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A Guide to Successfully Convert Severely Distressed Paved Roads to Engineered Unpaved Roads

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This document provides guidance on converting severely distressed paved roads to engineered unpaved roads. Chapter 1 provides background on unpaving and an introduction to the guide. Chapter 2 guides the practitioner through a process of deciding whether a road is a candidate for unpaving and introduces the importance of involving the public in the decision. Chapter 3 provides a step-by-step process for doing a road investigation. Simple tools to analyze test results and determine likely future performance of the road are introduced. Guidance for considering potential safety issues is also provided. Chapter 4 covers designing the engineered unpaved road, introduces tools for determining an optimum blend of the existing materials, and if necessary, provides supplemental materials that may be required to increase structural capacity or optimize performance. Guidance for selecting an appropriate chemical treatment is also provided. Links to web-based tools for material blending, unpaved road performance prediction, and chemical treatment selection are provided as well. Chapter 5 summarizes key factors to consider during the conversion process and when maintaining the converted road. Chapter 6 introduces tools to determine life-cycle costs for converting roads. And finally, Chapter 7 provides guidance for communicating with, and involving the public in, the decision to convert a road or road segment.

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Guidebook

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LIST OF ABBREVIATIONS

AADT	Annual average daily traffic
AASHTO	American Association of State Highway and Transport Officials
ASTM	American Society of Testing Materials
BLS	Bar linear shrinkage
CBR	California bearing ratio
CIMS	County Information Management System
DCP	Dynamic cone penetrometer
DPI	DCP penetration index
DSN_{800}	DCP structure number
FDE	Fundamental data elements
G_c	Grading coefficient
HCADT	Heavy commercial average daily traffic
LRRB	Local Road Research Board
LRSP	Local road safety plan
MIRE	Model inventory of roadway elements
MnDOT	Minnesota Department of Transportation
NDSU	North Dakota State University
NDLTAP	North Dakota Local Technical Assistance Program
PI	Plasticity index
RAP	Recycled asphalt pavement
S_p	Shrinkage product
SPP	Sulfonated petroleum product

EXECUTIVE SUMMARY

Minnesota has an extensive network of rural, low-traffic-volume roads. A large percentage of the roads in this network were paved in past decades, but unfortunately, funding to routinely maintain them has not always been available, which has accelerated the rate of deterioration. Now many of these roads are severely distressed (with, cracks, ruts, and potholes) and funds to continue trying to maintain them or to rehabilitate/reconstruct them are limited. Driving on distressed paved roads can present safety implications along with increased vehicle occupant discomfort and higher vehicle operating costs. Traffic volumes on many of these roads have also been reduced over the years, often to less than is justified for keeping them at a paved standard. Conversely, the size and weight of trucks and agricultural equipment that use these roads have increased significantly.

In situations where repairs are having little effect and/or where sufficient funding to rehabilitate the roads is not available, road agencies may consider converting these severely distressed, low-traffic, paved roads to engineered unpaved roads. Conversion involves pulverizing the existing road materials, with additional supplemental materials and chemical treatments where required, into a shaped and compacted unpaved road. Once converted, maintenance can be carried out with a grader, and dust levels can be kept to an acceptable standard with appropriate chemical treatments. If done correctly, the converted road should provide better, safer performance than the distressed paved road, and grader maintenance will be cheaper than labor intensive patching and crack sealing. The engineered unpaved road can always serve as a quality base for a paved surface if funds are made available later, or if increasing traffic volumes justify it.

This document provides guidance on converting severely distressed paved roads to engineered unpaved roads. Chapter 1 provides background on unpaving and an introduction to the guide. Chapter 2 guides the practitioner through a process of deciding whether a particular road is a candidate for unpaving and introduces the importance of involving the public in the decision. Chapter 3 provides a step-by-step process for doing a road investigation. Simple tools to analyze test results and develop an idea of likely future performance are introduced. Guidance for considering potential safety issues is also provided. Chapter 4 covers designing the engineered unpaved road and introduces tools for determining an optimum blend of the existing materials, and if necessary, provides supplemental materials that may be required to increase structural capacity or optimize performance. Guidance for selecting an appropriate chemical treatment is also provided. Links to web-based tools for material blending, unpaved road performance prediction, and chemical treatment selection are provided as well. Chapter 5 summarizes key factors that will need to be considered during the conversion process and when maintaining the converted road. Chapter 6 introduces tools to determine life-cycle costs for converting roads. Chapter 7 provides guidance for communicating with, and involving the public in, the decision to convert a road or road segment. Supporting information is provided in the appendices.

Following the guide should help practitioners to make informed decisions about whether a road is a candidate for conversion, how to design the road to ensure good performance, and how to convert the road to provide a safer and significantly improved level of service.

CHAPTER 1: INTRODUCTION

This guide was developed based on preliminary needs identified in *NCHRP Synthesis 485 Converting Paved Roads to Unpaved (1)* and has been tailored to address the need for dealing with severely distressed, lower-volume paved roads in Minnesota. The guide is divided into a series of chapters including:

- When a road a candidate for unpaving
- Road investigation
- Design and engineering an unpaved road
- Methods to successfully convert a paved road to an unpaved road
- Life-cycle costs
- Communicating about unpaving

The guide details a step-by-step process for deciding whether a road is a candidate for unpaving, conducting a road investigation, doing the road design, and additional factors that need to be considered during the actual conversion. The guide has been compiled to provide a quick, systematic, and easy process for practitioners to follow to ensure that informed decisions are made, that converted roads perform well, and that road users are satisfied with the result.

1.1 OVERVIEW

Low-volume rural roads serve as critical transport routes for industries, farmers, and residents. A majority of these rural roads have unpaved, aggregate surfaces and carry very low traffic volumes (i.e., typically less than 150 vehicles per day). Historically, unpaved roads have been considered the lowest level of service provided. In a demonstration of progress and an effort to improve road conditions for rural residents, many agencies paved low-volume roads in the latter half of the 20th century, with little or no base preparation, when asphalt and construction prices were low. Those asphalt roads have now aged well beyond their design service life, are rapidly deteriorating, and are both difficult and expensive to maintain (Figure 1.1). The increasing size of agricultural and commercial equipment including that used by the energy sector are compounding this deterioration in many areas. Traditionally, these roads were maintained or repaved at regular intervals, but with the increasing traffic loads, increasing cost of materials, and stagnant or declining road-maintenance budgets, many agencies do not have the funding to support these activities. Instead many local road agencies are looking to convert these deteriorated paved roads to unpaved as a more manageable solution (Figure 1.) and viable alternative to continuing to try and maintain the road with a paved surface, or rehabilitating it to a satisfactory performance level.

Figure 1.1 Distressed paved road.

Figure 1.2: Engineered unpaved road

1.2 HISTORY OF ROAD CONVERSIONS

The practice of converting paved roads to unpaved is relatively widespread. In a 2015 survey *(Figure 1.1)*, documented cases of road conversion projects were found in 27 states and two Canadian provinces. Roads that have been converted to date typically have annual average daily traffic (AADT) of between 20 and 100 vehicles, suggesting that many of the roads that are being converted should not have been paved initially, or that road usage patterns have changed significantly since paving.

The state-of-the-practice for converting paved roads to unpaved roads has involved reclaiming or recycling the deteriorated pavement surface, supplementing existing materials as needed, compacting, and for some, applying or incorporating a surface treatment such as a soil stabilizer or dust abatement product. In a few cases, no recycling of the old pavement is done, and new surface aggregate is simply placed over the deteriorated road surface. However, most agencies that have done conversions recycle the old surface in-place and reshape and compact it as a base for a new aggregate surfacing.

Figure 1.3: Safety concerns on distressed paved road.

Local road agencies are converting roads primarily due to a lack of funding for maintenance and construction, safety issues associated with the distressed surface (e.g., vehicles exiting their lane to avoid distresses), and/or complaints from the public (Figure 1.). Road budgets have remained stagnant or have declined in recent decades, but costs of labor, materials, and equipment have continued to increase. Consequently, local road agencies have been left underfunded and are struggling to maintain their existing road network. Limited maintenance of deteriorating roads (e.g., pothole patching) is often all that can be done within existing resources, with repaving often cost-prohibitive. In seeking a cost-effective alternative to continued maintenance and repair of deteriorating pavement, agencies have begun to recognize that many roads with very low traffic volumes can be maintained more economically and at a higher level of service with an unpaved surface.

Local road agencies have experienced positive outcomes by converting roads in terms of lower maintenance costs compared to the costs of continuing maintenance of the deteriorated paved road, or rehabilitation. However, the public needs to be involved in the discussion and appropriate levels of investigation, design, and construction procedures must be followed to ensure that the converted road provides a better level of service than the distressed paved road. To accomplish this, agencies need direction in planning projects that will lead to optimal use of available materials and equipment, as well as a smooth, safe, and maintainable driving surface upon completion. This guidance document aims to address this need.

1.3 FACTORS DRIVING THE CONSIDERATION FOR UNPAVING

Numerous factors can drive road agencies to consider converting distressed, low-volume paved roads to unpaved roads, with the most common being economic and safety considerations.

1.3.1 Economic Considerations

Figure 1.4: Ineffective patching.

Labor-intensive maintenance of severely distressed paved roads is very expensive and results in limited improvement in serviceability (Figure 1.4). Although potentially more cost-effective over the design life of the pavement, rehabilitating the road to provide a satisfactory level of service for current and expected traffic volumes is usually cost-prohibitive for local agencies that primarily work with fluctuating annual budgets and do not have capital resources to take on projects of this scale. Converting a distressed paved road to an engineered unpaved road, as explained in this guide, is relatively inexpensive compared to a full-scale rehabilitation. Costs are usually limited to importing supplemental gravel if needed, pulverizing and mixing the materials, shaping, compaction, reinstating drains, and where appropriate applying a chemical dust suppressant. Chemically treating or stabilizing granular surfaces to control dust, reduce the rate of aggregate loss, reduce grader maintenance frequency, and improve all-weather passability is in most instances the most cost-effective approach to managing unpaved roads after conversion (Figure 1.5). There is also the added benefit of being able to surface this maintained layer with asphalt concrete or a chip seal at a later date if increased traffic volumes dictate the need for it, or if funds become available. Stabilization procedures can also improve safety and raise the level of public acceptance.

Figure 1.5: Chemically treated road.

1.3.2 Safety Considerations

Figure 1.6: Safety issues.

Safety considerations are a significant factor in deciding whether to convert a distressed paved road to an engineered unpaved road. Examples of safety issues on distressed paved roads include but are not limited to (Figure 1.6):

- Vehicles swerving into oncoming traffic or leaving the road to avoid potholes
- Tire or vehicle damage caused by potholes and/or islands of remaining surfacing
- Aquaplaning caused by ponding water
- Rollovers caused by swerving to avoid distresses
- Reduced visibility on dusty sections of road where the surfacing has completely disintegrated
- Windshield and other vehicle damage caused by loose pieces of surfacing dislodged by passing traffic
- Difficulty in applying and maintaining striping
- Injuries to road workers repairing the distresses

CHAPTER 2: WHEN IS A ROAD A CANDIDATE FOR UNPAVING?

2.1 OVERVIEW

A number of factors need to be taken into consideration when deciding on whether a distressed paved road is a candidate for unpaving. These factors include:

- Economics
  - Economic considerations for unpaving are typically based on the conversion and subsequent maintenance being less expensive than continuing to maintain the road or rehabilitate it to restore a satisfactory level of paved road performance.
  - Additional factors that will need to be considered include expenditures for additional equipment if required, retraining of staff, additional safety actions (e.g., more signs), and annual rejuvenation of chemical treatments.
- Safety
  - Safety considerations for unpaving are based on the converted road being safer for both the traveling public and agency staff than the current distressed paved road.
  - Additional signage and annual dust control treatments may be needed to maintain a satisfactory level of safety.
- Traffic
  - Roads with annual average daily traffic less than 100 to 150 vehicles per day (i.e., 8 to 12 vehicles per hour over a 12-hour period) are good candidates for unpaving. Higher traffic volumes can be accommodated; however, cost analyses will need to be undertaken to determine if conversion is still the most cost-effective option.
  - Unpaved roads with higher traffic volumes require more frequent maintenance and chemical treatment rejuvenations. Note that improving the road may also attract additional traffic.
  - Higher traffic volumes imply more road users that will need to be convinced that unpaving is an appropriate rehabilitation action.
- Causes of distress
  - Roads with distresses that are associated with age and/or delayed maintenance are usually good candidates for unpaving.
  - Roads with serious structural deficiencies (e.g., absence of base layers, weak subgrades, etc.) or drainage-related problems will need to have these problems addressed to ensure satisfactory performance after conversion.
- Environment
  - Environmental considerations are typically associated with potential environmental problems associated with dust (e.g., air pollution, crop damage, reduced pasture palatability), erosion, water pollution, and frequent gravel replacement.
  - Most of these concerns can be addressed by appropriate gravel selection and implementation of chemical treatment programs. Note that some or all of these environmental problems may also be applicable to severely distressed paved roads.
- Public complaints
  - Public complaints are often a key reason for considering unpaving. Although conversion is not typically what the public consider as an appropriate solution, they will often accept it when they

understand that this is an affordable option that will result in a significant improvement to the current road condition.

- Agency resources
  - Road conversions will require communicating with the public.
  - Conversions will also require agency expertise to undertake the conversion process described in this guide and then to maintain the unpaved road at a satisfactory level of service.

2.2 SUGGESTED DECISION PROCESS

The decision process will need to consider all of the above factors. A decision to proceed with a road investigation is usually based on the outcome from a desktop study (discussed in Section 3.2) during which these factors are quantified. A flowchart illustrating this decision process is shown in Figure 2.1.

2.3 PUBLIC RELATIONS AND INVOLVING THE PUBLIC IN THE PROCESS

Involving the public before, during, and after the conversion is a critical part of ensuring a successful process. Guidance on public involvement is provided in Chapter 7.

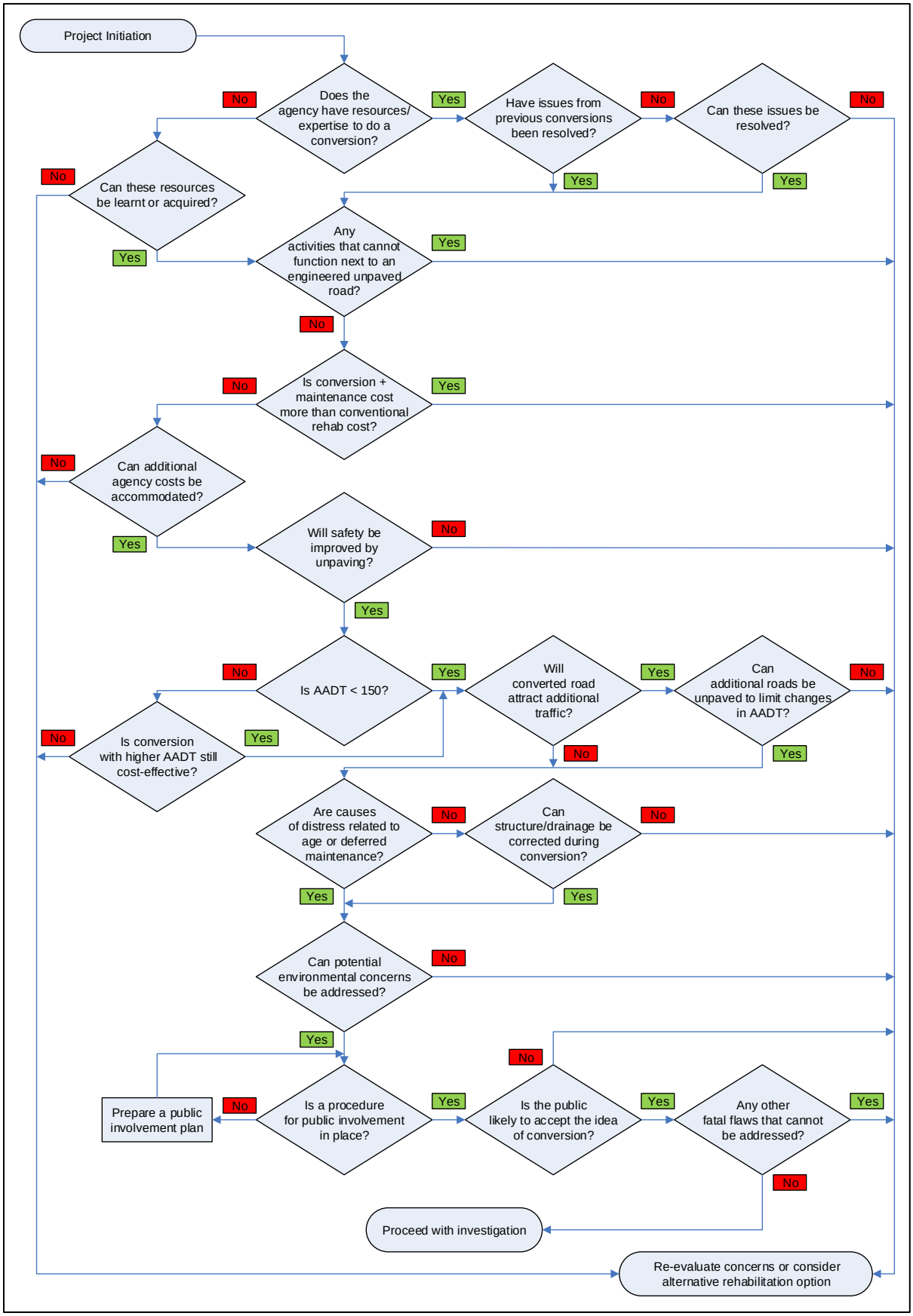


Figure 2.1: Flowchart for deciding whether a road is a candidate for unpaving.

CHAPTER 3: ROAD INVESTIGATION

3.1 INTRODUCTION

The road investigation is a key part of the road conversion process. It provides information on what is out there and why it looks like it does. Findings from the investigation, along with the results of tests on materials sampled, will be used to confirm that the road is a suitable candidate for unpaving and whether there are sufficient materials in place to do the job, or whether additional materials will be required. The costs of doing a thorough investigation are negligible in terms of the costs of the total project. Skipping the investigation could have expensive and embarrassing consequences if safety issues arise or if the converted road deteriorates quickly because of factors that were not considered or foreseen.

The road investigation is done in three stages;

1. A desktop study to gather relevant information;
2. The site investigation; and
3. Material testing and documentation of the results.

3.2 DESKTOP STUDY

The desktop study is done to collect relevant history and road information, determine traffic using the road, and understand weather-related factors. Potential safety issues are also considered in this part of the investigation. Each of these is discussed below and a checklist (Form #1) is provided in Appendix A for answering the questions.

3.2.1 Information about the Road

Information about the road, if available, is always useful for understanding current condition and factors influencing current performance. This information helps to get an idea of what needs to be done to ensure that satisfactory and safe future performance can be achieved after the road is converted. The information can be collected from as-built records and maintenance logs if they have been kept, accident records, or from the recollections of long-serving staff. Questions that need to be answered include the following:

- When was the road originally built (to better understand if the distresses are related simply to age or whether other factors such as traffic and climate dominate)?
- What design philosophy was used for the road?
  - Was a standard engineering design followed (i.e., compacted subgrade, imported compacted base layer using materials that meet a standard base course specification, and surfacing meeting a mix specification and placed according to a specification [Figure 3.1])?
  - Or, did the road evolve over time from a track to a gravel road that was eventually surfaced (Figure 3.2)?

Figure 3.1: Example engineered road.

- When was the first asphalt concrete or surface treatment placed?
- How many times has the road been resurfaced since the original surface was placed?
- How often does the road require maintenance and what are the primary distresses requiring maintenance (e.g., pothole patching [Figure 3.3], crack sealing, edge break, localized flood repair, frost heave, etc.)?
- Are there any obvious reasons for the current poor condition of the road (e.g., age of the surfacing, delayed maintenance, severe weather events, significant increase in traffic volume, or significant change in vehicle type)?
- Have any safety studies been done on the road and/or are there any known safety concerns on the road, including areas where frequent incidents occur? Safety-related information relevant to the investigation includes model inventory of roadway elements (MIRE), road safety audits, and local road safety plans (LRSPs).

Figure 3.2: Example evolved road.

Figure 3.3: Frequent patching.

3.2.2 Traffic

Information about the traffic is important for determining whether unpaving is a viable option, and if it is, for determining the gravel thickness that will be required to ensure all weather pass ability and the type of chemical treatment that can be used to retain fines/reduce dust. Key questions that nee d to be answered include the following (use Form #1):

- What is the annual average daily traffic (AADT)?
- What is the annual heavy commercial average daily traffic (HCADT, usually a percentage of AADT)?
- Is there seasonal variation in the traffic and if yes, when and for how long does this occur?
- Has traffic grown or declined over the years?
- Is traffic expected to increase for any reason in the future (e.g., energy sector developments)?

An accurate estimate of the AADT is very important. Under-estimating the traffic could result in rapid deterioration of the road after conversion. AADT can be determined from historical knowledge of the road, or from traffic counts. It is important to factor in potential traffic growth resulting from drivers using the improved road as an alternative to other better, but longer routes or other distressed routes. *Unpaving is often not appropriate on roads with an AADT of more than 150 because of the frequency of required maintenance, but careful material selection, good construction, and the use of suitable chemical treatments on the road can facilitate higher traffic volumes*.

