



U.S. Department
of Transportation
**Federal Highway
Administration**

Gravel Roads

Maintenance and Design Manual

South Dakota Local Transportation
Assistance Program (SD LTAP)

November 2000



Notice

This document is disseminated under the sponsorship of the Department of Transportation in the interest of information exchange. The United States government assumes no liability for its contents or use thereof.

Gravel Roads Maintenance and Design Manual

Ken Skorseth

Ali A. Selim, Ph.D., P.E.

Acknowledgements

The need for a comprehensive manual that addresses most issues that deal with gravel road maintenance has been recognized by several entities across the states and the world.

The Federal Highway Administration (FHWA) asked the South Dakota Local Transportation Assistance Program (SD LTAP) to put together a new Gravel Road Manual that can be used by all regions of the United States and even other countries. The SD LTAP formed a technical review committee to help guide the project. They critiqued several versions of this manual at various stages of development.

Our sincere appreciation is extended to the following committee members:

Dan Cady, Nebraska LTAP
Pete Coughlin, Maine LTAP
Alan Gesford, Pennsylvania LTAP
Mark Hoines, South Dakota Division, Federal Highway Administration
John Hopkins, Idaho LTAP
Arlie Long, South Dakota LTAP
Jody Paden, Oklahoma LTAP

The support and encouragement of Mr. Raymond McCormick of the Federal Highway Administration is greatly appreciated. The assistance of Marv Espeland, FHWA (retired), and Gene Calvert, formerly with Wyoming LTAP, is also appreciated.

The graphic illustrations were made possible through the assistance of SDSU graduate student Muhammed S. Ali. The Office of University Relations at South Dakota State University put the Manual into its final form.

Ali Selim, Ph.D., P.E., Director, SD LTAP
Ken Skorseth, Field Operation Manager, SD LTAP

Table of Contents

Acknowledgement	i	Areas of Concern	20
Table of Contents	ii	Dealing with Corrugation	20
Definition of Terms	iv	Intersections	22
List of Acronyms	v	Intersection with Paved Roads	23
List of Figures	vi	Bridge Approaches	24
List of Tables	vii	Superelevation in Curves	25
Forward	viii	Rail Crossings	27
Introduction	ix	Driveways	27
		Cattle Guards	29
		Soft and Weak Subgrade	30
Section I: Routine Maintenance		Section II: Drainage	33
and Rehabilitation	1	Ditches	35
Understanding Road Cross Section	1	Culverts and Bridges	36
Routine Shaping Principles	4	Underdrains	37
Operating Speed	4	Section III: Surface Gravel	39
Moldboard Angle	4	What is Good Gravel?	39
Moldboard Pitch	6	Difference in Surface Gravel and Other Uses	39
Motorgrader Stability	7	Good Gradation	40
Articulation	7	Benefit of Crushing	40
Windrows	8	Recycled Asphalt	40
Crown	9	The Benefit of Testing Aggregates	41
Road Shoulder	12	Reasons for Testing	41
High Shoulders (Secondary Ditches)	13	Sampling	41
Causes of High Shoulders	14	Sieve Analysis	42
Recovering and Spreading on Roadway	14	Fines and Plasticity Index	42
Breaking up Sod and		Reduced Blading and Maintenance Costs	43
Vegetation in Recovered Material	15	Process for Obtaining Good Gravel	43
Pulling and Covering	16	Establish Specifications	43
Benefit of Mowing	17	Communicate with Suppliers	44
Gravel Road Rehabilitation	18	Handling Gravel	44
Reshaping Surface and Shoulder	18	Pit/Quarry Operations	44
Reshaping Entire Cross Section	18	Loading from Stockpiles	47
Erosion Control	19	Roadway Preparation	47
		Calculating Quantity	48
		Hauling and Dumping	48
		Windrowing, Equalizing and Spreading	49

