Durability of Concrete

Lecture No. 22
IS-456-2000, classifies the exposure conditions into five categories:

- **Mild**: Concrete surfaces protected against weather or aggressive conditions, except those situated in coastal area.

- **Moderate**: Concrete surfaces sheltered from severe rain or freezing whilst wet. Concrete exposed to condensation and rain. Concrete continuously under water. Concrete in contact or buried under nonaggressive soil/ground water. Concrete surfaces sheltered from saturated salt air in coastal area.

- **Aggressive**: Concrete surfaces exposed to severe rain, alternate wetting and drying or occasional freezing whilst wet or severe condensation. Concrete completely immersed in sea water. Concrete exposed to coastal environment.
IS-456-2000, classifies the exposure conditions into five categories:

- **Severe**: Concrete surfaces exposed to sea water spray, corrosive fumes or severe freezing conditions whilst wet. Concrete in contact with or buried under aggressive sub-soil/ground water

- **Extreme**: Surface of members in tidal zone Members in direct contact with liquid/solid aggressive chemicals

Table 3 Environmental Exposure Conditions (Clauses 8.2.2.1 and 35.3.2) IS 456 – 2000 Page No. 18
Factors affecting the durability of concrete

- Environmental Factors
- Quality of Constituent Materials
- Quantity of Constituent Materials
- Quality of Workmanship
- Cover to the Reinforcement
- Inadequate Design
- Improper Use of Structure
Strength and Durability Relationship

- The demand is catered by high early strength cement, use of very low W/C ratio through the use of increased cement content and reduced water content.

- The above steps result in higher thermal shrinkage, drying shrinkage, modulus of elasticity and lower creep coefficients. With higher quantity of cement content, the concrete exhibits greater cracking tendencies because of increased thermal and drying shrinkage.

- As the creep coefficient is low in such concrete, there will not be much scope for relaxation of stresses. Therefore, high early strength concretes are more prone to cracking than moderate or low strength concrete.
Impact of W/C Ratio on Durability

- The permeability is the contributory factor for volume change and higher W/C ratio is the fundamental cause of higher permeability.

- Therefore, use of higher W/C ratio — permeability — volume change — cracks — disintegration — failure of concrete is a cyclic process in concrete.

- Therefore, for a durable concrete, use of lowest possible W/C ratio is the fundamental requirement to produce dense and impermeable concrete.
Impact of W/C Ratio on Durability

- There is a tremendous change in the micro structure of concrete made with high W/C ratio and low W/C ratio.

- With low W/C ratio the permeability decreases to such a level that these concretes are impervious to water.

- This does not mean that they do not contain interconnected network of capillaries, but these capillaries are so fine that water cannot flow any more through them.

- When such concretes are tested for chloride ions permeability test, it is found that chloride ions diffuse such concretes at a rate 10 — 50 times slower than that of high W/C ratio concrete.
Minimum And Maximum Cement Content

- Generally, the cement content itself would not have a direct role on the strength of concrete; if cement content is required to increase the workability of concrete mix for a given water-cement ratio, then the compressive strength may increase with the richness of the mix.

- However, for a particular water-cement ratio there would always be an optimum cement content resulting in 28-day compressive strength being the highest.

- Increasing the cement content above the optimum value may not increase the strength of concrete specially for mixes with low water-cement ratio and larger maximum size aggregate.
Recommendations for making durable concrete in various codes of practices envisage limits for maximum water-cement ratio, minimum cement content, cover thickness, type of cement and amount of chlorides and sulphates in concrete, etc.

The cement content, it should ensure sufficient alkalinity (PH value of concrete) to provide a passive environment against corrosion of steel, for example, in concrete in marine environment or in sea water, a minimum cement content of 350 kg/m3 or more is required for this consideration.
Minimum And Maximum Cement Content

- Secondly, the cement content and water-cement ratio is so chosen as to result in sufficient volume of cement paste to overfill the voids in the compacted aggregates.

- A cement content of 400 kg/m³ and water-cement ratio of 0.45 will result in paste volume being 30 percent which may be suitable for the crushed rock of 20 mm maximum size aggregate, whereas cement content of 300 kg/m³ and water cement ratio of 0.50 will result in 25 percent paste volume being sufficient to overfill the voids in 20mm rounded gravel aggregates.
Minimum And Maximum Cement Content

- For severe conditions such as thin sections under hydrostatic pressure on one side only and sections partly immersed, considerations should be given to a further reduction of water-cement ratio, and if necessary an increase in the cement content to ensure the degree of workability needed for full compaction and thus minimum permeability.

- In appropriate circumstances, the maximum limit of cement content in the concrete may also have to be specified. This is because concrete mixes having high cement content may give rise to shrinkage, cracking and creep of concrete also increases with the cement paste content.