Aerated concrete is reasonably durable. Due to its larger voids it has good resistance to Erost and rate of water penetration through it is much slower. However untreated aerated concrete should not be exposed to an aggressive atmosphere. If reinforcement, is to be used in aerated concrete, the same should be treated before use by dipping in a suitable anticorrosive liquid.

4.4 FIBRE REINFORCED CONCRETE

High strength concrete with compressive strength more than 25 N/mm^2 is being increasingly used in reinforced and prestressed concrete construction of buildings, bridges and other structures. One of the drawbacks of high strength concrete is that it is brittle. The failure could be sudden and catastrophic, particularly in structures subject to earthquakes, blasts or suddenly applied loads, unless special precautions are taken in designing, detailing and constructing these structures. An ideal solution to overcome this serious disadvantage of concrete, is to add fibres in concretes to achieve ductility and avoid sudden failures.

The use of fibres in concrete is of relatively recent origin. Although the concept of reinforcing brittle materials is quite old, the recent interest in reinforcing portland cement based materials with randomly distributed fibres was generated by pioneering research on steel fibers conducted in USA and UK in the 1960s. Since then there have been substantial research and development activities throughout the world, attempts have also been made in India to improve the properties of concrete by introducing materials like fibres and polymers.

4.4.1 Definition of Fibre Concrete

Fibre concrete is defined as concrete made from hydraulic cements with or without aggregates of various sizes, and incorporating discrete the fibre reinforcements. For reasons of volume instability it is very doubtful if the cement paste alone can ever be used as the matrix in practical composites. All fibre concrete composites are, therefore, likely to contain some aggregate inclusions, with the possible exception of asbestos cement products.

4.4.2 Definition and Types of Fibre

Fibres suitable for reinforcing concrete have been produced from steel, glass, ceramics and organic polymers. Some minerals, for example, asbestos, occur in the fibrous form and there are many types of natural vegetable fibres, for example, cotton, jute and sisal fibres which are available in various sizes and shapes.

It is very difficult to provide a strict definition of a fibre. The ACI considers that the aspect ratio of a fibre (i.e. fibre length divided by an equivalent fibre diameter) is the most convenient numerical parameter by which a fibre can be described. However, since in the production of fibre concrete the range of diameters and lengths of various fibres used is very extensive and some of the fibre like glass are used in the form of bundle, it is not possible to classify fibres by their aspect ratios alone.

Types and Properties of Fibres

Some of the important properties of the fibres which are already in use or are potentially useful as concrete reinforcement are listed in Table 2.

Table 2 : Properties of Some Typical Commonly Used Fibres

Fibre	Diameter (μm)	Density (10^3 k/gm ^{3})	Young's Modulus (kN/mm ^{2})	Tensile strength (kN/mm ^{2})	Elongation at break (%)
Asbestos					
a) Chrysolite	0.02 – 20	2.55	164	3.1	2 – 3
b) Crocidolite	0.1 – 20	3.37	196	3.5	2 – 3
Carbon					
a) Type - I	3	1.90	380	1.8	- 0.5
b) Type - II	9	1.90	230	2.6	- 1
Polypropylene	20 – 200	0.9	5	0.5	- 29
Nylon (type242)	> 4	1.14	4	0.9	- 15
Kevlar					
a) PRD 49	- 10	1.45	133	2.9	2.6
b) PRD 29	12	1.44	69	2.9	4.0
Sisal	10 – 15	1.5	–	0.8	- 3
Glass	9 – 15	- 2.6	- 80	2.4	2 – 3.5
Steel	5 – 500	7.8	200	1.3	3 – 4

Of these, on economic grounds, asbestos, steel wire, glass fibre, mineral wool, polymer fibres such as nylon and polypropylene, and natural vegetable fibres look attractive. Cement reinforced with asbestos fibres has been extensively used in construction industry for 50 years or more. Interest in other fibres of more recent origin and their applications in concrete increasing is rapidly.

4.4.3 Matrix Properties

In fibre concrete materials, the function of the matrix is to bind the fibres together, to protect them and to take part in the transfer of stress to and from the fibres. The possibilities of fibre concrete made from various types of cements, portland, aluminous, regulated set cement etc. are being explored. But in view of its predominant position in the construction industry much of the work, to date, has been carried out with portland cement.

