PROPERTIES of CONCRETE Aggregates

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CONCRETE AGGREGATES

- Cost
- Provide dimensional stability
- Influence hardness, abrasion resistance, elastic modulus

Concrete =

- 25-40% cement

  (absolute volume of cement = 7-15% ; water = 14-21%)

- Up to 8% air (depending on top size of coarse aggregate)

Therefore:

Aggregates make up
60-75% of total volume
of concrete.

What is an

AGGREGATE?

Aggregate: the inert filler materials, such as sand or stone, used in making concrete

Physical Properties of Aggregates:

1.Unit Weight and Voids

2. Specific Gravity

3. Particle Shape and Surface Texture

4. Shrinkage of Aggregates

5. Absorption and Surface Moisture

6. Resistance to Freezing and Thawing

Unit Weight

(unit mass or bulk density)

The weight of the aggregate required to fill a container of a specified unit volume.

- **Volume is occupied by both the aggregates and the voids between the aggregate particles.**
- **Depends on size distribution and shape of particles and how densely the aggregate is packed**
  - **Loose bulk density**
  - **Rodded or compact bulk density**

Weight	Examples of Aggregates Used	Uses for the Concrete
ultra-lightweight	vermiculite, ceramic	can be sawed or nailed, also used for its insulating properties
lightweight	expanded clay, shale or slate, crushed brick	used primarily for making lightweight concrete for structures, also used for its insulating properties
normal weight	crushed limestone, sand, river gravel, crushed recycled concrete	used for normal concrete projects
heavyweight	steel or iron shot; steel or iron pellets	used for making high density concrete for shielding against nuclear radiation

Voids

- Void content affects mortar requirements in mix design; water and mortar requirement tend to increase as aggregate void content increases.

- Void content between aggregate particles increases with increasing aggregate angularity.

- Void contents range from 30-45% for coarse aggregates to about 40-50% for fine aggregates.

- Total volume of voids can be reduced by using a collection of aggregate sizes.

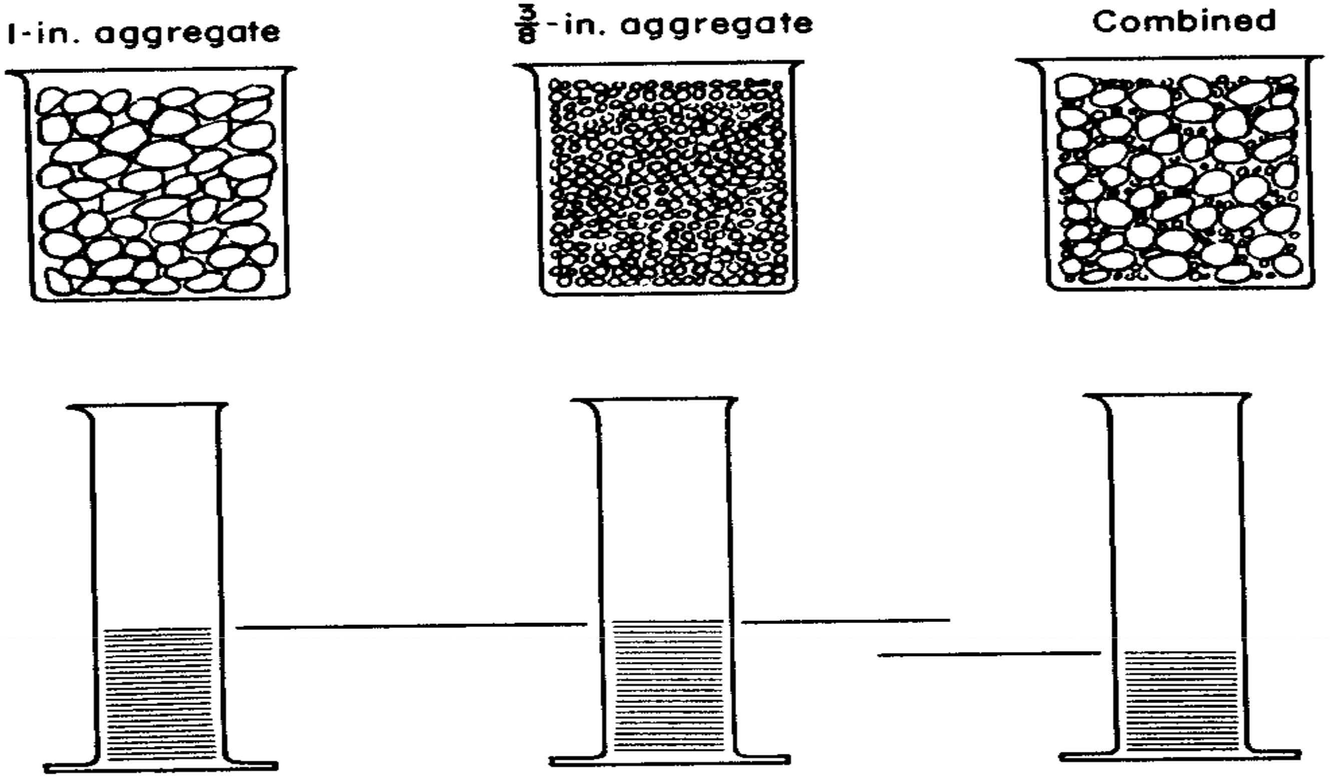


Fig. 4-4. The level of liquid in the graduates, representing voids, is constant for equal absolute volumes of aggregates of uniform but different size. When different sizes are combined, the void-content decreases. The illustration is not to scale.

The cement paste requirement for concrete is proportional to the void content of the combined aggregate.

Specific Gravity (Relative density)

Absolute: the ratio of the weight of the solid to the weight of an equal volume of water (both at a stated temperature)

- refers to volume of the material excluding all pores

Apparent: ratio of the weight of the aggregate (dried in an oven at 212- 230ºF for 24 hours) to the weight of water occupying a volume equal to that of the solid including the impermeable pores

- volume of solid includes impermeable pores (but not capillary pores)

Used for calculating yield of concrete or the quantity of aggregate required for a given volume of concrete.

Particle Shape and Surface Texture

- Rough textured, angular, elongated particles require more water to produce workable concrete than do smooth, rounded, compact aggregates.

- Aggregates should be relatively free of flat and elongated particles (limit to 15% by weight of total aggregate).

- Important for coarse and crushed fine aggregate - these require an increase in mixing water and may affect the strength of the concrete, if cement water ratio is not maintained.

Absorption and Surface Moisture

If water content of the concrete mixture is not kept constant, the compressive strength, workability, and other properties will vary from batch to batch.

Moisture Conditions of Aggregates:

1. **Oven dry**- fully absorbent
2. **Air dry**- dry at the particle surface but containing some interior moisture
3. **Saturated surface dry (SSD)** –neither absorbing water nor contributing water to the concrete mixture
4. **Wet or moist-** containing an excess of moisture on the surface

Absorption Capacity: maximum amount of water aggregate can absorb

- Absorption Capacity (%) = $[(W_{SSD} – W_{OD})/W_{OD}] \times 100$

Surface Moisture: water on surface of aggregate particles

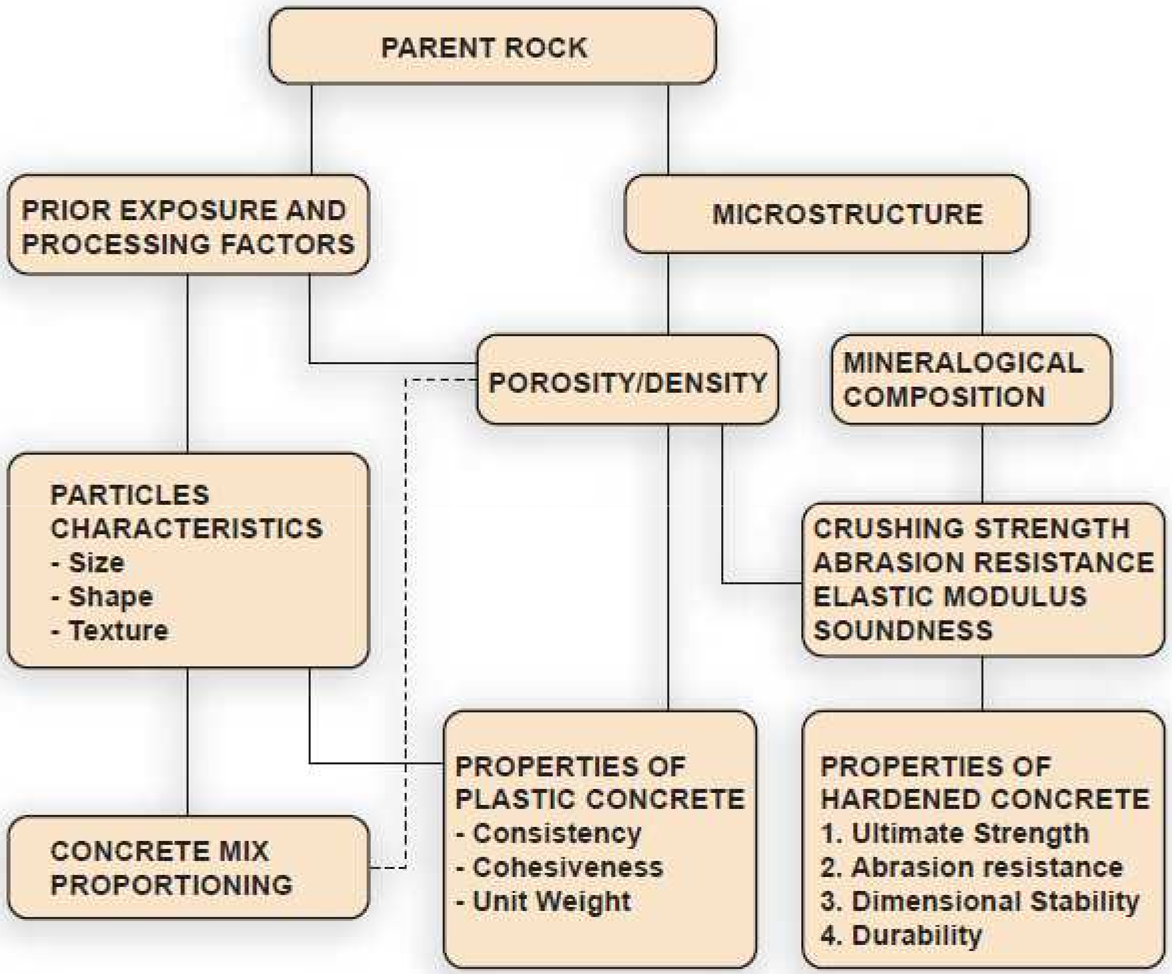
- Surface Moisture (%) = $[(W_{WET} – W_{SSD})/W_{SSD}] \times 100$

Moisture Content: of an aggregate in any state

- Moisture Content (%) = $[(W_{AGG} – W_{OD})/W_{OD}] \times 100$

Resistance to Freezing and Thawing

- Important for exterior concrete.
- Affected by an aggregate's high porosity, absorption, permeability and pore structure.
- If aggregates or concrete absorbs so much water that when the water freezes and expands the concrete cannot accommodate the build up of internal pressure, pop–outs may occur.


PARENT ROCK
PRIOR EXPOSURE AND PROCESSING FACTORS
MICROSTRUCTURE
POROSITY/DENSITY
MINERALOGICAL COMPOSITION
PARTICLES CHARACTERISTICS
- Size
- Shape
- Texture
CRUSHING STRENGTH
ABRASION RESISTANCE
ELASTIC MODULUS
SOUNDNESS
CONCRETE MIX PROPORTIONING
PROPERTIES OF PLASTIC CONCRETE
- Consistency
- Cohesiveness
- Unit Weight
PROPERTIES OF HARDENED CONCRETE
1. Ultimate Strength
2. Abrasion resistance
3. Dimensional Stability
4. Durability

- Portland Cement Concrete → binding medium (mortar) / → relatively inert filler materials (aggregates)

- In concrete mixtures the proportions of cement paste & aggregates is controlled by the following factors:
  1) Suitable workability & placeability of fresh mass.
  2) Adequate strength & durability of hardened product.
  3) Minimum cost of the final product

- The aggregate occupies ~70-75% of the volume of concrete, so its quality is of great importance.

