Aggregate Gradation

Important Properties

Gradation

Relative density and absorption

Hardness (resistance to wear)

Durability (resistance to weathering)

Shape and surface texture

Deleterious substances

Crushing strength

Soft and lightweight particles

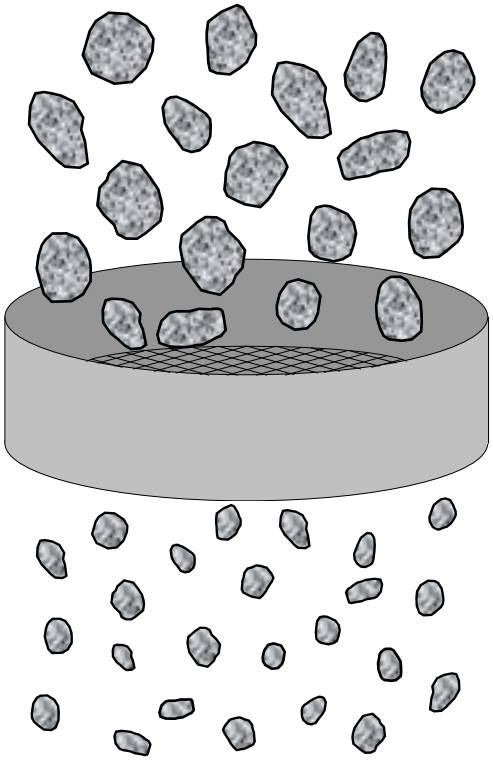
Chemical stability

Gradation Analysis

A gradation analysis (or sieve analysis) is a procedure used to assess the particle size distribution (gradation) of a granular material by allowing the material to pass through a series of sieves of progressively smaller mesh size and weighing the amount of material that is stopped by each sieve as a fraction of the whole mass. The size distribution is often of critical importance to the way the material performs in use.

