Section 12
Roadway Materials

Introduction

Why do we care about Materials for the roads? Roadway materials, and particularly roadway surfacing materials, such as aggregate or paving, can be half the cost of a road. Selection of materials directly affects the function, structural support, rider comfort, environmental impact and safety of the road and user.

Where are they needed?
Materials and quality control of those materials are needed in the following:

- In roadway surfacing materials.
- In the road subgrade.
- In structural fill embankments.
- In quarries and borrow pits.

The Driving Surface

On low-volume roads, a variety of surfacing options exist. The most common surfacing types, shown on Figure 12.1, are:

- Native Soil
- Crushed Aggregate
- Cobblestone or Concrete Block
- Bituminous Seal Coats
- Asphalt Concrete

Selection of surfacing materials depends on availability of materials, their cost, and road use (weight and amount of traffic). Native soil is the least expensive, and often poorest material. Crushed aggregate is the most common improved surfacing material. Asphalt concrete is the best, smoothest, and most expensive surface.

Dust palliatives may be used to reduce dust. Common palliatives are water, lignins, chlorides, and oils. Use depends on product costs, soils, and pattern of road use.

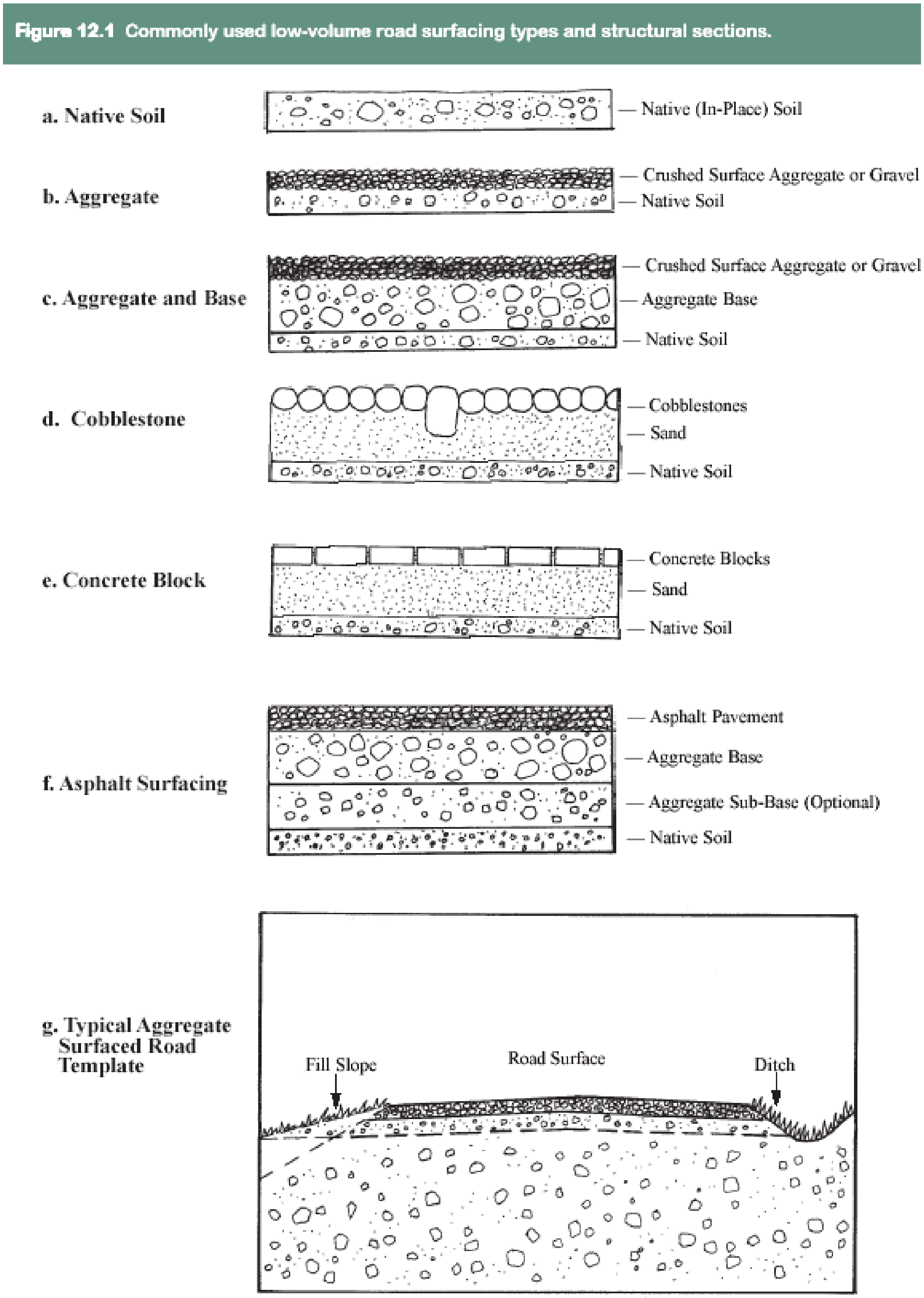


Figure12.1 Typical Road Surfacing Types