- Aggregates may affect the following properties of concrete:
  - Strength
  - Durability
  - Structural Performance
  - Economy

Aggregates have 3 main functions in concrete:

1) To provide a mass of particles which are suitable to resist the action of applied loads & show better durability then cement paste alone.
2) To provide a relatively cheap filler for the cementing material.
3) To reduce volume changes resulting from setting & hardening process & from moisture changes during drying.

The properties of concrete are affected by the properties of aggregate:

1. The mineral character of aggregate affects the strength, durability, elasticity of concrete.
2. The surface characteristics of aggregate affects the workability of fresh mass & the bond between the aggregate & cement paste in hardened concrete. If it is rough, workability decreases & bond increases.
3. The grading of aggregate affects the workability, density & economy.
4. The amount of aggregate in unit volume of concrete

- Higher aggregate amount/unit volume of concrete
  - Results in less volume changes during setting & hardening or moisture changes. (increase in volume stability)
  - Increase in strength & durability
  - Decrease in cost

- It is a common practice to use as much aggregate as possible in concrete

- However, all aggregates are not inert:
  - <u>The physical action</u>: swelling & shrinkage
  - <u>The chemical action</u>: alkali-agg. Reaction
  - <u>The thermal action</u>: expansion & contraction

- Like the other ingredients of concrete, aggregates must also be chosen with certain care to end up with a satisfactory concrete.

CLASSIFICATION OF AGGREGATES

- According to Source:
  1. <u>Natural aggregate</u>: Native deposits with no change in their natural state other than washing, crushing & grading. (sand, gravel, crush stone)
  2. <u>Artificial aggregates</u>: They are obtained either as a by-product or by a special manufacturing process such as heating. (blast furnace slag, expanded perlite)

- According to Petrological Characteristics:
  1. <u>Igneous rocks</u>: are formed by solidification of molten lava. (granite)
  2. <u>Sedimentary rocks</u>: are obtained by deposition of weathered & transported pre-existing rocks or solutions. (limestone)
  3. <u>Metamorphic rocks</u>: are formed under high heat & pressure alteration of either igneous & sedimentary rocks (marble).

- According to Unit Weight:

1. Heavy weight agg.: Hematite, Magnetite Specific Gravity, $G_s > 2.8$
2. Normal weight agg.:Gravel, sand, crushed stone $2.8 < G_s < 2.4$
3. Light weight agg.:Expanded perlite, burned clay $G_s < 2.4$

Normal-Weight Aggregate

ASTM C 33

Most common aggregates

- Sand
- Gravel
- Crushed stone

Produce normal-weight concrete 2200 to 2400 kg/m^3

Lightweight Aggregate (1)

ASTM C 330

Expanded

- Shale
- Clay
- Slate
- Slag

Produce structural lightweight concrete
1350 to 1850 kg/m^3

Lightweight Aggregate (2)
ASTM C 330

- Pumice
- Scoria
- Perlite
- Vermiculite
- Diatomite

Produce lightweight insulating concrete—250 to 1450 kg/m^3

Heavyweight Aggregate

ASTM C 637, C 638 (Radiation Shielding)

- Barite
- Limonite
- Magnetite
- Ilmenite

- Hematite
- Iron
- Steel punchings or shot

Produce high-density concrete up to 6400 kg/m^3

- According to Size:
  1. <u>Fine aggregate</u>: d ≤ 4 mm
  2. <u>Coarse aggregate</u>: d > 4 mm

- Aggregates containing a whole range of particles are named as “all-in” or “pit-run” aggregates.

Fine Aggregate

- Sand and/or crushed stone
- < 4 mm
- F.A. content usually 35% to 45% by mass or volume of total aggregate

Coarse Aggregate

- Gravel and crushed stone
- ≥ 4 mm
- typically between 5 and 32 mm

Aggregate Characteristics and Tests

Characteristic	Test
Abrasion resistance	ASTM C 131 (AASHTO T 96), ASTM C 535, ASTM C 779
Freeze-thaw resistance	ASTM C 666 (AASHTO T 161), ASTM C 682, AASHTO T 103
Sulfate resistance	ASTM C 88 (AASHTO T 104)
Particle shape and surface texture	ASTM C 295, ASTM D 3398
Grading	ASTM C 117 (AASHTO T 11), ASTM C 136 (AASHTO T 27)
Fine aggregate degradation	ASTM C 1137
Void content	ASTM C 1252 (AASHTO T 304)
Bulk density	ASTM C 29 (AASHTO T 19)

Aggregate Characteristics and Tests

Characteristic	**Test**
Relative density	ASTM C 127 (AASHTO T 85)—fine aggregate ASTM C 128 (AASHTO T 84)—coarse aggregate
Absorption and surface moisture	ASTM C 70, ASTM C 127 (AASHTO T 85), ASTM C 128 (AASHTO T 84), ASTM C 566 (AASHTO T 255)
Strength	ASTM C 39 (AASHTO T 22), ASTM C 78 (AASHTO T 97)
Def. of constituents	ASTM C 125, ASTM C 294
Aggregate constituents	ASTM C 40 (AASHTO T 21), ASTM C 87 (AASHTO T 71), ASTM C 117 (AASHTO T 11), ASTM C 123 (AASHTO T 113), ASTM C 142 (AASHTO T 112), ASTM C 295
Alkali Resistance	ASTM C 227, ASTM C 289, ASTM C 295, ASTM C 342, ASTM C 586, ASTM C 1260 (AASHTO T 303), ASTM C 1293

SAMPLING

- Tests in the lab is carried out on the samples. So, certain precautions in obtaining a sample must be taken to obtain "representative sample".

- The main sample is made up of portions drawn from different points. The minimum number of portions, increment, is 10 & they should add up to a weight not less than:

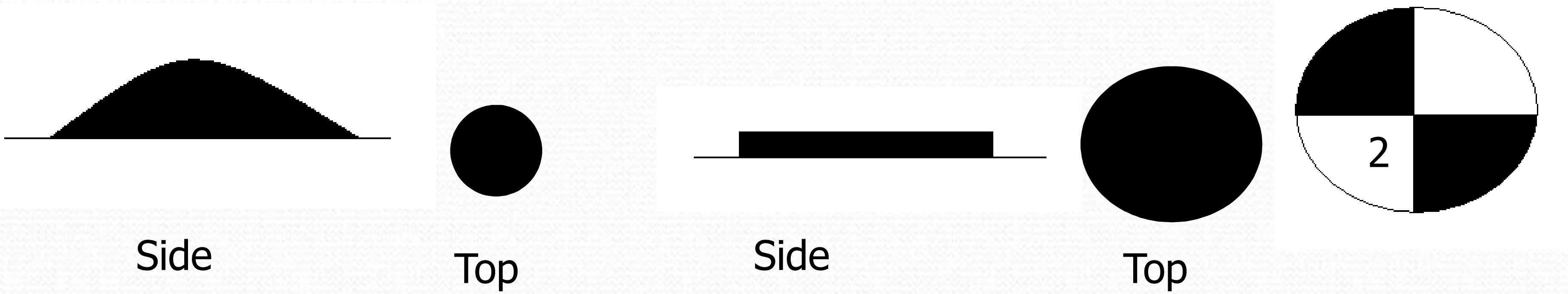
Max. Particle Size	Min. Weight of Sample (kg)
> 25 mm	50
25-5 mm	25
< 5 mm	13

* Details are provided in ASTM D 75 & TS 707

Methods of reducing the amount of sample:

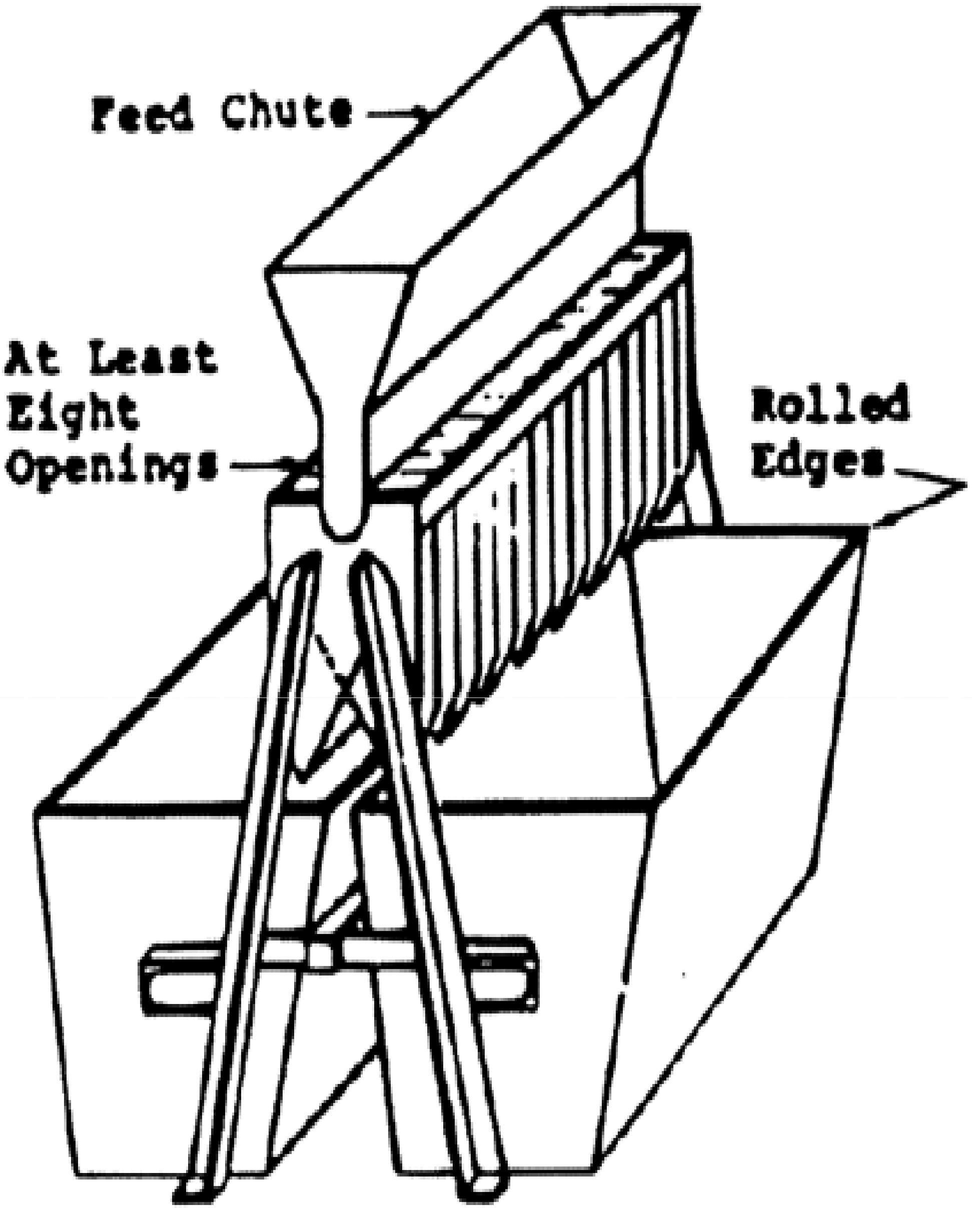
1) <u>Quartering</u>:

- Mix the field sample over three times on a level surface.
- Shovel the sample to a conical shape.
- Press the apex & flatten the conical shape.
- Divide them into four equal quarters.
- Discard two diagonally opposite quarters & use the remainder.
- If this remainder is still too large follow the same path.

