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DEPARTMENT OF CIVIL ENGINEERING

FACULTY OF ENGINEERING & TECHNOLOGY

Topics to be covered:

- Testing of Cement (Continues…)
- Admixtures in Cement
- Water, Its Properties and Testing
- Problems Related to the Topics Discussed

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TESTING OF CEMENT (CONTINUES…)

STANDARD CONSISTENCY TEST :

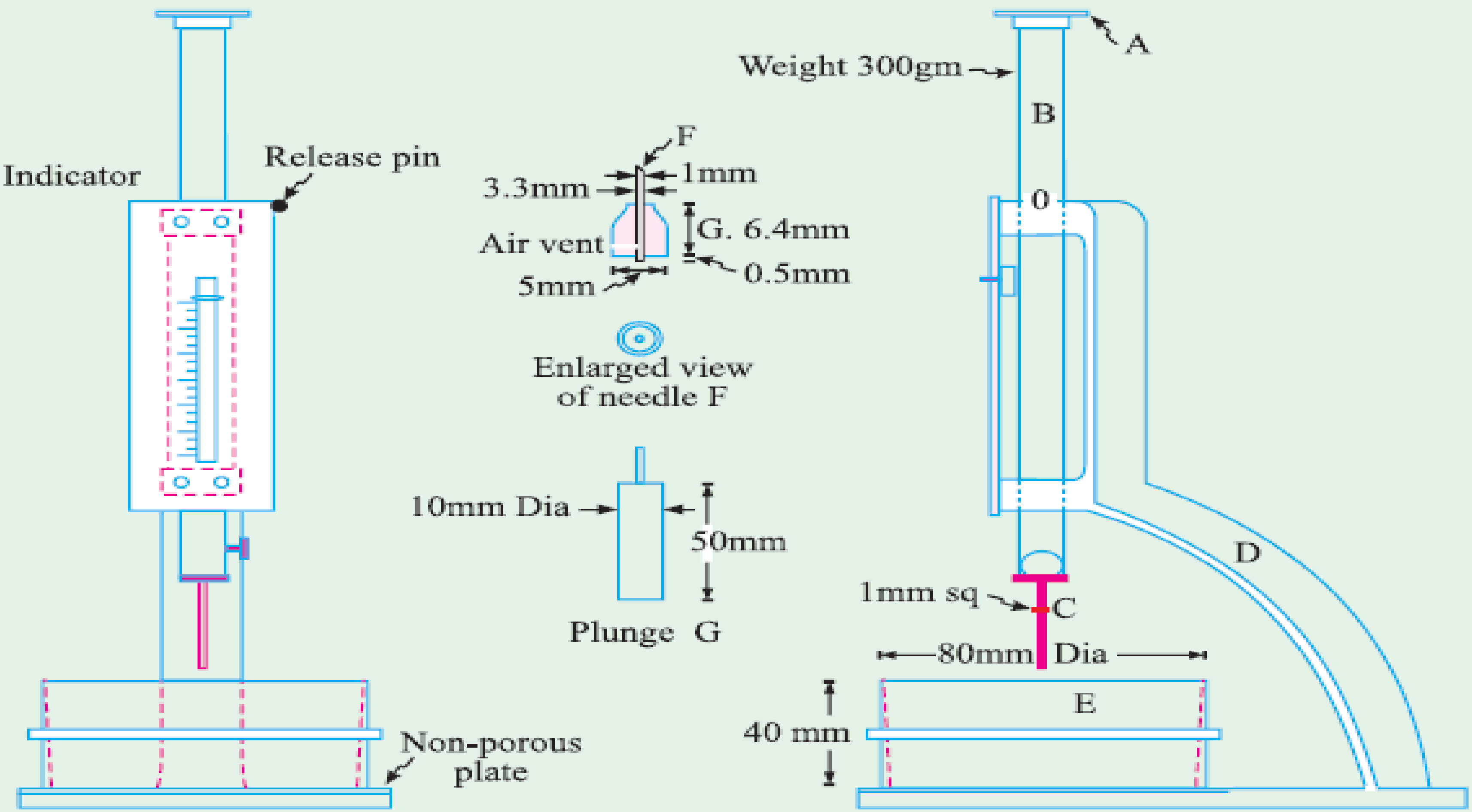
- For finding out initial setting time, final setting time and soundness of cement, and strength a parameter known as standard consistency has to be used.
- It is pertinent at this stage to describe the procedure of conducting standard consistency test.
- The standard consistency of a cement paste is defined as that consistency which will permit a Vicat plunger having 10 mm diameter and 50 mm length to penetrate to a depth of 33-35 mm from the top of the mould. The apparatus is called Vicat Apparatus.
- This apparatus is used to find out the percentage of water required to produce a cement paste of standard consistency.
- The standard consistency of the cement paste is some time called normal consistency (CPNC).