Aggregate Base and Surfacing Requirements

Agggregate needs to be a well graded mix of coarse particles with sufficient fines to maximize density but not lose the strength of the rock.

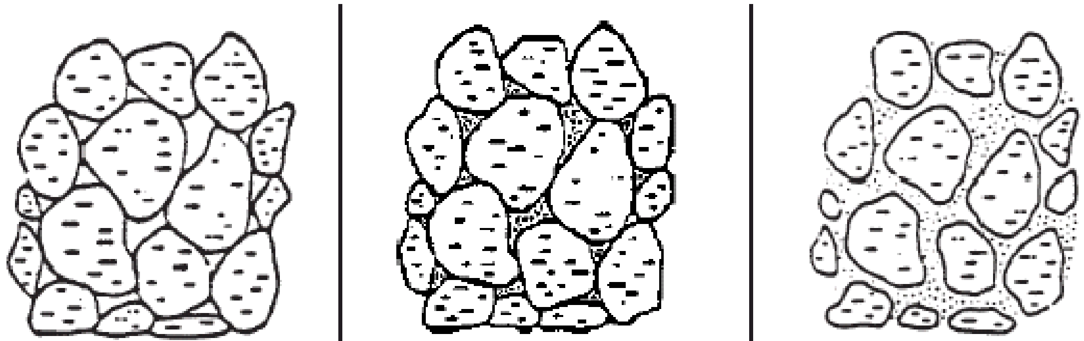
Figure 12.2 shows the need for the need for an ideal soil-aggregate mixture with not too many-not too few fines. Figure 12.3 show this relationship on a grain size distribution curve. Figure 12.4 shows the typical gradations and specifications used by the U.S. Forest Service and other agencies for Base Course and Surface Course

Aggregate.Specifications include the allowable gradation ranges, as well as materials quality test requirements.

- **Gradation**
  - -Use Base Course where confined under a seal coat or pavement (2-9% fines).
  - -Use Surface Course aggregate where placed directly on the road surface (6-15% fines).

- **Durability** -(35 Min) and Abrasion Resistance (40 Max).
- **Plasticity** -PI=6 Max for Base, PI= 5-10 for Surface Course Aggregate. Note that in wet climates the PI may be dropped and the % fines increased).

Figure 12.3 Physical states of soil-aggregate mixtures. *(Adapted from Yoder and Witczak, 1975)*



Aggregate with no Fines

- Grain-to-grain contact
- Variable density
- High Permeability
- Non-Frost Susceptible
- High stability when confined, low if unconfined
- Not affected by water
- Difficult to compact
- Ravels easily