An accurate estimate of the truck traffic and other heavy vehicles using the road (e.g., agricultural or energy sector equipment) is also very important. Factors to consider include:

- Trucks tend to cause more damage to roads than cars.

- Empty trucks can cause more damage than loaded trucks, because they travel faster causing more dust (loss of fines) and more bouncing, which breaks up the surface leading to washboarding and potholes.
- The number and weight of trucks dictates the thickness of gravel that will be required to ensure all-weather passability (Figure 3.4).
- Most agricultural equipment with large treaded tires (Figure 3.5) typically have limited load- or speed-related impacts, but sharp cornering can tear up the surface, while riding on the shoulder can cause localized rutting and impacts to side drains.
- Most road agencies do not enforce weight or vehicle-type restrictions on local roads during planting or harvest periods.
- Energy sector vehicles associated with solar or windmill installations typically have short-term impacts during construction of the facility and thereafter limited maintenance activity. Vehicles associated with oil field activities typically have longer-term impacts.

Figure 3.4: Large truck used during harvesting.

Figure 3.5: Agricultural equipment on public road.

3.2.2.1 Seasonal Variation of Traffic

It is important to understand seasonal variation in the traffic so that the road can be designed and maintained to accommodate traffic during the busiest periods. Factors that can influence peaks in the traffic include but are not limited to agricultural activities (e.g., increased truck traffic and agricultural implements during harvesting activities), recreation and tourism, and cultural events.

3.2.3 Weather-Related Factors

The weather has a significant impact on the performance of roads and more so on unpaved roads. Understanding these impacts and how they contribute to factors impacting the road will assist in the design and maintenance of the road. Some impacts such as the loss of base and subgrade support during spring thaw can often be anticipated, but others like high intensity rainfall, flooding, and prolonged droughts may not. Even with careful planning frost boils, rutting, slippery conditions, or dust may occur, all of which can have large impacts on road performance, the road user, and maintenance programs (Figure 3.6 and Figure 3.7).

Figure 3.6: Road damage caused by high intensity rainfall.

Figure 3.7: Road damage caused by frost boils.

3.2.4 Safety Considerations

Unpaved roadways have unique challenges not present on paved roadways, primarily related to the materials used in the wearing course layer, changing weather conditions, and changes in traffic type and driving patterns, all of which can effect functionality. Key concerns include but are not limited

to dust during dry conditions, slipperiness during wet conditions, erosion during high intensity storms, potholes and ruts, loose aggregate, washboarding, windrows of loose material along wheelpaths, and frost boils. Safety issues during routine road maintenance also need to be considered from both the traveling public and road worker perspective.

Users of rural unpaved roads usually live and/or work in the area and are therefore familiar with the roads and the changes that occur on them. However, there will always be some users that are not familiar with driving on unpaved roads in general, and will not be aware and may not know how to deal with specific conditions on a particular stretch of road.

Understanding and planning for these challenges can reduce safety risks and further efforts to achieve zero fatalities and serious injuries.

Limited safety data is available on roads that have been converted from paved to unpaved. Anecdotally it has been found that there is actually a potential for improving safety on well-designed and maintained converted roads, because drivers no longer have to swerve or brake hard to avoid distresses. Surveys have also shown that properly maintained, converted roads are generally accepted by the public because of the improved driving surface and increased safety *(1)*.

3.2.5 Other Considerations

Other factors that may need to be considered during the desktop study and noted on the checklist include, but are not limited to:

- Changes in maintenance programs and equipment requirements
- The number of complaints received about the road and how they were responded to
- Key issues learned from previous unpaving projects
- The number of houses/businesses along the length of road being considered for unpaving, or that use the road to access their property
- Potential impacts to houses/businesses if the road is unpaved
- Response from discussions with the public about unpaving and the relative importance of the road

3.2.6 Desktop Study Report

The completed checklist (Form #1) can be used as the desktop study report. The checklist includes sections for noting any fatal flaws that will impact the decision to proceed with an unpaving project and for recommendations on how to proceed if no fatal flaws were identified. *The completed checklist can be filed to show transparency in the investigation and decision-making process*.

3.3 FIELD STUDY

The field study is done to collect information about the current condition of the road and why it looks like it does, to collect safety related information and identify potential safety-related concerns, and to collect material samples for testing to determine whether the in situ materials are sufficient, or whether supplemental materials will be required.

3.3.1 Equipment for the Field Investigation

The following tools and equipment will be needed for the investigation:

- Clipboard and visual assessment forms (example Form #2 through Form #6 in Appendix A).
- Pens and permanent markers.
- Camera.
- Geological pick (for checking surface integrity).
- Steel nails (3 in.) (for layer thickness measurements).
- Tape measures (25 ft and 150 ft, for accurate measurements of width and section detail).
- Measuring wheel (for recording specific visual assessment locations and locations for testing and sampling [Figure 3.8]).
- Bubble level (4 ft) with 12 in steel square rule and spring clamp (for measuring rut depths and crown).
- Dynamic cone penetrometer (DCP, explained in Appendix B, for measuring layer thicknesses and bearing capacity/shear strength).
- Pick and shovel (or mechanical augur, for checking layer thickness and for sampling materials).
- 5-gallon buckets with lids or other suitable sample containers (for transport and storage of material samples).

Figure 3.8: Bubble level for measuring crown and rut depth.

3.3.2 Setting Project Boundaries

Setting the project boundaries is essentially just identifying the start and end points of the project to ensure that the correct section of road is investigated and that accurate quantities of supplemental material and chemical treatments, if required, can be calculated.

3.3.3 Doing the Visual Assessment

Figure 3.9: Visual assessment.

The visual assessment is a systematic evaluation typically completed by walking the length of the planned project (Figure 3.9). Too much can be missed by only driving through the road section. The best time to do the assessment is during the spring or during the rainy season, when freeze/thaw and moisture related problems are likely to be observed. The assessment must include the sides of the road, drainage, and notes of any specific activities that may influence future performance of the road (e.g., agricultural activities). Record observations and the photographs taken on an appropriate form (example Visual Assessment Form [Form #2 in Appendix A], which can also be used as a checklist). Use the measuring wheel to record the distances from the start of the project, and to any observations that require specific attention. Key issues to consider during the assessment include:

- Percentage of road that is already unpaved
- Type of distress and the reasons for it:

- It is important to distinguish between distress related primarily to aging of the road (e.g., alligator cracking over the full road surface, with multiple patches of various ages [Figure 3.10]), distress related to structural issues (e.g., the structure is not thick/strong enough to support the traffic, usually indicated by rutting and fatigue cracking or where extensive and repeat maintenance [e.g., multiple patches] has been undertaken [Figure 3.11]), and/or distress related to environmental issues (e.g., drainage or freeze-thaw, indicated by potholes and heaving, respectively [Figure 3.12]).
- Roads with age-related distresses are good candidates for unpaving. Structural problems are common on roads that have evolved over time from tracks to gravel to paved, without any significant engineering improvements and will typically need correction during the unpaving process (e.g., importing additional material and/or improving drainage).

Figure 3.10: Examples of age-related distresses.

Figure 3.11: Examples of structural-related distresses.

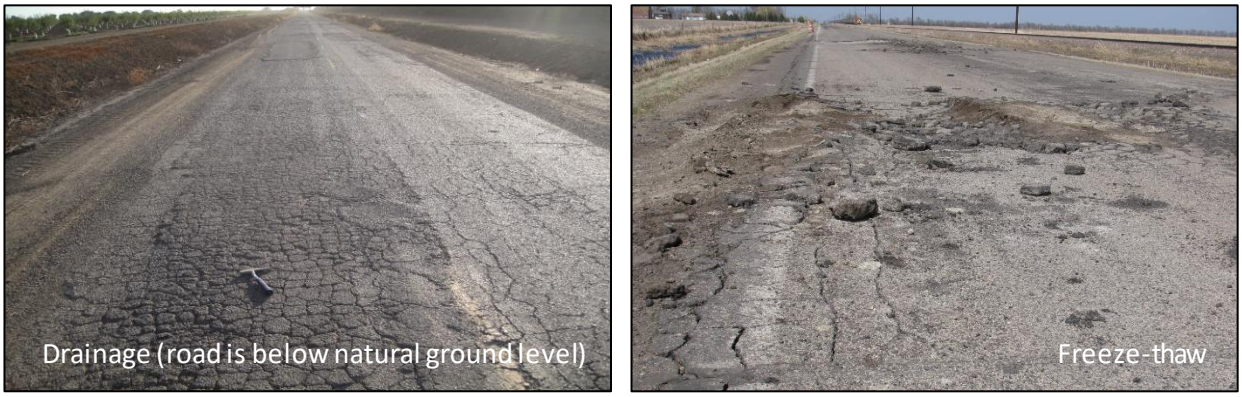


Figure 3.12: Examples of age plus environment-related distresses.

- Consider how any structural problems can be best corrected during the unpaving process (e.g., importing additional material, mechanical or chemical stabilization, improving drainage, etc.).
- Anticipate whether any of the observed problems will impact how the converted unpaved road will perform in the future.

- Variability along the length of the project (examples shown in Figure 3.13):
  - Variability is typically identified by changes in material properties, layer thickness (i.e., height of pavement above natural ground), or distinct areas of distress. The causes of these distresses, if not age-related, and typically identified by multiple repairs, may need to be corrected during the unpaving process.

Paved and unpaved sections.

Outer wheelpath failures

Change in base materials.

Drained and poorly drained sections.

Figure 3.13: Examples of variability.

- Variability can also be attributed to changes in traffic type or volume (e.g., road conditions are different on either side of an intersection or property access road, or one lane of the road may

be severely distressed and the other side not due to loaded trucks travelling in one direction and returning unloaded in the other direction).

  - Consider how this variability will need to be factored into the design of the unpaving project (e.g., changing the project boundaries, or having different designs for different sections, etc.).

- Potential drainage problems (example drainage problems are shown in Figure 3.14):
  - Drainage problems include poor road shape (i.e., crown is insufficient to allow water to drain off the road), and/or the absence of drains, damaged drains, insufficient drain capacity, blocked drains (including property access), eroded drains (i.e., high water velocity), use of drains and backfilling drains for agricultural purposes, wet spots, low lying areas, standing water, wheel ruts, potholes, etc. Drainage problems are often particularly severe in cuts and in the transition from cut to fill.

Good crown of paved low volume road (3 to 4%).

Poor crown (note potholes in flat areas [<2%]).

Blocked drains.

Blocked drain access.

Road below natural ground level.

Figure 3.14: Examples of drainage problems.

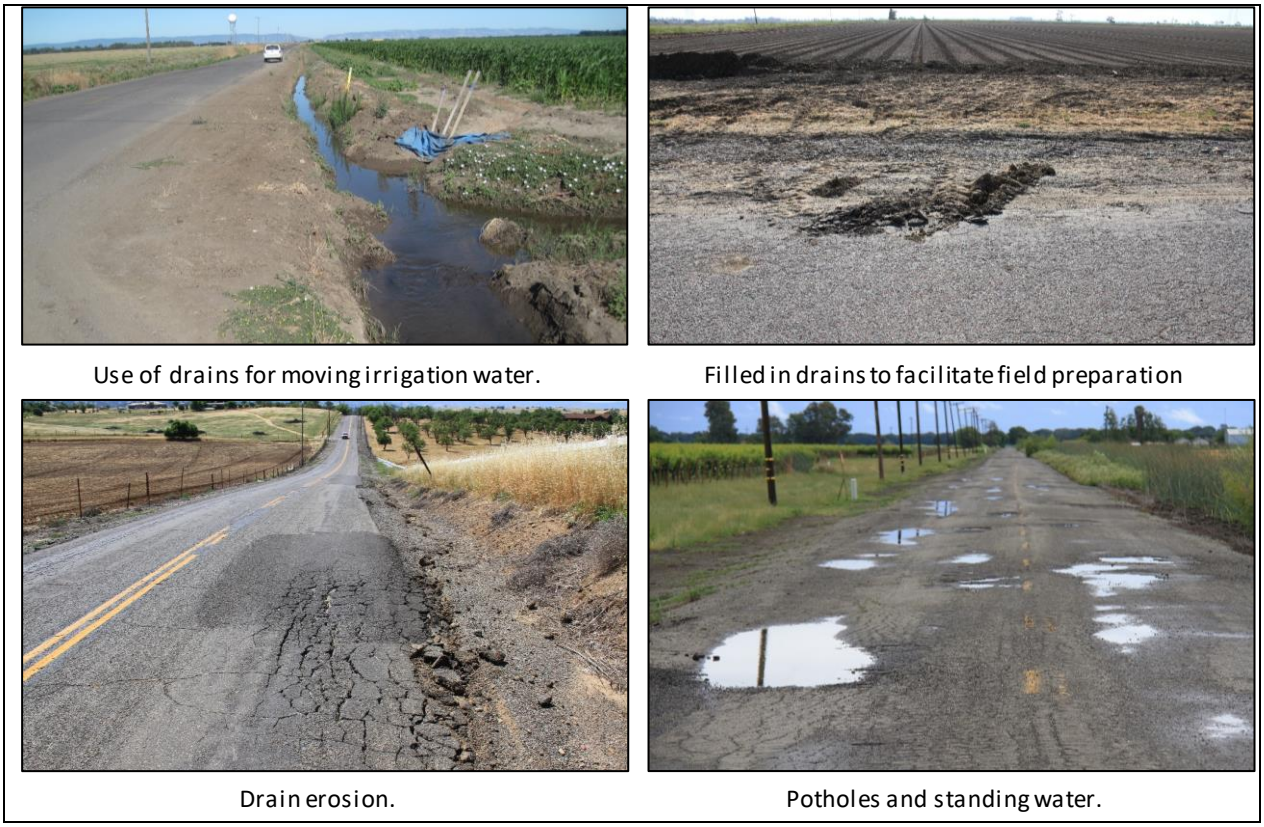


Figure 3.14 ***(continued).***

- Consider how these drainage problems can be corrected during the unpaving process (e.g., raise the road above natural ground level by importing new material, improving the crown, digging side drains and drain turnouts, repairing/installing culverts, installing pipes under property access roads, etc.). To ensure satisfactory performance, water must be able to drain off the road and then away from the road.
- Keep in mind that paved roads are typically designed and built with a two percent crown, whereas unpaved roads typically need to be constructed and maintained with a crown of four or five percent to ensure rapid draining of water over the rougher surface without causing erosion.

- Potential geometric problems after conversion (example geometric problems are shown in Figure 3.15):
  - Potential geometric problems include steep slopes that may become impassable or will erode during wet weather, sharp curves that may be a safety hazard under dusty or wet, snowy, or icy weather conditions, superelevations that may be susceptible to erosion, and intersections that do not merge or drain satisfactorily into adjoining roads.
- Potential environmental problems:
  - Potential environmental problems are usually associated with dust and/or drainage and associated pollution of natural water courses.
- Issues that may impact the road conversion:
  - Issues that could impact the road conversion include but are not limited to shallow underground utilities and cross drains (this may limit recycling depth), and extensive crack sealing (thick "ropes" of crack sealant, may not be effectively milled during recycling []).

Steep slope that may be impassable after unpaving.

Sharp corner.

Drainage problems at intersection.

Poor vertical alignment at intersection.

Figure 3.15: Examples of potential geometric problems.

Figure 3.16: Example of cracked sealed road and sealant requiring manual removal during recycling.

3.3.4 Doing the Safety Assessment

The safety assessment, which can be done as part of a road safety audit (a list of resources for conducting road safety audits is provided in Appendix C), should be undertaken by someone familiar with these types of assessments and at the same time as the visual assessment so that the implications can be discussed with the project engineer. Potential safety problems include but are not limited to:

- Areas where roadway departures are likely, including sharp corners, unexpected alignment changes, and inappropriate super-elevation transitions.
- Road furniture, structures, isolated trees, and obstacles that are very close to the edge of the road.

- Steep inclines and drop-offs.
- Insufficient signs warning drivers of upcoming hazards, including sharp curves, intersections and driveway entrances, limited stopping, horizontal and/or vertical sight distances, narrow bridges, narrow road sections, bumps and dips, etc.
- Potential reduced visibility associated with dust. Unpaving of frontage roads that run adjacent to busy highways may lead to dust effecting visibility on those highways.
- Potential reduced stopping distances related to loose gravel and/or slippery conditions.
- Potential for aquaplaning in areas where water ponds, including potholes and wheel ruts.

Update the Model Inventory of Roadway Elements (MIRE) and Fundamental Data Elements (FDE, segment identifier, functional class, type of governmental ownership, begin point segment identifier, and end point segment identifier) for the road as part of the safety assessment.

3.3.5 Identify Testing and Sampling Locations

Mark potential points for dynamic cone penetrometer (DCP) tests, layer thickness evaluations, and material sampling as the visual assessment progresses. The frequency of these points will depend on the variability of road conditions, with frequency increasing with increasing variability or change in pavement structure or apparent thickness:

- Mark one DCP measurement and layer thickness evaluation point at least every 500 yds if the road and/or in situ material appear consistent and the terrain is relatively flat and featureless. Alternate between left and right lanes. Increase the frequency to every 100 yds or less in areas with variability. Use spray paint on the road surface or temporary stakes on the side of the road.
- Mark additional measurement points in potential problem areas (e.g., failed areas on existing pavements, changes in moisture condition, change between cut and fill, soil type, roadside vegetation type, etc.).
- Mark potential material sampling points at representative locations along the length of the project. If the materials and layer thicknesses appear consistent, two sampling locations (e.g., at the one-thirds point and at the two-thirds point along the length of the project) will usually be sufficient. If there is variability along the project, mark the start and end points of apparent uniform sections and then mark a representative material sampling point within each uniform section. Small excavations in the distressed areas with the geological pick will provide an indication of variability in the wearing course thickness. These points may need to be adjusted based on the DCP and layer thickness evaluation results.
- Draw a schematic with explanatory notes in the space provided on the assessment form (an example is provided in Figure 3.17).

3.3.6 DCP Testing, Layer Thickness Evaluation, and Material Sampling

DCP testing and thickness evaluations are usually done after the visual assessment is completed so that the number and location of the testing points can be refined based on the observations for the entire project.

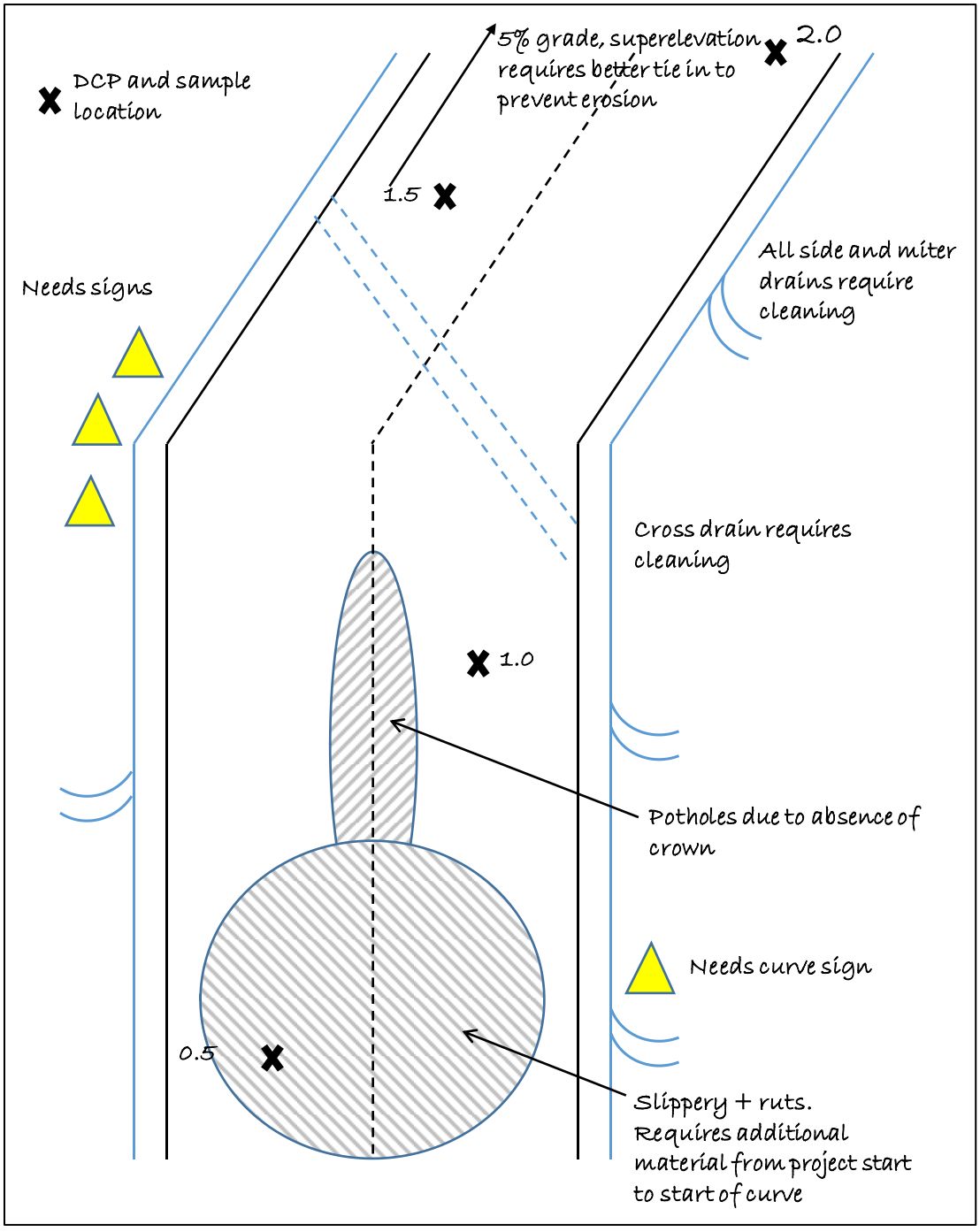


Figure 3.17: Example schematic on visual assessment form.

