

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.

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.



Aggregate sieves used to separate material by size (gradation). 1/2 inch or 12.5mm sieve visible on right.

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							

Sample Aggregate Gradation for AASHTO #1. 100% in the 4" size means everything passes through a 4" screen opening. 0-5% in the 3/4" 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 3/4" 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 mixtures 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 from 40 to 55 depending on the aggregate type and intended use.

- **Soundness:** Soundness is the resistance of an aggregate to disintegration by weathering, due to freeze-thaw cycles in particular. Soundness is important for aggregates that will be exposed to repeated freeze thaw cycles, generally anything on the surface or buried less than 24” in Pennsylvania. Soundness is measured by Sodium Sulfate testing that mimics ice crystal formation during freezing. A lower value indicates a more sound or degradation resistant aggregate. A maximum soundness value of 20 percent is used for DSA. PennDOT Specs have limits ranging from 10-20 depending on the aggregate type and intended use.
- **Plasticity Index (PI):** Plasticity is an approximation (not a direct measure) of the clay content of the fine material in an aggregate. Open-graded aggregates are essentially non-plastic (no clay) because they lack fine material by definition. Plasticity is particularly important for base and surface aggregates as a high clay content can lead to problems with moisture retention and deformation. A PI of 0 is “non-plastic”, meaning levels of clay in the aggregate are insignificant. DSA has a PI range of 0-4. Once PI starts creeping over 6, the material starts to behave more similar to a cohesive soil than an aggregate.



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



Rutting due to clay content (high plasticity index) in a surface aggregate

Commonly Used Aggregates in DGLVR Program:

- **PennDOT 2A:** 2A was designed as a base for placing asphalt. It has a top size of 2” and can act as either an open or well graded aggregate based on the fine content, which is allowed to vary from 0-10%. 2A is typically used as base material, pipe bedding, and road fill. It is a “traditional” surfacing aggregate used by municipalities although it varies widely in its effectiveness based on its gradation.
- **Modified or 2A modified:** “modified” is NOT an official specification, but the term is used by many municipalities and quarries. Modified is usually a 2A aggregate that has been “modified” with the addition of another aggregate, typically additional fine material to make a more well-graded aggregate.
- **PennDOT 2RC:** A widely varying specification with a top size of 2” and few other restrictions. 2RC typically has an extremely high clay content and may contain soil and even organic components. Because it is easy to make, it is usually cheap and can make good pipe bedding or road fill.
- **DSA:** Similar to PennDOT 2A, except with a higher fine content (10-17%) and additional specifications to make it more resistant to the degradation and erosion forces on the road surface.
- **AASHTO #1 (PA #4):** This open-graded aggregate ranges has a top size of 4” with 85-100% of the gradation being larger than 1.5” in size. This is typically the aggregate of choice for subsurface drainage features such as underdrains or French mattresses.
- **Rip-Rap:** A generic term for open-graded rock larger than AASHTO #1. It comes in various size specifications and is typically used for stabilization of banks, channels, and outlets.
- **Other Commonly Used Materials:** These are not “aggregates” and do not have a specification.
 - **Shale:** Shale has specification for size, soundness, or abrasion resistance, and typically breaks down fairly readily. Shale’s availability and low cost make it ideal for large fill projects.
 - **Pit-run:** A minimally processed material usually excavated right from the ground. Varies widely in quality and typically only used for fill material.
 - **Bankrun Gravel:** Not actually an “aggregate”, but the result of mining an alluvial (water) deposited gravel. Varies widely in parent material, size, and quality. It is also typically rounded in shape and must be crushed before use. Bankrun is an ideal cheap source of fill material in some areas of PA.

Common Coarse Aggregates for Road Applications in PA

	AGGREGATE SPECIFICATION		Common Name	General Size Description	Common Road Uses	TOTAL PERCENT PASSING													
	AASHTO	PA				100mm	90mm	63mm	50mm	37.5mm	25mm	19mm	12.5mm	9.5mm	4.75mm	2.63mm	1.18mm	0.15mm	0.075mm
						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*

* DSA up to 17% fines if PI ≤ 2

Where these specifications come from:

- AASHTO (American Association of State and Highway Transportation Officials) labels aggregate specifications from 1 to 10 according to the largest stone size in the mixture, with 1 being the largest (all material passing a 4" sieve opening) and 10 being the smallest (all material passing a 3/8" sieve opening). Multi-digit specifications represent a blend of one or more of the ten basic specifications (i.e. AASHTO 57 is a blend of AASHTO 5 and AASHTO 7). AASHTO Specifications are technically open graded or clean aggregates.
- PA Specifications are maintained by PennDOT and most can be found in their "Publication 408", section 703. DSA is the only product in the above table that is tested by Conservation Districts or the Center prior to purchasing. Other products in the table must meet PennDOT gradation and testing requirements.
- Specifications below that begin with an "R" designation are set by the National Crushed Stone Association.

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"	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		
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												

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