NATIONAL COOPERATIVE
HIGHWAY RESEARCH PROGRAM REPORT 254

SHOULDER GEOMETRICS AND USE GUIDELINES

TRANSPORTATION RESEARCH BOARD
NATIONAL RESEARCH COUNCIL

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM REPORT **254**

SHOULDER GEOMETRICS AND USE GUIDELINES

HUGH G. DOWNS, JR., and DAVID W. WALLACE
Hugh Downs—RK&K
Baltimore, Maryland

RESEARCH SPONSORED BY THE AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS IN COOPERATION WITH THE FEDERAL HIGHWAY ADMINISTRATION

AREAS OF INTEREST:
- FACILITIES DESIGN
- PAVEMENT DESIGN AND PERFORMANCE
- MAINTENANCE
- TRANSPORTATION SAFETY
- (HIGHWAY TRANSPORTATION)
- (OTHER)

TRANSPORTATION RESEARCH BOARD
NATIONAL RESEARCH COUNCIL
WASHINGTON, D.C. DECEMBER 1982

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Systematic, well-designed research provides the most effective approach to the solution of many problems facing highway administrators and engineers. Often, highway problems are of local interest and can best be studied by highway departments individually or in cooperation with their state universities and others. However, the accelerating growth of highway transportation develops increasingly complex problems of wide interest to highway authorities. These problems are best studied through a coordinated program of cooperative research.

In recognition of these needs, the highway administrators of the American Association of State Highway and Transportation Officials initiated in 1962 an objective national highway research program employing modern scientific techniques. This program is supported on a continuing basis by funds from participating member states of the Association and it receives the full cooperation and support of the Federal Highway Administration, United States Department of Transportation.

The Transportation Research Board of the National Research Council was requested by the Association to administer the research program because of the Board's recognized objectivity and understanding of modern research practices. The Board is uniquely suited for this purpose as: it maintains an extensive committee structure from which authorities on any highway transportation subject may be drawn; it possesses avenues of communications and cooperation with federal, state, and local governmental agencies, universities, and industry; its relationship to its parent organization, the National Academy of Sciences, a private, nonprofit institution, is an insurance of objectivity; it maintains a full-time research correlation staff of specialists in highway transportation matters to bring the findings of research directly to those who are in a position to use them.

The program is developed on the basis of research needs identified by chief administrators of the highway and transportation departments and by committees of AASHTO. Each year, specific areas of research needs to be included in the program are proposed to the Academy and the Board by the American Association of State Highway and Transportation Officials. Research projects to fulfill these needs are defined by the Board, and qualified research agencies are selected from those that have submitted proposals. Administration and surveillance of research contracts are the responsibilities of the Academy and its Transportation Research Board.

The needs for highway research are many, and the National Cooperative Highway Research Program can make significant contributions to the solution of highway transportation problems of mutual concern to many responsible groups. The program, however, is intended to complement rather than to substitute for or duplicate other highway research programs.

NCHRP REPORT 254

Project 1-22 FY '81
ISSN 0077-5614
ISBN 0-309-03424-8
L. C. Catalog Card No. 82-74119

Price: $7.60

NOTICE

The project that is the subject of this report was a part of the National Cooperative Highway Research Program conducted by the Transportation Research Board with the approval of the Governing Board of the National Research Council, acting in behalf of the National Academy of Sciences. Such approval reflects the Governing Board's judgment that the program concerned is of national importance and appropriate with respect to both the purposes and resources of the National Research Council.

The members of the technical committee selected to monitor this project and to review this report were chosen for recognized scholarly competence and with due consideration for the balance of disciplines appropriate to the project. The opinions and conclusions expressed or implied are those of the research agency that performed the research, and, while they have been accepted as appropriate by the technical committee, they are not necessarily those of the Transportation Research Board, the National Research Council, the National Academy of Sciences, or the program sponsors.

Each report is reviewed and processed according to procedures established and monitored by the Report Review Committee of the National Academy of Sciences. Distribution of the report is approved by the President of the Academy upon satisfactory completion of the review process.

The National Research Council was established by the National Academy of Sciences in 1916 to associate the broad community of science and technology with the Academy's purposes of furthering knowledge and of advising the Federal Government. The Council operates in accordance with general policies determined by the Academy under the authority of its congressional charter of 1863, which establishes the Academy as a private, nonprofit, self-governing membership corporation. The Council has become the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in the conduct of their services to the government, the public, and the scientific and engineering communities. It is administered jointly by both Academies and the Institute of Medicine. The National Academy of Engineering and the Institute of Medicine were established in 1964 and 1970, respectively, under the charter of the National Academy of Sciences.

The Transportation Research Board evolved from the 54-year-old Highway Research Board. The TRB incorporates all former HRB activities and also performs additional functions under a broader scope involving all modes of transportation and the interactions of transportation with society.

Special Notice

The Transportation Research Board, the National Academy of Sciences, the Federal Highway Administration, the American Association of State Highway and Transportation Officials, and the individual states participating in the National Cooperative Highway Research Program do not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the object of this report.

Published reports of the

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

are available from:

Transportation Research Board
National Academy of Sciences
2101 Constitution Avenue, N.W.
Washington, D.C. 20418

Printed in the United States of America.

FOREWORD

By Staff
Transportation Research Board

This report contains the results of a study of highway shoulder design practices and operational uses throughout the United States. The study has determined that the shoulders along highways are subjected to a variety of uses by the traveling public, adjacent property and business owners, agencies that build and maintain the highways, law enforcing agencies, and organizations that provide public services. Guidelines are provided for shoulder design elements such as width, surface type, cross slope, special signing, and markings that best satisfy the requirements for each identified shoulder use for various classifications of highways. The report will be of interest to transportation agencies and personnel responsible for the design, maintenance, and operation of all types of highways from local roads to freeways.

Shoulders are an important element of a highway system. Well-designed and maintained shoulders are essential for safe traffic operations and serve as lateral structural support for the traveled way. Shoulders provide space for emergency stops, recovery space for errant vehicles, clearance to signs and guardrails, space for maintenance operations, and other functions. To accommodate this variety of functions, highway agencies use a wide range of geometric design standards and elements. In some cases the range of design considerations and resulting nonuniformity between agencies may violate driver expectancy when the intended use is not clear. The objective of Project 1-22 was to develop guidelines for optimum utilization of highway shoulders considering such factors as safety, economics, traffic operations, highway functional classification, and traffic volume. The research was conducted by Hugh Downs—RK&K, a joint venture of Hugh G. Downs, Jr. and Rummel, Klepper & Kahl, Consulting Engineers.

As background for preparation of *NCHRP Synthesis of Highway Practice 63*, "Design and Use of Highway Shoulders," a questionnaire was used in 1977 to obtain information from state highway and transportation agencies on their policies and procedures, design, and operations regarding highway shoulders. The Project 1-22 researchers, as a follow-up to *Synthesis 63*, collected more detailed information on shoulder design and use practices (1) by an extensive review of the literature on shoulder design and use, (2) by visits to and interviews with appropriate personnel of 17 highway agencies, and (3) by updates of the 1977 Questionnaire requested from the state highway agencies not visited. A large number of photographs taken during the agency visits illustrate the variety of operational uses being made of shoulder.

The research reveals considerable nonuniformity in the design and modification of highway shoulders to safely, economically, and efficiently satisfy the many uses they serve. Some nonuniformity can be attributed to local laws that permit certain shoulder uses in some states that are illegal in other states. Considerable nonuniformity results from differing signing and marking practices employed to control shoulder use because the "Manual on Uniform Traffic Control Devices," published by the Federal Highway Administration, permits alternatives for some signing and marking practices. Table 5 in this report, "Shoulder Geometrics and Use Guidelines," presents acceptable and optimal combinations of shoulder widths, surface types, cross slopes, special signing and markings, and conditions of use that best satisfy the requirements of each of the identified shoulder uses on freeways, arterials, collectors, and local roads and streets.

Appendixes E, F, and G of the agency report covering review of the literature, details of agency visits and interviews, and shoulder occupancy data are not included in this publication but are contained in an Addendum to NCHRP Report 254. Copies of the addendum have been distributed to the program sponsors and are available to other interested persons by contacting the Director, Cooperative Research Programs, Transportation Research Board, 2101 Constitution Avenue, N.W., Washington, D.C. 20418.

CONTENTS

ACKNOWLEDGMENTS

The research conducted under NCHRP Project 1-22 was performed by Hugh Downs—RK&K, a joint venture of Hugh G. Downs, Jr., of Reisterstown, Maryland and Rummel, Klepper & Kahl, Consulting Engineers, of Baltimore, Maryland. The work was performed in the Transportation Planning Department of Rummel, Klepper & Kahl, directed by John L. Bell, P.E., Partner.

Mr. Hugh G. Downs, Jr., P.E., was the principal investigator. Mr. David W. Wallace, P.E., was the assistant principal investigator and co-author of the report. The contributions of Mr. William S. Wilkinson, P.E. (Annotated Bibliography), Mr. Steven D. Rosen (Shoulder Occupancy Data), and Mr. Dudley J. O'Donnell (Accident Data) are gratefully acknowledged.

Special thanks are extended to the highway and traffic engineers in the numerous agencies who assisted in this research effort, both in providing responses to the questionnaires and participating in the interviews. The authors also extend a special thanks to the following individuals for their invaluable contributions: Messrs. Billy Cooper and Robert Walters (Arkansas); Harry Pistel and John Trenner (Baltimore County, Maryland); Vince Barsi, J. H. Chaudoin, Jack Kassel, Cal Lee, Len Newman, and Earl Rogers (California); Carl Bard and Thomas Cressey (Connecticut); Alton Dowd and Burton Riddle (Georgia); Max Jensen (Idaho); Tom Bright and Charles McLean (Illinois); Ronald Fritz and Martin Buehler (Lake County, Illinois); Thomas Hicks and Irvin Hughes (Maryland); Jess Truby, Jr., and Walt Witt (Nebraska); Edwin Dayton (New Jersey); George Baca, Anthony Lopez, and Fred Torrez (New Mexico); Blaise Carriere (New Orleans, Louisiana); Anthony DeNigro, Roger Edwards, and Michael Hof (New York); James Graham and George Wells (North Carolina); Robert Lewis, Richard McCasland (TTI), Jerry Selby, and R. Williamson, Jr. (Texas); Norman Roush and Jack Samples (West Virginia).

SHOULDER GEOMETRICS AND USE GUIDELINES

SUMMARY

The objectives of the research reported herein were threefold: to identify the highway shoulder design practices and the various operational uses of shoulders throughout the United States; to determine optimum utilization of highway shoulders after consideration of such factors as safety, economics, traffic operations, and roadway classifications; and to encourage greater uniformity with the development of shoulder geometric design and use guidelines.

Toward this end, data were collected by reviewing existing research literature and available in-house reports and policy manuals prepared by nearly 35 representative highway agencies. Additional data concerning current shoulder uses, design policies and practices were obtained through interviews with officials representing highway agencies throughout the country and on-site observations of shoulder conditions and actual practices. These agencies were selected to represent all geographical and climatic conditions in both rural and urban locations in the contiguous United States.

The state, county and city highway agencies interviewed for this research were: Arkansas; Baltimore County, Maryland; California; Connecticut; Georgia; Idaho; Illinois; Lake County, Illinois; Maryland; Nebraska; New Jersey; New Mexico; New Orleans, Louisiana; New York; North Carolina; Texas; and West Virginia. Additional information concerning the participation of agencies and the selection and interview process is included in Appendix A and summarized in Table A-1.

The results of the research indicate that highway shoulders are subjected to a variety of uses by the traveling public, by the adjacent property and business owners, and by the agencies that build and maintain highways, enforce laws, and provide other public services. Twenty-three uses of highway shoulders were identified, and design geometric and operational practice data were collected for each use. Each use was examined to determine the reason for the use, the safety of the use, the extent of the use among the sampled agencies, the problems the use may solve, the problems the use may invoke and their solutions, the economics of the use, the signing and marking required, the geometric designs the use may require, the public acceptance of the use, and the conditions of the use.

The findings of the research reveal that significant numbers of agencies, in attempts to provide adequate shoulders and to improve traffic service at minimum costs, give special consideration to certain uses which shoulders must serve. Some of these special practices are noted as follows:

- Provide shoulders on those highways that warrant the need, i.e., high traffic volume highways are provided with wide shoulders.
- Stabilize or pave shoulders on low-volume roads only where anticipated uses warrant such costs.
- Pave or stabilize only a portion of shoulder width, with the remainder graded turf.
- Allow stopping for mechanical difficulty or other emergencies on shoulders of all highway classifications regardless of shoulder width or condition.
- Restrict parking at hazardous locations.
- City and urban residential streets provide the area adjacent to curbs (shoulder) for recovery, emergency stopping, additional traffic during peak hours, and most importantly, for parking.
- Provide special truck stopping areas by widening and/or strengthening shoulders along or at the crest of long grades, thus reducing the shoulder deterioration caused by repetitive truck parking.
- Stabilize area beyond paved shoulders under bridges to reduce rutting caused by repetitive truck parking.
- Public interest in the use of carpools has resulted in increased use of highway shoulders for parking, and although agencies are constructing park-and-ride lots, the rendezvous sites are selected by the users primarily for their convenience.
- In mountainous regions, terrain conditions severely restrict space for both highways and adjacent rural developments, leaving residents no choice but to park on the narrow shoulders adjacent to their properties.
- Because parking on shoulders is common in rural areas for recreational fishing, hunting, and skiing, some agencies widen and/or stabilize the existing shoulders.
- Except on freeways and other controlled access highways, mail and other deliveries are permitted from the shoulders. To reduce wear from repetitive use of unpaved shoulders, several agencies provide special mailbox turnouts and/or construct paved shoulders sufficiently wide to allow delivery vehicles to clear the traveled way.
- Where warranted, widen and strengthen shoulders at intersections to allow right-turns and passing of left-turning vehicles. Carefully sign and mark converted shoulders to indicate permitted uses.
- Provide proper warning signs for safety of the public and agency maintenance personnel during routine highway maintenance and utility operations involving shoulder closing.

- Remove snow from shoulders to restore use of shoulders to traveling public, except in high snowfall regions. Slope shoulders away from traveled lanes to prevent refreezing of snow-melt on roadways.
- In arid (desert) regions, remove obstacles such as curbs and parapets that may trap blowing sand, and set roadway grades above surrounding terrain to assure self-cleaning. In addition, provide water barrels and shoulder areas of sufficient width and strength to permit stopping and servicing of overheated vehicles.
- Reconstruct and/or strengthen shoulders if required before using them as temporary traffic lanes during major highway and bridge reconstruction.
- Construct full-strength shoulder pavements about 2-ft wide adjacent to main lanes as part of full-width, lesser strength shoulder pavements. Along ramps or turning lanes, provide shoulder on left and curbs along right of pavement on insides of curves.
- To accommodate off-tracking vehicles on highways without paved shoulders, construct minimal width (1- to 2-ft) paved shoulders to provide main-lane pavement edge support.
- Construct turnouts off the traveled way for disabled and slow-moving vehicles, where continuous shoulders are not possible.
- Convert shoulders to climbing lanes or passing lanes for slow-moving vehicles to operate on shoulders along two-lane routes to allow safe passing (to reduce congestion and queuing) by faster moving vehicles. Provide special lane marking and signing to identify location where uses of shoulders as passing lanes and climbing lanes are permitted.
- The laws of at least two states allow slow-moving vehicles to pull onto shoulders to allow faster vehicles to pass along two-lane routes.
- Provide shoulder bicycle lanes, minimally 4-ft wide, separated from remainder of roadway by a 2-ft buffer space (indicated by suitable pavement marking and signs) and paved with smooth pavement.
- Provide strengthened pavements (concrete pads) at bus stops to prevent deterioration of shoulder and curb-lane pavements from repetitive use by transit buses.
- Strengthen and widen existing shoulders to provide additional full running lanes on urban arterials where sufficient rights-of-way exist. To obtain maximum numbers of traffic lanes within existing rights-of-way, evenly divide total widths of widened pavements to produce the maximum number of 10- to 12-ft wide traffic lanes.
- Provide solutions to traffic bottlenecks by converting short sections of shoulders (2 miles ±) on urban freeways to full running lanes. Each location must be carefully studied and tailored to suit anticipated operating conditions.

- Allow the "permissive" use of shoulder as a running lane on urban freeways during rush hours by erecting signs such as "3 PM -7 PM/OK/TO DRIVE/SHOULDER".
- Provide rumble strips or textured shoulders to delineate pavement edges to alert errant drivers at high run-off-the-road accident locations.
- Provide escape ramps on or adjacent to shoulders with turnouts and means for stopping runaway trucks on long downgrades.
- Provide increased pavement (strength and/or width as required) on shoulders where weigh-crews routinely use portable and semi-portable scales for truck weight enforcement.
- Provide call boxes and/or public telephones at shoulder edge for use by motorists with disabled vehicles.

This research also reveals nonuniformity in agency practices in designing for, and retrofitting, highway shoulders to safely, economically, and efficiently satisfy the uses that highway shoulders are required to serve. Some of this nonuniformity can be attributed to motor vehicle codes. Uses of shoulders that may be allowed by law in some states may be illegal in neighboring states. Considerable nonuniformity results from differing signing and marking practices that are employed to control shoulder uses. Some of this may be because the MUTCD (36) allows alternatives for signing and marking.

Based on the successful practices of representative highway agencies throughout the country, the research results suggest preferences for shoulder geometrics and signing and marking of shoulders. Chapter Three of this report presents acceptable and optimal combinations of shoulder widths, surface types, cross slopes, special signings and markings, and conditions of uses which best satisfy the requirements of each of the identified shoulder uses on freeways, arterials, and collectors and locals. The application of these guidelines should encourage greater uniformity for a given shoulder use. On the basis of the experiences of representative highway agencies in all sections of the country, the guidelines also allow determinations of the suitabilities of various shoulder designs to satisfy the diverse needs of the users of highway shoulders.

CHAPTER ONE

INTRODUCTION AND RESEARCH APPROACH

When highways in the United States were first paved with bituminous materials, travel ways were narrow and easily raveled by wheel loadings at the edges of pavements. In response to this problem, highway departments installed an additional strip of material along the "shoulders" of these highways to provide lateral support and prevent raveling of pavement edges. In many areas, these shoulders were constructed of portland cement concrete and not only served to support main-lane macadam pavements, but also provided delineation and wider surface areas for passing. As vehicle sizes and traffic volumes increased, these main-lane and shoulder pavements were typically overlayed to serve as new, wider main lanes. Often, new, wider shoulders were also added. New construction kept pace with this trend towards wider pavements, resulting in today's standard 12-ft wide lanes with paved shoulders.

NCHRP Project 1-22, "Shoulder Geometrics and Use Guidelines," was initiated to evaluate current shoulder uses throughout the country and to develop geometric guidelines to correlate shoulder designs with uses, commensurate with operational requirements.

PROBLEM STATEMENT

The design of shoulders has historically been compatible with the American Association of State Highway and Transportation Official's (AASHTO's) definition of shoulders as "... the portion of the roadway contiguous with the traveled way for accommodation of stopped vehicles, for emergency use, and for lateral support of base and surface courses." (3, p. 352). Their use, however, has broadened considerably beyond that described in the AASHTO definition. The following shoulder uses were considered in NCHRP Project 1-22:

SHOULDER GEOMETRIC DESIGN FUNCTIONS

1. Lateral support of main lanes.
2. Delineation of traveled way.
3. Roadway drainage.

SHOULDER USES

1. Emergency Stopping (Mechanical Difficulty).
2. Parking.
3. Mail and Other Deliveries.
4. Turning and/or Passing at Intersections.
5. Routine Maintenance.
6. Snow Storage.
7. Arid Areas.
8. Major Reconstruction and Maintenance Activities.
9. Off-tracking.
10. Encroachment.
11. Slow Moving Vehicles.
12. Pedestrians.
13. Bicycles.
14. Mass Transit.
15. Full Running Lanes - Nonfreeways.
16. Full Running Lanes - Freeways.
17. Errant Vehicles.
18. Emergency Vehicle Travel.
19. Law Enforcement.
20. Emergency Call Box Service and Public Telephones.
21. Roadside Sales.
22. Garbage Pickup.
23. Miscellaneous (funerals, snowmobiles).

In order to accommodate this wide variety of shoulder functions and uses, highway agencies have developed different solutions by varying the geometric and structural design of shoulders which, in many instances, have increased the utility of highway facilities. In some cases, however, these solutions have resulted in nonuniformity, which violates driver expectancy and creates other problems when the intended shoulder use is not clear. For example, the driver of a slow-moving vehicle traveling west along U.S. Route 380 in Texas is permitted to pull onto the shoulder to allow faster vehicles to pass, while across the state line in New Mexico, this driver is not permitted to perform the same manuever.

RESEARCH OBJECTIVE

The objectives of NCHRP Project 1-22 were threefold: to determine and compare the varied highway shoulder policies and uses throughout the United States; to evaluate the effects safety, traffic, economics, and roadway classification factors have on shoulder design and use; and to develop a set of shoulder geometric design and use guidelines. This research addresses shoulder geometrics (items such as width, slope, pavement surface) and conditions of use, but not shoulder structure (composition and strength).

Although the end product of this research is a set of shoulder geometric design and use guidelines (Table 5 in Chapter Three), the variability of shoulder usage and policy throughout the country precluded the easy categorization of all the findings into tabular form.

RESEARCH APPROACH

The approach used in this research effort consisted of a literature review and evaluation; interviews with 17 representative highway agencies; collection of updated shoulder occupancy data; and the preparation of shoulder geometric and use guidelines.

Literature Review

Four hundred thirty-five research abstracts relating to highway shoulders were obtained from the Highway Research Information Service. These abstracts were reviewed and copies of all full reports relevant to this project were obtained for analysis. Relevant reports are reviewed in Appendix E (see Addendum to the NCHRP Report 254), and the findings from this review are covered in Chapter Two.

As a follow up to NCHRP Synthesis of Highway Practice 63 "Design and Use of Highway Shoulders" (17), updates of the 1977 Questionnaire were requested from all states not scheduled for a visit as part of this project. The findings on highway shoulders from these nonvisited agencies are summarized in Appendix D.

As part of the interviews with the 17 agencies and the requests for an update of the Synthesis 63 Questionnaire, copies of in-house agency research reports were obtained. These reports are also reviewed in Appendix E in the Addendum to NCHRP Report 254 and are also included in the "Findings", Chapter Two.

Agency Interviews

Seventeen agencies responsible for the planning, design, construction, operation and maintenance of highway shoulders were visited (App. A). A detailed questionnaire on shoulder designs and uses was completed by sixteen of these agencies. Site trips were also taken to observe shoulder operations at a variety of locations. These interviews and site visits formed the primary source of information for this research project. The findings of agency interviews are summarized in Chapter Two and presented in greater detail in Appendix F (see Addendum to NCHRP Report 254).

Updated Shoulder Occupancy Data

A special study was conducted to determine the relative accuracy of previously collected shoulder occupancy data (in terms of stops per thousand vehicle-miles of travel) with shoulder occupancies observed on six commuter facilities in the Baltimore Metropolitan Area. The findings of this limited update are included in Chapter Two. The data collection procedure and analysis methodology are summarized in Appendix G (see Addendum to NCHRP Report 254).