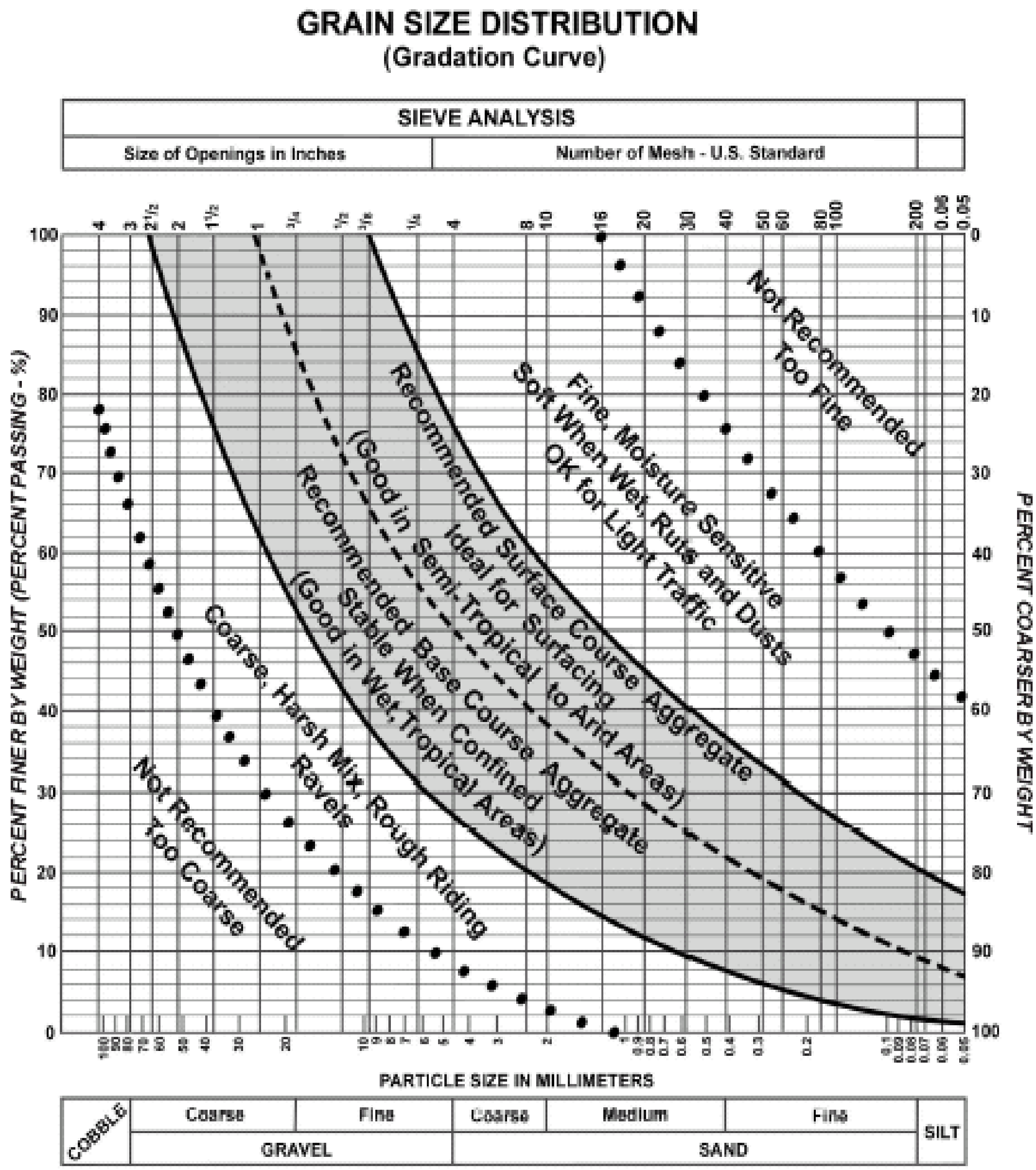
Aggregate with Sufficient Fines for Maximum Density

- Grain-to-grain contact with increased resistance against deformation
- Increased to maximum density
- Low permeability
- Frost susceptible
- Relatively high stability in confined or unconfined conditions
- Not greatly affected by adverse water conditions
- Moderately easy to compact
- Good road performance

Aggregate with High Amount of Fines (>30 percent)

- Grain-to-grain contact destroyed, aggregate is "floating" in soil
- Decreased density
- Low permeability
- Frost susceptible
- Low stability and low strength
- Greatly affected by water
- Easy to compact
- Dusts easily

Figure 12.2 Soil-Aggregate Mixtures.



NOTE: Gradation Ranges Shown Are Approximate.

The best roadbed surfacing materials have some plasticity and are well graded. They have gradations parallel to the curves shown above, and are closest to the "Ideal" dashed curve in the middle of the gradation ranges shown.

Figure 12.3 Ideal Gradation Ranges for Base and Surface Course Aggregates.

