Non destructive methods for materials testing

Test methods

- Tests for checking **quality** of concrete
  - to establish whether the concrete **has attained a sufficient strength** or concrete has set sufficiently for stressing, opening to traffic etc. .
  - to **detect the variation of quality** of concrete being supplied for a given specification
  - **specific purposes**: status (consistency survey) and research aims
    - **locate a destroyed part** for further investigations
    - **locate corrosion processes**
    - **locate cracks** etc.

Test methods

- Tests on fresh concrete
  - **Workability Tests (e.g. slump test)**
  - Bleeding
  - Air content
  - Setting time
  - Segregation resistance
  - Unit weight
  - Wet analysis
  - Temperature
  - Heat generation
- Tests on hardened concrete
  - **Compressive strength (cylinder, cube, core)**
  - Tensile strength: Direct tension
  - Modulus of rupture
  - Indirect (splitting) test
  - Density
  - Shrinkage
  - Creep resistance
  - Modulus of elasticity
  - Absorption

Test methods

- Tests on hardened concrete
  - Permeability Tests on Concrete
  - Freeze/thaw resistance
  - Resistance to aggressive chemicals
  - Resistance to abrasion
  - Bond to reinforcement
  - Analysis for cement content and proportions
- In situ tests: **Schmidt Hammer**, **Concrete pull-out**, break-off, cones etc.
- **Ultrasonic, georadar, nuclear**

Test methods

DESTRUCTIVE

Compressive strength test and slump test in practice for quality control because:

1. All or most other properties of concrete are related to its compressive strength.
2. CS is the **easiest,** most economical or **most accurately** determinable test.
3. CS is the best means available to determine the **variability of concrete**.
4. Slump tests also **checks for variation of construction materials** in mix, mainly water-cement ratio.
5. Slump test is **easy and fast to determine quality of concrete before placement based**
6. Slump test is **most economical** because it is done at site and does not require any laboratory or expensive testing machine.
7. Slump tests: **rejected mix can be discarded** before pouring into the structural member.

NON-DESTRUCTIVE

Schmidt hammer

Concrete pull-off

Ultrasonic

Georadar

Nuclear (X-ray, neutron)

