LECTURE NOTE

ON

TH-(4) Concrete Technology

6th SEMESTER

DEPARTMENT OF CIVIL ENGINEERING

PREPARED BY- ER.Rajashree Sahoo

LECTURER IN CIVIL ENGINEERING

JAJPUR ROAD

1.1- GRADES OF CONCRETE

- **Concrete is generally graded according to its compressive strength. The various grades of concrete as stipulated in IS: 456-2000 and IS: 1343-1980 are given in Table 1.1.**
- **In the designation of concrete mix, the letter M refers to the mix and the number to the specified characteristic strength of 150 mm work cubes at 28 days, expressed in MPa (N/mm^2).**
- **The concrete of grades M5 and M7.5 is suitable for lean concrete bases, simple foundations, foundations for masonry walls and other simple or temporary reinforced concrete constructions. These need not be designed.**
- **The concrete of grades lower than M15 is not suitable for reinforced concrete works and grades of concrete lower than M30 are not to be used in the prestressed concrete works.**

Table 1.1 Grades of concrete

Group	Ordinary concrete			Standard concrete							High strength concrete				
Grade designation	M10	M15	M20	M25	M30	M35	M40	M45	M50	M55	M60	M65	M70	M75	M80
Specified characteristic strength at 28 days, MPa	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80

2-ADVANTAGES AND DISADVANATGES OF CONCRETE-

ƆVANTAGES OF CONCRETE

Concrete as a construction material has the following advantages:

1. Concrete is economical in the long run as compared to other engineering materials. Except cement, it can be made from locally available coarse and fine aggregates.

2. Concrete possesses a high compressive strength, and the corrosive and weathering effects are minimal. When properly prepared its strength is equal to that of a hard natural stone.

3. The green or newly mixed concrete can be easily handled and molded or formed into virtually any shape or size according to specifications. The formwork can be reused a number of times for similar jobs resulting in economy.

4. It is strong in compression and has unlimited structural applications in combination with steel reinforcement. Concrete and steel have approximately equal coefficients of thermal expansion.

5. Concrete can even be sprayed on and filled into fine cracks for repairs by the guniting process.

6. Concrete can be pumped and hence it can be laid in difficult positions also.

7. It is durable, fire resistant and requires very little maintenance.

DISADVANTAGES OF CONCRETE

The following are the disadvantages of concrete:

1. Concrete has low tensile strength and hence cracks easily. Therefore, concrete is to be reinforced with steel bars or meshes or fibers.

2. Fresh concrete shrinks on drying and hardened concrete expands on wetting. Provision for construction joints has to be made to avoid the development of cracks due to drying shrinkage and moisture movement.

3. Concrete expands and contracts with the changes in temperature. Hence, of expansion joints have to be provided to avoid the formation of cracks due to be thermal movement.

4. Concrete under sustained loading undergoes creep, resulting in the reduction of prestress in the prestressed concrete construction.

5. Concrete is not entirely impervious to moisture and contains soluble salts which may cause efflorescence.

6. Concrete is liable to disintegrate by alkali and sulphate attack.

7. The lack of ductility inherent in concrete as a material is disadvantageous with respect to earthquake resistant design.

End

CHAPTER:-02 -Cement

Introduction:

- Cement is a building material for binding bricks, stones or aggregates.
- It has cohesive and adhesive properties in the presence of water.
- Cement was inverted by ' Joseph Aspdin ' in England in 1824.
- Used for making mortar or concrete.
- Natural cement:-burning and crushing of stones and lime.
- Artificial cement:-burning at high temperature and gypsum is added.

2.1-COMPOSITION OF ORDINARY CEMENT

- The ordinary cement contains two basic ingredients, namely, argillaceous and calcareous.
- In argillaceous materials, the clay predominates and in calcareous materials, the calcium carbonate predominates.

Ingredient	Percentage	Range
Lime	(CaO) 62	62 to 67
Silica	(SiO_2) 22	17 to 25
Alumina	(Al_2O_3) 5	3 to 8
Calcium sulphate	($CaSO_4$) 4	3 to 4
Iron oxide	(Fe_2O_3)............. 3	3 to 4
Magnesia	(MgO)............... 2	1 to 3
Sulphur	(S) 1	1 to 3
Alkalies	1	0.2 to 1
	Total. 100	

ydration of Cement

- The chemical reaction that takes place between cement and water is referred to as hydration of cement.
- This reaction is exothermic in nature i.e., considerable amount of heat is liberated in this reaction, which is called as heat of hydration.

