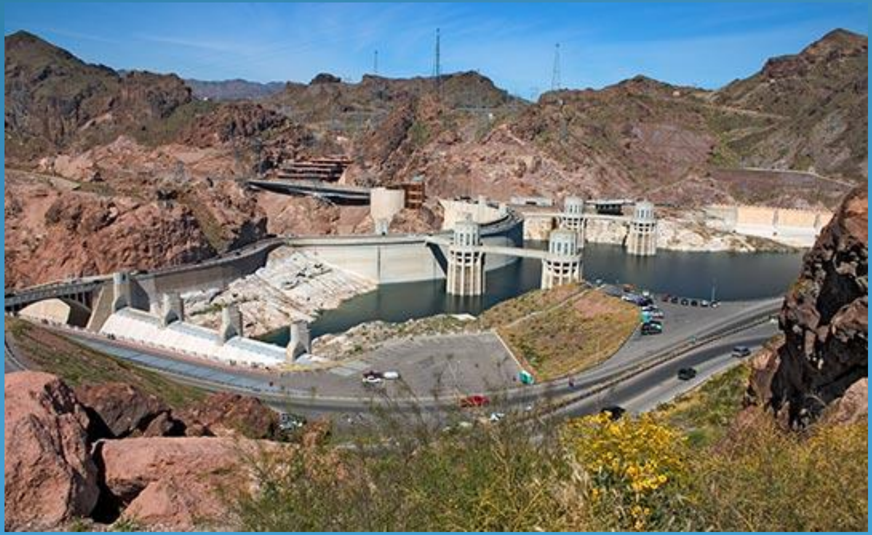
PROPERTIES of CONCRETE
Concrete-I

Prof. Dr. Halit YAZICI

D. E. U. Civil Engineering Department

http://halityazici-deu.com

CONCRETE



What is Concrete?

- Concrete is one of the most commonly used building materials.
- Concrete is a **composite material** made from several readily available constituents (aggregates, sand, cement, water).
- Concrete is a versatile material that can **easily be mixed** to meet a variety of special needs and formed to virtually **any shape**.

Advantages

- Ability to be cast
- Economical
- Durable
- Fire resistant
- Energy efficient
- On-site fabrication

Disadvantages

- Low tensile strength
- Low ductility
- Volume instability
- Low strength to weight ratio

Constituents

Cement

Water

Fine Agg.

Coarse Agg.

Admixtures

PROPERTIES OF FRESH CONCRETE

- Workability
- Consistency
- Segregation
- Bleeding
- Setting Time
- Unit Weight
- Uniformity

WORKABILITY

It is desirable that freshly mixed concrete be relatively easy to transport, place, compact and finish without harmful segregation.

A concrete mix satisfying these conditions is said to be **workable**.

Factors Affecting Workability

- Method and duration of transportation
- Quantity and characteristics of cementing materials
- Aggregate grading, shape and surface texture
- Quantity and characteristics of chemical admixtures
- Amount of water
- Amount of entrained air
- Concrete & ambient air temperature

WORKABILITY

- Workability is the most important property of freshly mixed concrete.
- There is no single test method that can simultaneously measure all the properties involved in workability.
- It is determined to a large extent by measuring the "**consistency**" of the mix.

CONSISTENCY

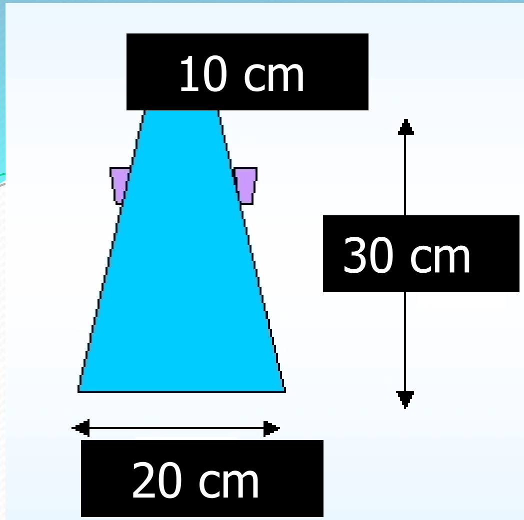
- Consistency is the fluidity or degree of wetness of concrete.
- It is generally dependent on the shear resistance of the mass.
- It is a major factor in indicating the workability of freshly mixed concrete.

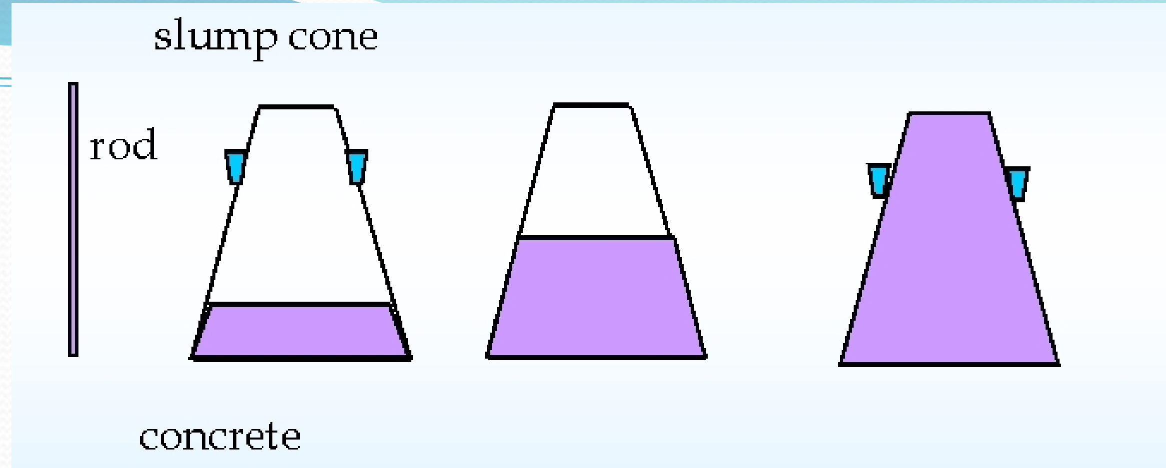
CONSISTENCY

Test methods for measuring consistency are:

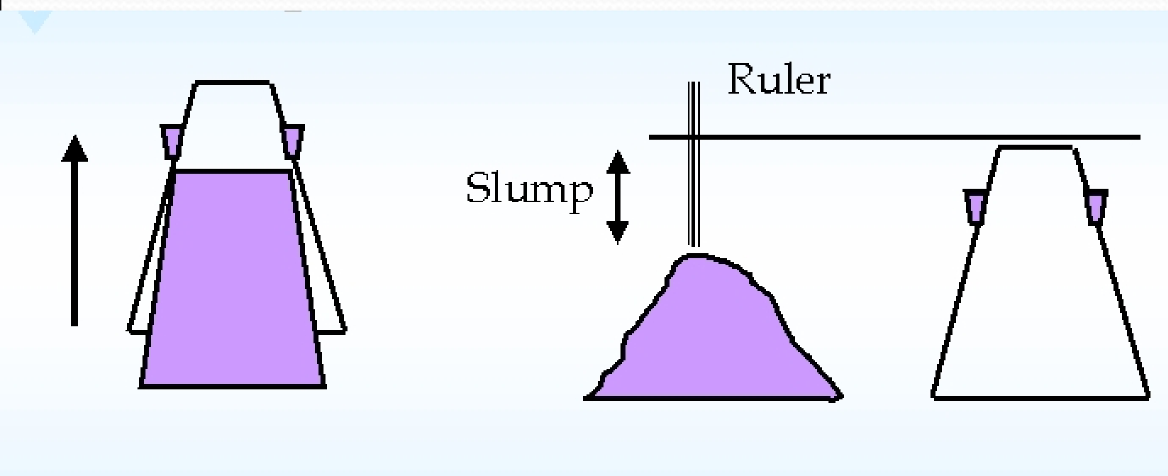
- Flow test → measures the amount of flow
- Kelly-Ball test → measures the amount of penetration
- Slump test (Most widely used test!)

- Slump Test is related with the ease with which concrete flows during placement (TS 2871, ASTM C 143)

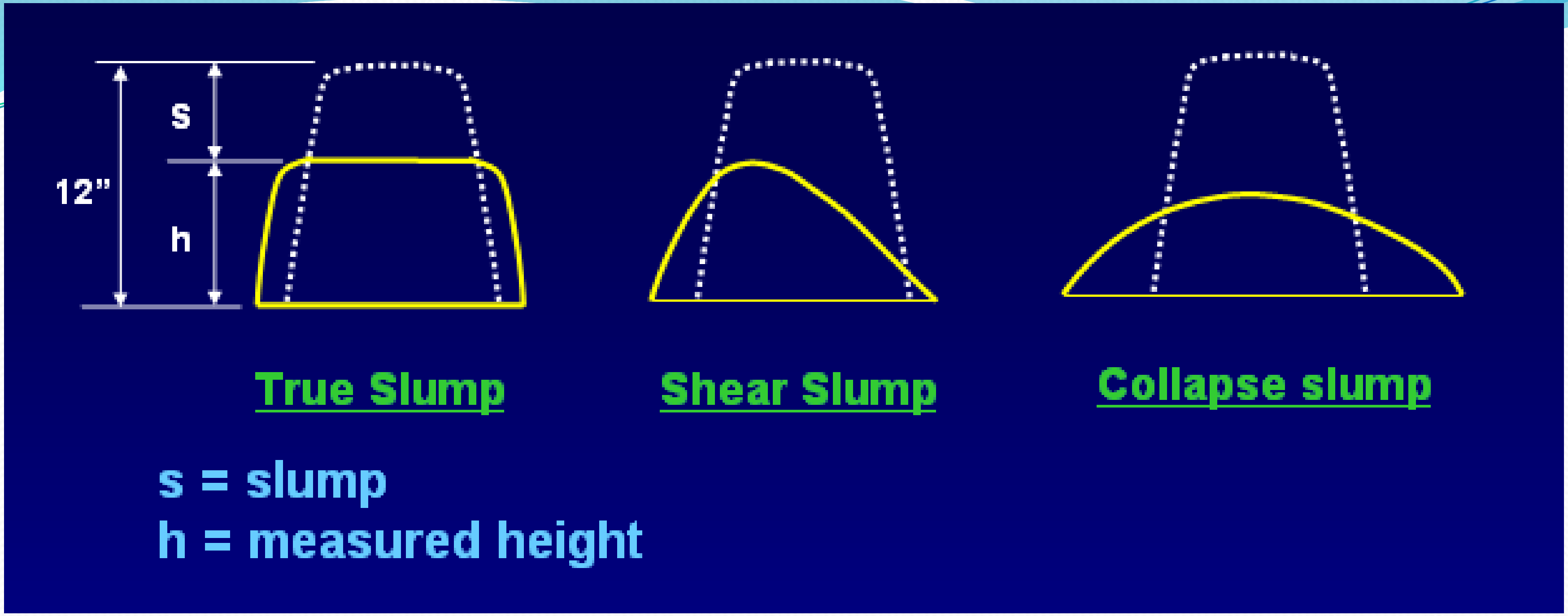




The slump cone is filled in 3 layers. Every layer is evenly rodded 25 times.



Measure the **slump** by determining the vertical difference between the top of the mold and the displaced original center of the top surface of the specimen.


12"
s
h
True Slump
Shear Slump
Collapse slump
s = slump
h = measured height

SEGREGATION

- Segregation refers to a separation of the components of fresh concrete, resulting in a non-uniform mix

- **The primary causes of segregation are differences in specific gravity and size of constituents of concrete. Moreover, improper mixing, improper placing and improper consolidation also lead to segregation.**

	Sp.Gr.	**Size**
Cement	3-3.15	5-80 μm
C.Agg.	2.4-2.8	5-40 mm
F.Agg.	2.4-2.8	< 5 mm

SEGREGATION

Some of the factors affecting segregation:

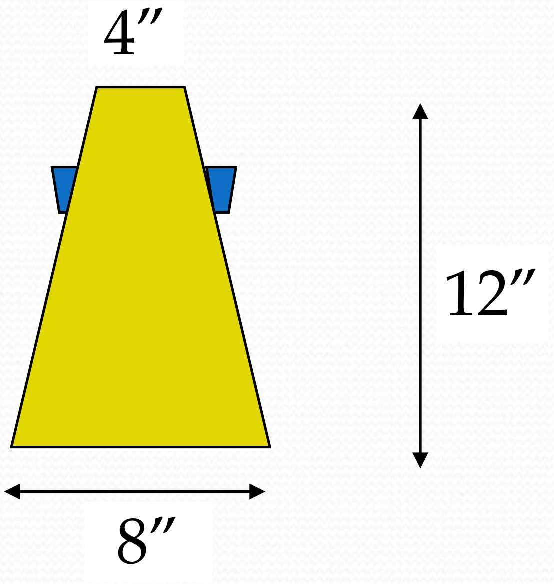
- Larger maximum particle size (25mm) and proportion of the larger particles.
- High specific gravity of coarse aggregate.
- Decrease in the amount of fine particles.
- Particle shape and texture.
- Water/cement ratio.

Properties of fresh concrete

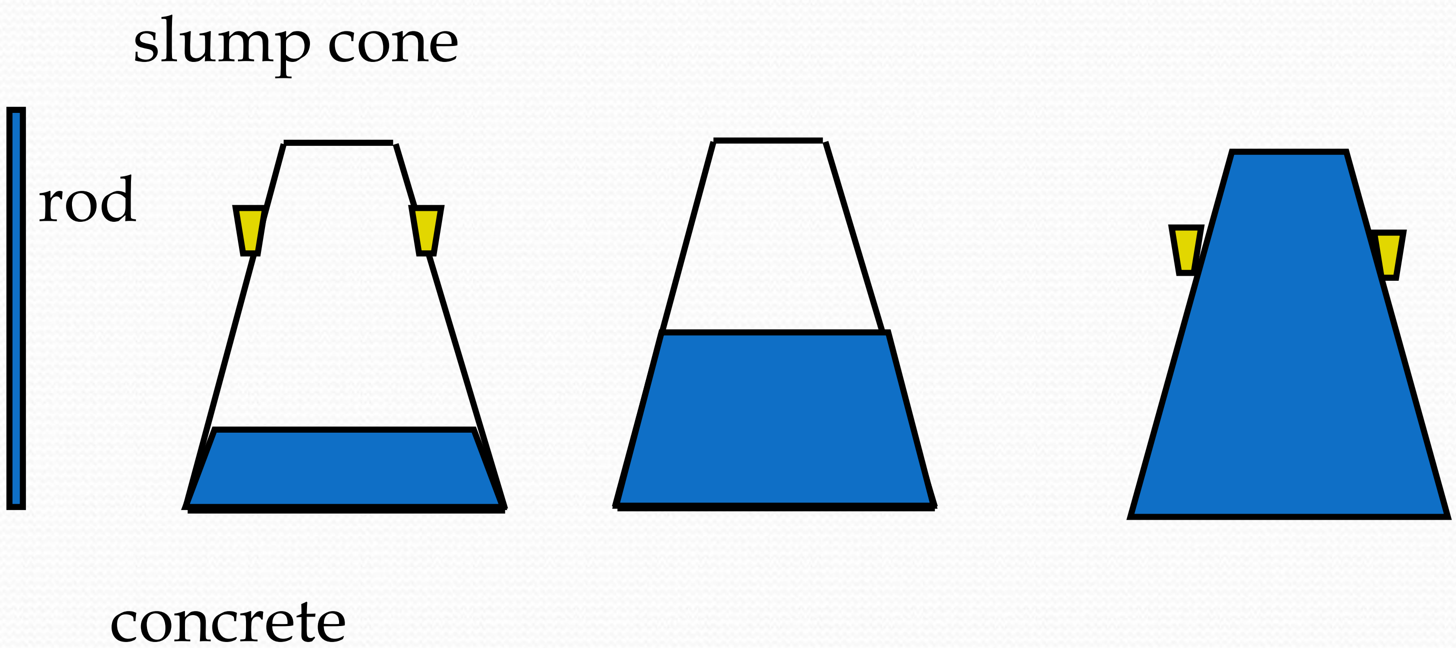
- Workability
  - ease of placement
  - resistance to segregation
  - homogeneous mass
- Consistency
  - ability to flow

Slump Test

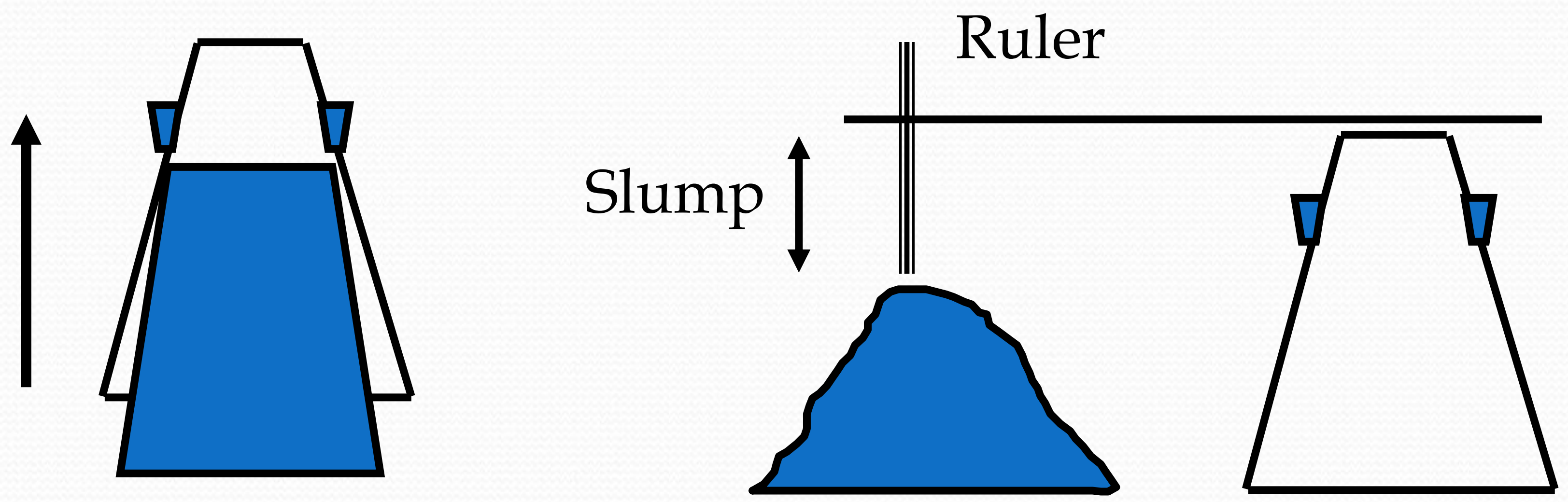
- Inverted cone
- fill it up with three layers of equal volume
- rod each layer 25 times
- scrape off the surface



Slump Test



Slump test



Slump test results

- stiff 0-5 cm
  - massive sections, little reinforcement
  - use vibration
- medium 5-10 cm
  - columns, beams, retaining walls
- Fluid 10-20 cm
  - heavily reinforced section, flowable concrete

Factors affecting slump

- water cement ratio
  - w/c = weight of water / weight of cement

example:

weight of water mixed at the plant

weight of cement

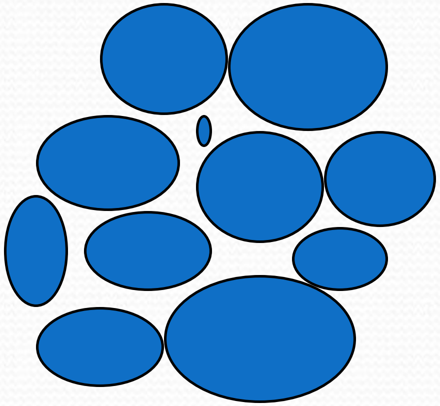
Factors affecting slump- paste content

- constant water cement ratio
  - increase paste content
    - increase slump
    - NO GOOD
- constant cement content
  - increase water content
    - increase slump
    - NO GOOD

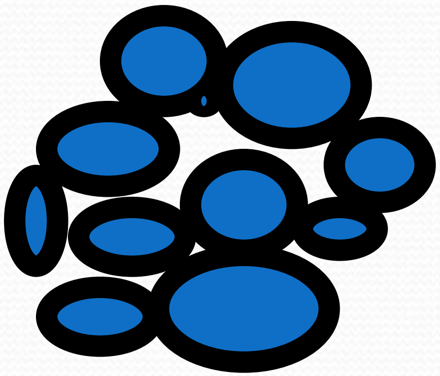
Factors Affecting Slump-Water Content

- Add water at the constant cement content, w/c increases, slump increases.
- Add water at a constant water cement ratio, have to increase cement as well, slump increases.

