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Earth and Aggregate
Surfacing Design Guide



Natural
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AEN-4 Earth and
Aggregate Surfacing
Design Guide

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Introduction

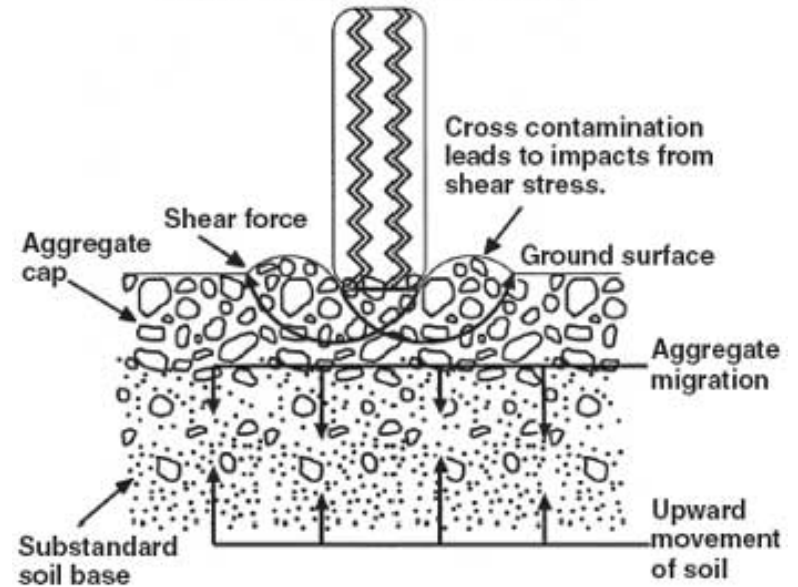
This document provides technical design guidance for aggregate surfacing on existing soils (subgrade) and applies to the conservation practices (CP) listed below.

- Access Road (Code 560)
- Heavy-Use Area Protection (Code 561)
- Trails and Walkways (Code 575)
- Stream Crossing (Code 578)



Content

- Literature Review
- Aggregate and Similar Surface Materials
- Aggregate Components
- Aggregate Surfaced CP Planning and Field Investigation
- Design of Unpaved-Aggregate Access Roads
- Design of Heavy-Use Area Protection (HUAP)
- Design of Animal Trails and Walkways
- Design of Stream Crossings
- Subgrade Stabilization



Failure Mode of Aggregate Surfaced Road (U.S. Forest Service, 2008)



Literature Review

Low-volume, unpaved roads are often built on poor subgrades. Much of the criteria developed to date originated with the construction of footings over soft subgrades. For very soft and soft cohesive soil conditions, saturation is often assumed, and the bearing capacity of the soil is defined by a localized shear equation—

$$q_{ult} = (\gamma B/2)N_\gamma + CN_c + q_{ob}N_{ob}$$

Where:

γ is the unit weight of the soil,

B is the footing width,

C is the soil's cohesion parameter,

q_{ob} is the vertical overburden pressure on the footing.

N_γ , N_c , and N_{ob} are bearing capacity factors that are dependent upon the angle of internal friction of the soil, ϕ

Literature Review



- For a rapidly loaded footing on the surface of a soil, the conditions are approximately undrained, and ϕ is approximately zero. Since the load is applied to the surface, q_{ob} is also zero. Thus, for these conditions, the bearing capacity of the footing depends upon the cohesion of the material or C .
- For rapid cyclic loading conditions in pavements, the allowable subgrade stress is defined by the simplified ultimate bearing capacity described in Terzaghi et al. (1996), as—

$$q_{ult} = CN_c$$

Where q_{ult} is the ultimate bearing capacity of the soil, C is the shear strength of the soil or cohesion for saturated clays, and N_c is the bearing capacity factor.

Literature Review



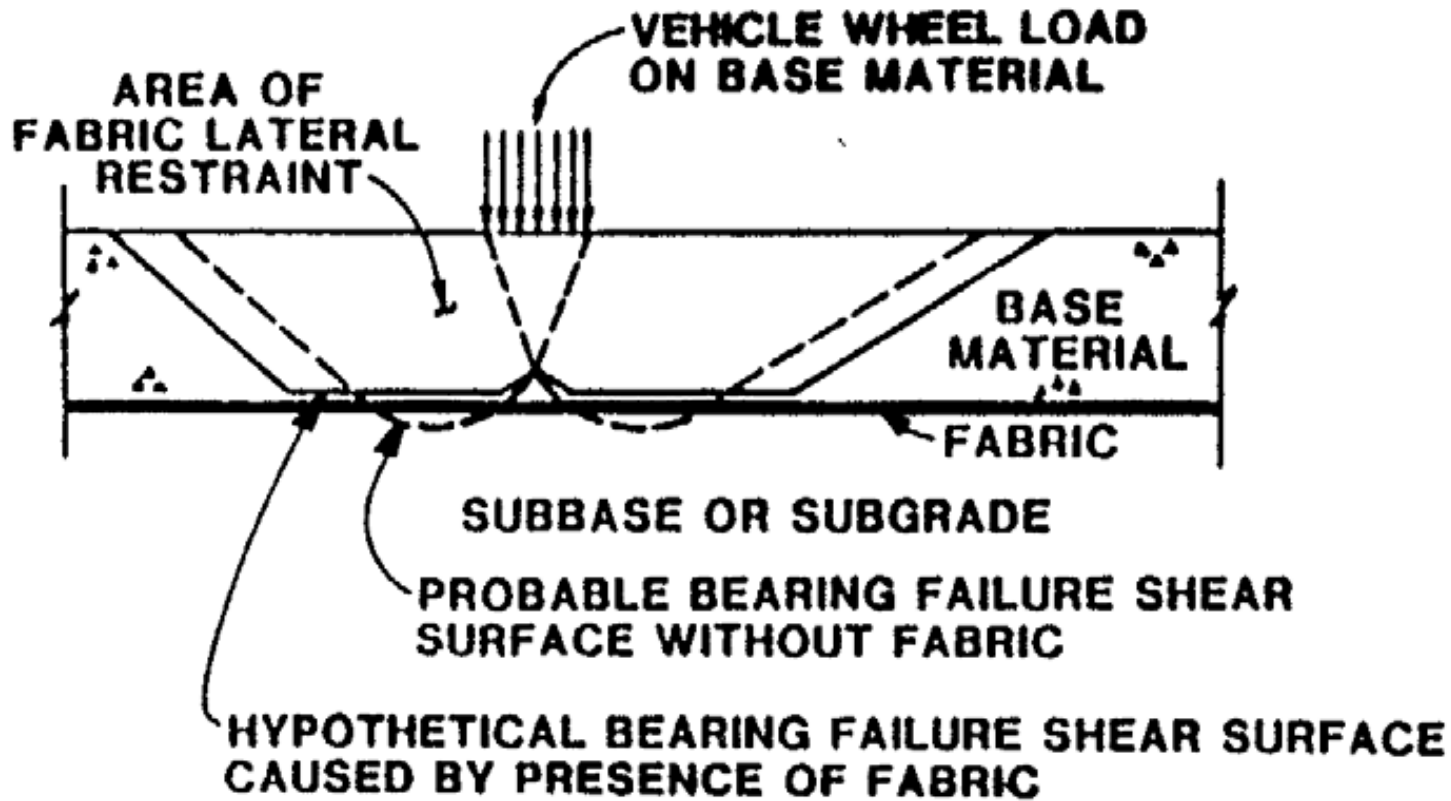
Summarizing the ultimate bearing capacity theory in terms of the Mohr-Coulomb failure criteria for soils. The Mohr-Coulomb soil shear strength is—

