

Course: Concrete Technology

Lecture 4: Aggregates: Testing and Quality Control

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Aggregate Quality and ASTM C33

Physical Properties of Aggregates

- Key properties: bulk density, specific gravity, void content
- Defined by ASTM International (ASTM C33)
- Used to evaluate aggregate suitability for concrete
- Compliance ensures strength and long-term durability



Source: Bradley, B. (2010)

Aggregate Gradation, Classification, and Size Criteria (ASTM C33)

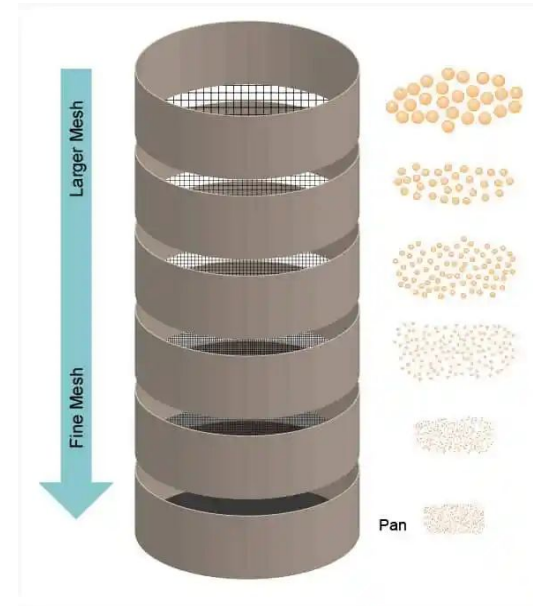
- Gradation defines particle size distribution and aggregate classification
- Proper gradation improves workability and particle packing
- Fine: passes 3/8"; coarse: retained on No. 4 sieve
- Maximum size limited by geometry and constructability
- Nominal size and combined aggregates optimize packing density



Source: Turner, N. (2025)

Fine Aggregate Gradation and Fineness Modulus

- Gradation evaluated through sieve analysis
- Fineness modulus (FM) represents average particle size
- Recommended FM range: 2.3–3.1 (ASTM C33)
- FM variations affect workability, strength, and water demand



Source: Mahajan, B. (n.d.)

Deleterious Substances in Aggregates

- Clay lumps and friable particles limited to 3%
- Coal/lignite: 1% (general), 0.5% (architectural)
- Impurities create weak zones in concrete
- Reduce strength and durability



Source: National Ready Mixed Concrete Association. (n.d.)

Durability-Related Properties of Aggregates

- Sulfates and chlorides affect durability and corrosion
- Organic matter delays hydration and reduces strength
- Excess fines increase water demand and weaken bonding
- Soundness test evaluates resistance to weathering



Sulfate attack on concrete. Source: CTLGroup Qatar. (2019))