Factors affecting slump-paste content

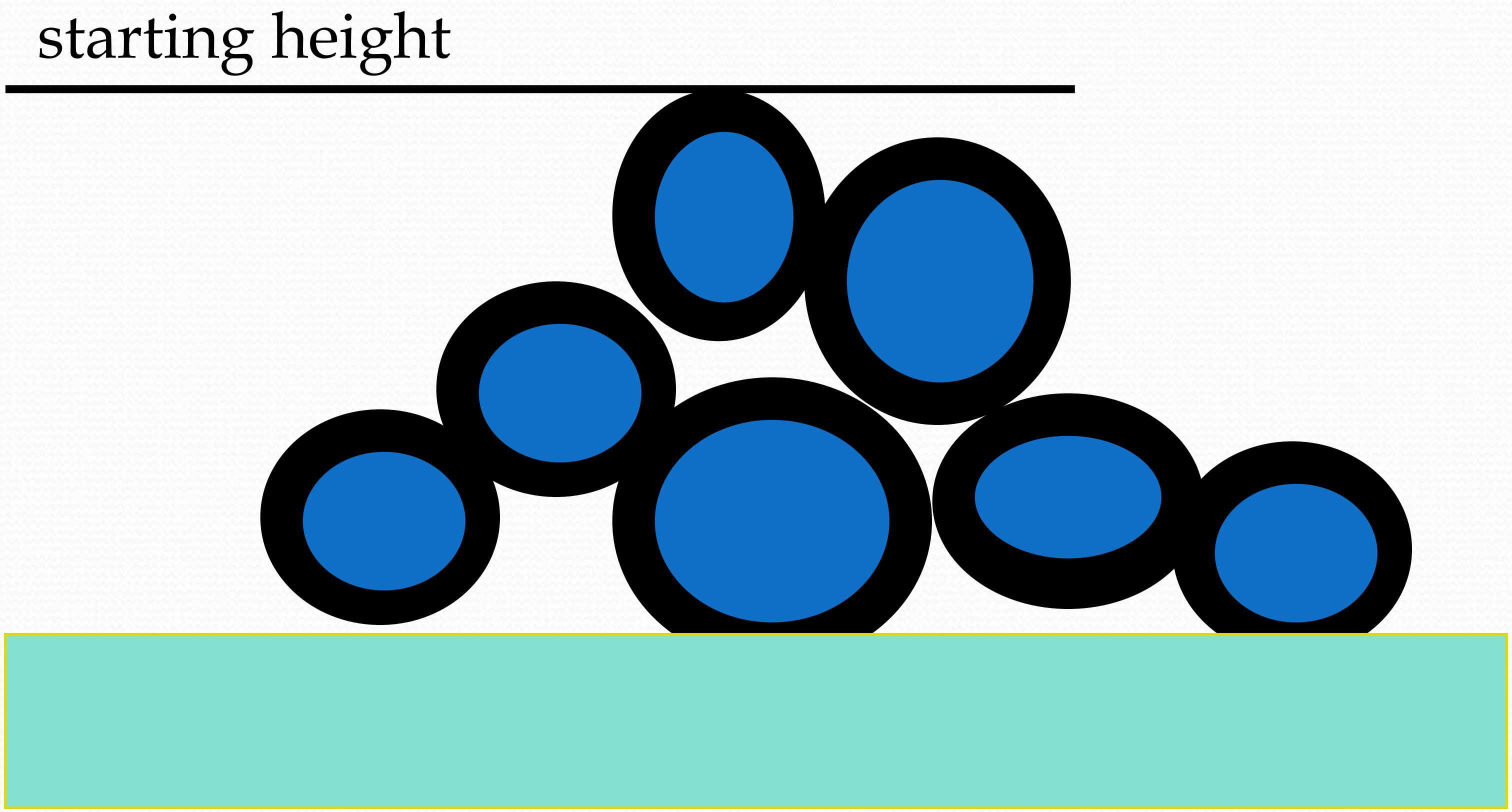


Low paste content
Harsh mix

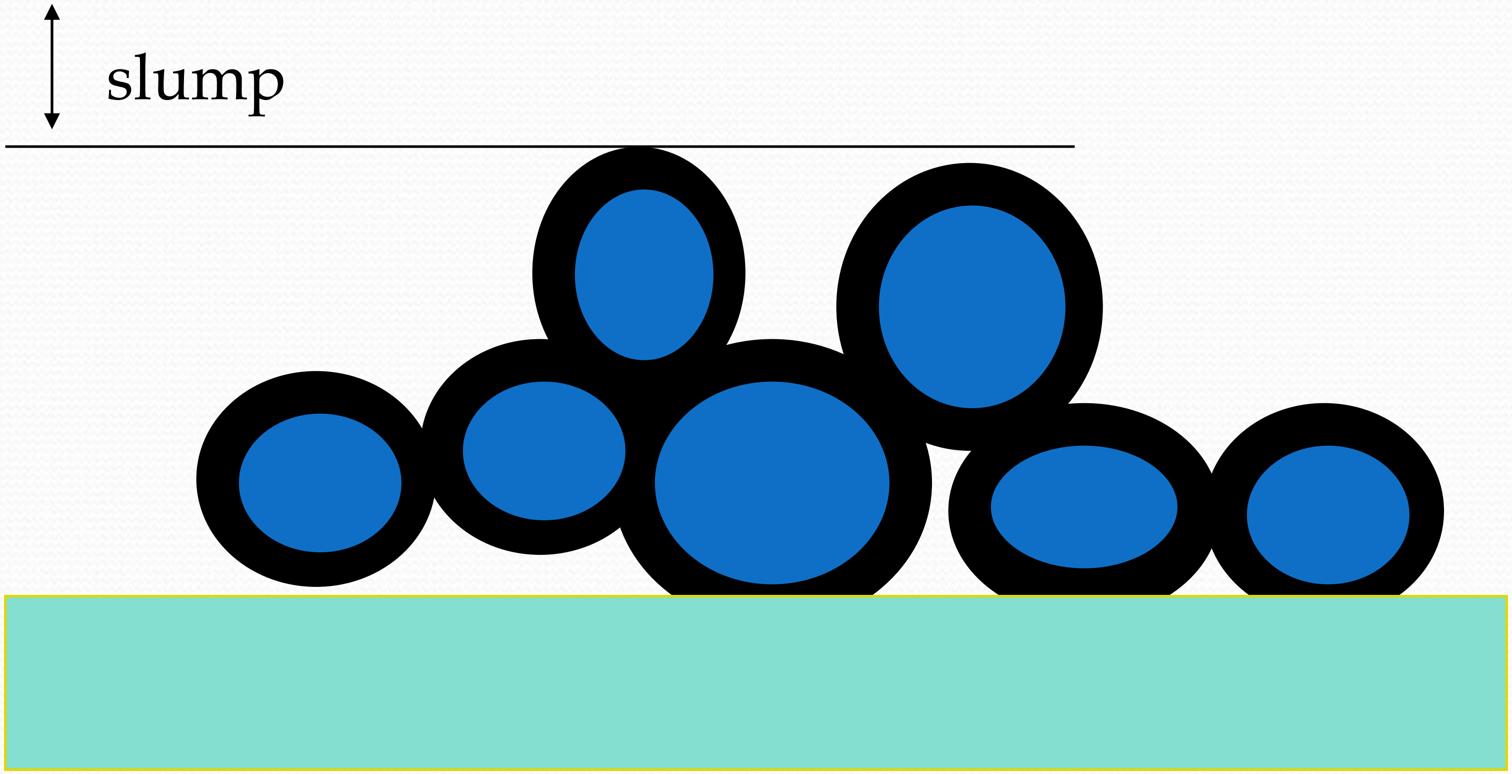


High paste content
Rich mix

ball bearing effect-start



ball bearing effect-end



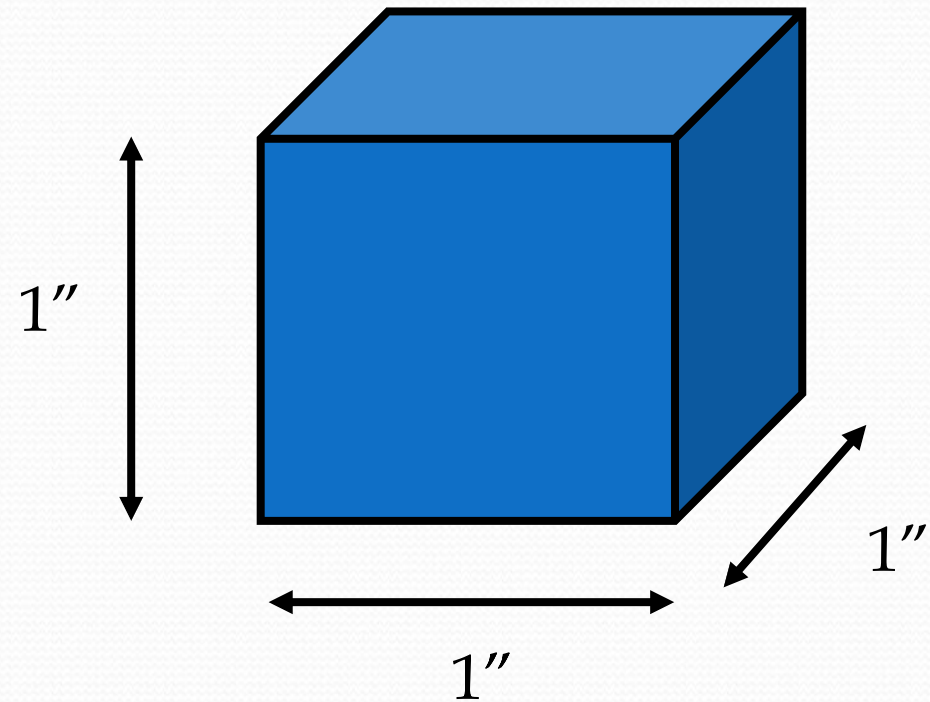
Admixtures

- set retarding admixtures
- set accelerating admixtures
- water reducing admixtures
- superplasticizers
- air entraining admixtures

Factors affecting slump

- Aggregates
  - grading the larger the particle size, the higher the slump for a given paste content

effect of aggregate size

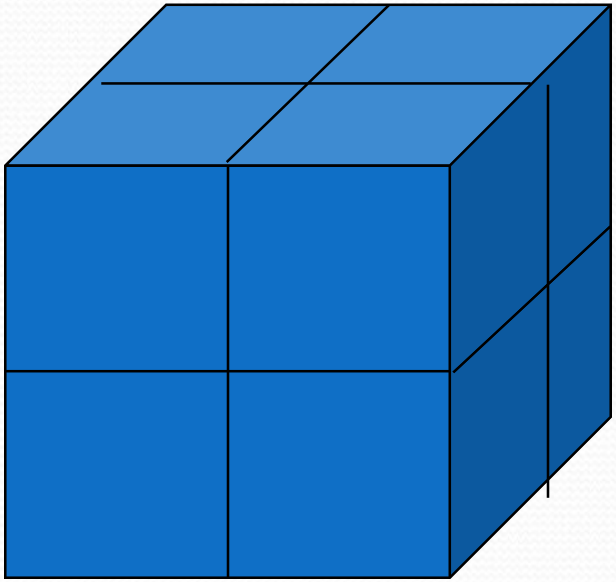


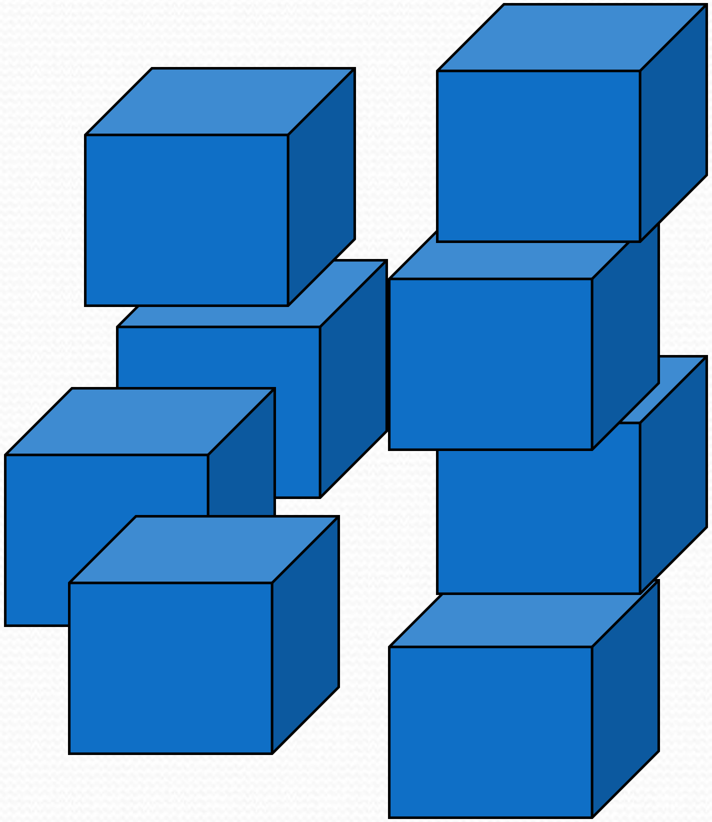
Consider a single aggregate the size of 1″x1″x1″

Compute the surface area as you break up the particles

block surface area = 0.5*0.5*6=1.5

block surface area = 1*1*6= 6

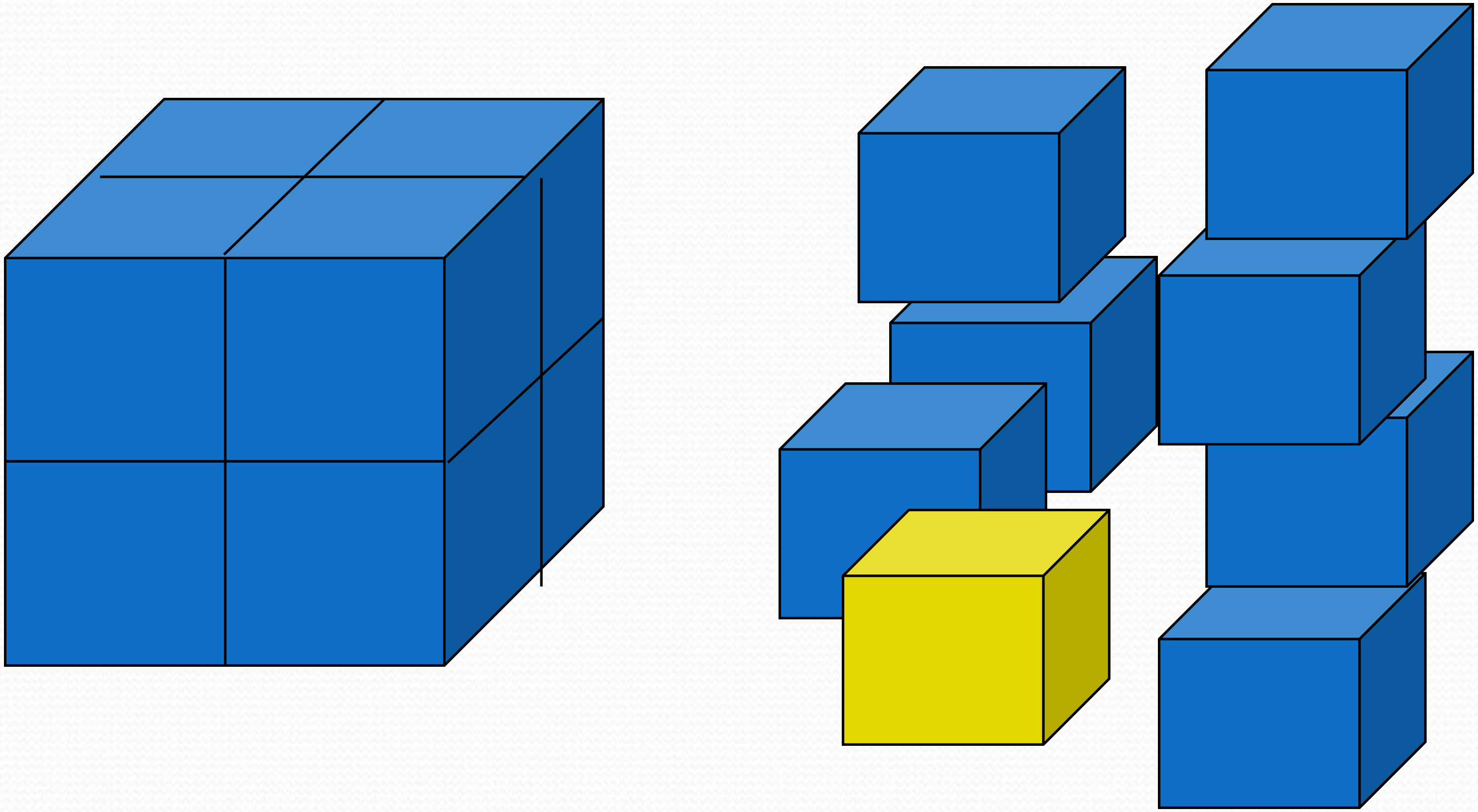




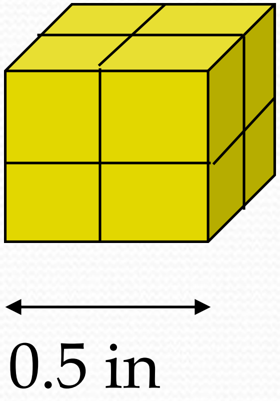
volume = 1 cubic in
surface area = 6 square inches

volume = 1 cubic in
surface area = 1.5*8= 12 square inche

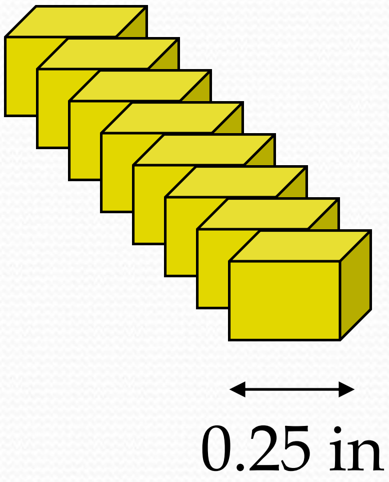
Break it up further



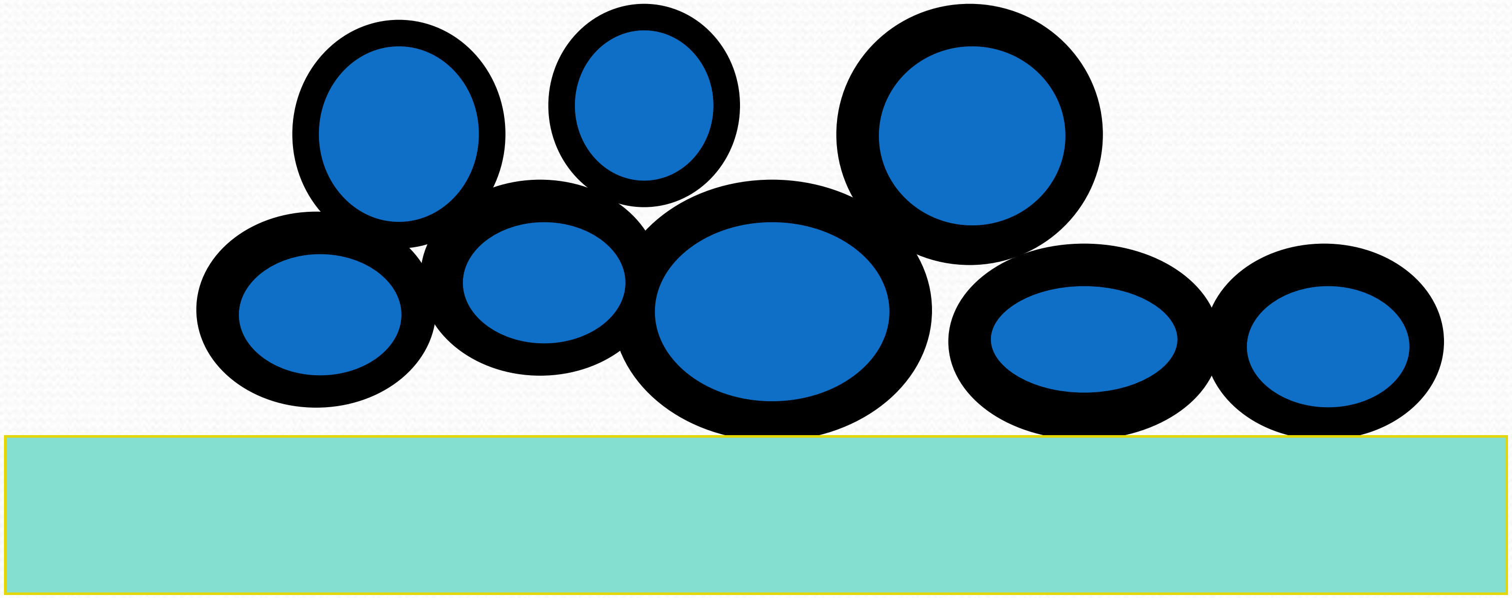
Compute the surface area



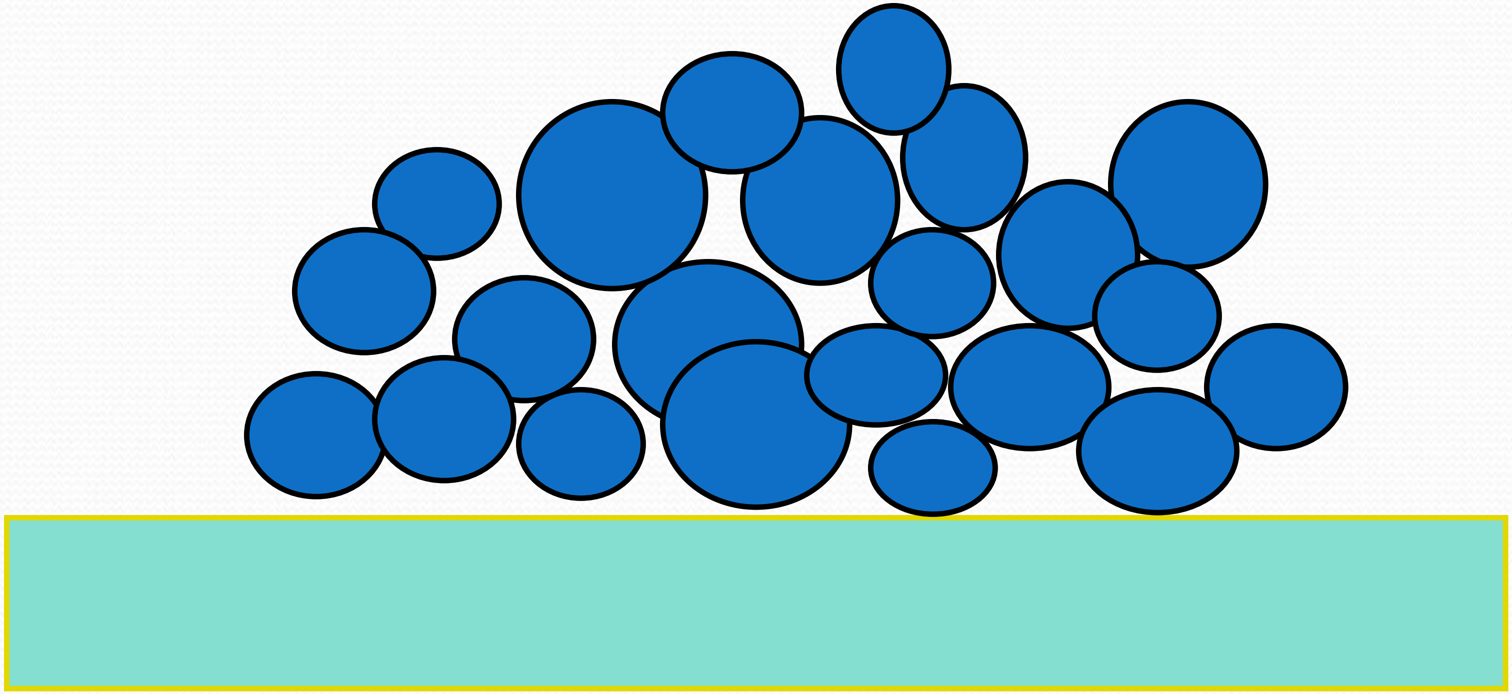
surface area = 0.25*0.25*6*8*8=24



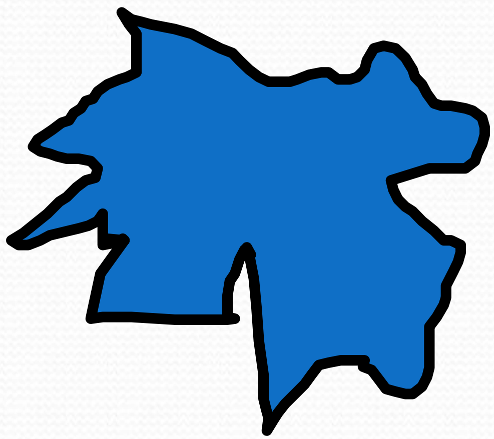
Larger particles, less surface area, thicker coating, easy sliding of particles



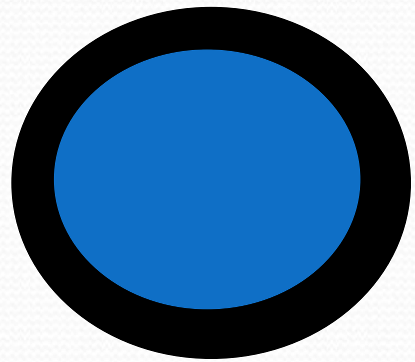
Smaller particles, more surface area, thinner coating, interlocking of particles