Gradation Analysis

percent coarser
or
percent retained

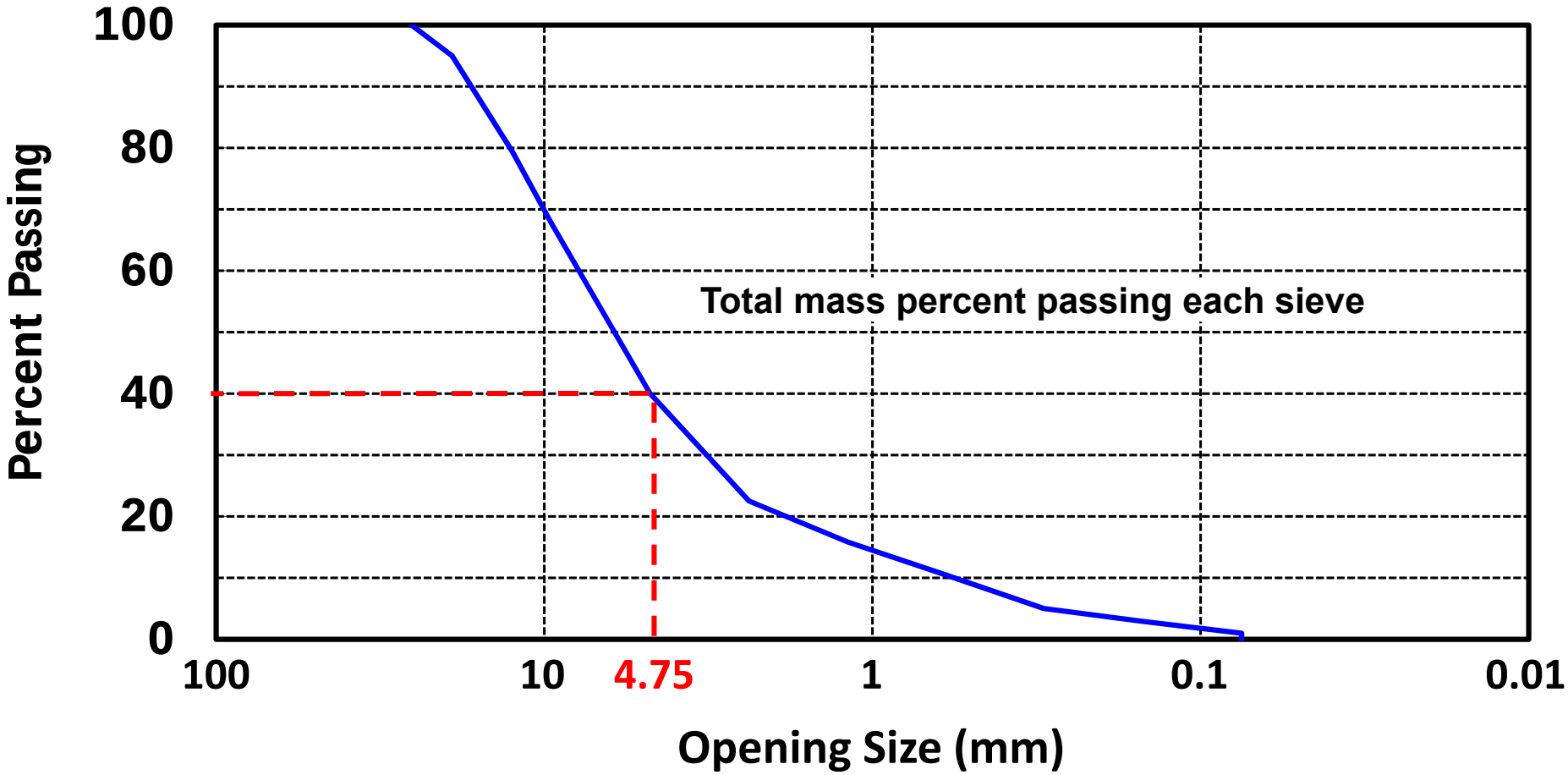


percent finer
or
percent passing

Percentages are calculated by mass

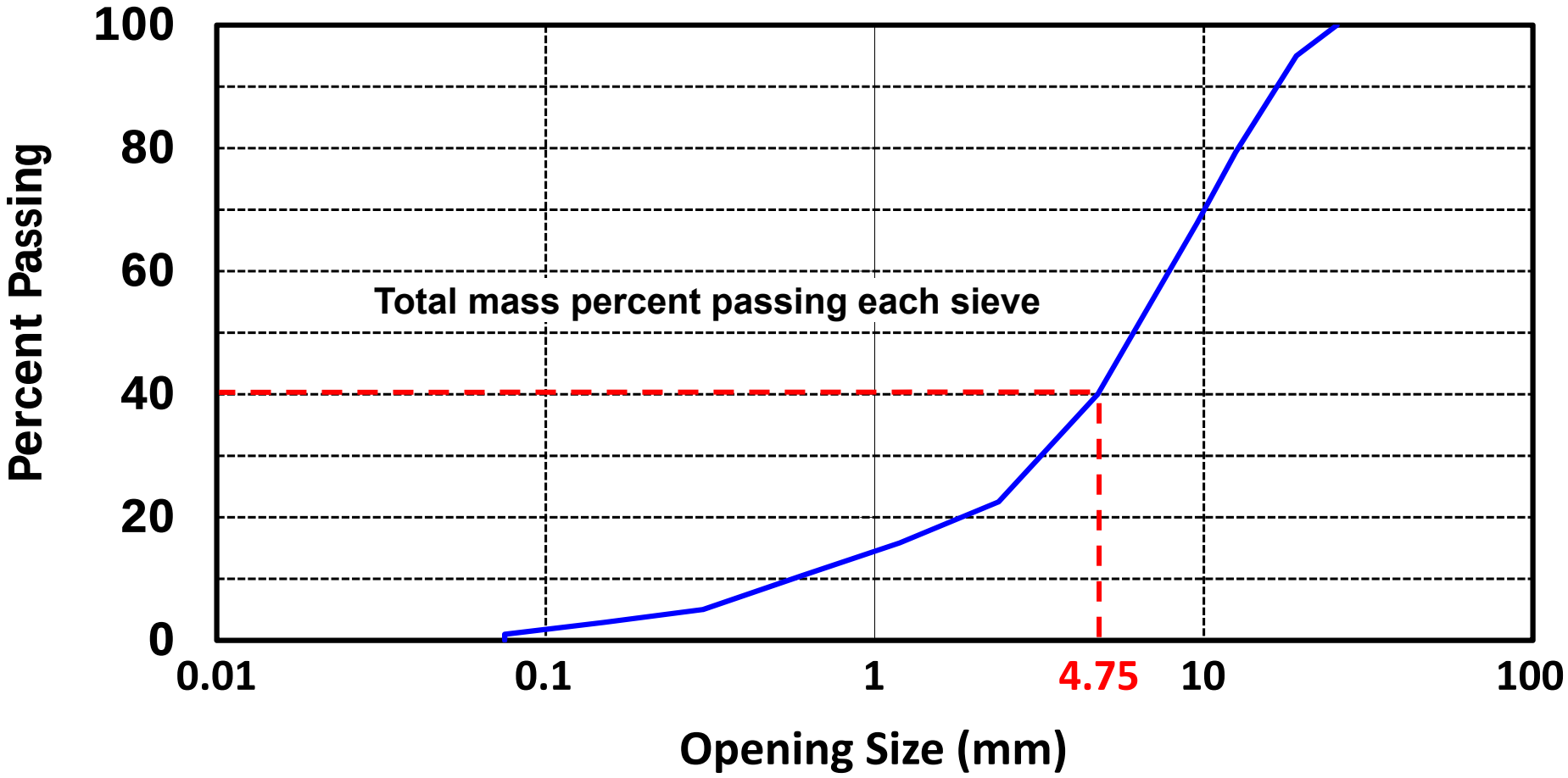
Gradation Chart

(typically used for soil)



Gradation Chart

(typically used for aggregate)



Sieve Shakers

Mary Ann Shaker

Screen Shakers

Gilson Shaker

Sieve Sizes Used in Construction

Sieve Designation	
Traditional	*Metric*
3 in.	75 mm
2½ in.	63 mm
2 in.	50 mm
1½ in.	37.5 mm
1 in.	25.0 mm
3/4 in.	19.0 mm
1/2 in.	12.5 mm
3/8 in.	9.5 mm
No. 4	4.75 mm
No. 8	2.36 mm
No. 16	1.18 mm
No. 30	600 μm
No. 50	300 μm
No. 100	150 μm
No. 200	75 μm