Coarse Aggregate Gradation Requirements

Huso	TMN	Porcentaje que pasa por los tamices normalizados													
		100 mm (4")	90 mm (3.5")	75 mm (3")	63 mm (2.5")	50 mm (2")	37.5 mm (1.5")	25 mm (1")	19 mm (3/4")	12.5 mm (1/2")	9.5 mm (3/8")	4.75 mm (N°4)	2.36 mm (N°8)	1.18 mm (N°16)	300 µm (N°50)
1	90 mm a 37.5mm (3.5" a 1.5")	100	90 a 100	-	25 a 60	-	0 a 15	-	0 a 5	-	-	-	-	-	-
2	63 mm a 37.5mm (2.5" a 1.5")	-	-	100	90 a 100	35 a 70	0 a 15	-	0 a 5	-	-	-	-	-	-
3	50 mm a 25mm (2.0" a 1.0")	-	-	-	100	90 a 100	35 a 70	0 a 15	-	0 a 5	-	-	-	-	-
357	50 mm a 4.75mm (2.0" a N°4)	-	-	-	100	95 a 100	-	35 a 70	-	10 a 30	-	0 a 5	-	-	-
4	37.5 mm a 19.0mm (1.5" a 3/4")	-	-	-	-	100	90 a 100	20 a 55	0 a 5	-	0 a 5	-	-	-	-
467	37.5 mm a 4.75mm (1.5" a N°4)	-	-	-	-	100	95 a 100	-	35 a 70	-	10 a 30	0 a 5	-	-	-
5	25 mm a 12.5mm (1.0" a 1/2")	-	-	-	-	-	100	90 a 100	20 a 55	0 a 10	0 a 5	-	-	-	-
56	25 mm a 9.5mm (1.0" a 3/8")	-	-	-	-	-	100	90 a 100	40 a 85	10 a 40	0 a 15	0 a 5	-	-	-
57	25 mm a 4.75mm (1.0" a N°4)	-	-	-	-	-	100	95 a 100	-	25 a 60	-	0 a 10	0 a 5	-	-
6	19 mm a 9.5mm (3/4" a 3/8")	-	-	-	-	-	-	100	90 a 100	20 a 55	0 a 15	0 a 5	-	-	-
67	19 mm a 4.75mm (3/4" a N°4)	-	-	-	-	-	-	100	90 a 100	-	20 a 55	0 a 10	0 a 5	-	-
7	12.5 mm a 4.75mm (1/2" a N°4)	-	-	-	-	-	-	-	100	90 a 100	40 a 70	0 a 15	0 a 5	-	-
8	9.5 mm a 2.36mm (3/8" a N°8)	-	-	-	-	-	-	-	-	100	85 a 100	10 a 30	0 a 10	0 a 5	-
89	12.5 mm a 9.5mm (1/2" a 3/8")	-	-	-	-	-	-	-	-	100	90 a 100	20 a 55	5 a 30	0 a 10	0 a 5
9^	4.75 mm a 1.18mm (N°4 a N°16)	-	-	-	-	-	-	-	-	-	100	85 a 100	10 a 40	0 a 10	0 a 5

Deleterious Substances and Durability Limits in Coarse Aggregates (ASTM C33)

- Limits defined by ASTM International for coarse aggregate quality control
- Clay lumps and friable particles: maximum 5% by mass
- Coal/lignite: 1% (general use), 0.5% (surface-critical concrete)
- Material passing No. 200 sieve: 1% (up to 1.5% if free of harmful fines)
- Chert limited to 5% due to potential disintegration and reactivity
- Soundness limits: $\leq 12\%$ (Na_2SO_4) and $\leq 18\%$ (MgSO_4) mass loss after cycles

Mechanical Strength of Aggregates

- Evaluated using Los Angeles abrasion test
- Max loss: 50% (natural), 35% (manufactured)
- Impact test limit: 30% mass loss
- Indicates resistance to handling and service loads



Los Angeles abrasion machine. Source: Matest. (n.d.).



Aggregate Testing

Aggregate Sampling (ASTM D75)

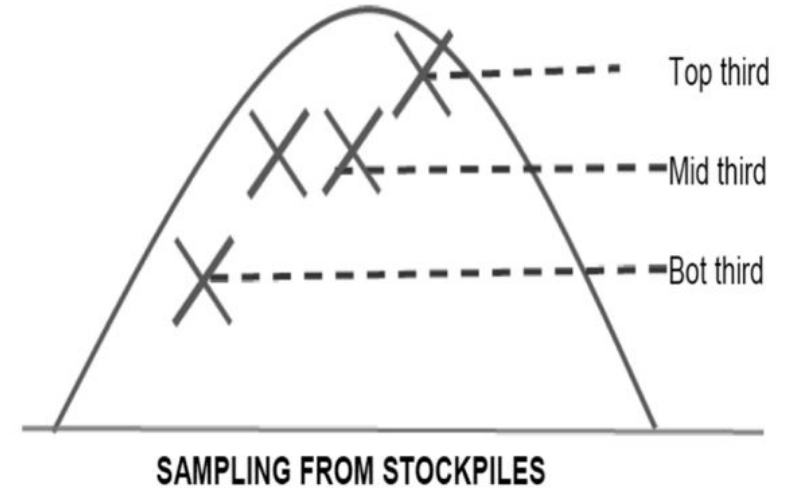
- Objective: obtain representative sample
- Tools: shovels, scoops, containers
- Optional: sampling tubes for depth extraction
- Sealed storage and field documentation recommended



Source: Tri-County Technical College. (n.d.)

