Report No. CDOH-DTD-R-90-2

EXPERIMENTAL GRAVEL SHOULDERS

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Final Report
January 1990

Prepared in cooperation with the
U.S. Department of Transportation
Federal Highway Administration

The contents of this report reflect the views of the author who is responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views of the Colorado Department of Highways or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
CDOH-DTD-R-90-2		

4. Title and Subtitle	5. Report Date
Experimental Gravel Shoulders	January, 1990
	6. Performing Organization Code: 55.00 (1577A)
7. Author(s): David A. Price	8. Performing Organization Report No.: CDOH-DTD-R-90-2
9. Performing Organization Name and Address: Colorado Department of Highways, 4201 E. Arkansas Avenue, Denver, Colorado 80222	10. Work Unit No. (TRAIS)
	11. Contract or Grant No.: HPR B
12. Sponsoring Agency Name and Address: Colorado Department of Highways, 4201 E. Arkansas Avenue, Denver, Colorado 80222	13. Type of Report and Period Covered: Final Report, 6 Years
	14. Sponsoring Agency Code: 740.056

15. Supplementary Notes
Prepared in Cooperation with the U.S. Department of Transportation, Federal Highway Administration

16. Abstract

When the costs of highway construction began to accelerate in the late 70's due to higher energy costs and inflationary pressures, an effort was put forth in the CDOH to find ways to implement savings in highway construction and maintenance. One of the suggestions for cost savings was the use of gravel shoulders in place of paved shoulders. There were three major concerns with this suggestion: 1) maintenance costs on gravel shoulders, 2) safety, and 3) premature failure at the edge of pavement between the gravel shoulder and roadway.

Two sites were constructed for evaluation of these concerns. One was constructed in the Denver area on S. Kipling st. The other was located on SH-40 west of the town of Granby. The two sites were chosen because of the large difference in their Average Daily Traffic. The sites were evaluated for maintenance costs, safety, and overall condition for several years.

Implementation

Gravel shoulders need to be implemented on a project by project basis looking at each projects Design Hourly Volume for possible implementation. Evaluations show that gravel shoulders work well on low volume roadways. However, as Average Daily Traffic rises maintenance requirements become greater and overall cost savings of the gravel shoulder is reduced as well as safety.

17. Key Words	18. Distribution Statement
Shoulders, Gravel, Aggregate Base Course,	No Restrictions: This report is available to the public through the National Information Service, Springfield, Virginia 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	39	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

TABLE OF CONTENTS

SECTION	TITLE	Page NO.
	Disclaimer	i
	Technical Report Documentation Page	ii
	Table of Contents	iii
	List of Figures	iv
I.	INTRODUCTION	1
II.	CONSTRUCTION	2
III.	EVALUATION	5
IV.	SAFETY	11
V.	COST COMPARISON	13
VI.	CONCLUSIONS	14
VII.	IMPLEMENTATION	15
APPENDIX A	TRAFFIC ACCIDENT DATA	A1
APPENDIX B	PHOTOGRAPHS	B1
APPENDIX C	COST COMPARISON	C1

LIST OF FIGURES

FIGURE	TITLE	PAGE NO.
1	PROJECT LOCATION MAP - IXM-1115(7)	3
2	TYPICAL SECTION - IXM-1115(7)	4
3	PROJECT LOCATION MAP - HES 0003(22)	6
4	TYPICAL SECTION - HES 0003(22)	7

I. INTRODUCTION

When the costs of highway construction began to accelerate in the late 70's due to higher energy costs and inflationary pressures, an effort was put forth in the Colorado Department of Highways to find ways to implement savings in highway construction and maintenance. A group called the Design Standards and Review Committee was formed. Their purpose was to review the design of highways for more efficient and effective methods of carrying out the construction programs at less cost. A project coming up, at that time, was the reconstruction of a portion of S. Kipling St., an arterial two-lane road in a rapidly expanding suburban area with an average daily traffic (ADT) of 16,301. The design was for a 4-lane divided highway to carry the predicted future increases in traffic.

The current geometric design standards for 4-lane divided highways specified a 10-foot paved outside shoulder and a minimum 4-foot paved inside shoulder. A design decision was made on project IXM 1115(7), to use a 2-foot paved outside shoulder with an 8-foot gravel (Aggregate Base Course, Class 6) surfaced shoulder, and a 2-foot paved inside shoulder adjacent to a 2-foot gravel shoulder. This design was made as a result of the Design Standards and Review Committee (acting as a "downscoping" committee) which recognized the potential initial cost savings, but were concerned for the effect on (1) maintenance costs, (2) safety, and (3) premature edge failure. The purpose of this study was to evaluate the completed project looking at those three items of concern.

In order to further investigate the above concerns, a second site was later included into the evaluation. This site, constructed during the 1986 construction season, allowed for evaluation of gravel shoulders on a 2-lane mountainous terrain with a lower ADT (ADT of approximately

2,350) than that of the site on S. Kipling. Project HES 003(22) was located on SH-40 west of Granby at m.p. 209.9.

II. CONSTRUCTION

A. S. Kipling St.

IXM 115(7) was constructed in the fall of 1983. Figure 1 shows the location of the project on S. Kipling St., and Figure 2 is a typical cross section plan showing the construction of the roadway and shoulders. This project consisted of construction of the northbound traffic lanes. These lanes were to carry two-way traffic until some time in the future when the southbound lanes could be constructed. Construction of this northbound lane was that of half of a four-lane divided roadway. On the outside shoulder the Class 6 base course was placed from the edge of the driving lane out 10 feet at a depth of 4 inches. A 2 foot Hot Bituminous Pavement (HBP) was placed adjacent to the driving lane on top of the class 6 base course at a depth of 2 1/2 inches. This brought the HBP shoulder up level with the driving lane. After completing the HBP, 2 1/2 inches more of the base course material was placed on the remaining 8 foot shoulder to bring the shoulder to grade. This gave a total of 6 1/2 inches of base course material forming the gravel shoulder. The inside shoulder incorporated 2 feet of 2-1/2 inch thick HBP with 2 feet of ABC Class 6 with a depth of 6-1/2 inches carried out from the paved edge giving an inside shoulder measurement of 4 feet. Photo 1 in Appendix B shows the completed outside shoulder (2 feet paved and 8 feet gravel).

