NOTES FROM NINTH INTERNATIONAL CONFERENCE
ON
LOW-VOLUME ROADS

Current Issues Facing Low-Volume Roads Managers

Prepared by
Standing Committee on Low-Volume Roads, Transportation Research Board

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FOREWORD

Conferences in the Transportation Research Board International Conference on Low-Volume Roads series have been held every four years since 1975. The ninth conference held in Austin, Texas, June 24-27, 2007 brought together transportation specialists from six continents and more than 30 different countries to share their experiences and innovations. Low-volume roads transcend language, culture, topography, climate, and politics. Due to their basic necessity, they tend to drive innovation in design, material use, maintenance, and social development. Two sessions at the conference were devoted to discussing "Hot Topics" with subject-matter experts, working in focus groups to expand the discussions and gather information useful to practitioners and researchers. Based on those discussions, Ann Johnson, a member of the TRB Standing Committee on Low-Volume Roads compiled a set of notes on the current issues facing rural road managers. This document presents that set of notes taken and was reviewed by members of the Low-Volume Roads Committee: Dr. Ronald W. Eck, West Virginia University; Mr. Mark J. Nahra, County Engineer, Delaware County, Iowa; and Mr. Michael T. Long, Oregon Department of Transportation.

ACKNOWLEDGMENTS

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INTRODUCTION – Current Issues Facing Low-Volume Roads Managers

This set of notes summarizes 12 current issues facing low-volume roads managers, in two categories – New Materials and Preservation/Management and Planning, Design, and Safety.

Under **New Materials and Preservation/Management**, the following topics are discussed:

1. Dirt/gravel road base stabilization - new techniques and methods
2. Full depth reclamation
3. Local Technical Assistance Program (LTAP) centers and the International Community
4. Use of geosynthetics
5. Use of recycled aggregates from construction waste
6. To Pave or Not to Pave – Information provided to support decision making of when to upgrade gravel road

The following topics are discussed under **Planning, Design, and Safety**, and are listed as follows:

1. Low cost safety improvements
2. Traffic engineering on low-volume roads
3. Geometric design of very low-volume roads
4. Indian Reservation Road (IRR) LVR planning and administration
5. Farm to market road issues
6. Best practices and resources in pavement design methods for LVR

Set of notes taken at each topic is individually authored; the authors' names as well as discussion leaders' names are noted at the beginning of each description. The set of notes represent information presented at "Hot Topic" sessions held at the TRB 9th International Conference on Low-Volume Roads in Austin, Texas, June 24-27, 2007.

New Materials and Preservation/Management

Topic 1: Dirt/gravel road base stabilization - new techniques and methods

Discussion Leaders: David Jones, University of California at Davis, and Alex Visser, University of Pretoria, South Africa

Summary authored by: John Lowery, University of Texas at Austin

Non-traditional soil additives are not widely used despite the availability of guides and published information. This may be due to the lack of protocols and guidelines on conducting and assessing research. Development of such documents may make wide scale implementation of a product possible.

Reasons frequently given for not using a non-traditional soil additive are:

- There is a lack of consistent guideline documentation for products that engineers can use to make informed decisions
- Poor quality design and research on experiments that lead to insufficient published or documented information
- Most reports have conclusions based on a limited number of observations, which are only applicable to the road on which the experiments were conducted
- Experimental results are not often accompanied with thorough scientific interpretation. As a result, failures may often be attributed to the product when the failure might have been the result of inappropriate or incorrect application techniques

Generally, justification for the use of non-traditional additives on a wide scale is based on small in-house experiments. Typically the success of 200-meter test sections is cited to justify the use of a product. However, it is also noted that during the construction of the 200 meter test sections one is not aware that future applications of the product may be necessary.

