Pavement Materials & Design

3.1_Aggregates for road constructions_ Part 1

Dr. Hamza Alkuime

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Aggregate

Definition

- Aggregate” is
  - *A collective term for the mineral materials such as sand, gravel and crushed stone that are used with a binding medium (such as water, bitumen, Portland cement, lime, etc.) to form compound materials (such as asphalt concrete and Portland cement concrete).*
- By volume, aggregate generally accounts for
  - **92 to 96 percent of HMA**
  - 70 to 80 percent of Portland cement concrete.
  - *Aggregate is also used for base and subbase courses for both flexible and rigid pavements.*

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Aggregate

Sources

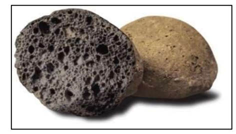
- Natural
  - *Sand and Gravel*
  - *Crushed Stone*
- Synthetic (artificial)
  - *Lightweight*
  - *Slag*
    - Blast Furnace
    - Steel Slag
- Recycled
  - *Reclaimed (or recycled) Asphalt Pavement (RAP)*
  - *Recycled Concrete*

Sand and Gravel

Crushed Stone

Steel Slag

Blast Furnace slag



Lightweight

RAP

Recycled Concrete

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Aggregate

RAP

a)

b)

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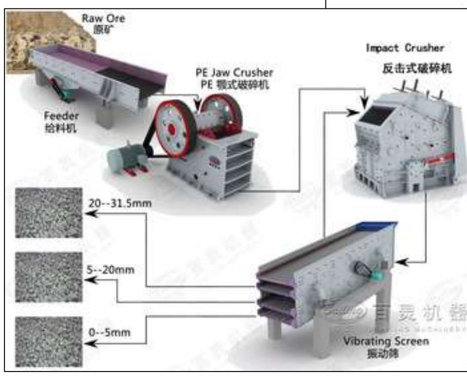
Aggregate

Production process

- Excavations
- Transportation
- Crushing
- Sizing
- Stockpiling



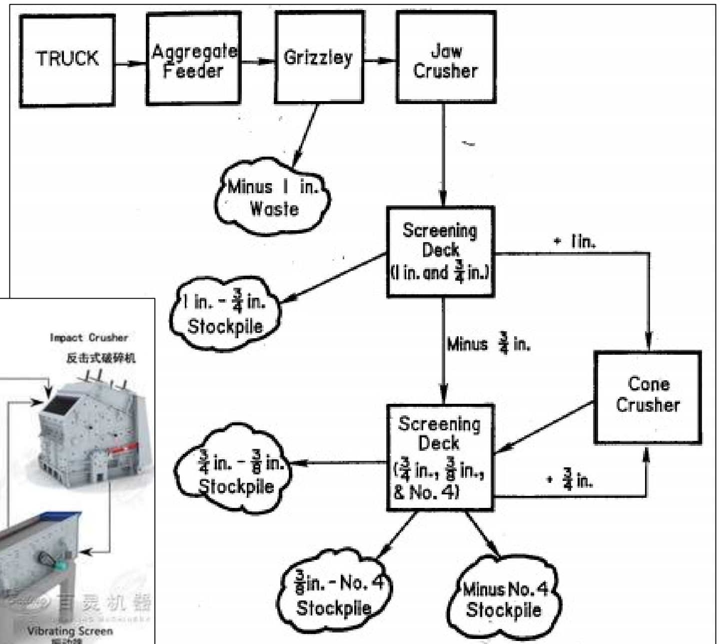


Image source: https://www.bailingmachinery.com/news/366.html

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Aggregate Production

https://www.youtube.com/watch?v=7gN7jcAx9Bg

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Aggregate Production

https://www.youtube.com/watch?v=iChSAX816aw

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Aggregate Production

Sizing and stockpiling

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Aggregate Sto

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Pavement Materials & Design

Aggregates

Properties

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Properties of Aggregates

1. Particle size and gradation.
2. Hardness or resistance to wear
3. Durability or resistance to weathering.
4. Chemical stability
5. Particle shape and surface texture.
6. Freedom from deleterious particles or substances.
7. Specific gravity & absorption.

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Pavement Materials & Design

Aggregates

: Particle size distribution

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Particle size distribution (gradation)

- Gradation
  - ***Blend of particle sizes in the mix.***
  - *It is the most important property of an aggregate*

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Importance of Aggregate Gradation for

Subgrade Layer

- **Soil Stability:**
  - *Proper gradation provides uniform particle distribution, increasing the stability and bearing capacity of the subgrade.*
  - *Well-graded subgrade improves the overall support to the pavement structure.*
- **Compaction Efficiency:**
  - *Well-graded aggregates facilitate better compaction, leading to a denser and more uniform subgrade.*
  - *Enhances the foundation's ability to resist traffic loads without excessive deformation.*
- **Load Distribution:**
  - *A well-graded subgrade ensures even distribution of loads, minimizing stress on underlying soils.*
  - *Prevents rutting and surface deflection, improving the durability of the pavement.*

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Importance of Aggregate Gradation for

Base/Subbase Layers

- **Structural Stability:**
  - *Well-graded aggregates provide dense packing, leading to higher stability and resistance to deformation.*
  - *Ensures load distribution, preventing localized stress that can cause rutting.*
- **Permeability and Drainage:**
  - *Controls void spaces within the aggregate, ensuring proper drainage.*
- **Compaction and Density:**
  - *Well-graded materials compact to higher densities, improving load-bearing capacity.*
  - *Minimizes settlement and movement under traffic loads.*

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Importance of Aggregate Gradation for

Asphalt Mixture Layer

- **Structural Strength**:
  - *Well-graded aggregates provide a dense particle arrangement, contributing to the strength and durability of the asphalt layer.*
  - *Ensures high load-bearing capacity and resistance to traffic-induced stresses.*
- **Compaction and Density**:
  - *Proper gradation allows for optimal compaction, leading to higher density and improved performance of the asphalt mixture.*
  - *Reduces air voids, increasing the durability and fatigue resistance of the asphalt pavement.*
- **Workability and Mix Stability**:
  - *Well-graded aggregates improve the workability of the asphalt mix during construction.*
  - *Provides a stable mix that resists segregation.*
- **Resistance to Deformation (Rutting)**:
  - *Adequate gradation reduces susceptibility to permanent deformation (rutting) under heavy traffic loads.*
- **Durability and Resistance to Cracking**:
  - *Proper gradation enhances the asphalt's ability to resist cracking, particularly thermal and fatigue cracking.*

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Sieve Analysis

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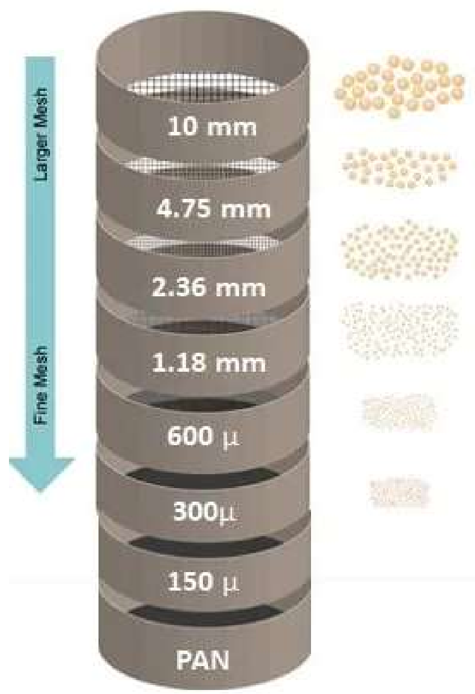
Particle size distribution (gradation)

- Gradation is evaluated by passing the aggregates through a series of sieves
  - *Called "Sieve analysis"*
- Sieve analysis:
  - *Determination of particle size distribution of fine and coarse aggregates by sieving,*
  - *Expressed as %*
  - *Grain size analysis data are plotted on aggregate gradation chart*



https://civiconcepts.com/blog/sieve-analysis

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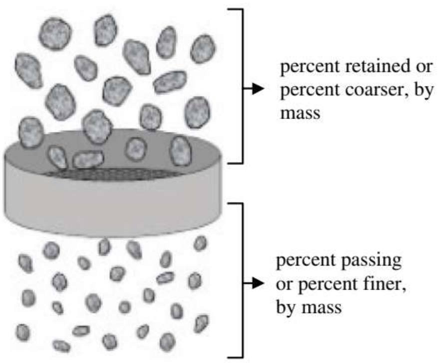
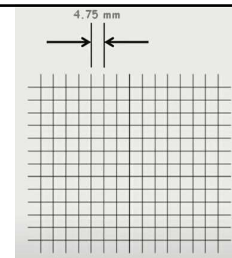
Mechanical Sieve

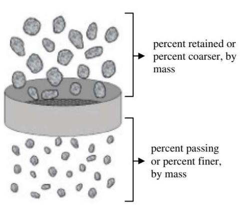




https://www.youtube.com/watch?v=AM-NrQoRlYY

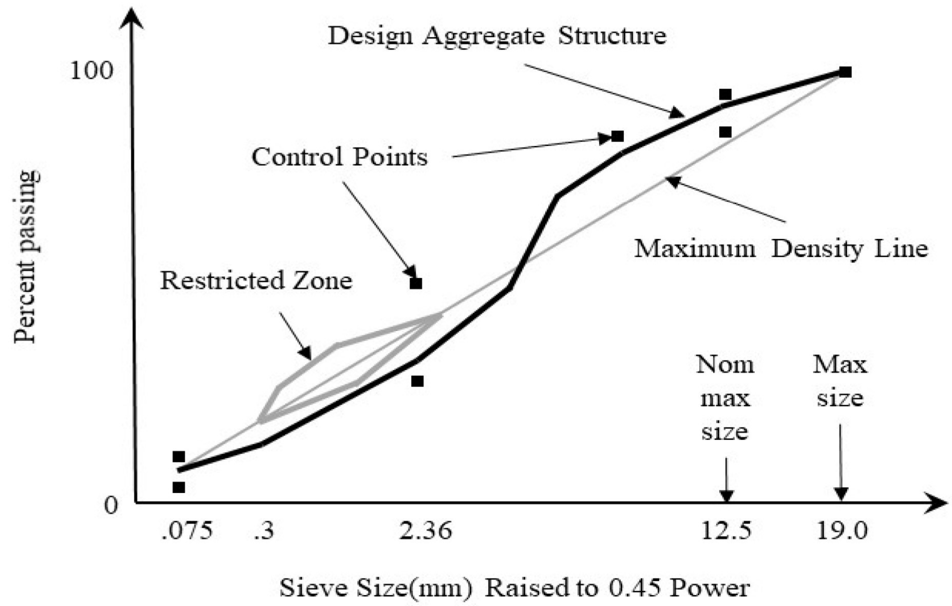
Sieve Analysis example

Example -2



Sieve Designation	Aggregate weight retained (g)	Aggregate percent retained (%)	Cumulative weight retained (g)	Cumulative percent retained (%)	Cumulative percent passing (%)
12.5	0	0	0	0	100
9.5	480	4.8	480	4.8	95.2
4.75	1540	15.6	2020	20.4	79.6
2.36	2240	22.6	4260	43	57
1.18	1300	13.1	5560	56.1	43.9
0.6	1650	16.7	7210	72.8	27.2
0.3	740	7.5	7950	80.3	19.7
0.15	720	7.3	8670	87.6	12.4
0.075	930	9.4	9600	97	3
0	300	3	9900	100	0
Total	9600				

Sieve Analysis results



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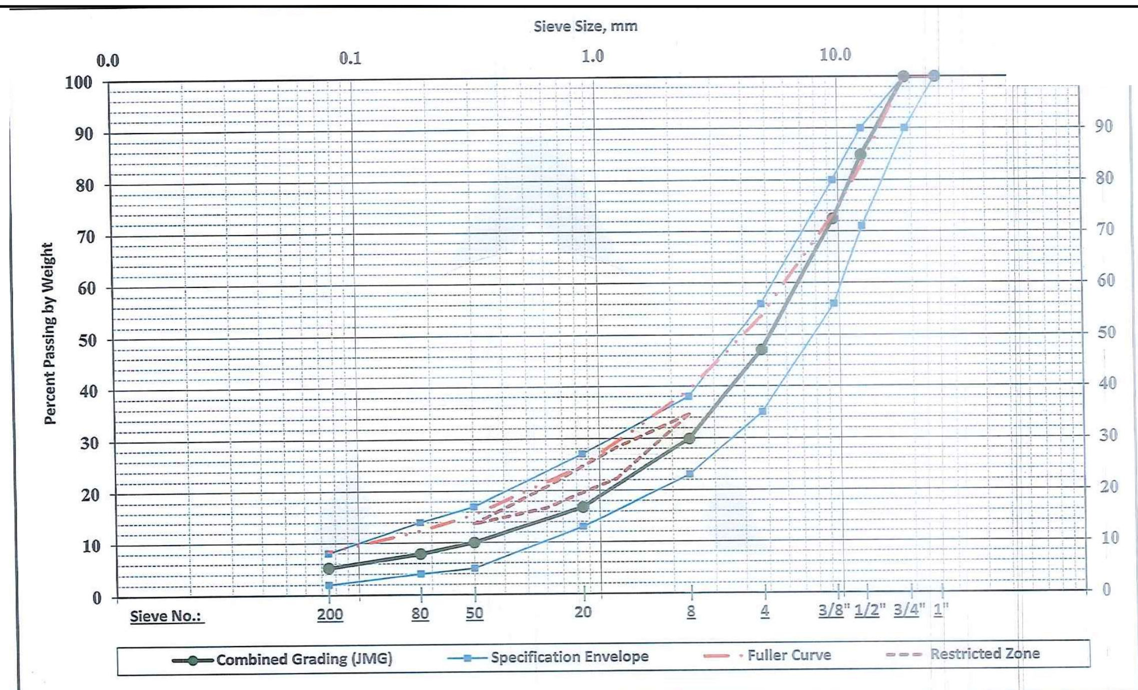

Figure 1: Job Mix Grading, Specification Envelope, Fuller Curve and the Restricted Zone