$$S_u = C + \sigma_n \tan \phi$$

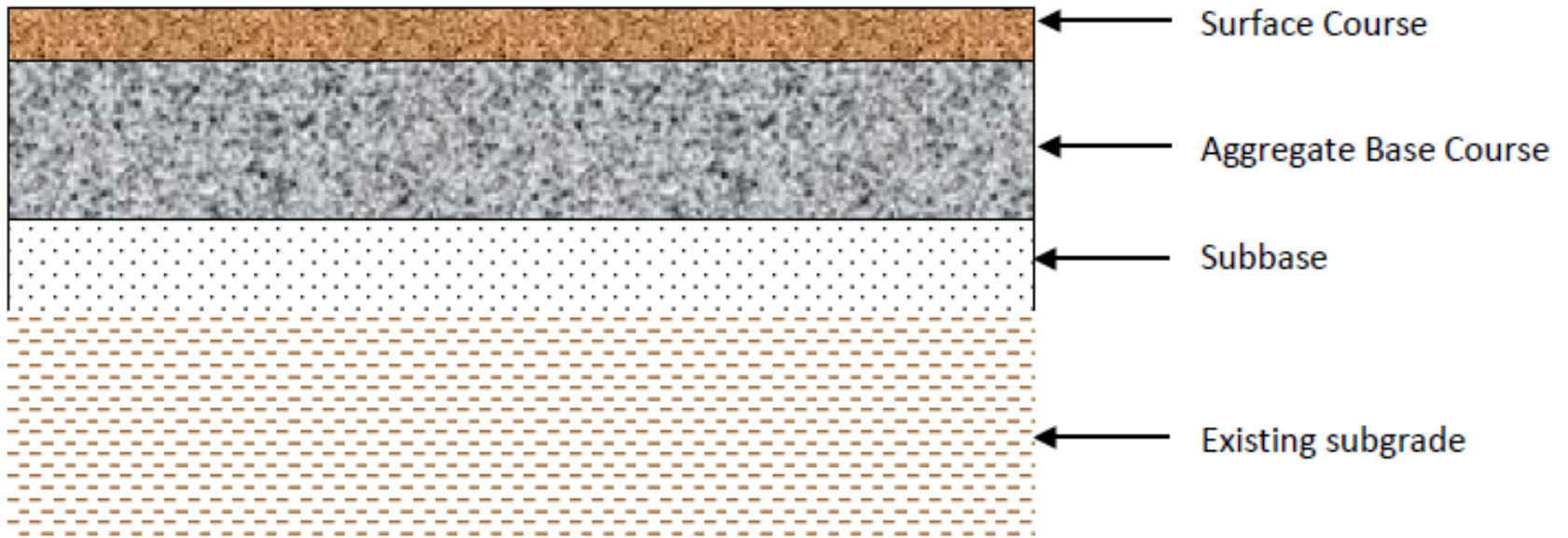
Where S_u is the undrained shear strength of the soil, C is the cohesion, σ_n is the effective normal stress, and ϕ is the soil's angle of internal friction. For soft saturated clay and subgrades, ϕ is approximately zero indicating the soil shear strength is approximately equal to its cohesion.



Literature Review



Aggregate Components



Aggregate Components



Surface Course.—The top layer of applied materials. The surface course carries the traffic load, provides a finished surface for traffic and livestock comfort.

Aggregate Base Course.—A support or stabilizing layer of applied materials.

Subbase.—A foundation layer placed over the subgrade and below the aggregate base course layer. The subbase typically consists of a compacted granular material that helps transition the aggregate base course to subgrade.

Subgrade. —The in-place material (usually the natural soil). Note that the subgrade is typically scarified to a depth of at least 6 to 12 inches to remove any organic or deleterious materials. The subgrade is the most important part of the aggregated layer system

Aggregate Components



Subgrade. —The in-place material (usually the natural soil). Note that the subgrade is typically scarified to a depth of at least 6 to 12 inches to remove any organic or deleterious materials. The subgrade is the most important part of the aggregated layer system.

- Layer on which the remainder of the structure is supported and helps resist the destructive effects of traffic and weather.
- Acts as a construction platform for building subsequent layers.
- If there are any subgrade performance issues due to lack of strength or uniformity, the entire section will have to be removed and replaced to correct the problems.
- The subgrade soil type, undrained shear strength and the water table's location within the subgrade will determine the design of the succeeding component layers of aggregate materials.

Aggregate Surfaced CP Planning and Field Investigation

In advance of a site reconnaissance/Field Investigation:

- Review of subsurface investigations (historical data) at or near the project site
- Review of construction and records of structural performance problems at nearby projects
- Review of U.S. Geological Survey (USGS) maps, reports, publications, and Web sites (<https://www.usgs.gov/>)
- Review of State geological survey maps, reports, and publications
- Review of the NRCS Web Soil Survey or soil maps (<http://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm>)



Aggregate Surfaced CP Planning and Field Investigation

Design and construction plans:

- Project purpose
- Construction materials
- Access restrictions for equipment
- Location of underground and overhead utilities
- Obstructions
- Right-of-way constraints
- Environmental issues



Aggregate Surfaced CP Planning and Field Investigation

General site conditions:

- Geologic setting
- Drainage
- Precipitation
- Escarpments, outcrops, erosion features, and surface settlement
- Flood levels



Subsurface Investigation

- **Subgrade Depth – Understand 6-12 in. subgrade removed.**
- **Subgrade Classification**
 - ASTM D 2488, Description and Identification of Soil (Visual-Manual Procedure).
 - ASTM D 2487, Classification of Soils for Engineering Purposes (Unified Soil Classification System)



Subgrade Classification

American Association of State Highway and Transportation Officials (AASHTO) soil classification system (A-1 thru A-7)

General Classification	Granular Materials								Silt-Clay Materials						
	35 percent or less of total sample passing No. 200 (75 µm)								More than 35 percent of total sample passing No. 200 (75 µm)						
Group Classification	A-1		A-3 ^[1]		A-2				A-4		A-5	A-6		A-7	
	A-1-a	A-1-b	A-3	A-3a	A-2-4	A-2-5	A-2-6	A-2-7	A-4a	A-4b		A-6a	A-6b	A-7-5	A-7-6
Sieve analysis, percent passing:															
No. 10 (2 mm)	50 max					*					*				*
No. 40 (425 µm)	30 max	50 max	51 min	^[2]					^[3]	^[4]					
No. 200 (75 µm)	15 max	25 max	10 max	35 max	35 max	35 max	35 max	35 max	36 min	50 min	36 min		36 min		36 min
Characteristics of fraction passing No. 40															
Liquid limit	—	—	Non-Plastic	—	40 max	41 min	40 max	41 min	40 max	41 min	41 min	40 max		41 min	
Plasticity index	6 max	6 max		6 max	10 max	10 max	11 min	11 min	10 max	10 max	10 max	11 – 15	16 min	≤LL-30	>LL-30
Group Index	0				4 max				8 max		12 max	10 max	16 max	20 max	
Usual types of significant constituent materials	Stone fragments, gravel and sand		Fine sand	Sand	Silty or clayey gravel and sand				Silty soils		Clayey soils				
General rating as subgrade	Excellent to good								Good to fair						

Notes

With the test data available, the classification of a soil is found by proceeding from left to right on the chart. The first classification that the test data fits is the correct classification.

* A-2-5 is not allowed under 703.16.B. A-5 and A-7-5 is not allowed under 703.16.A. See "Natural Soil and Natural Granular Soils" (203.02.H) in this manual

** A-4b is not allowed in the top 3 feet (1.0 m) of the embankment under 203.03.A.

[1] The placing of A-3 before A-2 is necessary in the "left to right" process, and does not indicate superiority of A-3 over A-2.

[2] A-3a must contain a minimum 50 percent combined coarse and fine sand sizes (passing No. 10 but retained on No. 200, between 2 mm and 75 µm).

[3] A-4a must contain less than 50 percent silt size material (between 75 µm and 5 µm).

[4] A-4b must contain 50 percent or more silt size material (between 75 µm and 5 µm).

Subgrade Strengths



Field Tests:

- **Pocket penetrometer or miniature torvane – ASTM D4648**
- Corps of Engineers (COE) Static Cone Penetrometer – ASAE S313.3
- COE Dual Mass Dynamic Cone Penetrometer (DCP) – ASTM D6951
- Field Vane Shear (FVS) – ASTM D2573
- Field California Bearing Ratio (CBR) – ASTM D4429
- Standard Penetration Test (SPT) – ASTM D1586
- Cone Penetrometer Test (CPT) - ASTM D5778



Torvane Tests



Torvane Device - Directly measures undrained c parameter



Very Soft - Less than 250 psf

Soft - 250 - 500 psf

Medium - 500 - 1,000 psf

Stiff - 1,000 - 2,000 psf

Very Stiff - 2,000 - 4,000 psf

Hard - > 4,000 psf

Soft Clays – Field – Torvane Tests

Torvane Device - Directly measures undrained c parameter

TORVANE COMPUTATION WORKSHEET

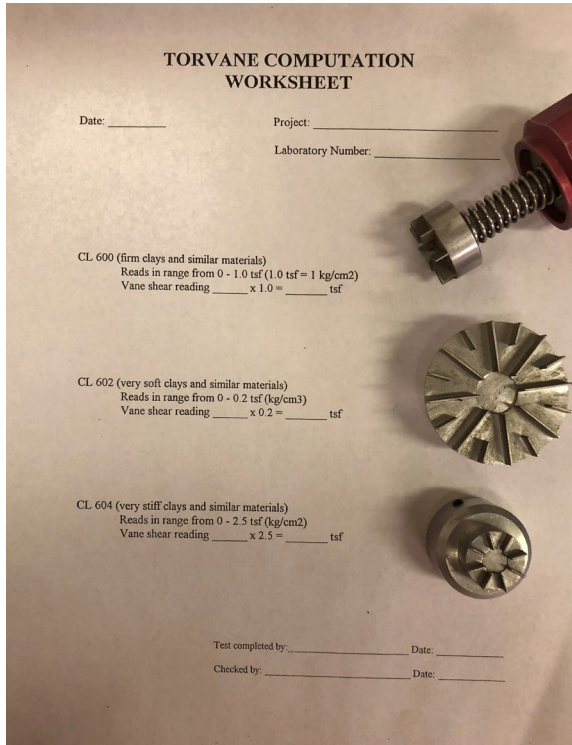
Date: _____ Project: _____
Laboratory Number: _____

