Dirt Gravel and Low Volume Road Program

WEBINAR

Stream Crossings: the good, the bad, and the in-between

2/11/21 Starts at 9am

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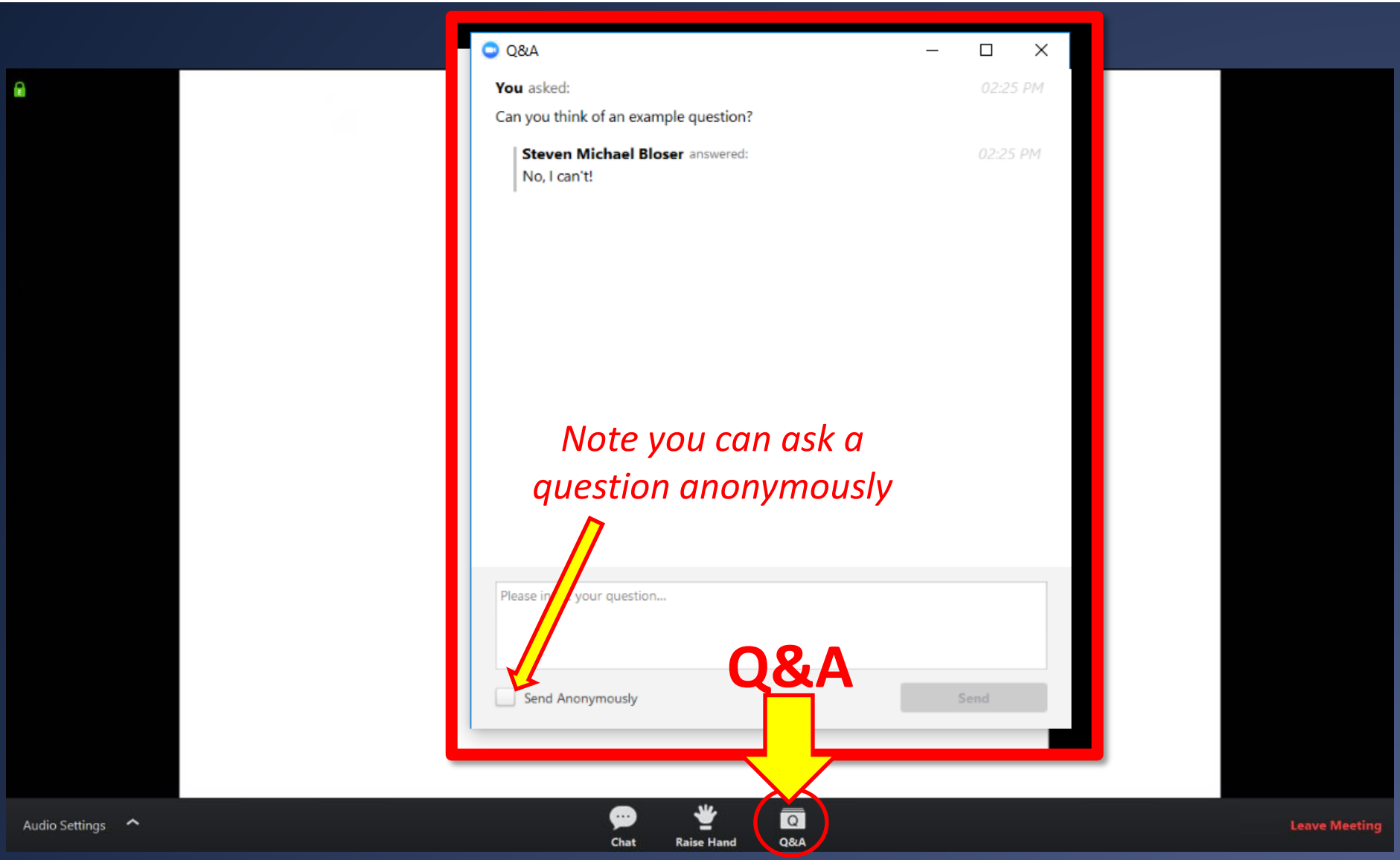
Pennsylvania SCC State Conservation Commission

PENNSTATE

Center for Dirt and Gravel Road Studies

Road Aggregates 101



For audio via phone: 646-876-9923

Road Aggregates 101

Road Aggregates 101

Purpose

- Introduce the updated "Aggregates 101" technical bulletin.
- Provide an introduction to commonly used road aggregates, especially for new CD staff.

Road Aggregates 101

Update and expanded “Aggregates 101” technical bulletin

Technical Bulletin

1/2021

Center for Dirt and Gravel Road Studies

Aggregates 101 - Common Aggregates in PA

Aggregate: A mixture of coarse to fine-grained particulate material used in construction, typically including sand, gravel, and crushed stone.

Sandstone Aggregate in SW PA.

Aggregate sieves used to separate material by size (gradation). ½ inch or 12.5mm sieve visible on right.