- The hydration of cement is not an instantaneous one. The reaction is faster in the early periods and continues indefinitely at a decreasing rate.
- During hydration, C_3S and C_2S react with water and calcium silicate hydrate (C-S-H) is formed along with calcium hydroxide [$Ca(OH)_2$].

$$2\,C_3S + 6H \rightarrow C_3S_2\,H_3 + 3Ca(OH)_2$$

$$2C_2S + 4H \rightarrow C_3S_2\,H_3 + Ca(OH)_2$$

- Calcium silicate hydrate is the most important product of hydration and it determines the good properties of cement.
- It can be seen from the above reactions that C_3S produces more quantity of calcium than C_2S.
- It has been estimated that on an average 23% of water by weight of cement is required for chemical reaction with Portland cement compounds. As this 23% of water chemically combines with cement, it is called as bound water.
- A certain quantity of water is imbibed within the gel pores. This water is known as gel water. The bound water and gel water are complementary to each other.
- It has been estimated that 15% water by weight of cement is required to fill up the gel pores.

- Therefore, a total of 38% of water by weight of cement is required for the complete chemical reaction of cement and occupy the space within gel pores.
- If water equal to 38% by weight of cement is only used then it can be notices that the resultant paste will undergo full hydration and no extra water will be available for the formation of undesirable capillary cavities.

Water-Cement Ratio:

- It is defined as the ratio of the weight of free water available to that of the weight of cement in a mix.
- Cement being the binding agent in Concrete, the strength of concrete mainly depends on the strength of the cement paste.
- The strength of the cement paste in turn depends on the percentage of cement present in it. Thus the strength of concrete decreases with increase in water cement ratio, as the percentage of cement present in the cement paste decreases with increase in water cement ratio.
- This relationship is known as Abram's law.
- This law states that the compressive strength of hardened concrete is inversely proportional to the water cement ratio, provided the mix is workable.

- *It has to be noted here that* with a decrease in water-cement ratio the strength of *the concrete* increases, but it will become more and more difficult to achieve *complete* compaction of concrete.
- Further, when the water-cement ratio is below a practical limit, the strength of the concrete falls rapidly as some cement will be left unreacted and air voids are introduced.
- Generally, the water - cement ratio lies in the range of 0.35 to 0.65.

Compressive strength:

- It is one of the important properties of cement.
- The strength tests, generally carried out in tension on samples of neat cement, are of doubtful value as an indication of ability of the cement to make concrete strong in compression.
- Therefore, these are largely being superseded by the mortar cube crushing tests and concrete compression tests.
- These are conducted on standardized aggregates under carefully controlled conditions and therefore give a good indication on strength qualities of cement.

- Cement mortar cubes (1:3) having an area of 5000 mm^2 are prepared and tested in compression testing machine.
- For ordinary Portland cement, the compression strength at three and seven days curing shall not be less than 16 MPa and 22 MPa, respectively.

Fineness:

- The fineness of a cement is a measure of the size of particles of cement and is expressed in terms of *specific surface of cement.*
- It can be calculated from particle size distribution or one of the air permeability methods.
- It is an important factor in determining the *rate of gain of strength and uniformity of quality.*
- For a given weight of cement, the surface area is more for a finer cement than for a coarser cement.
- The finer the cement, the higher is the rate of hydration, as more surface area is available for chemical reaction. This results in the early development of strength.

- The effect of fineness on the compressive strength of cement is shown in Fig. 2.13.
- If the cement is ground beyond a certain limit, its cementative properties may be adversely affected due to prehydration by atmospheric moisture.

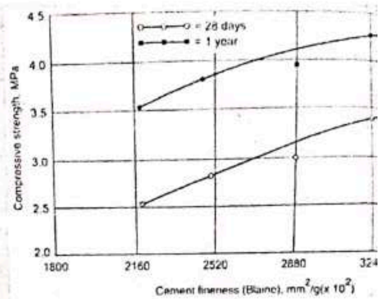


Fig. 2.13 The effect of fineness of cement on the compressive stre

- As per Indian Standard Specifications, the residue of cement should not exceed 10 percent when sieved on a 90-micron IS sieve.
- In addition, the amount of water required for constant slump concrete decreases with the increase in the fineness of cement.