Gradation Requirements for Base and Surfacing Aggregate

Base Aggregate

Size of Screen	Percent Passing		
	Gradations for CALTRANS		FHWA
	Grading 1 ($1^1/_2$")	Grading 2 ($^3/_4$")	Grading D
2"	100		
1 $^1/_2$"	90-100		100
1"		100	97-100
$^3/_4$"	50-85	90-100	
$^1/_2$"			($^3/_8$") 56-70
#4	25-45	35-60	39-53
#8			
#30	10-25	10-30	(#40) 12-21
#200	2-9	2-9	4-8

Note: Durability (AASHTO T-210) >35 minimum, Plasticity (AASHTO T-90) = 6 maximum; CALTRANS Resistance Value = 78 minimum (CBR [AASHTO T-193] = 50 minimum). (FHWA Grading D = non plastic)

Road Surface Aggregate (for USDA-Forest Service)

Size of Screen	Percent Passing		
	Grading B	Grading C	Grading D
2"	100		
1 1/2 "	60-90		100
1"		100	
3/4"		60-90	70-100
1/2"	44-70		
#4	28-50	30-55	36-60
#8	20-41	22-43	24-47
#30	9-26	11-27	12-31
#200	6-12	6-15	6-15

Note: Plasticity (AASHTO T-90) = 2-9; Abrasion Loss (AASHTO T-96) = 40 maximum; Durability = 35 minimum

Figure 12.4 Typical gradations and specifications used for Base Course and Surface Course Aggregate.

Subgrade Reinforcement

On low-volume roads, Subgrade Reinforcement (to achieve a strong structural section) is most often achieved using a layer of crushed aggregate placed over a weaker in-place subgrade soil. Structural section thickness requirements are a function of soil type, vehicle weight, and amount of traffic. The USDA Forest Service Earth and Aggregrate Surfacing Design Guide (1996) offers useful design information for aggregate surfacing.

Figure 12.5 shows three typical aggregate surfacing options used on Low-volume roads:

- Over most granular soils, a 4 to 6 inch layer is sufficient.
- Over soft, clay rich soils or moisture sensitive silty soils, with light to moderate traffic, 8 to 12 inches of base aggregate is common.
- Over very soft soils or with heavy traffic, surfacing thicknesses may be 12 to 24 inches, or more.

Figure 12.6 shows the relationship of aggregate thickness, soil strength measured as CBR (California Bearing Ratio), and traffic used to design aggregate thickness for high and low quality aggregate. Figure 12.7 shows some approximate relationships between soil CBR and Unified Soil Classification (USCS) types for different soil densities. This is useful to estimate a design CBR value.

Over very weak soils (CBR<3) reinforcement and separation with layers of geosynthetics can reduce needed aggregate thickness and be cost effective.

Where aggregate is not available or very expensive, other methods of soil stabilization are used.