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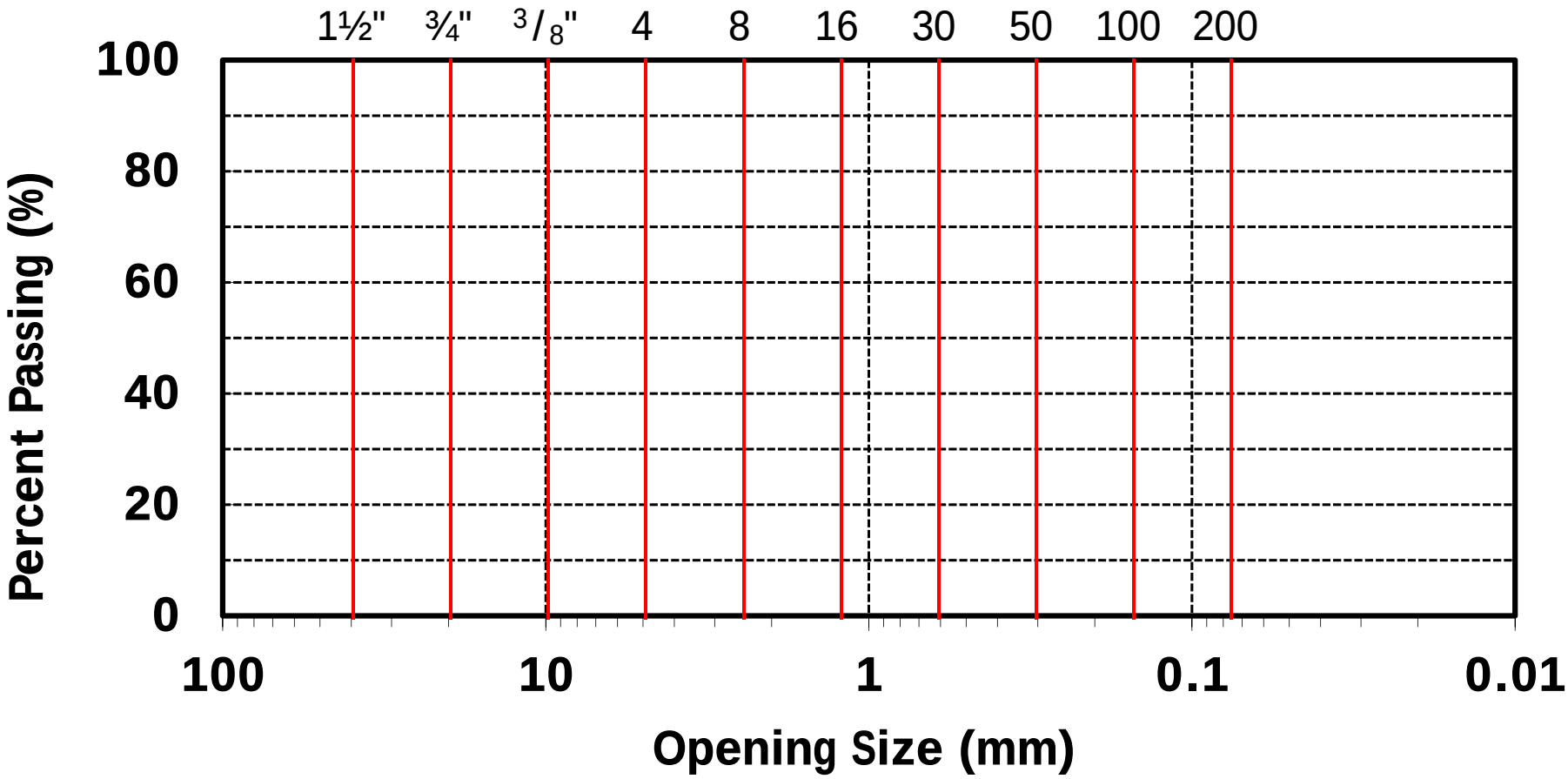
No. 30	600	μm
No. 50	300	μm
No. 100	150	μm
No. 200	75	μm

Openings vary by a factor of two

Gradation Chart



Gradation Example

Sample: 5/8" Gravel **Initial Weight:** 992 g **Date:** _____

Sieve Designation	Cumulative Weight Retained (g)	Cumulative Percent Retained (g)	Cumulative Percent Passing (%)
1/2 in.			
3/8 in.			
No. 4			
No. 8			
No. 16			
No. 30			
No. 50			
No. 100			
Pan			

Cumulative Weight Retained in Pan must be within 0.3% of the Initial Weight

Gradation Example

Sample: 5/8" Gravel **Initial Weight:** 992 g **Date:**

Sieve Designation	Cumulative Weight Retained (g)	Cumulative Percent Retained (g)	Cumulative Percent Passing (%)
1/2 in.	0	0.0	100.0
3/8 in.	49	4.9	95.1
No. 4	204	20.5	79.5
No. 8	439	44.2	55.8
No. 16	573	57.6	42.4
No. 30	743	74.7	25.3
No. 50	819	82.4	17.6
No. 100	894	89.9	10.1
Pan	994	100.0	0.0

