UNIT-3 WATER

Structure

3.1 INTRODUCTION

You have already studied about the Cement and Aggregates in the previous units as a concrete making materials.

Now water is the most important ingredient for concrete making and also least expensive. When water mixed with other ingredients, forms a matrix in which cement and aggregates remain in suspension until hydration of cement proceeds. During hydration, cement is converted into hydrated gel which is little more than two times the volume of original unhydrated cement volume. Hence the space filled originally by water is gradually replaced by hydrated cement gel. However cement requires about 23 percent of its own weight of water for complete hydration and about 14 percent of its own weight of water to fill up the gel pores which are small pores in-built into gel. This imbibed gel water is not available for hydration. So for complete hydration, water of about 38 percent weight of cement is required for complete hydration. Space occupied by extra water than 38 percents, added during mixing remains unfilled by hydrated gel and forms capillary voids in the hardened concrete. These capillary void, reduces strength of concrete and makes concrete non durable. Hence quantity of water is to be carfully controlled during manufacture of concrete.

It is not only the quantity but quality of water has also got equal bearing on performance of hardened concrete. In practice, very often great control on properties of cement and aggregate is exercised, but the control on the quality of water is often neglected. Since quality of water affects the strength, it is necessary for us to go into the quality aspect of water also.

Objectives

Many a times while mentioning about ingredients of concrete, we omit to mention about water. In fact water is the most important ingredient in concrete making. If it is not used in proper quality and quantity, it can lead to very poor concrete even though one has used other ingredients of very high quality and exercised very good quality control while producing the concrete.

After studying this unit, you will be able to :

* know the effect of quantity of mixing water on Hardened concrete,
* describe effect of various impurities in water on properties of concrete, and
* discuss effect of sea water on concrete (when used as mixing water or used as curing water or both).

3.2 QUANTITY OF MIXING WATER

In case of moist curing i.e. when water will be applied from outside after final setting time of capillary voids in the concrete. As the water-cement ratio is increased the quantum of capillary voids increases. So long these capillary pores do not form a continuous channel, the resulting concrete member generally performs well so far as durability and impermeability is concerned. The absence of continuous capillaries is ensured by adopting due to a combination of suitable water-cement ratio and a sufficiently long period of moist curing. The actual time required to achieve such segmentation depends or characteristics of cement used, but can be gauged approximately from the data given in Table 3.1.

Table 3.1 : Time Required to Become Capillaries Segmented

Sl. No.	Water/Cement ratio by weight	Time required
1)	0.40	3 days
2)	0.45	7 days
3)	0.50	14 days
4)	0.60	6 months
5)	0.70	1 year
6)	over 0.70	Impossible

For water-cement ratios above about 0.7, even complete hydration would not produce enongh gel to block all the capillaries. For extremely fine cement the maximum water-cement ratio would be higher, possibly up to 1.0; conversely, for coarse cements it would be below 0.7.

In case of hydration in a sealed specimen, when the combined water becomes about one-half of the original water content no further hydration will take place. It follows also that full hydration in a sealed specimen is possible only when the mixing water is at least twice the water required for chemical reaction i.e. the mix has a water-cement ratio of about 0.5 by weight. A water-cement ratio below 0.5 will not allow full hydration. However it is seen that at all water-cement ratio, the sealed specimen will have capillary voids. Hence it is accepted as a good practice to have first one or two days of moist-curing and then to go for membrane curing.

In any case increase in water-cement ratio will increase capillary voids and thus will reduce strength as shown in Figure 3.1.

