SULPHATE ATTACK IN CONCRETE AND ITS PREVENTION

- Sulfate attack is a chemical breakdown mechanism where sulfate ions attack components of the cement paste.
- The compounds responsible for sulfate attack are water-soluble sulfate-containing salts, such as alkali-earth (calcium, magnesium) and alkali (sodium, potassium) sulfates that are capable of chemically reacting with components of concrete.

Sulfate attack might show itself in different forms Depending on :

- The chemical form of the sulfate
- The atmospheric environment which the concrete is exposed to

What happens when sulfates get into concrete?

- It combines with the C-S-H, or concrete paste, and begins destroying the paste that holds the concrete together. As sulfate dries, new compounds are formed, often called **ettringite**.
- These new crystals occupy empty space, and as they continue to form, they cause the paste to crack, further damaging the concrete.

Sulfate sources:

1. **Internal Sources:**

This is more rare but, originates from such concrete-making materials as hydraulic cements, fly ash, aggregate, and admixtures.

- portland cement might be over-sulfated.
- presence of natural gypsum in the aggregate.
- Admixtures also can contain small amounts of sulfates.

2. External Sources:

External sources of sulfate are more common and usually are a result of high-sulfate soils and ground waters, or can be the result of atmospheric or industrial water pollution.

- Soil may contain excessive amounts of gypsum or other sulfate.
- Ground water be transported to the concrete foundations, retaining walls, and other underground structures.
- Industrial waste waters.

Nature of reaction: (chemical, Physical)

SULFATE ATTACK processes decrease the durability of concrete by changing the chemical nature of the cement paste, and of the mechanical properties of the concrete.

1. Chemical process:

The sulphate ion + hydrated calcium aluminate and/or the calcium hydroxide components of hardened cement paste + water = ettringite (calcium sulphoaluminate hydrate)

C3A.Cs.H18 + 2CH +2s+12H = C3A.3Cs.H32

C3A.CH.H18 + 2CH +3s + 11H = C3A.3Cs.H32

The sulphate ion + hydrated calcium aluminate and/or the calcium hydroxide components of hardened cement paste + water = gypsum (calcium sulphate hydrate)

$Na_2SO_4 + Ca(OH)_2 + 2H_2O = \underline{CaSO_4.2H_2O} + 2NaOH$

$MgSO_4 + Ca(OH)_2 + 2H_2O = \underline{CaSO_4.2H_2O} + Mg(OH)_2$

Two forms of Chemical reaction depending on

- Concentration and source of sulfate ions .Diagnosis
- Composition of cement paste in concrete.

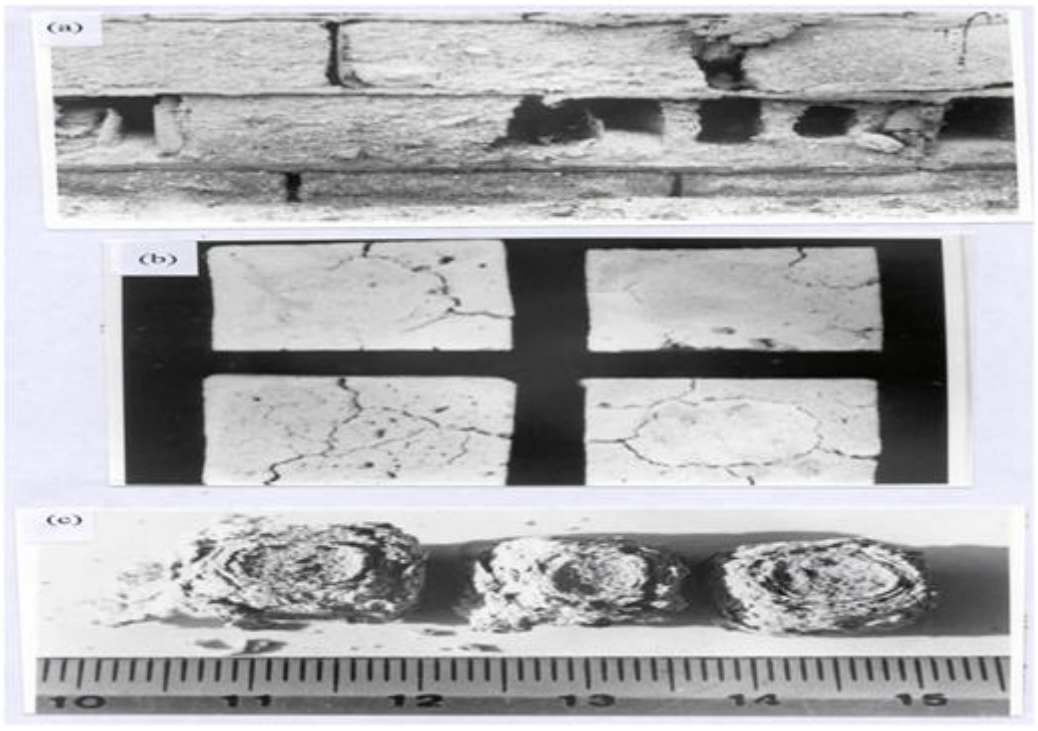
2. Physical process:

- The complex physico-chemical processes of "sulfate attack" are interdependent as is the resulting damage.
- physical sulfate attack, often evidenced by bloom (the presence of sodium sulfates Na_2SO_4 and/or $Na_2SO_4.10H_2O$) at exposed concrete surfaces.
- It is not only a cosmetic problem, but it is the visible displaying of possible chemical and micro structural problems within the concrete matrix.

Both chemical and physical phenomena observed as sulfate attack, and their separation is inappropriate.

Diagnosis

- Spalling due sulfate attack.


(a)
(b)
(c)
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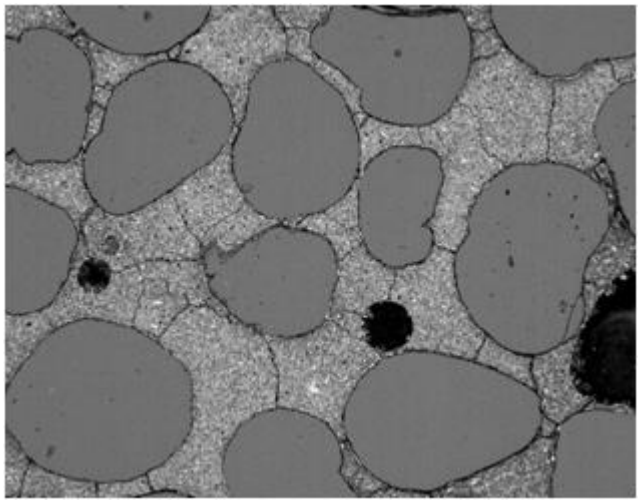
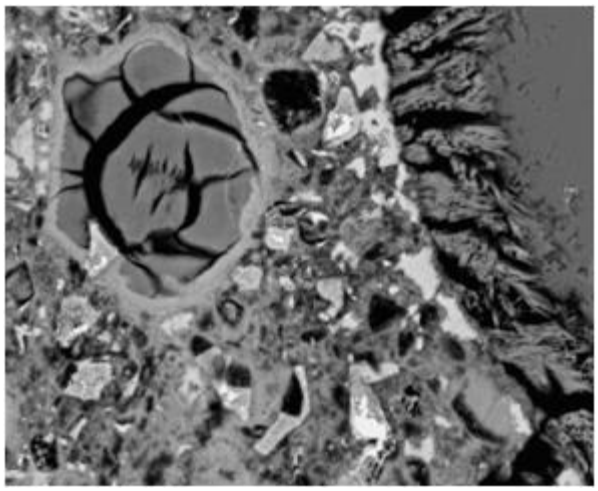
Microscopical examination





Prevention measures

Main factors affecting sulfate attack:

1. Cement type and content:

The most important mineralogical phases of cement that affect the intensity of sulfate attack are: C3A, C3S/C2S ratio and C4AF.

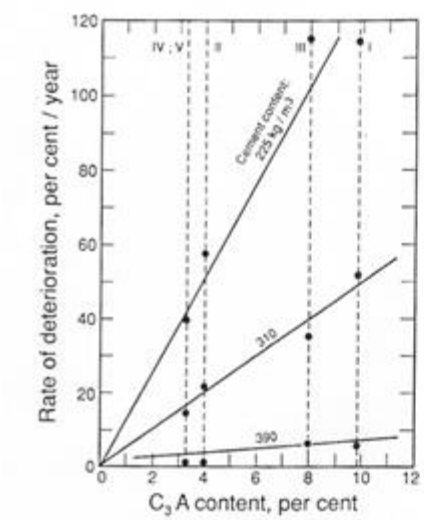


Fig. 9.5. Effect of the C_3A content in Portland cement on the rate of deterioration of concrete exposed to sulphate bearing soils. (Adapted from Ref. 9.14.)

