Concrete

- The heat of the day was intense as it radiated off the concrete buildings that lined the concrete street we were walking beside. I paused momentarily to lean against a concrete lamp post and concentrate my slurry of thoughts into a more rigid mass. The men in dark suits continued to move me along this set journey.
- Concrete is a **Masonry work**; consider the aggregate particles as brick or masonry unit
- Concrete is a **matrix of inert materials**; hydrated cement is the binder

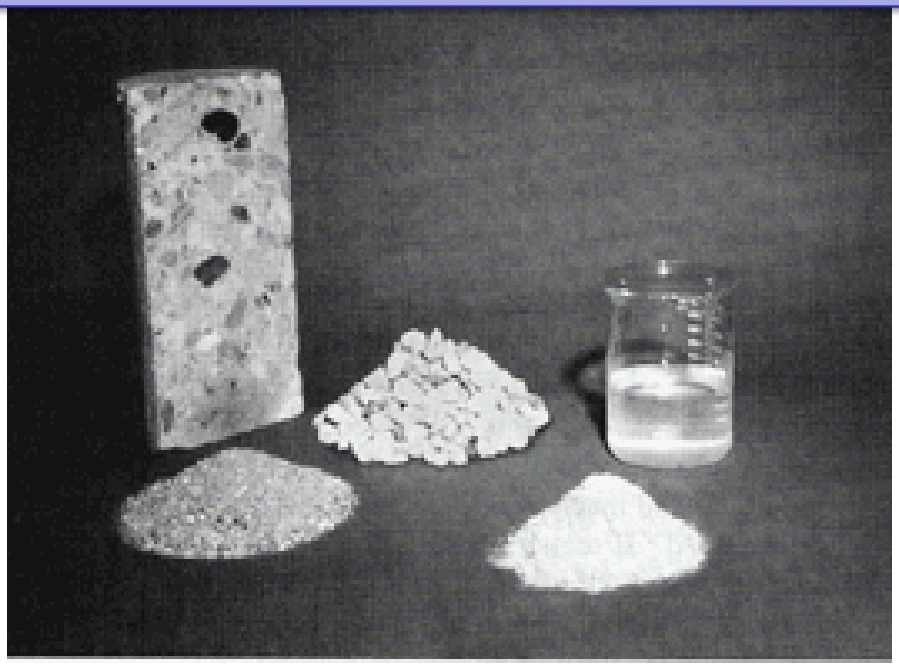
Importance of concrete technology

Cooking biriani = making concrete

•Spices •Rice •Proportions •Heating •Much more	•Cement •Aggregates •Proportion •Curing •Much more

- **What are the requirements for a successful concrete structure?**
- The concrete must have sufficient strength to carry the loads imposed
- The concrete must be able to endure under the conditions of exposure to which it will be subjected
- The concrete must be economically produced in comparison with other materials equally strong and durable, which might be used.

Summary =
strength
+ durability
+ economy



1. When was concrete first made?
   9000 BC **500 BC** 100 AD 1756 1824
2. How can you make concrete set:
   faster? **add calcium chloride or "accelerator"**
   slower? **add sugar or "set retarder"**
3. Is concrete stronger in compression, tension, or the same in either?
   It is stronger in compression.
4. How strong can concrete or cement be (in pounds per square inch (psi))?
   50,000 20,000 5000 2000
5. How long can concrete last (in years)?
   50,000 5000 500 50

Ingredients of Concrete

- Cement
- Water?
- Aggregates
  - Fine Aggregate
  - Coarse Aggregate
- Admixtures?
- Concrete is a composite material that consists of a binding medium embedded with fine aggregate and coarse aggregate

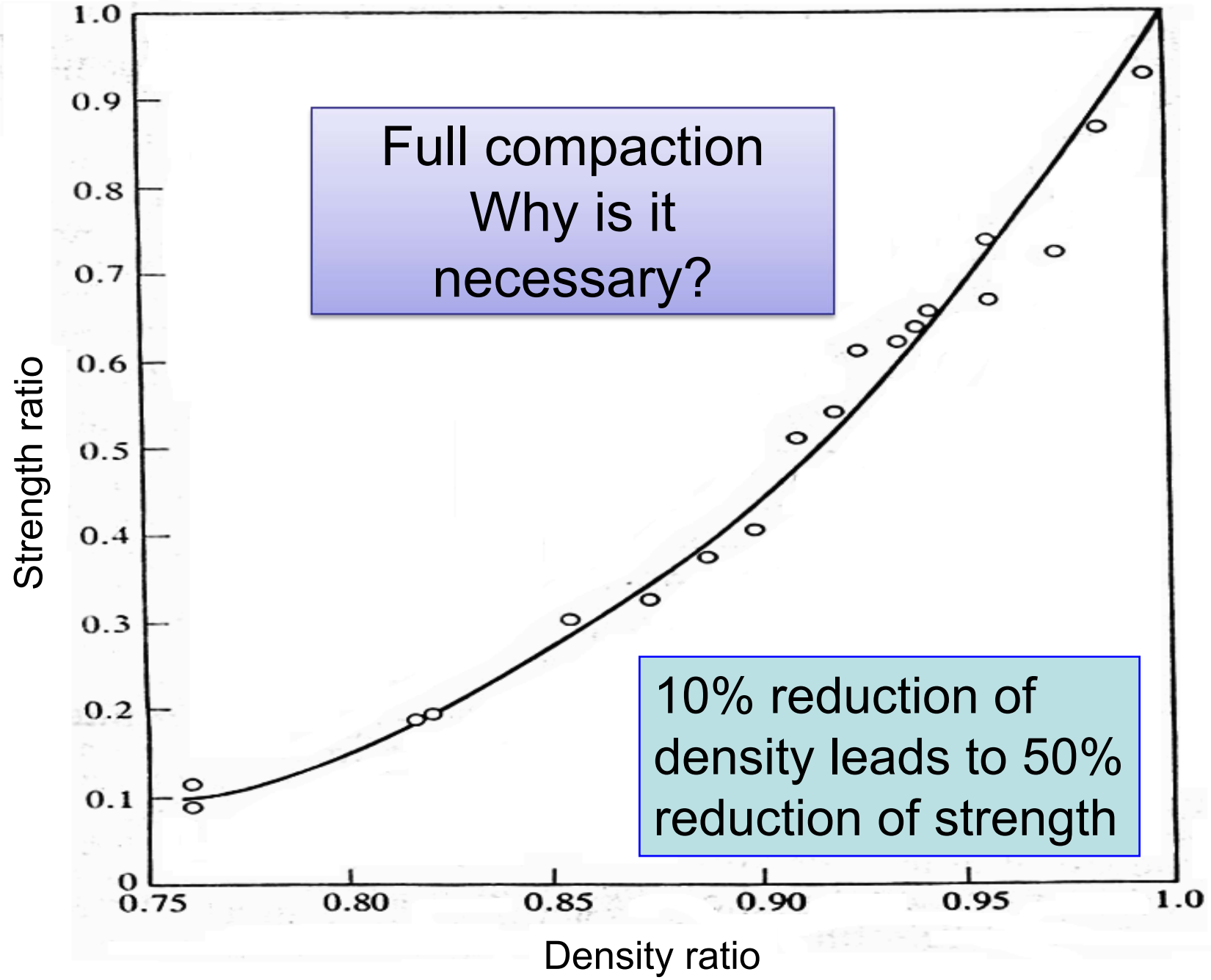
- Water - Drinking water is the best
- Admixtures
  - Additives to modify concrete properties?
- Mix Ratio (volumetric)
  - C : FA : CA
  - 1 : 1.5 : 3
  - 1 : 2 : 4
  - 1 : 3 : 6
- Agg/cement = ?
- Concrete >> Mortar >> Grout?