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Aggregates

Typical Gradations for asphalt Mixtures

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Aggregate

Typical Gradations

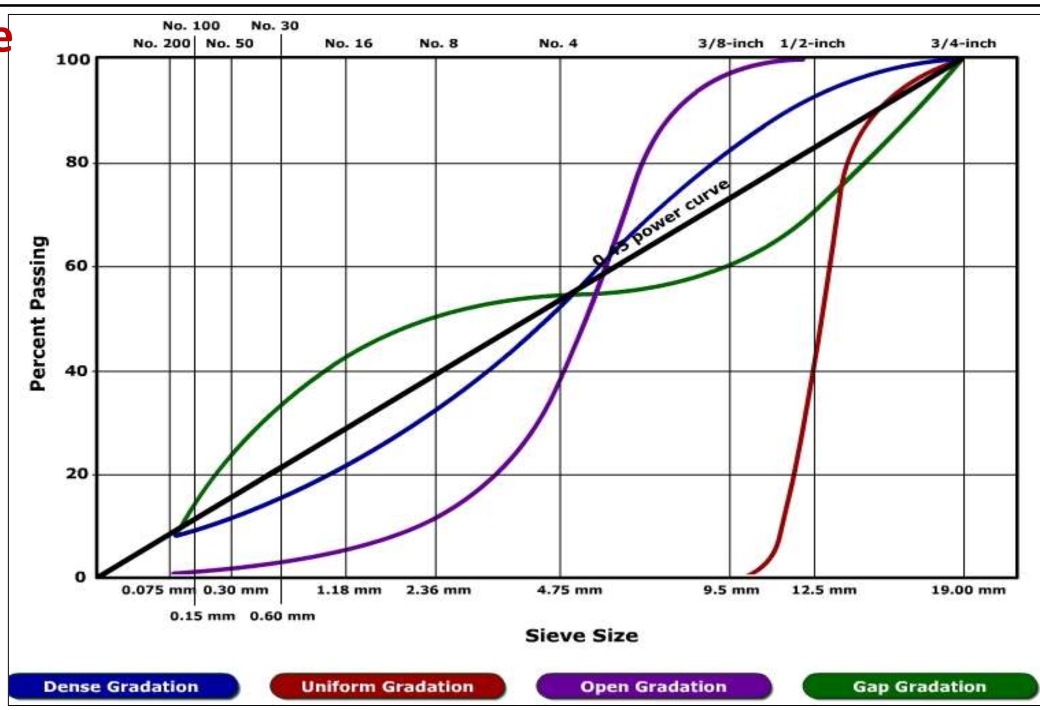

Image source: https://pavementinteractive.org/reference-desk/materials/aggregate/gradation-and-size/

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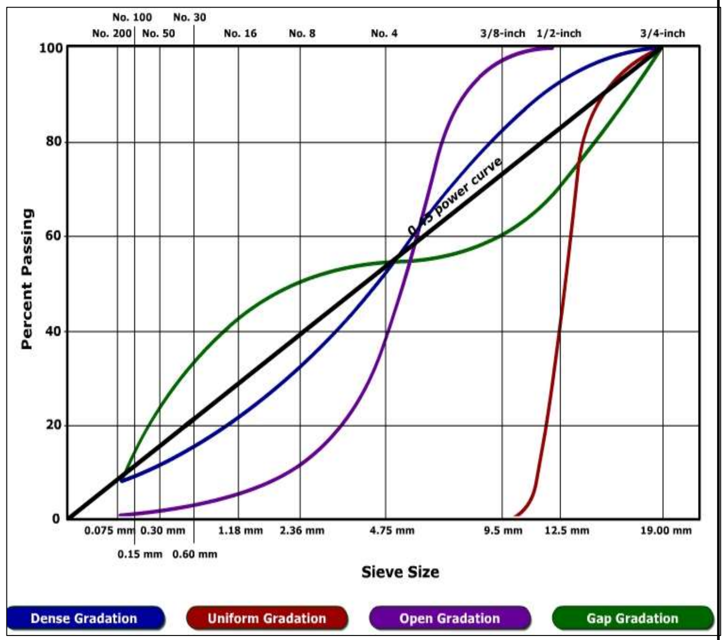
Aggregate Particle size distribution (gradation)

Gradation Types

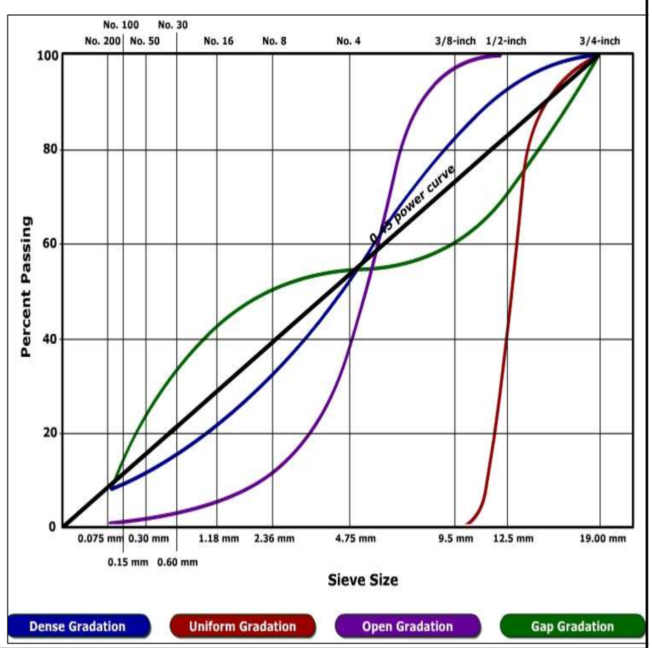
- **Well-Graded Aggregate**:
  1. *Contains a wide range of particle sizes, allowing smaller particles to fill the voids between larger ones.*
  2. ***Benefits**: High density, good stability, reduced permeability, and better load distribution.*
  3. ***Application**: Ideal for base courses, subbase layers, and dense asphalt mixes.*
- **Poorly Graded Aggregate (Uniform Graded)**:
  1. *Consists of particles of similar size, leading to more voids and lower density.*
  2. ***Benefits**: Good drainage properties but less stability.*
  3. ***Application**: Suitable for filter layers and drainage applications but not ideal for structural layers.*



Aggregate Particle size distribution (gradation)

Gradation Types

- **Gap-Graded Aggregate (Stone Matrix Asphalt (SMA)** :
  1. *Missing intermediate particle sizes, with a mix of large and small particles.*
  2. ***Benefits**: High durability and resistance to cracking, commonly used in stone mastic asphalt (SMA).*
  3. ***Application**: Used in specialized pavement layers like surface courses where durability is critical.*
- **Open-Graded Aggregate**:
  1. *Contains mostly larger particles with fewer fines, creating significant void spaces.*
  2. ***Benefits**: High permeability, excellent drainage, and reduced hydroplaning risks.*
  3. ***Application**: Often used for permeable layers, porous asphalt, and drainage layers.*



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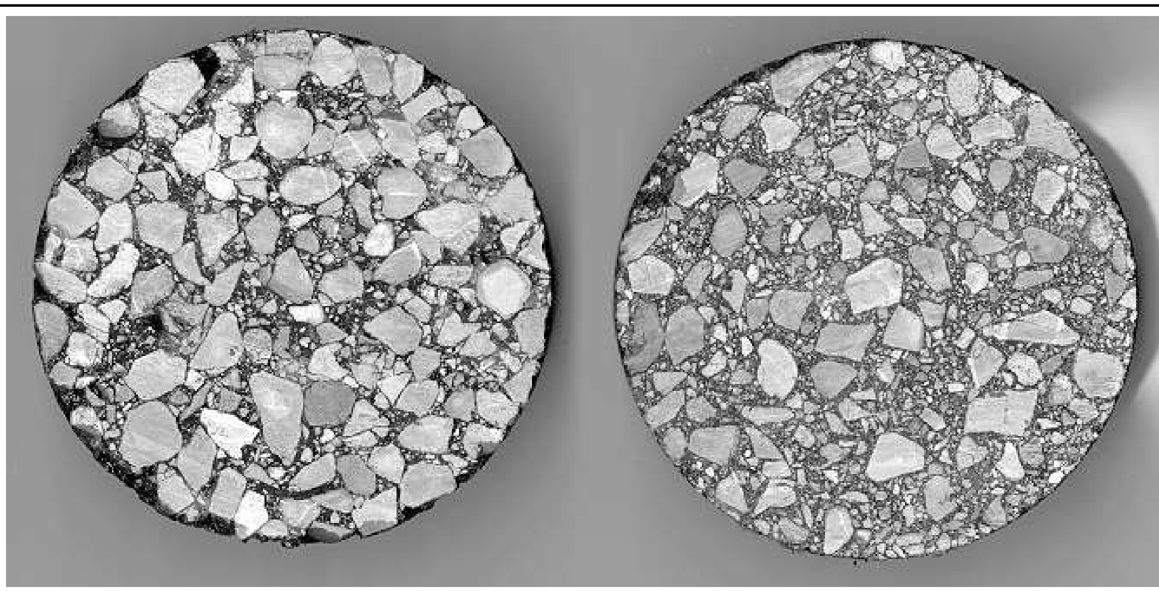

Gap-graded or
Stone Matrix Asphalt (SMA)

Dense-graded

https://www.ndltap.org/events/asphalt/downloads/2013_stone_matrix_asphalt.pdf 28

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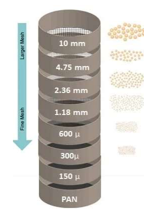
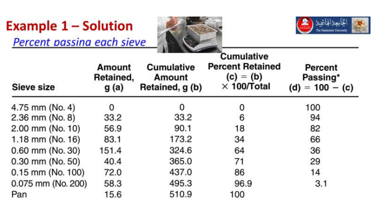
Sieve Analysis

Application

Sieve Analysis

Analysis of grain size distribution of available aggregate Stockpiles

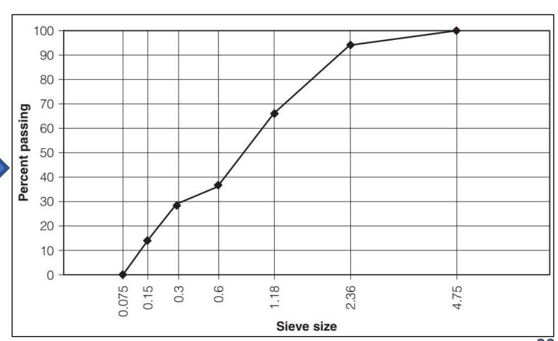




Example 1 – Solution

Percent passing each sieve

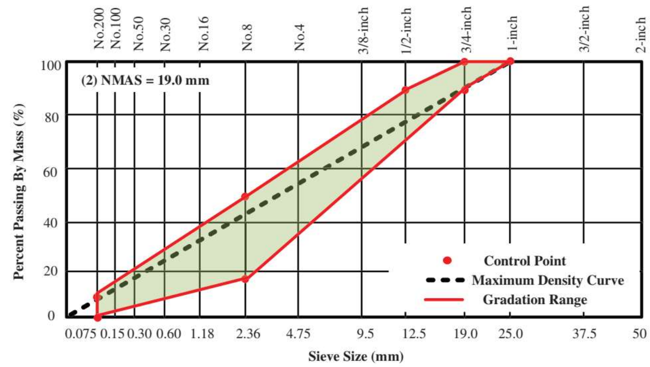
Sieve size	Amount Retained, g (a)	Cumulative Amount Retained, g (b)	Cumulative Percent Retained (c) = (b) × 100/Total	Percent Passing* (d) = 100 − (c)
4.75 mm (No. 4)	0	0	0	100
2.36 mm (No. 8)	33.2	33.2	6	94
2.00 mm (No. 10)	56.9	90.1	18	82
1.18 mm (No. 16)	83.1	173.2	34	66
0.60 mm (No. 30)	151.4	324.6	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			

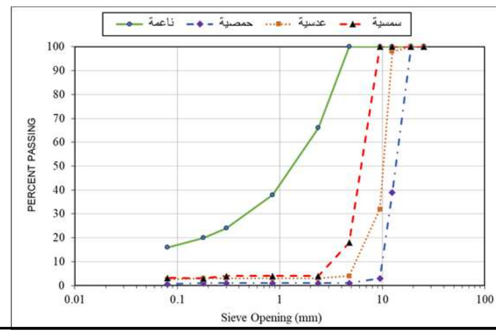


Sieve Analysis

Selection of aggregate Gradation

Mix Performance Requirement



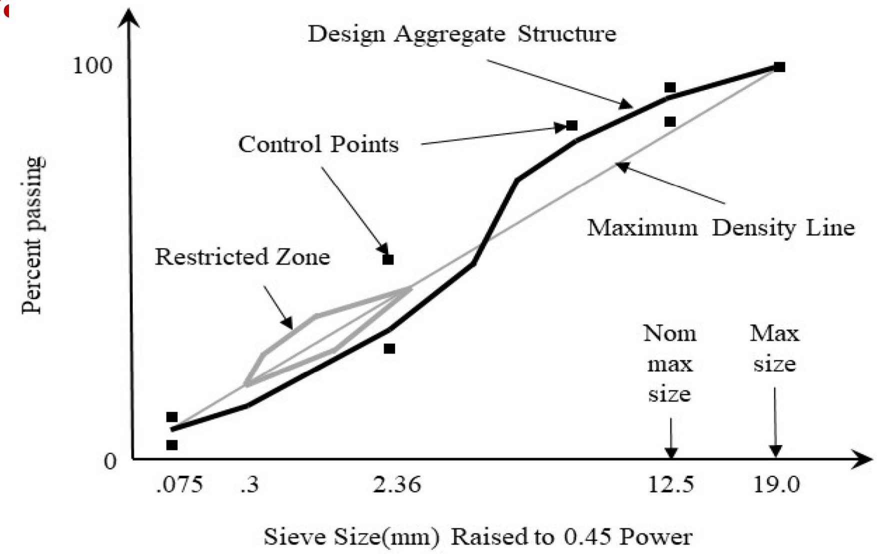


Gradation Chart Parameters

https://www.mdpi.com/2076-3417/9/10/1988/htm

Gradation Chart Parameters

- ❑ Aggregate structure
- ❑ Maximum Size
- ❑ NMAS
- ❑ Maximum Density Line
- ❑ Restricted Zone
- ❑ Control Points



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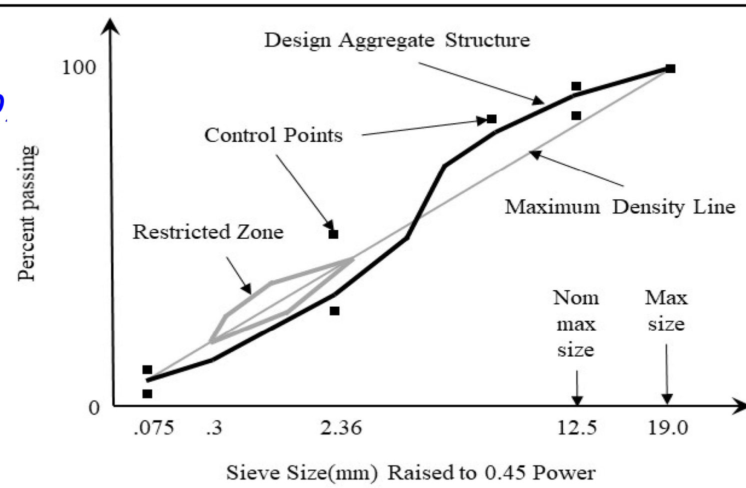
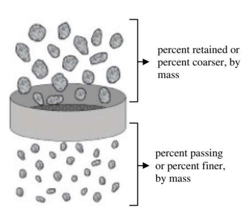
Aggregate