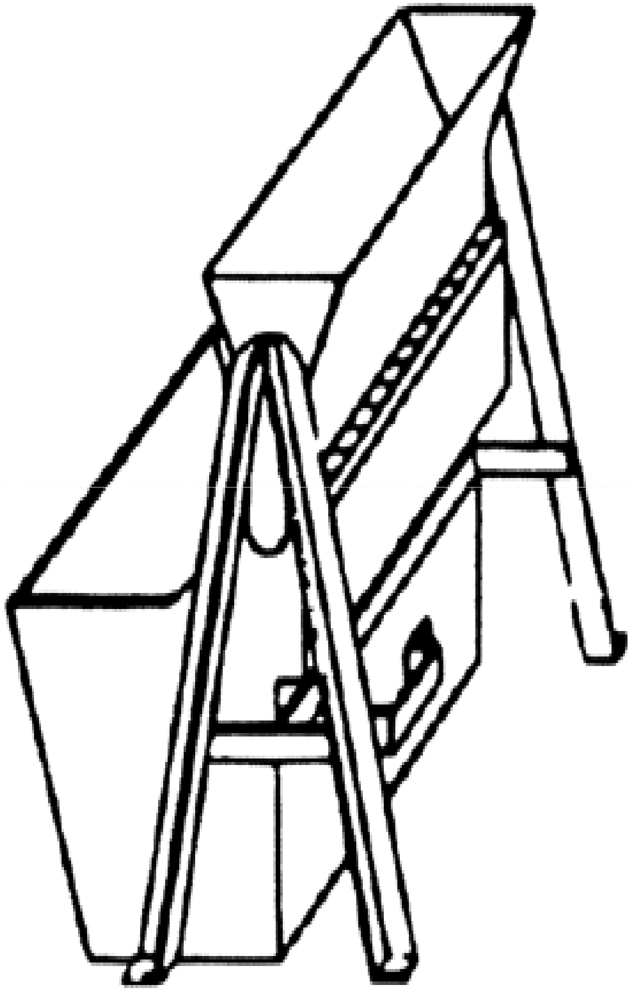


2) Splitting:

- Use the "sample splitter" to divide the aggregate sample into two.
- Sample splitter is a box with an even # of chutes alternately discharging to two sides.
- The width of each chute should be greater than 1.5 times the size of the largest aggregate size.
- If the remainder is still too large follow the same path.



Riffle Sample Splitter



Riffle Bucket and
Separate Feed Chute Stand

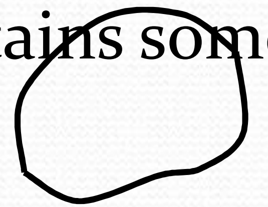
PARTICLE SHAPE & SURFACE TEXTURE

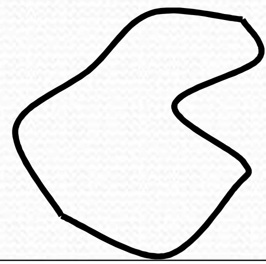
- In addition to petrological character, the external characteristics, i.e. The shape & surface texture of aggregates are of importance.

Particle Shape

- Rounded: Completely water worn & fully shaped by attrition. (River Gravel)

- Irregular: Partly shaped by attrition so it contains some rounded edges. (Land Gravel)

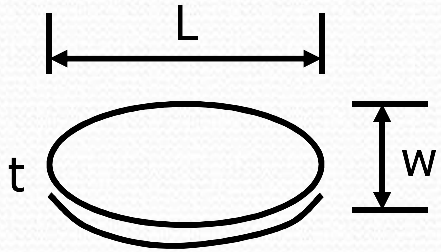




- Angular: Has sharp corners, show little evidence of wear. (Crushed Stone)

- Flaky: Thickness is relatively small with respect to two other dimensions. (Laminated Rocks)

- Elongated: Have lengths considerably larger than two other dimensions



FLAT

ELONGATED

ANGULAR

ROUND

- Rounded aggregates are suitable to use in concrete because flaky & elongated particles reduce workability, increase water demand & reduce strength.

- In the case of angular particles, the bond between agg. Particles is higher due to interlocking but due to higher surface area, angular particles increase water demand & therefore reduce workability. As a result, for the same cement content & same workability rounded agg. Give higher strength. ?

Surface Texture

- This affects the bond to the cement paste & also influences the water demand of the mix.

  Smooth: Bond b/w cement paste & agg is weak.

- *Rough*: Bond b/w cement paste & agg. is strong.

- Surface texture is not a very important property from compressive strength point of view but agg. Having rough surface texture perform better under flexural & tensile stresses.

SMOOTH

ROUGH

Grading of Aggregates

—Grading is the particle-size distribution of an aggregate as determined by a sieve analysis using wire mesh sieves with square openings.

ASTM C 33

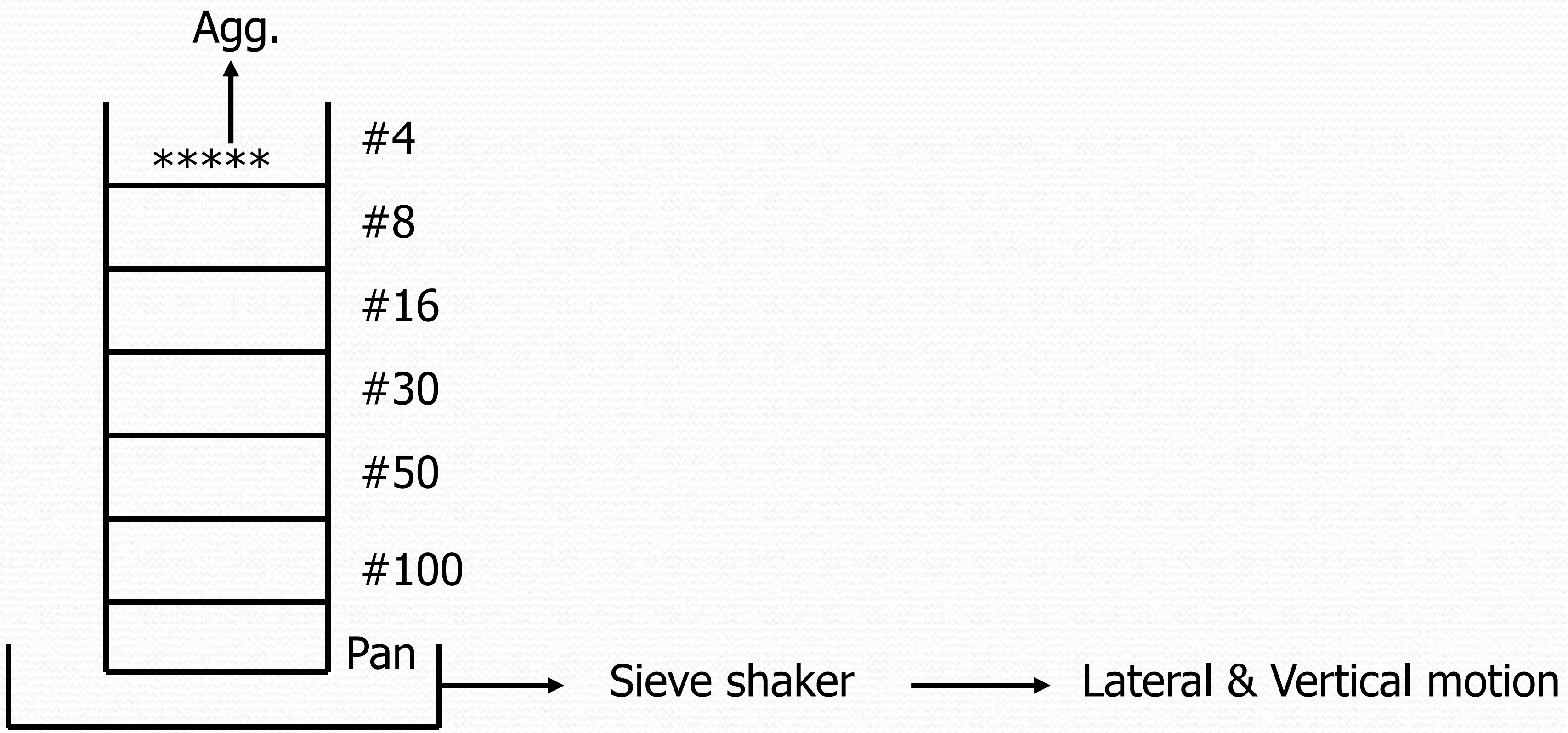
Fine aggregate—7 standard sieves with openings from 150 µm to 9.5 mm

Coarse aggregate—13 sieves with openings from 1.18 mm to 100 mm

TS 706	125 mm
	90 mm
	63 mm
	31.5 mm
	16 mm
	8 mm
	4 mm
	2 mm
	1 mm
	0.5 mm
	0.25 mm

ASTM C 33	125 mm
	100 mm
	90 mm
	75 mm (3")
	63 mm
	50 mm (2")
	37.5 mm (1-1/2")
	25 mm (1")
	12.5 mm (1/2")
	9.5 mm (3/8")
	4.75 mm (#4)
	2.38 mm (#8)
	1.19 mm (#16)
	0.595 mm (#30)
	0.297 mm (#50)
	0.149 mm (#100)

- The material is sieved through a series of sieves that are placed one above the other in order of size with the largest sieve at the top.
- Dry agg. is sieved to prevent lumps.




Diameter

- The particle size distribution in an aggregate sample is known as “gradation”.

- Strength development of concrete depends on degree of compaction & workability together with many other factors. So, a satisfactory concrete should be compacted to max density with a reasonable work.

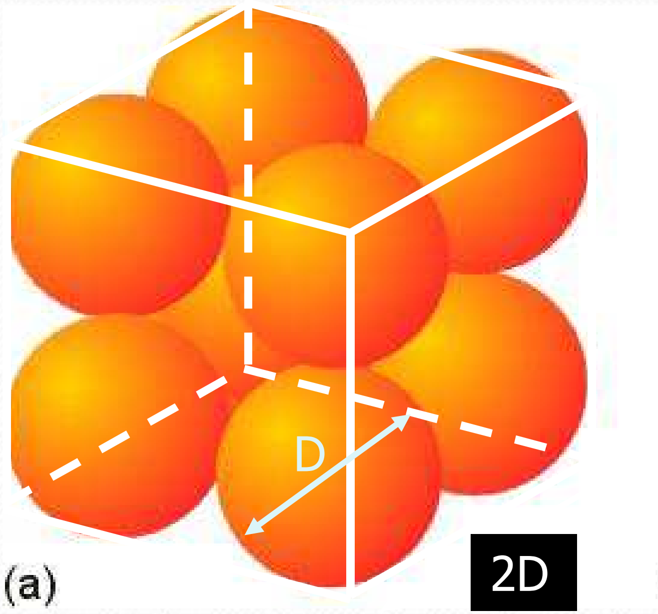
- On the other hand, in good concrete all aggregate particles must be covered by cement paste.

- The grading of aggregate must be so that the workability, density & volume stability of concrete may not be adversely affected by it.

- Fine Particles → higher cost
- Coarse Particles → less workability

- A reasonable combination of fine & coarse aggregate must be used. This can be expressed by maximum density or minimum voids concept.