Preparation of Guidelines

The shoulder geometric and use guidelines, presented in Chapter Three of this report, were developed from the findings of the literature review and the agency interviews.

CHAPTER TWO

FINDINGS OF THIS RESEARCH

This chapter summarizes the findings of the literature review and the interviews with the 17 highway agencies who participated in this research project. Geometric design policies and procedures are presented for the shoulder uses identified as part of this research. In addition, the findings of a limited study conducted to update shoulder occupancy data are also included in this chapter. Shoulder design and use guidelines are presented in Chapter Three (Table 5).

GEOMETRIC DESIGN POLICIES AND PROCEDURES

Introduction

This research was undertaken to determine optimum utilization of highway shoulders and to develop shoulder design and use guidelines. To this end, agencies that participated were selected to represent a cross section of public agencies that design, construct, maintain, and operate highways throughout the country. These agencies were chosen with special regard to obtaining representative samples of the varieties of shoulder design practices and highway shoulder uses that are currently experienced in all regions, and to include all types of terrain and climatic conditions, as well as a representative range of urban and rural traffic conditions (Table A-1 and Fig. A-1).

While all of these agencies base shoulder design standards and specifications generally on AASHTO Policy (App. B), in many cases, the uses, i.e. the normal and extraordinary traffic services which highway shoulders must provide, are not directly considered as factors in the design of shoulders.

Minimum-width shoulders were originally constructed adjacent to highway pavements to provide lateral support to main-lane pavements. This structural support prevented raveling of pavement edges. As highway designs improved to accommodate increasing numbers of vehicles, the obvious need to provide safe areas in which emergency stops would not impede main-lane traffic flow led to the use of shoulders of sufficient width to provide this service. AASHTO geometric design policy provides design criteria and policies for the traditionally accepted "uses" of highway shoulders (1, 3, 4). Current AASHTO design policy considers these basic uses of highway shoulders by basing design criteria generally on highway classifications and on main-lane traffic volumes.

Current Shoulder Geometric Design Policies and Practices

Each highway agency has established shoulder design policies that are in general conformance with AASHTO policy but also reflect the special needs and conditions that are experienced by each individual agency. Five agencies base the type of shoulders on highway classification, three on traffic volumes, one on a combination of highway classifications and traffic volumes, and one on the proposed use; one agency selects shoulder type through a special design committee. Six agencies pave shoulders to the same strength as the adjacent main-lane pavements.

Seven of the 17 representative agencies do not consider specific shoulder uses as controlling factors in shoulder design (Table 1). Ten of the 17 agencies, however, include selected uses of shoulders in their shoulder design criteria. Those uses affecting shoulder designs anticipate uses of shoulders as future traffic lanes (by 4 agencies), turning lanes at intersections (by 2 agencies), truck weight enforcement areas (1 agency), snow removal areas (1 agency), and special industrial uses and parking (1 agency). Although six agencies typically provide full strength shoulders on all roadways, designed in accordance with AASHTO geometric design policy, only three do so in anticipation of practically any use of shoulders.

Table 1. **Anticipated shoulder use as a specific shoulder design factor**

AGENCY	DESIGNS CONSIDER ANTICIPATED USES	ANTICIPATE USES THAT AFFECT DESIGN
Arkansas	No	
Baltimore County	No	
California	Shoulder designed on the basis of truck traffic which permits most shoulder uses.	
Connecticut	Yes	Future traffic lane, climbing lane, snow removal
Georgia	Yes	Added width and strength for truck weight enforcement at selected locations
Idaho	Full pavement strength designs for shoulders allow most shoulder uses.	
Illinois	Yes	Turning movements and parking
Lake County	No	
Maryland	Yes	Turning movements at intersections
Nebraska	Yes	Mobile home industry, loaded truck parking at grain elevators
New Jersey	No	
New Mexico	Yes	Future traffic lane
	Full pavement strength designs for shoulders allow most shoulder uses.	
New Orleans	Yes	Future traffic lane
New York	No	
North Carolina	Sometimes	Future traffic lane
Texas	Provision of full sub-base under shoulder (carried out to fore-slope) accommodates most shoulder uses and permits eventual conversion to traffic lanes.	
West Virginia	No	

Past and recent economic conditions have forced many agencies to "down-scope" both new construction and reconstruction projects to minimize initial construction costs. These conditions have resulted in instances of reduced paved shoulder widths and/or reduced shoulder pavement strengths. Design practices of the interviewed agencies are discussed in Appendix C. Generally, these practices are in conformance with AASHTO recommended widths and cross slopes for most new construction projects, but have been downscoped from AASHTO on many reconstruction projects or new construction on low volume roads. For example, extensive research by California DOT (Caltrans) on accident rates and shoulder widths (50) has led to acceptance of 2-ft wide shoulders along two-lane rural highways with an ADT of 1,000 or less -- while current AASHTO policy permits this 2-ft wide width only on highways with an ADT of 400 or less.

Shoulder Delineation Practices

Shoulder delineation practice consists of white edge line stripe for all agencies; extra delineation is obtained with diagonal or perpendicular stripes. A few agencies attempt to maintain color contrasts between main-lane and shoulder pavements, and although some excellent color contrasts were observed, most agencies consider the edge line stripe to be just as effective, less costly, and easier to maintain. The use of contrasting surface texturing to achieve shoulder delineation has been tried by nearly all of the visited agencies (Fig. 1). Because of additional initial construction costs and relatively short life of texturing methods, most agencies have discontinued surface texturing except at high run-off-the-road (ROR) accident locations. California (29) has successfully tested 3-ft wide rumble, texturing with raised bars on vibrator rollers to roll depressions into asphalt shoulders at high ROR accident locations. Table 2 outlines the shoulder delineation practices of the sampled agencies.

Although Table 2 indicates a difference of opinion regarding the placement of the edge line stripe, it is important to note that all agencies use edge line stripes to delineate their highways.

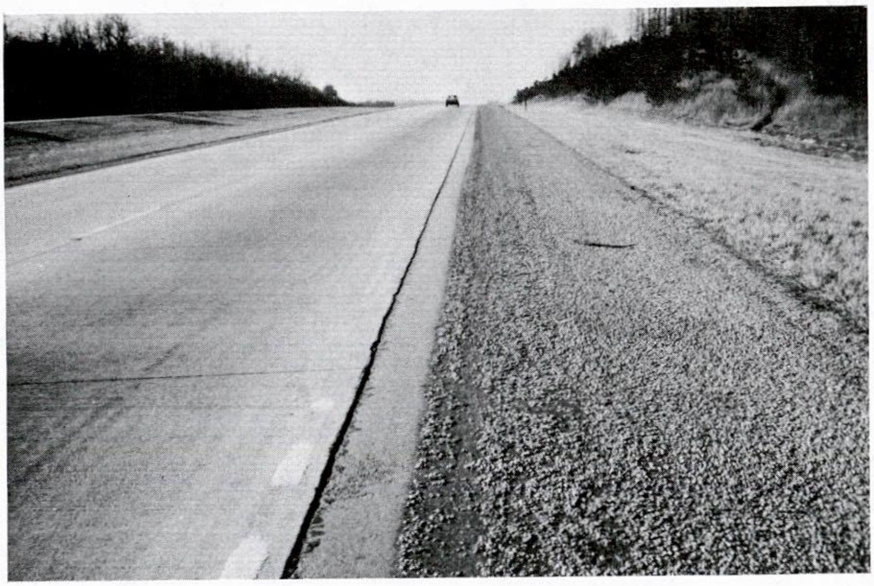


Figure 1. Surface treatment along paved right shoulder provides good texture contrast.

Table 2. **Shoulder delineation practices.**

LOCATION OF EDGE LINE STRIPE PLACED ON PAVEMENT	PLACED ON SHOULDER	PROVIDE COLOR CONTRAST	PROVIDE TEXTURAL CONTRAST	REMARKS
ARKANSAS				
Conc. & asph. pav. w/asph. shoulder.	Conc. pave. with conc. shoulder	Only when conc. pav. is used with ashp. shoulders	Corrugations in concrete shoulders with conc. pave.	
BALTIMORE COUNTY				
Yes	No	None	None	
CALIFORNIA				
Shld. width less than 5 feet	Shld. width 5 feet or more	Only with conc. pav. asph. shld.	No except at special locations	Research indicates texture delineation is not always cost-effective. Often used on long desert highways. Recent research using special rollers on new asphalt shoulders indicates that texture may be economically achieved (29).
CONNECTICUT				
Yes	No	Only with conc. pavement and ashp. shoulders	None	
GEORGIA				
Yes	No	Conc. pavement and asph. shld.	Surface treat. shoulders	Strong advocate of textured shoulders -- mild winters extend life of surface treatment
IDAHO				
No	Yes	Only by a mixture of materials	Chip seal rumble strips used in areas of high ROR accidents (corrugations in conc.)	Studies of use of chip seal rumble strips conclude that effects are lost after 2 to 3 years
ILLINOIS				
Yes	No	Concrete pavement & asph. shoulders	None	Seal coats asphalt shoulders to maintain contrast
LAKE COUNTY				
Yes	No	No	Granular and turf shoulders	
MARYLAND				
Yes	No	Concrete pavement with asph. shoulders	Older highways and secondary roads are surface treated	Older designs required surface treating of asphalt shoulders with asphalt pavement discontinued) -- texture used at problem locations only

LOCATION OF EDGE LINE STRIPE				
PLACED ON PAVEMENT	PLACED ON SHOULDER	PROVIDE COLOR CONTRAST	PROVIDE TEXTURAL CONTRAST	REMARKS
NEBRASKA				
If shld. is granular or turf	If shld. is paved	No	No	Attempts to delineate between shoulder and traffic lane by use of different materials, mixes and armour coats--not always successful
NEW MEXICO				
No	Yes	Only with conc. pavement and asphalt shoulder	None	Main-lane skid resistant resurfacing stopped 1-ft beyond pavement edge provides excellent color and 5/8 in. texture bump -- also surface treatment used occasionally
NEW ORLEANS				
Yes	No	Only if shell shoulders used	Only if shell shoulders used	Parking shoulders striped if parking bays are marked
NEW YORK				
Yes	No	Only with conc. pavement and asphalt shoulder	None	Older designs provided a 2-ft surface treatment strip on shoulder adjacent to pavement but has been discontinued because too costly to construct and maintain
NORTH CAROLINA				
Yes	No	Conc. pavement & asphalt shoulder	Surface treatment used on 4-ft & 10-ft paved shoulders	Surface treatment and seal coats are being discontinued to reduce cost
TEXAS				
No	Yes	Limited use of contrasting aggregate for color or turf	Use corrugations, rumble strips and turf	Edge striping is not used on many low-volume roads
WEST VIRGINIA				
Yes	No	Concrete pavement and asphalt shoulders	Use surface treatment on asphalt shld. & corrugations on concrete	Edge stripe only if pavement is 20-ft wide or more if ADT is 250 or more

Roadway and Shoulder Drainage Practices

To carry roadway drainage beyond the paved surface area, most of the interviewed agencies design shoulder pavements with a greater cross slope than the main-lane pavement. City streets and some freeways and arterials are designed with curbs and gutters at the outer shoulder edge to collect roadway drainage. Agencies also reported using subsurface drains (under drains), shoulder drains, or extensions of the subgrade to the foreslope to improve the stability of main-lane and shoulder pavements.

Lateral Support

Agencies reported several practices that provide lateral support for the main-lane pavements, including restriping two-lane highways slightly narrower, extending full depth pavement 18 in. to 3 ft into the shoulder area, paved "normal" depth shoulders, and shoulders paved to full main-lane strength (Table 4).

USES OF HIGHWAY SHOULDERS

In order to consider all operational uses which may, or may not, be significant factors in the design of highway shoulders, this research has identified the following general categories of uses that highway shoulders must satisfy. Although some of these uses are of significance only in limited terrain or climatic conditions (e.g. climbing lanes and snow storage), and others should be considered permissible only on certain classes of highways (e.g. parking and mail deliveries), highway designers should be aware of each of these possible uses in order to make sound judgments as to whether or not such uses should be anticipated in each project design.

Emergency Stopping (Mechanical Difficulty)

The most obvious and necessary operational use of highway shoulders is to provide safe stopping space for inoperative vehicles (Fig. 2). Studies completed by New Jersey in 1948 and 1949 indicate that passenger cars made emergency stops because of mechanical difficulties on the average of once every 13,450 vehicle-miles, while trucks made emergency stops because of mechanical difficulties once every 5,200 vehicle-miles (7). These figures were updated by Billion (8) in 1959, who determined that highway vehicles made emergency stops on the average of once every 12,000 vehicle-miles on rural highways. A stopped vehicle survey completed in 1969-1970 in Illinois indicated similar rates (43).

Figure 2. Tire changing along paved right shoulder of a freeway.

Recently collected shoulder occupancy data continue to indicate high rates of shoulder use. During AM and PM rush hours, stopping for mechanical difficulty occurred significantly more frequently than leisure stops (for further discussion, see Appendix E and G in Addendum to NCHRP Report 254).

These shoulder occupancy data indicate that all highways must accommodate disabled vehicles. From the standpoint of public safety, this problem ranges from relatively insignificant on low-volume rural highways to critical on high-volume freeways. If shoulder space is available, most disabled vehicles are able to maneuver to a point as far off of the traveled lane as possible before coming to a stop. Many drivers are reluctant, however, to venture beyond the limits of shoulder pavements. Taragin (56) noted, from studies of driver behavior, that in order not to influence main-lane traffic, stopped vehicles should clear main-lane pavement edges by at least 4 ft. Although many current designs provide relatively flat and obstacle-free fore-slope areas, which provide ample area for clearances of this magnitude, the majority of highways now in operation do not, and because of right-of-way restrictions, cannot provide such desirable additional space. Many agencies construct turnouts for stopping clear of traveled lanes on highways with poor horizontal and vertical alignments.

Two-thirds of the nation's total highway system mileage consists of low-volume rural roads, many of which have only minimal shoulders. Emergency stops on these roads must, therefore, encroach on traveled lanes. Glennon (24) has estimated that for an ADT of 400, such roads are subjected to 0.3509 emergency stops per mile per day. This low use of traveled lanes for emergency stops does not usually create critical safety problems on these low-volume highways.

Emergency services for vehicles with mechanical difficulties are normally provided by the traffic enforcement agency or passing motorist. A few rural freeways and many urban areas provide call boxes. On several urban freeway systems the state maintains a fleet of emergency vehicles to assit motorists.

Parking

Parking on City Streets and Residential Roadways

In addition to any or all of the other uses which roadway shoulders must serve, parking for access to adjacent commercial and residential properties is a major use of curb lanes on city streets and residential roadways (Fig. 3). These lanes are often converted to travel lanes during rush hours. Although off-street parking has increased in recent years, it has not relieved the need for curb lane parking.

Figure 3. Eight-feet wide parking lane or parking shoulder along multilane divided city arterial street (note white edge stripe line).

Truck Parking

In addition to emergency stops that cannot be avoided, long-haul trucks routinely stop at intervals to check loads and or mechanical conditions of vehicles as well as to allow drivers to rest. Drivers of heavily loaded trucks typically select locations at tops of downgrades to assure ease of acceleration when rejoining traffic. Many truck, as well as passenger vehicle drivers, choose parking locations under bridges because of the protection afforded from weather at such locations. Parking is also common on shoulders of highways that allow access to restaurants and other business establishments. Repetitive uses of the same locations on shoulders, especially by heavy vehicles, usually result in accelerated deterioration of both shoulder pavements and fore-slopes if such use has not been considered in shoulder designs. Table 3 "Truck Parking Controls," indicates actions and successes of agencies in controlling truck parking problems.

As a solution, several states have constructed widened shoulders at the top of downgrades for use by trucks (Fig. 4).

Table 3. **Truck parking controls.**

ACTIONS TAKEN	REMARKS
• Errect "No Parking" signs at areas of repetitive parking.	• Signs are ingored. Police reluctant to enforce. Many enforcement officers and highway agency officials believe it safer to allow truckers to stop and rest or check mechanical operation rather than have a drowsy driver or a vehicle with mechanical problems trying to make the next exit, rest area, or service area.
• Construct paved tapers to paved area under bridges.	• Length of paved area and taper insufficient to accommodate a truck.
• Place granular material to stabilize area used by trucks.	• Provides sufficient area for trucks, but requires constant maintenance.
• Construct paved truck turnouts or strengthen & widen shoulders at crest of hill and along the downgrade, with signs requiring brakes to be checked or advising of truck stop (Fig. 4).	• If mandatory and manned, the trucks obey. If not manned, a sufficient number of trucks will stop to warrant construction.
• Construct sufficient rest areas for all vehicles to stop, rest, and check vehicles.	• Rest Areas are too far apart, too costly, and are normally only constructed on freeways.

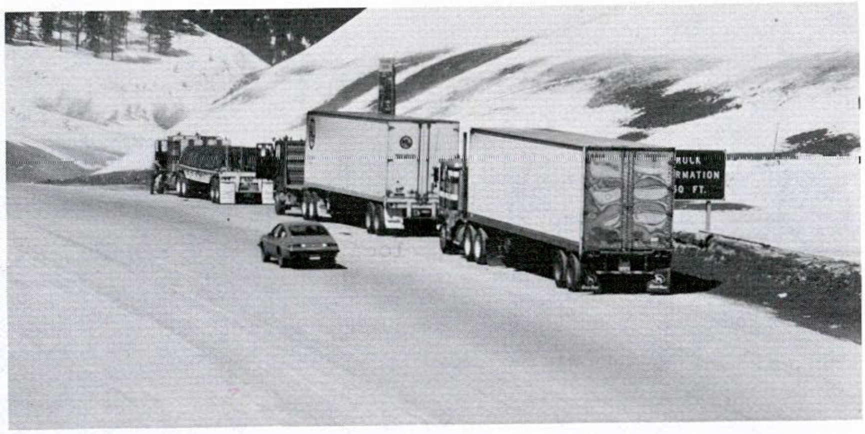


Figure 4. Widened paved shoulder at crest of grade to provide truck stop and check point.

Park and Ride Use of Shoulders

Recent public interest in the use of carpools has resulted in increased use of highway shoulders for this purpose. As shown in Figure 5, locations on the shoulders of secondary roads near interchanges of freeways are usually most popular. Such repetitive use of shoulder pavements also results in accelerated deterioration of shoulder surface conditions, and can create unsafe operating conditions. The construction of park-and-ride lots at strategic locations is successful in eliminating much shoulder parking; however, rendezvous sites are selected by users for their convenience, and it is common to find vehicles parked on shoulders along rural routes.

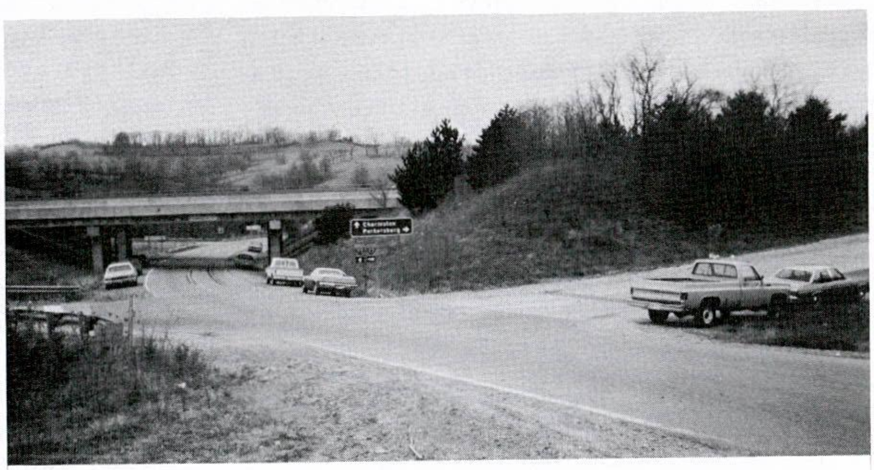


Figure 5. Parallel park-and-ride parking at rural interchange (note parking on shoulder under bridge and along ramp).

Residential and Recreational Parking on Rural Highway Shoulders

As shown on Figure 6, terrain conditions severely restrict space available for both highways and adjacent rural developments, especially in mountainous regions. In many such cases along narrow, secondary roads, residents have little choice but to park on the narrow shoulders adjacent to their properties.

Figure 6. Rural residential parking on granular shoulder along two-lane arterial.

In these and other rural areas, parking on shoulders is common for recreational hunting, fishing, and picnicing. Such uses can usually be anticipated near stream crossings, or where other recreational attractions are nearby. Except along Interstate routes where law enforcement agencies usually control all except emergency parking, and where obviously dangerous traffic conditions would be created (near intersections and along sharp curves with narrow shoulders), little is done to prevent such uses of shoulders. In fact, shoulders or the areas adjacent to shoulders are often stabilized to provide rural and recreational parking clear of traveled lanes.

Casual Parking for Rest and Personal Needs

Motorists normally stop on shoulders at regular intervals to rest, change drivers, consult maps or for other personal needs. The 1948-1949 New Jersey Study (7) determined that passenger cars make leisure stops on shoulders once in about every 980 vehicle-miles of travel, while trucks make such stops every 150 vehicle-miles of travel. Billion (8), however, reported "leisure" stops at the rate of only one every 2,800 vehicle-miles of travel.

Parking, Abandoned Vehicles

Vehicles left parked on highway shoulders for more than 24 to 48 hours in some states are legally towed away as abandoned vehicles.

Accidents Resulting from Parking on Shoulders

Vehicles parked on highway shoulders (or on the traveled way) may contribute to "hit parked vehicle," "rear end," "sideswipe," and "pedestrian" accidents. Sufficient data are not available to identify whether such accidents usually result from emergency, leisure, or other types of parking. A study (14) by FHWA's Bureau of Motor Carrier Safety, which investigated 2006 accidents, revealed that 58 accidents involved vehicles that were stopped on shoulders. Negligent and nonemergency parking were contributing factors in 21 percent of these accidents. It was further revealed that 52 percent of these accidents occurred between 11:31 PM and 5:30 AM, with 90 percent of these being "rear-end" type collisions.

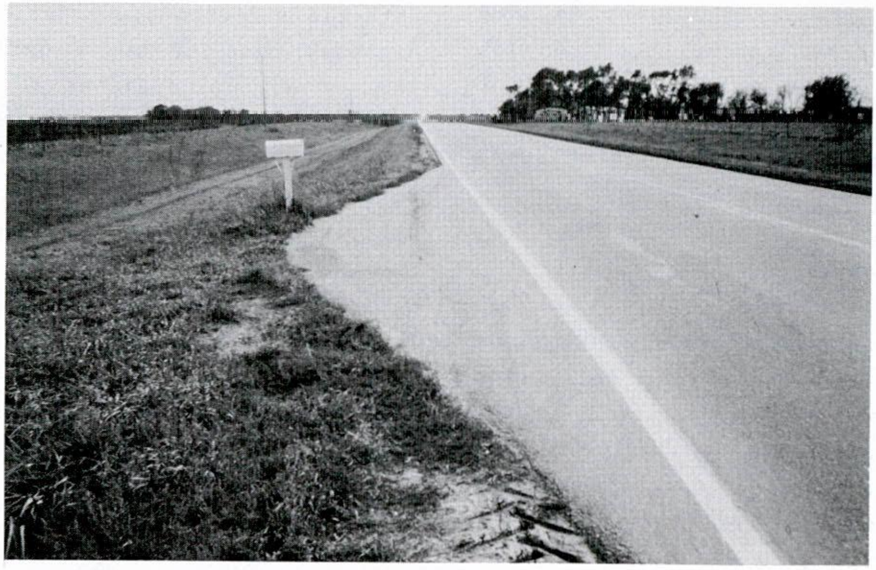
California reported a total of 36 fatalities resulting from vehicles being struck while stopped on freeway shoulders in 1980 (23). Twenty-five of these occurred at night. Georgia reports that 92 percent of fatal accidents involving stopped vehicles occurred at night, with 84 percent on rural facilities.