Angularity and surface texture of aggregates

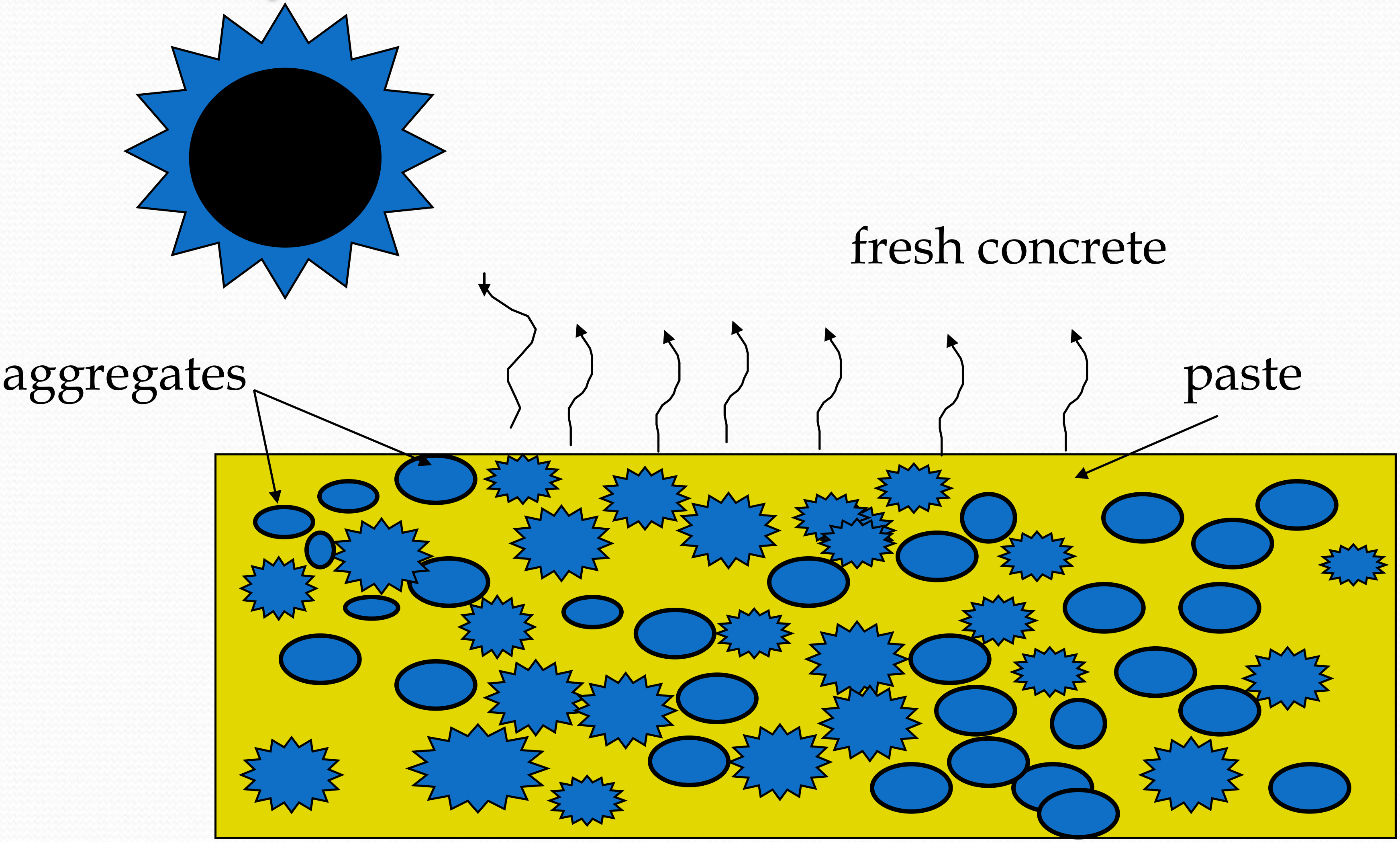


angular and rough aggregate

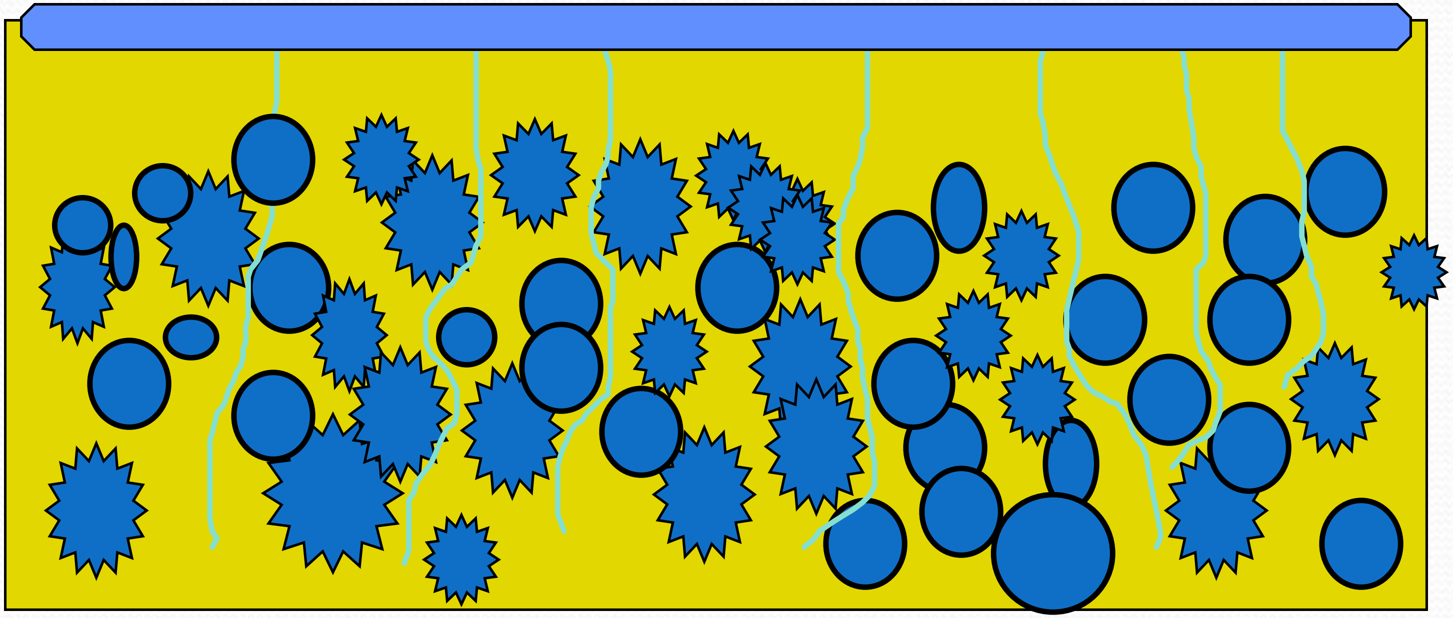


smooth aggregate
river gravel

Temperature

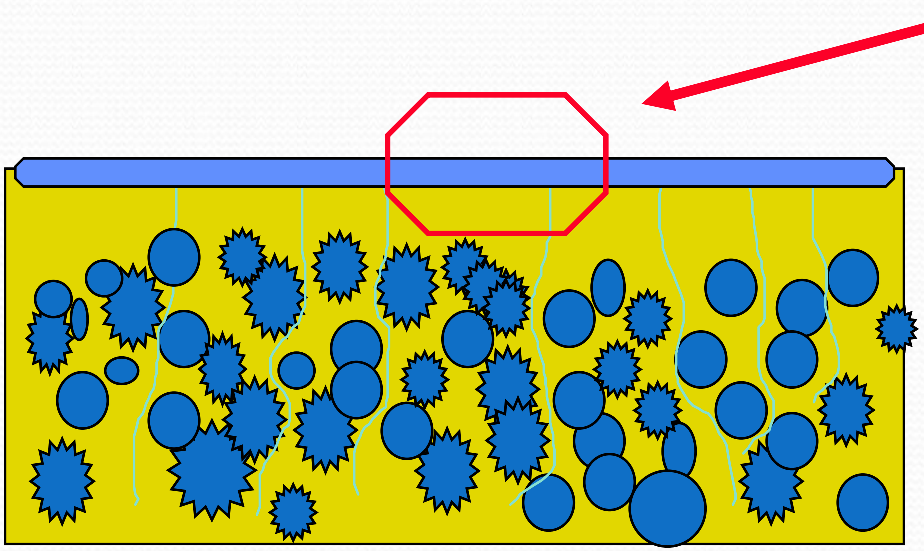


Bleeding

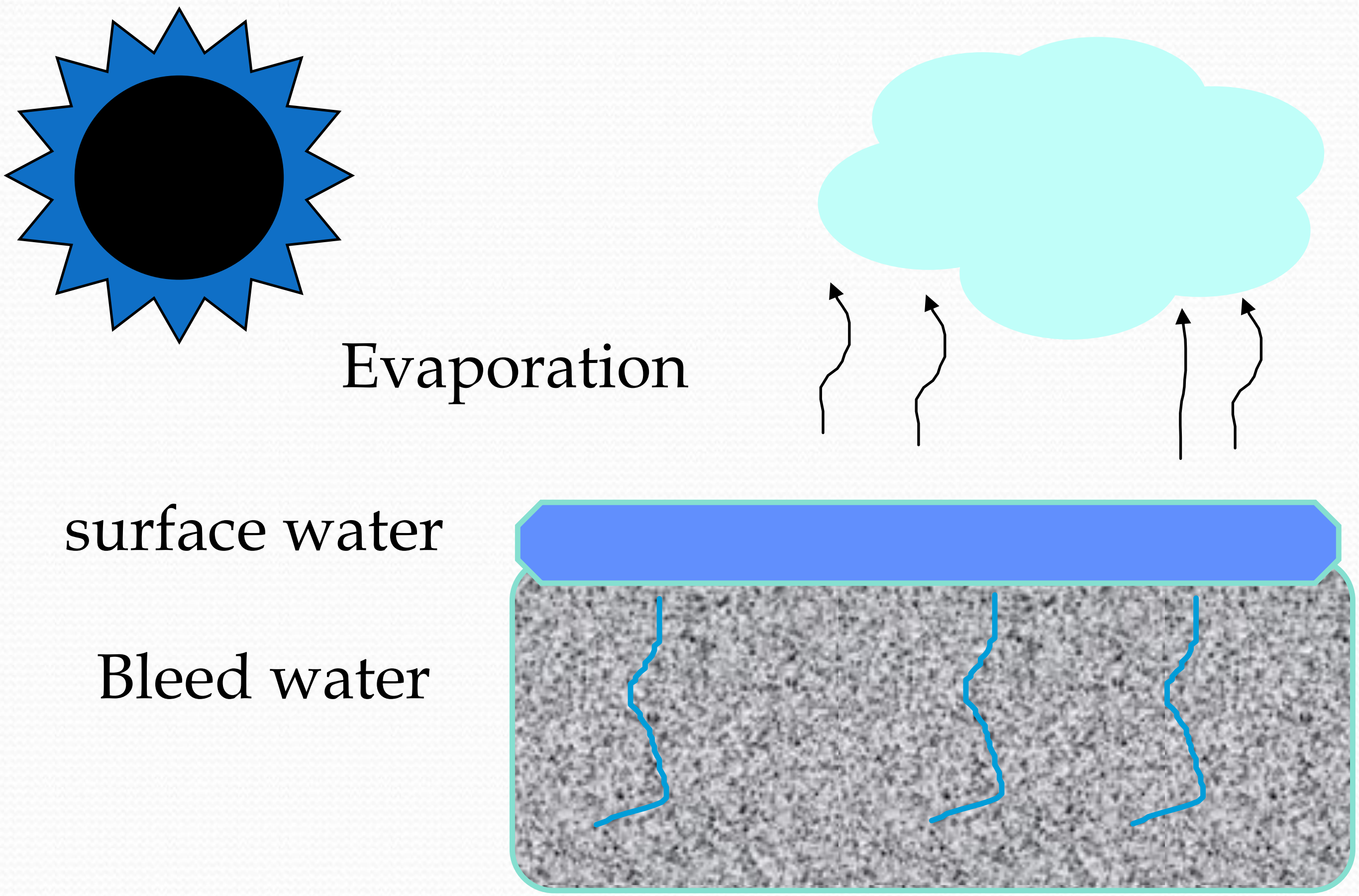


Water accumulation on surface

Examine the concrete surface

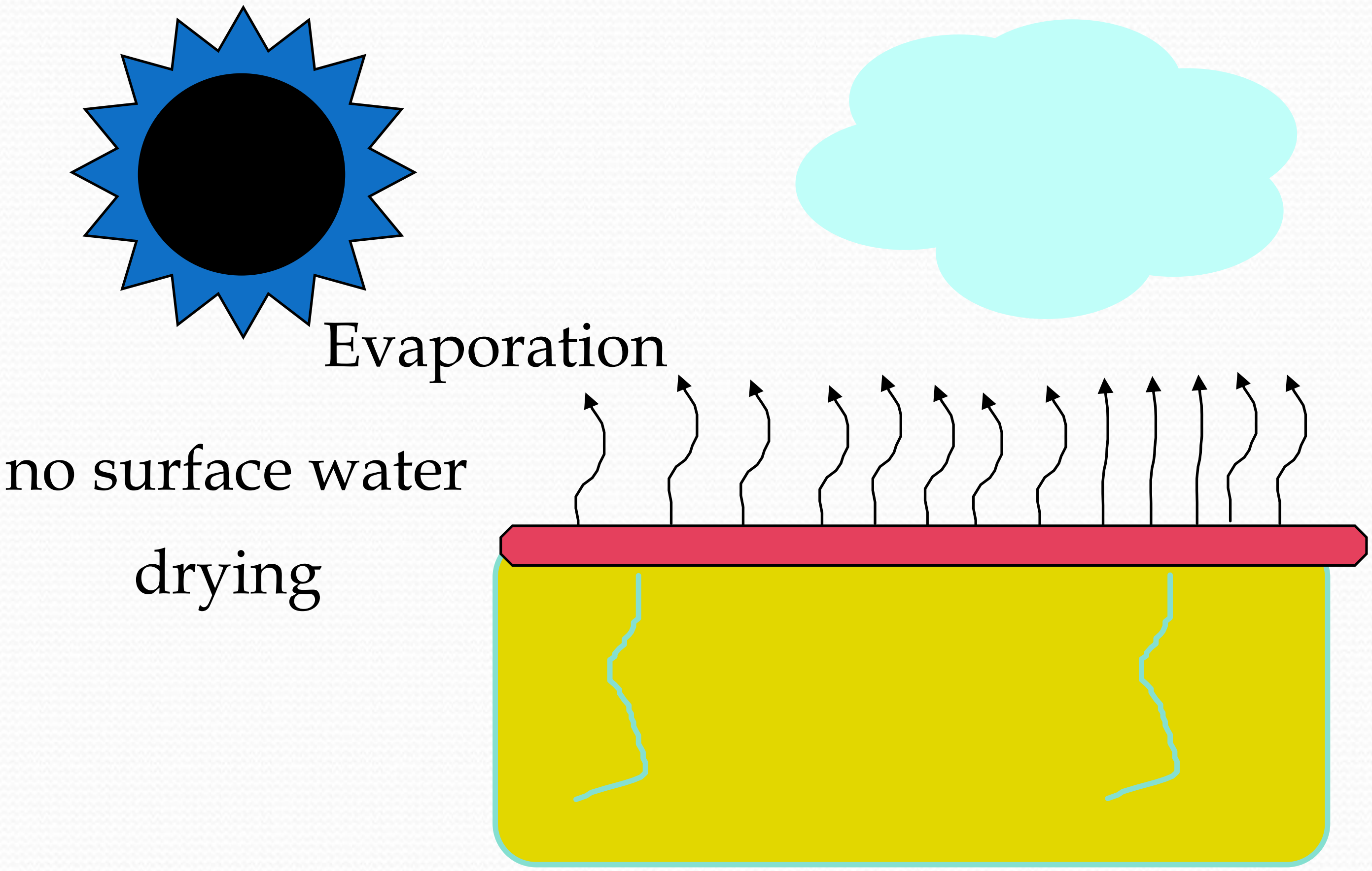


Interaction between bleeding and evaporation



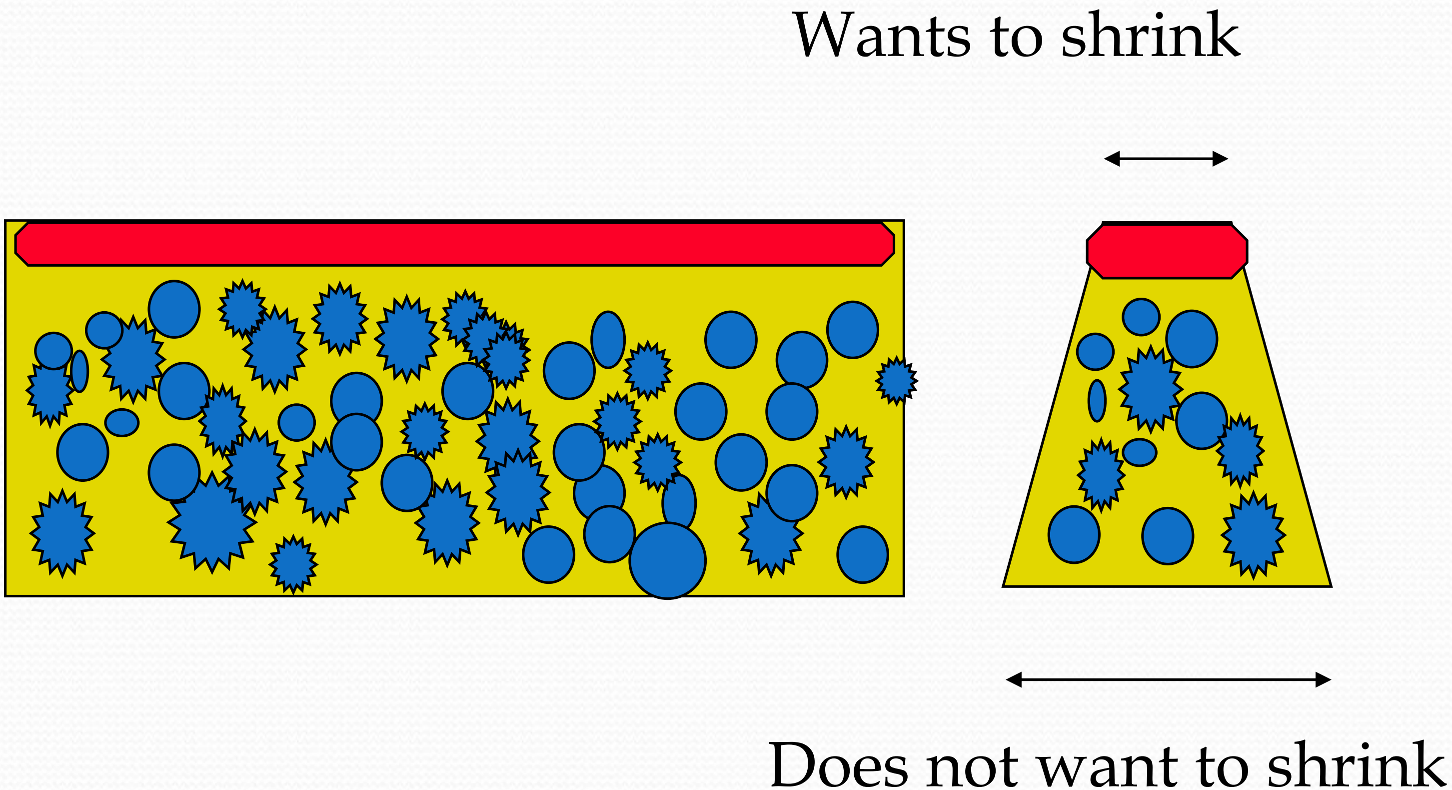
Bleed water = evaporation

Too much evaporation leads to surface cracking

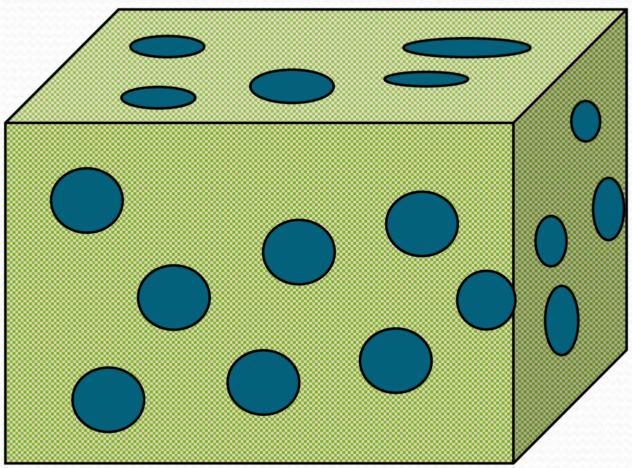


Bleed water < Evaporation

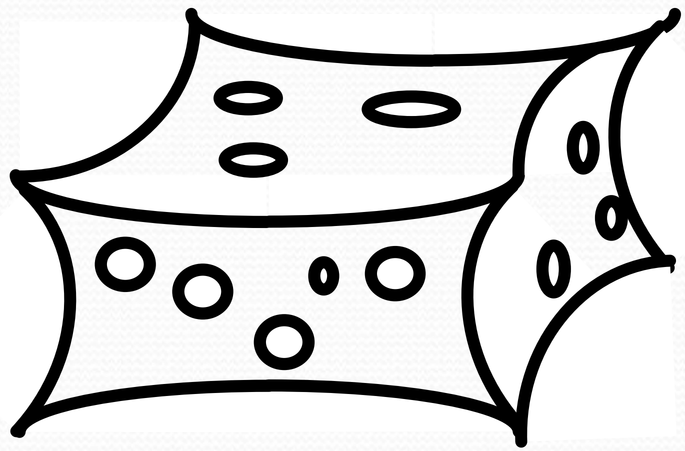
Side diagram of surface contraction



Free Shrinkage, causes volume change, but no stresses

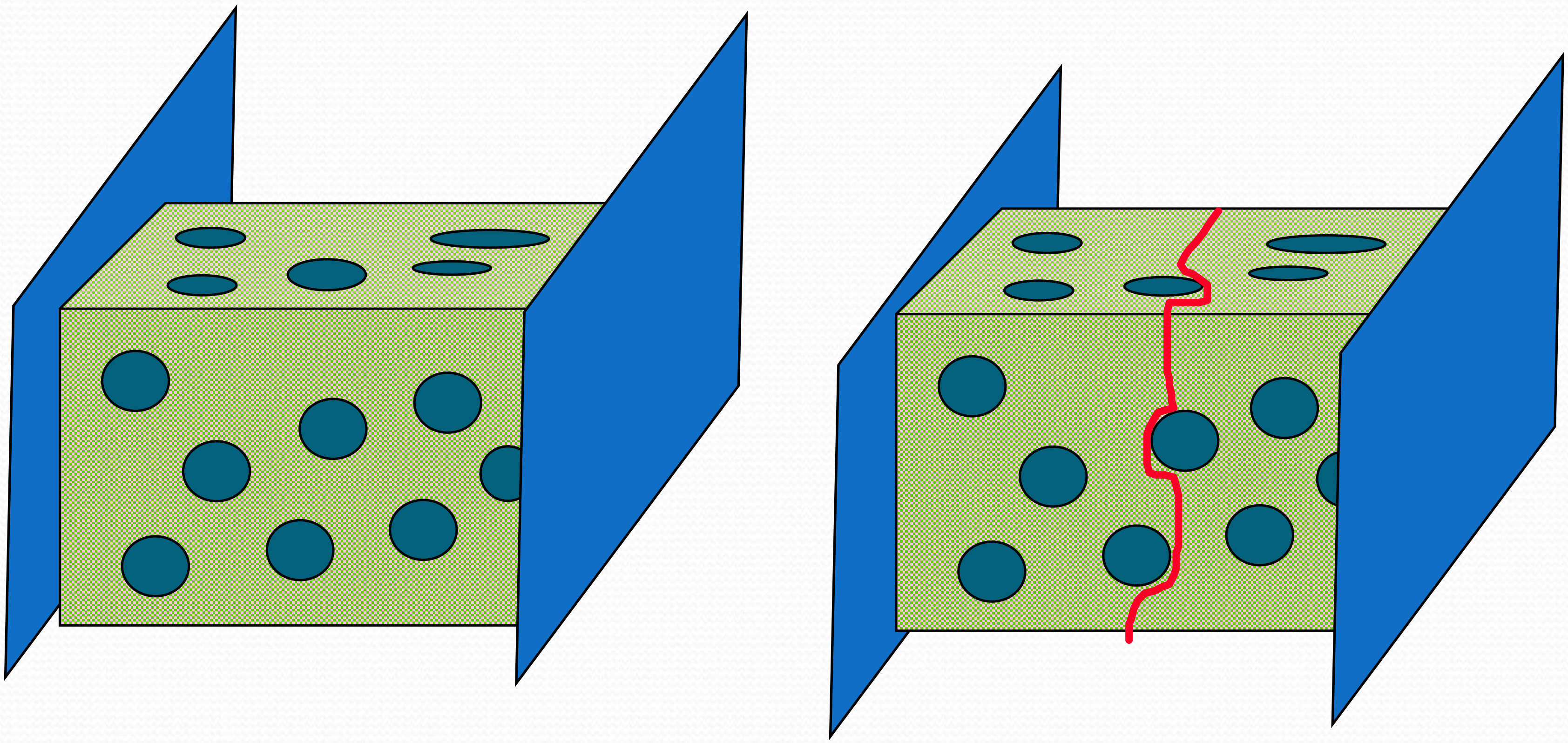


before shrinkage



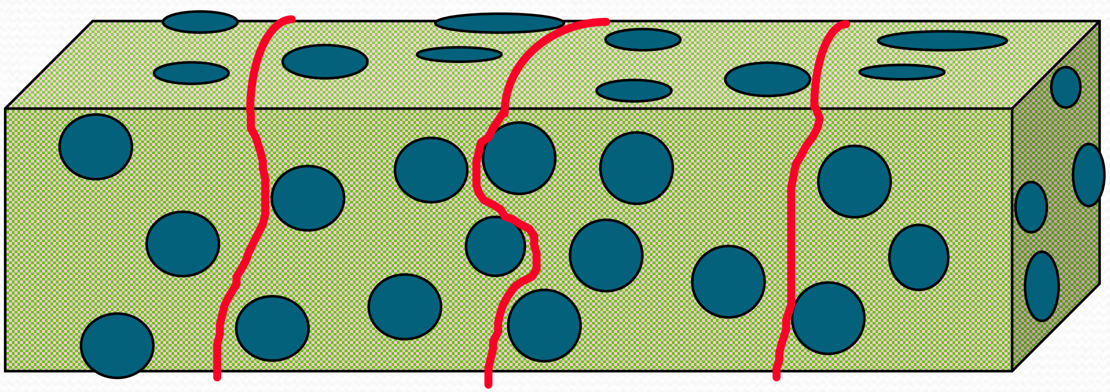
After Shrinkage

Restrained Shrinkage- creates stresses, which may cause cracking



Restrained shrinkage cracking

Parallel cracking perpendicular to the direction of shrinkage



Bleeding and its control

- Creates problems:
  - poor pumpability
  - delays in finishing
  - high w/c at the top
  - poor bond between two layers

- causes
  - lack of fines
  - too much water content
- Remedies
  - more fines
  - adjust grading
  - entrained air
  - reduce water content

Causes of Plastic Shrinkage Cracking

- water evaporates faster than it can reach the top surface
- drying while plastic
- cracking

Plastic Shrinkage Cracking-Remedies

- Control the wind velocity
- reduce the concrete's temperature
  - use ice as mixing water
- increase the humidity at the surface
  - fogging
  - cover w/polyethylene
  - curing compound
- Fiber reinforcement

Curing

- The time needed for the chemical reaction of portland cement with water.

Curing tips

- water
- do not let it dry
- dry concrete = dead concrete, all reactions stop
- can not revitalize concrete after it dries
- keep temperature at a moderate level
- concrete with fly ash requires longer curing

Temperature effects on curing

- The higher the temperature the faster the curing
- best temperature is room temperature
- If concrete freezes during the first 24 hrs., it may never be able to attain its original properties.

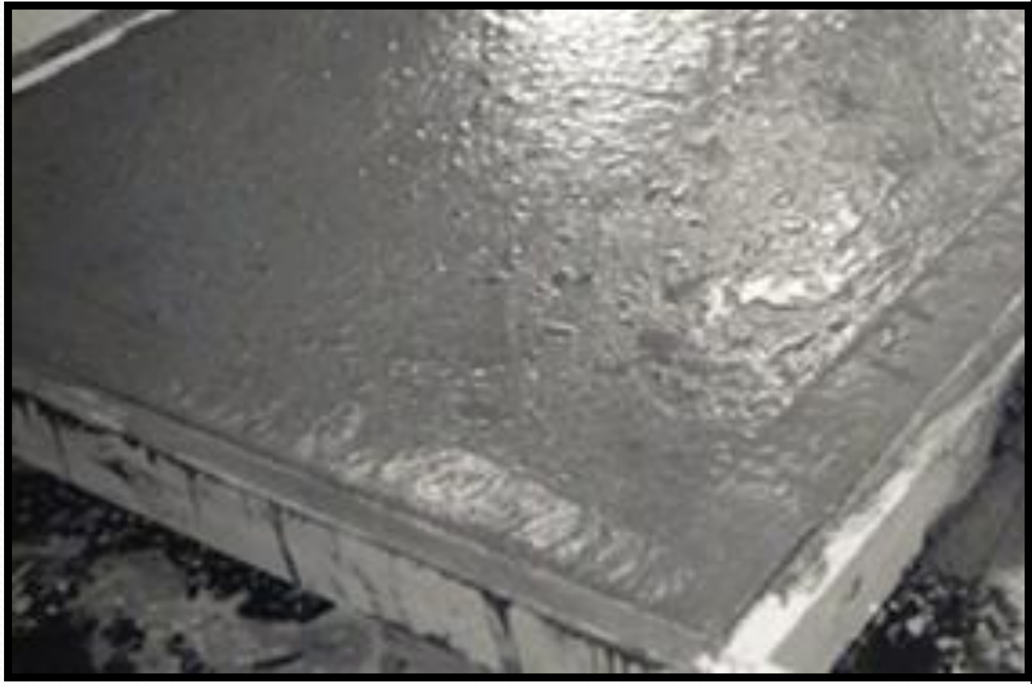
Temperature effects on curing

- real high temperatures can cause serious damage since cement may set too fast.
- accelerated curing procedures produce strong concrete, but durability might suffer.
- autoclave curing.

BLEEDING

- Bleeding is the tendency of water to rise to the surface of freshly placed concrete.

- It is caused by the inability of solid constituents of the mix to hold all of the mixing water as they settle down.
- A special case of segregation.



BLEEDING

Undesirable effects of bleeding are:

- With the movement of water towards the top, the top portion becomes weak & porous (high w/c). Thus the resistance of concrete to freezing-thawing decreases.
- Water rising to the surface carry fine particles of cement which weaken the top portion and form laitance. This portion is not resistant to abrasion.
- Water may accumulate under the coarse agg. and reinforcement. These large voids under the particles may lead to weak zones and reduce the bond between paste and agg. or paste and reinforcement.