A cube with a dimension of 2Dx2Dx2D is filled with spheres of diameter D



$V_{cube}=(2D)^3=8D^3$

$1V_{sphere}=(4/3)\pi(D/2)^3\approx 0.52D^3$

$8*V_{sp}=8*0.52D^3\approx 4.2D^3$ (solid volume)

Void Volume$=8D^3-4.2D^3=3.8D^3$

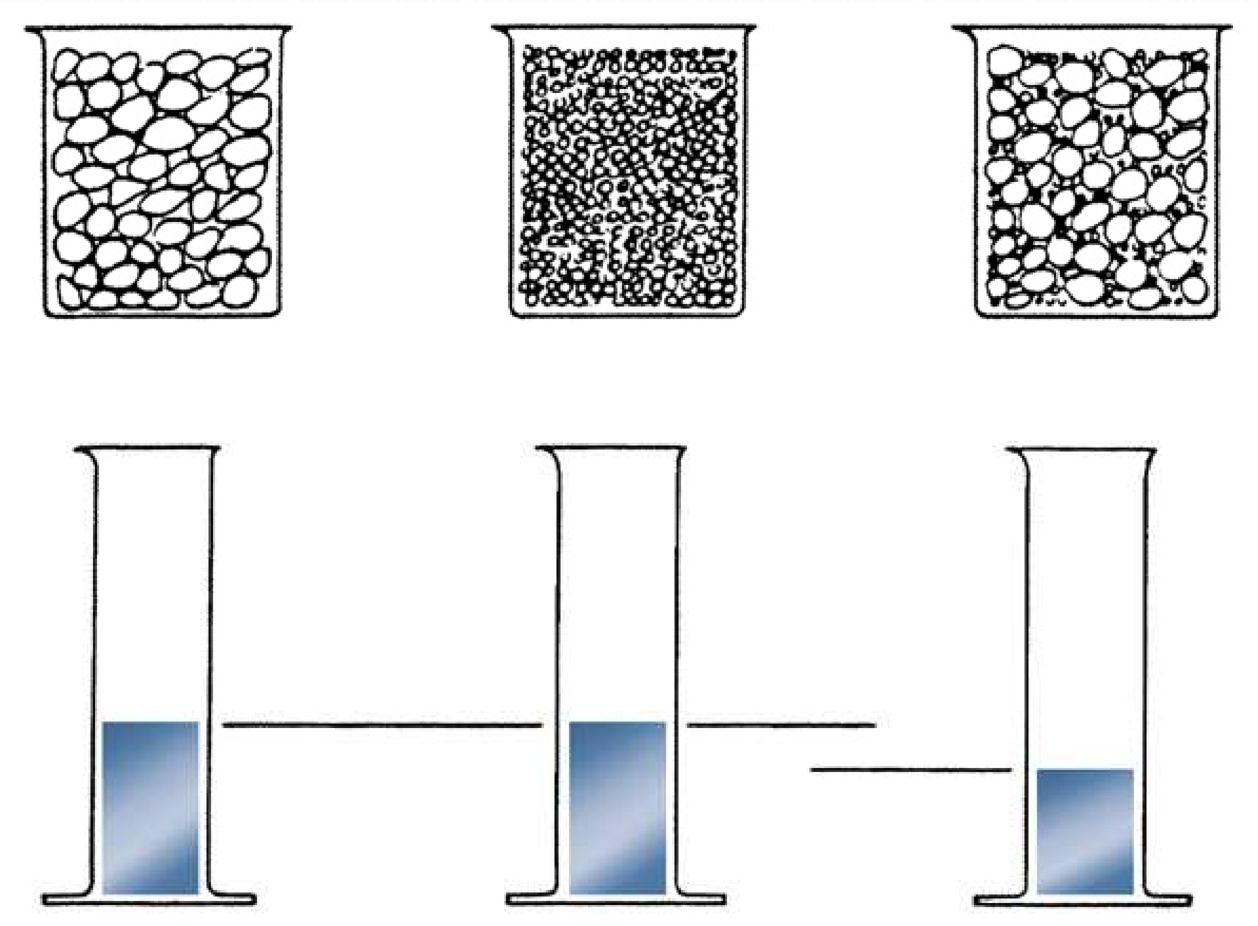
- Same cube filled with spheres of diameter D/4.

Solid Volume = $\underbrace{8*8*8}_{\#\text{of spheres}}*(4/3)\pi(D/8)^3 \approx 4.2D^3$

Void Volume $\approx 3.8D^3$

- Size of agg. is not important. If an agg. with the same size is used amount of void volume will not change. So, to overcome this different sizes of particles should be used.
- However, you should not forget that as agg. get finer, the surface area increases.
- More surface area → more paste & water requirement

Reduction of Voids



Factors Affecting a Desired Grading

1) *Surface area of the Aggregate*

   The lower the surface area, the lesser is the paste requirement.

2) *Relative Volume of Agg. in Concrete*

   Higher volume of agg.:

→economical

→higher strength, higher volume stability

→less workability !

3) *Workability*: The ease with which a concrete mixture can be mixed, transported, placed in theform & compacted without any segregation.

Workability increases as the amount of paste b/w fine agg. part increases. It also increases as the amount of mortar b/w coarse agg. particles increases.

4) *Segregation*: Seperation of the particles with different sizes & specific gravities.

The requirements of workability and absence of segregation tend to oppose each other. Thus, these two factors are interrelated. The major of these is workability which, in turn, affects most of the properties of concrete.

Determination of the Grading of Aggregate

- There are two different methods for determining the agg. grading:
- Fineness Modulus (FM)
- Granulometry

- The grading of the particles in an agg. sample is performed by “sieve analysis”. The sieve analysis is conducted by the use of “standard test sieves”. Test sieves have square openings & their designation correspond to the sizes of those openings.

1) Fineness Modulus (FM):

- FM is a single figure which is the sum of cumulative % retained on a series of sieves having a clear opening half that of the preceeding one. Usually determined for fine agg.

$$FM = \frac{\Sigma\ (\%\ \text{cumulative retained on each sieve})}{100}$$

- For Fine Agg.→#4, #8, #16, #30, #50, #100
  {practical limits→2-3.5}
- For Coarse Agg.→Fine set+3/8”+3/4”+1 ½”+3”
  {practical limits→5.5-8.0}
- The FM of the mixture of two or more agg. is the weighted average of the FM of that two more agg.

Ex: A 500gr sample of a Fine Agg. was sieved. Determine FM?

Sieve	Amount Retained on (gr)	Amount Retained on (%)	% Cumulative Retained on
3/8"	**0**	0	0
#4	**30**	6	6
#8	**80**	16	22
#16	**100**	20	42
#30	**120**	24	66
#50	**125**	25	91
#100	**35**	7	98
Pan	**10**	2	100

$$FM = \frac{6+22+42+66+91+98}{100} = 3.25$$

- Pan is not included.
- Only standard sieves are included, if we were given #10 sieve you should not use that in calculations

Ex: Determine the FM for the 1000gr sample of Coarse Agg.

Sieve	Amount Retained on (gr)	Amount Retained on (%)	% Cumulative Retained on
2"	**70**	7	7
1 1/2"	**230**	23	30
3/4"	**350**	35	65
3/8"	**250**	25	90
#4	**100**	10	100

$$FM = \frac{\text{Fine Set} + 3/8'' + 3/4'' + 1\ ½'' + 3''}{100}$$

$$FM = \frac{30+65+90+100+100+100+100+100+100}{100} = 7.85$$

Ex: The fine agg. with the FM=3.25 and the coarse agg. with the FM=7.85 are available. Combine them in such a way that the FM becomes 6.8

X : Volume of Fine agg.

$$\frac{3.25X+7.85(100-X)}{100} = 6.8 \longrightarrow X = 23$$

*23% of fine agg. and 77% of coarse agg. should be mixed.

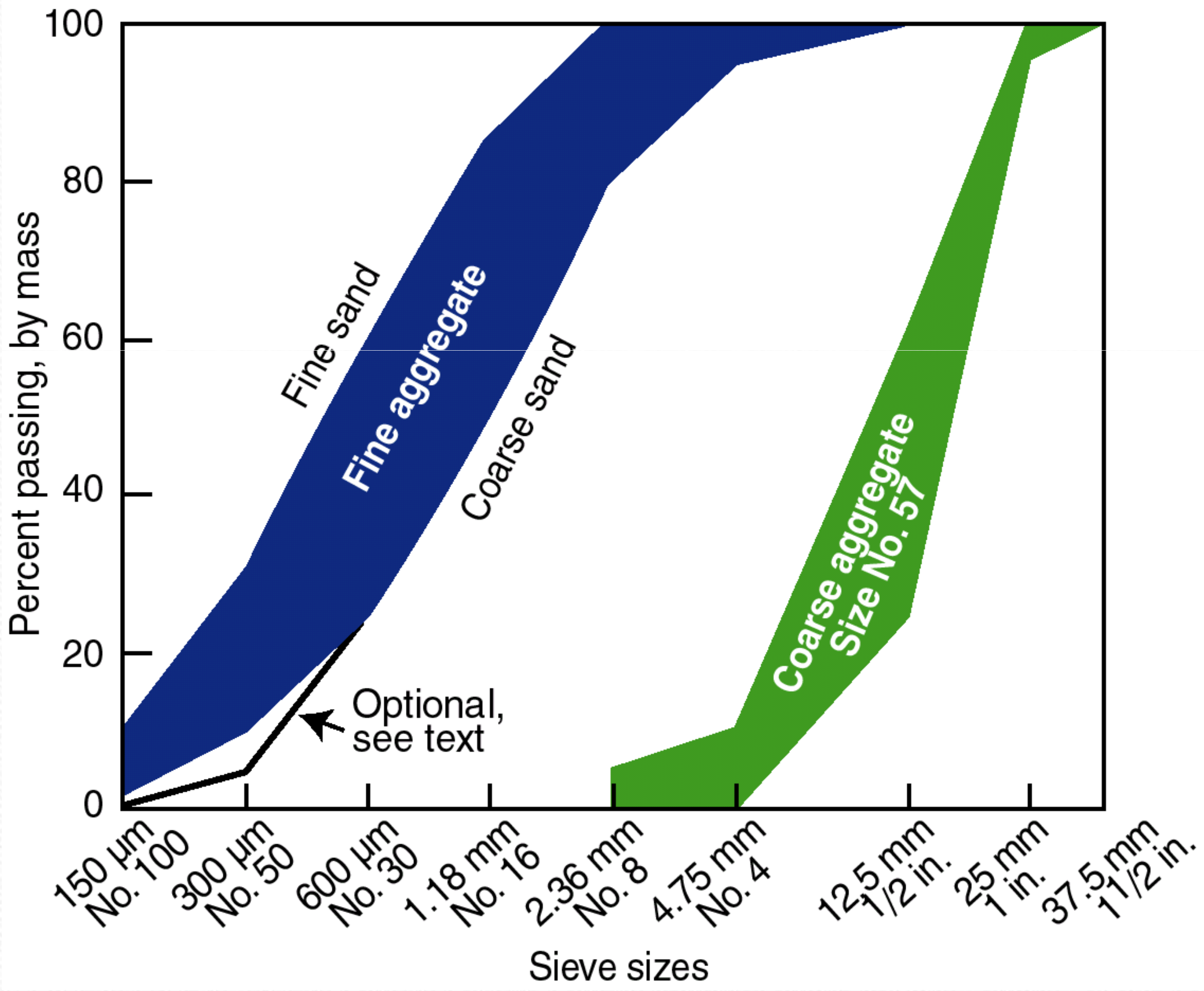
2) Granulometry:

- The FM is not always representative of the gradation of an aggregate sample and various gradation curves may give the same FM.
- In the gradation curves, the vertical axis represents the % passing & the horizontal axis represents the sieve opening.
- A logarithmic scale is used for horizontal axis.

FIGURE 5.8 Semi-log aggregate gradation chart showing a gradation example. See Table 5.2.

- A good aggregate gradation for a particular concrete is the one that leads to a workable, dense & uniform concrete, without any segregation of particles.

There is no single "ideal" grading curve. Instead, standards provide upper & lower limits.