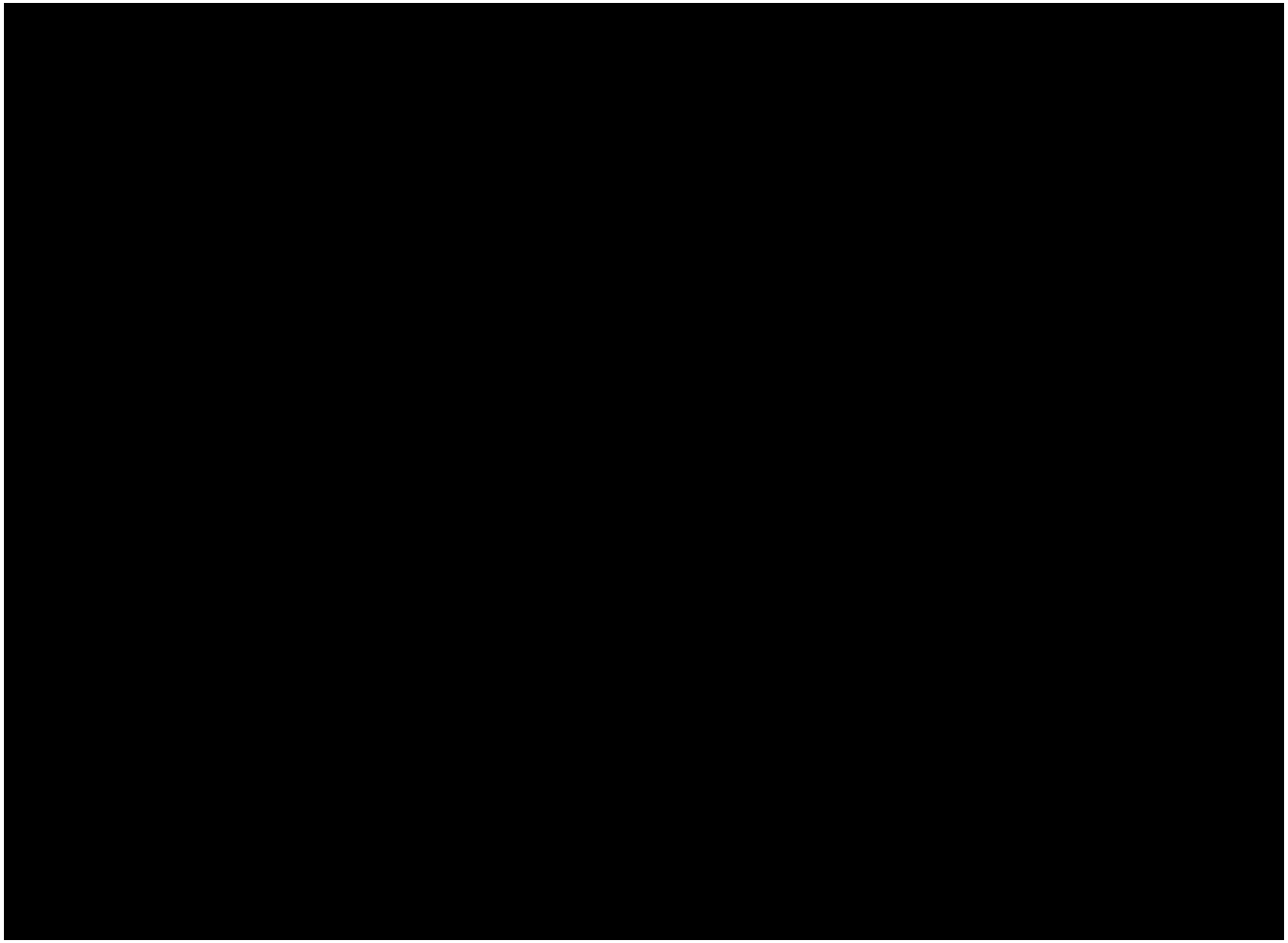
Compressive strength test

- Compressive strength of concrete depends on water-cement ratio, cement strength, quality of additives etc
- **Cylinder**
- **size: 15 cm x 30 cm**
- PROCEDURE:
  - Cast the cylinder and cure for 28 days.
  - Takeout the specimen from the curing tank.
  - Wipe out the excess water from the surface of specimen.
  - Place the specimen vertically on the platform of compression testing machine.
  - Apply the load continuously and uniformly without shock at the rate of 315 kN/min. And continue the loading until the specimen fails.
  - Record the maximum load taken.

Compressive strength test

- **Cube**
- specimens of **15 cm X 15 cm X 15 cm** or
- specimens of 10 cm X 10 cm x 10 cm depending upon the size of aggregate are used
- STEPS:
  - poured in the mould and tempered properly so as not to have any voids
  - after 24 hours moulds are removed and test specimens are put in water for curing
  - tested by compression testing machine after 7 days curing or 28 days curing. Load should be applied gradually at the rate of 140 kg/cm^2 per minute till the Specimens fails. **Load at the failure divided by area of specimen gives the compressive strength of concrete.**

Compressive strength test

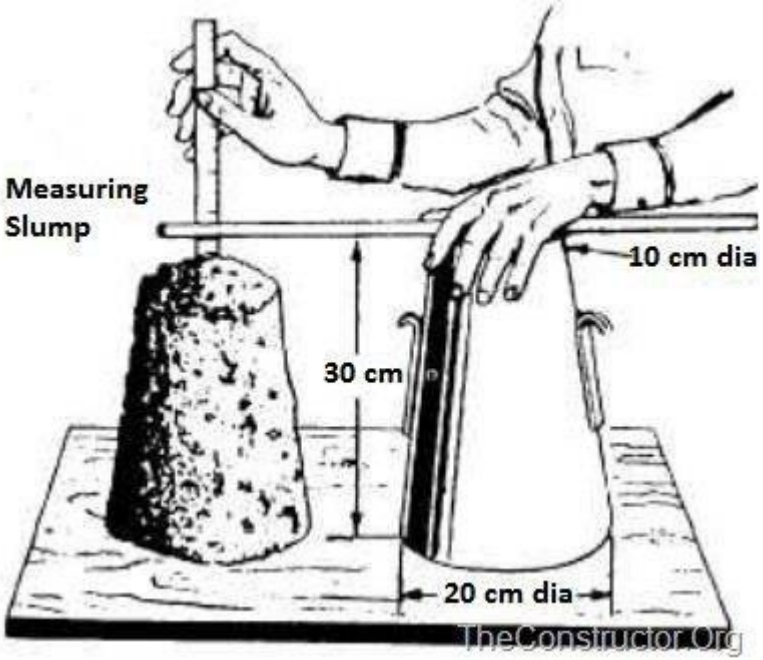


Slump test

- determine the workability or consistency of concrete mix
- **concrete slump value** indicates **water-cement ratio**, but there are various factors including properties of materials:
  - **mixing methods**, **dosage**, **admixtures**
  - material properties like chemistry, fineness, **particle size distribution**
  - size, texture, cleanliness and moisture content of the **aggregates**,
  - **moisture content** and temperature of cementitious materials
  - **air content** of concrete
  - temperature of the concrete
  - sampleing of concrete, slump-testing technique and the condition of test equipment
  - **amount of free water in the concrete**
  - time since mixing of concrete at the time of testing.