3.3.6.1 DCP Testing

Follow a standard and consistent testing process:

- Record the location and other pertinent data on the DCP form (example Form #3 in Appendix A).
- At each selected location, position the DCP in the outer wheelpath, and seat the cone with a few taps of the hammer until the shoulder (widest part) of the cone is level with the road surface.
- Note the depth on the underside of the ruler guide as the starting measurement and enter this in the "0 blows" box on the form.

- Lift the weight to the top of the rod (be careful to not pull the cone out of the road) and let it go. Repeat five times. Record the depth in the "5 blows" box on the form. Use millimeters (inch fractions are difficult to read on the DCP scale).
- Repeat the process until a depth of 800 mm plus the starting depth is achieved (e.g., if the starting depth was 43 mm, then the last set of five blows will be when the depth equals or exceeds 843 mm).
- Review the results as follows:
  - On each recording sheet, mark the depths where apparent notable changes in penetration rate are observed. This will provide a quick indication of the uniformity of layer thickness over the length of the project (a more detailed analysis using a spreadsheet will be done later after completion of the field work [see Section 3.5]).
  - Note locations that have distinctly different DCP results from the other locations. Consider doing a more detailed layer thickness evaluation in these locations if the reason is not obvious.
    - If the number of blows required to penetrate to 800 mm is considerably lower than the others, this can indicate thinner layers, poorer quality materials, or locations with higher moisture contents. Identify the cause in each location.
    - If the number of blows required to penetrate to 800 mm at one location is considerably higher than at others, this can indicate thicker layers, better quality materials, or excessively stony areas. Dry materials, especially clay, are considerably stiffer than wet materials. DCP tests in stony materials tend to have a distinctly different sound to well-graded and finer materials when the hammer hits the anvil.
    - Do additional DCP tests if required to determine the extent (length and/or width) of any problems.
    - Record all relevant observations on the visual assessment form.
  - Using this information, refine the locations for additional layer thickness evaluations and material sampling, ensuring that at least one location per uniform section is evaluated and sampled.

3.3.6.2 Layer Thickness Evaluation and Material Sampling

Although the DCP test will provide a good indication of the different layer thickness, at least one physical check per uniform section is recommended. The check includes the following:

- Record the location on the visual assessment form
- At each selected location, remove a 3 ft by 3 ft square of the surfacing material. Look at the thickness and integrity of the surfacing material and determine whether it can be effectively recycled back into the underlying material as part of the unpaving process with available equipment or by a local contractor, or whether it will have to be removed and used elsewhere or disposed of.
- If this location is also designated as a material sampling location, place the removed surfacing material in one of the sampling buckets. Label the bucket with a permanent marker.

- Use a pick and shovel, mechanical augur (Figure 3.18), or backhoe to excavate a hole through the imported gravel layers and approximately 6 in. into the subgrade. At sampling locations, separate the material from the various layers and place into individual labeled sampling buckets.

Figure 3.18: Sampling with a mechanical augur.

- Check the moisture content of each layer by doing a simple "squeeze" test. This entails taking a handful of material from the hole and squeezing it tightly together.
  - Materials that crumble when released (Figure 3.19a) are typically at equilibrium moisture content or drier, indicating that there are no moisture-related problems. Materials that hold the shape of a ball but do not exude any water (Figure 3.19b) are typically around the optimum compaction moisture content of the material, indicating that some moisture problems may exist (e.g., recent heavy rainfall, poor drainage, etc.). Materials leaving a sheen of water on the skin are typically wet indicating that moisture problems exist and will need to be addressed.

[a] [b] [c]

Figure 3.19: Squeeze test for assessing moisture content ([a] dry, [b] moist, and [c] wet).

- Once all material has been removed from the hole, hammer a nail into each layer boundary and then measure the thickness of each layer (distance between the surface and first nail, and then between nails) with a tape measure. Record the results on the visual assessment form. Note any other key observations that may require consideration during the conversion design (e.g., excessively moist, excessively stony, presence of fabrics, etc.).
- Remove the nails and fill the hole with repair materials or materials from the side of the road. Compact the material with a hand compactor to ensure that a pothole will not form.

3.3.7 Sampling Supplemental Materials

If the DCP tests and material thickness evaluations indicate that an additional layer or layers may be required, or if a preliminary evaluation of the materials indicate that mechanical modification may improve the material performance (e.g., the addition of plastic [clay] or non-plastic [coarse aggregate] materials) then sources of these materials should be identified and sampled so that they can be tested along with the materials sampled from the road. Recycled asphalt pavement (RAP) can be considered as an alternative to coarse aggregate for improving performance of fine clay materials, or as an alternative to aggregate base materials for increasing layer thickness.

3.4 MATERIAL TESTING

Key material properties influencing unpaved road wearing course performance include the grading (or particle size distribution), particle shape, the fines content, the clay content, and the material shear strength. The following indicator tests to determine these properties are required for each layer of material in the road and for the supplemental materials if required:

- A grading analysis (e.g., AASHTO T 27, ASTM C136, or MnDOT Laboratory Manual Method 1202/1203).
- A plasticity test (e.g., Atterberg limits [AASHTO T 89 and T 90, ASTM D4318, or MnDOT Laboratory Manual Method 1303/1304] or bar linear shrinkage [Texas Tex-107-E, or method provided in Appendix D]), and
- A strength test (e.g., California Bearing Ratio [AASHTO T 193 or ASTM D1883] or R-Value [MnDOT Laboratory Manual Method 1307]).
- Density and optimum moisture content (AASHTO T 180, ASTM D1557, or MnDOT Laboratory Manual Method 1305), required for the California Bearing Ratio (CBR) test and for determining quantities of supplemental material, if required.

These indicator tests are simple to perform and costs of doing them in house or in a commercial laboratory are negligible in terms of the costs of gravel replacement and selection of the most appropriate chemical treatment if one is used. These costs can potentially be recovered many times over when better material selection results in extended road life and reduced grader maintenance requirements.

The very small up-front savings enjoyed by skipping material testing will invariably mean higher costs later on because of early replacement of gravel and more frequent maintenance.

Most unpaved road specifications are based on these or similar tests.

Summarize the test results on an appropriate form to facilitate further analysis, which is discussed in Section 3.6. Attach the test result sheets to the form. An example test result summary form is provided in Appendix A (Form #4).

Asphalt concrete and chip seal surfacing from the road, or from a RAP pile in the case of supplemental materials, may need to be crushed to get a representative grading. Use a 10 in. jaw crusher with a maximum opening of 0.75 in. Alternatively, use the grading provided in Appendix E, which is representative of crushed RAP or RAP that is recycled in place with a recycler. Bar linear shrinkage and/or Atterberg limit tests are not required for asphalt concrete and chip seal materials.

If RAP materials are being considered as an alternative to virgin aggregates for supplementary wearing course materials, then the degree of aging of these materials should be checked to determine whether they will agglomerate over time, forming a rough, intact surface that is difficult to maintain. A simple test to check this is to spread a representative sample (about 3 lb) on a metal tray and then to place the tray in an oven set at between 120°F to 140°F (use higher temperature in hot climate areas) for 72 hours. Check the materials immediately after removing from the oven for any softening, agglomerations,

stickiness, binder oozing, etc. If this is noted, then care will need to be taken in how this RAP material is used. Note any relevant observations on the test result form (Form #4 in Appendix A).

3.5 ANALYZING DCP RESULTS

3.5.1 Procedure

Various software programs and guides (e.g., the MnROAD User Guide to the Dynamic Cone Penetrometer *[2]*) are available for analyzing DCP test data and practitioners are encouraged to use these, if they have access to them, to determine layer thicknesses and to estimate the CBR of each layer. However, entering the data into a spreadsheet and plotting penetration against number of blows will provide sufficient information about these two parameters for the purposes of understanding the road in terms of unpaving it.

The DCP Penetration Index (DPI) or DCP Number (DN) is the DCP rate of penetration in millimeters per hammer blow (mm/blow). This provides an indication of the relative shear strength of the material at the depth where it was calculated. On most soils this shear strength will typically reduce with increasing depth (unless bedrock is present or the surface layer is very wet). The DCP Structure Number (DSN_{800}) is the total number of blows required to penetrate to 800 mm, and provides an indication of the overall structure of the road.

Empirical relationships have been developed in a number of countries to relate the penetration rate to the CBR and other properties such as unconfined compressive strength and effective layer stiffness. Although these relationships provide useful indications to identify and evaluate potential problem areas, the CBR and other values obtained should be regarded as approximations only. A commonly used CBR relationship, developed by the US Army Corps of Engineers, is shown in Equation 1. A summary of DPI ranges and corresponding calculated CBR values is provided in Table 1.

$$\log CBR = 2.46 - 1.12 \log DPI \qquad \textbf{Eq 1}$$

Table 1: Example relationship between DPI and CBR

DPI Range (mm/blow)	Approx. CBR Range[1] (%)
<4	>70
4 – 5	50 – 70
6 – 8	30 – 50
9 – 14	15 – 30
15 – 19	10 – 15
20 – 25	7 – 10
26 – 30	3 – 7
31 – 35	1 – 3
>35	<1

[1] Values are approximate only and should be used with caution and only as a guide.

3.5.2 Analysis

Follow these steps for the DCP analysis:

- For each test location, plot the DPI against depth (example in Figure 3.20). This can be done with software or in a spreadsheet. Look for distinct changes in the plot and use the points to identify different layer boundaries, changes in material type, material properties, or moisture conditions. The example plot shows some variability between the four DCP test locations in terms of base layer thickness and subgrade strength. Determine the approximate CBR using software, Equation 1, or Table 1 for each layer. Summarize the layer thickness, DPI, and CBR for each layer and the DSN_{800} for the structure in a table, and add comments if applicable (example in Table 2 [Form #5 in Appendix A]).
- If there is minimal variability in terms of layer thickness and material consistency along the project, plot the DSN_{800} (i.e., number of blows to 800 mm) against distance. This will show the location of any potential problem areas that may require additional attention. Low DSN_{800} values will indicate potential problem areas. An example using the data from Table 2 is provided in Figure 3.21, which shows a weaker/thinner structure at the beginning of the project that gets progressively stronger (increasing base layer thicker as shown in Figure 3.20) along the project. This observation would need to be taken into consideration when doing the thickness design for the conversion.
- If there is variation in terms of layer thickness and/or material consistency, plot the DPI's of each layer at each measuring location to understand the extent of the variability and identify uniform sections. An example plot of the subgrade DPIs for a 3 mile unpaving project is shown in Figure 3.22. In the example, eight uniform sections can be identified, which can be further divided into three different zones. Zone A has DPIs between 15 and 25 and can be considered reasonably strong. Zone B has DPIs between 30 and 40 and can be considered to have marginal strength, while Zone C has DPIs between 45 and 55 and is clearly very weak indicating potentially wet, clay soils. Zone C may require additional attention (e.g., additional supplemental material, excavation and replacement, or additional drainage prior to starting the conversion).

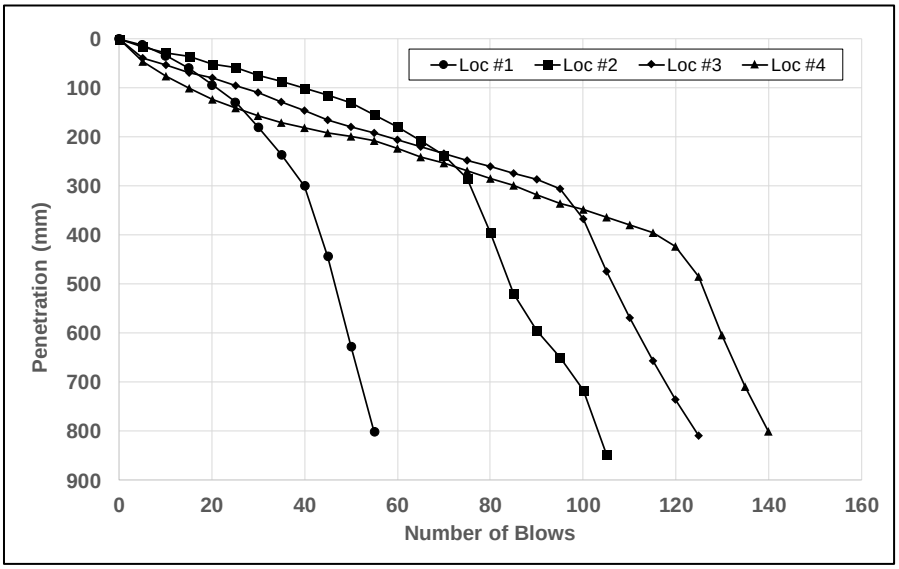


Figure 3.20: Example plot of DCP penetration vs. number of blows.

Table 2: Summary of DCP test result analysis.

Parameter	Location					Notes
	#1	#2	#3	#4	#5	
Base thickness (in.)	5.0	7.1	11.8	15.4	-	Loc. #1 has thinner/weaker base
Subbase thickness (in.)	N/A	N/A	N/A	N/A	-	No subbase present
DPI Base (mm/blow)	5	3	3	3	-	
DPI Subbase (mm/blow)	N/A	N/A	N/A	N/A	-	
DPI SG (mm/blow)	22	15	17	16	-	
DSN_{800} (blows)	55	105	125	140	-	
CBR-base	50	70	70	70	-	From Table 1
CBR-subbase	N/A	N/A	N/A	N/A	-	
CBR-subgrade	7	10	12	12	-	From Table 1

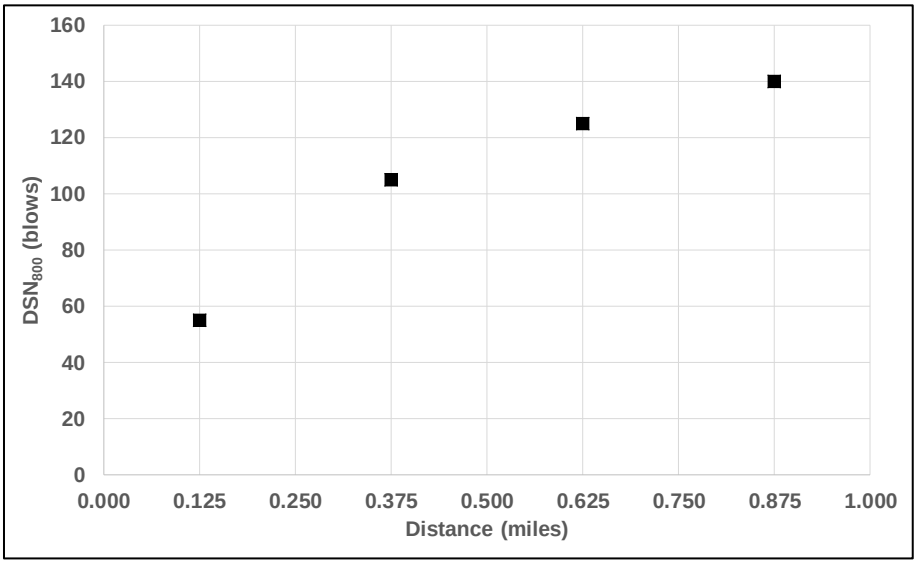


Figure 3.21: Example plot of DSN800 values vs. distance on a 1-mile project.

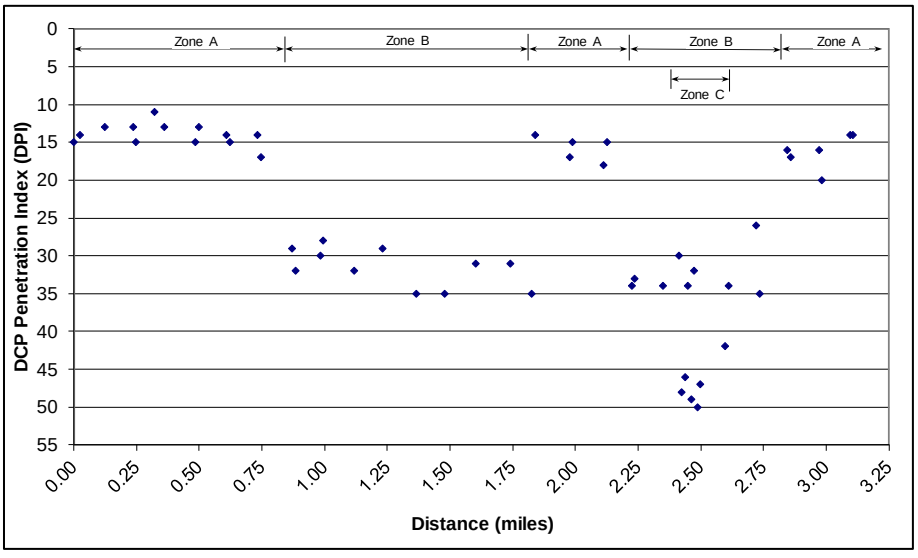


Figure 3.22: Example plot of DPI values for subgrade on a 3-mile project.

3.6 ANALYZING MATERIAL TEST RESULTS AND EXPECTED PERFORMANCE

The aggregate gradation and plasticity (or lack thereof) determined from the material tests are both key indicators of the likely performance of unpaved roads. Consequently, they need to be evaluated together and not individually, as is the case in most unpaved road guidance. A simple three-step procedure can be used to interpret test results, check material blending ratios, assess the applicability of local material specifications, and understand how the unpaved road is likely to perform if a particular material, or material blend, with a specific grading and plasticity index is used. The procedure can be done manually or by using a web-based tool (*www.ucprc.ucdavis.edu/unpavedroad*). The procedure is also used for chemical treatment selection.

3.6.1 Step-1 – Test Result Analysis Procedure

3.6.1.1 Grading Analysis

In this recommended approach, five key sieve sizes from a standard laboratory grading analysis test are required for understanding material performance and selecting an appropriate chemical treatment. These key sieve sizes are 1.0 in., #4, #8, #40, and #200. The first three are used to check for an appropriate mix of coarse, intermediate, and fine particles using the following simple formula known as the *grading coefficient* (G_c) *(3)*:

$$G_c = ((P1.0\text{ in.} - P\#8) \times P\#4) / 100$$

where P is percent passing

The percentage of material passing the #40 sieve is used together with a plasticity test to understand the effects of clay in the material and is discussed in the following section. The percentage of material passing the #200 sieve is used as an input for selecting appropriate chemical treatments, discussed in Section 4.5 .

Although the grading coefficient is determined using material passing the 1 in. sieve, and many specifications list this as a maximum size, some larger aggregate (up to 1½ in. to 1¾ in.) is usually acceptable to provide adequate all-weather passibility. The use of aggregates larger than this will reduce ride quality, make the road noisy to travel on, and cause problems for the maintenance grader operator. *As a general rule, the maximum aggregate size should never exceed one-third of the thickness of the compacted layer*.

Visually check the angularity of the aggregate during the sieve analysis. Cubic/angular material (Figure 3.23) has better interlock than rounded material (e.g., uncrushed alluvial aggregates [Figure 3.24]) and compacts into a dense layer. Rounded aggregate should be crushed to obtain at least two fracture faces to enhance interlock and prevent raveling.

Figure 3.23: Cubicle aggregate.

Figure 3.24: Rounded aggregate.

3.6.1.2 Clay Content

The plasticity index, determined from the Atterberg limit tests (or preferably the less commonly used bar linear shrinkage [BLS] test [Appendix D]), is used together with the percent passing the #40 sieve (i.e., the material on which the Atterberg limit and BLS tests are conducted) to evaluate the influence of clay content on likely performance, using the following simple formula known as the *shrinkage product* (S_p):

$S_p = (PI \times 0.5) \times P\#40$ if plasticity index is used, or
$S_p = BLS \times P\#40$ if the bar linear shrinkage is used

Note that using the bar linear shrinkage to determine the shrinkage product is more accurate than using the plasticity index, especially for silty non-plastic or slightly plastic materials. These materials often have a plasticity index of zero, and consequently also a shrinkage product of zero if the formula is used with plasticity index results. However, these materials will usually have some measurable linear shrinkage [i.e., BLS>1], thereby providing a non-zero number to work with to better estimate expected performance. Recommendations for dealing with these situations when only plasticity index values are available are as follows (Figure 3.25):

- If the PI of the material is equal to or greater than one, use the actual PI value without modification.
- If the material is non-plastic (i.e., PI=0) and the percent passing the #200 sieve is less than 20 percent, set the PI to zero in the shrinkage product equation.
- If the material is non-plastic and the percent passing the #200 sieve is more than 20 percent, set the PI to 1 in the equation.

