Matanuska – Susitna Borough

Engineering Guide

Evaluating & Upgrading

Gravel Roads

For Paving

Version 1
June 2010

Preface

Fact: Given **sufficient preparation**, nearly any gravel road can be paved with a minimal-thickness hot mix asphalt concrete pavement or even a low cost asphalt surface treatment (AST), and it can be relied on to survive low-volume traffic for a decade or two. What does "sufficient" mean in terms of design and materials? And, perhaps more importantly, how much is "sufficient" going to cost?

This engineering guide provides tools to aid evaluation, development and management of Matanuska-Susitna Borough's gravel-to-pavement projects.

The guide serves an additional purpose. It documents the engineering bases for design features and specification requirements used in certain Matanuska-Susitna Borough construction contracts in case of legal disputes.

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1. Introduction

Scenario: The Matanuska-Susitna Borough wants to consider paving an existing gravel road. As a Borough engineer you are assigned to develop and/or manage such a project. The road must handle only light, local traffic, and you would therefore like to pave it at the lowest possible cost. As an engineer you need a comfortable degree of confidence that you can properly design the new pavement, and that it can be justified, economically and otherwise.

Is it possible to simply go ahead and apply new hot mix asphalt concrete or an asphalt surface treatment (AST) pavement to that old gravel road surface? For a number of good reasons that would not be prudent. As the engineer assigned to the project, your involvement begins with a couple of basic questions:

- Is the Borough committed to a road management program, including new maintenance and load restriction policies that will sustain the service life of the new pavement?
- Have you considered the public's: opinions, user costs, and safety issues?

You must answer these questions before this engineering guide will be of use.

Then, in order to provide Borough management with realistic estimates of economic feasibility, and design requirements, you must answer these questions:

- Do predicted traffic levels confirm that asphalt concrete pavement is appropriate?
- What kind of asphalt pavement is best?
- Are you prepared, in terms of engineering time and resources, to evaluate and upgrade the existing gravel road, as necessary, to obtain a predictable service life?
    - Is the candidate gravel road in nearly good enough condition to receive pavement?
    - Does the existing road need to be significantly upgraded prior to paving?
    - If upgrading is needed, what type and how much is necessary?

These latter questions are directly related to evaluating the existing gravel road and designing for a new asphalt pavement surface — the subject of this guide.

1.1. How to Use the Guide

Assuming you have no prior Alaska pavement design experience, start by reading Section 2. This provides you with essential technical and philosophical background. This helps you to think of the gravel road as an engineering structure, the strength of which is primarily controlled by Alaska's freeze/thaw cycles. The section then introduces you to important issues that will influence your decisions about modifying that structure. **If you have significant Alaska pavement design experience go directly to Section 3.**

Section 3, Table 1 outlines a strategy that guides you through evaluating the existing gravel road as well as the subsequent design process. Follow the decision process outlined in Table 1 from top to bottom. The table offers a sequence of defensible economic and design decisions leading to paving or toward a no-pave decision.

2. Basic Gravel-To-Pavement Concepts

2.1. Understanding the Gravel Road as a Pavement Structure

The following discussion is based on information contained in the Alaska Department of Transportation & Public Facilities (ADOT&PF) Asphalt Surface Treatment Guide [1].

In addition to the cost of the pavement surface itself, a significant capital investment will likely be necessary to improve the existing gravel road to a paveable condition. It is essential that you pay attention to the quality of materials that underlie your proposed pavement or that pavement may not survive its first spring thaw. The following discussion explains why.

For your existing gravel road, the few inches of existing gravel surfacing material (gravel "pavement") is the top layer of a "pavement structure." Pavement structure is an important concept, defined for our purpose as the total thickness of material that "feels" significant compression stresses (and therefore strain) under a vehicle's wheel loading, i.e., the material that must support that load. Most of the support comes from a limited thickness of material under the gravel surfacing layer. For example we can say that a square inch of granular material located only 6 inches directly beneath the load "feels" high load stress, while distribution of wheel load through the granular mass insures that a square inch of material at a depth of, say, 60 inches receives only a relatively tiny amount of stress. This brings up a few questions: (1) What is the critical thickness of material must be relied upon to support those relatively high wheel-load induced stresses near the surface? (2) What quality of material is required within this critical thickness? (3) What happens if poor quality materials are used within the critical thickness?

The empirically derived rule-of-thumb adopted for use in Alaska is that normal highway loads are carried by the asphalt concrete pavement plus an additional 3.5 feet of structurally competent granular materials. The pavement layer (asphalt or gravel pavement) plus the additional 3.5 feet of competent material are together defined as the pavement structure. The ADOT&PF excess fines design method defines the pavement structure based on this rule-of-thumb. The excess fines method requires that the quality of all material to a depth of 3.5 feet below the bottom of the pavement layer be accounted for in every pavement design analysis. For very heavy design loads, including heavy aircraft, the total thickness of materials influenced significantly by the live load can substantially exceed the 3.5-foot rule-of-thumb. Such heavy loads are handled by special design methods not discussed here.

Two kinds of asphalt concrete pavement surfaces are considered in this engineering guide. These are:
1) minimal-thickness hot mix asphalt concrete pavement (2 inches), and
2) asphalt surface treatment (AST) pavement.

It is important to realize that a thin AST pavement (normally ¾ inch) is not structural layer. Therefore, adding an AST atop an existing gravel surface adds almost <u>no</u> additional strength to the existing gravel road's pavement structure. A 2-inch thick hot mix asphalt concrete pavement provides significant structural benefit compared to the AST alternative. The hot mix structural advantage is accounted for in Section 3.1 of this engineering guide (selecting pavement type based on expected traffic).

Alaska research found that the quality of unbound aggregate materials within the pavement structure is highly correlated with the percentage of fines (weight percent of particles finer than the #200 sieve (also known as $P_{200,}$ minus 75 micron, or $P_{0.075\ mm}$). The P_{200} content usually controls the aggregate's ability to support vehicular load, especially during the springtime thaw period. This assumes that the aggregate material is compactable, well-graded and otherwise acceptable (quality-wise) as a road construction material. The general relationship is: low P_{200} content = good support and high P_{200} content = poor support. The P_{200} content matters less as depth below the asphalt concrete pavement surface increases. At a depth greater than 3.5 feet, a high P_{200} content is acceptable (assuming standard highway-type loadings).

Why is the P_{200} content so important? P_{200} content is related to the frost susceptibility of the material, i.e., the tendency of a material to accumulate ice content during the wintertime freezing process. In general, a higher P_{200} content means higher frost susceptibility, which causes more wintertime ice accumulation within the material, which in turn leads to greater thaw-weakening during rapid spring thawing. A thaw-weakened material cannot stand up to high stresses.