Source: (Geologic Origin) Most Pennsylvania aggregates are mined from sedimentary rock such as limestone and sandstone. In the glaciated regions of NW and NE PA, aggregate is often mined glacial till, or pit-run gravel. In general, limestone is the hardest of the rocks, with shale being the softest, while pit-run varies widely in its usefulness as a road aggregate.

Gradation: Gradation is the distribution of different sized stones comprising an aggregate by percent of weight. Gradation is determined by filtering an aggregate through successively smaller sieves and measuring the weight retained on each sieve. Fine content (-#200 sieve or smaller than ~0.003 inches) is determined by washing the aggregate to separate this fine material from the larger pieces.

Aggregate specifications have an allowable range of different stone sizes, expressed as a percentage of the total weight of sample. This **gradation specification** is reported on a table or chart (see example below). The *nominal* maximum size of an aggregate specification is defined as the smallest sieve opening through which 100% of the aggregate can pass.

AASHTO Number	100 mm (4")	90 mm (3 1/2")	63 mm (2 1/2")	50 mm (2")	37.5 mm (1 1/2")	25.0 mm (1")	19.0 mm (3/4")	12.5 mm (1/2")	9.5 mm (3/8")	4.75 mm (No. 4)	2.36 mm (No. 8)	1.18 mm (No. 16)	150 µm (No. 100)	75 mm (No. 200)
1	100	90-100	25-60		0-15		0-5							

Sample Aggregate Gradation for AASHTO #1. 100% in the 4" size means everything passes through a 4" screen opening. 0-5% in the ¾"size means that a maximum of 5% (by weight) of the material can be retained on that sieve, so at least 95% of the aggregate by weight must be larger than ¾" in size.

Open-graded (clean) aggregates: are “porous” with notable air voids between individual stones, and little to no “fines”. These mixtures drain effectively, but do not compact well to form a dense conglomerate. Road applications include use as base material and for subsurface drainage.

Well-graded aggregates: Dense mixturures with few air voids between individual stones. These mixtures are not suitable for drainage but are preferred for use when compaction is important such as pipe bedding, fill, and road surfaces.

Open graded (left) -versus- Well graded (right)

Other Aggregate Qualities: Note that the qualities below are based on the parent material of the aggregate. These values generally stay the same regardless of the gradation the material is crushed to meet.

- **Abrasion Resistance (toughness):** Measures the resistance of the parent material to degradation due to abrasion such as traffic pressure or grading. While not as important for aggregates that will be buried or used for rip-rap, it is a key factor in longevity of aggregates used for road surfacing. Measured by “Los Angeles (LA) Abrasion” testing with lower numbers meaning more durable aggregates. DSA has a maximum LA Abrasion of 40 while many PennDOT Specs have limits ranging [illegible] depending on the aggregate type and intended use.

- Soundness

dness is the resistance of an aggregate to eathering, due to freeze-thaw cycles in ss is important for aggregates that will be freeze thaw cycles, generally anything on ied less than 24" in Pennsylvania. ed by Sodium Sulfate testing that mimics ring freezing. A lower value indicates a ation resistant aggregate. A maximum percent is used for DSA. PennDOT ging from 10-20 depending on the ded use.

lasticity is an approximation (not a y content of the fine material in an aggregates are essentially non- ey lack fine material by definition. mportant for base and surface ontent can lead to problems with mation. A PI of 0 is “non-plastic”, aggregate are insignificant. DSA e PI starts creeping over 6, the e similar to a cohesive

Disentegration of “unsound” rip-rap due to one year of freeze/thaw cycles.

Rutting

R Program

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Common Coarse Aggregates for Road Applications in PA

	AGGREGATE SPECIFICATION AASHTO	AGGREGATE SPECIFICATION PA	Common Name	General Size Description	Common Road Uses	TOTAL PERCENT PASSING 100mm 4"	90mm 3.5"	63mm 2.5"	50mm 2"	37.5mm 1.5"	25mm 1"	19mm 3/4"	12.5mm 1/2"	9.5mm 3/8"
open graded	#1	#4	ballast, #4s	4"- 3/4" clean	Base, mattress, underdrains									
	#3	3A		2.5" - 1/2" clean						0-15			0-5	
	#57	2B		1.5" - 3/32" clean						35-70	0-15			0-5
	#8	1B		0.5" - 3/32" clean	chip surfacing					100	95-100			25-60
	#10		grit, screenings	less than 3/8"										100
well graded		2A	2A, subbase	2" - fine	road base, road surface				100				52-100	
		2RC	misc., reclaim	varies widely	fill, pipe bedding, surface				100					85-1
		DSA	driving surf. agg	1.5" - fine	unbound road Surface			100					65-97	100
														36-1

Where these specifications come from:

