One Page Guides and Other References for 2020 ND LTAP Classes

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NORTH DAKOTA DEPARTMENT OF TRANSPORTATION

SPECIAL PROVISION

GRAVEL SURFACING

DESCRIPTION

This work consists of furnishing and placing aggregate as a roadway surface course.

EQUIPMENT

Equipment	Section
Tow-Type Pneumatic-Tired Rollers	151.01 A.2
Self-Propelled Pneumatic-Tired Rollers	151.01 A.3
Water Trucks	152.01 B
Aggregate Trucks	152.01 C

MATERIALS

A. General.

Sieve Size Or Testing Method	Aggregate Gravel Surfacing Percent passing or Test Limit
1"	100
¾"	70 – 100
No. 4	38 – 75
No. 8	22 – 62
No. 30	12 – 45
No. 200	7 - 15
Plasticity Index (PI)	3 - 9
ND T 113, Shale (max %)	12.0%
AASHTO T 96, L.A. Abrasion (max %)	50%
NDDOT 4, Fractured Faces[1]	10%

[1]Minimum weight percentage allowable for the portion of the aggregate retained on a No. 4 sieve having at least 1 fractured face.

The Engineer's testing procedures will follow Section 302 of the Field Sampling and Testing Manual. Frequencies will follow this specification.

B. Acceptance of Aggregate.

1. **Gradation.**
   The Engineer will collect three samples for each 1,000 tons of material placed, except when more than 1,000 tons are placed in a day. If more than 1,000 tons are placed in a day, the Engineer will collect three samples for that day's placement. If the aggregate fails to meet the specified gradation, the Engineer will apply a price reduction as specified in Section 302.06 B, "Contract Price Adjustments".

Authored By: NDDOT ETS

Do not incorporate additional aggregate if two consecutive lots deviate from the specified gradation. Restart placement operations after taking corrective actions and passing a gradation test.

2. **Plasticity Index (PI).**
The Engineer will collect three samples for each 5,000 ton lot of material produced. If a fractional lot is less than 1,500 tons it will be included in the previous lot. The Engineer will determine the PI.

The Engineer will average the results of the tests to determine the PI for the lot of material. If the PI for the lot is below 2.0 or above 9.0, the Engineer will reject the material. If the PI is between 2.0 and 9.0, the Engineer will implement the cost adjustment factors in Table 1.

If the material represented by a PI lot is subject to a unit price reduction for gradation, shale content, or both, the highest cost adjustment factor for that will be applied for PI is 1.0.

3. **Miscellaneous Properties.**
The Engineer will collect three samples for each 10,000 ton lot of material produced. If a fractional lot is less than 2,500 tons it will be included in the previous lot. The Engineer will determine shale content and the number of fractured faces.

If the material fails to meet the requirement for fractured faces, make corrections to the stockpile before incorporating additional material into the work.

If the material exceeds the maximum shale content by less than 3 percentage points, the Engineer will apply a price reduction as specified in Basis of Payment B, "Contract Price Adjustments". The Engineer will reject the material if the maximum shale content is exceeded by 3 or more percentage points.

CONSTRUCTION REQUIREMENTS

A. Stockpiling Aggregate.
In addition to the requirements of Section 106.05, "Stockpiling Aggregate and Salvaged Materials", do not operate equipment on stockpiles that will remain the property of the Department.

B. Placement and Compaction.

1. **General.**
Place aggregate in lifts not exceeding 6 inches of compacted material.

Uniformly mix aggregate placed in windrows before spreading.

Compact aggregate, utilizing pneumatic-tired rollers, until the surface is tightly bound and shows no rutting or displacement occurs under the roller operation.

2. **Limitations.**
   Do not place material on frozen subgrade.

   When the roadway is open to traffic, the following limitations apply:
   - The maximum windrow length is three miles; and
   - Spread material within 48 hours of placing the material in a windrow.

METHOD OF MEASUREMENT

The Engineer will measure, completed and in place, as specified in Section 109.01, "Measurement of Quantities".

BASIS OF PAYMENT

A. General.

Spec and Code	Pay Item	Pay Unit
350 - 0500	Gravel Surfacing	Ton
350 - 0501	Gravel Surfacing	Cubic Yard
350 - 0600	Stockpiled Gravel Surfacing	Ton
350 - 0601	Stockpiled Gravel Surfacing	Cubic Yard

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

B. Contract Price Adjustments.

1. **General.**
   The Engineer will determine contract price adjustments by multiplying the applicable adjustment factor by the contract unit price for the aggregate and the amount of material in the lot represented by the test.

   If contract price adjustments are warranted in more than one category, a contract price reduction will be applied for each area of deficiency.

2. **Aggregate Gradation Adjustment Factor.**
   The Engineer will determine the aggregate gradation adjustment factor if aggregate base does not meet the specified gradations for all required samples, as calculated:

   $$\text{Aggregate Gradation Adjustment Factor} = 5 \times \text{Sum of deviations from range limits on all sieves}$$

3. **Shale Content Adjustment Factor.**
   The Engineer will determine the shale content adjustment factor if the limits for shale are exceeded, as calculated:

   $$\text{Shale Content Adjustment Factor} = 5 \times (\text{Average of 3 Samples} - \text{Allowable Percentage})$$

4. Plastic Index Adjustment Factor.
The Engineer will determine the PI content adjustment factor using the Table 1.

Table 1	
PI Average	Pay Adjustment Factor
> 9.1	Non Acceptance
7.1 – 9.0	1.0
4.0 – 7.0	1.05
3.0 – 3.9	1.0
2.0 - 2.9	0.85
< 1.9	Non Acceptance

BAR LINEAR SHRINKAGE TEST METHOD

SCOPE

This method covers the determination of the linear shrinkage of soil when it is dried from a moisture content equivalent to the liquid limit to the oven-dry state.

DEFINITION

The linear shrinkage of a soil for the moisture content equivalent to the liquid limit, is the decrease in one dimension, expressed as a percentage of the original dimension of the soil mass, when the moisture content is reduced from the liquid limit to an oven-dry state.

APPARATUS

- Bar linear shrinkage (BLS) mold, stainless steel or brass (Figure 1), with inside dimensions of 150 mm ± 0,25 mm long by 10 mm ± 0,25 mm wide, and 10 mm ± 0,25mm deep
- Flat stainless steel or brass plate 200 mm by 200 mm by 6 mm
- Flexible spatula, with a blade approximately 100 mm (4 in.) long × 19 mm (0.75 in.) wide
- Pair of dividers and a millimeter scale ruler
- Drying oven, maintained at 110°C ± 5°C (230°F ± 9°F)
- Small, thick-bristle paint brush, about 6 mm (0.25 in.) wide

Figure 1: Bar linear shrinkage mold.

MATERIALS

- Petroleum jelly
- Distilled or deionized water

PREPARING THE MOLD

Prepare the mold by spreading a thin, even layer of petroleum jelly over inside of the mold using the paint brush. Place the prepared mold on the plate.

PREPARING THE SAMPLE

The bar linear shrinkage test is done on material passing the 0.425 mm (#40) sieve and should be done in conjunction with the Atterberg limit tests (AASHTO T 89 and T 90 or ASTM D4318). The moist soil sample remaining after the completion of the liquid limit test (AASHTO T 89) should be used to form the soil bar. This should be done immediately so that the moist material can be used without further mixing. If insufficient material is available, prepare a new sample as described in AASHTO T 89.