BLEEDING

The tendency of concrete to bleeding depends largely on properties of cement. It is decreased by:

- Increasing the fineness of cement
- Increasing the rate of hydration (C_3S, C_3A and alkalies)
- Adding pozzolans
- Reducing water content

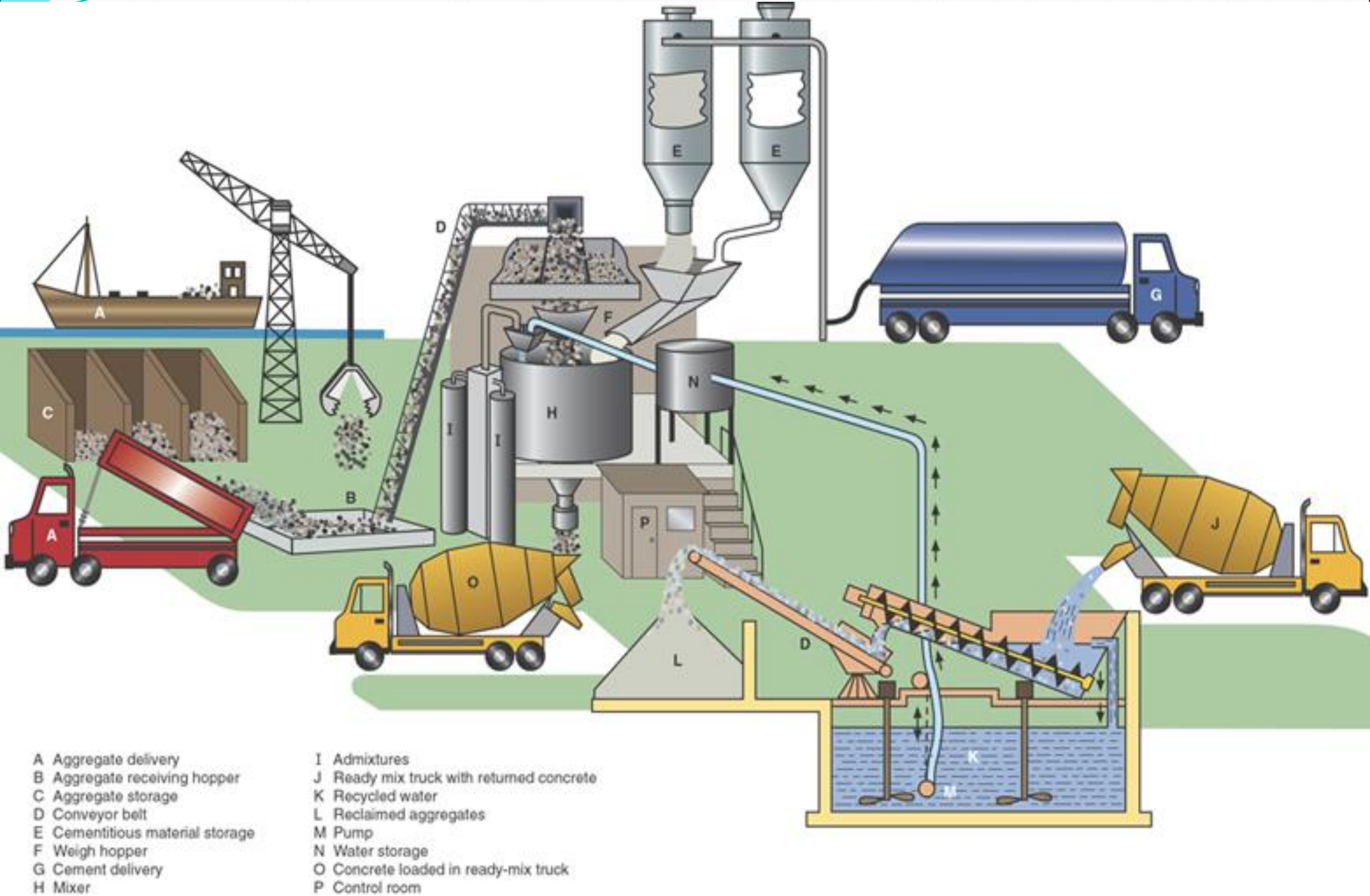
MIXING OF CONCRETE

- The aim of mixing is to blend all of the ingredients of the concrete to form a uniform mass and to coat the surface of aggregates with cement paste.

MIXING OF CONCRETE

- Ready-Mix concrete: In this type ingredients are introduced into a mixer truck and mixed during transportation to the site.
  - Wet – Water added before transportation
  - Dry – Water added at site
- Mixing at the site
  - Hand mixed
  - Mixer mixed

Ready Mix Concrete



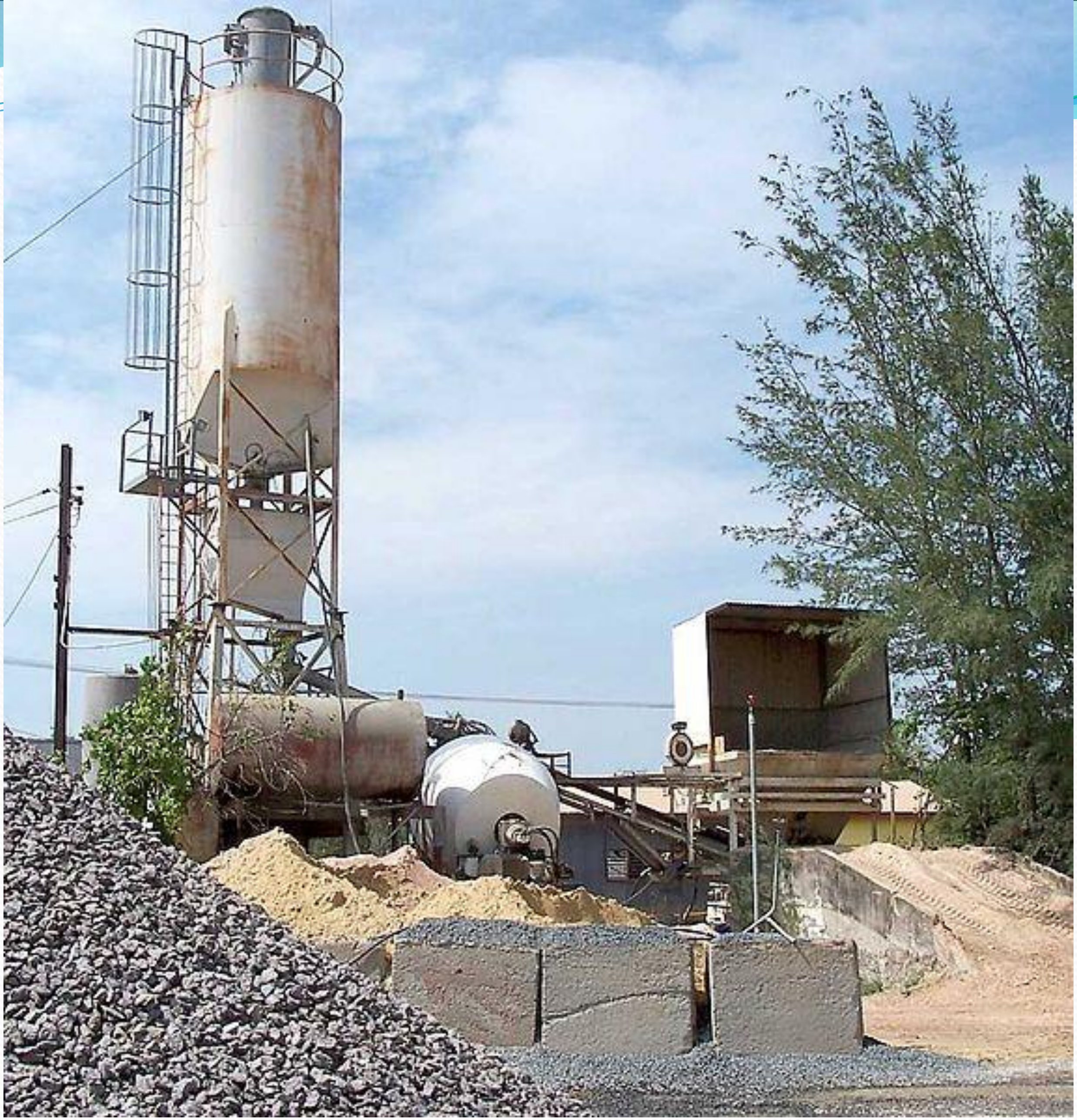
Mixing at Site

MIXING OF CONCRETE

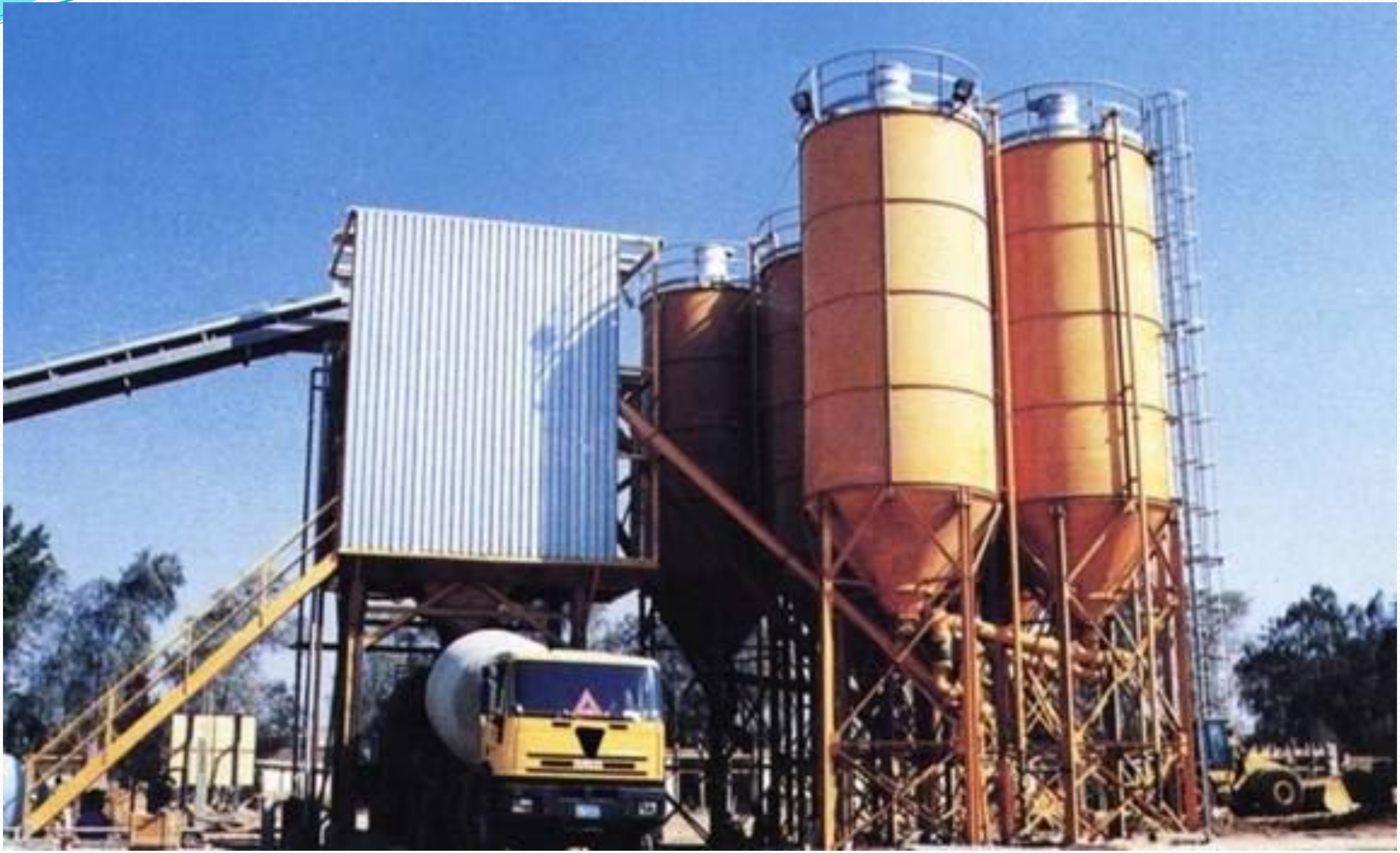
Mixing time should be sufficient to produce a uniform concrete. The time of mixing depends on the type of mixer and also to some properties of fresh concrete.

- Undermixing → non-homogeneity
- Overmixing → danger of water loss, brekage of aggregate particles

Mixing Equipment



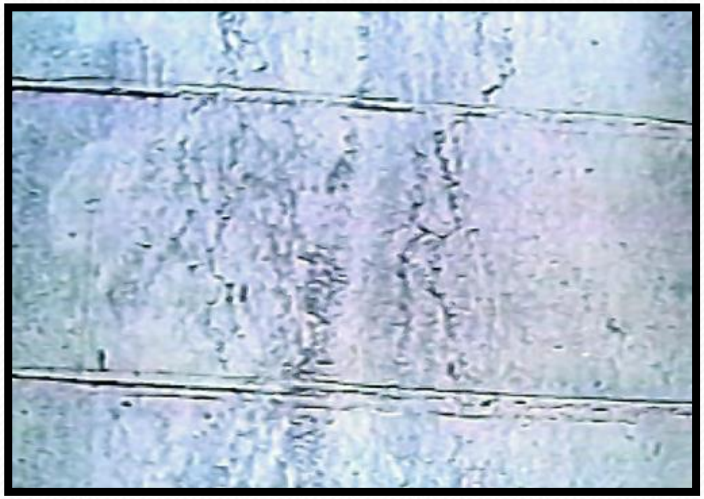
small batching plant for local small deliveries




Mini Concrete Mixer

This portable concrete/mortar mixer has wheels and a towing tongue so that it can be towed by a motor vehicle and moved around the worksite by hand, and its rotation is powered by mains electricity. The lever allows the concrete/mortar to be tipped into a wheelbarrow.

CONSOLIDATING CONCRETE



Inadequate consolidation can result in:

- Honeycomb
- Excessive amount of entrapped air voids (bugholes)
- Sand streaks
- Placement lines (Cold joints)

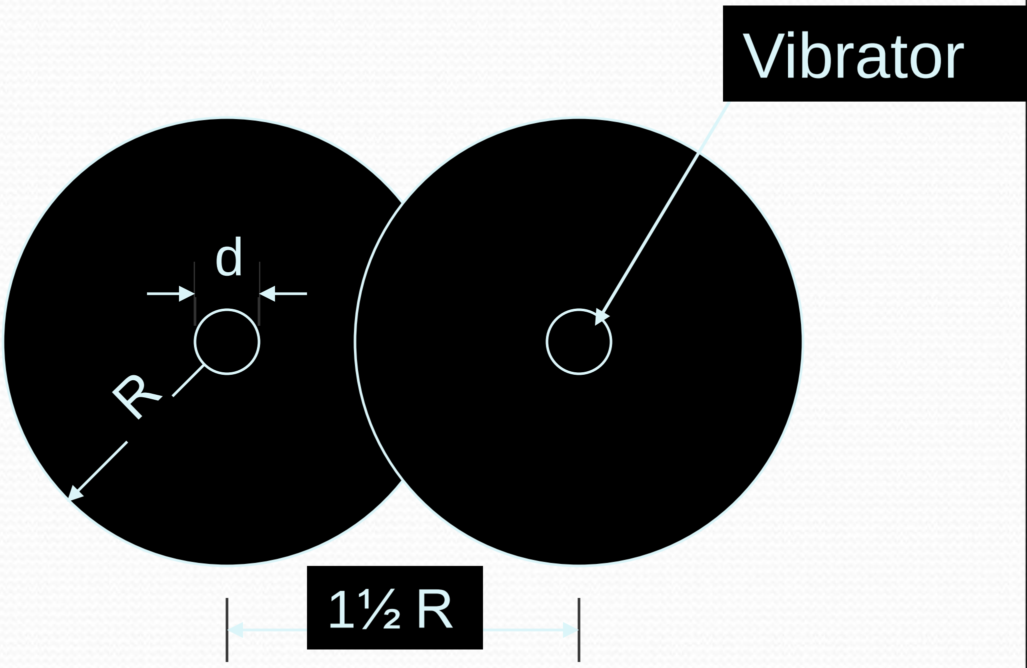
VIBRATION OF CONCRETE

- The process of compacting concrete consists essentially of the elimination of entrapped air. This can be achieved by:
  - Tamping or rodding the concrete
  - Use of vibrators

VIBRATORS

- Internal vibrator: The poker is immersed into concrete to compact it. The poker is easily removed from point to point.
- External vibrators: External vibrators clamp direct to the formwork requiring strong, rigid forms.

Internal Vibration



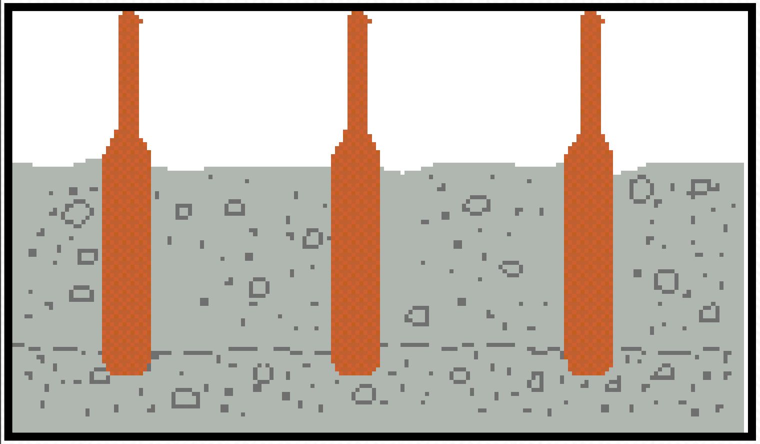
Radius of Action

Internal Vibrators

Adapted from ACI 309

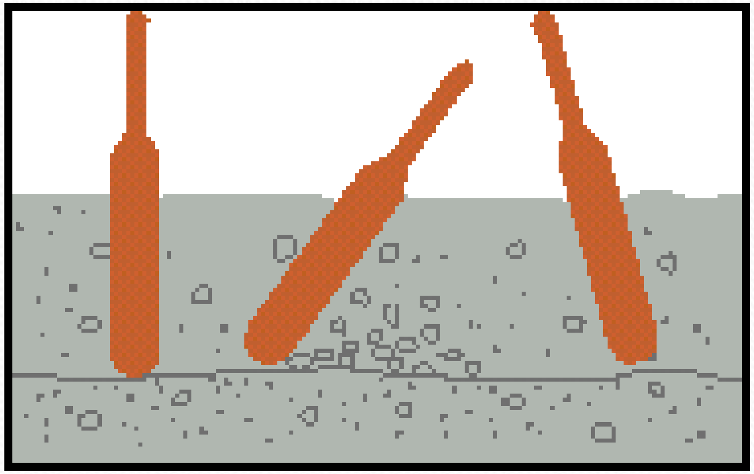
Diameter of head, (mm)	Recommended frequency, (vib./min.)	Approximate radius of action, (mm)	Rate of placement, (m^3/h)	Application
20-40	9000-15,000	80-150	0.8-4	Plastic and flowing concrete in thin members. Also used for lab test specimens.
30-60	8500-12,500	130-250	2.3-8	Plastic concrete in thin walls, columns, beams, precast piles, thin slabs, and along construction joints.
50-90	8000-12,000	180-360	4.6-15	Stiff plastic concrete (less than 80-mm slump) in general construction .

Systematic Vibration



CORRECT

Vertical penetration a few inches into previous lift (which should not yet be rigid) of systematic regular intervals will give adequate consolidation



INCORRECT

Haphazard random penetration of the vibrator at all angles and spacings without sufficient depth will not assure intimate combination of the two layers

Internal Vibrators

- To aid in the removal of trapped air the vibrator head should be rapidly plunged into the mix and slowly moved up and down.

- **The actual completion of vibration is judged by the appearance of the concrete surface which must be neither rough nor contain excess cement paste.**

External Vibrators

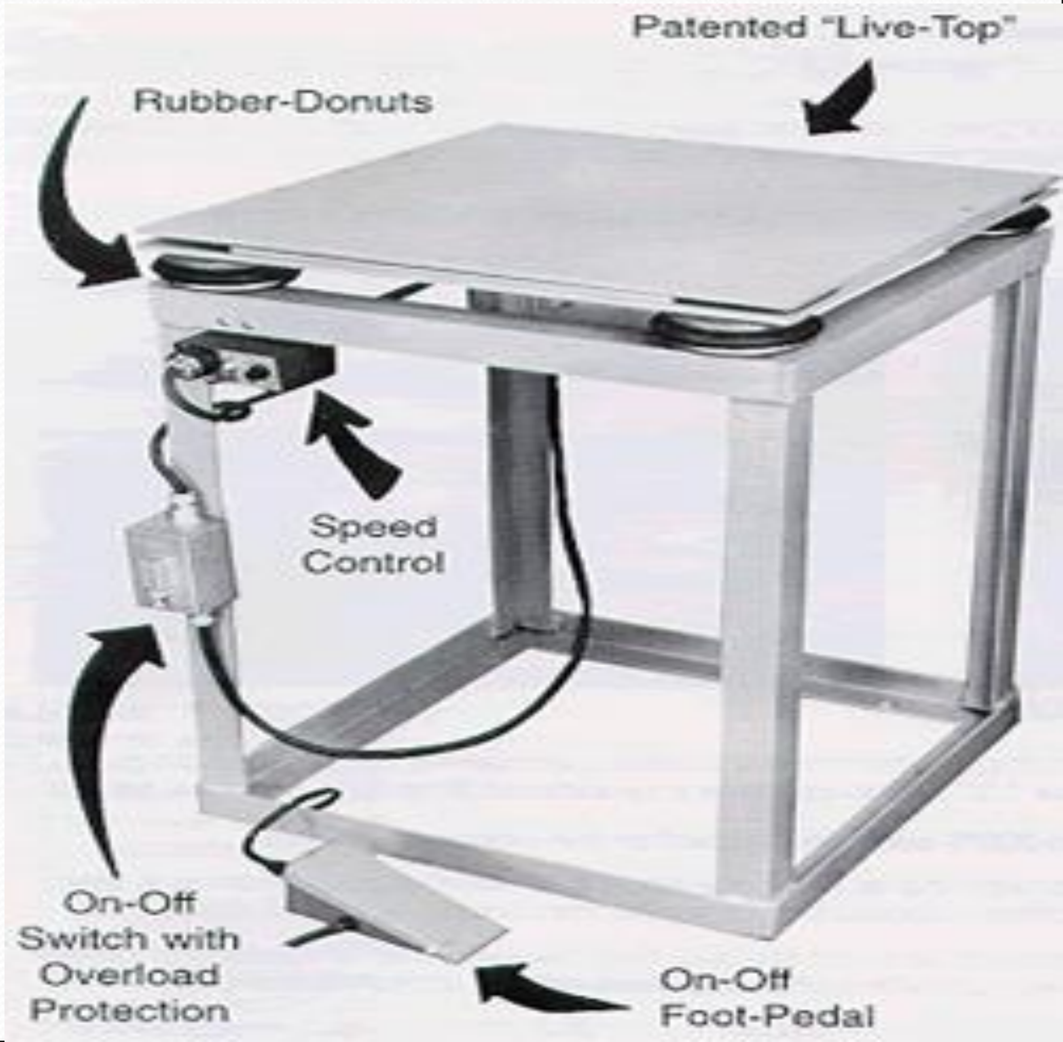
- Form vibrators
- Vibrating tables (Lab)
- Surface vibrators
  - Vibratory screeds
  - Plate vibrators
  - Vibratory roller screeds
  - Vibratory hand floats or trowels

External Vibrators

- External vibrators are rigidly clamped to the formwork so that both the form & concrete are subjected to vibration.
- A considerable amount of work is needed to vibrate forms.
- Forms must be strong and tied enough to prevent distortion and leakage of the grout.

External Vibrators

- Vibrating Table: used for small amounts of concrete (laboratory and some precast elements)



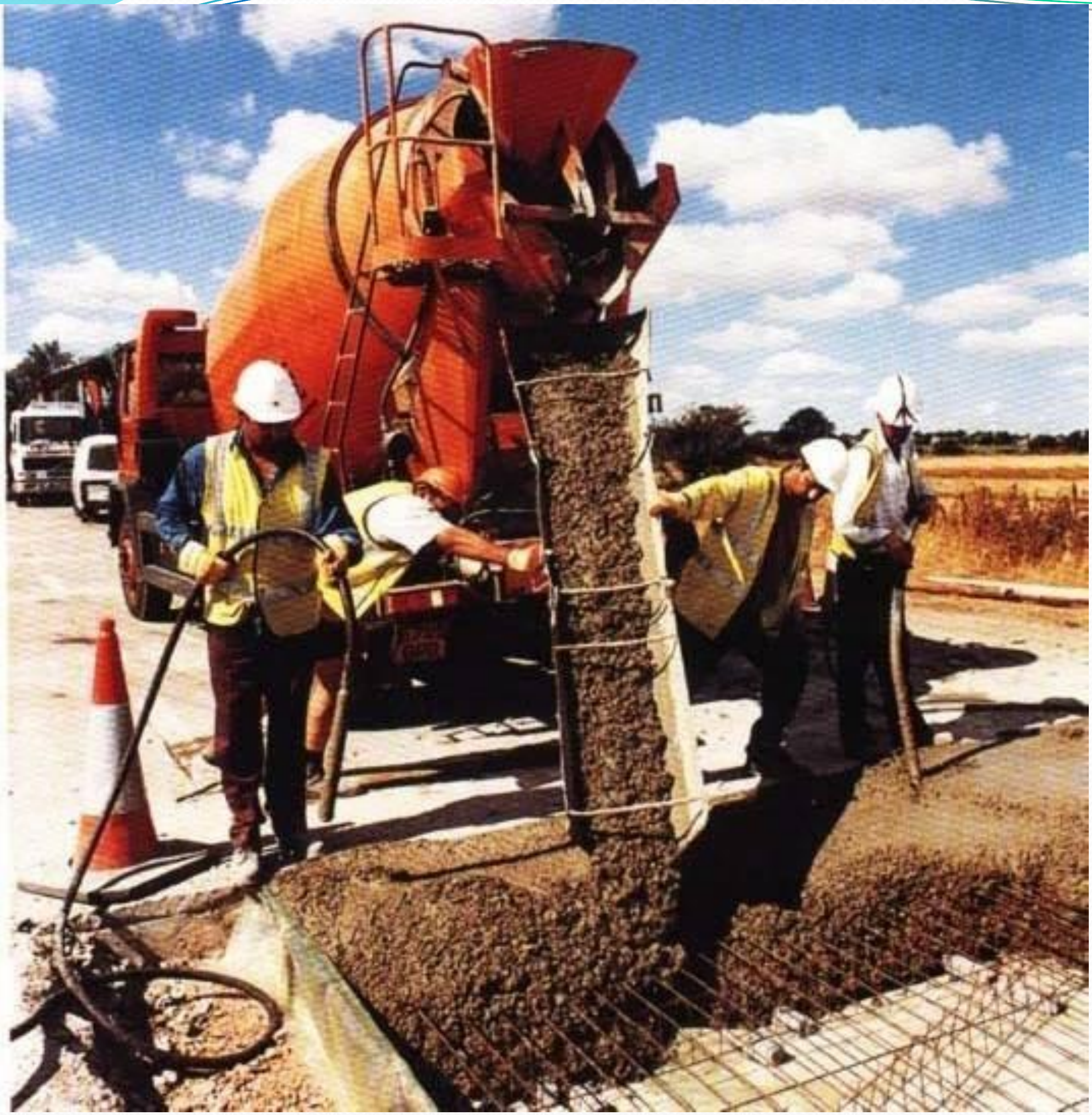
Concrete Transporting Equipment

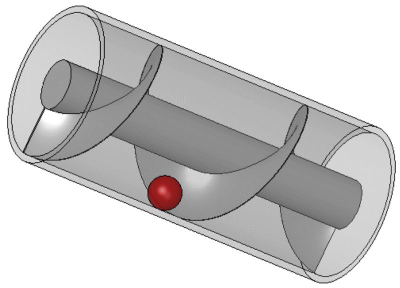
A rear–discharge concrete transport truck

Volumetric Concrete Mixer

7 cuM. transit mixer

1.6cum. transit mixer





The inside of a transit mixer uses a simple Archimedes' screw to mix and to lift the concrete to the delivery chute.

