THE UNIVERISTY OF ZAMBIA

School of Engineering

Department of Civil and Environmental Engineering

CEE 3111 - CIVIL ENGINEERING MATERIALS AND CONSTRUCTION PRACTICES

2023 ACADEMIC YEAR

SEMESTER 1

2

TOPIC 3

Concrete and its constituents

Aggregates

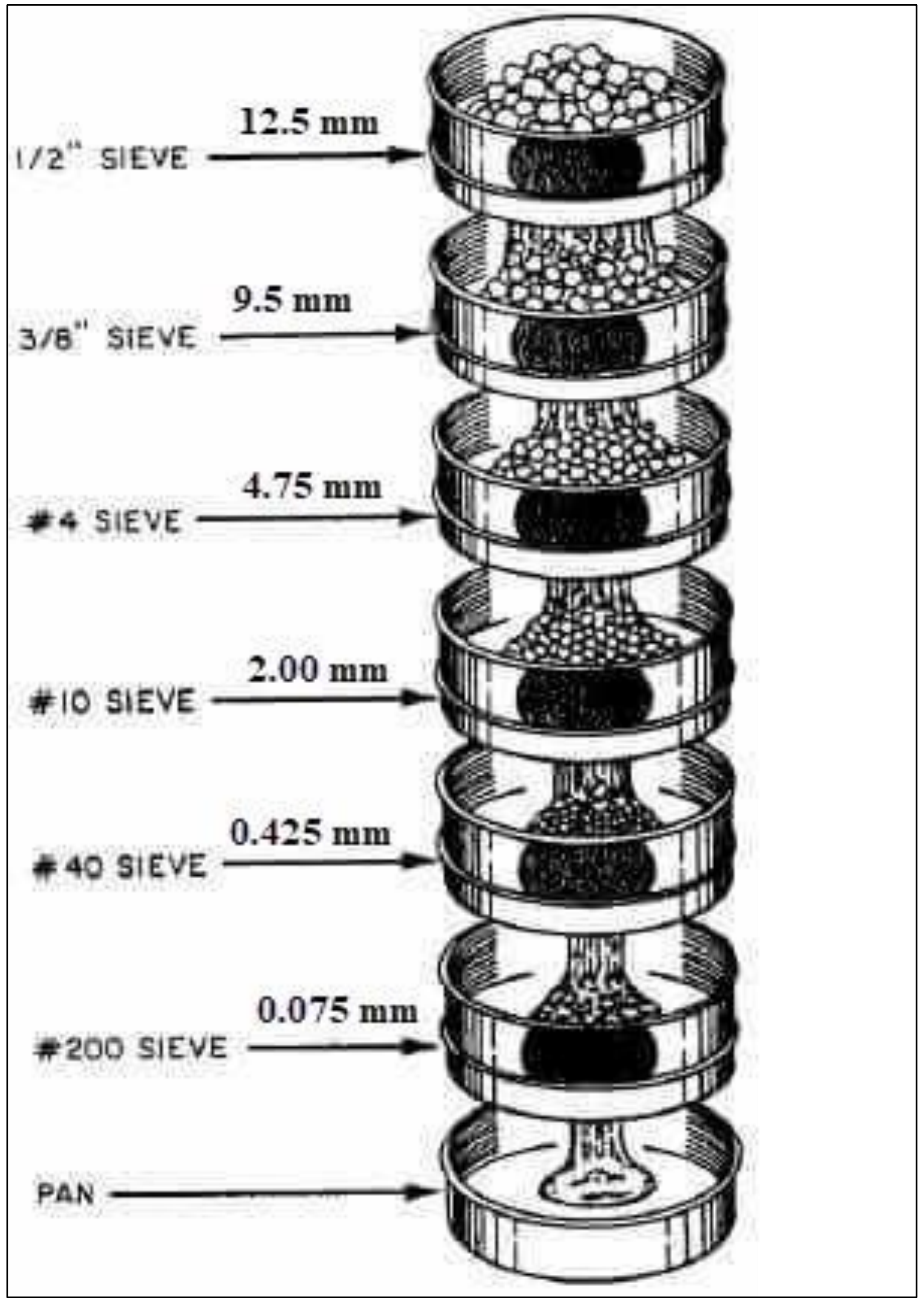
10. Gradation

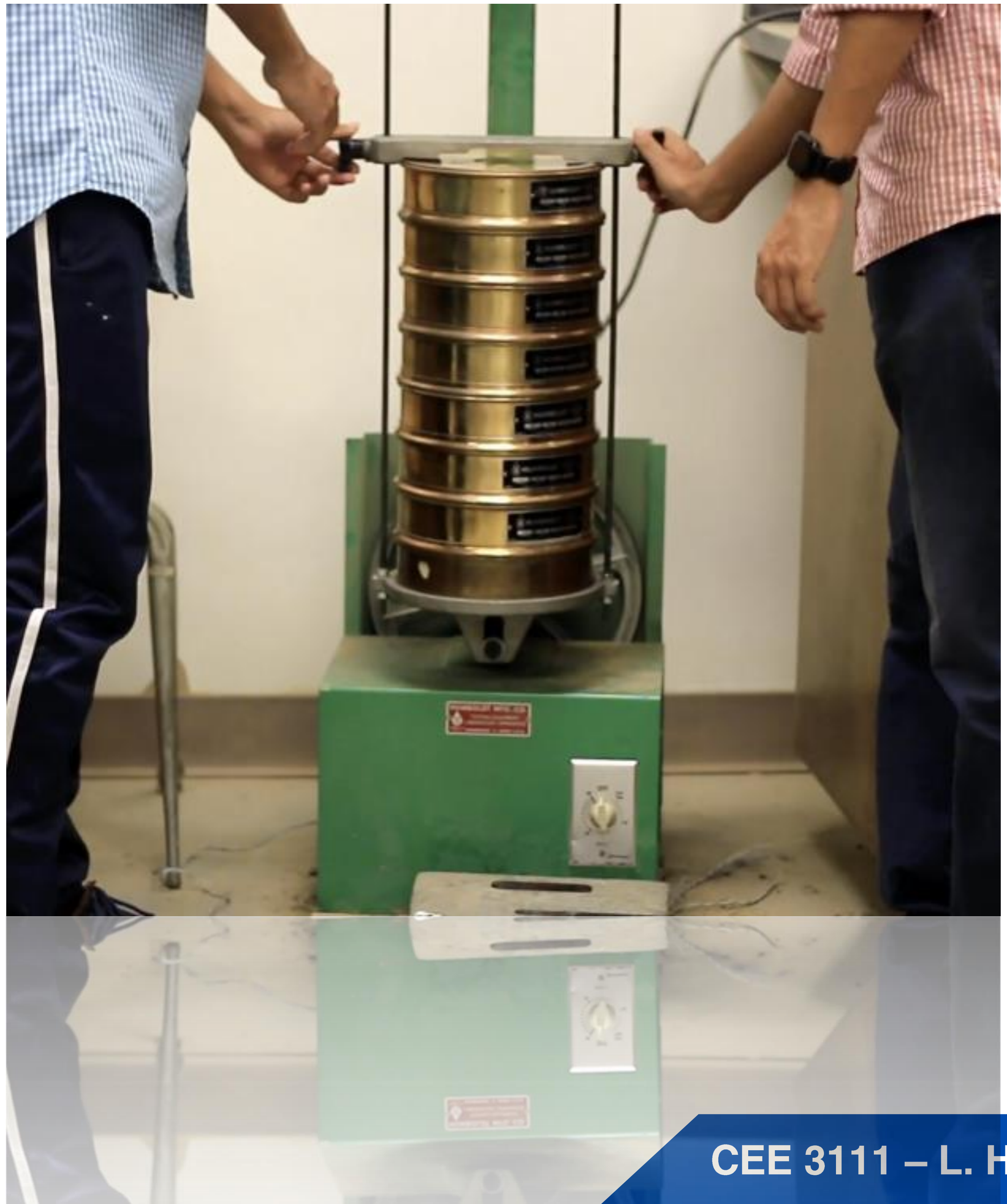
- Describes aggregate particle size distribution
- Large aggregates require less binder because they have less surface area, making them cheaper in portland cement and asphalt concrete.
- Large aggregate mixtures of asphalt or portland cement concrete, are difficult to work with. Thus, the need to consider construction considerations such as:
  - ✓ equipment capability,
  - ✓ dimensions of construction members,
  - ✓ clearance between reinforcing steel, and
  - ✓ layer thickness,
  - ✓ limit the maximum aggregate size.