Field Sampling Procedure

- Sampling from stockpiles in three layers
- Extract at least five portions (top, middle, bottom)
- Include internal and external zones
- Combine and homogenize into composite sample



Source: Tri-County Technical College. (n.d.)

Sample Size Requirements

- Fine aggregate: minimum 10 kg
- Coarse: 10–165 kg depending on size
- Typical range: 15–50 kg for common sizes
- Based on nominal maximum aggregate size (MAS)

MAS	Minimum sample mass (kg)
Fine Aggregate	
Nº8	10
Nº4	10
Coarse Aggregate	
3/8"	10
1/2"	15
3/4"	25
1"	50
1 1/2"	75
2"	100
2 1/2"	125
3"	150
3 1/2"	175

Source: Author's own elaboration

Sample Reduction Methods

- Governed by ASTM C702
- Ensures representative subsamples
- Methods: mechanical splitter and quartering
- Minimizes variability during testing



Source: The Concrete Society.
(2025)

Splitting and Quartering

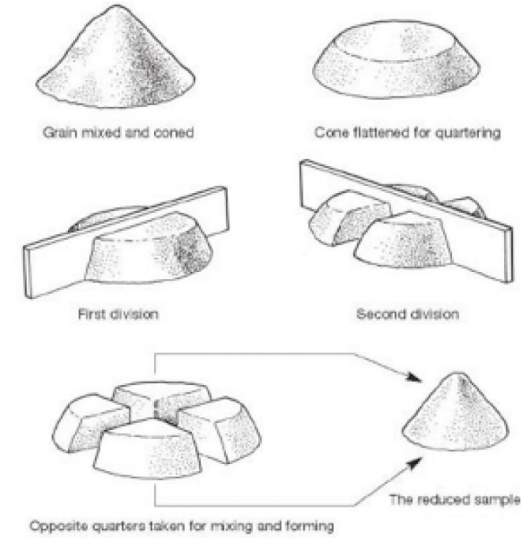
- Mechanical splitter divides sample into equal fractions
- Requires even chutes ($\geq 1.5 \times$ max particle size)
- Quartering: coning, mixing, and flattening process
- Ensures homogeneous and representative samples



Sample splitter. Source: Matest. (n.d.).

Manual Quartering Procedure

- Flattened sample: diameter = 4–8× thickness
- Divided into four equal quarters
- Opposite quarters discarded; remaining remixed
- Repeated until required sample size is obtained



Source: Suryakanta. (2015)

Sieve Analysis of Aggregates (ASTM C136)

- Determines particle size distribution (gradation)
- Uses standardized sieve series
- Evaluates compliance with specifications
- Key for workability, strength, and durability



Source: Turner, N. (2025)

Equipment for Sieve Analysis

- Precision balances for fine and coarse aggregates
- Accuracy: $\sim 0.1\%$ of sample mass
- Drying oven at 110 ± 5 °C required
- Ensures correct dry mass determination



Woven Wire Mesh Sieves. Source: Matest. (n.d.).

Sample Size for Sieve Analysis

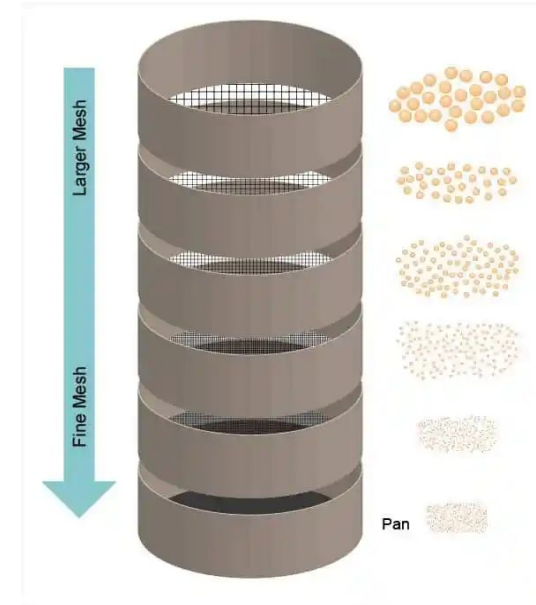
- Fine aggregate: minimum 500 g
- Coarse: 1.5–16 kg depending on size
- Larger sizes require greater sample mass
- Ensures statistical representativeness