- AASHTO (American Association of State and Highway Transportation Officials) labels aggregate spec the largest stone size in the mixture, with 1 being the largest (all material passing a 4" sieve opening) an passing a 3/8" sieve opening). Multi-digit specifications represent a blend of one or more of the ten bas a blend of AASHTO 5 and AASHTO 7). AASHTO Specifications are technically open graded or clean a
- PA Specifications are maintained by PennDOT and most can be found in their “Publication 408”, section above table that is tested by Conservation Districts or the Center prior to purchasing. Other produc gradation and testing requirements.
- Specifications below that begin with an “R” designation are set by the National Crushed Stone Associa

Common Large “Rip-Rap” Aggregates for Road Applications in PA

SPEC / NAME	Size Range	Average Size	General Uses	TOTAL PERCENT PASSING 42"	30"	24"	18"	15"	12"	9"	6"	4"	3"
R-8	15-42"	28"	abutments	100		15-50		0-15					
R-7	12-30"	20"	streambanks		100		15-50		0-15				
R-6	9-24"	14"	streambanks			100		15-50		15-50	0-15		
			banks / ditches				100		100			0-15	
											15-50		0-1
											100		15-5

Road Aggregates 101

- **Background**
- Important Aggregate Properties
- Commonly Used Aggregates
  - Coarse Aggregates
  - Larger “rip-rap” aggregates

Road Aggregates 101

Background

- **Aggregate**: A mixture of coarse to fine-grained particulate material used in construction, typically including sand, gravel, and crushed stone.

- **Sources**:
  - Limestone
  - Sandstone

Road Aggregates 101

Background

- **Making Aggregates:**
  - **Blast**
  - Crush
  - Sieve

https://www.geoengineer.org/news/last-blast-at-thornton-quarry-creates-a-new-reservoir

Road Aggregates 101

Background

- **Making Aggregates:**
  - **Blast**
  - **Crush**
  - Sieve

https://www.terex.com/finlay/en/product/jaw-crushers/j-1480

Road Aggregates 101

Background

- **Making Aggregates:**
  - Blast
  - Crush
  - Sieve

https://www.quarrymagazine.com/2020/03/19/blending-of-recycled-glass-and-crushed-rock-in-road-pavements/

Road Aggregates 101

Background

- **Gradation**: Size distribution of particle in an aggregate by percent weight
- **Example**: AASHTO #1
  - Mixture of 2-3 inch stones with no fine material

http://www.pennsysupply.com/construction-materials/aggregate.asp

Background

- **Gradation**: Size distribution of particle in an aggregate by percent weight
- **Example**: AASHTO #1
  - Mixture of 2–3 inch stones with no fine material

https://laurelaggregates.com/products/aashto-1/

Everything must pass a 4” opening

At least 85% of material larger than 1.5”

Max 5% by weight can pass ¾” opening

AASHTO Number	Total Percent Passing													
	100 mm (4")	90 mm (3 1/2")	63 mm (2 1/2")	50 mm (2")	37.5 mm (1 1/2")	25.0 mm (1")	19.0 mm (3/4")	12.5 mm (1/2")	9.5 mm (3/8")	4.75 mm (No. 4)	2.36 mm (No. 8)	1.18 mm (No. 16)	150 µm (No. 100)	75 µm (No. 200) ***
1	100	90-100	25-60		0-15		0-5							

Road Aggregates 101

Background

- **Gradation**: Size distribution of particle in an aggregate by percent weight
  - Some Gradations can be crushed directly
  - Some may have to be mixed after crushing
  - Gradation is about size, It is independent of aggregate quality. Both good and bad parent material can be crushed to the same gradation.

Mixing 2A and fines to make DSA

Road Aggregates 101

Background

- **Gradation**: Size distribution of particle in an aggregate by percent weight
- **Open -vs- Well graded aggregates:** drainage and compaction are mutually exclusive