Cumulative Weight Retained in Pan must be within 0.3% of the Initial Weight

Typical Aggregate Gradations

Uniformly graded aggregate

All of the particles are approximately the same size

Open-graded aggregate

Very little fine aggregate thus lots of void space between particles

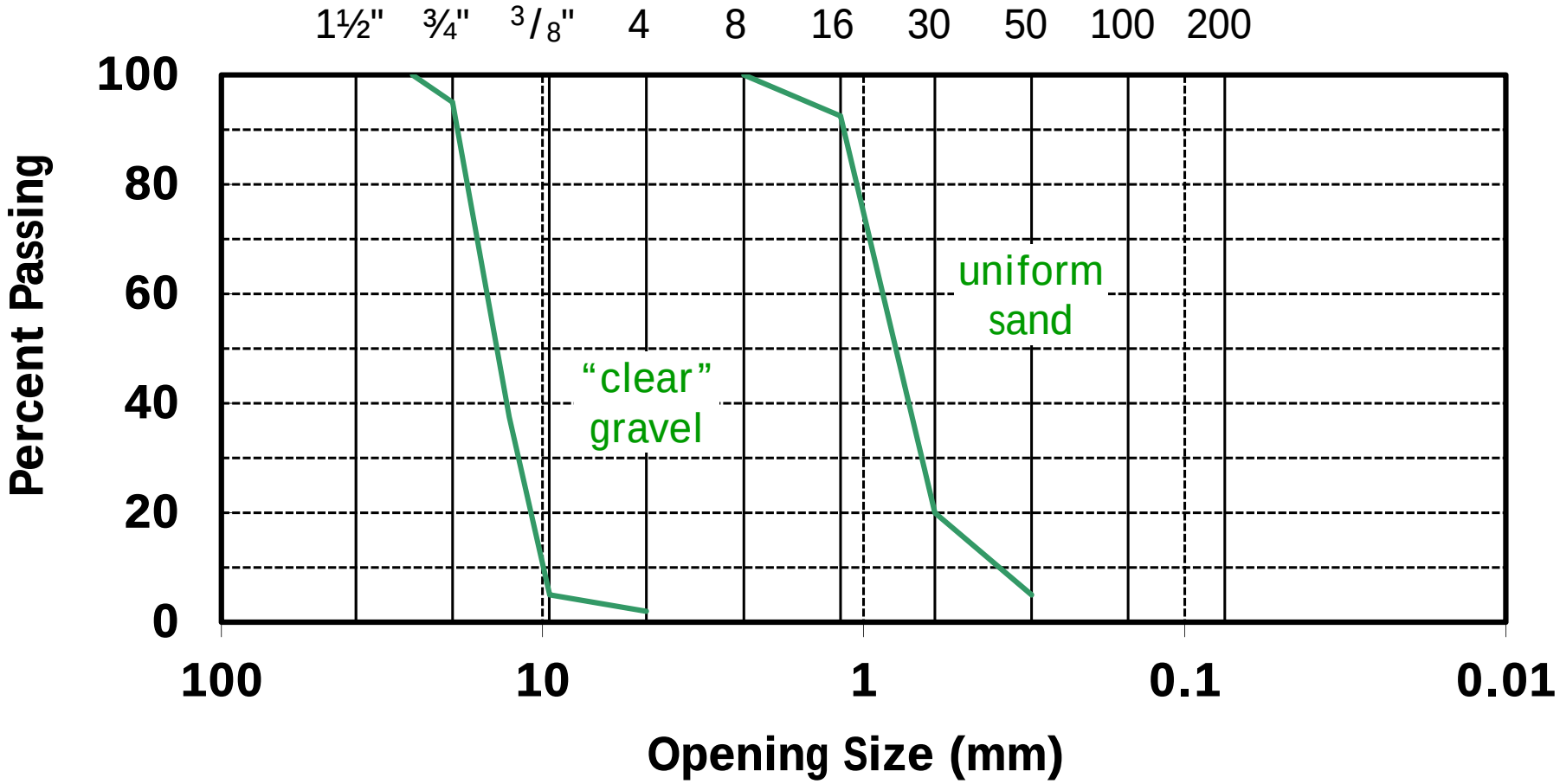
Gap-graded aggregate

Very little aggregate in the medium size range

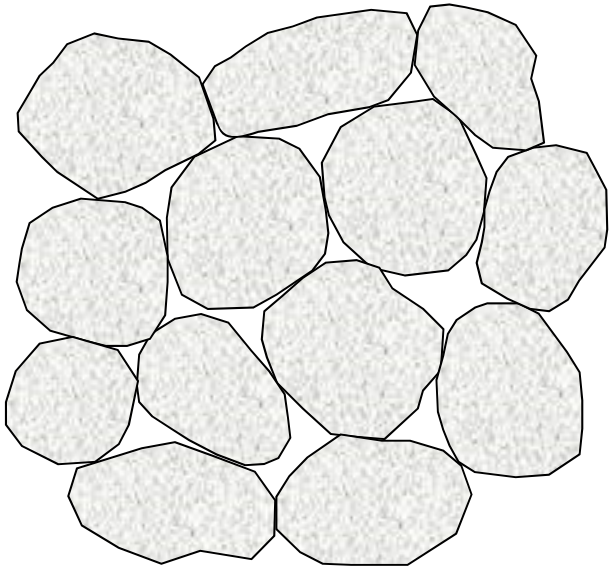
Dense-graded aggregate

Lots of different particle sizes thus very little void space