PROCEDURE

1. Fill one half of the mold with the moist soil by taking small pieces of soil on the spatula and pressing the soil down against one end of the mold and working along until the whole side is filled and the soil forms a diagonal surface from the top of one side to the bottom of the opposite side.
2. Turn the mold around and fill the other portion in the same manner.
3. Fill the hollow along the top of the soil in the mold so that the soil is raised slightly above the sides of the mold.
4. Remove the excess material by drawing the blade of the spatula once only from the one end of the mold to the other. Press down on the blade with an index finger so that the blade moves along the sides of the mold. Gently push the wet soil back into the mold with the spatula if it pulls away from the end of the mold during this process. **The soil surface should on no account be smoothed or finished off with a wet spatula.**
5. Air dry the soil bar at room temperature until the soil color starts to change, then place the mold and plate with wet material in the drying oven and dry at a temperature of between 105°C and 110°C (221°F and 230°F) until all shrinkage has stopped and constant mass has been reached. As a rule, the material is dried out overnight (12 hours), but three hours is usually sufficient.
6. Remove the mold and plate from the oven and allow to cool in the air.
7. If the bar has curved after drying, gently press it back into the mold, blow any dust and loose particles away, and then gently push the pieces together at one end of the mold to ensure that the individual pieces fit together tightly but without causing any further abrasion.
8. Measure the length of the dry bar with a steel ruler or dividers together with a steel ruler to the nearest 0.5 mm.

CALCULATIONS

Determine the linear shrinkage as a percentage of the original length of the bar using the following formula:

$$LS = 100 \times (L_W - L_D) / L_W$$

where:
L_W = length of the wet soil bar (150 mm)
L_D = length of the dry soil bar in mm

REPORT

Report the linear shrinkage to the nearest whole percent.

Example Contract Price Adjustment for Gravel Surfacing (2020 Spec SSP 6, Section 302.06 B)

Bid Price/Ton, $: 10

	Gradation (SSP6 Sec B.1.)					
Sieve	1"	3/4"	No. 4	No. 8	No. 30	No. 200
Upper Limit	100	100	75	62	45	15
Lower Limit		70	38	22	12	7

Plasticity Index (SSP6 Sec B.2.)	Misc. Properties (SSP6 Sec B.3.)
9	Shale: 12% Max
3	%FF: 10% Min

Date	Sample #	Tons	Gradation Test Results						Gradation Price Adjust	Plasticity Test & Price Adjustment		Misc. Properties Tests & Price Adjust.		Remarks
10,1,20	1	405	100	73	42	18	15	7.1	Gradation Lot 1, 1000 Tons		Plasticity Index Lot 1: 5000 Tons			
	2	775	100	85	50	22	18	9.4		4		8.4%	(Shale)	
	3	1125	100	70	38	19	14	7.6				22%	(% Fracture)	
Average Test Result			100	76	43	20	16	8.0						Contractor thinks there are dirtier areas of the pit that he can crush
Deviation from spec						2								
Sum of Deviations (A):								2						
Percent Deduction = 5 x (Sum of Deviations, A):								10.0%					Miscellaneous Properties Lot 1: 10,000	
Deduct = (tons in lot) x (bid price) x (Percent Deduction, B):									$1,125					
10,2,20	4	1520	100	74	44	20	17	9.2	Gradation Lot 2, 1000 Tons					Dirty areas of the pit didn't help, contractor indicates he will search for overburden buried during earlier pit reclamation
	5	2020	100	83	48	22	14	7.5						
	6	2520	100	71	29	20	15	8.1		1				
Average Test Result			100	76	40	21	15	8.3						
Deviation from spec						1								
Sum of Deviations (A):								1						
Percent Deduction = 5 x (Sum of Deviations, A):								5.0%						
Deduct = (tons in lot) x (bid price) x (Percent Deduction, B):									$698					
10,3,20	7	2820	100	72	40	22	17	9.4	Gradation Lot 3, 1000 Tons					Avg PI = 2 for 5000 ton lot, Pay Adj Factor = 0.85. Pay Adjustment = .15 x 5000 x $10 = $7500
	8	3450	100	80	44	22	13	6.5						
	9	3920	100	72	29	21	16	8.6		2				
Average Test Result			100	75	38	22	15	8.2						
Deviation from spec														
Sum of Deviations (A):								0						Contractor plans to import 10% overburden containing clay
Percent Deduction = 5 x (Sum of Deviations, A):								0.0%						
Deduct = (tons in lot) x (bid price) x (Percent Deduction, B):									$0		$7,500			

Example Contract Price Adjustment for Gravel Surfacing (2020 Spec SSP 6, Section 302.06 B)

Bid Price/Ton, $: 10

	Gradation (SSP6 Sec B.1.)					
Sieve	1"	3/4"	No. 4	No. 8	No. 30	No. 200
Upper Limit	100	100	75	62	45	15
Lower Limit		70	38	22	12	7

Plasticity Index (SSP6 Sec B.2.)	Misc. Properties (SSP6 Sec B.3.)
9	Shale: 12% Max
3	%FF: 10% Min

Date	Sample #	Tons	Gradation Test Results						Gradation Price Adjust	Plasticity Test & Price Adjustment		Misc. Properties Tests & Price Adjust.		Remarks
10,5,20	10	4450	100	71	41	24	20	11.5	Gradation Lot 4, 1000 Tons		Plasticity Index Lot 2: 5000 Tons			Contractor indicates imported overburden has PI of 20 and P200 of 60%
	11	5020	100	79	47	27	22	14.8						
	12	5620	100	73	35	25	21	12.4		8		6.5%	(Shale)	
Average Test Result			100	74	41	25	21	12.9				18%	(% Fracture)	
Deviation from spec														
Sum of Deviations (A):								0						
Percent Deduction = 5 x (Sum of Deviations, A):								0.0%					Miscellaneous Properties Lot 1:	
Deduct = (tons in lot) x (bid price) x (Percent Deduction, B):									$0					
10,6,20	13	6320	100	69	43	27	22	10.5	Gradation Lot 5, 1000 Tons					
	14	6950	100	81	51	29	22	13.7						
	15	7780	100	74	36	25	23	11.7		7				
Average Test Result			100	75	43	27	22	12.0						
Deviation from spec														
Sum of Deviations (A):								0						
Percent Deduction = 5 x (Sum of Deviations, A):								0.0%						
Deduct = (tons in lot) x (bid price) x (Percent Deduction, B):									$0					
10,7,20	16	8570	100	71	41	24	20	11.5	Gradation Lot 6, 1000 Tons			7.8%	(Shale)	**Plasticity Lot 2** Average = 8.7 --> no deduct
	17	9290	100	79	47	27	22	14.8				20%	(% Fracture)	
	18	9950	100	73	35	25	21	12.4		11				**Shale Lot 1** Average = 7.6 --> no deduct
Average Test Result			100	74	41	25	21	12.9						
Deviation from spec														
Sum of Deviations (A):								0						
Percent Deduction = 5 x (Sum of Deviations, A):								0.0%						
Deduct = (tons in lot) x (bid price) x (Percent Deduction, B):									$0					

10,000 Ton Pay Adjustment Summary		
Test	Deduction	%
Gradation	$1,823	1.8%
PI	$7,500	7.5%
Shale	0	0.0%
%Fracture	0	0.0%
LA Abrasion	not applicable	
Total:	**$9,323**	

Testing Costs for 10.000 Tons Gravel (1)			
# Tests	$/test	Total $	% of Contract
18	$136	$2,448	2.45%
6	$110	$660	0.66%
3	$75	$225	0.23%
3	$95	$285	0.29%
0	$250	$0	0.00%
		$3,618	3.62%

(1) Testing costs from a North Dakota Consulting Lab

Please use the link shown below, or Google: "Montana Guide Specification for Gravel Surfacing"

https://www.mdt.mt.gov/other/webdata/external/research/docs/research_proj/oil_boom/Guide_Spec_Gravel_Road_Surfacing_2018.pdf

Guide for Using NRCS Web Soil Survey (WSS) to Locate Gravel & Clay Sources (2-29-2020)

By stevemonlux@gmail.com on 2-29-2020 (Feedback is desired)

Purpose of Guide: Provide a recon tool to help locate potential gravel & clay sources where soil surveys exist to improve the efficiency of field investigations.