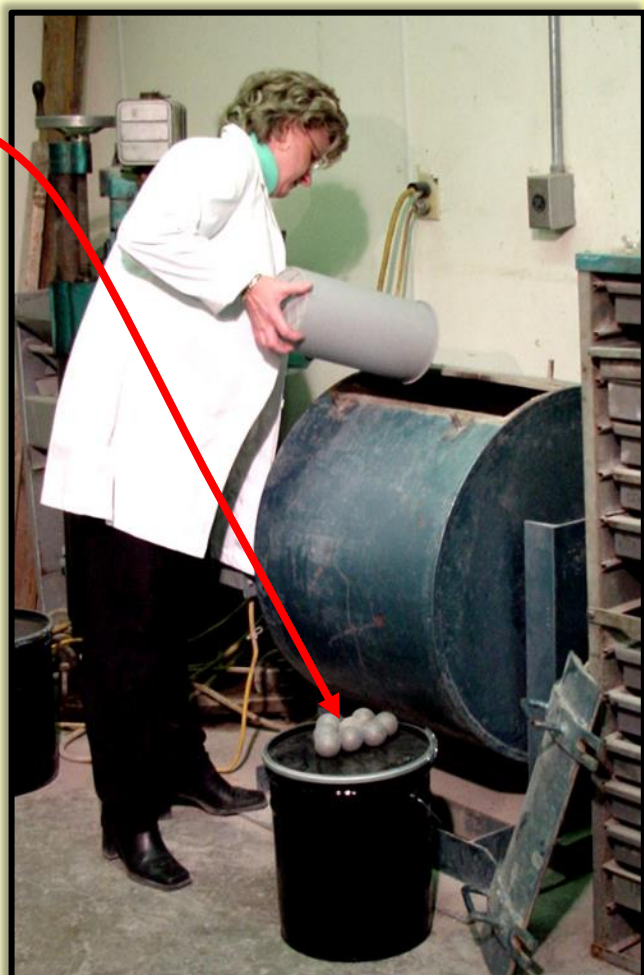
Road Aggregates 101

- Background
- **Important Aggregate Properties**
- **Commonly Used Aggregates**
  - **Coarse Aggregates**
  - **Larger “rip-rap” aggregates**

Aggregate Quality Properties

Abrasion Resistance: Resistance to mechanical breakdown. Measured by "LA Abrasion"

- Aggregate is placed in steel drum with steel spheres and rotated.
- Results are expressed as % loss
  Lower % = less crushing = harder aggregate



Aggregate Quality Properties

Abrasion Resistance: Resistance to mechanical breakdown.

- Abrasion resistance is most important for surface aggregates to resist traffic, grading, etc.
  - Driving Surface Aggregate (DSA) (max LA Abrasion of 40)
  - Anything used as a surface (most DOT aggregates range from 40-55)

- Abrasion resistance less important if aggregate is to be buried or used off of the cartway.

Aggregate Quality Properties

Soundness: Resistance to weathering, specifically by freeze thaw cycles

Have you ever seen a rock do this is as little as one year?

That is poor soundness.

Aggregate Quality Properties

Soundness: Measured by Sodium Sulfate test

- Aggregate is soaked in sodium sulfate then dried 5 times, which mimic freeze thaw cycles.
- Results are expressed as % loss
  Lower % = less breakdown = more sound aggregate

BEFORE

AFTER

Aggregate Quality Properties

Soundness: Measured by Sodium Sulfate test

- Soundness is most important for anything exposed to freezing temperatures
  - Surface aggregates
  - Shallow bases
  - Rip Rap
  - Shallow or exposed subsurface drains
  - Anything not buried at least 18-32 inches

- Soundness is less important for material buried below frost depth such as large fill projects.

Aggregate Quality Properties

Plasticity Index: PI is an approximation of clay in an aggregate

- **Impacts of clay in aggregate**
  - Retain water
  - Remains mobile (dust and sediment)
  - Remain flexible (rutting)