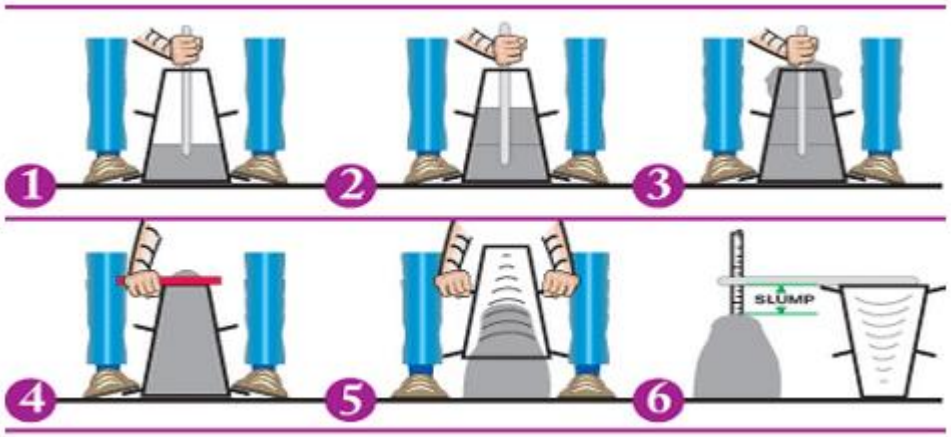
Slump test

- device



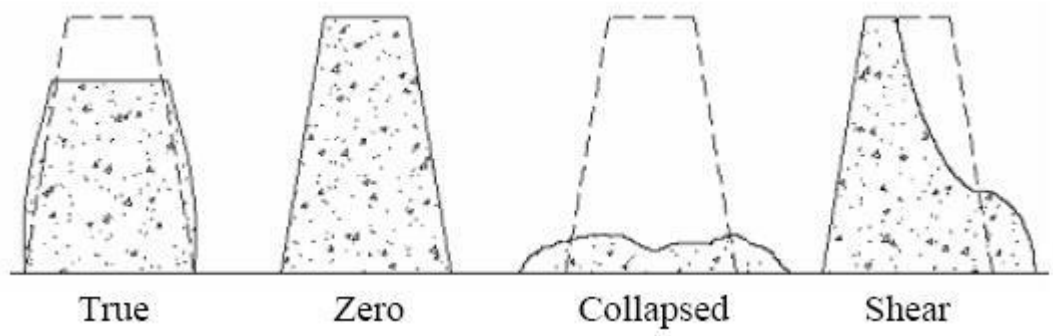
Slump test

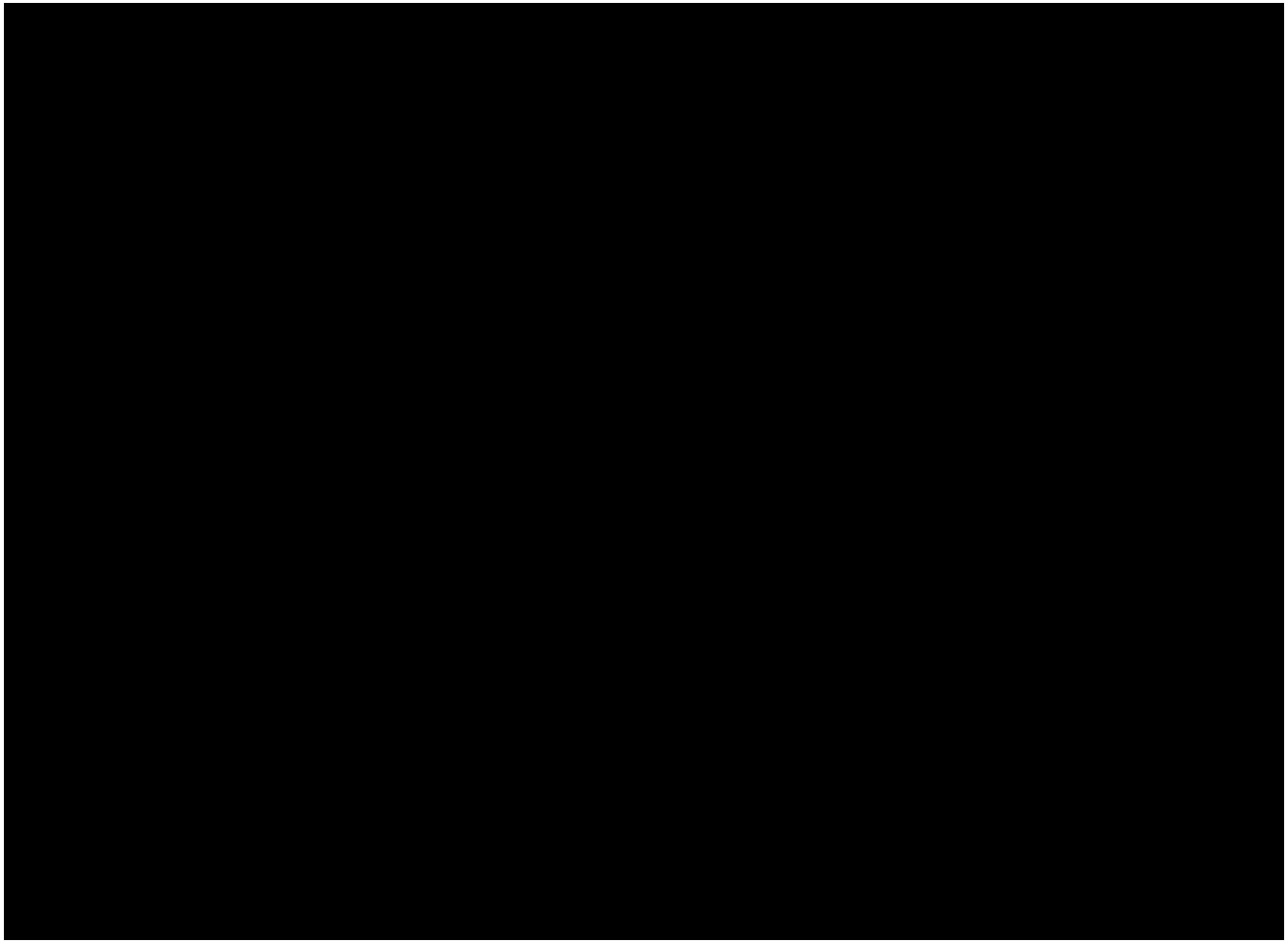
- Device:
  - **Clean** the internal surface of the mould and **apply oil**.
  - **Fill the mould** with the prepared concrete mix in 4 approximately equal layers.
  - **Tamp each layer with 25 strokes** of the rounded end of the tamping rod in a uniform manner over the cross section of the mould. For the subsequent layers, **the tamping should penetrate into the underlying layer**.
  - **Remove the excess concrete**
  - **Raise the mould** from the concrete immediately and slowly in vertical direction.
  - **Measure the slump** as the difference between the height of the mould and that of height point of the specimen being tested.