PROJECT NO. IXM-1115(7)

S. KIPLING ST.

PROJECT LOCATION

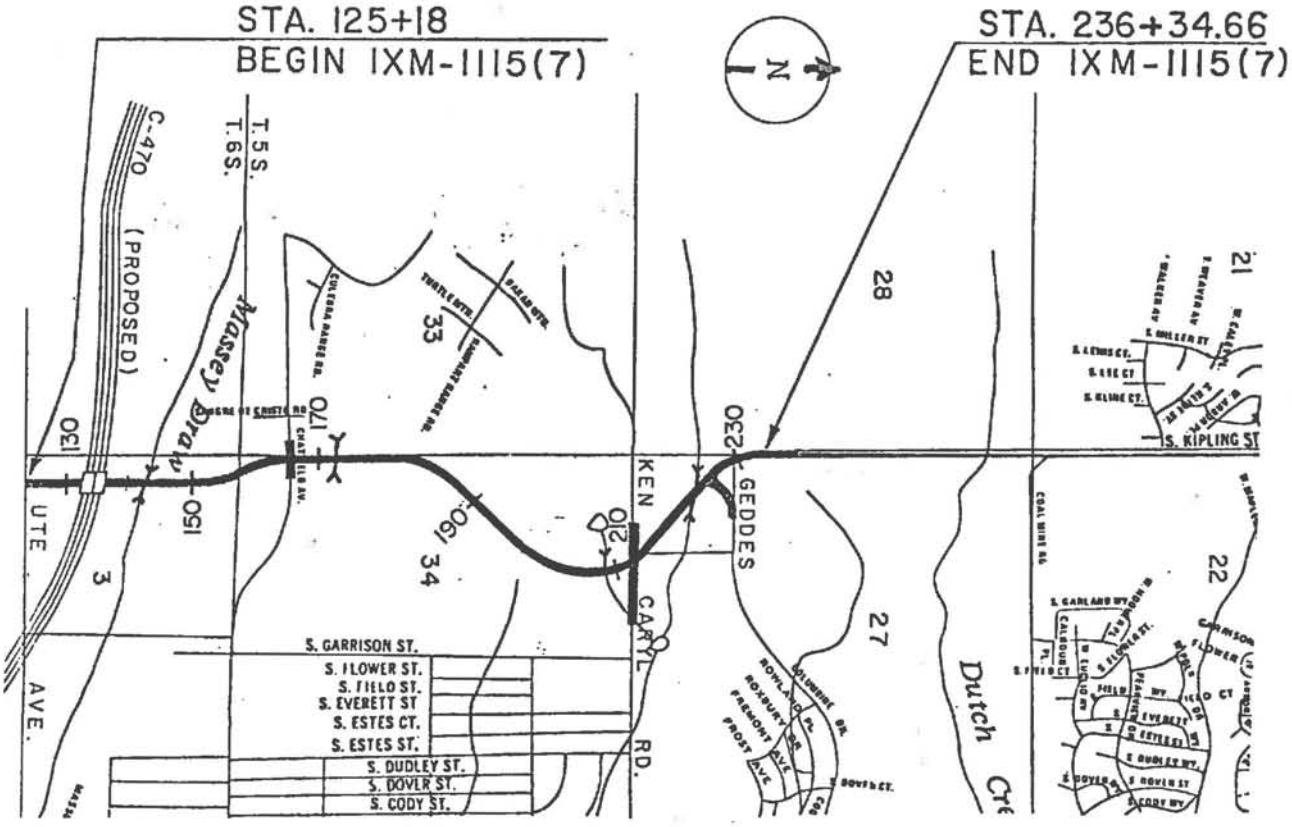


FIGURE 1

PROJECT NO. IXM-1115(7)

S. KIPLING ST.

TYPICAL SECTION

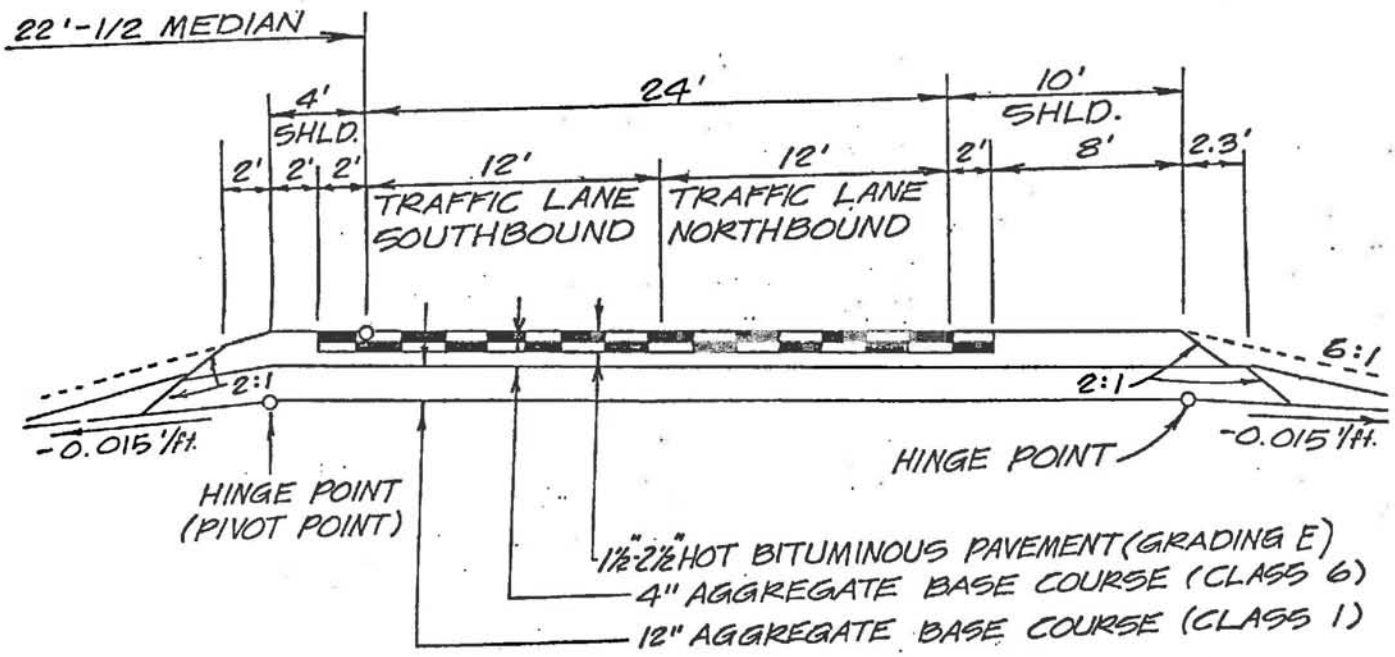


FIGURE 2

B. SH-40

Project HES 003(22) was constructed during the 1986 construction season. This project was chosen to be monitored under this study because of differences in ADT between SH-40 and S. Kipling St. Figure 3 shows the location of this project on SH-40 between m.p. 209.90 and m.p. 210.93 just north of the SH-34 intersection. The shoulders on this site were constructed totally of gravel (ABC Class 6 material). The width of the shoulder on both sides of the roadway was 8 feet with an approximate 8 inch base course material depth.

III. EVALUATION

The evaluation on the two sites consisted of primarily visual inspections, maintenance personnel experiences, accident data, maintenance cost records, and construction costs which together generated a cost analysis for this project.