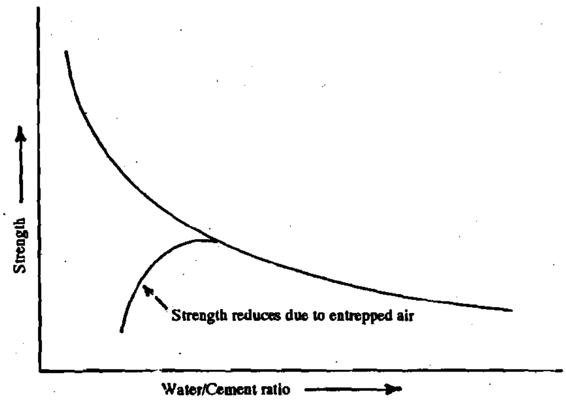

Figure 3.1 : Strength of Concrete with Water/Cement Ratio

On the other hand reduction in water-cement ratio will not ensure full hydration and compaction becomes difficult (poor workability) which in turn will introduce more entrapped air leading to once more reduction in strength. It may be added at this juncture that unhydrated cement is not detrimental to strength and, in fact, among pastes all with a gel/space ratio of 1.0 those with a higher proportion of unhydrated cement (i.e. a lower water/cement ratio) have a higher strength, possibly because in such pastes the layers of hydrated grains are thinner. The among all ingredients i.e. unhydrated cement gel, fine aggregate and coarse aggregates. Abrams obtained strengths of the order of 280 N/mm^2 using mixes with a water/cemten ratio of as low as 0.08 by weight, but clearly considerable pressure is necessary to obtain properly consolidated mix of such proportions.

3.3 QUALITY OF WATER

A popular yardstick to the suitability of water for mixing concrete is that, if water is fit for drinking it is also fit for making concrete. This does not appear to be a true statement for all conditions. Some waters containing a small amount of sugar would be suitable for drinking but not for mixing concrete and conversely water suitable for making concrete may not necessarily be fit for drinking. Some specifications require that if the water is not obtained from source that has proved satisfactory, the strength of concrete on mortar made with questionable water should be compared with similar concrete or mortar made with pure water. Some specifications also accept water for making concrete if the pH value of water lies between 6 and 8 and the water is free from organic matter. Instead of depending upon pH value and other chemical composition, the best course to find out whether a particular source of water is suitable for concrete making or not, is to make concrete with this water and compare its 7 days and 28 days strength with companion cubes made with distilled water. If the compressive strength is upto 90 percent, the source of water may be accepted. This criteria may be safely adopted in places like coastal area and marshy area or in other places where the available water is brackish in nature and of doubtful quality. However, it is logical to know what harm the impurities in water do to the concrete and what degree of impurity is permissible for mixing concrete and curing concrete.

3.3.1 Suspended Particles

The presence of suspended particles of clay and silt in the mixing water upto 0.02 percent by weight of water does not affect the properties of concrete. Even higher percentage can be tolerated so far as strength is concerned, but other properties of concrete like setting and hardening properties, bond characteristics are considerably affected. IS 456-1978 allows 2000 rpm of suspended matter in water. Mixing water with a high content of suspended solids should be allowed to stand in a settling basin for sufficient period before it is used for concrete making.

3.3.2 Miscellaneous Inorganic Salts

The presence of salts of manganese, tin, zinc, copper and lead in water causes reduction in the strength of concrete. The zinc chlorides retard the set of concrete to such an extent that no strength tests are possible at 2 and 3 days. The effect of lead nitrate is completely destructive.

Some salts like sodium iodate, sodium phosphate, sodium arsenate and sodium borate reduce the initial strength of concrete to an extraordinarily high degree.

Carbonates and bi-carbonates of sodium and potassium affect the setting time of cement. While sodium carbonate may cause quick setting, the bi-carbonates may either accelerate or retard the setting. The other higher concentrations of these salts will materially reduce the concrete strength. If some of these salts exceeds 1000 ppm tests for setting time and 28 days strength should be carried out. In lower concentration they may be accepted.

Brackish water and the sea water generally contains 3.5 percent of dissolved salts, about 78 percent of which is sodium chloride and 15 percent chloride and sulphate of magnesium. The salts present in sea water reduce the ultimate strength of concrete. The reduction in strength of concrete may be of the order of 10 to 20 percent. However, the major concern is the risk of corrosion of reinforcing steel due to chlorides. In general, the risk of corrosion of steel is more when the reinforced concrete member is exposed to air then when continuously submerged under water, including sea water. The presence of chlorides in water is responsible for effloresence. It should not therefore be used where surface finish is of importance. The sea water should not be used in reinforced concrete and prestressed concrete constructions. Under unavoidable circumstances, it may be used for plain concrete when it is constantly submerged air entrainment in concrete. Algae which are present on the surface of aggregate have the same effect as in that of the mixing water.