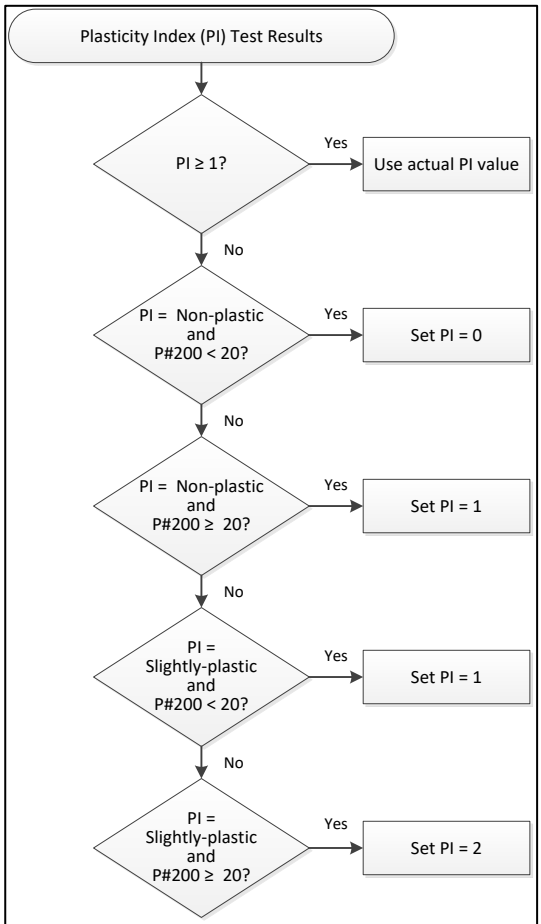


Figure 3.25: Plasticity Index result interpretation.

- If the material is termed "slightly plastic" in the laboratory test results and the percent passing the #200 sieve is less than 20 percent, set the PI to 1 in the equation.
- If the material is termed "slightly plastic" and the percent passing the #200 sieve is more than 20 percent, set the PI to 2 in the equation.

3.6.1.3 Shear Strength

The California Bearing Ratio (CBR), which is performed on material in the laboratory, is the most commonly used shear strength or bearing capacity test for granular materials used in unpaved roads. No formulas are required to interpret the results from this test.

3.6.2 Step-2 – Test Result Interpretation

Optimal unpaved road performance will usually be achieved when the wearing course materials meet the following criteria *(3)*:

- The grading coefficient is between 15 and 35. Although fines content is not directly measured in the grading coefficient formula, a fines content (material passing the #200 sieve) of between 12 and 20 percent is typically required to meet optimal grading coefficient requirements.
- The shrinkage product is between 100 and 365 (or between 100 and 250 if dust is a major concern and no dust control treatment is planned). Depending on the fine material fraction (percent passing the #200 sieve), the lower limit can usually be relaxed for lower traffic volumes (e.g., the shrinkage product can be relaxed to 50 and 75 for traffic volumes of 50 and 75 vehicles per day, respectively, provided that the fines content is between 12 and 20 percent). *Many unpaved road specifications based on those for paved road base courses limit or exclude any clay content, incorrectly assuming that this will reduce dust. On the contrary, small amounts of clay bind aggregate particles together, preventing washboarding and reducing dust.*
- Assuming that the unpaved road has a quality base course with adequate soaked CBR, the soaked CBR of the wearing course should be above a minimum of 15 percent (determined at 95 percent of AASHTO T 180 or ASTM D1557 compaction). If truck traffic predominates and the road is in a high rainfall area or storms of high intensity are common, a higher soaked CBR may be desirable if passability problems are an issue. However, higher soaked CBR materials tend to have low clay contents and consequently washboarding may be a problem. Therefore, a balance between soaked CBR and shrinkage product must be determined for optimal performance for specific traffic scenarios. Experience has shown that materials complying with the grading coefficient and shrinkage product limits discussed above will invariably have a soaked CBR strength (compacted to 95 percent of the laboratory-determined maximum dry density [AASHTO T 180 or ASTM D1557]) in excess of about 20 percent *(3)*.

Summary of Test Results Interpretation

Grading Coefficient -	15 to 35
Shrinkage Product -	100 to 365
	100 to 250 if dust is a concern
	50 to 75 as lower limit for low traffic volumes (20-75 AADT)
CBR -	Minimum 15, increase in wet areas and on roads with high number of trucks

A simple chart plotting grading coefficient (x-axis) and shrinkage product (y-axis) along with the optimal limits described above can be used to obtain an indication of the expected performance of the material on the road (example in Figure 3.26).

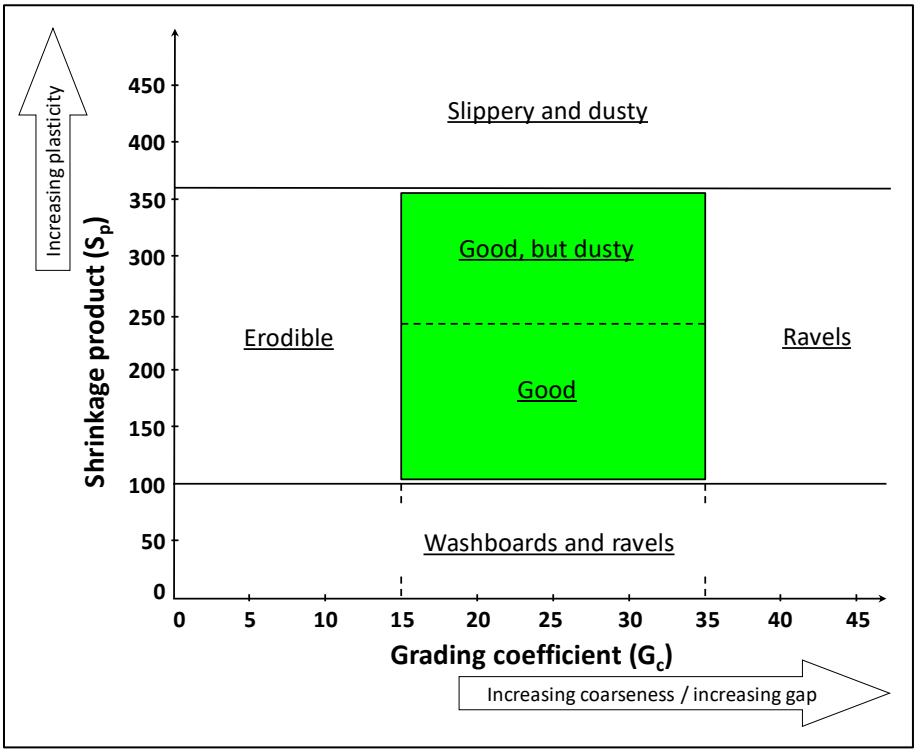


Figure 3.26: Material performance predictor chart (adapted from Paige-Green *[3].*)

Local calibrations of the grading coefficient and shrinkage product ranges may be needed. For local calibrations, practitioners can sample materials from good and poor performing roads in their jurisdiction, test these materials, check if they meet local specifications, analyze the results according to Step-1 above, and plot the results on the chart shown in Figure 3.26. The grading coefficient and shrinkage product ranges can then be adjusted to accommodate these local performance observations. Future material acquisitions can be based on these new defined ranges. Examples of local refinements could include but are not limited to:

- Lowering the upper level of the shrinkage product range (e.g., to 250) on roads with high truck traffic volumes, roads that are shaded for most of the day, and roads in areas with high annual average rainfall and/or high-intensity storms.
- The lower level of the shrinkage product range can be reduced (e.g., to 50 or 75) for roads with very low traffic volumes and/or slow-moving vehicles, and also for roads that are shaded most of the day, and roads in areas with high annual average rainfall and/or high-intensity storms.

3.6.3 Existing Road and Supplemental Materials

Tabulate the grading coefficient, shrinkage product, and other relevant test results on an appropriate form (example Form #4 in Appendix A). Plot the grading coefficient and shrinkage product of each sample on the performance prediction chart (example Form #4). Review the expected performance of

the material in each layer to understand how the properties are likely to influence the blended materials after conversion.

3.6.4 Blending Existing and Supplemental Materials

In most instances, the existing materials on the road will be blended to form a new wearing course layer with properties that meet agency specifications (e.g., MnDOT *[4]*) and a grading coefficient and shrinkage product that meets the requirements of a "good" material on the plot shown in Figure 3.26. On roads with insufficient material, or materials that do not meet specification and grading coefficient and shrinkage product requirements, the materials will need to be blended with supplemental materials. Blending scenarios include the following:

- Adding locally available clay (e.g., from the subgrade, fill dirt from agricultural activities, or material cleared from drains, etc.) or commercially obtained bentonite to raise the shrinkage product to prevent washboarding and raveling.
- Adding coarse material (e.g., aggregate base or RAP) to reduce the shrinkage product to prevent slippery conditions, increase the CBR, and/or increase the grading coefficient
- Adding supplementary material (e.g., aggregate base or RAP) to increase the layer thickness. Some blending with existing materials will usually be required to meet the shrinkage product and potentially the grading coefficient given that the fines and clay content of aggregate base and RAP materials are very low (RAP should not have any clay in it and typically has less than three percent passing the #200 sieve).

Make notes on the test result sheet (Form #5) with regard to the use of existing materials and whether supplemental materials will likely be required. This information will be used in the thickness design and materials design discussed in Section 4.2 and Section 4.3 , respectively.

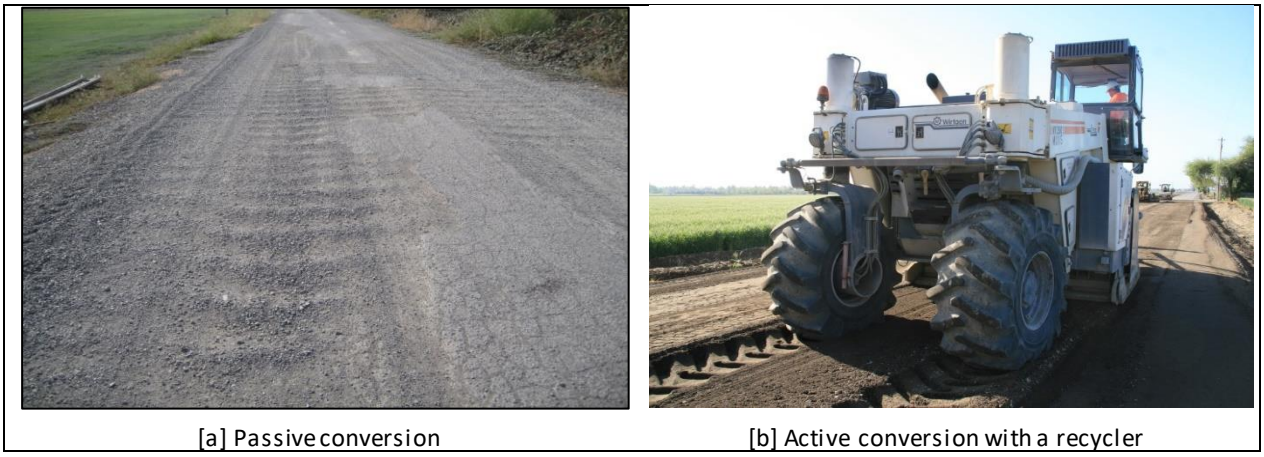
3.7 ROAD INVESTIGATION REPORT

Attach all the forms and test result sheets together to form a road investigation report. This can be added to the desktop study report (see Section 3.2.4) as a record of the investigation and support for the decision made.

CHAPTER 4: DESIGNING AN ENGINEERED UNPAVED ROAD

4.1 INTRODUCTION

There are two types of unpaving, namely passive (Figure 4.1a), where the road changes from a paved road to an unpaved road over time with no intervention from the road agency, and active (Figure 4.1b), where the agency does an investigation and design, and then proceeds with a conversion along the full length of the project using appropriate equipment and procedures. Passive conversion is not recommended as material properties are difficult to control, ride quality and safety can be severely impacted, and maintenance of the surface and crown are very difficult to perform. Consequently, passive unpaving is not covered in this guide.



[a] Passive conversion [b] Active conversion with a recycler

Figure 4.1: Examples of passive and active conversion.

Designing for the conversion of a distressed paved road to an engineered unpaved road requires a number of steps, including:

- A thickness design (based on the number of loaded trucks likely to use the road)
- A material design (to ensure that an appropriate blend of in situ materials, and if necessary, supplemental imported materials, is achievable)
- A drainage design (to ensure that rain water will drain off the road and then away from the road)
- Chemical treatment selection (if fines preservation/dust control or material stabilization is required)
- Determining additional safety requirements if deemed necessary
- Preparation of a road conversion plan
- Preparation of project specifications for construction

4.2 THICKNESS DESIGN

It is important to have a sufficiently thick structure to carry the traffic that will use the road. In most instances, all-weather passability will be important, and therefore the thickness design will need to be based on spring thaw and wet conditions when the material is weakest and most susceptible to rutting and contamination with subgrade soils. Trucks and agricultural equipment will cause the most damage and must therefore be the basis of the design.

- Use the guidance provided for thickness design in Table 3, which is based on the Federal Highway Administration (FHWA) *Gravel Roads Construction and Maintenance Guide (5)*. Use the CBR of the subgrade material determined during the project investigation (discussed in Section 3.4).
- Use the notes from the visual assessment and the layer thickness measurements from the DCP analysis to determine whether there is sufficient material on the road to satisfy the thickness requirements. If not, identify areas along the project were thickness adjustments will be required and determine how much supplemental material will be required to satisfy these adjustments.
- Identify problem areas that may need additional supplemental material (e.g., subgrade problems, areas with standing water, etc.). Add the estimated quantity of additional material to that determined in the previous step.

Table 3: Suggested layer thickness design *(5)*.

Estimated Daily Truck Traffic	Subgrade Shear Strength (CBR)	Suggested Minimum Gravel Thickness (in.)
0 to 5	<3 3 to 10 >10	7 6 5
5 to 10	<3 3 to 10 >10	9 7 6
10 to 25	<3 3 to 10 >10	12 9 7
25 to 50	<3 3 to 10 >10	15 12 9
50 to 75	<3 3 to 10 >10	18 15 12

4.3 MATERIAL DESIGN

4.3.1 Design Scenarios

The material design uses the observations from the visual assessment and results from the material tests and analysis discussed in Sections 3.4 and 3.6 to determine whether the existing surfacing can be incorporated into the new unpaved road wearing course, what depths the materials need to be blended to, whether supplemental materials are required, and if yes, how much and to what depth will they need to be blended. A number of design scenarios are therefore possible, including:

- Scenario #1: The existing asphalt surface is removed from the road and the existing base, which meets the thickness, grading coefficient, and shrinkage product requirements, is bladed and shaped to serve as the new wearing course.
  - No material design is required for this scenario.
  - Removed materials may be used elsewhere for another purpose, taken to an asphalt plant for crushing and used on this or another project, taken to landfill, etc.

- Scenario #2: Supplemental material meeting the grading coefficient and shrinkage product requirements is added directly on top of the existing road and shaped and compacted without removal of, or blending with, the existing materials.
  - The material design is limited to the supplemental materials.
  - This scenario is typical for roads where the asphalt surfacing has been placed directly onto high plasticity subgrade materials and pulverizing and mixing the surfacing into the subgrade materials will not satisfy the thickness, and/or grading coefficient and shrinkage product requirements (example in Figure 4.2).

Figure 4.2: Converted road with high plasticity materials.

- Scenario #3: The existing asphalt surface is removed from the road after which the existing base and underlying materials are mixed to create a "new" material with a satisfactory grading coefficient and shrinkage product.
  - The material design for this scenario includes determining the mixing depth to achieve a satisfactory blend that meets the thickness, grading coefficient, and shrinkage product requirements.
  - In most instances, this will entail mixing a small amount of the subgrade material into the base to increase the fines content and shrinkage product to the required levels.
- Scenario #4: The existing asphalt surfacing is mixed into the existing materials to create a "new" material with a satisfactory grading coefficient and shrinkage product.
  - The material design will include determining the mixing depth to ensure a satisfactory blend that meets the thickness, grading coefficient, and shrinkage product requirements.
  - On roads where the materials beneath the surfacing have a high plasticity, incorporating the old asphalt surfacing may reduce the shrinkage product to a satisfactory level, provided that the asphalt surfacing is sufficiently thick.
  - Appropriate equipment will need to be used to ensure that a satisfactory grading and blend is achieved and that no oversized chunks of asphalt or strips of the old surfacing are left in the road (example in Figure 4.3).

Figure 4.3: Strip of asphalt surfacing left after conversion.

- Scenario #5: Supplemental material is added on top of the existing road and mixed with the underlying materials to achieve a satisfactory blend that meets the thickness, grading coefficient and shrinkage product requirements.
  - The material design will include determining the quantity of supplementary material(s) required and the mixing depth to achieve the design targets.

- Supplementary materials could include small amounts of local clay or commercially procured bentonite to raise the shrinkage product to an acceptable level, coarse materials to reduce the shrinkage product, or base course materials or crushed recycled asphalt pavement from another project to increase the thickness and/or adjust the grading coefficient. Only one source of supplemental material will typically be required, but more than one can be incorporated if necessary (e.g., new aggregate base that is deficient in clay/fines and where the subgrade material will not provide the required properties). Note that supplemental materials can only be spread on the surface.
- Appropriate equipment will need to be used to ensure that a satisfactory grading and blend is achieved and that no oversized chunks of asphalt or strips of the old surfacing are left in the road.

4.3.2 Procedure for Determining Mixing Depths and Supplemental Material Quantities

Use the iterative procedure provided in Appendix F or another appropriate method to determine optimal mixing depths and supplemental material quantities. This procedure uses the test results discussed in Section 3.6 to achieve a material blend that should perform well as an unpaved road wearing course. The procedure can be done manually or by using an automated version in a web-based tool (*www.ucprc.ucdavis.edu/unpavedroad*).

Regardless of the method used to determine mixing depths and the amount of supplemental material required, the proposed blend will need to be formulated and tested in the laboratory (Figure 3.26), and the results checked against target specifications and plotted on the performance prediction chart to verify that the blend will provide satisfactory performance. If the predicted performance is not optimal, re-run the procedure with adjustments to mixing depth and/or quantities of supplemental materials, followed by testing of the new blend, until a satisfactory blend is achieved. Use the density (test results from Section 3.4 of each material to determine the weights of each proportion.

Calculate the quantity of supplemental materials required to achieve the layer thickness determined in Section 4.2. Multiply the project length by the width to determine the surface area, and then multiply the surface area by the required thickness. Multiply this number by the density (test results from Section 3.4), and allow for a 30 percent bulking/compaction factor, to determine the tons of material required.

4.4 DRAINAGE DESIGN

The recommended crown for unpaved roads is between four and five percent *(5)*. It is therefore recommended that the converted road is designed with a five percent crown and that it is subsequently maintained at between four and five percent.

Paved roads are typically designed and built with a two percent crown whereas unpaved roads need a crown of four or five percent to ensure rapid draining of water over the rougher surface without causing erosion.

Determine where changes to the side drains are required using the observations from the visual assessment. Changes could include changing the width and/or depth to accommodate more runoff water, adding more miter drains to direct water away from the road, adding culverts to move water from one side of the road to the other to prevent ponding, installing velocity retardation berms on steep slopes, etc.

Guidance on improving drainage is well documented in Federal Highway Administration (FHWA) *(5)* and U.S. Forest Service *(6)* guidelines and is therefore not repeated in this guide.

4.5 CHEMICAL TREATMENT SELECTION

Experience across the United States over the past 100 years has shown that using chemical treatments on unpaved roads is a cost-effective road management strategy. Although the primary objective is usually dust control, numerous studies nationwide have shown that preserving the fines in the road surface prevents washboarding and raveling, resulting in significant reductions in required grader maintenance and in the rate of gravel loss. The costs of the chemical treatment are covered by these savings, freeing up funds for maintenance and improvement on other roads.

Choosing the right chemical treatment for the road and environmental conditions is an important step. A comprehensive chemical treatment selection guide *(7)* and associated web-based tool (accessed at *www.ucprc.ucdavis.edu/dustcontrol*) were recently prepared to assist practitioners with this task and this procedure should be followed for this part of the design. Use the material properties of the blended material determined in Section 4.3.2 for the selection process.

The selection procedure is centered around the practitioner understanding the seven different chemical treatment categories; understanding the roads that require treatment in terms of traffic, climate, geometry, and materials; and then choosing an objective for applying a chemical treatment. Based on the information collected and the objectives set for the project, the most appropriate chemical treatment categories for a given situation can be selected using a series of charts and then ranked using a simple equation (this process is automated in the web-based tool). This selection procedure also provides basic guidance on environmental considerations, the effects of soil chemistry, and maintainability with a grader. Guidance is also provided on procuring and specifying and applying chemical treatments, as well appendices with treatment category details (chemical treatment uses, origins, form of supply, attributes, application rates and methods, potential environmental impacts, and limitations), understanding unpaved road materials, an example mix design test program, and example specification language.

