PERFORMANCE EVALUATION OF ASPHALT PAVEMENT TYPES E, F, AND G NOBLE/GARFIELD COUNTIES

Final Report
June 1997

Wilson B. Brewer, Jr.
Research Project Manager

Steven Sawyer
Transportation Specialist

Research, Development, and Technology Transfer
Oklahoma Department of Transportation
200 N.E. 21st Street, Room 2A2
Oklahoma City, OK 73105
(405)521-2671
FAX (405)521-6528

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16. ABSTRACT

In 1991 the Oklahoma Department of Transportation (ODOT) initiated an experimental project investigating the performance of three asphalt mix designs; Types E, F, and G. Type E is a relatively fine aggregate mix with 100% passing the 12.5 mm (½ inch) sieve. Type F is more coarsely graded with 100% passing the 38 mm (1½ in) sieve. And Type G is a very coarse mix with 100% passing the 76 mm (2½ in) sieve. (Full gradations in Appendix A.) It was hoped that a Type E surface course over a large aggregate base course would resist rutting.

The large aggregate mixes (F and G) provided problems from the beginning. The top size aggregate had to be removed and replaced with smaller aggregate before they would fit properly in the standard density molds. Therefore, the test results were not representative of actual field densities. During construction, segregation was evident and field compaction densities were essentially not comparable to laboratory densities. Placement of the Type E (fine aggregate) surface course went smoothly.

After one year, rutting had begun. Coring revealed major stripping in the large aggregate mixes; as evidenced by the presence of loose aggregate only partially coated with asphalt. Rutting worsened each year and other distresses, including raveling and spot bleeding, became increasingly serious.

Because of the poor performance of the underlying large aggregate base courses, the Type E surface course could not be properly evaluated.

The problems encountered with F and G mixes were many and serious; thus, both mixes were removed from the ODOT Specifications and are currently not used.

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SI (METRIC) CONVERSION FACTORS

Approximate Conversions to SI Units					*Approximate Conversions from SI Units*				
Symbol	When you know	Multiply by	To Find	Symbol	Symbol	When you know	Multiply by	To Find	Symbol
		LENGTH					LENGTH		
in	inches	25.40	millimeters	mm	mm	millimeters	0.0394	inches	in
ft	feet	0.3048	meters	m	m	meters	3.281	feet	ft
yd	yards	0.9144	meters	m	m	meters	1.094	yards	yd
mi	miles	1.609	kilometers	km	km	kilometers	0.6214	miles	mi
		AREA					AREA		
in^2	square inches	645.2	square millimeters	mm	mm^2	square millimeters	0.00155	square inches	in^2
ft^2	square feet	0.0929	square meters	m^2	m^2	square meters	10.764	square feet	ft^2
yd^2	square yards	0.8361	square meters	m^2	m^2	square meters	1.196	square yards	yd^2
ac	acres	0.4047	hectares	ha	ha	hectares	2.471	acres	ac
mi^2	square miles	2.590	square kilometers	km^2	km^2	square kilometers	0.3861	square miles	mi^2
		VOLUME					VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL	mL	milliliters	0.0338	fluid ounces	fl oz
gal	gallons	3.785	liters	L	L	liters	0.2642	gallons	gal
ft^3	cubic feet	0.0283	cubic meters	m^3	m^3	cubic meters	35.315	cubic feet	ft^3
yd^3	cubic yards	0.7645	cubic meters	m^3	m^3	cubic meters	1.308	cubic yards	yd^3
		MASS					MASS		
oz	ounces	28.35	grams	g	g	grams	0.0353	ounces	oz
lb	pounds	0.4536	kilograms	kg	kg	kilograms	2.205	pounds	lb
T	short tons (2000 lb)	0.907	megagrams	Mg	Mg	megagrams	1.1023	short tons (2000 lb)	T
		TEMPERATURE (exact)					TEMPERATURE (exact)		
°F	degrees Fahrenheit	(°F-32)/1.8	degrees Celsius	°C	°C	degrees Celsius	9/5+32	degrees Fahrenheit	°F
		FORCE and PRESSURE or STRESS					FORCE and PRESSURE or STRESS		
lbf	poundforce	4.448	Newtons	N	N	Newtons	0.2248	poundforce	lbf
lbf/in^2	poundforce per sq inch	6.895	kilopascals	kPa	kPa	kilopascals	0.1450	poundforce	lbf/in^2

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Wilson B. Brewer, Jr.
Project Manager