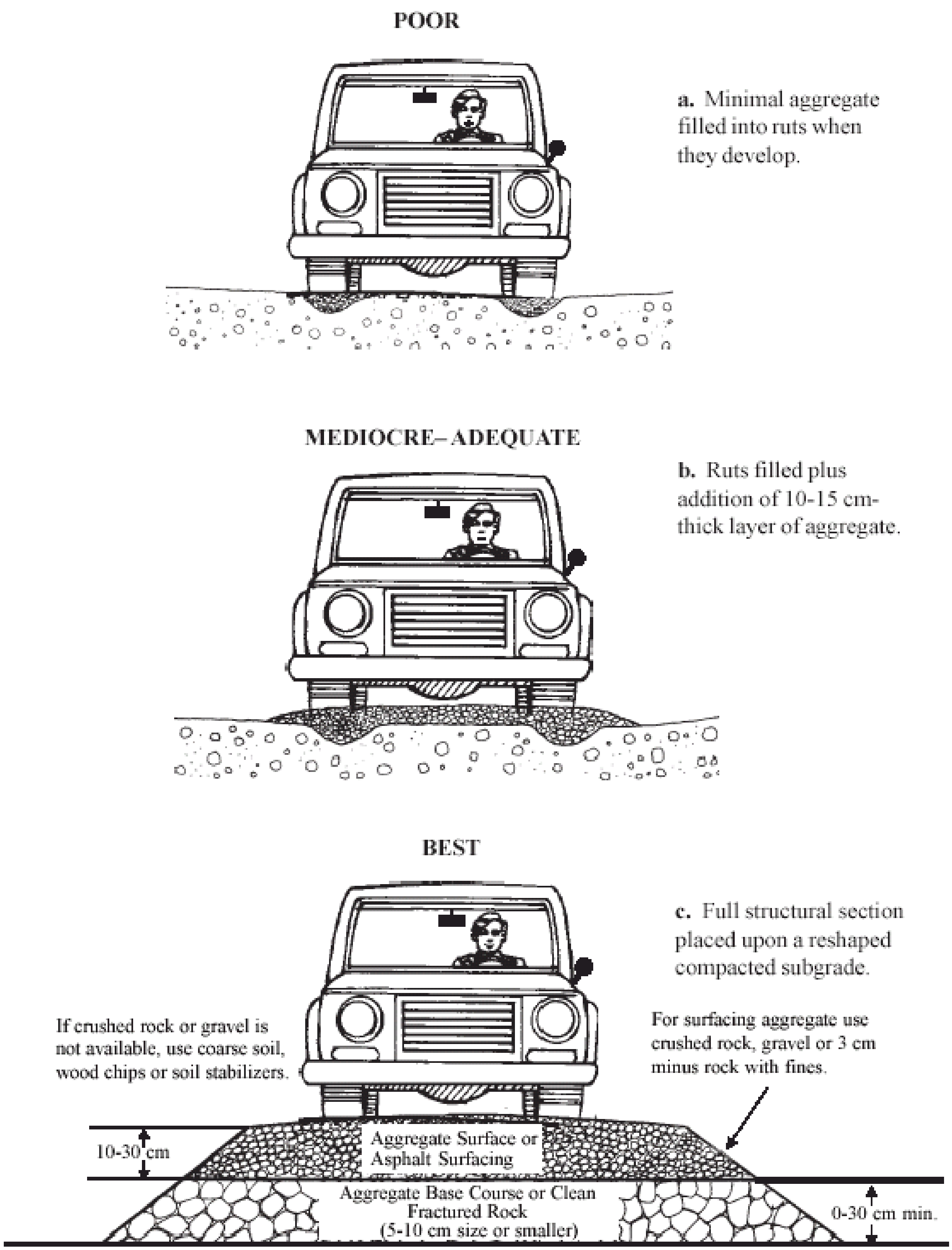


Figure12.5 Aggregate Surfacing Options- Poor to Best.