The following chemical treatment categories cover most of the treatments available in the U.S.:

- Water and water with surfactant
- Water absorbing
  - Calcium and magnesium chloride and various brines.
- Organic non-petroleum
  - Plant-based products including glycerin/glyceride, lignosulfonate, molasses, plant oil (e.g., soy, linseed, rapeseed, canola, or palm oils), and tall oil pitch rosin.
- Organic petroleum
  - Treatments derived from petroleum refining including diluted asphalt emulsions, base and mineral oils, petroleum resins, and synthetic fluids.
- Synthetic polymer emulsion
  - Acrylates (homopolymers and co-polymers), acetates (homopolymers and co-polymers), and styrene butadiene copolymer emulsions, either neat or in combination

- Concentrated liquid stabilizer
  - Enzymes, electrochemical additives, sulfonated oils, sulfonated petroleum products (SPPs), and ionic stabilizers.
- Clay additive (used for mechanical stabilization [e.g., bentonite)

4.6 SAFETY CONSIDERATIONS

Addressing specific safety considerations identified during the visual assessment or raised by the public should be included in the design. Road surface related concerns (e.g., slipperiness, passability, skid resistance) will likely be addressed by following the recommended thickness, material, and drainage design steps discussed above. Dust related concerns can be addressed by following the recommended material design and by implementing a chemical treatment program. Other concerns will need to be addressed by appropriate road furniture, primarily signs that warn the road user of potential hazards.

Compiling or updating local road safety plans should also be considered at this stage of the design.

4.7 ROAD CONVERSION PLAN

The road conversion plan is a summary of the design that can be used to prepare project specifications and bid documents and serves as a guide during the conversion process to check that the design is being implemented as envisioned and that problems identified during the investigation are being satisfactorily addressed. An example of a road conversion plan form is included in Appendix A (Form #7).

4.8 PROJECT SPECIFICATIONS

Project specifications will need to be prepared based on the conversion plan. These specifications need to be sufficiently comprehensive to be enforceable. Example specification language for unpaved road construction in general and specifically for chemical treatment applications is provided in the chemical treatment selection guide *(7)* discussed in Section 4.5. Additional information with regard to unpaved road specifications are detailed in the FHWA guide *(5)* and in the MnDOT specifications *(4)*. Key issues that need to be covered in the specification include but are not limited to:

- Layer thicknesses
- Mixing depth
- Material properties after blending
- Material processing, including mix-in applications of chemical treatments (i.e., the chemical treatment replaces or supplements the compaction water)
- Compaction
- Crown
- Drains
- Chemical treatment applications

CHAPTER 5: METHODS TO SUCCESSFULLY CONVERT A PAVED ROAD TO UNPAVED

5.1 INTRODUCTION

Converting a distressed paved road to an engineered unpaved road essentially follows the same procedure as constructing or rehabilitating an unpaved road. The steps to doing this correctly are covered in detail in the FHWA *Gravel Roads Construction and Maintenance Guide (5)* and therefore only key issues related directly to unpaving are covered in this chapter. Guidance specific to applying chemical treatments is covered in the *Guidelines for the Selection, Specification and Application of Chemical Dust Control and Stabilization Treatments on Unpaved Roads (7)* and this information is not repeated in this guide. Instead only a summary is provided.

5.2 EQUIPMENT

The equipment used for unpaving is similar to that used for conventional unpaved road construction and regraveling/rehabilitation. Choice of equipment for incorporating the existing asphalt surfacing and/or supplemental material into the existing pavement structure will depend on the thickness and condition of these materials and local availability of equipment. Three options can be considered:

- Recycler/reclaimer/pulverizer
  - These machines (examples shown in Figure 5.1) are ideal for converting distressed paved roads into engineered unpaved roads. Various options are available, ranging from smaller machines that mount into bucket loaders or onto tractors, to dedicated recyclers that can effectively pulverize, stabilize, and mix to depths exceeding 12 in. These machines are versatile in that they can mill down to the design depth, while mixing in situ materials with supplemental materials that have been spread on the road surface. They will pulverize the distressed asphalt into a well-graded aggregate material. Most machines have the capability to connect to water or chemical treatment tankers and to spray the water or treatment into the mixing chamber to ensure uniform and consistent mixing of the compaction water/treatment throughout the full depth of the layer. All milling and mixing is done in a single pass at approximate walking speed, which results in significantly higher production rates, and a more consistent layer and wearing course compared to other procedures. The costs of renting this equipment, or awarding a contract to do it, will be offset by better long-term road performance that will lead to savings in future grader maintenance and regraveling costs.
- Grader
  - A grader with a ripper bar can be used to break down thin, highly distressed surface treatments and asphalt concrete surfacings (Figure 5.2). A tractor-mounted crusher, tractor-mounted pulverizer, mobile hammer mill, or a padfoot roller is then used to break down the larger lumps of asphalt, after which the grader can rip the material to the required mixing depth and then mix the materials by moving them back-and-forth with the blade. Water is sprayed onto the ripped material as needed to facilitate mixing. The process is time consuming, depth control is difficult,

and material grading, consistency, and mixing is often poor. *A grader is not suitable for converting roads with thick (e.g., >2 in.) asphalt surfacing.*

Recyling unit attached to a bucket loader.

Pavement recycling machine.

Figure 5.1: Examples of recycling machines and milled/mixed materials.

- Grader and tractor with disc plough
  - A grader and disc plough working in tandem will improve the mixing of materials and result in better mix and moisture uniformity. However, depth control and material grading will still be poor compared to that achieved with a recycler (i.e., large lumps of the old surfacing are often left behind.

Figure 5.2: Grader ripper bar used to breakdown and mix materials.

Figure 5.3: Disc plough used to mix materials after ripping with a grader.

The following additional equipment will also be required:

- Water truck for mixing and compaction water.

- If a recycler is used, the water tanker is connected to it so that water or chemical treatment is injected during the recycling process. This ensures a uniform distribution of the compaction water or chemical treatment throughout the layer, which in turn results in more consistent and effective compaction.
- A water tanker is also used to spray water on the surface during shaping and final compaction to ensure that a tightly bound surface is achieved.

- Padfoot and/or steel drum roller
  - The roller type and weight will depend on the thickness of the layer being compacted. A guide for choosing the primary roller type and weight is shown in Figure 5.4.
  - If mixing depth is less than 7 in, a vibrating single smooth drum roller will usually suffice.
  - If mixing depth exceeds 7 in, primary compaction is best carried out with a padfoot roller to ensure that the material is evenly compacted over the full depth of the layer. Once the padfoot roller has "walked out" of the layer (i.e., it no longer leaves impressions) the road can be shaped and then rolled with a smooth drum and/or rubber tired roller to achieve final compaction. Layer thicknesses greater than 12 in. are not recommended because it is difficult to achieve satisfactory compaction at this depth, especially over soft subgrade materials.

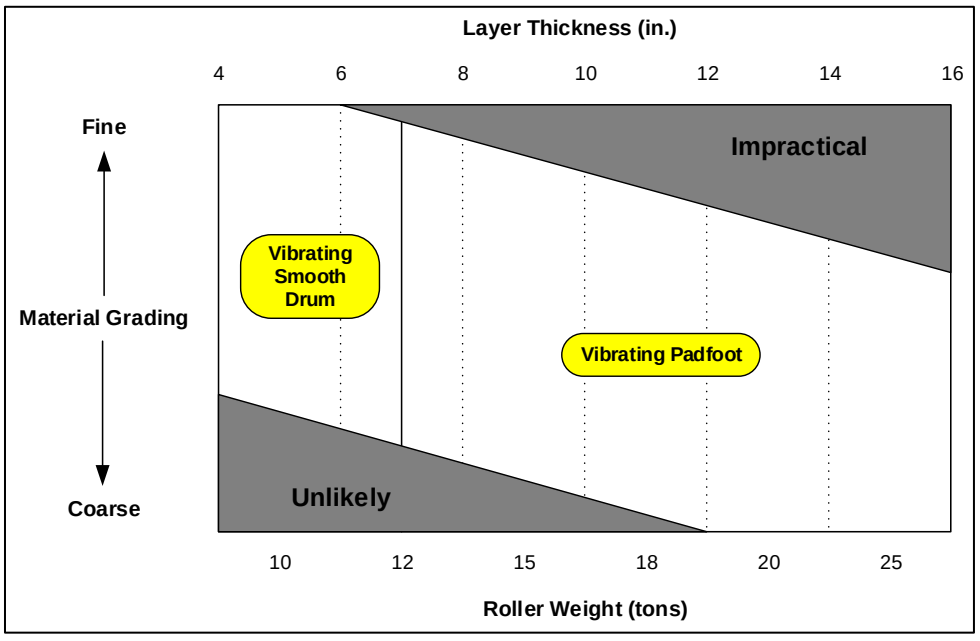


Figure 5.4: Guide for selecting roller type and weight.

- Rubber tired roller (if available) for secondary compaction and "slushing"
  - Rubber tired rollers are used to achieve a more tightly bound surface in combination with the steel drum roller. When final density has been achieved, wetting the surface, followed by a series of passes with the rubber tired roller, will bring excess fines to the surface, enhancing binding and sealing of the wearing course.

5.3 IMPORTING AND SPREADING SUPPLEMENTAL MATERIALS

Follow the procedures in the FHWA *Gravel Roads Construction and Maintenance Guide (5)* for importing and spreading supplemental materials on the road prior to mixing. Take special care in ensuring that the spread material meets the design grading coefficient and shrinkage product requirements. Too thin or too thick could influence later performance of the road required. If the road conversion consists of only spreading and compacting gravel on top of the existing road (i.e., Scenario #2 in Section 4.3.1), no mixing will be required, and final shaping and compaction will follow after the material is spread to the design thickness.

5.4 RECYCLING AND MIXING

The procedures followed during recycling and mixing will depend on the design scenario discussed in Section 4.3.1.

- Scenario #1. This scenario requires careful removal of the asphalt surfacing. Thin distressed surfaces can usually be removed with a grader, while thicker surfacings typically require a milling machine. Load the removed material into trucks and dump it in predetermined designated sites (e.g., asphalt plant or quarry where it can be crushed and reused in pavement layers). Take care not to damage or remove any of the existing base. Once removed, the road can be shaped and recompacted to achieve the design crown and surface finish.
- Scenario #2. No recycling or mixing is required in this scenario.
- Scenario #3. This scenario also requires careful removal of the asphalt surfacing as explained above. A recycler or grader is then used to mix the base and the underlying materials to achieve the target grading coefficient and shrinkage product. This will be based on the design mixing depth, which needs to be strictly controlled to ensure an optimal blend of materials. Mixing depths that are too deep typically result in excess fines and clay being incorporated into the wearing course layer (Figure 5.5), potentially leading to slipperiness and impassibility during wet weather and dust during dry conditions. Mixing depths less than the design depth may result in the target shrinkage product not being met, which can lead to washboarding and raveling of the wearing course (Figure 5.6).
- Scenario #4 and Scenario #5. These scenarios require pulverizing and mixing the asphalt with the underlying materials only (Scenario #4) or with both supplemental and the underlying materials (Scenario #5). This is best achieved with a recycler/reclaimer to achieve optimal depth control and mixing quality.

Check mixing depths at frequent intervals using a T-bar and string line (Figure 5.7). Also check material grading (*maximum size should not exceed 1.5 in. in a 5 in. layer*), mixing consistency (Figure 5.8), and moisture content (with the squeeze test [Figure 3.19]). Communicate needed changes to the equipment operator as required.

Figure 5.5: Excess fines resulting from exceeding the design depth during mixing.

Figure 5.6: Washboarding resulting from not meeting the design mixing depth.

Figure 5.7: Depth control measurements with a T-bar.

Figure 5.8: Checking material grading, mixing consistency, and moisture content behind the recycler.

5.5 PRIMARY COMPACTION

Primary compaction will be critical to the long-term performance of the road**. Do not use water tankers or general traffic to compact the road.** The rate of gravel loss and general deterioration is significantly faster on traffic-only compacted roads and rutting of the surface material is likely to occur. These roads will also lose their shape quickly, which will affect drainage.

Converted roads should be compacted to refusal density, defined below, rather than to a percentage of a laboratory-determined density value. The additional cost of compacting to refusal density is negligible (i.e., limited to a few extra roller passes), but the advantages in terms of preventing rutting, loss of shape through densification, and reducing the rate of gravel loss are significant. Determining the refusal density is carried out during the primary phase of compaction as follows:

- Roll a short section (± 150 ft) of the road to the point that the roller operator believes that refusal density has been reached. Use high amplitude vibration settings and ensure that roller speeds do not exceed 2 mph.
- Count the number of complete passes required to reach this point.
- Take a density measurement of the compacted area and note the result.
- Have the roller operator apply another complete pass and measure the density again at the same location. If the density has not changed, refusal density has been achieved. If the density is higher than the previous measurement, roll the section again and take another density measurement. Continue doing this until the density does not change.
- Note the total number of complete roller passes required to achieve refusal density. This will be the rolling pattern. Repeat the process each day and whenever there is a significant change in material properties or layer thickness.

5.5.1 Initial Compaction Behind Recyclers/Reclaimers

Initial compaction behind a recycler/reclaimer is different than that behind a grader. Although the material exiting the recycler is in a loose state, the rear wheels of the recycler and the wheels of the water tanker, if it is behind the recycler, run on this material, resulting in compaction of the loose material in the equipment wheelpaths (Figure 5.9). The in-place density of this compacted material is at least 10 percent higher than that of the adjacent uncompacted material. It is therefore imperative that the material between the recycler's wheelpaths first be compacted to at least the same density as that in the wheelpaths before any additional processing is initiated. **Grading prior to completion of initial compaction, or failure to compact this material in an appropriate sequence will result in a permanent density differential, which could lead to early rutting in the wheelpaths after opening to traffic.** Follow these steps to prevent differential compaction-related problems:

- First run the roller down the center of the recycling train wheelpaths, ensuring that the drum of the roller bridges the wheelpaths (Figure 5.10). Run the second and third passes over any loose, untrafficked material on either side of the wheelpaths. The loose material between and adjacent to the wheelpaths should now be level with and of a similar density to that in the wheelpaths.
- Now follow a conventional rolling pattern to obtain uniform compaction of the recycled material.

Figure 5.9: Differential compaction in recycling train wheelpaths.

Figure 5.10: First roller pass.

- If the recycler works at about 25.0 ft/min, the primary roller, which typically operates at 165 ft/min can make five unidirectional passes while keeping pace with the recycling train. If more than five passes are required to achieve refusal density, the speed of the recycling train will need to be reduced, or an additional roller used. If a second roller is used, it should be the same make and model as the first, with the same vibration settings. If the roller falls too far behind the recycling train (i.e., typically more than 150 ft, or when the material dries out and the specified density cannot be achieved throughout the layer), the train must be stopped until the roller catches up.
- If a padfoot roller is used, the increasing compactive effort as more roller passes are applied results in increasing density in the lower regions of the recycled layer. This in turn increases the resistance to penetration of the individual pads on the roller, allowing the roller to "walk out" of the material (Figure 5.11). Only minor indentations, which can be skimmed by the grader during leveling, should be left on the surface after completion of initial compaction with the padfoot roller.

Figure 5.11: First and final pass of a padfoot roller.

5.6 SHAPING

Follow the procedures in the FHWA *Gravel Roads Construction and Maintenance Guide (5)* for shaping the road. A crown of about 5 percent is recommended. Take special care at intersections, driveway entrances, transitions to and from superelevation changes, railroad crossings, and transitions between

unpaved and paved sections, including bridges. If a padfoot roller was used for primary compaction, make sure that any indentations left by the pads are removed with the grader.

5.7 FINAL COMPACTION

Final compaction should be carried out after completion of all work with the blade to achieve a tightly bound, smooth surface. This can be done with either a steel drum or rubber tired roller. Spray the road with water during the rolling operations (Figure 5.12) to achieve a tightly bound surface.

Figure 5.12: Final compaction.

5.8 DRAINAGE

As noted throughout this guide, good drainage (getting water off and away from the road) will be a critical part of ensuring long-term good performance of the road. Follow the procedures in the FHWA *Gravel Roads Construction and Maintenance Guide (5)* for providing appropriate drainage measures. Ensure that side drains are deep enough and correctly sloped to accommodate runoff from typical storms. Also ensure that there are sufficient miter (turnout) drains to move the water away from the road and to limit standing water for extended periods next to the road. Consider installing culverts to move water from one side of the road to the other to prevent ponding of water, and installing suitable pipes at driveway entrances if they are not already in place.

5.9 APPLYING CHEMICAL TREATMENTS

Apply chemical treatments according to the procedure documented in the *Guidelines for the Selection, Specification and Application of Chemical Dust Control and Stabilization Treatments on Unpaved Roads (7)* (Figure 5.13). Given that most unpaving projects require some mixing of materials, it is recommended that **75 percent of the recommended dosage of chemical treatment is mixed into the material in conjunction with the compaction water, or as a replacement for the compaction water**. If the mixing is done with a recycler/reclaimer, the treatment will be uniformly mixed throughout the layer ensuring optimal stabilization and fines retention. **Spray the remaining 25 percent of the dosage as a surface application after final compaction to seal the surface and to achieve optimal fines retention and dust control**. Mixing chemical treatments into the road as opposed to spraying them onto the surface after compaction will result in significantly better and longer performance of the treatment, with longer intervals between required grader maintenance and rejuvenation of the chemical, and reduced rates of gravel loss.

Figure 5.13: Chemical treatment application.

5.10 MAINTENANCE OF CONVERTED ROADS

5.10.1 Untreated Roads

Follow the recommendations in the FHWA *Gravel Roads Construction and Maintenance Guide (5)* for maintaining untreated unpaved roads. Key things to remember include:

- Blade when the road is moist (i.e., after rain). Spray the road with water prior to blading if necessary.
- Maintain the crown at 5 percent. Check the crown with a level after blading.
- If possible, compact the road after blading. This will seal the surface, preserve the crown, and slow the rate of gravel loss. Rubber tired rollers are most appropriate for this. Attachments that fit behind the grader (example in Figure 5.14) work well.
- Make sure that there are no windrows at the side of the road that will prevent water from running off the road (Figure 5.15).
- Make sure that all drains are functioning.

Figure 5.14: Roller attached to grader.

Figure 5.15: Windrows blocking water flow from the road.

5.10.2 Chemically Treated Roads

Follow the recommendations in the *Guidelines for the Selection, Specification and Application of Chemical Dust Control and Stabilization Treatments on Unpaved Roads (7)* for maintaining treated unpaved roads and/or the recommendations provided by the supplier of the chemical being used. Key things to remember in addition to those listed above include:

- The surface of a road treated with chemicals in the moisture absorbing and organic non petroleum categories should be sprayed with water to soften the crust prior to blading.
- Consider spraying a light application of the treatment after grader maintenance to seal the surface and rejuvenate the product.

CHAPTER 6: LIFE-CYCLE COSTS

Life cycle cost analyses usually show that it is more cost-effective to seal unpaved roads with an asphalt surface treatment or with asphalt concrete when traffic volumes reach a certain number. This number will vary depending on road maintenance costs, the number of contractors in the area, costs of materials, and the condition and structural capacity of the road. The benefits of paving are, however, accrued over the design life of the pavement. Rehabilitating severely distressed paved roads require a large capital outlay, and sufficient future funds to, maintain the road thereafter. Securing these capital funds is very difficult for local agencies and actions that can be managed within fluctuating annual budgets are often the only option that can be considered even if they are more expensive in the long-term. Consequently, converting the distressed paved road to an engineered unpaved road will usually be much cheaper in the short-term compared to rehabilitating the road back to an acceptable paved condition. For lower traffic volumes (i.e., typically less than 100 to 150 vehicles per day), this option will usually be cheaper in the long-term as well. However, cost analyses are usually required to support the decision to unpave and justify the action to county commissioners, county boards of supervisors, residents, and businesses that will be affected by the decision.

Costs associated with unpaving can vary greatly based on the effort required. Limited cost information captured from a survey of unpaving projects that have occurred in Minnesota found costs to range from:

- Kittson County, MN – 0.5 miles reclaimed deteriorated asphalt concrete at a cost of $3,993 (unknown year), equating to a cost per mile of $7,986.
- Lincoln County, MN - 3 miles converted to gravel, with per mile bids ranging from $4,833 to $6,983.

These cost estimates for unpaving can be used as general guidance when estimating costs. Cost estimates typically include:

<u>Unpaving Costs</u>

- Equipment costs, whether in-house or rental, including investigation and conversion (i.e., construction)
- Person-hour costs including investigation, design, and conversion supervision
- Laboratory testing costs
- Purchase of supplemental materials and/or chemical treatments
- Trucking costs for hauling out unused milled materials and/or hauling in supplemental materials
- Dumping fees if applicable

<u>Gravel Road Maintenance Costs</u>

- Blading (equipment and personnel, may include a water tanker and roller)
- Chemical treatments (stabilization or dust control)
- Supplemental gravel (regravel), materials as needed

6.1 TOOLS TO ESTIMATE COST

Numerous life-cycle cost analysis tools are available for comparison of life-cycle costs of various strategies for dealing with distressed paved roads, unpaved options for addressing distressed pavements, including repaving the road, maintaining the existing severely distressed pavement, unpaving the road, and maintaining a gravel road.

6.1.1 Local Road Surface Selection Tool

North Dakota State University (NDSU) and North Dakota Local Technical Assistance Program (NDLTAP) developed a web-based surface selection tool *(8)* that allows users to compare costs associated with applying and maintaining different road surfaces including asphalt concrete, asphalt surface treatments, gravel, gravel with dust control treatments, and gravel with stabilization treatments. The tool has been set up for use and tested in Minnesota. Although individual Minnesota counties can be selected in the online tool, at this time the analysis is only run at the regional level and defaults to 2017 inputs.