A. S. Kipling St. Visual Inspection

After completion of construction on S. Kipling St., the initial evaluation of the completed shoulder was performed. Photos 1 and 2 in Appendix B show the newly constructed gravel shoulder. At this point the shoulders looked good and well constructed. However, a visit to this site in November 1983, after some precipitation had fallen, showed that moisture had produced soft spots in the gravel shoulders. Photos 3 thru 5 in Appendix B were taken approximately 48 hours after snow had fallen. Temperatures were high enough to melt the snow and allow some drying of the gravel, however. extreme rutting was caused. Up until this point the shoulders had not been bladed.

PROJECT NO. HES 0003 (22)

STATE HIGHWAY 40

PROJECT LOCATION MAP

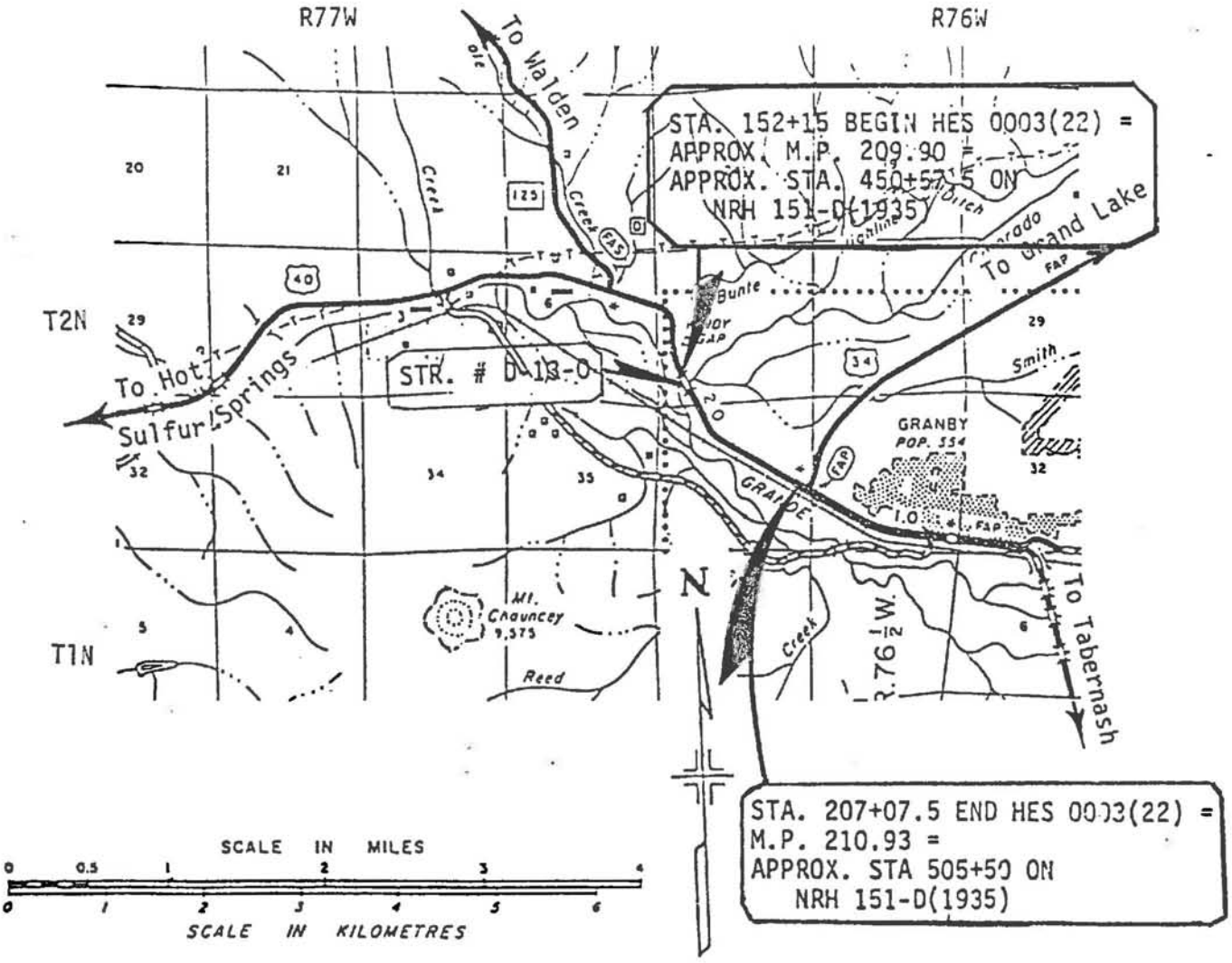


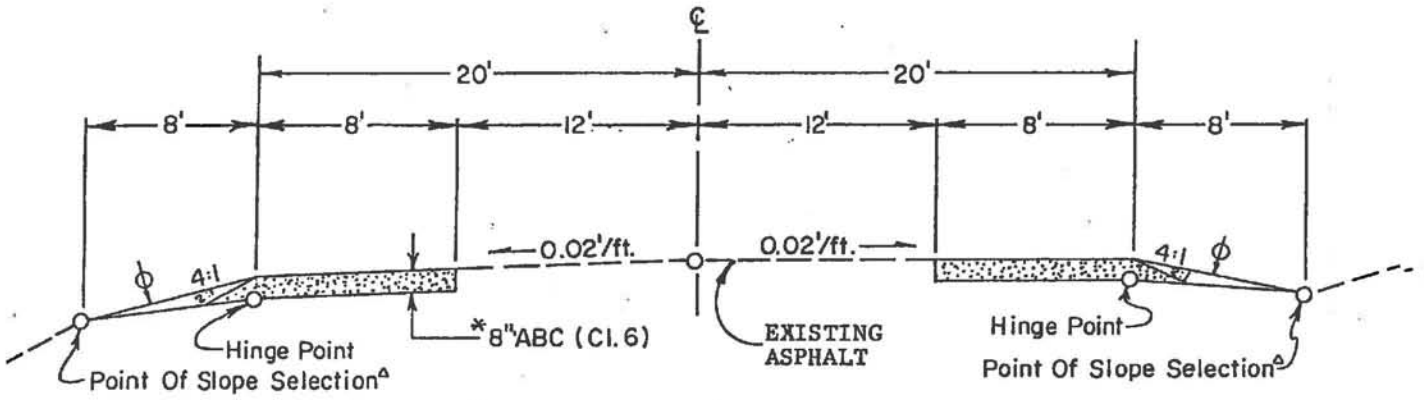
FIGURE 3

PROJECT NO. HES 0003 (22)

STATE HIGHWAY 40

TYPICAL SECTION

STATION 156+57.5 to 185+57.5



* Approximate Thickness

△ For Slope Selection see Cross Sections

ϕ The Contractor will be required to place (or blade) suitable Embankment Material to this line after placing Shoulder Gravel. (Approx. 7.5 Cu.Yds. per side / station).