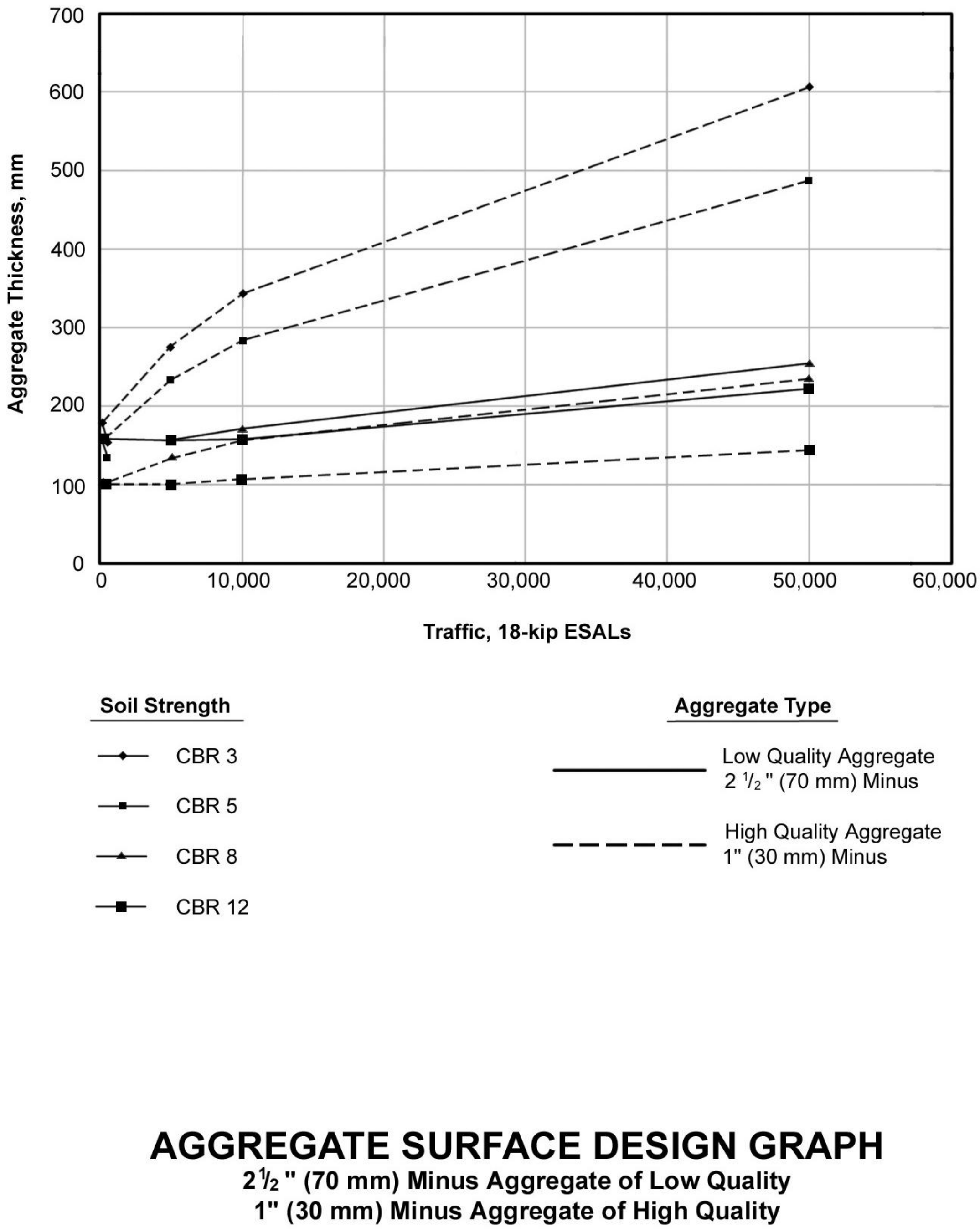


Figure 12.6 Aggregate Surface Design for High and Low Quality Aggregate.

USCS Classification	CBR Range			
Cohesive	85% Maximum	90% Maximum	95% Maximum	100% Maximum
GM_u	2.5-4	5-8	10-16	20-32
SM_u	1.0-2.5	2-5	4-10	8-20
ML	0.5-2.0	1-4	2-8	4-16
CL	0.5-2.0	1-4	2-8	4-16
OL	0.3-0.6	0.6-1.2	1.2-2.4	2.4-4.8
MH	0.5-2.0	1-4	2-8	4-16
CH	0.5-2.0	1-4	2-8	4-16
OH	0.3-0.6	0.6-1.2	1.2-2.4	2.4-4.8
Granular				
GW	17-33	22-43	29-56	37-73
GP	13-25	17-33	22-42	29-55
SP	4-17	5-22	7-29	9-37
Intermediate				
GM	8-12	14-20	23-35	39-59
GC	4-8	7-14	12-23	20-39
SM	3-8	5-14	9-23	15-39
SC	1-4	2-7	3-12	5-20

"Maximum" refers to maximum density that can be obtained at the optimum moisture content for that particular soil.

Figure 12.7 CBR values for various USCS soil classifications and soil density.

<u>Compaction</u>

Compaction is the single most efficient and cost-effective way to improve a soil's properties, including density, strength, moisture resistance, and reduced swell potential.

- First representative soil samples are obtained.
- Soil compaction tests are run on the samples (Proctor (AASHTO T-99) or Modified Proctor tests (T-180)) to determine the Maximum Density and Optimum Moisture Content.
- The appropriate target density is specified for field compaction (to produce the needed or maximum soil strength).
- Field compaction is best achieved near the Optimum Moisture Content with a number of passes using appropriate compaction equipment. For <u>granular</u> soils, a vibratory compactor is best. In <u>clay</u> soils a kneading compactor, such as a sheepsfoot roller is used. Vibratory rubber tyre rollers are all-purpose.
- Field density is determined during construction using a "nuclear gauge", sand cone, or balloon density measuring equipment.

Soil Improvement or Reinforcement Methods

- Compact native soils (as outlined above).
- Remove and replace with Select Material.
- Drain the road subgrade (underdrains/filter blankets).
- Use Geotextiles plus aggregate cover.
- Limit road use during wet periods.
- Improve the native soil in-place by mixing with cement, lime, asphalts, resins, chemicals, enzymes, etc. (Each soil additive has particular requirements for use and effectiveness)

Sources of Materials

On site quarries or borrow pits, relatively near a project, can produce major cost savings for a project.

- The site should be investigated for quantity and quality of materials.

- Locate the site to minimize environmental impacts.

- The site should have a **Pit Development or Operating Plan** to insure that the site is well laid out, to define the areas of excavation, road access, space for equipment and stockpiles, safe and stable back slopes, proper drainage, etc.

- The site should have a **Pit Reclamation Plan** to guarantee environmentally sound end use after closure, and funds to accomplish the reclamation. Pit reclamation measures can include reshaping the pit, drainage measures, flattened slopes and fences for public safety, topsoil stockpiling and reapplication, revegetation and other erosion control, etc.