Aggregate classifications- b

- ❑ <u>ASTM standard</u>
  - ➢ ***Coarse aggregate:***
    - ❖ Aggregate **retained** on Sieve <u>**No. 4**</u> (4.75 mm)
  - ➢ ***Fine aggregate:***
    - ❖ Aggregate **passing** Sieve **No. 4** (4.75 mm) and retained on Sieve **No. 200** (75 mm)
  - ➢ ***Mineral fillers/dust/fines:***
    - ❖ Aggregate **passing** Sieve **No. 200** (0.075 mm)





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A

https://www.mogroup.com/insights/blog/aggregates/grain-size-meaning/

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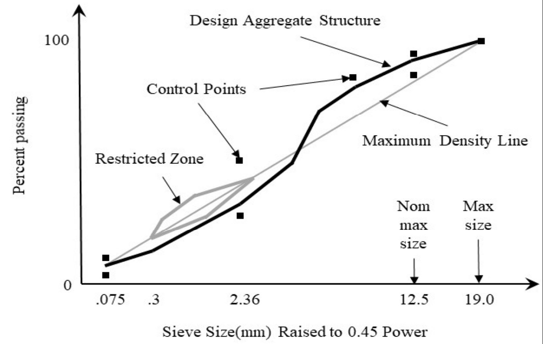
Maximum Aggregate Size

- Maximum aggregate size is important property to ensure good performance
  - *If the maximum size is too small*
    - The mix may be unstable (a low stiffness that has a poor resistance to rutting)
  - *If the maximum size is too large*
    - Workability and segregation may be problems
- Two parameters are used to represent the maximum aggregate size
  1. *Nominal Maximum Aggregate Size (NMAS)*
     - is the smallest sieve that **retains** some of the aggregate particles but generally not more than 10 percent by weight (according to ASTM standard)
  2. *Maximum aggregate size*
     - The smallest sieve through which 100 percent of the aggregate sample particles pass (or retained 0) (according to ASTM standard)



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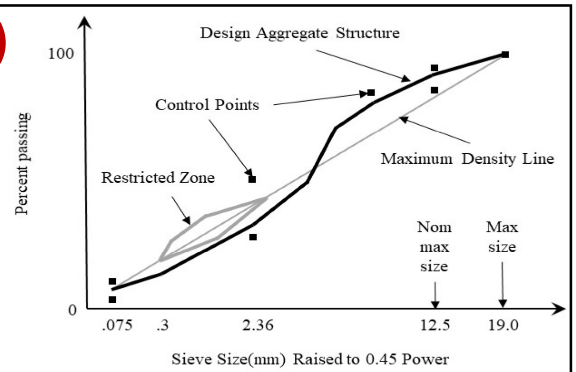
Maximum Density Line (gradation)

- Theoretically, **the best gradation or HMA mix is the one that gives the densest particle packing (or maximum density)**
  - *Pros*
    - It would provide the increased stability through increased interparticle contacts and reduced void in mineral aggregates.
  - *Cons*
    - Sufficient air void space is need to permit enough asphalt cement to be incorporated to ensure durability and to avoid bleeding and/or rutting



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Asphalt Mixture

The volumetric relationship HMA

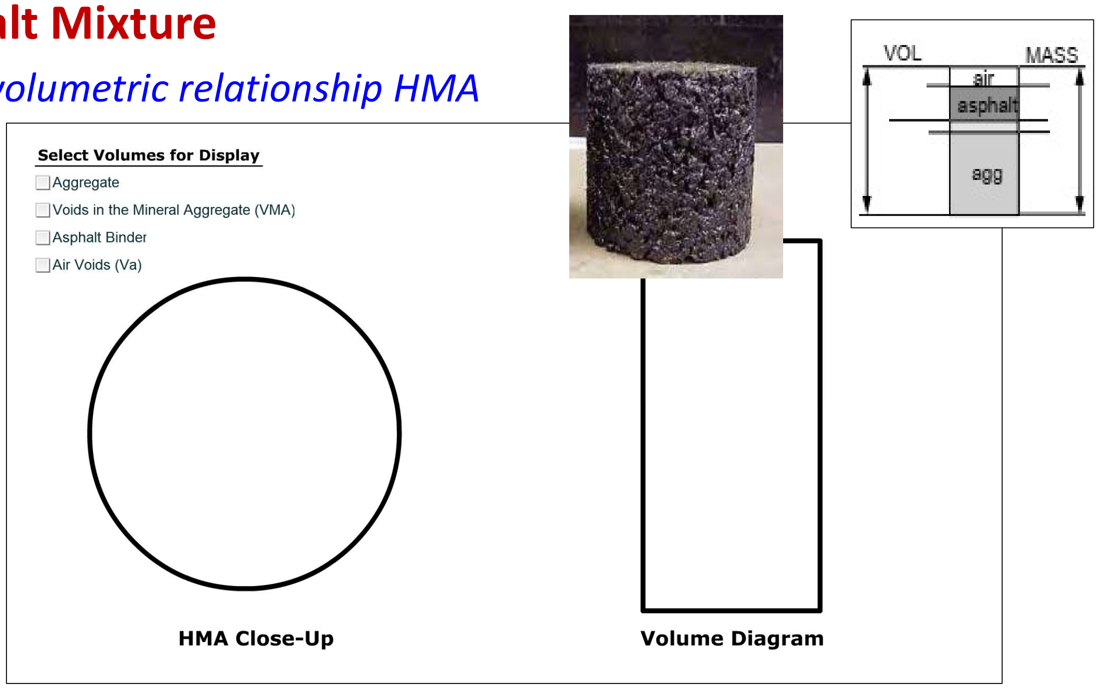

Image source:https://pavementinteractive.org/reference-desk/design/mix-design/hma-weight-volume-terms-and-relationships/

Asphalt Mixture

The volumetric relationship HMA

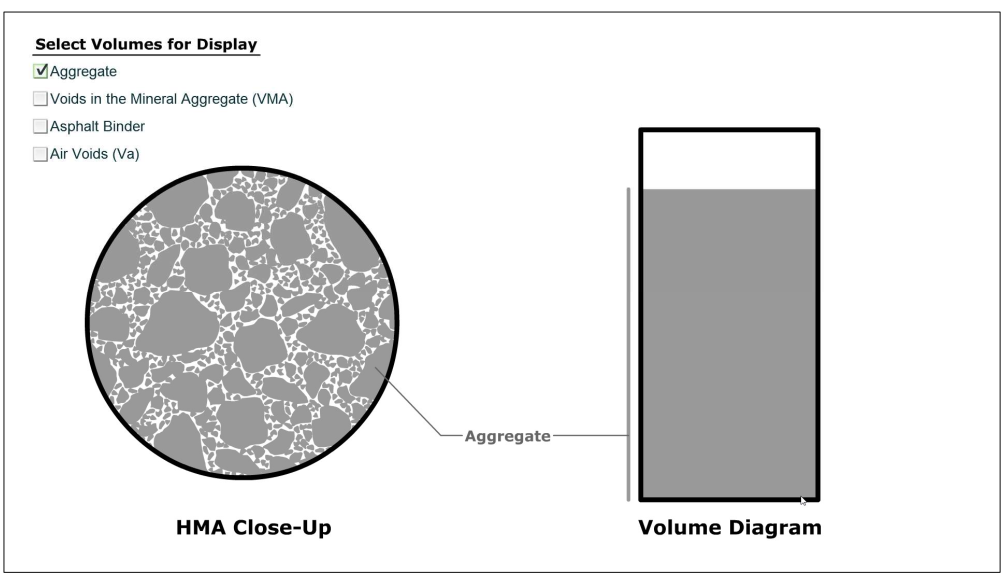

Image source:https://pavementinteractive.org/reference-desk/design/mix-design/hma-weight-volume-terms-and-relationships/

Asphalt Mixture

The volumetric relationship HMA

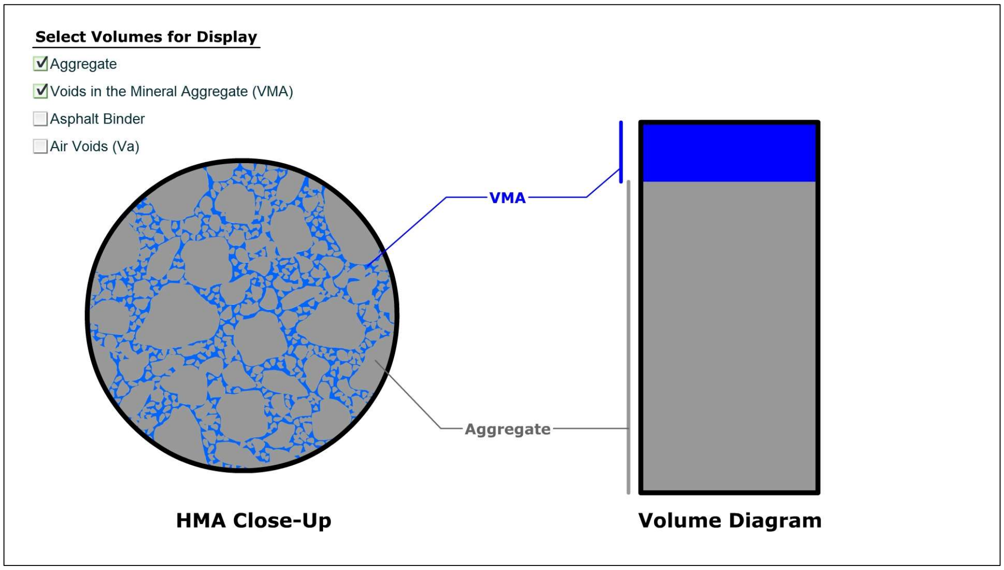

Image source:https://pavementinteractive.org/reference-desk/design/mix-design/hma-weight-volume-terms-and-relationships/

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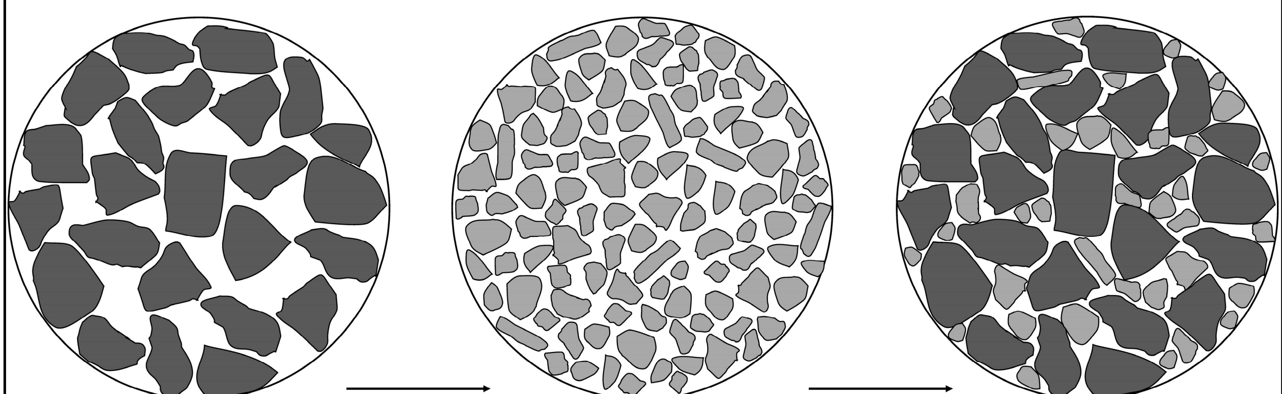
Asphalt Mixture

The volumetric relationship HMA



Larger aggregate | Smaller aggregate | Aggregate packing

Image source:https://pavementinteractive.org/reference-desk/design/mix-design/hma-weight-volume-terms-and-relationships/

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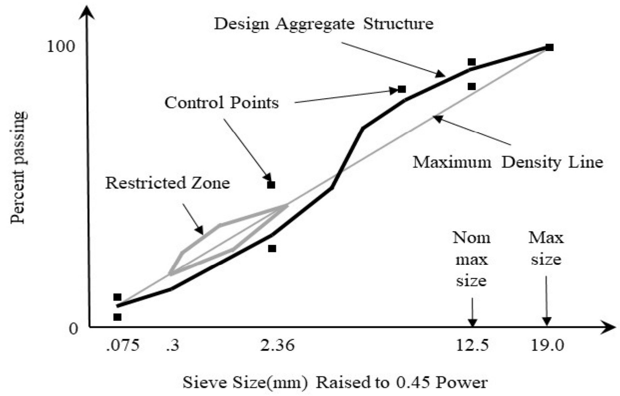
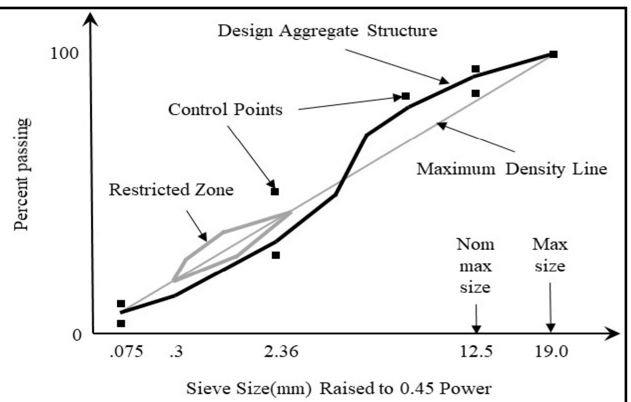
Ideal aggregate gradation

- A widely used equation to describe a maximum density gradation for a given maximum aggregate size.
- It is developed by Fuller and Thompson in 1907
  - $P_i = 100 \times \left(\frac{d_i}{D}\right)^{0.45}$
  - *where*
    - P_i : Percent passing a sieve size of d_i
    - d_i = The sieve size
    - D= Maximum size of the aggregate
    - N is fitting factor
      - Federal Highway Administration recommended a value of 0.45 for *n* and introduced the "0.45 power"