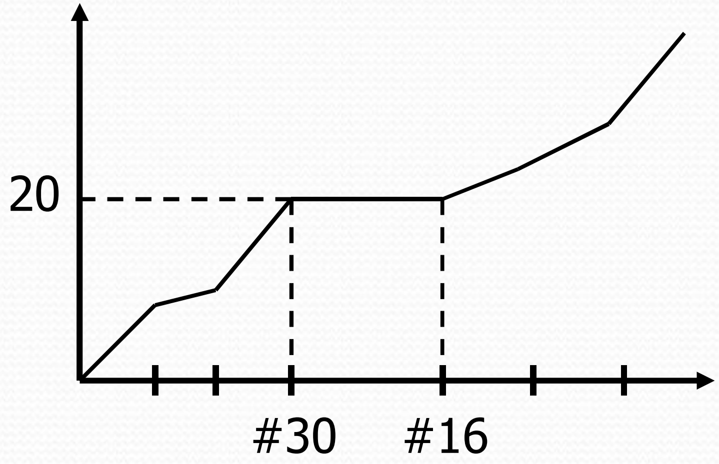
ASTM Requirement for FA	
Sieve	**% Passing**
3/8"	100
#4	95-100
#8	80-100
#16	50-85
#30	25-60
#50	10-30
#100	2-10

ASTM Requirement for CA			
Sieve	**% Passing**		
	1 ½"- #4	**3/4" - #4**	**1/2" - #4**
3"	–	–	–
2 ½"	–	–	–
2"	100	–	–
1 ½"	95-100	–	–
1"	–	100	–
3/4"	35-70	90-100	100
1/2"	–	–	90-100
3/8"	10-30	20-55	40-70
#4	0-5	0-15	0-15
#6	–	0-5	0-5

* Changes with max aggregate size

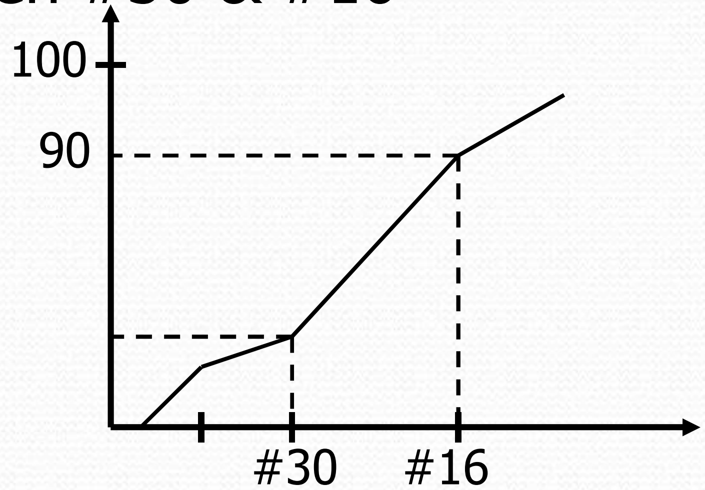
* Gap Graded agg.

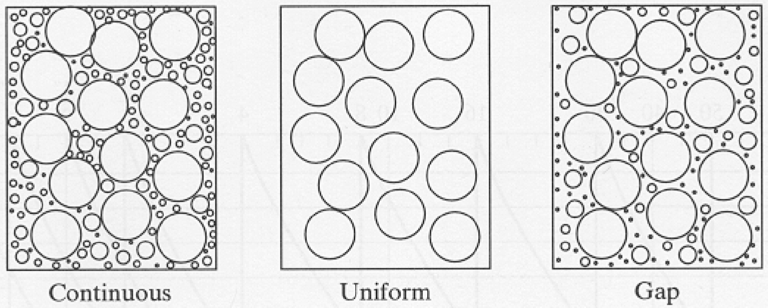
No particles between #30 & #16



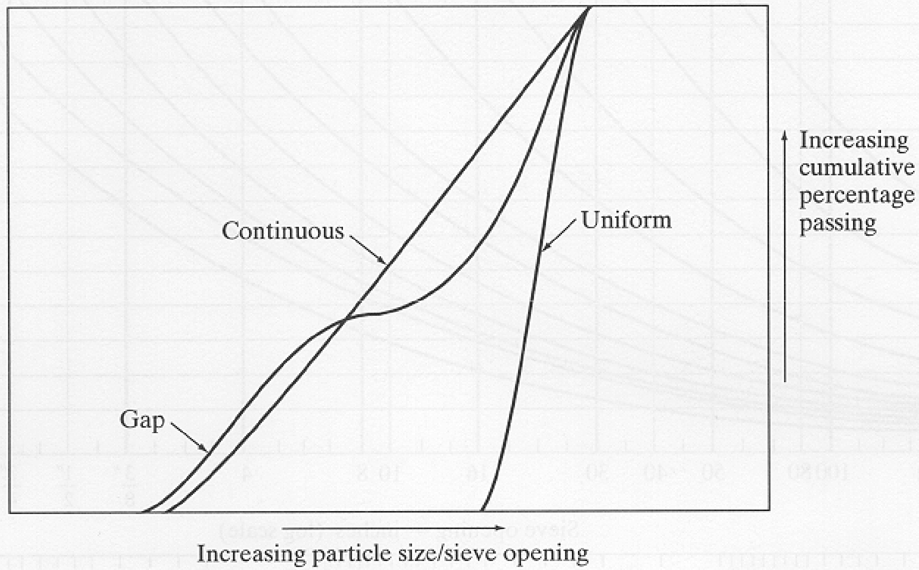
* Single sized agg.

Most of the particles are between #30 & #16





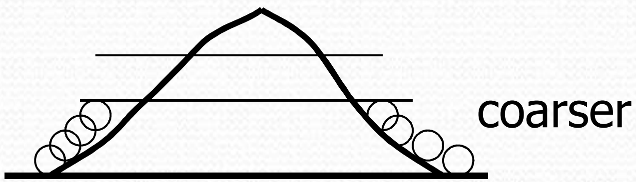
(a)



(b)

Handling & Stockpiling of Agg.

- Handling and stockpiling of coarse aggregates may easily lead to segregation. To overcome this segregation CA are handled and stockpiled in different size fractions, such as 5-15^{mm}, 15-25^{mm}, and these aggregates are mixed in specified proportions only when fed into the mixer.



Segregation: seperation of particles having different sizes

SPECIFIC GRAVITY

Specific gravity is the ratio of the weight oa a unit volume of material to the
Weight of the same volume of water at 20º to 25ºC.

$$G = \frac{\dfrac{Wt}{V}}{\dfrac{Wt_w}{V}} = \frac{\gamma}{\gamma_{H_2O}}$$

where :

G = specific gravity

Wt = weight of material

V = volume

Wt_w = weight of water

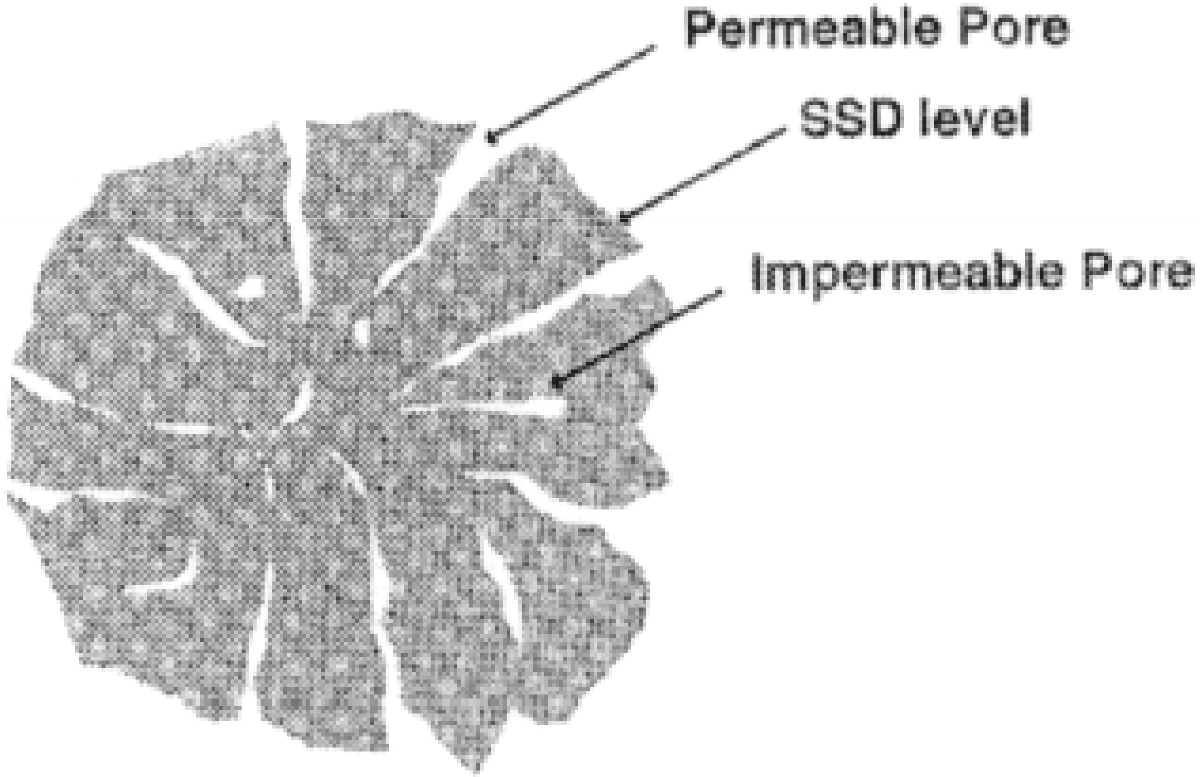
SPECIFIC GRAVITY OF AGG.

$$\text{Sp.Gr.} = \frac{\text{Weight of Agg. } (W_A)}{\text{Weight of an equal volume of water } (V_A * \rho_w)}$$

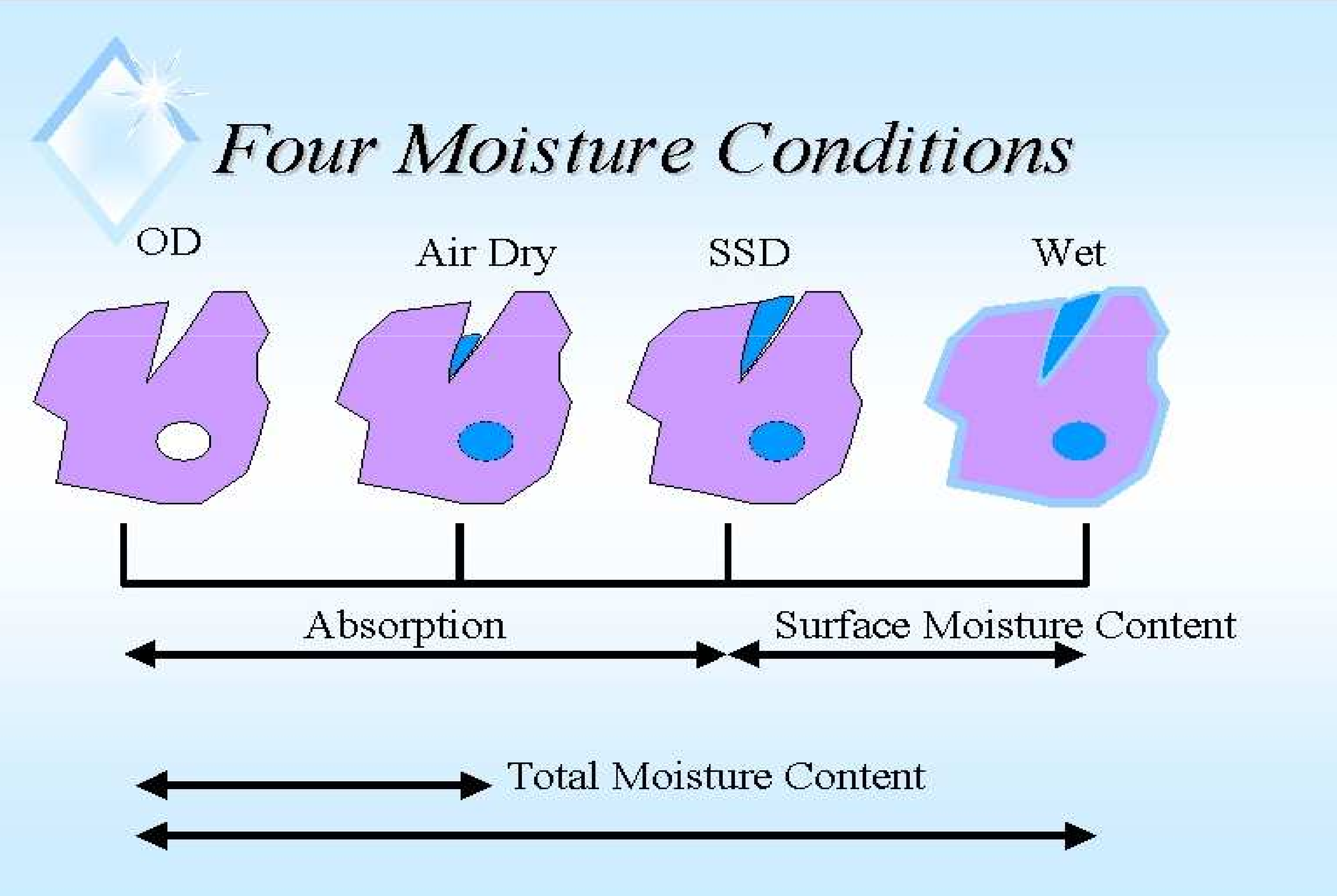
$$= \frac{W_A}{V_A * \rho_w} = \frac{\rho_A}{\rho_w} \quad \begin{array}{l} \rho_A \longrightarrow \text{Density of Agg.} \\ \rho_w \longrightarrow \text{Density of Water} \end{array}$$