FIGURE 4

Visual inspections were performed annually for the next five years. The inspections showed the same problem described above concerning moisture within the gravel causing soft spots in the shoulder. The only cure for this was for maintenance crews to add additional ABC Class 6 material and blade the shoulder level to the pavement.

Other noticeable problems occurred where the pavement edge meets the gravel shoulder. Erosion of the gravel at this point was produced by moisture running off the pavement and washing away the ABC material and vehicle tires leaving the roadway which caused rutting to occur. As the gravel shoulder level began to drop, it allowed for a weak spot in the adjacent HBP. Vehicles driving over the shoulder caused this weak point to break off and spall. Photo 6 in Appendix B shows a spalled pavement edge on S. Kipling St. The spalling problem severity depends upon how well maintenance patrols are able to keep the gravel shoulder at the same grade as the asphalt roadway. On S. Kipling St. some spalling has occurred, but as of the fall of 1989, this condition is not a major problem.

B. SH-40 Visual Inspection

Yearly evaluations were made on the SH-40 gravel shoulder site. The same basic observations were noted here as were on the S. Kipling St. site. These are the basic problems with a gravel shoulder: 1) The shoulders became soft when moisture was present, 2) rutting occurred between the shoulder ABC Class 6 and the asphalt roadway (due to water erosion and vehicle traffic leaving the roadway), 3) spalling of the asphalt shoulder occurred in spots. However, the severity of these problems rides on the ability of the

maintenance patrols to grade and maintain the shoulder. During inspections of the SH-40 project, the above mentioned problems occurred, but were not severe. The maintenance patrol in this area kept the gravel shoulder at grade with the asphalt pavement, preventing many of the faults associated with gravel shoulders. Photo 7 and 8 in appendix B show the gravel shoulders at this site in the fall of 1989, three years after construction.

During the fall 1989 evaluation of the SH-40 site, rutting between the pavement and the gravel shoulder was measured. The overall results varied from 0 inches to 1 inch in depth. Photo 8 in appendix B shows an average rut adjacent to the asphalt pavement.

C. Maintenance Experience

Maintenance personnel that patrol the Granby SH-40 test section were interviewed for their opinions and experiences with the gravel shoulder vs. paved shoulders. This particular patrol maintains approximately 50% paved shoulders and 50% gravel shoulders. It was stated during the interview that 80% of their work is spent maintaining the highway sections with gravel shoulders. This includes blading base course back up to the pavement edge, compaction, and patching at the pavement edge where spalling has occurred.

The Granby maintenance patrol mentioned that most of their problems with gravel shoulders occurred on the heavily traveled SH-40 sections. Highways with lower ADT did not appear to be as significant of a problem. This patrol also performs maintenance operations on SH-125 heading east from the SH-40 intersection near Granby. SH-125 has an ADT of 414, considerably less than that of

SH-40 (with ADT=2350). Maintenance personnel on SH-125 for example performed grading operations once per year, compared to a minimum of 3 times per year on SH-40. An inspection of the shoulders on SH-125 showed little if any problem with the ABC material or pavement spalling. Maintenance crews stated that they felt gravel shoulders were cost effective on low ADT roadways; however, as ADT rates increase so does maintenance costs on gravel shoulders.

D. Maintenance Records

Records from Staff Maintenance were examined and showed a comparison of charges related to the 8 foot gravel shoulders west of Granby and 8 foot paved shoulders east of Granby on SH-40. Table B shows the cost comparison and additional costs related to the gravel shoulders. The main difference is in blading and restoring of shoulders (maintenance code 162). Paved shoulders show a savings in maintenance on this item of 58% over gravel.

The CDOH Roadway Design Manual briefly discusses the use of gravel shoulders in Section 302.3.

> "Shoulders for minor roadways may be graded to cross slopes of 4:1 or flatter and covered with gravel, or other suitable all weather material; however, roadways with DHV's [1] greater than 100 require a minimum of 3 foot paved shoulders, e.g. shoulder 6 foot in width may be paved 3 ft. and graveled 3 ft. Roadways that require shoulders to be used for escape or to provide refuge parking should be paved full width when frequent use is expected."

---

[1] DHV is defined as the 30th highest hourly volume occurring in a year. The DHV for any section of road may be determined by applying the given factor to the annual average section volume. DHV factors range from 0.08 in urban areas to 0.34 in mountain recreational areas.

This statement appears to be a good guideline. Both test sections are well above the 100 DHV limit recommended, S. Kipling DHV = 1,793 and SH-40 DHV = 712. and have required constant maintenance. However, SH-125 heading east from SH-40 intersection according to maintenance personnel is graded once per year and appears to remain in good condition between maintenance operations. The section of roadway has a DHV of 66, well below the recommended limit.

IV. SAFETY

Gravel shoulders that are not well maintained can be a hazard. However, the same holds true at the edge of paved shoulders where the aggregate base course material is placed next to the asphalt shoulder. The main difference with the two shoulders is that a driver is allowed more time to correct the course of the vehicle before leaving the paved way. Washouts, ruts and soft areas within a gravel shoulder can capture a vehicle and prevent it from returning safely to the roadway. This holds especially true for vehicles traveling at higher speeds. Colorado accident data shows that 40 to 45% of all fatal highway crashes are caused by single car run-off-road accidents. This type of accident is responsible for more fatal accidents than any other type of crash in Colorado. For this reason it can be seen why it is so important that if gravel shoulders are to be used, they must be well maintained, so this figure will not increase.

Accident reports were gathered from CDOH Staff Traffic for both sites, SH-40 near Granby, and the project on S. Kipling St. in Englewood. The reports were gathered from the construction date on each project, through October 1988. The reports show run-off-road accidents only.

A. S. Kipling St. Gravel Shoulders

Accident reports from S. Kipling St. showed no evidence of accidents being directly related to the gravel shoulders. A total of 15 run-off-road accidents occurred during a five year period. Out of the 15 accidents, eight were at an intersection where the possibility of the intersection being the problem and not the shoulders is very likely. Three accidents occurred during icy conditions with no mention in the report of shoulder related problems such as rollover due to over compensation of steering at the shoulder edge. This could have occurred at any location, gravel shoulders or paved shoulders. This leaves four accidents where vehicles left the roadway and may have been influenced by the gravel shoulders. Appendix A-2 is the accident data sheet for the S. Kipling project.

B. SH-40 Gravel Shoulders

Appendix A-3 shows the accident data sheet for SH-40 gravel shoulders west of Granby for an area of two miles from m.p. 209 to m.p. 211. A total of seven run-off-road accidents occurred during a 2-1/2 year period following construction of the gravel shoulders. Three of these accidents occurred on a curve with the shoulders being a possible factor in the safe return of the vehicles to the roadway. The other accidents here appeared to be non-preventable by the shoulder, whether it was paved or not.