As a matrix, portland cement has some extremely attractive properties, e.g. it is about 6 times stiffer and one-hundred times cheaper than many resins, it is durable under various environmental conditions and does not present any fire hazard, but it has one over-riding disadvantage, that of very low failure strain. The main consequence of this incompatibility in failure strains between the matrix and the reinforcement is that under stress, the composite exhibits the phenomenon of multiple cracking of the matrix beyond a not very well-defined elastic limit.

To overcome the difficulty of low elongation at break and possibly of high stiffness in cement systems, attempts are being made to modify the matrix by polymer inclusions.

Addition of rubber-like polymer dispersions of various types has been proposed but no definite picture of the usefulness of these substances regarding the durability of the composite material has emerged.

The cement matrix is highly alkaline and in the case of portland cement it remains so throughout in spite of carbonation. Some fibers including those made from glass, are chemically attacked and suffer some loss in strength, the extent of which depends on the actual composition of the fiber used. It has been suggested that additions of a suitable quantity of sand or pozzolanic materials, such as pulverised fuel ask, may be beneficial. Such additions may also control, along with the judicious choice of appropriate water/cement ratios, the shrinkage and swelling strains suffered by the matrix due to moisture movement. Improvement in other properties, for example freeze-thaw behaviour, may also result. It is thus very important that careful attention is given to the mix design aspects in the production of fiber concrete. As many of the applications of these fiber concrete materials will be in the form of thin sheets, due consideration should also be given to the effect of carbonation.

4.4.4 Fabrication Of Fibre Concrete

The principal objective in the fabrication of the fibre composite is to arrange the fibres in the matrix in such a way as to allow them to perform their designed functional role and to achieve a composite action between the fibres and the matrix. Fibres can be arranged in regular or random array, the choice depending on the type of fibre, its form, the application of the composite and the assumed stress distribution. Fabrication techniques should ensure that fibres are bonded well to the matrix and that the porosity of the composite can be easily controlled by applying the standard niethods used in concrete technology.

The methods of manufacturing asbestos cement, such as the wet or Hatschek Process, the semi-dry or Magnani Process, the dry or Manville Process, are well-known. Considerable progress has also been made in establishing practical methods for both steel and glass fiber concrete. In general, the production methods for fibre concrete made from these new fibres, are still in the development stage and no firm ideas have yet emerged as to how these materials are best manufactured. Many of the standard manufacturing methods used in fiber reinforced plastics technology are being applied.

Fibre made from glass, carbon and various polymers which are attainable as continuous filaments can be incorporated into the matrix by

a) the winding process,

b) the spray-up process, and

c) the lay-up process.

The fabrication technique used determines the orientation of the fibre and it has been demonstrated in practical cases that one, two or three-dimensional orientation of the fibre can easily be achieved. It is also possible to disperse short fibres randomly in the matrix or in preferred orientations. Steel fibres, which are generally available in the form of chopped wire, are incorporated into concrete using standard concrete mixers. Polypropylene fibres have also been introduced in concrete in this way. The details of these fabrication techniques may be found in State of Art Reports prepared by Concrete Society in UK and ACI (FRC Composites, Tech. Report 51.067, Concrete Society, London, July '73, pp.77 and State of Art Report on FRC, ACI Committee 544, J. Amer. Conc. Inst., Vol. 70, No. 11, Nov. '73, pp. 729 - 744). In the recent times, it has been possible to place steel fibre concrete using the gunnite technique. The method is applicable to glass and polypropylene fibers as well. Short steel fibres can be placed in preferred orientation in the fresh mix under vibration using a magnetic field or other simpler techniques.

Using the winding method it has been possible to introduce more than 0.15 volume fractions of fiber in concrete. By the spray-tip process (which produces a two-dimensional random array of short fibers), fiber volume fractions in excess of 0.10 have been incorporated in the matrix. Premixing of the fibre with concrete before moulding or placing allows a much smaller proportion of the fibre to be introduced, its volume being less than 0.05% in most cases. In the case of steel fiber concrete, fiber volume fractions greater than 0.03 can be realised only with great difficulty.