Aggregates

Gradation

- Gradation is evaluated by passing the aggregates through a series of Sieves as shown below:

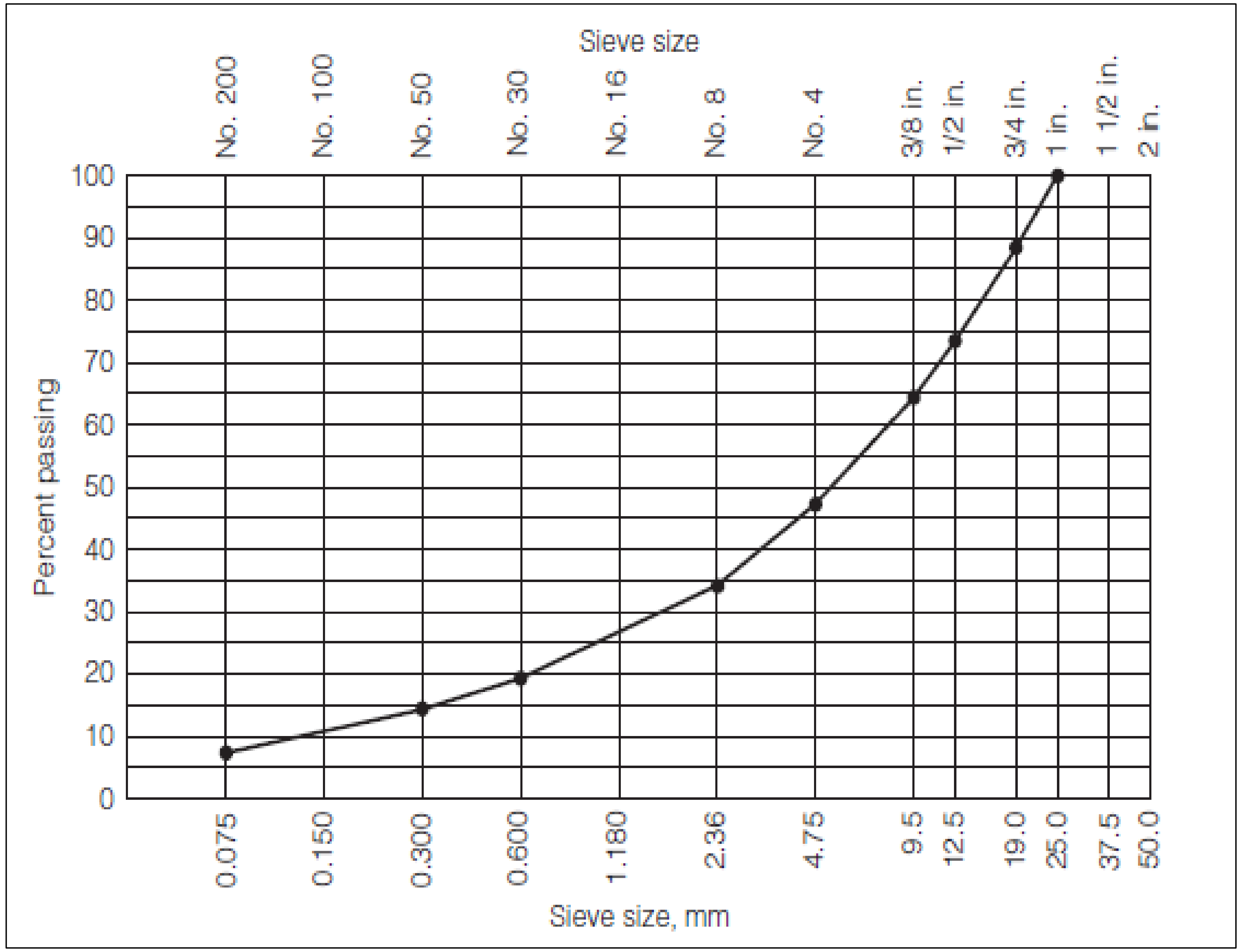




Aggregates

Gradation

- Gradation results are described by the cumulative percentage of aggregates that either pass through or are retained by a specific sieve size.
- Percentages are reported to the nearest whole number, except that if the percentage passing the 0.075-mm (No. 200) sieve is less than 10%, it is reported to the nearest 0.1%.
- Gradation analysis results are generally plotted on a semi log chart.



Aggregates

Gradation

- Classified by size. ASTM defines aggregates as:
  - ✓ coarse aggregates - retained on the 4.75-mm
  - ✓ fine aggregates - passing 4.75-mm sieve
  - ✓ mineral fillers (fines) - passing the 0.075-mm

- Gradation specifications define maximum and minimum cumulative percentages of material passing each sieve.

- Aggregates are commonly described as being either coarse or fine, depending on whether the material is predominantly retained on or passes through a 4.75-mm (No. 4) sieve.