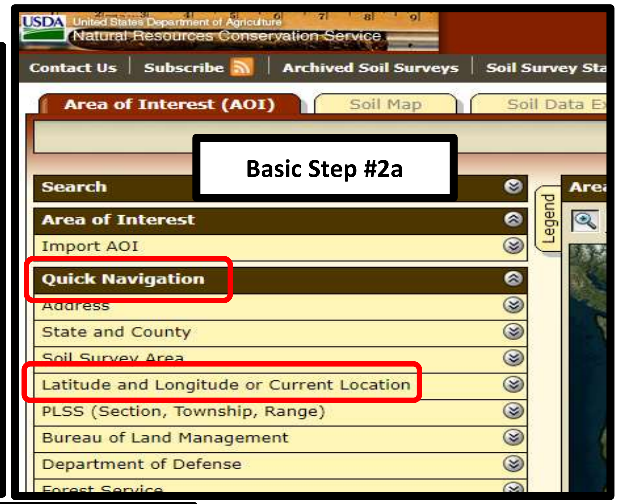
Limitations: The depth of soil surveys only extends from five to seven feet below the surface. The WSS rating system for gravel sources may not fit the intended purpose for gravel, so an Engineering Properties report should be reviewed to ensure correct interpretation. Some Federal lands are not surveyed.

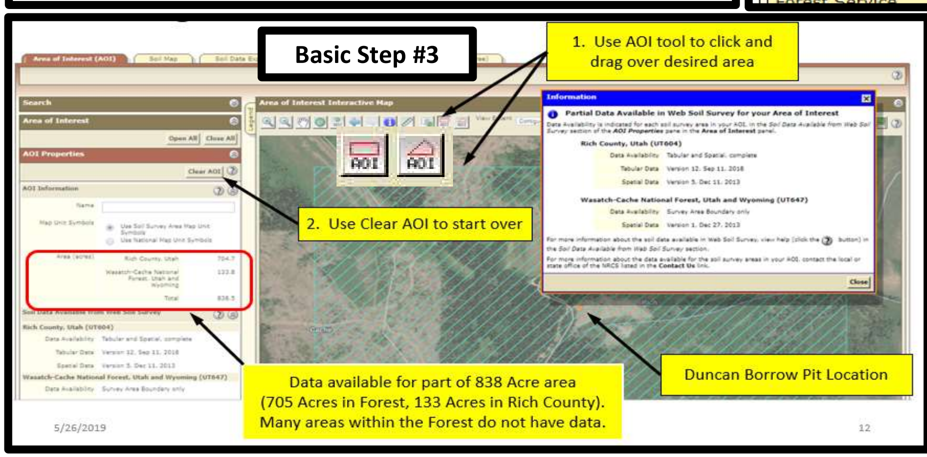
Basic Steps for Using WSS

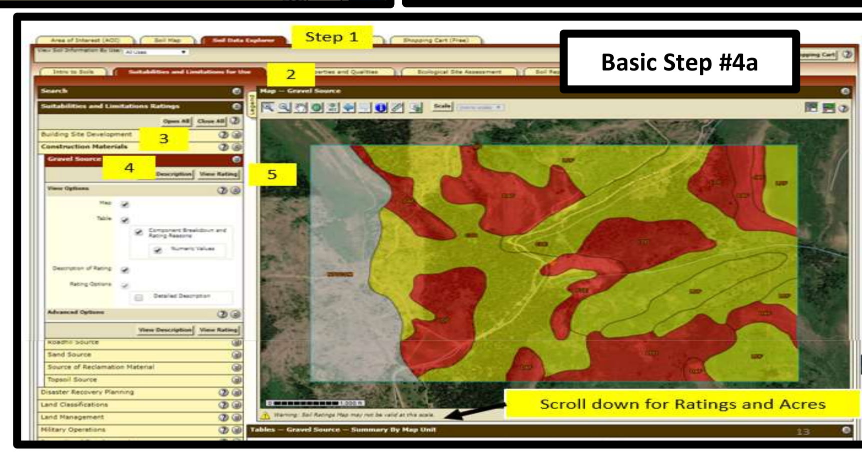
1. Google "NRCS WSS" (https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm) & click on the green button
2. Use one of the "Quick Navigation" tools to find the desired location for gravel. The example screen shots shown below use coordinates to find the desired location.
3. Use one of the "AOI" buttons to outline the Area of Interest, then click on "View".

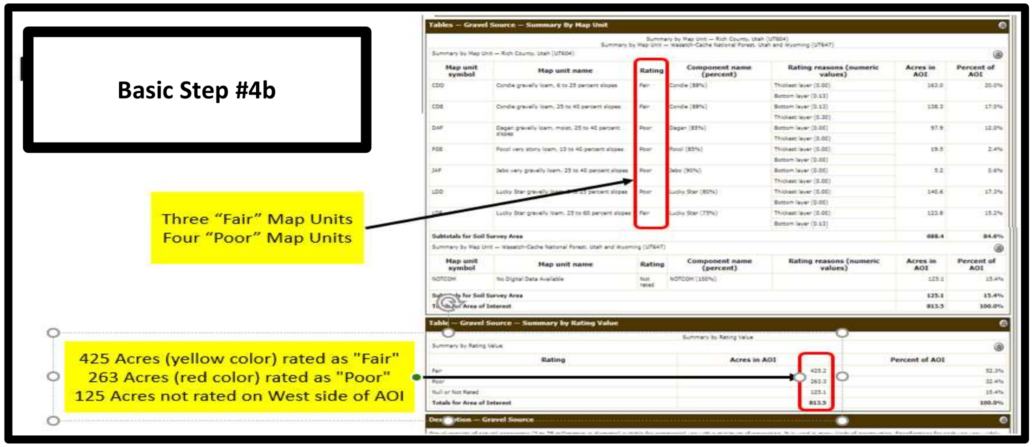
4. To do a rating of "Gravel Sources" within the AOI. Click on the following: (1) "Soil Data Explorer" (2) "Suitabilities and ..." (3) "Construction Materials" (4) "Gravel Source" (5) "View Rating"
5. To get specific information on Gradation and Plasticity Index (clay content). Click on the following: (1) "Soil Data Explorer" (2) "Soil Reports" (3) Soil Physical Properties" (4) "Engineering Properties" (5) "View Soil Report". To save report, select "Printable Version" name the report, the "View"
6. Determine if the desired quantities are likely available. Remember, if gravel exists at the maximum survey depth, it likely goes deeper
7. Outline potential areas to investigate and look for rock outcrops in the area on Google Earth

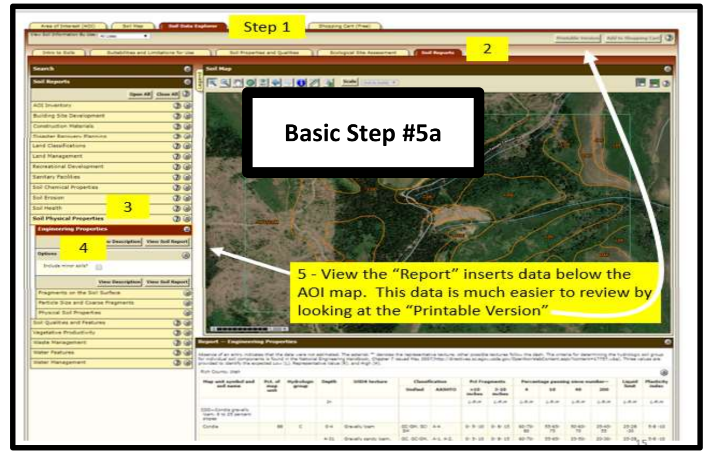
Screen Shots to Illustrate "Basic Steps" in the Process