THE FOLLOWING PROCEDURES IS ADOPTED TO FIND OUT STANDARD CONSISTENCY :

- Take about 500 gms of cement and prepare a paste with a weighed quantity of water (say 24 per cent by weight of cement) for the first trial.
- The paste must be prepared in a standard manner and filled into the Vicat mould within 3-5 minutes.
- After completely filling the mould, shake the mould to expel air.
- A standard plunger, 10 mm diameter, 50 mm long is attached and brought down to touch the surface of the paste in the test block and quickly released allowing it to sink into the paste by its own weight.
- Take the reading by noting the depth of penetration of the plunger.
- Conduct a 2nd trial (say with 25 per cent of water) and find out the depth of penetration of plunger.
- Similarly, conduct trials with higher and higher water/cement ratios till such time the plunger penetrates for a depth of 33-35 mm from the top.

TESTING OF CEMENT (CONTINUES…)

- That particular percentage of water which allows the plunger to penetrate only to a depth of 33-35 mm from the top is known as the percentage of water required to produce a cement paste of standard consistency.
- This percentage is usually denoted as 'P'. The test is required to be conducted in a constant temperature (27° + 2°C) and constant humidity (90%).



TESTING OF CEMENT (CONTINUES…)

SETTING TIME TEST :

An arbitrary division has been made for the setting time of cement as initial setting time and final setting time. It is difficult to draw a rigid line between these two arbitrary divisions. For convenience, initial setting time is regarded as the time elapsed between the moment that the water is added to the cement, to the time that the paste starts losing its plasticity. The final setting time is the time elapsed between the moment the water is added to the cement, and the time when the paste has completely lost its plasticity and has attained sufficient firmness to resist certain definite pressure.

In actual construction dealing with cement paste, mortar or concrete certain time is required for mixing, transporting, placing, compacting and finishing. During this time cement paste, mortar, or concrete should be in plastic condition. The time interval for which the cement products remain in plastic condition is known as the initial setting time. Normally a minimum of 30 minutes is given for mixing and handling operations. The constituents and fineness of cement is maintained in such a way that the concrete remains in plastic condition for certain minimum time. Once the concrete is placed in the final position, compacted and finished, it should lose its plasticity in the earliest possible time so that it is least vulnerable to damages from external destructive agencies. This time should not be more than 10 hours which is often referred to as final setting time. Table 2.5 shows the setting time for different cements.

The following procedure is adopted. Take 500 gm. of cement sample and gauge it with 0.85 times the water required to produce cement paste of standard consistency (0.85 P). The paste shall be gauged and filled into the Vicat mould in specified manner within 3-5 minutes. Start the stop watch the moment water is added to the cement. The temperature of water and that of the test room, at the time of gauging shall be within 27°C ± 2°C.

TESTING OF CEMENT (CONTINUES…)

INITIAL SETTING TIME : Lower the needle (C) gently and bring it in contact with the surface of the test block and quickly release. Allow it to penetrate into the test block. In the beginning, the needle will completely pierce through the test block. But after some time when the paste starts losing its plasticity, the needle may penetrate only to a depth of 33-35 mm from the top. The period elapsing between the time when water is added to the cement and the time at which the needle penetrates the test block to a depth equal to 33-35 mm from the top is taken as initial setting time.

FINAL SETTING TIME :

Replace the needle (C) of the Vicat apparatus by a circular attachment (F) . The cement shall be considered as finally set when, upon, lowering the attachment gently cover the surface of the test block, the centre needle makes an impression, while the circular cutting edge of the attachment fails to do so. In other words the paste has attained such hardness that the centre needle does not pierce through the paste more than 0.5 mm.