Depending on traffic intensity, weather and groundwater level, excess fines will cause springtime softening in layers supporting the asphalt pavement. If softening occurs, visualize the situation as a cracker (the asphalt pavement) on a thick layer of cream cheese—the pavement is unsupported and highly vulnerable. Even a small amount of truck traffic can quickly destroy the pavement as damage progresses from cracking to potholing, and finally, to complete loss of the pavement surface. The chance of poor asphalt pavement performance increases enormously as you increase fines contents beyond specified limits at a given depth. The relationship between depth and allowable fines content is accounted for in this guide's Section 6 design procedure.

A relationship between frost susceptibility of materials (therefore thaw-weakening) and $P_{0.02\ mm}$ was first defined by A. Casagrande's early research into the frost heave phenomena [2]. Casagrande determined that soils containing less than 3 percent $P_{0.02\ mm}$ are usually non-frost-susceptible (NFS). Based on comprehensive Alaska research in the late 1970s, ADOT&PF engineers adopted an NFS criterion based on P_{200}. Since then, ADOT&PF has classified most natural soils and manufactured aggregates containing $\leq$ 6 percent P_{200} as NFS. Interestingly, gradation data from many Alaska soils/aggregates indicates that the $P_{0.02mm}$ content usually runs approximately half the P_{200} content. Therefore, it is no surprise that material containing ≤ 6 percent P_{200} (and likely containing ≤ 3 percent $P_{0.02mm}$) should be classified as NFS. The benefit here of course is that it is much easier to measure the P_{200} content of a sample (requires only sieve analysis) than it is to measure the $P_{0.02\ mm}$ content (requires expensive hydrometer analysis).

For the limited truck traffic and generally smaller vehicle loadings expected for gravel-to-pavement projects, the ADOT&PF excess fines pavement design method can be modified:

- Design thickness of the pavement structure has been decreased from 42” to 36”

- Acceptable fines content for near-surface materials has been increased from 6 percent to 10 percent

The pavement design method presented in Section 6 incorporates these modifications

2.2. Expected Pavement Service Life

Based on Alaska experience and Canadian estimates discussed below, **you can probably expect a 15 to 20 year service life**. This service life expectancy assumes that a properly constructed and maintained asphalt concrete surface (hot mix or AST) is placed on a properly evaluated and prepared gravel road. Specifically, the main assumptions are:

- Good drainage can be achieved and maintained.
- Foundation issues are recognized and resolved.
- The pavement structure is designed and constructed according to Section 6 of this guide.
- After hot mix or AST paving is completed, the road will continue to serve generally low volume, light vehicle traffic as defined in Table 2 of this guide.
- Proper maintenance will continue over the life of the pavement.
- Effective load restriction will occur during every spring thaw period.

If you know that one or more of these six assumptions cannot be met, it is your responsibility to either resolve the problem(s) or express the opinion that asphalt concrete pavement is not viable.

Where did the estimated service life of 15 to 20 years come from? For ASTs, the more vulnerable of the two pavement types considered in this guide, the estimate is based on Canadian research. Appendix A provides a summary of this research. Table 2 limitations on traffic volumes should help ensure that the Canadian performance estimates of AST service life are fairly conservative.

How about the estimated service life for 2 inches of hot mix asphalt concrete? Based on Table 2, the predicted traffic level may require that a 2-inch hot mix pavement be used instead of an AST. This decision does not change the design method you will use to prepare the existing gravel road (see Section 6). Alaska experience indicates that the 2-inch thick hot mix pavement should last 15 to 20 years if the 4,000 AADT and < 2 percent trucks criteria are not exceeded.

If you expect that your pavement may routinely have to carry a considerable amount of truck traffic (>2 percent), or that Table 2 AADT design expectations (>4,000) will be exceeded, or that load restriction policies will be ineffective, your traffic design parameters are outside the scope of this guide. In that case the pavement structure must be designed by an engineer who specializes in such work. A design to meet such requirements, and provide a predictable service life, will require detailed analysis of the pavement structure, with due consideration of traffic [Equivalent Single Axle Loads (ESALs), Average Annual Daily Traffic (AADT), and seasonal traffic distribution], and knowledge of the seasonal strength variability of materials from below the AST surface.

3. A Gravel-To-Pavement Decision Strategy

Follow the 3-step evaluation and decision process shown in Table 1.

1. Does road (really) need to be paved? (See Section 3.1)

If No

- Consider selection and use of palliative (See Section 8)

If Yes

- Evaluate foundation, gravel road surface condition, and drainage (See Section 4)
- $ Estimate costs for improving: foundation + surface condition + drainage = cost subtotal 1

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2. Is paving economically feasible based on cost subtotal 1?

If No

- Consider using dust palliative (See Section 8)

If Yes

- Evaluate quality of existing materials (See Section 5)
- Design pavement structure using simplified excess fines method (See Section 6)
- Select a pavement type according to Section 3.1, Table2
- Determine if additional right-of-way is needed
- Design for additional traffic safety requirements (striping, signs, etc.)
- $ Estimate costs of additional standard aggregate + AST or hot mix pavement + new traffic safety requirements = cost subtotal 2
- $ Estimate total cost = cost subtotal 1 + cost subtotal 2

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3. Is pavement still economically feasible (based on cost subtotals 1 + 2)?

If No

- Consider using dust palliative (See Section 8)

If Yes

- Obtain additional right-of-way if necessary
- Make necessary corrections to roadway condition (See requirements of Section 5)
- Add new thickness of material as required by the pavement structure design
- Pave road with AST or hot mix asphalt concrete
- Add necessary safety requirements (striping, signs, etc.)

Table 1. Decision Sequence

3.1. Justifying Paving & Selecting a Pavement Type

Select between gravel and asphalt concrete pavement types based on Table 2. Average annual daily traffic (AADT) represents the total traffic count (sum of both directions) for the road. The AADT shown in Table 2, and the one you will use for design purposes, is an estimated average over the design life of the new project.

AADT *	Functional Classification	Minimum Recommended Pavement Type **
< 120	Local – Low Use, Hillside / Mountain	Gravel Surfacing
120 – 600	Local – High Use, Including Residential	Gravel Surfacing with Dust Palliative
600 – 2,000	Minor Collector	Asphalt (concrete) Surface Treatment (AST)
2,000 – 4,000	Major Collector	Hot Mix Asphalt Concrete (2”)

* Assumes generally less than 2 % trucks
** For various reasons the service district may wish to use a higher quality surfacing type

Table 2. AADT Justification for Various Levels of Road Surfacing

3.1.1. Limitations of AST Versus Hot mix Pavement

ASTs provide serviceable pavements within the AADT limitations indicated in Table 2. However, you should be aware of the inherent limitations of AST pavements. It may seem obvious to you that a ¾ inch thick AST pavement is not going to be as robust as a 2-inch hot mix pavement. AST serviceability is in fact quite vulnerable to engineering mistakes, construction problems, and poor materials. For example, special care must be taken to place ASTs on high quality, compacted materials that are at least as good as or better than materials used under hot mix pavements. Failure to pay attention to the quality of materials under the AST can lead to rapid failure.