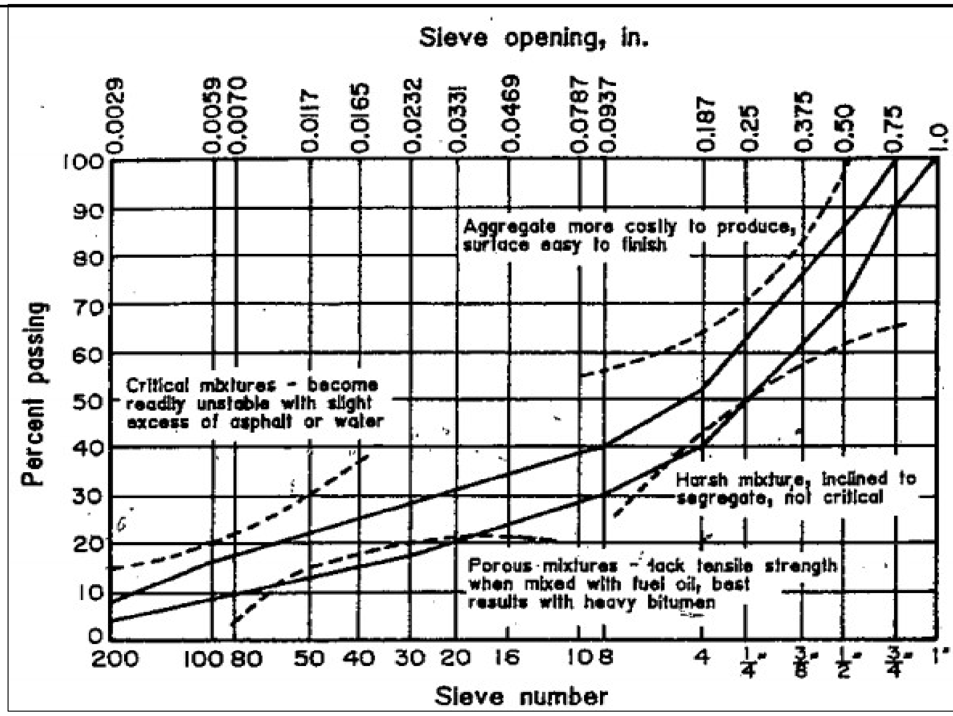
Control points

- **Control points** in refer to specific sieve sizes with defined upper and lower limits on the percentage of material passing through those sieves.
- These limits help ensure that the aggregate blend used in pavement materials, such as asphalt mixtures or base layers, is within a specified range to optimize performance characteristics like stability, durability, and workability.



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

Gradation specifications (limits) importance



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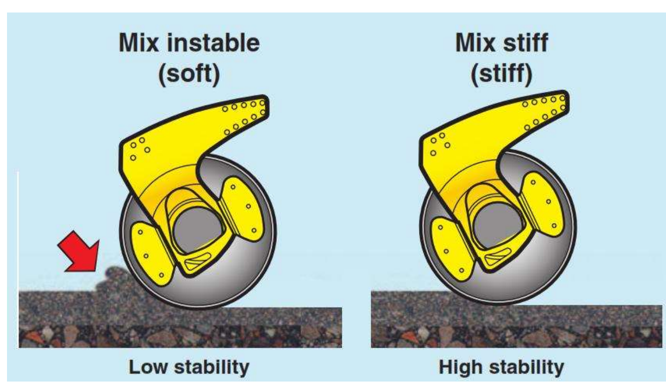
Tender asphalt mixes (Unstable asphalt mixes)

- Tender asphalt mixes are those that exhibit excessive lateral displacement, shoving, and/or check cracking while being compacted



https://img1.wsimg.com/blobby/go/46f29b2e-a52b-4a60-83c1-5f6cf767d44e/downloads/1c8kucura_740155.pdf?ver=1623720222784

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Gradation specifications (limits)

Control point of different NMAS (AASHTO M323).

Table 2. Control point of different NMAS (AASHTO M323).

	Maximum aggregate size- percentage passing of control points, %											
	37.5 mm		25.0 mm		19.0 mm		12.5 mm		9.5 mm		4.75 mm	
Sieves, mm	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
50.0	100	–	–	–	–	–	–	–	–	–	–	–
37.5	90	100	100	–	–	–	–	–	–	–	–	–
25.0	–	90	90	100	100	–	–	–	–	–	–	–
19.0	–	–	–	90	90	100	100	–	–	–	–	–
12.5	–	–	–	–	–	90	90	100	100	–	100	–
9.5	–	–	–	–	–	–	–	90	90	100	95	–
4.75	–	–	–	–	–	–	–	–	–	90	90	100
2.36	15	41	19	45	23	49	28	58	32	67	–	–
1.18	–	–	–	–	–	–	–	–	–	–	30	60
0.075	0	6	1	7	2	8	2	10	2	10	6	12

https://www.tandfonline.com/doi/full/10.1080/10298436.2018.1430365

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Gradation Specifications

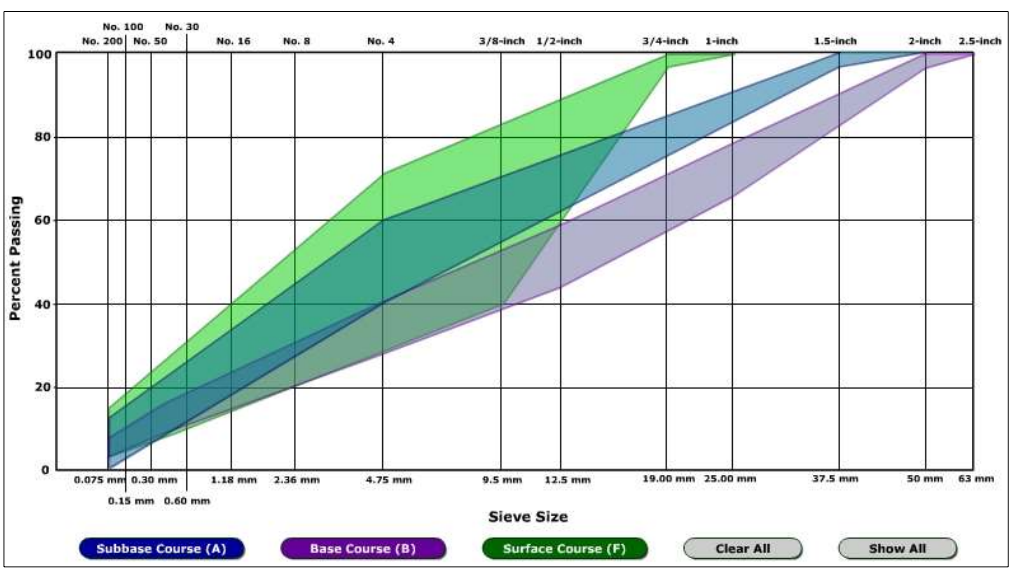

Image source: https://pavementinteractive.org/reference-desk/materials/aggregate/gradation-and-size/

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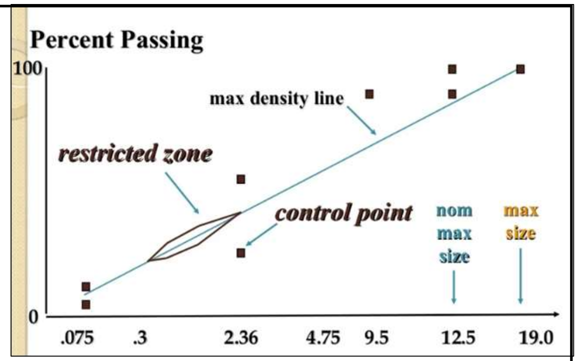
Gradation Specifications

Restricted Zone

- The restricted zone is that area on the FHWA's 0.45 power chart in Superpave specifications through which aggregate gradations **are not allowed** to pass through.
- Mixtures with gradations passing through the restricted zone are hypothesized to be susceptible **to tenderness and rutting.**
- In Superpave, it was originally observed that asphalt mixtures **closely following** the maximum density line on the 0.45 power chart in the finer gradation provided unacceptably low voids in mineral aggregate (VMA) values due to the excess of natural sand.
  - Low VMA values typically lead to insufficient asphalt coating the individual aggregate particles (less effective asphalt binder).



12.5 mm Superpave Gradation

Sieve Size mm	% Pass. Control Points		Restricted Zone Min	Restricted Zone Max
19		100		
12.5	90.0	100.0		
9.5				
4.75				
2.36	28.0	58.0	39.1	39.1
1.18			25.6	31.6
0.6			19.1	23.1
0.3			15.5	15.5
0.15				
0.075	2.0	10.0		

https://www.slideshare.net/mmfaisalg/road-aggregates-01

Image source: https://pavementinteractive.org/reference-desk/materials/aggregate/gradation-and-size/

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Pavement Materials & Design

Aggregates

Example

Dr. Hamza Alkuime

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Sieve Analysis example

Example -1

- 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

- Calculate the percent passing each sieve
- Draw a 0.45 power gradation chart with the use of a spreadsheet program.
- Determine the gradation chart parameters

Example 1 – Solution

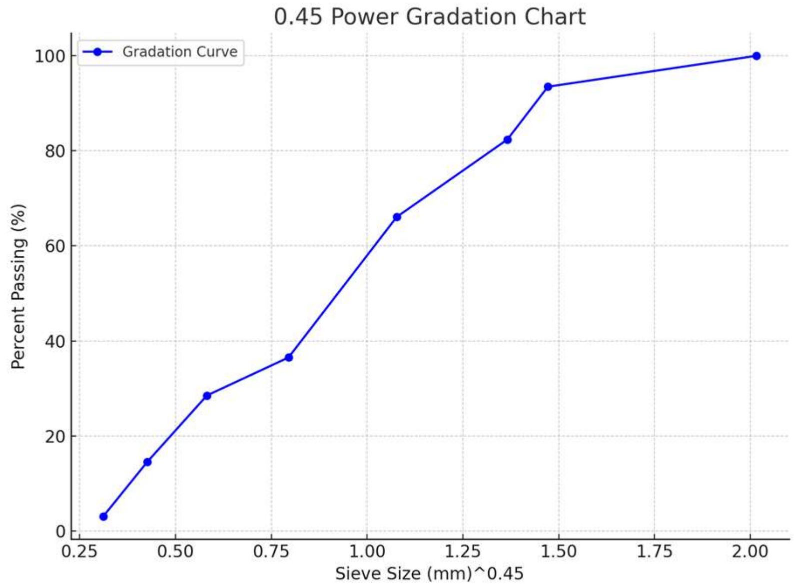
Percent passing each sieve

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			

Example 1 – Solution

Draw a 0.45 power gradation chart

1	2	3
Sieve Size (mm)	Sieve to the 0.45 Power	Percent Passing
4.75	2.02	100
2.36	1.47	94
2	1.37	82
1.18	1.08	66
0.6	0.79	36
0.3	0.58	29
0.15	0.43	14
0.075	0.31	3.1



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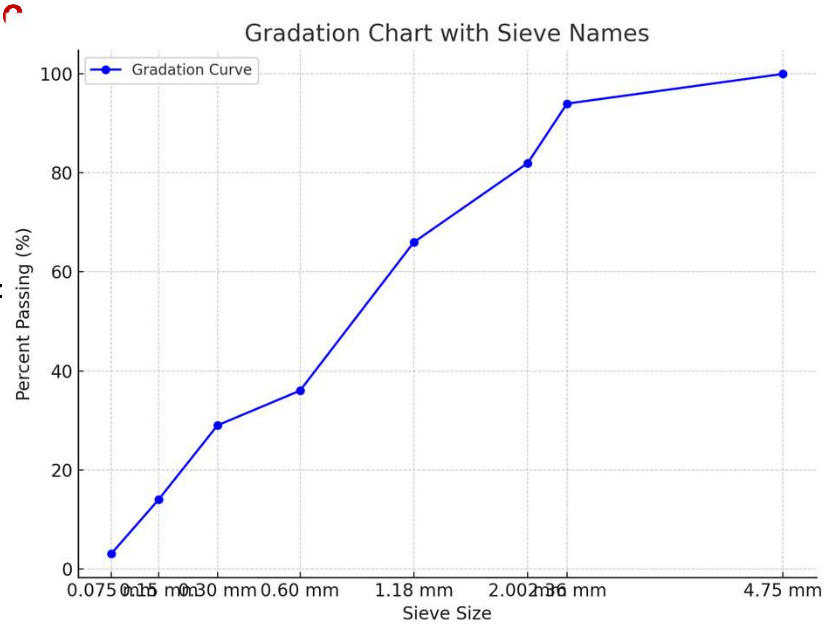
Sieve Analysis example

- ❑ **Summary of Results:**

1. **Coarse Aggregate**: 0%
2. **Fine Aggregate**: 96.9%
3. **Mineral Fillers/Dust/Fines**: 3.1%
4. **Maximum Aggregate Size**: 4.75 mm
5. **Nominal Maximum Aggregate Size**: 2.36 mm



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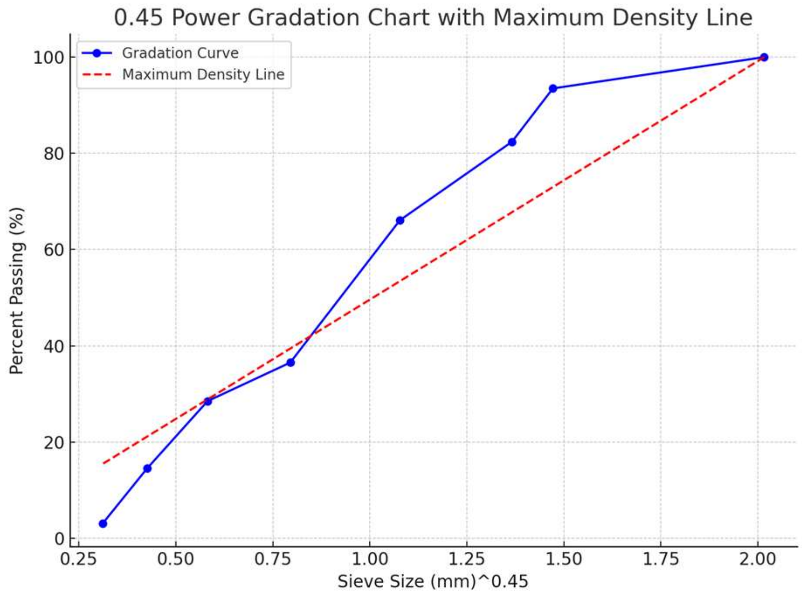
Sieve Analysis example

