Durability

Durability can be defined as the ability of the concrete to resist attack from the environment in which it is placed. The nature of the attack can take two basic forms.

Physical

- Abrasion
- Impact
- Ice Growth
- Permeation/Diffusion

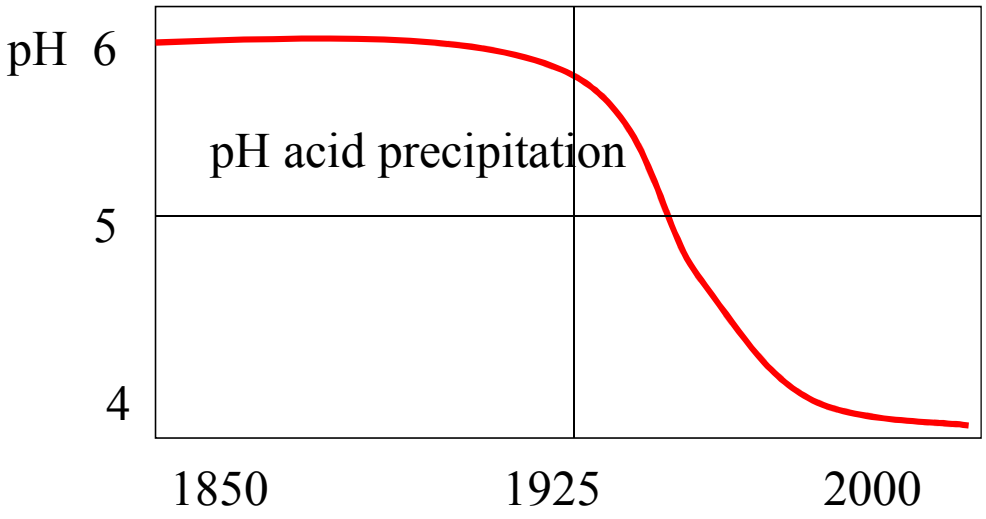
Chemical

- Sulphates
- Chlorides
- Carbon Dioxide

} Corrosion of Reinforcement

- Alkalis
- Acids

Environmental influences – pH of rainfalls



Carbonation (neutralization): $Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O$

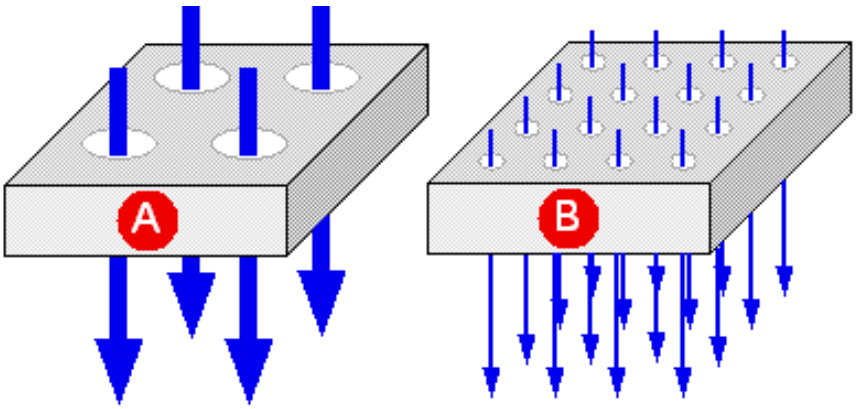
Alkaline calcium hydrate, pH ≈12,5+ carbonic-acid gas → calcite, pH < 9,0 + water