MAS	Minimum sample mass (kg)
3/8"	1.5
1/2"	3.0
3/4"	6.0
1"	11.0
1 1/2"	16.0
Agregado fino	0.5

Source: Author's own elaboration

Sieve Analysis Procedure

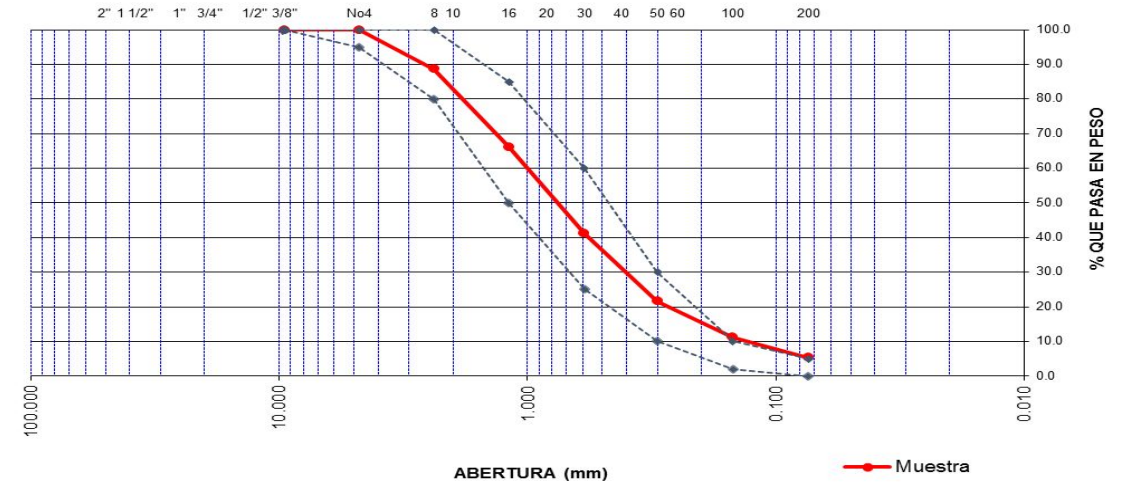
- Dry sample and cool before testing
- Arrange sieves in decreasing size order
- Sieve manually or mechanically until stable
- Weigh retained μm and verify mass balance ($\pm 0.3\%$)



Source: Mahajan, B. (n.d.)

Gradation Results and Interpretation

- Calculate % retained, cumulative, and passing
- Plot gradation curve (semi-log scale)
- Compare with standard limits (fine aggregate)
- Identify grading band for coarse aggregate



Source: Author's own elaboration

Fine Material by Washing (ASTM C117)

- Determines fines passing No. 200 sieve
- Removes clays, silts, and soluble materials
- Uses washing to separate fine particles
- Assesses impact on concrete performance



Source: Author's own elaboration

Equipment for Washing Test

- Balance with 0.1% sensitivity
- Oven at 110 ± 5 °C
- Sieves: at least No. 16 and No. 200
- Enables separation and quantification of fines



Source: Certified MTP. (n.d.)

Washing Test Procedure

- Dry sample, then wash with water
- Agitate to detach fine particles
- Decant through sieves until clear
- Dry retained material and compute mass loss

Procedure:

$$A = \frac{B - C}{B} \times 100$$

A: Percentage passing the No. 200 sieve

B: Dry weight of the initial sample (g)

C: Dry weight of the washed sample (g)

Report the result to the nearest 0.1%

Sample Size for Washing Test

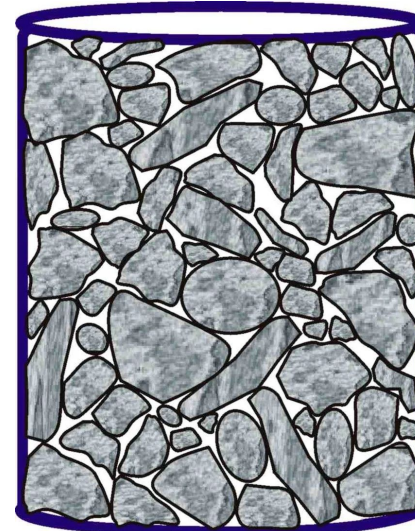
- Fine aggregate: ~500 g sample
- Coarse aggregate: 1–5 kg
- Depends on nominal maximum size
- Ensures accurate quantification of fines