Slump test

- True Slump – True slump is the only slump that can be measured in the test
- Zero Slump – Zero slump is the indication of very **low water-cement ratio**, which results in dry mixes. These type of concrete is generally used for road construction
- Collapsed Slump – This is an indication that the **water-cement ratio is too high**, i.e. concrete mix is too wet or it is a high workability mix, for which a slump test is not appropriate.
- Shear Slump – The shear slump indicates that the result is incomplete, and concrete to be **retested**.



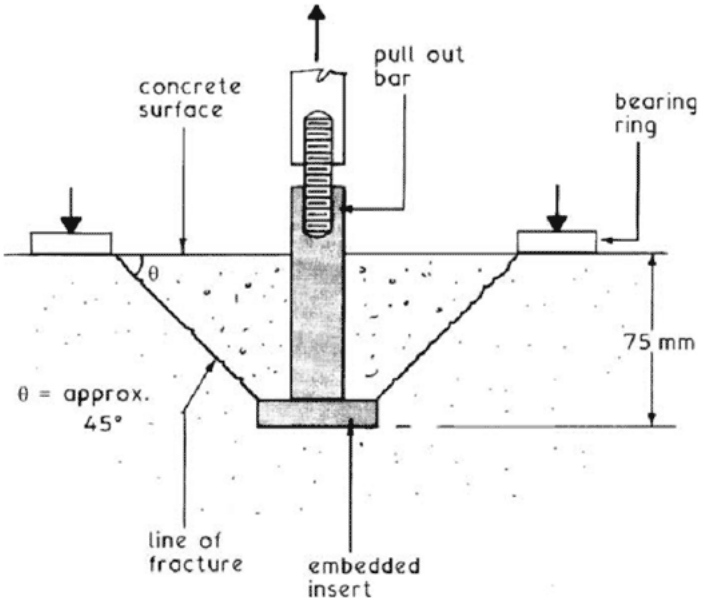


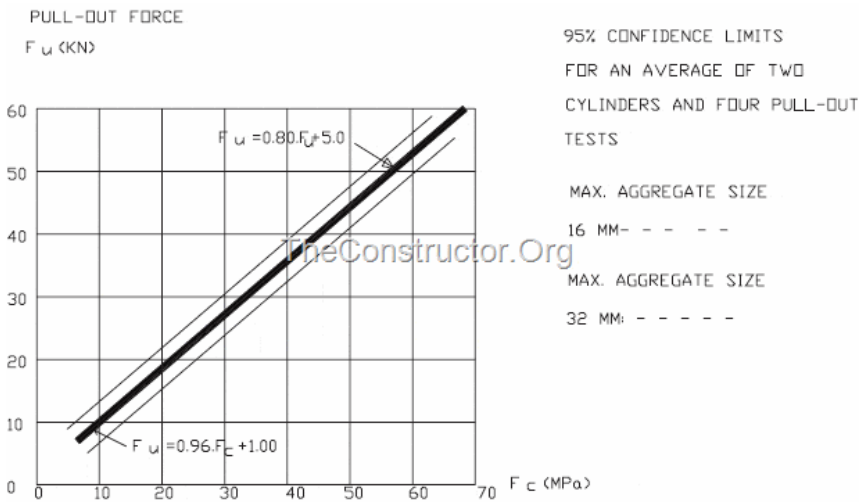
Schmidt hammer

- The hammer hits the surface with a chosen energy. The measure of the rebound is related to the hardness of the surface
- Depends on:
  - where it is done (sample or wall)
  - wall thickness
  - number of repetitions (min. 15)
- Characteristics
  - Estimates the compressive strength
  - Calculated according to an empirical relation
  - Need of a calibration curve
  - Easy, cheap
  - Non-absolute, only indicative