TESTING OF CEMENT (CONTINUES…)

STRENGTH TEST :

a) The compressive strength of hardened cement is the most important of all the properties.

b) Therefore, it is not surprising that the cement is always tested for its strength at the laboratory before the cement is used in important works.

c) Strength tests are not made on neat cement paste because of difficulties of excessive shrinkage and subsequent cracking of neat cement.

d) Strength of cement is indirectly found on cement sand mortar in specific proportions. The standard sand is used for finding the strength of cement. It shall conform to IS 650-1991.

e) Take 555 gms of standard sand (Ennore sand), 185 gms of cement (i.e., ratio of cement to sand is 1:3) in a non-porous enamel tray and mix them with a trowel for one minute, then add water of quantity P/4 + 3.0 per cent of combined weight of cement and sand and mix the three ingredients thoroughly until the mixture is of uniform colour.

f) The time of mixing should not be less than 3 minutes nor more than 4 minutes.

g) Immediately after mixing, the mortar is filled into a cube mould of size 7.06 cm.

h) The area of the face of the cube will be equal to 50 sq cm. Compact the mortar either by hand compaction in a standard specified manner or on the vibrating equipment (12000 RPM) for 2 minutes.

i) Keep the compacted cube in the mould at a temperature of 27°C ± 2°C and at least 90 per cent relative humidity for 24 hours.

j) Where the facility of standard temperature and humidity room is not available, the cube may be kept under wet gunny bag to simulate 90 per cent relative humidity.

k) After 24 hours the cubes are removed from the mould and immersed in clean fresh water until taken out for testing.

TESTING OF CEMENT (CONTINUES…)

Moulding of 70.7 mm Mortar Cube Vibrating Machine.

SOUNDNESS TEST :

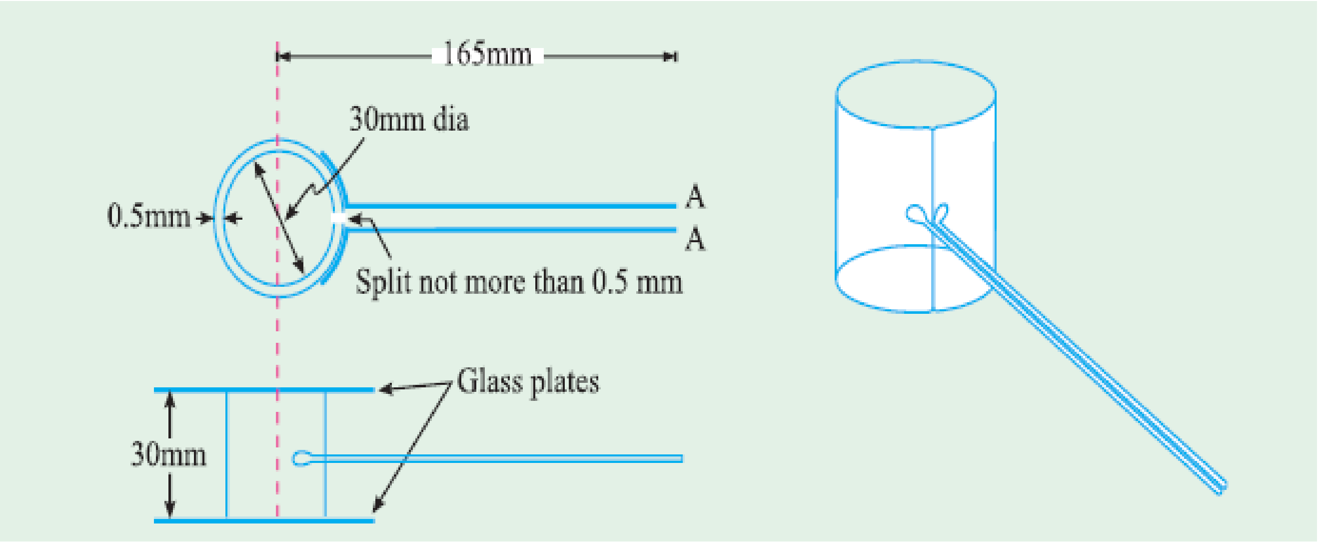
It is very important that the cement after setting shall not undergo any appreciable change of volume. Certain cements have been found to undergo a large expansion after setting causing disruption of the set and hardened mass. This will cause serious difficulties for the durability of structures when such cement is used. The testing of soundness of cement, to ensure that the cement does not show any appreciable subsequent expansion is of prime importance.