Keep in mind:
ASTs **DO** provide a permanent dust palliative driving surface if constructed properly.
ASTs **DO NOT** strengthen the pavement structure.
ASTs **MUST** be repaired as soon as possible after they are damaged

3.1.2. Selecting Between Two AST Pavement Types

Table 2 indicates use of an AST pavement if your design AADT is between 600 and 2,000. Normally, you will be choosing between the two most common AST types, i.e., a double-layer “chip” job and a high float AST. As usually constructed, both AST types are approximately ¾ inch thick and both pavement types provide approximately the same level of service. Both types need to be applied on a smooth, firmly compacted surface, properly set for crown and grade.

Appendix B discusses important factors you may want to consider as part of your selection of AST type.

4. Gravel Road Condition Surveys and Standards for Upgrading to Pavement

If all quality requirements discussed in this section are met, expect a 15 – 20 year service life for gravel-to-pave, low volume roads. In addition to meeting these requirements the designer must also correctly assume:

- The pavement structure is designed and constructed according to Section 6 of this guide.
- After pavement construction, the road will continue to serve generally low volume, light vehicle traffic.
- Proper maintenance will continue over the life of the pavement.
- Effective load restriction will occur during every spring thaw period.

4.1. Need to Recognize and Repair Significant Foundation Problems

All significant foundation problems should be recognized, evaluated, and if necessary, resolved prior to proceeding with the gravel road upgrade. This process may require special geotechnical engineering expertise.

Don't assume that all foundation problems can be handled as insignificant, incidental items of your intended gravel road upgrade. Difficult foundation problems can require considerable design and construction effort. At times, such work may be best handled as a separate project.

4.2. Survey of Drainage and Quality Requirements

Is drainage on and around the roadway important? **YES!** Excellent drainage is so important that it can minimize, or perhaps eliminate, many other problems. Poor drainage almost guarantees the early demise of otherwise well designed and constructed roads. The famous hydrologist Harry R. Cedergren is often quoted as saying that three of the most important considerations for roadway design are drainage, drainage, and drainage.

- Minimum Freeboard
  - For fill condition:
    - No ditch – 24 inches minimum between nominal natural ground surface and bottom of pavement
    - Ditch – 24 inches minimum between ditch bottom and bottom of pavement
  - For cut condition: 24 inches between ditch bottom and bottom of pavement

- Ditches and Culverts

  Every design effort should be made to keep water from lingering (as pond areas) on the surface of the road and away from the road embankment. It may be necessary to hire a hydrologist to properly evaluate drainage potential for design-flood events, to design ditches, size culverts, etc.

- Ponding

  On the road – none allowed

  At roadside – 24 inches minimum between water surface and bottom of pavement (keep ponding away from the embankment sideslope if possible)

4.3. Surface Condition Survey and Quality Requirements

- General Surface Problems

  Crown

  2% for hot mix asphalt concrete pavements

  3% for double-layer and high float ASTs

  Low areas – correct for crown, centerline grade, and drainage

- Localized Problems

  Localized problem areas may need special attention before paving can be considered. Some, perhaps most, will likely be noticeable only during springtime thawing conditions or after heavy storm activity. If the problem areas are very large, the cost to prepare the gravel road for paving may be unacceptably high.

  - Localized Problem Types

    Soft areas

    Rutting

    Surface movement under foot

    Weeping at the surface

    Frost boils

    Alligator cracking

    Historically Poor Performing Areas

    Query locals via questionnaire

    Query maintenance personnel including contractors

  Appendix C (to be added later) is a catalog containing photographic examples of localized damage problem described above.

  - Repair of localized problems

    Repair of these areas should be accomplished through the Section 6 design method **AND** through close attention to providing good drainage.

It is very important to identify and delineate all problem areas so that each can be sufficiently sampled and characterized for design (see Section 5).

4.4. Pavement Structure Quality Requirements

The quality of the pavement structure must be high enough to sufficiently support the pavement against vehicle loads applied for a number of years and during all seasons. Pavement structure quality must meet or exceed the requirements of the Simplified Excess Fines Flexible Pavement Design Method explained step-by-step in Section 6 of this guide.

The results of the pavement design will indicate whether the existing pavement structure meets minimum quality requirements to allow for paving or requires upgrading. If upgrading is necessary, the pavement design process will quantify the upgrade requirements.

4.4.1. Minimum Thicknesses Requirements

The Section 6 design method accounts for the critical minimum thickness of certain layers.

Minimum 4” base course thickness (or equivalent stabilized material)

Minimum 24” embankment thickness

5. Evaluate Existing Pavement Structure Materials

5.1. Selecting Sample Locations (Sampling Frequency)

The importance of correctly sampling the existing roadway's granular material layers cannot be overstressed.

In this guide, sampling frequency is defined as the centerline distance between test holes. At each test-hole location you will obtain samples needed to characterize the existing pavement structure layers. Your decisions regarding sampling frequency defines the limit of your knowledge about the existing road structure, and therefore directly controls the success of your pavement design effort.

What sampling frequency is best? Common sense helps answer this question better than anyone's hard and fast rules. Basically, you must sample frequently enough to characterize each discretely identifiable section of the gravel road.

For long sections of uniform roadway, sample using a test-hole frequency of not less than every 500 centerline feet. For individual sections between 500 and 1,000 feet, two test-holes per section are recommended. For sections shorter than 500 feet, select one test-hole location per section.

Select test-hole locations in the approximate center of the most highly trafficked lane.

Suggestions for identifying road section candidates for separate sampling:

- Road sections known to have been constructed at different times
- Sections differentiated by performance (disregard performance differences caused by local variations in drainage, elevation, etc.)
- Sections differentiated by documented or anecdotal maintenance requirements
- Sections differentiated by seasonal trafficability or visually identifiable strength differences
- Sections differentiated based on comments of local residents

5.1.1. Sampling Depths and Size

At each test-hole location, obtain three (3) samples. Obtain a 25-pound (minimum) sample from within each of the following depth intervals:

0” to 6”
6” to 18”
18” to 36”

Obtain samples using methods of Alaska Testing Methods Manual (ATM) [3] , WAQTC FOP for AASHTO T 2, *Sampling Aggregates*, Section 301.

ADOT&PF’s ATM is available by download from the Internet site:
http://www.dot.state.ak.us/stwddes/desmaterials/mat_waqtc/pop_testman.shtml

The samples may be excavated from the road by any means that doesn’t excessively crush and/or abrade the material. Hand excavation (pick & shovel), backhoe, and use of solid-stem auger drilling equipment are three of the more common ways to obtain samples.

Because of time constraints it may be necessary to obtain samples during the winter. Pneumatic and electric “jack” hammer equipment has been successfully used in Alaska in the winter to obtain frozen samples of granular material. This high-energy method is capable of altering the size of particles at any location that the tool point contacts the granular material. Minimize abrasion and crushing of material by hammering out large pieces of frozen gravel – instead of attempting to hammer the frozen material to the consistency of loose gravel. The sides of the large frozen pieces can be brushed clean of loose, material before those samples are placed in containers. This prevents sample contamination with degraded particles created by the sampling process itself.