Aggregates

Gradation

- Portland cement concrete requires separate specifications for aggregates.
- The ASTM C33 specifications for fine aggregates is given below:

Sieve	Percent Passing
9.5 mm (3/8″)	100
4.75 mm (No. 4)	95–100
2.36 mm (No. 8)	80–100
1.18 mm (No. 16)	50–85
0.60 mm (No. 30)	25–60
0.30 mm (No. 50)	10–30
0.15 mm (No. 100)	0–10

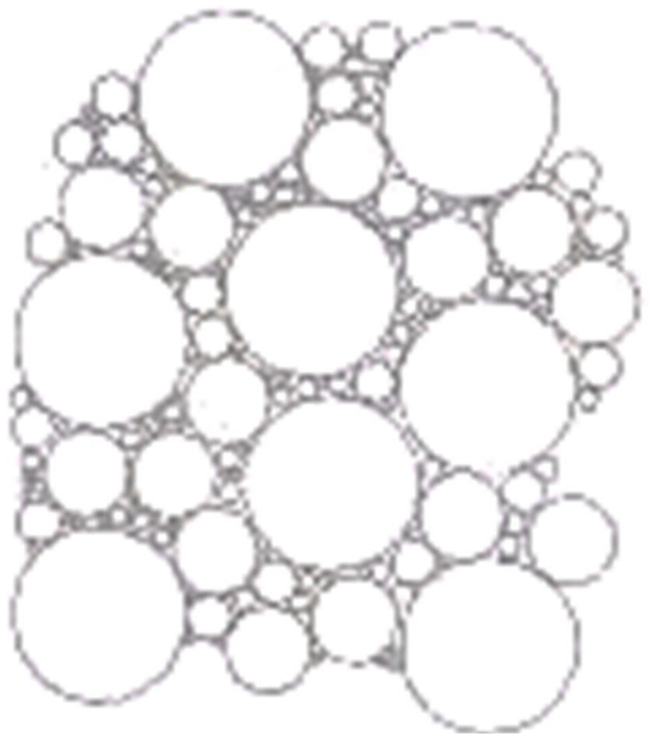
Aggregates

Gradation

Aggregate Grading Requirements for Superpave Hot Mix Asphalt (AASHTO MP-2)

	Nominal Maximum Size (mm)					
Sieve Size, mm (in.)	**37.5**	**25**	**19**	**12.5**	**9.5**	**4.75**
50 (2 in.)	100	—	—	—	—	—
37.5 (1 1/2 in.)	90–100	100	—	—	—	—
25 (1 in.)	90 max	90–100	100	—	—	—
19 (3/4 in.)	—	90 max	90–100	100	—	—
12.5 (1/2 in.)	—	—	90 max	90–100	100	100
9.5 (3/8 in.)	—	—	—	90 max	90–100	95–100
4.75 (No. 4)	—	—	—	—	90 max	90–100
2.36 (No. 8)	15–41	19–45	23–49	28–58	32–67	—
1.18 (No. 16)	—	—	—	—	—	30–60
0.075 (No. 200)	0.0–6.0	1.0–7.0	2.0–8.0	2.0–10.0	2.0–10.0	6.0–12.0

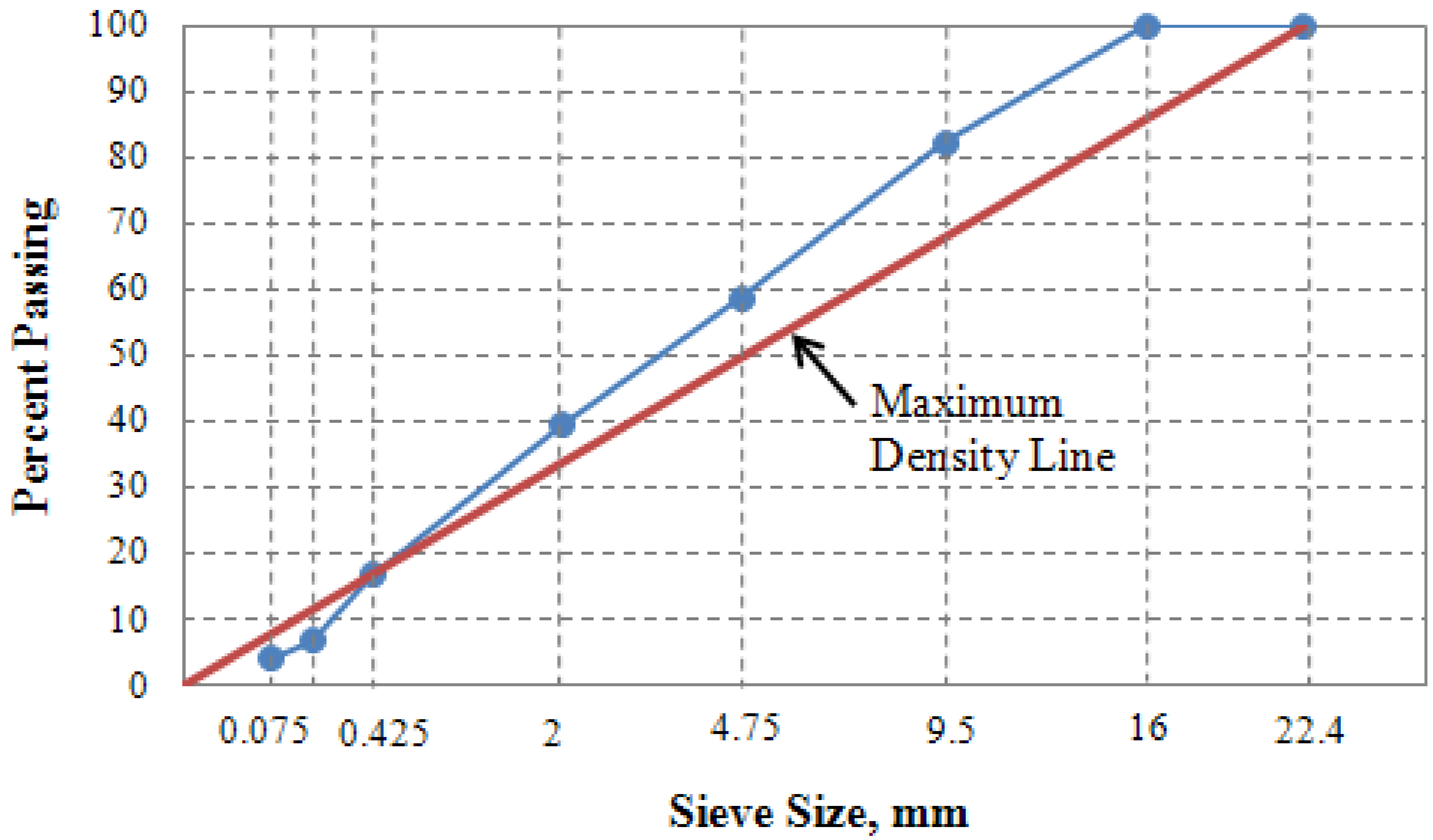
Aggregates



Gradation

Maximum Density Gradation (well-graded)

- Fuller established the relationship for predicting aggregate distribution with maximum density or minimum voids in 1907:



$$P_i = (\frac{d_i}{D})^n$$

Where $P_i = percent\ passing\ sieve\ of\ size d_i\ and\ D = maximum\ aggregate\ size.$

- Fuller suggests 0.5 for n while FHWA recommends 0.45.