Pull-off test

- correlates with the compressive strength
- planned before
- measuring the force required to pull a steel disc or ring, embedded in fresh concrete, against a circular counter pressure placed on the concrete surface concentric with the disc/ring





IR termography

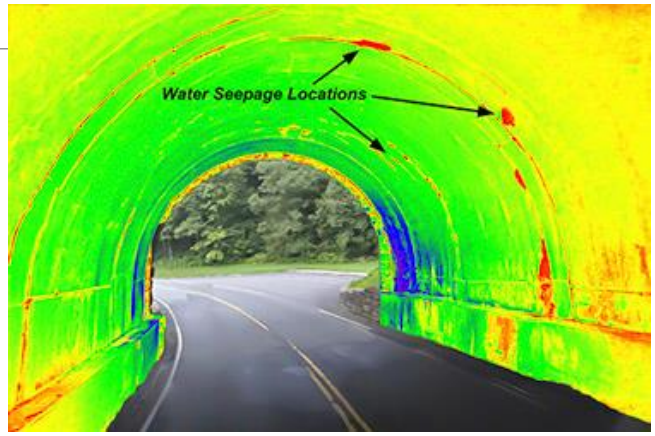
- Passive or active

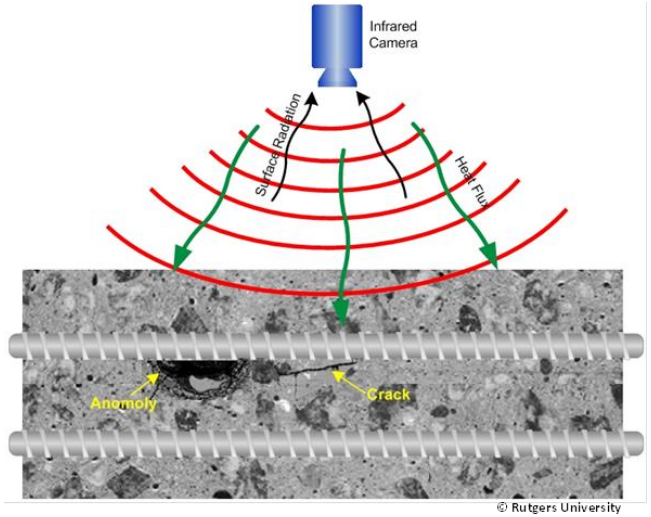
Passive wavelength: 3-14 µm

Active wavelength: 0.17-1.4 µm

Instrument: CCD camera

- The IR wave is partly absorbed and partly scattered from the surface
- Where cracks or surface discontinuities exist, the scattered intensity is increased, and the local dissipated heat is larger





