## Chemicals Attacks

### Sulfate attack

- Solid salts do not attack concrete but, when present in solution, they can react with hydrated cement paste.
- Particularly common are sulfates of sodium, potassium, magnesium, and calcium which occur in soil or in groundwater.
- Sulfates in groundwater are usually of natural origin but can also come from fertilizers or from industrial effluents.
- This type of attack occurs in concrete in the ground (foundations, retaining walls, ect)
- The reactions of the various sulfates with hardened cement paste are as follows.

## Sulfate attack

✓ Sodium sulfate attacks Ca(OH)2:

$$Ca(OH)_2 + Na_2SO_4.10H_2O \rightarrow CaSO_4.2H_2O + 2NaOH + 8H_2O$$

- This is an acid-type attack. In flowing water, $Ca(OH)_2$ can be completely leached out but if NaOH accumulates, equilibrium is reached, only a part of the $SO_3$ being deposited as gypsum.
- The reaction with calcium aluminate hydrate can be formulated as follows:

$$2(3CaO.Al_2O_3.12H_2O) + 3(Na_2SO_4.10H_2O) \rightarrow 3CaO.Al_2O_3.3CaSO_4.32H_2O + 2Al(OH)_3 + 6NaOH + 17H_2O$$

✓ Calcium sulfate attacks only calcium aluminate hydrate, forming calcium sulfoaluminate **($3CaO.Al_2O_3.3CaSO_4.32H_2O$)** known as **Ettringite**.

# Sulfate attack

- ✓ **magnesium sulfate** attacks calcium silicate hydrates as well as $Ca(OH)_2$ and calcium aluminate hydrate. The pattern of reaction is:

$$3CaO.2SiO_2.aq + 3MgSO_4.7H_2O \rightarrow 3CaSO_4.2H_2O + 3Mg(OH)_2 + 2SiO_2.aq. + xH_2O.$$

**Try to watch this video on YouTube**

https://www.youtube.com/watch?v=xmaj7-KdkZs

## Effects of sea water on concrete

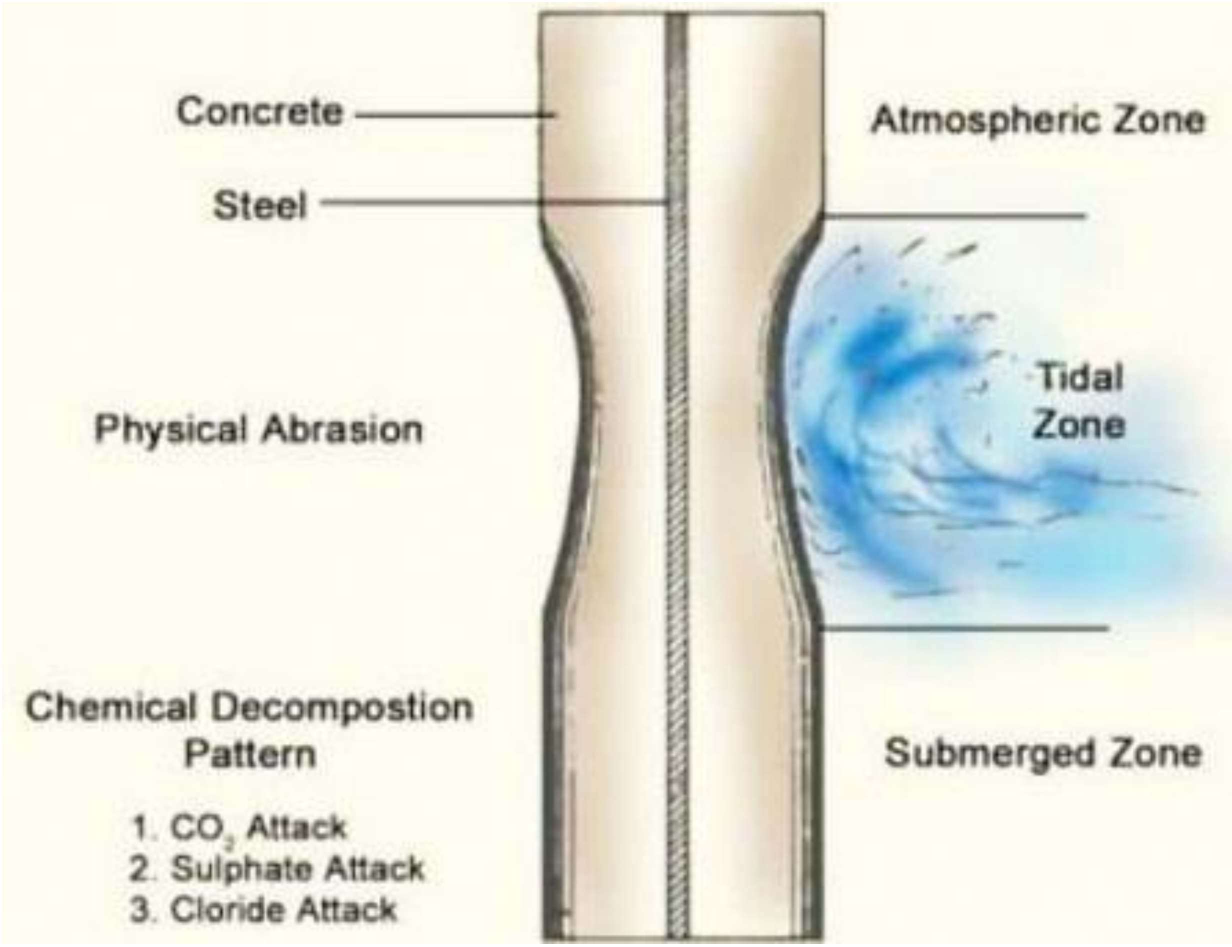
- Concrete exposed to sea water can be subjected to various chemical and physical actions.
- These include chemical attack, chloride-induced corrosion of steel reinforcement, freeze–thaw attack, salt weathering, and abrasion by sand in suspension and by ice.
- The presence and intensity of these various forms of attack depend on the location of the concrete with respect to the sea level.
- Chemical action of sea water on concrete arises from the fact that sea water contains a number of dissolved salts.
- The total salinity is typically 3.5 percent. 4.3 per cent in the Arabian Gulf. The Dead Sea is the extreme case: its salinity is 31.5 per cent, that is, nearly 9 times that of the oceans.