Fresh Concrete

- U like Fresh Vegetables!
  - What about Fresh Concrete?
  - Harmful for skin and body
- Good Concrete
  - Two criteria (Fresh and Hardened State)?
- Fresh Concrete ➔ Hardened Concrete
  - So, take care of the fresh state of concrete
- Strength << degree of compaction << workability << w/c, agg, agg/cement, etc

Fresh Concrete

- Workability
  - Consistence (Degree of wetness)
  - Factors
    - Water, agg, agg/c
  - Measurement of workability (e.g. Slump test)
- Segregation
  - Opposite of Cohesion
- Bleeding
  - Or Water gain


Full compaction
Why is it
necessary?
10% reduction of
density leads to 50%
reduction of strength
Strength ratio
Density ratio
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.75
0.80
0.85
0.90
0.95
1.0

Workability

- Amount of useful internal work necessary to produce full compaction
- Workability is inverse of energy required
- Energy/work is required to overcome internal friction between the individual particles

Factor Affecting Workability of Fresh Concrete

- Water content *****
- Aggregate
  - Agg type
  - Grading ***
- Agg/cement ratio
  - Inverse relation
- Admixture
- Fineness of cement

Factors are interacting

Why? How?

- Advise
  - Pls read pp. 63-64 of Concrete Technology (by Neville and Brooks)
  - Effect of grading on workability is well described here

Effect of grading of aggregate on workability

- Four interacting factors
  - Surface area,
  - Agg/cement,
  - Segregation potential,
  - Amount of fines

Surface Area

- Smaller particles need more cement paste and water
- But fine particle (less than 150 micron) act as lubricant

Agg/cement ratio

- Well graded agg and cement paste exactly necessary to coat the particles ➔ harsh and unworkable mix
- Excess cement increase workability
- Excess mortar improves workability

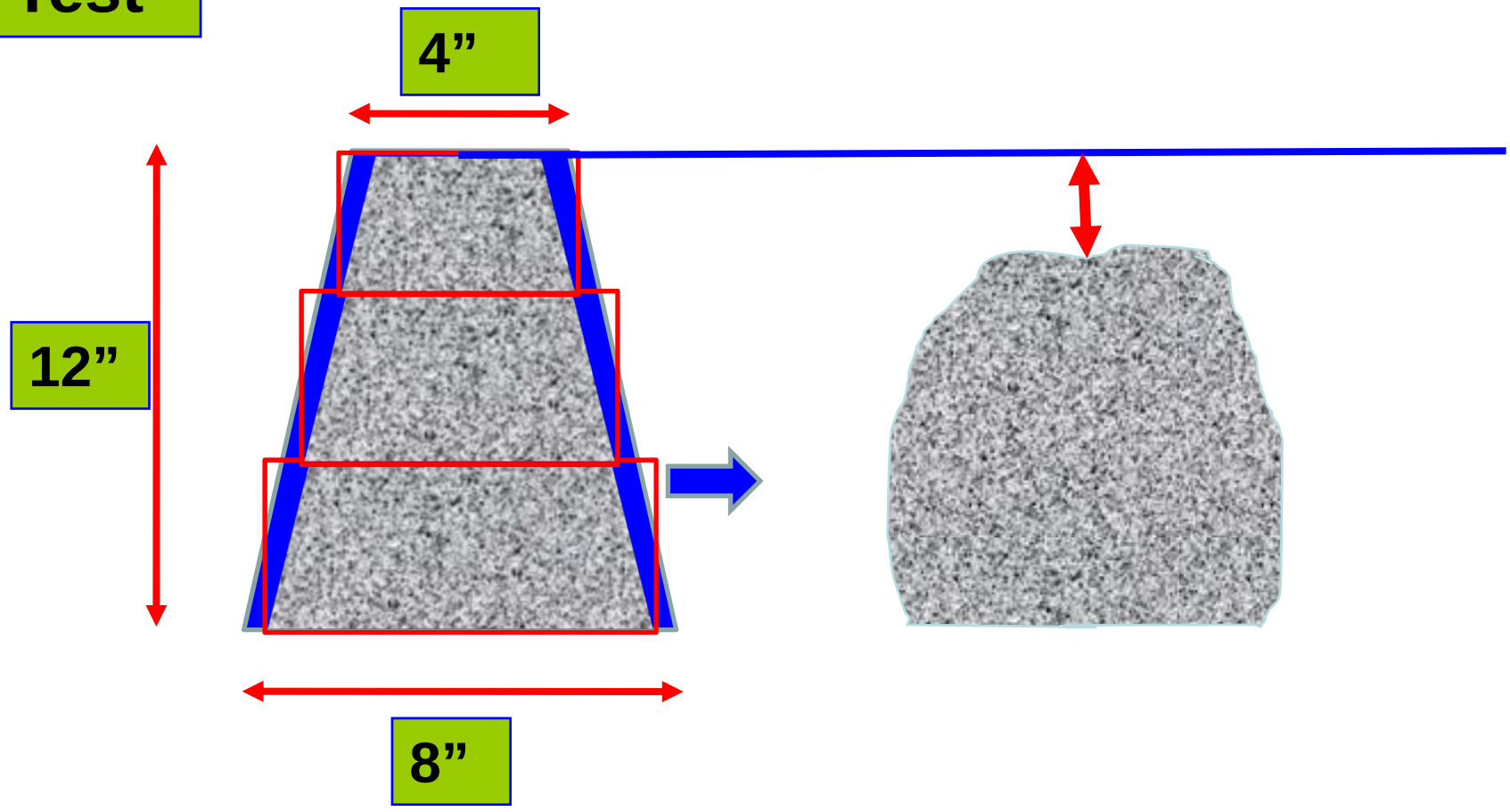
Effect of grading of aggregate on workability

- Segregation Potential
  - Well graded agg lead to a dense concrete
  - But small particles can segregate in dry state creating voids in agg
  - What is the relation with workability?
    - Segregation leads to less workable mix

- Amount of fine particles in aggregate
  - Less than 300 micron
  - These are very fine sand
  - Some amount of fine particles are necessary for workability of concrete

Measurement of Workability

Slump Test



1. 3 layers
2. 25 tamping per layer
3. Tamping rod 16mm

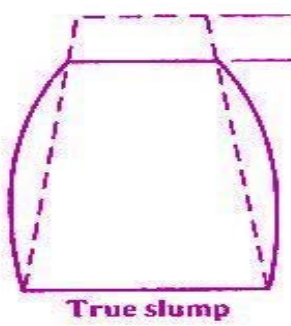
Measurement of Workability

Slump Test

•Zero Slump

Upto 125 mm

•True Slump

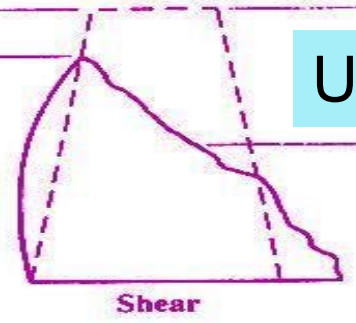


In case of shear slump, repeat the slump test

25-50 mm

Upto 150 mm

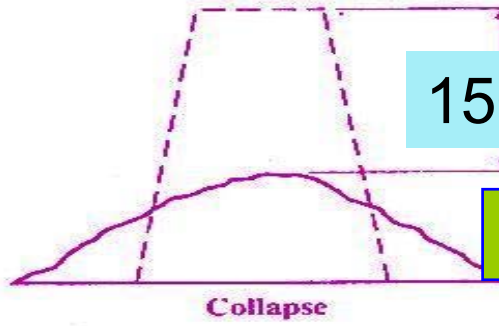
•Shear Slump



Disadvantage of Slump Test
• Lean Mix > Shear type or collapse at low w/c ratio

150-250 mm

•Collapse



Strength of Concrete

- Factors affecting strength of concrete
  - w/c ratio, degree of compaction
  - Agg/cement ratio
  - Agg properties
    - Shape of agg
    - Size and grading of agg
  - Age