MAS	Minimum sample mass (kg)
1 ½" o mayor	5000
1" a ¾"	2500
½" a 3/8"	1000
Agregado fino	500

Source: Author's own elaboration

Unit Weight of Aggregates (ASTM C29)

- Determines loose and compacted unit weight
- Applicable to fine, coarse, and combined aggregates
- Key parameter for concrete mix design
- Used to estimate volumetric proportions



Source: Hosen, K., et al. (2024)

Equipment for Unit Weight Test

- Balance with 0.1% precision
- Cylindrical container of known volume
- Tamping rod with hemispherical tip
- Container geometry: height \approx diameter



Source: Matest. (n.d.).

Unit Weight Test Procedure

- Loose condition: pour without compaction
- Compacted: layers with 25 rod blows each
- Level surface and determine total mass
- Repeat tests and average results



Source:Tri-County Technical College. (n.d.)

Data Recording and Calculations

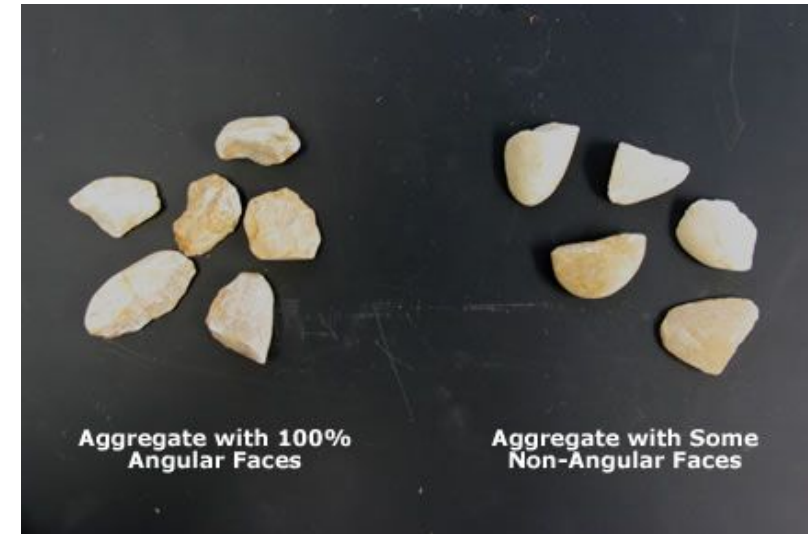
- Record container and aggregate mass
- Calculate unit weight from measured values
- Use standardized data table
- Ensures consistency and traceability

Sample		1	2	3
Mold + sample weight	(g)			
Mold weight	(g)			
Sample weight	(g)			
Mold volume	(cm ³)			
Density	(g/cm ³)			
Bulk Unit Weight			g/cm ³	

Source: Author's own elaboration

Fractured Particles in Coarse Aggregate (ASTM D5821)

- Measures % of particles with fractured faces
- Indicates angularity and interparticle friction
- Improves shear strength and stability
- Enhances bond with cement paste



Source: Pavement Interactive. (n.d.)

Equipment for Fractured Particles Test

- Balance with 0.1% precision
- Standard sieve set for size separation
- Clean tray for inspection
- Spatula for handling and sorting



Source: Pavement Interactive. (n.d.)

Fractured Particles Test Procedure

Aggregate Size		A	B	C	D	E
Passing sieve	Retained on sieve	(g)	(g)	$((B/A) \times 100)$	(%)	CxD
1 1/2"	1"					
1"	3/4"					
3/4"	1/2"					
1/2"	3/8"					
Total						
Percentage with one fractured face			(Total E / Total D)			

Source: Author's own elaboration

A: Sample weight (g)

B: Weight of material with fractured faces (g)

C: Percentage of fractured faces (%)