CL 600 (firm clays and similar materials)
Reads in range from 0 - 1.0 tsf (1.0 tsf = 1 kg/cm²)
Vane shear reading _____ x 1.0 = _____ tsf

CL 602 (very soft clays and similar materials)
Reads in range from 0 - 0.2 tsf (kg/cm²)
Vane shear reading _____ x 0.2 = _____ tsf

CL 604 (very stiff clays and similar materials)
Reads in range from 0 - 2.5 tsf (kg/cm²)
Vane shear reading _____ x 2.5 = _____ tsf

Test completed by: _____ Date: _____
Checked by: _____ Date: _____



1. Select vane size.
2. Make sure zero on dial is aligned with index mark.
3. Test surface should be flat.
4. Press torvane into soil to the depth of blades and maintaining a constant vertical pressure while turning the knob.
5. Time the rate of rotation such that failure develops in 5 to 10 seconds.
6. After failure develops release the remaining spring tension slowly and the index mark on the knob will indicate the max shear value.

Pocket Penetrometer



The pocket penetrometer measures the compressive strength (q_u) of the soil. Most penetrometers available today contain units of tons/ft² or kg/cm², and the compressive strength is read directly from the gauge. Some common conversions are:

1 ton/ft² = 2000 psf = 13.9 psi

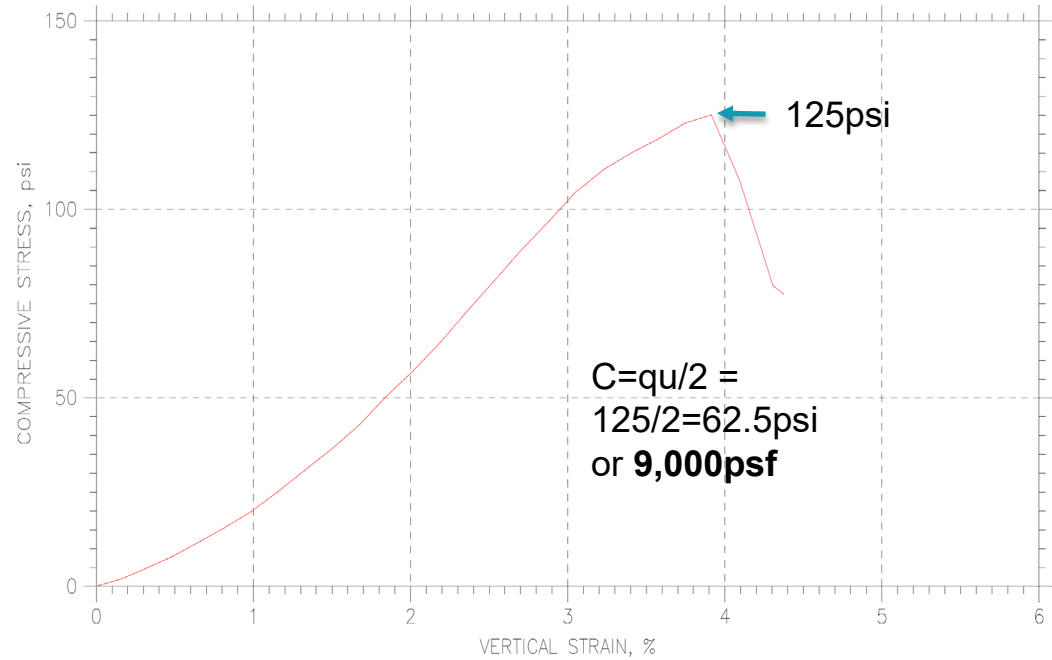
$C = q_u/2$

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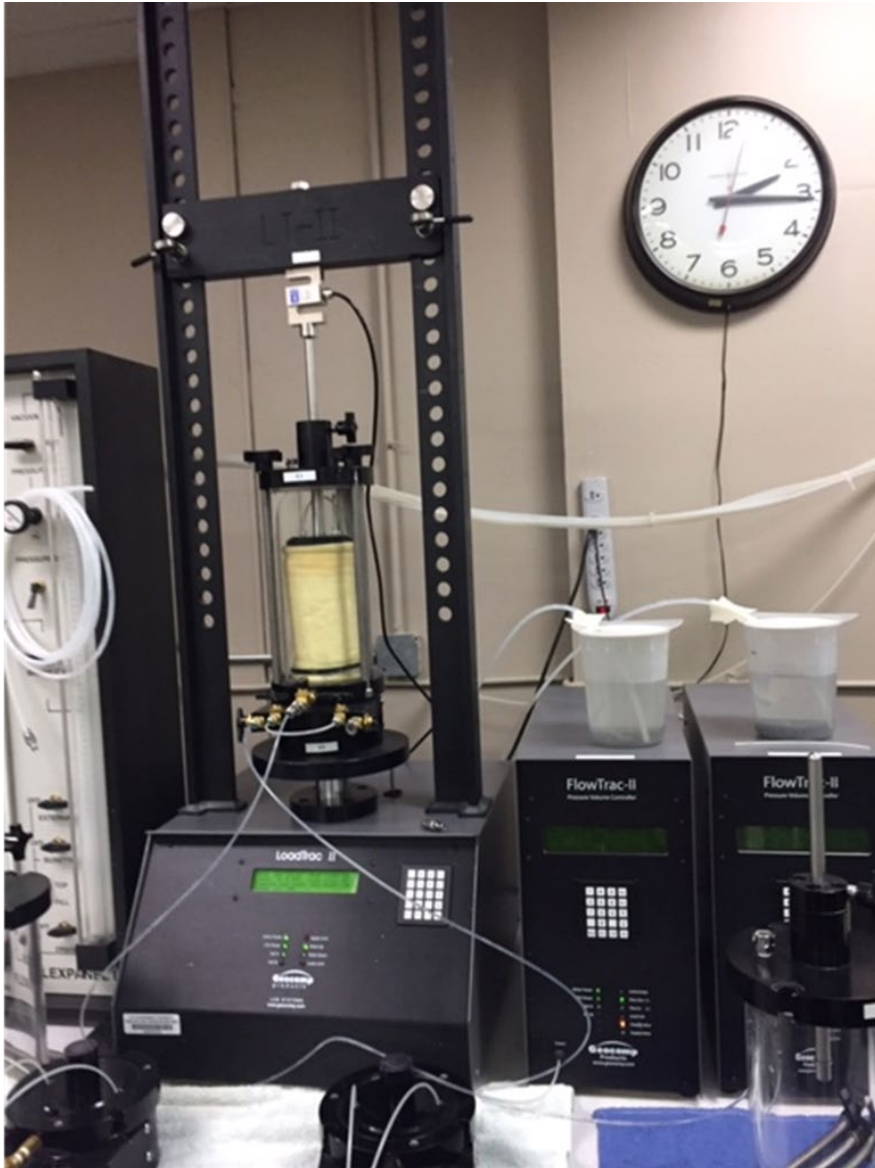




UNCONFINED COMPRESSION TEST REPORT







Laboratory Shear Tests:

Unconfined Compression (q_u)

Triaxial Shear

- Unconsolidated Undrained (UU)
- Consolidated Undrained (CU)
- Consolidated Drained (CD)
- Consolidated Undrained w, pore water pressure measured (CUBar)