Mixer truck with attached pump and long–reach boom. Trailerable pumping rigs use hoses

•Mobile

Mobile crane

The most basic type of mobile crane consists of a truss or telescopic boom mounted on a mobile platform - be it on road, rail or water.

Truck-mounted crane

A crane mounted on a truck carrier provides the mobility for this type of crane. Generally, these cranes are able to travel on highways, eliminating the need for special equipment to transport the crane. When working on the jobsite, outriggers are extended horizontally from the chassis then vertically to level and stabilize the crane while stationary and hoisting.

Truck-mounted crane

All terrain crane

A mobile crane with the necessary equipment to travel at speed on public roads, and on rough terrain at the job site using all-wheel and crab steering. AT's combine the roadability of Truck-mounted Cranes and the manoeuvrability of Rough Terrain Cranes.

Fixed

Exchanging mobility for the ability to carry greater loads and reach greater heights due to increased stability, these types of cranes are characterised that they, or at least their main structure does not move during the period of use. However, many can still be assembled and disassembled.

Tower crane

Tower cranes are a modern form of balance crane that consist of the same basic parts. Fixed to the ground on a concrete slab (and sometimes attached to the sides of structures as well), tower cranes often give the best combination of height and lifting capacity and are used in the construction of tall buildings.

Self-erecting crane


Compactors Types

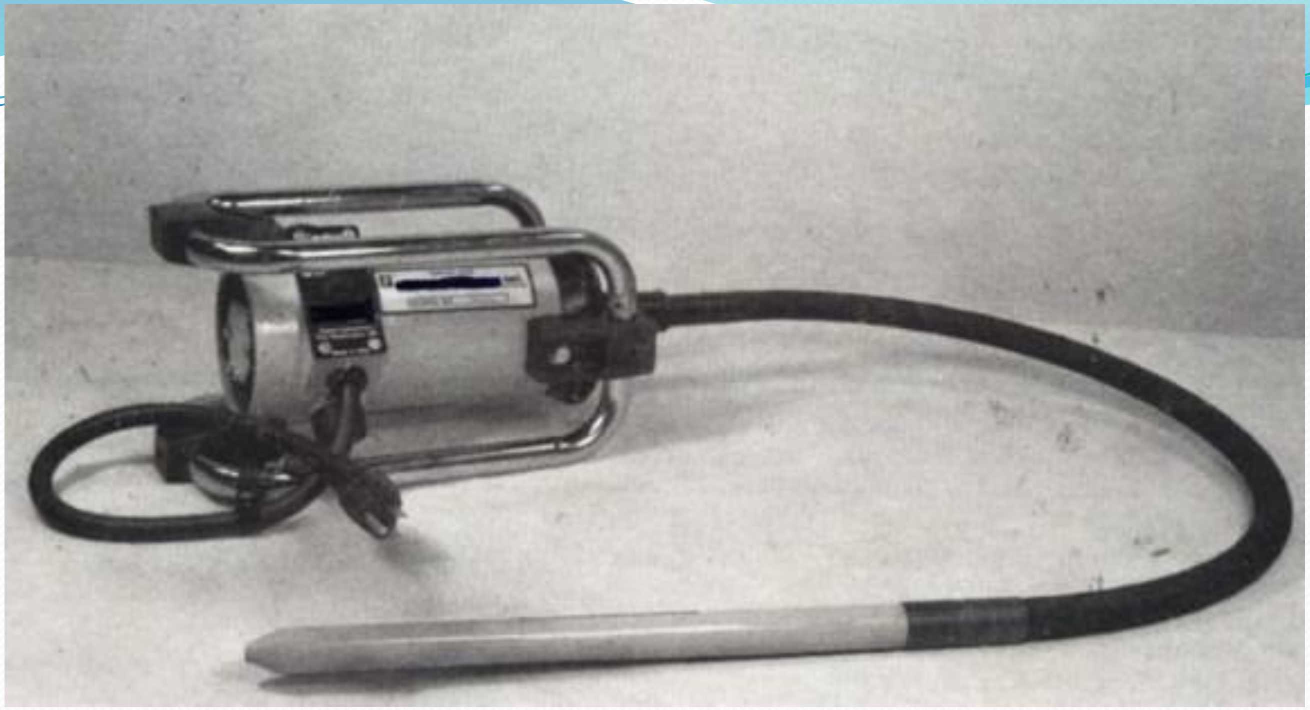
Vibrators & Compactors الهزازات و الدكاكات

Plate Compactor MS60(previous MS10)

Tamping Rammer(MR68H, MR75R

"Jumping Jack" compactor

The jumping jack type is mainly used to compact the backfill in narrow trenches for water or gas supply pipes etc.



Vibrators are used in many different industrial applications both as components and as individual pieces of equipment.

Concrete vibrators consolidate freshly poured concrete so that trapped air and excess water are released and the concrete settles firmly in place in the formwork. Improper consolidation of concrete can cause product defects, compromise the concrete strength, and produce surface blemishes such as bug holes and honeycombing. An internal concrete vibrator is a steel cylinder about the size of the handle of a baseball bat, with a hose or electrical cord attached to one end. The vibrator head is immersed in the wet concrete.

External concrete vibrators attach, via a bracket or clamp system, to the concrete forms. There are a wide variety of external concrete vibrators available and some vibrator manufacturers have bracket or clamp systems designed to fit the major brands of concrete forms. External concrete vibrators are available in hydraulic, pneumatic or electric power.

Motor

Concrete Vibrator (poker/الزمبة)

Poker (الزمبة)

Transformer to operate the vibrator

A **compactor** eht ecuder ot desu msinahcem ro enihcam a si .noitcapmoc hguorht lios ro lairetam etsaw fo ezis

portable vibrator poker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Powered by




concrete-boom-pump-truck

[Electromotor]()

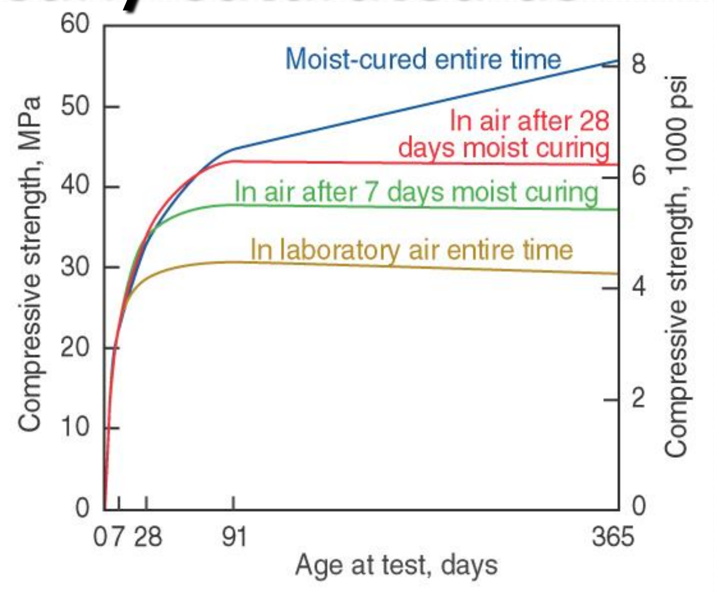
Concrete Boom Pump

CURING OF CONCRETE

- Properties of concrete can improve with age as long as conditions are favorable for the continued hydration of cement. These improvements are rapid at early ages and continues slowly for an indefinite period of time.
- Curing is the procedures used for promoting the hydration of cement and consists of a control of temperature and the moisture movement from and into the concrete.

CURING OF CONCRETE

- **The primary objective of curing is to keep concrete saturated or as nearly saturated as possible.**
- Hydration reactions can take place in only saturated water filled capillaries.



Curing Methods

1. Methods which supply additional water to the surface of concrete during early hardening stages.
   - Using wet covers
   - Sprinkling
   - Ponding

Curing Methods

2. Methods that prevent loss of moisture from concrete by sealing the surface.
   - Water proof plastics
   - Use liquid membrane-forming compounds
   - Forms left in place

Curing Methods

3. Methods that accelerate strength gain by supplying heat & moisture to the concrete.
   - By using live steam (steam curing)
   - Heating coils.

Hot Weather Concrete

- Rapid hydration → early setting → rapid loss of workability
- Extra problems due to
  - Low humidity
  - Wind, excessive evaporation
  - Direct sunlight

Solutions

Low heat of hydration cement

Pozzolans

Set retarders

  - Windbreaks
  - Cooled Concrete Ingredients
  - Water ponding (cooling due to evaporation)
  - Reflective coatings/coverings

Cold Weather Concrete

- Keep concrete temperature above 5 °C to minimize danger of freezing

Solutions

High early strength cement (and hydration heat high)

Increase cement content, decrease W/C ratio

Accelarators

- Heated enclosures, insulation
- Rely on heat of hydration for larger sections
- Heated ingredients --- concrete hot when placed
- High early strength cement

UNIFORMITY OF CONCRETE

- Concrete uniformity is checked conducting tests on fresh and hardened concretes.
  - Slump, unit weight, air content tests
  - Strength tests

UNIFORMITY OF CONCRETE

- Due to heteregeneous nature of concrete, there will always be some variations. These variations are grouped as:
  - Within-Batch Variations : inadequate mixing, non-homogeneous nature
  - Batch-to-Batch Variations : type of materials used, changes in gradation of aggregates, changes in moisture content of aggregates

PROPERTIES OF HARDENED CONCRETE

- The principal properties of hardened concrete which are of practical importance can be listed as:

1. Strength
2. Permeability & durability
3. Shrinkage & creep deformations
4. Response to temperature variations

Of these compressive strength is the most important property of concrete. Because;

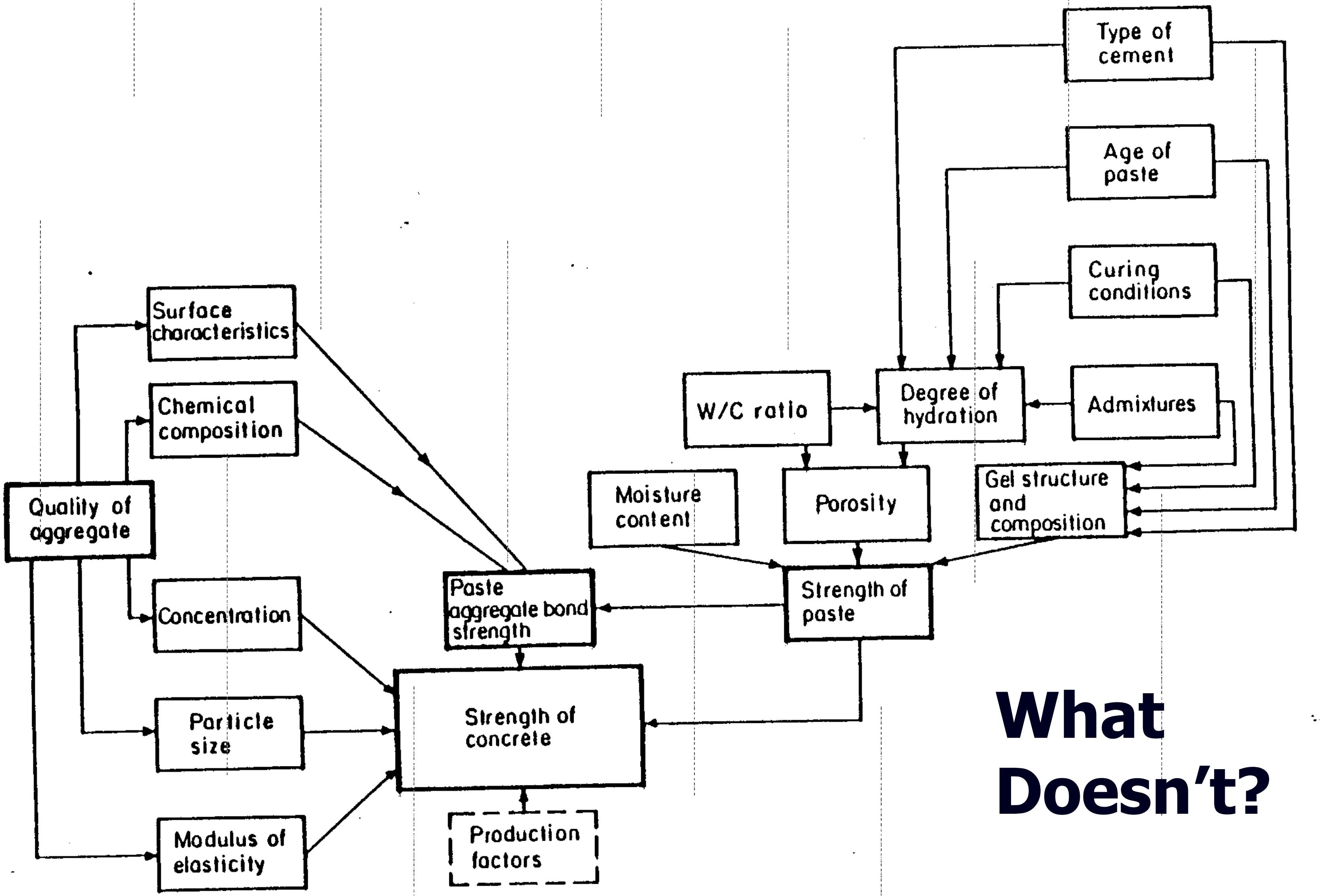
PROPERTIES OF HARDENED CONCRETE

Of the abovementioned hardened properties compressive strength is one of the most important property that is often required, simply because;

1. Concrete is used for compressive loads
2. Compressive strength is easily obtained
3. It is a good measure of all the other properties.


AMERICAN ENGINEERING TESTING, INC.

What Affects Concrete Strength



What Doesn't?

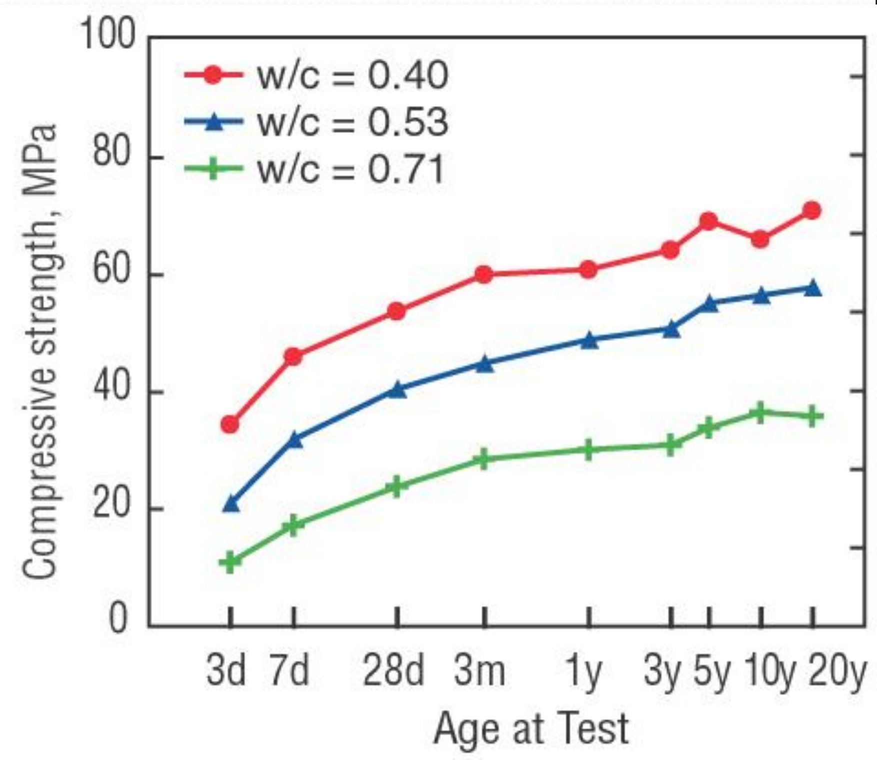
Factors Affecting Strength

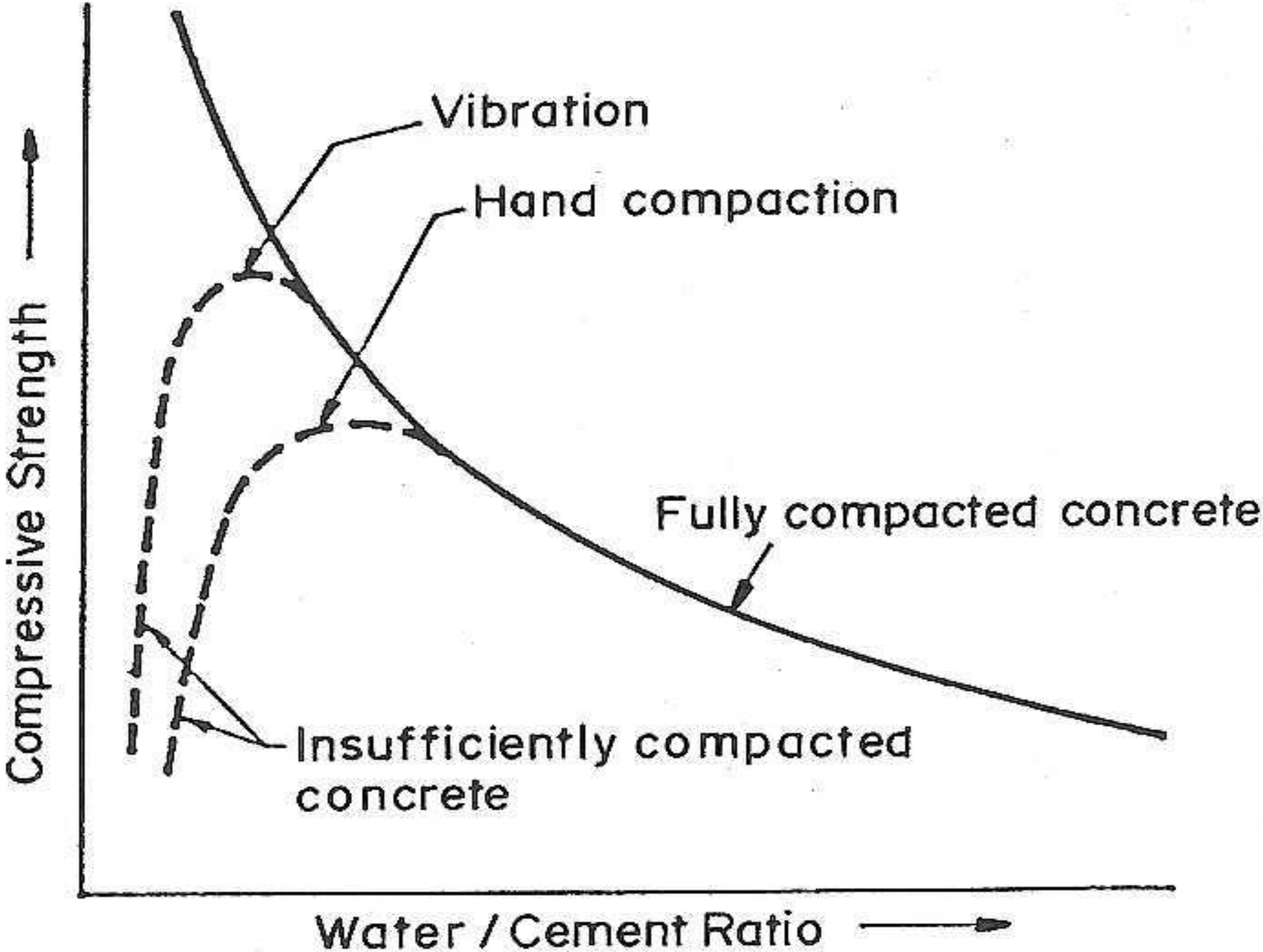
- Effect of materials and mix proportions
- Production methods
- Testing parameters

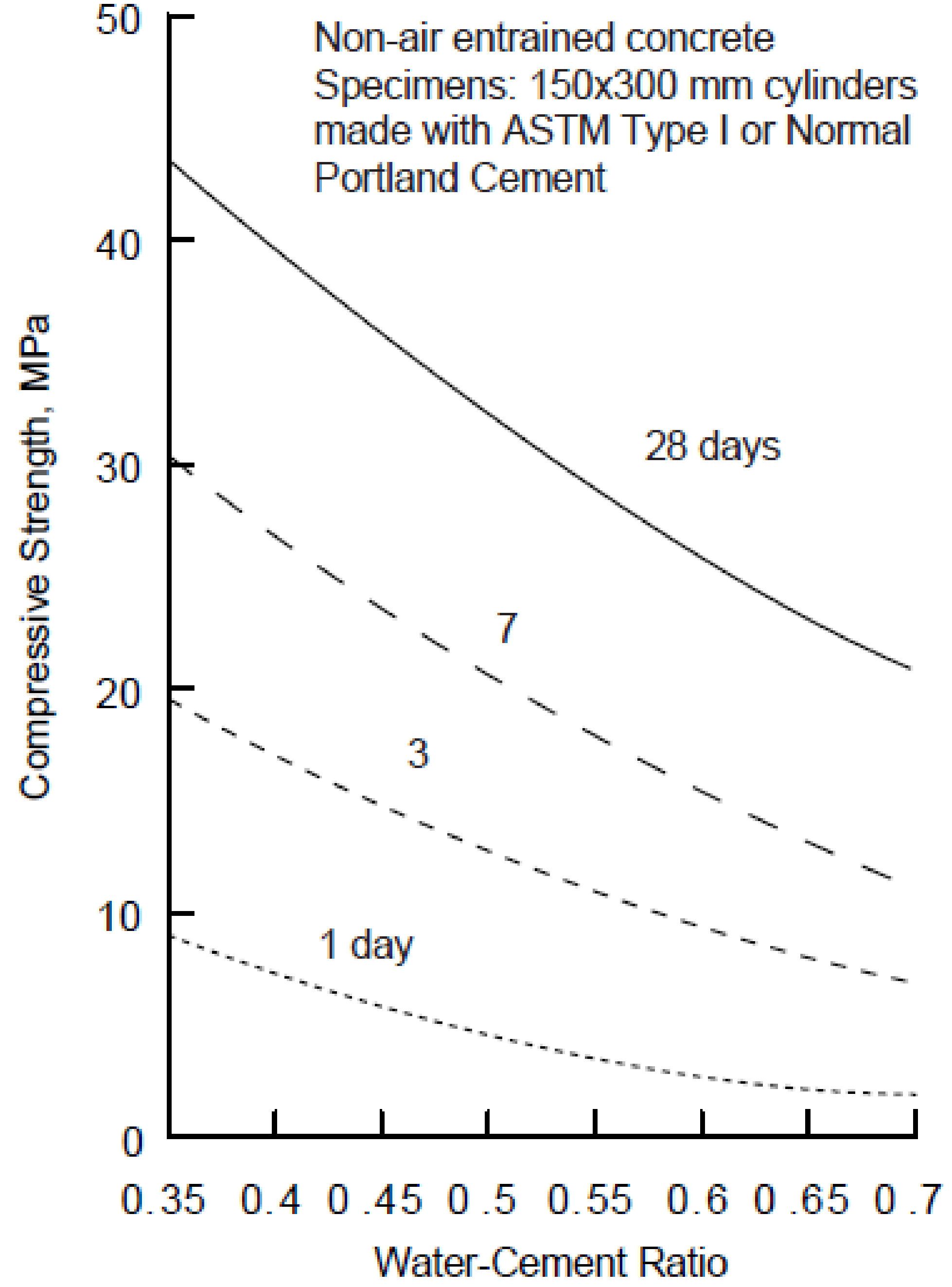
STRENGTH OF CONCRETE

- The strength of a concrete specimen prepared, cured and tested under specified conditions at a given age depends on:

1. w/c ratio
2. Degree of compaction



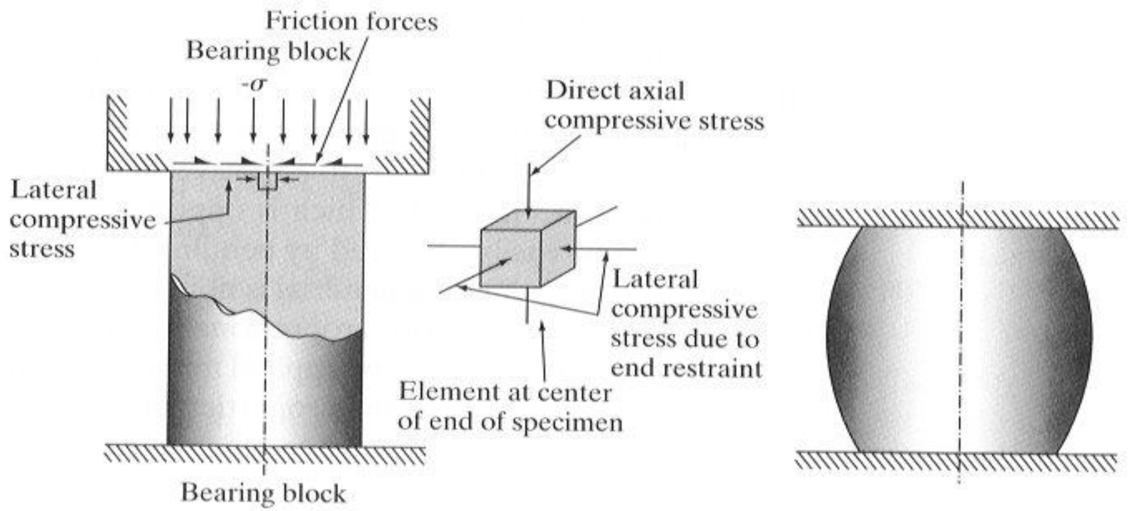

Vibration
Hand compaction
Fully compacted concrete
Insufficiently compacted concrete
Compressive Strength
Water / Cement Ratio



Non-air entrained concrete
Specimens: 150x300 mm cylinders
made with ASTM Type I or Normal
Portland Cement
28 days
7
3
1 day
Compressive Strength, MPa
0
10
20
30
40
50
0.35
0.4
0.45
0.5
0.55
0.6
0.65
0.7
Water-Cement Ratio

COMPRESSIVE STRENGTH

- <u>Compressive Strength</u> is determined by loading properly prepared and cured cubic, cylindrical or prismatic specimens under compression.