Generally, users desire to have the following information from the additive suppliers to justify wide scale use without constructing new experiments: Documentation of the product results from previous projects. However, previous documentation of a product's success may not always serve as a sufficient evidence to justify the wide-scale use of that product. To move away from a repetitive cycle of small scale experiments, future research on non-traditional soil additives may need to consider collecting technical information for various soil types on application procedures. It is recognized, however, that laboratory tests are unable to incorporate particular soil characteristics and traffic patterns, and therefore it may be unrealistic to expect products to provide suggested application procedures under various circumstances. Also, most practitioners do not want to try products that are unfamiliar to them because generally there is a shortage of funds. Effectiveness of products information may accelerate wider use of additives if fit-for-purpose certification system is used. Wider use of additives may be assisted if test procedures are provided by the product suppliers before any particular product can be considered. Many products are temperature sensitive, and a fit-for-purpose certification system may help provide consistent product information. A fit-for-purpose certification system may also alleviate some of the safety and environmental concerns related to the use of some of the non-traditional products. A certification system is, however, too costly and time-consuming. A system that classifies products in to the following three types is ideal: dust control, compaction, and stabilizers.

Generally, the AASHTO guidelines do not meet the needs of unsurfaced roads. Hence, often there is a need for a driving force to establish guidelines for unsurfaced roads. If the supplier assists the construction team on proper application, it may lead to the success of a project. There is a lack of funding for adequate data collection. Hence, consideration to encourage graduate students to perform data collection and analysis is attractive. Public perception of the environmental impacts of a particular product often dictates the use of that product. A university, federal agency, or NCHRP may consider conducting a comprehensive literature search, laboratory and field testing on use of non-traditional additives for soil stabilization. Such a study has potential for developing protocols on how to evaluate the products inexpensively and usually with limited field trials. However, it is noted that new products are constantly introduced to the market. Many products may be similar but since information about a product is proprietary it makes it difficult to classify the product or compare the product with other products already on the market.

Topic 2: Full depth reclamation

Discussion leader: Dave Cannon, Asphalt Recycling and Reclaiming Association
Summary authored by: Eleni Harris Pappas, Vanderbilt University

Full Depth Reclamation (FDR) is an effective recycling method for low-volume roads. Aged, worn-out roads can be rebuilt using the existing materials from the roadway. For FDR, generally fewer materials are needed and hence fewer trucks are needed to transport the materials. FDR is also considered environmentally friendly because it decreases the amount of materials entering a landfill.

Rehabilitation Techniques
Many roadway rehabilitation techniques exist. The document, *Engineering Values of Reclaimed Base,* describes three techniques:

1. A 3” (75mm) hot mix overlay
2. Road Reconstruction, including full depth asphalt removal, re-shape and compaction of the base
3. Full depth reclamation to 8” (200mm) and stabilization with 2.0 gallons (7.57 liters) of emulsion per square yard (square meter) with a 3” (75mm) overlay.

Strength of a pavement is calculated using the concept of Structural Number (SN). A structural coefficient is given to each material. These coefficients are combined to create the Structural Number for the pavement. The document Engineering Values of Reclaimed Base has a break down of how each of the Structural Numbers is calculated. A higher SN typically indicates a stronger pavement. Generally, improvement to the base of a roadway results in a stronger pavement. A pavement engineer typically looks at initial cost as well as life cycle cost when comparing different rehabilitation techniques.

Mix Design

For full depth reclamation, the first step is the most important in the process. Before the reclamation begins, it is necessary to prepare and understand the materials in the existing pavement. Core samples are taken from different locations along the roadway and these samples are tested in a laboratory environment. Laboratory tests try to mimic the different environmental conditions the road will experience. Based on the laboratory test results effective mix designs are developed.

There are many different materials on the market. Therefore, it is important to understand the abilities of each material. For example, Pennsylvania requires all materials that are used in road design to undergo an evaluation process so that the materials used work effectively in a pavement.

Topic 3: Local Technical Assistance Programs and the International Community

Discussion leader: Bruce W. Drewes, Training and Research Manager, Idaho LTAP
Summary authored by: Migdalia Carrion, University of Puerto Rico at Mayaguez

Technological innovation in communication, systems management, and transportation continues to drive a more dynamic global economy. Around the world, countries are applying innovative technologies. One of the means used to exchange technological information is the development of Technology Transfer Centers in different countries. There is information available on how to establish such centers. Also, it is important to look at the current information for the development of these contacts and ways that both the United States transportation community and other countries can use to have more efficient and effective technology transfer.