- Sp.Gr. is used in certain computations for concrete mix design or control work, such as, absolute volume of aggregate in concrete. It is not a measure of the quality of aggregate.

Volume of Aggregate?

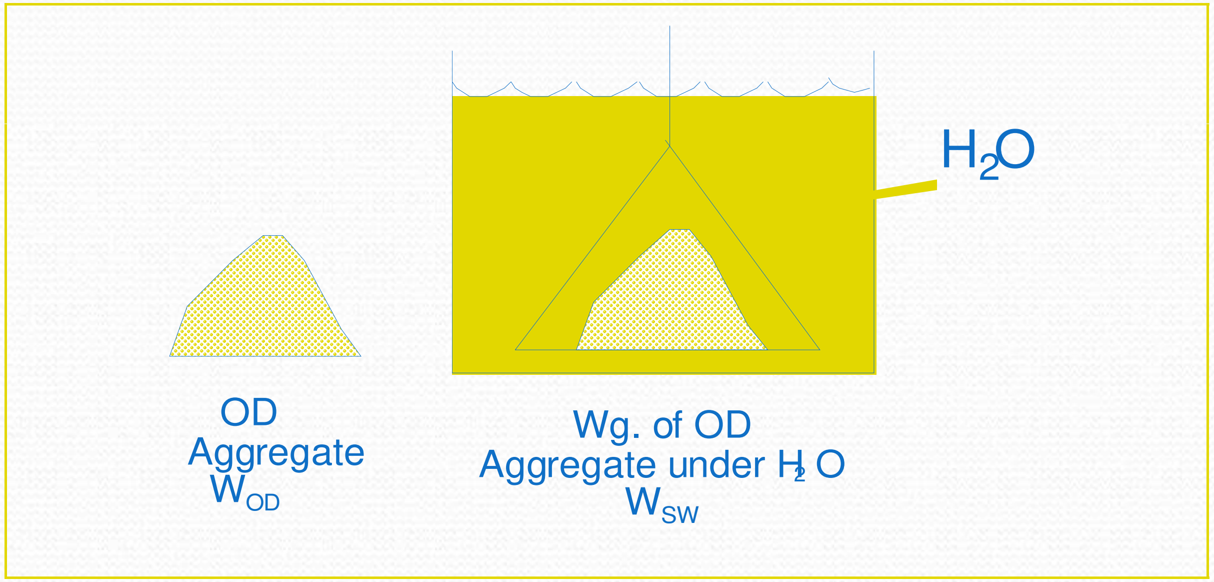


MOISTURE CONDITION OF AGGREGATES



Determination of Sp. Gr. of Aggregates

Archimedes Principle



$$G_a = \frac{W_{OD}}{W_{OD} - W_{SW}}$$

1) Coarse Agg.

- Aggs are oven dried at 105±5°C overnight & the weight is measured as (A)→oven dry weight
- Aggs are soaked in water for 24 hours
- Aggs are taken out from water & rolled in a large absorbent cloth, until all visible films of water are removed & then weighed (B)→saturated surface dry weight
- Aggs are then weighed in water (C)

$$\% \text{ Absorption} = \frac{B-A}{A} * 100$$

$$\text{Apparent Specific Gravity} = \frac{A}{A-C}$$

$$\text{Dry Bulk Specific Gravity} = \frac{A}{B-C}$$

$$\text{SSD Bulk Sp.Gr.} = \frac{B}{B-C}$$

2) Fine Agg.

- Aggs are oven dried to constant weight at 105±5°C. Measure the dry weight as (A)
- Soak them in water for 24hrs
- Stir the sample to bring it to SSD condition. Use the Cone Test for Surface Moisture Determination (Weight as S)
- Fill the aggs in SSD condition into a pycnometer (to a calibrated level) and weight it, (water+pyconometer+agg) (C)
- Fill the pyconometer with water only (to a calibrated level) and weight it (water+pyconometer) (B)

Specific Gravity Test for Sand

SSD Aggregate (S)

OD Aggregate (A)

Container with H_2O (B)

Container with H_2O and with Aggregate (C)

$$\% \text{ Absorption} = \frac{S-A}{A} * 100$$

$$\text{Apparent Specific Gravity} = \frac{A}{B+A-C}$$

$$\text{Dry Bulk Specific Gravity} = \frac{A}{B+S-C}$$

$$\text{SSD Bulk Sp.Gr.} = \frac{S}{B+S-C}$$

BULK DENSITY (UNIT WEIGHT)

- The weight of aggregate that will fill a unit volume. Unit weight depends on:

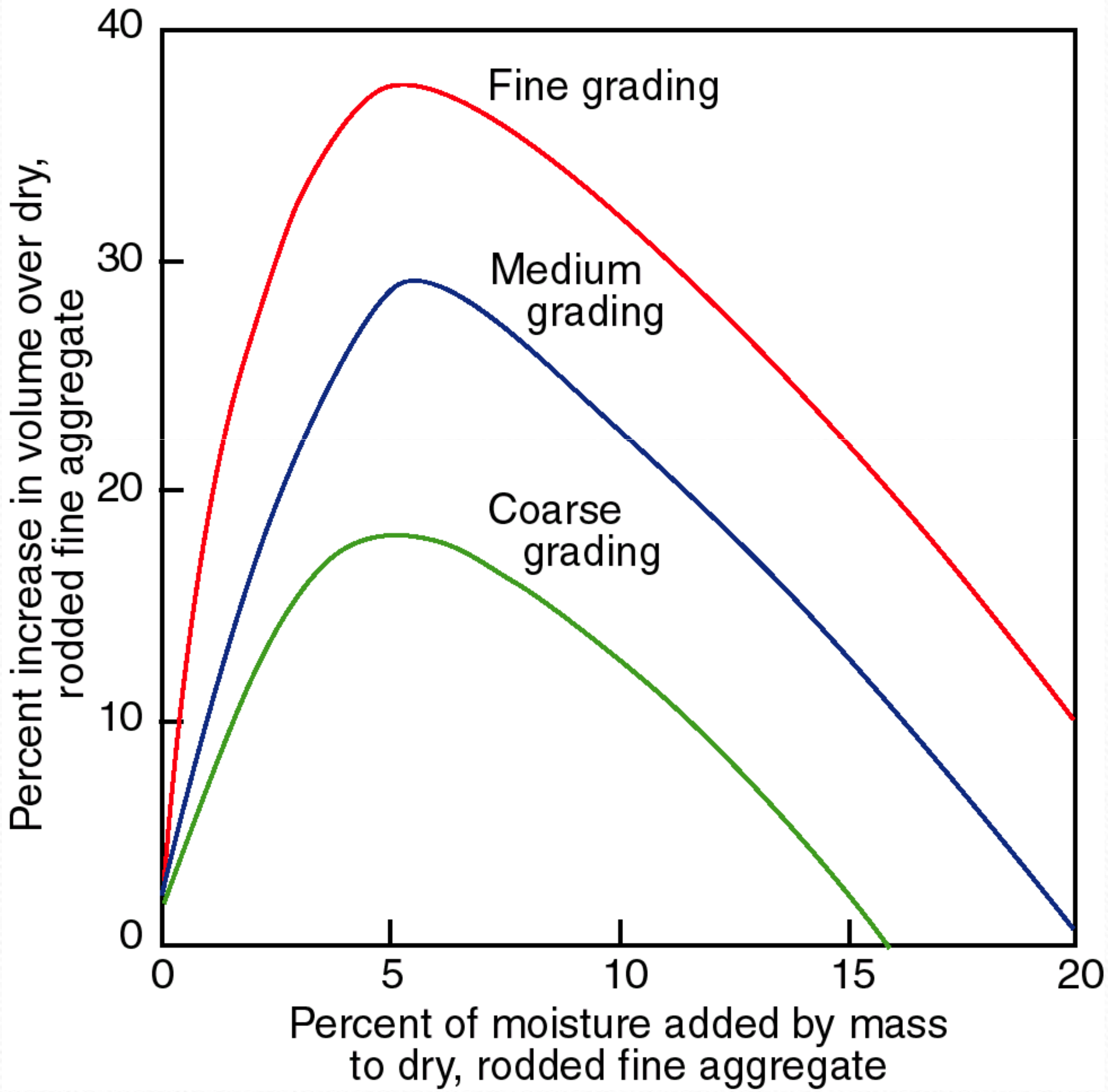
1. Size distribution
2. Shape of particles
3. Compaction
4. Moisture content → especially for fine agg. at an optimum water content packing efficiency increases.