Place each sample in an appropriate cotton bag, geotextile sample bag, or appropriate sized plastic bucket. Protect and store the samples until you are ready to deliver them to a qualified materials testing laboratory for gradation testing.

5.2. Laboratory Testing

Require that all samples be prepared using methods of ATM, WAQTC FOP for AASHTO T 248, *Reducing Samples of Aggregate to Test Size*, Section 303 (or acceptable equivalent).

Require that all samples be tested using methods of ATM, WAQTC FOP for AASHTO T 27/T 11, *Sieve Analysis of Aggregates & Soils*, Section 304 (or acceptable equivalent).

Require sieve analysis data reported as percent passing of standard sieve sizes such as:
1 ½ inch, 3/4 inch, 3/8 inch, #4, #8, #50, #100, and #200. These sieves have been selected because they form a standard series and because the data can be used for a number of purposes including classification of the material as base course. Sizes larger than 1 ½ inch should be accounted for if

present. A rule-of-thumb for obtaining generally useful gradation data is that each successively smaller sieve size should be about half the size of the next larger one. Engineers often use standard plots (% passing) of such data to help evaluate such characteristics as ease of compaction, etc., although further discussion of gradation analysis / interpretation are outside the scope of this guide.

The P_{200} content from each sieve analysis test is critical to the gravel road evaluation process. The P_{200} content of each sample will be used in the pavement design process described in Section 6.

Keep a record of all sieve analysis data, keyed to centerline location and sample depth, in case further analysis is required.

6. Simplified Excess Fines Flexible Pavement Design Method

This design method provides structural support for AST and thin (2 inch) hot mix asphalt concrete pavements assuming the design AADT limitations defined in Table 2.

6.1. Design Method Origin and Principles

Some of the background information presented below is a brief summary of that presented in Section 2. This synopsis is included so that this section can be removed from the guide and used as a stand-alone pavement design document.

The simplified excess fines design method was derived from the Alaska Department of Transportation & Public Facilities' (ADOT&PF) Flexible Pavement Design Manual [4]. The ADOT&PF method aims at limiting springtime thaw weakening of asphalt concrete paved road structures in Alaska. The ADOT&PF method was developed from research work that found a strong relationship between flexible pavement performance and the percent content of minus #200 (P_{200}) sieve size material at a given depth within the flexible pavement structure. Pavement structures correctly designed over the past 25 years according to the ADOT&PF Flexible Pavement Design Manual's excess fines method have routinely provided acceptable service in Alaska.

The ADOT&PF's Flexible Pavement Design Manual is available by download from the Internet site: http://www.dot.state.ak.us/stwddes/desmaterials/mat_pvmtmgt/pop_flexpaveman.shtml

In terms of gravel materials commonly used for embankment construction, too much P_{200} may be bad or not so bad depending on how the material is used. P_{200} content is related to the frost susceptibility of the material, i.e., the tendency of a material to accumulate ice content during the wintertime freezing process. In general, a higher P_{200} content means higher frost susceptibility, which causes more wintertime ice accumulation, which in turn leads to greater thaw-weakening during rapid spring thawing.

Acceptable performance requires a very low P_{200} content (limited thaw-weakening) near the pavement surface. The P_{200} content can be allowed to increase at greater depths without negatively affecting pavement performance. Such depth-wise control of P_{200} correlates with the soil mechanics principle that high stresses generated by wheel loads at the surface are distributed laterally with depth in granular material. Those stresses are therefore very much attenuated in the lower layers. Lower stresses mean that more P_{200} (greater thaw weakening) can be allowed in lower layers. The concept of allowable P_{200} versus depth is implemented in this guide as the design curve in Figure 1. Excess fines at any particular depth are defined as a P_{200} content that plots to the right of the Figure 1 design curve.

The design method requires:

- Control of P_{200} to a defined depth (36")
- Minimum total embankment thickness of 24" (above ditch bottom in cut sections and above nominal natural ground surface in fill sections)
- Minimum base course thickness (4") – acceptable base course may be created through various stabilization methods if necessary

6.2. Use of Standard Cover Fill

In principle, the simplified excess fines design process evaluates the P_{200} content of three layers of the existing gravel road pavement structure, and determines the amount of additional cover fill needed for each layer to support vehicle loads. Each of the three layers is evaluated <u>individually</u> to determine the additional *Standard Cover Fill* requirement. The three layers evaluated are: 1) Surface Layer (0" to 6"), 2) Subsurface Layer (6" to 18"), and 3) Embankment Material Layer (18" to 36"). The amount of new *Standard Cover Fill* that must be added to the surface of the existing embankment is the largest of the three fill requirements.

6.2.1. Standard Cover Fill Specifications

Standard Cover Fill shall consist of a readily compactable granular material that meets or exceeds the requirements of ADOT&PF Highway Construction Specification 703-2.09 for Subbase Course, Gradings A, B, C, or D. Fill material meeting Base Course C-1 and D-1 requirements of ADOT&PF Specification 703-2.03 is acceptable.

6.3. Design Steps

(a design example is provided at the end of this section)

Step 1 – Determine standard cover fill requirement for the 0" to 6" surface material layer
On the horizontal P_{200} scale (SP_{200} line) of Figure 1, locate the percent of P_{200} determined by laboratory test for the surface material layer. Place a point at this location. From this point on the SP_{200} line, draw a vertical line downward until it intersects the P_{excess} line. The required thickness of standard cover fill is represented by the vertical distance between the point on the SP_{200} line and the P_{excess} line. If the laboratory P_{200} content plots to the left of the P_{excess} line at 0" depth, the surface material requires no additional cover fill.

Step 2 – Determine standard cover fill requirement for the 6" to 18" subsurface material layer
On the horizontal P_{200} scale of Figure 1, locate the percent of P_{200} determined by laboratory test for the subsurface material layer. From this point on the P_{200} scale, draw a vertical line downward to where it intersects the SSP_{200} line. Place a point at this intersection. Extend a vertical line from the point until it intersects the P_{excess} line. The required thickness of standard cover fill is represented by the vertical distance between the point on the SSP_{200} line and the P_{excess} line. If the laboratory P_{200} content plots to the left of the P_{excess} line at 6" depth, the subsurface material requires no additional cover fill.

Step 3 – Determine standard cover fill requirement for the 18” to 36” embankment material layer
On the horizontal P_{200} scale of Figure 1, locate the percent of P_{200} determined by laboratory test for the embankment material layer. From this point on the P_{200} scale, draw a vertical line downward to where it intersects the EP_{200} line. Place a point at this intersection. Extend a vertical line from the point until it intersects the P_{excess} line. The required thickness of standard cover fill is represented by the vertical distance between the point on the EP_{200} line and the P_{excess} line. If the laboratory P_{200} content plots to the left of the P_{excess} line at 18” depth, the embankment material requires no additional cover fill.