D: Percentage retained in the original gradation

E: Average percentage of fractured faces

Sample Size for Fractured Particles Test

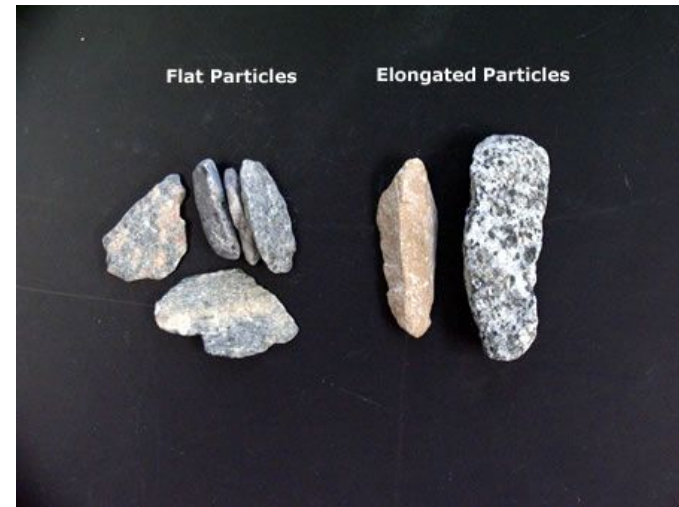
- Depends on nominal maximum size
- Smaller sizes: ~300 g minimum
- Larger sizes: up to 2000 g or more
- Ensures representative sampling

Aggregate size	Minimum sample mass (g)
1 ½" a 1"	2000
1" a ¾"	1500
¾" a ½"	1200
½" a 3/8"	300

Source: Author's own elaboration

Flat and Elongated Particles (ASTM D4791)

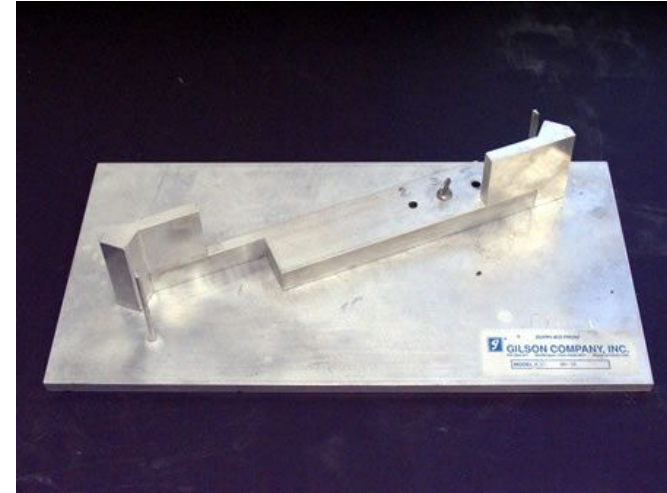
- Measures % of unfavorable particle shapes
- Flat/elongated particles reduce workability
- Negatively affect compaction and strength
- Important for concrete quality control



Source: Pavement Interactive. (n.d.)

Equipment for Shape Evaluation

- Proportional caliper (ratio gauge)
- Common ratios: 1:2, 1:3, 1:4, 1:5
- 1:3 ratio widely used in practice
- Balance with 0.5% precision required



Source: Pavement Interactive. (n.d.)

Flat and Elongated Particles Test Procedure

Aggregate Size		Weight	Flat		Elongated	
Passing sieve	Retained on sieve	(g)	Weight (g)	Particles	Weight (g)	Particles
1 1/2"	1"					
1"	3/4"					
3/4"	1/2"					
1/2"	3/8"					
3/8"	N°4					
Total						
%						
Percentage of flat and elongated particles						

Source: Author's own elaboration

Sand Equivalent Test (ASTM D2419)

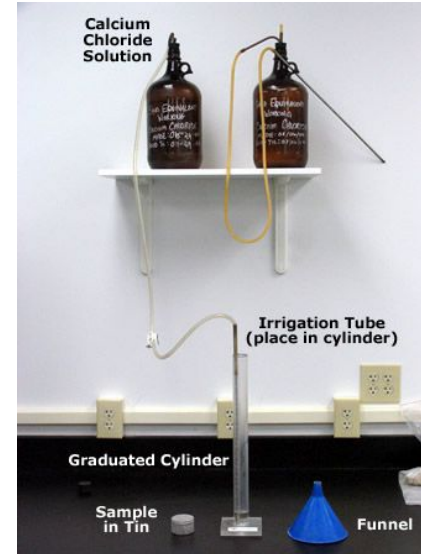
- Measures proportion of sand vs. clay/silt fines
- Indicates cleanliness of fine aggregate
- High fines content reduces concrete performance
- Key parameter for workability and strength



Source: Pavement Interactive. (n.d.)