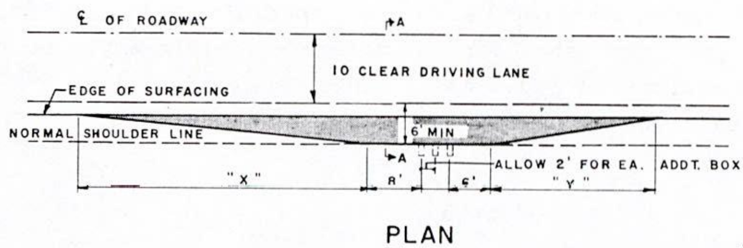
Mail and Other Deliveries

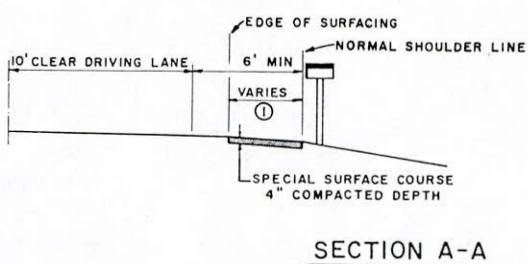
Except on freeways and other controlled-access highways, mail and other deliveries are permitted from the shoulders of all types of rural and urban roadways. Mailboxes and newspaper boxes normally erected at the outer edge of shoulders result in daily use of shoulders by delivery vehicles. Depending on the type, strength, and condition of shoulder surfaces, this daily repetitive use can cause wear, rutting, or pavement drop-off, especially on narrow roads where delivery vehicles often travel with one set of wheels continually on the shoulder. Several states construct mailbox turnouts as a solution to this problem (Fig. 7).

Although this use of highway shoulders by delivery vehicles certainly provides potentials for unsafe traffic operating conditions, none of the agencies interviewed report any significantly related safety problems. Neither postal authorities nor highway agencies usually require any special identifying signs, lights, etc., on delivery vehicles. Some individual drivers at their own discretion, however, equip their vehicles with signs and/or lights.

The mailbox support at the edge of shoulder is a safety problem and has been a fixed object that many run-off-the-road vehicles hit. Trailer courts often errect mailboxes in rows on horizontal timber supports that can be devastating when hit. Texas has developed and will errect, upon request, a traffic-safe mailbox support. Other agencies require single mailboxes to be errected along entrance radii, or groups of mailboxes at special turnouts that provide the delivery vehicle ample room to clear traffic lanes.







SHOULDER WIDITH	"X"	"Y"
4'	16'	10'
5'	20'	13'
6'	24'	15'
7'	28'	18'
8'	32'	20'
9'	36'	23'
10'	40'	25'

Figure 7. Photograph, plan, and cross section of mailbox turnout used in Nebraska.

Turning and/or Passing at Intersections

As indicated by Fambro (22) in his study of driving on shoulders in Texas, if space is available, most motorists will use shoulder areas to pass left-turning vehicles or to make right-turns at intersections (Fig. 8). To reduce congestion and improve levels of traffic service, most agencies, following studies to determine through and turning traffic volumes at such locations, strengthen and widen shoulder pavements as necessary to convert shoulders to turning and/or passing lanes. In his paper on bypass lanes at rural intersections in Illinois, Buchler (11) notes that accidents can be reduced by providing properly designed lengths for such converted passing lanes. Cottrell (15) has developed guidelines for right-turn treatments on both two-lane and four-lane highways. Fourteen of the sampled agencies conducted traffic studies before conversion or have established warrants for this use. Several reported that passing to the right is illegal or only allowed if a left-turn bay is provided.

At some intersections, signs are erected designating "Right Turn Only" from the converted shoulder lane (Fig. 9). Agencies mark the by-pass, left-turn or fly-by two basic ways. One method tapers the pavement edge line to the outer shoulder edge, similar to the right-turn marking, and then tapers the edge line back to the edge of pavement after the intersection. This marking allows the motorist the option of staying in the normal traffic lane or moving to the by-pass lane to pass a left-turning vehicle (Fig. 10). The other marking creates a left-turn bay and requires all traffic to move to the right; left-turning traffic then moves into the left-turn bay, as shown in Figure 11. This latter method seems safer and is the one preferred by many agencies.

Figure 8. Paved shoulder along two-lane rural highway used by vehicle to pass truck making a left turn into driveway entrance (note edge line stripe at main-lane pavement edge).

Figure 9. Paved right and left shoulders along multilane divided suburban arterial striped and marked for turns.

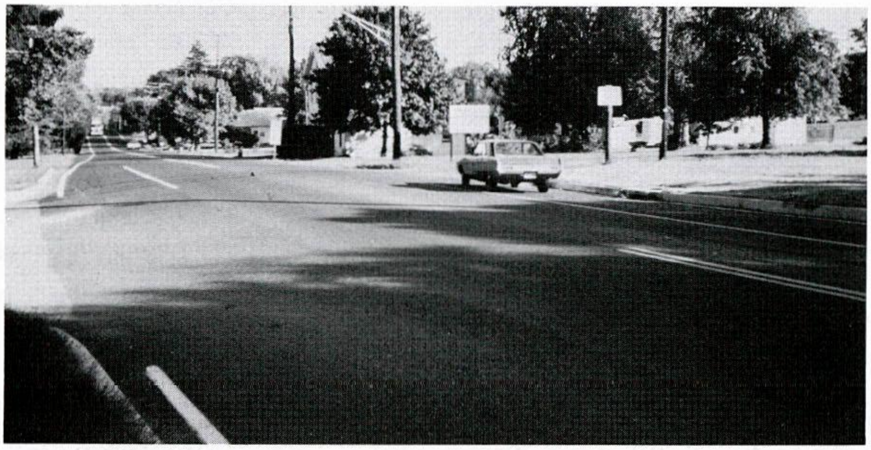


Figure 10. Paved shoulders along two-lane suburban highway striped for use as either right-turn lanes or by-pass lanes for left-turning vehicles.

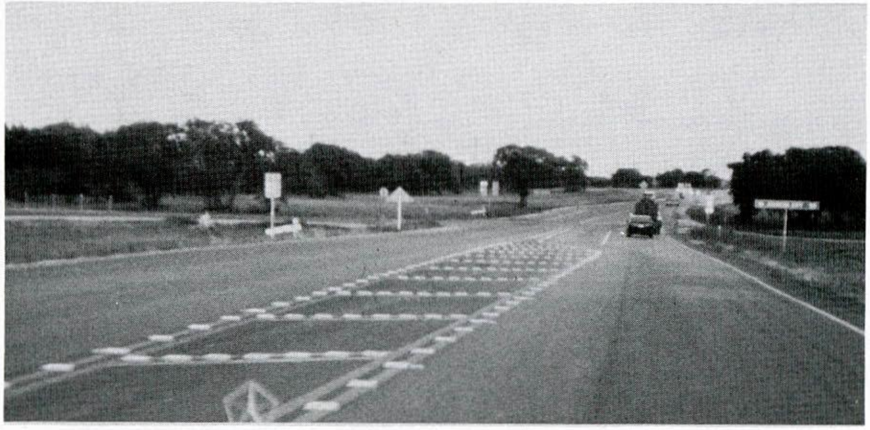


Figure 11. Pavement striping and marking shifts all traffic onto paved shoulder along two-lane rural highway to create left-turn bay.

Routine Maintenance

Highway shoulders are commonly used during routine highway maintenance operations. In most instances, such operations require the temporary closing of portions of shoulders. Shoulder closing standards have been developed by the agencies for the safety of the traveling public and of maintenance personnel.

Because utilities are generally not permitted within the rights-of-way of freeways and other controlled access highways, routine maintenance of utilities is not normally a concern on these facilities. Utilities are usually permitted, however, in all other types of roadway rights-of-way. Provisions for routine maintenance of these utilities are normally defined in the standard permits governing the use of highway rights-of-way by other utilities (18, 48, 59). Utilities are required to use the same warning signs and protection devices as used by the highway agencies.

Snow Storage

In regions where snowfalls are sufficient to require plowing, highway shoulders are used for both temporary and/or permanent storage of snow that is plowed from traveled lanes. In areas where snowfalls total up to about 40 in. during about 10 to 15 storms per season, most agencies maintain sufficient equipment to ensure removal of stored snow from shoulders during the second plowing. Where seasonal snowfalls total between about 40 and 100 in., most agencies maintain capacity to remove temporarily stored snow from shoulders shortly after each storm.

In many mountainous and north-central regions, total snowfalls exceed 300 in. per season. Agencies in these regions have developed warrants for snow removal that allow temporary storage of snow on shoulders until manpower and equipment are available, permanent storage on other routes (Fig. 12), or road closure on a few other routes. (See Adddendum to NCHRP Report 254 for further details of specific practices in Idaho, a state with heavy snowfall.)

Several states designate sections of shoulders to permit vehicles to stop and put on or remove tire chains along "chain only" routes.

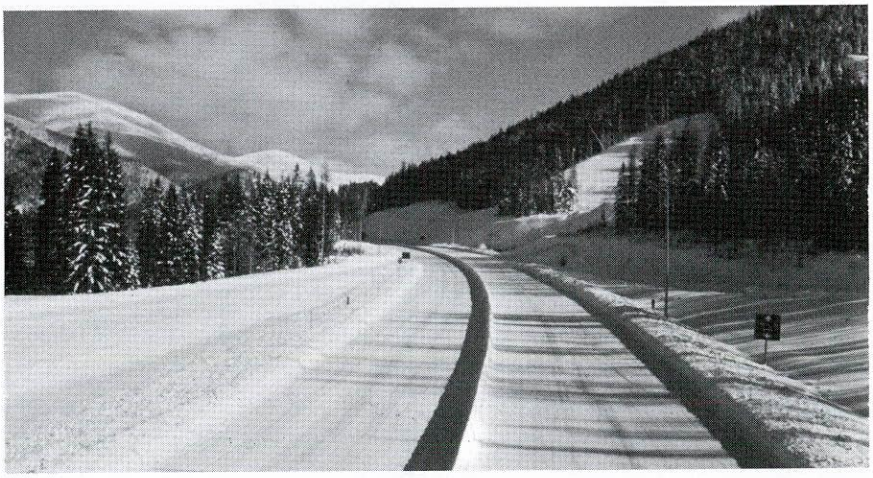


Figure 12. Permanent snow storage on shoulder of four-lane divided freeway in mountainous region.

Arid Areas
(Temperature and Sand Considerations)

Shoulders are commonly used in desert regions for stopping of overheated vehicles. Water barrels are sometimes provided for servicing these vehicles. This results in repetitive use of specific shoulder areas and the resulting accelerated damages to shoulders by heavy wheel loads.

Although blowing sand in arid regions can be compared to snow problems in other areas, the sand must be removed from the highway because no-one routinely stores sand on highway shoulders. Highways must be free of all obstructions such as curbs, bridge parpapets, and guardrails and roadway grades set higher than the surrounding terrain so that the sand will blow completely across the highway.

Major Reconstruction and Maintenance

To maintain traffic service on high-volume freeways and arterials, shoulders are sometimes converted to serve as temporary traffic lanes during maintenance and/or reconstruction operations that require closing of main lanes, as shown in Figure 13. Use of shoulders as detour traffic lanes requires careful planning, especially of traffic control, tailored to each specific project. Anticipating such use of shoulders during initial project design, or during major redesign, can greatly facilitate conversion of shoulders to temporary traffic lanes. Examples of such uses and special traffic controls were observed in many of the sampled states. Although general guidelines are available, each specific location requires careful study for success.

Reconstruction of bridge decks typically requires the temporary use of highway and bridge shoulders to maintain an acceptable level of service on high-volume urban facilities.

Figure 13. Reconstruction of the Eden's Expressway in Chicago used the existing three lanes and shoulder of one roadway to maintain two lanes of traffic in each direction.

Off-Tracking

Off-tracking is defined as the inadvertent or careless running of vehicle wheels closely along, or beyond, the edges of highway pavements. While this usually results in serious deterioration of main-lane pavement edges in locations where shoulders do not provide structural edge support to main-lane pavements, repetitive off-tracking can also seriously damage shoulders that are constructed with less than full strength pavements. This problem is usually severe in energy producing and agricultural regions of the country, because many highways are narrow two-lane roadways with unpaved shoulders. Table 4 summarizes shoulder designs and maintenance procedures practiced by the agencies to accommodate off-tracking.

Table 4. **Off-tracking: shoulder design and maintenance.**

Agency	PAVED SHOULDER DESIGN			OTHER SHLDR. DESIGNS		MAINTENANCE PROCEDURES			
	Full Pavement Depth	2 Ft or more of Full Depth Pavement	Less than Pavement	Granular	Turf	Const. 1-Ft to 2-Ft Asphalt Strip	Extent Resurf 1 Ft to 2 Ft	Pave or Coat	Add Material and Grade
Arkansas	-	-	Yes	Yes	-	Yes	-	-	-
Baltimore Co.	Yes[1]	-	Yes	-	-	-	-	-	-
California	-	-	Yes[2]	Yes	-	-	Yes	-	Yes
Connecticut	Yes	-	-	-	-	-	-	-	-
Georgia	-	-	Yes	-	Yes	Yes	-	-	-
Idaho	Yes	-	-	-	-	-	-	Yes	-
Illinois	-	-	Yes	Yes	-	-	-	Yes	-
Lake County	Yes	-	-	-	-	-	-	-	-
Maryland	-	Yes[3]	Yes	Yes	-	-	-	Yes	Yes
Nebraska	-	-	Yes	Yes	Yes	-	-	-	Yes
New Mexico	Yes	-	-	-	-	-	-	-	-
New Orleans	Yes	-	-	Yes	-	-	-	-	-
New York	-	-	Yes	-	-	-	Yes	Yes	-
North Carolina	-	Yes	Yes	Yes	Yes	-	-	-	Yes
Texas	-	Yes	Yes	-	Yes	-	-	Yes	Yes
West Virginia	-	-	Yes	Yes	-	-	-	Yes	Yes

1 Only with curbed sections.

2 Use 2 percent of truck volumes.

3 Ten-year projection of 500 trucks per day one way, pavement extended 2 ft. Minimum of 4-in. bituminous concrete if highway truck volume exceeds 500 ADT.

Encroachment

Encroachment is defined as the use of shoulders or adjacent roadway areas by special-purpose vehicles that may be too wide to operate in normal highway traffic lanes. Local uses by wide farm equipment (and in a few locations, horse-drawn equipment) in agricultural areas, on low-volume roads, or near towns and cities where such equipment is serviced, are usually uncontrolled by highway agencies. Few problems with such uses are reported, however, because local motorists willingly accommodate this traffic, and any resulting damages to shoulders are handled as normal maintenance items.

More specialized uses, most commonly by the mobile-home industry (in some areas widths of 14 ft to 16 ft), and other special oversized industrial hauling, are strictly regulated (Fig. 14). Because permits are usually required to operate on selected routes, where shoulder pavements are adequate for such uses, abnormal pavement damages or threats to public safety do not usually result from this use of highway shoulders.

Figure 14. Typical encroachment of wide load onto paved shoulder along freeway.

Slow-Moving Vehicles

Where adequate shoulders are provided on two-lane highways, slow-moving vehicles often operate on shoulders as a courtesy to safely allow passing by faster moving vehicles. It is interesting to note that this maneuver is permitted by law nearly everywhere in some states (e.g., Texas), only where signed in others (e.g., Washington) and prohibited in others (e.g., New Mexico). One agency reported an unacceptable shoulder use for passing slow-moving vehicles where the high-speed vehicle passed to the right of slower moving vehicle. "Do Not Drive On Shoulder" signs were erected to control this illegal use.

On long ascending grades with high volumes of slow-moving vehicles, shoulders are often strengthened and used as climbing lanes. Special markings and signing (Fig. 15) are usually required for satisfactory conversions of shoulders to climbing lanes. Other uses of shoulders by slow-moving vehicles (i.e. farm equipment and wide loads) were previously noted in the discussion of "Encroachment".

Figure 15. Paved shoulder along two-lane rural highway converted to climbing lane (note tapering of edge line stripe and advisory sign "SLOWER/TRAFFIC/KEEP/RIGHT").

The conversion of shoulders to passing lanes is used by agencies to relieve queuing caused by slow-moving vehicles and operates similar to climbing lanes except they normally are used along two-lane roads with few passing zones. Turnouts may be constructed along mountainous routes with narrow shoulders to also relieve this queuing.

Several agencies have designed and constructed a combination shoulder - climbing lane. Because only slower moving traffic uses the combined lane, the 14- to 16-ft wide lane provides sufficient room for slower moving vehicles to pass stopped vehicles.

Pedestrians

The use of shoulders on freeways and other controlled access highways by pedestrians is prohibited by laws in most states. Although such routes are usually fenced and signed, enforcement of antipedestrian statutes is difficult. Habitual violators are hitch-hikers, and where patrolling is infrequent motorists either hitch-hike or walk for mechanical assistance. Some states, however, allow hikers on freeways for short distances if alternative routes are not convenient.

Pedestrians are normally allowed on all other highways, and where sidewalks are not provided they use the shoulders. Joggers are persistent users of all classes of highways and normally expect to be accommodated even where adequate shoulders are not provided (Fig. 16).

Pedestrian fatalities on shoulders account for significant numbers of all pedestrian fatal accidents. Of a total of 141 fatalities on the state freeway system in 1980, California reports that 27 percent involved pedestrians on shoulders. Of a total of 2,390 pedestrian accidents on the entire statewide highway system in 1980, Georgia reports that 7 percent involved pedestrians on highway shoulders.

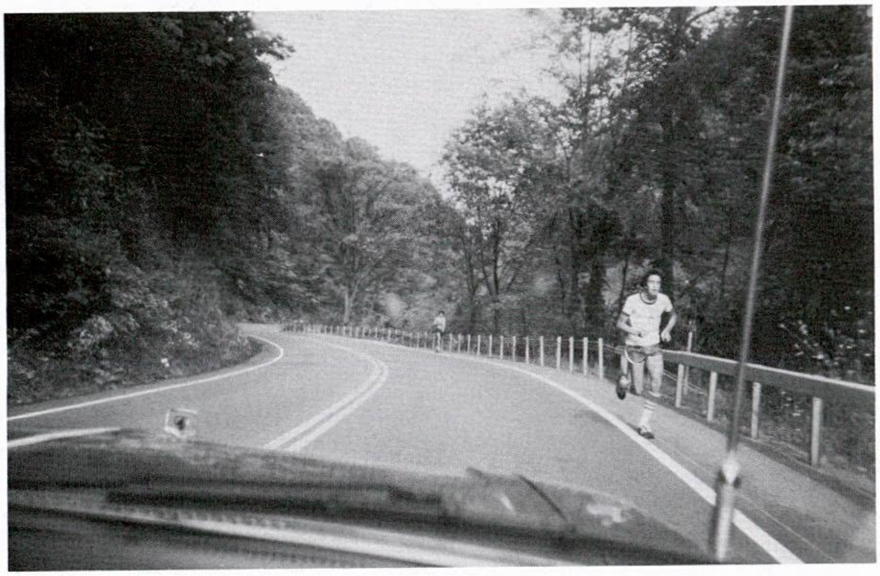


Figure 16. Jogger continues along edge line of narrow paved shoulder of two-lane rural highways, even as a vehicle approaches.

Bicycles

Except for freeways, bicycles are generally allowed on streets and roadways throughout the country. In some locations, if no other feasible routes are available, bicycles are also allowed on specified segments of freeway shoulders.

Although bicyclists may legally operate within main lanes on most roadways, they generally prefer to use paved shoulders if suitably smooth shoulder surfaces are provided. Normally, only carefully planned bicycle routes are designated as such where demands warrant. California has determined (45) that it is inappropriate to designate highway shoulders as bicycle routes where bicycle traffic is light.

Shoulders designated as bike routes are normally marked with a 4-in. white painted stripe. Several agencies require a minimum of 2-ft separation between the shoulder edge stripe and the bike-lane stripe, which provides a safer operation of the bike lane. Signing includes the upright "Bike Path" sign and several painted messages and decals on the bike path such as "Bike Lane," "Bike Only," a bicycle decal or a diamond shape which (although observed) is not considered appropriate, as it seems to conflict with the "High Occupancy Vehicle Lane" designation. Painted arrows in the bike path are also used to denote the direction of a one-way bike route.

Mass Transit

On bus transit routes, buses normally stop on shoulders or curb lanes in urban areas to take-on and discharge passengers. On improperly designed pavements, this repetitive use by these heavy vehicles results in rutting and/or rolling of asphalt pavements. To correct this, some agencies construct concrete stopping pads at transit stops. On suburban routes where roadway shoulders are not paved, buses normally stop on main-lane pavements. This, of course, results in blocking of traffic and damage to unsupported edges of main-lane pavements.

Transit stops have been established by some agencies on the shoulders of collector - distributor roads of freeway interchanges. Walkways and steps provide passengers access to the secondary highway.

Properly designed shoulders on freeways and major arterials are often converted to full traffic lanes for use by high occupancy vehicles (HOV). These lanes are designated as such by special marking and signing (Fig. 17), which reserves them for exclusive use by buses, vans, and loaded passenger cars.

In states which require that school buses stop at all railroad grade crossings, adjacent shoulder pavements on high-volume routes may be strengthened and widened to provide safe stopping of school buses without impeding other traffic.

Figure 17. Use of right shoulder along elevated freeway for "Buses and Carpools Only" (note diagonal striping and diamond pavement markings).

Full Running Lanes—Nonfreeways

As traffic volumes on two-lane urban arterials approach 10,000 ADT, public demands for improved traffic service often result in upgrading shoulders and converting them to additional running lanes. It is usually expedient and economical to convert two-lane highways with shoulders to three-or four-lane roadways without shoulders, and four-lane highways with shoulders to five-or six-lane facilities without shoulders. Center lanes of converted three- and five-lane arterials are usually operated as continuous left-turn lanes or as reversible running lanes during morning and afternoon peak hours. Other agencies prohibit parking in the curb lane during rush hours and operate the curb lane as a traffic lane.

Shoulders that are converted to full running lanes in this manner lose their identity as shoulders. Designers must then weigh the needs and advantages of providing additional shoulders against the costs of additional rights-of-way on project-by-project basis. The converted shoulders provide a quick and inexpensive method of temporarily increasing the capacity of the highway facility.

Studies by Turner et al. (57) have determined that total numbers of accidents are reduced by converting shoulders to full traffic lanes on two-lane arterials only when traffic volumes exceed 3,000 ADT.

Full Running Lanes — Freeways

To maximize use of existing facilities at minimal cost and provide improved traffic service, approximately 75-miles of urban freeway shoulders in 11 metropolitan areas have been converted for use as either full-time (Fig. 18) or part-time traffic lanes (Fig. 19). McCasland and Biggs (38) identify common freeway operational problems that may be solved by converting shoulders to traffic lanes for relieving overloading of existing lanes, for by-passing queues on main lanes to relieve bottlenecks, for relieving merging conflicts, for allowing preferential HOV operations, and for maintaining traffic through construction sites.