Step 4 – Determine standard cover fill and base course requirements for the existing gravel road

4a – If the standard cover fill requirements determined in Steps 1, 2, and 3 = 0”
No additional standard cover fill is required. If laboratory test results show that the 0” to 6” surface layer meets or exceeds the requirements of C-1 or D-1 base course specifications (ADOT&PF Specification 703-2.03), then no new base course layer is required. If the material does not meet base course requirements, then you have two choices:

1. Add an additional 4” layer of new material meeting base course specifications.

or

2. Stabilize the existing material. Use soil stabilization additive sufficient to bond the existing material to a non-frost-susceptible state. The degree of aggregate bonding ability must be functionally equivalent to adding asphalt cement at 3% by dry weight of material. The additive must provide permanent stabilization. See Section 6.2, Stabilization Guidelines for more information.

Skip Step 4b and go to Step 5.

4b – If one or more of the standard cover fill requirements determined in Steps 1, 2, or 3 are > 0”
The required additional cover fill is the largest of the cover fill values. A 4” thickness of new base course material will be required that meets C-1 or D-1 base course requirements of ADOT&PF Specification 703-2.03.

Step 5 – Check minimum total roadway embankment thickness requirement
The total roadway embankment thickness is defined as the total thickness of the roadway from the natural ground surface (or ditch bottom in cut sections) to top of base course determined in Step 4. It is measured as the sum of the existing roadway material + the added thickness of standard cover fill (if any) + new base course (if any).

If the total roadway embankment thickness is less than 24”, add additional standard cover fill until the 24” requirement is met.

Design process is finished.

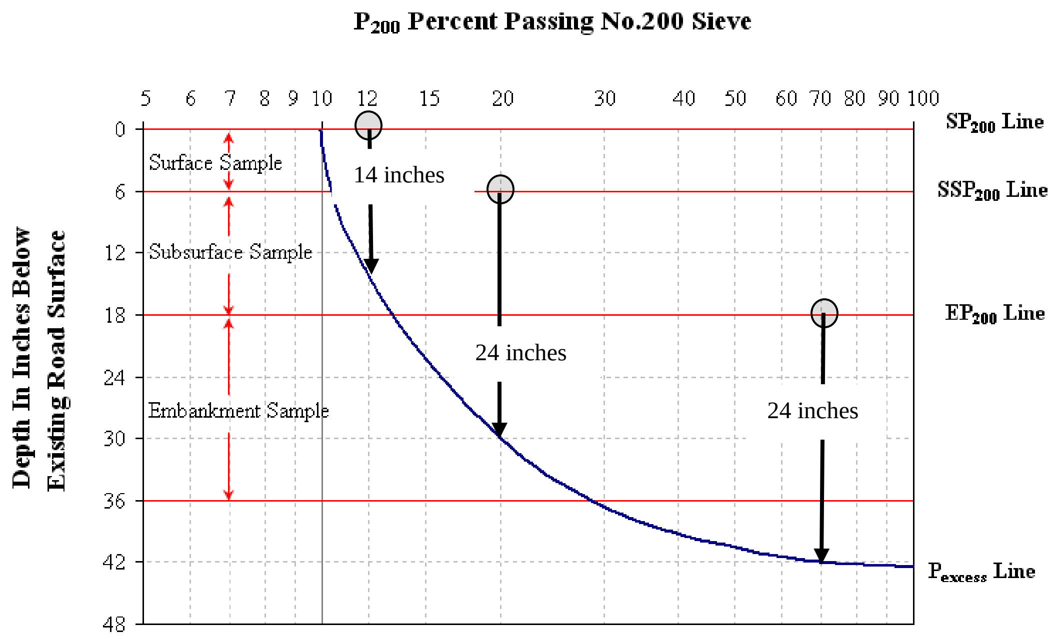


Figure 1. Simplified Excess Fines Design Method

6.3.1. Design Example

Given:

Embankment height = 12" above nominal natural ground surface.

P_{200} of surface material = 12%

P_{200} of subsurface material = 20%

P_{200} of embankment = 70%

These P_{200} points are plotted in Figure 1.

Determine standard cover fill requirements as shown in Figure 1:

- Using Design Step 1. Surface material cover requirement = 14"
- Using Design Step 2. Subsurface material cover requirement = 24"
- Using Design Step 3. Embankment material cover material = 24"

Because cover is required by one or more of the existing gravel road layers, use Design Step 4b:

- Cover requirement = 24" (the largest of the cover requirements indicated above). Then adjust thickness of standard cover fill requirement as indicated below.
- Add 4" base course material, and reduce thickness of standard cover fill requirement by 4".
- Adjusted standard cover fill requirement = 20"

Check minimum total embankment thickness requirement required in Design Step 5

- 12" + 20" = 32"   This is ≥ the minimum 24" total embankment thickness. OK.

End Design Example

<u>**Appendix D contains a pavement design worksheet and full-size design graph.**</u>

6.4. Stabilization Guidelines

Use methods described in the Alaska Soil Stabilization Design Guide [5] by R.G. Hicks to select a base course stabilization method that is most compatible with the materials you are using.

The ADOT&PF's Soil Stabilization Guide is available by download from the Internet site: http://www.dot.state.ak.us/stwddes/research/assets/pdf/fhwa_ak_rd_01_06b.pdf

The ADOT&PF has found that a mixture of frost susceptible base course and 2 to 3 percent (by total weight of mix) asphalt cement will produce a non-frost-susceptible base course. For this to work, the original base course must be an otherwise acceptable, well graded, compactable gravel material.

Many other stabilizers, including a number of proprietary synthetics, etc., may do a good job of stabilizing a frost susceptible material. Selection criteria:

- Compatible for use with the material to be stabilized (see ADOT&PF Stabilization Guide referenced above)
- Nontoxic, environmentally acceptable, etc., based on information contained in its material safety data sheet (obtain MSDS from Internet)
- Meets or exceeds U.S. Cold Regions and Engineering Laboratory (CRREL) "low" heave rate classification (≤ 2.0 mm/day, 48 to 72 hour average heave rate, ADOT&PF frost heave test method)

7. If You Decide Not to Pave the Gravel Road

7.1. Surfacing material

If a decision is made not to pave the gravel road, the Borough may decide to evaluate and/or upgrade the existing road's gravel surface. In its 2004 Standard Construction Specifications for Highways, ADOT&PF offers two gravel surfacing gradations. These are listed as gradings E-1 and F-1 in Section 703-2.03 *Aggregate for Base and Surface Course*. Surfacing material must also meet the quality requirements for base course in that specification section. There are a few rules of thumb for gravel surface course materials that have worked in Alaska:

- Use well graded gravel with a maximum particle size of 1 inch
- The P_{200} content should probably be in the 10% to 14% range although ADOT&PF allows 8% to 20% depending on grading.
- Require material that compacts well – ideal material will plot as a straight or nearly straight line on 0.45 power paper (obtainable from regional offices of ADOT&PF materials engineers).
- The best surface course materials contain a small percentage of natural clay (not more than 2 to 3%).