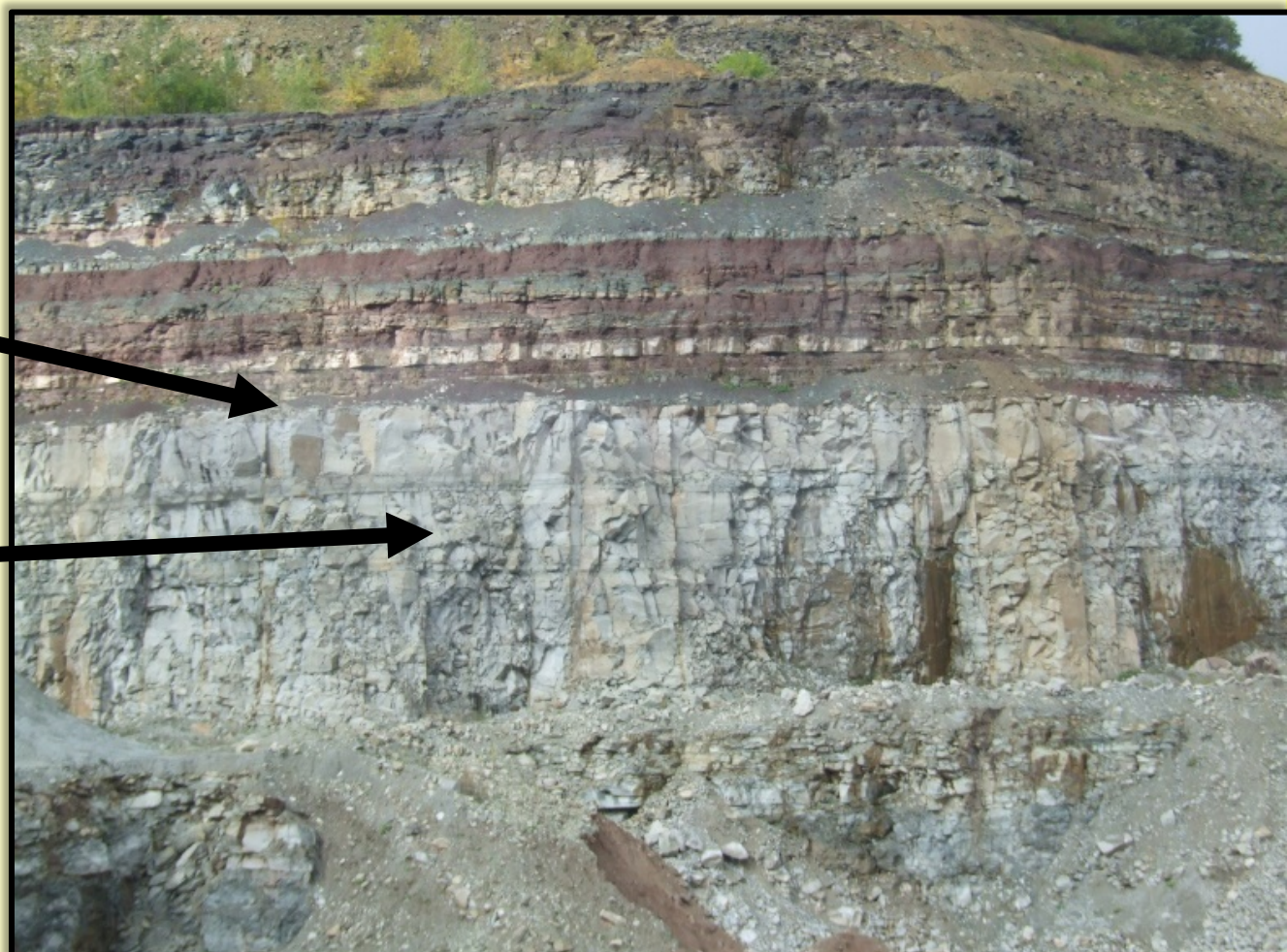
Aggregate Quality Properties

Plasticity Index: PI is an approximation of clay in an aggregate

Where does clay come from?

How much overburden may get mixed in?

Are there clay seems in this limestone?



Aggregate Quality Properties

Plasticity Index: PI is an approximation of clay in an aggregate

- Plasticity is only run on material passing the #40 (<1mm)
- Open graded or clean aggregate are “non plastic” by default
    - Plasticity index
        - 0 = “non-plastic” (negligible clay / silt content)
        - 1-4 = some clay / silt
        - 4-6 = clay content can make material “sticky”
        - 6+ = starts to behave more like soil than aggregate

IMPORTANT

Abrasion Resistance, Soundness, and Plasticity are related to properties of the parent material.

- They can vary slightly from one rock face to another within the same quarry.
- They essentially remain the same regardless of the gradation or level of crushing done to the aggregate

Road Aggregates 101

- Background
- Important Aggregate Properties
- **Commonly Used Aggregates**
  - **Coarse Aggregates**
  - **Larger “rip-rap” aggregates**

Aggregates

A word about specifications

- **AASHTO (American Association of State and Highway Transportation Officials)** Federal spec on open-graded or clean stone

- **PA Specifications are maintained by PennDOT largely for well-graded aggregates (**“Publication 408”, section 703).

note some redundancy, for example ASSHTO #1 = PA #4

- Specifications that begin with an “R” designation are set by the **National Crushed Stone Association.**

Road Aggregates 101

Common Coarse Aggregates

http://www.pennsysupply.com/construction-materials/aggregate.asp

PENNDOT 2A: well-graded

- Designed as base for asphalt
- Very common “standard” aggregate
- 2” top size
- Fine content ranges from 0-10%
  - Near 0, behaves almost as an open-graded aggregate
  - Near 10, very well graded, approaching DSA
- No plasticity specification

	AGGREGATE SPECIFICATION		Common Name	General Size Description	Common Road Uses	TOTAL PERCENT PASSING													
						100mm	90mm	63mm	50mm	37.5mm	25mm	19mm	12.5mm	9.5mm	4.75mm	2.63mm	1.18mm	0.15mm	0.075mm
	AASHTO	PA				4"	3.5"	2.5"	2"	1.5"	1"	3/4"	1/2"	3/8"	#4	#8	#16	#100	#200
open graded	#1	#4	ballast, #4s	4"- 3/4" clean	Base, mattress, underdrains	100	90-100	25-60		0-15		0-5							
	#3	3A		2.5" - 1/2" clean				100	90-100	35-70	0-15		0-5						
	#57	2B		1.5" - 3/32" clean						100	95-100		25-60		0-10	0-5			
	#8	1B		0.5" - 3/32" clean	chip surfacing								100	85-100	10-30	0-10	0-5		
	#10		grit, screenings	less than 3/8"										100	85-100			10-30	
well graded		2A	2A, subbase	2" - fine	road base, road surface				100			52-100		36-70	24-50	16-38	10-30		0-10
		2RC	misc., reclaim	varies widely	fill, pipe bedding, surface				100						15-60			0-30	
		DSA	driving surf. agg.	1.5" - fine	unbound road Surface					100		65-97			30-65		15-30		10-15*

