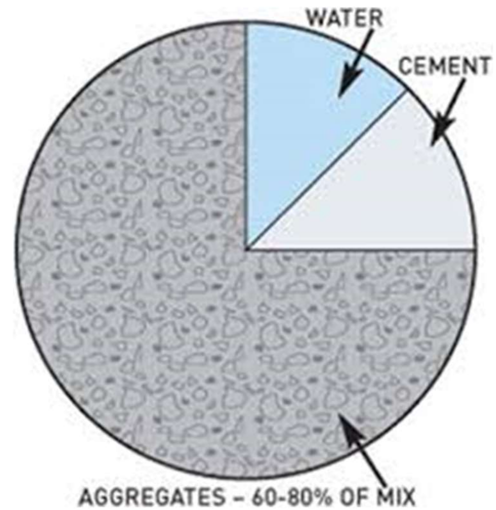
Normal Aggregates

Chapter 4

Introduction

- Aggregates generally occupy 60% to 80% of the concrete volume and strongly influence the concrete's fresh and hardened properties such as workability, durability and strength in addition to mixture proportions, and economy.



- Aggregates must be clean, hard, strong, and durable particles that are largely free of absorbed chemicals, coatings of clay, and other fine materials in amounts that could affect hydration and bond of the cement paste.

- From the economic viewpoint, it is advantageous to use a mix with as much aggregate and as little cement as possible, but the cost benefit has to be balanced against the desired properties of concrete in its fresh and hardened state.

Aggregate Geology

Concrete aggregates are a mixture of rocks and minerals. Rocks are classified as igneous, sedimentary, or metamorphic, depending on their geological origin.

Rock and Mineral Constituents in Aggregates

Minerals	Minerals (continued)	Igneous rocks	Sedimentary rocks	Metamorphic rocks
Silica	Zeolite	Granite	Conglomerate	Marble
Quartz	Carbonate	Syenite	Sandstone	Metaquartzite
Opal	Calcite	Diorite	Quartzite	Slate
Chalcedony	Dolomite	Gabbro	Graywacke	Phyllite
Tridymite	Sulfate	Peridotite	Subgraywacke	Schist
Cristobalite	Gypsum	Pegmatite	Arkose	Amphibolite
Silicates	Anhydrite	Volcanic glass	Claystone, siltstone,	Hornfels
Feldspars	Iron sulfide	Obsidian	argillite, and shale	Gneiss
Ferromagnesian	Pyrite	Pumice	Carbonates	Serpentinite
Hornblende	Marcasite	Tuff	Limestone	
Augite	Pyrrhotite	Scoria	Dolomite	
Clay	Iron oxide	Perlite	Marl	
Illites	Magnetite	Pitchstone	Chalk	
Kaolins	Hematite	Felsite	Chert	
Chlorites	Goethite	Basalt		
Montmorillonites	Ilmenite			
Mica	Limonite			

Aggregate Classification

- **Based on density**, aggregates are classified into three categories:
  - Normal-weight (Bulk density ranges from 1200 kg/m^3 to 1750 kg/m^3)
  - Lightweight (Bulk density ranges from 560 kg/m^3 to 1120 kg/m^3)
  - Heavyweight (Bulk density typically over 2100 kg/m^3)

Lightweight aggregates

- **Based on source**, aggregates are classified into
  - Natural aggregate
  - Manufactured aggregate

- **Based on size**, aggregates are classified into
  - Fine aggregates
  - Coarse aggregates

Aggregate Classification

Natural aggregate

Those from the river beds, river sand and ex-mines. Normally rounded in shape and have smooth surface texture. The quality (or soundness) of natural aggregate depends on the bedrock from which the particles were derived and the mechanism by which they were transported.

Manufactured aggregate

produced by crushing sound parent rock at stone crushing plants. As a result of the crushing operation, manufactured aggregates often have a rough surface texture, are more angular in nature, tend to be cubical or elongated in shape, and more uniform in size. Manufactured aggregates are less likely to be contaminated by deleterious

Aggregate Classification

Fine aggregates

Those aggregates which pass through 4.75 mm sieve or aggregates with size less than 5 mm.

Coarse aggregates

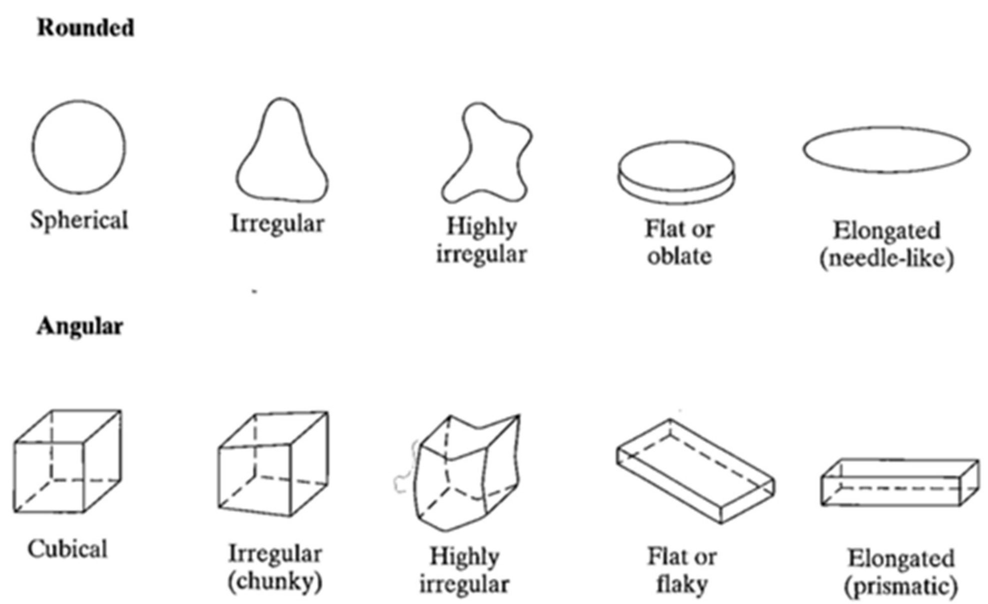
Those aggregates Passing through 75 mm sieve and entirely retained on 4.75 mm sieve OR those aggregates with size greater than 5 mm.

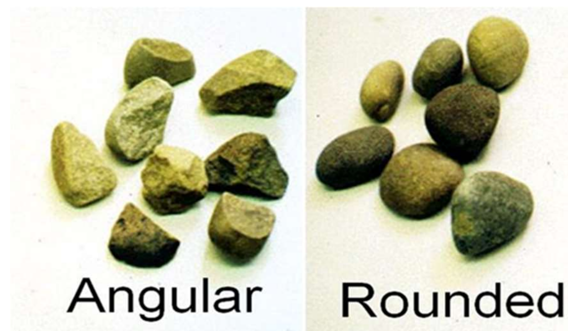
Particle Shape and Surface Texture

The external characteristics of the aggregate, in particular the particle shape and surface texture, are of importance with regard to the properties of fresh and hardened concrete.