Various fabrication parameters control the amounts of fibres which can be introduced into concrete, the most important among them being the aspect ratio of the fibre and the geological properties of the matrix. The properties of the hardened composite bear a strong dependence on its porosity and, hence, the water cement ratio used in manufacturing the composite plays a very significant role. Some control over the water to cement ratio can be exercised by the addition of flow assisting admixtures.

4.4.5 Properties of Fresh Fibre Concrete

Fibres in a concrete mix essentially act as inclusions with a large surface area. The geometry of the fibre encourages building and interlocking of the fibres, where as the large surface area reduces immediately the free water available for workability of the fresh mix. The flowability and compactability characteristics of fiber concrete mixes can be greatly improved by the incorporation of suitable amounts of crushed fines or fly ash or by the addition of liquid admixtures which would reduce the interparticle friction between aggregates and other inclusions. Care must hc taken to ensure that admixtures are compatible with the fibre and do not adversely affect the long term performance of the composite. Polymer dispersion has also been successfully used to improve the flowability of the matrix, its cohesiveness and cracking strain, ductility and strength of the matrix-fiber interfacial bond.

The change in the flow characteristics of fresh concrete as a result of the mixed-in short fibres of polypropylene, glass and steel fibres is quite marked. Tests on the rheological properties of a variety of concrete mixes reinforced with polypropylene fibres of different types and in varying amounts show that the addition of 0.125% of fibre by weight (V_f - 0.3%) reduced the slump by approximately half the original value in all cases. With a wet mix (C/A = 1:4.5, W/C = 0.55), the slump is reduced from 85 mm for plain concrete to zero with 0.5% by weight of fibres. 2.5 volume percent chopped glass fibre dispersed in concrete also gave zero slump. Conventional tests used to measure bleeding and rate of stiffening have been shown to be equally applicable to fibre concrete mixes containing chopped polypropylene and steel fibres. These fibre mixes exhibit a significant reduction in surface bleeding, improve cohesion greatly and show increased internal resistance with increase in fibre concentration. The increase in the rate of development of stiffness of the fresh fibre mix implies a reduction in lateral pressure on formwork, and may facilitate early striking. Premixing glass fibres in conventional mixers would need additives such as polyethylene oxide or methylcellulose and special precautions would need to be taken. There is some evidence that composites made by the premixing process may not be as efficient as those fabricated by the spray-suction technique. The effect of using aggregates greater than 5 mm with glass fibres is not well-established and may reduce the efficiency of the fibres. Long mixing times may lead to shredding of polymer and glass fibres.

The great advantage of short discontinuous steel fibres is that they can be used for either factory or in-site construction. One of the important problems encountered with the use of such fibres is their tendency to cling and rest together by fibre interlocking. This may occur during the introduction of the fibres from storage into the mixing system or during mixing. The former can be controlled manually or mechanically by the use of dispersions and vibrating screens. Segregation and balling during mixing is influenced by fibre geometry. The relative volume proportions of fibre and coarse aggregate, the mixing sequence and duration of mixing. Too dry or too wet mixes cause fibre bundling, but experience shows that fibre agglomeration can be avoided hy adding fibres to the wet concrete matrix. Flat fibres generally show less tendency for balling and agglomeration where as fine fibres show a particular proneness to this action.

Apart from the fibre geometry and fibre volume, the size, shape and volume fraction of coarse aggregates also have a pronounced influence on the fibre-aggregate interaction and the rheology of the fresh fibre matrix. It is generally advantageous to increase the fibre size as the aggregate size is increased

4.4.6 Properties of Hardened Fiber Concrete

The distinctive properties of fibre reinforced cement composites are improved tensile and bending strength, greater ductility, greater resistance to cracking and, hence improved impact strength and toughness. Concrete with continuously aligned fibres of carbon (12% by volume) and steel (9% by volume) can have an ultimate tensile strength of the order of 100 to 180 N/mm^2. These fibre contents are very large compared to the practical fibre composites, and the failure strengths are achieved after extensive cracking, so that the real strengths usable in design are much smaller; similarly high flexural strengths have also been obtained with aligned carbon fibres, the modulus of rupture varying from 70 to 170 N/mm^2 for 10% fibre volume, depending upon the type of fibre.