The unsoundness in cement is due to the presence of excess of lime than that could be combined with acidic oxide at the kiln. This is also due to inadequate burning or insufficiency in fineness of grinding or thorough mixing of raw materials. It is also likely that too high a proportion of magnesium content or calcium sulphate content may cause unsoundness in cement. For this reason the magnesia content allowed in cement is limited to 6 per cent.

TESTING OF CEMENT (CONTINUES…)

can be recalled that, to prevent flash set, calcium sulphate is added to the clinker while grinding. The quantity of gypsum added will vary from 3 to 5 per cent depending upon C3A content. If the addition of gypsum is more than that could be combined with C3A, excess of gypsum will remain in the cement in free state. This excess of gypsum leads to an expansion and consequent disruption of the set cement paste. Unsoundness in cement is due to excess of lime, excess of magnesia or excessive proportion of sulphates. Unsoundness in cement does not come to surface for a considerable period of time. Therefore, accelerated tests are required to detect it. There are number of such tests in common use.

The apparatus consists of a small split cylinder of spring brass or other suitable metal. It is 30 mm in diameter and 30 mm high. On either side of the split are attached two indicator arms 165 mm long with pointed ends. Cement is gauged with 0.78 times the water required for standard consistency (0.78 P), in a standard manner and filled into the mould kept on a glass plate. The mould is covered on the top with another glass plate. The whole assembly is immersed in water at a temperature of 27°C – 32°C and kept there for 24 hours.



TESTING OF CEMENT (CONTINUES…)

Measure the distance between the indicator points. Submerge the mould again in water. Heat the water and bring to boiling point in about 25-30 minutes and keep it boiling for 3 hours. Remove the mould from the water, allow it to cool and measure the distance between the indicator points. The difference between these two measurements represents the expansion of cement. This must not exceed 10 mm for ordinary, rapid hardening and low heat Portland cements. If in case the expansion is more than 10 mm as tested above, the cement is said to be unsound.

The Le Chatelier test detects unsoundness due to free lime only. This method of testing does not indicate the presence and after effect of the excess of magnesia. Indian Standard Specification stipulates that a cement having a magnesia content of more than 3 per cent shall be tested for soundness by Autoclave test which is sensitive to both free magnesia and free lime. In this test a neat cement specimen 25 × 25 mm is placed in a standard autoclave and the steam pressure inside the autoclave is raised in such a rate as to bring the gauge pressure of the steam to 21 kg/ sq cm in 1 – 11/4 hour from the time the heat is turned on.

This pressure is maintained for 3 hours. The autoclave is cooled and the length measured again. The expansion permitted for all types of cements is given in Table 2.5. The high steam pressure accelerates the hydration of both magnesia and lime. No satisfactory test is available for deduction of unsoundness due to an excess of calcium sulphate. But its content can be easily determined by chemical analysis.

Automatic / Manual 5 litre Mortar Mixer.

Autoclave.

TESTING OF CEMENT (CONTINUES…)

HEAT OF HYDRATION :

a) The reaction of cement with water is exothermic. The reaction liberates a considerable quantity of heat. This can be easily observed if a cement is gauged with water and placed in a thermos flask.

b) Much attention has been paid to the heat evolved during the hydration of cement in the interior of mass concrete dams.

c) It is estimated that about 120 calories of heat is generated in the hydration of 1 gm. of cement. From this it can be assessed the total quantum of heat produced in a conservative system such as the interior of a mass concrete dam. A temperature rise of about 50°C has been observed.

d) This unduly high temperature developed at the interior of a concrete dam causes serious expansion of the body of the dam and with the subsequent cooling considerable shrinkage takes place resulting in serious cracking of concrete.

e) The use of lean mix, use of pozzolanic cement, artificial cooling of constituent materials and incorporation of pipe system in the body of the dam as the concrete work progresses for circulating cold brine solution through the pipe system to absorb the heat, are some of the methods adopted to offset the heat generation in the body of dams due to heat of hydration of cement.

f) Test for heat of hydration is essentially required to be carried out for low heat cement only. This test is carried out over a few days by vaccum flask methods, or over a longer period in an adiabatic calorimeter. When tested in a standard manner the heat of hydration of low heat Portland cement shall not be more than 65 cal/gm. at 7 days and 75 cal/g, at 28 days.