Particle shape

A convenient broad classification of particle shape is given in diagram bellow





Elongated

Flat or Flaky

Particle Shape and Surface Texture

<u>Particle shape</u>

Particle shape can be identified by the following

1. Roundness: measures the relative sharpness or angularity of the edges and corners of a particle.
2. Angularity of Aggregate: Since the degree of packing of particles all of one size depends on their shape, the angularity of aggregate can be estimated from the proportion of voids among particles compacted in a prescribed manner. BS 812: Part 1:1975 quantified angularity by the angularity number.

- <u>Angularity Number</u>

- It measures the percentage of voids between particular aggregates in excess of that between the most rounded gravel assuming that the solid volume of the most rounded aggregates in a specific container occupy 67% of its volume or it have 33% voids.
- Angularity No. = (solid volume of aggregates / volume of container)X100 – 33

Particle Shape and Surface Texture

Particle shape

- The higher the number, the more angular the aggregate, the range for practical aggregates being between 0 and 11.
- Example: If the void content of the aggregate is 33% the angularity of such aggregate is considered 0. If the void is 44%, the angularity number of such aggregate is considered 11.

3. Sphericity

- Another aspect of the shape of coarse aggregate is its sphericity, defined as a function of the ratio of the surface area of the particle to its volume (specific surface).
- Particles with a high ratio of surface area to volume are of particular interest. Elongated and flaky particles are of this type.

Particle Shape and Surface Texture

Elongated and flaky particles

- The classification of such particles is made by means of the simple gauges shown. (flakiness apparatus down, elongation up)
- A particle is flaky if its thickness (least dimension) is less than 0.6 times the mean sieve size of the size fraction to which the particle belongs.
- Similarly, a particle whose length (largest dimension) is more than 1.8 times the mean sieve size of the size fraction is said to be elongated.
- The mass of flaky particles, expressed as a percentage of the mass of the sample, is called the *flakiness index. Elongation index* are similarly defined.

- The presence of elongated or flaky particles in excess of 10 to 15 per cent of the mass of coarse aggregate is generally considered undesirable.

Particle Shape and Surface Texture

Surface texture

- The classification of the surface texture is based on the degree to which the particle surfaces are polished or dull, smooth or rough; the type of roughness has also to be described.
- Visual estimate of roughness is quite reliable.

Effect of particle shape and texture in properties of fresh and hardened concrete.

- Irregular, flat and elongated particles will interfere with adjacent particle and decrease workability.
- Irregular particle, flat and elongated usually have high surface - to - volume ratio and needs more paste to cover the surface and fill the voids.
- Concrete containing Irregular flat and elongated particle are more prone to segregation.

Particle Shape and Surface Texture

Effect of particle shape and texture in properties of fresh and hardened concrete - continued

- Flaky particles can adversely affect the durability of concrete as they tend to be oriented in one plane, with water and air voids forming underneath.
- Rough surfaces aggregates requires more lubrication or more paste.
- Irregular particles that has higher surface area can enhance bonding and influence strength favorably.
- Rough surface particles will also improve the bond.

The ideal aggregate particle in concrete industry is considered the one that is close to spherical in shape (Well rounded and compact), with relatively smooth surface.

Characteristics of Aggregates

The important characteristics of aggregates for concrete include

- The mechanical properties of aggregates such as strength, toughness and hardness or abrasion resistance.
- The physical properties of aggregates such as grading, porosity, absorption, specific gravity and unit weight.
- Durability of aggregates

- Normal-weight aggregates should meet the requirements of ASTM C33, or AASHTO M 6 and AASHTO M 80. These specifications limit the permissible amounts of deleterious substances and provide requirements for aggregate characteristics.

Mechanical properties of aggregates

Strength and toughness

- Clearly, the compressive strength of concrete cannot significantly exceed that of the major part of the aggregate contained therein. Usually Aggregate strength become important in high strength concrete. In practice there is no direct test to measure aggregate strength.
- Toughness can be defined as the resistance of aggregate to failure by impact, and it is usual to determine the aggregate impact value of bulk aggregate using the aggregate Impact Test. Toughness from impact test is related to aggregate strength and it is important for concrete used in heavy-duty concrete floor finishes and pavement.

Impact Test

Mechanical properties of aggregates

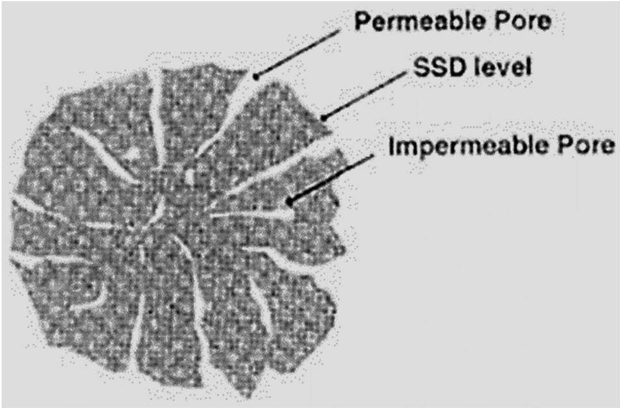
Hardness (Abrasion resistance)

- Hardness is the resistance to wear. it is an important property of concrete used in roads and in floor surfaces subjected to heavy traffic
- The Los Angeles test is The most common test for abrasion resistance.
- The test gives results which show a good correlation not only with the actual wear of the aggregate in concrete, but also with the compressive and flexural strengths of concrete when made with the same aggregate.

Physical Properties of Aggregates

Physical properties include absorption, moisture content, specific gravity, unit weight and grading which are relevant to the behavior of aggregate in concrete and to the properties of concrete made with the given aggregate.