Regarding the last item above, there is a problem that is common to most Alaska gravel materials with respect to use as gravel surfacing, i.e., lack of natural cohesion. Lack of cohesion means that even those gravel surfaces made using well-graded, densely-compacted material likely produce a lot of dust. Dust is an environmental problem and the raveling caused by loss of fines leads to considerable material loss over time. Presence of a small amount of natural clay provides cohesion. It is possible to obtain cohesion by adding commercially-available montmorillonite clay or other commercial "stabilizer" additives to existing gravel. Correct dosage rates for clay or any other stabilizers must be determined, by testing, for a specific gravel material.

7.2. Dust Palliatives

In today's literature you can find many documents dedicated to the subject of soil stabilization in general and dust palliatives in particular. Keep in mind that dust palliatives are simply a specialized application of soil stabilization technology. For the sake of simplicity, the writer picked two, reasonably definitive, and useful documents for reference in this section.

> The *Dust Palliative Selection and Application Guide* written for the U.S. Department of Agriculture, Forest Service [6]
> This manual is available by download from the USDA Internet site:
> http://www.airquality.nrcs.usda.gov/Documents/USFS_DustGuide.pdf
>
> Section IV, *Dust Control and Stabilization* of South Dakota's Maintenance and Design Manual [7]
> This manual is available by download from the Federal Government's EPA Internet site:
> http://www.epa.gov/owow/nps/gravelroads/

As of this writing, the Matanuska-Susitna Borough uses calcium chloride ($CaCl_2$) as a dust palliative for gravel roads with an application rate of about 6 tons per centerline-mile on 2-lane roads.

ADOT&PF's Northern Region M&O uses calcium chloride to treat 2-lane gravel roads with annual application rates usually ranging between 5 and 10 tons per centerline-mile – most commonly 5 to 6 tons per mile. ADOT&PF may use an initial application rate of nearly 10 tons/mile for new gravel road surfaces (surfaces previously untreated with $CaCl_2$).

Sodium montmorillonite (brand name, Stabilite) was used more than 10 years ago as a surface course stabilizer/dust palliative for the Fort Yukon runway. With occasional grading, it provided more than a decade of acceptable, relatively dust free service. The montmorillonite was added to the surface course gravel at about 3 percent, by total weight, of treated surfacing gravel.

Common materials, such as calcium chloride or montmorillonite clay, may be your safest bet as a reliable dust palliative although many other materials are available. Be aware that proprietary dust palliatives may need extensive testing before they can be accepted for routine use. Be sure to require an MSDS as part of evaluating any proprietary products.

8. Construction Specifications & Care After Construction

8.1. Construction Specifications

Refer to in-house design/construction resources available from Matanuska-Susitna Borough engineering offices. The Borough will have developed construction methods for AST and hot mix pavements that work within their geographical area of operation. Some of the Borough's specifications may have been developed from other government agencies including ADOT&PF standards indicated below.

8.1.1. Hot Mix Construction Specifications

ADOT&PF standard construction specifications should be a useful resource. These specifications can be downloaded from the ADOT&PF's Design and Engineering Services ("Standard Specifications for Highways") Internet site:
http://www.dot.state.ak.us/stwddes/dcsspecs/resources.shtml

In addition to the statewide standards, standard modifications as well as special provisions used by ADOT&PF Central Region should be good references for the Matanuska-Susitna Borough. Some of these are available from the above Internet site. However, some of the special provisions (especially the newer ones) that are used by the Central Region may need to be obtained directly from the Highway Design Chief located in the ADOT&PF office on International Airport Road, Anchorage (contact 907-269-0566).

8.1.2. AST Construction Specifications

Use Matanuska-Susitna Borough's AST construction specifications [8].

In addition, the ADOT&PF standard construction specifications should be a useful resource for AST construction specifications (see specification Section 405, S*urface Treatment*). Some of the newer special provisions used by ADOT&PF's Northern Region may be particularly useful. Contact Northern Region's Highway Design Chief (907-451-2271) about the newest available Northern Region special provisions for AST pavements. Except for construction start/end dates, Northern Region ideas and specifications should be particularly useful since that region has been involved in constructing a large number of AST jobs over the past few decades.

The ADOT&PF Surface Treatment Guide (referenced in Section 2.1) is another excellent source of general information covering almost all aspects of AST materials and construction methods used in Alaska 1. The ADOT&PF's Surface Treatment Guide is available by download from the Internet site:
http://www.dot.state.ak.us/stwddes/research/assets/pdf/fhwa_ak_rd_01_03.pdf

8.2. Care After Construction

The design method you used in Section 6 relies on simplifying assumptions regarding materials properties and design vehicle traffic. The design method is quick to learn and easy to use. It produces a relatively low budget pavement with minimal investment in geotechnical investigation, pavement engineering, and materials. This simplified engineering approach comes with tradeoffs. The consequence of the budget approach is that there will remain a need for careful attention to maintenance and monitoring of vehicle usage throughout the life of the pavement.

All of the elements mentioned below are important maintenance issues. However, they are much more critically important if the pavement is an AST.

1. Standard Maintenance Practices – Employ all standard maintenance practices normally used for paved roads in the Borough.

2. Pothole Repairs – Fill potholes as soon as possible after they are noticed. This is especially important if the pavement is an AST. Potholes or other open areas in ASTs enlarge very quickly because the thin (≈ ¾ inch) pavement has almost no resistance to tensile or shear stresses.

3. Annual Load Restrictions – Apply annual load restrictions (trucks at 50%) for the duration of the spring thaw period as defined by the Matanuska-Susitna Borough. This restriction compensates for material sampling limitations associated with the design process used in this guide. In other words, load restrictions are imposed in prudent recognition of the many unknowns associated with minimally upgrading an existing roadway structure instead of starting from "scratch." Annual load restrictions are particularly beneficial to the longevity of AST pavements. ASTs are inherently delicate in the face of any substantial springtime thaw weakening of the pavement structure. If spring load restrictions are not possible, the pavement structure should be designed according to the ADOT&PF Flexible Pavement Design Manual 4 (see last paragraph of Section 2.2).

After several years of springtime performance observations, Borough engineers may notice that the road appears to remain very solid during the springtime period. If so, it may be possible to reduce or even remove load restrictions. It would be prudent to support such a decision with more than just visual "data." You should consider contacting the ADOT&PF, Central Region Materials Engineer (Tudor Road, Anchorage, 907-269-6200) about using the Falling Weight Deflectometer to aid your decision. Also, ADOT&PF's Pavement Design Engineer (same location, 907-269-6214) is perhaps Alaska's definitive source of technical expertise regarding all aspects of evaluating the need for load limits on new or existing roads.

4. Snow Damming – During times of persistent thawing, pay special attention to keeping the roadway shoulders clear of accumulated snow. Snow berms will facilitate ponding of water on or near the pavement. Ponding of water on or near the pavement combined with the action of traffic most often leads to very rapid pavement failure.

5. Useful Tattletales – It is much to the Borough's advantage to keep a carful eye on roads that have recently received gravel-to-pavement upgrading. This is especially true for the first year or two following construction.