## Effects of sea water on concrete

- The pH of sea water varies between 7.5 and 8.4. **What does that mean?**
- The presence of a large quantity of sulfates in sea water could lead to the expectation of sulfate attack.
- Indeed, the reaction between sulfate ions and both $C_3A$ and C-S-H takes place, resulting in the formation of Ettringite, but this is not associated with deleterious expansion because Ettringite, as well as gypsum, are soluble in the presence of chlorides and can be leached out by the sea water.
- The chemical action of sea water on concrete is as follows. The magnesium ion present in the sea water substitutes for the calcium ion:

$$MgSO_4 + Ca(OH)_2 \rightarrow CaSO_4 + Mg(OH)_2$$

# Effects of sea water on concrete



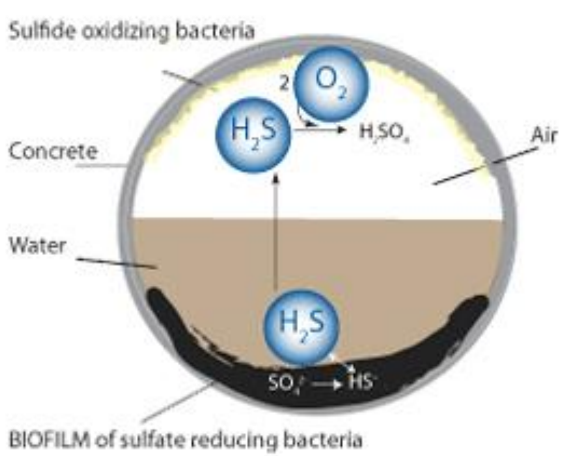

Cited from internet resource

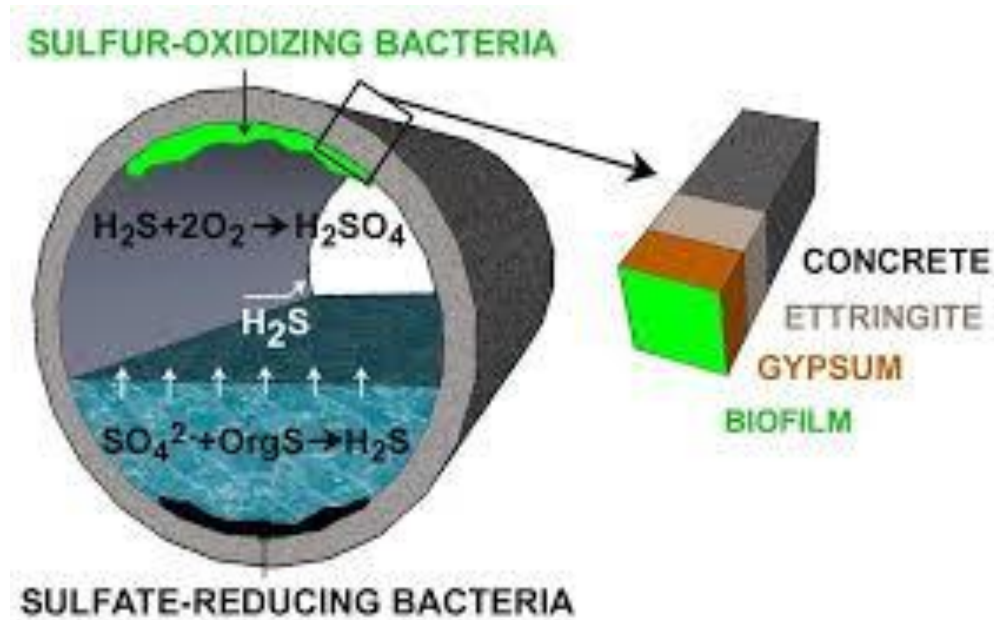
# Acid attack on concrete

- Concrete can be attacked by liquids with a pH value about 6.5 but the attack is severe only at a pH below 5.5; below 4.5, the attack is very severe.
- Acid rain, which consists mainly of sulfuric acid and nitric acid and has a pH value between 4.0 and 4.5, may cause surface weathering of exposed concrete. When this attack could take place?
- Although domestic sewage by itself is alkaline and does not attack concrete, severe damage of sewers has been observed in many cases, especially at fairly **high temperatures**, when sulfur compounds become reduced by anaerobic bacteria to $H_2S$.