Heat of hydration Apparatus.

TESTING OF CEMENT (CONTINUES…)

Chemical Composition Test

A fairly detailed discussion has been given earlier regarding the chemical composition of cement. Both oxide composition and compound composition of cement have been discussed. At this stage it is sufficient to give the limits of chemical requirements. The Table 2.6 shows the various chemical compositions of all types of cements. Ratio of percentage of lime to percentage of silica, alumina and iron oxide, when calculated by the formulae, $\frac{CaO - 0.7\,SO_3}{2.8\,SiO_2 + 1.2\,Al_2O_3 + 0.65\,Fe_2O_3}$

Not greater than 1.02 and not less than 0.66

The above is called lime saturation factor per cent.

TESTING OF CEMENT (CONTINUES…)

Table 2.5. Physical Characteristics of Various Types of Cement.

Sl.No.	Type of Cement	Fineness (m^2/kg) Min.	Soundness By: Le chatelier (mm) Max.	Soundness By: Autoclave (%) Max.	Setting Time: Initial (mts) min.	Setting Time: Final (mts) max.	Compressive Strength: 1 Day min. MPa	Compressive Strength: 3 Days min. MPa	Compressive Strength: 7 Days min. MPa	Compressive Strength: 28 Days min. MPa
1.	33 Grade OPC (IS 269-1989)	225	10	0.8	30	600	N S	16	22	33
2.	43 Grade OPC (IS 8112-1989)	225	10	0.8	30	600	N S	23	33	43
3.	53 Grade OPC (IS 12269-1987)	225	10	0.8	30	600	N S	27	37	53
4.	SRC (IS 12330-1988)	225	10	0.8	30	600	N S	10	16	33
5.	PPC (IS 1489-1991) Part I	300	10	0.8	30	600	N S	16	22	33
6.	Rapid Hardening (IS 8041-1990)	325	10	0.8	30	600	16	27	N S	N S
7.	Slag Cement (IS 445-1989)	225	10	0.8	30	600	N S	16	22	33
8.	High Alumina Cement (IS 6452-1989)	225	5	N S	30	600	30	35	N S	N S
9.	Super Sulphated Cement (IS 6909-1990)	400	5	N S	30	600	N S	15	22	30
10.	Low Heat Cement (IS 12600-1989)	320	10	0.8	60	600	N S	10	16	35
11.	Masonry Cement (IS 3466-1988)	*	10	1	90	1440	N S	N S	2.5	5
12.	IRS-T-40	370	5	0.8	60	600	N S	N S	37.5	N S

TESTING OF CEMENT (CONTINUES…)

Table. 2.6. Chemical Characteristics of Various Types of Cement.

Sr. No.	Type of Cement	Lime Saturation Factor (%)	Alumina Iron Ratio (%) Min.	Insoluble Residue (%) Max.	Magnesia (%) Max.	Sulphuric Anhydride	Loss on Ignition (%) Max.
1	33 Grade OPC (IS 269-1989)	0.66 Min. 1.02 Max.	0.66	4	6	2.5% Max. When C_3A is 5 or less 3% Max. When C_3A is greater than 5	5
2	43 Grade OPC (IS 8112-1989)	0.66 Min. 1.02 Max.	0.66	2	6	2.5% Max. When C_3A is 5 or less 3% Max. When C_3A is greater than 5	5
3	53 Grade OPC (IS 12269-1987)	0.8 Min. 1.02 Max.	0.66	2	6	2.5% Max. When C_3A is 5 or less 3% Max. When C_3A is greater than 5	4
4	Sulphate Resisting Cement (IS 12330-1988)	0.66 Min. 1.02 Max.	N S	4	6	2.5% Max.	5
5	Portland Pozzolana Cement (IS 1489-1991) Part I	N S	N S	$x+\frac{4(100-x)}{100}$	6	3% Max.	5
6	Rapid Hardening Cement (IS 8041-1990)	0.66 Min. 1.02 Max.	0.66	4	6	2.5% Max. When C_3A is 5 or less 3% Max. When C_3A is greater than 5	5
7	Slag Cement (IS 455-1989)	N S	N S	4	8	3% Max.	5
8	High Alumina Cement (IS 6452-1989)	N S	N S	N S	N S	N S	N S
9	Super Sulphated Cement (IS 6909-1990)	N S	N S	4	10	6% Min.	N S
10	Low Heat Cement (IS 12600-1989)	N S	0.66	4	6	2.5% Max. When C_3A is 5 or less 3% Max. When C_3A is greater than 5	5
11	IRS-T40	0.8 Min. 1.02 Max.	0.66	2	5	3.5% Max.	4