Setting time:

- Cement when mixed with water forms paste which gradually becomes less plastic, and finally a hard mass is obtained.
- In this process of set this stage of setting, a stage is reached when the cement paste is sufficiently rigid to withstand a definite amount of pressure.
- The time to reach this stage is termed as *setting time*. The time is reckoned from the instant when water is added to the cement.

- The setting time is divided into two parts, namely, the *initial and the final setting times.*
- The time at which the cement paste loses its plasticity is termed the *initial setting time.*
- The time taken to reach the stage when the paste becomes a hard mass is known as the final setting time.
- It is essential for proper concreting that the initial setting time be sufficiently long for finishing operations, i.e., transporting and placing the concrete.
- The setting process is accompanied by temperature changes. The temperature rises rapidly from the initial setting to a peak value at the final setting.
- The setting time decreases with rise in temperature up to 30°C and vice versa.
- For an ordinary Portland cement, *the initial setting time should not be less than 30 minutes* and *final setting time should not be more than 600 minutes.*

oundness:

- The unsoundness of cement is caused by the undesirable expansion of some of its constituents, sometimes after setting.

- The large change in volume accompanying expansion results in disintegration and severe cracking.
- The unsoundness is due to the presence of free lime and magnesia in the cement.
- The free lime hydrates very slowly because it is covered by the thin film of cement which prevents direct contact between lime and water.
- After the setting of cement, the moisture penetrates into the free lime resulting in its hydration.
- Since slaked lime occupies a larger volume, the expansion takes place resulting in severe cracking.
- The unsoundness due to the presence of magnesia is similar to that of lime.
- The unsoundness may be reduced by

  (a) limiting the MgO content to less than 0.5 per cent,

  (b) fine grinding,

  (c) allowing the cement to aerate for several days, and

  (d) thorough mixing.

- The chief tests for soundness are the Le Chatelier and Autocalve tests.

- The expansion carried out in the manner described in IS: 269-1989 should not be more than 10 mm in the Le Chatelier test and 0.8 per cent in Autoclave test.

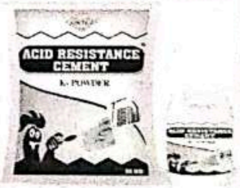
TYPES OF CEMENT

In addition to ordinary cement, the following are the other important varieties of cement:

(1) Acid-resistant cement	**(8) Pozzolana cement**
(2) Blast furnace cement	**(9) Quick setting cement**
(3) Coloured cement	**(10) Rapid hardening cement**
(4) Expanding cement	**(11) Extra rapid hardening cement**
(5) High alumina cement	**(12) Sulphate resisting cement**
(6) Hydrophobic cement	**(13) White cement.**
(7) Low heat cement	

(1) Acid-resistant cement: ***An acid-resistant cement is composed of the following:***

(i) acid-resistant aggregates such as quartz, quartzites, etc.;



(ii) additive such as sodium fluosilicate $Na_2 SiF_6$; and

(iii) aqueous solution of sodium silicate or soluble glass.

- The acid-resistant cement is used for acid-resistant and heat-resistant coatings of installations of chemical industry.
- By adding 0.50 per cent of linseed oil or 2 per cent of ceresit, its resistance to the water is increased and it is then known as the *acid and water resistant cement.*

(2) Blast furnace cement:

- For this cement, the slag as obtained from blast furnace is used.
- The slag is a waste product in the manufacturing process of pig-iron and it contains the basic elements of cement, namely, alumina, lime and silica.
- The clinkers of cement are ground with about 60 to 65 per cent of slag.
- The properties of this cement are more or less the same as those of ordinary cement.
- Its strength in early days is less and hence it requires longer curing.

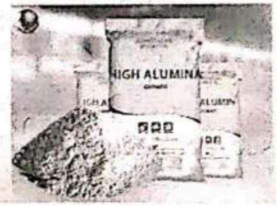
(3) Coloured cement:

- The cement of desired colour may be obtained by intimately mixing mineral pigments with ordinary cement.
- The amount of colouring material may vary from 5 to 10 per cent. If this percentage exceeds 10 per cent, the strength of cement is affected.
- The chromium oxide gives green colour. The cobalt imparts blue colour. The iron oxide in different proportions gives brown, red or yellow colour. The manganese dioxide is used to produce black or brown coloured cement.
- The coloured cements are widely used for finishing of floors, external surfaces, artificial marble, window sill slabs, textured panel faces, stair treads, etc.