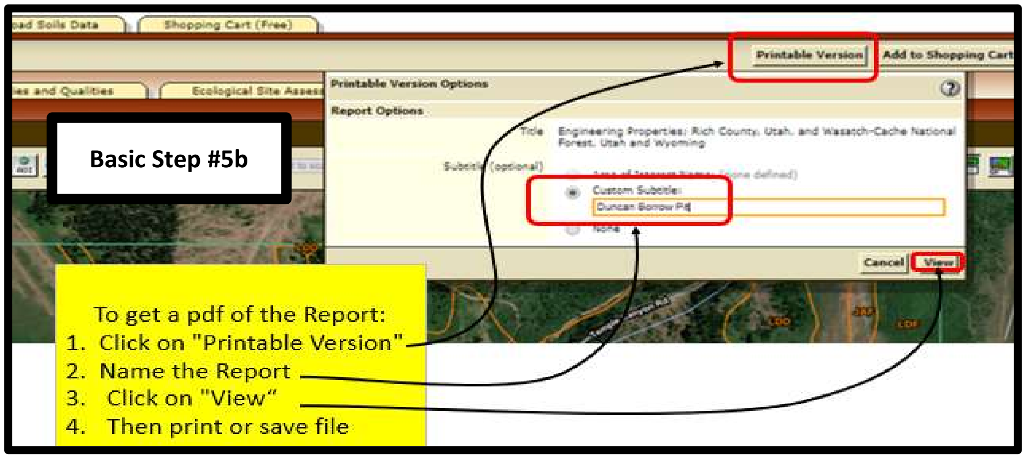


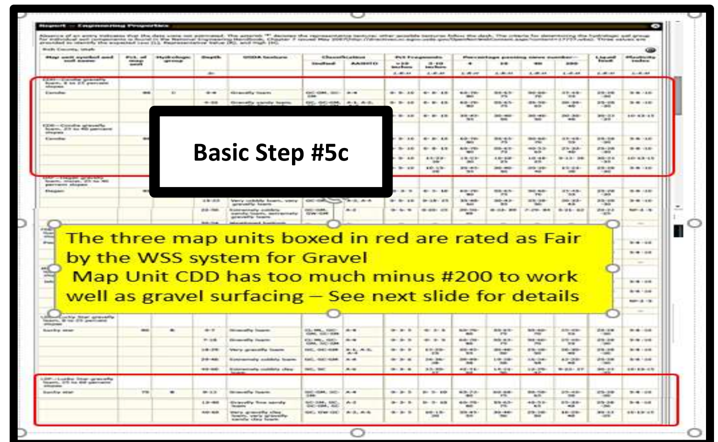


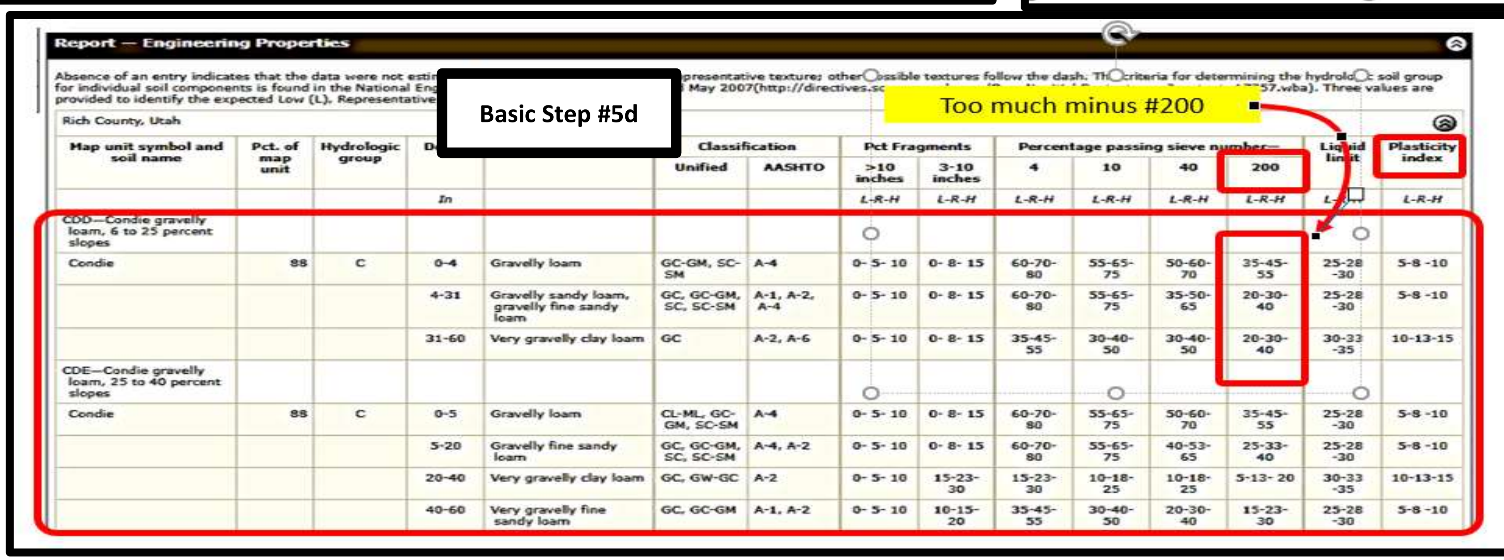












Map unit symbol and soil name	Pct. of map unit	Hydrologic group	D		Classification Unified	AASHTO	Pct Fragments >10 inches	3-10 inches	Percentage passing sieve number— 4	10	40	200	Liquid limit	Plasticity index
			In				L-R-H	L-R-H	L-R-H	L-R-H	L-R-H	L-R-H	L-R-H	L-R-H
CDD—Condie gravelly loam, 6 to 25 percent slopes														
Condie	88	C	0-4	Gravelly loam	GC-GM, SC-SM	A-4	0- 5- 10	0- 8- 15	60-70-80	55-65-75	50-60-70	35-45-55	25-28-30	5-8-10
			4-31	Gravelly sandy loam, gravelly fine sandy loam	GC, GC-GM, SC, SC-SM	A-1, A-2, A-4	0- 5- 10	0- 8- 15	60-70-80	55-65-75	35-50-65	20-30-40	25-28-30	5-8-10
			31-60	Very gravelly clay loam	GC	A-2, A-6	0- 5- 10	0- 8- 15	35-45-55	30-40-50	30-40-50	20-30-40	30-33-35	10-13-15
CDE—Condie gravelly loam, 25 to 40 percent slopes														
Condie	88	C	0-5	Gravelly loam	CL-ML, GC-GM, SC-SM	A-4	0- 5- 10	0- 8- 15	60-70-80	55-65-75	50-60-70	35-45-55	25-28-30	5-8-10
			5-20	Gravelly fine sandy loam	GC, GC-GM, SC, SC-SM	A-4, A-2	0- 5- 10	0- 8- 15	60-70-80	55-65-75	40-53-65	25-33-40	25-28-30	5-8-10
			20-40	Very gravelly clay loam	GC, GW-GC	A-2	0- 5- 10	15-23-30	15-23-30	10-18-25	10-18-25	5-13- 20	30-33-35	10-13-15
			40-60	Very gravelly fine sandy loam	GC, GC-GM	A-1, A-2	0- 5- 10	10-15-20	35-45-55	30-40-50	20-30-40	15-23-30	25-28-30	5-8-10

Gravel Source Investigation Guide (3-9-2020)

Purpose:

- Assist Agencies or Consultant firms they hire to investigate gravel sources
- Decrease rock crushing costs
- Increase quality of crushed gravel
- Determine gravel characteristics (potential quantities, gravel deposit layer thicknesses, estimated pit run gradation, and plasticity)
- Assist rock crushing contractors in more accurate bidding (reduce bidding contingencies, more realistic specifications, reduce contract disputes, etc.)
- This process has been reviewed by Consulting firms and crushing Contractors. This is a work in progress and improvements can be made. Please provide feedback to stevemonlux@gmail.com (406-544-1919). A power point presentation is available for this process.

Office Work:

1. For existing sources, compile all information from previous operations including site maps, field investigations, and test results.
2. Use the NRCS Web Soil Survey (WSS) to locate the best areas to investigate for new sources, and for more efficient investigation of existing sources. The WSS is an efficient tool for determining gradations and plasticity to depths of up to seven feet. A two-page step by step guide is available.
3. Print out a Google Earth image of the source with contours and mark potential test hole locations and pit boundaries.
4. Determine the desired quantities of gravel needed for both the next crushing contract and the life of the source.