(a) End restraint in compression

(b) Barrel-shaped specimen resulting from end restraint

COMPRESSIVE STRENGTH

- Cubic: 15x15x15 cm

  Cubic specimens are crushed after rotating them 90° to decrease the amount of friction caused by the rough finishing.

- Cylinder: h/D=2 with h=15

  To decrease the amount of friction, capping of the rough casting surface is performed.

COMPRESSIVE STRENGTH

Bonded sulphur capping

Unbonded neoprene pads

STRENGTH CLASSES (TS EN 206-1)

- The compressive strength value depends on the shape and size of the specimen.

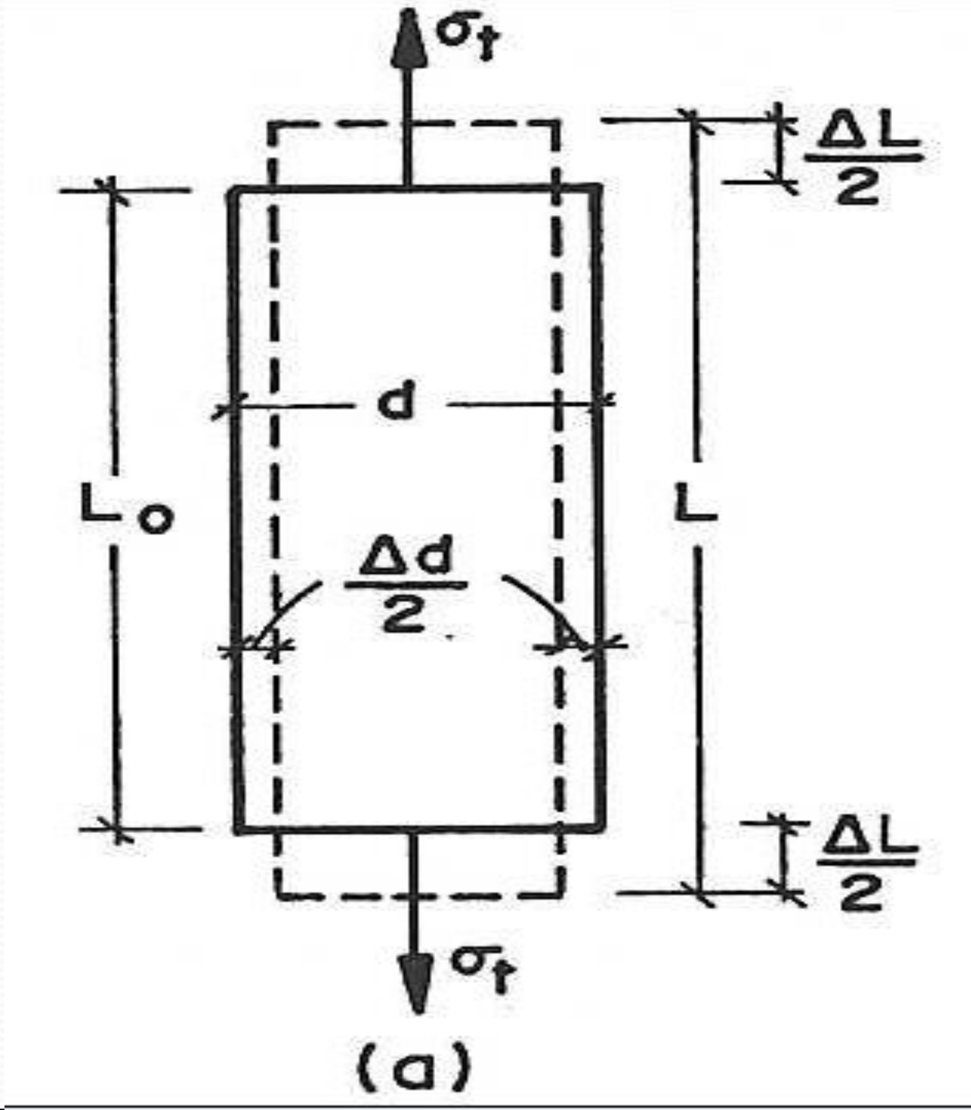
Basınç dayanımı sınıfı	En düşük karakteristik silindir dayanımı $f_{ck,sil}$ N/mm^2	En düşük karakteristik küp dayanımı $f_{ck,küp}$ N/mm^2
C 8/10	8	10
C 12/15	12	15
C 16/20	16	20
C 20/25	20	25
C 25/30	25	30
C 30/37	30	37
C 35/45	35	45
C 40/50	40	50
C 45/55	45	55
C 50/60	50	60
C 55/67	55	67
C 60/75	60	75
C 70/85	70	85
C 80/95	80	95
C 90/105	90	105
C 100/115	100	115

TENSILE STRENGTH

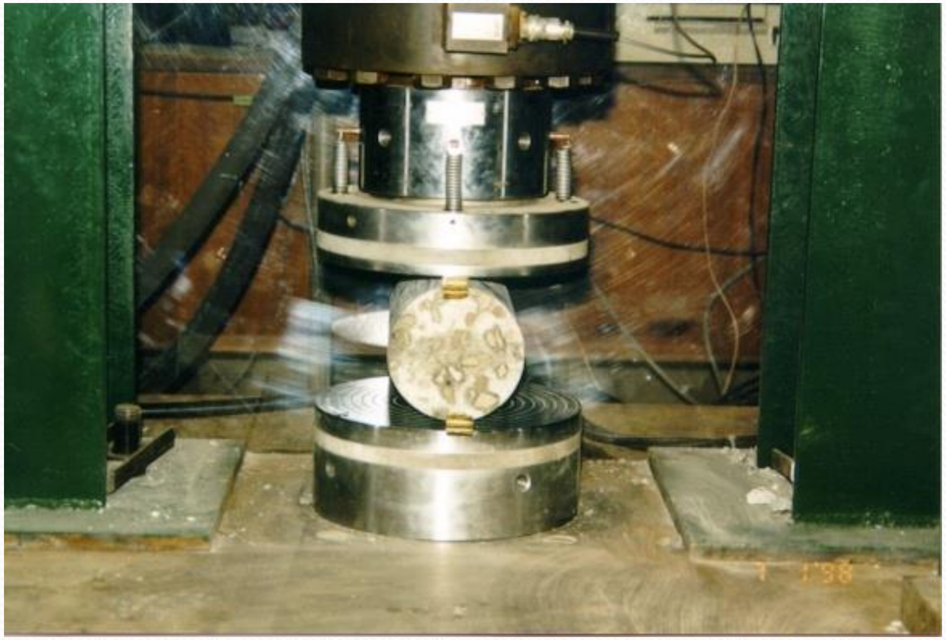
- Tensile Strength can be obtained either by direct methods or indirect methods.

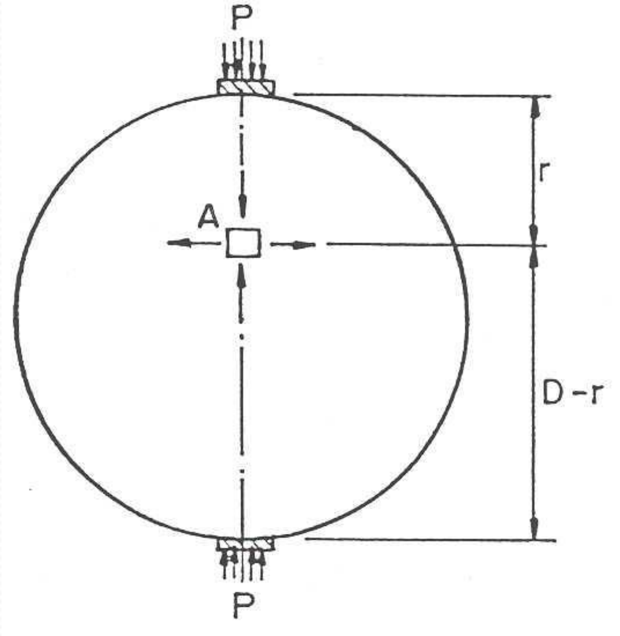
  Direct methods suffer from a number of difficulties related to holding the specimen properly in the testing machine without introducing stress concentration and to the application of load without eccentricity.

DIRECT TENSILE STRENGTH



SPLIT TENSILE STRENGTH





Due to applied compression load a fairly uniform tensile stress is induced over nearly 2/3 of the diameter of the cylinder perpendicular to the direction of load application.

$$\sigma_{st} = \frac{2P}{\pi D l}$$

Splitting Tensile Strength

P: applied compressive load

D: diameter of specimen

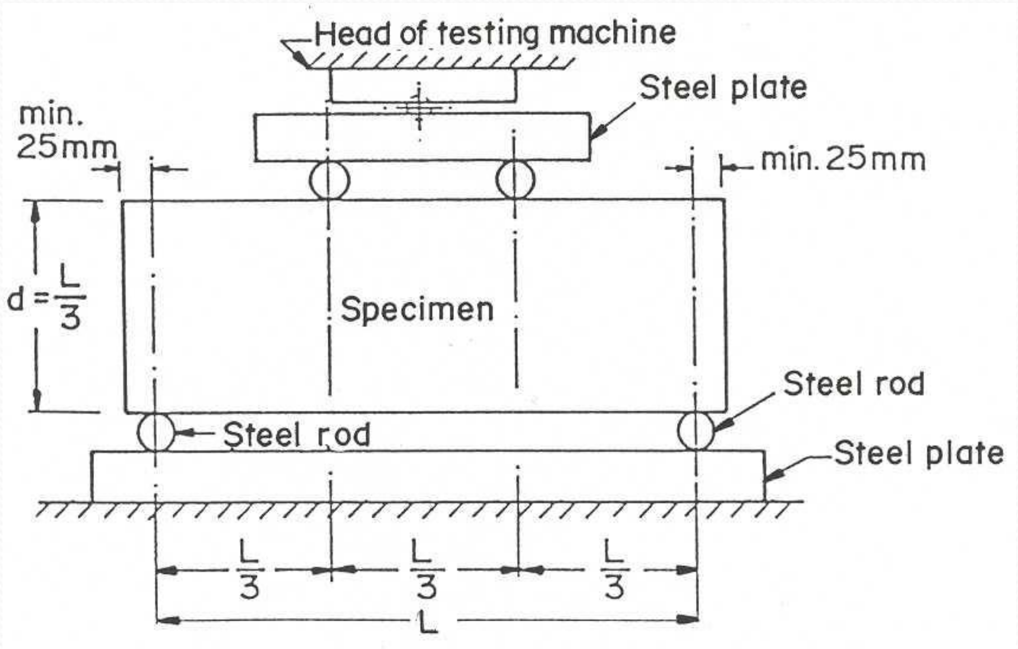
l: length of specimen

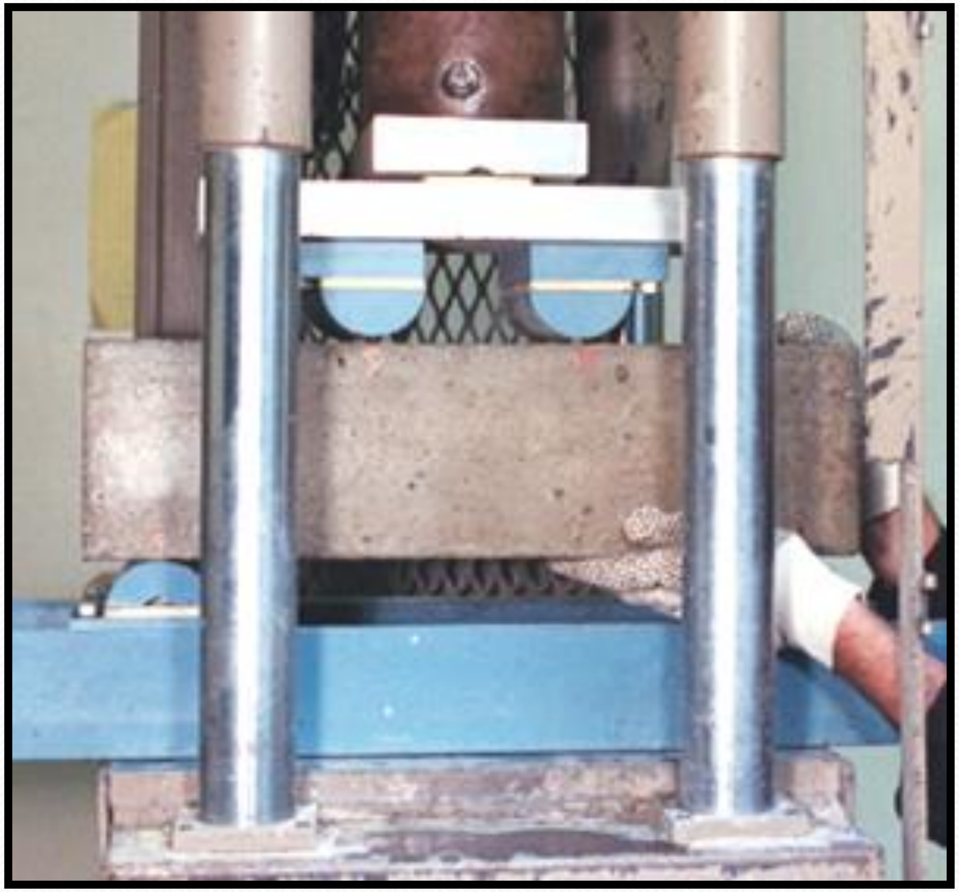
- The advantage of the splitting test over the direct tensile test is the same molds are used for compressive & tensile strength determination.
- The test is simple to perform and gives uniform results than other tension tests.

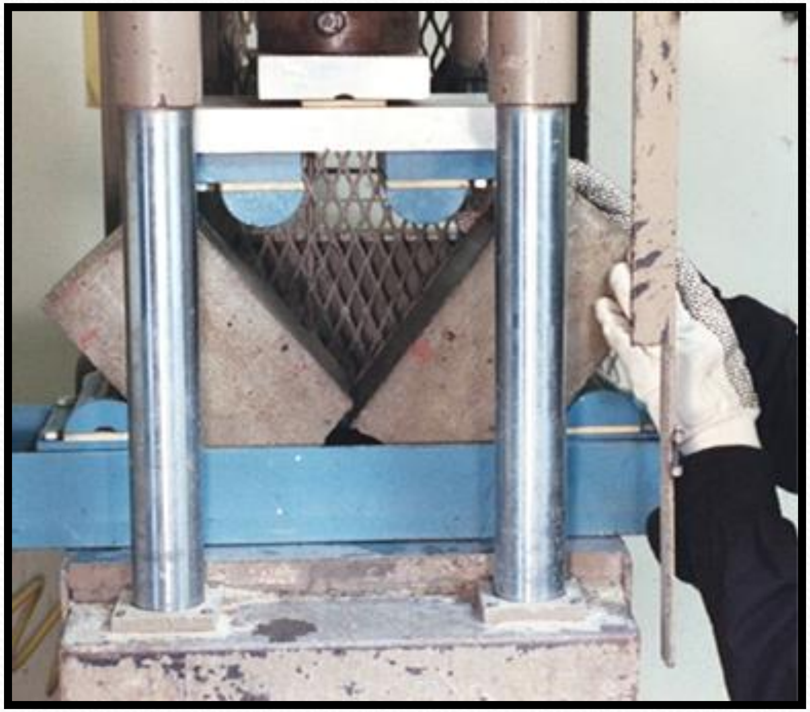
FLEXURAL STRENGTH

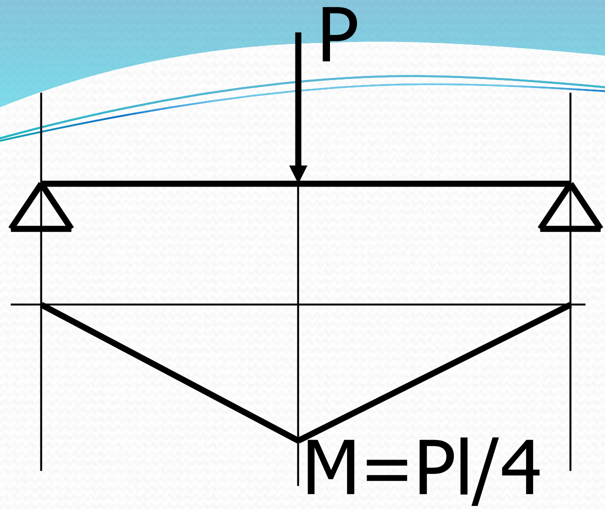
The flexural tensile strength at failure or the modulus of rupture is determined by loading a prismatic concrete beam specimen.

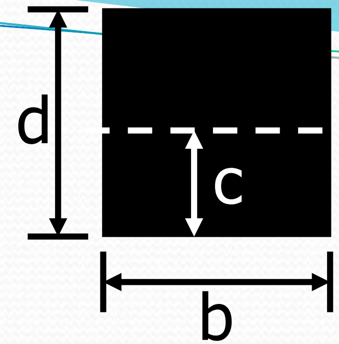
The results obtained are useful because concrete is subjected to flexural loads more often than it is subjected to tensile loads.





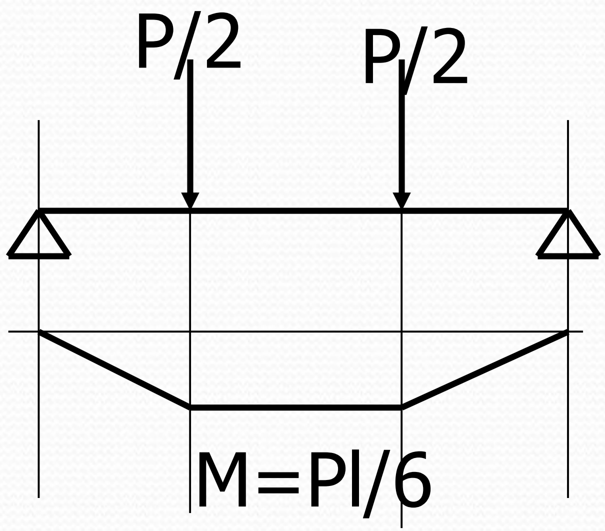






$$I = \frac{bd^3}{12}$$

$$\sigma = \frac{M\,c}{I} = \frac{(Pl/4)\,(d/2)}{bd^3/12} = \frac{3}{2}\;\frac{Pl}{bd^2}$$

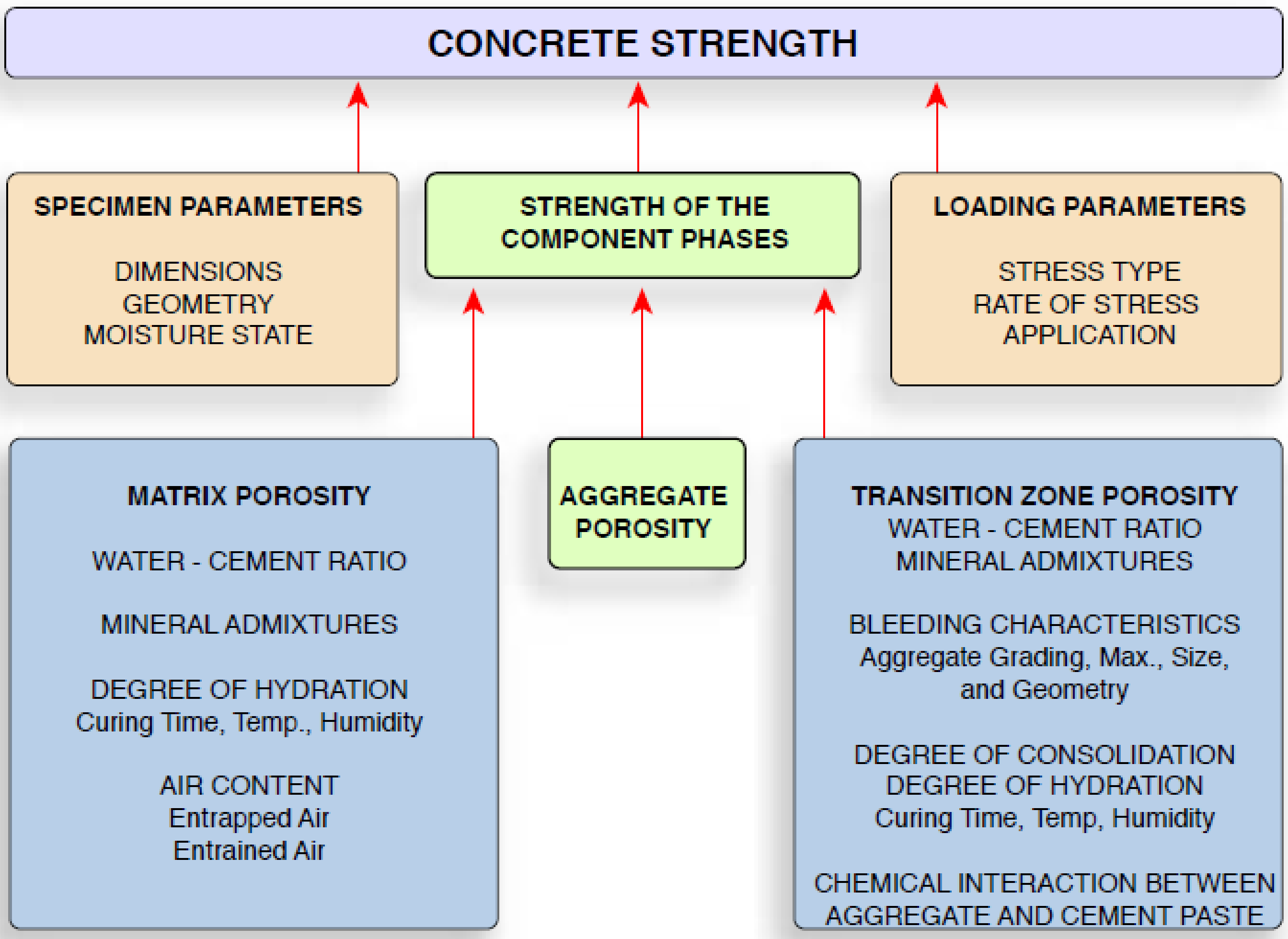


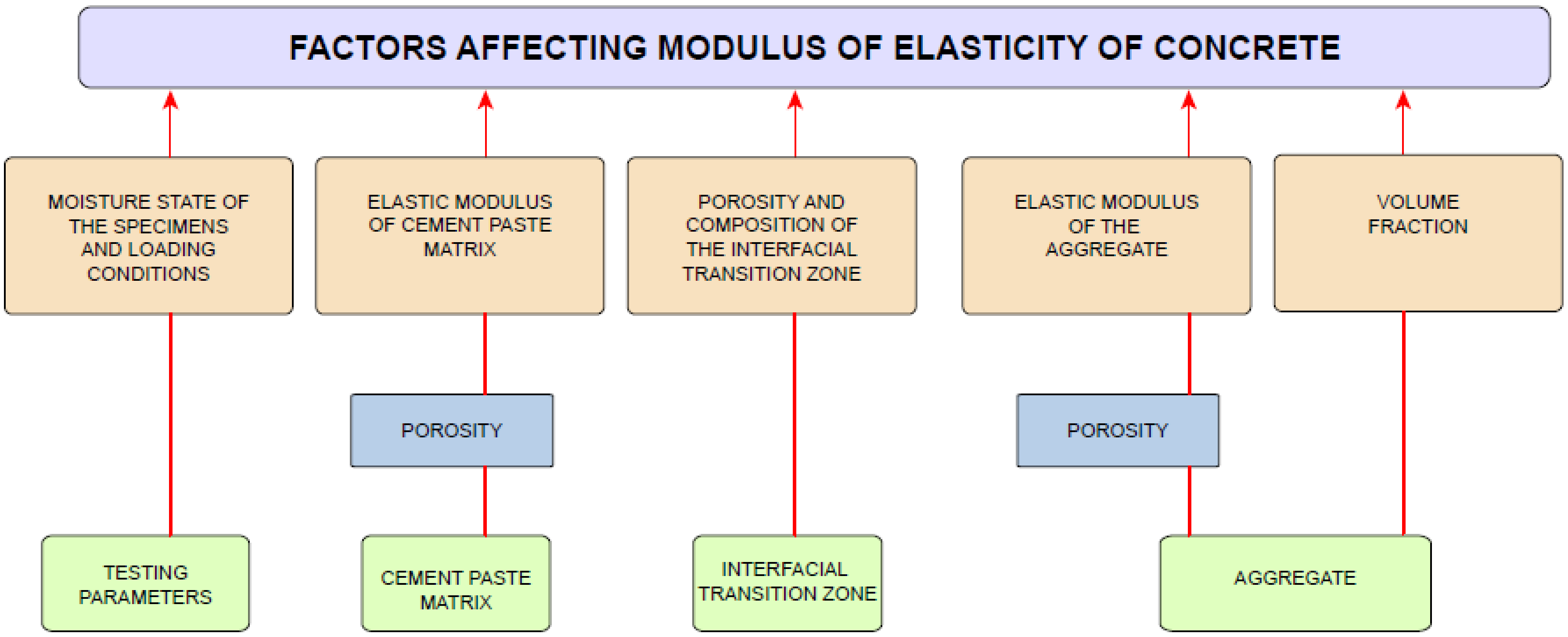
$$\sigma = \frac{(Pl/6)\,(d/2)}{bd^3/12} = \frac{Pl}{bd^2}$$

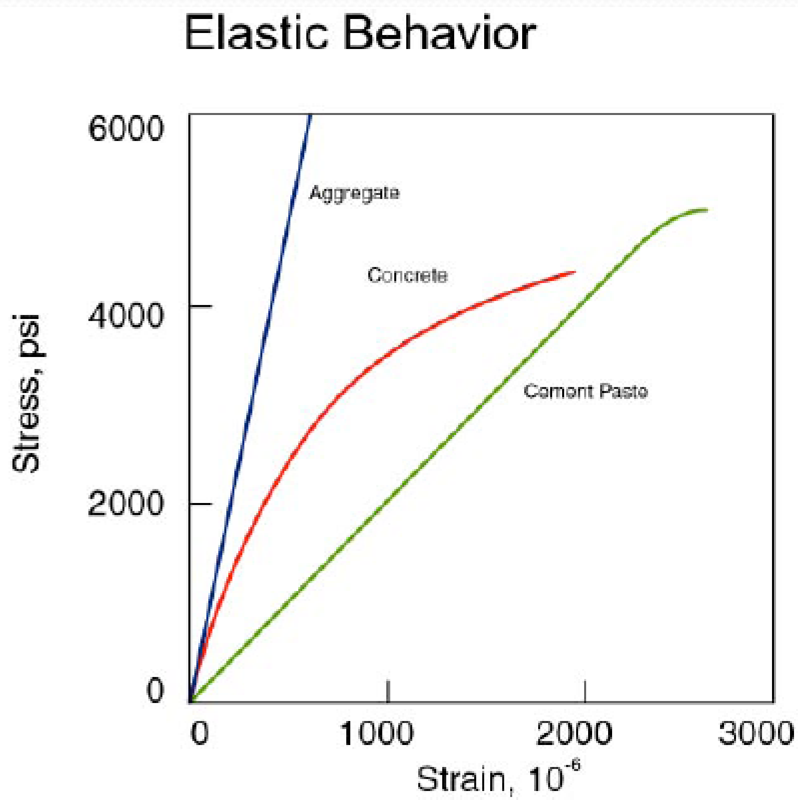
Factors Affecting the Strength of Concrete