) Expanding cement:

- This type of cement is produced by adding an expanding medium like sulpho-aluminate and a stabilising agent to the ordinary cement. Hence, this cement expands whereas other cements shrink.
- The expanding cement is used for the construction of water retaining structures and also for repairing the damaged concrete surfaces.

) High alumina cement:



- This cement is produced by grinding clinkers formed by calcining bauxite and lime. The bauxite is an aluminium ore.
- It is specified that total alumina content should not be less than 32 per cent and the ratio by weight of alumina to the lime should be between 0.85 and 1.30.

(6) Hydrophobic cement:

- This type of cement contains admixtures which decrease the wetting ability of cement grains.
- The usual hydrophobic admixtures are acidol, naphthenesoap, oxidized petrolatum, etc. These substances form a thin film around cement grains.
- When hydrophobic cement is used, the fine pores in concrete are uniformly distributed and thus the frost resistance and the water resistance of such concrete are considerably increased.

(7) Low heat cement:

- The considerable heat is produced during the setting action of cement. In order t reduce the amount of heat, this type of cement is used.
- It contains lower percentage of tricalcium aluminate C_3A of about 5% and higher percentage of dicalcium silicate C_2S of about 46%.

- The initial setting time is about one hour and final setting time is about 10 hours.
- It is mainly used for mass concrete work.

(8) Pozzolana cement:

- The Pozzolana is a volcanic powder. The percentage of Pozzolana material should be between 10 to 30.
- This cement is used to prepare mass concrete of lean mix and for marine structures. It is also used in sewage works and for laying concrete under water.

(9) Quick setting cement:

- This cement is produced by adding a small percentage of aluminium sulphate and by finely grinding the cement.
- The addition of aluminium sulphate and fineness of grinding are responsible for accelerating the setting action of cement.
- The setting action of cement starts within five minutes after addition of water and it becomes hard like stone in less than 30 minutes or so.
- The extreme care is to be taken when this cement is used as mixing and placing of concrete are to be completed in a very short period.

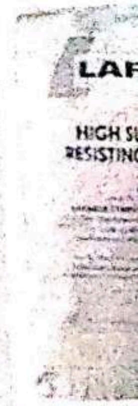
- This cement is used to lay concrete under static water or running water.

(10) Rapid hardening cement:

- The initial and final setting times of this cement are the same as those of ordinary cement. But it attains high strength in early days.
- It contains high percentage of tricalcium silicate C_3S to the extent of about 56%.
- This cement is used for the formwork of concrete that can be removed earlier.

(11) Extra rapid hardening cement:

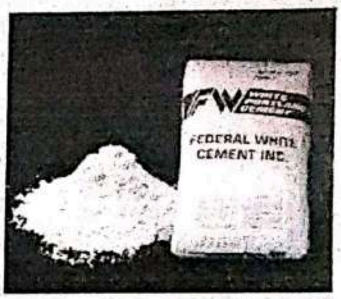
- It is obtained by inter-grinding calcium chloride with rapid hardening Portland cement.
- The normal addition of calcium chloride should not exceed 2% by the weight of rapid hardening cement.
- This type of cement should be transported, placed, compacted and finished within 20 minutes after mixing.



(12) Sulphate resisting cement:

- It is a cement with low C_3A content and comparatively lower C_4AF content. The percentage of C_3A (tricalcium aluminate) is kept below 5 per cent and it results in the increase in resisting power against sulphate attack.
- Sulphate resisting cement is used for the structures which are likely to be damaged by severe alkaline conditions such as canal linings, culverts, siphons,etc.

13) White cement:



- It is prepared from such raw materials which are practically free from colouring oxides of iron, manganese or chromium.
- It is white in colour and it is used for floor finish, plaster work, ornamental work, etc.

end

CHAPTER:-03-Aggregate, Water and Admixtures

Introduction:

- In the construction industry, aggregates are used as filler material in the production of concrete and mortar.
- Aggregates occupy around 70 to 80 percent of the volume of the concrete, reduc shrinkage effects and minimize costs.

3.1-Classification of Aggregates:

A. Based on Geological Origin:

On the basis of origin, aggregates can be classified into *natural aggregates and artificial aggregates.*

(i) Natural Aggregates:

The aggregates which are obtained by crushing igneous, sedimentary or metamorphi rocks are called natural aggregates. Aggregates obtained from igneous rocks have the best engineering properties; hence they are the most widely used aggregates.

ii) Artificial Aggregates:

The aggregates which are obtained from man-made processes are called artificial aggregates. Surkhi (powdered broken brick), Blast furnace slag aggregates and synthetic aggregates are some of the examples of artificial aggregates.