Critical pH ≈10,5 – 11,0

Corrosion: $2Fe + 1{,}5\ O_2 + H_2O \rightarrow 2FeO(OH)$

Iron, volume 100% Rust, volume 250 %

Permeability



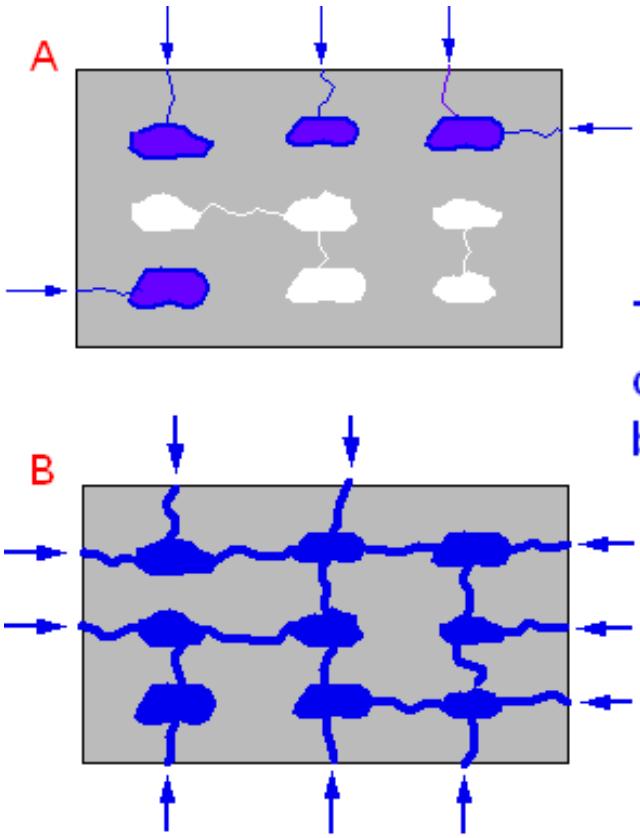
The larger diameter pores in A will create less resistance to flow.

The smaller diameter pores in B will create more resistance to flow.

Greater Permeability

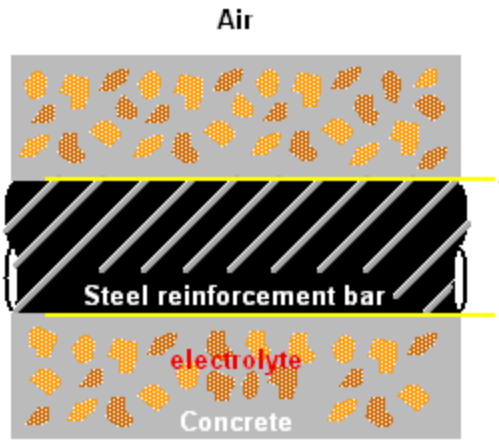
Less Permeability

Permeability



The pores in system A are less well connected (or segmented) so it will be less permeable than system B.

Corrosion



The corrosion of steel reinforcement is complex, but basically it is an electro-chemical reaction similar to that of a simple battery.

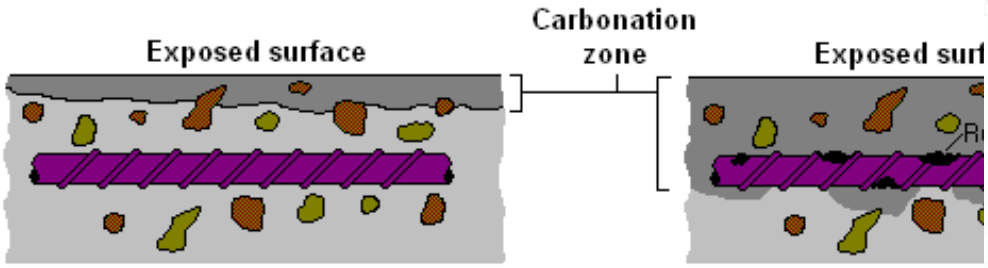
The composition of mild steel varies along its length and potential anodic (more negatively charged) and cathodic (more positively charged) sites can be set up at various points.

Concrete is capable of conducting an electric current and acts as the electrolyte with the circuit being completed by the bar through which the electrons can flow.

However the highly alkaline environment (pH about 12.8) provided by good quality concrete produces a protective layer around the steel preventing the flow of the current. This is known as passivation.

Carbonation

Acidic gases like carbon dioxide react with any free alkali that may be present, which can lead to a drop in the alkalinity of the concrete. This process, which starts at the surface of the concrete, slowly penetrates deeper and deeper. The penetration is nearly proportional to $\sqrt{\text{Time}}$.