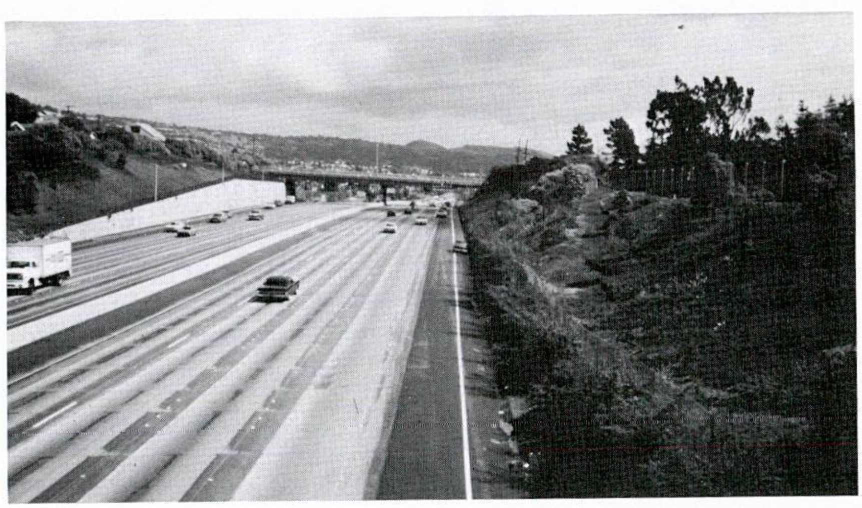


Figure 18. Freeway shoulder conversion: four existing 12-ft wide lanes and paved right shoulder converted to five 11-ft wide lanes and narrow right shoulder. Median shoulder not used. Raised pavement markers used to delineate traffic lanes.

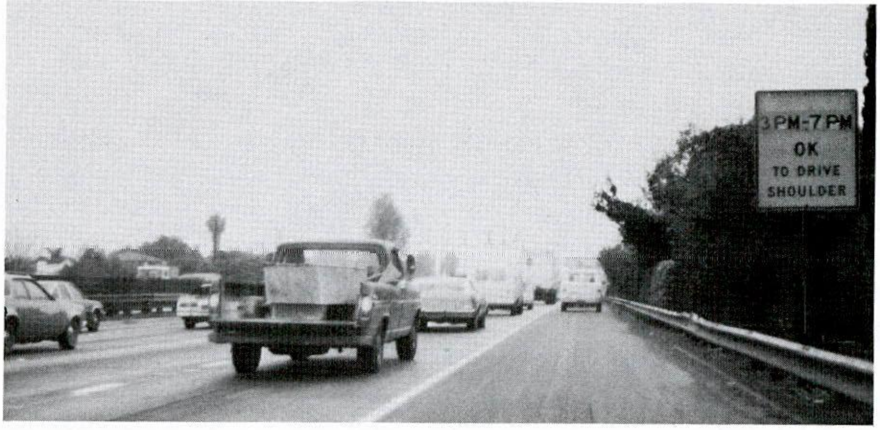


Figure 19. Permissive use of shoulder as a running lane, "3PM-7PM/OK/TO DRIVE/SHOULDER" (note normal white edge line stripe at edge of main lanes).

The conditions that usually govern the use of freeway shoulders as running lanes are listed in the following; the general rule, however, is that such conversions must have potentials for reducing greater numbers of congestion-related problems and accidents than will be produced by the resulting lack of full shoulders for normal shoulder uses.

Conditions of Use

The following indicate some of the conditions under which the interviewed agencies consider converting freeway shoulders to running lanes.

- Shoulder conversions should not be used to provide extra travel lanes along freeways for distances greater than about 2 miles.
- Shoulder conversions should be considered if AM or PM peak periods begin to exceed 3 hours in duration.
- Shoulder conversions should use the median shoulder when practical, and retain the right shoulder for emergency stopping unless there is ample graded width beyond the right shoulder to provide additional shoulder areas.
- Shoulder conversions should provide long-term solutions to the congestion problems.
- Ramp metering during peak periods should be considered as a part of the overall traffic control plan to improve the effectiveness of shoulder conversions. At locations with limited ramp geometry, it may be necessary to close an entrance ramp to permit smooth traffic operations along the main lanes.
- To solve local ramp merging traffic problems, shoulder conversion should be between two interchanges -- three at the most (right shoulder normally used in these cases).
- To solve local exit ramp traffic congestion caused when the local street system cannot absorb the ramp traffic, main-lane right shoulders and ramp shoulders may be converted to traffic lanes.
- Shoulder conversions should not transfer congestion to other locations along freeway routes.
- Shoulder conversions should reduce more "congestion" accidents than induce "lack of shoulder" accidents.
- If sufficient graded areas do not exist, turnouts should be constructed at available areas for emergency use.
- Surveillance of traffic operations on shoulder conversion is necessary to ensure maximum effectiveness.

If space is available, median shoulders are normally converted to full traffic lanes when needs for additional lanes arise. This practice maintains existing right lanes, including ramp connections and right shoulders for normal uses (Fig. 20). Conversions of right shoulders are more acceptable if sufficient additional space is available within existing rights-of-way to permit emergency stopping beyond converted shoulders (Fig. 21).

Six studies of freeway segments on which shoulders have been converted to running lanes were reviewed (19, 20, 37, 44, 52, 54). Three studies report substantial reductions of accident rates, while one reports no change in accident rates. Two report some increases in accident rates after conversion. All report, however, that the goals of increasing traffic capacities were achieved and that reduced lane widths could not be identified as contributing to increases in accidents.

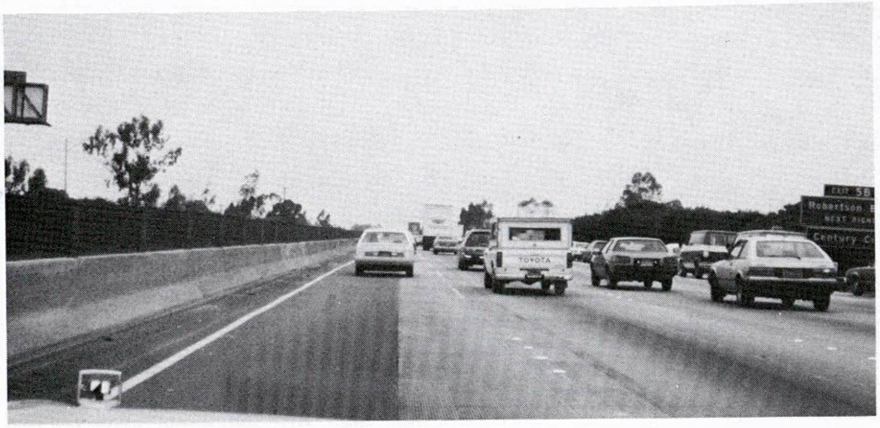


Figure 20. Conversion of the majority of the median shoulder to full running lane retains right shoulder.

Figure 21. Acceptable conversion of right shoulder to full running lane because of ample flat graded area between freeway and frontage road (note pavement deterioration at old shoulder - main-lane joint).

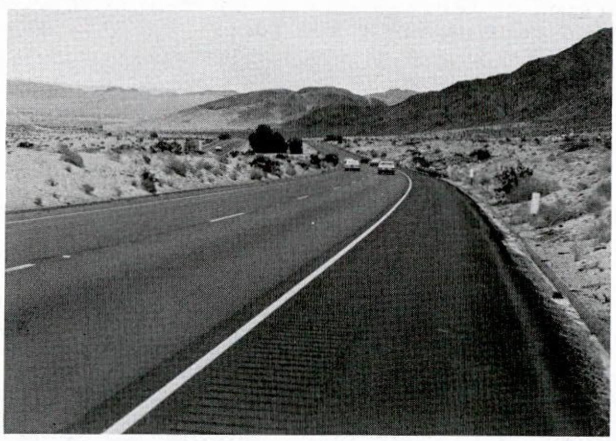
Errant Vehicles

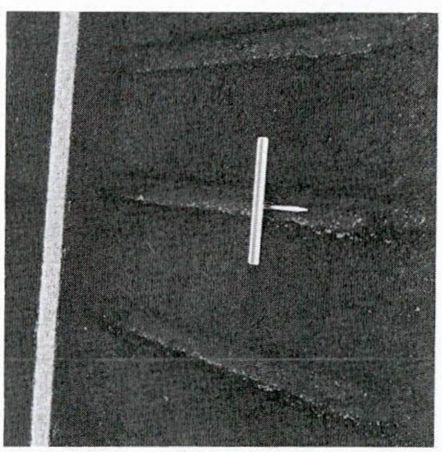
Shoulders provide important recovery areas for vehicles that inadvertently leave the traveled lanes. More importantly, however, shoulders also provide valuable maneuvering space for vehicles that may be performing emergency maneuvers to avoid accidents, or that may be experiencing mechanical problems such as loss of brakes or damaged tires.

Shoulders provide the first warning to the dozing driver that the vehicle has left the main-lane. Although contrasting pavement textured surfaces have been the principal method of providing audio signal to the inattentive driver, only a few agencies are now using textured shoulders or rumble strips. Because pavement contrasts are difficult and expensive to maintain, most agencies only provide texturing or rumble strips at high run-off-the-road accident locations.

In July 1982, the California DOT published their report on shoulder rumble strips along Interstate Route 15 and 40 (29). The rumble strips were constructed during resurfacing operations at a cost of approximately $0.05 per foot, as shown in Figure 22. The analysis of accident data, using one-year before-and-after studies with controlled sections, reports 16 percent reduction in overall accidents and 52 percent reduction in run-off-road accidents.

Run-away trucks on long downgrades in mountainous regions create special problems that can only be partially solved by use of shoulders. In especially sensitive locations, shoulders may be converted to serve as portions of carefully designed escape ramps. These ramps serve to guide run-away vehicles out of main-lane traffic to level areas or upgrades as terrain permits, where controlled thickness of loose gravel or other means to stop such vehicles are provided. Other agencies sign and mark shoulders for all trucks to stop and check brakes prior to descent of long grades.





(Detail of impressions)

Figure 22. Rumble strips along Route 15 in California, installed in fresh asphalt overlay by means of bars welded onto modified roller. Impressions are 3-ft wide, 1 1/2-in. deep, spaced 8-in. apart and semicircular in shape.

Emergency Vehicle Travel

Shoulders provide important access by emergency vehicles, especially during peak periods on high-volume routes. Main-lane traffic temporarily occupies shoulder areas to allow emergency vehicles to pass, or emergency vehicles use shoulders to avoid congestion on through-traffic lanes.

Law Enforcement

All types of shoulders are commonly used by law enforcement agencies for stopping violators and for temporary use by surveillance vehicles. Extra shoulder widths and full strength pavements are sometimes provided at selected locations for use of weigh-crews in the enforcement of truck weight and size laws (see Fig. 23).

Emergency Call Service

Call boxes to summon emergency assistance are usually only located adjacent to shoulders along high-volume urban freeways. A limited number of agencies have installed call boxes along rural freeways. Public telephones, for emergency and other uses, may be located adjacent to shoulders on arterials and other types of highways. Shoulders are typically used for parking in the vicinity of these services.

Roadside Sales

Shoulders are commonly used for parking in rural and residential areas to allow motorists access to fruit and vegetable stands, flea-markets, and yard sales, which are operated either on roadway rights-of-way or on adjacent private properties. Such

Figure 23. Use of specially constructed shoulder by enforcement agency to weigh (portable scales) and measure trucks.

temporary or intermittent activities are usually not discouraged or controlled unless the safety of the traveling public is threatened by particular activities.

Larger commercial activities, such as live-stock sales, create special problems in some areas and typically require wide shoulders and parking supervision.

Garbage Pick-Up

Because refuse vehicles routinely produce some of the heaviest single-axle loads which must be accommodated, serious maintenance problems result unless full strength pavements are provided on shoulders and curb lanes where garbage collections occur on a regular basis.

SHOULDER OCCUPANCY DATA

This section summarizes shoulder occupancy data collected along six commuter highways in the Baltimore Metropolitan area. Because shoulder use affects both traffic safety and shoulder wear, shoulder occupancy data were collected as a part of NCHRP Project 1-22.

The purpose of this limited shoulder occupancy study was to determine the number of vehicles that a driver might encounter parked on the shoulder during one pass along a highway in the peak hour. In addition, this study attempted to determine the relative frequency of left- and right-shoulder use for both mechanical and non-mechanical related stops. As described in Appendix G (see Addendum to NCHRP Report 254), this study consisted of limited sample sizes and, therefore, limited statistical analyses. The results, however, indicate the need for a new and comprehensive study of shoulder occupancy -- as it affects traffic safety and shoulder pavement design (strength).

Literature Review

Prior to the late 1950's, the use of highway shoulders for leisure and emergency stops was not a major concern of highway engineers. In 1957, Taragin (56) published an article entitled "Role of Highway Shoulders in Traffic Operation," which, although primarily concerned with the effect of shoulders on traffic operations, included some data on the frequency of shoulder use. With these data, Taragin was able to determine a relationship between shoulder usage and highway capacity and safety.

Following Taragin's study, Bellis (7) published an article in 1958 entitled "Shoulder Use," which discussed the results of a study performed in 1947 and 1948 for the New Jersey State Highway Department to determine the frequency of shoulder uses for leisure and emergency stops along state highways. General discussions of this study at the 1958 Highway Research Board meeting pointed out the need for additional studies to determine to what extent leisure and emergency shoulder stops should be provided for, or prohibited, on various highway systems.

As a result of that discussion at the HRB meeting, the Traffic Surveys and Study Section of New York's Bureau of Highway Planning scheduled a study of driver behavior to collect and analyze information pertaining to highway shoulder occupancy. Results of this study were presented by Billion (8) in an article entitled "Shoulder Occupancy on Rural Highways." Included as the "Discussion" at the end of the Billion article, Blensby, Planning Survey Engineers, and Byars, Supervising Statistician, Oregon State Highway Department, discussed data obtained from the 1958 Oregon survey on shoulder use on the Baldock Freeway. The Oregon Study was the first study which involved a major freeway as the study section.

As a part of a study to determine the benefits of a motorist aid system along I-80 in Illinois, Illinois DOT conducted an intensive stopped-vehicle survey in late 1969 and early 1970 (43). Data were collected along 9 miles of this route similar to Billion's study (8). The range in the number of vehicle-miles per stopped vehicle compares variably with the New York data (8) during the winter and with the Oregon data (8 - Discussion) during the summer.

Conclusions

The following conclusions, based on the observations and findings of the limited NCHRP Project 1-22 study of shoulder occupancy, are compared to the Bellis, New York, Oregon, and Illinois studies.

1. No significant difference in shoulder usage was observed between the AM and PM peak hours. This finding is generally supported by the New York (Billion) and Illinois (Pekala) studies.

2. Along the six study sections investigated by this NCHRP Project 1-22 study, mechanically related stops occurred much more frequently than the nonmechanically related stops. This conclusion is supported by the Illinois (Pekala) study.

The Bellis and New York (Billion) studies concluded the opposite. The ratio of leisure to emergency stops for the Bellis study was 24.6 to 1 and for the New York study 4.3 to 1. One possible reason for this contradiction is that the six routes analyzed by the Project 1-22 study are primarily commuter routes, consisting of short trips, where leisure stops are seldom needed. The routes analyzed in the Bellis and New York studies were primarily rural highways, where the majority of trips are not work related. (The New York study estimates that 36 percent of the total daily trips are work related).

3. Approximately 91 percent of the stopped vehicles used the right shoulder and 9 percent used the left shoulder. This was typical along all six routes studied. Motorists use the right shoulder more often because in most cases it is wider than the left shoulder and provides a safer location to park the vehicle. There is no mention of use between the left and right shoulders by the Bellis, New York, Illinois, or Oregon studies.

4. The Bellis and Illinois (Pekala) studies were the only studies able to accurately tabulate the numbers of stopped vehicles during specific time periods within the study limits. According to the New York, Oregon, and NCHRP 1-22 studies, the actual numbers of stopped vehicles on shoulders during the times analyzed would probably be somewhat greater than what was observed. The Oregon study indicated that approximately 25 percent of the stops were not observed by mobile observers. Based on Oregon's experience, there is a possibility that the analyzed stops on the New York sections could be only 65 to 75 percent of the total stops. The NCHRP 1-22 study was unable to determine the percentage of total stops along each route because the procedure used determined only the number of vehicles stopped on the shoulder which a single passing vehicle is likely to encounter.

CHAPTER THREE

INTERPRETATION, APPRAISAL, APPLICATION

INTRODUCTION

A comparative review of Review Draft #2A of the AASHTO publication "A Policy on Geometric Design of Highways and Streets" (1) with the earlier Redbook "A Policy on Design of Urban Highways and Arterial Streets -- 1973" (3) and Bluebook "A Policy on Geometric Design of Rural Highways -- 1965" (4) confirms today's increased emphasis on maximizing the transportation capabilities of the nation's highway and street system. As summarized in Appendix B, "AASHTO Shoulder Design Policy," AASHTO's broadened list of shoulder "advantages" (uses) reflects some of the focus of this research project. "Additional emphasis has been placed on the joint use of transportation corridors by pedestrians, cyclists and public transit vehicles.... Cost-effective design is also emphasized." (1, pp i-ii).

The following two sections discuss the adequacy of AASHTO design standards and policies in regard to the shoulder uses identified in NCHRP Project 1-22. While the majority of the shoulder uses are adequately provided for by AASHTO, there are several other specific and localized uses of highway shoulders that are either inadequately provided for or not discussed by AASHTO. This omission is primarily because the new AASHTO publication addresses new highway designs and major reconstruction (1, p.i), and, therefore, does not consider the possible uses of highway shoulders as temporary solutions to traffic congestion problems.

This chapter also includes Table 5, which presents acceptable and optimal geometric design, signing/marking, and conditions of use guidelines for shoulder uses on freeways, arterials, and collectors and locals.

This chapter concludes with suggested limitations on uses of these shoulder guidelines (Table 5).

SHOULDER USES ADEQUATELY PROVIDED FOR BY AASHTO

The following shoulder uses, identified in NCHRP Project 1-22, are adequately provided for by AASHTO design standards and policies:

Emergency Stopping (mechanical difficulty)

Parking (commercial and residential, recreational, and leisure, park-and-ride)

Mail and Other Deliveries

Routine Maintenance

Arid Areas

Off-tracking

Encroachment

Pedestrian

Bicycles

Mass Transit

Full Running Lanes -- Nonfreeways

Errant Vehicles

Emergency Vehicle Travel

Emergency Call Box Service and Telephones

Garbage Pickup

As evident from this list, the identified shoulder uses consist typically of "traditional" shoulder uses such as emergency stopping, mail deliveries, off-tracking, etc., and "newer" uses such as full running lanes along nonfreeways and emergency call box and telephone services. In addition, the increased emphasis on accommodating pedestrians and bicyclists along transportation corridors adequately addresses the use of shoulders to serve these demands.

Snow storage, although explicitly stated in AASHTO (1, p. IV-9), is not fully addressed, especially in areas of the country with high snowfall (in excess of 100 in. per year). Based on the findings of this research, snow removal is an extremely costly portion of many agency's maintenance budgets, and snow removal policy, especially for shoulders, must be tailored to suit the resources available. It would be desirable to include a brief discussion in AASHTO of the snow removal practices and the use of shoulders for putting on or removing chains within a state with heavy snowfall.

SHOULDER USES NOT DISCUSSED BY AASHTO

The following shoulder uses, identified in NCHRP Project 1-22, are not discussed by AASHTO design standards and policies. Based on the findings of this research, it would be desirable to include consideration of these shoulder uses in AASHTO's "A Policy on Geometric Design of Highways and Streets" (1).

Truck Parking Along Highway Shoulder

Although AASHTO adequately addresses "normal" emergency stopping (for mechanical difficulty) for all vehicles, including trucks, this research identified one important parking emergency use of highway shoulder that is not included in AASHTO. This use, stopping at the top of long upgrades or downgrades, occurs primarily along freeways and major arterial highways in areas of rolling or mountainous terrain. Because this repetitive use by heavily loaded vehicles quickly deteriorates normal highway shoulders and presents safety problems to the adjacent lane of traffic (14), consideration should be given to wider and stronger shoulders at these locations.

Turning and/or Passing at Intersections

Although the discussion of "At-Grade Intersections" in Chapter IX fully covers all of the traffic movements identified in this research, it would be desirable if specific consideration were included to address the use of shoulders as auxiliary lanes. The dual uses of this pavement area as both auxiliary lanes and shoulders for low to moderate volume intersections would reduce construction costs.

Major Reconstruction and Maintenance Activities

The use of highway shoulders for major reconstruction and maintenance activities is obviously not covered in AASHTO's publication on design of new highway facilities. Because the AASHTO publication serves as the primary reference book for highway designers, it would, however, be desirable to briefly discuss these uses and reference several of the pertinent NCHRP reports on this subject.

Slow Moving Vehicles

Although AASHTO fully discusses and provides warrants for full climbing lanes and combination climbing lanes/shoulders, the use of shoulders for dedicated climbing lanes (with no adjacent shoulder) is not considered. The Texas and Washington experiences with the use of shoulders by slower moving vehicles to permit passing on any terrain require additional study before consideration by AASHTO.

Full Running Lanes — Freeways

While it is true that the geometric design values contained in the AASHTO publication "will provide more satisfactory design for... major modification of the existing facilities" (1, p i), these design values are often not cost-effectively achieved when major urban freeways are being modified to increase capacity. This research further documents the successes several metropolitan highway agencies have had in both the full time and permissive use of freeway shoulders to reduce congestion and improve safety. Although clearly not a panacea for the problems of the urban freeway, it can provide temporary solutions to urban freeway congeston problems.

Law Enforcement

One aspect of law enforcement that is not included in the AASHTO publication is the use of highway shoulders by truck weighing crews to measure and weigh trucks. Crews with either portable or semiportable scales frequently use shoulders to enforce truck size and weight limits, and consideration of wider and stronger shoulders at selected locations for this use should be included in AASHTO.

Roadside Sales

The use of highway shoulders by vendors for nearly everything from "apples to sinks" is rapidly increasing. This use, which could develop into a safety problem, requires better enforcement of current statutes and accommodation of this use at locations beneficial to both the seller/buyer and the highway agency.

SHOULDER GEOMETRIC AND USE GUIDELINES

Table 5 presents "acceptable" and "optimal" geometric design data and signing/marking and conditions of use guidelines for the shoulder uses identified in NCHRP Project 1-22 for use on freeways, arterials, and collectors and locals. The following data are included in this table:

- Right Shoulder Width - in feet (SI: 1 foot = 0.305 meters)

  Where relevant, traffic volumes (including necessary truck data) have been listed to further classify the geometric design data. Left-shoulder widths on divided highways would be in accordance with AASHTO (App. B).