Shown below in Figures 12.8 a and b are a typical Quarry Developement Plan Drawing and Development Notes. Figure 12.9 shows some Do's and Don'ts of roadside quarry development.

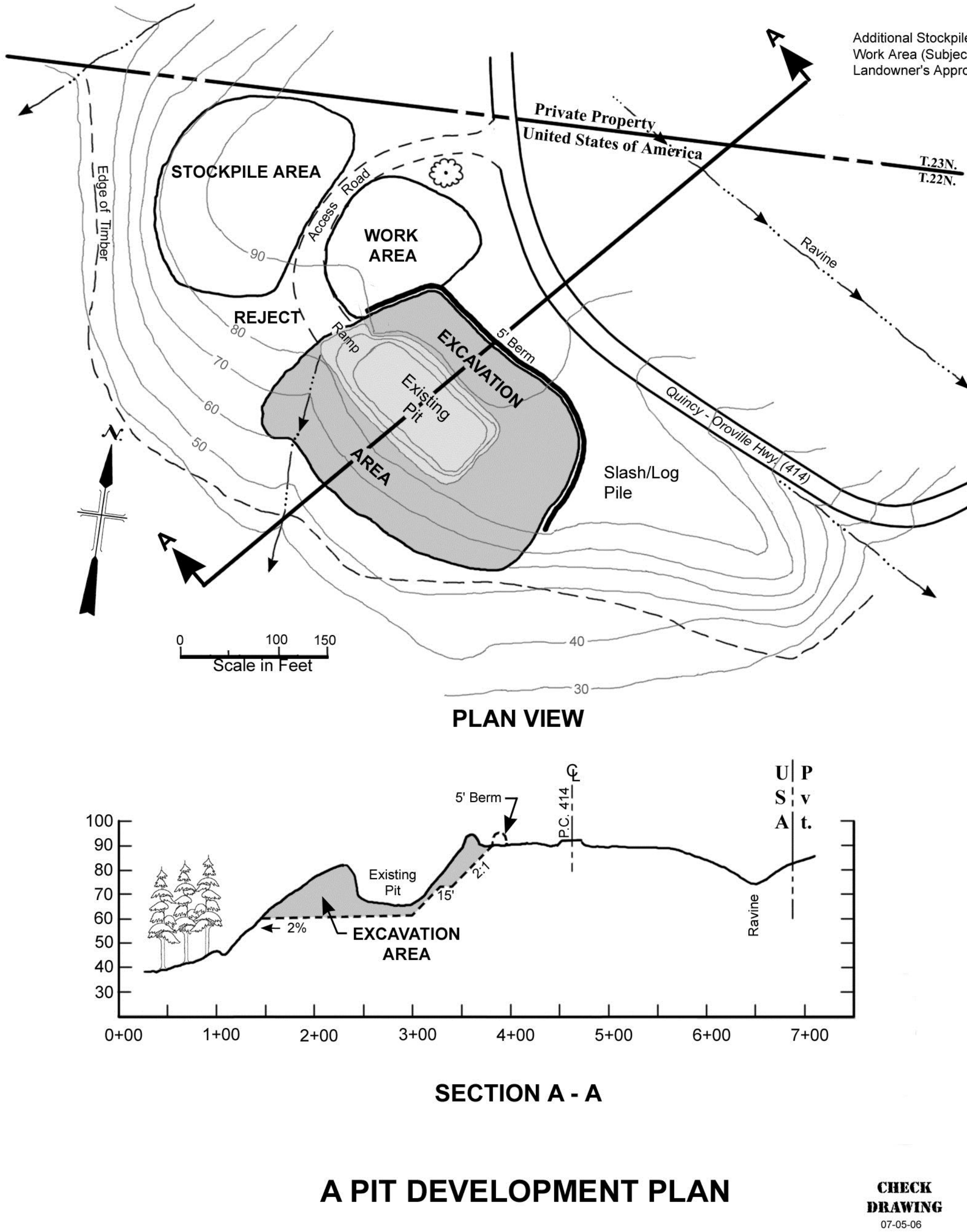


Figure 12.8a- Typical Pit Development Plan Drawings.