Early stages

Carbonation pr

Carbonation results in general corrosion along full length of the bar.

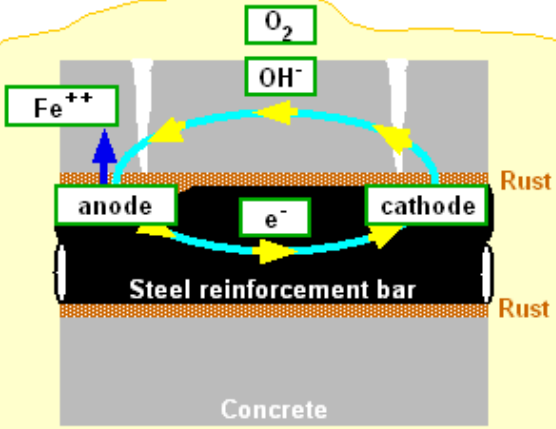
Cooling towers

Maintenance of cooling towers

Prefabricated Balcony

Question on corrosion

1 What is the pH value provided by a good quality concrete? **12.5 - 13.5**



2 Drag the correct labels into the green boxes.

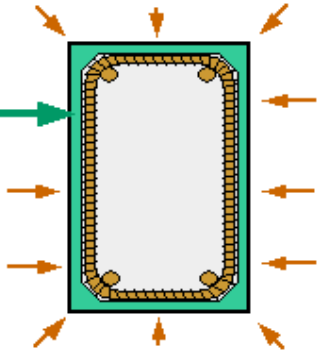
3 What is the critical pH value below which passivation is lost ?

10.5 - 11.0

4 Which two mechanisms lead to a breakdown in the passivating layer ? **Chlorides and Carbonation**

Minimizing the risk of corrosion

The quality and depth of concrete in the cover zone are all important in minimising the risk of corrosion.



Quality

Quality is controlled largely by minimising the permeability.

Depth

Recommendations for mimimum depths of cover are given in the Codes of Practice and are based on exposure conditions and minimum cement contents. Higher cement contents infer lower water/cement ratios leading to permitted reductions in cover.

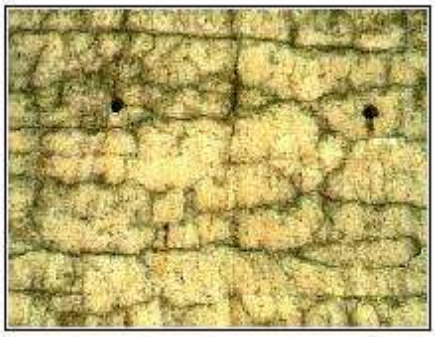
At no time should the normal cover be less than the maximum size of aggregate + 5mm.

Frost attack

Frost attack is particularly common on large flat areas such as road pavements, where the top surface becomes saturated, either from free water within, or from the outside (e.g. rain), or both.

As the temperature drops below zero the water freezes causing the concrete surface to crack and break up.

Note : This freeze / thaw process may have to be repeated many times before deterioration occurs.