Ultrasound measurement

- Transmitted sound wave method

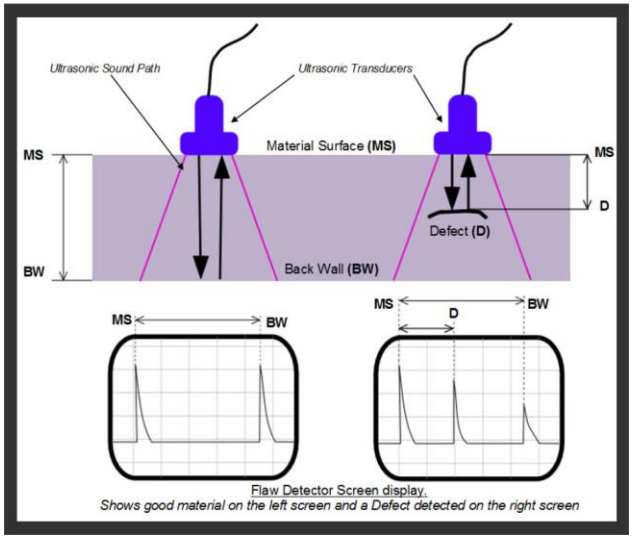
Parallell walls

The place of the crack, etc. cannot be determined

- Impulse reflected sound wave method

Needs a calibration

The place of the crack cann be determined



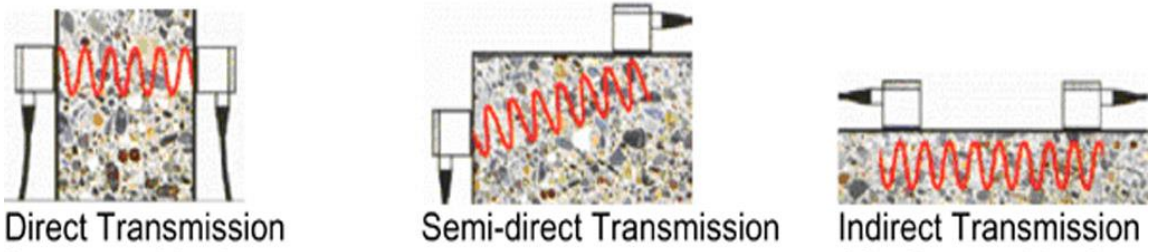
Ultrasound method

Discontinuities and cracks slow down the wave

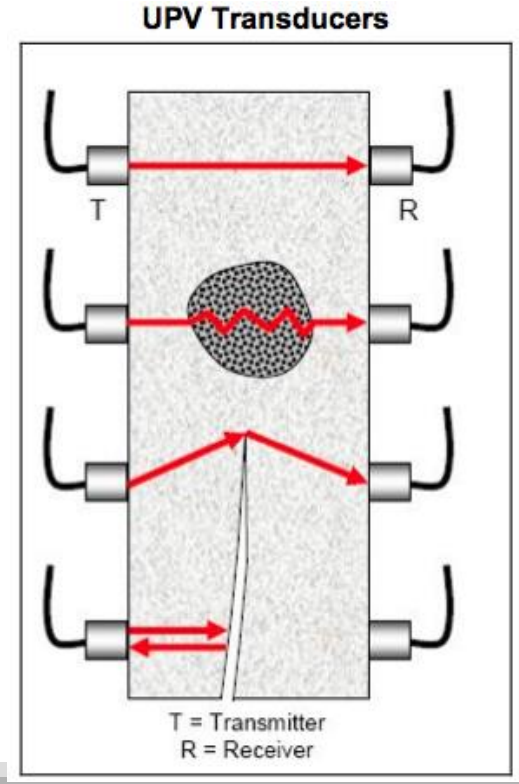
Higher wave velocity: better quality

There is an relation between the sound energy/ intensity and the studied concrete block quality