Sieve Size (mm)	Sieve to the 0.45 Pov	Percent Passing	MDL Percent Passin
4.75	2.02	100.0	100.0
2.36	1.47	94.0	72.9958679727986
2.0	1.37	82.0	67.756563894541
1.18	1.08	66.0	53.4361030810549
0.6	0.79	36.0	39.414492442934
0.3	0.58	29.0	28.853097299328 6
0.15	0.43	14.0	21.1217035198373
0.075	0.31	3.1	15.461991998699 082



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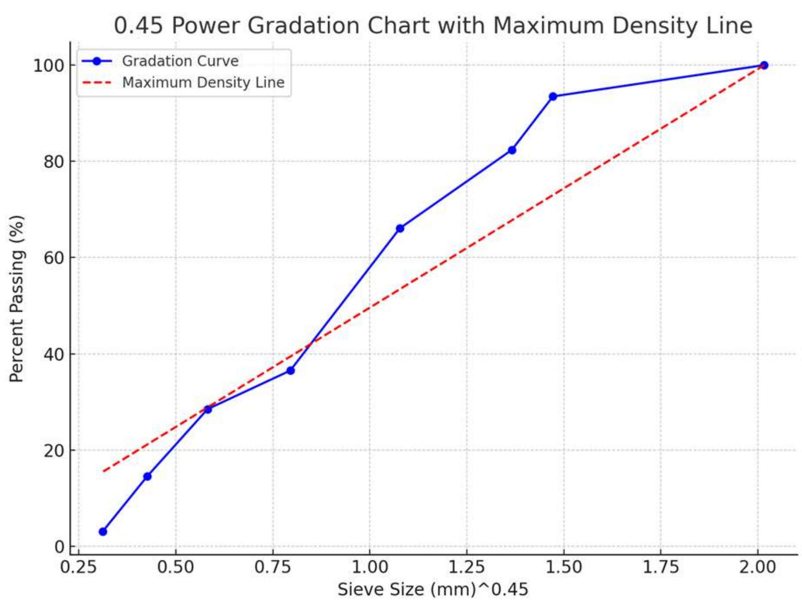
Sieve Analysis example

Sieve Size (mm)	Sieve to the 0.45 Pov	Percent Passing	MDL Percent Passin
4.75	2.02	100.0	100.0
2.36	1.47	94.0	72.9958679727986
2.0	1.37	82.0	67.756563894541
1.18	1.08	66.0	53.4361030810549
0.6	0.79	36.0	39.414492442934
0.3	0.58	29.0	28.853097299328 6
0.15	0.43	14.0	21.1217035198373
0.075	0.31	3.1	15.461991998699 082



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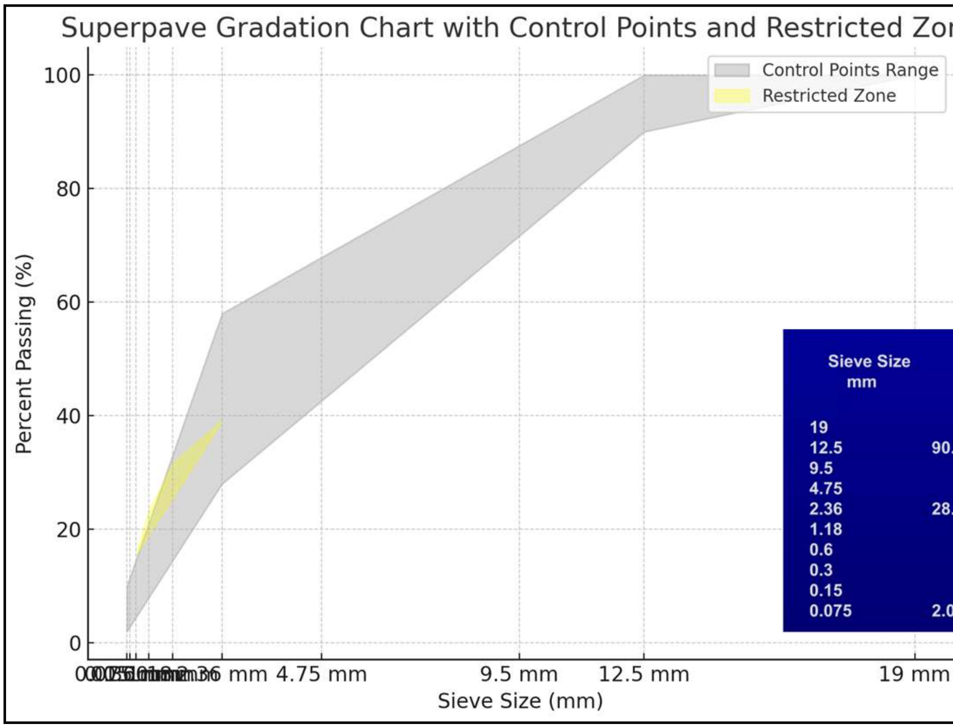

Sieve Size mm	% Pass. Control Points		Restricted Zone Min	Ma
19		100		
12.5	90.0	100.0		
9.5				
4.75				
2.36	28.0	58.0	39.1	39.1
1.18			25.6	31.6
0.6			19.1	23.1
0.3			15.5	15.5
0.15				
0.075	2.0	10.0		

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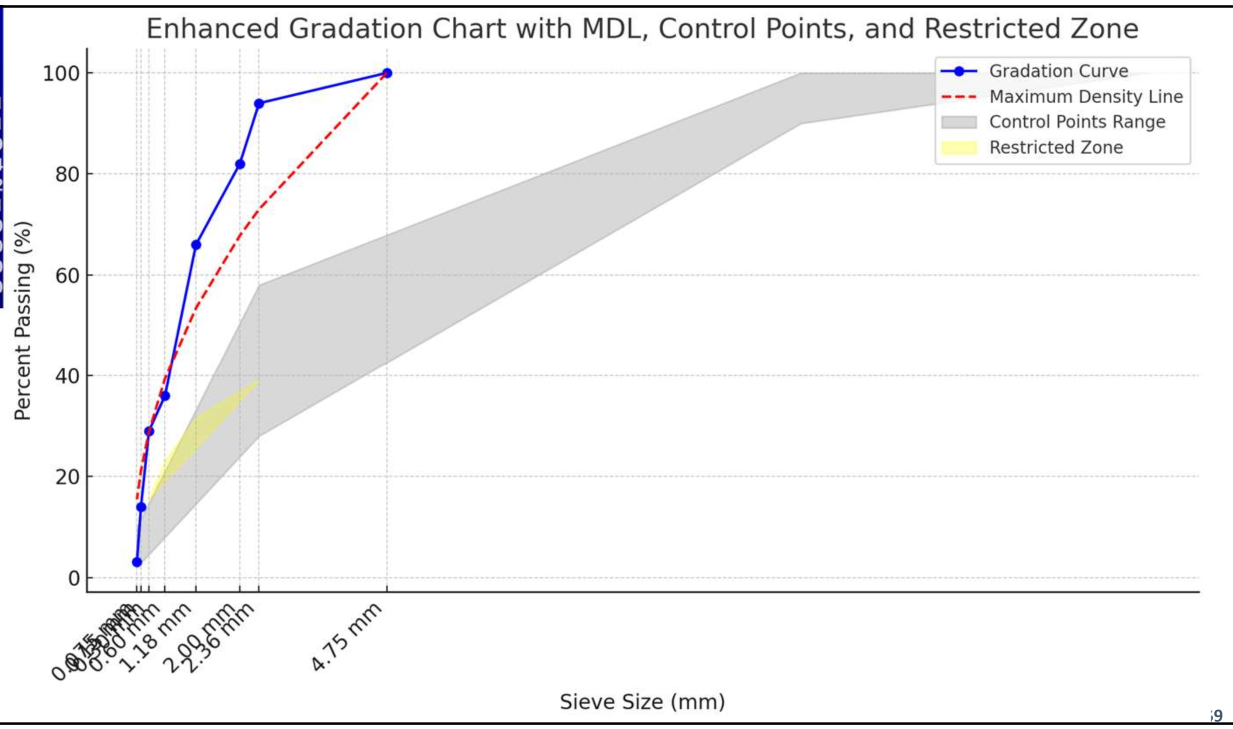
1 1 9 4 2 1 0 0 0 0



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Pavement Materials & Design

Aggregates

Gradation curve interpretation

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How to interpret the gradation curve

Example 1

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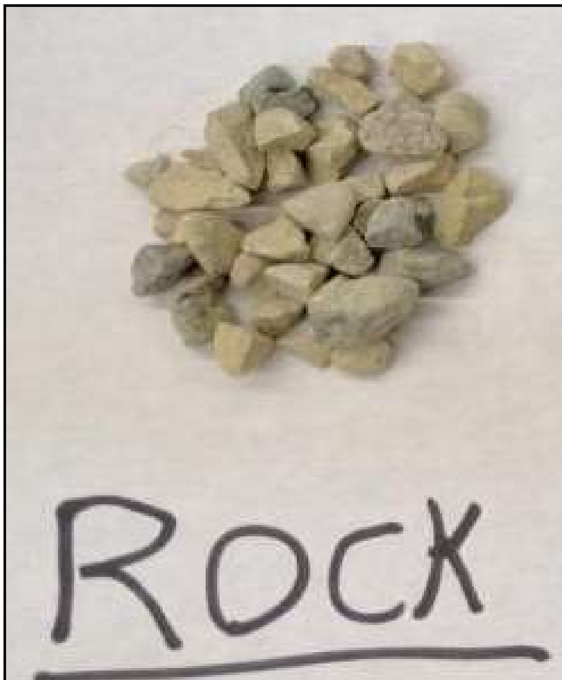

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	N Fines	Rock	Washed Dust	Dirty Dust
Sieve Size	**% Passing**	**% Passing**	**% Passing**	**% Passing**
5/8" (16mm)	100.0	100.0	100.0	100.0
1/2" (12.5mm)	100.0	100.0	100.0	100.0
3/8" (9.5mm)	100.0	63.0	100.0	100.0
#4 (4.75mm)	90.0	2.0	81.0	81.0
#8 (2.36mm)	76.0	1.0	42.0	53.0
#16 (1.18mm)	62.0	1.0	25.0	37.0
#30 (0.6mm)	47.0	1.0	13.0	28.0
#50 (0.3mm)	26.0	1.0	9.0	21.0
#100 (0.15mm)	5.0	1.0	4.0	13.0
#200 (0.075mm)	2.9	1.0	2.2	10.8
Pan	0.0	0.0	0.0	0.0

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	N Fines	Rock	Washed Dust	Dirty Dust
Sieve Size	**% Passing**	**% Passing**	**% Passing**	**% Passing**
5/8" (16mm)	100.0	100.0	100.0	100.0
1/2" (12.5mm)	100.0	100.0	100.0	100.0
3/8" (9.5mm)	100.0	63.0	100.0	100.0
#4 (4.75mm)	90.0	2.0	81.0	81.0
#8 (2.36mm)	76.0	1.0	42.0	53.0
#16 (1.18mm)	62.0	1.0	25.0	37.0
#30 (0.6mm)	47.0	1.0	13.0	28.0
#50 (0.3mm)	26.0	1.0	9.0	21.0
#100 (0.15mm)	5.0	1.0	4.0	13.0
#200 (0.075mm)	2.9	1.0	2.2	10.8
Pan	0.0	0.0	0.0	0.0

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Sieve Size	N Fines % Passing	Rock % Passing	Washed Dust % Passing	Dirty Dust % Passing
5/8" (16mm)	100.0	100.0	100.0	100.0
1/2" (12.5mm)	100.0	100.0	100.0	100.0
3/8" (9.5mm)	100.0	63.0	100.0	100.0
#4 (4.75mm)	90.0	2.0	81.0	81.0
#8 (2.36mm)	76.0	1.0	42.0	53.0
#16 (1.18mm)	62.0	1.0	25.0	37.0
#30 (0.6mm)	47.0	1.0	13.0	28.0
#50 (0.3mm)	26.0	1.0	9.0	21.0
#100 (0.15mm)	5.0	1.0	4.0	13.0
#200 (0.075mm)	2.9	1.0	2.2	10.8
Pan	0.0	0.0	0.0	0.0

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Sieve Size	N Fines % Passing	Rock % Passing	Washed Dust % Passing	Dirty Dust % Passing
5/8" (16mm)	100.0	100.0	100.0	100.0
1/2" (12.5mm)	100.0	100.0	100.0	100.0
3/8" (9.5mm)	100.0	63.0	100.0	100.0
#4 (4.75mm)	90.0	2.0	81.0	81.0
#8 (2.36mm)	76.0	1.0	42.0	53.0
#16 (1.18mm)	62.0	1.0	25.0	37.0
#30 (0.6mm)	47.0	1.0	13.0	28.0
#50 (0.3mm)	26.0	1.0	9.0	21.0
#100 (0.15mm)	5.0	1.0	4.0	13.0
#200 (0.075mm)	2.9	1.0	2.2	10.8
Pan	0.0	0.0	0.0	0.0

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	N Fines	Rock	Washed Dust	Dirty Dust
Sieve Size	% Passing	% Passing	% Passing	% Passing
5/8" (16mm)	100.0	100.0	100.0	100.0
1/2" (12.5mm)	100.0	100.0	100.0	100.0
3/8" (9.5mm)	100.0	63.0	100.0	100.0
#4 (4.75mm)	90.0	2.0	81.0	81.0
#8 (2.36mm)	76.0	1.0	42.0	53.0
#16 (1.18mm)	62.0	1.0	25.0	37.0
#30 (0.6mm)	47.0	1.0	13.0	28.0
#50 (0.3mm)	26.0	1.0	9.0	21.0
#100 (0.15mm)	5.0	1.0	4.0	13.0
#200 (0.075mm)	2.9	1.0	2.2	10.8
Pan	0.0	0.0	0.0	0.0

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Pavement Materials & Design

Aggregates

Local aggregate classification system

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Aggregate classifications by size

Local classification

العدسية

الفولية

الجوزية

رمل

الناعمة (السمسية)

الحمصية

Imagez source: https://www.slideserve.com/avel/4803086

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Aggregate classifications by size