# Acid attack on concrete

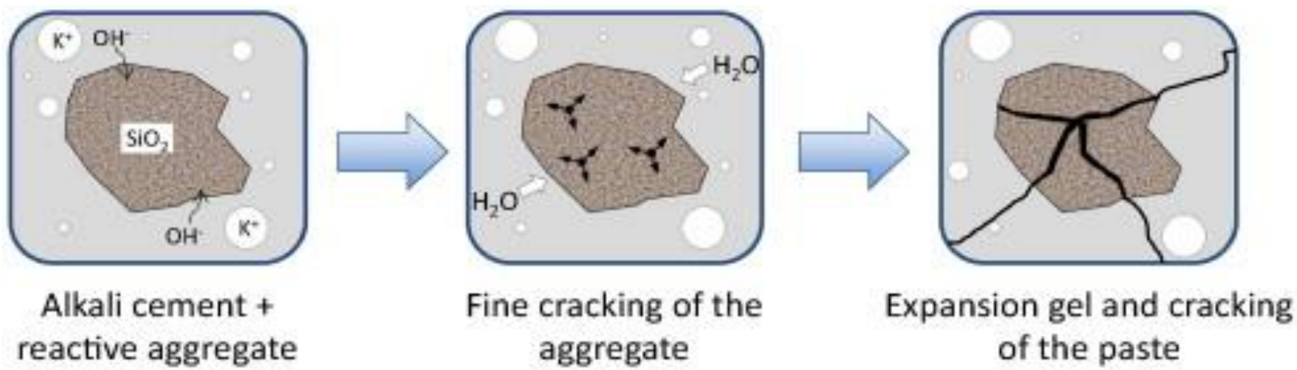
- This is not a destructive agent in itself, but it is dissolved in **moisture films** on the exposed surface of the concrete and undergoes oxidation by aerobic bacteria, finally producing sulfuric acid.
- Sulfuric acid is particularly aggressive because, in addition to the sulfate attack of the aluminate phase, acid attack on $Ca(OH)_2$ and C-S-H takes place.



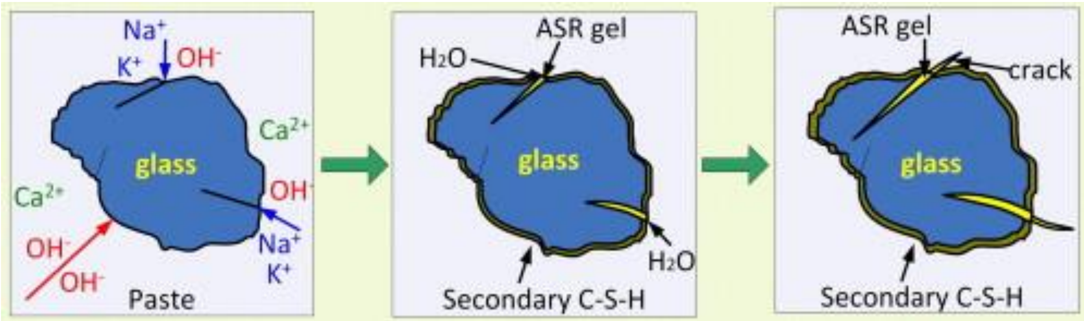



## Alkali–aggregate reaction

- The reactions between the alkalis and reactive silica and some carbonates in aggregate can be disruptive and manifest itself as cracking.
- The crack width can range from 0.1 mm to as much as 10 mm in extreme cases.
- The cracks are rarely more than 25 mm, or at most 50 mm, deep. In most cases, the alkali–silica reaction adversely affects the appearance and serviceability of a structure.
- The pattern of surface cracking induced by the alkali–silica reaction is irregular, somewhat reminiscent of a huge spider's web.



# Alkali–aggregate reaction




# Alkali–aggregate reaction

| reactive aggregate + | sufficient alkali + | sufficient moisture |
|---|---|---|
| amount of reactive silica in aggregate | amount of cement | volume-surface area ratio |
| reactive level of silica | cement alkali content | water-to-cement ratio |
| aggregate particle size | alkali from aggregate, admixtures, etc. | permeability |
| distribution in mixture | migration leaching of alkalis | climate and exposure. |

accelerated by elevated temperature and external sources of alkali