1. Resources

   National Highway Institute (NHI) provides at no cost, single copies of NHI course materials to national and international transportation organizations and educational institutions as identified by those international partners. NHI can also provide up to two seats for foreign country participants in NHI courses subject to space availability and at no charge to the participant for course fees but would not be responsible for any participant costs related to travel, lodging, meals, translation or incidental expenses. It is also possible to arrange NHI training for transportation agencies in other countries for cost of travel per diem for FHWA instructors and materials, and/or for negotiated fees for contractor instructors.

   For additional information on this resource contact National Highway Institute of FHWA.

2. Overview of Traffic Safety Review course

This course is supported by the LTAP/TTAP Centers. This training course on Road System Traffic Safety Review describes a method of systematically reviewing roads throughout a local jurisdiction to make annual road safety improvements, primarily related to consistent application of signs and markings. This method is particularly attractive to rural local governments, and complements other recommended practices and courses, including Road Safety Audits (RSA), low cost safety improvements (LCSI), Strategic Highway Safety Plans, and the use of sound engineering judgment.

3. Overview of Roadway Safety Fundamentals Course

Statistics show that 30 percent of the nation's fatal crashes occur on local rural highways. This reality challenges smaller road agencies to reconcile cost-effective road improvements with the need to increase safety. Roadway Safety Fundamentals is designed to help local and Tribal road agency personnel understand the critical relationships between roads, roadside, road user behavior, and safety. Because many of these agencies have no licensed professional engineers on staff, this publication and training reviews the proper use of common traffic control devices such as signs and markings. It also describes the core concepts local and tribal road agency professionals can use to evaluate and improve their safety operations. Information in Roadway Safety Fundamentals helps road agency professionals to use a systematic approach to improve safety and roadways in a manner that makes best use of available resources and manpower. Local LTAP centers can be contacted for more information.

Topic 4: Use of geosynthetics

Discussion leader: John M. Allen, M. S., Director of Geosynthetic Laboratory at TRI/Environmental
Summary authored by: Melissa R. Thompson, Michigan State University

The four main applications for geosynthetics in roads are:

- subgrade separation and stabilization
- base reinforcement
- overlay stress absorption, and
- overlay reinforcement.

New geosynthetic products are constantly being introduced to the market. Hence, it is a good practice to check with manufacturers regarding new products that are available for a specific application. Examples of such products are geocomposites that act as drains and separators.

A number of studies investigating pavement base reinforcement are currently under way. Chehab, Palomin, and Tang at Pennsylvania State University investigated the correlation between rutting depth of a pavement cross section with the frictional characteristics of the geogrid reinforcements used. Steve Perkins, University of Montana is using large-scale mechanistic design testing which results in measurements of the system modulus and coefficient of interaction for the pavement system. Also, an index test known as bending stiffness is being developed at TRI geosynthetics laboratories in Austin, Texas, as a bench scale test for evaluating geogrid interaction with site specific base materials.

The following information may be of interest to geosynthetic users:

- Generally, standards for conducting on-site field experiments with geosynthetics are not available, which makes it difficult to compare results of one experiment with another.
- Pennsylvania State University study measured rut depths to compare different materials.
- Geocells have been used on All Terrain Vehicle trails to prevent generation of excess mud.
- Use of alternative fill material, such as wood chips and shredded recycled tires, has been investigated using test plots. Typically, wood chips do not resist tensile forces, and are thus considered less stable.
- An innovative idea is to use a "sandwich" method with granular material between two layers of geotextile to reduce overall base layer thickness in a pavement system. This approach may not be a good alternative for most roads, but it may have potential for application in a low-volume unpaved forest road.

Topic 5: Use of recycled aggregates from construction waste

Discussion leaders: Eddie Johnson, Mn/DOT and Woody Raine, Texas DOT
Authored by: Renee Alsup, University of Texas at Austin

Summary of use of recycled materials, the use of shingles in roadway construction, and the use of other common recycled materials such as glass and slag is as follows:

Texas DOT experience with projects on use of recycled aggregates shows increased durability of the roads from using rubber in the aggregate. Also, there was money savings due to the use of local recycled materials.