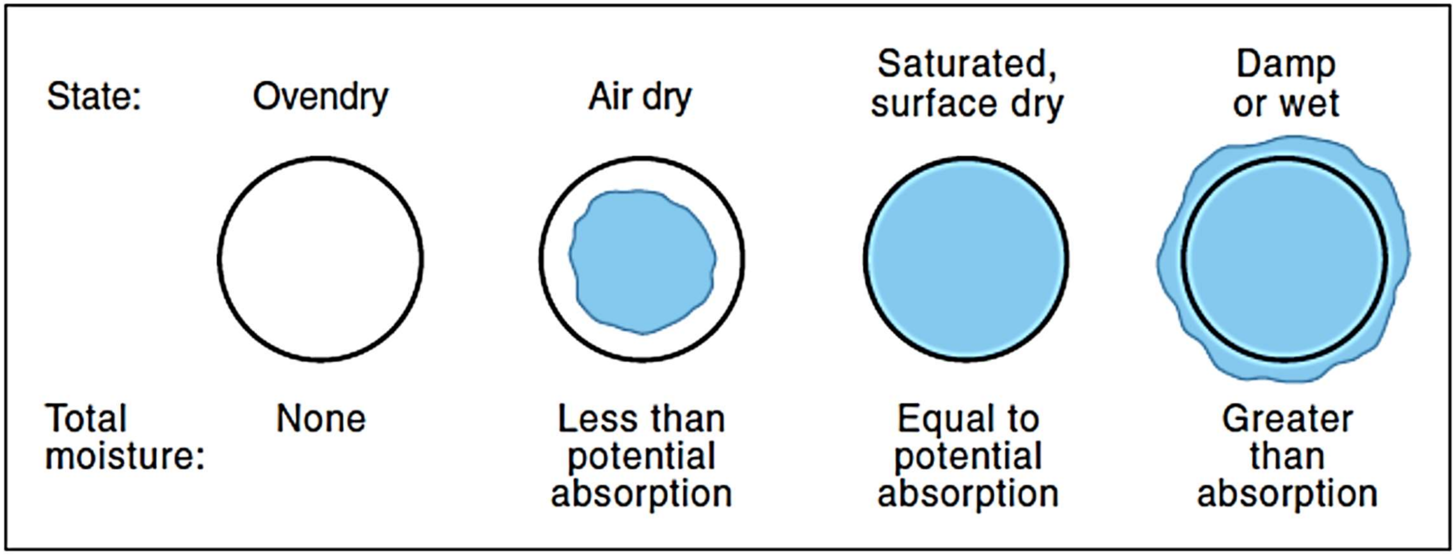
❖ Absorption and Moisture Content



- Aggregates contain some porosity, Some of the pores are wholly within the solid (impermeable) whilst others open onto the surface of the particle (permeable).
- Water can be absorbed into the body of the particles. Also, water can be retained on the surface of the particle as a film of moisture.
- It is necessary to have information about the moisture content, since if aggregates can absorb water, it will be removed from the paste. If excess water is present at its surfaces, extra water will be added to the paste.

Physical Properties of Aggregates

Moisture conditions of aggregates (States)



- **Oven Dry (OD)** all moisture removed by heating to 105°C to constant weight.
- **Air dry (AD)** all moisture removed from surface but internal pores partially full
- **Saturated, surface dry (SSD)** All pores filled with water, but no film of water on the surface.
- **Wet** all pores filled with water with a film of water on the surface

Physical Properties of Aggregates

❖ Absorption and Surface Moisture

Absorption (A) : represents the maximum amount of water the aggregate can absorb. It is calculated from the difference in weight between the SSD and OD states, expressed as a percentage of the OD weight

$$A = \frac{W_{SSD} - W_{OD}}{W_{OD}} \times 100\%$$

Effective Absorption (EA): Represent the amount of water required to bring aggregates from AD state to SSD state.

$$EA = \frac{W_{SSD} - W_{AD}}{W_{SSD}} \times 100\%$$

- Most normal-weight aggregates (fine and coarse) have absorption capacities in the range of 1 to 2%. Abnormally high absorption capacities indicate high-porosity aggregates, which may have potential durability problems.

Physical Properties of Aggregates

❖ Absorption and Surface Moisture

Moisture Content

Moisture content is the water in excess of the saturated, surface dry condition (SSD). Thus, the total water content of a moist aggregate is equal to the sum of absorption and moisture content.

$$MC = \frac{W_{AD} - W_{SSD}}{W_{SSD}} \times 100\%$$

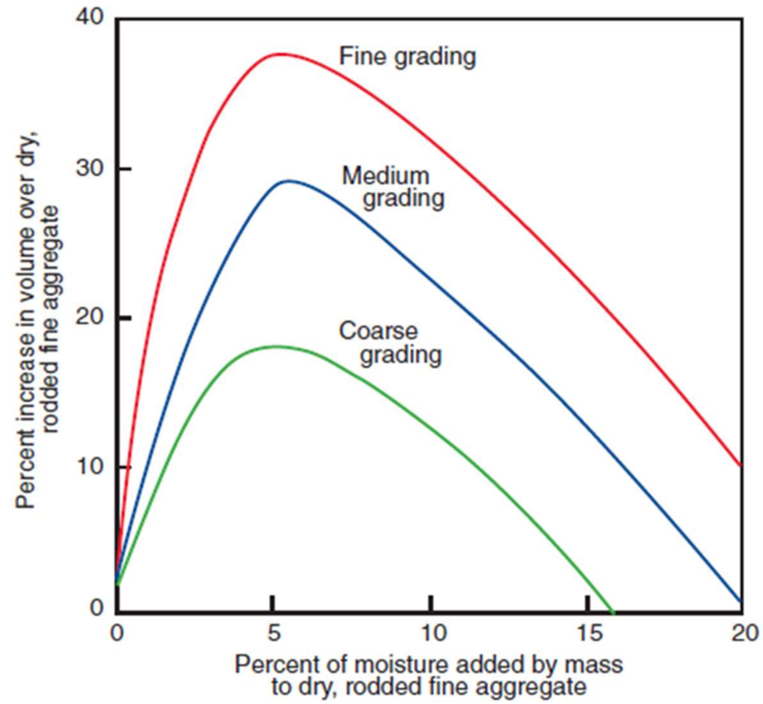
The moisture content must be allowed for in the calculation of batch quantities and of the total water requirement of the mix. In effect, the mass of water added to the mix has to be decreased and the mass of aggregate must be increased by an amount equal to the mass of the moisture content.

Moisture in aggregate (especially fine) can case increase in the volume of material. The phenomena is known as sand buckling

Physical Properties of Aggregates

Bulking of Sand

- Bulking is the increase in total volume of moist fine aggregate over the same mass in a dry condition.
- It is caused by the surface tension in the moisture which holds the particles apart, causing an increase in volume.
- The figure illustrates how the amount of bulking of fine aggregate varies with moisture content and grading;
- Fine gradings bulk more than coarse gradings for a given amount of moisture.



Physical Properties of Aggregates

❖ Specific Gravity

According to ASTM C 127-04, specific gravity is defined as the ratio of the density of a material to the density of distilled water at a stated temperature; hence, specific gravity is dimensionless.

- Since aggregate generally contains pores, both permeable and impermeable the meaning of the term specific gravity (or relative density) has to be carefully defined, and there are indeed several types of this measure.

- The absolute specific gravity refer to the volume of the solid material excluding all pores. It is theoretical so not used in concrete calculations.
- Apparent specific gravity (ASG) refer to the volume of solid material including the impermeable pores, but not the capillary ones.
- Bulk specific gravity (BSG) refer to the volume of solid material including all pores. It can calculated based on OD and SSD conditions. The BSG is the realistic measure that is used in mix design.

Physical Properties of Aggregates

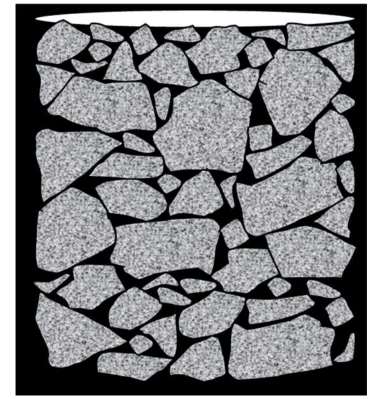
❖ **Specific Gravity**

- In reality, porosity of aggregates used in concrete production is only of the order of 1-2%, so the values of all the specific gravity is approximately the same.
- BSG of most rocks are in the range of 2.5 – 2.8, values bellow this range may indicate high porosity rocks.
- Specific gravity is usually determined using the displacement method, in which the volume of aggregates is determine by submerging in water and determining the displaced volume.