Equipment for Sand Equivalent Test

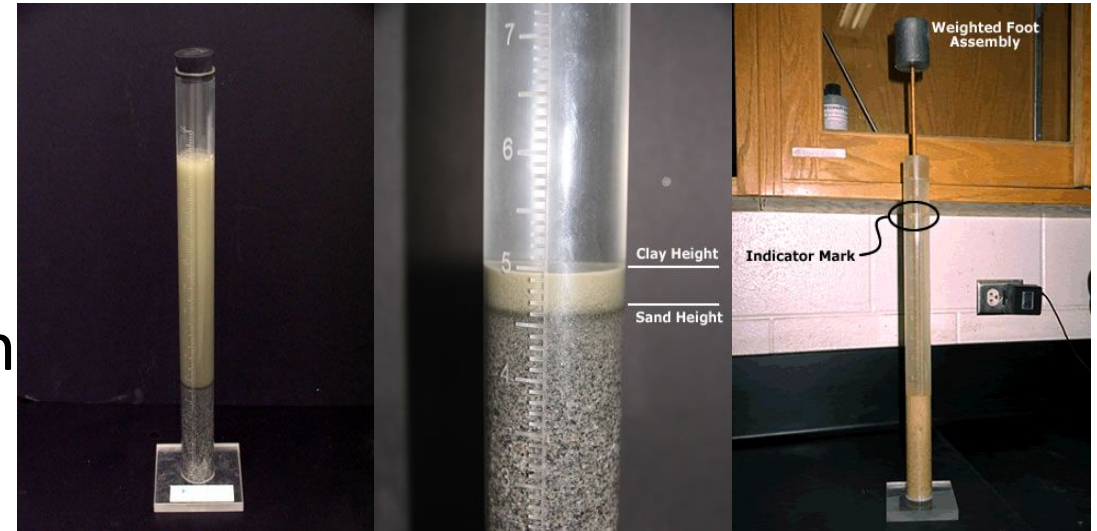
- Graduated cylinder, irrigator tube, shaker
- Oven at 110 ± 5 °C
- Funnel, sieve (No. 4), filter paper
- Stock solution (CaCl₂, glycerin, formaldehyde)



Source: Pavement Interactive. (n.d.)

Sand Equivalent Test Procedure

- Prepare and saturate sample in solution
- Apply controlled agitation and washing
- Allow sedimentation (sand vs. clay layers)
- $SE = (\text{sand height} / \text{clay height}) \times 100$



Source: Pavement Interactive. (n.d.)

Specific Gravity and Absorption of Fine Aggregate (ASTM C128)

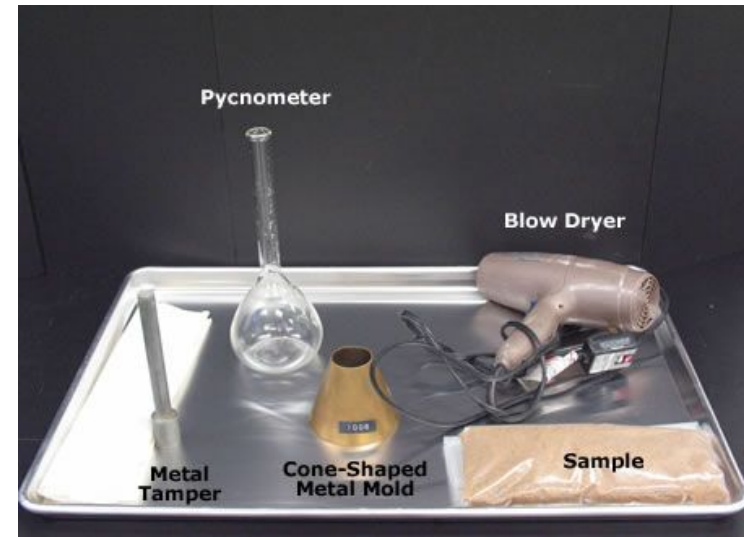
- Determines OD, SSD, and apparent specific gravity
- Measures absorption after 24-hour immersion
- Essential for mix design calculations
- Controls effective water content



Source: Pavement Interactive. (n.d.)