Unit Weight

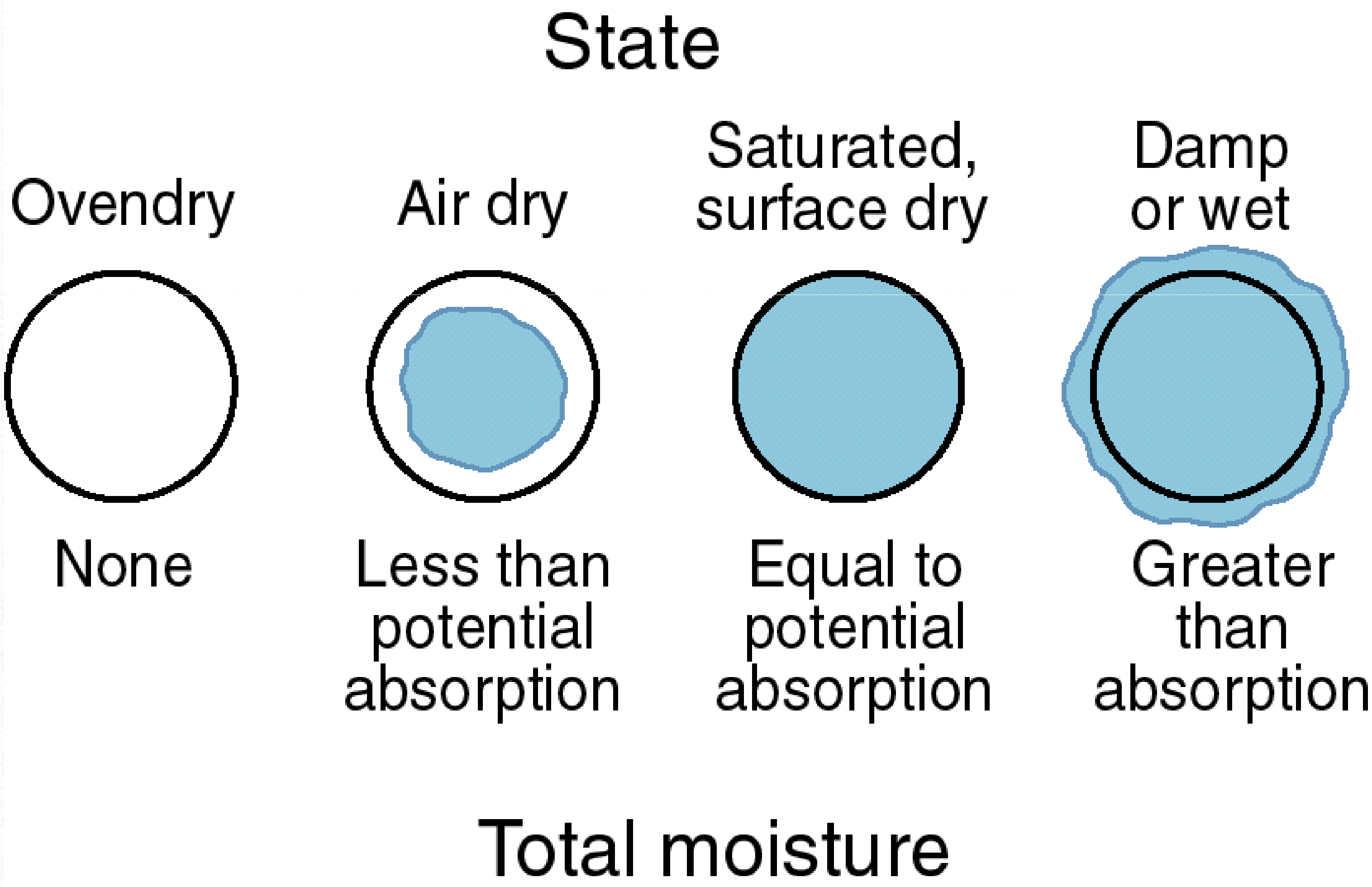
Loose → Agg. are dropped to a container at a specified height ($\rho_l = W_1/V$)

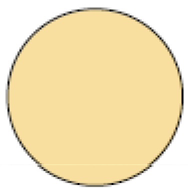
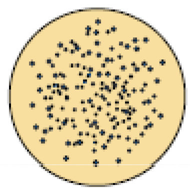
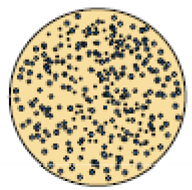
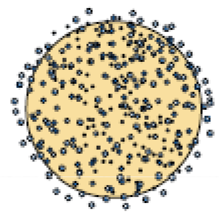
Compacted → Agg. are compacted in three layers, each layer is rodded 25 times ($\rho_c = W_2/V$)

Bulking of Sand

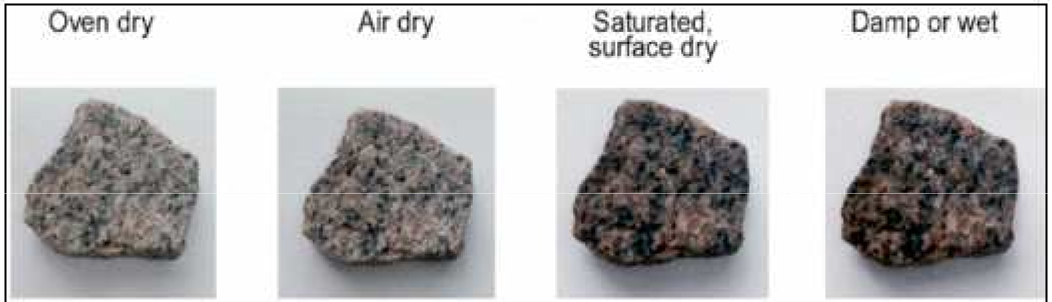


MOISTURE CONDITION OF AGGREGATES



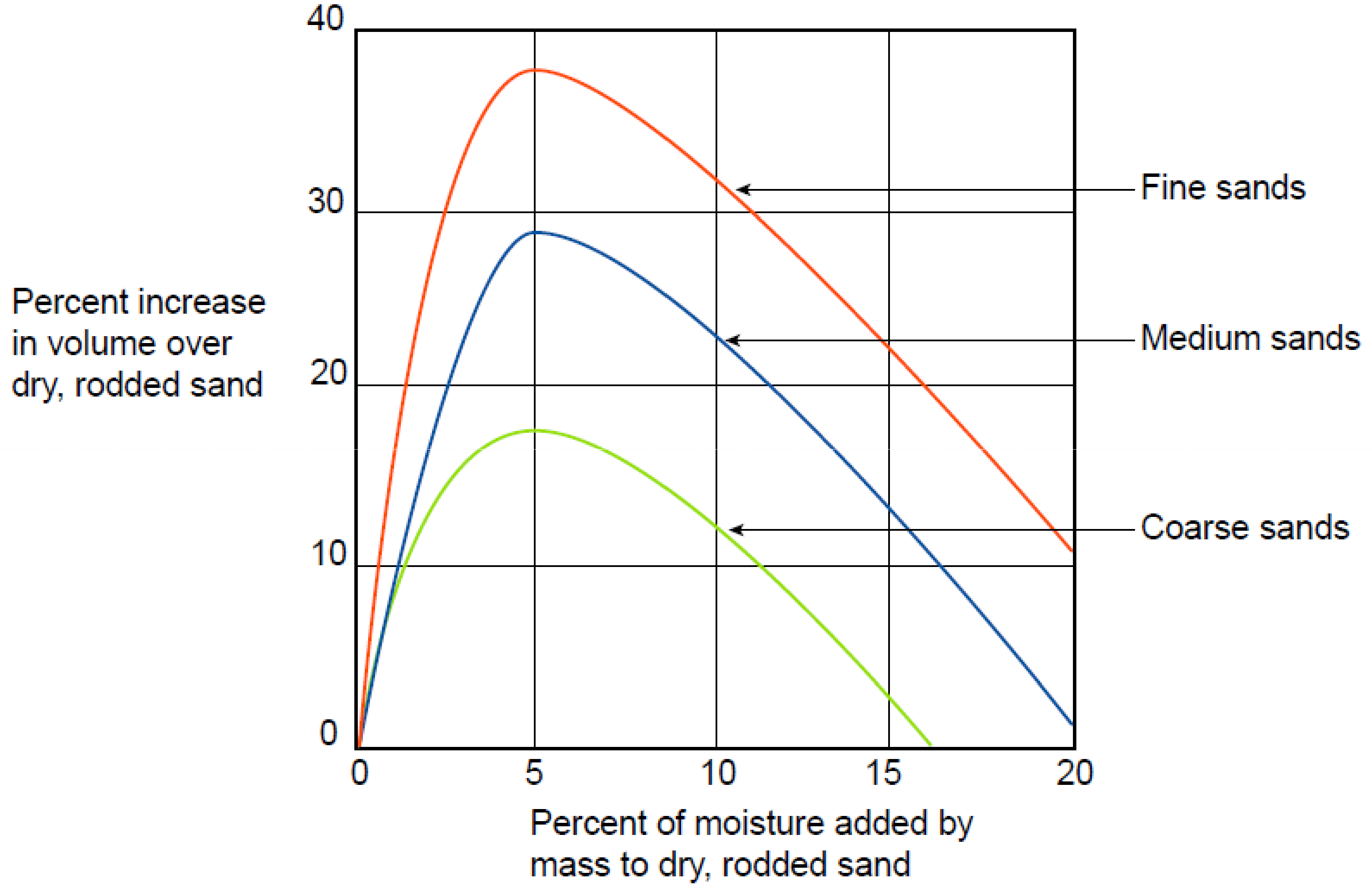
State	Oven dry	Air dry	Saturated, surface dry	Damp or wet
				
Total Moisture	None	Less than potential absorption	Equal to potential absorption	Greater than absorption

Moisture conditions of aggregates



Granite aggregate at various moisture conditions

(b)


Percent increase
in volume over
dry, rodded sand
40
30
20
10
0
0
5
10
15
20
Percent of moisture added by
mass to dry, rodded sand
Fine sands
Medium sands
Coarse sands

SIGNIFICANCE OF DETERMINING THE MOISTURE STATE & ABSORPTION CAPACITY

- SSD Condition → Equilibrium for Mositure Condition

1. If total moisture content = 0 → Agg. is bone-dry (oven dry)
2. If total moisture content < absorption capacity → It can absorb water
3. If total moisture content > absorption capacity → There is free water on the surface of agg.

- Mix Design Calculations are Based on Aggs in SSD Condition. Therefore, for aggs not being in that condition corrections have to be made
- w/c ratio → w should be "free water"

Porosity / Absorption of Aggregates

Porosity or permeability of aggregates and its absorption may affect the following factors:

- The bond between aggregate and cement paste
- Resistance to freezing & thawing of concrete
- Chemical stability
- Resistance to abrasion
- Specific gravity
- Yield of concrete for a given weight of agg.

DELETERIOUS MATERIALS IN AGGREGATES

- Organic Impurities in natural aggs may interfere with the setting & hardening of concrete. They can be detected by tests, ASTM C40, TS 3673

DELETERIOUS MATERIALS IN AGGREGATES

- Very Fine Particles: They can appear in the form of clay and silt or in the form of stone dust → they increase the water requirement or in other words decrease workability.
  - They can appear as coatings on the surface of agg particles → they affect bonding properties.
  - TS 3527→ particles smaller than 63μm
  - ASTM C 117→ #200 sieve (75μm)

DELETERIOUS MATERIALS IN AGGREGATES

- <u>Weak & Unsound Materials *Light weight materials (coals, lignide)*</u>: In excessive amounts may affect durability of concrete. If these impurities occur at or near the surface, they may disintegrate & cause pop-outs & stains.

DELETERIOUS MATERIALS IN AGGREGATES

- *Soft particles* : they are objectionable because they affect the durability adversely. They may cause pop-outs & may brake up during mixing and increase the water demand.
- *Salt contamination* : Most important effects are:
  - Corrosion of reinforcement
  - Effloresence: presence of white deposits on the surface of concrete.

SOUNDNESS OF AGGREGATES

- Soundness is the ability of agg to resist volume changes to environmental effects.
  - Freezing & Thawing
  - Alternate Wetting & Drying
  - Temperature Changes

SOUNDNESS OF AGGREGATES

- Aggs are said to be unsound when volume changes induced by the above, results in deterioration of concrete. This effect may be:
  - Local scaling
  - Extensive surface cracking
  - Disintegration over a considerable depth

SOUNDNESS OF AGGREGATES

To detect unsound particles, aggs are treated with Na_2SO_4 or $MgSO_4$ solutions.

- 18 hours of immersion
- Dry at 105°C+5°C to constant weight
- After 5 cycles determine the loss in weight of the agg.

SOUNDNESS OF AGGREGATES

- According to TS following limits should not be exceeded.

	Na_2SO_4	$MgSO_4$
Fine Agg.	19%	27%
Coarse Agg.	15%	22%

ABRASION RESISTANCE

- Especially when concrete is used in roads or floor surfaces subjected to heavy traffic load.

- Hardness, or resistance to wear (abrasion) is determined by Los-Angeles abrasion test.