The following information is required to perform an analysis. Actual information rather than guesses should be used:

- Road segment length (miles)
- Road width (ft),
- Annual average daily traffic (vehicles per day),
- Analysis period (years),
- Discount rate (percent),
- Base user cost per vehicle (cents/mile).
- Number of times an activity is undertaken per year
- Year interval between applications
- Initial year of application
- Unit cost (in dollars)

Output from the tool includes total initial cost, total maintenance cost, salvage value, total agency cost for each surface treatment, cumulative cost for each surface treatment over time (in 5-year increments up to 20 years).

6.1.2 Gravel and Paved Road Management Tools

An online Excel-based Gravel Road Management Tool has been developed for the Minnesota DOT Local Roads Research Board and is tailored for use in Minnesota *(9)*. The tool is designed to be a data management resource for county engineering offices to better track and manage gravel roads. It can be used as an inventory tool and data hub for maintenance and construction of the gravel road system.

Numerous other gravel and paved road management tools are available. Some of the tools were specifically developed for paved roads but can be modified to work for gravel roads by entering data specific to gravel roads. A synthesis of gravel road management tools *(10)*, prepared by MnDOT/LRRB in 2014 identified the following six software tools that were appropriate for use in Minnesota and provides a summary table of information on each.

- County Information Management System (CIMS)
- *Lucity* – *www.lucity.com*
- *PubWorks* – *www.pubworks.com*
- *Road System Management Software (RSMS11)* – *www.rsms.info*
- *WinCAMs* – *www.csscams.com*
- *Work Central (RT Vision)* – *www.rtvision.biz*

These online tools provide a variety of benefits including;

- The ability to track conditions of gravel roads
- Define when and how to measure performance
- Provide guidance on how to schedule maintenance/prioritize routes (condition rating)
- GIS compatibility
- Track summer and winter maintenance costs
- Determine the costs to upgrade a road from gravel to paved
- Cost and budgeting

A summary of additional pavement management tools that may be useful can be found in *NCHRP Synthesis 485 Converting Paved Roads to Unpaved Roads (1)*.

6.1.3 Cost to Unpave, and Maintain

Long-Term Life-Cycle Maintenance Costs

Long-term maintenance for gravel roads should be considered prior to unpaving a road. Long term maintenance includes seasonally blading or reshaping the road surface, drainage maintenance, dust control or soil stabilization, regraveling, sign maintenance, etc. An example summary table that can be used to help assess long-term maintenance costs prior to unpaving is provided in Table 4.

Table 4: Example summary cost table

Maintenance Type	Recommended Frequency	Effort Required or Equipment & # of personnel	Costs	Notes
Blading / reshaping	Seasonally, as needed	Motor grader, 1 person	Motor grader: Personnel:	
Drain cleaning	Seasonally, as needed	Motor grader, backhoe, 3 persons	Motor grader: Backhoe: Personnel:	
Dust control	Seasonally, as needed	Likely contracted out	Contractor bids:	
Regravel	Multi year	Dump truck, motor grader, roller, water tanker, 2+ persons	Gravel $/ton: Dump truck/delivery fee: Motor grader: Roller: Water tanker: Personnel:	
Stabilization	With regravel	Likely contracted out	Contractor bids:	
Sign maintenance	As required	2 persons	Personnel: Replacement signs:	
Etc.				
Other:				

CHAPTER 7: COMMUNICATING ABOUT UNPAVING

7.1 INTRODUCTION

One of the challenges faced during the unpaving process is how the road user will feel about the change in the road surface. Public opinion can make or break an unpaving project. To set up an unpaving project for success, strong public involvement, transparency, and open communication with the public, road users, and adjacent landowners are encouraged.

Communication with the public and adjacent landowners should be a part of the unpaving plan and should occur early and often in the process. Communications should provide:

- Openness and clarity
- A forum for letting road users, landowners, and the public feel part of the process and the solution
- Help in identifying creative solutions and funding options
- An atmosphere that creates buy-in on the process and outcome
- A point person at the agency to receive feedback, provide information, and serve as the public face for the process

One concerning complaint from the public about some unpaving projects is that one day they had a paved road and the next day it was gravel, and they were not made aware of the conversion or allowed to provide input.

Once a road has been identified as a candidate for unpaving, effectively communicating with the public is key to the success of the next steps. **Error! Reference source not found.** provides an example process of how to communicate with the public and stakeholders as decisions are made.

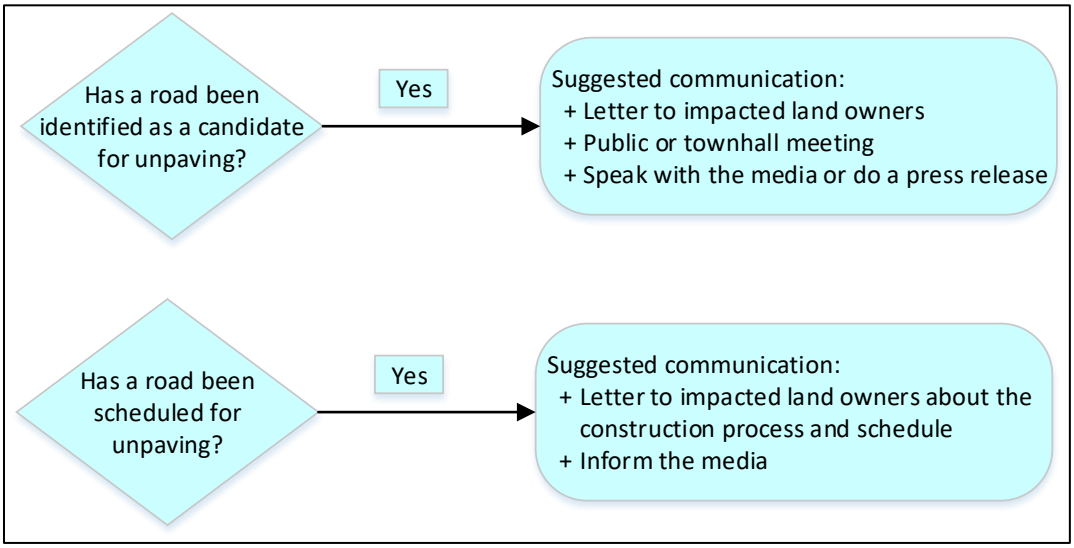


Figure 7.1 Process for communicating unpaving status to the public.

Effective communication is key to building trust and essential for successful outcomes in unpaving projects. When developing communications for specific stages of the unpaving process, the five C's of effective communication (Figure 7.2) can be very helpful in structuring the message.

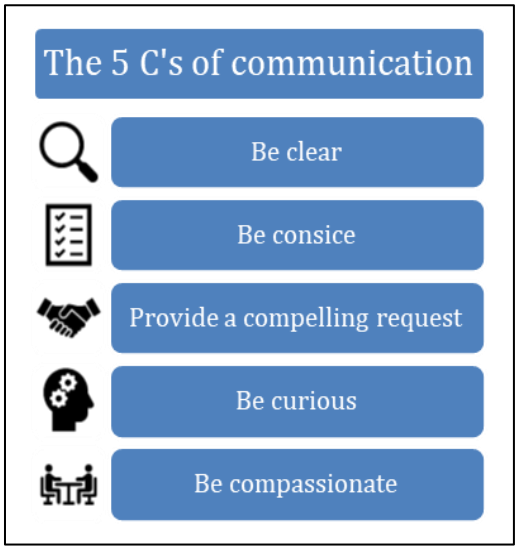


Figure 7.2. The five C's of communication.

When writing letters, preparing for town hall meetings, or creating fact sheets and presentations, apply the five C's to your message:

1. Be clear.
    a. In this stage of communication with the public, it is important to understand why the road is a candidate for unpaving, so that the reasons can be shared with transparency. Key issues about the road should be identified and potential solutions proposed. Be clear about the expectations of road performance for all potential solutions proposed.
    b. Be transparent about options for road improvement, rehabilitation costs, road maintenance, costs, and the pros and cons of the various options.
2. Be concise and to the point.
3. Provide a compelling request. Share:
    a. Why the road is a candidate for unpaving.
    b. The information used to make this decision (e.g., road condition, importance of the road in the network, cost of options, availability of funds, pros and cons, current maintenance costs, long-term maintenance costs, etc.).
    c. How a good-quality, engineered unpaved road can be a better and safer driving surface than a severely distressed paved road; use photographs and videos.
4. Be curious.
    a. Allow for engagement with the public.
    b. Use public meetings and public comment periods to capture ideas and feedback from the public.
5. Be compassionate.
    a. Take time to hear the public's concerns—information may be all people seek.
    b. Be understanding of the change and how it may impact the public.

c. Being transparent with information with the public allows people to be made aware of the complexity of the decision-making process.

7.2 TOOLS FOR EFFECTIVE COMMUNITY ENGAGEMENT

There are numerous ways of communicating with the public. Using a combination of these ways is usually best to reach a spectrum of people. Know your expected audience when selecting an appropriate tool or combination of tools.

7.2.1 Websites and Social Media

Electronic forums are the easiest way to communicate with the public. These include agency websites, Facebook pages, and Twitter accounts. Websites can accommodate all relevant information, including "frequently asked questions" sections, information about meetings and timelines, and options for collecting and addressing public concerns. Facebook and Twitter are ideal for providing updates and notifications.

7.2.2 Letters

Letters are a formal method of communicating with interested and affected parties. They can be mailed and/or emailed. The contents can be carefully prepared with sufficient content. Letters should:

- Inform road users and landowners of the issues with the road.
- Present information on why unpaving the road is an option being considered.
- Provide information on how to comment on or participate in the process.
- Provide a contact for more information.
- Provide information on upcoming meetings and proposed timing of the work.
- Identify any anticipated changes to the road surface, conditions, and/or restrictions.

An example form letter that can be used as a communication tool for informing the public about candidate unpaving projects is provided in Appendix G. The letter can be modified to keep the public updated on the process.

7.2.3 Town Hall Meetings

Town hall meetings provide an opportunity for interested and affected parties to meet with the agency, listen to reasoning behind wanting to convert the road, discuss options, and voice concerns. An informative PowerPoint presentation should be prepared and presented. An experienced facilitator should run the meeting to ensure that order is maintained and that sufficient time is provided for the agency representative to present and for the audience to respond. Care must be taken to ensure that one or two individuals do not dominate the proceedings. Example presentation slides are provided in Appendix G.

7.2.4 Fact Sheets

Fact sheets provide a summary of why unpaving is being pursued , the proposed conversion process, benefits of unpaving, frequently asked questions, links to additional information, and procedures for submitting queries and concerns. Fact sheets can be attached to letters and emails, included on websites and handed out at town hall meetings. An example fact sheet is provided in Appendix G.

7.2.5 Press Releases

Press releases published in local and regional newspapers and aired on local radio and television stations will reach a broad spectrum of people within the community. Although limited information can be provided in this way, links to where more detailed information is available can be provided. Example press releases are provided in Appendix G

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APPENDIX A
CHECKLISTS AND FORMS

Checklists and Forms

The following checklist and forms are provided in this appendix and available in their original format at http://mndot.gov/research/reports/2019/201942-checklistsforms.docx. Appendix F contains examples of completed forms.

- Form #1: Desktop study
- Form #2: Visual assessment
- Form #3: Dynamic cone penetrometer (DCP) record
- Form #4: Material testing results and performance prediction chart
- Form #5: Dynamic cone penetrometer (DCP) result analysis
- Form #6: Material design
- Form #7: Conversion plan

DESKTOP STUDY FORM												Form #1
Date		Evaluator			Road #			Road Name				
Start Point			End Point									
Year Constructed			Conventional		Y	N		Evolved		Y	N	
Year First Paved			Year Last Paved					Times Paved				
Maint. Frequency												
Repair Type	Potholes		Cracks		Edge break			Flood		Frost		
	Other											
Reason for Distress	Age		Funds		Drainage			Weather		Traffic		
	Vehicle		Other									
Traffic	AADT				AADTT							
	Seasonal Change Details											
	Expected Growth/Decline											
	Other											
Weather Factors												
Complaints	Number		From									
	Action											
Issues from Previous Projects												
Affected Properties	House		Business		Farm							
Potential Impacts from Unpaving												
Potential Safety Issues												
Provisional Response About Unpaving												
Potential Fatal Flaws												
Other Notes												
Continue with Investigation	Y	N										

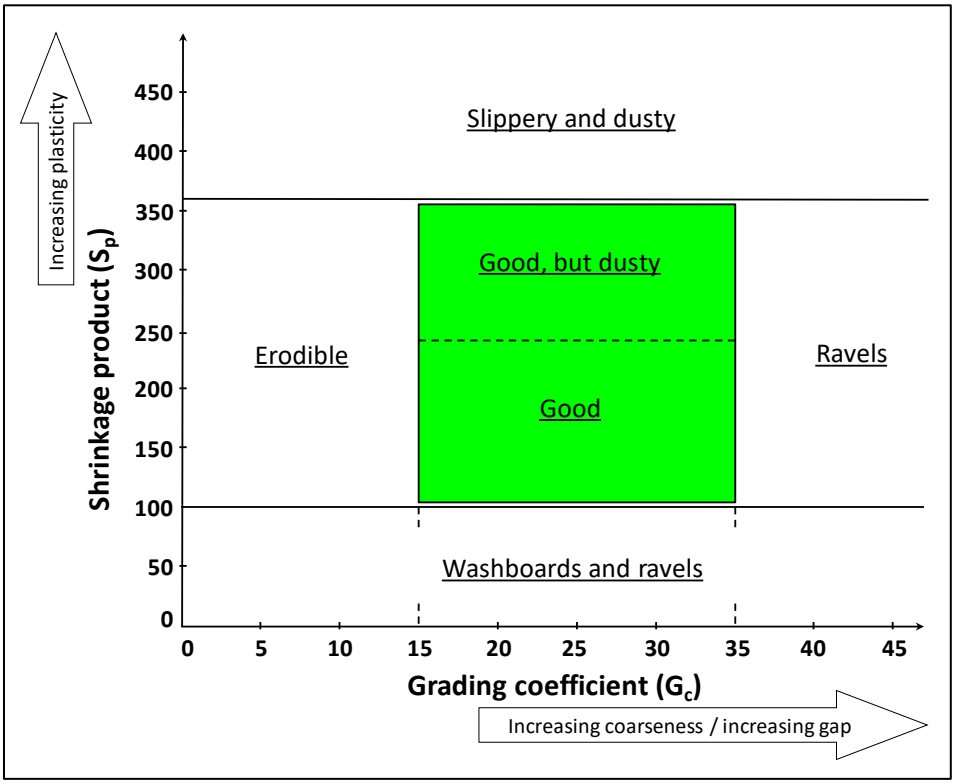
VISUAL ASSESSMENT FORM												Form #2
Date		Evaluator		Road #		Road Name						
Start Point		End Point										
% Road Unpaved		Passive Convert	Y	N	Active Convert	Y	N					
Types of Distress	Potholes		Cracks		Ruts		Stone Loss		Edge break			
	Flood		Frost									
	Other											
Reason for Distress	Age		Funds		Drainage		Weather		Traffic			
	Vehicle		Other									
Required Corrective Actions to Address Problems												
Will Problems Affect Converted Road?												
Variability	Material		Thickness		Moisture		Distress		Patching			
	Crack Seal		Traffic		Geometrics							
	Notes/Other											
Required Corrective Actions for Variability												
Drainage	Good		Poor		Crown (%)		Geometry Problems					
	Water Moves off the Road				Water Moves Away from Road				Puddles			
	Property Access Problems				Broken Culverts				Cut to Fill			
	Notes/Other											
Side Drains	Clear		Blocked		Eroded		Capacity		Ponding			
	Notes/Other											
Required Corrective Actions for Drainage	Crown		Raise		Side Drains		Culverts		Pipes			
Safety (Attach separate assessment if applicable)	Geometry		Dust		Slipperiness		Passibility					
	Notes/Other											
Required Corrective Actions for Safety												
Testing and Sampling Locations (Distance from Start)	DCP											
	Layer Thickness											
	Material Sample											
Utilities	Y	N										

VISUAL ASSESSMENT FORM																	Form #2
DCP Tests (Form #3)	**Notes**																
Layer Thickness																	
Location	1		2		3		4		5		6		7		8		
Surface																	
Layer 1																	
Layer 2																	
Layer 3																	
Moisture																	
Sample Taken	**Y**	**N**	**Y**	**N**	**Y**	**N**	**Y**	**N**	**Y**	**N**	**Y**	**N**	**Y**	**N**	**Y**	**N**	
Schematic											**Photo #**		**Description**				
Fatal Flaws	**Y**	**N**															
Continue with Investigation			**Y**	**N**													

DCP RECORDING FORM											Form #3
Date		**Evaluator**			**Road #**			**Road Name**			
Test 1				**Test 2**				**Test 3**			
Distance	**0+**			**Distance**	**0+**			**Distance**	**0+**		
Position	L	C	R	**Position**	L	C	R	**Position**	L	C	R
0				0				0			
5	155			5	155			5	155		
10	160			10	160			10	160		
15	165			15	165			15	165		
20	170			20	170			20	170		
25	175			25	175			25	175		
30	180			30	180			30	180		
35	185			35	185			35	185		
40	190			40	190			40	190		
45	195			45	195			45	195		
50	200			50	200			50	200		
55	205			55	205			55	205		
60	210			60	210			60	210		
65	215			65	215			65	215		
70	220			70	220			70	220		
75	225			75	225			75	225		
80	230			80	230			80	230		
85	235			85	235			85	235		
90	240			90	240			90	240		
95	245			95	245			95	245		
100	250			100	250			100	250		
105	255			105	255			105	255		
110	260			110	260			110	260		
115	265			115	265			115	265		
120	270			120	270			120	270		
125	275			125	275			125	275		
130	280			130	280			130	280		
135	285			135	285			135	285		
140	290			140	290			140	290		
145	295			145	295			145	295		
150	300			150	300			150	300		
Moist. Content											
DPI											
DSN_{800}											
Notes											

MATERIAL TEST RESULTS												Form #4
Road #		**Road Name**					**Sampling Location**					
Surface Layer												
Description												
Aggregate Shape	Cubicle?	Y	N	Rounded?	Y	N	Crushed?	Y	N	Natural?	Y	N
Grading	P1			P#4			P#8			P#40		
Compaction	MDD			OMC								
Add. RAP Tests	Tested?	Y	N	Estimate?	Y	N	Crushed?	Y	N	Agglom.?	Y	N
Notes												
Layer #2												
Description												
Aggregate Shape	Cubicle?	Y	N	Rounded?	Y	N	Crushed?	Y	N	Natural?	Y	N
Grading	P1			P#4			P#8			P#40		
Plasticity	BLS			PI			PI/2					
Strength	CBR											
Compaction	MDD			OMC								
Notes												
Layer #3												
Description												
Aggregate Shape	Cubicle?	Y	N	Rounded?	Y	N	Crushed?	Y	N	Natural?	Y	N
Grading	P1			P#4			P#8			P#40		
Plasticity	BLS			PI			PI/2					
Strength	CBR											
Compaction	MDD			OMC								
Notes												
Subgrade												
Description												
Grading	P1			P#4			P#8			P#40		
Plasticity	BLS			PI			PI/2					
Strength	CBR											
Compaction	MDD			OMC								
Notes												
Supplementary Material												
Description												
Aggregate Shape	Cubicle?	Y	N	Rounded?	Y	N	Crushed?	Y	N	Natural?	Y	N
Grading	P1			P#4			P#8			P#40		
Plasticity	BLS			PI			PI/2					
Strength	CBR											
Compaction	MDD			OMC								
Add. RAP Tests	Tested?	Y	N	Estimate?	Y	N	Crushed?	Y	N	Agglom.?	Y	N
Notes												

