CRACKING OF CONCRETE

Whenever tensile stress in concrete, caused by various effects, exceeds the tensile strength of concrete, concrete will crack.

In the early stage of concrete formation, concrete strength is relatively weak, and this makes it vulnerable to cracking.

Broadly divided into:

(a) Non-structural cracks

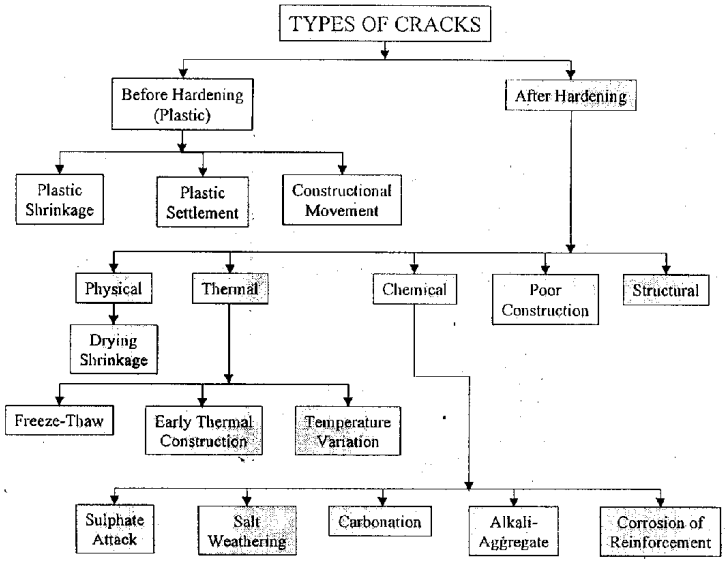
(due to environmental factors and construction process)

(b) Structural cracks

(due to applied loadings)

Cracking phenomena begin with the plastic state, right after casting, and continues through the hardened state and service life. The volumetric changes in concrete during hardening are a major factor for cracking.

Concrete is subjected to cracking both at the plastic and hardened state.

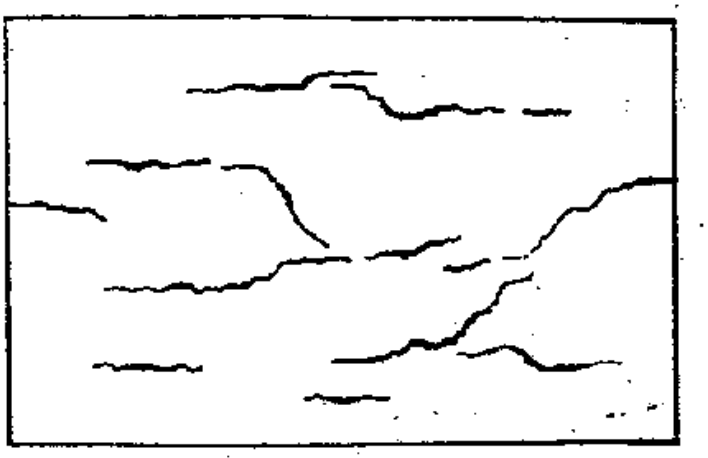


Cracking in Plastic State

- Plastic shrinkage
- Plastic settlement
- Construction movement

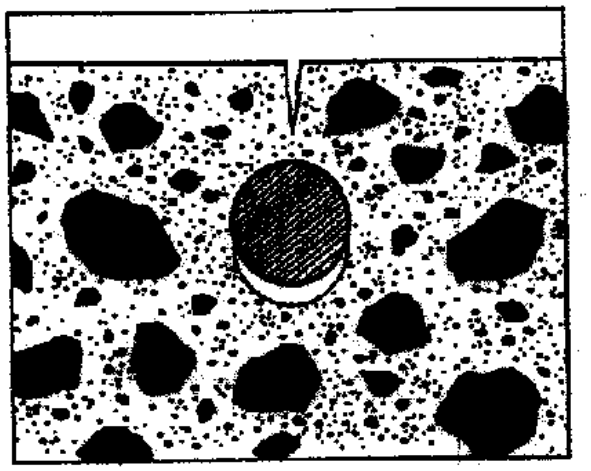
Plastic Shrinkage

- Caused by rapid loss of moisture due to wind, low relative humidity and high differential temperature
- Occurs within few hours of casting
- Typically few cm deep; wider at top
- Slab, wall-type members vulnerable



Plastic Settlement

- ► Takes place after casting and finishing
- ► Upward movement of water ↑ downward movement of solids ↓ during consolidation
- ► Results in cracks or void under **rebar** or **large aggregate** or obstacles
- ► Cracks usually run along the rebar
- ► Happens within ١٠ mins – ٣ hrs.



Construction Movement

Cracking due to accidental movement of formwork within a few hours of casting.