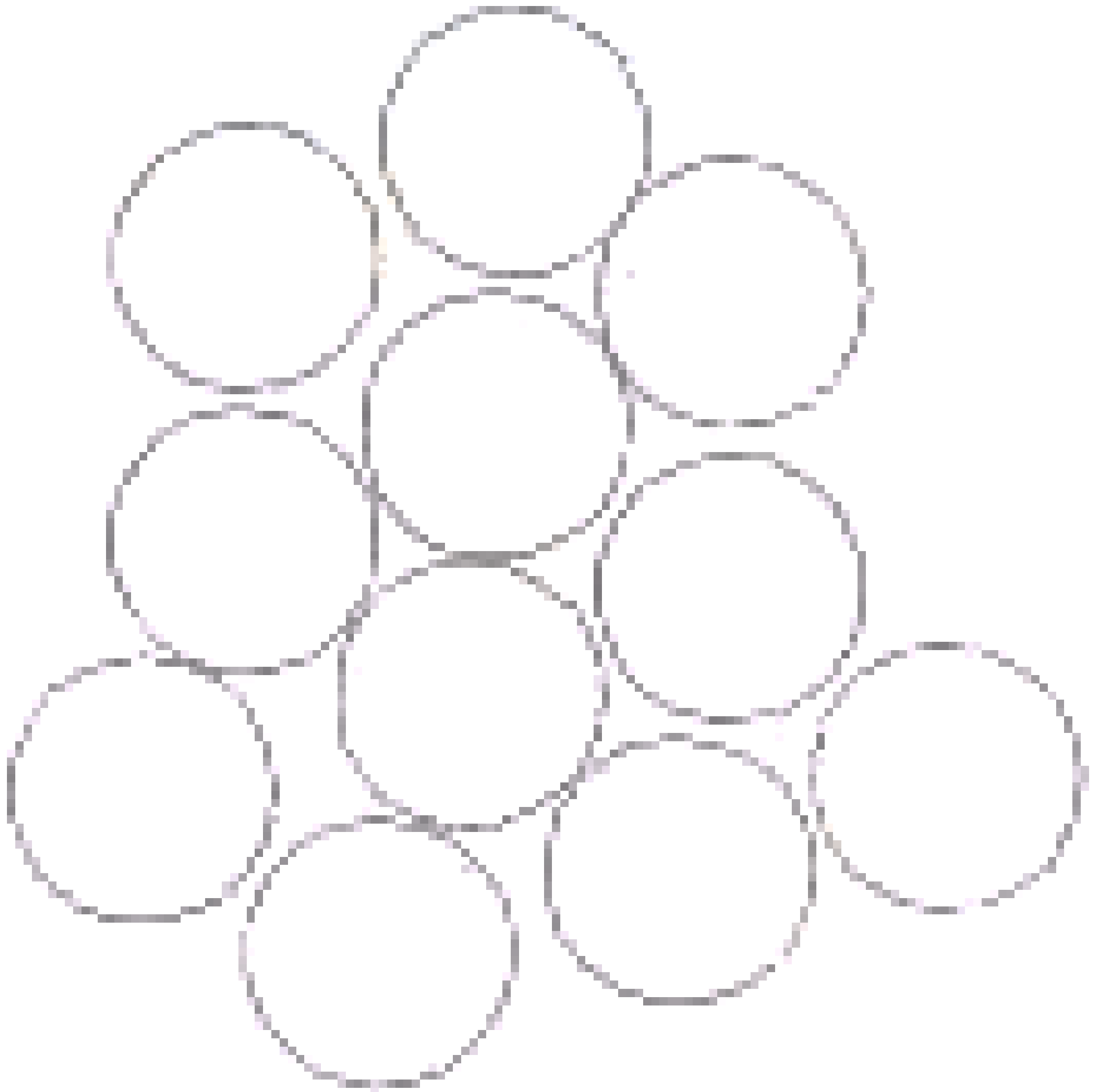
Aggregates

Gradation

- In addition to maximum density (i.e., well-graded), aggregates can have other characteristic distributions, and be classified as:

1. One-Sized (Poorly graded):

   - ✓ majority of aggregates passing one sieve an being retained on the next smaller sieve
   - ✓ majority of the aggregates have essentially same diameter
   - ✓ their gradation curve is nearly vertical
   - ✓ have good permeability
   - ✓ but poor stability
   - ✓ used in such applications as chip seals of pavements



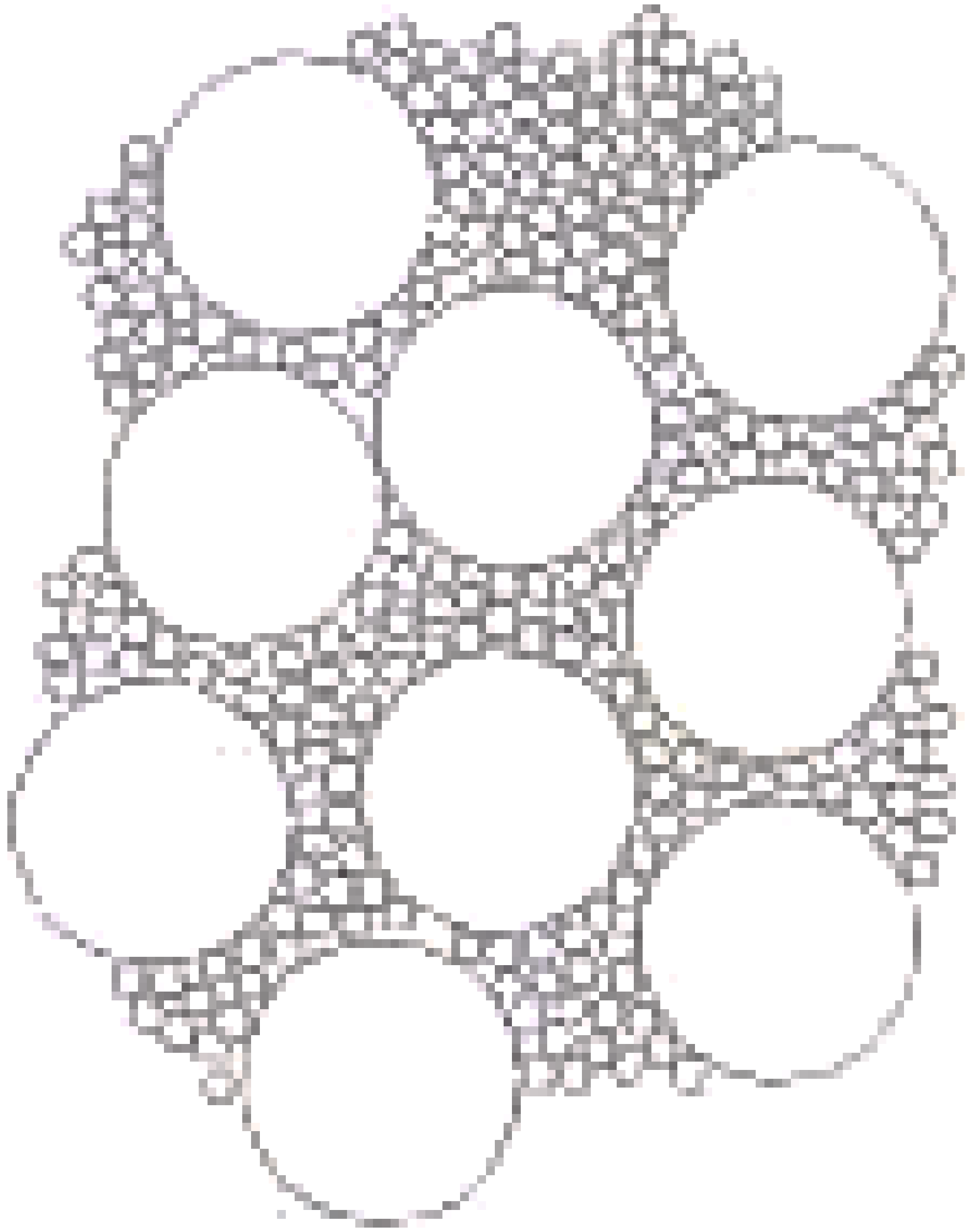
Poorly Graded

Aggregates

2. Gap-graded aggregates:

   ✓ missing one or more sizes of material

   ✓ gradation curve has a near horizontal section indicating that nearly the same portions of the aggregates pass two different sieve sizes