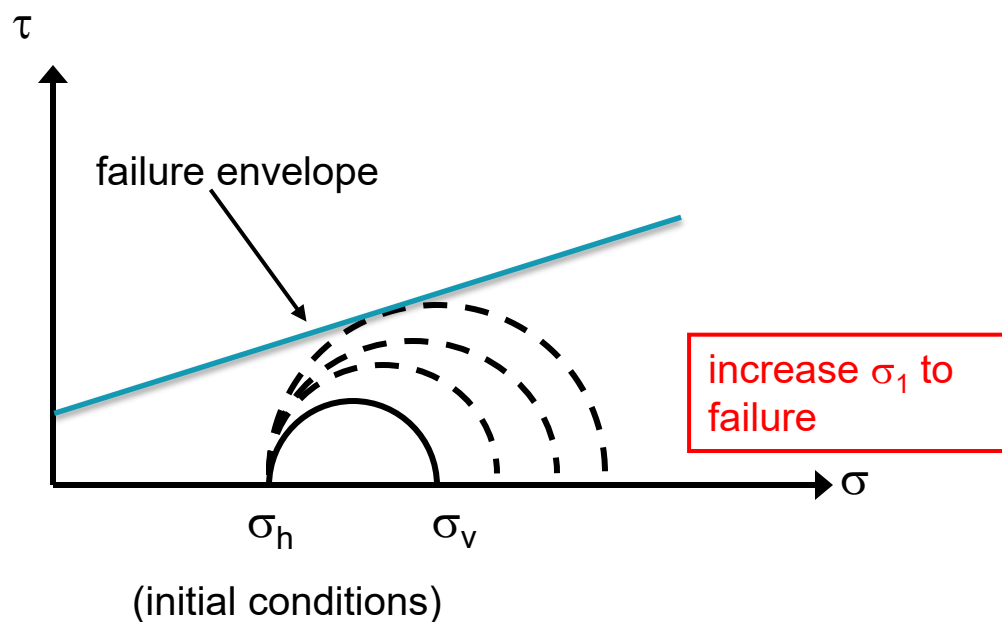
Direct Shear (CD)

Field Tests

Shear Tests for UU Conditions

Unconsolidated, undrained conditions

- Rapid loading \rightarrow footing, embankment



Undrained Shear Strength

Table 3: Undrained Shear Strength Estimates

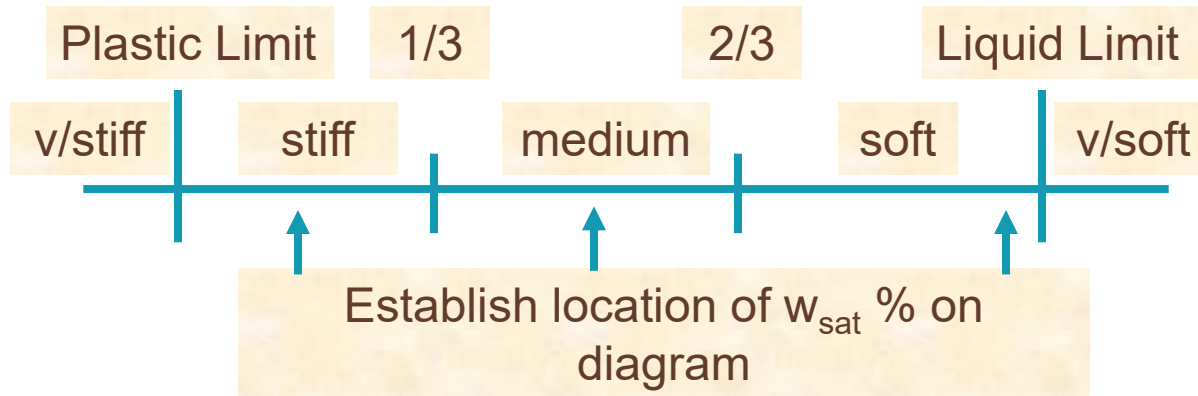
Consistency	Identification Procedure	Undrained Shear Strength (C), Psf	N ₆₀ (SPT) Blows/Ft.
Very Soft	Thumb penetrates > 1 inch, extruded between fingers	< 250	< 2
Soft	Thumb penetrates 1 inch, molded by light finger pressure	250-500	2-4
Medium	Thumb penetrates 1/4 inch, molded by strong finger pressure	500-1,000	4-8
Stiff	Indented by thumb but not penetrated	1,000-2,000	8-15
Very Stiff	Not Indented by thumb, but indented by thumbnail	2,000-4,000	15-30
Hard	Not Indented by thumbnail, Indented with knife	> 4,000	> 30



Steps in Evaluating Consistency of Saturated Clay



Obtain data - LL, PI, either γ_{dry} or $w_{sat}(\%)$
 Calculate PL (not usually reported)
 $PL = LL - PI$



Evaluating Consistency of Saturated Clay

Steps to determine w_{sat} (%):

- For **saturated** deposit, obtain sample and measure oven dry $w(\%)$.
- For **unsaturated** deposit, measure dry density, assume value for G_s and calculate theoretical saturated $w(\%)$.

$$w_{sat} (\%) = \left[\frac{\gamma_w}{\gamma_d} - \frac{1}{G_s} \right] \times 100$$



Example



What is the saturated water content of the following clay compared to its LL and PL?

**Given: LL = 59, PI = 36, $\gamma_{dry} = 1.28 \text{ g/cm}^3$
Assume $G_s = 2.70$**

$$w_{sat} (\%) = \left[\frac{\gamma_w}{\gamma_d} - \frac{1}{G_s} \right] \times 100$$



Example

Begin Constructing a consistency diagram by locating the LL value of 59.



Example



Next, calculate the Plastic Limit, which is equal to the LL minus the PI and plot that.

$$PL = 59 - 36 = 23$$



Example



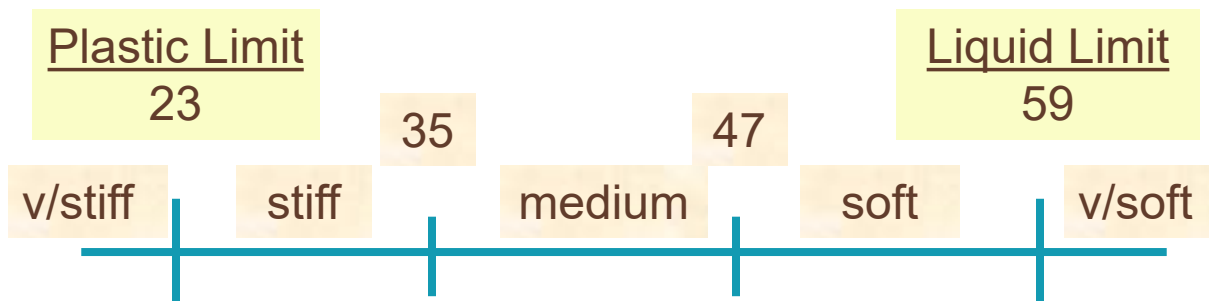
Now, divide the range between the LL and PL into thirds ($PI \div 3$) = $(36 \div 3)$ = 12.



Example



Now label the ranges as shown:



Example



**Next, Calculate the saturated water content,
given that $\gamma_{dry} = 79.9 \text{ lb/ft}^3$ and $G_s = 2.70$**

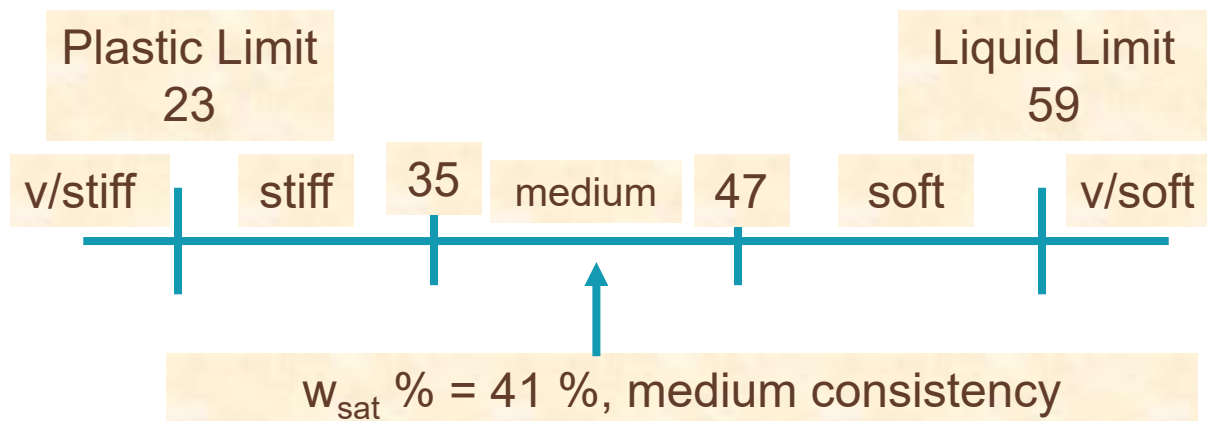
$$w_{sat}(\%) = \left[\frac{62.4}{79.9} - \frac{1}{2.70} \right] \times 100 = 41.1(\%)$$



Example



Plot the saturated water content on the diagram to identify its consistency.