Hardened Concrete

Cracks can develop due to various causes. They can be grouped into:

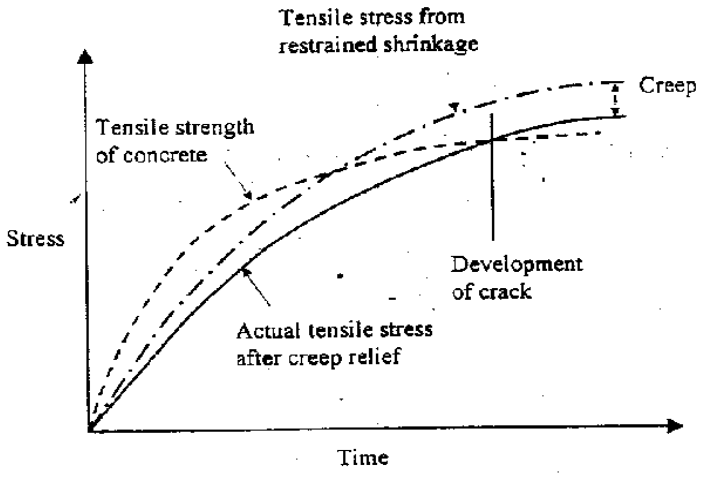
Volumetric changes,

Environmental factors,

Chemical attack, and load effects.

Drying Shrinkage

- Shrinkage from continual loss of moisture
- Support restraints produce tensile stress
- If tensile stress > tensile strength, cracks occur
- Several weeks to months
- Rapid drying at top results in deeper cracks



Evolution of Tensile Strength and Influence of Shrinkage and Creep on Cracking.

Chemical Effects

- Sulphate attack
- Salt-weathering
- Carbonation
- Alkali-aggregate reaction
- Corrosion of reinforcement

Sulphate Attack

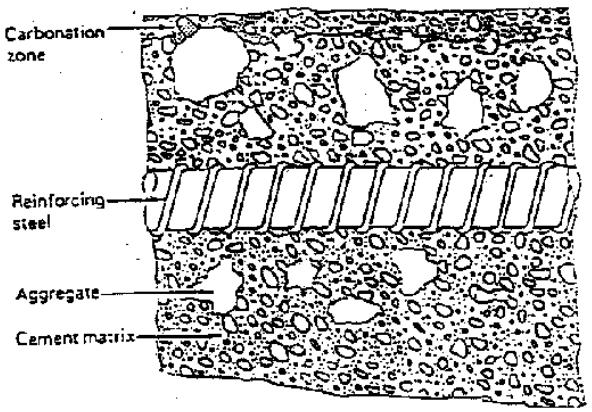
- sulphates react with tricalcium aluminate and forms calcium sulphoaluminate
- results in volume expansion
- leads to cracking / spalling
- moisture is a key accessory

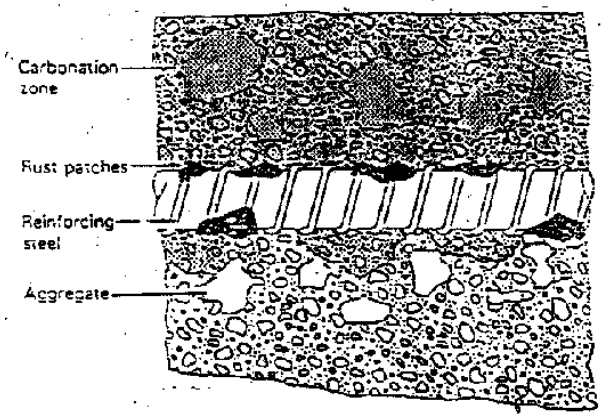
Salt-Weathering

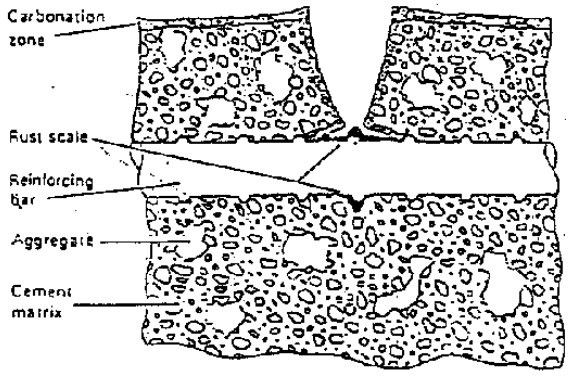
- Evaporation of salt water absorbed by concrete leaves salt crystals
- Can cause rupture of aggregates or matrix
- Attack proceeds from the surface to inward
- Vulnerable areas: *above ground level and splash zones*
- Takes few years to develop cracks

Carbonation

- Alkalinity reduced by acidic gases (CO_2, SO_2) that penetrates into concrete, by forming carbonates and sulphates.
- The Ph value greatly reduced.
- If the carbonated front advances to rebar, passivity of rebar is destroyed.
- Rebar becomes *vulnerable to corrosion.*