MATERIAL TEST RESULTS **Form #4**



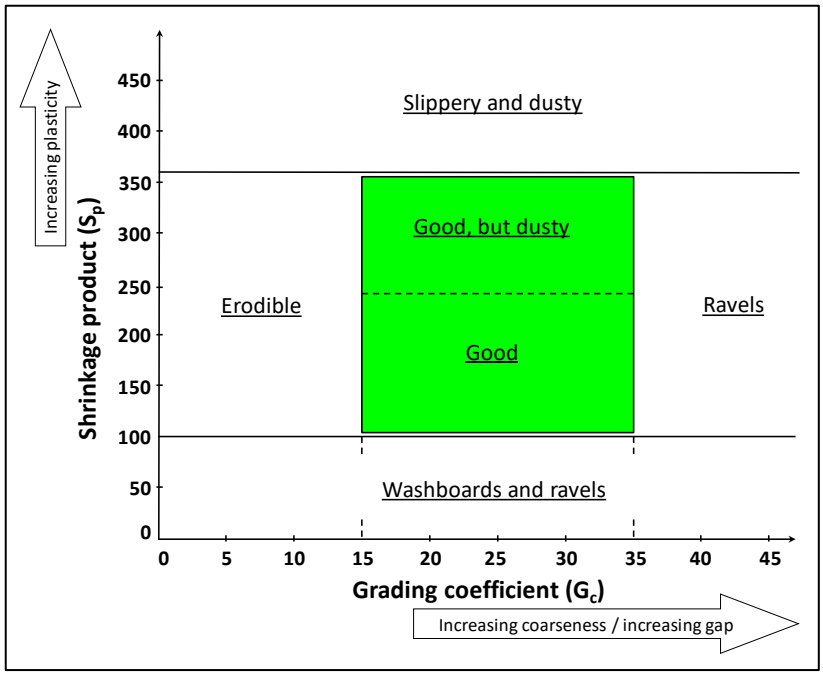
Notes

DCP ANALYSIS																Form #5
Test Number	**1**			**2**			**3**			**4**			**5**			**Notes**
Distance	0+			0+			0+			0+			0+			
Position	L	C	R	L	C	R	L	C	R	L	C	R	L	C	R	
Parameter																
Base thickness (mm)																
Subbase thickness (mm)																
DPI Base (mm/blow)																
DPI Subbase (mm/blow)																
DPI SG (mm/blow)																
DSN_{800} (blows)																
CBR-base																
CBR-subbase																
CBR-subgrade																
Test Number	**6**			**7**			**8**			**9**			**10**			
Distance	0+			0+			0+			0+			0+			
Position	L	C	R	L	C	R	L	C	R	L	C	R	L	C	R	
Parameter																
Base thickness (mm)																
Subbase thickness (mm)																
DPI Base (mm/blow)																
DPI Subbase (mm/blow)																
DPI SG (mm/blow)																
DSN_{800} (blows)																
CBR-base																
CBR-subbase																
CBR-subgrade																
Test Number	**11**			**12**			**13**			**14**			**15**			
Distance	0+			0+			0+			0+			0+			
Position	L	C	R	L	C	R	L	C	R	L	C	R	L	C	R	
Parameter																
Base thickness (mm)																
Subbase thickness (mm)																
DPI Base (mm/blow)																
DPI Subbase (mm/blow)																
DPI SG (mm/blow)																
DSN_{800} (blows)																
CBR-base																
CBR-subbase																
CBR-subgrade																
Notes																

MATERIAL DESIGN FORM						Form #6
Layer	Layer Description and Material Properties	Column 1	Column 2	Column 3	Column 4	Column 5
		P1	P#4	P#8	P#40	BLS
1						
2						
3						
4						
Target Wearing Course Thickness						

Layer	Calculate Thickness Proportions	Column 1	Column 2	Column 3	Column 4
		Existing Thickness	Sum of Thickness	Thickness in Target Depth	Proportion
1					
2					
3					
4					

Layer	Calculate Estimated Material Properties	Column 1	Column 2	Column 3	Column 4	Column 5
		P1	P#4	P#8	P#40	BLS
1						
2						
3						
4						
New Unpaved Wearing Course Layer						
Grading coefficient						
Shrinkage product						



New Wearing Course Test Results		
P1		
P#4		
P#8		
P#40		
P#200		
BLS		
CBR		
MDD		
OMC		
Grading Coefficient		
Shrinkage Product		
Accept	Y	N

CONVERSION PLAN										Form #7
Date		Evaluator		Road #		Road Name				
Start Point		End Point								
% Road Unpaved		Passive Convert	Y	N	Active Convert	Y	N			
Thickness Design										
Notes										
Corrective Actions	Isolated Problem									
	Geometry									
	Variability									
	Safety									
	Utilities									
Material Design Scenario	#1		#2		#3		#4		#5	
	Supplemental Material Thickness				Tons Required					
	Supplemental Material Source				Mixing Depth					
	Details (from Form #6)									
Drainage Design	Crown									
	Side Drains									
	Culverts									
	Geometry									
	Driveways									
	Notes									
Chemical Treatment	Product				Application Rate					
	Application Method									
	Notes									
Equipment	Recycle/Mixing				Primary Compaction					
	Final Compaction									
Specifications										
Additional Notes										

APPENDIX B
DYNAMIC CONE PENETROMETER

Dynamic Cone Penetrometer

The dynamic cone penetrometer (DCP) is a simple tool consisting of a steel rod with a conical, hardened steel tip that is driven into the road pavement using a drop hammer of standard mass (17.6 lb) (Figure B.1). The penetration rate, measured in mm/blow, provides an indication of the thicknesses and in-situ strengths of the materials in the different pavement layers. DCP probes are normally driven to a depth of 800 mm to ensure a good understanding of the full pavement structure as well as the underlying subgrade materials.

DCP measurements correlate well with the California Bearing Ratio (CBR) in fine and sandy materials (and reasonably well for coarse granular materials) at in situ density and moisture content.

DCP investigations require a series of tests along the road to ensure acceptable reliability since the coefficient of variation is often relatively high (resulting from inherent material and moisture content variability, stones, compaction, etc.).

Procedures for using the DCP are described in MnROAD User Guide to the Dynamic Cone Penetrometer *(2)* and ASTM D6951.

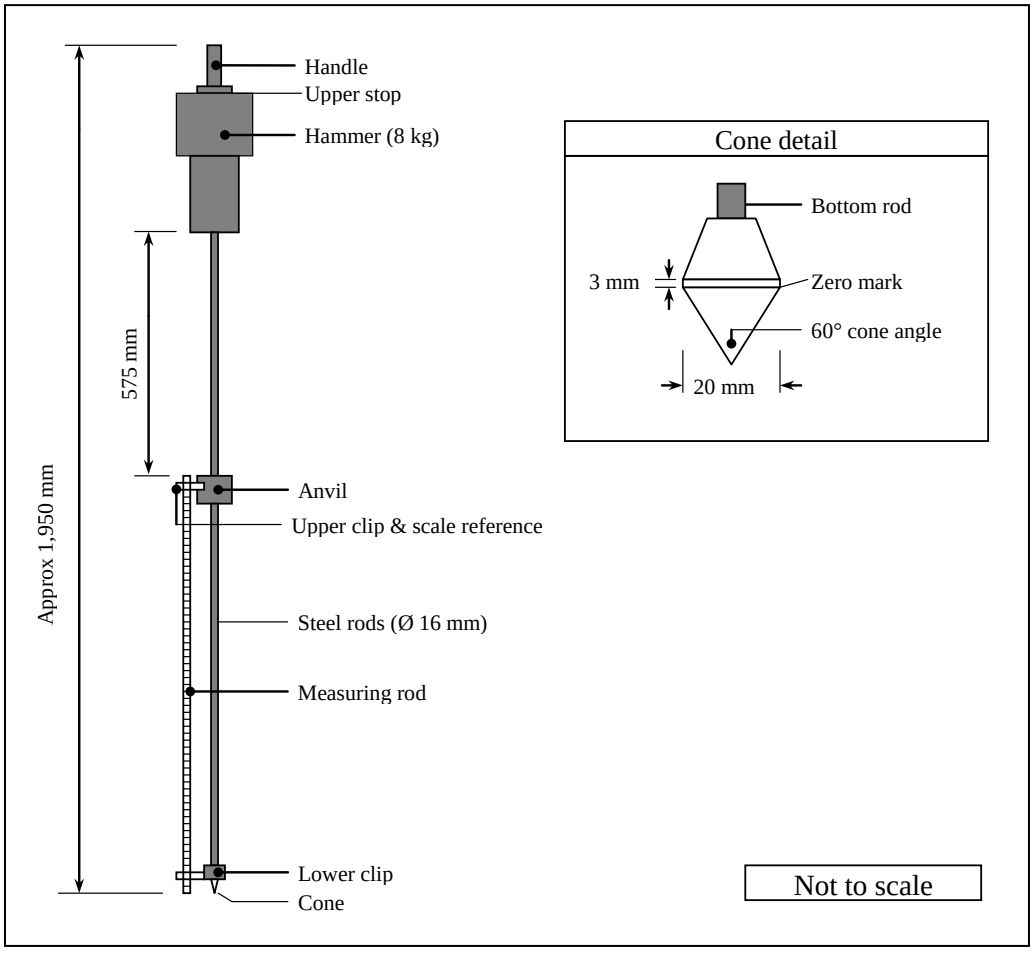


Figure B.1: Dynamic cone penetrometer (DCP).

APPENDIX C
RESOURCES FOR ROAD SAFETY ASSESSMENTS

Resources for Road Safety Assessments

C.1 General Road Safety Information

- National Highway Traffic Safety Administration (NHTSA) Traffic Safety Facts (https://www.nhtsa.gov/research-data)
- National and international safety coalitions such as Vision Zero (https://visionzeronetwork.org/)
- Toward Zero Deaths (https://www.towardzerodeaths.org/)
- Road to Zero (https://www.nsc.org/road-safety/get-involved/road-to-zero)
- Minnesota's Toward Zero Deaths initiative (http://www.minnesotatzd.org/)
- Unpaved Safety Webinar. National Center for Rural Road Safety. (https://ruralsafetycenter.org/wp-content/uploads/2017/12/Presentation_SC_Unpaved_Nov_Webinar_2017-11-30.pdf)
- Unpaved Road Safety. Michigan Local Road Safety Peer Exchange. (http://ctt.mtu.edu/sites/default/files/workshops/Presentations/2018/Safety_Exchange/13_Rose marie_Anderson.pdf)
- Safety Analysis of Low-Volume Rural Roads in Iowa, (http://publications.iowa.gov/21127/1/IADOT_InTrans_07_309_Safety_Analysis_Low_Volume_Rural_Roads_Iowa_2010.pdf)
- The National Center on Rural Road Safety, Unpaved Road Safety Webinar, (https://ruralsafetycenter.org/resources/list/unpaved-road-safety/)
- FHWA Road Safety Information Analysis, A Manual for Local Road Owners, (https://safety.fhwa.dot.gov/local_rural/training/fhwasa121/lrro_data.pdf)
- A Guide for Effectively Partnering with State Highway Safety Officers, (https://www.ghsa.org/resources/partnering18)
- A series of webinars recorded by the National Center for Rural Road Safety, (https://ruralsafetycenter.org/training-education/safety-center-trainings/archived-safety-center-trainings/)
- FHWA Local Roads' Safety Checklist, (https://safety.fhwa.dot.gov/local_rural/training/fhwasa13029/checklist.cfm)
- FHWA Intersection Safety, A manual for local rural road owners, (https://safety.fhwa.dot.gov/local_rural/training/fhwasa1108/fhwasa1108.pdf)
- FHWA Speed Management, A manual for local rural road owners, (https://safety.fhwa.dot.gov/local_rural/training/fhwasa1108/fhwasa1108.pdf)
- FHWA Non-Motorized User Safety, A manual for local rural road owners, (https://safety.fhwa.dot.gov/local_rural/training/fhwasa1108/fhwasa1108.pdf)
- FHWA Roadway Departure Safety, A manual for Local Rural Road Owners, (https://safety.fhwa.dot.gov/local_rural/training/fhwasa1108/fhwasa1108.pdf)
- Every Day Counts 5, Reducing Rural Roadway Departures, FoRRRwD, (https://www.fhwa.dot.gov/innovation/everydaycounts/edc_5/roadway_departures.cfm)

C.2 Road Safety Audits

- Federal Highway Administration (FHWA) Road Safety Audit. (https://safety.fhwa.dot.gov/rsa/)
- FHWA Unpaved Roads: Safety Needs and Treatments. (https://safety.fhwa.dot.gov/local_rural/training/fhwasa14094/unpaved.pdf)
- Tribal Road Safety Audits Case Study (https://safety.fhwa.dot.gov/rsa/tribal_rsa_studies/tribal_rsa_studies.cfm)

C.3 Road Safety Plans

- Developing Safety Plans: A Manual for Local Road Owners. FHWA. (https://safety.fhwa.dot.gov/local_rural/training/fhwasa12017/)
- FHWA Systemic Safety Project Selection Tool (https://safety.fhwa.dot.gov/systemic/)
- FHWA Roadway Safety Data Program (https://safety.fhwa.dot.gov/rsdp/)
- The FHWA Center for Accelerating Innovation and information on the use the Data-Driven safety Analysis (https://www.fhwa.dot.gov/innovation/everydaycounts/edc_4/ddsa.cfm), (https://www.youtube.com/watch?v=Wzdm798MoI8&feature=youtu.be), and (https://www.youtube.com/watch?v=jVds3AWWqbk&feature=youtu.be)
- Local Road Safety Plan template (https://www.countyengineers.org/assets/docs/Template%20for%20%20a%20County%20Safety%20Plan.docx)

Systemic Safety Selection Tool in Minnesota

As a part of the FHWA Every Day Counts (EDC-4) program, Minnesota participated in the Data-Driven Safety Analysis (DDSA) program using the Systemic Safety Selection Tool. This included:

- Development of Road Safety Plans (RSPs) for participating counties to identify specific safety projects that would directly address safety factors associated with severe crashes in these counties.
- Analysis of the data which showed there were more severe crashes on the county road system, with the majority occurring in rural areas, involving roadway departures and curves more than 50% of the time.
- Identification of countermeasures for each crash type, which were assessed based on crash data, effectiveness, cost, agency policies, procedures and experience.
- Identification of 32 high-priority curves, from a total of 504, for safety improvements.
- Selection of three priority safety strategies including enhanced road edges with rumble strips and 6 in. edge lines, enhanced curve delineation (chevrons), and upgraded traffic signs and streetlights for intersections.

More information can be found at
https://cloud.3dissue.com/35928/36543/190460/DDSAInteractive-Minnesota/index.html?r=36

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Local Road Safety Plans (LRSP)

An LRSP is a tool that has been developed to frame the safety issues and needs on the local transportation network. A data-driven safety analysis can provide insights into prevalent behavioral issues (e.g. impaired driving, distracted driving, unbelted drivers, young drivers, older drivers); intersections and segments that have the potential for safety improvements; and/or unsafe roadway characteristics. The six steps of an LRSP include:

1. Establish leadership.
2. Analyze safety data
3. Determine emphasis areas
4. Identify strategies
5. Prioritize and incorporate strategies
6. Evaluate and update the LRSP

Some Minnesota counties have already developed LRSPs (http://www.dot.state.mn.us/trafficeng/safety/rsa/CRSPphaseVreportFINAL20140313.pdf). If your county has one, it is recommended that you review it to ensure that unpaved roads are addressed as part of the document. If your county does not have an LRSP, ensure that when you create it, you incorporate unpaved roads as well.

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C.4 Safety Counter Measures

- FHWA proven infrastructure-related safety countermeasures (https://safety.fhwa.dot.gov/provencountermeasures/)
- NHTSA's safety behavior-related countermeasures https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/812478_countermeasures-that-work-a-highway-safety-countermeasures-guide-.pdf
- Crash modification factors clearinghouse (http://www.cmfclearinghouse.org/)
- CDC's motor vehicle prioritizing interventions and cost calculator (MV PICCS) https://www.cdc.gov/features/motorvehiclesafety/index.html
- Toward Zero Deaths and Serious Injuries Report (http://www.towardszerofoundation.org/wp-content/uploads/2016/10/Zero_road_deaths-SafeSystems.pdf)
- NCHRP 500: Guidance for Implementation of the AASHTO Strategic Highway Safety Plan (http://www.trb.org/Main/Blurbs/152868.aspx)
- NHTSA's public awareness campaigns (https://www.trafficsafetymarketing.gov/)

C.5 Best Road Safety Management Practices

- FHWA's Unpaved Roads: Safety Needs and Treatments, (https://safety.fhwa.dot.gov/local_rural/training/fhwasa14094/unpaved.pdf)
- Wyoming LTAP: Road Geometry, Surface Materials Are Key to Safety on Gravel Roads, (https://safety.fhwa.dot.gov/newsletter/safetycompass/2012/fall/)

APPENDIX D
BAR LINEAR SHRINKAGE TEST METHOD

Bar Linear Shrinkage Test Method

SCOPE

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

DEFINITION

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

APPARATUS

- Bar linear shrinkage (BLS) mold, stainless steel or brass (Figure D.1), with inside dimensions of 6.0 in. long by 0.39 in. wide by 0.39 in. deep (150 mm ± 0,25 mm long by 10 mm ± 0,25 mm wide, and 10 mm ± 0,25mm deep)
- Flat stainless steel or brass plate 8 in. by 8 in. by 0.2 in (200 mm by 200 mm by 6 mm)
- Flexible spatula, with a blade approximately 4 in. long by 0.75 in. wide (100 mm long by 19 mm wide)
- Pair of dividers and a millimeter scale ruler
- Drying oven, maintained at 230°F ± 9°F (110°C ± 5°C)
- Small, thick-bristle paint brush, about 0.25 in. (6.0 mm) wide

Figure D.1: Bar linear shrinkage mold.

MATERIALS

- Petroleum jelly
- Distilled or deionized water

PREPARING THE MOLD

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

PREPARING THE SAMPLE

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

PROCEDURE

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

CALCULATIONS

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

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

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

REPORT

Report the linear shrinkage to the nearest whole percent.

APPENDIX E
EXAMPLE GRADATION FOR CRUSHED/RECYCLED ASPHALT

Example Gradation for Crushed/Recycled Asphalt

Table E.1: Example Gradation for Crushed/Recycled Asphalt Pavement

Layer	Percent passing						Bar Linear Shrinkage	Plasticity Index
	1.5 in	1 in.	#4	#8	#40	#200		
RAP	100	85	28	18	6	3	0	0

APPENDIX F
GUIDE FOR DETERMINING MATERIAL BLENDING RATIOS

Guide for Determining Material Blending Ratios

A step-by-step process for determining target blending ratios is provided below. Note that determination of blending ratios will be required for Scenario #3 though Scenario #5 discussed in Section 4.3.1. An example for each scenario is also provided. Given that this is an arithmetical process, the calculated target blending ratios will need to be verified with tests of the blended material to ensure that satisfactory performance will be achieved on the road. More than one iteration may be required. The information required to complete the process includes the following:

- Grading analysis results, specifically the percent passing the 1 in., #4, #8, and #40 sieves, for each material that will be incorporated, obtained from Form #5.
- Bar linear shrinkage results for each material that will be incorporated, obtained from Form #5. If the bar linear shrinkage test cannot be performed, then plasticity index divided by two can be used as an alternative.
- Existing and required layer thicknesses, obtained from Form #4.

The procedure for determining the mixing depth will be recursive during the process until an optimal blend of materials is achieved (using the web-based tool will speed up this process). Follow these steps:

1. Copy the material properties from Form #5 into a table (Table F.1 [or example Form #6 in Appendix A]) or spreadsheet. Round numbers to the nearest whole number.
   + Include the asphalt surfacing if it will be used and any supplemental materials (e.g., new aggregate base, additional clay/fines, coarse aggregate).
   + Layer-1 will be the top layer (i.e., the existing base in Scenario 3, asphalt surfacing, in Scenario 4, and supplemental material in Scenario 5). If more than one supplemental material is required, then the second supplemental material will be Layer-2 (e.g., Scenario 5 where the primary supplemental material is deficient in clay/fines and where the subgrade material will not provide the required properties, or is too deep in the structure to be included in the new layer). Note that supplemental materials can only be spread on the surface.

Table F.1: Material Properties

Layer	Description	Column 1	Column 2	Column 3	Column 4	Column 5
		P1	P#4	P#8	P#40	BLS
1						
2						
3						
4						

2. Select the target required wearing course thickness based on the current layer thicknesses and/or the thickness design. The thickness should not exceed 12 in. If a thicker layer is required, then the project should be designed as two layers, with the underlying layer designated as a base layer using

existing plus supplemental materials if required, and the second layer being a wearing course constructed with supplemental materials only.

3. Enter the layer thicknesses into a second table (Table F.2) or into the spreadsheet. Round the valued to the nearest whole number
   - Enter the target wearing course thickness
   - Enter the existing thicknesses in Column 1.
   - Calculate the sum of thickness for each layer (i.e., for Layer-2, add Layer-1 to Layer-2, etc.) and enter these in Column 2.
   - Calculate the thickness that each layer will contribute to the target thickness and enter these in Column 3.
   - Calculate the proportion that each layer will contribute as a ratio of the target wearing course thickness and enter these in Column 4. Note that the sum of all values in Column 4 should be 1.0.

Table F.2: Layer Thicknesses

Target Wearing Course Thickness					
Layer	Description	Column 1	Column 2	Column 3	Column 4
		Existing Thickness	Sum of Thickness	Thickness in Target Depth	Proportion
1					
2					
3					
4					

4. Calculate the estimated material properties of the converted pavement structure layers in a third table (Table F.3) or into the spreadsheet. Round the values to the nearest whole number.
   - Multiply the values in each cell in Columns 1 through 5 in Table F.2 by the corresponding proportions in Column 4 in Table F.3 and enter the results in Columns 1 through 5 in Table F.3.
   - Add the values in each column and enter the sum in the second to last row ("new wearing course") in the table. This will be the new wearing course in the converted pavement.