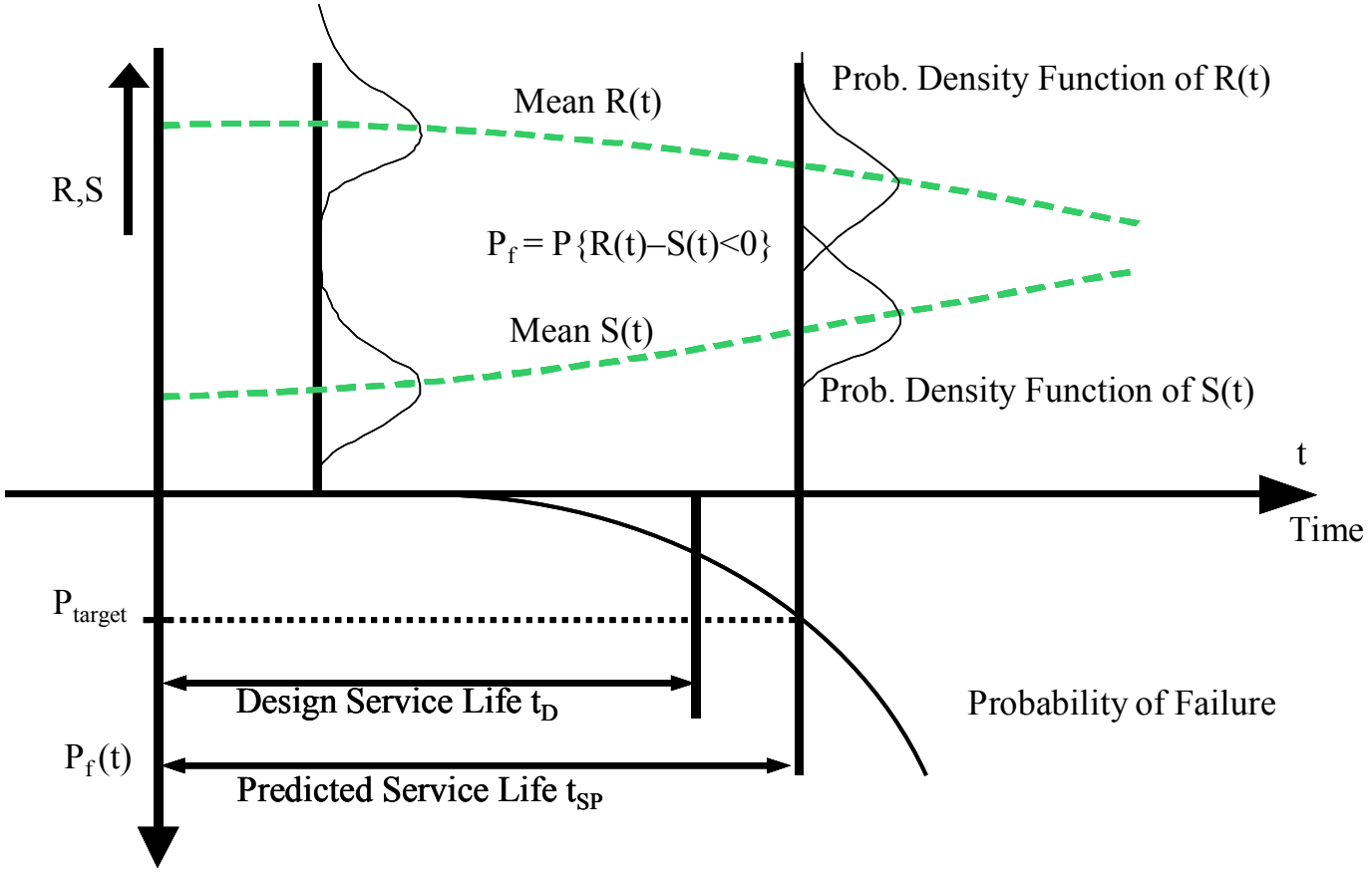
Some frosty questions

1	The mechanism of frost attack in hardened concrete is a twofold process resulting from:	Osmotic Pressure Hydraulic Pressure
2	When water freezes it increases in volume by approximately ?	9%
3	What are the two best ways of minimising the risk of damage due to frost attack ?	Keep the permeability as low as possible. Use an air entraining agent.
4	What is the approx diameter of the entrained air bubbles ?	0.05 to 1.25mm
5	What is the normal amount of air entrainment in concrete ?	4% to 6%

Exam Questions

- Two basic form of environmental attack
- Concept of service life and design service life
- Factors affecting permeability
- Carbonation process and corrosion of reinforcements
- Breakdown in passivating layer - critical pH of concrete
- Process of frost attack - the best way to minimize it