3.3.3 Acids and Alkalies

Water contaminated with industrial waste may be acidic or alkaline. Such water may be proved to be unsuitble for concrete making. As thumb rute water having pH value higher than 6 may measure of the amount of acid. So it is the total acidity which should be measured. This can be measured by titrating 100 ml of sample of water with 0.1 normal NaOH using phenolphthalein as indicator. The amount of such 0.1 N_2 NaOH solution to neutralize 100 ml sample of water should not be more than 1 ml. This acidity is equivalent to 49 ppm of H_2SO_4 or 36 ppm of HCL.

The limit of alkalinity is guided by the requirement that the amount of 0.1 normal HCL required to neutralize 100 ml of sample should be less than 5ml. This alkalinity is equivalent to 265, 420 and 685 ppm of carbonates (as Na_2CO_3), bi-carbonates (as NaHCO3) and the sum of the two respectively.

3.3.4 Algae

Algae in mixing water may cause a marked reduction in strength of concrete by combining with cement to reduce the bond or by causing large amount of effect the strength of concrete. If the concentration of mineral oil is upto 2 percent by weight of cement, a significant increase in strength has been noticed. For a percentage of mineral oil more than 8 percent, the strength is slightly reduced. The vegetable oils have detrimental effect on the strength of concrete particularly at later ages. The tolerable limits of concentrations of various impurities in mixing water are shown in Table 3.2.

Table 3.2 : Limits of Some Impurities in Mixing Water

Impurity	Tolerable concentration
Sodium and potassium, Carbonates and bi-carbonates	1000 ppm (total sodium and potassium). If this is exceeded, it is advisable to make tests both for setting time and 28 day strength.
Chlorides	10,000 ppm
Sulphuric anhydride	3,000 ppm
Calcium Chloride	2 percent by weight of cement in non-prestressed concrete.
Sodium iodate, Sodium Sulphate, Sodium arsenate, Sodium borate	Very low
Sodium Sulphide	Even 100 ppm warrants testing.
Sodium hydroxide	0.5 per cent by weight of cement, provided quick set is not induced.
Silt and suspended particles	2,000 ppm. Mixing water with a high content of suspended solids should be allowed to stand in a settling basin before use.
Total dissolve salts	15,000 ppm
Organic material	3,000 ppm. Water containing humic acid or such organic acids may adversely affect the hardening of concrete. 780 ppm of humic acid are reported to have seriously impaired the strength of concrete. In case of such water further testing is necessary.
pH	4.5 to 8.5

3.3.5 Sugar

If the amount of sugar present in the mixing water is less than 0.05 percent by weight of water there is no adverse effect on the strength of concrete. Small amounts of sugar upto 0.15 percent by weight of cement retard the setting of cement and the early strengths may be reduced whereas the 28-day strength may be improved. When the quantity of sugar is increased to 0.20

percent by weight of cement, setting is accelerated. When quantity is further increased, rapid setting may result and 28-day strength reduced.

3.3.6 Oil Contamination

Mineral oils not mixed with animal or vegetable oils in mixing water have no adverse effect on the strength of concrete. If the concentration of mineral oils is upto 2 percent by weight of cement, a significant increase in strength has been noticed. For a percentage of mineral oils more than 8 percent, the strength is slightly reduced. The vegetable oils have detriments effect on water.

3.4 USE OF SEA WATER FOR MIXING CONCRETE

Sea water has a salinity of about 3.5 percent. Sea water also contains sulphates and it attacks the hardened concrete which is known as sulphate attack. Of all the sulphates, attack of magnesium sulphate is more severe under certain condition than other sulphates due to low solubility of $Mg(OH)_2$. Sulphates attack calcium aluminate hydrate and calcium silicate hydrate (hydrated cement product) forming calcium sulphoaluminate within the framework of the hydrated cement paste. Since the increase in the volume of the solid phase is 227 percent gradual disintegration of concrete results. However, due to presence of chloride in sea water calcium sulphoaluminate go into solution and may leach out. Thus the expansive force in case of sea water is much less than for in lab. This is known as sulphate attack. In addition to the chemical action, crystallization of the salts in the pores of the concrete may result in its disruption owing the pressure exerted by the salt crystals. Because crystallization takes place at the point of evaporation of water this form of attack occurs in the concrete above water level. Since, however, the salt solution rises in the concrete by capillary action, the attack takes place only when the water can penetrate into the concrete so that impermeability of the concrete is once again its most important attribute.