Experiences of other states include use of recycled aggregate in shoulders and road surfacing. Such applications showed effective dust control on low volume road surfaces. However, the idea of using roads as a "linear landfill" is not universally attractive because of the concern that undesirable materials may end up in the recycled aggregate that may compromise the quality of the roads. However, it is also recognized that it will continue to become more difficult to find and transport natural aggregate hence the recycled aggregate is becoming an increasingly important material.

Shingles are recycled as binder material in asphalt pavements. In Minnesota, shingles are a common material added to asphalt binder. The total amount of binder added to the asphalt is changed because of the asphalt content of the shingles; information is available on how much the mixture has to be changed. A key concern expressed is nails in the shingles that could end up being mixed into the binder. Texas, for instance, has approved the use of new shingles as binder but has not approved the use of tear-off shingles because of the risk of deleterious materials ending up in the binder.

Topic 6: "To Pave or Not to Pave" — Information provided to support decision making of when to upgrade gravel road

Discussion leader: Ann M. Johnson, P.E., Professional Engineering Services
Summary authored by: Danielle E. Steinke, Rose-Hulman Institute of Technology

"To Pave or Not to Pave: Making Informed Decisions on When to Upgrade a Gravel Road" is a Power Point presentation that was created to help users inform the public at local board or public information meetings. This slideshow can be customized for individual agencies to help explain the decisions that have been made for the improvement of their low-volume roads. There are two versions of the Power Point presentation available, one with audio and one without.

The purpose of the presentation and materials developed as well as some other details are available online at: http://www.mnltap.umn.edu/pdf/2006PavingGuide.pdf

The Power Point presentation incorporates results from two research project reports. The first is the "Cost Comparison of Treatments Used to Maintain and Upgrade Aggregate Roads". It was completed in 2005 and funded by Minnesota Local Road Research Board. This report shows threshold values for when to upgrade a gravel road to a paved road. The threshold values are calculated by comparing costs of surface construction and maintenance. Based on the project report the presentation provides the following:

- Maintenance costs/mile for different roadway surfaces
- Effects on maintenance costs/mile
- How to compare gravel roadways and paved roadways
- Cumulative maintenance costs/mile over time for a gravel roadway
- Present worth analysis

All of the above can be adjusted to reflect individual agencies costs and roadways.

The second report was the "Local Road Surfacing Criteria" which was completed in 2004 and funded by South Dakota Department of Transportation. This report describes a tool that allows users to determine the most economical surface type for their roadways. Users enter information about the road section, actual maintenance and construction costs for each surface type, user costs, and other non-economic factors. The computerized tool then calculates the total cost for building and maintaining each roadway type. This helps the user choose one surfacing alternative over another based on the input information.

Planning, Design and Safety

Topic 1: Low-Cost Safety Improvements

Discussion leader: Sue Miller, Engineer, Freeborn County, MN/NACE Secretary
Summary authored by: Andrew Karl, Manhattan College, New York City, New York

Generally, motorists have difficulties in traveling on low-volume roads and the problems underlying those difficulties need to be resolved. Effective use of signs, skid resistance, pavement edge striping practices, and geometric design considerations are some of the potential solutions. A slideshow that contains numerous examples of improvements around the country is available as well as a list of websites to serve as references to low-cost safety improvements.