Model for predicting service life



ISO 13823 Design of Structures for Durability

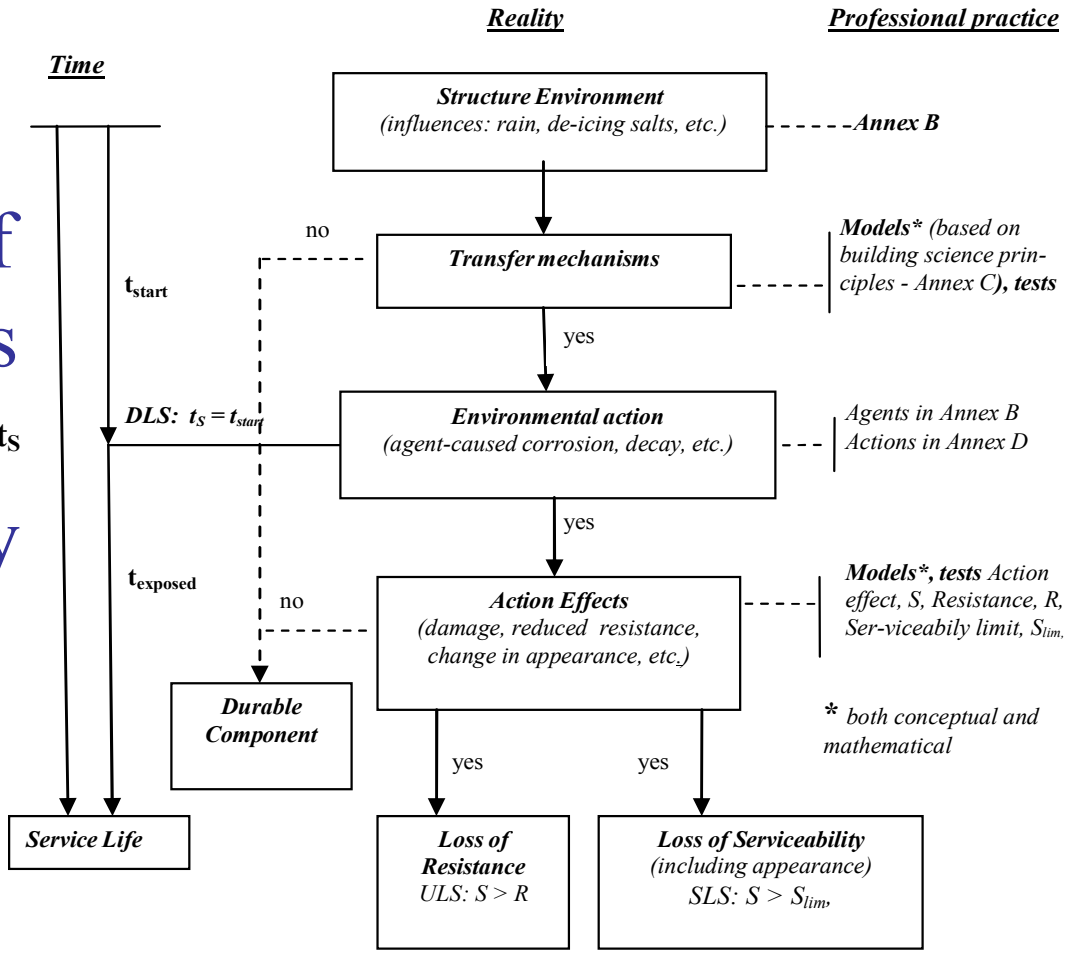
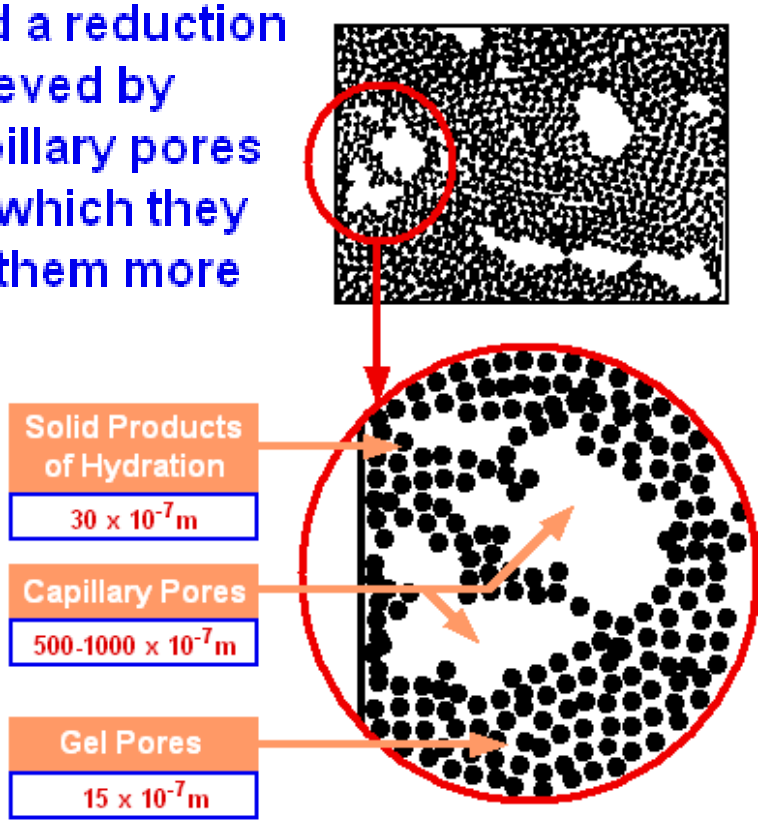