3. Based on Size:

According to size, aggregates can be classified as *coarse aggregates and fine aggregates.*

(i) Coarse Aggregates:

The aggregates which pass through the 80 mm sieve and are retained on the 4.75 mm sieve are called as coarse aggregates.

(ii) Fine Aggregates:

All the aggregates which pass through the 4.75 mm sieve are called as fine aggregates. On the basis of particle size distribution, the fine aggregates are classified into four zones (i.e.) Zone I to Zone IV. The grading zones are progressively finer from grading Zone I to grading Zone IV.

C. Based on Shape:

Based on the shape of the aggregates, they are classified as rounded, irregular, angular and flaky.

(i) Rounded Aggregates:

The aggregates which are obtained from river or sea shores are generally close to spherical in shape and are called as rounded aggregates. These aggregates have minimum surface area to the volume and have poor interlocking bond, making them unsuitable for the production of concrete.

(ii) Irregular Aggregates:

These aggregates are irregular in shape and require more cement paste compared to rounded aggregates. Because of the irregularity in shape, these aggregates form good interlocking bond and are suitable in the production of concrete.

(iii) Angular Aggregates:

These aggregates are sharp, have angular shape and rough texture. These aggregates are best suited for the preparation of high strength concrete.

(iv) Flaky Aggregates:

The aggregates whose thickness is less than 0.6 times the mean dimension are called are Flaky Aggregates.

(v) Elongated Aggregates:

The aggregates whose length is 1.8 times the mean dimension are called as Elongated Aggregates.

Characteristics of Aggregates:

1. Strength of aggregate:

- **The strength of concrete cannot exceed that of the bulk of aggregate contained therein. Therefore, so long as the strength of aggregate is of an order of magnitude stronger than that of the concrete made with them, it is sufficient.**
- **Generally three tests are prescribed for the determination of strength of aggregate, namely, aggregate crushing value, aggregate impact value and 10 per cent fines value.**
- **Crushing strength of good coarse aggregate is about 200 N/mm².**

2. Particle shape and texture:

- The physical characteristics such as *shape, texture and roughness of aggregates,* significantly influence the mobility (i.e., the workability) of fresh concrete and th *bond* between the aggregate and the mortar phase.
- Rounded particles produce smoother mix for a given water cement ratio.
- Angular or flaky particles reduce workability and demand more cement and water to give specified strength of concrete mix.

3. Specific gravity:

- The specific gravity of an aggregate is defined as the ratio of the mass of solid in given volume of sample to the mass of an equal volume of water at the same temperature.
- Since the aggregate generally contains voids, there are different types of specifi gravities.
- The average specific gravity of majority of natural aggregates lie between 2.5 an 2.8.

4. Bulk density:

- **The bulk density of an aggregate is defined as the mass of the material in a given volume and is expressed in kilograms/liter.**
- **The bulk density of an aggregate depends on how densely the aggregate is packed in the measure.**
- **The other factors affecting the bulk density are the particle shape, size, the grading of the aggregate and the moisture content.**
- **The shape of the particles greatly affects the closeness of the packing that can be achieved.**
- **For a coarse aggregate of given specific gravity, a higher bulk density indicates that there are fewer voids to be filled by sand and cement.**

5. Voids:

- **The empty spaces between the aggregate particles are termed voids.**
- **It is the difference between the gross volume of aggregate mass and the volume occupied by the particles alone.**

6. Porosity and absorption of aggregates:

- **Due to the presence of air bubbles which are entrapped in a rock during its formation or on account of the decomposition of certain constituent minerals by *atmospheric action, minute holes or cavities* are formed in it which are commonly known as *pores.***
- **The percentage of water absorbed by an aggregate when immersed in water is termed the *absorption of aggregate.***
- **The porosity of some of the commonly used rocks varies from 0 to 20 per cent.**
- **The *permeability and absorption* affect the bond between the aggregate and the cement paste.**

7. Moisture content of aggregate:

- **The surface moisture expressed as a percentage of the weight of the saturated surface dry aggregate is termed as moisture content.**
- **Since the absorption represents the water contained in the aggregate in the saturated-surface dry condition and the moisture content is the water in excess of that, the total water content of a moist aggregate is equal to the sum of absorption and moisture content.**

- **A high moisture content will increase the effective water-cement ratio to an appreciable extent and may make the concrete weak unless a suitable allowance is made.**