- Shoulder Surface Type:

  T - Turf, including native soils
  S - Stabilized with gravel, shell, crushed rock courses
  P - Paved, asphaltic or concrete pavements including bituminous surface treatments

- Shoulder Strength:

  ND - Normal depth (traditional shoulder practice - if less than full depth)

  FD - Full main-lane pavement depth

- Shoulder Cross Slope (percent)
- Special Signing and Marking
- Conditions of Use (Remarks)

Although this table supports the overall project objectives of promoting greater uniformity in shoulder designs the salient finding of this research is that shoulder design must be carefully tailored to fit each agency's needs and budget. While shoulders and flat fore-slopes seem perfectly reasonable along almost any road in the open areas of New Mexico and Texas, simply finding a flat strip 16-ft wide to provide a local road is often nearly impossible in portions of rural West Virginia. It now seems evident that shoulder uniformity is probably only mandatory on freeways and other high traffic volume arterials, desirable on new or reconstructed arterials and collectors, and nice for new locals; but it is practically unattainable on many existing collectors and locals. This research further indicates that the optimal shoulder widths shown in the tables are goals, and existing right-of-way and/or terrain constraints may control the degree to which these goals are attainable. Each project must, therefore, be analyzed for traffic service and safety of operations on its own merit, and within the constraints that govern each individual project.

LIMITATIONS ON USES OF THE SHOULDER GUIDELINES

Table 5 presents acceptable and optimal shoulder geometric criteria for the specific shoulder uses identified in this research. While desirable, this table is clearly limited in the uniform application to all highways and shoulder uses in the country. As mentioned previously, achievement of shoulder use uniformity is simply not attainable on much of the country's existing highway network. For this reason, each highway agency must evaluate these guidelines in consideration of safety, economy, and maintenance.

Table 5: Shoulder Geometrics and Use Guidelines.

	FREEWAYS				ARTERIALS			
	ACCEPTABLE		OPTIMAL		ACCEPTABLE		OPTIMAL	
SHOULDER FUNCTION OR USE	WIDTH & SLOPE	TYPE & STRENGTH	WIDTH & SLOPE	TYPE & STRENGTH	WIDTH & SLOPE	TYPE & STRENGTH	WIDTH & SLOPE	TYPE & STRENGTH
ROADWAY & SHOULDER DRAINAGE	1' gutter 2%	P ND	10' 6% Max.	P ND	1' gutter 2%	P ND	8' 6% Max.	P ND
LATERAL SUPPORT OF MAINLANE PAVEMENT	18" 6%	P FD	3' 2%	P FD	18" 6%	P ND	3' 2%	P FD
EMERGENCY STOPPING (Mechanical Difficulty)	8' 12' with high truck volumes 6% Max.	S,P ND	10' 12' with high truck volumes 6% Max.	P ND	6' low to moderate volume highways 8' along high volume hwys. 6% Max.	T,S,P ND	8' low to moderate volume highways 10' along high volume hwys. 6%	S,P ND
PARKING								
• Truck stopping along or at the top of long upgrades and downgrades	10' if ADT less than 5,000 12' to 14' if ADT 5,000 or more 6% Max.	S,P ND P FD	12' if ADT less than 5,000 12' to 20' if ADT 5,000 or more 6% Max.	P ND P FD	10' if ADT less than 5,000 12' to 14' if ADT 5,000 or more 6% Max.	S,P ND P FD	12' if ADT less than 5,000 12' to 20' if ADT 5,000 or more 6% Max.	S,P ND P FD
• Stopping under bridges	This use should not be encouraged. Standard shoulder section should be carried under structure, and granular material placed between paved surface and ditch or toe of embankment.							
• Parking for recreational activities	This use not permitted - consider lots along adjacent routes or at interchanges				10' 6% Max.	T,S,P ND	10' 6% Max.	S,P ND
• Residential	This use not permitted.				8' 6% Max.	S,P ND	8' 6% Max.	S,P ND
• Commercial	This use not permitted.				10' 6% Max.	S,P ND	10' 6% Max.	S,P ND
• Park and ride	This use not permitted - consider lots along adjacent routes or at interchanges.				8' 6%	G,S,P ND	10' 6%	S,P ND
• Vehicle abandonment	Enact statutory provisions for removal of vehicles after a 24 to 48 hour time period.							
MAIL AND OTHER DELIVERIES	This use prohibited.				6' 6% Max.	S,P ND	8' 6% Max.	S,P ND
TURNING AND/OR PASSING AT INTERSECTIONS								
• Right turns	This use not permitted.				10' 6% Max.	P ND[a]	12' 2%	P F,D

FOOTNOTE

a) Sample life expectancy of existing paved shoulder pavement - if 5 years or greater, use as is; if less than 5 years, strengthen and repave.

COLLECTORS & LOCALS					
ACCEPTABLE		OPTIMAL			
WIDTH & SLOPE	TYPE & STRENGTH	WIDTH & SLOPE	TYPE & STRENGTH	SPECIAL SIGNING AND MARKING	CONDITIONS OF USE (REMARKS)
1' gutter 2%	P ND	6' 6% Max.	P ND	-	Shoulders designed to drain both surface and subsurface of roadway. "Valley" type paved shoulders may often serve this function for collectors and locals.
1' 6%	S,P ND	3' 2%	P FD	-	-
6'Min. along low to moderate volume hwys. 8'Min. along high volume highways 6% Max.	T,S,P ND	6'Min. along low to moderate volume hwys. 8'Min. along high volume highways 6% Max.	S,P ND	Highway departments and enforcement agencies should develop a procedure to service or remove disabled vehicles. This procedure can range from the informal monitoring by patrol cars to a formalized emergency network as employed along the freeway systems in many urban areas. In addition, this procedure should address hazardous wastes and spills.	
This use, which is not common on Collectors and Locals, may be accommodated by turnouts				Advance signing, break edge stripe line at entrance and exit to turnout.	Practice limited to very long upgrades, to permit vehicles to cool engines, check shifting cargo loads, etc., and on long downgrades to permit vehicles to check brakes. On downgrades, consider sign "All Trucks Must Stop to Check Brakes". If truck ADT 1,500 or more, consider offsite manned inspection stations.
8' 6% Max.	T,S,P ND	10' 6% Max.	S,P ND	Limits and duration of parking	-
7' 6% Max.	T,S,P ND	7' 6% Max.	S,P ND	Limits and duration of parking	Parking meters frequently used to limit use
8' 6% Max.	T,S,P ND	8' 6% Max.	S,P ND		
6' 6%	S,P ND	10' 6%	S,P ND	-	Consideration should be given to provide a minimum of 2' of clearance between traveled lanes and parked vehicles. If park and ride lots are located nearby, place notes on vehicles advising where lots are located.
2' 6% Max.	T,S,P ND	6' 6% Max.	S,P ND	The presence of mail or newspaper boxes provides the motorists with the best visual indication of use.	In lieu of full paved shoulders, mailbox turnouts could be provided (Fig. 7), or mailboxes could be grouped on the radii of driveway entrances or at special "common" turnouts for numerous users.
9' 6% Max.	P ND[a]	12' 2%	P ND[a]	Continue white edge stripe line along edge of paved surface, add white solid separation line and pavement turn arrows. Consider overhead signs and "Right Lane Must Turn Right" signs at high volume intersections	Use typically limited to intersections with high right turning volumes - consider establishing warrants (see reference 15).

Table 5: Shoulder Geometrics and Use Guidelines.

	FREEWAYS				ARTERIALS			
	ACCEPTABLE		OPTIMAL		ACCEPTABLE		OPTIMAL	
SHOULDER FUNCTION OR USE	WIDTH & SLOPE	TYPE & STRENGTH	WIDTH & SLOPE	TYPE & STRENGTH	WIDTH & SLOPE	TYPE & STRENGTH	WIDTH & SLOPE	TYPE & STRENGTH
TURNING AND/OR PASSING AT INTERSECTIONS (Continued)								
• Left turns on divided highways	Use limited to emergency vehicles							
	6' 6% Max.	S,P ND	10' 4%	S,P ND	10' 6% Max.	P ND[a]	12' 2%	P FD
• Left turns on undivided highways	Not Applicable				Widths shown are lane widths after conversion.			
					10' 6% Max.	P ND[a]	12' 2%	P FD
					Consider rehabilitation of existing shoulders to carry traffic loads and conversion of total paved roadway surface to a 3 or 5-lane roadway with continuous center left turn lanes.			
ROUTINE MAINTENANCE (Normal highway and utility maintenance activities)	8' 6% Max.	T,S,P ND	12' 6% Max.	S,P ND	8' 6% Max.	T,S,P ND	10' 6% Max.	S,P ND
	Routine maintenance for utilities is normally discouraged.							
SNOW STORAGE								
• Temporary	To some extent, temporary storage of snow occurs along nearly every route where there is snow. In most areas, the snow is cleared from the shoulder areas on subsequent passes of the snow plows or after the storm.							
• Permanent	In areas of high snowfall (typically 100" or more per year), shoulders are typically closed for the winter. Each state must gear its snow removal program to the economy of the state, service requirements of the populace, and the availability of manpower and equipment.							
ARID AREAS (Water barrels for overheating engines)	Where experience indicates that this use occurs, use shoulder geometric designs listed under "PARKING - Stopping at the Top of Long Upgrades".							
MAJOR RECONSTRUCTION & MAINTENANCE ACTIVITIES								
• Highway reconstruction and/or bridge decks - in urban areas	9' 6% Max.	P Adequate depth for anticipated traffic loads	12' 4%	P Adequate depth for anticipated traffic loads	9' 6% Max.	P Adequate depth for anticipated traffic loads	12' 4%	P Adequate depth for anticipated traffic loads
• Highway reconstruction and/or bridge decks - in rural areas	Use of shoulder to maintain traffic along rural highways is not typically required - normally the temporary loss of through travel lane is acceptable. At other locations, new traffic patterns are established and portions of the shoulder are used to maintain traffic.							

FOOTNOTE

a) Sample life expectancy of existing paved shoulder pavement - if 5 years or greater, use as is; if less than 5 years, strengthen and repave.

COLLECTORS & LOCALS					
ACCEPTABLE		OPTIMAL			
WIDTH & SLOPE	TYPE & STRENGTH	WIDTH & SLOPE	TYPE & STRENGTH	SPECIAL SIGNING AND MARKING	CONDITIONS OF USE (REMARKS)
9' 6% Max.	S,P ND[a]	12' 2%	P ND[a]	Continue yellow edge stripe line along edge of paved surface, add solid white separation line. Consider overhead signs and pavement turn arrows at high volume locations.	
Widths shown are lane widths after conversion 9' 6% Max.	P ND[a]	12' 2%	P ND[a]	Sign all traffic to bypass lane, paint median island, and provide "sheltered" left turn lane.	Consider rehabilitation of shoulders within the vicinity of the intersection to carry traffic loads and spread intersection approaches to provide for left turns.
6' 6% Max.	T,S,P ND	10' 6% Max.	S,P ND	These activities are normally completed in accordance with rather strict maintenance manuals and standards. Advance signing, flagmen and/or flashing arrowboards are used.	Activities generally limited to daylight, non-rush periods. Special care required at locations where equipment storage is required.
In areas of light snowfall, snow is often not cleared from any portion of the roadway until it melts.				Criteria that should be considered in establishing standards for snow removal include traffic volumes; accident reduction cost-benefit analyses; number of steep grades, sharp curves, intersections, ramps and other hazardous areas; and the availability of resources. In mountainous areas with high annual snowfall (300" or more), segments of local roads are often closed during winter.	
Collectors and Locals are not typically located in undeveloped arid areas.					
9' 6% Max.	S,P Adequate depth for anticipated traffic loads	11' 4%	P Adequate depth for anticipated traffic loads	Advance warning signs, diagrametric signs indicating lane shift; arrow boards at point of diversion; transition pavement marking and overhead signing; lane closure signs, traffic controls at entrance ramps, speed advisory signs, and other signing and marking as necessary.	Use limited to locations where the loss of a through travel lane would create intolerable peak period delay and reasonable parallel alternate travel routes do not exist. At other locations, new traffic patterns are established and portions of the shoulders are used to maintain traffic.

Table 5: Shoulder Geometrics and Use Guidelines.

	FREEWAYS				ARTERIALS			
	ACCEPTABLE		OPTIMAL		ACCEPTABLE		OPTIMAL	
SHOULDER FUNCTION OR USE	WIDTH & SLOPE	TYPE & STRENGTH	WIDTH & SLOPE	TYPE & STRENGTH	WIDTH & SLOPE	TYPE & STRENGTH	WIDTH & SLOPE	TYPE & STRENGTH
OFF-TRACKING Erratic driving, inside of sharp ramp or mainlane curves, or at channelized intersections	2' 6% Max.	S,P ND If truck ADT 500 or more in 10th year P FD	4' 6% Max.	P ND If truck ADT 500 or more in 10th year P FD	2' 6% Max.	S,P ND If truck ADT 500 or more in 10th year P FD	4' 6% Max.	P ND If truck ADT 500 or more in 10th year P FD
ENCROACHMENT (Due to wide load or wide vehicles)	2' 6% Max.	P ND	4' 6% Max.	P Nd	2' 6% Max.	P ND	6' 6% Max.	P ND
SLOW MOVING VEHICLES								
• Combination design for climbing lane/shoulder	14' 6% Max.	P FD	16' 2%	P FD	14' 6% Max.	P FD	16' 2%	P FD
• Conversion of shoulder to climbing lane	10' 6% Max.	P ND[a]	12' 2%	P ND[a]	10' 6% Max.	P ND[a]	12' 2%	P ND[a]
• Conversion of shoulder for passing zones	Not Applicable				10' 6% Max.	P ND[a]	12' 2%	P ND[a]
PEDESTRIANS	This use, which is generally not permitted on freeways, occasionally occurs along some freeways where alternate routes either do not exist or are too circuitous. In these few instances, pedestrians (primarily hikers) may travel the far right adge of the shoulder (6' min. width) or the foreslope. Any surface type is satisfactory for hikers. Signs are typically posted advising pedestrians about extent of shoulder usage.				4' 6% Max.	T,S,P ND	6' 6% Max.	P ND
BICYCLES	This use, which is generally not permitted on freeways, occasionally occurs along some freeways where alternate routes either do not exist or are too circuitous. In these few instances, bicyclists may travel on the far right edge of the shoulder (6' min. width). Shoulder surface should be paved and smooth (no contrasting surface texture). Signs are typically posted advising bicyclists about extent of shoulder usage.				4' 6% Max.	P Smooth ND	6' 6% Max.	P Smooth ND

FOOTNOTE

a) Sample life expectancy of existing paved shoulder pavement - if 5 years or greater, use as is; if less than 5 years, strengthen and repave.

COLLECTORS & LOCALS					
ACCEPTABLE		OPTIMAL			
WIDTH & SLOPE	TYPE & STRENGTH	WIDTH & SLOPE	TYPE & STRENGTH	SPECIAL SIGNING AND MARKING	CONDITIONS OF USE (REMARKS)
2' 6% Max.	P ND	4' 6% Max.	P ND	Consider placing edge stripe line on mainline pavement.	Width shown indicates minimum width of stabilized or paved shoulder, not total shoulder width. Another option would be to install curbs with 1' to 2' offsets from ramp lanes.
2' 6% Max.	S,P ND	6' 6% Max.	P ND		Width and strength depend on type and frequency of encroaching vehicles. Vehicles with wide loads require permits - routes with adequate shoulders can be selected.
14' 6% Max.	P ND	16' 2%	P FD	Sign "Slower Traffic Keep Right", edge line stripe at 12'.	See AASHTO Warrants (1, Chapter III). Combination design provides a good ecomonical solution to separate high and low speed traffic.
9' 6%	P ND	12' 2%	P ND[a]	Shift all traffic right, sign "Keep Right Except to Pass".	See AASHTO Warrants (1, Chapter III). This design is generally only necessary on existing facilities with high ADT's and/or high truck ADT's.
9' 6% Max.	P ND	12' 2%	P ND[a]	"All Traffic Keep Right Except To Pass".	In accordance with AASHTO criteria (1, Chapter III), the entire paved roadway surface could be restriped to provide for the widened section.
4' 6% Max.	T,S,P ND	6' 6% Max.	T,S,P ND	Special signing in school zones or along hiker trails.	Consider sidewalks and other separated pedestrian walkways along facilities with high pedestrian volumes.
4' 6% Max.	P Smooth ND	6' 6% Max.	P Smooth ND	Signing in accordance with MUTCD, but in no case should left edge stripe line for bicycles be located nearer than 2' from pavement edge stripe line.	Consider providing a minimum 2' wide buffer between traveled lane and bicycle path. Bicyclists will use any available shoulder if the surface is paved and smooth.

Table 5: Shoulder Geometrics and Use Guidelines.

SHOULDER FUNCTION OR USE	FREEWAYS				ARTERIALS			
	ACCEPTABLE		OPTIMAL		ACCEPTABLE		OPTIMAL	
	WIDTH & SLOPE	TYPE & STRENGTH	WIDTH & SLOPE	TYPE & STRENGTH	WIDTH & SLOPE	TYPE & STRENGTH	WIDTH & SLOPE	TYPE & STRENGTH
MASS TRANSIT								
• Limited HOV/ By-Pass lanes	10' 6% Max.	P ND[a]	12' 2%	P FD	9' 6% Max.	P ND[a]	12' 2%	P FD
• Full HOV lane	10' 6% Max.	P ND[a]	12' 2%	P FD	9' 6% Max.	P ND[a]	12' 2%	P FD
• Transit bus stops	12' 6% Max.	P ND[a]	16' 2%	P FD	10' 6% Max.	P ND[a]	12' 2%	P FD
• School bus stops at RR crossings	Not Applicable.				10' 6% Max.	P ND	12' 2%	P ND[a]
FULL RUNNING LANES	As a part of shoulder conversions for full time shoulder use, entire paved surface width is often restriped with narrower lanes to accommodate the additional through lane. No special signing is required for this full time use.							
• Along entrance and exit ramps, preferences for HOV	10' 6% Max.	P ND[a]	14' 2%	P FD	Not Applicable			
• Extensions of exit ramp deceleration lanes or entrance ramp acceleration lanes	10' 6% Max.	P ND[a]	12' 2%	P FD	Not Applicable			
• Auxiliary lanes between interchanges	10' 6% Max.	P ND[a]	12' 2%	P FD	Not Applicable			
• Mainlanes, including HOV use	10' 6% Max.	P ND[a]	12' 2%	P FD	10' 6% Max.	P ND[a]	12' 2%	P FD
• Parking lanes (shoulder)	Not Applicable				10' 6% Max.	P ND[a]	12' 6% Max.	P FD
• Conversion of shoulders to one or two more through lanes and/or continuous center left turning lanes	Not Applicable				10' 6% Max.	P ND[a]	12' 6% Max.	P FD
ERRANT VEHICLES (Run off road)	Some form of texturing should desirably be added along shoulders of older facilities without adequate clear zone recovery areas. Examples include corrugations, rumble strips, and chip seal. These measurers are typically effective in reducing ROR accidents and are recommended at high ROR accident locations.							
	3' 6% Max.	S,P Textured	10' 6%	S,P Textured	3' 6%	S,P Textured	10' 6%	S,P Textured
EMERGENCY VEHICLE TRAVEL	6' 6%	T,S,P ND	10' 6%	S,P ND	6' 6%	T,S,P ND	10' 6%	S,P ND

FOOTNOTE

a) **Sample life expectancy of existing paved shoulder pavement - if 5 years or greater, use as is; if less than 5 years, strengthen and repave.**

COLLECTORS & LOCALS					
ACCEPTABLE		OPTIMAL			
WIDTH & SLOPE	TYPE & STRENGTH	WIDTH & SLOPE	TYPE & STRENGTH	SPECIAL SIGNING AND MARKING	CONDITIONS OF USE (REMARKS)
Not Applicable				"Buses and Carpools ___ Lane OK" and time period. Use diamond lane markings.	Use at bottlenecks and areas of ramp metering where the loss of a normal lane is not acceptable.
Not Applicable				"Buses and Carpools ___ Lane OK", and time period. Use diamond lane markings.	See "Full Running Lanes - Mainlanes"
10' 6%	P ND[a]	12' 2%	P FD	Advisory signs for bus drivers.	For freeways, use is limited to shoulders along ramps or collector - distributor roads. Along other facilities, consider concrete bus stop pads when mainlane pavement is asphalt.
9' 6% Max.	S,P ND[a]	12' 2%	P ND[a]	Advisory signs for bus drivers.	
With permissive use, lane striping is typically not altered. Special signing is, however, required for this use. (Widths shown are lane widths after coversion)					
Not Applicable				If permissive use, time period and "OK To Drive Shoulder"	Conversion made to provide additional peak period capacity - often in conjunction with ramp metering. Use may be full time or permissive.
Not Applicable				If permissive use, time period and "OK To Drive Shoulder"	Conversion made at high volume ramps to improve mainlane traffic flow. Use may be full time or permissive.
Not Applicable				If permissive use, time period and "OK To Drive Shoulder"	Conversion typically made at locations with high weaving volumes. Use may be full itme or permissive.
9' 6% Max.	P ND[a]	11' 2%	P FD	If permissive use, time period and "OK To Drive Shoulder"	Conversion should desirably use left shoulder for a maximum distance of 2 miles ±, retaining right shoulder for emergency stopping. Use may be full time or permissive.
9' 6% Max.	P ND[a]	12' 6% Max.	P FD	Prohibition of parking during peak hours.	Permissive use of parking lane as traffic lane during peak hours.
9' 6% Max.	P ND[a]	12' 6% Max.	P FD	-	In accordance with AASHTO (1, Chapter III), the entire paved roadway surface could be restriped to provide for the additional lanes.
Although a strip of contrasting surface texturing 2' or wider is desirable in reducing ROR accidents, most Collectors and Locals do not have a significant enough of an ROR problem to warrant the expenses for special texturing.					On long downgrades, provide escape ramps on or adjacent to shoulders with turnouts and means for stopping runaway vehicles.
6' 6%	T,S,P ND	10' 6%	S,P ND		This is typically an infrequent use, except on high volume urban freeways.

Table 5: Shoulder Geometrics and Use Guidelines.

SHOULDER FUNCTION OR USE	FREEWAYS				ARTERIALS			
	ACCEPTABLE		OPTIMAL		ACCEPTABLE		OPTIMAL	
	WIDTH & SLOPE	TYPE & STRENGTH	WIDTH & SLOPE	TYPE & STRENGTH	WIDTH & SLOPE	TYPE & STRENGTH	WIDTH & SLOPE	TYPE & STRENGTH
LAW ENFORCEMENT								
o Traffic monitoring and speeding	8' 6% Max.	T,S,P ND	10' 6% Max.	S,P ND	8' 6% Max.	T,S,P ND	10' 6% Max.	S,P S,P
o Truck weight and size	10' 6% Max.	P ND[a]	16' 2%	P FD	10' 6% Max.	S,P ND[a]	16' 2%	P FD
EMERGENCY CALL BOX SERVICE AND TELEPHONES	Call boxes are typically only warranted on very heavily traveled routes or very lightly traveled routes. Public telephones are not typically provided along freeways.				Telephones provided and serviced by local telephone company. Call boxes are typically not warranted.			
	8' 6% Max.	S,P ND	10' 6% Max.	P ND	8' 6% Max.	S,P ND	10' 6% Max.	P ND
ROADSIDE SALES (fruit and vegetable stands, yard sales, etc.)	Not Applicable				8' 6% Max.	T,S,P ND	10' 6% Max.	S,P ND
GARBAGE PICKUP	Not Applicable				6' 6% Max.	T,S,P ND	10' 6% Max.	S,P ND

LEGEND

1 Right Shoulder Widths - in feet (SI: 1 foot = 0.305 meters)

Left Shoulder Widths on divided highways should be in accordance with AASHTO. Surface types are typically the same as listed for right shoulders. (App. B)

2 Shoulder Surface Types
- T - Turf, including native soils
- S - Stabilized with gravel, shell, crushed rock courses
- P - Paved, asphaltic or concrete pavements including bituminous surface treatments

3 Shoulder Strengths for Paved Shoulders
- ND - Normal Depth (Traditional)
- FD - Full Depth Mainlane Pavement

FOOTNOTE

a) Sample life expectancy of existing paved shoulder pavement - if 5 years or greater, use as is; if less than 5 years, strengthen and repave.