Consistency	Identification Procedure	Undrained Shear Strength (C), Psf	N ₆₀ (SPT) Blows/Ft.
Very Soft	Thumb penetrates > 1 inch, extruded between fingers	< 250	< 2
Soft	Thumb penetrates 1 inch, molded by light finger pressure	250-500	2-4
Medium	Thumb penetrates 1/4 inch, molded by strong finger pressure	500-1,000	4-8
Stiff	Indented by thumb but not penetrated	1,000-2,000	8-15
Very Stiff	Not Indented by thumb, but indented by thumbnail	2,000-4,000	15-30
Hard	Not Indented by thumbnail, Indented with knife	> 4,000	> 30





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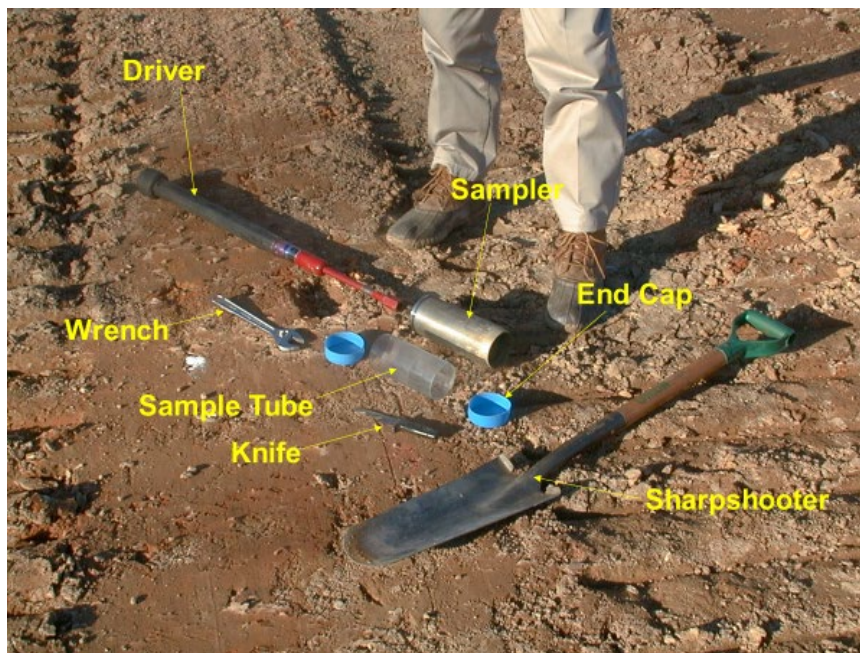


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Shelby Hand Sampler





Ready For
Labeling And
The Lab

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Volume-Weight Review



Volume of Sample

- Measured directly using a cylinder of known dimensions





Creative undisturbed sampling

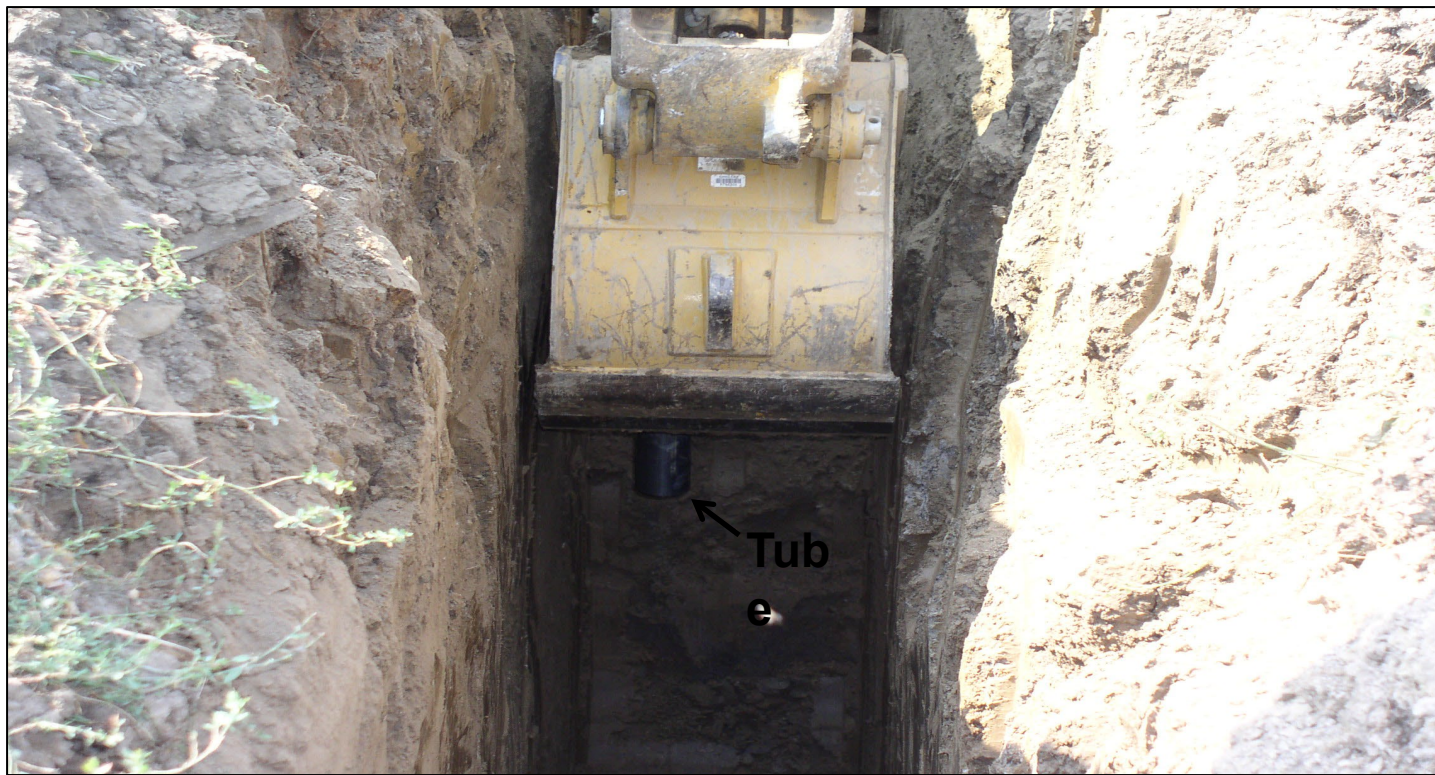


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Pushing tube with hoe bucket



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Volume-Weight Review

Volume of Sample

- Measured Directly and Indirectly
- Indirect
 - Nuclear Meter
 - E-Gage
 - Sand cone
 - Rubber Balloon
 - Drive Cylinder



Design of Heavy-Use Area Protection (HUAP)

Covers the stabilization of areas frequently and intensively used by livestock, people and light-weight vehicles or machinery by constructing layers of aggregate materials over subgrade.

The design of any heavy-use area protection involves an analysis of each of the components of the system, which include the surface course, base course, and subgrade.



HUAP Aggregate Pad Design Procedure

1. Determine the sites loading conditions including animal type and the type of vehicles.
2. Perform a site reconnaissance and soils investigation, see Aggregate Surfaced CP Planning and Field Investigation.
3. Determine subgrade soil strength, see Aggregate Surfaced CP Planning and Field Investigation.
4. Stress on the Subgrade Soil
 - S (Permissible Subgrade Stress) = $q_{ult} = CN_c$
 - Permissible subgrade stress **without a geotextile** is:
 - $S=C(2.8)$
 - Permissible subgrade stress **with a geotextile** is:
 - $S=C(5.0)$



HUAP Aggregate Pad Design Procedure

Table 7: Permissible Subgrade Stress

Undrained Shear Strength (C), PSF	Permissible Stress (Ult. Bearing Capacity) Without geotextile	Permissible Stress (Ult. Bearing Capacity) With a Geotextile
150	420	750
250	700	1,250
500	1,400	2,500
750	2,100	3,750
1000	2,800	5,000
1500	4,200	7,500
2000	5,600	10,000
3000	8,400	15,000
4000	11,200	20,000



HUAP Aggregate Pad Design Procedure

5. Determine aggregate base thickness.

Table 8: Aggregate Base Thickness (D) for HUAP

Load Description	Ground pressure (psi)	Permissible Stress						
		CNc= 150-250 psf D(in)	CNc= 250-400 psf D(in)	CNc= 400-575 psf D(in)	CNc=575-720 psf D(in)	CNc=720-1,300 psf D(in)	CNc= 1,300-2,000 psf D(in)	CNc >2000 psf D(in)
Horses/dairy cattle 1,400lbs	50	25	18	15	12	10	8	6
Beef cattle 1200lbs	37.5	20	16	12	10	8	6	6
Swine	25	15	12	10	8	6	6	6
Sheep/goats	14.5	8	6	6	6	6	6	6
Light trucks or farm machinery	GVW<10,000 lbs	30	24	18	15	12	8	6

HUAP Aggregate Pad Design Procedure

5. Determine aggregate base thickness.

- The aggregate base is the support or stabilizing layer and immediate support for the surface course.
- The design thickness of aggregate for heavy-use protection can be determined using table 8.
- Table 8 was developed based on the assumption the base course material is hard crushed angular rock well-graded with particle size between 2½ to ¾ inches.
- The base course is to be compacted to a CBR of 80 or to about 125 to 135 pcf. This can be accomplished with three or four passes of a crawler tracker or vibratory roller.