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Aggregate classifications

https://www.aggbusiness.com/ab3/feature/new-crushing-and-screening-equipment

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Aggregate class

Local classification

Aggregate Identification		Coarse Agg.	Medium Agg.	Medium-Fine Agg.	Fine Agg.
		Limestone Aggregate			
		حصية	عدسية	سمسمية	ناعمة
		ركام جيري			
Test Name		Test Result			
- Sieve Analysis: -		% Passing by Weight			
Sieve Number (Size, mm):	1" (25.4)	100	100	100	100
	3/4" (19.0)	100	100	100	100
	1/2" (12.7)	39	98	100	100
	3/8" (9.50)	3	32	100	100
	No. 4 (4.75)	1	4	18	100
	No. 8 (2.36)	1	3	4	66
	No. 20 (0.85)	1	3	4	38
	No. 50 (0.30)	1	3	4	24
	No. 80 (0.18)	1	3	3	20
	No. 200 (0.075)	0.6	2.6	3.2	16

Image source: https://www.slideserve.com/avel/4803086

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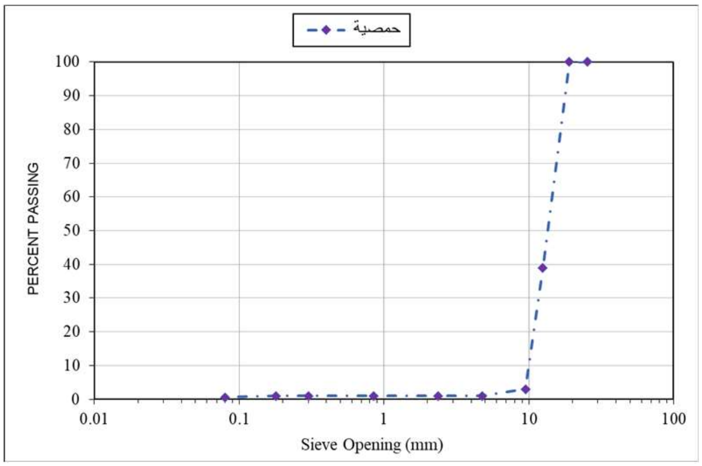
Aggregate classifications by size

Local classification



Test Name		Coarse Agg. حصية
- Sieve Analysis: -		
Sieve Number *(Size, mm)*:	**1"** *(25.4)*	100
	3/4" *(19.0)*	100
	1/2" *(12.7)*	39
	3/8" *(9.50)*	3
	No. 4 *(4.75)*	1
	No. 8 *(2.36)*	1
	No. 20 *(0.85)*	1
	No. 50 *(0.30)*	1
	No. 80 *(0.18)*	1
	No. 200 *(0.075)*	0.6

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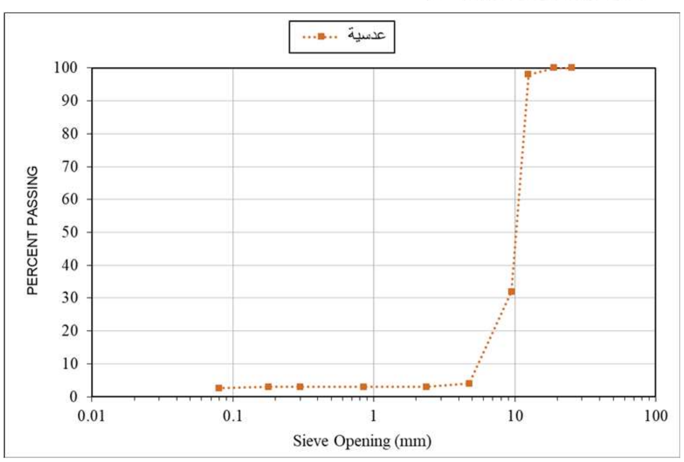
Aggregate classifications by size

Local classification



Test Name		Medium Agg. *Limestone* عدسية جيري Test R
- Sieve Analysis: -		% Passing b
Sieve Number *(Size, mm)*:	**1"** *(25.4)*	100
	3/4" *(19.0)*	100
	1/2" *(12.7)*	98
	3/8" *(9.50)*	32
	No. 4 *(4.75)*	4
	No. 8 *(2.36)*	3
	No. 20 *(0.85)*	3
	No. 50 *(0.30)*	3
	No. 80 *(0.18)*	3
	No. 200 *(0.075)*	2.6

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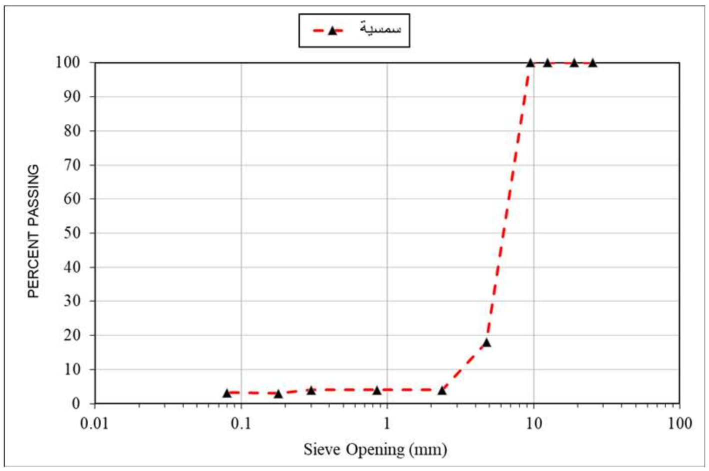
Aggregate classifications by size

Local classification



Test Name		Medium-Fine Agg. / Aggregate / سمسية / ركام
- Sieve Analysis: -		Result by Weight
Sieve Number (Size, mm):	1" (25.4)	100
	3/4" (19.0)	100
	1/2" (12.7)	100
	3/8" (9.50)	100
	No. 4 (4.75)	18
	No. 8 (2.36)	4
	No. 20 (0.85)	4
	No. 50 (0.30)	4
	No. 80 (0.18)	3
	No. 200 (0.075)	3.2

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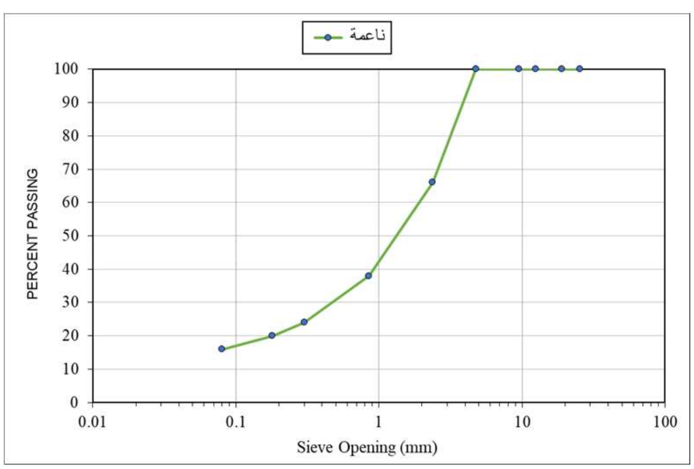
Aggregate classifications by size

Local classification



Test Name		Fine Agg. / ناعمة
- Sieve Analysis: -		
Sieve Number (Size, mm):	1" (25.4)	100
	3/4" (19.0)	100
	1/2" (12.7)	100
	3/8" (9.50)	100
	No. 4 (4.75)	100
	No. 8 (2.36)	66
	No. 20 (0.85)	38
	No. 50 (0.30)	24
	No. 80 (0.18)	20
	No. 200 (0.075)	16

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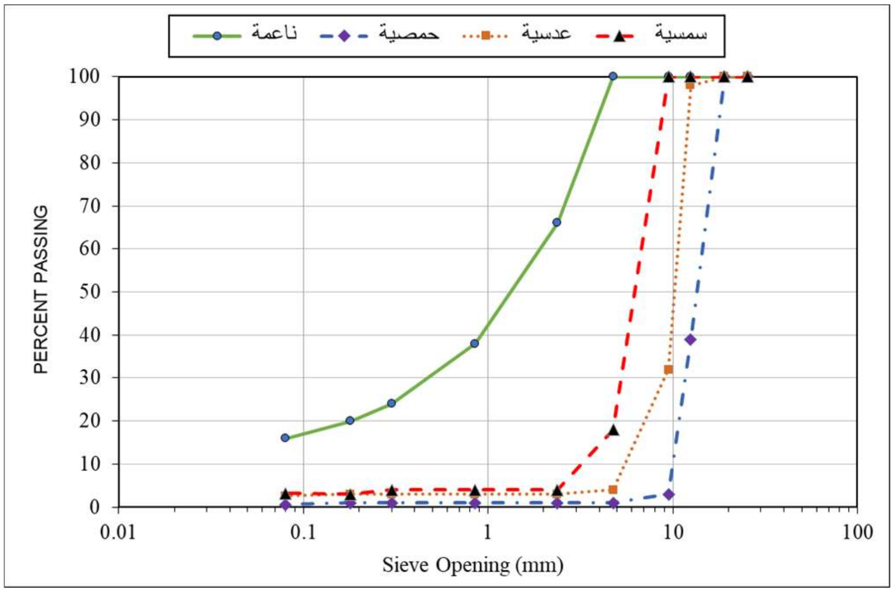
Aggregate classifications by size

Local classification



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Pavement Materials & Design

Aggregates

Aggregates Blending

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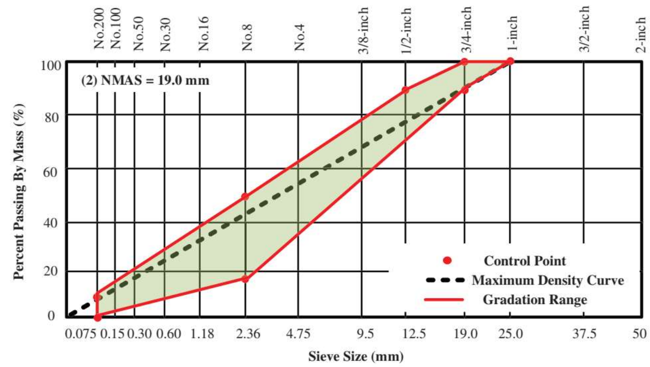
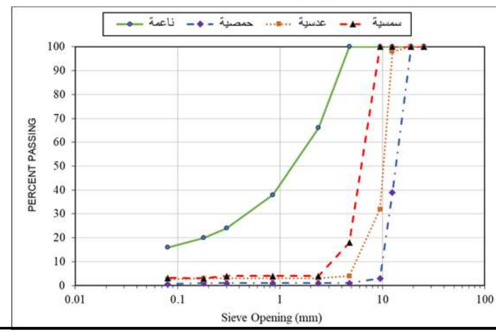
Sieve Analysis

Selection of aggregate Gradation

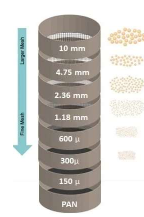
Mix Performance Requirement





Sieve Analysis

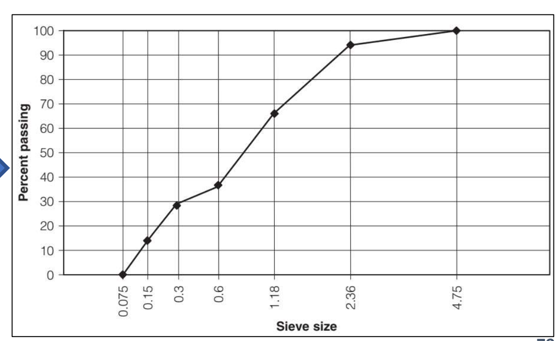
Analysis of grain size distribution of available aggregate Stockpiles



Example 1 – Solution

Percent passing each sieve

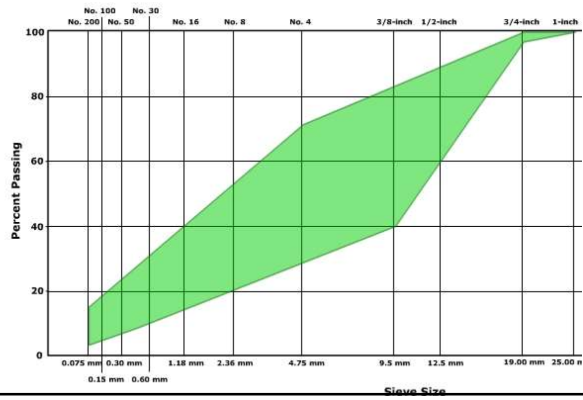
Sieve size	Amount Retained, g (a)	Cumulative Amount Retained, g (b)	Cumulative Percent Retained (c) = (b) × 100/Total	Percent Passing* (d) = 100 − (c)
4.75 mm (No. 4)	0	0	0	100
2.36 mm (No. 8)	33.2	33.2	6	94
2.00 mm (No. 10)	56.9	90.1	18	82
1.18 mm (No. 16)	83.1	173.2	34	66
0.60 mm (No. 30)	151.4	324.6	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			

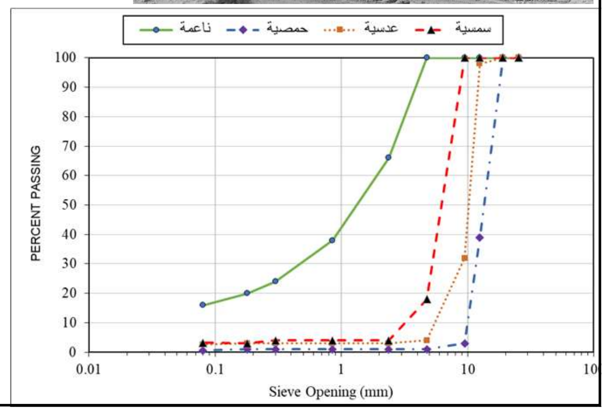


Aggregate

Aggregate blending

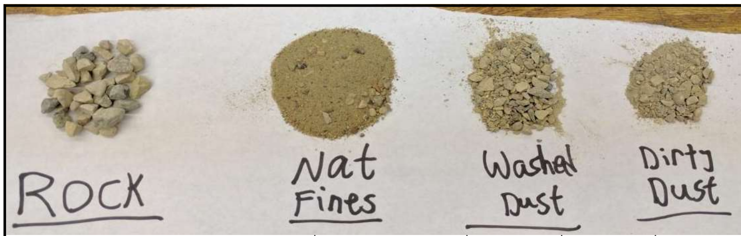
- A single aggregate source is generally **unlikely to meet gradation** requirements for Portland cement or asphalt concrete mixes
  - Thus, blending of aggregates from two or more sources would be required to satisfy the specifications.