Field Work:

1. Sampling Equipment: shovel, small scoop, one-gallon zip lock bags, five-gallon buckets or sample sacks (2-3 per test hole), sample tags, ¾" sieve (12" diameter), hanging scale, stakes, tape measure, yard stick, smart phone camera, drone with camera, measuring wheel and forms.
2. Excavate at least three test holes in the pit boundary (10 or more test holes may be necessary where desired quantities are large or where the subsurface layer depths and characteristics differ). Locate test holes far enough apart to obtain the desired gravel quantity and enough intermediate holes to define the layer depths with reasonable degree of certainty.
3. Excavate test holes in horizontal layers. Place each bucket load in windrows so that material differences can be identified, and depths recorded during the excavation (See Figure 1). Place a stake in the windrow where any changes occur. All cave-in material should be placed in a single pile away from the windrows. After the hole is excavated, photograph the windrows with a yardstick to show relative size of larger rock. Photograph the trench wall with a tape measure showing depth from the ground surface. A video of the trench

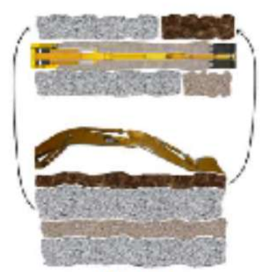


Figure 1

wall can be made by attaching the smart phone camera to the backhoe/excavator bucket – never get in the trench.

4. For EACH test hole, record the following information: GPS location, photographs of the depth of layers within each hole (with tape measure), description of materials encountered, and depth to water table (if applicable). Record information on the included Gravel Source Investigation Form.
5. Do not collect samples of topsoil. Collect 1-2-pound samples of overburden for sieve analysis and plasticity index testing in a one-gallon zip lock bag. Collect one or more 75 to 100-pound samples of ¾" minus from each test hole for sieve analysis and plasticity index. If significantly different layers exist in one test hole, take separate samples of each and record layer thickness and location in the test hole.
6. For each gravel sample, use a 12-inch diameter sieve with ¾" mesh on a five-gallon bucket to remove the larger particles to obtain the ¾" minus gravel for laboratory testing. Retain the material collected on the sieve in a separate bucket. Weigh the amount of minus ¾" and plus ¾" gravel (the 45Kg hanging digital scale by Brecknell works well for weighing buckets - Electro Samson Model ES-99). If very large cobbles and boulders are present but not weighed, estimate the maximum size and percent by weight. Record all information on the included Gravel Source Investigation Form. Discard the plus ¾". Label the ¾" minus sample for laboratory testing with the pit name, test hole number, layer location, and date.
7. For exposed highwalls, remove slough material, photograph the fresh cut face with a tape measure and then sample each layer from top to bottom by digging into the face. Proceed with sample separation on the ¾" sieve and weighing as in #6 above.
8. Sample all existing stockpiles over 1000 cubic yards. Locate the backhoe/excavator on top the pile if possible. Dig a hole to near floor depth making a sampling stockpile with each bucket load. Flatten the top of the sampling stockpile and take shovelfuls from the flattened surface (ASTM D75 Paragraph 5.3.3.1). If forced to sample from the stockpile side, dig into the pile to remove slough and sample as an exposed highwall at two or more locations around the pile. Estimate volumes of existing stockpiles using field
9. After all holes have been dug, take a drone photo of each stockpile and one photo that includes all the test hole locations. Make a site sketch showing approximate test hole locations and distance between holes.
10. Backfill all test holes at the end of each day.

Report Requirements:

The final report will provide critical information for contract preparation and historical use. The report should organize all the office, field, and lab work in a logical manner in electronic format for incorporation into contract documents. Make a pit plan site drawing that shows test hole locations, cross section views of each hole location with approximate top of hole elevation and layer depths. Summarize all field and laboratory test data on forms shown on page 3 and 4 of this document. Organize photos by Test Hole. Determine the estimated pit run gradation for each test hole following the example calculations on page 3. Make an estimate of the maximum quantities available for crushing based on area and suggested mining layer thickness. Provide recommendations on realistic crushed gradation and plasticity index limits.

Approximate Costs for Consulting Firms (Backhoes or Excavators are provided by County):

Mobilization ($/mile & $/day): Report (Lump Sum $): Washed Gradation ($/ea.):
Field Work ($/hr.): Plasticity Index($/ea.):

Gravel Source Investigation Form

Client: ______________________________ Page ____ of ____

Personnel: ______________________ Source Name: ______________________ Date: ______________

Test Hole Info				Test Sample Info										
Test Hole #	Coordinates		Elev. ft	Sample #	Material Description	Depth, ft.		Photos	Wgt 3/4" minus, lbs. (a)	Wgt 3/4" plus, lbs. (b)	% Not Weighed, Estimated (c)	Max Size (100% Passing), in. (d)	3/4" minus gradation multiplier	Plasticity, etc.
	North 46°	West 114°				From	To							
1	51' 3.01"	4' 24.61"	4000	1A	Overburden	0.0	1.0							Yes
				1B	Gravel w/cobbles	1.0	10.0		75	20	10	6"	0.71	Marginal
					Water Table	10.0								
2														

Spreadsheet available from stevemonlux@gmail.com

Example Calculations for 3/4" Minus Gradation Multiplier for Determining Estimated Pit Run Gradation

(a) = 75 lbs (b) = 20 lbs (c) = 10% (d) = 6 in

3/4" minus multiplier: (1.0-c)(a/(a+b)) = (1.0-.10)(75/(75+20)) = 0.71

Gradation & PI Test Report Template

Test Hole #		Example Calculations															
Sieve Size		Over-burden Lab Test	3/4" Minus Lab Test	Pit Run Gradation		Over-burden Lab Test	3/4" Minus Lab Test	Pit Run Gradation		Over-burden Lab Test	3/4" Minus Lab Test	Pit Run Gradation		Over-burden Lab Test	3/4" Minus Lab Test	Pit Run Gradation	
Std.	mm			% Overburden				% Overburden				% Overburden				% Overburden	
			0.71	0%	5%			0%				0%				0%	
3/4"	19.00	100	100	71	72												
1/2"	12.50	100	90	64	66												
3/8"	9.00	100	75	53	56												
#4	4.760	100	60	43	45												
#8	2.380	100	50	36	39												
#16	1.190	100	42	30	33												
#30	0.595	100	35	25	29												
#40	0.420	100	30	21.3	25.2												
#100	0.149	80	25	18	21												
#200	0.074	60.0	12	9	11												
Plasticity Index		28	4	3	8												

Spreadsheet available from stevemonlux@gmail.com

3/4" Minus Multiplier	See example calculations in the text box on **Gravel Source Investigation Form.**
Percent Overburden	The maximum percent overburden is based on depth of overburden that can be used versus the depth of pit run gravel layer to be mined. Where gravel lacks minus #200, either reduce mining depths, reject some large rock or import an outside source of minus #200. Also, be aware that mininig permits may require saving some overburden for pit restoration.

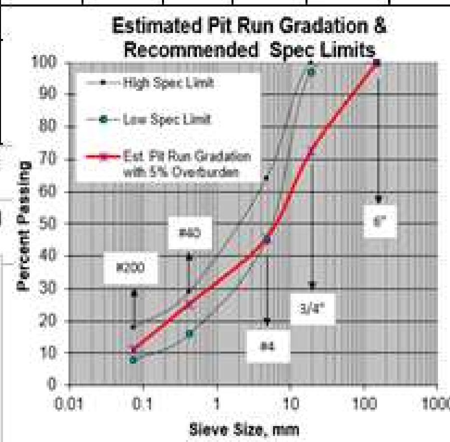
Estimate for **Pit Run Gradation with Overburden** (OB) = (% OB)*(OB % Pass) + (1-%OB)*)(% Pass Pit Run Grad w/o OB)

Estimate for **Pit Run PI with Overburden** (OB) = (% OB)*(OB PI)/[(%OB*OB%Pass) + (1-%OB)*(Pit Run %Pass)] +(1-%OB)*(Pit Run PI)/[(%OB*OB%Pass) + (1-%OB)*(Pit Run %Pass)]

Notes Placed on Pit Plan

Disclaimer for Test Results on Gravel Pit: "The quality of material in the provided pit is acceptable in general, but may contain layers or pockets of unacceptable materials. It is not feasible to ascertain from samples the quality of material for an entire deposit, and variations may be expected."