COLLECTORS & LOCALS					
ACCEPTABLE		OPTIMAL			
WIDTH & SLOPE	TYPE & STRENGTH	WIDTH & SLOPE	TYPE & STRENGTH	SPECIAL SIGNING AND MARKING	CONDITIONS OF USE (REMARKS)
6' 6% Max.	T,S,P ND	10' 6% Max.	S,P ND		Enforcement officers frequently select strategic locations concealed from motorists view for use in radar operations.
10' 6% Max.	S,P ND[a]	16' 2%	P FD		This use is typically a temporary use, set up by truck weight enforcement agencies. In addition, specialized locations may be selected to conduct repetitive weighing with portable weigh crews. In these cases, shoulders are typically 14' to 16' wide with 0% cross slope at scale pads.
Telephones provided and serviced by local telephone company. Call boxes are typically not warranted.					
6' 6% Max.	S,P ND	10' 6% Max.	P ND	Advance and site specific signing	In lieu of widened shoulders, special turnouts 10' to 14' wide may be provided.
8' 6% Max.	T,S,P ND	10' 6% Max.	S,P ND	Signs posted to prohibit parking at driveways, entrances, near intersections, and other hazardous locations.	-
6' 6% Max.	T,S,P ND	10' 6% Max.	S,P ND	-	-

CHAPTER FOUR

CONCLUSIONS AND SUGGESTED RESEARCH

This research brings into focus the correlation between the designs and practices by highway agencies throughout the country, and the wide varieties of uses which highway shoulders must serve. Highway shoulders are subjected to uses by the traveling public and adjacent property owners, in addition to special uses by the agencies which build and maintain highways, enforce laws, and provide other public services. The uses of shoulders range from emergency stopping by disabled vehicles through formal conversions to full-service traffic lanes. The findings of this research discuss the uses of highway shoulders identified in this research.

The major results of this research are the guidelines for the evaluation of shoulders and the selection of optimal shoulder geometric design criteria for each shoulder use identified in this research. Table 5 presents acceptable and optimal geometric design data and signing/marking and conditions of use guidelines for the identified shoulder uses for freeways, arterials, and collectors and locals.

CONCLUSIONS

The major conclusion of this research is that highway agencies have developed, primarily as necessitated by limited resources, special geometric and operational solutions to accommodate a variety of shoulder uses and, thereby, to increase the utility of highway facilities. While some of these practices have been applied uniformally throughout the country, highway agencies typically tailor shoulders to cost-effectively meet specific demands and constraints of individual and uniquely different problems. Although Table 5 may serve to promote greater uniformity in shoulder use, shoulder uniformity is probably only mandatory on freeways and high traffic volume arterials, desirable on new or reconstructed arterials and collectors, and nice for new locals; but it is practically unattainable on many existing collectors and local highways and streets.

Other important conculsions of this research include:

1. Highway shoulders could more efficiently and economically serve the needs of highway users if increased consideration were given to the full range of uses to which shoulders are subjected, and if these uses were adequately provided for during design and maintenance of highways. Table 5 summarizes specific geometric design, signing/marking, and conditions of use for the identified shoulder uses.
2. Emergency stopping and parking, must, by necessity, be accommodated along most highways. Wide, stabilized shoulders enhance both safety and utility for users and passing motorists.

3. Narrow strips of stabilized or paved shoulder adjacent to traveled lanes increase the durability of main-lane pavements by providing lateral support, improving drainage, and accommodating shoulder uses that would normally tend to ravel pavement edges (off-tracking and encroachment).

4. Highway agencies have successfully used a variety of special shoulder designs to cost-effectively provide portions of "shoulders" only at locations that are considered absolutely necessary (e.g., mailbox turnouts, right- and left- turn lanes, and paved areas for truck weighing).

5. Most highway agencies consider the white edge line stripe as adequate delineation between main lanes and shoulders, except at high run-off-the-road (ROR) accident locations. At these high ROR accident locations, several agencies construct textured shoulders or rumble strips to alert errant drivers.

6. Highway agencies have successfully used paved shoulders along two-lane mountainous roads and other highways with limited passing zones to function as climbing or passing lanes, thus separating slower moving vehicles from the main traffic flow.
7. Highway agencies have successfully widened and strengthened shoulders in mountainous areas at the crest of long grades to accommodate repetitive truck parking (to cool engine, and check brakes or shifting cargo).

8. Highway agencies have succesfully converted paved shoulders along major high volume freeways and arterials as traffic lanes to increase capacity, reduce bottlenecks, and accommodate mass transit/carpool/vanpool vehicles. Conversion of highway shoulders to full-service traffic lanes, whether temporary or permanent, however, must be considered on case-by-case bases, and the benefits of converting shoulders to full-service traffic lanes must be carefully weighed against the disadvantages of losing shoulder areas for emergency and other uses.

SUGGESTED RESEARCH

During the course of this research, several areas of concern that warrant further research and study were identified as follows:

1. Billion's (8) and Pekala's (43) studies have been used by several researchers to predict anticipated numbers of shoulder uses. An update and continuance of these studies should be conducted, and should include both urban and rural routes of several highway classifications. Such a study should develop methods of estimating numbers of shoulder uses on various types of facilities. (i.e. numbers of axle-loads, etc. in relationship to main-lane ADT and to other anticipated uses that shoulders may serve). Such data would permit rational design of shoulders and aid in establishing of warrants for shoulder designs, turnouts, and motorists aid systems.

2. Testing and studies of feasible methods of providing and maintaining suitable differences in pavement surface textures between main-lane and shoulder pavements should be continued. Parallel studies have determined the benefits of preventing run-off-the-road (ROR) accidents. The goals of the suggested research would be to establish both lasting and cost-effective methods of providing pavement texture differences at high ROR accident locations. The study should include texturing methods that could be applied after initial construction or during resurfacing.

3. This research determined that many of the capacity problems on urban freeways, which resulted in the conversion of shoulders to traffic lanes, were the result of compliance to the AASHTO "N-1 lane balance" theory during initial design (3, pp 541-543). Further research is needed to determine the desirability of strict compliance with this lane balance theory and AASHTO recommended lengths of auxiliary lanes, especially in urban areas where freeways must operate at or near capacity.

4. Further testing of the operational and design constraints that should govern if and where pulling to the right to permit passage of faster moving vehicles should be encouraged or allowed. This "maneuver" allows (by law in Texas and Washington) slow-moving vehicles to move onto the shoulder of two-lane roadways to permit faster moving vehicles to pass without encroaching on the opposing lane. Most other agencies expressed concern as to the accident potential of this maneuver. This use of shoulders may have greater potential for improved safety, however, than the conventional passing maneuver on two-lane highways where vehicles must enter the opposing lane of traffic in order to pass. Although Texas has conducted research on this use of shoulders, a broader study is needed to determine the desirability of expanding this use into other areas of the country.

5. Further testing and reporting of operational results of the various methods of shoulder marking and signing to allow use as turning lanes, climbing lanes, detour lanes, permitted parking, etc., would be desirable. The goal of such research would be to recommend uniformly recognizable and workable marking and signing for the most common uses of shoulders.

6. AASHTO, in its broadened list of advantages (uses) of shoulders, identifies shoulders as space for stopping free of traveled lanes because of mechanical difficulty and for occasional stopping to consult road maps, and to rest. This study determined that trucks routinely stop at the crests of grades for all of the above reasons. This repetitive parking, often in fore-slopes beyond the shoulder pavement, causes accelerated deterioration of shoulder pavements and fore-slopes. Recognizing that trucks repeatedly stop at the same locations, several agencies have widened and strengthened shoulders at these locations. Additional study is needed to determine if formal creation of regularly used parking areas adjacent to traffic lanes may cause safety problems to other traveling vehicles as slow-moving trucks leave and enter main traffic lanes.

REFERENCES

As an aid to the reader, appropriate cross-references to shoulder design practices or shoulder uses are listed at the end of each entry, and are underlined. Where no cross-reference is listed, the reference is applicable to the overall subject.

1. "A Policy on Geometric Design of Highways and Streets." Review Draft #2A of NCHRP Project 20-7, Task 14 (March 1981) Volumes I and II.

2. American Association of State Highway and Transportation Officials, "Geometric Design Guide for Local Roads and Streets." Washington, D.C. (1970) 322 pp.

3. American Association of State Highway Officials, "A Policy on Design of Urban Highways and Arterial Streets--1973." Washington, D.C. (1973) 740 pp.

4. American Association of State Highway Officials, "A Policy on Geometric Design of Rural Highways--1965." Washington, D.C. (1966) 650 pp.

5. American Association of State Highway Officials, "Highway Design and Operational Practices Related to Highway Safety." Washington, D.C. (Feb. 1967) 71 pp.

6. "An Evaluation of Shoulder Performance in New York State." Soil Mechanics Bureau Report, State of New York Department of Transportation (September 1979) 13 pp. Strength

7. BELLIS, Wesley R., "Shoulder Use." Highway Research Board Bulletin 170, Traffic Design, and Research Section, New Jersey State Highway Department (January 1957) pp 51 to 53. Emergency Stopping

8. BILLION, C.E., "Shoulder Occupancy on Rural Highways." Highway Research Board Proceedings Volume 38, Washington, D.C. (1959), pp 547-575. Emergency Stopping

9. "Bicycle and Pedestrian Facilities." Chapter 18.00 Highway Design Manual (Volume 1), Facilities Design Subdivision, New York State Department of Transportation (Revised August 1980) 33 pp. Pedestrians and Bicycles

10. BRYDEN, James E., "Performance of Shoulder and Median Contrast Treatments" Report No. FHWA-NY-79-RR71, Engr. Research and Development Bureau, New York State Department of Transportation (May 1979) 27 pp. Delineation

11. BUCHLER, Martin G., "By-Pass Lanes at Intersections on 2-Lane Roads." Lake County Highway Department, Libertyville, Illinois (October 20, 1978) 43 pp. Turning/Passing at Intersections

12. "Chapter XX - Snow Removal and Ice Control." Maintenance Manual, Department of Transportation (Caltrans) (October 1, 1975) 1 p. Snow Storage

13. "Chip Seal Rumble Strips." Category 2 Experimental Project 72-14-01 Final Report, I-15-1(63)47(I-15 Milepost 47 to Milepost 55) McCammon to Inkom, Division of Highways, Idaho Transportation Department (June 1980) 4 pp. Delineation

14. "Commercial Vehicles in Collisions Involving Vehicles Parked or Stopped on Highway Shoulders." Bureau of Motor Carrier Safety Special Report, FHWA (June 1977) 22 pp. Parking

15. COTTRELL, Jr., Benjamin H., "Guidelines for The Treatment of Right-Turn Movements on Rural Roads." Virginia Highway and Transportation Research Council, Charlottesville, Virginia (December 1981) 34 pp. Turning/Passing at Intersections

16. "Current Practices in Shoulder Design, Construction, Maintenance and Operation." Hwy. Res. Circular No. 142 (April 1973) 15 pp.

17. "Design and Use of Highway Shoulders." NCHRP Synthesis 63, Washington, D.C. (1979) 26 pp.

18. Encroachment Permit: DM-M-P-202A (Rev. 2/82), General Provisions to Encroachment Permit: DM-M-P-202B (Rev. 2/82), Utility Maintenance Provisions to Encroachment Permit: DM-M-P-228 (Rev. 2/82), Department of Transportation (Caltrans) Routine Maintenance

19. ENDO, G. and ANDERSON, R., "Safety Evaluation of the Part-Time Shoulder Lane and Ramp Control on the Southbound Santa Ana Freeway between Route 7 and the East Los Angeles Interchange." Freeway Operation Branch Report No. 77-9, Dept. of Transportation District 7 Los Angeles, California Business and Transportation Agency (May 1977) 24 pp. Full Running Lanes - Freeways

20. ENDO, G. and PADILLA R., "Safety Evaluation of Part-Time Shoulder Lane and Ramp Control on the Santa Ana Freeway Southbound between Route 605 and San Antonio Drive On-Ramp." Freeway Operation Branch Report No. 76-5, Dept. of Transportation District 7 Los Angeles, California Business and Transportation Agency (September 1976) 15 pp. Full Running Lanes - Freeways

21. "Evaluation of Shoulder Improvements" Safety Projects Services, Traffic Engineering Section, Arizona Department of Transportation (January 1978) 14 pp. Geometrics

22. FAMBRO, Daniel B., TURNER, David S. and ROGNESS, Ranney O. "Operational and Safety Effects of Driving on Paved Shoulders in Texas." Report No. FHWA-TX-81/3+265-2F, Texas Transportation Institute, Texas A&M University and Texas State Department of Highways and Public Transportation (January 1981) pp. 35 to 92 and 110. Geometrics

23. "Freeway Fatal Accidents - 1980." California Department of Transportation (May 1981) 21 pp.

24. GLENNON, John C., "Design and Traffic Control Guidelines for Low Volume Rural Roads." NCHRP Report 214, Washington, D.C. (1979) 41 pp.

25. GRAHAM, Jerry L. and HARDWOOD, Douglas W., "Effectiveness of Clear Recovery Zones." NCHRP Report 247, Washington, D.C. (May 1982). Out-of-Control Vehicles

26. "Guidelines for Bikeway Operations." Illinois Department of Transportation (January 1980) 19 pp. Bicycles

27. HEIMBACH, Clinton L., "Investigation of the Relative Cost-Effectiveness of Paved Shoulders on Various Types of Primary Highways in North Carolina for the Purpose of Establishing Priority Warrants." Report No. ERD-110-71-1, Highway Research Program, North Carolina State University at Raleigh (June 1972) 135 pp. Geometrics

28. HICKS, R.G., BARKSDALE, R.D., and EMERY D.K., "Design Practices for Paved Shoulders." Transp. Res. Record 594, Washington, D.C. (1976) pp. 48-56.

29. "Interstate Routes 15 and 40 Shoulder Rumble Strips", California Department of Transportation (July 1982) Delineation

30. JOHNSON, Leroy F., "Design of Shoulders to Provide Safer Winter Travel." Highway Research Board Bulletin 151, Washington, D.C. (January 1956) Snow Storage

31. JONES, Gregory M., "On-Road Improvements for Bicyclists in Maryland." Baltimore County Department of Traffic Engineering, Towson, Maryland. Transportation Research Record 739, Washington, D.C. (1979) pp. 37-44 Bicycles

32. JORGENSEN, Roy and Associates, Inc. "Cost and Safety Effectiveness of Highway Design Elements." NCHRP Report 197, Washington, D.C. (1978) 237 pp. Geometrics

33. LARRANAGA, L.A., "Effectiveness and Safety Impact of Raised Pavement Markers Used for Delineation on New Mexico Roadways." 95 pp. Delineation

34. LOUTZENHEISER, D.W., "Desirable Criteria for the Geometric Design and Operation of Highway Shoulders." Hwy. Res. Circular No. 142, Washington, D.C. (Apr. 1973) pp 2-7.

35. "Mailbox Installations." Administrative Circular No. 99-81, Texas State Department of Highways and Public Transportation (August 7, 1981) 4 pp. Mail and Other Deliveries

36. "Manual on Uniform Traffic Control Devices - for Streets and Highways." U.S. DOT, FHWA, Washington, D.C. (1978).

37. McCASLAND, William R., "The Use of Freeway Shoulders to Increase Capacity." Report No. FHWA TX 78-210-2, Texas Transportation Institute, Texas A&M University, College Station, Texas (September, 1978) 51 pp. Full Running Lanes - Freeways

38. McCASLAND, William R., and BIGGS, Raymond G., "Freeway Modification to Increase Traffic Flow." Technology Sharing Report FHWA-TS-80-203, Texas Transportation Institute, Texas A&M University, College Station, Texas (January 1980) 109 pp. Full Running Lanes - Freeways

39. McCOY, Patrick T. and TOBIN, John R., "Utilization of Additional Through Lanes at Signalized Intersections." Civil Engineering Department, University of Nebraska, Lincoln (January 1982) 22 pp. Turning/Passing at Intersections

40. McHENRY, Steven R., "Evaluation of Asphalt Slurry for Bikeways." Report No. FHWA-MD-R-78-5, Maryland State Highway Administration (March 1978) 47 pp. Bicycles

41. MUNN, Harold C., "Bicycles and Traffic." Vol. 101 No. TE4 Transportation Engineering, Journal of ASCE (November 1975) pp. 753-762. Bicycles

42. "Paved Shoulder Problem - Stevenson Expressway." Research and Development Report No. 19, Illinois Division of Highways (July 1967) 28 pp. Lateral Support

43. PEKALA, Michael P. and McDERMOTT, Joseph M. "Summary Analysis: 'Before' Study Data Collection for the I-80 Motorists Aid Communication System." Illinois Department of Transportation, Expressway Surveillance Unit, Bureau of Materials and Physical Research, Emergency Stopping Physical Report No. 47 (March 1974) 28 pp.

44. PEROVICH, M., "Supplemental Report on the Use of Shoulders as Traveled Way on the Westbound Santa Monica Freeway from Junction of Route 10 to Alameda Street." Freeway Operation Dept. Report No. 70-3, Division of Highways District 7 Los Angeles, Dept. of Public Works California Transportation Agency (September 1968) 9 pp. Full Running Lanes - Freeways

45. "Planning and Design Criteria for Bikeways in California." Business and Transportation Agency, California Department of Transportation (June 30, 1978) 50 pp. Bicycles

46. "Policy for Mailbox Turnouts." Order 16-8, Illinois Department of Transportation (October 1, 1977) 11 pp. Mail and Other Deliveries

47. "Policy on Permits for Access Driveways to State Highways." Bureau of Traffic, Department of Transportation, State of Illinois (June 1974) 56 pp. Roadside Sales

48. "Policy on the Accommodation of Utilities on Rights-of-Way of the Illinois State Highway System." Division of Highways, Illinois Department of Transportation (May 1979) 49 pp. Routine Maintenance

49. PORTIGO, J.M., "State-of-the-Art Review of Paved Shoulders." Transp. Res. Record 594 (1976) pp. 57-64.

50. RINDE, E.A., "Accident Rates vs. Shoulder Width." Report No. CA-DOT-TR-3147-1-77-01, California Department of Transportation (September 1977) 57 pp. Geometrics

51. ROWAN, N.J., "Survey on Shoulder Design and Operation Practices." Hwy. Res. Circular No. 142 (April 1973) pp. 1-2.

52. SCHAEFER, W.E., NEWMANH, L., MEIS, G.T., BRANAGAN, B. and BLANCO, A., "Evaluation of Use of Shoulders as Travelled Way on the Westbound Santa Monica Freeway from Jct. of Rte. 10 to Alameda St." Freeway Operation Dept. Report No. 68-6, Division of Highways District 7 Los Angeles, Department of Public Works, California Transportation Agency (September 1968) 28 pp. Full Running Lanes - Freeways

53. SCHAEFER, W.E., NEWMAN, L. and DUNNET, A., "Effect on Traffic Operation of Use of Shoulder as Travelled Way on Portions of Sante Monica Freeway." Freeway Operations Dept. Report No. 68-1, Division of Highways District 7 Los Angeles, Department of Public Works, California Transportation Agency (January 1968) 44 pp. Full Running Lanes - Freeways

54. "Shoulder Requirement for Bicycle Travel." Policy and Procedure No. P78-14, Office of Bicycle Facilities, Division of Highways, California Department of Transportation (February 24, 1982) 3 pp. Bicycles

55. TARAGIN, A., and KILPATRICK, Morgan J. (Committee on Shoulders and Medians), "Highway Shoulder Use Study Procedure Guide." Highway Research Board Bulletin 359, Washington, D.C. (November 1962) 29 pp. Geometrics

56. TARAGIN, A., "Role of Highway Shoulders in Traffic Operation." Highway Research Board Bulletin 151, Washington, D.C. (January 1956) pp 23, 24. Emergency Stopping

57. TURNER, Daniel S., ROGNESS, Ranney O. and FAMBRO, Daniel B. "Shoulder Upgrading Alternatives to Improve the Operational Characteristics of Two-Lane Highways." Texas Transportation Institute, Texas A&M University, College Station, Texas (January 1982) 32 pp. Full Running Lanes - Nonfreeways

58. TYE, E.J. "Devices to Prevent Run-Off-Road Accidents." Report No. CA-DOT-TR-1269-1-76-01, Office of Traffic, California Department of Transportation (February 1976) 50 pp. Delineation

59. "Utility Accommodation Policy for All Federal Aid Work and MFT Construction Projects on County and Township Highways and Municipal Streets in Illinois" (October 1980) 8 pp. Routine Maintenance

60. ZEGEER, Charles V. and MAYES, Jesse G., "Cost-Effectiveness of Lane and Shoulder Widening of Rural Two-Lane Roads in Kentucky." Division of Research Report No. 524, Kentucky Bureau of Highways (July 1979) 49 pp. Geometrics

61. ZEGEER, Charles V. and PERKINS, David D., "Effect of Shoulder Width and Condition on Safety: A Critique of Current State-of-the-Art." Transportation Research Record 757, Washington, D.C. (1980) 10 pp. Geometrics

APPENDIX A —

AGENCY INTERVIEWS, METHODOLOGY, PARTICIPATION, AND QUESTIONNAIRE

The purpose of this appendix is to describe the selection and interview process used for the 17 agencies visited during this research project, the questionnaire used during the interview, the site trips made during each agency visit, and the evaluation of the collected data.

SELECTION OF AGENCIES

An important source of current information and a primary activity of this research consisted of visits to, and interviews with, selected highway agencies throughout the country. On the basis of a review of the responses to the NCHRP Synthesis of Highway Practice 63 Questionnaire (App. D), the following general criteria were established to identify agencies potentially suitable for participation in this research:

1. Varieties of shoulder uses.
2. Design practices for specific uses of shoulders different from the "normal usage."
3. Design practices for shoulders on all types of highways.
4. Geographic distribution for climate, terrain, urban/rural mix, traffic volumes, and driver behavior.

The principal investigator then conducted an informal telephone survey of the candidate agencies and selected the agencies to be visited. Agency interviews began in September 1981. The 17 agencies visited during this research, whose practices represent a broad range of current shoulder design, operation, and maintenance policies and procedures, are mapped on Figure A-1 and given in Table A-1.