Section IV: Dust Control/Stabilization	51	Summary.....	62
Types of Stabilizers	51	References.....	63
Chlorides	51	Appendix A: Gravel Road Thickness	
Resins	51	Design Methods	A1
Natural Clays	51	Appendix B: Gradation and P.I. Determination ..	B1
Asphalts	52	Appendix C: Quantity Calculations	C1
Soybean Oil	52	Appendix D: When To Pave a Gravel Road	D1
Other Commercial Binders	52	Appendix E: Walk-around Grader Inspection ...	E1
Benefits of Stabilization.....	52	Index	
Reduced Dusting	52		
Reduced “Whip Off” of Aggregate.....	52		
Reduced Blade Maintenance	52		
Application Tips.....	53		
Need for Good Surface Gravel	53		
Road Preparation.....	53		
Applying the Product.....	54		
Optimum Moisture	55		
Test Sections	55		
Section V: Innovations	57		
Changes in Gravel Maintenance	57		
Changing Conditions—Equipment, Trucks, Cars	57		
New Innovations	58		
Innovative Equipment and Methods.....	58		
Windrow Pulverizers	58		
New Cutting Edges	59		
Shouldering Disks	60		
Grader-Mounted Dozer Blade.....	60		
Grader-Mounted Roller.....	61		
Rakes	61		
Other Tractor-Mounted Blading Devices	61		

Definition of Terms

Articulation: As used in this manual, it refers to a machine with a jointed main frame. This assists in steering the machine, allowing it to work in an angled configuration, yet move forward in a straight line.

Ballast: Extra weight added to a machine such as iron weights mounted to the wheels or frame. Liquid material such as a water/calcium chloride solution placed in the tires can also serve as ballast.

Density: The weight of material in pounds or kilograms per unit of volume (cubic feet or meters).

Grader: Any device either self-propelled or mounted on another machine used for final shaping and maintenance of earth or aggregate surfaces. Occasionally, a simple, towed drag-type device is referred to as a grader.

Gravel: A mix of stone, sand and fine-sized particles used as sub-base, base or surfacing on a road. In some regions, it may be defined as aggregate.

Moisture Content: (in percent) That portion of the total weight of material that exists as water.

Moldboard: The part of the grader that is actually used to cut, mix, windrow and spread material.

Motor Grader: Any self-propelled machine designed primarily for the final mixing and shaping of dirt or surfacing material. Sometimes referred to as a maintainer, patrol, or simply a "blade."

Optimum Moisture: The percentage of water (by weight) in material that allows it to be compacted to achieve greatest density.

Paved Road: Any road that has a semi-permanent surface placed on it such as asphalt or concrete. Gravel surfaced roads are virtually always referred to as unpaved roads.

Pit: An area where a natural deposit of stone, sand and/or fine material is removed from the earth.

Quarry: An area where solid stone is removed from the earth generally by ripping, drilling and/or blasting. The stone is then crushed and processed into useable sizes.

Segregation: A problem that arises when the coarse and fine material separates and no longer forms a uniform blend of material.

Windrow: A ridge or long, narrow pile of material placed by grader while performing construction or maintenance operations.

List of Acronyms

AASHTO	American Association of State Highway and Transportation Officials
ADT	Average Daily Traffic
ASTM	American Society of Testing and Materials
Δ PSI	Allowable serviceability loss
DOT	Department of Transportation
E_{BS}	Elastic modulus of aggregate base layer
E_{SB}	Elastic modulus of aggregate sub-base layer
ESAL	Equivalent single axle load (18,000 lbs.)
FHWA	Federal Highway Administration
LL	Liquid Limit
LTAP	Local Transportation (Technical) Assistance Program
M_R	Resilient Modulus
MUTCD	Manual on Uniform Traffic Control Devices
PI	Plasticity Index = $LL - PL$
PCF	Pounds per cubic foot
PL	Plastic Limit
PSI	Pounds per square inch
RD	Allowable rutting in surface layer
ROW	Right-of-Way

List of Figures

1	The components of the roadway cross section.	1
2	Illustration of an articulated motorgrader.	7
3	Proper shape of controlled intersection.	22
4	Proper shape of an uncontrolled intersection.	22
5	Illustration of a gravel road intersecting a paved road.	23
6	Illustration of the transition from a normal crown to the superelevated shape needed in a curve.	25
7	Improper matching of driveway and road edge.	27
8	Proper matching of driveway and road edge.	27
9	Stack of sieves for testing the gradation of aggregates.	41
10	The Six Climatic Regions in the United States.	A2
11	Design Chart for Aggregate-Surfaced Roads Considering Allowable Serviceability Loss.	A5
12	Design Chart for Aggregate-Surfaced Roads Considering Allowable Rutting.	A6
13	Chart to Convert a Portion of the Aggregate Base Layer Thickness to an Equivalent Thickness of Sub-base.	A6
14	Total Damage versus Thickness for Serviceability and Rutting Criteria.	A9
15	Standard Analysis Sheet from the South Dakota Department of Transportation.	B1
16	Gravel Road Maintenance Cost Per Mile.	D6
17	Paving Options (Costs and road life are estimates and may vary).	D6
18	Impacts of Gravel Surfaces on Users Costs.	D7
19	Walk-around Inspection Diagram.	E2
20	Motorgrader Preventative Maintenance Check List.	E3