Road Aggregates 101

Common Coarse Aggregates

PENNDOT 2A: well-graded

- Uses
  - **Road base and subbase**
  - Pipe bedding
  - Road fill (in areas where cost is low)
  - Traditional road surface (not recommended due to variability of fines)

	AGGREGATE SPECIFICATION		Common Name	General Size Description	Common Road Uses	TOTAL PERCENT PASSING												
						100mm	90mm	63mm	50mm	37.5mm	25mm	19mm	12.5mm	9.5mm	4.75mm	2.63mm	1.18mm	0.15mm	0.075mm
	AASHTO	PA				4"	3.5"	2.5"	2"	1.5"	1"	3/4"	1/2"	3/8"	#4	#8	#16	#100	#200
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	#10		grit, screenings	less than 3/8"										100	85-100			10-30	
well graded		2A	2A, subbase	2" - fine	road base, road surface				100			52-100		36-70	24-50	16-38	10-30		0-10
		2RC	misc., reclaim	varies widely	fill, pipe bedding, surface				100						15-60			0-30	
		DSA	driving surf. agg.	1.5" - fine	unbound road Surface					100		65-97			30-65		15-30		10-15*

Common Coarse Aggregates

PENNDOT 2A "Modified"

- "Modified" does NOT exist as a spec.
- Some quarries and townships will still use the term.
- What is it?
  - 2A with extra fines
- Purchase at your own risk since there is no spec.

	AGGREGATE SPECIFICATION		Common Name	General Size Description	Common Road Uses	TOTAL PERCENT PASSING													
						100mm	90mm	63mm	50mm	37.5mm	25mm	19mm	12.5mm	9.5mm	4.75mm	2.63mm	1.18mm	0.15mm	0.075mm
	AASHTO	PA				4"	3.5"	2.5"	2"	1.5"	1"	3/4"	1/2"	3/8"	#4	#8	#16	#100	#200
open graded	#1	#4	ballast, #4s	4"- 3/4" clean	Base, mattress, underdrains	100	90-100	25-60		0-15		0-5							
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		2RC	misc., reclaim	varies widely	fill, pipe bedding, surface				100						15-60			0-30	
		DSA	driving surf. agg.	1.5" - fine	unbound road Surface					100		65-97			30-65		15-30		10-15*

Road Aggregates 101

Common Coarse Aggregates

PENNDOT 2RC: well-graded

http://www.pennsysupply.com/construction-materials/aggregate.asp

- Wide ranging in size and quality
- Very common “standard” aggregate
- 2” top size
- Fine content ranges from 0-30%
  - Near 0, behaves almost as an open-graded aggregate
  - Near 30…you just bought dirt
- Can contain soil and even organics
- Typically, high PI (lots of clay)

	AGGREGATE SPECIFICATION		Common Name	General Size Description	Common Road Uses	TOTAL PERCENT PASSING												
						100mm	90mm	63mm	50mm	37.5mm	25mm	19mm	12.5mm	9.5mm	4.75mm	2.63mm	1.18mm	0.15mm	0.075mm
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		2RC	misc., reclaim	varies widely	fill, pipe bedding, surface				100						15-60			0-30	
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Road Aggregates 101

Common Coarse Aggregates

PENNDOT 2RC: well-graded

- Uses
  - Pipe bedding / backfill
  - Road fill
  - Traditional road surface
    (not recommended due to variability of fines and clay content)

	AGGREGATE SPECIFICATION		Common Name	General Size Description	Common Road Uses	TOTAL PERCENT PASSING													
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		2RC	misc., reclaim	varies widely	fill, pipe bedding, surface				100						15-60			0-30	
		DSA	driving surf. agg.	1.5" - fine	unbound road Surface					100		65-97			30-65		15-30		10-15*

Road Aggregates 101

Common Coarse Aggregates

Driving Surface Aggregate (DSA)

- Like PennDOT 2A, BUT:
  - Fine content is 10-17
  - Stricter specs on abrasion resistance, soundness, and plasticity
  - Additional specifications on placement
- Designed for compaction and longevity as a wearing surface

2/4: Remote Training: "DSA Day": Feb 4, 9am-noon

	AGGREGATE SPECIFICATION		Common Name	General Size Description	Common Road Uses	TOTAL PERCENT PASSING													
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	#8	1B		0.5" - 3/32" clean	chip surfacing								100	85-100	10-30	0-10	0-5		
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		2RC	misc., reclaim	varies widely	fill, pipe bedding, surface				100						15-60			0-30	
		DSA	driving surf. agg.	1.5" - fine	unbound road Surface					100		65-97			30-65		15-30		10-15*

Road Aggregates 101

Common Coarse Aggregates

AASHTO #1 (PA#4)

- Most used free-draining spec
- Gradation
  - Top size of 4”
  - Only 15% can be smaller than 1.5”
  - Only 5% can be smaller than ¾”
- Uses
  - Subsurface drainage
  - Base stabilization