Pit Development Notes

Plan of Operation

1. **Pit excavation area, crushing, stockpile, and access areas shall be limited to the areas shown on the plans and as staked on the ground. No trees outside the working areas shall be damaged.**
2. **Aggregate shall meet the requirements specified in this contract.**
3. **All material processed shall be utilized. No oversized material shall be left in the pit.**
4. **Final backslopes in the excavation area shall be left on slopes no steeper than 2:1.**
5. **The excavation, crusher and stockpile areas shall be left smooth and uniform. The pit shall drain to the west.**
6. **A 20 foot wide ramp shall be constructed at the northwest end of the pit area to access and enlarge the excavation.**
7. **Slash shall be piled near the log deck area for future burning.**
8. **Excavation shall begin along the east edge of the pit.**
9. **A 5 foot high berm of shot rock along the edge of the excavation area shall be maintained.**

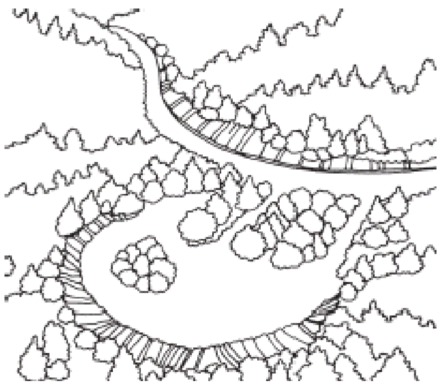
Restoration Plan

1. **Topsoil shall be removed during initial pit development and stockpiled for final restoration.**
2. **The pit shall be regraded and topsoil spread over the pit area.**
3. **The area shall be seeded and mulched for erosion control.**

Figure 12.8b. Typical Pit Development and Restoration Notes.

Figure 12.5 Good and bad roadside quarry development practices. *(Adapted from Visual Quality Best Management Practices for Forest Management in Minnesota, 1996)*

Good Practices for Quarry Development



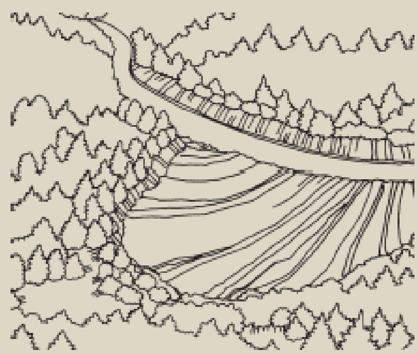
DO!

- Screen pit area from road
- Leave gentle slopes
- Reshape and smooth the area
- Leave pockets of vegetation
- Seed and mulch the area
- Use drainage control measures
- Replace Topsoil

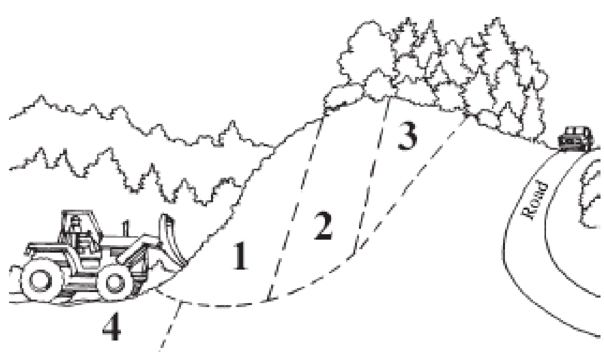
Poor Practices for Quarry Development

DO NOT!

- Expose large, open area
- Leave area barren
- Leave steep or vertical slopes



Ideal Location and Sequence of Excavation



Locate borrow areas out of sight of the road.
(NOTE: Safe backslope excavation height depends on soil type. Keep backslopes low, sloped or terraced for safety purposes.)

Figure 12.9 Roadside Quarry Practices.

Quality Control/Sampling and Testing

Quality control of materials being used in a project includes guaranteeing that the material has appropriate properties, such as durability, hardness, strength, compaction, or gradation. Such control is kept through selection of representative samples of the material and testing to insure that they meet the appropriate materials properties.

Reject or modify materials that do not meet specifications.

You get what you inspect, not what you expect!

Summary

What is most important about roadway materials and materials sources?

- **Know your Soil Types and Traffic.**
- **Select the Appropriate Surfacing Standard.**
- **Use Appropriate Aggregate Gradation (Base or Surface Aggregate).**
- **Consider In-place Soil Stabilization if Cost-effective.**
- **Use Cost-Effective Local Materials.**
- **Use Adequate Quality Control and Sampling & Testing.**
- **Compact your Soils and Aggregates.**
- **Drain your Materials.**
- **Develop Quarries…then Reclaim Them!**

Roadway Materials
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