❖ **Bulk Unit Weight (UW)**

- The bulk density or unit weight of an aggregate is the mass or weight of the aggregate required to fill a container of a specified unit volume. It depends on:
  - The degree of compaction. (rodding)
  - The size distribution and shape of the particles
  - Moisture content of aggregates. (use of OD aggr.)
- As shown, the volume of the container is occupied by both aggregates and the voids between aggregate particles.
- The voids ratio which can be calculated using UW, indicates the volume of mortar required to fill the space between the coarse aggregate particles.

$$V_v = 1 - \frac{UW}{BSG \times \rho_w}$$

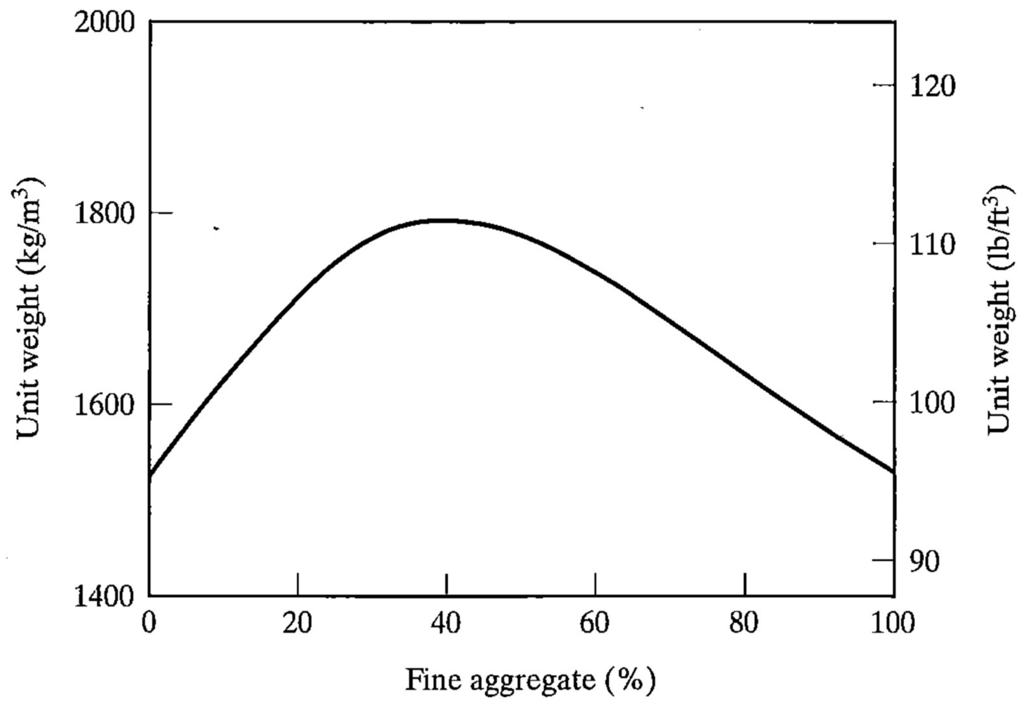


Physical Properties of Aggregates

❖ Bulk Unit Weight (UW)

- The maximum bulk density of a mixture of fine and coarse aggregates is achieved when the mass of the fine aggregate is approximately 35% to 40% of the total mass of aggregate.

- The UW of coarse aggregates is also required for the volume method of mix proportioning. It is used to convert quantities by mass to quantities by volume.



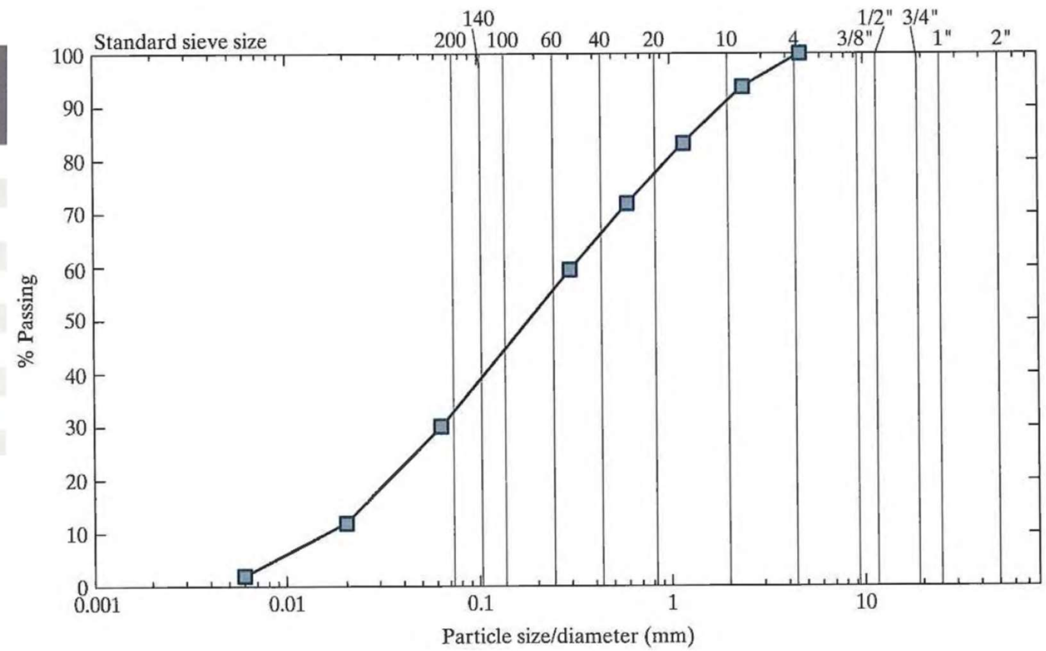
Aggregates Grading

- Definition: Grading is the particle-size distribution of an aggregate as determined by a sieve analysis
- The aggregate particle size is determined using wire-mesh sieves with square openings. The seven standard ASTM C33 (AASHTO M 6/M 80) sieves for fine aggregate have openings ranging from 150 µm to 9.5 mm (No. 100 sieve to 3⁄8 in.). The 13 standard sieves for coarse aggregate have openings ranging from 1.18 mm to 100 mm (0.046 in. to 4 in.).