HUAP Components



Coarse aggregate must be well-graded 2½ inches to ¾ inches in size.

Fine aggregate can range from ¾-inch to No. 200 sieve size with 10-percent fines or 10 percent passing the #200 sieve.

Use a woven or nonwoven needle-punched geotextile fabric with a minimum tensile strength of 180 lbs. and minimum weight of 8 ounces per square yard.





Two-Layer System

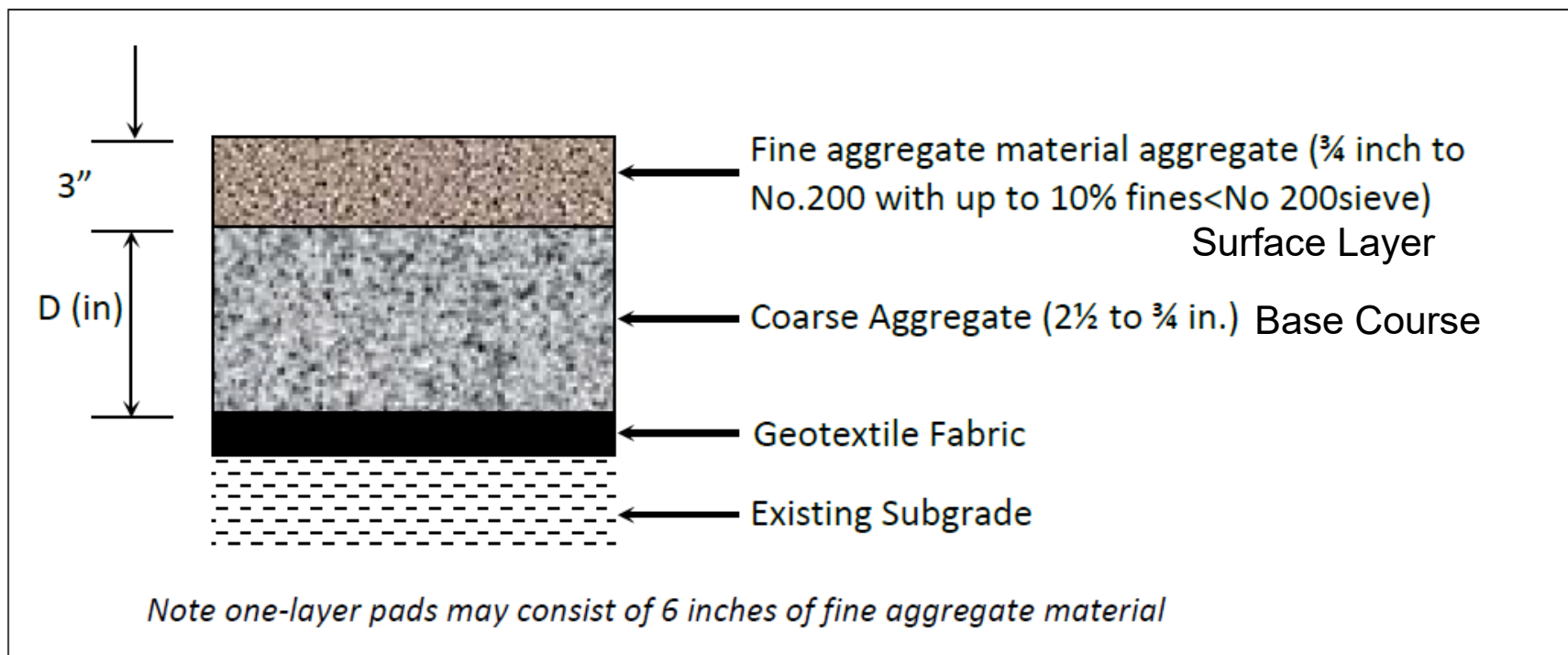
HUAPs typically consist of a two-layer aggregate pad with a geotextile between the aggregate base course and subgrade, for subgrades with undrained shear strength less than 720 psf. The geotextile will improve the permissible stress or ultimate bearing capacity of the subgrade. Figure 11 provides a detail of a two-layer pad.



Two-Layer System



Figure 11 – Detail for an Aggregate Pad



HUAP Aggregate Pad Design Procedure



5. Determine aggregate base thickness.

Table 8: Aggregate Base Thickness (D) for HUAP

Load Description	Ground pressure (psi)	Permissible Stress						
		CNc= 150-250 psf D(in)	CNc= 250-400 psf D(in)	CNc= 400-575 psf D(in)	CNc=575-720 psf D(in)	CNc=720-1,300 psf D(in)	CNc= 1,300-2,000 psf D(in)	CNc >2000 psf D(in)
Horses/dairy cattle 1,400lbs	50	25	18	15	12	10	8	6
Beef cattle 1200lbs	37.5	20	16	12	10	8	6	6
Swine	25	15	12	10	8	6	6	6
Sheep/goats	14.5	8	6	6	6	6	6	6
Light trucks or farm machinery	GVW<10,000 lbs	30	24	18	15	12	8	6



Design of Stream Crossings



A major concern with aggregate layered stream crossings is the contamination of the aggregate with the underlying soft fine-grained or loose sandy subgrade soils:

- Penetration of the aggregate into the weak subgrade due to localized bearing capacity failure under stresses exerted by repeated stresses by animals and wheel loads
- Intrusion of fine-grained soils into the aggregate because of pumping or subgrade weakening due to excess pore water pressure buildup



Stream Crossing Design procedure

The design procedure consists of the following steps:

1. Perform a site reconnaissance/investigation and determine the design loading, animal type and the type of vehicles.
2. Determine the subgrade soil undrained shear strength, C using soil consistency correlations from Table 3, field tests, lab shear tests.
3. Stress on the Subgrade Soil (Geotextile is required)
 - S (Permissible Subgrade Stress) = $q_{ult} = CN_c$
 - Permissible subgrade stress **with a geotextile** is:
 - » **$S=C(5.0)$**



Stream Crossing Design procedure

4. Determine Aggregate Base Thickness (D) - Enter Table 8.

Table 8: Aggregate Base Thickness (D) for Heavy-Use Protection Design (HUAP)