Steven Sawyer
Transportation Specialist

Under the Supervision
of
Lawrence J. Senkowski, P.E.
Assistant Division Engineer
Research, Development, & Technology Transfer
Oklahoma Department of Transportation
200 Northeast 21st Street, Room 2A2
Oklahoma City, Oklahoma 73105

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EXECUTIVE SUMMARY

In 1991 the Oklahoma Department of Transportation (ODOT) initiated an experimental project investigating the performance of three asphalt mix designs; Types E, F, and G. Type E is a relatively fine aggregate mix with 100% passing the 12.5 mm (½ inch) sieve. Type F is more coarsely graded with 100% passing the 38 mm (1½ in) sieve. And Type G is a very coarse mix with 100% passing the 76 mm (2½ in) sieve. (Full gradations in Appendix A.) It was hoped that a Type E surface course over a large aggregate base course would resist rutting.

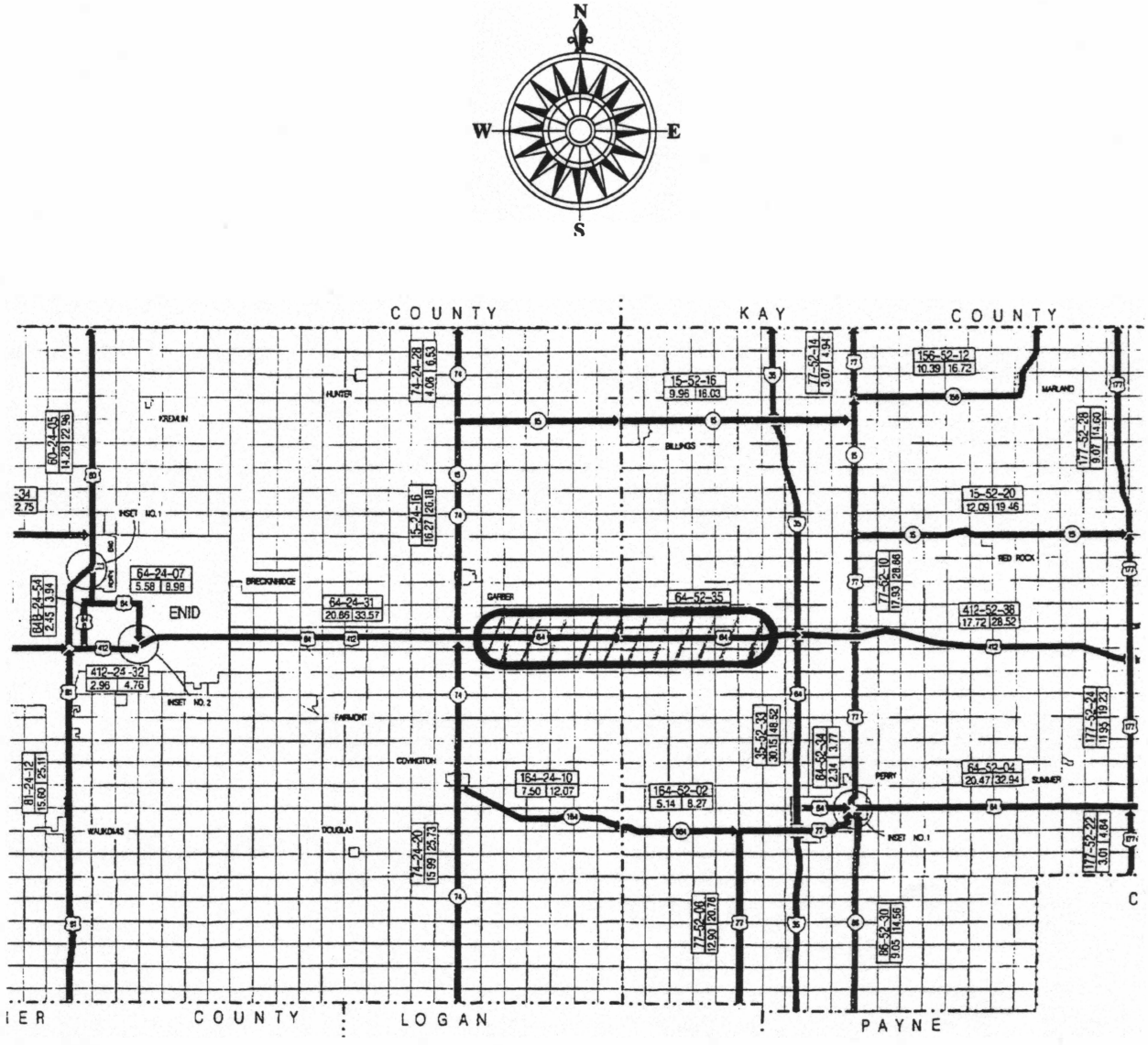
The large aggregate mixes (F and G) provided problems from the beginning. The top size aggregate had to be removed and replaced with smaller aggregate before they would fit properly in the standard density molds. Therefore, the test results were not representative of actual field densities. During construction, segregation was evident and field compaction densities were essentially not comparable to laboratory densities. Placement of the Type E (fine aggregate) surface course went smoothly.