Thermal Cracking

Three possibilities:

- Freeze-thaw
- Early thermal contraction
- Temperature variation

Early Thermal Contraction

- Heat of hydration increases temp. within concrete
- This causes a small expansion in volume
- As concrete cools, it contracts
- Any restraint to contraction causes tensile stress
- Can occur within one day to ٢ weeks from casting

Freeze-Thaw

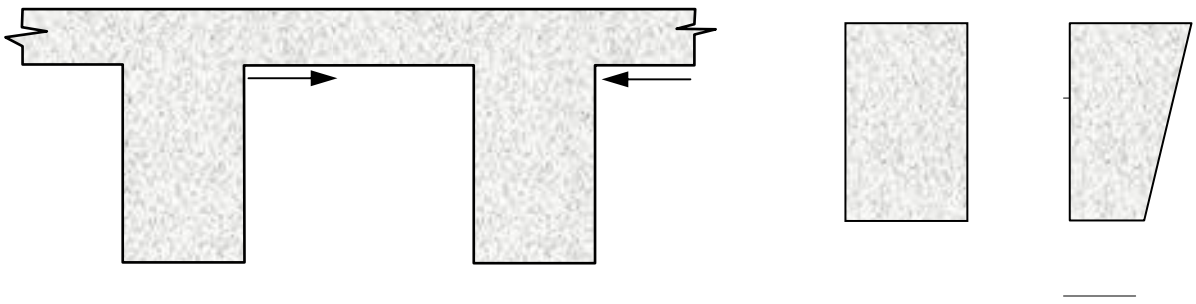
- In low temp., moisture within concrete and pore water freezes.
- The expansion due to freezing causes internal pressure.
- Repeated freeze-thaw causes damage.

Temperature Variation

Two effects:

(a) Expansion / contraction

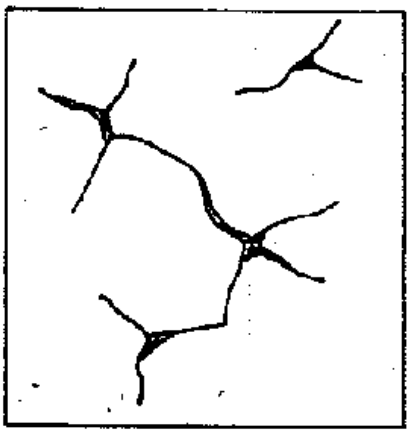
(b) Thermal gradients



Another effect: Thermal incompatibility of aggregates

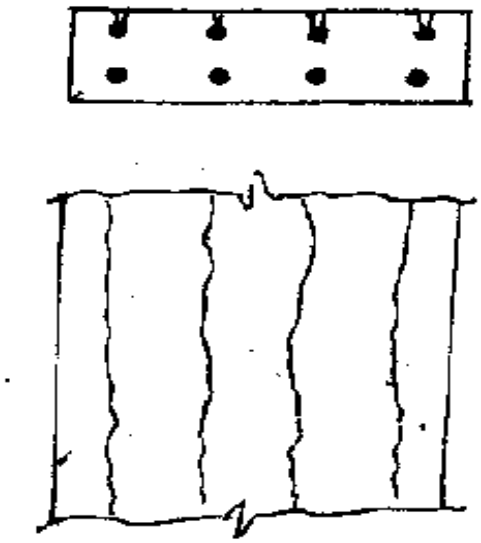
Alkali-Aggregate Reaction

- Reaction of some aggregates with alkali to form expansive products in **moist environment**
- Common form of reaction alkali-silica, though alkali-carbonate also may occur.
- Moisture is necessary for such reaction



Corrosion of Rebars

- Formation of anodic and cathodic cells
- Transformation of metallic ion into rust causes large volume expansion
- Volumetric expansion leads to cracking
- Corrosion cracks runs parallel to bars



Chloride-induced Corrosion

- Predominate cause of corrosion
- Chloride destroys the passivity
- Concrete has the ability to chemically bind some chloride
- Excess chloride triggers corrosion
- Needs moisture and oxygen for electrochemical corrosion

Sources of Chlorides

- contaminated aggregates } (internal)
- mixing / curing water
- external – salt-laden environment (sabkha, coastal belts, etc.)
- several mechanisms for chloride penetration into concrete
- chloride diffusion and absorption are common mechanisms

Poor Construction

- Improper practice can help the cracking phenomena and magnify cracks due to various causes:

Improper *mix design, construction methods, design & detailing*

Structural Cracks

- Stress-induced cracking from external loads and forces
- Usually fine for well-designed members
- Under excessive tensile stress (tension, bending and torsion), cracks can be wide and well-formed.