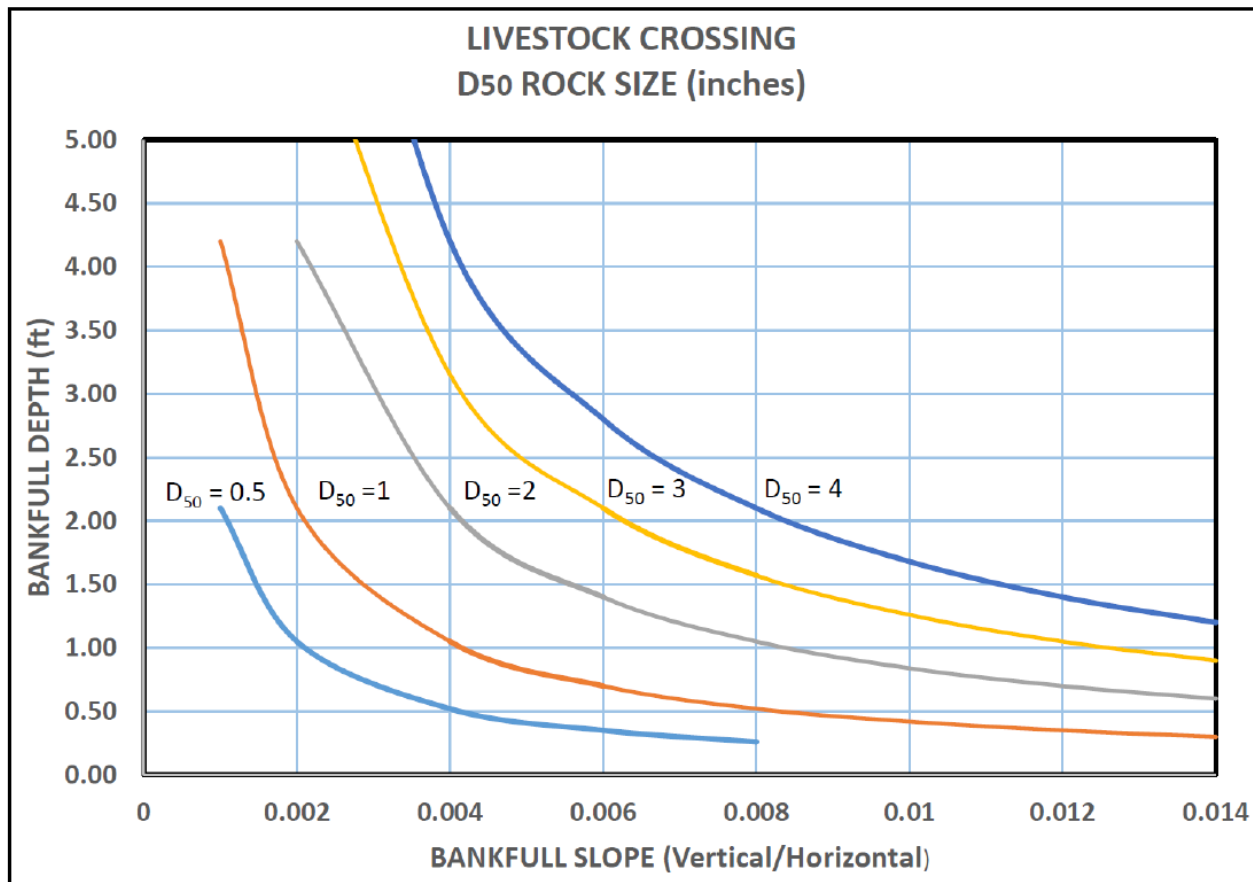
Load Description	Ground pressure (psi)	Permissible Stress						
		CNc= 150-250 psf D(in)	CNc= 250-400 psf D(in)	CNc= 400-575 psf D(in)	CNc=575-720 psf D(in)	CNc=720-1,300 psf D(in)	CNc= 1,300-2,000 psf D(in)	CNc >2000 psf D(in)
Horses/dairy cattle 1,400lbs	50	25	18	15	12	10	8	6
Beef cattle 1200lbs	37.5	20	16	12	10	8	6	6
Swine	25	15	12	10	8	6	6	6
Sheep/goats	14.5	8	6	6	6	6	6	6
Light trucks or farm machinery	GVW<10,000 lbs	30	24	18	15	12	8	6



Stream Crossing Design procedure

5. Obtain the aggregate D_{50} size from figure 12 to prevent the washing and movement of the aggregate

Figure 12 – D_{50} Rock Size



Design of Unpaved – Aggregate Access Roads

The design procedure consists of the following steps:

1. Determine the design loading, typically the maximum axle loading.
2. Determine the subgrade soil strength and convert to an equivalent value of cohesion, C .
3. Select an appropriate value for the bearing capacity factor, N_c . A value of 2.8 is used for unreinforced roads and 5.0 is used for geotextile-reinforced roads.



Design of Unpaved – Aggregate Access Roads

4. Stress on the Subgrade Soil

- S (Permissible Subgrade Stress) = $q_{ult} = CN_c$
 - Permissible subgrade stress **without a geotextile** is:
 - $S = C(2.8)$
 - Permissible subgrade stress **with a geotextile** is:
 - $S = C(5.0)$



Design of Unpaved – Aggregate Access Roads

5. Enter the appropriate design curve (single, dual, or dual tandem load configuration), with design load and permissible stress and determine the required aggregate depth with and without a geotextile.

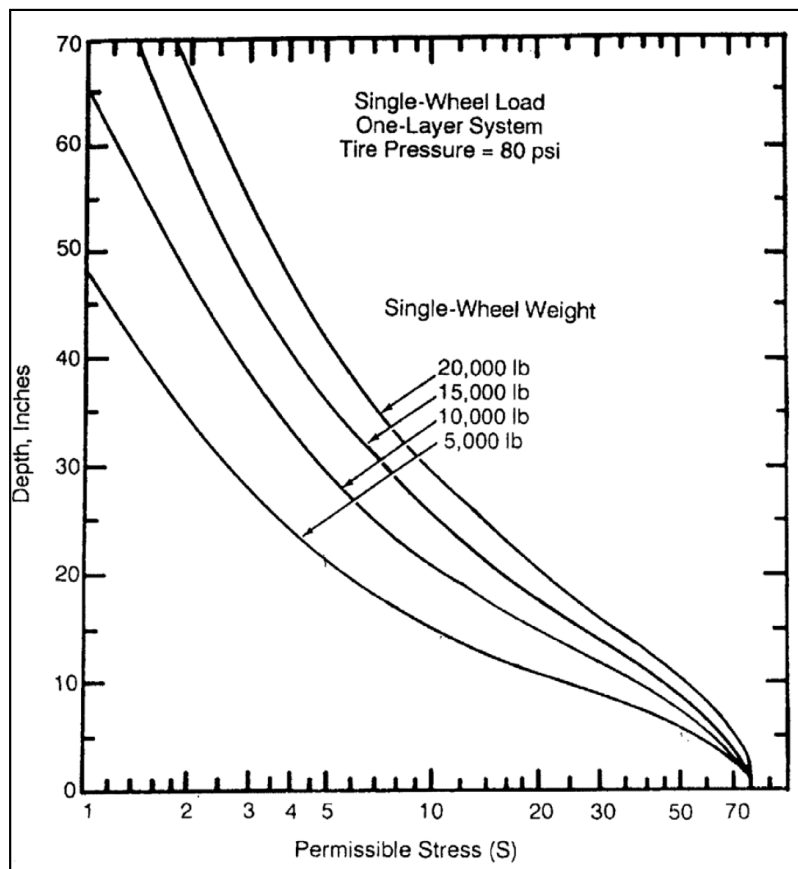


Figure 8 – Single Wheel Load One-Layer System (Stewart et al., 1977)





Vehicle Type (Choose Category Nearest the Actual Design Vehicles)	Axles S - Single T - Tandem	Wheels S - Single D - Dual	Axle Loads (lb)	Wheel Loads ¹ (lb)	Typical ² Tire Inflation Pressure (psi)	Contact Pressure ³ (psi)	Wheel Contact Area B ² (in ²)	One Side of Square Contact Area B (in)
Highway Legal Vehicles								
Haul trucks ⁴ - F Axle (stone, concrete)	S	S	18,000	9,000	110	110	82	9
R Axle	T	D	18,000	10,800	110	3	130	11.4
Tractor trailer - F Axle (18 wheeler) - R Axle	S	S	18,000	9,000	120	120	75	8.7
	T	D	18,000	10,800	120	90	120	11
Off Highway Legal Vehicles⁵								
35-ton trucks - F Axle (CAT 769C) - R Axle	S	S	48,000	24,000	90	90	267	16.3
	S	D	89,200	44,600	90	68	656	25.6
Wheel Loader - F Axle (CAT 910) - R Axle	S	S	24,000	12,000	50	50	240	15.5
	S	S	10,000	5,000	50	50	100	10
Wheel Loader - F Axle (CAT 930) - R Axle	S	S	37,000	18,500	60	60	308	17.6
	S	S	14,000	7,000	60	60	117	10.8
Wheel Loader - F Axle (CAT 966C) - R Axle	S	S	65,000	32,000	60	60	542	23.3
	S	S	25,000	12,500	60	60	208	14.4
Wheel Loader - F Axle (CAT 988B) - R Axle	S	S	136,000	68,000	85	85	800	28.3
	S	S	55,000	27,500	85	85	324	18
Wheel Loader - F Axle (CAT 992) - R Axle	S	S	290,000	145,000	70	70	2071	45.5
	S	S	120,000	60,000	60	60	1000	31.6
Scraper - F Axle (CAT 31D) - R Axle	S	S	88,600	44,300	80	80	554	23.5
	S	S	75,400	37,700	75	75	503	22.4
Scraper - F Axle (CAT 651B) - R Axle	S	S	120,000	60,000	85	85	706	26.6
	S	S	110,800	55,400	80	80	692	26.3
<p>NOTES:</p> <ol style="list-style-type: none"> 1. Wheel load is one-half the axle load and increased by 20% if the wheel is on a tandem axle. 2. Maximum tire inflation pressure is given for each class vehicle. Using tires with lower inflation pressures would lower the contact pressures and allow for less thickness of the aggregate structural section. 3. Same as tire inflation pressure except that a factor of 0.75 times the inflation pressure must be used for all dual wheels. 4. Trucks used on and off-highway generally use lower inflation pressure tires requiring only 75 to 90 psi. 5. Manufacturers' specifications should be consulted for off-highway vehicles. Wide ranges of different inflation pressure tires are available for these vehicles. 								