WATER, ITS PROPERTIES AND TESTING :

Table 4.2. Permissible limit for solids as per IS 456 of 2000

Material	Tested as per	Permissible limit Max.
Organic	IS 3025 (pt 18)	200 mg/l
Inorganic	IS 3025 (pt 18)	3000 mg/l
Sulphates (as SO_3)	IS 3025 (pt 24)	400 mg/l
Chlorides (as Cl)	IS 3025 (pt 32)	2000 mg/l for concrete work not containing embedded steel and 500 mg/l for reinforced concrete work
Suspended	IS 3025 (pt 17)	2000 mg/l

Algae in mixing water may cause a marked reduction in strength of concrete either by combining with cement to reduce the bond or by causing large amount of air entrainment in concrete. Algae which are present on the surface of the aggregate have the same effect as in that of mixing water.

USE OF SEA WATER FOR MIXING CONCRETE : Sea water has a salinity of about 3.5 per cent. In that about 78% is sodium chloride and15% is chloride and sulphate of magnesium. Sea water also contain small quantities of sodium and potassium salts. This can react with reactive aggregates in the same manner as alkalies in cement. Therefore sea water should not be used even for PCC if aggregates are known to be potentially alkali reactive. It is reported that the use of sea water for mixing concrete does not appreciably reduce the strength of concrete although it may lead to corrosion of reinforcement in certain cases. Research workers are unanimous in their opinion, that sea water can be used in un-reinforced concrete or mass concrete. Sea water slightly accelerates the early strength of concrete. But it reduces the 28 days strength of concrete by about 10 to 15 per cent. However, this loss of strength could be made up by redesigning the mix. Water containing large quantities of chlorides in sea water may cause efflorescence and persistent dampness. When the appearance of concrete is important sea water may be avoided.

WATER, ITS PROPERTIES AND TESTING :

- The use of sea water is also not advisable for plastering purpose which is subsequently going to be painted.
- 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 research workers did not find the risk of corrosion due to the use of sea water.
- Experiments have shown that corrosion of reinforcement occurred when concrete was made with pure water and immersed in pure water when the 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 to the reinforcement was given.
- From this it could be inferred that the factor for corrosion is not the use of sea water or the quality of water where the concrete is placed. The factors effecting corrosion is permeability of concrete and lack of cover.
- However, since these factors cannot be adequately taken care of always at the site of work, it may be wise that sea water be avoided for making reinforced concrete.
- The use of sea water must be avoided in pre-stressed concrete work because of stress corrosion and undue loss of cross section of small diameter wires.
- The latest Indian standard IS 456 of 2000 prohibits the use of Sea Water for mixing and curing of reinforced concrete and pre-stressed concrete work. This specification permits the use of Sea Water for mixing and curing of plain cement concrete (PCC) under unavoidable situation.

It is pertinent at this point to consider the suitability of water for curing. Water that contains impurities which caused staining, is objectionable for curing concrete members whose look is important. The most common cause of staining is usually high concentration of iron or organic matter in the water. Water that contains more than 0.08 ppm. of iron may be avoided for curing if the appearance of concrete is important. Similarly the use of sea water may also be avoided in such cases. In other cases, the water, normally fit for mixing can also be used for curing.

“Thank you”

Have Any Query ?

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