After one year, rutting had begun. Coring revealed major stripping in the large aggregate mixes; as evidenced by the presence of loose aggregate only partially coated with asphalt. Rutting worsened each year and other distresses, including raveling and spot bleeding, became increasingly serious.

Because of the poor performance of the underlying large aggregate base courses, the Type E surface course could not be properly evaluated.

The problems encountered with F and G mixes were many and serious; thus, both mixes were removed from the ODOT Specifications and are currently not used.

The Garfield County project began at the junction of US 64 and SH 74 in Garfield Co. and extended eastward 10.6 km (6.6 mi) on US 64 to the county line. The Noble County project extended eastward from the county line and continued to the junction with I-35. The new construction added two west bound lanes to the existing east bound lanes providing a four lane divided highway. The construction site is circled in Figure 1.



One grid square equals one square mile.

Figure 1. Project Location.

INVESTIGATION

Noble County

The Noble County project included three typical sections. All three consisted of 150 mm (6 in) of Fly Ash treated subgrade, a 200 mm (8 in) lift of Type G, a 75 mm (3 in) lift of Type F, and a 20 mm (0.75 in) surface course of Type E.

After one year, rutting was already measurable. The magnitude increased each year until, in the final evaluation at +5 years, the measurements ranged from 10 mm (0.4 in) to 36 mm (1.2 in). Rutting greater than 13 mm (0.5 in) results in a roadway condition rating of "poor" for that distress category. The final rut measurements graphed (Figure 2) were taken at regular intervals and do not necessarily include the maximum and/or minimum values.