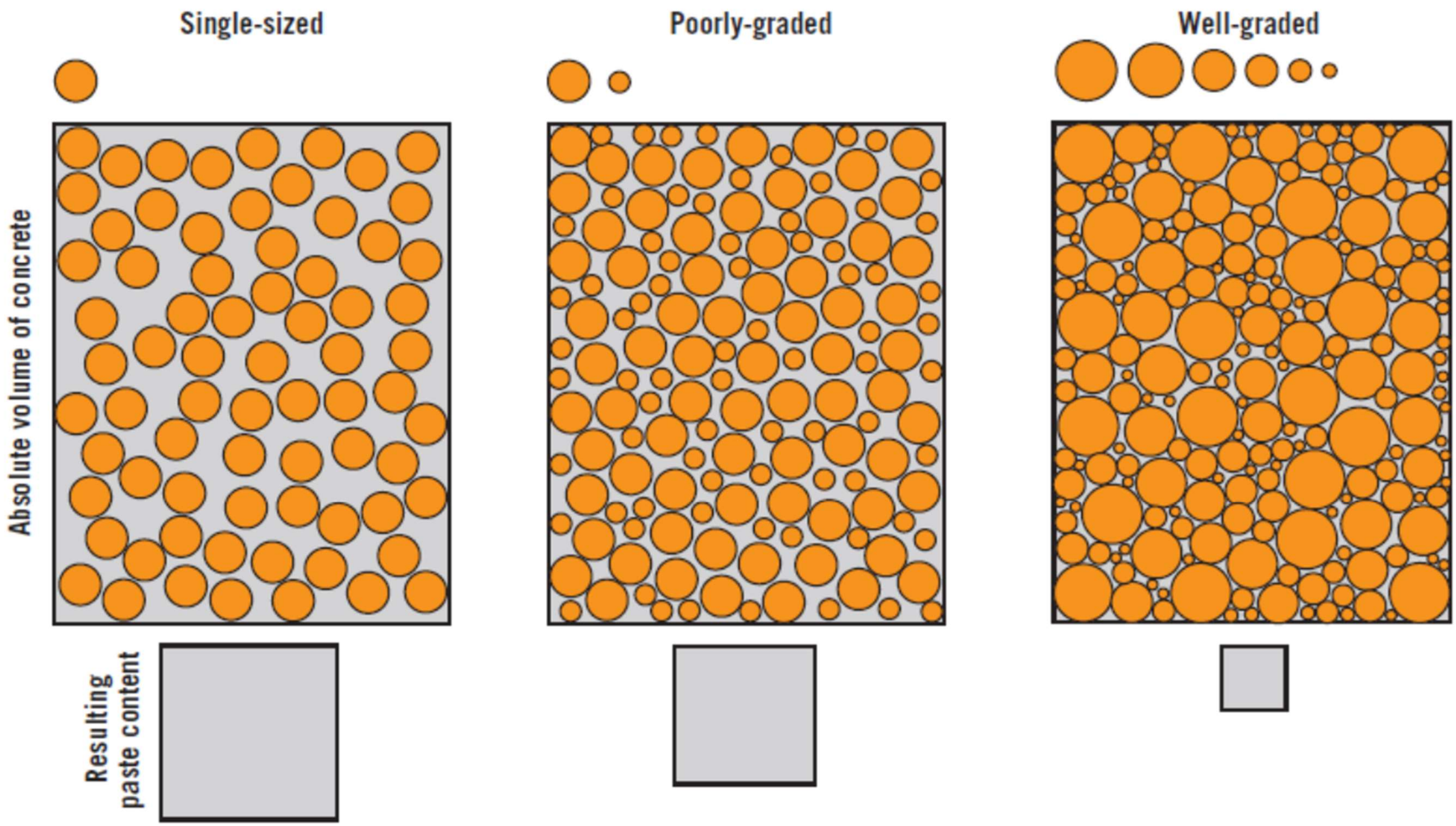
Grading Curves

Grading curve is a plot of the cumulative percentages passing or retained against each sieve size plotted on a grading chart, where the ordinates represent the cumulative percentage passing and the abscissae are the sieve apertures plotted to a logarithmic scale

Sieve opening size (mm)	Retained amount (g)(A)	Cumulative retained amount (g)(B)	Cumulative retained amount (percent) ($C = \frac{B}{Total} \times 100$)	Percent finer or Percent passing (D = 100 − C)
4.75	0	0	0	100
2.36	32.5	32.5	6.1	93.9
1.18	57.0	89.5	16.8	83.2
0.6	61.8	151.3	28.4	71.6
0.3	63.9	215.2	40.4	59.6
0.063	157.7	372.9	70.0	30.0
0.02	95.9	468.8	88.0	12.0
0.006	53.3	522.1	98.0	2.0
Pan	10.6	532.7	100	
Total amount	532.7			

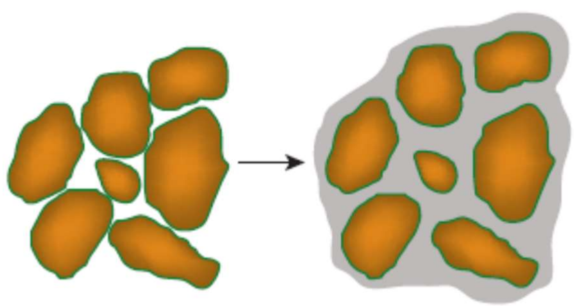


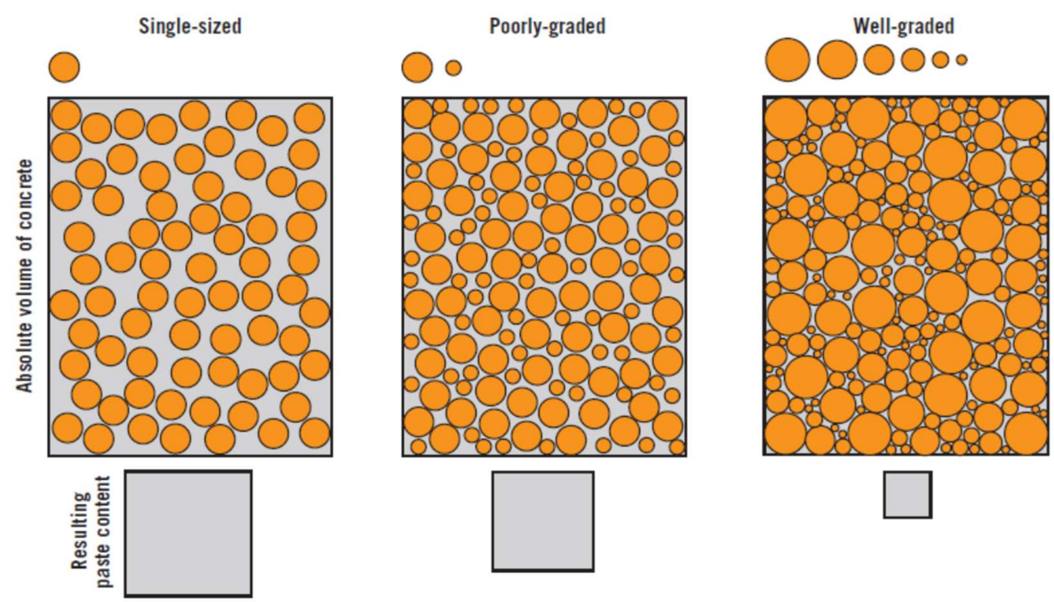
Benefits of Grading limits



Benefits of Grading limits

- It is more economical to use as much aggregate as possible relative to paste, since it is cheaper than the cement paste. The paste requirement for concrete is dictated by the void content and the surface area of the aggregates, as the paste role in the mix is to Coat and wet the surface of solids and to Fill the voids between particles so using well graded aggregate with extended size will ensure economy of the mix.





Benefits of Grading limits

- To ensure workability of the mix that can be influenced by : **the surface area of the aggregate, the relative volume occupied by the aggregate and the amount of fines in the mix.**

  - **For example**

  Smaller particles **(<150 µm) appear to act as a lubricant** and do not require wetting in the same way as coarser particles although it have higher surface area.
- **Grading limits is necessary to reduce segregation**

Grading - Fineness modulus (FM)

- The fineness modulus (FM) is defined as the sum of the cumulative percentages by mass retained on the sieves of the standard series, divided by 100. it is usually calculated for fine aggregates.

$$\text{FM} = \frac{\Sigma\,(\text{cumulative percent retained on standard sieves})}{100}$$

- The specified sieves for determining FM are: 150 µm (No. 100), 300 µm (No. 50), 600 µm (No.30), 1.18 mm (No. 16), 2.36 mm (No. 8), 4.75 mm (No. 4), 9.5 mm (3/8 in.), 19.0 mm (3/4 in.), 37.5 mm (11/2 in.), 75 mm (3 in.) and, 150 mm (6 in.).
- Fineness modulus is an index of the fineness of an aggregate. In general, the higher the FM, the coarser the aggregate. Typical values range from 2.3 and 3.0.