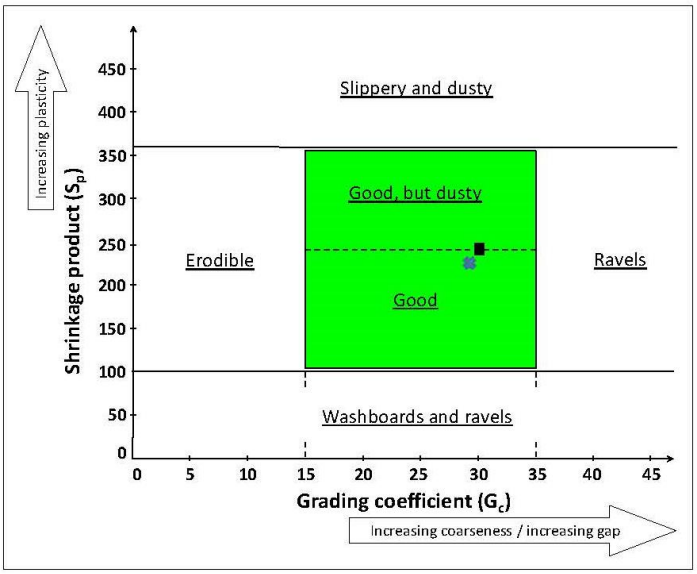
Table F.3: Estimated Material Properties of New Wearing Course

Layer	Description	Column 1	Column 2	Column 3	Column 4	Column 5
		P1	P#4	P#8	P#40	BLS
1						
2						
3						
4						
New Wearing Course						
Grading coefficient						
Shrinkage product						

5. Calculate the grading coefficient and shrinkage product for the new wearing course layer and plot the values on the performance prediction chart (Form #6). If the values plot in the "good" performing area of the chart the calculations are complete. If the values plot elsewhere in the chart, rerun the process with adjusted values (e.g., different recycling depth, more or less supplemental material(s), or different supplemental materials) until a satisfactory result has been achieved.
6. Run grading analysis and bar linear shrinkage (or Atterberg Limits) tests on this material and confirm that it meets the required performance criteria. Refine the proportions and rerun the test if it does not. Run a California Bearing Ratio test on the final proportioned material if all-weather passability is a concern. Document the final set of results on the form. Note that the results for the percent material passing the #200 sieve is included at this stage because this parameter is required for chemical treatment selection.

F.1 Example for Scenario #3

MATERIAL DESIGN FORM						Form #6
Layer	Layer Description and Material Properties	Column 1	Column 2	Column 3	Column 4	Column 5
		P1	P#4	P#8	P#40	BLS
1	Base	100	64	52	20	6
2	Subgrade	100	95	91	83	18
3						
4						
Target Wearing Course Thickness		7 in.				
Layer	Calculate Thickness Proportions	Column 1	Column 2	Column 3	Column 4	
		Existing Thickness	Sum of Thickness	Thickness in Target Depth	Proportion	
1		6	6	6	0.85	
2		Infinite	7	1	0.15	
3						
4						
Layer	Calculate Estimated Material Properties	Column 1	Column 2	Column 3	Column 4	Column 5
		P1	P#4	P#8	P#40	BLS
1		85	54	44	17	5
2		15	14	14	13	3
3						
4						
New Unpaved Wearing Course Layer		100	68	58	30	8
Grading coefficient		29				
Shrinkage product		240				



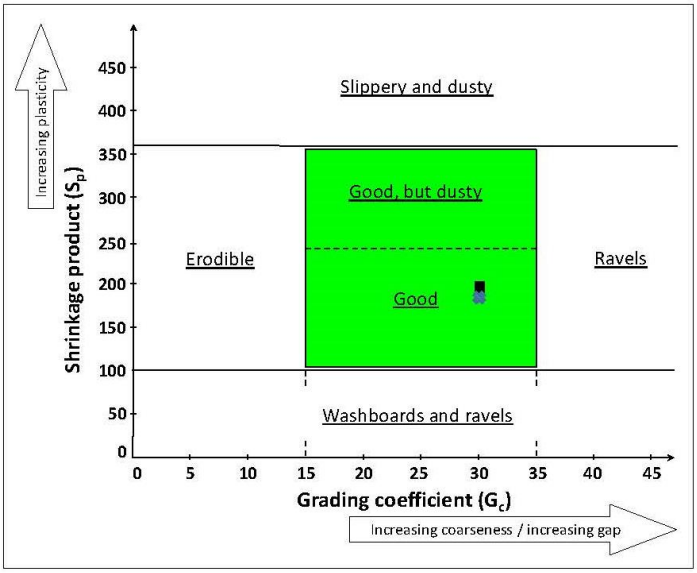
New Wearing Course Test Results	
P1	100
P#4	62
P#8	56
P#40	28
P#200	12
BLS	8
CBR	24
MDD	130
OMC	6
Grading Coefficient	28
Shrinkage Product	224
Accept	Y N

This estimated properties of the blend plots in the "good" performing area of the chart, but the shrinkage product is close to the boundary of "good, but dusty". The test results from the blend indicate a similar plot. If there are concerns about dustiness, the issue could be corrected by slightly reducing the thickness

of the layer, thereby reducing the amount of subgrade material that is incorporated. Alternatively, a chemical treatment can be considered.

F.2 Example for Scenario #4

MATERIAL DESIGN FORM						Form #6
Layer	Layer Description and Material Properties	Column 1	Column 2	Column 3	Column 4	Column 5
		P1	P#4	P#8	P#40	BLS
1	Asphalt surface	100	28	18	5	0
2	Base	100	64	52	20	6
3	Subgrade	100	95	91	83	18
4						
Target Wearing Course Thickness		7 in.				
Layer	Calculate Thickness Proportions	Column 1	Column 2	Column 3	Column 4	
		Existing Thickness	Sum of Thickness	Thickness in Target Depth	Proportion	
1		2	2	2	0.30	
2		4	6	4	0.55	
3		Infinite	7	1	0.15	
4						
Layer	Calculate Estimated Material Properties	Column 1	Column 2	Column 3	Column 4	Column 5
		P1	P#4	P#8	P#40	BLS
1		30	8	5	2	0
2		55	35	29	11	4
3		15	14	14	13	3
4						
New Unpaved Wearing Course Layer		100	57	48	26	7
Grading coefficient		30				
Shrinkage product		182				

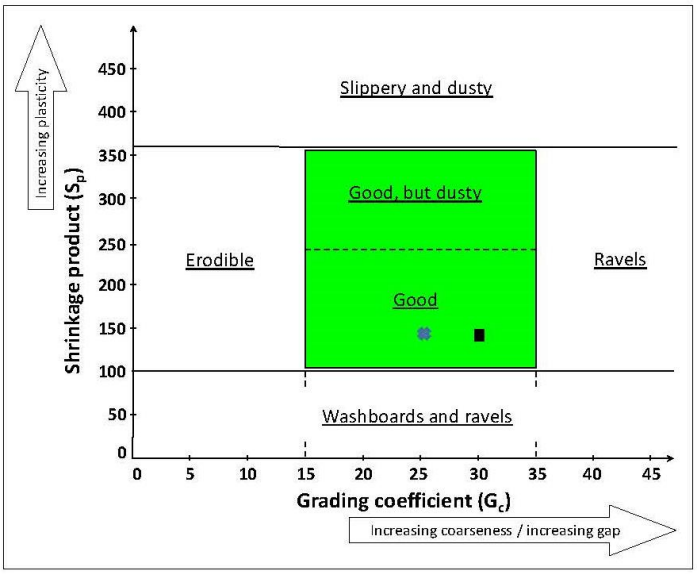


New Wearing Course Test Results	
P1	100
P#4	59
P#8	50
P#40	25
P#200	12
BLS	7
CBR	24
MDD	129
OMC	6.5
Grading Coefficient	30
Shrinkage Product	175
Accept	Y N

This estimated properties of the blend plot in the "good" performing area of the chart. The test results from the actual blend indicate a similar plot, and the blend can therefore be accepted.

F.3 Example for Scenario #5

MATERIAL DESIGN FORM						Form #6
Layer	Layer Description and Material Properties	Column 1	Column 2	Column 3	Column 4	Column 5
		P1	P#4	P#8	P#40	BLS
1	Supplemental	100	47	40	18	0
2	Asphalt surface	100	28	18	5	0
3	Base	100	64	52	20	6
4	Subgrade	100	95	91	83	18
Target Wearing Course Thickness		8 in.				
Layer	Calculate Thickness Proportions	Column 1	Column 2	Column 3	Column 4	
		Existing Thickness	Sum of Thickness	Thickness in Target Depth	Proportion	
1		3	3	3	0.38	
2		1	4	1	0.12	
3		3	7	3	0.38	
4		Infinite	8	1	0.12	
Layer	Calculate Estimated Material Properties	Column 1	Column 2	Column 3	Column 4	Column 5
		P1	P#4	P#8	P#40	BLS
1		38	18	15	7	0
2		12	4	2	1	0
3		38	24	20	8	2
4		12	11	11	10	3
New Unpaved Wearing Course Layer		100	57	48	26	5
Grading coefficient		30				
Shrinkage product		130				



New Wearing Course Test Results	
P1	100
P#4	51
P#8	44
P#40	22
P#200	13
BLS	6
CBR	39
MDD	131
OMC	7.0
Grading Coefficient	25
Shrinkage Product	132
Accept	X / N

The estimated properties of the blend plots in the "good" performing area of the chart. The test results from the actual blend indicate a similar shrinkage product, but a lower grading coefficient, but still plotting in the good performing area of the plot. The blend can be accepted.

APPENDIX G
COMMUNICATION MATERIALS

Communicating Materials

The following items are provided in this appendix:

- Example letter and template for communicating with the public, http://www.dot.state.mn.us/research/reports/2019/201942-letter.docx
- Example press releases, http://www.dot.state.mn.us/research/reports/2019/201942-pressrelease.docx
- Unpaving fact sheet, http://www.dot.state.mn.us/research/reports/2019/201942-factsheet.docx
- Example presentation template for communicating with the public, http://www.dot.state.mn.us/research/reports/2019/201942.pptx

Example letter for informing the public about candidate unpaving projects.

Letter Head

Date
Name
Address
City, State, Zip Code

Re: Landowners along [Road Name Here]

Dear Landowner:

The pavement condition of [Road Name Here, e.g., County Road XX] has [define issues with the road] deteriorated and is in need of [extent of issue(s)] repair. After exploring several options, we have identified [Road Name Here] as a candidate for unpaving, or conversion to an engineered unpaved road surface.

[Explain why the road is a candidate for unpaving]

[Example text that can be modified to fit your situation: Due to the low traffic volume, we have determined that it is more cost effective to maintain a gravel surface as opposed to bituminous on this stretch of road. An overlay or reseal would not adequately address the problems and would only be a short-term fix as more [enter type of repair] would be required on a continuous basis.]

[Explain the pros and cons of unpaving the road]

[Example text that can be modified to fit your situation: One benefit of an engineered unpaved road would be eliminating the year around 5-ton weight restriction currently in place on County Road XXX. A gravel surface would only be subject to a 5-ton road limit in the spring. The road will remain a County Road.]

Explain the timeline

[Example text that can be modified to fit your situation: Our plan is to complete this between ??/??/20?? and ??/??/20??.]

[Provide information on any public meetings and or open comment periods]

Please contact me with any questions or concerns at [phone number and or email].

Thank you.

Sincerely,

[Sign here]

Name
Title
Phone Number
Email Address

Example press release to inform the public about a public meeting that will provide initial information about road conversions.

Letter Head

Public Meeting on Proposed Roads Projects

[Date/Time/Location]

[Contact at your Agency: Name, Email, Phone]

[Agency Name] will hold a public meeting on [Date/Time] at [Location] to provide an informational update on the proposed road[s] that have been identified for conversion from a distress paved surface to an engineered unpaved surface. The following roads/road segments will be discussed:

- [Road, road segment]
- [Road, road segment]

In the public meeting, agency staff will provide an overview of each road project, including options that are being considered and the pros and cons of each, why converting the road is being considered as a viable option, current road conditions, future maintenance and surface treatment options, and costs. The public will have the opportunity to ask questions and submit comments.

[Add a paragraph that provides some background and current status information for context for members of the public who are not familiar with it. Also add links to any plans or information that are available from the agency. An example follows.]

PROJECT BACKGROUND: The [your Transportation Agency] is conducting these road rehabilitation projects as part of the 20xx infrastructure improvement plan. The roads being considered for unpaving were recommended by the [list who/agency that recommended] and approved by the [list agency that approved recommendation] in [list time frame or date]. The [City/County] is now collecting public input as part of the initial design process. [Optional: To view maps, plans, and background information for these projects, go to (weblink)].

Please contact [Name] (at the contact information provided above) with any questions or comments about this public meeting.

Example press release to inform the public about public comments submission and period.

Letter Head

Public Comment Period on Proposed Roads Projects

[Dates of Public Comment Period]

[Contact at your Agency: Name, Email, Phone]

The [Agency Name] is now accepting public comments on the plan to convert selected roads and road segments from distressed paved surfaces to engineered unpaved surfaces. Residents and local organizations are invited to submit questions or comments regarding the following roads/road segments, which have been identified as potential candidates:

- [Road, road segment]
- [Road, road segment]

[Agency name] is seeking input from the public on issues such as:

- Surface condition – what are your needs and expectations for this road?
- Maintenance – what are your expectations for maintenance of the current road surface?
- Maintenance -- What questions do you have about how an engineered unpaved surface would be maintained?

To **review project plans** and information prior to submitting comments, please go to [weblink]. If you do not have internet access, copies of the plans are available at [Name/address of Agency office].

To **submit comments online**, please go to [weblink]. Comments and questions can also be mailed or delivered to [Agency office address, attention [list staff contact]].

The deadline for submitting public comments is [date].

Please contact [Name] (at the contact information provided above) with any questions or comments.

[Add a paragraph that provides some background and current status information for context for members of the public who are not familiar with it.]

PROJECT BACKGROUND: The [your Transportation Agency] is conducting these road rehabilitation projects as part of the 20xx infrastructure improvement plan. The roads selected for unpaving were recommended by the [list who/agency that recommended] and approved by the [list agency that approved recommendation] in [list time frame or date]. The [City/County] is now collecting public input as part of the initial design process.

Example press release to inform the public about a scheduled unpaving project.

Letter Head

Notice of Road Construction/Rehabilitation on [Name of Road]

[Date to Date]

[Contact at your Agency: Name, Email, Phone]

The [road segment(s)] on [road(s)] is scheduled for construction/rehabilitation, **starting on [date]**. Construction is expected to be completed by [date] but may be subject to change depending on weather conditions or other factors. During this period, construction crews will generally be active at this location on [days of the week/times, for example "weekdays from 6:00 a.m. to 6:00 p.m."]

The construction/rehabilitation will consist of [describe broadly what will be done]. During this work, [describe what the road condition may be like during this time. For example, "travel may be periodically restricted to one lane of travel, so watch for flaggers and plan for delays" or "reduced speed limits will be in place" etc.].

Information about the project status and updates about road conditions will be available at [weblink].

[Agency Name] is managing this reconstruction project. Any questions or comments can be directed to Project Manager [Name] (at the contact information provided above).

Unpaving Fact Sheet

What is Unpaving?

Unpaving is the process of converting a severely distressed/failing paved road to a safe and well performing engineered unpaved road.

Before (Severely Distressed Paved Road)

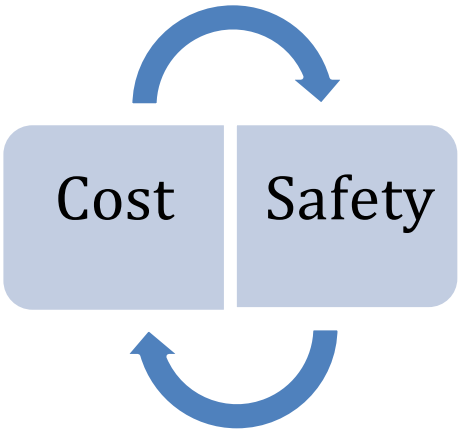
After (Unpaved Road)

Unpaving a road is one option in the pavement management Tool Box that can be considered for specific circumstances.

When is a road a candidate for Unpaving?

A road may be an unpaving candidate for one or more of these reasons:

- It is too costly to maintain as a paved surface with patching and pothole repair.
- The road has failed and sufficient funds do not exist to fix the road base and repave it.
- The severe distresses are a safety issue.
- An engineered unpaved road will provide safer driving conditions.
- Damage caused by oversized and/or overweight equipment is easier, quicker, and cheaper to repair when the road is unpaved.
- Average daily traffic is below 150 vehicles per day.
- Traffic patterns have changed on the road over time and no longer justify the cost of a paved road.



When is Unpaving the best option for a road?

- When it is a safer option
- When it is more cost-effective
- When it is a better use of resources

How can I become a part of the discussion on Unpaving decisions?

- Check the agency website for updates [provide web address here].
- Contact the local road authority via telephone or email and share your perspective.
- Ask for a schedule for public meetings and or comment periods.

Resources on Unpaving

A Guide to Successfully Convert Severely Distressed Paved Roads to Unpaved Roads
http://mndot.gov/research/reports/2019/201942.pdf

NCHRP Synthesis 485 Converting Paved Roads to Unpaved (2016)
http://www.trb.org/Publications/Blurbs/173716.aspx,

[Webinar] https://ruralsafetycenter.org/resources/list/converting-paved-roads-to-unpaved-roads/

Contact Information

Name:

Phone:

Email:

Website

http://www.web.address

What is Unpaving?

LRRB

What is Unpaving?

Unpaving is the process of converting a severely distressed or failing paved road to a safe and well performing engineered unpaved road.

Severely distressed paved road

Engineered unpaved road

Why are roads or road segments candidates for Unpaving?

Why are Roads or Road Segments Being Considered for Unpaving?

Funding Issues

- The road is too costly to maintain as a paved surface with patching and pothole repair.
- The road has failed and sufficient funds are not available to fix the road base and repave it.

Safety Issues

- The severe distresses are a safety issue.
- An engineered unpaved road will provide safer driving conditions.

Change in Road Use

- Damage caused by oversized and/or overweight equipment is easier, quicker, and cheaper to repair when the road is unpaved.
- Average daily traffic is below 150 vehicles per day.
- Traffic patterns have changed on the road over time and no longer justify the cost of a paved road.

When is Unpaving a Road an Appropriate Choice?

- ❑ When it is a safer option
- ❑ When it is more cost-effective
- ❑ When it is a better use of resources

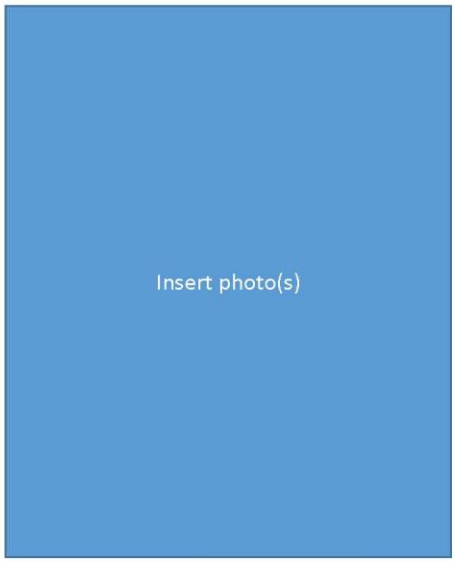
What roads or road segments are candidates for unpaving?

What Roads or Road Segments are Being Considered for Unpaving and Why?

For each road or road segment that is a candidate for unpaving:

* Insert photos, description, note all issues with the roads
* Insert analysis results for maintenance, repair, reconstruct/ repave costs, and effort.
* Explain why this specific road or road segment is a candidate for unpaving.

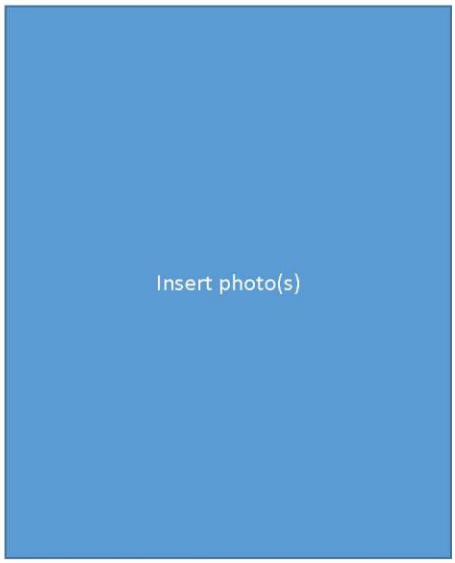
Road/Road Segment Candidate #1



Description of issues

Analysis output

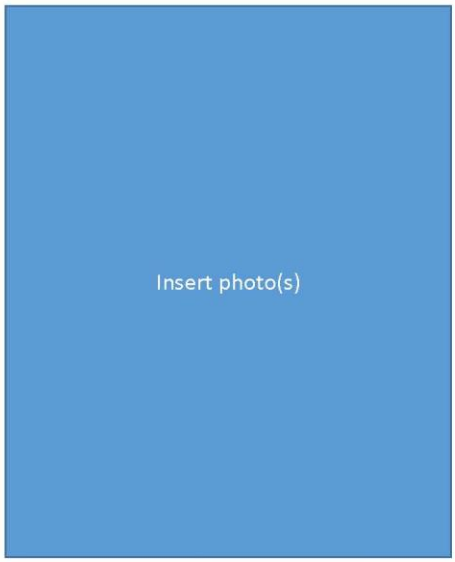
Road/Road Segment Candidate #2



Description of issues

Analysis output

Road/Road Segment Candidate #3



Description of issues

Analysis output

Who can I contact for more information or to provide feedback?

Local Road Contact Information

To provide input or ask questions about the unpaving process or candidate roads please call or email:

[Name]
[Title]
[Phone]
[Email]

Upcoming Events

Provide any information here on upcoming events:

- Comment period on proposed projects
- Townhall meeting
- Timing of unpaving projects
- Other?

Link to website with posted information:
[web address here]


Questions?
Contact person and title
xxx.xxx@state.mn.us
(651) xxx-xxxx
LRRB