Uniformly Graded Aggregate

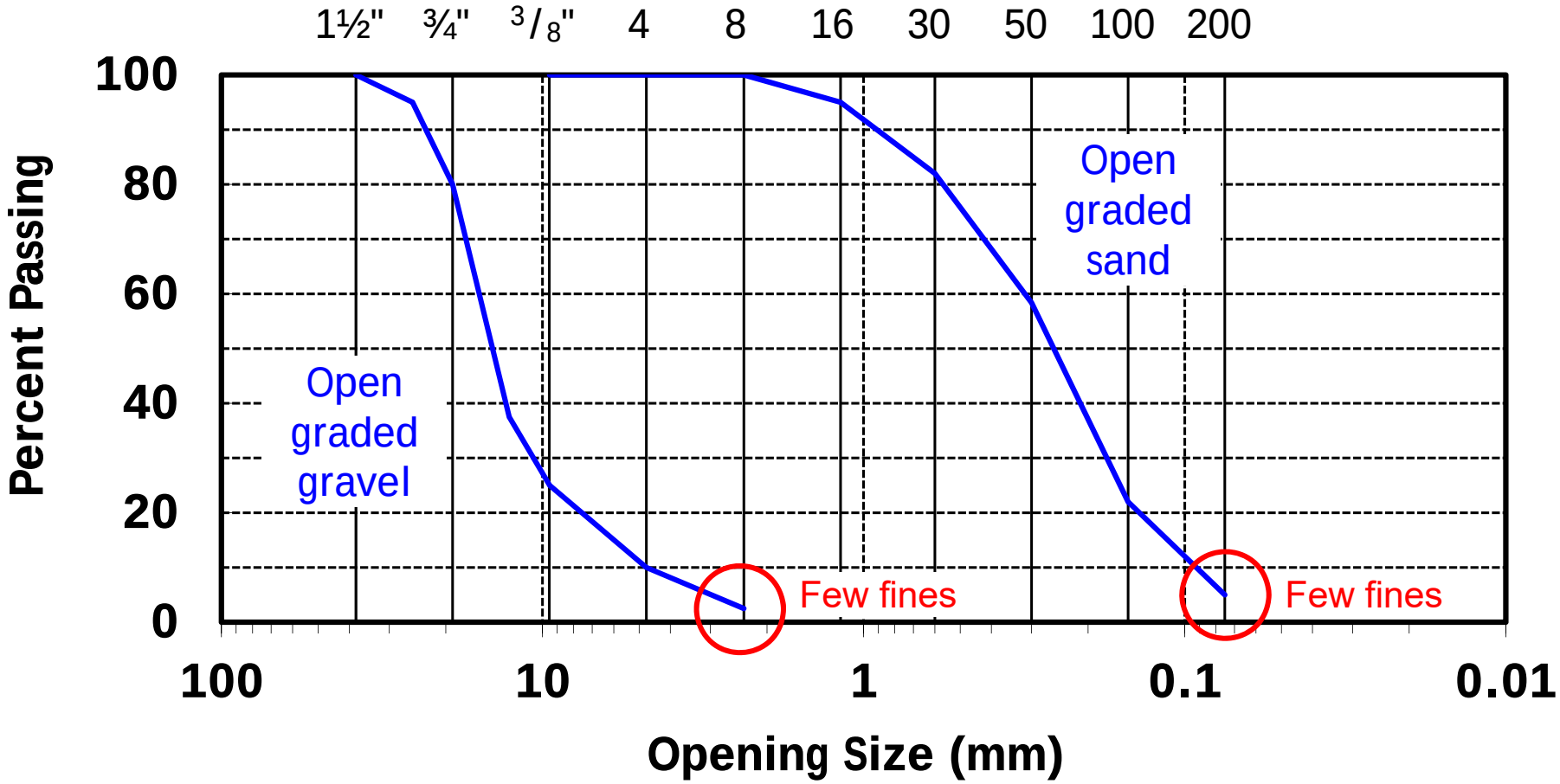


Uniformly Graded Aggregate

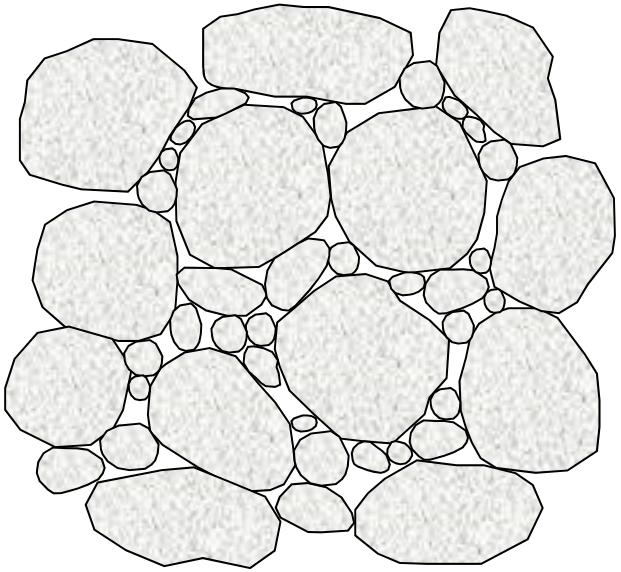


Narrow range of sizes
Grain-to-grain contact
High void content
High permeability
Low stability
Difficult to compact

Open-Graded Aggregate

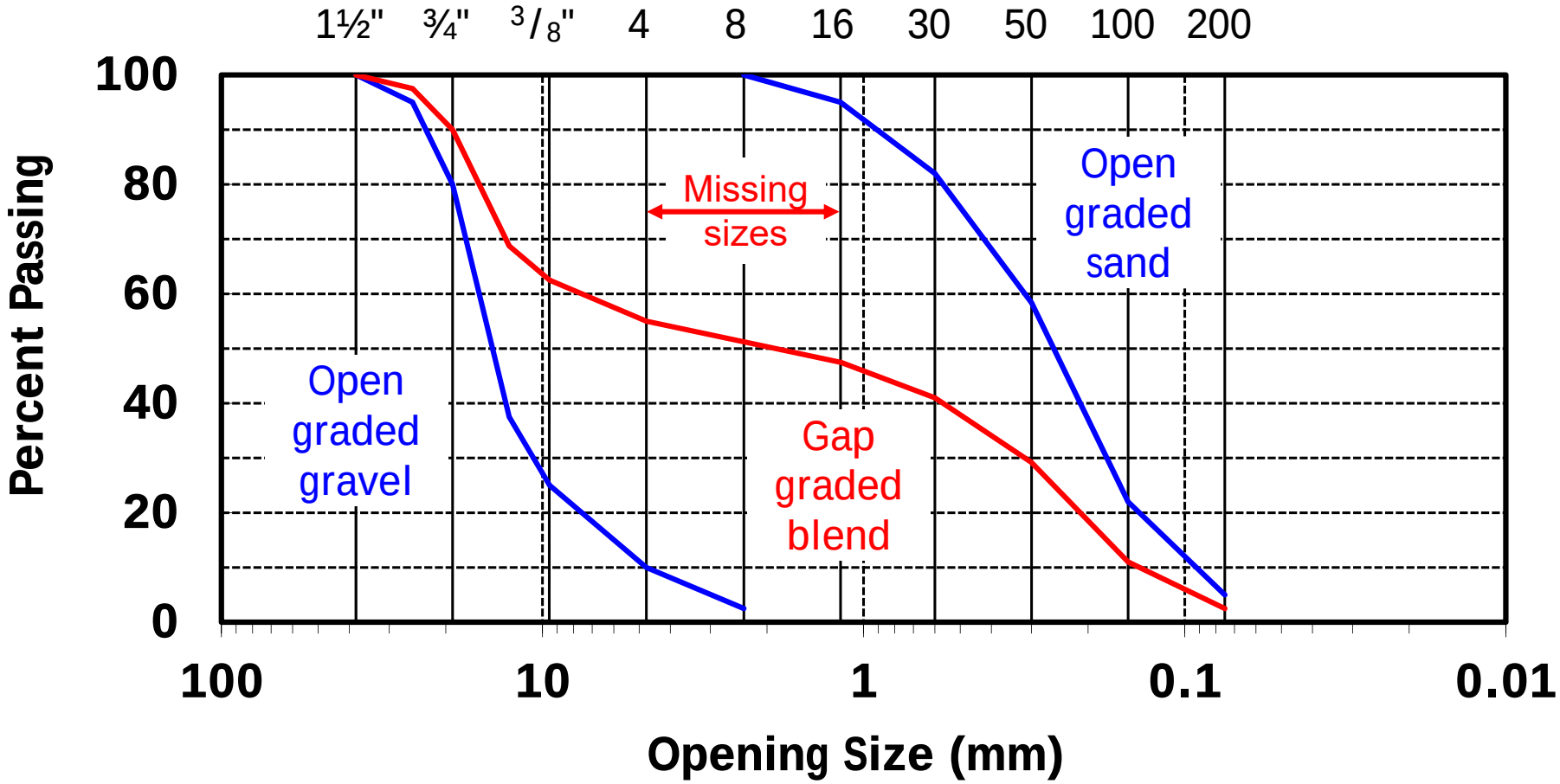


Open-Graded Aggregate

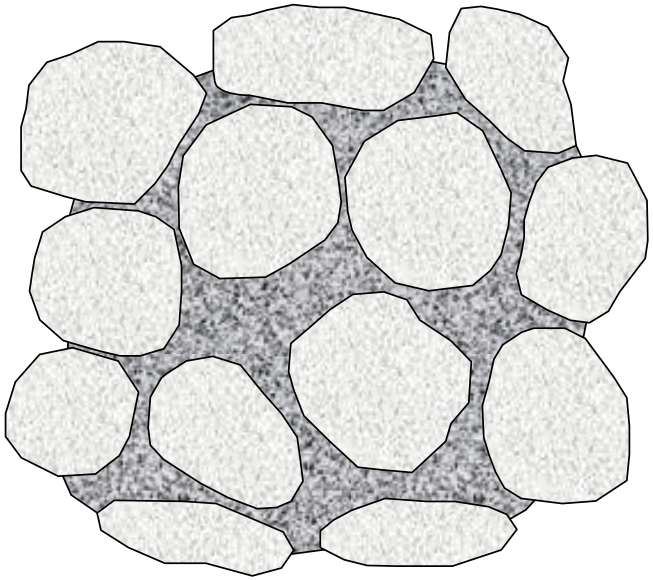


Decent range of sizes
Very few fine particles
Grain-to-grain contact
High void content
High permeability
High stability
Difficult to compact