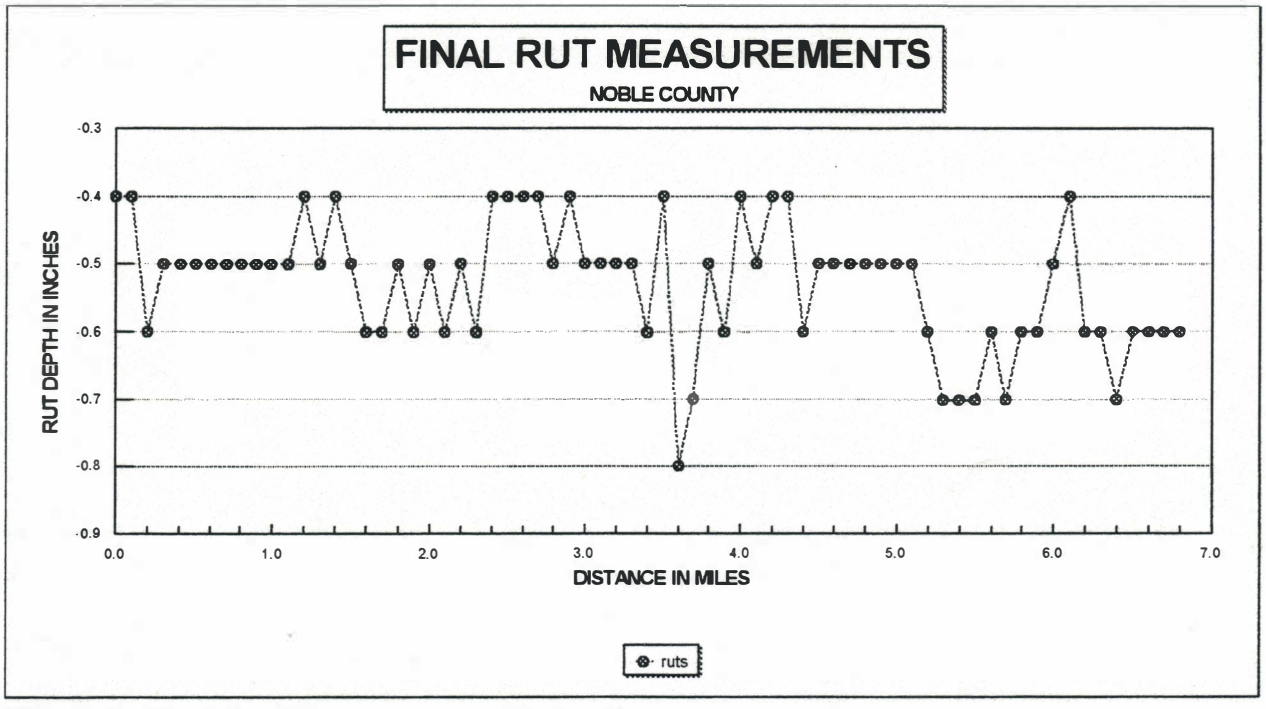


Figure 2. Final Rut Measurements - Noble County.

Longitudinal stress cracking covered eighty percent of the length of the pavement. Some transverse and random cracking was also recorded.

Pavement sampling operations were hampered by the deteriorated condition of the Type G base layer. Coring progressed fairly well through the Type E and F layers but major stripping in the Type G layer created a zone of loose aggregate that could not be readily retrieved. Also, core analysis indicated substantial stripping in the Type F layer.

After five years, the Flexible Pavement Condition Rating revealed rutting to be the primary distress, followed by cracking, minor raveling, and other distresses such as bleeding. The distresses were calculated at the following percentages.

Rutting	55%
Cracking	30%
Raveling	10%
Bleeding	5%

The total rating was 66 which is at the lower end of the "average" rating. Deflections and profilograph tracings were both within acceptable limits. (Condition Rating Sheets in Appendix B.)

Garfield County

The Garfield County project also included three typical sections. Each consisted of 150 mm (6 in) of Fly Ash treated subgrade, a 100 mm (4 in) lift of Type G, a 75 mm (3 in) lift of Type F, and a 20 mm (0.75 in) surface course of Type E.

The rutting in Garfield County was less severe, ranging from 5 mm (0.2 in) to 20 mm (0.8 in). The results from the Flexible Pavement Condition Rating were somewhat better here.

Rutting	45%
Cracking	35%
Raveling	15%
Bleeding	5%

The total rating was an average 75. As with the Noble County job, the deflections and profilograph tracings were good. The real problems were, again, with the F and G layers. Although the amount of loose aggregate from degraded G mix decreased, the large aggregate mixes were stripping badly and some cores broke in these layers.

CONCLUSIONS

Major obstacles to the use of large aggregate mixes include limited mix design knowledge, a lack of understanding of material behavior, inadequate testing molds, and poor constructability. These same problems have been documented by other state highway agencies (5).

Segregation occurred during transportation of the mix to the job site resulting in a critical reduction in homogeneity. A homogeneous blend is especially crucial for large stone mixtures because there must be sufficient fines to cushion larger particles under the stress of compaction (2).

Core evaluations consistently revealed major stripping in the F and G layers. Rutting and stress cracking occurred in the wheel paths of the outside lane where traffic is most heavily concentrated.

The rapid degradation of the large aggregate base layers made an objective evaluation of the Type E surface course impractical.

RECOMMENDATIONS

The Type F and Type G mix designs have been deleted from ODOT Specifications. Their use is, therefore, no longer permitted and the results from this project support that action. It is further recommended that no experimental mix designs be field tested without undergoing proper laboratory density testing. This may require the procurement of specialized equipment, e.g. large molds, or modifications of existing equipment and/or procedures. Under no circumstances should a specimen be altered, physically or chemically, to conform to test methods or equipment that do not accommodate a representative sample.

The Type E mix has not been used as a surface course since the removal of the Type F and Type G mixes from the ODOT Specifications. It is possible that the failure of the application documented here has led to a general abandonment of all three mixes. However, to determine the performance of the Type E mix, it should be analyzed alone in a separate project and compared with current performance standards for flexible surface courses. Standard research practices are dependent upon the isolation of the target variable. An analysis of multiple variables within a system is unequivocally discouraged, as the properties of one mix will affect the performance of other mixes.

IMPLEMENTATION

The two large aggregate mixes should remain deleted from ODOT specifications.

The fine aggregate mix (Type E) should be evaluated in a new project if there is any remaining interest in its use as a flexible pavement surface course.