- The fineness modulus can be used to detect slight variations in the aggregate from the source, which could affect the workability of the fresh concrete.

Grading - Fineness modulus (FM)

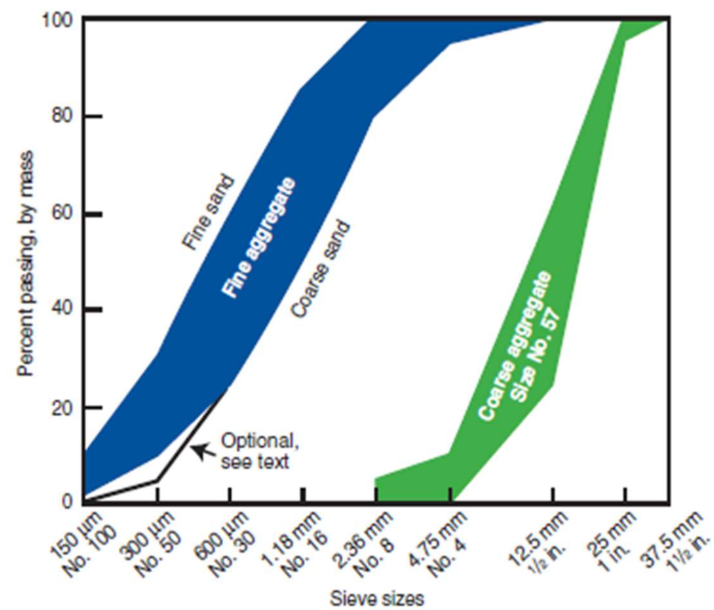
Example: Determination of Fineness Modulus of Fine Aggregates

Sieve size		Percentage of individual fraction retained, by mass	Percentage passing, by mass	Cumulative percentage retained, by mass
9.5 mm	(⅜ in.)	0	100	0
4.75 mm	(No. 4)	2	98	2
2.36 mm	(No. 8)	13	85	15
1.18 mm	(No. 16)	20	65	35
600 µm	(No. 30)	20	45	55
300 µm	(No. 50)	24	21	79
150 µm	(No. 100)	18	3	97
	Pan	3	0	—
Total		100		283

Fineness modulus = 283 ÷ 100 = 2.83

Grading limits

- The grading and grading limits are usually expressed as the percentage of material passing each sieve as shown in the shown curves which indicate the limits specified in ASTM C33 for fine aggregate and for one commonly used size number (grading size) of coarse aggregate.



- Reasons for specifying grading limits and a nominal maximum aggregate size:

- Grading affects relative aggregate proportions as well as cement and water requirements, workability, pumpability, economy, porosity, shrinkage, and durability of concrete.
- Variations in grading can seriously affect the uniformity of concrete from batch to batch.

Grading limits - Fine-Aggregate Grading

Sieve size		Percent passing by mass	
9.5 mm	(3/8 in.)	100	
4.75 mm	(No. 4)	95 to 100	
2.36 mm	(No. 8)	80 to 100	
1.18 mm	(No. 16)	50 to 85	
600 µm	(No. 30)	25 to 60	
300 µm	(No. 50)	5 to 30	(AASHTO 10 to 30)
150 µm	(No. 100)	0 to 10	(AASHTO 2 to 10)
75 µm	(No. 200)	0 to 3.0[A,B]	

[A] For concrete not subject to abrasion, the limit for material finer than the 75-µm (No. 200) sieve shall be 5.0% maximum.

[B] For manufactured fine aggregate, if the material finer than the 75-µm (No. 200) 5.0% maximum for concrete subject to abrasion, and 7.0% maximum for concrete not subject to abrasion.