AASHTO # 1 for French Mattress

	AGGREGATE SPECIFICATION		Common Name	General Size Description	Common Road Uses	TOTAL PERCENT PASSING													
						100mm	90mm	63mm	50mm	37.5mm	25mm	19mm	12.5mm	9.5mm	4.75mm	2.63mm	1.18mm	0.15mm	0.075mm
	AASHTO	PA				4"	3.5"	2.5"	2"	1.5"	1"	3/4"	1/2"	3/8"	#4	#8	#16	#100	#200
	#1	#4	ballast, #4s	4"- 3/4" clean	Base, mattress, underdrains	100	90-100	25-60		0-15		0-5							
open graded	#3	3A		2.5" - 1/2" clean				100	90-100	35-70	0-15		0-5						
	#57	2B		1.5" - 3/32" clean						100	95-100		25-60		0-10	0-5			
	#8	1B		0.5" - 3/32" clean	chip surfacing								100	85-100	10-30	0-10	0-5		
	#10		grit, screenings	less than 3/8"										100	85-100			10-30	
well graded		2A	2A, subbase	2" - fine	road base, road surface				100			52-100		36-70	24-50	16-38	10-30		0-10
		2RC	misc., reclaim	varies widely	fill, pipe bedding, surface				100						15-60			0-30	
		DSA	driving surf. agg.	1.5" - fine	unbound road Surface					100		65-97			30-65		15-30		10-15*

Road Aggregates 101

Common Coarse ~~Aggregates~~

Other Common Materials

- **Shale**
- **Pit Run**
- **Bankrun Gravel**
- These do NOT have a specification.
- Typically excavated directly from ground with no processing.
- They are highly variable in composition and quality
- Primarily used as cheap sources of fill

Road Fill RFQ available on Center's website

http://www.millcreeksandgravel.com/crush-gravel http://mccollumtrucking.com/gravel/

Road Aggregates 101

- Background
- Important Aggregate Properties
- **Commonly Used Aggregates**
  - Coarse Aggregates
  - **Larger “rip-rap” aggregates**

Road Aggregates 101

Common Coarse Aggregates

Rip Rap

- Generic Term for large clean stone
- Used for stabilization (ditches, outlets, channels, banks, etc.)
- **R-3: (2" - 6")**
- **R-4 (3" - 12")**
- **R-5 (4" - 18")**
- **R-6 (9" - 24")**
- **R-7 (12" - 30")**
- **R-8 (15" - 42")**

http://www.pennsysupply.com/construction-materials/aggregate.asp

https://mmlime.com/materials/

https://mmlime.com/materials/

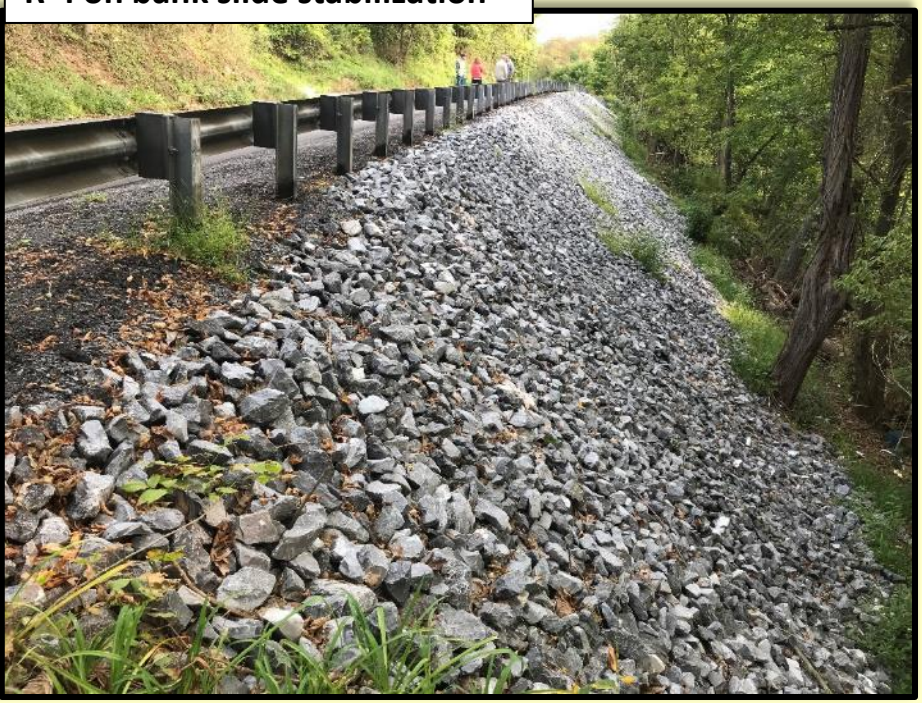
SPEC / NAME	Size Range	Average Size	General Uses	TOTAL PERCENT PASSING										
				42"	30"	24"	18"	15"	12"	9"	6"	4"	3"	2"
R-8	15-42"	28"	abutments	100		15-50		0-15						
R-7	12-30"	20"	streambanks		100		15-50		0-15					
R-6	9-24"	14"	streambanks			100			15-50		0-15			
R-5	4-18"	11"	banks / ditches				100			15-50		0-15		
R-4	3-12"	7"	ditches						100		15-50		0-15	
R-3	2-6"	3.5"	road subbase								100		15-50	0-15