Key Principles of Aggregate Blending

- **Blending Objective:**
  - *Achieve target gradation by combining materials from different stockpiles.*
- **Key Considerations:**
  - ***Stockpile Properties****: Individual gradations of each aggregate.*
  - ***Blend Proportions****: Percentage of each aggregate in the blend.*
  - ***Specification Limits****: Target gradation range for the final mix.*



28 Aggregate Gradation

	N Fines	Rock	Washed Dust	Dirty Dust	RAP Recycled Pavement	Blend Gradation	Lower Control Pt	Upper Control Pt
Sieve Size	% Passing	% Passing	% Passing	% Passing	% Passing	% Passing	% Passing	% Passing
5/8" (16mm)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1/2" (12.5mm)	100.0	100.0	100.0	100.0	98.0	99.6	90.0	100.0
3/8" (9.5mm)	100.0	63.0	100.0	100.0	91.0	91.5		
#4 (4.75mm)	90.0	2.0	81.0	81.0	74.0	66.2		
#8 (2.36mm)	76.0	1.0	42.0	53.0	55.0	41.3	28.0	58.0
#16 (1.18mm)	62.0	1.0	25.0	37.0	40.0	28.1		
#30 (0.6mm)	47.0	1.0	13.0	28.0	29.0	18.5		
#50 (0.3mm)	26.0	1.0	9.0	21.0	18.0	12.0		
#100 (0.15mm)	5.0	1.0	4.0	13.0	12.0	6.0		
#200 (0.075mm)	2.9	1.0	2.2	10.8	8.6	4.1	2.8	7.0
Pan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

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Aggregate Blending

2. Mathematical (Algebraic) Method

- **Overview:**
  - *A mathematical approach using algebraic formulas to compute the combined gradation of different stockpiles.*
  - *Uses the **weighted average** of the percent passing values of each stockpile to calculate the final blend.*
- **Formula:**

$$p^i_{blend} = f_A p^i_A + f_B p^i_B + f_C p^i_C + \dots$$

p^i_x = percent of material x passing sieve i

f_x = fraction of blend contributed by stockpile x

$\sum f_x = 1$

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Aggregate Blending

2. Mathematical (Algebraic) Method

- **Steps:**
  - *Obtain sieve analysis results for each stockpile.*
  - *Choose blending ratios for each stockpile (e.g., 50% A, 30% B, 20% C).*
  - *Apply the formula for each sieve size to compute the blended gradation.*
  - *Plot the blended gradation and compare with specification limits.*

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Pavement Materials & Design

Aggregates

Aggregates Blending_ Example 0

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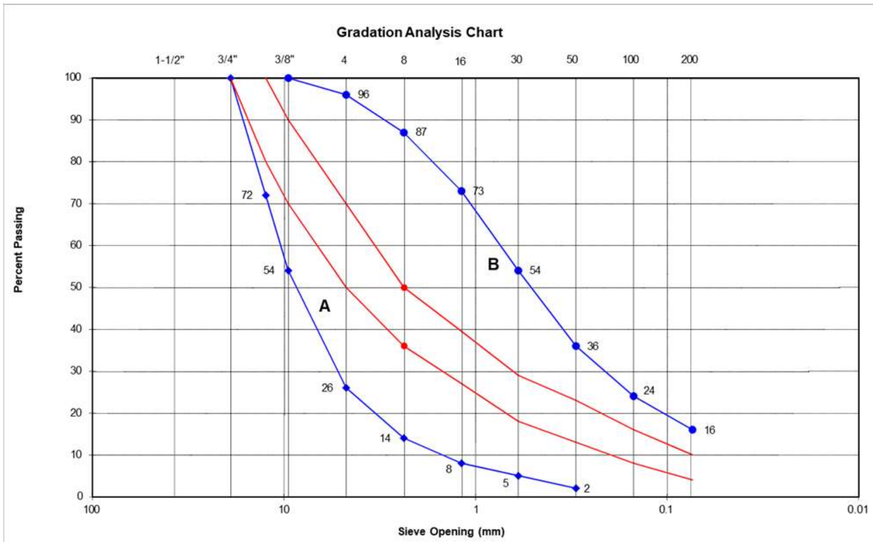
Aggregate Blending

Example 1

- Blue lines present the Gradation of two stockpiles (aggregates A and B)
- Determine a blend of that have
- f_A = 0.6
- f_B = 0.4



http://www.ce.memphis.edu/3137/slides/05a%20-%20Aggregate%20Blending.pdf

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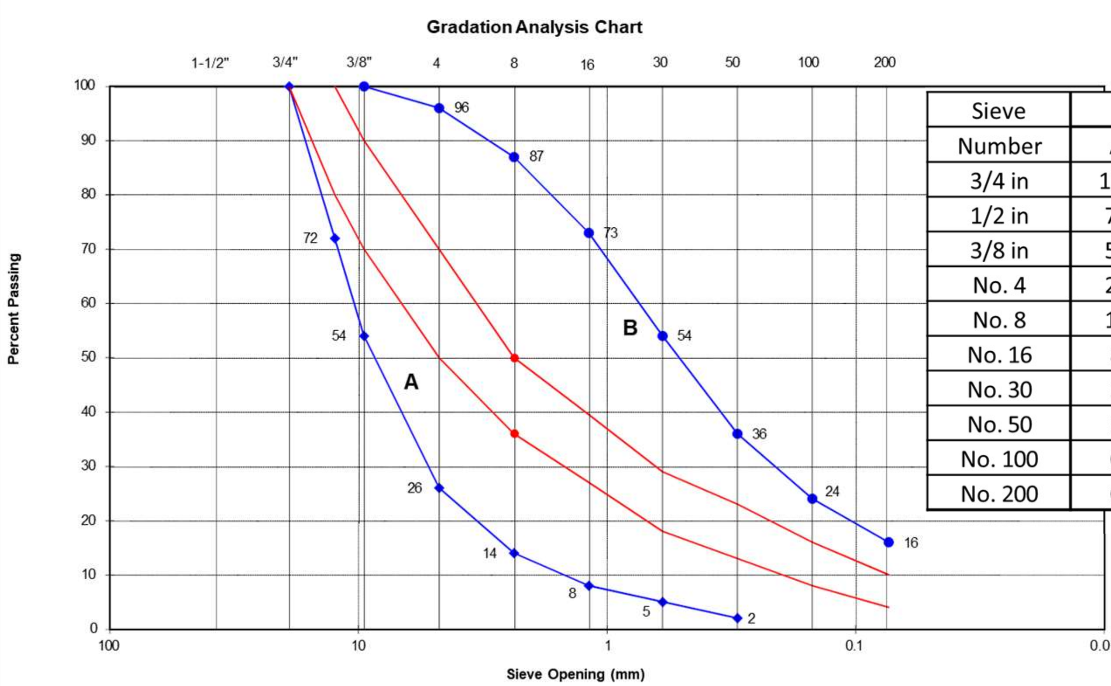

Sieve Number	A	B
3/4 in	100	100
1/2 in	72	100
3/8 in	54	100
No. 4	26	96
No. 8	14	87
No. 16	8	72
No. 30	5	54
No. 50	2	36
No. 100	0	24
No. 200	0	16

http://www.ce.memphis.edu/3137/slides/05a%20-%20Aggregate%20Blending.pdf

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Solution

How to apply the equation

$$p^i_{blend} = f_A p^i_A + f_B p^i_B$$

- $f_A = 0.6$
- $f_B = 0.4$

Sieve	Percent Passing		
Number	A	Blend	B
3/4 in	100		100
1/2 in	72		100
3/8 in	54		100
No. 4	26		96
No. 8	14		87
No. 16	8		72
No. 30	5		54
No. 50	2		36
No. 100	0		24
No. 200	0		16

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Solution

How to apply the equation

$$p^i_{blend} = f_A p^i_A + f_B p^i_B$$

- $f_A = 0.6$
- $f_B = 0.4$

Sieve	Percent Passing		
Number	A	Blend	B
3/4 in	100	0.6 (100) + 0.4 (100) = 100.0	100
1/2 in	72	0.6 (72) + 0.4 (100) = 83.2	100
3/8 in	54	0.6 (54) + 0.4 (100) = 72.4	100
No. 4	26	0.6 (26) + 0.4 (96) = 54.0	96
No. 8	14	0.6 (14) + 0.4 (87) = 43.2	87
No. 16	8	0.6 (8) + 0.4 (72) = 34.0	72
No. 30	5	0.6 (5) + 0.4 (54) = 24.6	54
No. 50	2	0.6 (2) + 0.4 (36) = 15.6	36
No. 100	0	0.6 (0) + 0.4 (24) = 9.6	24
No. 200	0	0.6 (0) + 0.4 (16) =6.4	16

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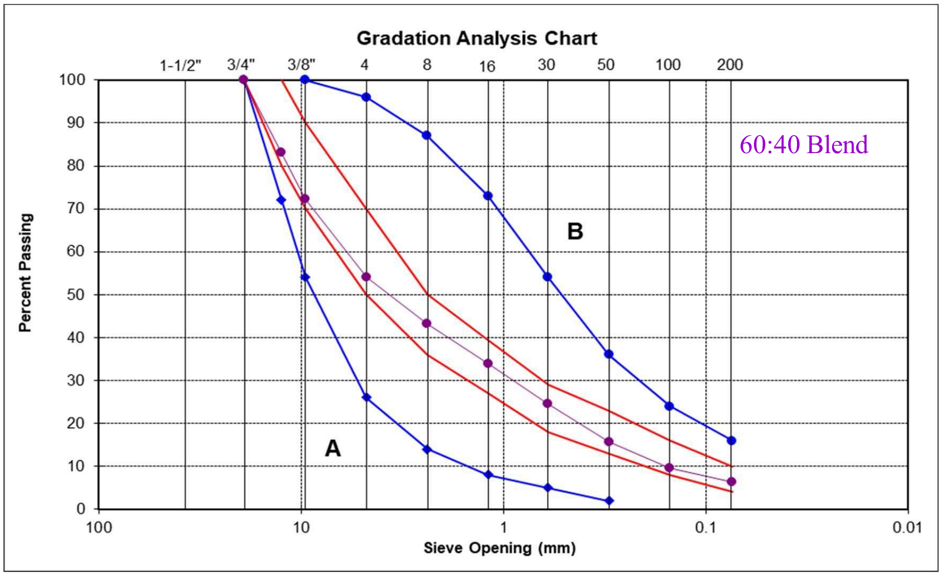
Solution

Check the limits

Sieve Number	
3/4 in	100.0
1/2 in	83.2
3/8 in	72.4
No. 4	54.0
No. 8	43.2
No. 16	34.0
No. 30	24.6
No. 50	15.6
No. 100	9.6
No. 200	6.4



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Pavement Materials & Design

Aggregates

2.8: Aggregates Blending_ Example 1

Dr. Hamza Alkuime

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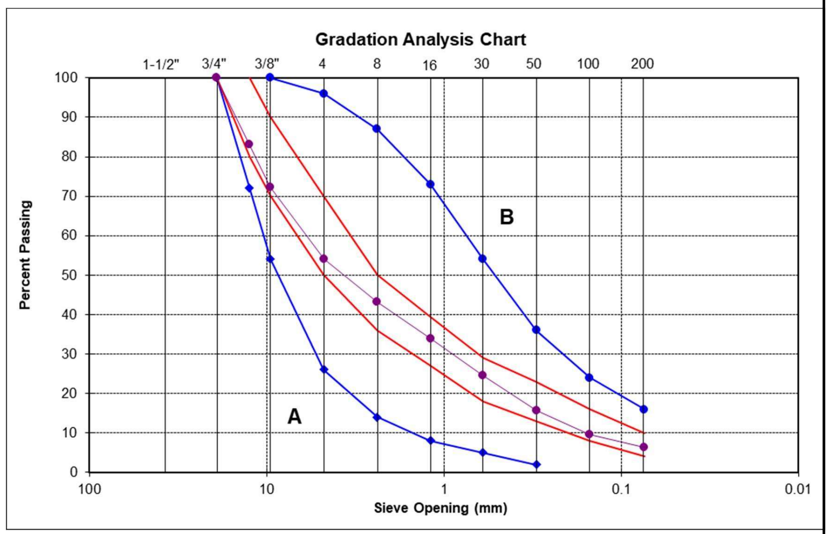
Aggregate Blending

Example 1

- ❑ Blue lines present the Gradation of two stockpiles (aggregates A and B)
- ❑ Specifications are represented in red lines
- ❑ The selected designed combined aggregate structure are in purple
- ❑ Determine the percentage from each stockpile to prepare the selected structure



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Aggregate Blending

Solution

- ❑ Pick a point in the middle of the gradation band
- ❑ E.g. 43% passing No. 8 sieve)

$$p_{blend}^{No.8} = f_A p_A^{No.8} + f_B p_B^{No.8} = 43\%$$

$$f_A + f_B = 1$$

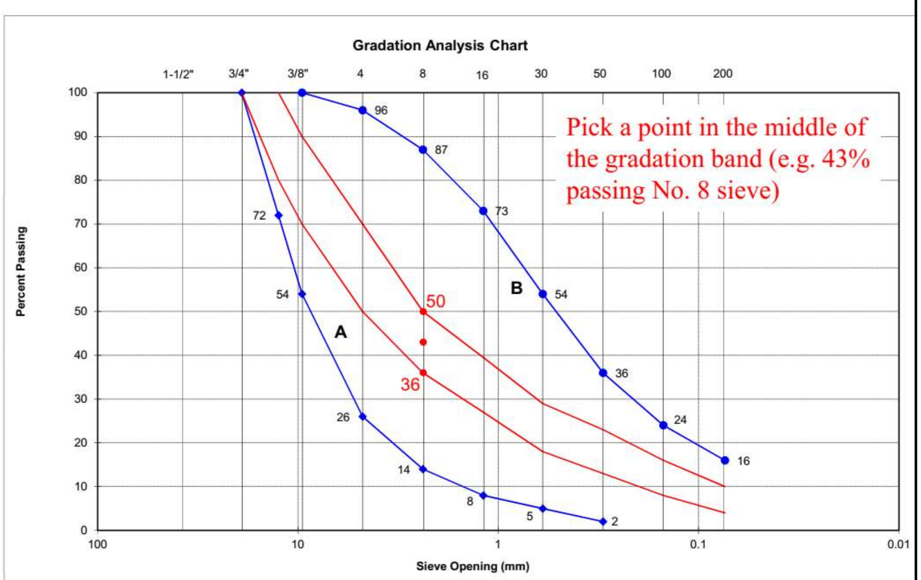
$$p_{blend}^{No.8} = f_A p_A^{No.8} + (1 - f_A) p_B^{No.8} = 43\%$$

$$43 = f_A 14 + (1 - f_A) 87$$

$$43 = f_A 14 + 87 - f_A 87$$

$$-44 = -73 f_A$$

$$f_A = 0.6$$



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Solution

Determine the fractions of the Blend

$$p^i_{blend} = f_A \, p^i_A + f_B \, p^i_B$$

- ❑ $f_A = 0.6$
- ❑ $f_B = 0.4$

Sieve	Percent Passing		
Number	A	Blend	B
3/4 in	100		100
1/2 in	72		100
3/8 in	54		100
No. 4	26		96
No. 8	14		87
No. 16	8		72
No. 30	5		54
No. 50	2		36
No. 100	0		24
No. 200	0		16