With discontinuous fibres, the strength increases are less dramatic, partly due to the reduced fibre content and partly due to fibre orientation. With GKC laminates both the tensile strength and modulus of rupture increase with fibre length and fibre volume. There is a limiting fibre volume fraction of 6-8% beyond which there is little improvement in tensile strength due to the porosity in the fibre bundle and the increased water demand for mixing. The strength in water storage is generally less than that in the air storage for GRC. The effect of fibres on compressive strength is marginal, and not more than ±10 %variation has been observed. However, the presence of fibres in compression can greatly enhance the strain capability of the un-reinforced matrix, and holds the composite together even after complete failure. This ability of the fibres to hold the composite together, after total failure, both in tension and compression, is another unique property of the fibre composite.

The resistance to crack propagation of the fibre reinforcement can also be used to enhance the ductility and toughness of the concrete. Tests show that bearing strength, ductility, shear and torsional strength, are increased by the incorporation of steel fibres. The resistance of the fibre reinforcement to crack propagation enables the composite to undergo extensive deformation even after the maximum load is reached. This ability to deform causes a considerable amount of energy to be expended before the composite fails. This ability to absorb energy depends on the fibre proportion and fibre volume, and leads to the superior dynamic properties of fibre composites.

Tests also show that fracture strength, as also impact strength, is substantially increased for steel, glass and carbon fibres in paste, mortars and concrete matrices. The role of fibres is not merely to increase fracture toughness or impact resistance, but they also prevent the total disintegration and shattering of concrete associated with shock loads. With explosive loading, the shock wave produced propagates as a compressional wave through a wall. It is reflected on the opposite face as a tensile wave which causes spalling and disintegration of concrete, Steel fibres reduce the fragment velocity by about 20% and more important, the fibre reinforcement enables the composite to retain its shape and integrity without being shattered into fragment.

Other properties like shrinkage, creep, and durability are not much altered.

4.4.7 Applications

Many of the applications of fibre concrete will be in areas where concrete, plain or reinforced, is used at present. Paving slabs, overlays of airfield, road pavements, industrial flooring, bridge decks, canal lining provide common examples. It can also be used for the fabrication of precast products like pipes, boats, beams, staircase steps, wall panels, roof panels marble cover, etc.

One of the main advantages of putting fibres into concrete is that the resultant material lends itself easily to moulding into intricate shapes. Components, such as cladding panels are produced commercially in glass fibre cement, these are aesthetically pleasing and architecturally adventurous.

4.5 CURING COMPOUNDS

Properties of hardened concrete, both strength and durability, not only depend on quality control of ingredients or quality control of the manufacture of concrete but also largely depend on proper curing, which is the last phase of quality control. As mentioned earlier, the main aim of curing is lo prevent the evaporation of the capillary water in the concrete, so that sufficient water is available for complete hydration of the cement in the concrete. Complete hydration can only lead to better end hydration products and thereby avoid plastic shrinkage, less voids, less permeability and hence lead to more durability and strength. The conventional methods of curing like water spraying, pounding, covering with wet burlaps, polyethylene sheets etc., are not only time consuming but also start almost after the initial evaporation of water after appearance of the first cracks. The ideal curing technique should begin as soon as possible after the casting of concrete.

Curing compounds are generally liquid membrane forming compounds, to be brushed or sprayed on the fresh concrete only once, the initial stages which is the critical hardening period of concretes or mortars. It forms a seamless film on the surface of the freshly cast concretes and mortars, sealing all the pores and capillaries and hence preventing any escape or ingress of water into the concretes or mortars. Thus it arrests the evaporation of water from the capillaries and prevents quick drying of concrete. The curing compounds neither affect the setting nor hardening of concrete nor in any other way affect properties of concrete. The curing compound disintegrates after about one month by virtue of its inbuilt film breaking system.

The evaporation of water from a concrete body depends mainly on air temperature, relative humidity, concrete temperature and velocity of wind. A curing compound protects concrete from the above mentioned influences. White pigmented curing compound aids in the reflection of Ultra Violet rays as well as aid the quality controller at site to ascertain that the full area is covered on account of its colour. It is very suitable for areas directly exposed to extreme sunlight and wind.