Los Angeles Abrasion Test:

- The agg with a specified grading is placed inside the L.A. Testing Machine
- Loose steel balls are placed inside the drum
- The apparatus is rotated for a specified cycles
- Finally the loss in weight is determined. by screening with #12 sieve.
- Resistant → <10% for 100 revolutions

  → <50% for 500 revolutions

Alkali- Aggregate Reactivity (AAR)

- — is a reaction between the active mineral constituents of some aggregates and the sodium and potassium alkali hydroxides and calcium hydroxide in the concrete.

  - Alkali-Silica Reaction (ASR)
  - Alkali-Carbonate Reaction (ACR)

Alkali-Silica Reaction (ASR)

- Visual Symptoms
  - Network of cracks
  - Closed or spalled joints
  - Relative displacements

Alkali-Silica Reaction (ASR)

- Visual Symptoms (cont.)
  - Fragments breaking out of the surface (popouts)

- Mechanism
  1. Alkali hydroxide + reactive silica gel ⇒ reaction product (alkali-silica gel)
  2. Gel reaction product + moisture ⇒ expansion

Alkali-Silica Reaction (ASR)

- Influencing Factors
  - Reactive forms of silica in the aggregate,
  - High-alkali (pH) pore solution
  - Sufficient moisture

If one of these conditions is absent — ASR cannot occur.

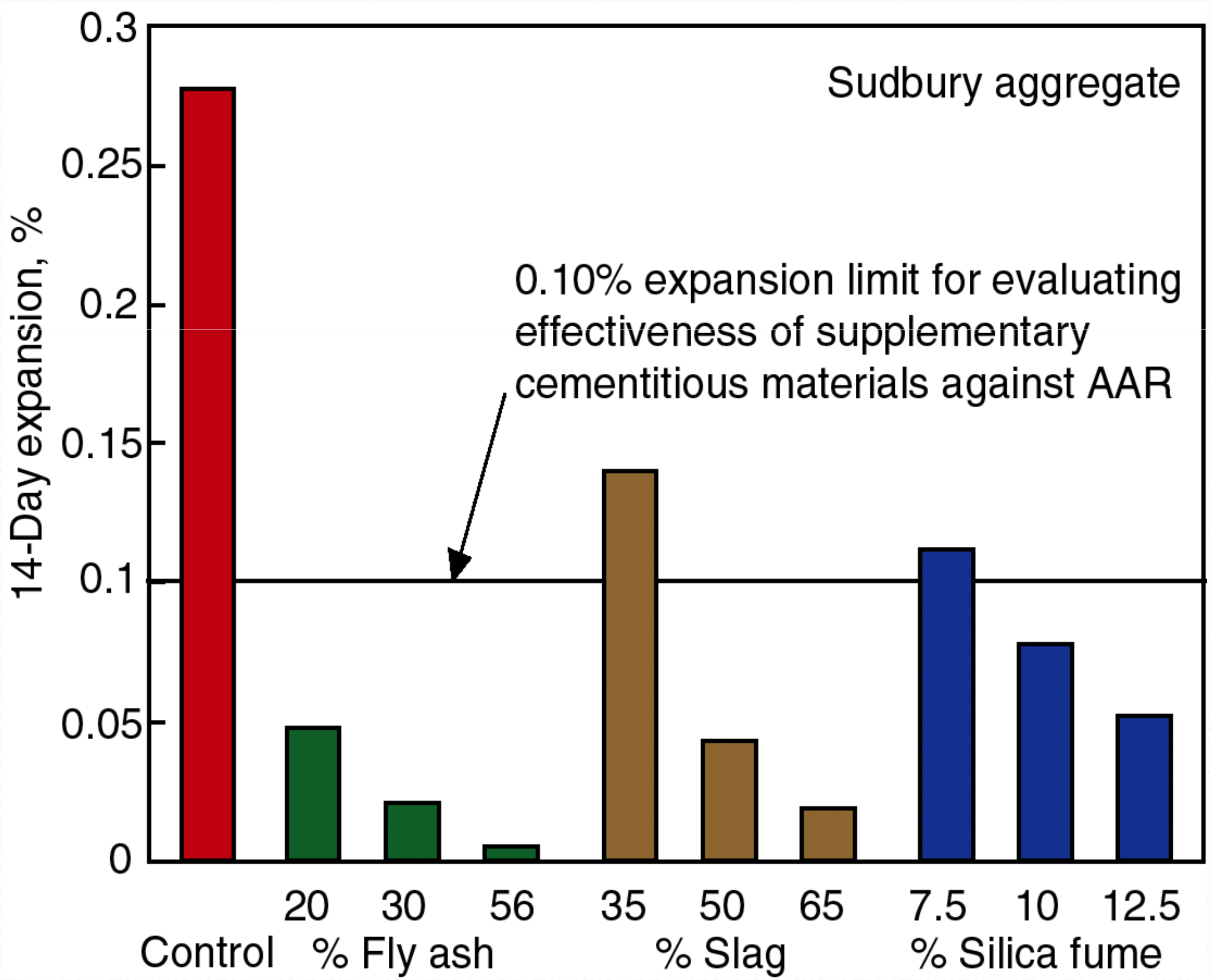
Alkali-Silica Reaction (ASR)

- Test Methods
  - Mortar-Bar Method (ASTM 227)
  - Chemical Method (ASTM C 289)
  - Petrographic Examination (ASTM C 295)
  - Rapid Mortar-Bar Test (ASTM C 1260)
  - Concrete Prism Test (ASTM C 1293)

Alkali-Silica Reaction (ASR)

- Controlling ASR
  - Non-reactive aggregates
  - Supplementary cementing materials or blended cements
  - Limit alkalis in cement
  - Lithium-based admixtures
  - Limestone sweetening (~30% replacement of reactive aggregate with crushed limestone

Effect of Supplementary Cementing Materials on ASR



MAX AGG SIZE

- It’s the smallest sieve size through which the entire amount of the agg particles can pass.

- The larger the size of agg, the smaller the surface area to be wetted per unit weight. Thus, extending the grading of agg to a larger max size lowers the water requirement of the mix. So, for the same workability & cement content higher strength will be obtained.

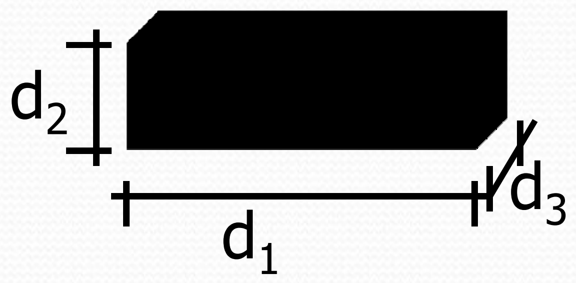
- Optimum max agg size for structural concrete is 25mm.

- Studies have shown that concrete’s made with max agg size greater than 40mm have lower strength. Because of the smaller surface area for the bond between agg to paste. Volume changes in the paste causes larger stresses at the interface.

Standard Limitations for Max Agg Size

- The concrete mix must be so that, it can be placed inside the molds and between the reinforcing bars easily without any segregation. So, max agg size (D_{max}) should not exceed:

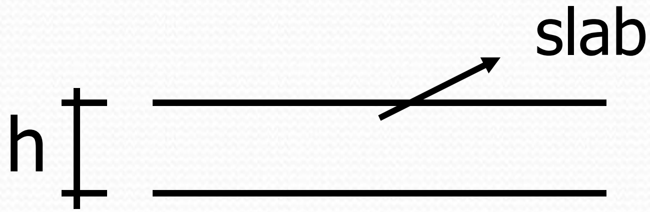
1) 1/5 of the narrowest dimension of the mold.



$$d = \min(d_1, d_2, d_3)$$

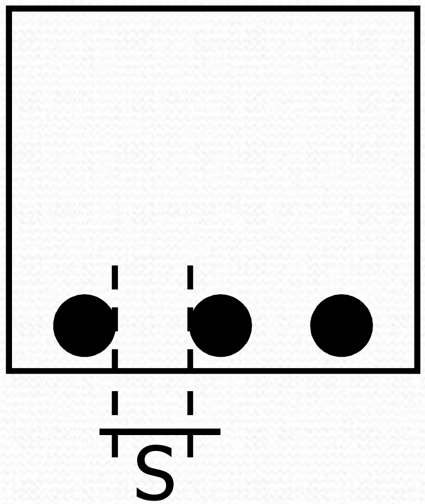
$$D_{max} < \frac{d}{5}$$

2) 1/3 of the depth of the slab



$$D_{max} < \frac{h}{3}$$

3) ¾ of the clear spacing between reinforcement

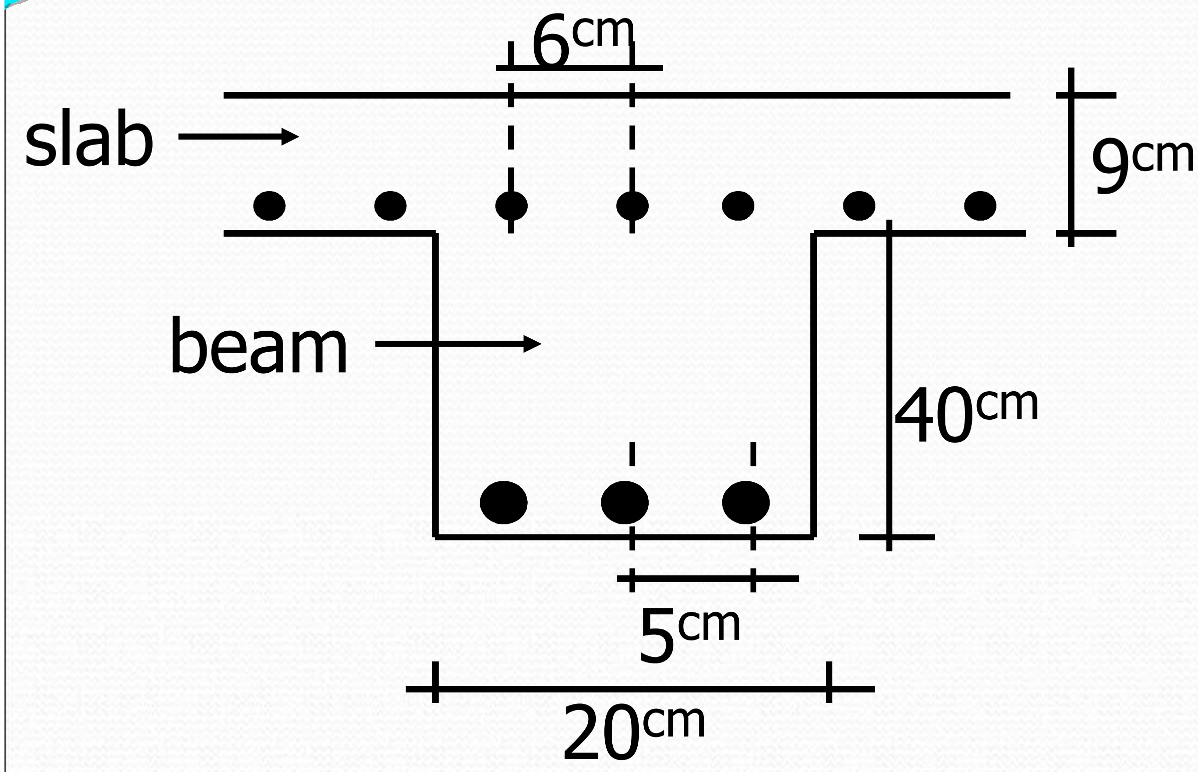


S:face of the distance

$$D_{max} < \frac{3}{4} S$$

4) $D_{max} < 40^{mm}$

Example:



$\Phi = 10^{mm}$

$D_{max} = ?$

1) $D_{max} < 1/5 \min(20,40) = 4^{cm}$

2) $D_{max} < 1/3(9) = 3^{cm}$

3) $D_{max} < 3/4(4) = 3^{cm}$

4) $D_{max} < 4^{cm}$

$\Longrightarrow$ $Dmax < 3^{cm}$

PROPERTIES of CONCRETE
Aggregates

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