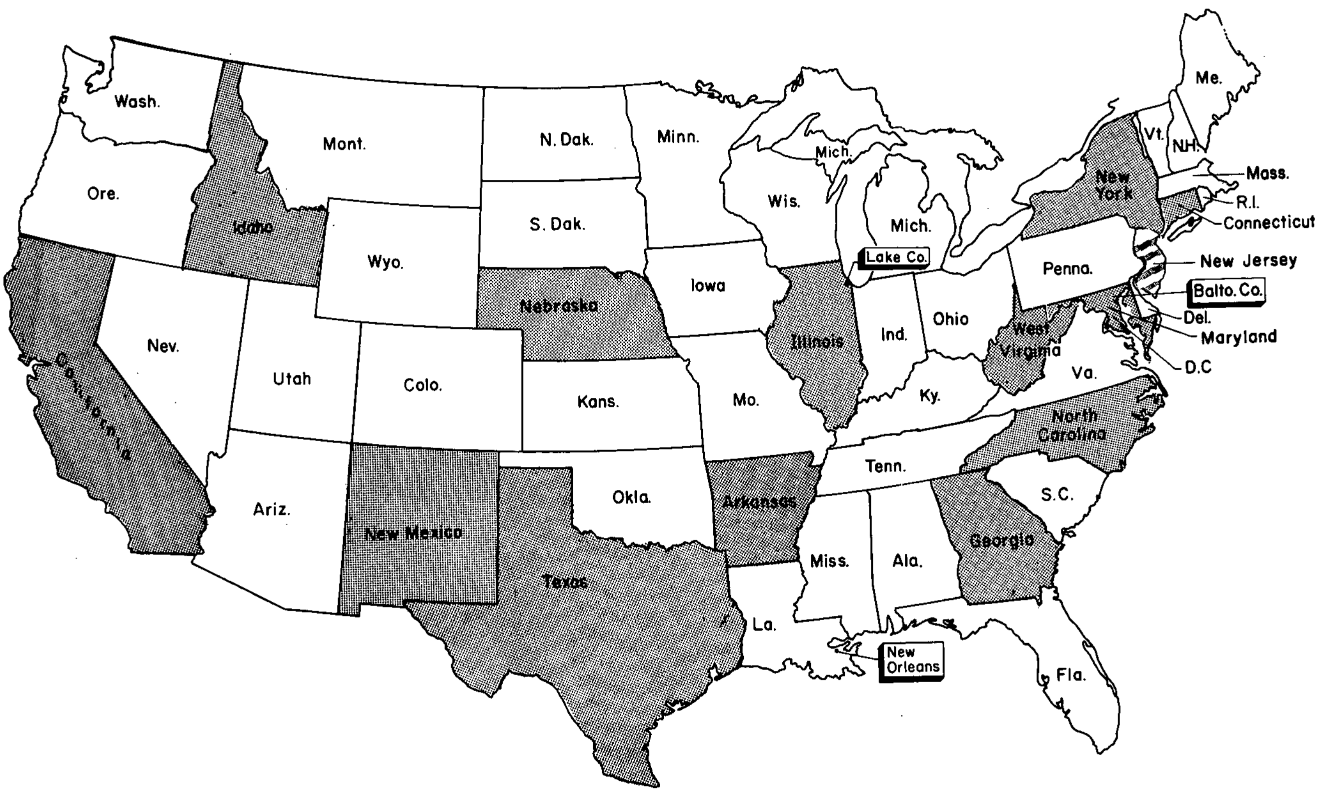


Figure A-1. Highway agencies participating in NCHRP Project 1-22.

Table A-1. Agencies interviewed on NCHRP Project 1-22.

PARTICIPATING AGENCY	REASON FOR SELECTION	DATE OF VISITATION
ARKANSAS Arkansas State Highway and Transportation Department	mountainous terrain, rural, light traffic volumes, farming	November 2 & 3, 1981
BALTIMORE COUNTY,MD Department of Public Works	urban/suburban/rural, varied traffic volumes	February 3, 1982
CALIFORNIA Department of Transportation		
Headquarters, Sacramento	all types of terrain (including mountains), land use, traffic volumes, and snow	March 22 & 23, 1982
District 7, Los Angeles	urban, heavy traffic volumes, freeway system	March 25, 1982
District 11, San Diego	urban, varied traffic volumes, arid	March 26, 1982
District 4, San Francisco/ Oakland	urban, heavy traffic volumes, special shoulder uses at approaches to Golden Gate Bridge	March 29, 1982
CONNECTICUT Department of Transportation Bureau of Highways	urban, snow, heavy traffic volumes	September 17, 1981
GEORGIA Department of Transportation, Highway Department	rural, rain, light traffic volumes, farming	February 8, 9, & 10, 1982
IDAHO Transportation Department	rural, snow, mountainous, light traffic volumes	March 31, 1982 April 1&2, 1982
ILLINOIS Department of Transportation		
District 1, Chicago	urban, heavy traffic volumes, extensive freeway network	September 30, 1981
Headquarters, Springfield	urban/rural, snow, heavy/light traffic volumes, farming	October 1 & 2, 1981
LAKE COUNTY, Ill. Highway Department	urban/suburban, varied street classifications	September 29, 1981
MARYLAND State Highway Administration Department of Transportation	urban/rural, varied traffic volumes, metropolitan areas of Baltimore and Washington, D.C.	December 11, 1981
NEBRASKA Department of Roads	rural, light traffic volumes, farming, mobile base industry	October 27-30, 1981
NEW JERSEY* Department of Transportation	urban/suburban, heavy traffic volumes	February 25, 1982

* Agency interview consisted of site trip of shoulder use recorded on film and additional design criteria and standards

Table A-1. (Continued)

PARTICIPATING AGENCY	REASON FOR SELECTION	DATE OF VISITATION
NEW MEXICO Highway Department		
Headquarters, Santa Fe	suburban/rural, arid, light traffic volumes, residential growth area	March 15, 1982
District 5, Santa Fe	suburban, low density development	March 16, 1982
District 3, Albuquerque	suburban, arid	March 17, 1982
NEW ORLEANS, La. Department of Public Works	urban/suburban, city street system, moderate to heavy traffic volumes	February 11&12, 1982
NEW YORK Department of Transportation		
Headquarters, Albany (Region 1)	urban/suburban/rural, snow, varied traffic volumes	September 14, 1982
Region 2, Uttica	interview and site visits	September 16, 1982
Region 8, Poughkeepsie	interview and site visits	September 17, 1982
NORTH CAROLINA Department of Transportation		
Headquarters, Raleigh	suburban/rural, varied terrain, snow, state highway dept. is responsible for all state and county roads	February 17, 1982
Division 4, Wilson	interview and site visits	February 18, 1982
Division 5, Durham	interview and site visits	February 19, 1982
TEXAS State Department of Highways and Public Transportation		
Headquarters - Austin	urban/rural, varied traffic volumes, wide right of way, heavy petroleum industry	November 6, 1981
District 15, San Antonio	suburban/urban, heavy traffic volumes	November 4, 1981
District 13, Yoakum	rural, farming, oil	November 5, 1981
Houston Urban Office	freeway system, high traffic volumes	February 15, 1982
WEST VIRGINIA Department of Highways	rural, mountainous, snow, state highway department is responsible for all state and county roads	November 16, 17, & 18, 1981

INTERVIEW QUESTIONNAIRE

A detailed questionnaire encompassing shoulder designs and practices was prepared by significantly expanding on the questionnaire previously used for NCHRP Snythesis of Highway Practice 63 (17) (see Appendix F, Addendum to NCHRP Report 254). This questionnaire addresses the following issues:

- Part A - Design Policy

  Ten questions concerning shoulder type, width, slope, strength, surface type, uses and operations.

- Part B - Operational Practices

  Traditional Shoulder Use

  Seven questions concerning parking, mail and other deliveries, stopping for mechanical difficulity, pedestrian, off-tracking recovery areas, snow (sand), and lateral support.

  Nontraditional Shoulder Use

  Nine questions concerning slow-moving vehicles, right-turning and/or passing maneuvers, emergency vehicles, routine maintenance, major construction, bicycle, full running lane, commercial use by property owners, and other uses.

  The full questionnaire is reproduced in Appendix E of the Addendum to NCHRP Report 254.

INTERVIEW PROCEDURE

The following steps were completed for each agency visited, although minor refinements in the procedure were made as the interviews progressed:

1. Several weeks prior to the visit, a copy of the questionnaire was sent to the agency. In most cases, copies of this questionnaire were circulated to the staff and preliminary responses prepared. At the time of the interview, these preliminary responses were reviewed and provided to the research team.
2. The interview, conducted by the principal investigator, was usually attended by 6 to 8 agency staff members. These staff members were selected from departments or bureaus responsible for the planning, design, construction, operation, and maintenance of highway shoulders. Using the prepared responses as a guide, a question by question discussion was held. The interview was taped, and it generally lasted 4 to 6 hours.
3. Site trips were taken to observe shoulder operations at a variety of locations. Normally, two or three agency representatives participated in these trips. Numerous slides were taken depicting shoulder use and operation. Color slides (35mm) were taken throughout the course of this research. Representative photographs depicting the variety of shoulder uses encountered are reproduced in Chapter Two of this report and in the Addendum to NCHRP Report 254.
4. A draft summary of each interview was prepared from the preliminary responses and the interview tapes. This draft summary was forwarded to the agency for review and comment. Corrections were then incorporated into the summary.
5. All research reports, design manuals, special in-house studies, and so on, received as a part of the interviews were evaluated as a part of the literture review.
6. A description of each slide was prepared, noting specific point(s) of interest.

EVALUATION OF COLLECTED DATA

The data collected for each use was examined to determine the reason for the use, the safety of the use, the extent of the use among the sampled agencies, problems the use may solve, problems the use may invoke and their solutions, the economics of the use, the signing and marking required, the geometric designs the use may require, the public acceptance of the use, and the conditions of the use.

APPENDIX B —

AASHTO SHOULDER DESIGN POLICY

OVERVIEW

Shoulder geometric design policy is defined for rural highways in the 1965 "Blue Book" (4) and for urban highways and arterial streets in the 1973 "Red Book" (3). The following summary, taken from Review Draft #2A of "A Policy on Geometric Design of Highways and Streets" (1), was used as the basis for defining the American Association of State Highway and Transportation Official's (AASHTO's) current shoulder geometric design policy because this forthcoming publication will supersede the 1965 and 1973 publications.

A comparison of the Review Draft #2A of the AASHTO publication "A Policy on Geometric Design of Highways and Streets" (1) with the earlier 1973 "Redbook" (3) and 1965 "Bluebook" (4) confirms today's increased emphasis on maximizing the transportation capabilities of the nation's highway and street system. "Additional emphasis has been placed on the joint use of transportation corridors by pedestrians, cyclists and public transit vehicles.... Cost-effective design is also emphasized." (1, pp i-ii). This is reflected in the broadened list of 13 important "advantages" (uses) of shoulders quoted from Chapter IV, "Cross Section Elements," of the new draft publication (1, pp IV-8, -9):

1. Space is provided for stopping free of the traffic lane because of mechanical difficulty, a flat tire, or other emergency.
2. Space is provided for the occasional motorist who desires to stop to consult road maps, to rest, or for other reasons.
3. Space is provided to escape potential accidents or reduce their severity.
4. The sense of openness created by shoulders of adequate width contribute much to driving ease and freedom from strain.
5. Sight distance is improved in cut sections, thereby improving safety.
6. Some types of shoulders enhance the esthetics of the highway; no well-designed and well-maintained shoulder affects the highway adversely.
7. Highway capacity is improved; uniform speed is encouraged.
8. Space is provided for maintenance operations such as snow removal and storage.
9. Lateral clearance is provided for signs and guardrails. When placed at the outer shoulder edge, they do not affect the lateral placement of vehicles.
10. Storm water can be discharged farther from the pavement, and seepage adjacent to the pavement can be minimized. This may directly reduce pavement breakup.
11. Structural support is given to the pavement.
12. Space is provided for pedestrian and bicycle use.
13. Space is provided for bus stops.

While the majority of the shoulder uses identified in NCHRP Project 1-22 are adequately provided for by AASHTO, there are several other specific and localized uses of highway shoulders that are either inadequately provided for or not included by AASHTO. This is due primarily to the fact that the new AASHTO publication is "not intended as a policy for resurfacing, restoration or rehabilitation (R.R.R.) projects" (1, p.i), and, therefore, does not address the possible use of highway shoulders in these circumstances.

The following summarizes current AASHTO policy for freeways, arterials, collectors, and locals.

FREEWAYS (pp. VIII-2, X-96, and X-124)

Shoulder Cross Slope: 2 percent minimum, 6 percent maximum; should be at least 1 percent more than pavement cross slope on tangent sections.

Main Lanes: Normal shoulder geometrics for four-lane highway: right shoulder width should be 10-ft minimum; left (median) shoulder width, 4- to 8-ft minimum, 4-ft paved (balance of shoulder should be surfaced to some extent). If 6 or more lanes, paved width of median shoulder should be 10-ft minimum. If truck DHV exceeds 250, paved width of both right and median shoulder should preferably be 12 ft.

Auxiliary Lanes along freeway main lanes should have adjacent shoulder widths of 8- to 12-ft desirable, 6-ft minimum.

Ramp Shoulders are normally constructed adjacent to acceleration and deceleration lanes with transitions to the freeway shoulder width at the taper ends. Paved roadway surface widths (dependent on ramp radius and traffic mix) include nominal shoulders, typically 2- to 4-ft wide on the left and 2- to 8-ft wide on the right.

ARTERIALS (pp. VII-4, 11, 13, 15, 34, 35)

Shoulder Cross Slope: 2 to 6 percent if paved, 4 to 6 percent if gravel, and 8 percent if turf.

Two-Lane Rural: These arterials should ideally have usable shoulders 10-ft wide. Because this width is not always economically feasible or justifiable, the logical approach is to provide a width related to traffic demands:

Design Traffic Volume		Recommended range of usable shoulder
Current ADT	DHV	widths[1] (ft)
250 to 400	-	4 to 8
400 to 750	100 to 200	6 to 10
-	200 to 400	8 to 10
-	Over 400	8 to 12

1 Paved or stabilized shoulder of adequate strength to support the majority of the vehicles that may use them for emergency parking.

Climbing Lanes on Two-Lane Rural arterials should have shoulders widths somewhat reduced from the allowed shoulder width, 4-ft minimum width.

Multilane Undivided Rural arterials should have shoulders of adequate strength, generally in conformance with the shoulder criteria for two-lane rural arterials.

Multilane Divided Rural arterials should have full shoulders: right shoulder should have usable width of 8-ft minimum, 10-ft desirable[1]; left (median) shoulder width should be 3-ft paved for four lanes; 8- to 10-ft for six or more lanes (extent of paving not defined).

Climbing Lanes on Multilane Rural Arterials require only a very narrow shoulder.

Multilane Undivided and Divided Urban Arterials typically are located in areas of restricted right-of-way, and shoulders are not provided. Whenever conditions require the construction of shoulders (or curbs), the shoulder design policy listed under "Freeways" or previously under "Arterials" applies.

Parking Lanes on Urban Arterials, which can function as a traffic-carrying lane and breakdown lane during peak periods, should be 10- to 12-ft wide.

1 Paved or stabilized shoulder of adequate strength to support the majority of the vehicles that may use them for emergency parking.

COLLECTORS (pp. VI-4, 9, 12)

Shoulder Cross Slope: 2 to 6 percent if paved, 4 to 6 percent if gravel, and 8 percent if turf.

Rural collectors should ideally provide paved roadway surface widths, dependent on design speed and traffic volumes, ranging from 20 to 24 ft with an adjacent graded shoulder area. The width of this graded area varies with traffic volumes as follows:

Design Traffic Volume Current ADT	DHV	Graded shoulder width each side of pavement (ft)
400 or less	-	2 (minimum)
more than 400	-	4
-	100 to 200	6
-	more than 200	8

Urban collectors should provide shoulder widths in excess of widths listed for rural collectors. In residential areas, a parallel parking lane 7- to 10-ft wide should be provided on one or both sides. In commercial and industrial areas, parking lanes should range from 8- to 10-ft wide, usually provided on both sides. In either case, parking lane width determinations should include consideration for ultimate conversion to a lane for moving traffic.

LOCALS (p. V-4, 15)

Shoulder Cross Slope: 2 to 6 percent if paved, 4 to 6 percent if gravel, and 8 percent if turf.

Rural and Urban locals should ideally provide paved roadway surface widths, dependent on design speed and traffic volumes, ranging from 16 to 24 ft, with an adjacent graded shoulder area. The width of this graded area varies with traffic volumes as follows:

Design Traffic Volume Current ADT	DHV	Width of graded shoulder (each side)(ft)
less than 400	-	2 (minimum)
400 or more	-	4
-	100 to 200	6
-	more than 200	8

Parking Lanes on Urban locals in residential areas should be at least 7-ft wide on one or both sides. In commercial and industrial areas, parking lane widths should be at least 9 ft, usually provided on both sides.

APPENDIX C —
DESIGN POLICIES OF REPRESENTATIVE AGENCIES

This appendix summarizes the shoulder geometric design policies for new construction used by the 17 agencies interviewed as part of this research. Many of these agencies report shoulder design policy "in conformance with AASHTO policy." Appendix B summarizes AASHTO shoulder design policy as presented in the Review Draft #2A of "A Policy on Geometric Design of Highways and Streets" (1).

Unless specifially noted, the shoulder geometric design policies listed below do not apply to "3-R" projects; most agencies adapt shoulder designs to fit the special requirements of individual "3-R" project constraints (primarily right-of-way).

ARKANSAS
Arkansas State Highway and Transporation Department

Shoulder widths are determined on the basis of highway classification, and except for local roads are based on AASHTO criteria. Shoulders along local roads typically are narrower than AASHTO criteria, and are based on available rights-of-way and funds.

Shoulder cross slopes are typically 1/2 in. per foot (4%) for paved shoulders and 3/4 in. per foot (6%) for earth shoulders.

Shoulder strengths, while a major concern, are not specifically designed, but rather, are based on previous experience.

BALTIMORE COUNTY, MD.
Department of Public Works

Shoulder widths are typically 8 ft for rural thoroughfares, collectors, and arterials; and 6 ft for local roads and minor collectors.

Shoulder cross slopes are typically 1/2 in. per foot (4%).

Shoulder strengths are not designed, but all shoulders are either stabilized (double surface treatment on 6 in. of crusher run stone) or paved full main-lane depth if used as a parking lane/off peak - running lane/peak.

CALIFORNIA
Department of Transportation

Shoulder widths along freeways are based on AASHTO criteria. For expressways and major highways without access control, shoulders are typically 8-ft wide. On four-lane convential highways, shoulder widths are 4 ft for less than 12,000 ADT, and 8 ft for 12,000 ADT or more. On two-lane roads, the following shoulder widths apply:

Two-Way ADT	Shoulder Width (ft)
less than 1000	2
1000 - 5000	4
5000 - 7000	8
more than 7000	10

Shoulder cross slopes are typically 5 percent for right shoulders, although narrower roadbed widths have cross slopes that range from 7 to 9 percent. Left shoulder cross slopes are typically 2 percent.

Shoulder strengths are designed on the basis of 2 percent of equivalent axle load (EAL) in adjacent lane, with a minimum traffic index of 5.0. The use of 2 percent of EAL was established after in-house research and discussions with other states. (That research also determined that about 3 percent of truck traffic encroaches 1 to 2 ft onto the shoulder in rural areas.)

CONNECTICUT
Department of Transportation, Bureau of Highways

Shoulder widths in urban residential areas are 8 ft for 3,000 ADT or less (a one way DVH of 600). In urban residential areas with more than 3,000 ADT and all urban commercial and industrial areas, shoulders widths are 10-ft wide right (and left where highway is divided). In rural areas, the following criteria apply.

ADT (one way DHV)	Shoulder Width (ft)
under 750	4
750 to 1490	6
1500 to 3000 (up to 550)	8
3010 and over (560 and over)	10 (right) 10 (left)

Shoulder cross slopes are 1/2 in. per foot (4%) without curbs and 3/4 in. per foot (6%) with curbs.

All shoulders are paved to the same design strength as main-lane pavements.

GEORGIA
Department of Transportation,
Highway Department

Shoulder widths (and strengths) are determined by the Pavement Design Committee, which considers truck and vehicle volumes in their deliberations. The following criteria serve as aids to the committee:

HIGHWAY CLASSIFICATION	ADT	SHOULDER WIDTH (ft) PAVED	TOTAL
Urban Freeway	-	10 (right) 4 (left)	12 (right) 8-10 (left)
Rural Freeway	-	10 (right) 4 (left)	12 (right) 10 (left)
Four or more lanes, (free or partial control of access)	-	10 (right) 4 (left)	12 (right) (left varies)
Two lanes	under 399	none	4 to 5
	400 to 999	none	6 to 8
	1000 to 1999	6 to 8	8 to 10
	2000 & over	8 to 10	10 to 12

Shoulder cross slopes are 1/2 in. per foot (4%) for paved shoulders and 3/4 in. per foot (6%) for turf shoulders.

IDAHO
Transportation Department

Shoulder widths on two-lane roads are based on traffic volumes, with the same pavement cross section used for the main lanes and shoulder (i.e., the edge stripe is the only delineation for shoulders).

TRAFFIC VOLUMES		
Current ADT	DHV (20th hour)	Shoulder Width (ft)
under 50	-	0 to 1
50 to 400	-	2
400 to 750	100 to 200	4
-	200 or more	6

Four-lane divided primary highways have shoulders 7-ft wide right (8-ft on Interstate facilities) and 3-ft wide left. As a part of Idaho's standards, a color-coded map has been developed that indicates the total widths of pavements for rural highways on the State Highway System. Shoulder widths are, in many cases, less than those shown in the chart above, but are considered to be cost-effective. One benefit of this map is that it provides for more uniform widths along a given route than would be achieved if widths were changed as traffic volumes varied from one category to another. The map also indicates practical widths attainable through environmentally sensitive areas (rather than widths based strictly on traffic volumes).

Shoulder cross slopes are typically 2 percent.

Shoulder strengths are typically designed the same as main-lane pavement.

ILLINOIS
Department of Transportation

Shoulder widths are based on highway classifications and traffic volumes in accordance with the following table:

Highway Class & No. of Lanes	Design ADT	Traffic DHV	Minimum Width (ft) of Paved Shoulder Right	Left
TRUNK				
6-lane	-	over 1700	10*	10
4-lane	-	under 1700	10	8
MAJOR				
4-lane	-	under 1800	10	8
2-lane	-	under 800 (two-way)	10	
AREA SERVICE				
4-lane	-	under 1800	10	8
2-lane	-	under 1200 (two-way)	10	
COLLECTORS AND LAND ACCESS				
4-lane	-	over 1425 (two-way)	8	6
2-lane	under 250	-	2	
	250 to 400	-	4	
	-	under 200 (two-way)	6	
	-	200 to 1425 (two-way)	8	

* May be 12 ft where truck traffic exceeds 250 DHV

On widening and resurfacing projects for 2-lane rural highways, shoulders are 8-ft wide (1-ft paved and 7-ft gravel) if the current ADT is over 5,000, and 4-ft wide (1-ft paved and 3-ft gravel) if the current ADT is 5,000 or less. On resurfacing projects for 2-lane rural highways 22- to 24-ft wide with a current ADT of 1,000 to 3,000, an 18 in. wide paved shoulder is added.

On 3R projects, shoulder widths are often reduced to provide greater widths for the main lanes.

Shoulder cross slopes are 1/2 in. per foot (4%) for paved, 3/4 in. per foot (6%) for granular, and 1 in. per foot (8%) for turf shoulders.