Equipment for Fine Aggregate SG Test

- Balance (0.1 g precision) and drying oven
- Calibrated pycnometer (500 cm³)
- Standard conical mold (sand cone)
- Tamping rod with defined dimensions



Source: Pavement Interactive. (n.d.)

Fine Aggregate SG Test Procedure

- Saturate sample for 24 hours
- Achieve SSD condition using cone test
- Weigh sample and place in pycnometer
- Remove air, adjust volume, and measure mass



Source: Pavement Interactive. (n.d.)

Calculations and Results (Fine Aggregate)

$$P_{em} = \frac{W_0}{(V - V_a)} \times 100$$

P_{em} : Mass specific gravity (g/cm³)

W_0 : Oven-dry weight of the sample in air (g)

V : Volume of the flask (cm³)

V_a : Volume of water added to the flask (cm³)

- SSD specific gravity (mass)

$$P_{eSSD} = \frac{500}{(V - V_a)} \times 100$$

- Apparent specific gravity

$$P_{ea} = \frac{W_0}{(V - V_a) - (500 - W_0)} \times 100$$

- Absorption

$$A_b = \frac{500 - W_0}{W_0} \times 100$$

Specific Gravity of Coarse Aggregate (ASTM C127)

- Determines SG and absorption for coarse aggregate
- Similar principles to fine aggregate test
- Not suitable for highly porous materials
- Important for volumetric mix calculations



Source: Pavement Interactive. (n.d.)

Equipment for Coarse Aggregate SG Test

- Balance with suspension system
- Wire basket and water tank
- No. 4 sieve and drying oven
- Measures mass in air and submerged



Source: Pavement Interactive. (n.d.)

Coarse Aggregate SG Test Procedure (ASTM C127)

- Saturate sample for 24 hours; size-dependent mass (2 kg to >100 kg)
- Achieve SSD condition by surface drying
- Measure mass in air (SSD) and submerged in water
- Oven-dry sample and determine final dry mass



Source: Pavement Interactive. (n.d.)

Calculations: Specific Gravity and Absorption

- SSD specific gravity (mass)

$$\text{Specific gravity} = 997.5 \times \frac{A}{B - C}$$

$$\text{Specific gravity} = 997.5 \times \frac{B}{B - C}$$

- Apparent specific gravity

$$\text{Specific gravity} = 997.5 \times \frac{A}{A - C}$$

- Absorption

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

A: Mass of the oven-dry sample (g)

B: Mass of the sample in SSD condition (g)

C: Apparent mass of the sample submerged in water (g)

997.5 kg/m³ is the density of water at 23 °C

Los Angeles Abrasion Test (ASTM C131/C535)

- Evaluates wear resistance of coarse aggregate
- Indicates hardness and durability
- Simulates mechanical degradation
- Key for structural performance assessment



Source: Pavement Interactive. (n.d.)

Equipment for Abrasion Test

- Los Angeles machine (rotating steel drum)
- Steel spheres (6–12 units, ~46.8 mm diameter)
- Standard sieves and balance (≥ 5000 g capacity)
- Setup depends on sample gradation



Source: Pavement Interactive. (n.d.)

Abrasion Test Procedure and Results

- Rotate sample + spheres (500 rev at 30–33 rpm)
- Sieve to remove generated fines
- Determine mass loss percentage
- Lower loss = higher durability and strength



Source: Pavement Interactive. (n.d.)

Conclusions

- ❑ Aggregates are the primary component of concrete ($\approx 60\text{--}80\%$ of volume), directly influencing mechanical strength, workability, and durability.
- ❑ Their properties—gradation, shape, texture, and strength—govern key performance aspects such as rheology, resistance to segregation, and long-term behavior.
- ❑ Proper application of standards from ASTM International ensures reliable, repeatable, and comparable test results.
- ❑ Controlled laboratory procedures (sampling, equipment calibration, and test execution) are essential to minimize variability and error.
- ❑ Comprehensive aggregate characterization provides the technical basis for evaluating material suitability.
- ❑ These results support the development of optimized, efficient, and durable concrete mix designs in civil engineering.

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