Suitability of the Gravel Pit: "The Contractor may have to selectively utilize materials from different areas of the source, blend, sort, reject, re-screen or import materials (clay, sand, etc.), as well as use special crushing, screening, excavation and other types of equipment to meet specifications. No additional compensation will be given for these efforts."



One Page Guide for Adding Bentonite to Road Gravel with a Water Truck (12-14-2020)

Guide Purpose: This one page guide provides a way to improve gravel with bentonite clay applied in slurry form with a water truck. Bentonite acts as a binder in gravel that will reduce washboards, raveling, gravel loss, dusting and blading. County Road Departments should consider this process where gravel has performance problems, leaving short sections untreated so that the benefits can be observed. Please provide feedback on this process to stevemonlux@gmail.com (406-544-1919) and call with any questions or comments. Special thanks to Stewart Krause of Wyo-Ben for sharing critical information.

Bentonite Sources: There are many types and forms of bentonite available from sources throughout the western states and southern Canada. The closest source is normally the least expensive. The best form of bentonite for making slurries is powder and can be purchased in 100 lb. bags, bulk bags (one to two ton), and in bulk shipments by pneumatic trailers. For first time users, bulk bags may be the most practical and the typical cost is around $120 per ton plus shipping. Some Bentonite sources are shown below..

Black Hills Bentonite, Casper WY 82601 (307) 265-3740
Canadian Clay Products, Wilcox SK 50G 5EO (306) 732-2085
Central Oregon Bentonite, Prineville OR 97754 (541) 477-3351
Minerals Technologies, Lovell WY 82431 (303) 551-5529
Performance Minerals, Lovell WY 82431 (307) 548-2271
Performance Minerals, Belle Fourche SD (307) 896-2596
Redmond Minerals, Aurora UT 84670 (866) 440-2529
Teague Mineral Products, Adrian OR 97901 (541) 339-3940
Tolsa Wyoming Bentonite, Casper WY 82604 (307) 224-5114
Western Clay Co, Aurora UT 84620 (888) 377-3719
Wyo-Ben, Greybull WY 82426 (406) 652-6351

Making Slurry: Turning the dry powered bentonite into a water slurry requires some initial work to get set up with a simple mixing device and a way to handle bulk bags. After initial set up, the process is quick and takes little effort. The mixing device can be fabricated in your shop or a "Jet Hopper" can be purchased from Wyo-Ben (406) 652-6351) for about $900 (See Figure 1). Building the Jet Hopper is a bit more complicated than it appears. With the Jet Hopper, it can take about 30 minutes to add one ton of powdered bentonite to 3000 gallons of water, when using a water truck pump that can generate a minimum flow of 80 gallons per minute at 40 psi pressure. Complete mixing may require some recirculation.

Fig 1. 3" Jet Hopper

Table 1, Bentonite Slurry Mixing (edit values in yellow cells)

Bentonite Bag Weight, lbs.:	2400	Mixing can be simplified by using an entire bulk bag of bentonite with a partial truck load of water. The water truck tank volume must exceed the "Gallons of Slurry" shown below
% Bentonite in Slurry (Percent Concentration by Weight)	10	Initially, no more than 10% concentration is suggested as the slurry can be more of a gel at higher concentrations. Depending on the bentonite, higher concentrations may be possible.
Water Needed for Chosen % Bentonite, Gal	2880	Amounts need not be exact. However, if values are significantly different, calculated values will be different than shown below
Gallons Slurry in Water Truck	3168	Amount should not exceed water truck tank volume

Slurry spreading and mixing is most efficient if both lanes can be done at once and traffic detoured. Spreading should be as uniform as possible and immediately bladed into the surface to keep traffic from pick up and tracking. If pumping of fines is desired, hot weather is needed and posting 10 mph signs has been found to help until the surface dries. When application rates exceed 0.30 gal/sy or where road grades exceed four percent, the application may have to be done in two passes to control runoff.

Table 2. Slurry Spreading and Mixing (edit values in yellow cells)

Desired Gravel Moisture Increase, %:	2	Moisture increase depends on in-place moisture during mixing. Suggest using 1% in Spring and 3% in Summer. If "pumping fines" to the road surface is desired, use percentages that are 1 to 2 percent higher
Road Width, Ft.:	22	Consider limiting treated width to 24 ft.
Gravel Mixing Depth, in:	1	Prior to treatment, the road crown should be built to 4 to 5 percent. This crown will not only reduce blading frequency but also improve road gravel performance by reducing potholes and gravel loss to the subgrade. Road surface scarification and shoulder berms may be necessary to improve uniformity of blade mixing, especially if "pumping fines" to the road surface is desired. If scarification is done, blading must cut to the bottom of the scarification depth to avoid problems caused by uneven compaction.
% Bentonite Added to Gravel:	0.20	Most gravels that need clay binder can benefit from bentonite contents up to around 2 to 3 percent by weight gravel. Going over that amount with multiple slurry applications over time can achieve and even exceed these percentages. The higher the percentage, the more likely that slippery road surfaces and even rutting in the spring months can occur. If problems do occur, blading to deeper depths can reduce the problem.
Slurry Spread Length, Ft.:	4850	This length is approximate. The length and width of spread as well as depth of mixing all influence the benefits of bentonite treatment. More is better, **except as indicated above.**
Slurry Application Rate, gal/SY:	0.27	Application may have to be split into two passes when rates exceed 0.30 gal/SY. Watch for runoff.

Warning: Do not add clay to totally worn-out gravel or where gravel layer thickness is less than 1 inch. Measure gravel thickness after re-building crown.

Adding Bentonite Clay with Water Truck

Concept: Make bentonite/water slurry, apply with water truck during road blading

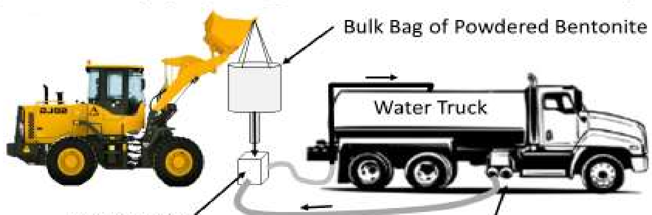
Details: Refer to one page guide

General Process

1. Determine desired clay content
2. Find source of bentonite, determine $/Ton & $/mi
3. Order bentonite in bulk bag(s)
4. Purchase or fabricate a 3 inch "Jet Hopper"
5. Mix 10% bentonite slurry (2400 lb bulk bag/3000 gallons water)
6. Spread slurry on one mile of worst washboard/reveled road segments and blade mix into gravel
7. Determine treatment value in Fall & following Spring seasons

Making and Applying Bentonite Slurry

Making Bentonite Slurry



Spreading Slurry

Blade Mixing Slurry

Amount of Bentonite Clay Needed to Fix Existing Gravel Problems

Existing Gravel Problems (Loose Rock, Dust and Washboards)	**% Bentonite Clay**, by Weight Gravel	**Gravel Mix Depth**, Inches	**Bentonite Application Rates**, #/SY	**Bentonite**, Tons per Road Mile for Treatment Width of 20 ft **(a)**
Low	1	1	1.0	6
Moderate	1.5	1.5	2.3	13
High	2	2	4.1	24
Extreme	2.5	2.5	6.3	37

Gradation Optimization for Granular Surface Materials

Developed in Iowa Highway Research Board Project TR-685

Purpose:

This program was developed based on a performance-based free-design approach used to recycle existing degraded surface materials of granular-surfaced roads by mixing in fresh quarry materials with or without subgrade to achieve an optimized target gradation. This program was developed in the IHRB Project TR-685 sponsored by the Iowa DOT.