Shoulder design is empirical, except where anticipated shoulder uses require greater shoulder strengths (such as in the vicinity of weigh stations, at locations of repetitive truck parking, and where shoulders will be used for maintenance of traffic during construction).

LAKE COUNTY, ILLINOIS
Department of Highway

Shoulder widths on the county system are designed for either open sections or closed sections. On open sections, shoulders are typically 8-ft wide (6-ft wide on widening projects), although adjacent to by-pass/right-turn lanes, shoulders 4-ft wide are used. On closed sections with curbs and gutters, sidewalk areas are graded 5-ft wide, with 4-ft paved for pedestrians.

Shoulder cross slopes are 1/2 in. per foot (4%) for open sections, and 1/2 in. to 1 in. per foot (4% to 8%) for closed sections.

Shoulder strengths are based on standard designs, and are not normally designed for each project.

MARYLAND

State Highway Administration
Department of Transportation

Shoulder widths are based on highway classifications, generally in accordance with AASHTO criteria as follows:

Highway Classification and No. of Lanes	Roadway Shoulder Width (ft) Right	Left
EXPRESSWAYS AND MAJOR ARTERIALS (divided)		
4 lanes	10	4
6 or more lanes	10	10
if concrete median barrier	10	12 to 15
ARTERIALS AND COLLECTORS (undivided)		
minor, less than 400 DHV	8	
major, 400 DHV or more	10	
RAMPS (other than inner loops)	10	4
INNER LOOP RAMPS	Curb	10
LOCAL ROADS & STREETS	AASHTO	Guide

Except on Interstate highways, shoulders on bridges vary with the bridge length.

Bridge Length	Bridge Shoulder Width (ft) Right	Left
Interstate	10	4 to 6
less than 750 feet	10	4
750 feet to 2500 feet	8	4
over 2500 feet	7	2

Shoulder slopes are normally 6 percent on outside shoulders and 4 percent on median shoulders.

Shoulder strengths are primarily designed on the basis of truck volumes. For less than 500 trucks per day one-way in 10th year, a 1-year life as through-lane is used for shoulder thickness design. Where greater than 500 trucks per day one-way in 10th year, a 2-year life as through-lane is used for shoulder thickness design.

On bituminous concrete paving projects with greater than 500 trucks per day in 10th year, the main-lane paving section (i.e., full depth) is extended 2 ft into shoulder area to compensate for vehicles tracking beyond the striping at the edge of road. On low type facilities, a lesser (thinner) section is provided.

Where shoulders are to serve as through-lanes, by-pass lanes, turning lanes, or extra paving at turning radii, the same paving sections as the main lanes are provided.

NEBRASKA

Department of Roads

Shoulder widths (and strengths) are based on traffic volumes, highway classifications, and proposed uses. In addition to extensive design charts, Nebraska has developed a "Surfaced Shoulder Map" for the State system, noting which highways are to have paved shoulders (6-ft wide or more, and less than 6-ft wide). Unpaved shoulders are typically turf. Generally, this map indicates that all Interstates, expressways, and high-volume major arterials will have surfaced shoulders in addition to local highways where specific uses require surfaced shoulders (for example, accommodation of the mobile home industry). The following chart summarizes shoulder widths for rural highways:

Classifications and 20 Year Traffic Data	Shoulder Width (ft) Paved Right	Paved Left	Total Right	Total Left
Interstate and Expressways	10	4	12.5	6.5
Major Arterials				
over 750 DHV	10	4	12.5	6.5
750 to 400 DHV	8	4	10	6
if two lanes	8		10	
400 to 200 DHV	*		10	
1700 to 850 ADT	*		8	
850 to 400 ADT	*		6	
under 400 ADT	none		4	

* Surfaced only if specified on "Surfaced Shoulder Map" - otherwise turf.

The same standards apply along municipal interstates and expressways, except that total shoulder widths are 0.5 ft less, right and left. Shoulders 8-ft wide are provided along municipal major arterials (10-ft wide if also for parking). Shoulders 6-ft wide are provided along municipal collectors and local roads. The following criteria apply to rural minor arterials, collectors, and local roads:

Road Classification	Current ADT	Shoulder Width (ft)
Minor Arterials	401 to 750	6
Minor Arterials, Collectors & Local	50 to 400	4
Minor Arterials, Collectors & Local	less than 50	3

Shoulder cross slopes are 0.04 ft per foot (4%) for surfaced and 0.06 ft per foot for turf (6%).

NEW JERSEY
Department of Transportation

Shoulder widths are determined on the basis of highway classifications:

Highway Classification	Paved Shoulder Width (ft) Right	Left
Interstates, Expressways and Principal Arterials	12	5 (4 lanes) 10 (6 or more lanes)
Major Arterials	10	10
Collector Roads & Ramps	AASHTO Criteria	
Auxiliary lanes		
if 12-ft lane	10	
if 13-ft lane	no shoulder	
Local Roads	widths vary	

Shoulder cross slope is typically 4 percent.

Shoulder strengths are typically designed to be 10 percent of the main-lane pavement design. The use of 10 percent is based on previous poor experience with shoulders of less strength.

NEW MEXICO
Highway Department

Shoulder widths are based on highway classifications and traffic volumes:

Highway Classification	Traffic Volumes Current ADT	20 Yr. DHV	Paved Shoulder Width (ft) Right	Left
Interstate	-	-	AASHTO	
Divided, 4-lanes	-	-	10	4 to 6
Undivided (2-lanes)	-	400 & over	8 to 12	
	-	200 to 400	8 to 10	
	400 to 750	100 to 200	6 to 10	
	250 to 400	-	4 to 8	
	50 to 250	-	4 to 6	
	less than 50	-	2 to 4	

Shoulder cross slopes are the same as adjacent main lanes, typically 0.015 ft per foot (1.5%).

Shoulders are constructed of the same materials as the main lanes. For concrete pavement with concrete shoulders, the shoulder is tapered from the traffic lane depth to 6 in. or 1/2 main-lane thickness, whichever is greater at outer edge of the shoulder. For flexible pavements on roadways with a curving and rolling alignment and/or where the truck volume is 12 percent or more of the traffic stream, the shoulder is of the same thickness as the main-lane. For flexible pavements on roadways where sight distances are good and truck volumes are less than 12 percent of the traffic stream, 80 percent less ADT is used for design of the shoulder strength.

NEW ORLEANS, LA.
Department of Public Works

Shoulder widths on older, narrow city streets and highways are determined on the basis of available right-of-way. As a result, "shoulders" are not normally provided. Parking lanes (shoulders) 8- to 10-ft wide are, however, very common throughout the city. On resurfacing projects without curbs, a compacted shell shoulder 4-ft wide is typically provided.

Shoulder cross slopes vary, depending on the cross slope of the main lanes (typically, 2.5%) and drainage requirements.

Shoulder strengths on older streets are not "designed," but are either compacted shell (depth varies) or 6 in. of compacted shell base with 4 in. of asphalt base course and a 1½ in. asphalt wearing surface. All city streets with parking lanes (shoulders) are designed to the same strength as main lanes.

NEW YORK

Department of Transportation

Shoulder widths are based on highway classifications and traffic volumes, and are designed in accordance with AASHTO criteria:

Highway Classification	Traffic Volumes Forcast Year DHV	Shld. Width(ft) Right	Shld. Width(ft) Left
Urban and Rural Freeways and Expressways	-	10	6* (4' paved)
Interstate, 6 or more Lanes	-	10	10
Rural Primary	-	6 to 10	6 to 10
Rural Secondary (2 lanes)	greater than 160		10
	100 to 160		8
	less than 100		6
Urban Arterials and Streets	-	2 if curbed 10 to 12 if parking	
Climbing Lanes	-	4	-
Ramps	-	0 to 10	0 to 6

Shoulder cross slopes are typically 3/4 in. per foot (6%), although flatter slopes are used if the parking shoulder is also used as a travel lane (1/2 in. per foot, 4%).

Shoulder strength is designed on the basis of traffic volumes and expected truck loads. For new construction, six recommended shoulder standards have been developed. Construction contractors choose and bid on a standard acceptable shoulder design that would cost the least to construct. Depending on the location and size of the project, full-depth shoulders have been provided, under this practice, at no increase in cost over more traditional shoulder designs.

NORTH CAROLINA

Department of Transportation

Shoulder widths (and strengths) are determined by the Planning Board, using traffic volumes and highway classifications. North Carolina recently approved a new "Paved Shoulder Policy" for all new construction or shoulder reconstruction. This policy applies to all except Interstate-funded projects. In order to provide continuity on the few remaining miles of Interstate highway in North Carolina, current practices of shoulder construction have been retained.

Roadway Type and 20-Year Design ADT	Paved Shoulder Width (ft) Right	Paved Shoulder Width (ft) Left	Remarks
Freeways, Expressways and other Divided Highways			
8 or more lanes	10	10	Subject to Planning Board Approval
6 lanes	10	2	Subject to Planning Board Approval
4 lanes			
30,000 ADT or more	10	2	Subject to Planning Board Approval
Under 30,000 ADT	2	2	
Interchange Ramps	2	2	Subject to Planning Board Approval
Multilane Undivided			
30,000 ADT or more	All Shoulder Widths to be Approved by the Planning Board on a Project-by-Project Basis		
Less than 30,000 ADT	2		

Roadway Type and 20 Year Design ADT	Paved Shoulder Width (ft) Right	Paved Shoulder Width (ft) Left	Remarks
Two Lanes			
New & Reconstructed Highways			
4,000 ADT or more	2		
Existing Roadways with no Major Construction Other Than Shoulders			All Shoulder Widths and Depths to be Approved by the Planning Board on a Project-by-Project Basis

Shoulder cross slopes are 1/2 in. per foot to 1 in. per foot (4% to 8%), except where paved shoulders are only 2-ft wide (same as main lanes).

TEXAS

State Department of Highways and Public Transportation

Shoulder widths are based on highway classifications and traffic volumes as follows:

Highway Classification	Design Year Traffic Volumes ADT	Design Year Traffic Volumes DHV	Paved Shoulder Width (ft) Right	Paved Shoulder Width (ft) Left
Controlled Access	over 20,000	over 1,200	10	4*
Multilane Rural, Non-Controlled Access:				
4 to 6 Lanes Divided	over 5,000	400 to 2,400	8 to 10	4
Undivided	up to 7,500	up to 600		8 to 10
Two-Lane Rural	2,200 to 7,500	475 to 1,400		8 to 10
	less than 2,200	less than 475		2
Two-Lane Rural Farm and Ranch to Market Roads	Current ADT 400 to 1,500			6 to 8
	Current ADT less than 400			3 to 4

* Minimum 10-ft inside shoulder on urban freeways with flush medians and 6 or more lanes.

Shoulder cross slopes vary, as follows:

Type of Shoulder	Shoulder Slope In Inches Per Foot
Paved	1/2 to 5/8
Gravel	5/8 to 3/4
Turf	3/4 to 1

Shoulder strengths are typically the same as the main lanes.

WEST VIRGINIA

Department of Highways

Shoulder widths are based on traffic volumes and available rights-of-way. Because many roads on the State system dead-end "up the hollow" (the State is responsible for all except private roads), design standards are very flexible to serve the specific needs of each area. Paved shoulder widths on Interstates and expressways are 10-ft right and 3-ft left (typically 6,000 or more current ADT). Undivided major "trunk-lines" with current ADT's of 3,000 to 5,999 have shoulders 10-ft wide (paved desirable, earth minimum). Shoulder widths for two-lane and rural access roads are as follows:

Two-Lane Roadway Type	Current ADT	Roadway Width (ft) (typically paved)	Shoulder Width (ft) (gravel or earth)
Trunkline	1,000 to 2,999	24	8
Feeder	400 to 999	24	6
Local Access	100 to 399	22	4
	less than 100	18 to 20	0 to 4
	4 to 10 parcels	16 (paved or gravel)	2
	1 to 3 parcels	12 (paved or gravel)	0 to 2

Shoulder cross slopes are 1/2 in. per foot (4%) on high volume highways and 3/4 in. per foot (6%) on low volume roads.

Shoulder strength is normally not designed. Normal practice is to provide aggregate and paving in the same overall thickness as the main lanes.

APPENDIX D —

UPDATE OF 1977 QUESTIONNAIRE
(NCHRP SYNTHESIS 63)

BACKGROUND

In August 1979, the National Cooperative Highway Research Program (NCHRP) published the NCHRP Synthesis of Highway Practice 63, "Design and Use of Highway Shoulders" (17). Synthesis 63 served as the starting point for NCHRP Project 1-22, "Shoulder Geometrics and Use Guidelines," and was instrumental in the initiation of the following tasks for this research:

- The identification and evaluation of highway agencies to be visited; and
- A basis for the historical overview of shoulder practice.

This appendix summarizes the update of the 1977 Questionnaire from Synthesis 63.

SELECTED UPDATING OF 1977 QUESTIONNAIRE

In an effort to collect current shoulder designs and practices from state highway agencies not selected for visitation on NCHRP Project 1-22, letters requesting an update of 10 questions from the 1977 questionnaire were distributed in late 1981. Letters were sent to 37 states (includes New Jersey, subsequently visited - see Appendix A), requesting a review of the agency's 1977 reply and an update of only those responses which have since been revised. Replies were received from 17 states, 9 of which indicated revisions in their shoulder geometrics and/or uses. These 9 responses, together with the responses from the 14 states visited during this research project, represent only slightly more than one-half of the total number of responses received on NCHRP Synthesis 63.

FINDINGS

For the 9 nonvisited states which cited revisions in their shoulder geometrics and/or uses between 1977 and 1981, the following listing highlights significant revisions adopted by each state. It is interesting to note the similar directions taken by many of the states in response to the limited funds available for shoulder construction and maintenance. In a similar manner, several states have increased the strength of a ribbon of the shoulder adjacent to the main-lane pavement to provide cost-effective lateral support and reduce long term maintenance expenses.

Current shoulder design practices for the 14 visited states (in addition to the 2 county and 1 city agencies) are presented in Appendix C of this report.

Delaware

- Greater emphasis placed on highway classification to select shoulder type.
- Use of two standardized shoulder sections for ease of construction: "normal" and "heavy duty" thickness.
- Less emphasis placed on the need for rehabilitation of existing shoulder prior to multiple use.
- Increased acceptance of multiple shoulder uses.

Kansas

- Minimum design volume criteria for aggregate or bituminous shoulders (instead of turf) increased from 1,500 vehicles per day (vpd) to 1,700 vpd.
- Reduced thickness of subbase required for stabilized shoulders adjacent to PCC pavement.

Louisiana

- On all primary routes, outside travel lane is constructed 15-ft wide, and striped at 12 ft, for lateral support.
- Shoulder maintenance cost, 1980-1981 fiscal year:

By Type

Unpaved	$121 per shoulder mile
Paved	$133 per shoulder mile

By Functional Class

Interstate	$220 per shoulder mile
Primary	$314 per shoulder mile
Secondary	$195 per shoulder mile
Farm/Market	$129 per shoulder mile

Michigan

- On roadway sections with guardrails, the additional width of graded shoulder increased from 2 ft on both sides to 5-ft right and 3-ft left.
- Left-side paved shoulder widths for rural freeway ramps increased from 3 ft to 5 ft.
- Implemented more definative policy for shoulder surface treatments.

Missouri

- Shoulder construction details revised to simplify construction and provide better lateral support.
- For new rigid pavement on facilities with less than 1,700 ADT in urban areas or with safety zones, the standard 3-in. granular or turf shoulder now includes a stabilized strip adjacent to the pavement 2-ft wide to provide better lateral support.
- For new rigid pavement on facilities with 1,700 to 3,500 ADT, the standard seal-coated shoulder with a 2-ft wide stabilized strip adjacent to the pavement has been replaced by a full width 2-in. asphalt overlay.

Ohio

- For rigid pavement (PCC), either rigid or flexible shoulder pavement is now satisfactory (policy in 1977 permitted only flexible shoulder pavement).
- Bituminous shoulders provided on all routes where current volume of median and heavy trucks is between 250 and 1,000 ADT (policy in 1977 for only arterials and collectors):

250 to 500 ADT	4-ft wide shoulder surface treated only
500 to 1,000 ADT	8-ft wide shoulder subbase and surface treated

- As a result of a detailed evaluation of pavement drainage (just underway in 1977), a new pavement drainage policy is now in effect, encompassing evaluation, design, construction and maintenance.

Pennsylvania

- For rigid pavements (PCC), only rigid shoulder pavements are constructed; for flexible pavements only flexible shoulder pavements are constructed (policy in 1977 permitted mixing pavement and shoulder types).
- Flexible pavement is extended full depth 2 ft into the flexible shoulder pavement in order to provide lateral support.
- While not a change from 1977, corrugated rumble strips in rigid shoulder pavement was just recently added back to the design standards, after a 2-year period of not being required.
- Shoulder maintenance cost, 1980-1981 fiscal year:

By Type

Unpaved	$407 per shoulder mile
Paved	$259 per shoulder mile

By Functional Class

Interstate	$361 per shoulder mile
Limited Access Freeways and Major Arterials	$352 per shoulder mile
Minor Arterials	$383 per shoulder mile
Collector Roads	$388 per shoulder mile
Local Roads	$289 per shoulder mile

Washington

- Overlays on existing shoulders now uniformally cross-sloped at 2 percent
- On two-lane rural highways, where passing is unsafe, recent legislation requires slow-moving vehicles to pull off of the roadway where safe area for the turn-out exists whenever five or more vehicles form in a line behind. Slow moving vehicle turnouts are provided along these routes designed as follows:

  width
  - 10-ft min. 12 ft desirable

  length
  - 100-ft min. plus tapers 1/4 mile maximum total length

  tapers
  - 25:1 approach 50:1 departure

  roadway surface
  - bituminous surface treatment or asphaltic concrete pavement

- Where properly signed and improved shoulders exist along any two-lane highway, drivers of slow-moving vehicles may pull onto the shoulder to permit overtaking vehicles to pass.
- Shoulder maintenance cost, 1981 fiscal year:

By Functional Class

Interstate	$306 per shoulder mile
Principal Arterial	$ 84 per shoulder mile
Minor Arterial	$122 per shoulder mile
Collector	$473 per shoulder mile

Wyoming

- Shoulder types and geometric characteristics now selected on the basis of functional classification (policy in 1977 was to construct only plant mix shoulders).
- Although the thickness of shoulder pavement remains the same as that for the traveled way, current policy is to square off the surfacing on the outside and place up fill material on the fore-slope.
- In conjunction with the squaring off of shoulder edges, current policy is to use a lesser design year for the initial surfacing thickness (main-lane and shoulder pavements) and a narrower shoulder. In about 10 years, the shoulders would be widened and a full width pavement overlay provided for the longer design year traffic projection.

ADDENDUM TO NCHRP REPORT 254

APPENDIXES E, F, G

Appendixes E, F, and G of the agency report, which cover review of the literature, findings of agency interviews, and shoulder occupancy data, are not published herewith, but are contained under separate binding and are available from the NCHRP. The contents of these appendixes are listed here for the convenience of researchers in the area of interest:

Part II - Overview of Shoulder Uses

1. Emergency Stopping (Mechanical Difficulty)

    Safety Problems
    Accident Data
    Safety Solutions
    Alterations of Standard Designs for Use by Vehicles with Mechanical Difficulties

2. Parking

    City Streets and Urban Residential Parking
    Truck Parking
    Park and Ride
    Rural Residential and Recreational Parking
    Rest and Personal Needs
    Abandoned Vehicles
    Accident Data
    National Safety Council Data

3. Mail and Other Deliveries

    Effect of Routine Deliveries on Shoulder Design and Maintenance
    Safety Problems
    Postal Authority's Safety Requirements
    Recommendations for Improvement of Deliveries
    Accident Data on the Use of Shoulders for Deliveries

4. Turning and/or Passing at Intersections

5. Routine Maintenance

    Utilities

6. Snow Storage

7. Arid Areas (Temperature & Sand Considerations)

8. Major Reconstruction and Maintenance

    Reconstruction
    Bridge Decks
    Traffic Control Plans

9. Off-Tracking

    Maintenance Problems
    Safety Problems

10. Encroachment

11. Slow-Moving Vehicles

    Voluntary Use by Slower Moving Vehicles
    Passing Lane Use
    Use as Climbing Lanes
    Combined Use as Shoulders and/or Climbing Lanes
    Use by Farm Equipment

12. PEDESTRIANS

    Pedestrian Safety Problems
    Pedestrian Accident Data
    National Safety Council Data
    Recommendations

APPENDIX F - FINDINGS OF AGENCY INTERVIEWS (Continued)

13. Bicycles

    Use Restrictions
    Contrasting Pavement Texture
    Signing
    Special Provisions for Bicycles
    National Safety Council Accident Data

14. Mass Transit

15. Full Running Lane - Nonfreeways

    Conditions of Use
    Shoulder Changes
    Signing and Marking
    Economic Factors
    Accident Data

16. Full Running Lane - Freeways

    Conditions of Use
    Shoulder Changes
    Signing and Marking
    Accident Data
    Future Plans for the Addition of a New Shoulder Adjacent to the Converted Shoulder

17. Errant Vehicles

    Runaway Vehicles

18. Emergency Vehicle Travel

19. Law Enforcement

20. Emergency Call Box Service and Telephones

21. Roadside Sales

22. Garbage Pick-Up

23. Miscellaneous

    Funeral Processions
    Snowmobiles

APPENDIX G - SHOULDER OCCUPANCY DATA

Procedure and Methodology I-83 (Pennsylvania-Maryland Line to I-695)
- I-83 (I-695 to Guilford Avenue)
- I-95 (I-495 to I-695)
- Baltimore-Washington Parkway (I-95 to I-695)
- Baltimore-Washington Parkway (I-695 to Waterview Avenue)
- Maryland Route 3 (Benfield Blvd. to I-695)

Conclusions

THE TRANSPORTATION RESEARCH BOARD is an agency of the National Research Council, which serves the National Academy of Sciences and the National Academy of Engineering. The Board's purpose is to stimulate research concerning the nature and performance of transportation systems, to disseminate information that the research produces, and to encourage the application of appropriate research findings. The Board's program is carried out by more than 270 committees, task forces, and panels composed of more than 3,300 administrators, engineers, social scientists, attorneys, educators, and others concerned with transportation; they serve without compensation. The program is supported by state transportation and highway departments, the modal administrations of the U.S. Department of Transportation, the Association of American Railroads, the National Highway Traffic Safety Administration, and other organizations and individuals interested in the development of transportation.

The Transportation Research Board operates within the National Research Council. The National Research Council was established by the National Academy of Sciences in 1916 to associate the broad community of science and technology with the Academy's purposes of furthering knowledge and of advising the Federal Government. The Council operates in accordance with general policies determined by the Academy under the authority of its congressional charter of 1863, which establishes the Academy as a private, nonprofit, self-governing membership corporation. The Council has become the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in the conduct of their services to the government, the public, and the scientific and engineering communities. It is administered jointly by both Academies and the Institute of Medicine.

The National Academy of Sciences was established in 1863 by Act of Congress as a private, nonprofit, self-governing membership corporation for the furtherance of science and technology, required to advise the Federal Government upon request within its fields of competence. Under its corporate charter the Academy established the National Research Council in 1916, the National Academy of Engineering in 1964, and the Institute of Medicine in 1970.

TRANSPORTATION RESEARCH BOARD
National Research Council
2101 Constitution Avenue, N.W.
Washington, D.C. 20418