1) Factors depended on the test type:
   - Size of specimen
   - Size of specimen in relation with size of agg.
   - Support condition af specimen
   - Moisture condition of specimen
   - Type of loading adopted
   - Rate of loading
   - Type of test machine

2. Factors independent of test type:
   - Type of cement
   - Type of agg.
   - Degree of compaction
   - Mix proportions
   - Type of curing
   - Type of stress situation

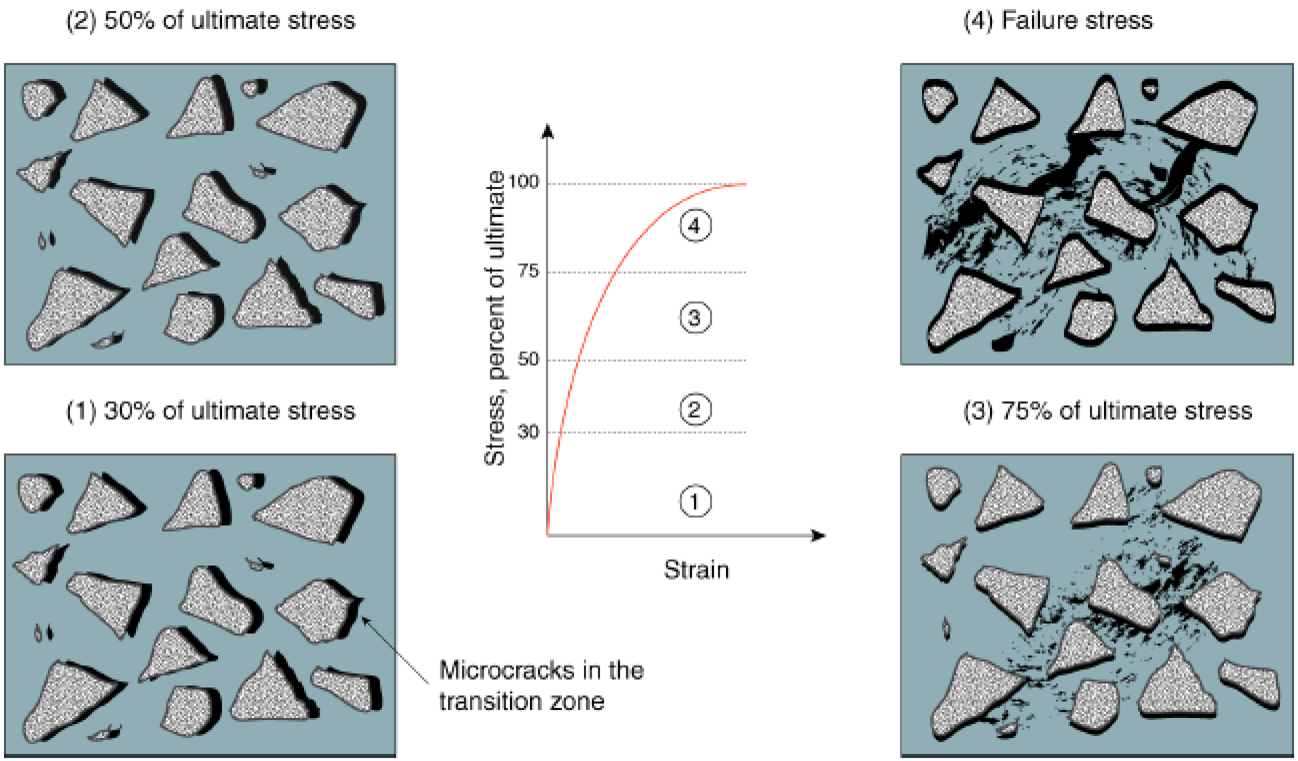

CONCRETE STRENGTH
SPECIMEN PARAMETERS
DIMENSIONS
GEOMETRY
MOISTURE STATE
STRENGTH OF THE COMPONENT PHASES
LOADING PARAMETERS
STRESS TYPE
RATE OF STRESS APPLICATION
MATRIX POROSITY
WATER - CEMENT RATIO
MINERAL ADMIXTURES
DEGREE OF HYDRATION
Curing Time, Temp., Humidity
AIR CONTENT
Entrapped Air
Entrained Air
AGGREGATE POROSITY
TRANSITION ZONE POROSITY
WATER - CEMENT RATIO
MINERAL ADMIXTURES
BLEEDING CHARACTERISTICS
Aggregate Grading, Max., Size, and Geometry
DEGREE OF CONSOLIDATION
DEGREE OF HYDRATION
Curing Time, Temp, Humidity
CHEMICAL INTERACTION BETWEEN AGGREGATE AND CEMENT PASTE


FACTORS AFFECTING MODULUS OF ELASTICITY OF CONCRETE
MOISTURE STATE OF THE SPECIMENS AND LOADING CONDITIONS
ELASTIC MODULUS OF CEMENT PASTE MATRIX
POROSITY AND COMPOSITION OF THE INTERFACIAL TRANSITION ZONE
ELASTIC MODULUS OF THE AGGREGATE
VOLUME FRACTION
POROSITY
POROSITY
TESTING PARAMETERS
CEMENT PASTE MATRIX
INTERFACIAL TRANSITION ZONE
AGGREGATE



Points to note:

- Aggregate and cement paste linear up to failure
- Concrete stress-strain response (elastic) in between aggregate and cement paste
- Concrete does not have a linear behavior up to failure



P.K. Mehta and P.J.M. Monteiro, Concrete: Microstructure, Properties, and Materials

- in freshly compacted concrete, water films form around the large aggregate particles. This would account for a higher water-cement ratio closer to the larger aggregate than away from it.
- Due to the high water-cement ratio, calcium hydroxide and ettringite in the vicinity of the coarse aggregate consist of relatively larger crystals, and therefore form a more porous framework than in the bulk cement paste or mortar matrix.
- The platelike calcium hydroxide crystals tend to form in oriented layers with the -axis perpendicular to the aggregate surface.

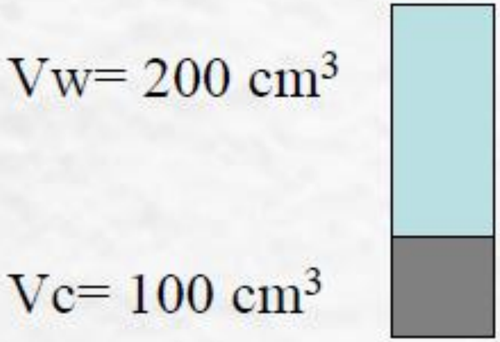
.K. Mehta and P.J.M. Monteiro, Concrete: Microstructure, Properties, and Materials

Let's study a cement paste with w/c= 0.63

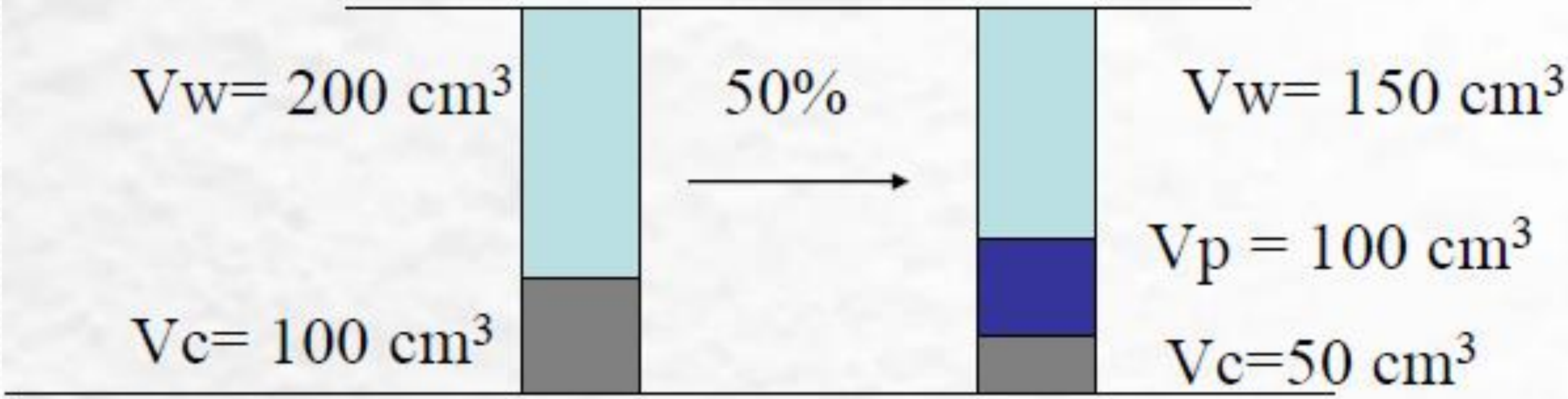
Start with 100 cm^3 of cement.

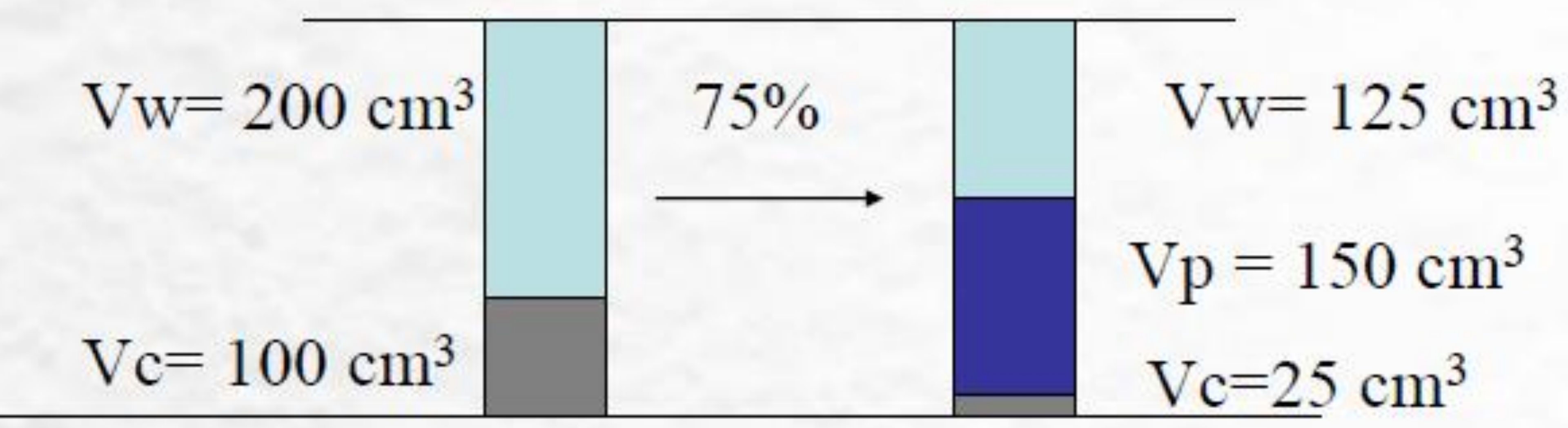
Compute the mass of cement: $Mc = 3.14 * 100 = 314$ g

Compute the mass of water: $Mw = 0.63 * 314 = 200$ g

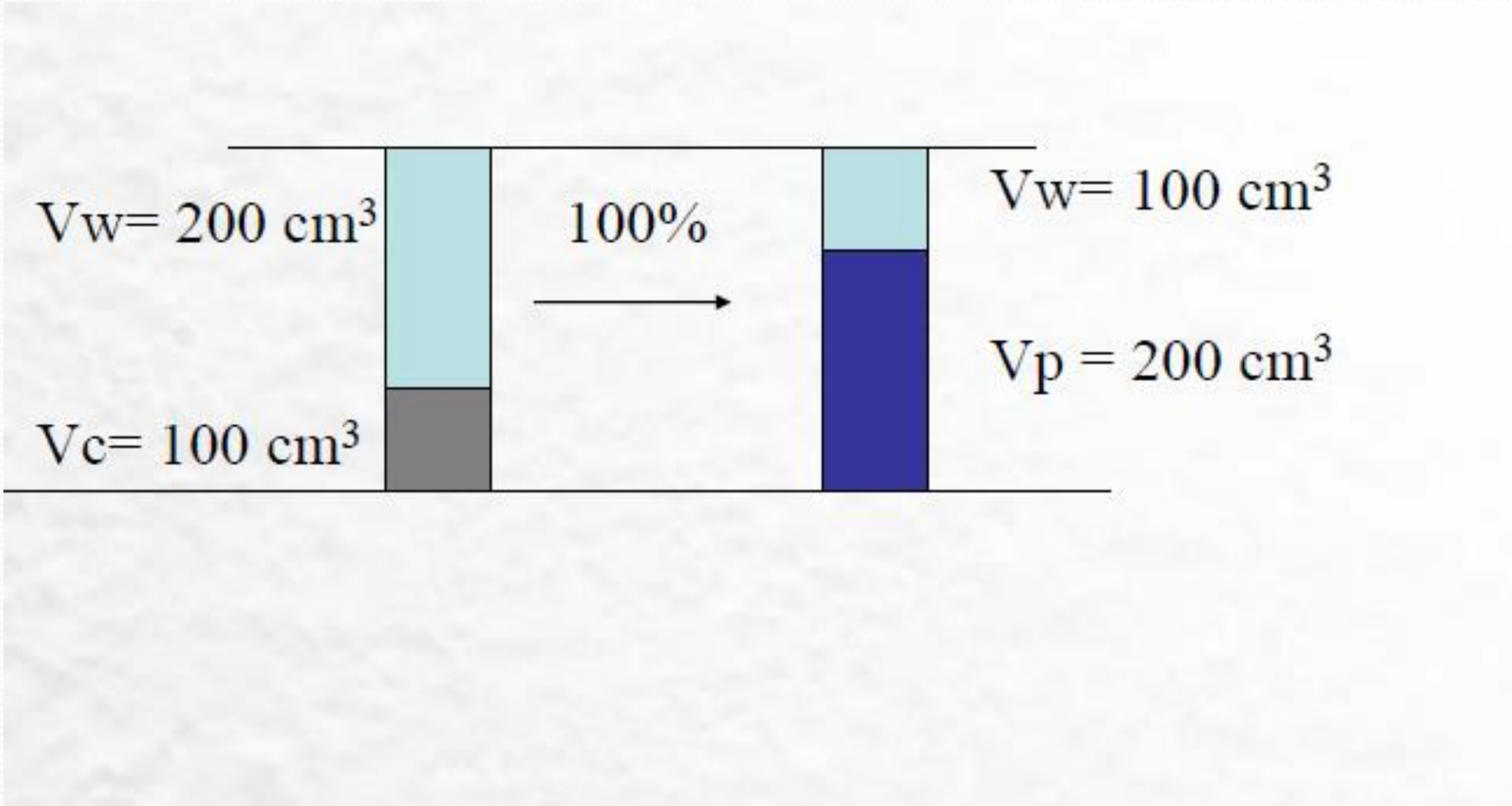


Miracle of hydration: $V_p = 2\ V_c$





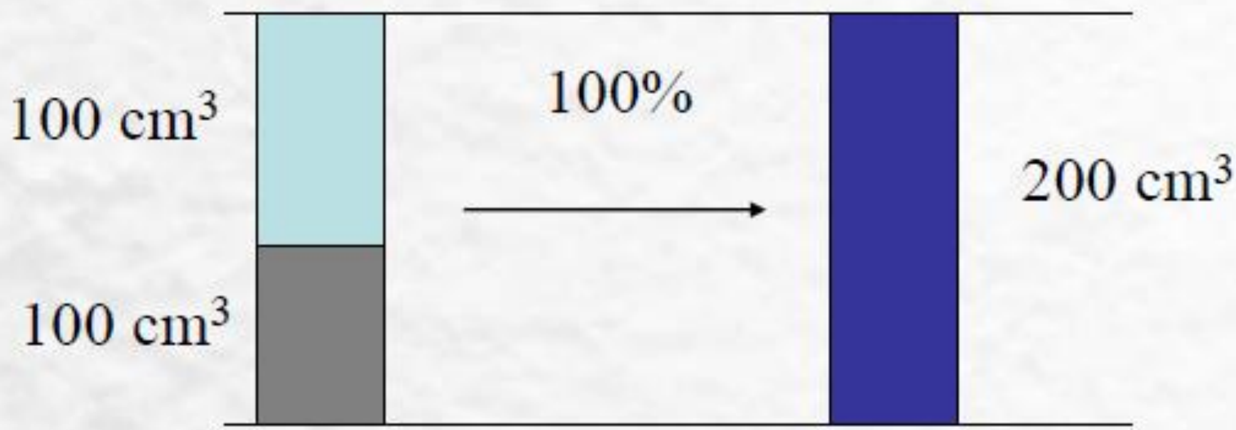
Vw= 200 cm3
Vc= 100 cm3
75%
Vw= 125 cm3
Vp = 150 cm3
Vc=25 cm3



Vw= 200 cm³
Vc= 100 cm³
100%
Vw= 100 cm³
Vp = 200 cm³

$$W/c = 100/100*3.14$$

$$W/c = 0.32$$



P.K. Mehta and P.J.M. Monteiro, Concrete: Microstructure, Properties, and Materials

- **Interlayer space in CSH**

  size = 5 to 25 Å

  No adverse effect on strength and permeability

  Some effect on drying shrinkage and creep

- **Capillary Voids**

  > 50 nm : detrimental to strength and impermeability

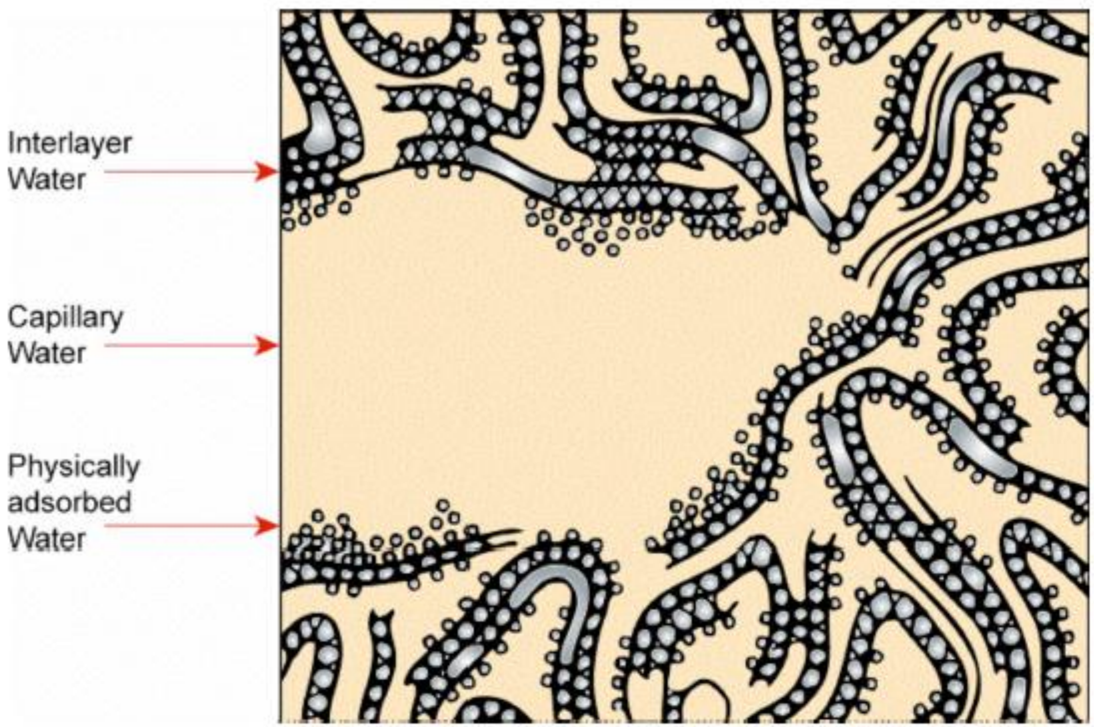
  < 50 nm: important to drying shrinkage and creep.

- **Air Voids**

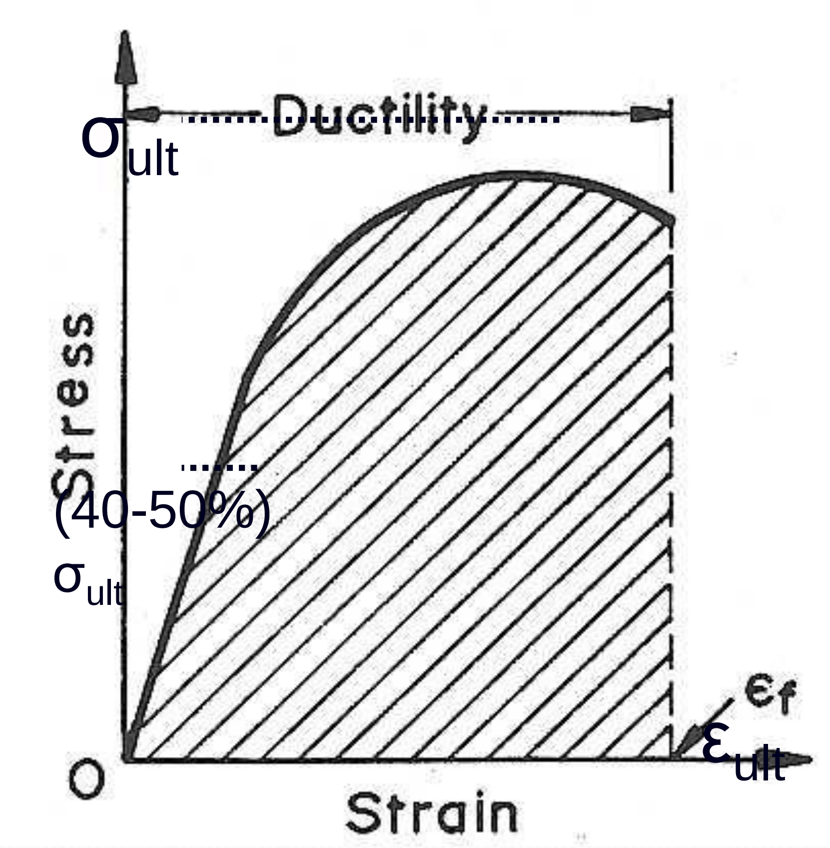
  entrapped air: ~ 3 mm

  entrained air: 50 to 200 microns

P.K. Mehta and P.J.M. Monteiro, Concrete: Microstructure, Properties, and Materials


Interlayer Water
Capillary Water
Physically adsorbed Water

STRESS-STRAIN RELATIONS IN CONCRETE

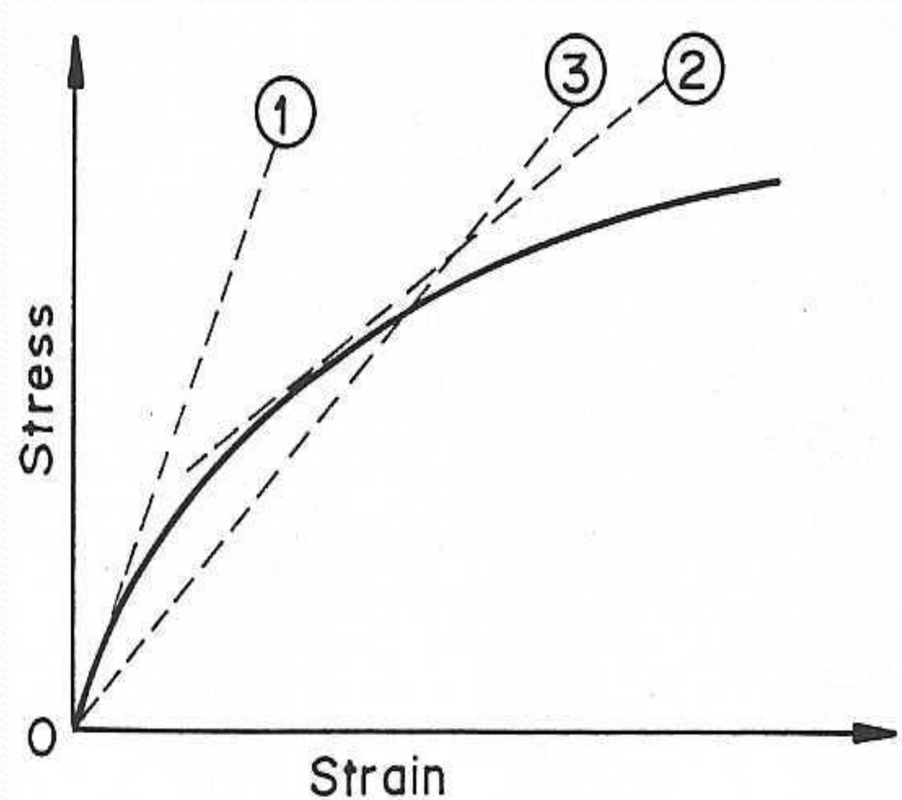


σ-ε relationship for concrete is nonlinear. However, specially for cylindrical specimens with h/D=2, it can be assumed as linear upto 40-50% of σ_{ult}

MODULUS OF ELASTICITY OF CONCRETE

Due to the nonlinearity of the σ-ε diagram, E is the defined by:

1. Initial Tangent Method
2. Tangent Method
3. Secant Method



ACI → E=15200 $\sigma_{ult}^{1/2}$ → 28-D cylindrical comp.str. (kgf/cm²)

TS → E=15500 W $^{1/2}$→ 28-D cubic comp.str. (kgf/cm²)