Theory:

This program calculates the target optimal gradation based on the maximum aggregate size (D_{max}) and particle size distribution shape factor (n) of Fuller's model. The optimal range of the n value is recommended based on experimental and field test results obtained in Project TR-685. The gradation of representative existing surface and/or subgrade materials need to be accurately determined by users. If the subgrade will be incorporated to improve the plasticity of the surface material, the gradation of the existing surface plus subgrade mixture will be calculated in the program and compared to the theoretical optimal gradation, and then the missing size ranges will be identified. Since the resulting target virgin material gradation may not be locally available, the program can also optimize the proportion of two or three locally available materials to provide the closest gradation to the target virgin material gradation.

Inputs:

The green color cells are the inputs that need to be provided by users. The dry unit weights of the surface and subgrade materials can be adjusted based on users' experience. The average thicknesses and representative gradations of the existing surface aggregate and/or subgrade need to be measured. If the subgrade will not be incorporated, enter 0 for the thickness and gradation of the subgrade. The target final thickness of the surface aggregate layer must be more than four times the top size of the virgin material.

Instructions:

1. Click "Enable Editing" and then "Enable Contents" in the yellow security warning ribbon above.
2. Fill in the green cells.
3. Enter the gradations of the available virgin materials.
4. If using only two materials, enter zeros in the Quarry Material C column.
5. Click the "INSTALL SOLVER" button to activate the Excel Solver Add-in.
6. Click the "RUN" button.
7. The optimized proportions and quantities of the virgin materials are shown in the blue cells.

District		Project	Granular Surfaced Road	Date	9,03,2017
County	Cass County	Note	This is a trial version of the program	Designer	Cheng Li

Road Geometry

Road Length	5280	ft
Average Road Width	26	ft

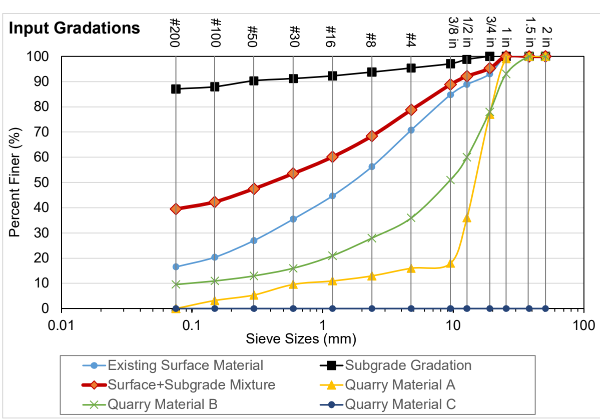
Final Design Parameter

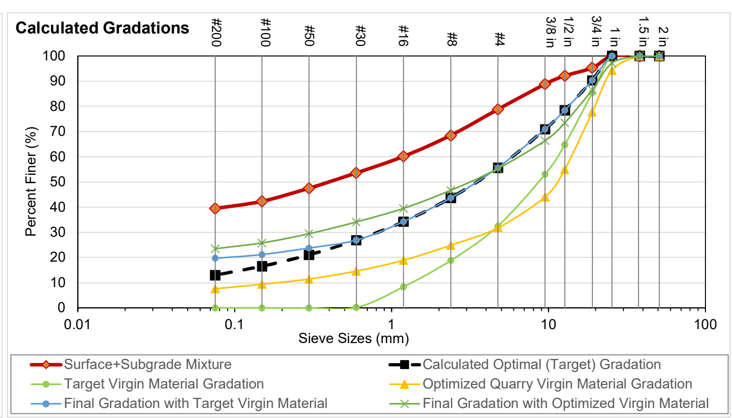
Target Final Thickness	5.00	in.
Target Maximum Aggregate Size (D_{max})	1.00	in.
Target Gradation Shape Factor (n)	0.35	0.35 to 0.40 is recommeded. The coarseness increases as the n value increases.

Properties of Existing Materials

Thickness of Existing Suface Material	1.50	in.
Dry Unit Weight of the Virgin Material	125	pcf
Thickness of Subgrade to be Incorporated into the Surface	1.00	in.
Dry Unit Weight of the Subgrade	90	pcf
Total Thickness of the Existing Surface and Subgrade	2.50	in.

			Input Gradations						Calculated Gradations			
Sieve No.	Sieve size (mm)	Optimal Gradation (%)	Existing Surface Material Gradation (%)	Subgrade Gradation (%)	Calculated Gradation of Existing Surface and Subgrade Mixture (%)	Quarry Material A (%)	Quarry Material B (%)	Quarry Material C (%)	Optimized Quarry Virgin Gradation (%)	Target Virgin Material Gradation (%)	Final Gradation with Target Virgin Material (%)	Final Gradation with Optimized Virgin Material (%)
2	50.8	100.0	100.0	100.0	100.0	100.0	100.0	0.0	100.0	100.0	100.0	100.0
1.5	38.1	100.0	100.0	100.0	100.0	100.0	100.0	0.0	100.0	100.0	100.0	100.0
1	25.4	100.0	100.0	100.0	100.0	99.0	93.0	0.0	94.3	100.0	100.0	97.1
3/4	19.00	90.3	93.0	100.0	95.3	77.0	78.0	0.0	77.8	85.4	90.3	86.5
1/2	12.70	78.5	88.9	98.8	92.1	36.0	60.0	0.0	55.0	64.8	78.5	73.5
3/8	9.51	70.9	84.8	97.1	88.8	18.0	51.0	0.0	44.1	53.0	70.9	66.4
#4	4.76	55.7	70.8	95.4	78.8	16.0	36.0	0.0	31.8	32.5	55.7	55.3
#8	2.38	43.7	56.3	93.8	68.5	13.0	28.0	0.0	24.8	18.9	43.7	46.7
#16	1.19	34.3	44.7	92.3	60.1	11.0	21.0	0.0	18.9	8.4	34.3	39.5
#30	0.595	26.9	35.5	91.2	53.6	9.6	16.0	0.0	14.7	0.2	26.9	34.1
#50	0.297	21.1	27.0	90.3	47.5	5.4	13.0	0.0	11.4	0.0	23.8	29.5
#100	0.149	16.6	20.4	88.0	42.3	3.2	11.0	0.0	9.4	0.0	21.2	25.8
#200	0.075	13.0	16.6	87.1	39.5	0.0	9.6	0.0	7.6	0.0	19.7	23.5
					Proportion (%)	21	79	0	100	100		
					Quantity (tons)	375.9	1411.6	0.0	1787.5	1787.5		





Detailed description of the curves:

Optimal Gradation (%)	(calculated)	Theoretical target gradation to reach. This is calculated from Fuller's model using the Dmax and n values.
Existing Surface Material Gradation (%)	**(user input)**	Measured gradation of existing granular surface materials.
Subgrade Gradation (%)	**(user input)**	Measured gradation of existing subgrade materials.
Calculated Gradation of Existing Surface and Subgrade Mixture (%)	(calculated)	Gradation of the mixture of existing surface materials and user-specified thickness of subgrade to incorporate.
Quarry Material A (%)	**(user input)**	Gradation of Quarry Material A.
Quarry Material B (%)	**(user input)**	Gradation of Quarry Material B.
Quarry Material C (%)	**(user input)**	Gradation of Quarry Material C.
Optimized Quarry Virgin Gradation (%)	(calculated)	Actual gradation of the mixture of Quarry Materials A, B and C blended in the calculated proportions shown below their gradation columns. This gradation will be blended with that of the thick red curve (existing materials) to try to reach the black (target) curve.
Target Virgin Material Gradation (%)	(calculated)	Theoretical gradation that would blend with the thick red curve (existing materials) to get as close as possible to the thick black (target) curve. The difference between this curve and the purple curve indicates how to get closer to the target (e.g. if purple is too high in sand range, need a quarry material with less sand to make it closer to green curve). If this curve reaches 0% finer then red curve is too high (gradation too fine) so reduce existing surface and/or subgrade materials.
Final Gradation with Target Virgin Material (%)	(calculated)	Theoretical final gradation that would be achieved by blending red (actual) and green (theoretical) curves.
Final Gradation with Optimized Virgin Material (%)	(calculated)	Actual final gradation that would be achieved by blending red (existing material) and purple (quary mixture) curves. The goal is to get this curve as close as possible to the black target gradation curve by trying different Quarry gradations A/B/C and varying the thickness of existing surface material and subgrade material to incorporate.