You will be looking for obvious signs of localized or extended areas of:

- Water bleeding from the pavement surface
  This indicates that excess water has collected near the bottom of the pavement during the freezing period. It usually signals one of two things, i.e., either poor roadside drainage or that frost susceptible material remains too close to the bottom of the asphalt concrete pavement layer.
  Repairs: If drainage is the problem, improve surface and or roadside drainage as necessary. If there are no drainage problems, remove 24 inches of granular material, replace using NFS material, repave. Application of geotextiles as part of this repair is not recommended.

- Alligator cracking, rutting, and/or other indications of surficial softness
  This is usually caused by the same mechanisms mentioned above. In this case the pavement has already been destroyed.
  Repairs: Same as above. Take special care to define the lateral extent of the soft area(s) very well before the repairs are made. As above, application of geotextiles as part of this repair is not recommended.

Such observations are most advantageous during prolonged thaw periods that produce at least 4 to 5 inches of thaw depth. During the springtime thaw period, the observations should continue occasionally until the thaw depth reaches about 24 inches.

Appendix A — Canadian AST Service Life Estimates

The following discussion is extracted, with only minor changes, from the ADOT&PF Asphalt Surface Treatment Guide 1.

The AST pavement service life for roadways with moderate truck traffic has been estimated in Canadian government studies. These estimates are probably very conservative with respect to low volume, lightly trafficked roads, and may underestimate the service life of such roads perhaps by a factor of two (author's opinion). The important point is that the Canadian estimates clearly demonstrate the importance of properly preparing the underlying pavement structure to receive the AST surfacing.

Canada's Yukon Government Community and Transportation Services developed estimates of AST pavement life as part of its management system for AST pavements on Yukon highways. AST life estimates are based on the quality of the pavement structure under the AST surface. The management system defines three classes of pavement structure quality:

1. Class 1—Includes all roads on which the AST has been applied to an unimproved road structure that has not been designed to any particular standard.

2. Class 2—Includes roads on which a 3 – 6 inch thick layer of crushed gravel base course is placed on the subbase prior to AST application.

3. Class 3—Includes roads with fully designed base and subbase layers on which AST has been applied as a substitute for hot mix asphalt concrete.

Estimates of average AST life are shown in the following table.

Canadian Estimates of AST Life*

For Class 1 Conditions	Expect 2 Years of Routine Maintenance	Expect 5 Years Before Reconstruction
For Class 2 Conditions	Expect 4 Years of Routine Maintenance	Expect 7 Years Before Reconstruction
For Class 3 Conditions	Expect 6 Years of Routine Maintenance	Expect 10 –12 Years Before Reconstruction

*Although Canadian estimates are for high float ASTs, life expectancy of a double-layer AST should be similar.

Canadian engineers also addressed the question of putting seal coats on older AST pavements. They found, in terms of overall economics, it is best not to seal coat older, damaged AST pavements. The seal coat adds nothing to the life of existing ASTs that were damaged because of a poor pavement structure. In the Yukon, older ASTs are not seal coated; they are "ripped and reshaped," then a new

AST is applied. Seal coating would be considered viable only on newer ASTs showing very minor damage.

Appendix B — Selecting Between AST Pavement Types

Both double-layer and high float AST pavements give approximately the same level of service. They provide approximately the same pavement thickness, and both need to be applied on a smooth, firmly compacted surface, properly set for crown and grade. The following may help you select one over the other.

Decision Based on Appearance:

To the average observer, a new double-layer AST will usually present a better appearance than a new high float AST. The new high float will produce more dust than a double-layer AST although both types are comparatively dust-free within a few weeks. As several years go by, the two kinds of AST tend toward a similar appearance. When constructed properly, older double-layer and high float ASTs can become almost indistinguishable from one another – or from a hot mix asphalt concrete pavement for that matter.

Decision Based on Ride Quality:

A new high float AST can be expected to produce a significantly rougher ride (and much more dust) than a new double-layer AST. Even several weeks to several months after construction, experience has found that most drivers will judge the double-layer AST to have at least slightly better ride quality.

As designer, you should invest enough time for a field trip to sample both kinds of AST that may already exist in your area. Your seat-of-the–pants education will teach all you need to know to address this decision item. Be sure to test drive examples of newer and older construction, so that you can form an opinion about ride quality versus time since construction.

Drive each section at the posted speed limit to get a realistic sense of roughness. It helps to have a second person along to assist in judging ride quality and with whom you can discuss ride quality immediately after driving a particular AST section. It is important that you recognize and disregard aspects of road roughness caused by poor foundation conditions.

During your field test, pay attention to the vehicle noise generated from different AST types—it will be necessary to stand at the side of the road for a while and listen to various types of vehicles passing.

Decision Based on Constructability:

Double-layer ASTs require two good construction days for applications of two layers of oil and cover aggregate. Since the first layer of materials must cure enough to be broomed, you need at least a few days of warm (+60˚F), dry weather between the two construction days. Near the end of the construction season or during a wet, cold summer period, there may be no interval of time long enough to be ideal for doing a double-layer AST.

A high float job is a one-step process. Therefore, only one good day is necessary for the construction process. Moreover, high float AST doesn’t require a second period of traffic control, the additional brooming, construction personal, time, and equipment required for the second layer of the double-layer AST.

Both AST types require a similar period of warm, dry weather for curing after construction. The single day required for application of high float materials therefore allows a few days extra time for final curing. This advantage may be especially meaningful for Matanuska-Susitna Borough construction projects given the short, cool summers of that area.

Decision Based on Capital Cost:

There are no shortcuts. You must assess materials costs for each job. Past estimates are not necessarily indicative of future costs. This is certainly the case with old estimates or with estimates made for other areas of Alaska.

Within the last 10 years, ADOT&PF’s M&O engineers have found that total material costs associated with high float ASTs usually run anywhere from 20 to 40 percent less than for double-layer ASTs. Occasionally, total material costs for both AST types have been about the same.

M&O has commented that a newly constructed high float AST surface may have a “rough finished texture.” This may require extra traffic control and patching during the first week after construction. M&O suggests that if the surface texture becomes too much of a problem, a seal coat may be needed at a later date. The extra monitoring and seal coating may increase the total cost of a high float AST to near that of a double-layer AST, but the end result would be about 12 mm thicker and perhaps slightly more durable.

The Final Decision:

Since maintenance and operating costs are roughly the same, a first assumption would be to select the AST type having the lowest initial cost. This choice usually (but not always) satisfies management and is the one usually favored by public opinion. If your role is to help management decide between a double-layer and high float AST, be prepared to discuss all of the above decision factors—including comparative costs.

Appendix C — Gravel Road Damage Catalog

Reserved for pictures & descriptions of gravel road damage

Appendix D — Pavement Design Graph & Worksheet

Use the following data input worksheet and design graph for designing flexible pavement structures as indicated in Section 6 of this Guide. Add the desired asphalt concrete pavement surface thickness (3/4 inch for AST and 2 inches for hot mix) to the adjusted thickness determined using the following table.