Primary factor is

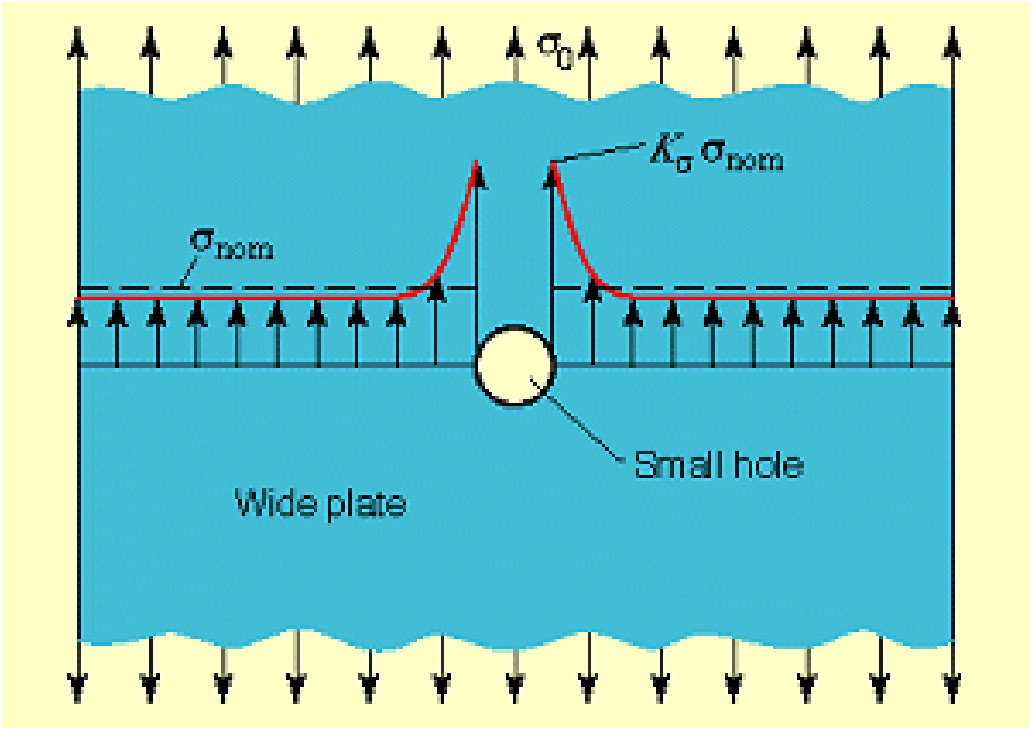
- POROSITY
  - The relative volume of pores or voids in the cement paste

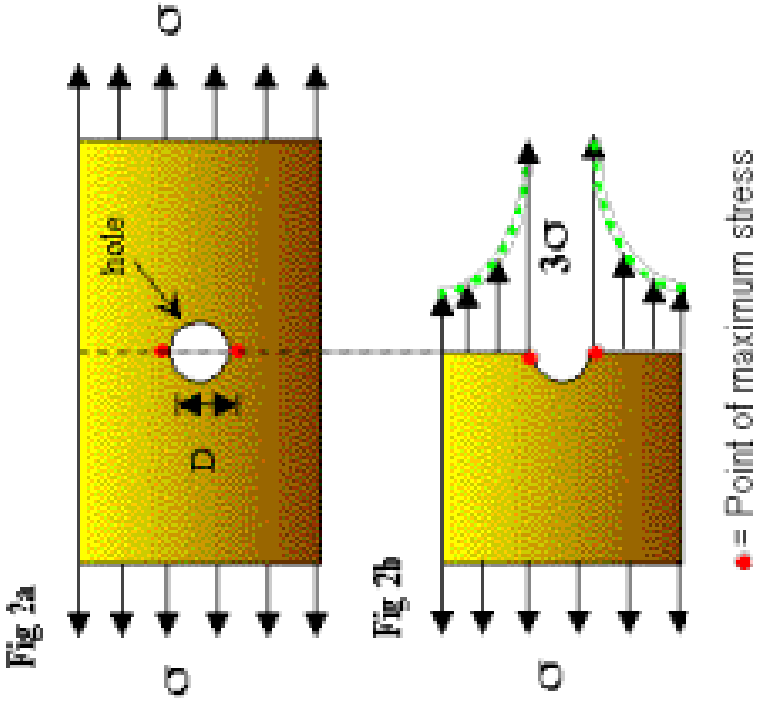
Then

- Flaws and
- Discontinuities

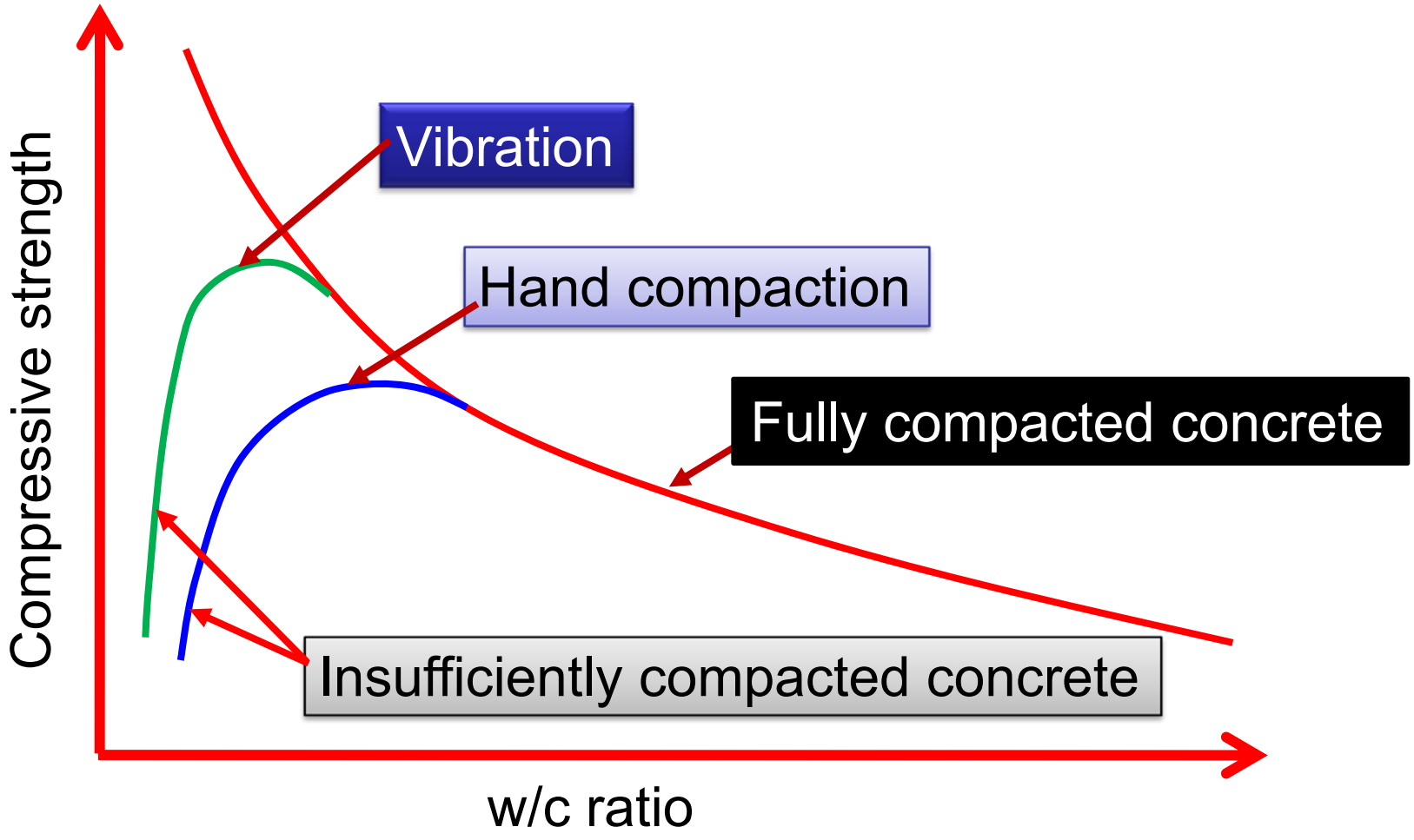
Stress concentration is the mechanism of strength reduction

