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Mechanics and Design of Concrete Structures:

Degradation, corrosion and analysis of the durability of concrete structures.

REINFORCED CONCRETE DETERIORATION:

1) PHISICAL PROCESSES

- Icing-deicing cycles
- Fire

2) CHEMICAL PROCESSES

- Sulphatic degradation
- Degradation due to seawater

3) MECHANICAL PROCESSES

- Abrasion
- Erosion
- Cavitation
- Impact

4) STRUCTURAL PROCESSES

- Overloads
- Settlements
- Fatigue

5) REBARS CORROSION

PHYSICAL PROCESSES

Icing-deicing cycles

- From the surface to the center of the section

Micro and macro cracks due to:

- Bigger volume of ice
- Higher water pressure in the inner pores

Fire

- <100 C (212 F) increase volume
- 100 C (212 F)-150 C (302 F) Decrease of volume due to thermal decomposition
- >500 C (932 F) fractures at the interfaces with rebars

CHEMICAL PROCESSES

Sulphatic degradation

- Occurs in environments rich in sulphates (Grounds, waters)
- Reaction between sulphates and hydrates components of concrete
- New products with bigger molecular volumes

Seawater degradation

- Usually between the high-low tide zone
- Mechanical processes (superficial erosion)
- Crystallization of salt into the pores of concrete

REBARS CORROSION:CAUSES

CONCRETE IS THE IDEAL ENVIRONMENT FOR REBARS. pH>13

REBARS ARE PASSIVATED UNTILL:

- **CARBONATION**

Due to the presence of CO_2 in the surounding environment

2) CHLORIDES ACTION

Due to the presence of chlorides in the environment or in the concrete itself

CORROSION DUE TO CARBONATION

- **CHANGE IN THE CONCETE pH**

Consumption of OH- ions due to
$CO_2 + Ca(OH)_2 = CaCO_3 + H_2O$

Extensive destruction of the passivating film

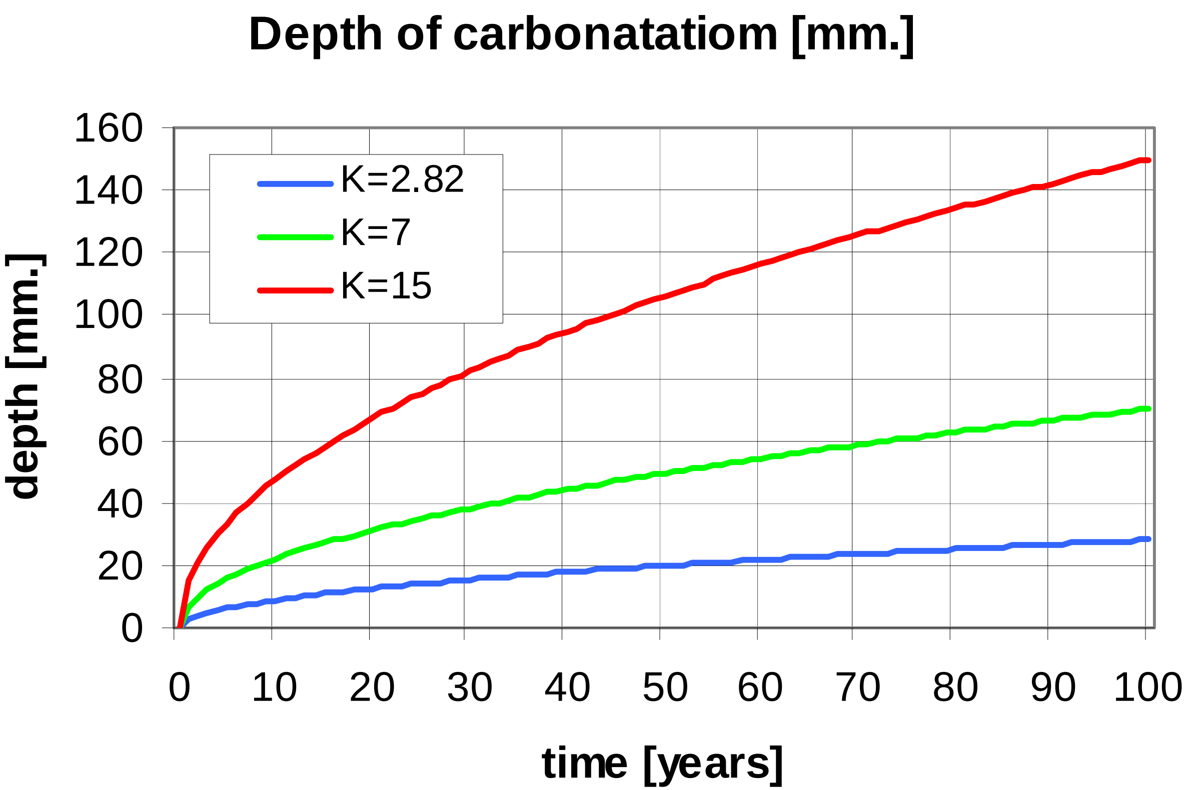
CORROSION DUE TO CARBONATION

Carbonation Depth:

$$s = K \cdot \sqrt{t}$$

Where K is the carbonation coefficient and it depends on:

- **Concentration of CO2**
- **External Environment**
- **Cement Used**



CORROSION DUE TO CHLORIDES

- High percentage of chlorides in either the external environment or in the concrete.

- The corrosion begings when the concentration of ions Cl- reaches a critical value

- Corrosion localized to small zones of the rbars due to the circulation of electrons and ions.