2. Fly ash addition

The addition of a pozzolanic admixture such as fly ash reduces the C3A content of cement.

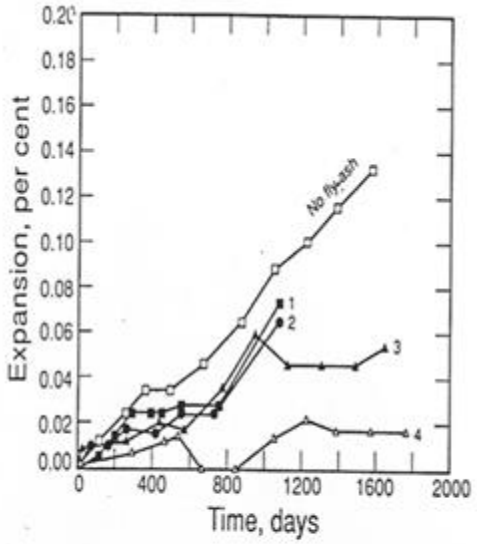


Fig. 9.8. Sulphate expansion of concrete containing low-calcium fly-ash of different compositions marked 1 to 4. (Adapted from Ref. 9.19.)

3. Sulfate type and concentration:

The sulfate attack tends to increase with an increase in the concentration of the sulfate solution up to a certain level.

4. Chloride ions

Other factors:

- The level of the water table and its seasonal variation
- The flow of groundwater and soil porosity
- The form of construction
- The quality of concrete

Control of sulfate attack

1. The quality of concrete, specifically a low permeability, is the best protection against sulfate attack.

- Adequate concrete thickness
- High cement content
- Low w/c ratio
- Proper compaction and curing

Effect of w/c ratio on <u>sulphate attack</u>

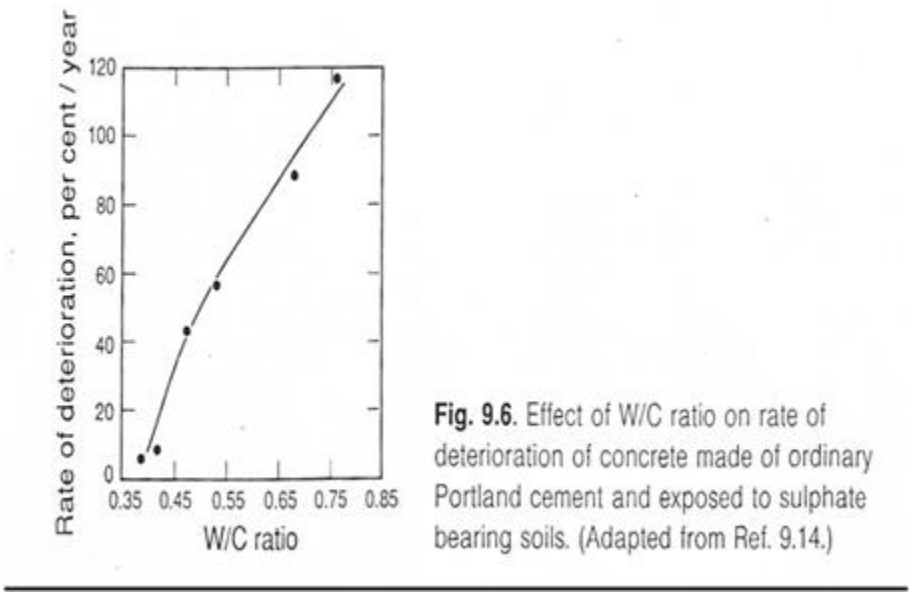


Fig. 9.6. Effect of W/C ratio on rate of deterioration of concrete made of ordinary Portland cement and exposed to sulphate bearing soils. (Adapted from Ref. 9.14.)

2. The use of sulfate resisting cements provide additional safety against sulfate attack

Exposure	Concentration of water-soluble sulfates in soil per cent	Concentration of water-soluble sulfates in water ppm
Mild	<0.1	<150
Moderate	0.1 to 0.2	150 to 1500
Severe	0.2 to 2	1500 to 10000
Very severe	>2	>10000