Figure 1: Limit states method for durability

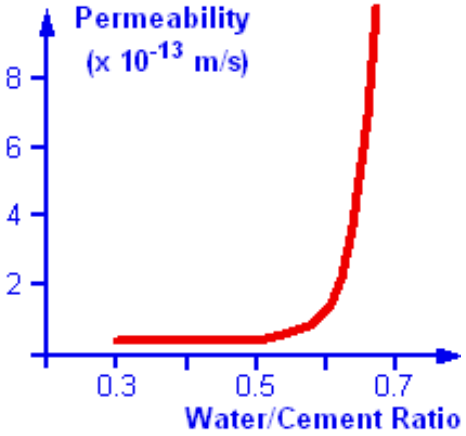
Damage of concrete surface

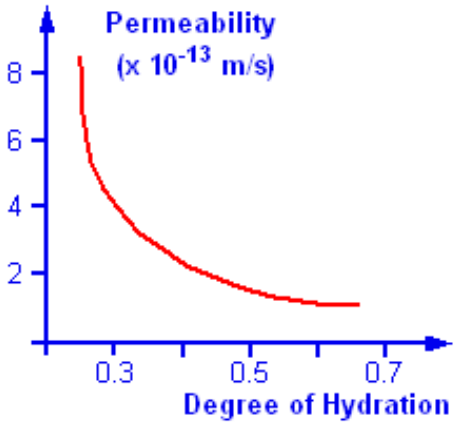
Pores

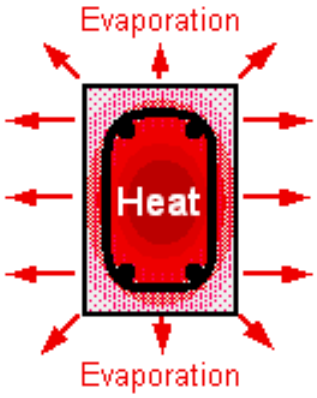
An increase in strength and a reduction in permeability can be achieved by reducing the volume of capillary pores and reducing the extent to which they are connected (i.e. making them more segmented).

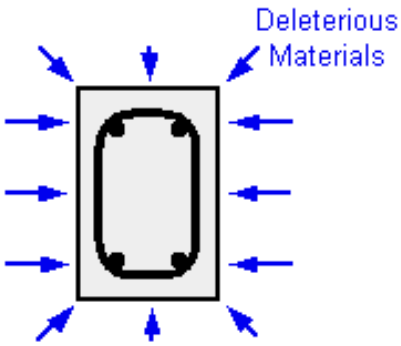


Factors affecting permeability









Concrete quality