Gap Graded

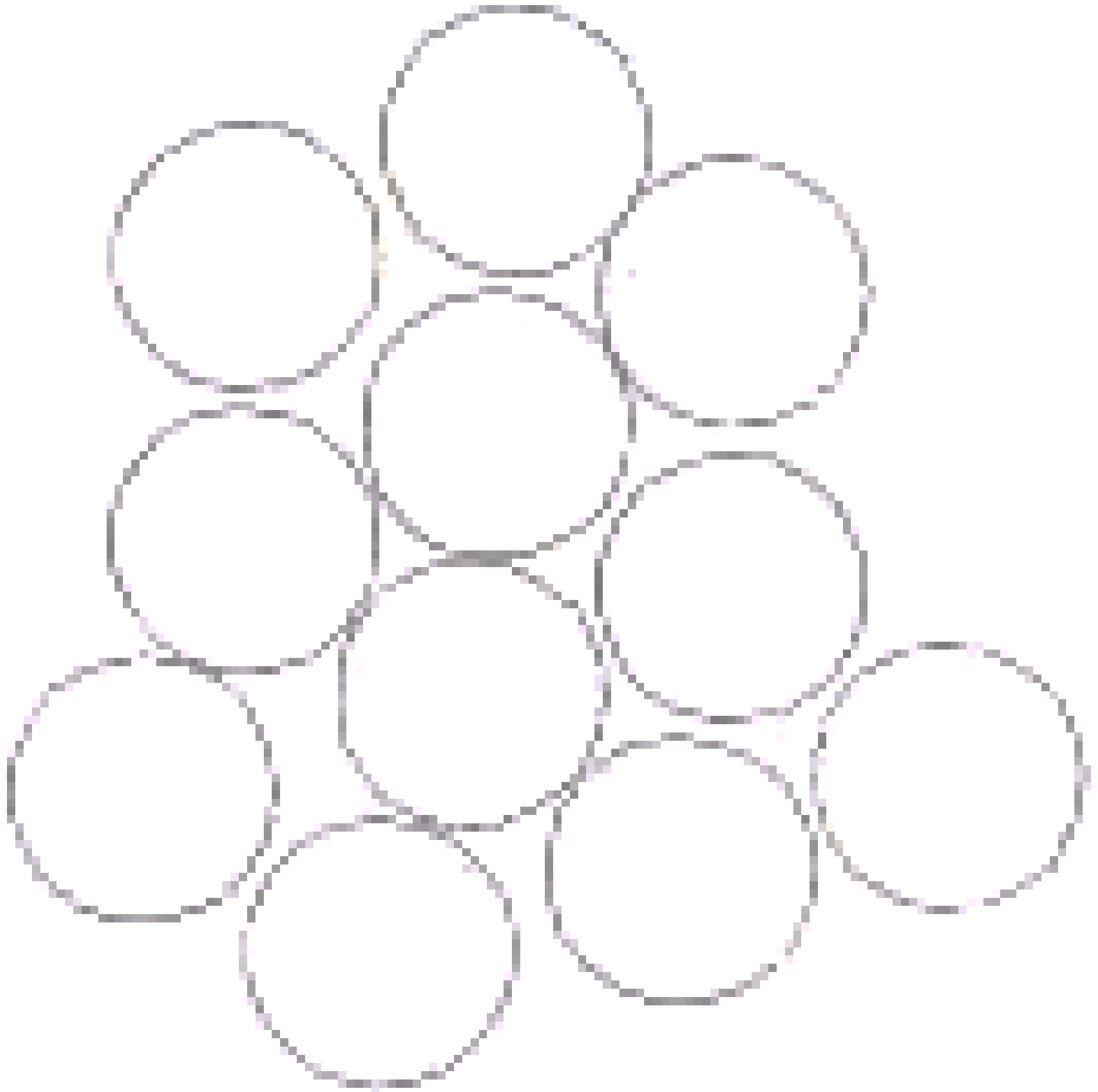
Aggregates

3. Open-graded aggregates

✓ missing small aggregate sizes that would block the voids between the larger aggregate

✓ Since there are a lot of voids

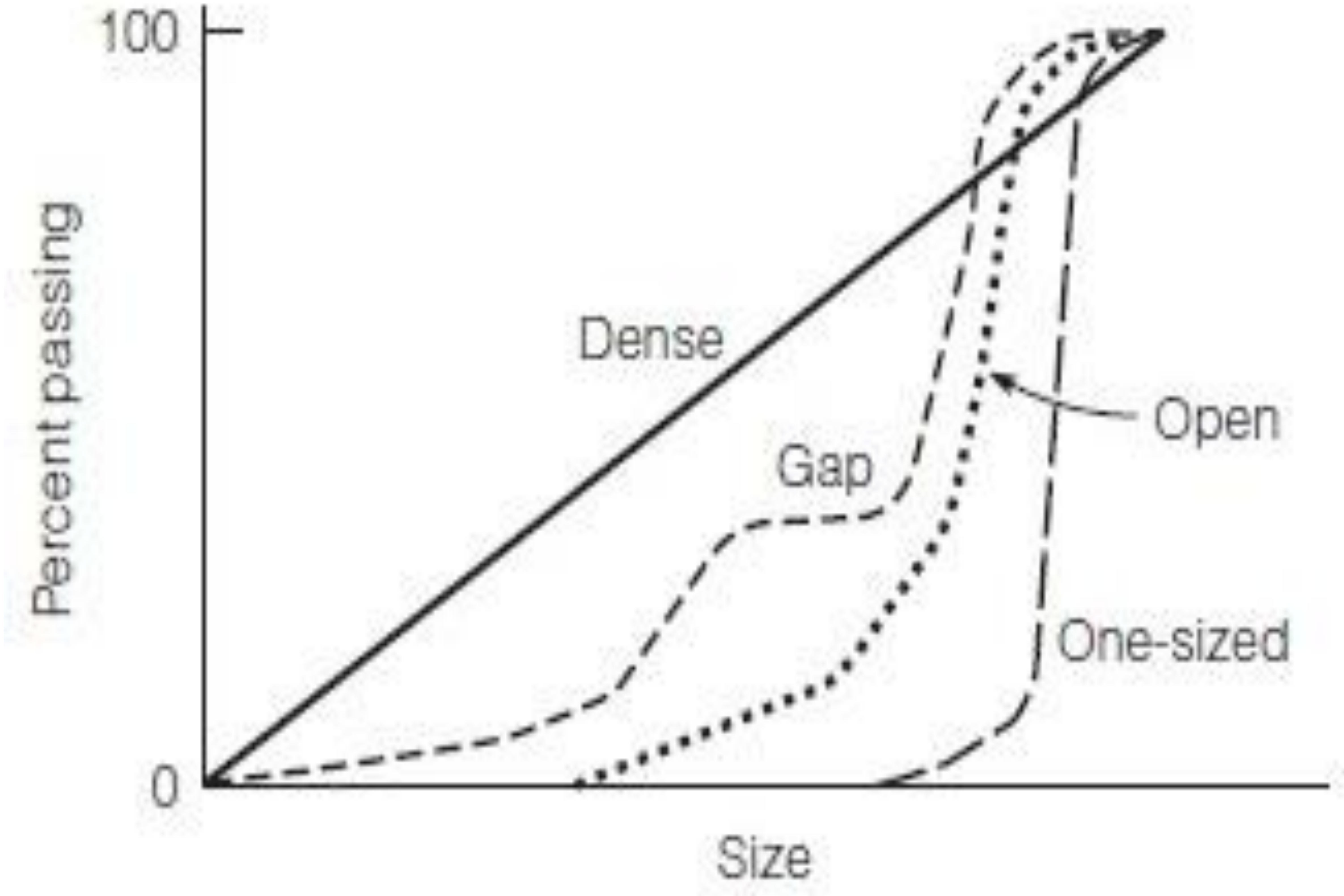
✓ material will be highly permeable but may not have good stability.