Common problems with low volume roads (LVRs) include:

- Typically there is not much law enforcement
- Generally, the signage is not standardized
- Typically roads designed for slow trucks are used by speeding cars and at a higher volume than anticipated
- The facility owner may be prone to liability and lawsuits
- Often some signs are no longer effective as drivers become accustomed to them and are comfortable with the road
- Generally, few local road agencies budget road safety improvements as a specific item
- To have long stretches of road is politically beneficial but it may compromise the road safety aspects
- Owners of some scenic areas do not like to put up signs because they adversely affect aesthetics and distract drivers from the scenery
- Generally, public is not equipped to deal with roads meant for logging trucks
- If environmentalists get involved, generally process of upgrading/fixing tends to slow down

Some of the possible solutions to the problems listed above are:

- Changes in signing based on analysis of crash reports are effective
- Use of cameras can assist in law enforcement
- Use of blinking LEDs, reflective striping, and markers surrounding the sign draws attention to signs
- Fog sealing a road shoulder makes a rumble strip or stripe stand out better
- Reflector posts on sides of roads guide drivers on roads without striping or other markings
- On gravel roads, turnouts help trucks get out of the way of cars
- Doing something proactive and preventive rather than “chasing fatalities”, is better

- Trained road maintenance teams or other public services (mailmen) helps to keep a watchful eye for problems on local roads

Topic 2: Traffic engineering for low-volume roads

Discussion leader: Don Bonifay, Retired County Engineer – Ector County, Texas, Adjunct Instructor, Texas Engineering Extension Service (TEEX), Texas A&M Univ. System, and Executive Secretary of the Texas Association of County Engineers and Road Administrators
Summary authored by: Eleni Harris Pappas, Vanderbilt University

Sometimes a low-volume road means a low-budget road, and a low-budget road may not be signed properly. For traffic engineering on low volume roads, proper use of the *Manual on Uniform Traffic Control Devices* (MUTCD), understanding sign problems, and roundabouts are important for local road agencies.

Manual on Uniform Traffic Control Devices
Almost all states in the United Sates of America use the U.S. *Manual on Uniform Traffic Control Devices*, but Texas has its own manual. Most of the regulations in the Texas manual are very similar, but some do differ. The *MUTCD* is very important, especially in rural agencies, where there is not an engineer on staff. For example, out of the 254 Texas counties approximately 45-50 have county engineers. For these counties that do not have a county engineer the *MUTCD* is a great resource.

In 2006, Texas' *MUTCD* added a chapter (chapter 5) specifically for low-volume roads. Despite the fact that the requirements for low volume roads are very similar to requirements for other classes of roads, the addition of chapter 5 is considered a step in the right direction. Low-volume roads differ from more heavily traveled roads but the regulations are the same. Most accidents on low- volume roads occur on curves, which illustrates the importance of signs and delineation in curves and visibility of the road alignment to drivers both day and night.

Signing Problems
The challenges of informing local road agencies about the MUTCD and significance of complying with it are important. Not complying with the MUTCD may increase the liability exposure.

A key safety concern with respect to signing is retroreflectivity. In December 2007, the minimum sign retroreflectivity standards were issued by the federal government. Therefore, there is a need for local agencies to consider developing management and assessment programs for their signs.

Roundabouts
Roundabouts are very popular overseas, but only relatively recently they have become popular in the United States. Americans' attitudes about roundabouts can be attributed to problems encountered with traffic circles. Traffic circles differ from roundabouts with respect to yielding, size, shape and access management. Roundabouts can be a safe and efficient way to move vehicles through an intersection.

Topic 3: Geometric Design for Very Low-Volume Roads

Discussion leader: Joe W. Ruffer, P.E., County Engineer/Public Works Director for Mobile County, Alabama
Summary authored by: Melissa R. Thompson, Michigan State University

Many design guidebooks address geometric design. Of these, “the big green book,” or AASHTO’s “A Policy on Geometric Design of Highways and Streets” is widely used. A similar book, “Guidelines for Geometric Design of Very Low-Volume Local Roads” referred to as “the little green book” is widely used for low-volume roads. There are other reference books used in geometric design.