Gap-Graded Aggregate

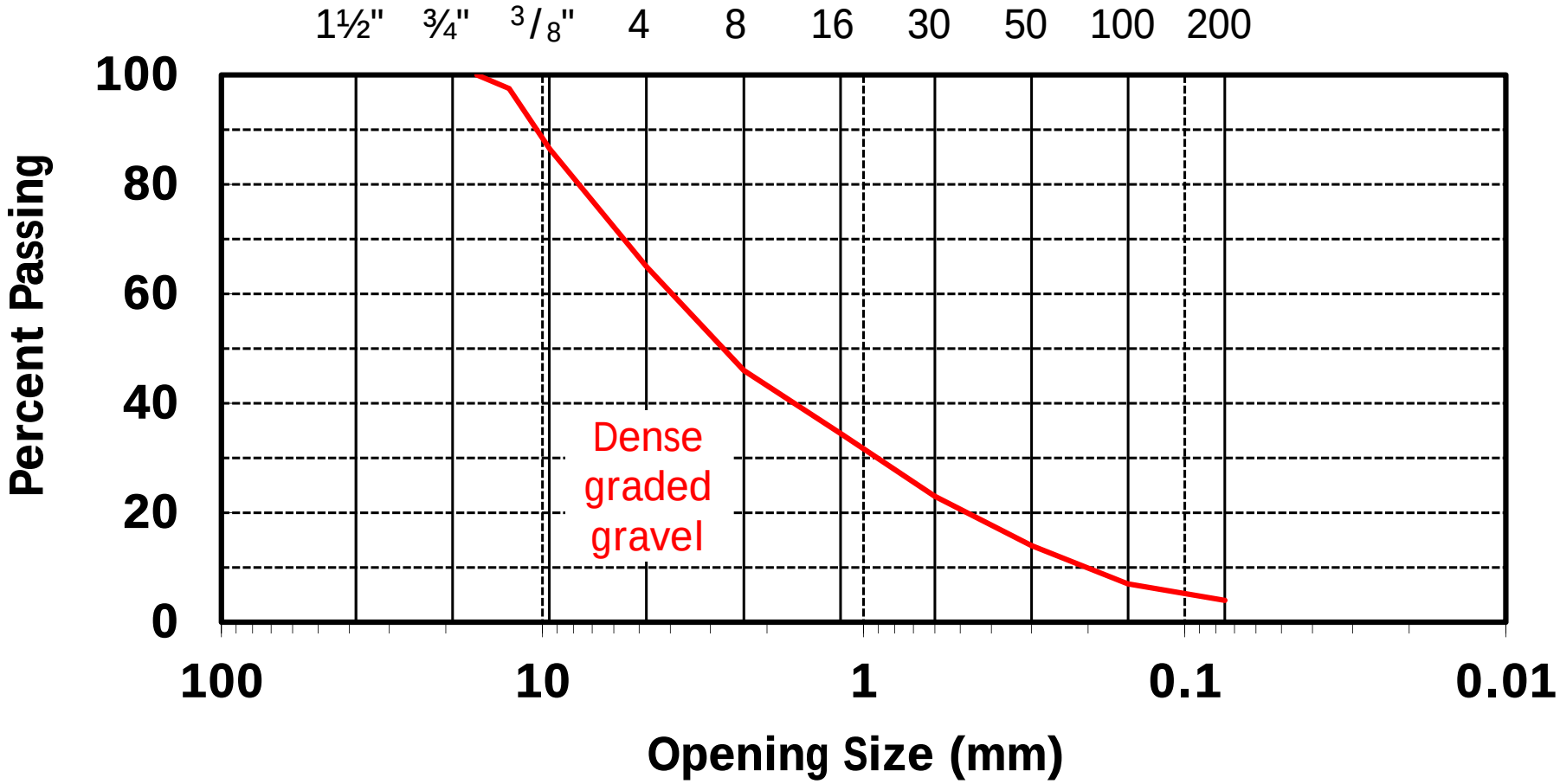


Gap-Graded Aggregate

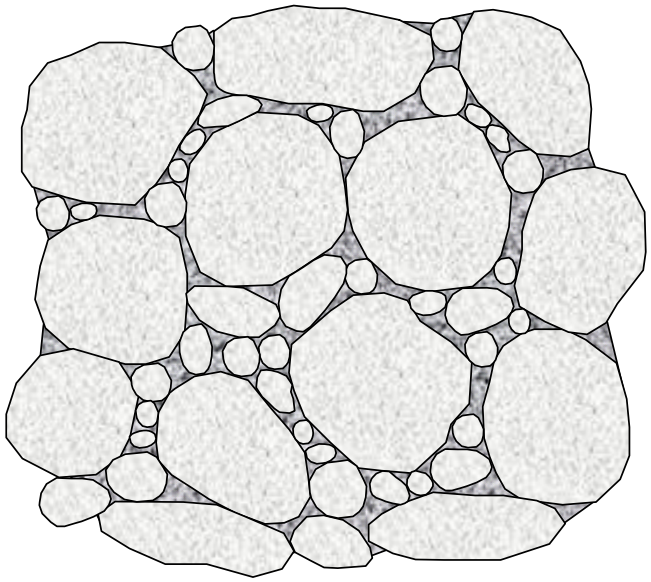


Wide range of sizes
Missing middle sizes
No grain-to-grain contact
Moderate void content
Moderate permeability
Low stability
Easy to compact

Dense-Graded Aggregate



Dense-Graded Aggregate



Wide range of sizes
Grain-to-grain contact
Low void content
Low permeability
High stability
Difficult to compact

Fuller's Curve

Fuller, W.B. and Thompson, S.E. "The laws of proportioning concrete," *Transactions of the ASCE*, v. 159, 1907.