Indicative method

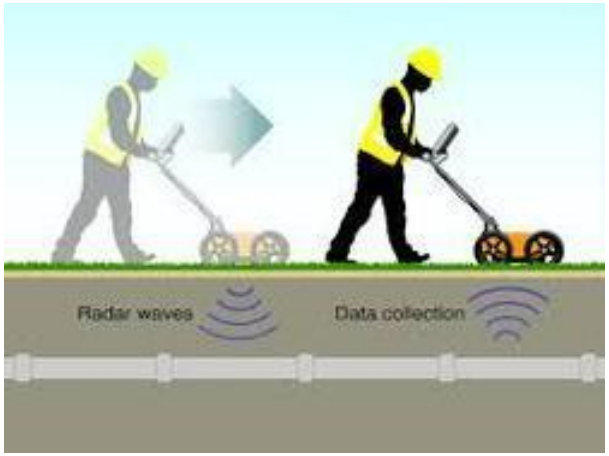


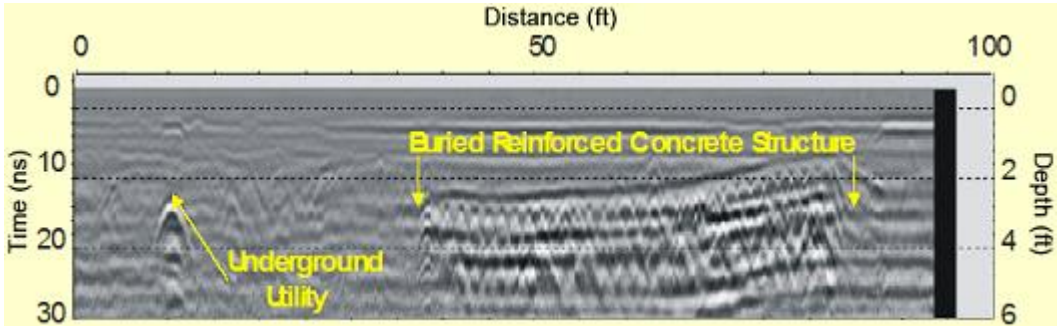
UPV - Different Test Methods



Ground penetrating radar

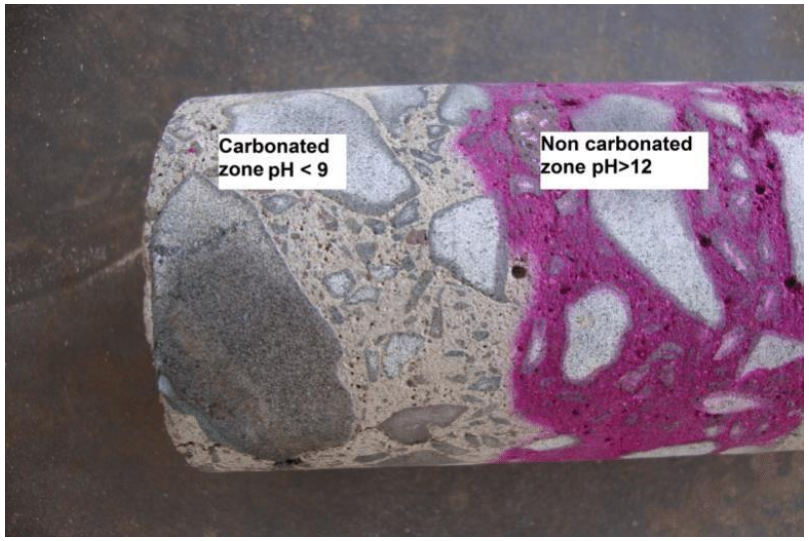
- geophysical method that uses radar pulses to image the subsurface
- electromagnetic radiation in the microwave band of the radio spectrum, and detects the reflected signals from subsurface structures

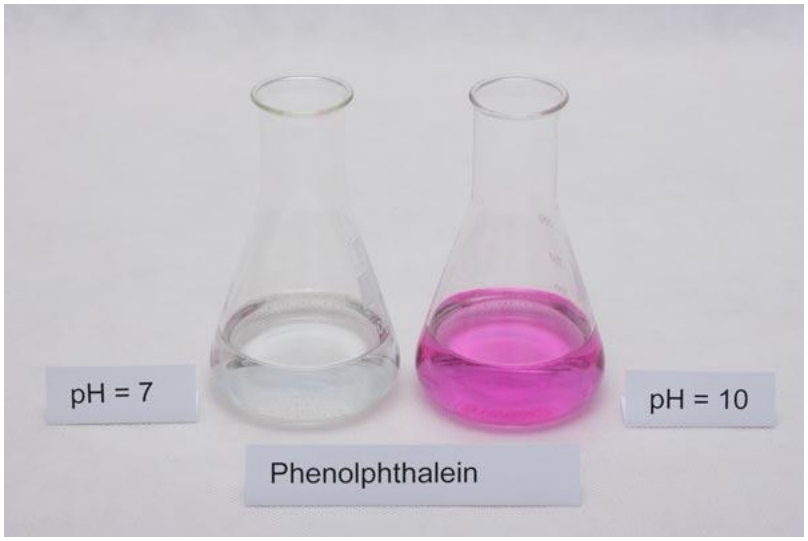




Phenolphtaleine indicator test

- Phenolphtaleine: acid-base indicator
- In presence of $Ca(OH)_2$ changes its color to pink
- In presence of $Ca(CO)_3$ is colorless





Concept of pH

pH: ”power” of Hydrogen (or hydronium ion H_3O^+)

pH: a numerical scale used to determine the acidity or basicity of an aqueous solution