Stress Concentration

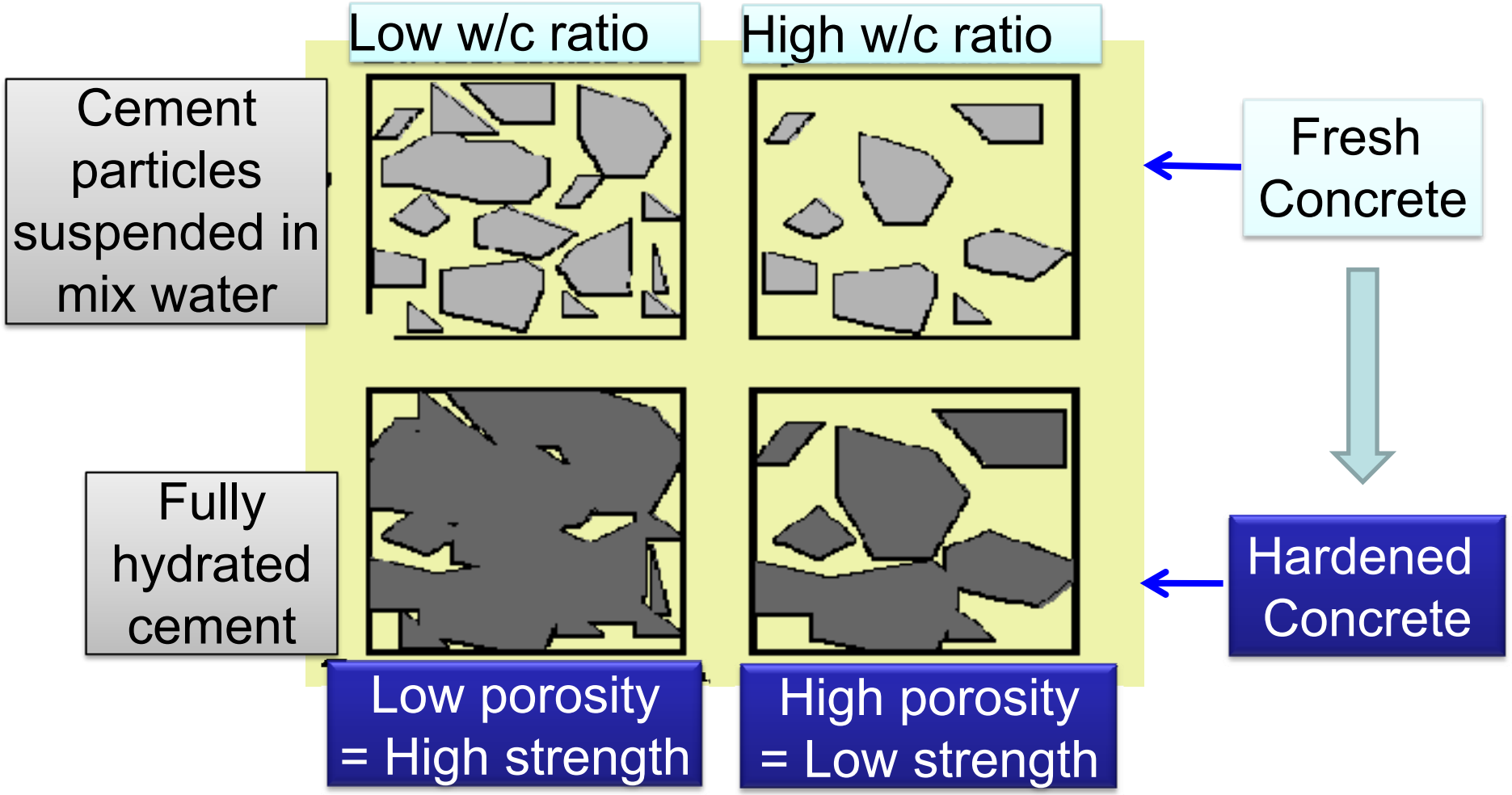




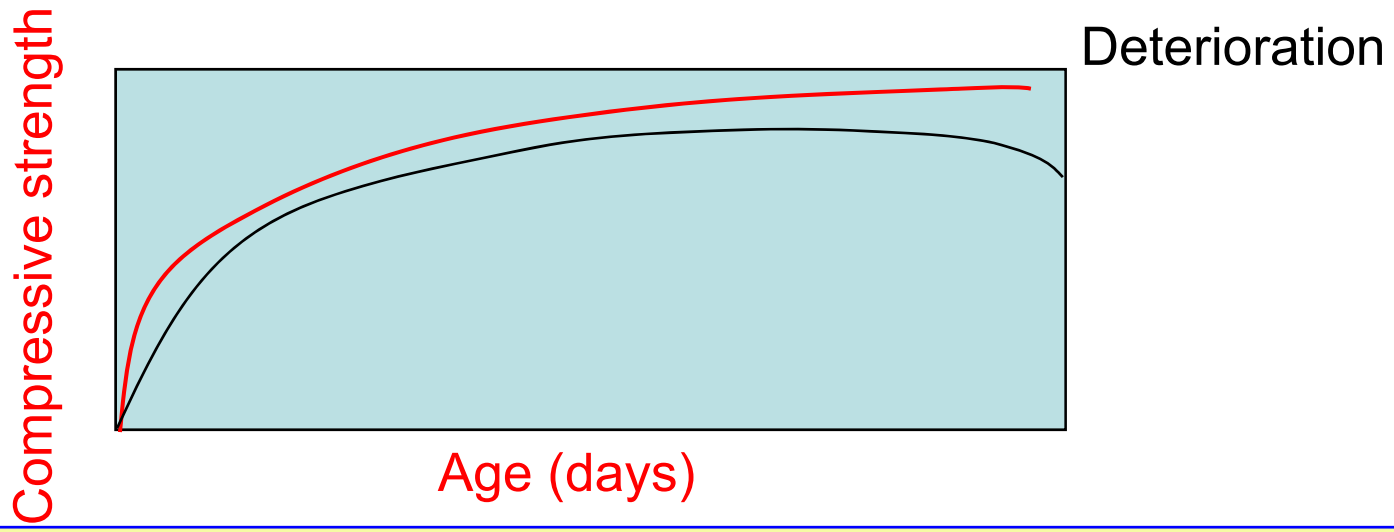
w/c ratio, degree of compaction, strength and workability are related. How?



Effect of w/c ratio on cement paste



Effect aging or something else?