Poorly Graded

Aggregates

Gradation



Aggregates

Gradation

- Amount of fines has a major effect on the characteristics of aggregate base materials.

- Aggregates with the percentage of fines equal to the amount required for maximum density have excellent stability and density, but may have a problem with permeability, frost susceptibility, handling, and cohesion.

- Proper stockpiling is required to retain gradation and avoid aggregate segregation

Aggregates - Fineness Modulus (FM)

- It is a measure of the aggregates' gradation, and is used primarily for portland cement concrete mix design

- It can also be used as a daily quality control check in the production of concrete.

$$F.M. = \frac{\sum (\textit{cumulative percentage retained on specified sieves})}{100}$$

where: F.M. = fineness modulus

specified sieves = 0.150 mm (No. 100), 0.30 mm (No. 50), 0.60 mm (No. 30), 1.18 mm (No. 16), 2.36 mm (No. 8), 4.75 mm (No. 4), 9.5 mm (0.375-in.), 19.0 mm (0.75-in.), 37.5 mm (1.5-in.), and larger increasing in the size ratio of 2:1.

Very Fine Sand	:	< 2.2
Fine Sand	:	2.2 - 2.6
Medium Sand	:	2.6 - 2.9
Coarse Sand	:	2.9 - 3.2

- When the FM is determined for fine aggregates, sieves larger than 9.5 mm (3/8 in.) are not used.

Aggregates

Maximum Density Gradation – Example

Given a coarse aggregate with maximum aggregate size of 25 mm, obtain the percentages for maximum density gradation.

Solution:

Sieve	$P_i = 100(d_i/D)^{0.45}$
25 mm (1 in.)	100
19 mm (3/4 in.)	88
12.5 mm (1/2 in.)	73
9.5 mm (3/8 in.)	64
4.75 mm (No. 4)	47
2.36 mm (No. 8)	34
0.60 mm (No. 30)	19
0.30 mm (No. 50)	14
0.075 mm (No. 200)	7.3

Aggregates

Gradation – Example

A sieve analysis test was performed on a sample of fine aggregate and produced the following results:

Sieve, mm	4.75	2.36	2.00	1.18	0.60	0.30	0.15	0.075	pan
Amount retained, g	0	33.2	56.9	83.1	151.4	40.4	72.0	58.3	15.6

1. Calculate the percent passing each sieve, draw a gradation chart, and state whether the aggregate meets the ASTM C 33 requirements for a fine aggregate for concrete.
2. Calculate the Fineness Modulus of the aggregate