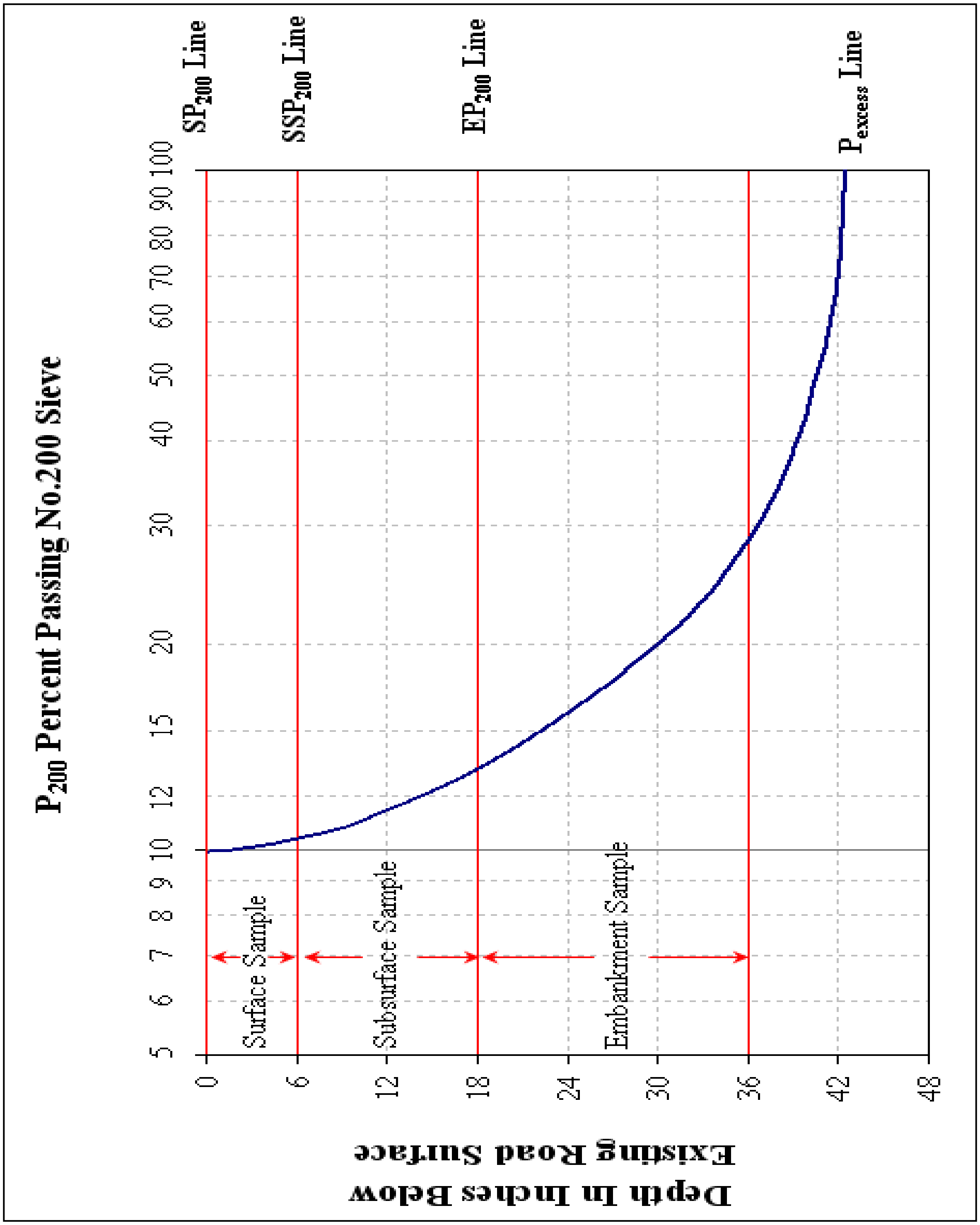
Determining Thickness of Granular Materials Added to Existing Gravel Roadway Embankment

Design Input Type	*Input Value*	*Comments*
Existing embankment thickness above nominal ground surface, inches* (* used in adjustments at bottom of table)		
P_{200} of Surface Material (0" to 6" depth)		
P_{200} of Subsurface Material (6" to 18" depth)		
P_{200} of Embankment Material (18" to 36" depth)		

Determine Standard Cover Requirement (using Appendix D design graph below)	*Standard Cover (inches)*	*Comments*
Requirement 1: Surface material (see Section 6, design step 1)		
Requirement 2: Subsurface material (see Section 6, design step 2)		
Requirement 3: Embankment material (see Section 6, design step 3)		
Standard Cover Requirement = maximum value from requirements 1, 2, or 3 above		

Base Course Adjustment for Standard Cover Requirement	*Adjusted Thickness (inches)*	*Comments*
If Standard Cover Requirement is ≤ 4": **use 4" base course and use no standard cover material**		
If Standard Cover Requirement is > 4": **add 4" base course to standard cover material**		

Embankment Height Adjustment for Standard Cover Requirement	*Adjusted Thickness (inches)*	*Comments*
If existing embankment* + standard cover material + base course thicknesses total < 24": **add standard cover material until total of thicknesses = 24"**		
If existing embankment* + standard cover material + base course thickness ≥ 24": **add no additional standard cover material**		


P200 Percent Passing No.200 Sieve
SP200 Line
SSP200 Line
EP200 Line
Pexcess Line
Surface Sample
Subsurface Sample
Embankment Sample
Depth In Inches Below Existing Road Surface
5 6 7 8 9 10 12 15 20 30 40 50 60 70 80 90 100
0 6 12 18 24 30 36 42 48

References

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[2] Casagrande, A., ***Discussion of Frost Heaving***, Proceedings, Highway Research Board, 1931.

[3] ***Alaska Test Methods Manual***, Alaska Dept. of Transportation & Public Facilities, Anchorage, Alaska, Revised Version of April, 2009.

[4] McHattie, R.L., ***Alaska Flexible Pavement Design Manual*****,** Alaska Dept. of Transportation & Public Facilities, Research Report FHWA-AK-RD-03-01, Fairbanks, Alaska, 2004.

[5] Hicks, R.G., ***Alaska Soil Stabilization Design Guide*****,** Alaska Dept. of Transportation & Public Facilities, Research Report FHWA-AK-RD-01-6B, Fairbanks, Alaska, 2002.

[6] Bolander, P. and Yamada, A., ***Dust Palliative and Selection Guide***, United States Department of Agriculture, Forest Service, Technology and Development Program, San Dimas Technology and Development Center, California, 1999.

[7] Skorseth, K., and Selim, A.A., ***Gravel Roads Maintenance and Design Manual***, South Dakota Local Transportation Assistance Program, 2000.

[8] Moses, Thomas, ***Matanuska-Susitna Borough Bid # 09- Chip Seal Application Project Special Provisions (Section 405*****),** specifications on file at Matanuska-Susitna Borough office, Palmer, Alaska, 2009.