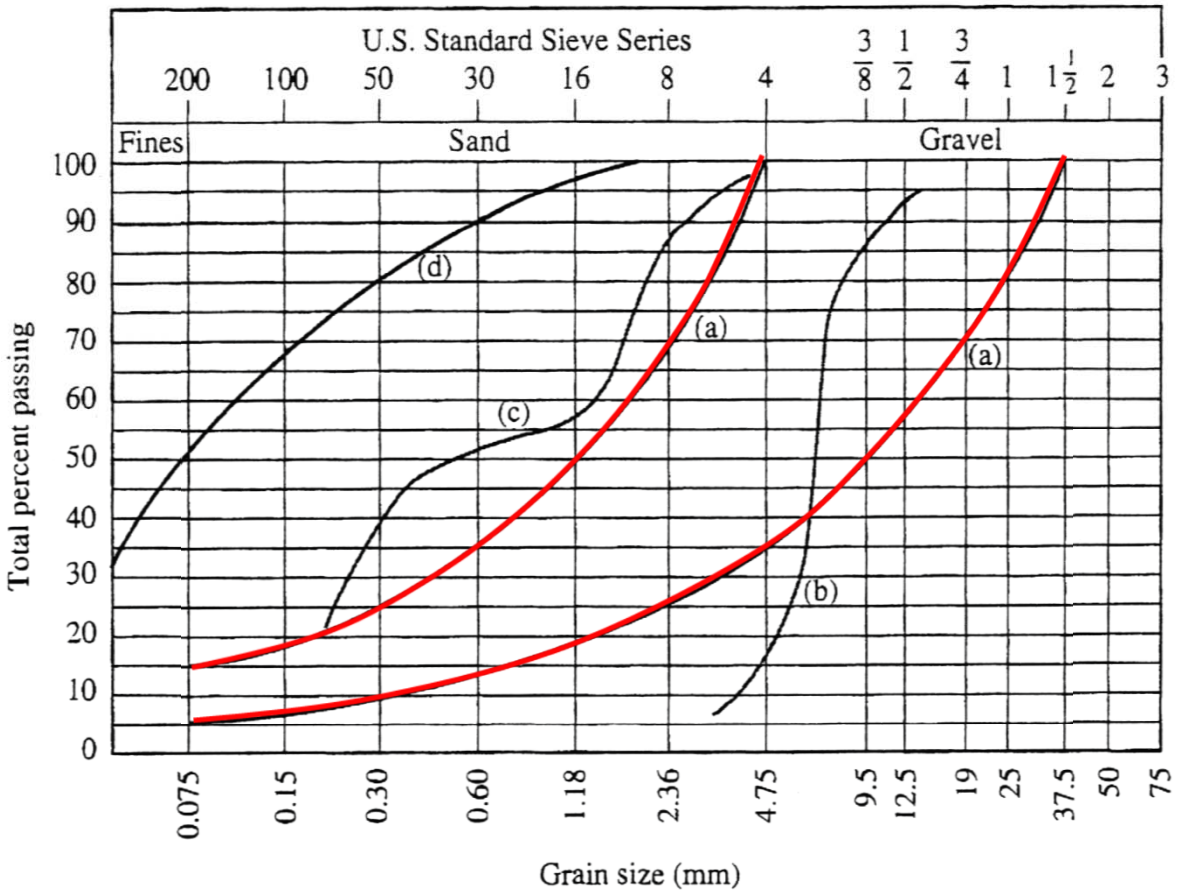
$$p_i = \left(\frac{d_i}{D}\right)^{0.50}$$

p_i = percent passing i^{th} sieve

d_i = opening size of i^{th} sieve

D = maximum particle size

Produces the highest density and lowest void content



Aggregate gradation curves: (a) maximum density gradations for 37.5 and 4.75 mm sizes based on the Fuller relationship; (b) a uniform aggregate; (c) a gap-graded aggregate; (d) screenings.

FHWA Maximum Density Curve

In 1962 FHWA published a modified version of Fuller's equation with a different exponent.