List of Tables

1	Example of Gradation Requirements and Plasticity for Two Types of Materials.	A2
2	Suggested Seasons Length (Months) for Six U.S. Climatic Regions.	A3
3	Suggested Seasonal Roadbed Soil Resilient Moduli, MR (psi), as a Function of the Relative Quality of the Roadbed Material.	A3
4	Chart for Computing Total Pavement Damage (for Both Serviceability and Rutting Criteria). Based on a Trial Aggregate Base Thickness.	A4
5	Aggregate Surfaced Road Design Catalog: Recommended Aggregate Base Thickness (in Inches) For Six U.S. Regions, Five Relative Qualities of Roadbed Soil, and Three Traffic Levels.	A10
6	Suggested Gravel Layer Thickness for New Or Reconstructed Rural Roads.	A11

Forward

There are over 1.6 million miles of unpaved roads (53% of all roads) in the United States. In some nations, the road network is predominantly unpaved and generally consists of gravel roads. This manual was developed with a major emphasis on the maintenance of gravel roads, including some basic design elements.

Gravel roads are generally the lowest service provided to the traveling public and are usually considered greatly inferior to paved roads. Yet, in many rural regions, the volume of traffic is so low that paving and maintaining a paved road is not economically feasible. In many cases, gravel roads exist to provide a means of getting agricultural products in and out of farm fields, timber out of forests, or as access to remote areas such as campgrounds and lakes. Many gravel roads serve rural residents as well. Many of these roads will remain unpaved due to very low traffic volume and/or lack of funds to adequately improve the subgrade and base before applying pavement layer(s). In some countries, economic constraints mean gravel roads are the only type that can be provided.

The purpose of this manual is to provide clear and helpful information for doing a better job of maintaining gravel roads. It is recognized that very little technical help is available to small agencies that are responsible for managing these roads. Gravel maintenance has traditionally been "more of an art than a science" and very few formal standards exist. This leads to many arguments between grader operators, managers, and motorists over questions such as: What is enough surface crown? What is too much? What causes corrugation? This manual contains guidelines to help answer these and other questions about the maintenance of gravel roads.

This manual is designed for the benefit of elected officials, managers, and grader operators who are responsible for designing and maintaining gravel roads. The information provided in this manual is as nontechnical as possible without sacrificing clear guidelines and instructions on how to do the job right.

Introduction

Good gravel road maintenance or rehabilitation depends on two basic principles: proper use of a motorgrader (or other grading device) and use of good surface gravel. The use of the grader to properly shape the road is obvious to almost everyone, but the quality and volume of gravel needed is not as well understood. It seems that most gravel maintenance/rehabilitation problems are blamed on the grader operator when the actual problem is often material related. This is particularly true when dealing with the problem of corrugation or “washboarding.” The problem is often perceived as being caused by the grader but is primarily caused by the material itself. This manual will help provide a better understanding of what makes good surface gravel.

Another important matter to consider is the dramatic change in the vehicles and equipment using low volume roads. Trucks and agricultural equipment are increasing in size and horsepower. The trend is toward even larger machinery. The effect of larger and heavier vehicles on our paved roads is well understood. There is a definite need to build stronger bases and pavements. But the effect on gravel roads is just as serious and often is not recognized. For this reason, a section on the design of gravel roads is included. The strength of the subgrade and depth of the material needed to carry today’s heavy loads must be considered. Proper drainage is also important.

The final section of the manual covers innovations in the gravel road maintenance/rehabilitation industry. Change is constant in almost every aspect of this modern world and maintaining gravel roads is no exception. There are new ways of stabilizing roads, new methods of dust control, new and different kinds of equipment available for maintenance/rehabilitation of gravel roads, and even new surface materials such as recycled asphalt being used. Not all of these innovations may be available or practical for every local government entity, but everyone is encouraged to take an objective look at each of them. Then an informed decision can be made about changing the way gravel roads are designed and maintained within a particular jurisdiction.