Aging, if one means merely the effect caused by the passage of time, has no effect on concrete. Of course concrete sets, hardens, gains strength, and exhibits reduced permeability with the passage of time, but it is not the passage of time alone that causes these things to happen. If the concrete is kept very cold, none of this will happen. If all moisture is removed, none of this will happen. Many or even most concretes are confronted with potential deteriorative service conditions. If the concrete has not been provided with immunity against these influences, it may well slowly deteriorate as time passes, but not simply because time passes. Concrete need not deteriorate.

Admixtures

Admixtures of ConMix

MegaFlow R is a retarding, water reducing concrete admixture. Conforms to Type B & D of ASTM C494-2004

MegaFlow P4 is a water reducing and retarding plasticising admixture. Conforms to Type D of ASTM C494-2004.

MegaFlow P401 is a water reducing, plasticising and retarding admixture. Conforms to Type D of ASTM C494-2004.

MegaFlow SP4 is a high range water reducing and set retarding concrete admixture. Conforms to Type G of ASTM C494-2004.

MegaFlow SP401 is an advanced superplasticiser, higher grade than SP4. Conforms to Type G of ASTM C494-2004

Admixtures

Admixtures of ConMix

MegaFlow SP102 is a high early strength and high range water reducing superplasticiser.

MegaFlow SP103 is a high range water reducing and accelerating, high performance superplasticiser.

MegaAir is an air entraining and plasticising concrete admixture. Conforms to ASTM C260.

MegaFlow MP is a normal setting and air entraining plasticiser. Conforms to BS:4887.

MegaAdd WL1 is a waterproofing admixture for concrete and mortar.

MegaAdd CI is a corrosion inhibiting admixture.

MegaAdd SAL is a liquid, shotcrete accelerating admixture.

Conplast® SP430 (FOSROC)

Uses

- To produce pumpable concrete
- To produce high strength, high grade concrete M30 & above by substantial reduction in water resulting in low permeability and high early strength.
- To produce high workability concrete requiring little or no vibration during placing.
- Conplast SP430 has been specially formulated to give high water reductions upto 25% without loss of workability or to produce high quality concrete of reduced permeability.
- As a guide, the rate of addition is generally in the range of 0.5 - 2.0 litres/100 kg cement.

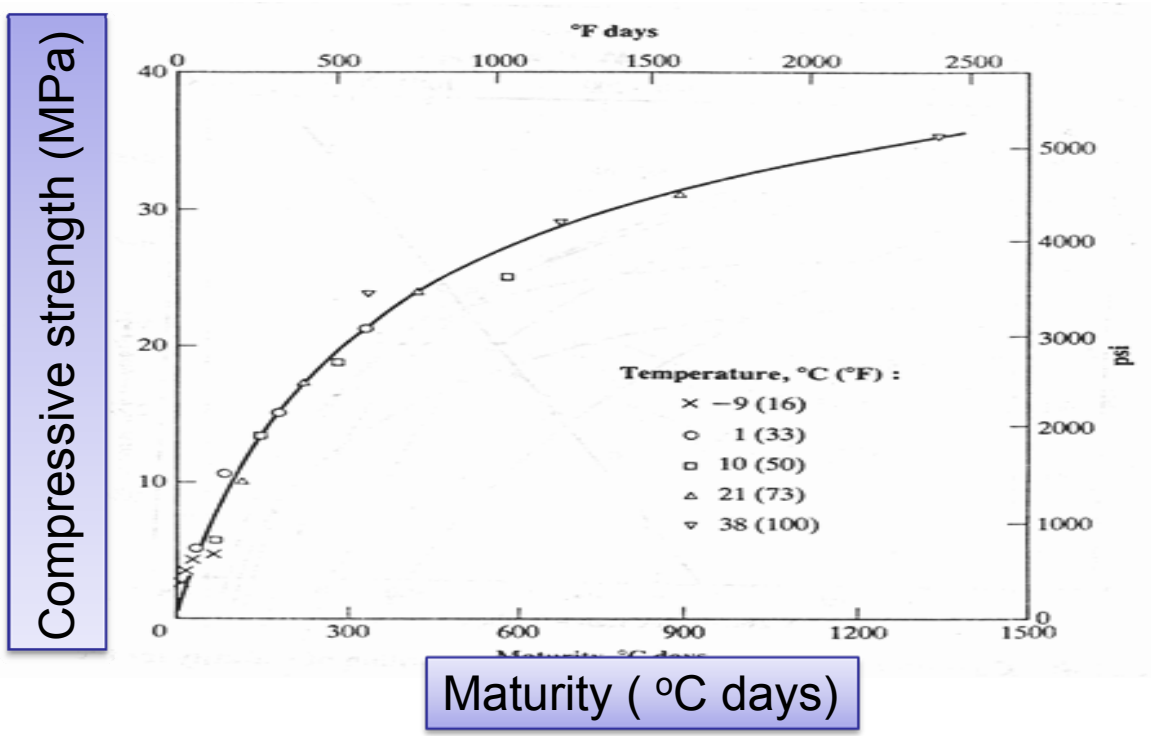
Curing of Concrete

- What is meant by curing of concrete?
- Why is curing important?
- Durability of concrete is dependent on length of curing. How?
- Types of curing
  - Normal curing
    - Spraying, ponding, covering with wet materials, membrane curing
  - Steam curing

- Disadvantage of membrane curing?
- Effect of curing temperature on strength
- What is maturity rule? What is the limitation of maturity rule?

- Durability, permeability and curing; how are they related?

Maturity Rule of Concrete



- M = ∑ T.dt
- Limitation
  - Adverse effect of early high temp could not be counted

Durability of concrete

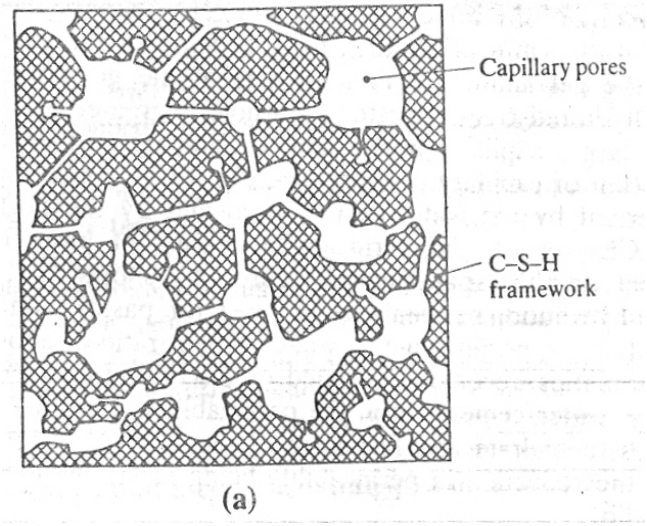
- *To make durable concrete*
  - 1. w/c ratio: w/c ratio as low as possible
  - 2. Compaction: proper compaction makes concrete durable
  - 3. Curing: Damage extent depends on concentration of sulphate and permeability of concrete
  - 4. Clear Cover:
  - 5. Type of Cement:
  - 6. Use of Admixture:

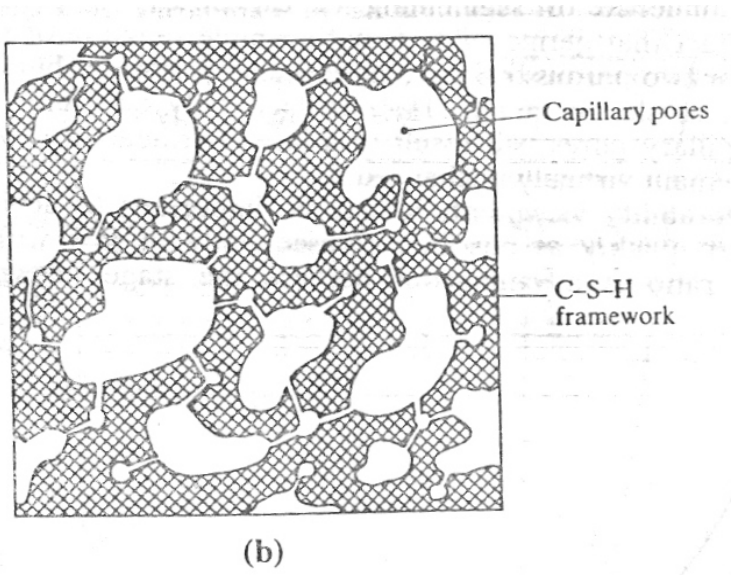
- *Questions:*

1. *Durability and permeability of concrete are related. Explain – how?*
2. *Explain the three main factors of durability of concrete.*

Hydration and porosity of concrete

- Cement paste contains an interconnected system of pores, when partially hydrated
  - >> lower strength, higher permeability >> vulnerable to chemical, freezing-thawing
- Pore system become segmented/isolated when degree of hydration is sufficiently high

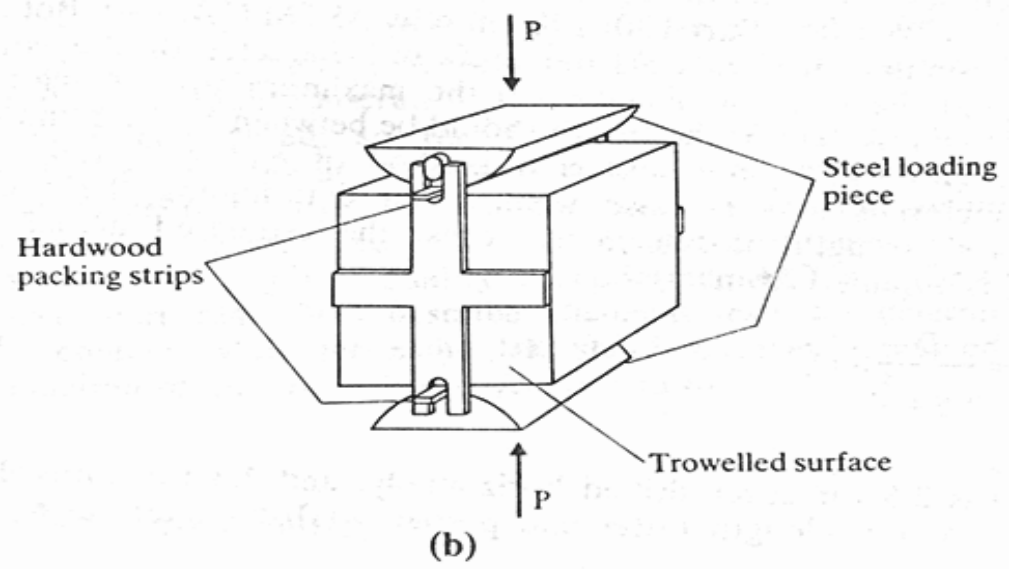


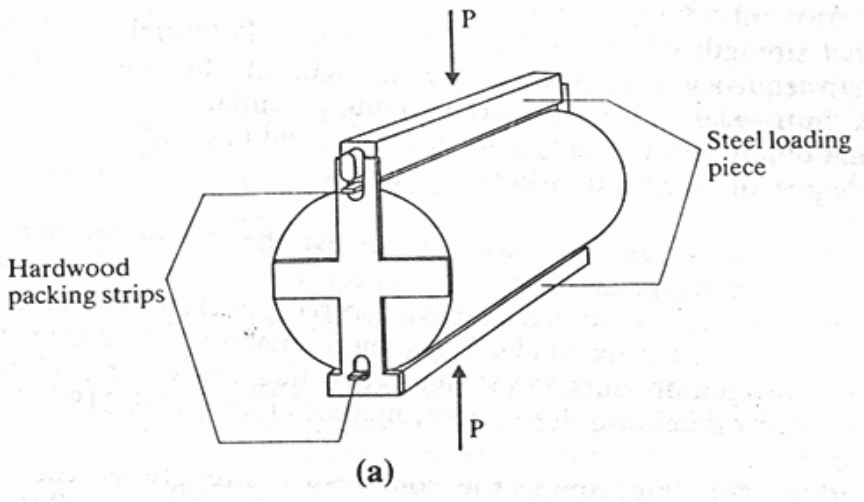


Durability of concrete – an example

- *Sulphate attack*
  - Symptoms: Whitish appearance, cracking and spalling of concrete
  - Mechanism: formation of calcium sulphate and calcium sulpho-aluminate (from C_3A + sulphate), products volume is greater than reactants, resulting expansion and disruption of concrete
  - Damage extent depends on concentration of sulphate and permeability of concrete
  - Remedy:
  - Use of blast furnace slag cement and Portland-pozzolan cement
  - Compaction, curing, clear cover >> durable concrete

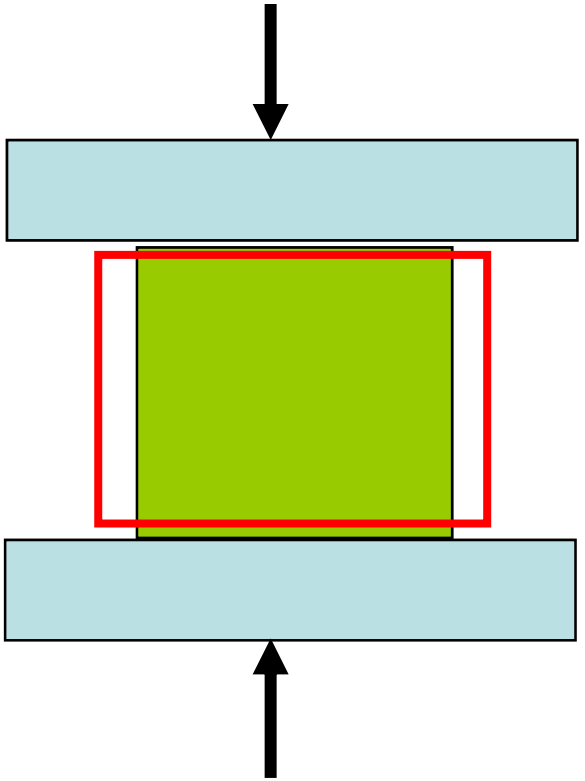
Testing of Concrete



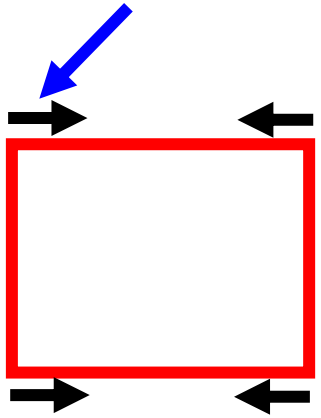


- Compressive strength
- Tensile strength (1/10 of comp strength)
  - Flexure test
  - Splitting test
    - Tensile splitting strength = $2P/(\pi Ld)$