Aggregates

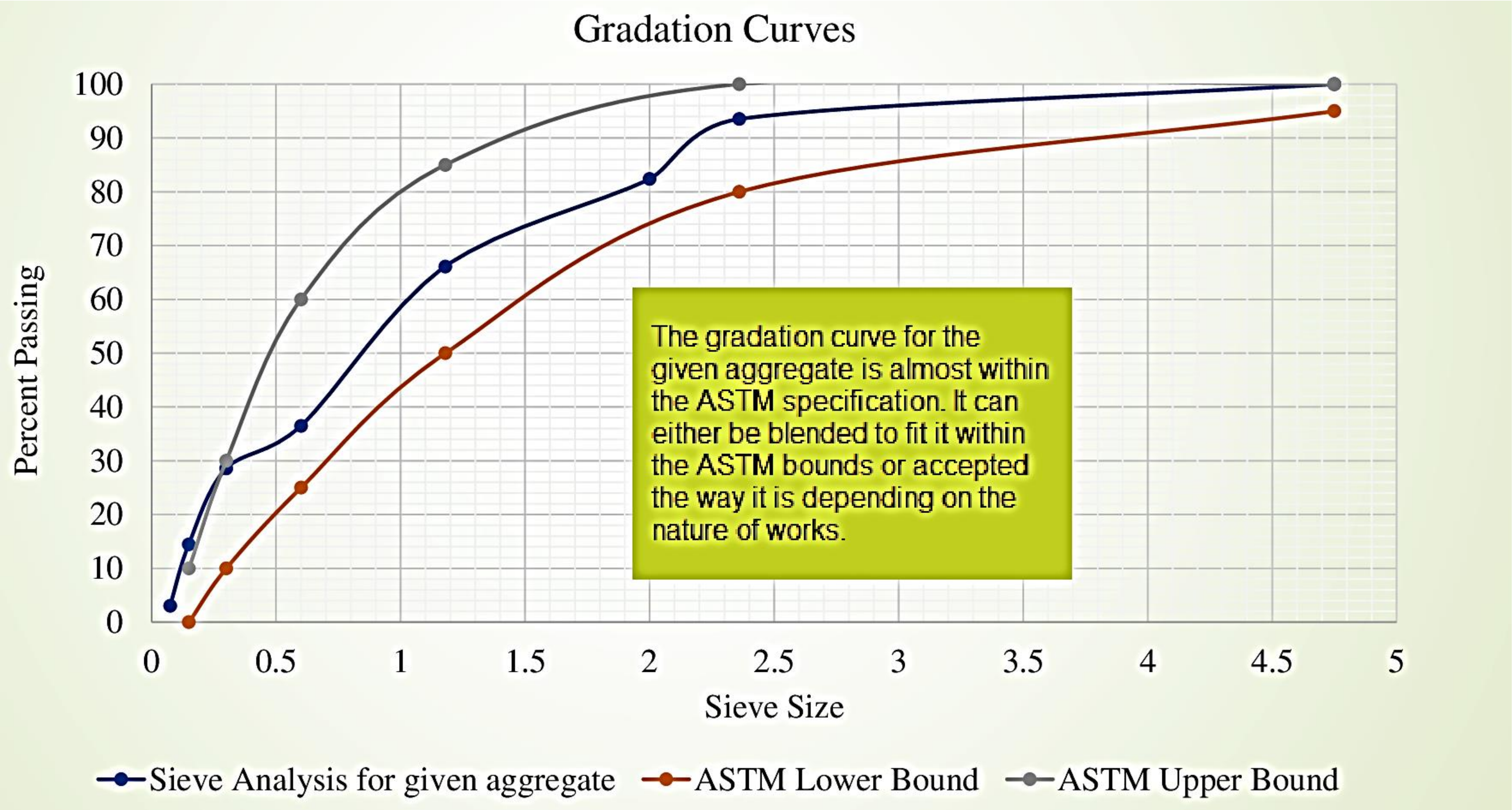
Gradation – Solution Part 1

Sieve size	Amount Retained, g (a)	Cumulative Amount Retained, g (b)	Cumulative Percent Retained (c) = (b) × 100/Total	Percent Passing* (d) = 100 − (c)
4.75 mm (No. 4)	0	0	0	100
2.36 mm (No. 8)	33.2	33.2	6	94
2.00 mm (No. 10)	56.9	90.1	18	82
1.18 mm (No. 16)	83.1	173.2	34	66
0.60 mm (No. 30)	151.4	324.6	64	36
0.30 mm (No. 50)	40.4	365.0	71	29
0.15 mm (No. 100)	72.0	437.0	86	14
0.075 mm (No. 200)	58.3	495.3	96.9	3.1
Pan	15.6	510.9	100	
Total	510.9			

*Percent passing is computed to a whole percent, except for the 0.075 mm (No. 200) material, which is computed to 0.1%.

Aggregates

Gradation – Solution Part 1 continued



Aggregates

Gradation – Example Part 2

- According to the definition of fineness modulus, sieves 2.00 and 0.075 mm (No. 10 and 200) are not included.

$$FM = \frac{\sum Cumulative\%retained\ on\ 0.15mm, 0.3mm, 0.6mm, 1.18mm, 2.36mm, 4.75mm, and\ 9.5mm}{100}$$

$$FM = \frac{86 + 71 + +64 + 34 + 6 + 0 + 0}{100} = 2.61$$

- The fineness modulus for fine aggregates should be in the range of 2.3 to 3.1, with a higher number being a coarser aggregate. Therefore, a value of 2.61 for the given aggregate is reasonable.

Aggregates - Blending

- One aggregate source rarely meets portland cement or asphalt concrete gradation criteria.

- To meet criteria, aggregates from many sources must be blended.

- Proportions are usually determined via trial-and-error. The basic mixing equation:

$$P_i = A_i a + B_i b + C_i c + \cdots$$

$P_i = percent\ of\ blended\ aggregate\ passing\ sieve\ i,$

$A_i, B_i, C_i = percent\ of\ aggregate\ A, B, C\ passing\ sieve\ i\ and$

$a, b, c = decimal\ fraction\ by\ weight\ of\ aggregates\ used\ in\ the\ blend\ where\ the\ total\ is\ 1.$

- The blend attributes are the weighted averages of the component values, except for specific gravity and density.

Aggregates

Weighted averages of the component values

$$X = P_1X_1 + P_2X_2 + P_3X_3 \ldots$$

where

X = composite property of the blend

X_1, X_2, X_3 = properties of fractions 1, 2, 3

P_1, P_2, P_3 = decimal fractions by weight of aggregates 1, 2, 3 used in the blend, where the total is 1.00

Aggregates

Composite specific gravity (or density)

$$G = \frac{1}{\frac{P_1}{G_1} + \frac{P_2}{G_2} + \frac{P_3}{G_3} + \ \ldots}$$

where

G = composite specific gravity

G_1, G_2, G_3 = specific gravities of fractions 1, 2, and 3

P_1, P_2, P_3 = decimal fractions by weight of aggregates 1, 2, and 3 used in the blend, where the total is 1.00