Grading limits – Course Aggregate Grading

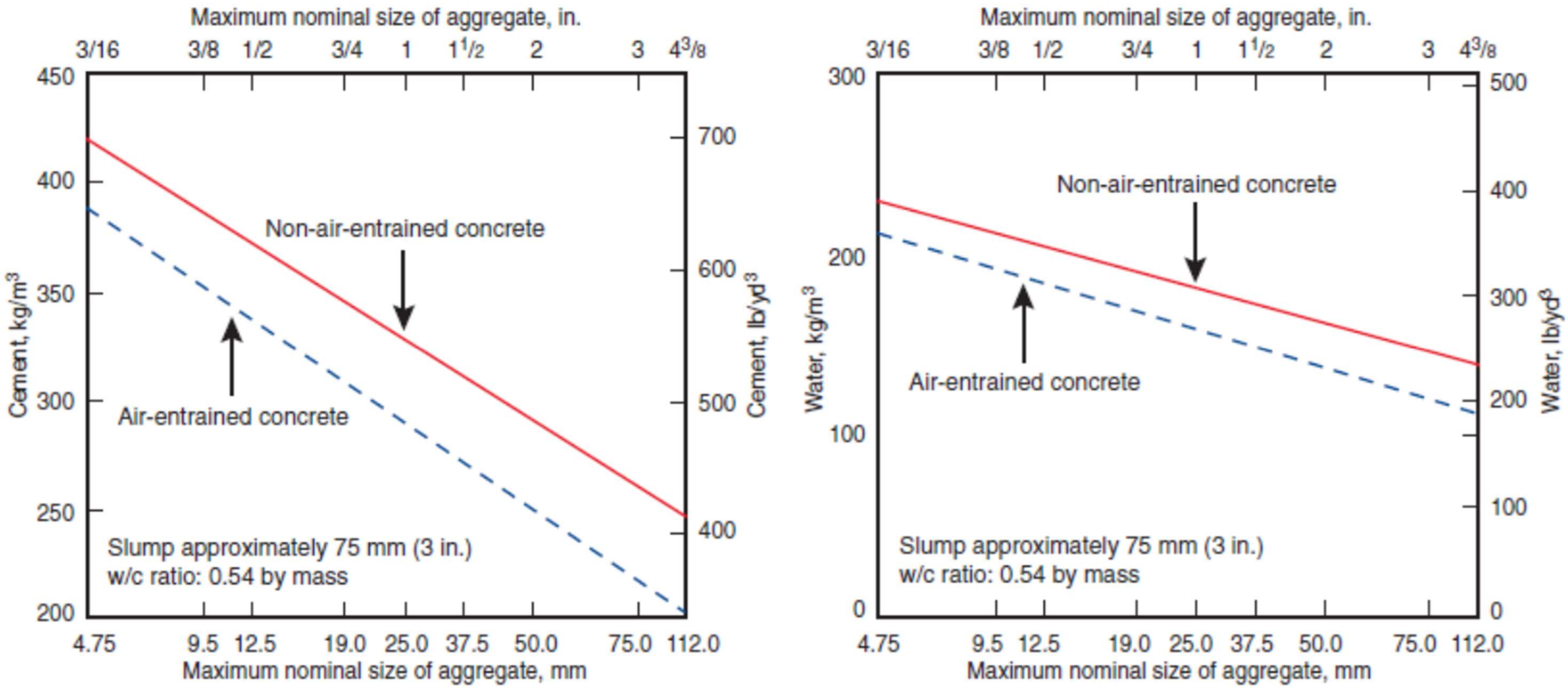
Size no.	Nominal size, sieves with square openings	Amounts finer than each laboratory sieve, mass percent passing												
		100 mm (4 in.)	90 mm (3½ in.)	75 mm (3 in.)	63 mm (2½ in.)	50 mm (2 in.)	37.5 mm (1½ in.)	25 mm (1 in.)	19 mm (¾ in.)	12.5 mm (½ in.)	9.5 mm (⅜ in.)	4.75 mm (No. 4)	2.36 mm (No. 8)	1.18 mm (No. 16)
1	90 to 37.5 mm (3½ to 1½ in.)	100	90 to 100	—	25 to 60	—	0 to 15	—	0 to 5	—	—	—	—	—
2	63 to 37.5 mm (2½ to 1½ in.)	—	—	100	90 to 100	35 to 70	0 to 15	—	0 to 5	—	—	—	—	—
3	50 to 25 mm (2 to 1 in.)	—	—	—	100	90 to 100	35 to 70	0 to 15	—	0 to 5	—	—	—	—
357	50 to 4.75 mm (2 in. to No. 4)	—	—	—	100	95 to 100	—	35 to 70	—	10 to 30	—	0 to 5	—	—
4	37.5 to 19.0 mm (1½ to ¾ in.)	—	—	—	—	100	90 to 100	20 to 55	0 to 15	—	0 to 5	—	—	—
467	37.5 to 4.75 mm (1½ in. to No. 4)	—	—	—	—	100	95 to 100	—	35 to 70	—	10 to 30	0 to 5	—	—
5	25.0 to 12.5 mm (1 to ½ in.)	—	—	—	—	—	100	90 to 100	20 to 55	0 to 10	0 to 5	—	—	—
56	25.0 to 9.5 mm (1 to ⅜ in.)	—	—	—	—	—	100	90 to 100	40 to 85	10 to 40	0 to 15	0 to 5	—	—
57	25.0 to 4.75 mm (1 in. to No. 4)	—	—	—	—	—	100	95 to 100	—	25 to 60	—	0 to 10	0 to 5	—
6	19.0 to 9.75 mm (¾ to ⅜ in.)	—	—	—	—	—	—	100	90 to 100	20 to 55	0 to 15	0 to 5	—	—
67	19.0 to 4.75 mm (¾ in. to No. 4)	—	—	—	—	—	—	100	90 to 100	—	20 to 55	0 to 10	0 to 5	—
7	12.5 to 4.75 mm (½ in. to No. 4)	—	—	—	—	—	—	—	100	90 to 100	40 to 70	0 to 15	0 to 5	—
8	9.5 to 2.36 mm (⅜ in. to No. 8)	—	—	—	—	—	—	—	—	100	85 to 100	10 to 30	0 to 10	0 to 5
89	9.5 to 1.18 mm (⅜ in. to No. 16)	—	—	—	—	—	—	—	—	100	85 to 100	10 to 40	0 to 10	0 to 5

The maximum size of coarse aggregate

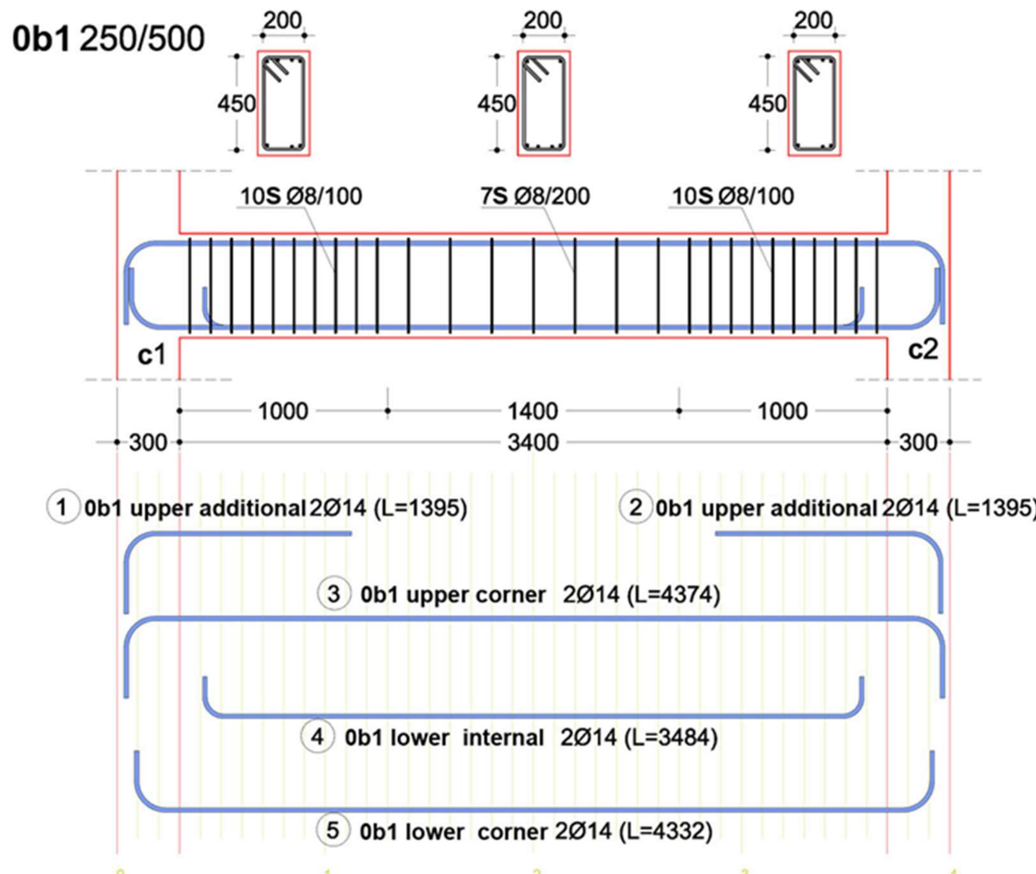
- Maximum size of coarse aggregate : is the largest sieve size that allows all the aggregates to pass
- Nominal maximum aggregate size : the first sieve to retain some aggregate, generally less than 10%

- Extending the grading of aggregate to a larger maximum size (up to a certain limit approx. 40 mm) lowers the water requirement of the mix so that for specified workability and richness of mix, the water/cement ratio can be reduced with a consequent increase in strength, lower-shrinkage and greater durability.
- OR Less cement and water are required in mixtures having larger coarse aggregate. See graphs in the next page.

The maximum size of coarse aggregate



Cement and water contents in relation to maximum size of aggregate.