Regarding design of low-volume roads, use of examples with step-by-step instructions along with reference to the appropriate guidebooks is an effective teaching approach. Following general information regarding design of low-volume roads is important:

- AASHTO “Guidelines for Geometric Design of Very Low-Volume Roads (ADT $\leq$ 400)” or “little green book” does not include guidelines for design of steepness of longitudinal alignment. In such cases, the “big green book” is used.
- The maximum friction factor in the “green book” is not based on the point where tires lose traction with pavement. It is based on driver comfort. For example, most drivers will accept feeling less comfortable in a turn at a lower speed than at a higher speed.
- The green book is a book of guidelines, not standards. However, in court it is considered to be on the same level as standards.
- To enhance safety, often clear zones are widened by mowing side of road to increase deer visibility and decrease deer hits. However, it is known that deer are attracted to the mowed areas, which may cause the number of hits to remain the same or increase.
- A one lane paved road that functions as a two-way road has no more than a one lane width of pavement, with at least half a lane of gravel on either side of the paved lane. If the paved section is between the width of one and two lanes, it may discourage drivers from pulling to the side of the road in the event of oncoming traffic.

Topic 4: Indian Reservation Road (IRR) LVR Planning and Administration

Discussion leaders: David Johnson, Bureau of Indian Affairs, Rocky Mountain Region, and Ronald Hall, Tribal Technical Assistance Program, Colorado State University
Summary authored by: Migdalia Carrion, University of Puerto Rico at Mayaguez

From a management perspective, the Indian Reservation Road (IRR) Program has a complex challenge to meet. Federal laws require the agency to make tribal self-determination in operation of programs, including the IRR Program, a primary objective. However, the agency has a history of providing road construction and maintenance activities directly for tribes. The transition from direct service to tribal self-determination is difficult for all involved. Through it all, there is a significant investment in transportation infrastructure on tribal lands that merits professional management strategies to address safety and asset management needs.

Very limited literature exists on this subject, but a recent NCHRP Synthesis identified innovations and model practices among tribal transportation programs. It summarizes the history and legal and administrative evolution of tribal transportation programs within the larger context of issues of tribal sovereignty and relationships with federal, state, and local governments, and local and regional planning agencies. The report serves as a milestone signifying the inclusion of tribal governments as an essential component of the transportation community and assesses future tribal capacity and resource needs. This report can be downloaded at: http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_syn_366.pdf

Information of interest with respect to IRR includes:

1. Functional Classification of IRR
2. Setting design and maintenance standards
    - AASHTO standards, or state and county standards that meet or exceed AASHTO can be used
3. Streamlining construction and maintenance administration
    - Changes in funding distribution
        - Tribal Shares vs. Regional Office Control
        - Road inventory impacts on funding formula
        - Tribal-FHWA funding agreements
        - 25 percent shift of construction dollars to maintenance
4. Environmental concerns and options for mitigation and streamlining
5. Identifying and assessing material sources

Topic 5: Farm to market road issues

Discussion leader: Mark Nahra, Engineer, Delaware County, Iowa
Summary authored by Renee Alsup, University of Texas at Austin

Main issues currently facing the farm-to-market roads, the economics involved, and future issues are described in the following paragraphs.

A short video shown at the Ninth International Conference on Low-Volume Roads included interviews with various experts about farm-to-market road issues. The video was on how loads impact roads. It focused on how roads deform as a truck drives on them. There was also a section on how different trucks impact the roads differently. This relates to restrictions put on the loads that can be transported on low-volume roads. Often, the restrictions are either not strict enough or generally disregarded. In some cases, exceptions are made during certain times of the year for agricultural vehicles, and these may cause problems for the roads.

Where the responsibility to change the roads and/or loads carried on them lies is an important aspect of farm-to-market roads. A combination of education of those driving on the roads and some re-engineering of the roads, and having trucking industry involvement may be a solution. Dialogue with the industries using the roads and their support in lobbying for more money may allow for the re-engineering and reconstruction of the roads to handle the loads that are being transported on them.

Finally, a major concern is how to raise enough money to re-engineer and repair the roads. One of the options is to increase the licensing fee on trucks. This is viewed as an easier option than convincing the industries using the roads to contribute funds for the repairs. Although it is generally unpopular, raising the gasoline tax is another option. However, it may be one of the easier ways to increase the funds for roadwork. In Iowa, a six-person committee published a report on needed changes and how to generate funds for these changes. These options were, however, not adopted by the Iowa Sate legislature. The report is, titled, TIME 21 (Transportation Investment Makes the Economy move in the 21st century) and is available on the Iowa DOT website.