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APPENDIX A

Aggregate Gradations

Gradations for the three mix designs used in the project as specified in the "Supplement to 1988 Standard Specifications for Highway Construction."

Sieve Size	% Passing (by weight)		
	Type E	Type F	Type G
2-1/2"			100
2"			95-100
1-1/2"		100	85-100
1"		95-100	60-75
3/4"		85-100	---
1/2"	100	55-70	40-55
3/8"	85-95	---	---
No. 4	45-60	30-50	20-40
No. 10	20-35	20-35	13-27
No. 40	9-19	8-18	5-14
No. 80	6-14	5-13	3-10
No. 200	*	*	*
% AC-20	4.8-7.5	3.5-6.5	3.0-6.0

*The ratio of the percent passing the No. 200 sieve to the percent asphalt cement shall be a minimum of 0.6 to a maximum of 1.2.

**Lower limit may be adjusted if the effective specific gravity of the combined aggregates is greater than 2.65.

The requirements for properties of laboratory molded specimens for asphalt concrete Type E shall be the same as those for asphalt concrete Type C and asphalt concrete Type F and G shall be the same as those for asphalt concrete Type A, except the minimum VMA for Type G shall be 11.5%. and the density, percent of maximum theoretical specific gravity, of laboratory molded specimens for Type G shall be 94-98 for all traffic volumes.

APPENDIX B

Flexible Pavement Condition Survey Results

Garfield County, May 5, 1995, 0.3 km (0.2 mi) intervals, 9.8 km (6.1 mi) total.

LEGEND FOR RATING CLASSES

CONDITION RATING	CRACKING	DISTORTION	RAVELING	SURFACE ROUGHNESS	BASE FAILURE	TOTAL SURFACE AREA OF RATING INTERVAL
1. 100-98% = EXCEL. 2. 97-90% = SUPER. 3. 89-80% = GOOD 4. 79-65% = AVER. 5. 64-50% = POOR 6. 50%-LESS= FAIL	1-2-3-4	1-2-3-4	1-2-3-4	1-2-3-4	1-2-3-4	1 = LESS THAN 5% 2 = 5% TO 15% 3 = 15% TO 30% 4 = 30% OR MORE

RATING INTERVAL (MI.)	CONDITION RATING (%)	CRACKING						DISTORTION						RAVELING				SURFACE ROUGHNESS				BASE FAILURE			RUT DEPTH			PATCH FT²	COMMENTS
		LONGITUDINAL	TRANSVERSE	RANDOM	BLOCK	ALLIGATOR	CRACKING	MINOR BLEEDING	INTER. BLEEDING	MAJOR BLEEDING	SHOVING	CORRUGATING	DISTORTION	MINOR	INTERMEDIATE	MAJOR	RAVELING	SMOOTH	MOD. ROUGH	ROUGH	SURFACE ROUGH	MODERATE	SEVERE	BASE FAILURE	0.1 or 0.2 INCH	0.3 or 0.4 INCH	0.5 or GREATER		
0.0	68	X		X			2							X			2								X	X			
0.2	82	X		X			2							X			1								X				
0.4	69	X		X		X	2							X			1								X	X			
0.6	70	X		X			1							X			1								X	X			
0.8	82	X		X			1							X			1								X				
1.0	70	X		X			2							X	X		2								X				
1.2	70	X		X			1							X	X		1								X	X			
1.4	82	X		X			1							X			1								X				
1.6	80	X		X			1							X	X		1								X				
1.8	80	X		X			1							X	X		1								X				
2.0	69	X		X		X	3							X	X		2								X				
2.2	70	X		X		X	1							X	X		1								X	X			
2.4	70	X	X	X			1							X	X		1								X	X			
2.6	69	X		X	X		2							X	X		1								X	X			
2.8	80	X		X	X		1							X	X		1								X				
3.0	62	X		X		X	2		X				1	X	X		1								X	X	X		