Design of Unpaved – Aggregate Access Roads

6. Choose the best alternative, either an aggregate depth with geotextile or an increased aggregate depth without geotextile.
7. Adjust Aggregate-Section Thickness for Aggregate Quality. Good quality well graded aggregate (CBR value of 80) or (125pcf-135pcf)
 - Thickness equivalency factors can be determined by comparing the CBR of the available aggregate to the design CBR of 80.
 - For example, assume a well-graded aggregate with a CBR of 55 would have an approximate thickness equivalency factor of $55/80=0.69$. then divide depth by the factor to determine the adjusted aggregate section thickness.
 - Alternative to above is to use Table 4



Design of Unpaved – Aggregate Access Roads

Table 4: Typical Compacted Strength Properties of Common Structural Materials

Material	CBR Range	Thickness Equivalency Factor
Crushed hard rock	80-100	1.00
Crushed medium-hard rock	60-80	0.85
Soft rock	20-40	0.45
Shell	40-60	0.75
Well-graded gravel	40-70	0.80
Sand-gravel mixtures	20-50	0.50
Clean Sand	10-30	0.40
Asphalt, concrete plant mix, high stability	>100	3.00
Lime-treated base ¹	>100	1.00-2.00
Cement-treated base ^{1,2}		
650 psi or higher	>100	1.60
400 psi to 650 psi	>100	1.40
400 or less	>100	1.05

¹ The strength of lime-treated and cement-treated bases depends on soil properties and construction procedures. Treated bases are also subject to long-term failure due to continuing chemical reactions over time.

² Compressive strength at 7 days.



Design of Unpaved – Aggregate Access Roads

8. Adjust Aggregate-Base Thickness for Service Life

The design method assumes that the pavement will be subjected to 1,000 passes of the maximum design axle load. If the traffic is greater than 1,000 passes, increase H (aggregate thickness) by the following percentages:

2,000 passes 8%

5000 passes 19%

10,000 passes 27%

If more than 10,000 passes, you need to increase the design thickness by 30 percent and monitor the performance of the road.



Aggregate and Similar Surface Materials

The term “Aggregate” generally refers to materials that started out as bedrock.

Aggregate is commonly used for subbase, base and surface courses for unpaved access roads, heavy-use area protection sites, stream crossings, trails and other projects that require subgrade stabilization.

Aggregate includes combinations of crushed rock (stone), gravel, crushed gravel, sand, or other mineral materials.

Aggregate and Similar Surface Materials

Aggregate includes combinations of crushed rock (stone), gravel, crushed gravel, sand, or other mineral materials. Aggregate is produced by crushing, screening, pit-run, or grid-rolling methods. Crushing and screening are the most used methods. Pit-run and grid-rolling methods generally produce lower quality aggregate.

- *Crushing* breaks stone and gravel into smaller particles. Crushing equipment also blends the various sizes together for the proper gradation.
- *Grid-rolling* means crushing rock in place. Rock sources include native materials or aggregate hauled from pits. A heavy steel roller with a waffle pattern rolls the material, crushing and compacting it at the same time.
- *Processing* can include screening and washing. Screening separates raw material or crushed material into uniform sizes. The material is moved or shaken on sorting screens. Washing cleans the aggregate such that an aggregate with little to no fines is produced.



Aggregate and Similar Surface Materials

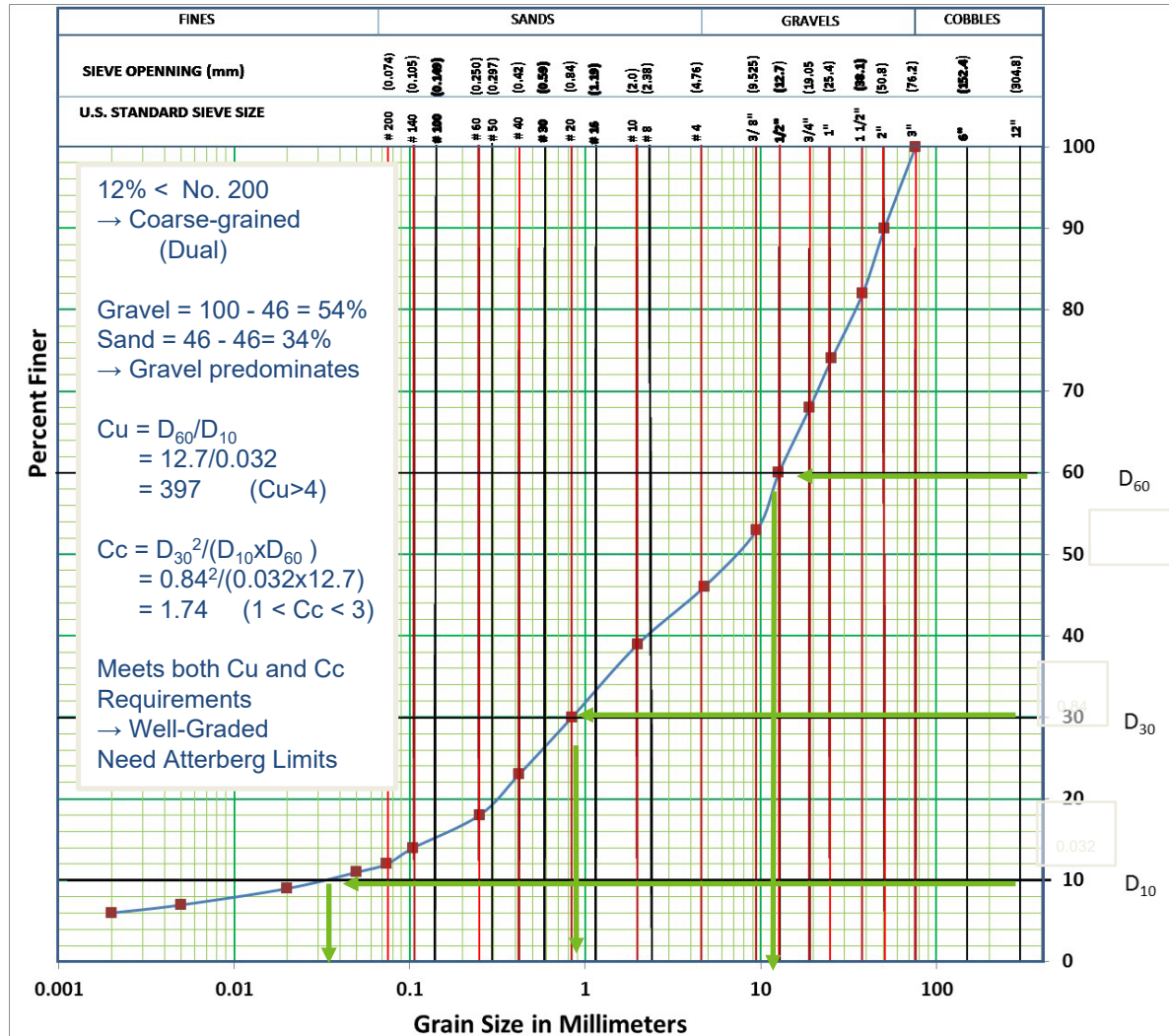
Aggregate can be graded for different applications (i.e., subbase, base, and surface courses for subgrade stability projects).

For aggregate-surface practices, well-graded aggregate are desirable.

achieve job specific gradation requirements or improve other characteristics, fillers, binders and chemical additives are sometimes added.



Grain-Size Distribution		
Sieve	Sieve Size (mm)	Percent Finer (%)
3 Inch	75	100
2 inch	50	90
1- 1/2 Inch	37.5	82
1 inch	25	74
3/4 inch	19	68
1/2 inch	12.5	60
3/8 inch	9.5	53
No. 4	4.75	46
No. 10	2.00	39
No. 20	0.85	30
No. 40	0.425	23
No. 60	0.25	18
No. 140	0.106	14
No 200	0.075	12
0.05 mm	0.05	11
0.02 mm	0.02	9
0.005 mm	0.005	7
0.002 mm	0.002	6





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