Effect of platen restraint

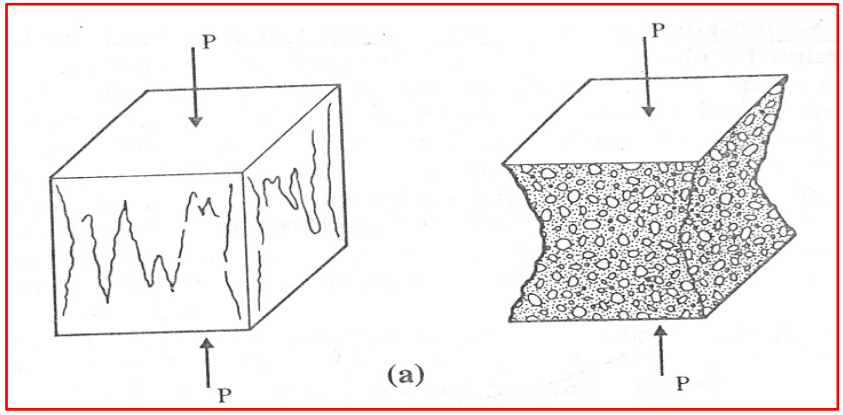


Lateral shearing stress

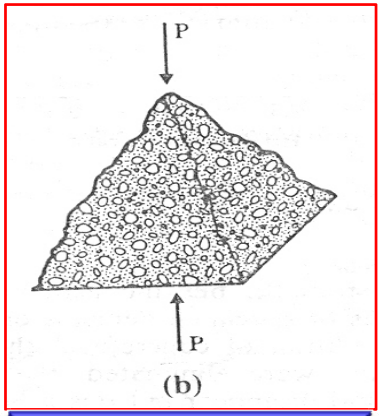


Why is cube strength is higher than cylinder strength?

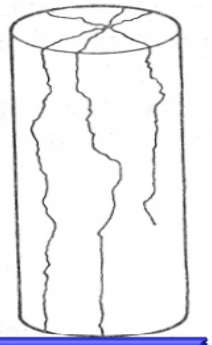
Failure Modes



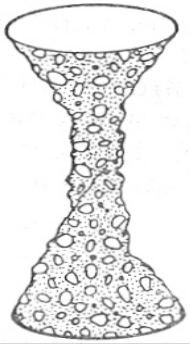
Non-explosive



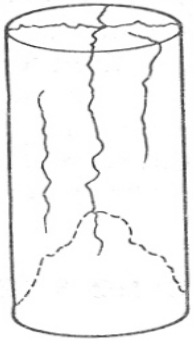
Explosive



Splitting



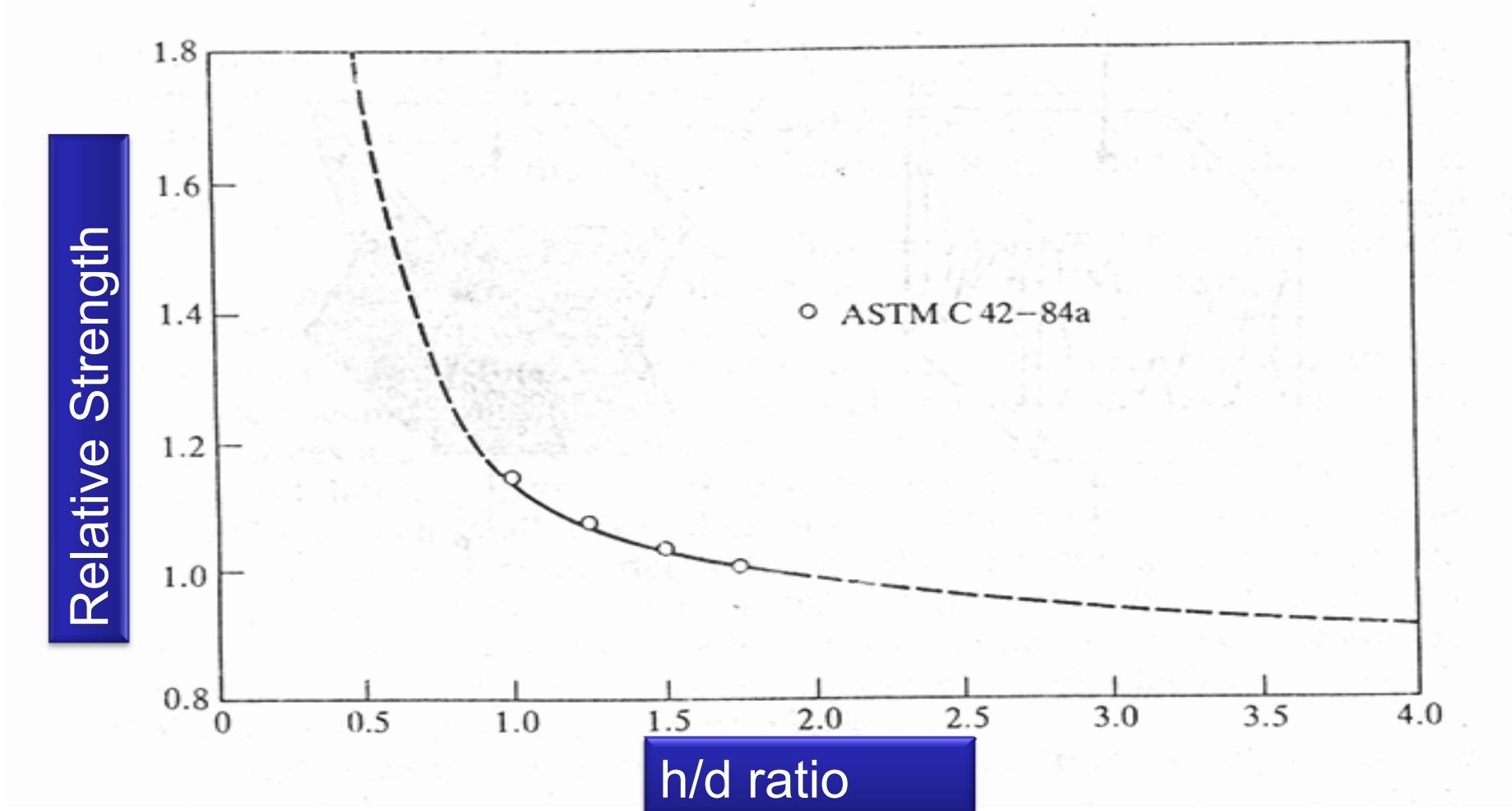
Shear (cone)



Splitting and Shear (cone)

Types of failure other than these are regarded as unsatisfactory and indicate a probable fault in the testing machine

- When h/d ratio increases, the influence of platen restraint decreases in the central part of specimen
- Cube strength = 1.25 * cylinder strength
- Merits and demerits of cylinder and cube test?



Merits and Demerits of Cylinder and Cube Test

Merits of Cylinder Test

- Less end restraint and more uniform distribution of stress over the cross section
- Cylinder strength is closer to true uniaxial compressive strength of concrete than the cube strength
- Casting and testing in same direction

Merits of Cube Test

- Capping is not required

Non-destructive test of concrete (NDT)

- Schmidt hammer / rebound hammer / impact hammer test
  - Rebound number >> comp strength
  - 10-12 readings are necessary for one spot
  - Plunger must be normal to surface of concrete
- Penetration resistance
- Pull out test
- Ultrasonic pulse velocity test