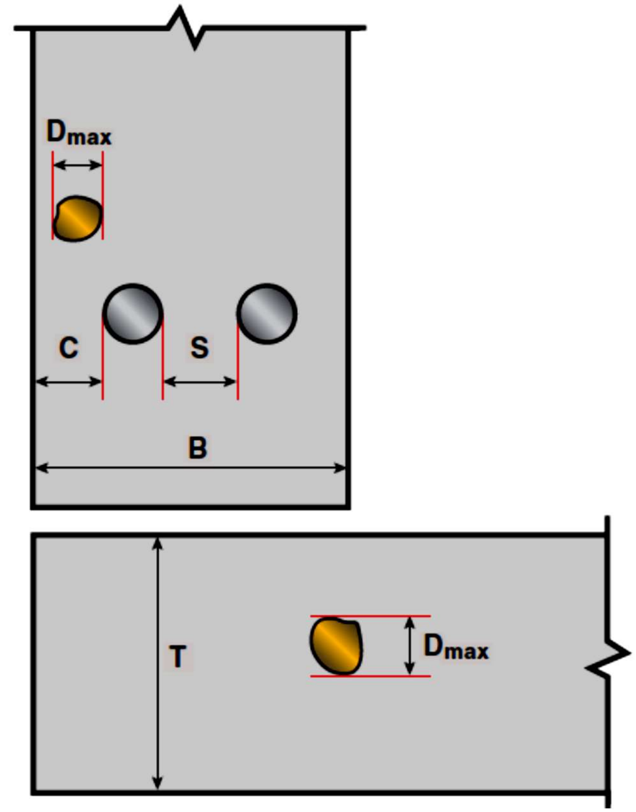


0b1 250/500
200
450
10S Ø8/100
7S Ø8/200
10S Ø8/100
c1
c2
1000
1400
1000
300
3400
300
1 0b1 upper additional 2Ø14 (L=1395)
2 0b1 upper additional 2Ø14 (L=1395)
3 0b1 upper corner 2Ø14 (L=4374)
4 0b1 lower internal 2Ø14 (L=3484)
5 0b1 lower corner 2Ø14 (L=4332)

The maximum size of coarse aggregate

The choice of nominal size is determined by job condition. in structural concrete, the maximum size is determined as follows

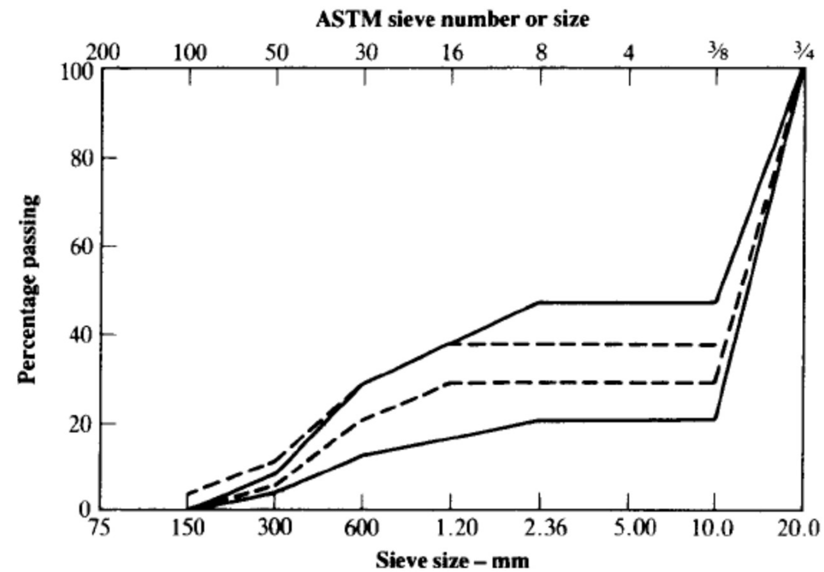
- One-fifth the narrowest dimension of a vertical concrete member: $D_{max} = 1/5\ B$
- Three-quarters the clear spacing between reinforcing bars and between the reinforcing bars and forms: $D_{max} = 3/4\ S$, and $3/4\ C$
- One-third the depth of slabs: $D_{max} = 1/3\ T$



ACI 318 requirements for nominal maximum size of aggregates, Dmax, based on concrete dimensions, B, T, and reinforcement spacing, S.

Gap-graded Aggregate

- In gap-graded aggregates certain particle sizes are intentionally omitted. Typical gap-graded aggregates consist of only one size of coarse aggregate with all the particles of fine aggregate able to pass through the voids in the compacted coarse aggregate.
- On the grading curve, gap-graded is represented by a horizontal line over the range of sizes omitted.



- To avoid segregation, gap-graded is recommended mainly for mixes of relatively low workability that are to be compacted by vibration; good control and care in handling are essential

Gap-graded Aggregate

➢ USE:

- In architectural concrete to obtain uniform textures in exposed-aggregate finishes.
- In pervious concrete mixtures to improve storm water management.
- can also be used in normal structural concrete to improve other concrete properties and to permit the use of local aggregate gradations

Durability of Aggregates

Physical Durability

1. Unsoundness due to volume changes

- Soundness refers to the ability of aggregate to resist excessive changes in volume as a result of changes in physical conditions such as freezing the thawing, variation in temperature, and alternate wetting and drying.
- If the aggregate is unsound, such changes in physical conditions result in a deterioration of the concrete in the form of local scaling, so-called pop-outs, and even extensive surface cracking.
- Unsoundness is usually related to aggregate porosity, absorption, permeability, and pore structure
- TEST: ASTM C 88-05 prescribe tests in which the aggregate is exposed to magnesium sulphate and to drying, The degree of unsoundness is expressed by the reduction in particle size after a specified number of cycles.

Physical Durability

2. Thermal properties

- Thermal Expansion: If the coefficient of thermal expansion of aggregate differs from that of cement paste, then durability of concrete subjected to freezing and thawing may be detrimentally affected.
- Fire resistance: In general, concrete containing a calcareous coarse aggregate performs better under fire exposure than a concrete containing quartz or siliceous aggregate such as granite or quartzite.

3. Wear resistance

- The abrasion resistance of an aggregate is often used as a general index of its quality. Abrasion resistance is essential when the aggregate is to be used in concrete subjected to abrasion, as in heavy-duty floors or pavements.
- To provide good skid resistance on pavements, the siliceous particle content of the fine aggregate should be at least 25%.

Chemical Durability

Aggregates may contain several harmful substances including organic impurities, silt, clay, shale, iron oxide, coal, lignite, mica, and certain lightweight and soft particles. Those deleterious substances can be categorized into three broad categories:

- impurities which interfere with the processes of hydration of cement,
- Coatings preventing the development of good bond between aggregate and cement paste,
- Certain individual particles which are weak or unsound in themselves

Chemical Durability

Potentially Harmful Materials in aggregates and their effect on concrete

Substances	Effect on concrete
Organic impurities	Affects setting and hardening, may cause deterioration
Materials finer than the 75-µm (No. 200) sieve	Affects bond, increases water requirement
Coal, lignite, or other lightweight materials	Affects durability, may cause stains and popouts
Soft particles	Affects durability
Clay lumps and friable particles	Affects workability and durability, may cause popouts
Chert of less than 2.40 relative density	Affects durability, may cause popouts
Alkali-reactive aggregates	Causes abnormal expansion, map cracking, and popouts