$$p_i = \left(\frac{d_i}{D}\right)^{0.45}$$

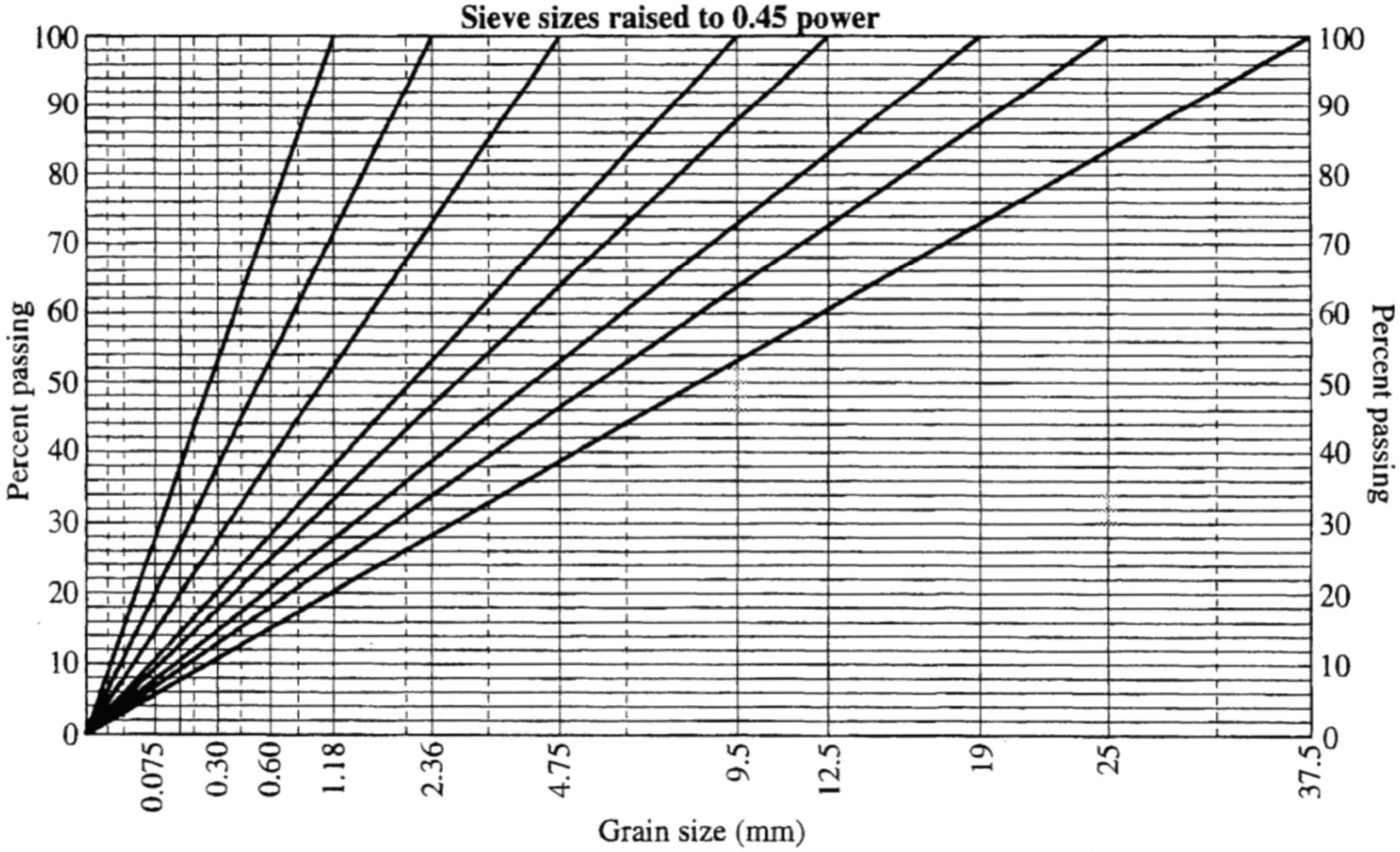
~~0.50~~

p_i = percent passing i^{th} sieve

d_i = opening size of i^{th} sieve

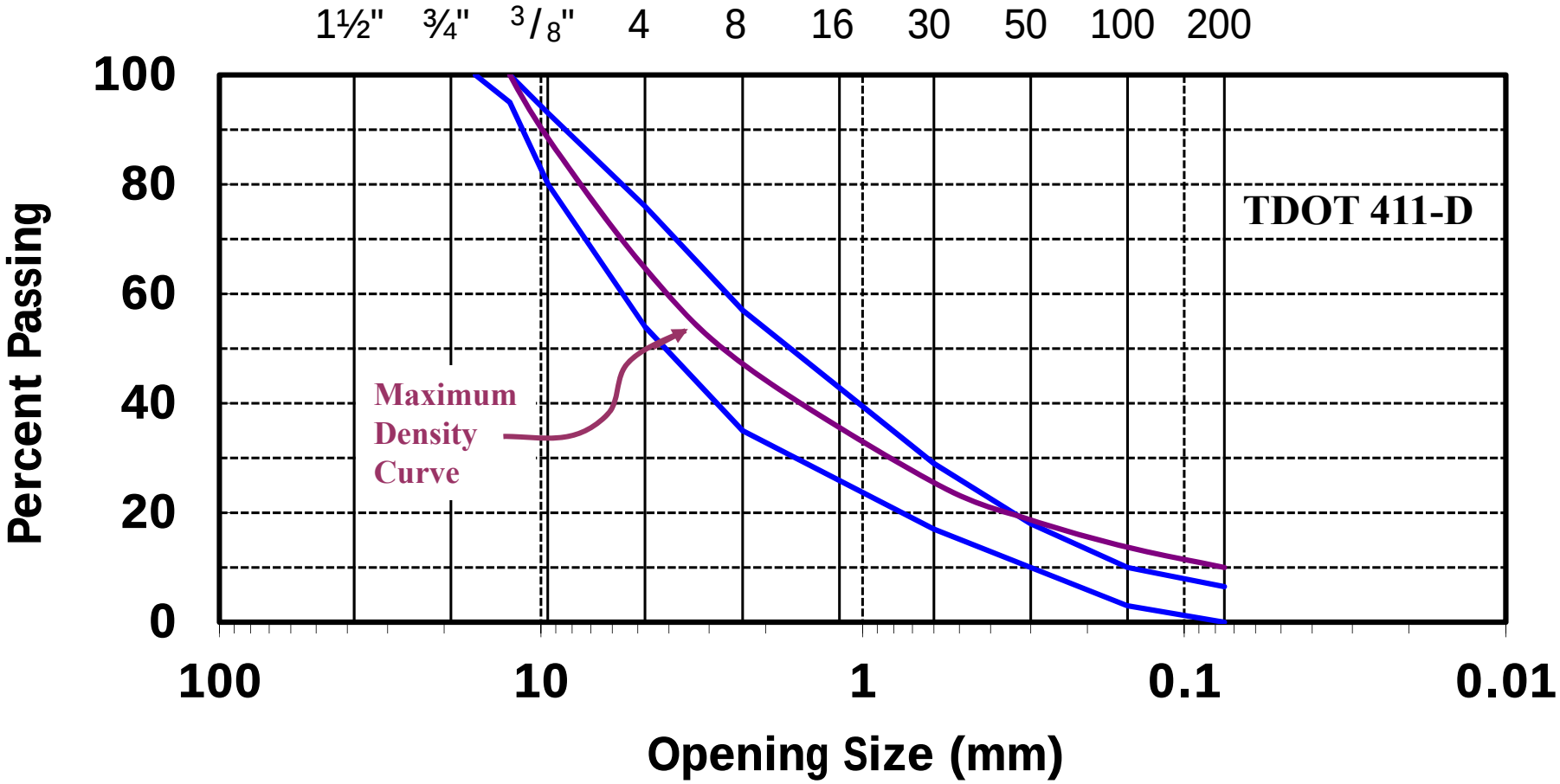
D = maximum particle size

Produces the highest density and lowest void content



Maximum density curves on Federal Highway Administration 0.45 power gradation chart.

Dense-Graded Aggregate



Dense-Graded Aggregate