Concrete between the tide marks, subjected to alternating wetting and drying, is severely attacked, while permanently immersed concrete is attacked least. The actual progress of attack by sea water varies, and is slowed down by the blocking of the pores in the concrete through deposition of magnesium hydroxide. In tropical climates the attack is more rapid.

In case of reinforced concrete, the absorption of salt establishes anodic and cathodic areas, the resulting electrolytic action leads to an accumulation of the corrosion products on the steel with a consequent rupture of the surrounding concrete, so that the effects of sea water are more severe on reinforced concrete than on plain concrete. However, divergent opinion exists on the question of corrosion of reinforcement due to the use of sea water. Some research workers cautioned about the risk of corrosion of reinforcement particularly in tropical climatic regions, whereas some did not find risk of corrosion due to the use of sea water within the limits of chloride content in sea water. It was found that corrosion of reinforcement occurred when concrete was made with pure water and immersed in pure water when concrete was comparatively porous; whereas, no corrosion of reinforcement was found when sea water was used for mixing and the specimen was immersed in salt water when the concrete was dense and enough cover was given to the reinforcement. With these findings it can be concluded that sea water can be used in case of plain and reinfored concrete both as mixing water as also as cusing water but mix proportion to be altered to make concrete dense (using rather high cement content and adopting low W/C ratio) and adequate cover to be provided on reinforcement. However, since these factors cannot be adequately taken care always at the work site, it may be wise that sea water be avoided for making reinforced concrete. However, the use of sea water must be avoided under any circumstances in prestress concrete work because of stress corrosion and undue loss of cross-section of small diameter wires.

Sea water slightly accelerates the setting time of cement. It also slightly accelerates the early strength of concrete. But it reduces 28 days strength of concrete by about 10 to 15 percent. However, this loss of strength could be made up by redesigning the mix. The salts in sea water may cause efflorescence and persistent dampness. When the appearance of concrete is important sea water may be avoided. The use of sea water is also not advisable for plastering purposes which is subsequently going to be painted.

SAQ 1

a) What do you understand by segmentation of Capillary Channels ?

b) What is the effect of oil contamination of water on concrete ?

c) Why strength and durability impaired when high water-cement ratio is adopted ?

d) List the tolerable concentration of impurities of the water for concrete making.

3.5 SUMMARY

Water is the most important but least expensive ingredient of concrete. The mixing water added to the concrete is utilized partly for hydration of cement, partly to fill gel pores of the hydrated gel and remaining to form capillary voids. Ideally, quantity of mixing water should be such that no water is left to form capillary voids. But the concrete containing water in this proportion will be very harsh and difficult to place. The additional water which forms capillary voids is many a times required to lubricate the mix, which makes the concrete workable. However, this additional water must be kept to a minimum, since both strength and durability of concrete is impaired. Use of superplasticizer can reduce the water requirement.

The strength and durability of concrete is also reduced due to the presence of impurities in the mixing water. The impurities can be in the form of silts, suspended particle, dissolved sodium and potassium bicarbonates, chlorides, suplphates or can be algae or dissolved salts of organic materials. They may delay or accelerate the setting and hardening, hinder with the hydration process or may cause corrosion or undue expansion in hardened concrete.

Sea water can be used both as mixing and curing water in concrete but to be used with caution in case of reinforced concrete. However, sea water should never be used in case of plastering or in case of prestressed concrete.

3.6 KEY WORDS

Dissolved salts	:	Salts dissolved in the water.
Suspended silt and clay	:	Silt and clay settled in the water.
Corrosion	:	Disintegration of material by chemical action.
Sulphate attack	:	Reaction of sulphates on concrete.
PPM	:	Parts Per Million.

3.7 ANSWERS TO SAQs

SAQ 1

Check the answers with the preceding text.