Guide for Adding Clay to Gravel Roads with Belly Dump Trailers (12-14-2020)

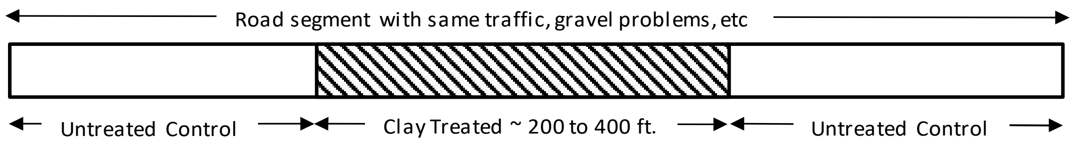
Feedback is desired: stevemonlux@gmail.com Special thanks to Clay (Teton Co ID) & Sparky (Sargent Co ND)

Guide Purpose: Encourage rural road departments to use bentonite clay to reduce washboards, raveling, blading and gravel loss on gravel roads. Show road crew personnel the benefits of clay by comparing gravel problems in clay treated gravel to untreated gravel. Page 1 is for spreading bentonite clay, page 2 is for spreading bank run clay which cost less.

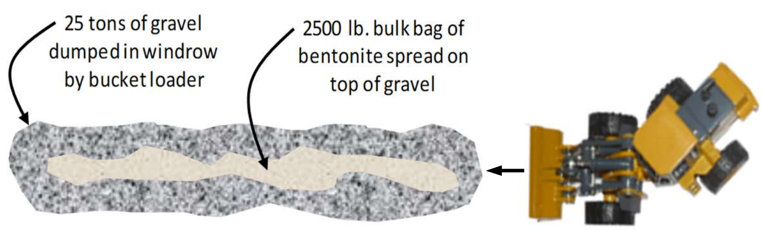
Warning: Do not add clay to totally worn-out gravel or where gravel layer thickness is less than 1 inch. Measure gravel thickness after re-building crown.

Guide Outline:

- Purchase a 2500 lb. bulk bag of granular bentonite for about $120. A list of bentonite suppliers is shown below.
- Locate a road segment about ¼ mile long that has consistent problems with raveling, wash boarding, dusting, etc. The amount of traffic on this segment should be similar from one end to the other. See diagram below.



- Water and then shape the road to the desired crown.
- Pull about 25 tons of gravel out of the stockpile and dump in a windrow on the pit floor. Spread the bulk bag of Bentonite on top the gravel windrow, then load out the belly dump starting at one end of the windrow.



- Spread the bentonite/gravel mix on about 200 to 400 feet of road. Stake the start and finish of the spread on the road shoulder and get a rough measurement between stakes.
- Note any areas that have bentonite concentrations.
- Blade mix the gravel-bentonite spread with in-place gravel to the depth shown in the table below

Inches of In-place Gravel to Mix with 25 Ton Gravel-Bentonite Blend in Belly Dump					
Road Width, ft	Spread lengths for Gravel/Bentonite Blend, ft (a)				
	100	200	300	400	500
16	4.2	2.1	1.4	1.0	0.8
20	3.3	1.7	1.1	0.8	0.7
24	2.8	1.4	0.9	0.7	0.6
(a) Mix depths with in-place gravel are based on achieving 2% bentonite by weight gravel, assuming one 2500 lb. bulk bag of bentonite is mixed with 25 tons of gravel					
2,500 lbs. bentonite will treat 125,000 lb gravel at 2% Bentonite. If 2,500 lbs. of bentonite is added to 50,000 lbs. of gravel in the belly dump, then another 75,000 lbs. of in-place gravel is needed to reach the 2% target.					

- Add water during blade mixing and when crown is achieved, wheel or roller compact.
- Visit the site monthly and after heavy rains to check conditions. If a slick clay surface develops, remix those areas to a deeper depth.
- Determine if the treated area has less washboards and raveling than the adjoining untreated areas. Make a final determination the following spring when moisture conditions are normally the highest.
- If results are good, refine the process using the table below as a guide for clay quantities needed for larger projects.

Existing Road Problems (Loose Rock, Dust and Washboards)	**Gravel Mix Depth**, Inches	**% Bentonite Clay** by Weight Gravel	Bentonite App. Rates, #/SY	Bentonite Quantity, Tons/mi (a) Treated Road Widths 16 ft.	20 ft.	24 ft.
Low	1	1	1.0	5	6	7
Moderate	1.5	1.5	2.3	11	13	16
High	2	2	4.1	19	24	29
Extreme	2.5	2.5	6.3	30	37	45

(a) Use three times the amount shown if bank run clays are used instead of bentonite clay.

Note: For the road widths and mixing depths shown, rotary mixing is much more efficient than blade mixing.

Bentonite Sources

Performance Minerals, Lovell WY 82431 (307) 548-2271
Performance Minerals, Belle Fourche SD (307) 896-2596
Black Hills Bentonite, Casper WY 82601 (307) 265-3740
BLM, Salmon ID 83467 (208) 756-5495
Canadian Clay Products, Wilcox SK 50G 5EO (306) 732-2085
Central Oregon Bentonite, Prineville OR 97754 (541) 477-3351
Minerals Technologies, Lovell WY 82431 (303) 551-5529
Redmond Minerals, Aurora UT 84670 (866) 440-2529
Teague Mineral Products, Adrian OR 97901 (541) 339-3940
Tolsa Wyoming Bentonite, Casper WY 82604 (307) 224-5114
Western Clay Co, Aurora UT 84620 (888) 377-3719
Wyo-Ben, Greybull WY 82426 (406) 652-6351

Warning: Do not add clay to totally worn-out gravel or where gravel layer thickness is less than 1 inch. Measure gravel thickness after re-building crown.

Spread Bank Run Clay with Belly Dump

Concept: Add bank run clay and gravel to belly dump to help clay flow and spread uniformly during high speed spreading

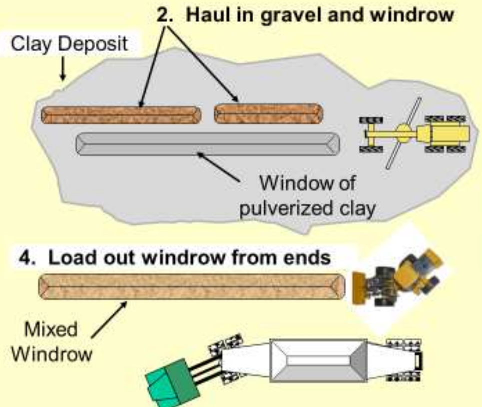
Details: Refer to one page guide

Note: If spread is poor, lower clay moisture or add more gravel

General Process:

1. Locate bank run clay source, dig holes to check moisture
2. Pulverize clay with blade, rotary mixer, disc, etc. & windrow with blade
3. Spread gravel windrow next to clay windrow and blade together
4. Reload belly dump with gravel clay mixture
5. Spread on 300 to 500 feet of road surface → If uneven spread, use more gravel on next load
6. Blade mixture into existing gravel

Belly Dump Clay Spreading



5. Spread on 300 to 500 ft of road

6. Water, Blade Mix and Compact

Amount of Bank Run Clay Needed to Fix Existing Gravel Problems

Existing Gravel Problems (Loose Rock, Dust and Washboards)	**% Bank Run Clay,** by Weight Gravel	**Gravel Mix Depth,** Inches	**Bank Run Clay Application Rates,** #/SY	**Bank Run Clay,** Tons per Road Mile for Treatment Width of 20 ft **(a)**
Low	3	1	3.0	20
Moderate	4.5	1.5	6.9	40
High	6	2	12.3	70
Extreme	7.5	2.5	18.9	110

Target Spread Length (ft) = (Belly Dump Load, Ton) x 2000 x (Parts clay) ÷ (Parts Gravel +1) / (Road width, ft) x (Mixing Depth in inches ÷ 12) x (Gravel Density of 135 lbs/CF) x (ClayTarget %) ÷ 100