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Solution

How to apply the equation

$$p^i_{blend} = f_A \, p^i_A + f_B \, p^i_B$$

- ❑ $f_A = 0.6$
- ❑ $f_B = 0.4$

Sieve	Percent Passing		
Number	A	Blend	B
3/4 in	100	0.6 (100) + 0.4 (100) = 100.0	100
1/2 in	72	0.6 (72) + 0.4 (100) = 83.2	100
3/8 in	54	0.6 (54) + 0.4 (100) = 72.4	100
No. 4	26	0.6 (26) + 0.4 (96) = 54.0	96
No. 8	14	0.6 (14) + 0.4 (87) = 43.2	87
No. 16	8	0.6 (8) + 0.4 (72) = 34.0	72
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No. 100	0	0.6 (0) + 0.4 (24) = 9.6	24
No. 200	0	0.6 (0) + 0.4 (16) =6.4	16

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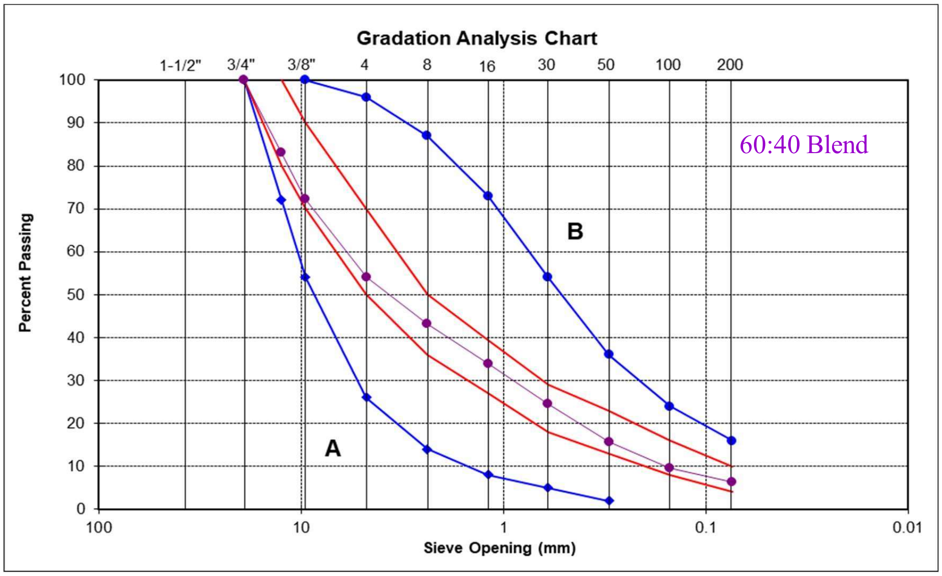
Solution

Check the limits

Sieve Number	
3/4 in	100.0
1/2 in	83.2
3/8 in	72.4
No. 4	54.0
No. 8	43.2
No. 16	34.0
No. 30	24.6
No. 50	15.6
No. 100	9.6
No. 200	6.4



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Pavement Materials & Design

Aggregates

Aggregates Blending_ Example 2

Dr. Hamza Alkuime

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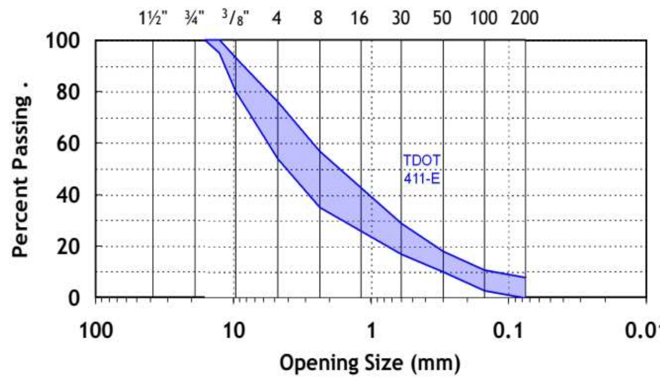
Trial-and-Error Solution

- An asphalt plant in Middle Tennessee had stockpiles of
  1. *No. 78 stone*
  2. *natural sand*
  3. *screenings.*
  - *What proportions of these three materials are needed to meet the* ***Jordanian specification****?*



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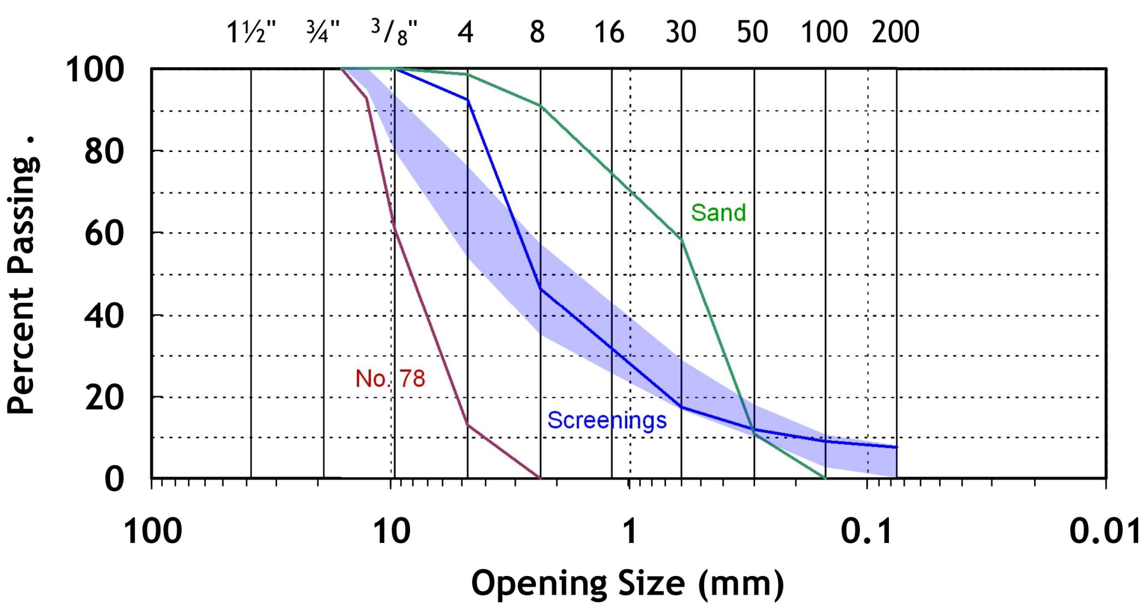
Trial-and-Error Solution



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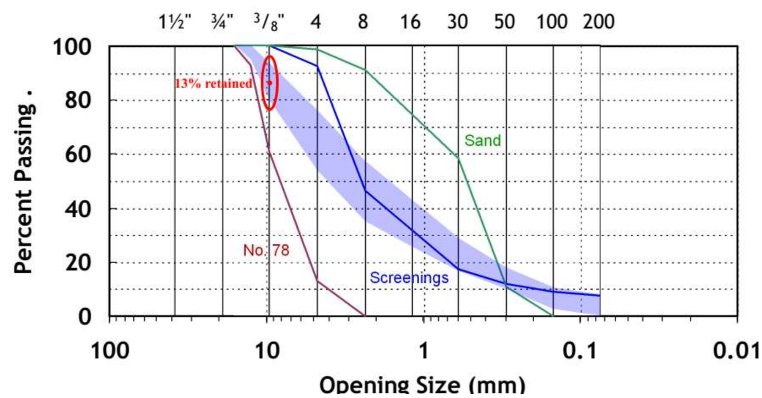
Aggregate Blending

- The specification requires approximately 13% be retained on the 3/8" sieve
  - *so all but the screenings and sand have nothing retained on that sieve,*
  - *of the coarse sizes will have to come from the crushed stone.*
- The crushed stone has 38% retained on the 3/8" sieve,
  - *so, the crushed stone should be roughly 13/38 ≈ 1/3 of the blend.*



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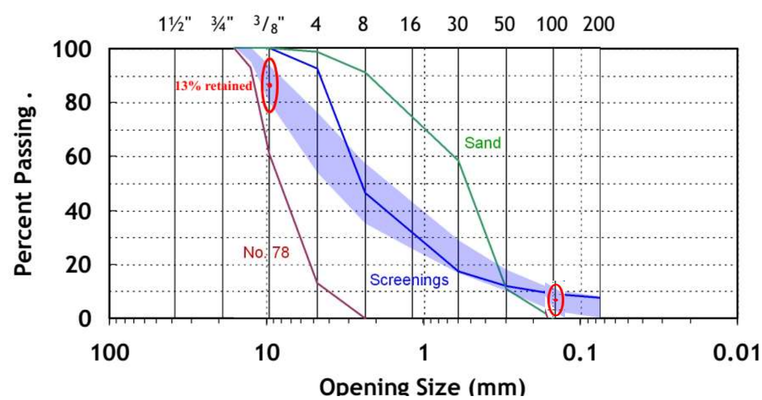
Aggregate Blending

- The specification requires approximately 6% pass the No. 100 sieve
  - *but the sand and stone have nothing passing the No. 100 sieve*
  - *so all of the fine sizes will have to come from the screenings.*
- The screenings have 9% passing the No. 100 sieve,
  - *so they will have to be 6/9 ≈ 2/3 of the blend.*
- This suggests that a blend of 1/3 crushed stone and 2/3 screenings will get us in the ballpark.



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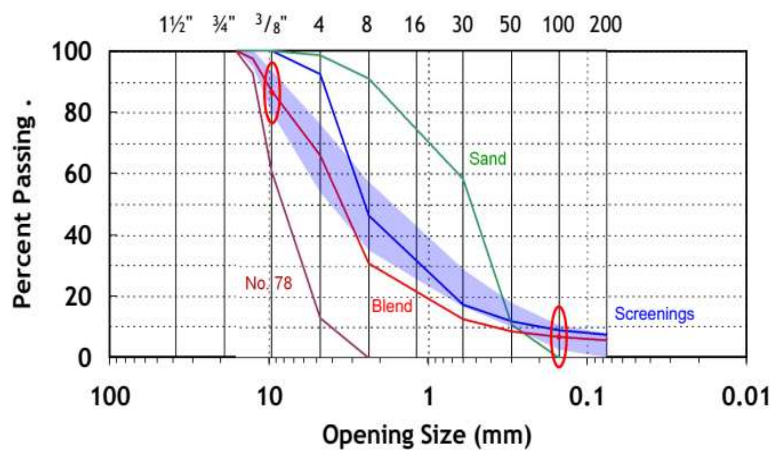
Aggregate Blending

- We fit the specifications at the two ends,
  - *but we don't have enough material between the No. 8 and No. 50 sieves.*
  - *That's where the sand comes in.*
    - Most of its particles are in that size range.

A blend of 1/3 crushed stone and 2/3 screenings will get us in the ballpark.



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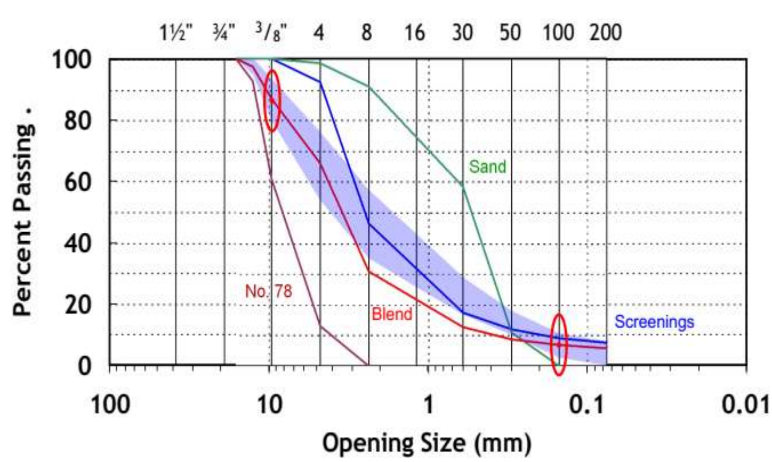
Aggregate Blending

- We now need to start adding sand into the blend until we get a gradation curve we're happy with.
- As the amount of sand goes up,
  - *the amount of screenings and stone will have to go down to make room.*

A blend of 1/3 crushed stone and 2/3 screenings will get us in the ballpark.



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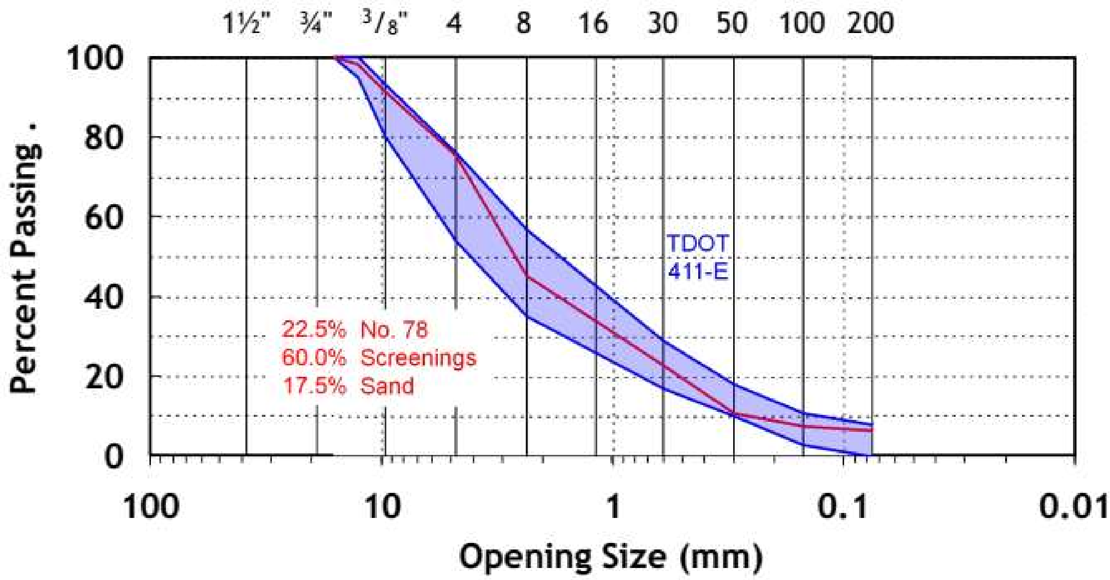
Aggregate Blending



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