Topic 6: Best Practices and Resources in Pavement Design Methods for LVR

Discussion leaders: Gordon Keller and Peter Bolander, US Forest Service
Summary authored by: John Lowery, University of Texas at Austin

There are a variety of manuals and guidelines on surfacing and pavement design methods. The following list of literature resources is helpful in design of pavements.

Road Surfacing Standards Selection (Aggregate, Bituminous Surface Treatment, Pavement, Other)

- World Bank "Road Economic Decision Model (RED)"
- NCHRP Report 63 "Economics of Design Standards for Low-Volume Rural Roads"
- FHWA "Context Sensitive Roadway Surfacing Selection Guide"
  - Includes the plusses and minuses of surfacing materials
  - Very comprehensive
- South African Development Community "Guideline for Low-Volume Sealed Roads"
  - Provides developing country perspective

Materials Source Development, Production and Quality Control

- AASHTO "Standard Specifications for Transportation Materials and Methods of Sampling and Testing"
- FHWA "Standards Specifications for Construction of Roads and Bridges on Federal Highway Projects (FP03)
- TRL Road Engineering for Development (CD-ROM)
  - Deals with safety and social issues

Aggregate Surfacing Design

- FHWA/South Dakota LTAP "Gravel Roads – Maintenance and Design Manual"
- USDA Forest Service "Earth and Aggregate Surfacing Design Guide for Low-Volume Roads"
  - Addresses surface course aggregate vs. base course aggregate
  - Includes gradation specifications
  - Accounts for seasonal variability
  - Addresses Unified Rock Classification, Unified Soil Classification and correlations from Dynamic Cone Penetrometer to help evaluate materials
- Australia Roads Research Board (ARRB) "Unsealed Roads Manual" (2000)

Bituminous Surface Treatments (Chip Seal, etc.) Design

- Asphalt Emulsion Manufacturers Association, "Seal Coat and Surface Treatment Construction and Design Using Asphalt Emulsions" by Dr. Norman McLeod
  - This publication is difficult to find and the University of Waterloo, Ontario, Canada may have copies of this publication
- NCHRP Synthesis 342 "Chip Seal Best Practices"

- Minnesota DOT “Minnesota Seal Coat Handbook 2006”
- Asphalt Institute “A Basic Asphalt Emulsion Manual” (MS 19)

Low-Volume Roads Pavement Design Methods

- ASCE/FHWA “A Guide for the Design and Maintenance of Paved Low-Volume Roads”
- AASHTO “Guide for the Design of Pavement Structures” (1993 Version)
- Minnesota DOT “Best Practices for the Design and Construction of Low Volume Roads”
- Asphalt Institute “A Simplified Method for Design of Asphalt Overlays for Light and Medium Traffic Pavements” (IS 139)

Pavement Management Tools and Distress Evaluation

- FHWA “Pavement Management Systems (PMS)”
- Asphalt Institute “A Pavement Rating System for Low-Volume Asphalt Roads (IS 169)”
- MTC “Pavement Condition Index Distress Identification Manual”

Other general information of interest is:

- The USDA Forest Service “Earth and Aggregate Surfacing Design Guide for Low-Volume Roads” covers the Unified Rock Classification System, which provides a way to look at local materials and determine whether they may be viable to use for surfacing or base.
- In the U.S., often, cement stabilized soils have not performed well. Use of too much cement might have been the cause of the cracking observed. Texas standard requires cement stabilized soils to have strength less than 350 psi.
- Typically not much concrete is used in LVR design or construction. However, there are exceptions such as Iowa where all county roads are concrete.
- There is limited use of pervious concrete and asphalt on low-volume roads.
- Most design guides have seasonality issues but do not consider the change in modulus of material with season.
- Use of a Dynamic Cone Penetrometer (DCP) may be a quick, easy, and low cost test for characterizing soils.
- Often many final decisions on design and materials are made by the field crew at the low-volume roads level.
- Surfacing of low volume roads may be dictated by actual needs of performance, availability of materials, and/or environmental concerns (such as erosion).