Road Aggregates 101

Common Coarse Aggregates

Rip Rap

R-4 on bank slide stabilization



R-5 on ditch stabilization

R-7 on streambank stabilization

Road Aggregates 101

Common Coarse Aggregates

Other terms for Large Aggregate

- These do NOT have a specification
- Very roughly graded and highly variable
- Terms you might hear:
  - **Surge**: ~10” and smaller
  - **Shot Rock**: essential rip-rap without a specification
  - **Gabion**: similar to AASSHTO #1 /#3

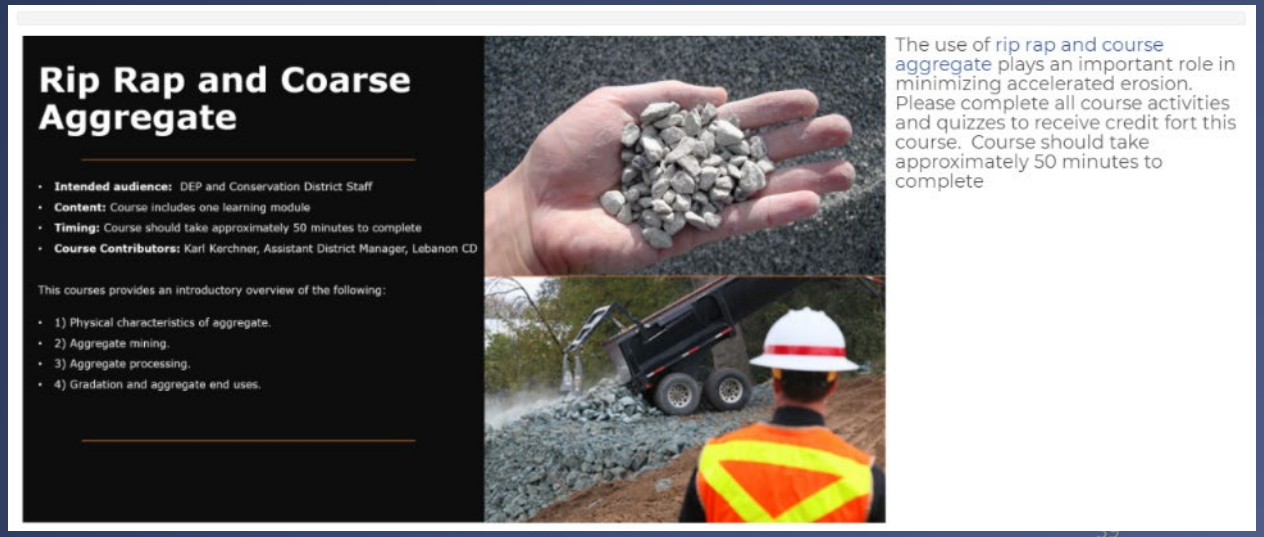
http://mccollumtrucking.com/gravel/

SPEC / NAME	Size Range	Average Size	General Uses	TOTAL PERCENT PASSING										
				42"	30"	24"	18"	15"	12"	9"	6"	4"	3"	2"
Surge	10"-fine	*varies*	subbase / fill	Surge, Gabion, and Shot Rock are relatively loose terms with broad size ranges and no exact specification.										
Gabion	4-8"	*varies*	baskets / ditches											
Shot Rock	*varies*	24"	abutments											

Road Aggregates 101

Additional Information

DEP Watershed Academy "Rip-Rap" and Coarse Aggregate



Road Aggregates 101

Road Aggregates 101

Dirt Gravel and Low Volume Road Program

Road Aggregates 101

WEBINAR

QUESTIONS ?

1/26-27: Remote ESM Training Jan 26 and 27, 8am-12:30 pm BOTH days:
1/28-29: Remote Administrative Training: 1/28 and 1/29, 9-11:30am BOTH days: Admin
2/4: Remote Training: "DSA Day": Feb 4, 9am-noon: NEW
2/11: Webinar: Stream Crossings, the good, the bad, and the ugly: Feb 11, 9am: NEW
2/16-17: Remote ESM Training Feb 16 and 17, 8am-12:30 pm BOTH days:
2/18: Webinar: Annual Summary Report Overview: February 18, 9am: NEW
2/23: Remote Training: "Bookkeeper Bootcamp": Feb 23, 9am-noon: NEW
2/25: Remote Training: "Streambank Stabilization": Feb 25, 9am-noon: NEW

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