C. SH-40 Paved Shoulders

For comparison, a section of roadway on SH-40 containing 8 foot paved shoulders with similar geometrics and ADT to that of the gravel shoulder test section, west of Granby, was analyzed for run-off-road accidents. Appendix A-4 shows the accident data sheet for this area. Within a two mile area from m.p. 215 to m.p. 217, 8 run-off-road accidents occurred. This data was taken during the same period as the test section west of Granby on SH-40. These eight accidents were very similar to the seven encountered on the gravel shoulder test section, indicating that the gravel shoulder may not be factor for decreased safety in this particular area.

V. OVERALL COST COMPARISON

Appendix C-1 demonstrates overall construction costs for gravel shoulders vs. paved shoulders for a one-inch thickness. For demonstration purposes, on Appendix C-1, assumptions were: two eight foot shoulders (one on each side of roadway), one-inch thick. Overall savings of construction costs of gravel shoulders over paved shoulders per mile per inch thickness of gravel vs. HBP = $8,373 or 71% savings over HBP costs.

Using the data from the above example, a cost analysis was performed on the SH-40 gravel shoulder project. The total length was 2150 ft. Appendix C-2 shows figures for this particular project, with the assumption that if a paved shoulder were to be constructed on this project it would have a depth the same as existing pavement of 3 inches. Table C shows overall cost of gravel shoulder to be $4,175 for the 2,150 foot construction project. If the shoulder were to be HBP then the calculated cost for this project would be $14,404, an increase of $10,279

over gravel shoulders. While looking at this, maintenance costs must also be included. Gravel shoulders are more expensive to maintain than HBP. Maintenance costs per year on a section of gravel shoulders 2150 ft. in length is $97.32 according to Staff Maintenance accounting. HBP shoulders show a maintenance cost of $40.72 per year for the same distance. This gives an increase in cost to gravel shoulders of $56.60 for the SH-40 test section. Of course, there are sure to be some hidden costs on both HBP and gravel shoulders. Such costs could be patching on the pavement edge were spalling has occurred. These costs are unavailable. They are accounted for as pavement repair and are not available in the shoulder accounting codes. Since there is no true way to account for these costs, the figures available are used for the most accurate comparison.

VI. CONCLUSIONS

The cost savings of construction on the SH-40 gravel shoulders for a distance of 2150 ft. amounted to $10,229. The overall maintenance on this section was $56.60 per year higher than on a paved shoulder. Maintenance costs may be much higher for gravel shoulders than paved shoulders; however, data received by CDOH Staff Maintenance is the most accurate available and it shows that gravel shoulder maintenance will not overrun the initial savings of construction. Perhaps, for a roadway with a much higher ADT this will not be true.

The next concern is premature pavement edge failure between the gravel shoulder and the roadway. While some spalling has occurred, inspections of the sites show this not to be a significant problem. Maintenance has maintained the few areas of spalling by patching.

The higher the ADT, the more likely maintenance will become a problem as in rutting of gravel and edge dropoffs. The sites evaluated under this study were well maintained, so accident reports did not show that any hazards existed with the gravel shoulder. On higher ADT roadways however, maintenance may not be able to keep up with the problems of rutting and spalling of the pavement at which time the shoulders do become a hazard. As noted in the evaluation section of this report, maintenance crews responsible for SH-125 at the intersection of SH-40 reported that routine maintenance such as grading of the gravel shoulder, is performed only once per year. This became an easy section to maintain. ADT on SH-125 is 414 while ADT on SH-40 at the intersection is 2350. Maintenance reports that this section must be graded at a minimum of 3 times per year. This shows that there is a significant increase in shoulder maintenance as ADT rises. Staff Design recommends a DHV maximum of 100 as the breakoff for gravel to paved shoulders. This figure may be somewhat low; however, it does appear to be a good general recommendation.

VII. IMPLEMENTATION

Gravel shoulders can lower project costs with little if any effect on maintenance or safety if used on roadways with low ADT. Staff Designs recommendation of 100 DHV maximum for the cutoff between gravel and paved is a very good standard to use when looking at the use of gravel shoulders and is supported by this study.

When gravel shoulders are to be used, ongoing maintenance is essential to safety.

APPENDIX A

ACCIDENT DATA

DEPARTMENT OF HIGHWAYS
STATE OF COLORADO
DIVISION OF HIGHWAYS
DOH Form No. 56
Rev. May, 1985

STAFF TRAFFIC ENGINEERING BRANCH

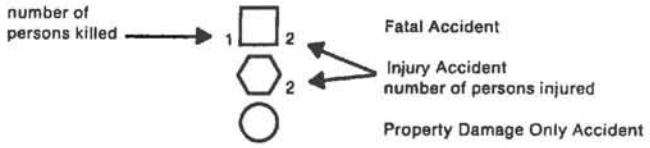
TYPICAL COLLISION DIAGRAM LEGEND FOR MOTOR VEHICLE TRAFFIC ACCIDENTS

ACCIDENT LOCATION

On-roadway | Off-roadway (right) | Off-roadway (left)

ACCIDENT TYPES	SYMBOL
OTR - Overturning	OTR
ONC - Other non-collision	ONC (type indicated)
HO - Head-on	HO
RE - Rear-end	RE or PC
PC - Parked car	
SSD - Sidewsipe-same direction	SSD
SOD - Sideswipe-opposite direction	SOD
AT - Approach turn	AT
OT - Overtaking turn	OT
PED - Pedestrian	
BS - Broadside	
T - Train	
B - Bicycle, Motorized bicycle	PED, BS T, B or AN (type indicated)
AN - Animal	
FO - Fixed object	FO or O (type indicated)
O - Other object	