4.5.1 Instructions for Application

Shake thoroughly before use. It is applied by means of a brush, roller or using normal knapsack sprayers (insecticide sprayers) having a suitable nozzle or in case of large areas by using motorised continuous spraying devices. However, while spraying, the nozzle of the spraying device should be held at about 0.7 to 1.0 metre distance from the surface, and it should he ensured that the complete area is covered. The pump pressure must be maintained throughout the operation to obtain a fine spray. The nozzles should be cleaned intermittently either by water or white spirit.

A curing compound should be applied as soon as possible after the casting of concrete and finishing, and immediately after the disappearance of water seen from the surfacc allowing time gap for evaporation of the bleed water. The time period preferable should be within about an hour of depending upon the temperatures. It should not be applied when standing water is present. If concrete has lost some of the surface water, it is recommended to fog down the surface before application. For curing of concrete which is retained in the form works, the concrete should be wetted thoroughly after opening the shuttering, then it should be sprayed or brushed.

4.5.2 Advantages

a) Minimizing the shrinkage cracks on account of curing at early stages,

b) Optimal hydration leading to stronger end hydration products,

c) Achieving proper compressive and flexual strength,

d) Single application, thereby saving of labour costs,

e) Enables better quality control at sites,

f) Ideal for overhead curing and for curing of normally inaccessible places as in chimneys etc.,

g) Reduces surface dusting,

h) Ideal for curing at places having water shortage,

i) Easy to apply,

j) Curing can be carried out hand in hand with concreting, therefore, no extra labour required,

k) eliminates the need for 28 days water spraying, hessian, PE films etc., and

l) Better solar reflectance, which lowers the temperature of concrete.

4.5.3 Curing Compounds Available in Indian Market

a) **Emcoril**, available in 200 kg drum or 30 kg pails, coverage – 125-150 gm/m^2 with 80% curing efficiency ASIM C-309-1973

b) Concrete Curing Membrane Translucent White Liquid, coverage – 150-200 gm/m^2, available in packing of 5, 25, 50 and 200 kgs. confirming to ASTM C-309-1973.

(It may be noted the list of available brand names and manufacturers are not exhaustive)

SAQ 2

1) What do you understand by curing ? Why is it essential ?

2) Explain the term capillary pores.

3) Why does increase in W/C ratio lead to decrease in concrete strength ?

4) Where you will use the fibre concrete?

5) What are the advantages of using curing compounds?

4.6 SUMMARY

Concrete is by far the most widely used structural material. Quality of concrete, however, depends not only on the quality of the ingredients from which it is made but also on many more parameters, like workmanship, placing, curing, water-cement ratio etc. In this unit we have discussed general classifications, grades, manufacture, properties and curing aspect of ordinary concrete.

By addition of one more ingredient to conventional concrete, certain special properties can be developed in the resulting concrete which has got special applications. Two such types of concrete, like aerated concrete and Fibre reinforced concrete, have been discussed with respect to their manufacture, properties and applications.

At the end, we have discussed the importance of curing, conventional methods of curing and various curing compounds presently available in the Indian market.

4.7 KEY WORDS

Cement	This is a fine powder like subtance which is used largely in construction as a binding materials.
Pine Aggregates :	Smaller size particles like sand called
Coarse Aggregates :	Bigger size (relatively with fine aggregates) particles like granite stones of size 1/2", 3/4", 1" etc.
Grades	Different types of concretes like M15 M2O etc. called as grades of concrete.
Hydration	Reaction of Cement with water.
water-cement Ratio :	This is a ratio of water mixed **with** cement to make good concrete.
Segregation	Separation of aggregate phase from part phase of concrete
Compaction	To make concrete dence.

Durability	Concrete working properly over a long period of time damage or disintegration.
Shrinkage	Reduction of volume due to decrease of moisture content/age etc.
Creep	Alongation accured in concrete due to load over a long period of time.
Foamed Concrete :	This is a concrete to made with the help of foaming agents.
Fiber Reinforced Concrete	This is a type of Concrete made by adding fibres to it.

4.8 FURTHER READINGS

A. M. Neville, **Properties of Concrete,** The English Language Book Society and Pitman Publication.

M. S. Shetty, **Concrete Technology,** S. Chand Publications, Delhi.

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State-of-Art Report on FRC, ACI Committee **544,** J. American, Conc. Inst, Vol 70, No. **II,** Nov. 1973.

4.9 ANSWERS TO SAQs

Check your Answers of all SAQs with respective preceding text of each **SAQ.**