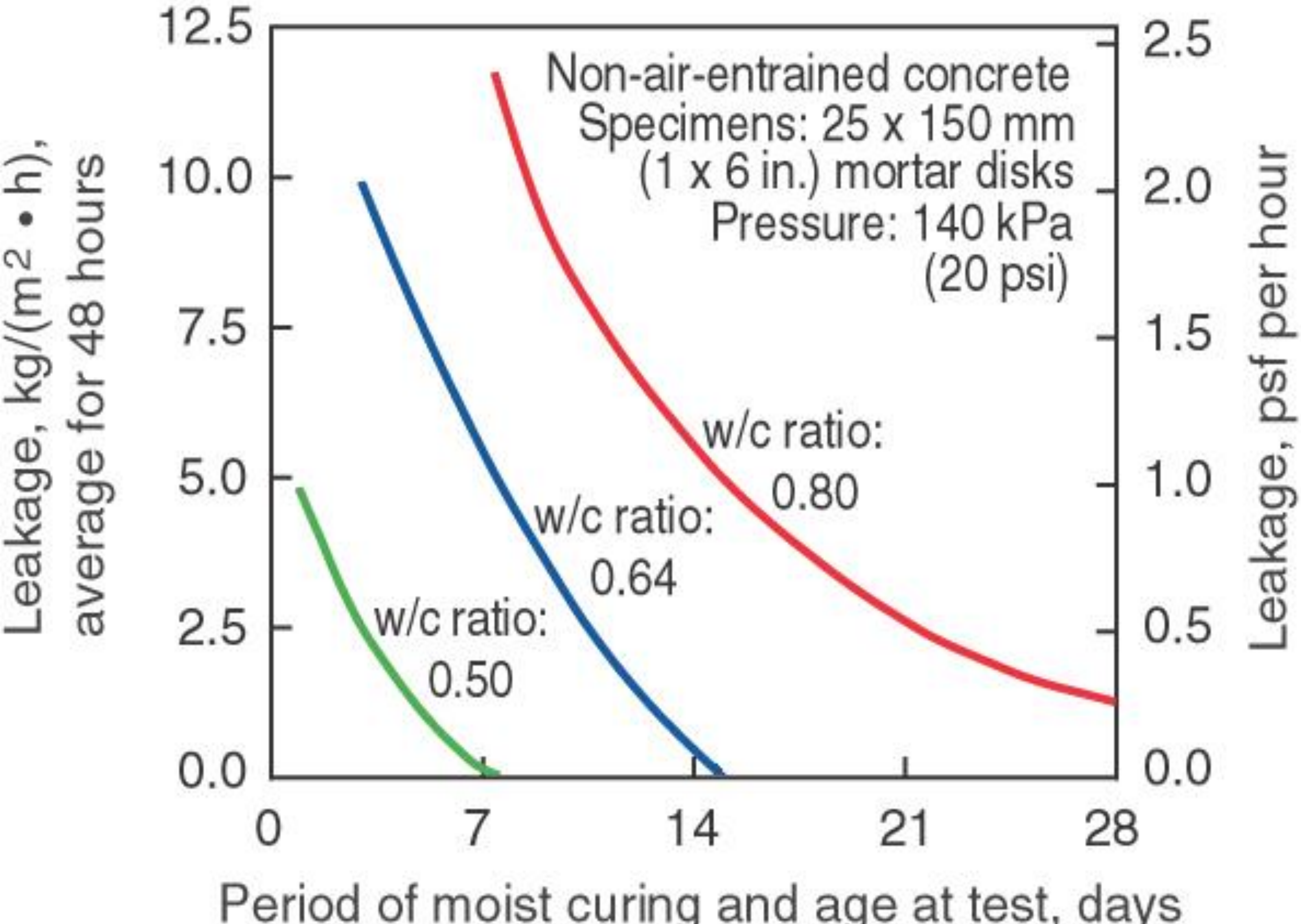
PERMEABILITY OF CONCRETE

- Permeability is important because:

1. The penetration of some aggresive solution may result in leaching out of $Ca(OH)_2$ which adversely affects the durability of concrete.
2. In R/C ingress of moisture of air into concrete causes corrosion of reinforcement and results in the volume expansion of steel bars, consequently causing cracks & spalling of concrete cover.
3. The moisture penetration depends on permeability & if concrete becomes saturated it is more liable to frost-action.
4. In some structural members permeability itself is of importance, such as, dams, water retaining tanks.

PERMEABILITY OF CONCRETE

- The permeability of concrete is controlled by capillary pores. The permeability depends mostly on w/c, age, degree of hydration.
- In general the higher the strength of cement paste, the higher is the durability & the lower is the permeability.



Non-air-entrained concrete
Specimens: 25 x 150 mm
(1 x 6 in.) mortar disks
Pressure: 140 kPa
(20 psi)
w/c ratio:
0.80
w/c ratio:
0.64
w/c ratio:
0.50
Leakage, kg/(m² • h), average for 48 hours
Leakage, psf per hour
Period of moist curing and age at test, days
12.5
10.0
7.5
5.0
2.5
0.0
2.5
2.0
1.5
1.0
0.5
0.0
0
7
14
21
28

MIXTURES

- W+C+C.Agg.+F.Agg.+Admixtures → Weights / Volumes?
- There are two sets of requirements which enable the engineer to design a concrete mix.

1. The requirements of concrete in hardened state. These are specified by the structural engineer.

2. The requirements of fresh concrete such as workability, setting time. These are specified by the construction engineer (type of construction, placing methods, compacting techniques and transportation)

PROPORTIONING CONCRETE MIXTURES

- Mix design is the process of selecting suitable ingredients of concrete & determining their relative quantities with the objective of producing as economically as possible concrete of certain minimum properties such as workability, strength & durability.

- So, basic considerations in a mix design is cost & min. properties.

- Cost → Material + Labor

$\Downarrow$

Water+Cement+Aggregate+Admixtures

$\Downarrow$

Most expensive (optimize)

Using less cement causes a decrease in shrinkage and increase in volume stability.

- Min.Properties →Strength has to be more than..

Durability→Permeability has to be

Workability→Slump has to be...

- In the past specifications for concrete mix design prescribed the proportions of cement, fine agg. & coarse agg.
- 1 : 2 : 4

↓	↓	↓
Weight of cement	Fine Agg.	Coarse Agg.

- However, modern specifications do not use these fixed ratios.

- Modern specifications specify min compressive strength, grading of agg, max w/c ratio, min/max cement content, min entrained air & etc.

- Most of the time job specifications dictate the following data:
  - Max w/c
  - Min cement content
  - Min air content
  - Slump
  - Strength
  - Durability
  - Type of cement
  - Admixtures
  - Max agg. size

PROCEDURE FOR MIX DESIGN

1. Choice of slump (Table 14.5)

Table 14.5 Recommended Slumps for Various Types of Construction

Type of Construction	Slump, mm Maximum	Slump, mm Minimum
Reinforced foundation walls	75	25
Reinforced footings	75	25
Plain footings	75	25
Substructure walls	75	25
Pavement and slabs	75	25
Mass concrete	50	25
Building columns	100	25
Beams	100	25
Reinforced walls	100	25

PROCEDURE FOR MIX DESIGN

2. Choice of max agg. size
   - 1/5 of the narrowest dimension of the mold
   - 1/3 of the depth of the slab
   - ¾ of the clear spacing between reinforcement
   - Dmax < 40mm

PROCEDURE FOR MIX DESIGN

3. Estimation of mixing water & air content (Table 14.6 and 14.7)

Table 14.6 Approximate Amounts of Mixing Water and Air Content Requirements for Non-Air Entrained Concrete

Slump, mm	Water Content kg/m^3 (Maximum Aggregate Size, mm) 9.5	12.5	19	25	37.5	50	75
25-50	207	199	190	179	166	154	130
75-100	228	216	205	193	181	169	145
150-175	243	228	216	202	190	178	160
Entrapped Air(%)	3	2.5	2	1.5	1	0.5	0.3

Table 14.7 Approximate Mixing Water and Air Content Requirements for Air- Entrained Concrete

Slump, mm	Water Content kg/m^3 (Maximum Aggregate Size, mm) 9.5	12.5	19	25	37.5	50	75
25 - 50	181	175	168	160	150	142	122
75 - 100	202	193	184	175	165	157	133
150 - 175	216	205	197	184	174	166	154
Recommended total air content for level of exposure (%):							
Mild exposure	4.5	4.0	3.5	3.0	2.5	2.0	1.5
Moderate exposure	6.0	5.5	5.0	4.5	4.5	4.0	3.5
Severe exposure	7.5	7.0	6.0	6.0	5.5	5.0	4.5

PROCEDURE FOR MIX DESIGN

4. Selection of w/c ratio (Table 14.8 or 14.9)

Table 14.8 Relationship between the "Water/Cement" Ratio and Compressive Strength of Concrete

Compressive Strength at 28 days, MPa	"Water/Cement" Ratio, by weight: Non-air-entrained concrete	"Water/Cement" Ratio, by weight: Air-entrained concrete
40	0.42	
35	0.47	0.39
30	0.54	0.45
25	0.61	0.52
20	0.69	0.60
15	0.79	0.70

Table 14.9 Maximum Permissible "Water/Cement" Ratios for Concretes in Severe Exposure

Type of Structure	Structures that will be wet continuously and exposed to freezing and thawing	Structures exposed to seawater or sulfates
Thin sections and sections with less than 25 mm cover over steel	0.45	0.40
All other structures	0.50	0.45

PROCEDURE FOR MIX DESIGN

5. Calculation of cement content with selected water amount (step 3) and w/c (step 4)
6. Estimation of coarse agg. content (Table 14.10)

Table 14.10 Volume of Coarse Aggregate per Unit Volume of Concrete

Maximum size of aggregate, mm	Volume of dry-rodded coarse aggregate per unit volume of concrete			
	Fineness Moduli of Fine Aggregate			
	2.40	2.60	2.80	3.00
9.5	0.50	0.48	0.46	0.44
12.5	0.59	0.57	0.55	0.53
19.0	0.66	0.64	0.62	0.60
25.0	0.71	0.69	0.67	0.65
37.5	0.75	0.73	0.71	0.69
50.0	0.78	0.76	0.74	0.72
75.0	0.82	0.80	0.78	0.76

PROCEDURE FOR MIX DESIGN

7. Calculation of fine aggregate content with known volumes of coarse aggregate, water, cement and air
8. Adjustions for aggregate field moisture

PROCEDURE FOR MIX DESIGN

9. Trial batch adjustments
   - The properties of the mixes in trial batches are checked and necessary adjustments are made to end up with the minimum required properties of concrete.
   - Moreover, a lab trial batch may not always provide the final answer. Only the mix made and used in the job can guarantee that all properties of concrete are satisfactory in every detail for the particular job at hand. That's why we get samples from the field mixes for testing the properties.

Example:

- Slump → 75-100 mm
- D_{max} → 25 mm
- $f'_{c,28}$ = 25 MPa
- Specific Gravity of cement = 3.15
- Non-air entrained concrete

	Coarse Agg.	Fine Agg.
SSD Bulk Sp.Gravity	2.68	2.62
Absorption	0.5%	1.0%
Total Moist.Content	2.0%	5.0%
Dry rodded Unit Weight	1600 kg/m^3	–
Fineness Modulus	–	2.6

1. Slump is given as 75-100 mm
2. D_{max} is given as 25 mm
3. Estimate the water and air content (Table 14.6)

Table 14.6 Approximate Amounts of Mixing Water and Air Content Requirements for Non-Air Entrained Concrete

Slump, mm	Water Content kg/m³						
	(Maximum Aggregate Size, mm)						
	9.5	12.5	19	25	37.5	50	75
25-50	207	199	190	179	166	154	130
75-100	228	216	205	193	181	169	145
150-175	243	228	216	202	190	178	160
Entrapped Air(%)	3	2.5	2	1.5	1	0.5	0.3

Slump and D_{max} → W=193 kg/m³

Entrapped Air → 1.5%

4. Estimate w/c ratio (Table 14.8)

Table 14.8 Relationship between the "Water/Cement" Ratio and Compressive Strength of Concrete

Compressive Strength at 28 days, MPa	"Water/Cement" Ratio, by weight	
	Non-air-entrained concrete	Air-entrained concrete
40	0.42	
35	0.47	0.39
30	0.54	0.45
25	0.61	0.52
20	0.69	0.60
15	0.79	0.70

f'_c & non-air entrained → w/c=0.61 (by wt)

5. Calculation of cement content

$W = 193\ kg/m^3$ and $w/c=0.61$

$C=193 / 0.61 = 316\ kg/m^3$

6. Coarse Agg. from Table 14.10

D_{max} and F.M. $\rightarrow V_{C.A} = 0.69\ m^3$

Table 14.10 Volume of Coarse Aggregate per Unit Volume of Concrete

Maximum size of aggregate, mm	Volume of dry-rodded coarse aggregate per unit volume of concrete — Fineness Moduli of Fine Aggregate 2.40	2.60	2.80	3.00
9.5	0.50	0.48	0.46	0.44
12.5	0.59	0.57	0.55	0.53
19.0	0.66	0.64	0.62	0.60
25.0	0.71	0.69	0.67	0.65
37.5	0.75	0.73	0.71	0.69
50.0	0.78	0.76	0.74	0.72
75.0	0.82	0.80	0.78	0.76

Dry $W_{C.A.} = 1600*0.69 = 1104\ kg/m^3$

SSD $W_{C.A.} = 1104*(1+0.005) = 1110\ kg/m^3$

7. To calculate the F.Agg. content the volumes of other ingredients have to be determined.

$$V = \frac{M}{Sp.Gr.*\rho_w}$$

$$V_{water} = \frac{193}{1.0*1000} = 0.193\ m^3$$

$$V_{cement} = \frac{316}{3.15*1000} = 0.100\ m^3$$

$$V_{C.Agg.} = \frac{1110}{2.68*1000} = 0.414\ m^3$$

$$V_{air} = 0.015\ m^3\ (1.5\%*1)$$

$$\Sigma V = 0.722\ m^3 \rightarrow V_{F.Agg} = 1\text{-}0.722 = 0.278\ m^3$$

$$W_{F.Agg} = 0.278*2.62*1000 = 728\ kg/m^3$$

Summary of Mix Design

- Based on SSD weight of aggregates

	Sp. Gr.	Weight (kg/m^3)	Volume (m^3)
Cement	3.15	316	0.100
Water	1	193	0.193
Coarse Agg.	2.68	1110	0.414
Fine Agg.	2.62	728	0.278
Air		-	0.015
Total		2347	1.000

8. Adjustment for Field Moisture of Aggregates

$W_{SSD} = W_{Dry} * (1+a)$ $\quad$ $W_{Field} = W_{Dry} * (1+m)$

Aggregates	Absorption	Moisture	Weight (kg/m^3)		
			SSD	Dry	Field
Coarse	0.005	0.02	1110	1104	1127
Fine	0.01	0.05	728	721	759

Correction for water

From coarse aggregate: 1127-1110 = 17

From fine aggregate: 759-728 = 31

48 kg extra

Corrected water amount : 193 – 48 = 145 kg

Summary of Mix Design

- Based on field weight of aggregates

Ingredient amount	Weight (kg/m^3)	
	SSD	Field
Cement	316	316
Water	193	145
Coarse Agg.	1110	1127
Fine Agg.	728	759
Total	2347	2347

9. Trial Batch

Usually a 0.02 m^3 of concrete is sufficient to verify the slump and air content of the mix. If the slump and air content are different readjustments of the proportions should be made.

Ingredient amount	Field Weight (kg/m^3)
Cement	6.3
Water	2.9
Coarse Agg.	22.5
Fine Agg.	15.2
Total	46.9

PROPERTIES of CONCRETE
Concrete Mix Design Example according to the TS standards

Prof. Dr. Halit YAZICI

D. E. U. Civil Engineering Department

http://kisi.deu.edu.tr/halit.yazici

25 p- C20 / 25 class concrete is used for RC wall construction project designed under static and earthquake loads of a structure that will be exposed to the medium level of harmful chemical environment (sulphate) in a region that does not freeze-thawing. The narrowest dimension of the RC wall is 25 cm and the concrete cover layer is 5.0 cm. The cement to be used has a strength of 42.5 MPa (density = 3.05 kg / dm3). The aggregate gradation to be used (Dmax = 32 mm) is close to the ideal granulometry curve (mixture: 20% I. MICIR (coarse aggregate) + 35% II MICIR (coarse aggregate) + 45% SAND). The properties of the materials and the tables to be used in the designs are given below. The plasticizer will not be used. The standard deviation from the cylinder samples in the concrete production of the plant is approximately 1,13 MPa (fca = fcd + 1,48s) in all concrete classes. Please design the concrete mixture using with given data below and calculate the corrected mix design according to the field moisture content of the aggregates.

Tablo 1

ÖZELLİK	I. MICIR	II. MICIR	KUM
Yoğunluk (g/cm3) -KYD	2,64	2,64	2,73
Su emme (%)	0,6	0,5	2,5
Stok nemi (%)	1,5	0,3	3,0

Tablo 2

Yapı elemanları	Çökme, cm
Betonarme temel duvarları ve ayaklar	8
Donatısız beton temeller, kesonlar ve altyapı duvarları	8
Kiriş, kolon, betonarme perdeler, tünel yan ve kemer betonları	10
Döşeme betonları	8
Tünel taban kaplama betonları	5
Baraj kütle betonu	5

Tablo 3

Yapı Elemanı Kesitinin En Dar Boyutu (cm)	En Büyük Agrega Tane Büyüklüğü (mm)			
	Donatılı perde, kiriş ve kolonlar	Sık donatılı döşemeler	Seyrek donatılı veya donatısız döşemeler	Donatısız perdeler
6 - 14	16	16	32	16
15 - 29	32	32	63	32
30 - 74	63	63	63	63

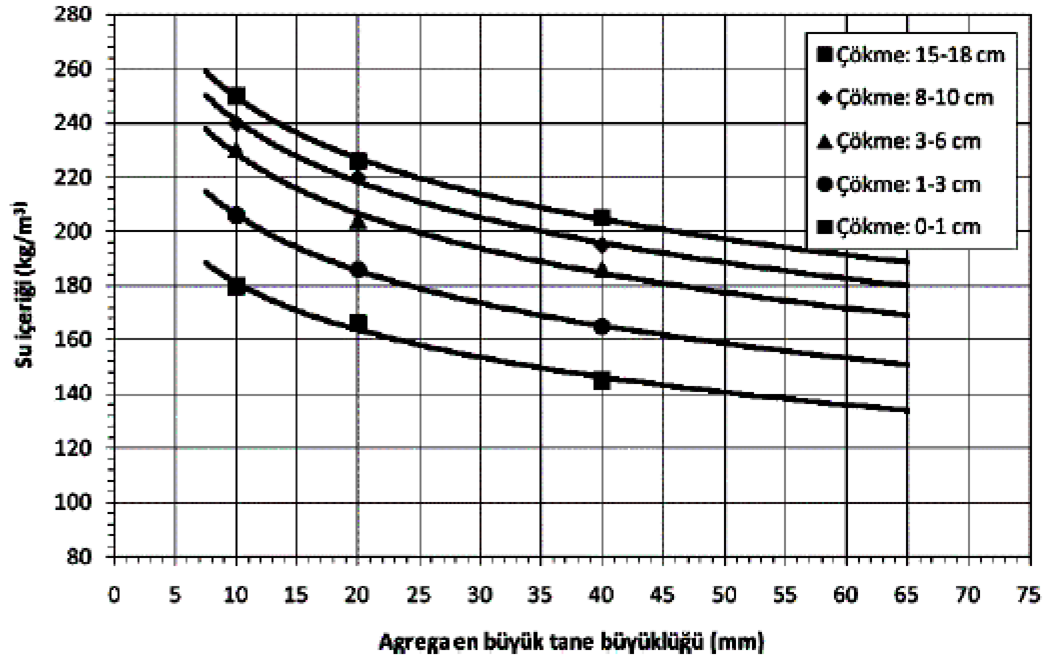
Tablo 4

28. günlük basınç dayanımı, MPa	S/Ç oranı (ağırlıkça)	
	Hava sürüklenmemiş beton	Hava sürüklenmiş beton
45	0.37	-
40	0.42	-
35	0.47	0.39
30	0.54	0.45
25	0.61	0.52
20	0.69	0.60
15	0.79	0.70

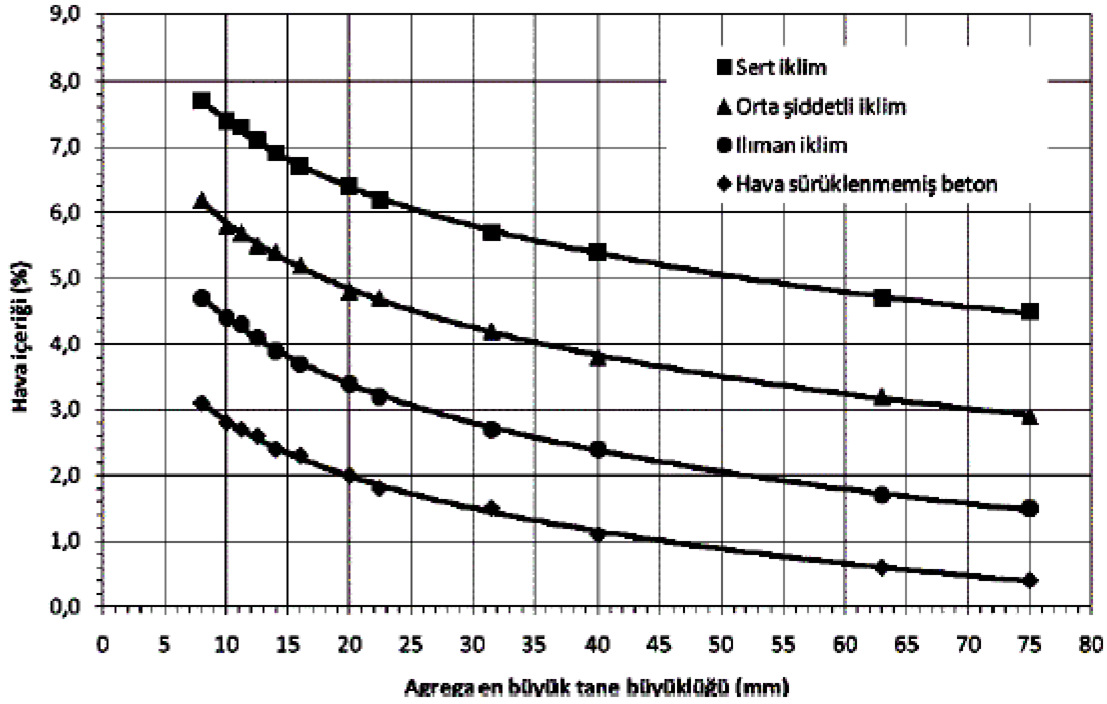
Tablo 5

Kriter	Etki sınıfları		
	XA1	XA2	XA3
En büyük S/Ç oranı	0,55	0,50	0,45
En küçük dayanım sınıfı	C30/37	C30/37	C35/45
En az çimento içeriği	300	320	360
Diğer		Sülfata dayanıklı çimento	

XA1: az zararlı kimyasal ortam
XA2: orta zararlı kimyasal ortam
XA3: çok zararlı kimyasal ortam



Çökme: 15-18 cm
Çökme: 8-10 cm
Çökme: 3-6 cm
Çökme: 1-3 cm
Çökme: 0-1 cm
Su içeriği (kg/m³)
Agrega en büyük tane büyüklüğü (mm)



Sert iklim
Orta şiddetli iklim
Ilıman iklim
Hava sürüklenmemiş beton
Hava içeriği (%)
Agrega en büyük tane büyüklüğü (mm)

3.1) From table -2 → slump = 100 mm

* for slump ~10mm and Dmax = 32mm $\xrightarrow[\text{grafic}]{\text{from}}$ watercontent = 204 lt

* from second graphic we read air entraind = %1,5

2) Dmax control

From Table 3 D can be the highest 32 mm. Our Dmax is 32 mm ✓.

3) C20/25 compressive strength was considered, but C30/37 was chosen based on Table 5.

4) $f_{co} = f_{ck} + 1,48\sigma$

$= 30 + 1,48 \cdot (1,13) = 32$ mPa

water / cement

		mPa	w/c	
* f_{ca} = 32 mPa	$\xrightarrow[\text{Table 4}]{\text{from}}$	35	0,47	> w/c = 0,51 (enterpolation)
		40	0,54	

* for XA_2 $\xrightarrow[\text{Table 5}]{\text{from}}$ w/c = 0,50 → w/c = 0,50

* w/c = 0,50 ; w = 204 lt ⇒ 0,50 = 204/c → c = 408 kg.

* Volume of cement = 408 / 3.05 = 134 dm^3
* Volume of water = 204 / 1 = 204 dm^3
* Volume of air = % 1,5 = 15 dm^3

+

ΣV = 353 dm^3

Volume of agg. = 1000 − 353 = 647 dm^3

Average aggregate density : $\bar{\rho}_a$

$$\bar{\rho}_a = \frac{1}{\frac{0,20}{2,64} + \frac{0,35}{2,64} + \frac{0,45}{2,73}} = 2,68$$

* Aggregate total weight = $647 \times 2,68 = 1734$ kg

I micir = $1734 \times 0,20 = 347$ kg

II micir = $1734 \times 0,35 = 607$ kg

Kum = $1734 \times 0,45 = 780$ kg

$$\begin{array}{r} + \\ \hline 1734 \end{array}$$

* Adjustment for moisture of aggregates:

$$\left.\begin{array}{l} \text{I micir} = 347 \times (0,006 - 0,015) = -3,123 \text{ lt} \\ \text{II micir} = 607 \times (0,005 - 0,003) = 1,214 \text{ lt} \\ \text{Kum} = 780 \times (0,025 - 0,03) = -3,9 \text{ lt} \end{array}\right] \Sigma = -6 \text{ lt is extra water}$$

water = $204 - 6 = \underline{198 \text{ lt}}$

I. MICIR = 347 + 3,12 = 350,12 kg

II. MICIR = 607 − 1,21 = 605,8 kg

SAND = 780 + 3,9 = 783 kg

	Saturated surface dry	Corrected
Cement —	408	408
Water —	204	198
I MICIR —	347	350
II. MICIR —	607	606
SAND —	780	784
+	2346	2346

PROPERTIES of CONCRETE
Concrete-I

Prof. Dr. Halit YAZICI

D. E. U. Civil Engineering Department

http://halityazici-deu.com