ACCIDENT SEVERITY



COLORADO DEPARTMENT OF HIGHWAYS

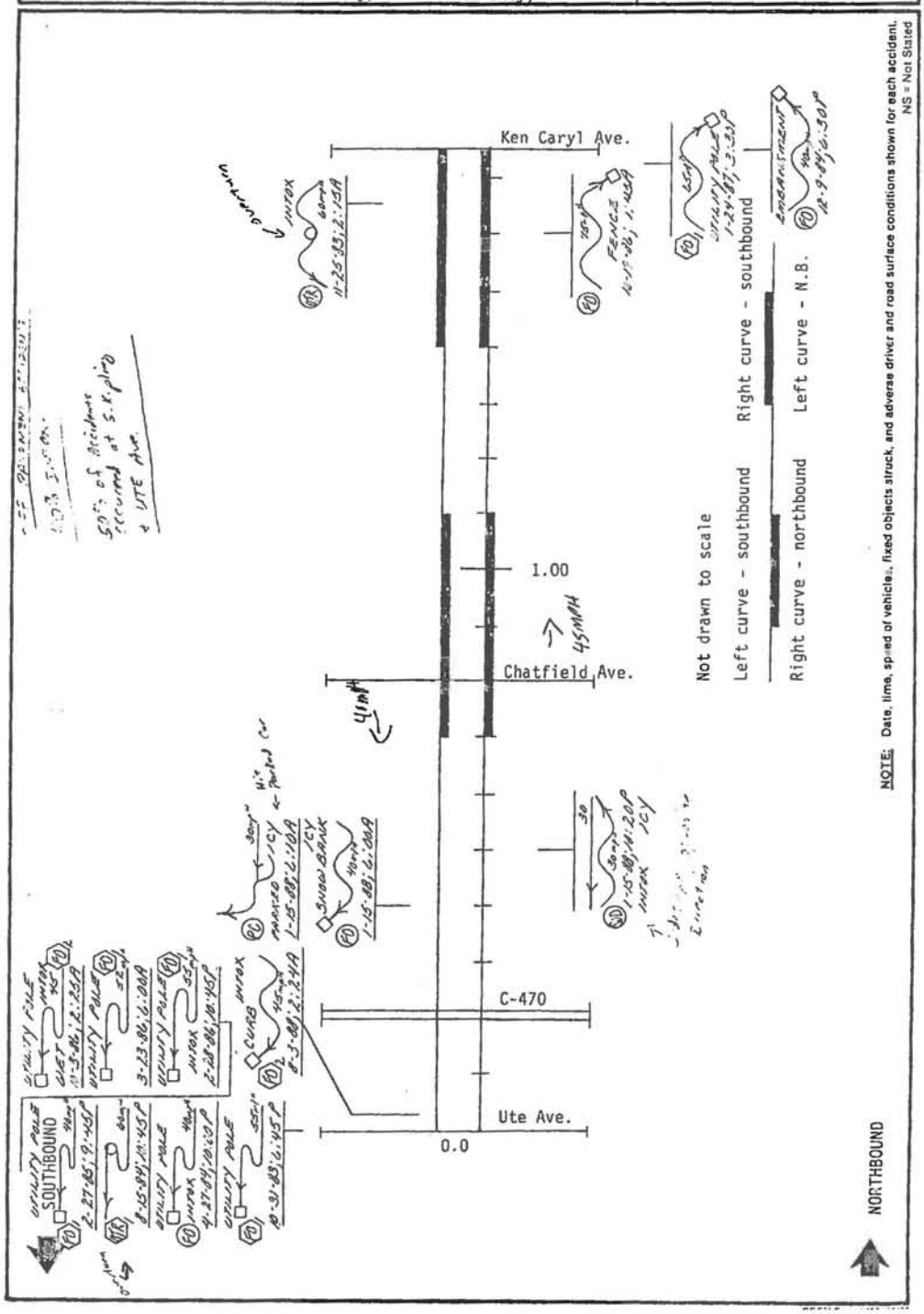
TRAFFIC ACCIDENT LOCATIONS

FILE NO.	882.11
	Jefferson
DATE	February 6, 1989
SHEET	2 OF 2

S.H. No.	NA	District	VI	Period:	January 1, 1983	To	October 1, 1988

Description: S. Kipling St. from the Intersection with Ute Ave. to the Intersection with Ken Caryl Ave. (Ran off road type accidents only)

Milepoint: NA To



COLORADO DEPARTMENT OF HIGHWAYS
TRAFFIC ACCIDENT LOCATIONS

FILE NO. 880.040.02

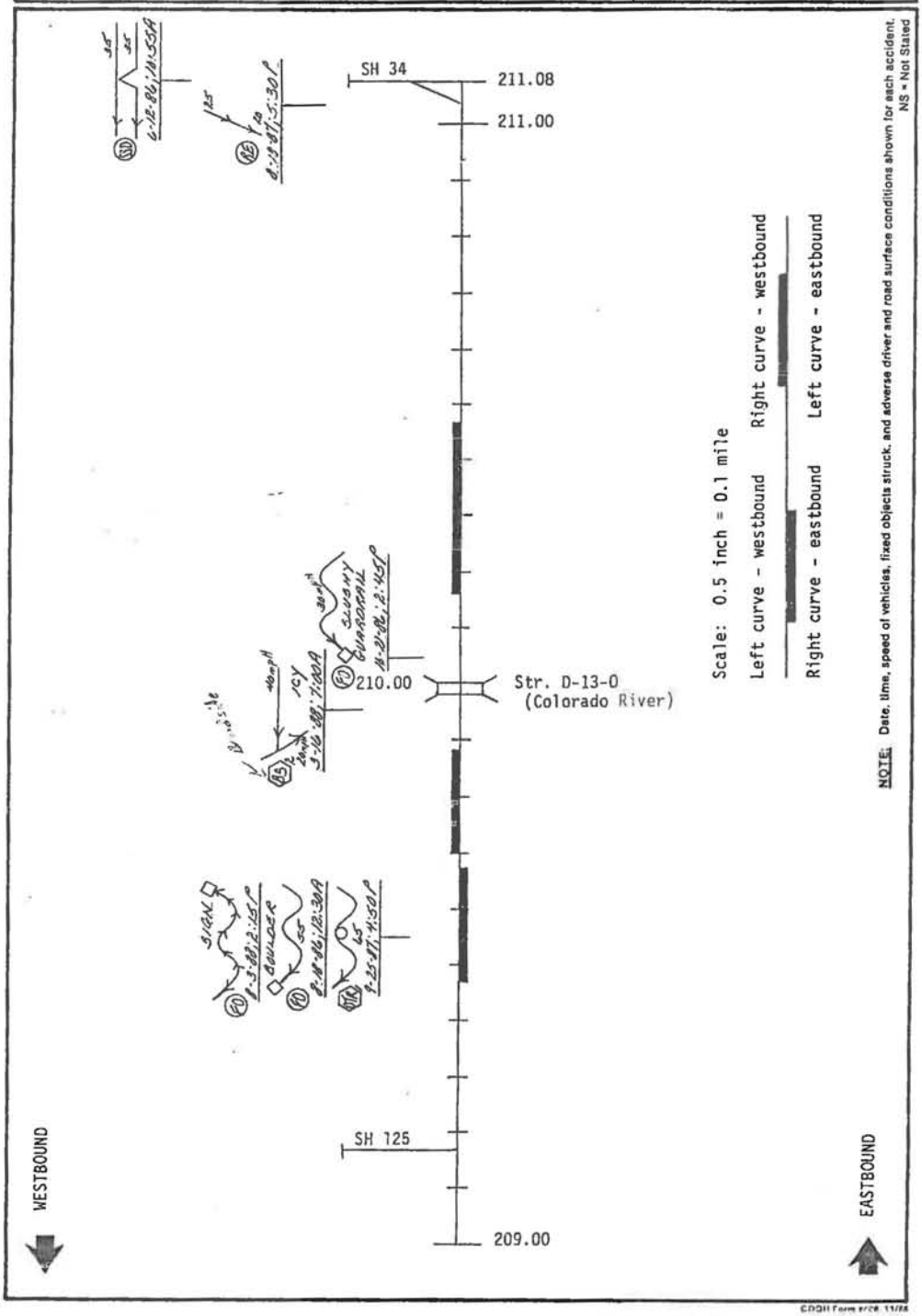
DATE February 3, 1989

SHEET 2 OF 2

S.H. No. 40	District III	Period: January 1, 1986 To October 1, 1988

Description SH 40 (US 40) from 0.17 mile west of the Junction of SH 125 to the Junction of SH 34 (US 34) west of Granby