8. Bulking of fine aggregate:

- **The increase in the volume of a given mass of fine aggregate caused by the presence of water is known as *bulking*.**
- **The bulking of fine aggregate is caused by the films of water which push the particles apart. The extent of bulking depends upon the percentage of moisture present in the sand and its fineness.**
- **With ordinary sands the bulking usually varies between 15 and 30 per cent.**
- **Finer sand bulks considerably more and the maximum bulking is obtained at a higher water content than the coarse sand.**
- **In extremely fine sand, the bulking may be of the order of 40 per cent at a moisture content of 10 per cent but such a sand is unsuitable for concrete.**
- **In the case of coarse aggregate, the increase in volume is negligible due to the presence of free water.**

Fineness Modulus (FM):

- The *fineness modulus* is a numerical index of fineness, giving some idea of the *mean size* of the particles present in the entire body of the aggregate.
- Fineness modulus is determined by sieve analysis.
- FM = The ratio of the cumulative percentage of material retained on each sieve/ 100.
- The value of fineness modulus is higher for coarser aggregate.
- For the aggregates commonly used, the fineness modulus of *fine aggregate* varies between 2.0 and 3.5, for *coarse aggregate* it varies between 5.5 and 8.0.

Grading of aggregate:

- The *particle size distribution* of an aggregate as determined by sieve analysis is termed *grading of the aggregate*.
- Sieve analysis is used for gradation.
- Sieve sizes 80 mm to 150 µ are used in the sieve analysis.
- The *grading* of fine aggregate has a much greater effect on workability of concrete than does the grading of the coarse aggregate.

2-QUALITY OF MIXING W

- The water used for the m
injurious amounts of del
- The unwanted situation
be a result of, among ot
quality.
- Potable water from th
concrete.
- In the case of doubt a
where water is deriv
water should be test

CURING WATER

- The use of water in
- If steps are taken
be needed as a pa

Scanned with OKEN Scanner

3.2-QUALITY OF MIXING WATER

- The water used for the mixing and curing of concrete should be free from injurious amounts of deleterious materials.
- The unwanted situations, leading to the distress of concrete, have been found to be a result of, among others, the mixing and curing water being of inappropriate quality.
- Potable water from the sources is generally considered satisfactory for mixing concrete.
- In the case of doubt about the suitability of water, particularly in remote areas or where water is derived from sources not normally utilized for domestic purposes, water should be tested.

CURING WATER

- The use of water in curing the concrete is intended to penetrate the concrete.
- If steps are taken to prevent loss of water from the concrete, no added water will be needed as a part of curing process except in the circumstances:

  (i) when the water-cement ratio is less than 0.4; and

  (ii) when the concrete is produced using expansive cement.

Fineness Modulus (FM):

- The *fineness modulus* is a numerical index of fineness, giving some idea of the *mean size* of the particles present in the entire body of the aggregate.
- Fineness modulus is determined by sieve analysis.
- FM = The ratio of the cumulative percentage of material retained on each sieve / 100.
- The value of fineness modulus is higher for coarser aggregate.
- For the aggregates commonly used, the fineness modulus of *fine aggregate* varies between 2.0 and 3.5, for *coarse aggregate* it varies between 5.5 and 8.0.

Grading of aggregate:

- The *particle size distribution* of an aggregate as determined by sieve analysis is termed *grading of the aggregate*.
- Sieve analysis is used for gradation.
- Sieve sizes 80 mm to 150 µ are used in the sieve analysis.
- The *grading* of fine aggregate has a much greater effect on workability of concrete than does the grading of the coarse aggregate.

3.2-QUALITY OF MIXING WATER

- **The water used for the mixing and curing of concrete should be free from injurious amounts of deleterious materials.**
- **The unwanted situations, leading to the distress of concrete, have been found to be a result of, among others, the mixing and curing water being of inappropriate quality.**
- **Potable water from the sources is generally considered satisfactory for mixing concrete.**
- **In the case of doubt about the suitability of water, particularly in remote areas or where water is derived from sources not normally utilized for domestic purposes, water should be tested.**

CURING WATER

- **The use of water in curing the concrete is intended to penetrate the concrete.**
- **If steps are taken to prevent loss of water from the concrete, no added water will be needed as a part of curing process except in the circumstances:**

  (i) when the water-cement ratio is less than 0.4; and

  (ii) when the concrete is produced using expansive cement.