$$\mathbf{pH = -lg[H_3O^+] = -lg[H^+]}$$

$$\mathbf{H_2O + H_2O \rightleftharpoons H_3O^+ + OH^-}$$

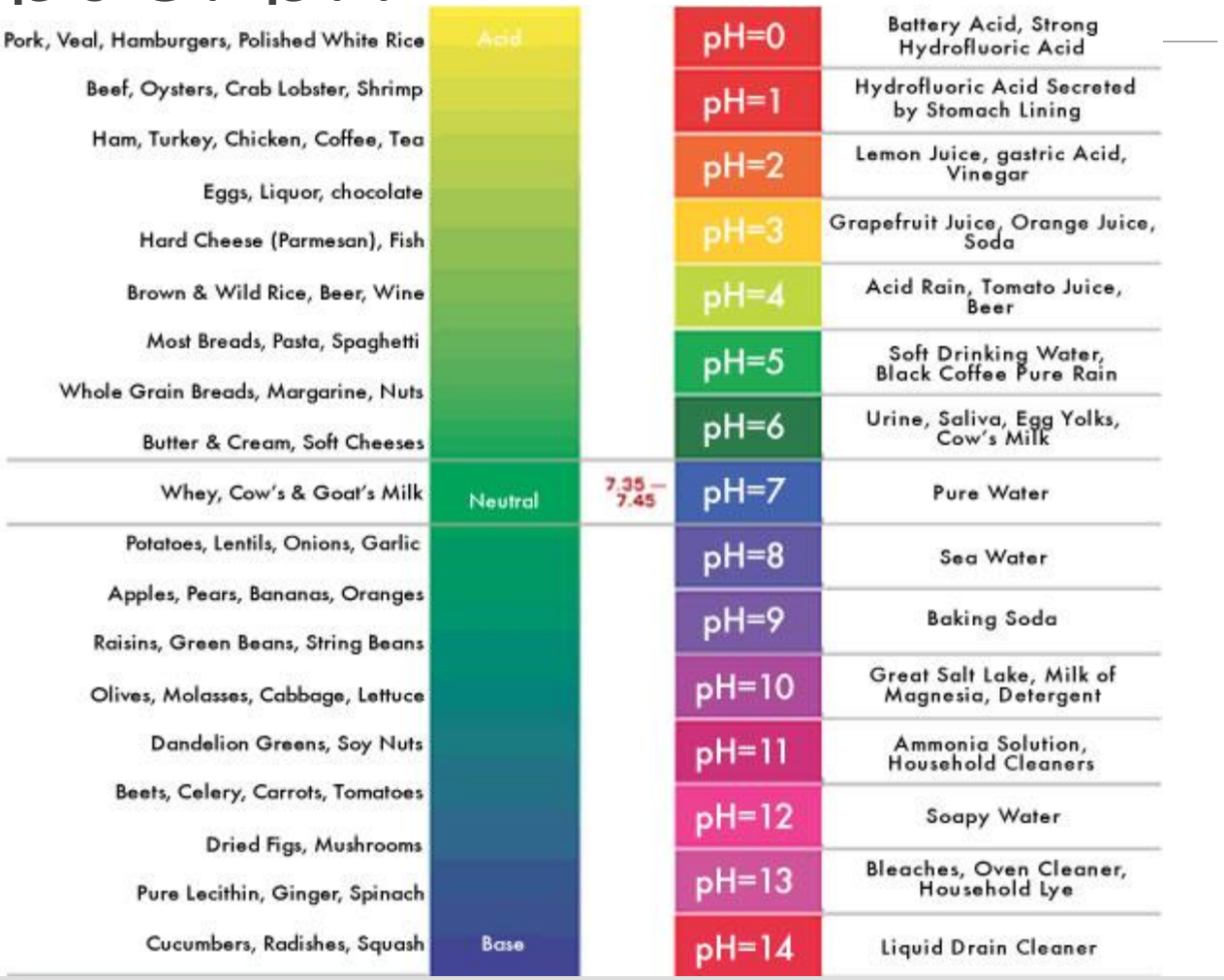
equilibrium process

$$[H_3O^+] = [OH^-] = 10^{-7}\ mol/dm^3$$

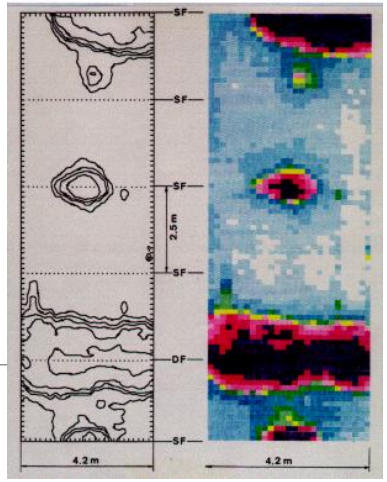
$$\mathbf{pH = -lg10^{-7} = 7}$$

Concept of pH

pH



Half cell potential measurement

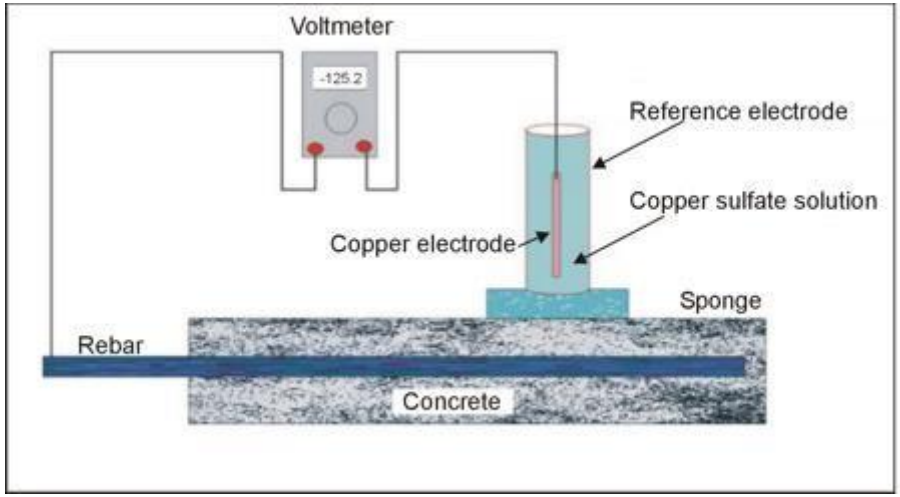


- Need of a reference electrode
- We measure the electrod potential difference in function of the place, where the electrode is placed
- Depends on: reference electrode, thickness of the concrete, moisture, concentration of the electrolite

Referecne electrode:

- $Cu/CuSO_4$
- Calomel: Hg/Hg2Cl2/KCl
- Ag/AgCl/KCl

- Cl^- ion concentration is high: negative potential
- Carbonated: positive potential



Rapid chloride ion penetrating test

- 60 V potential difference, 6h
- Sample is a wet and vacuumed dried concrete piece of 50mm thickness
- Cl^- ion diffusion is function of concrete age, porosity

Charge (C)	Diffusivity
>4000	High
2000-4000	Moderated
1000-2000	Low
100-1000	Very low
<100	Negligible