Milepoint 209.00 To 211.08



CDOH Form #208 11/86

STATE HIGHWAY - 40 SECTION - A

LOCATION FROM 2 TO 4*

SERIAL	MP IO LI EN T	KILLED	INJURED	LOCATION	ACCIDENT TYPE	VEHICLE TYPE	DOIF R EV CE TH I O1 N	VM EO HV IE C L1 E	VEHICLE MOVEMENT	DOIF R EV CE TH I O2 N	VM EO HV IE C L2 E	LIGHT	ROAD CONDITION	CONTOUR	DATE	TIME
110033	21550	0	1	R	OV	PICKUP	E	STRT				DA		CL	12/22/86	16:30
22352	21550	0	1	R	CU	CAR	E	STRT				TW	SN	CL	2/28/87	6:15
79704	21570	0	1	L	FE	PICKUP	W	STRT				DU		SG	9/19/87	3:00
32647	21570	0	1	L	OV	CAR	W	STRT				DU		SG	4/ 4/87	22:00
98045	21660	0	1	L	DP	CAR	W	STRT				DA	IC	SG	11/22/86	8:45
10180	21670	0	0	R	RE	CAR	S	STRT				DA	IC	SG	1/31/88	11:15
79182	21680	0	0	L	OT		W	LTRN	CAR&TR	W	STRT	DA		SL	9/12/88	11:20
48444	21699	0	0	R	DP	CAR	E	STRT				TW		SG	6/ 6/87	5:20
100814	21720	0	0	R	OV	CAR	W	STRT				DU	IC	CG	11/30/88	22:40
75985	21722	0	2	R	EM	CAR	E	STRT				DA		CG	8/29/88	16:01
100437	21730	0	0	L	OV	PICKUP	E	STRT				DU	SN	SG	11/29/86	22:20
1179	21745	0	0	L	OV	PICKUP	E	STRT				TW	SN	CG	1/ 2/87	16:00
29133	21750	0	0	R	OV	CAR	E	STRT				DA	IC	CG	3/27/87	9:15
16118	21790	0	1	L	OV	CAR	E	STRT				DU	IC	CG	2/15/87	5:10

LOCATION

L - Ran off left side
R - Ran off right side
T - Ran off T intersection

ACCIDENT TYPE

OV - Overturning accident
ON - Other Non-Collision accident
PD - School age to/from school
PD - All other pedestrians
BS - Broadside
HO - Head-On
RE - Rear-End
SS - Sideswipe-Same direction
SO - Sideswipe-Opposite direction
AT - Approach turn
OT - Overtaking turn
PC - Parked motor vehicle
TN - Railway vehicle
BK - Bicycle
BK - Motorized bicycle
AN - Domestic animal
AN - Wild animal

INVOLVING FIXED OBJECT

LP - Light pole
TS - Traffic signal
SI - Sign
BR - Bridge rail
GR - Guard rail
MB - Median barrier
BA - Bridge abutment
CP - Column or pier
CV - Culvert or headwall
EM - Embankment
CU - Curb
DP - Delineator post
FE - Fence
TR - Tree
LB - Large boulder
RO - Rocks in roadway
BC - Barricade
WA - Wall
CC - Crash cushion
OF - Other fixed object
OO - Involving other object
PB - Postal Box (Mail)

VEHICLE TYPE

CAR - Passenger car
CAR&TR - Car with trailer
PICKUP - Pickup truck
VAN&TR - Pickup or Van with trailer
TRUCK - Truck, self-contained
TANKER - Truck, tractor/tanker
SEMI - Truck, tractor/semi-trailer
M HOME - Self-propelled motorhome
SCHOOL - School bus
BUS - Non-school bus
M.C. - Motorcycle
BICYCL - Bicycle
M BICY - Motorized bicycle
FARM E - Farm equipment
OTHER - Other
H & R - Hit & run vehicle
COMBO - Truck, combination trailers
TRACT - Truck, tractor only

VEHICLE MOVEMENT

STRT - Going straight
BACK - Backing
LTRN - Turning left
RTRN - Turning right
WWAY - Wrong way
REDT - Turning on red light
DBLT - Double turn to left
DBRT - Double turn to right
STOP - Stopped in traffic

LIGHT

DA - Daylight
TW - Twi-light(Dawn or dusk)
DL - Dark, lighted
DU - Dark, unlighted

ROAD CONDITION

WT - Wet
MU - Muddy
SN - Snowy
IC - Icy

CONTOUR

SL - Staight, on-level
SG - Straight, on-grade
CL - Curve, on-level
CG - Curve, on-grade
HL - Hillcrest

APPENDIX B

PHOTOGRAPHS

Photo 1 - Completed gravel shoulder on S.Kipling Blvd.

Photo 2 - Same as above.

Photo 3 - This photograph and the next two show soft sections in the shoulder. The soft areas were caused by moisture.

Photo 4 - Soft areas, same as above photo.

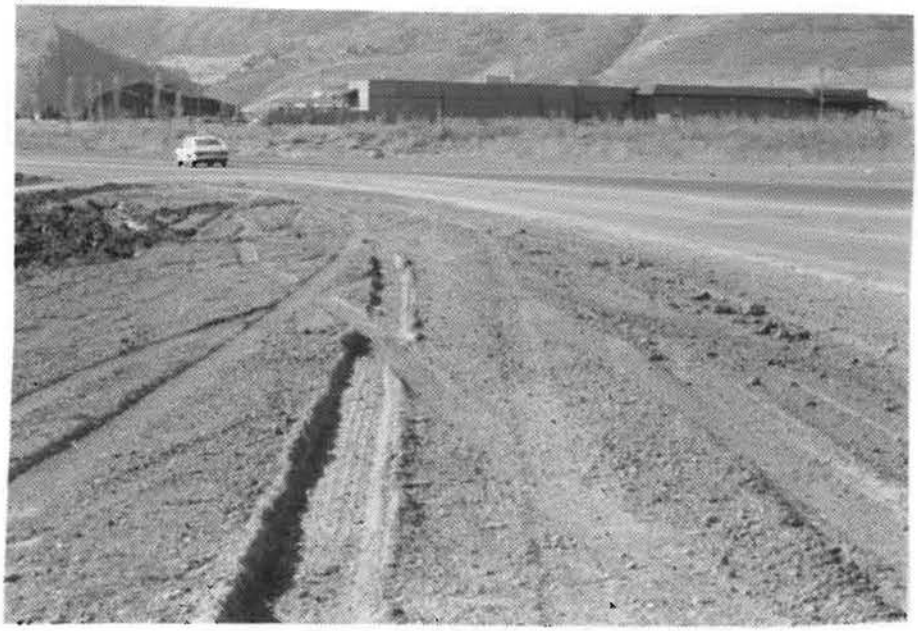


Photo 5 - Another soft area on the S.Kipling gravel shoulder.