CORROSION DUE TO CHLORIDES

- **DIFFUSION OF A CHEMICAL SPECIES IN POROUS MEDIA:**

$$\nabla^2 C = \frac{1}{D} \cdot \frac{\partial C}{\partial t}$$

- **DIFFUSION OF CHLORIDES INTO CONCRETE:**

$$\nabla^2 C = \frac{1}{D_{eff}} \cdot \frac{\partial C}{\partial t}$$

D_{eff} is the effective diffusivity matrix which is function of the concrete used .

- **WITH THE SOLUTION:**

$$C_x(t) = C_s \left(1 - erf \frac{x}{2 \cdot \sqrt{D_{eff} \cdot t}} \right)$$

DESIGN LIFE OF A STRUCTURE

- CORROSION DUE TO CARBONAION

$$t = t_i + t_p = \left(\frac{d}{K}\right)^2 + \frac{D^{cr}}{V^{corr}}$$

Where:
d=Cover thikness
K=carbonation coeficient
Dcr=Critical depth of corrosion in the rebars
Vcorr=velocity of corrosion

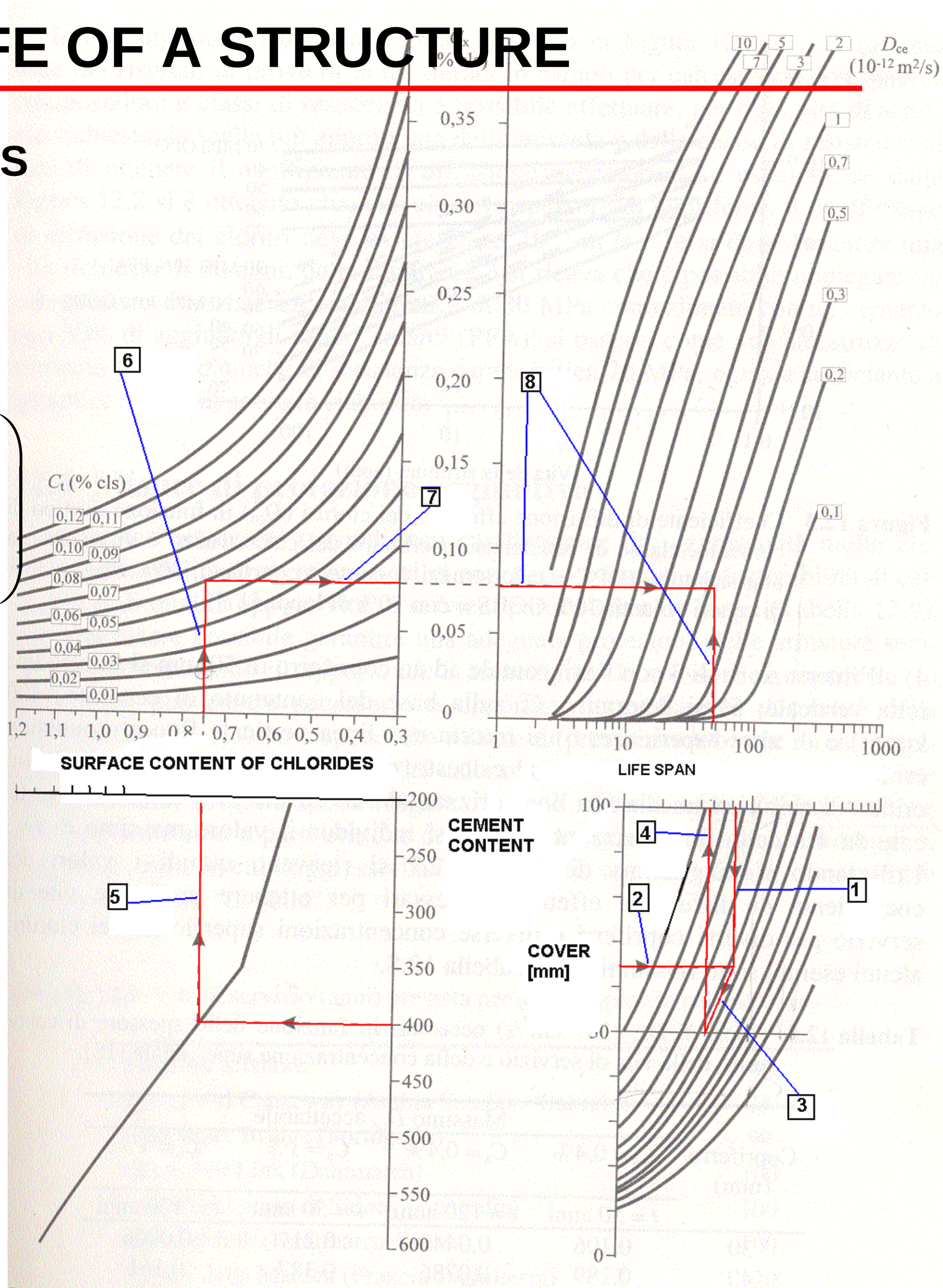
$$\boxed{K = \frac{d}{\sqrt{t - \frac{D^{cr}}{V^{corr}}}}}$$

DESIGN LIFE OF A STRUCTURE

➢CORROSION DUE TO CHLORIDES

In this case the design ife is only function of t_i

$$C_x(t) = C_s \left(1 - erf \frac{x}{2 \cdot \sqrt{D_{eff} \cdot t}} \right)$$



1. **It is possible to find the effective diffusivity that will provide the design if espected**
2. **Than the effective diffusivity is related to the concrete that must be used**

QUESTIONS

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