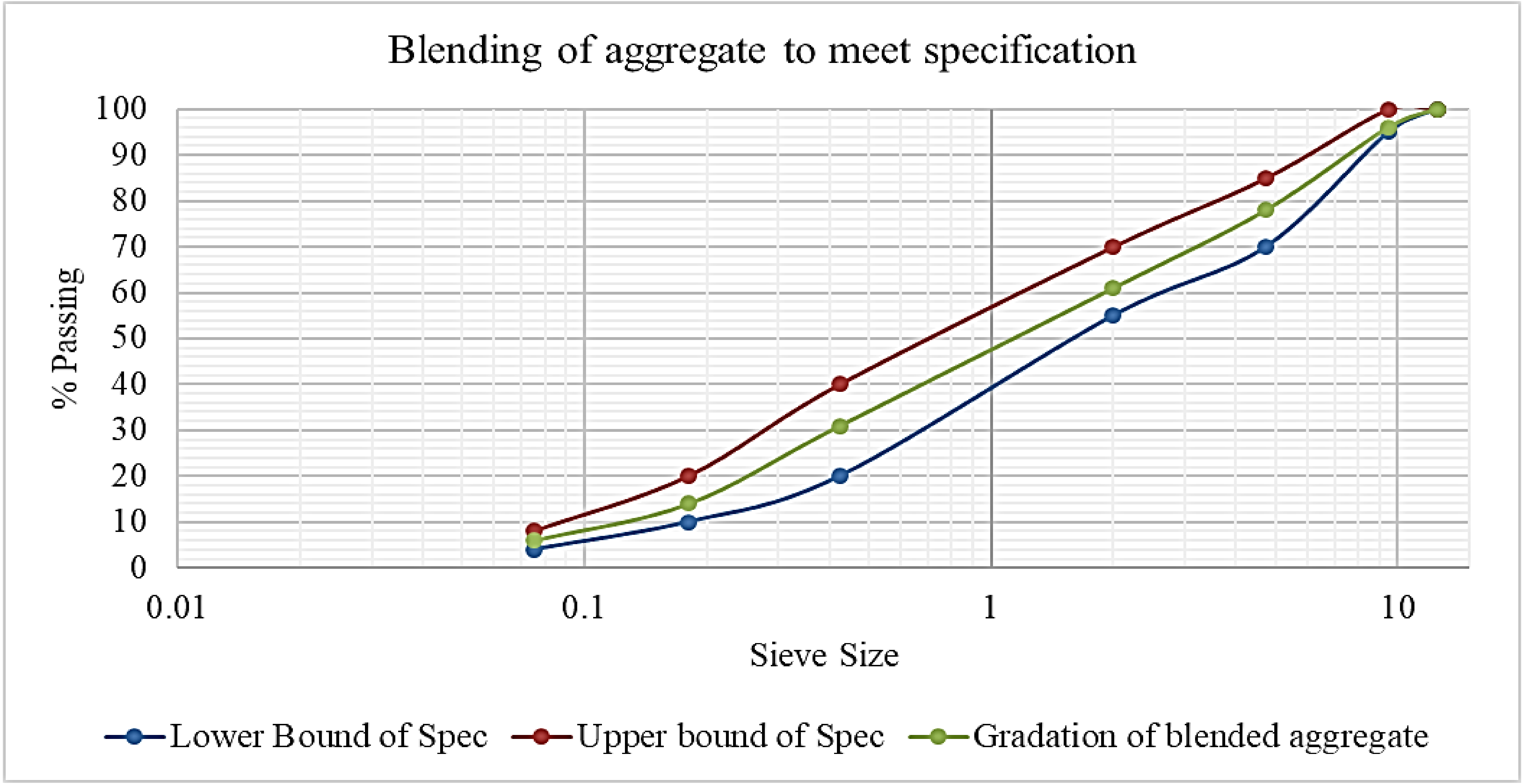
Aggregates

Blending Aggregates to Meet Specifications - Example

Sieve	12.5 mm 1/2 in	9.5 mm 3/8 in	4.75 mm No. 4	2.0 mm No. 10	0.425 mm No. 40	0.180 mm No. 80	0.075 mm No. 200
Specification	100	95-100	70-85	55-70	20-40	10-20	4-8
Target Gradation	100	98	77.5	62.5	30	15	6
% Passing Agg A (Ai)	100	100	98	90	71	42	19
% Passing Agg B (Bi)	100	94	70	49	14	2	1
30% of A (Ai*a)	30	30	29.4	27	21.3	12.6	5.7
70% of B (Bi*b)	70	65.8	49	34.3	9.8	1.4	0.7
Blend (Pi)	**100**	**96**	**78**	**61**	**31**	**14**	**6**

Aggregates

Blending Aggregates to Meet Specifications - Example



Aggregates

11. Cleanness and Deleterious Materials

- As a natural product, aggregates may be contaminated by clay, shale, organic waste, and coal.

- To limit clay concentration in asphalt concrete fine aggregates, the Superpave mix design approach uses the Sand Equivalency (SE) test, AASHTO T176.

$$SE = \frac{100_{sand}}{h_{clay}}$$

12. Affinity for Asphalt

- **Stripping, or moisture-induced damage** - is a separation of the asphalt film from the aggregate through the action of water, reducing the durability of the asphalt concrete

Aggregates – Affinity of Asphalt

- Relative affinity of the aggregate for either water or asphalt is an important factor
- Hydrophilic (water-loving) aggregates, such as silicates, have a greater affinity for water than for asphalt. They are usually acidic in nature and have a negative surface charge.
- Hydrophobic (water repelling) aggregates have a greater affinity for asphalt than for water. These aggregates, such as limestone, are basic in nature and have a positive surface charge.

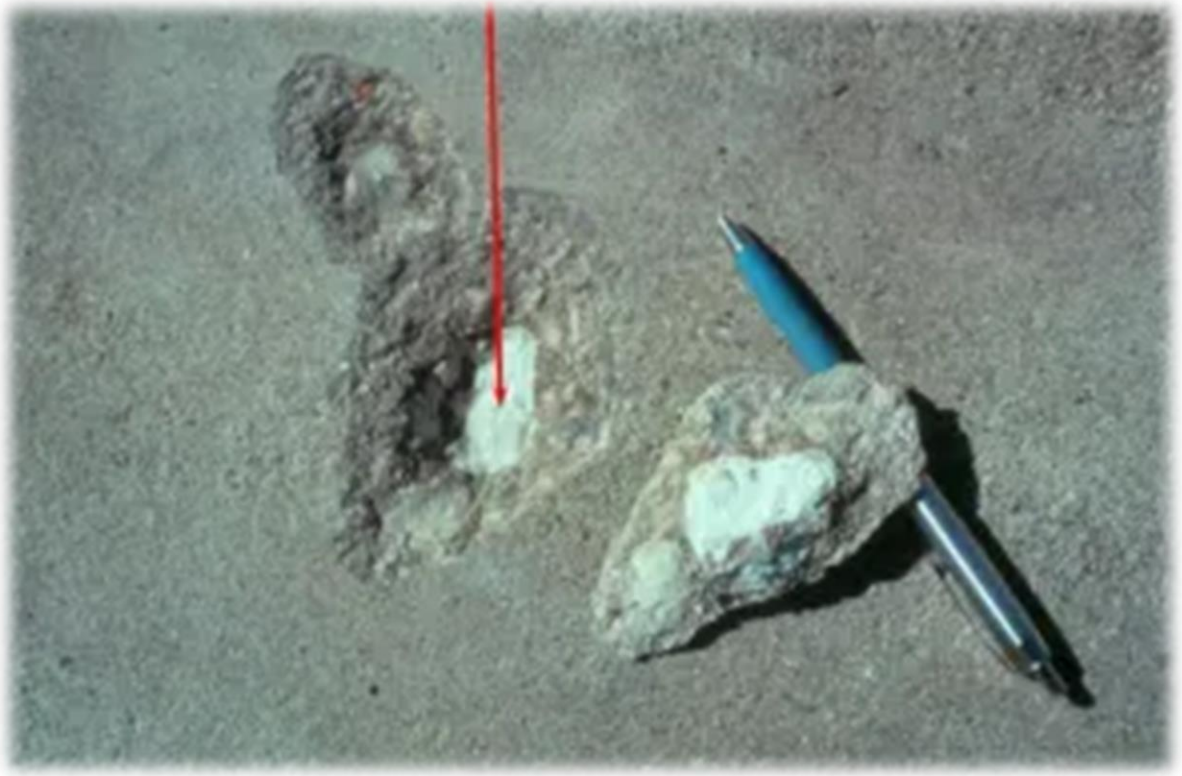
Aggregates – Affinity of Asphalt

- Hydrophilic aggregates are more susceptible to stripping than hydrophobic aggregates.
- Other stripping factors include porosity, absorption, and the existence of coatings and other deleterious substances.

Aggregates

13. Alkali–Aggregate Reactivity

- Some aggregates react with Portland cement, harming the concrete structure.
- Activity between aggregate silica and cement alkalis (sodium and potassium oxides) is the most prevalent reaction, especially in humid and warm regions.
- The alkali–silica reaction results in excessive expansion, cracking, or pop-outs in concrete



Aggregates

Sampling of aggregates

- For any of the tests in this chapter to be valid, the sample must represent the entire population of materials being quantified.

- This is a particularly difficult problem with aggregates due to potential segregation problems.

- Samples of aggregates can be collected from any location in the production process, that is, from the stockpile, conveyor belts, or from bins within the mixing machinery (ASTM D75)

Mixing Water

- Must be clean and salt free. Water has two functions in concrete:

  ✓ hydration reaction, which eventually gives hardness and strength to concrete.
  ✓ Increases the workability of the cement paste.

- Impurities in the mixing water can affect concrete set time, strength, and long-term durability.

- Chloride ions in can accelerate corrosion of reinforcing steel.

Admixtures for Concrete

- **Admixtures** - ingredients other than portland cement, water, and aggregates that may be added to concrete to impart a specific quality to either the plastic (fresh) mix or the hardened concrete.

Admixtures for Concrete

- Admixtures are classified by the following chemical and functional physical characteristics:
  - ✓ **Air entrainers** - produce tiny air bubbles in the hardened concrete to provide space for water to expand upon freezing.
  - ✓ **Water reducers** - give concrete required workability while maintaining quality. Superplasticizers (plasticizers), or high-range water reducers, can either greatly increase the flow of the fresh concrete or reduce the amount of water required for a given consistency.
  - ✓ **Retarders and accelerators** – Retarders are used when construction conditions require that the time between mixing and placing or finishing the concrete be increased. Accelerators do the opposite

QUIZ 5

Thank You!!!