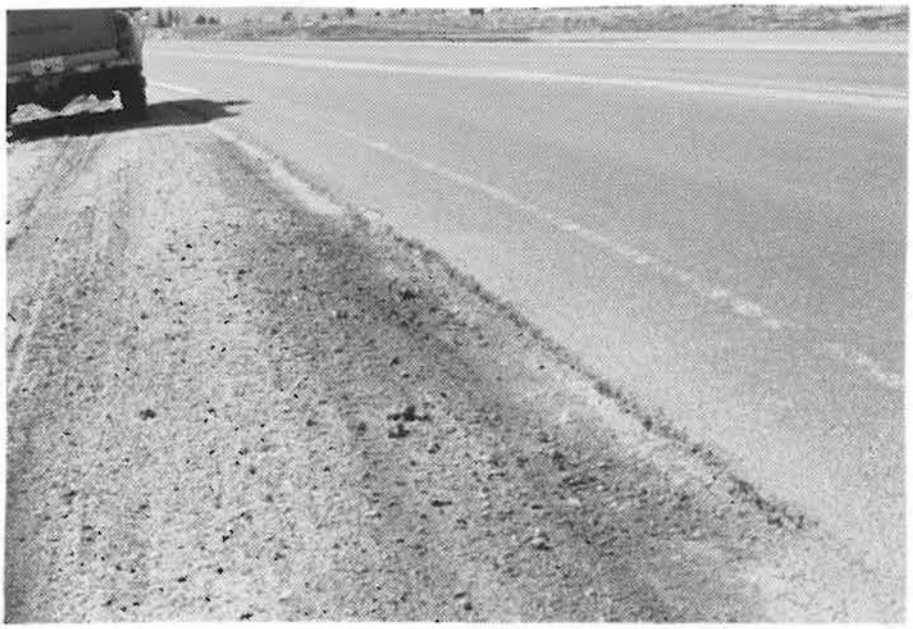


Photo 6 - This photo shows an area on S.Kipling where the pavement edge is spalling at the point where the gravel shoulder has been eroded away by vehicle traffic.

Photo 7 - Completed gravel shoulder on SH-40 near the town of Granby.

Photo 8 - Approximately 1 inch of rutting has occured directly off the pavement within 3 weeks of maintenance work on the area.

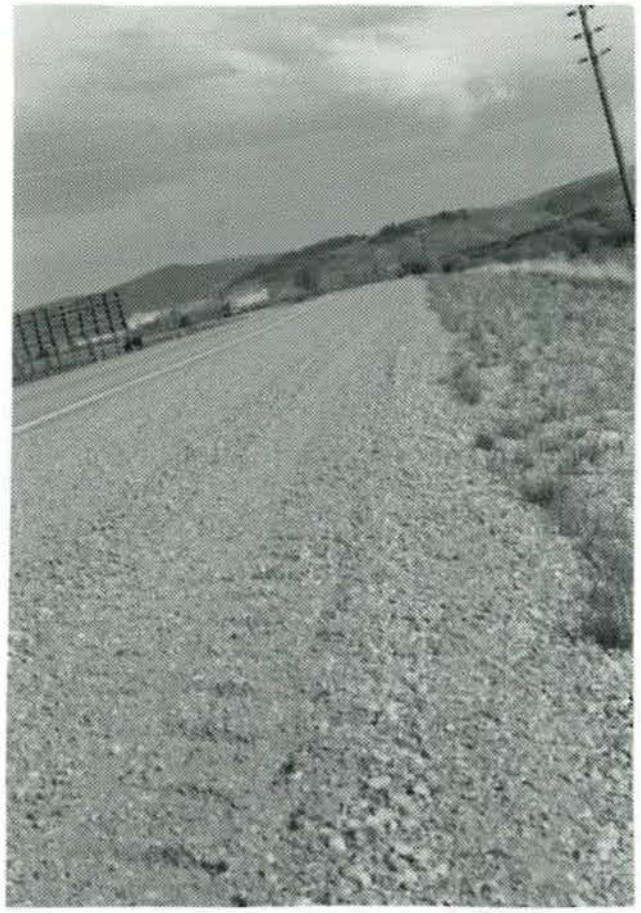


Photo 9 - Shouldering material in good condition on SH-40.

Photo 10 - Photo's taken in early spring before maintenanc crews had rebladed the area. This photo taken from the S.Kipling site.

Photo 11 - Same as above. An obvious hazard exists if these shoulders are not properly maintained.

MAINTENANCE CHARGES RELATED TO 8 FT GRAVEL SHOULDER VS. 8 FT. PAVED SHOULDER ON SH-40 PER 1989 STAFF MAINTENANCE RECORDS.

Maintenance Code	Description	Cost	
		Gravel	Paved
162	Blading and Restoring Shoulder	$239/mile	$100/mile
163	Building Shoulders	$4.23/lin-ft.	$4.23/lin-ft.

SH-40 PROJECT CONSTRUCTION COST

PROJECT LENGTH = 2150 FT.

2 - 8 FT. SHOULDERS

MATERIAL - HBP 3 INCH DEPTH
- ABC CLASS 6 3 INCH DEPTH

GRAVEL SHOULDER

- GRAVEL SHOULDER COST PER MILE PER 1 INCH THICK = $3,417.86

- TOTAL COST OF 1 FT. LENGTH OF GRAVEL SHOULDERS = $3,417.86 \ 5280 = $0.65

- TOTAL COST OF 1 FT. LENGTH OF GRAVEL SHOULDERS AT 3 INCH DEPTH = $0.65 X 3 = $1.94

- PROJECT COST = $1.94 X 2150 = $4,175

PAVED SHOULDER

- HBP SHOULDER COST PER MILE PER 1 INCH THICK = $11,791

- TOTAL COST OF 1 FT. LENGTH OF PAVED SHOULDERS = $11,791 \ 5280 = $2.23

- TOTAL COST OF 1 FT. LENGTH OF HBP SHOULDERS AT 3 INCH DEPTH = $2.23 X 3 = $6.70

- PROJECT COST = $6.70 X 2150 = $14,404

MAINTENANCE COSTS

- MAINTENANCE COST PER YEAR ON GRAVEL = $239 / MILE OR $97.32 FOR PROJECT TEST SECTION OF 2,150 FT.

- MAINTENANCE COST PER YEAR ON HBP = $100 / MILE OR $40.72 FOR PROJECT TEST SECTION OF 2,150 FT.

OVERALL MAINTENANCE COST ARE $56.60 HIGHER ON GRAVEL SHOULDERS

HBP COST $10,229 HIGHER ON 2,150 FT. IF SHOULDERS WERE PAVED ON THIS PROJECT.