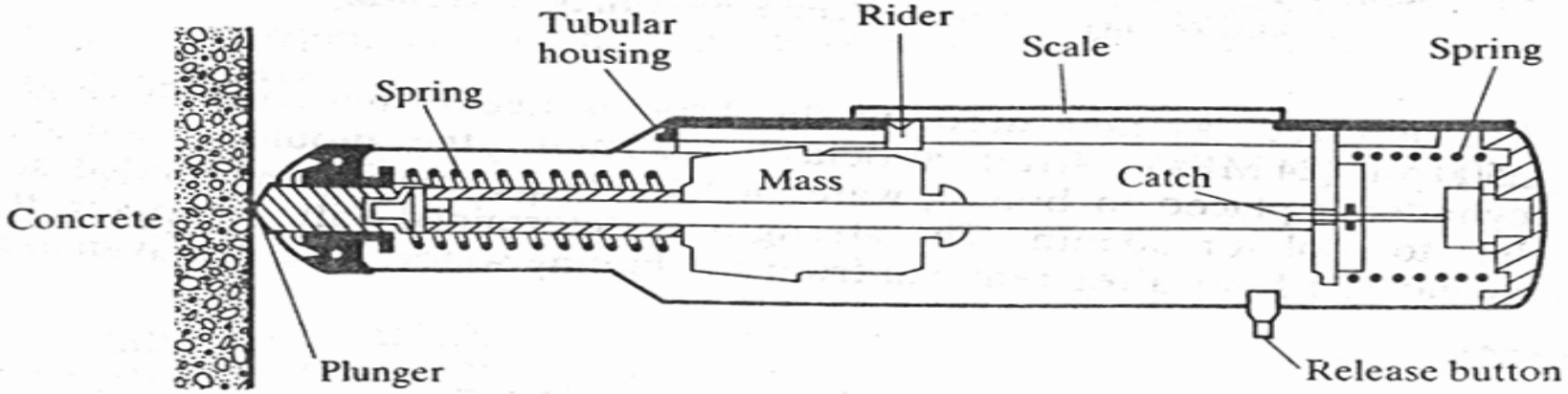
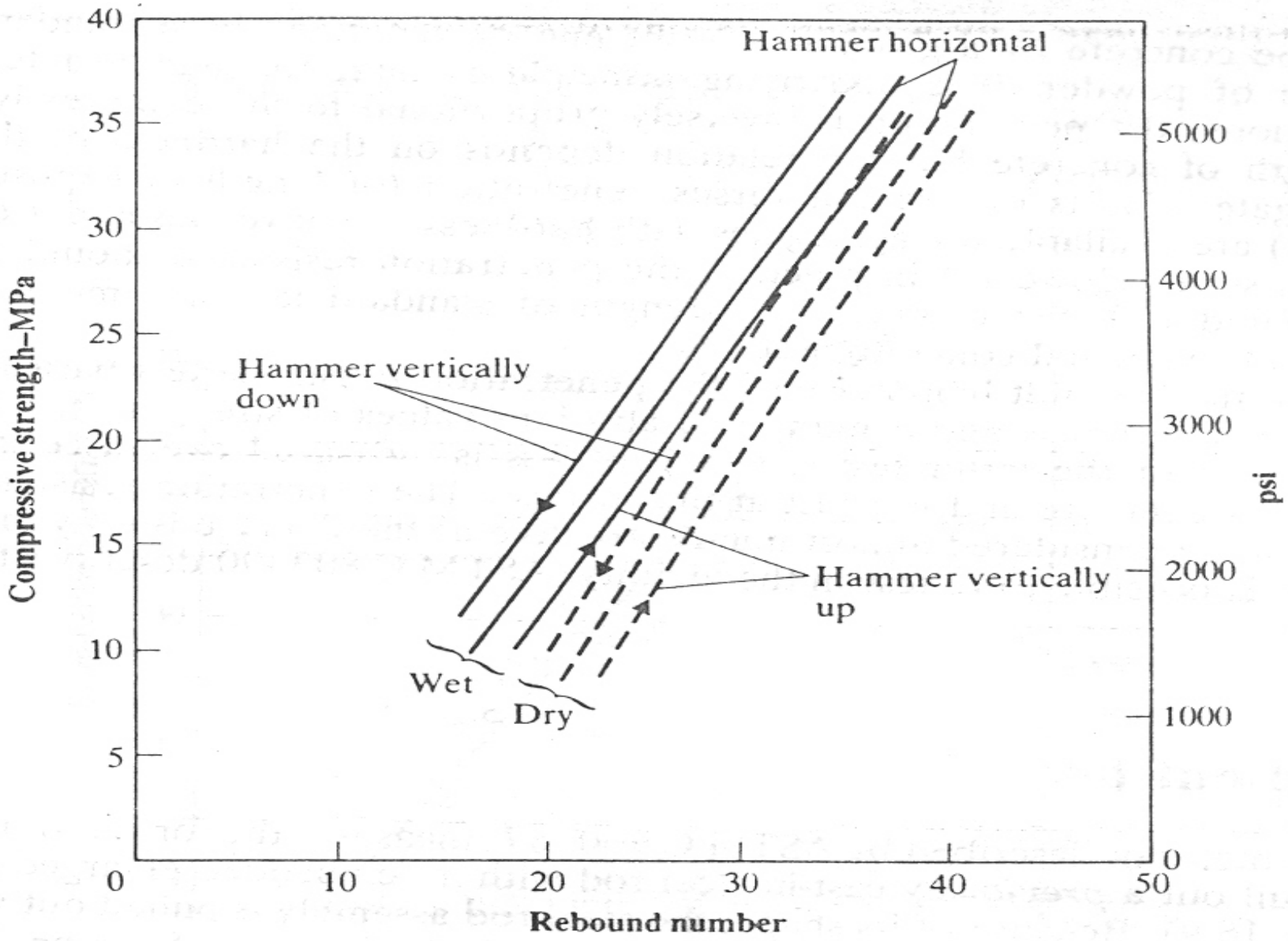


Fig. 16.7: Rebound hammer

Calibration of rebound hammer



Quality Control of Concrete by Testing

- The ACI code specifies that a pair of cylinders must be tested for each 150 yd^3 of concrete or for 5000 ft^2 of surface area actually placed, but not less than once a day.
- To ensure adequate concrete strength in spite of such scatter, the ACI code stipulates that concrete quality is satisfactory if
  - (1) no individual strength test result (the average of a pair of cylinder tests) falls below the required f_c' by more than 500 psi when f_c' is 5000 psi or less or by more than 0.10 f_c' when f_c' is more than 5000 psi, and
  - (2) every arithmetic average of any three (pair) consecutive strength tests equals or exceed f_c'

$$\sigma = standard\ deviation$$

$$f_c' = design\ compressive\ strength$$

$$f_{cr}' = average\ compressive\ strength$$

$$f_{cr}' = f_c' + 1.34\sigma$$

OR

$$f_{cr}' = f_c' + 2.33\sigma - 500\ for\ f_c' \leq 5000psi$$

$$f_{cr}' = 0.90f_c' + 2.33\sigma\ for\ f_c' > 5000psi$$

TABLE 5.3.2.2—REQUIRED AVERAGE COMPRESSIVE STRENGTH WHEN DATA ARE NOT AVAILABLE TO ESTABLISH A STANDARD DEVIATION

Specified compressive strength, f_c', psi	Required average compressive strength, f_{cr}', psi
Less than 3000	$f_c' + 1000$
3000 to 5000	$f_c' + 1200$
Over 5000	$1.10f_c' + 700$

Specified compressive strength, f_c', MPa	Required average compressive strength, f_{cr}', MPa
Less than 21	$f_c' + 7.0$
21 to 35	$f_c' + 8.5$
Over 35	$1.10f_c' + 5.0$

Quality Control of Concrete - Example

- Example – 1: design compressive strength of concrete of a structure is 4000 psi. the test results of concrete are as follows:
  - Day 1: (2500 psi, 4500psi), (3000 psi, 4680 psi), (4200 psi, 4520 psi)
  - Day 2: (3500 psi, 4050 psi), (3800 psi, 3900 psi)
  - Day 3: (4100 psi, 4360 psi)
  - Day 4: (4500 psi, 4150 psi)

  Are these results satisfactory?