LEGEND FOR RATING CLASSES																															
CONDITION RATING		CRACKING						DISTORTION						RAVELING				SURFACE ROUGHNESS				BASE FAILURE						TOTAL SURFACE AREA OF RATING INTERVAL		
		1-2-3-4						1-2-3-4						1-2-3-4				1-2-3-4				1-2-3-4									
1. 100-98% = EXCEL. 2. 97-90% = SUPER. 3. 89-80% = GOOD 4. 79-65% = AVER. 5. 64-50% = POOR 6. 50%-LESS= FAIL		CRACKING						DISTORTION						RAVELING				SURFACE ROUGHNESS				BASE FAILURE			RUT DEPTH			1 = LESS THAN 5% 2 = 5% TO 15% 3 = 15% TO 30% 4 = 30% OR MORE		
RATING INTERVAL (MI.)	CONDITION RATING (%)	LONGITUDINAL	TRANSVERSE	RANDOM	BLOCK	ALLIGATOR	CRACKING	MINOR BLEEDING	INTER. BLEEDING	MAJOR BLEEDING	SHOVING	CORRUGATING	DISTORTION	MINOR	INTERMEDIATE	MAJOR	RAVELING	SMOOTH	MOD. ROUGH	ROUGH	SURFACE ROUGH	MODERATE	SEVERE	BASE FAILURE	0.1 or 0.2 INCH	0.3 or 0.4 INCH	0.5 or GREATER	PATCH FT^2	COMMENTS		
3.2	70	X	X	X			2			X			1	X	X		2								X						
3.4	68	X	X	X			2							X			2								X	X					
3.6	74	X	X	X			2							X			2								X						
3.8	65	X	X	X			2	X					1	X	X		2								X	X					
4.0	74	X	X	X			2	X					2	X	X		1								X						
4.2	82	X		X			1	X					1	X			1								X						
4.4	80	X	X	X			2	X					1	X			1								X						
4.6	69	X		X			2	X					1	X			1								X	X					
4.8	70	X		X			1	X			X		1	X			1								X	X					
5.0	85	X					1							X			1								X						
5.2	88	X					1																		X						
5.4	88	X					1																		X						
5.6	88	X					1																		X						
5.8	85			X			1							X			1								X	X					
6.0	71	X					1																		X	X					
6.1	71	X					1																		X	X					

Noble County, May 5, 1995, 0.3 km (0.2 mi) intervals, 9.9 km (6.2 mi) total.

LEGEND FOR RATING CLASSES																																
CONDITION RATING		CRACKING						DISTORTION						RAVELING				SURFACE ROUGHNESS				BASE FAILURE			RUT DEPTH			TOTAL SURFACE AREA OF RATING INTERVAL			
		1-2-3-4						1-2-3-4						1-2-3-4				1-2-3-4				1-2-3-4										
1. 100-98% = EXCEL. 2. 97-90% = SUPER. 3. 89-80% = GOOD 4. 79-65% = AVER. 5. 64-50% = POOR 6. 50%-LESS= FAIL		CRACKING						DISTORTION						RAVELING				SURFACE ROUGHNESS				BASE FAILURE			RUT DEPTH			1 = LESS THAN 5% 2 = 5% TO 15% 3 = 15% TO 30% 4 = 30% OR MORE			
RATING INTERVAL (MI.)	CONDITION RATING (%)	LONGITUDINAL	TRANSVERSE	RANDOM	BLOCK	ALLIGATOR	CRACKING	MINOR BLEEDING	INTER. BLEEDING	MAJOR BLEEDING	SHOVING	CORRUGATING	DISTORTION	MINOR	INTERMEDIATE	MAJOR	RAVELING	SMOOTH	MOD. ROUGH	ROUGH	SURFACE ROUGH	MODERATE	SEVERE	BASE FAILURE	0.1 or 0.2 INCH	0.3 or 0.4 INCH	0.5 or GREATER	PATCH FT[a]	COMMENTS			
0.0	62	X	X				2	X					1	X			1								X	X	X					
0.2	62	X		X			2	X					1	X			1								X	X	X					
0.4	69	X		X			2							X			1								X	X						
0.6	70	X					1							X			1								X	X						
0.8	70	X					1							X			1								X	X						
1.0	69	X	X				2							X			1								X	X						
1.2	64	X					1							X			1								X	X	X					
1.4	70	X					1							X			1								X	X						
1.6	69	X	X				2	X					1	X			1								X	X						
1.8	62	X					1							X			2								X	X	X					
2.0	62	X	X				2							X			2								X	X	X					
2.2	62	X					1							X			1								X	X	X					
2.4	70	X	X				2							X			1								X	X						
2.6	70	X	X				2							X			1								X	X						
2.8	70	X	X				2							X			1								X	X						
3.0	64	X	X				1							X			1								X	X	X					

LEGEND FOR RATING CLASSES																														
CONDITION RATING		CRACKING						DISTORTION						RAVELING				SURFACE ROUGHNESS				BASE FAILURE						TOTAL SURFACE AREA OF RATING INTERVAL		
1. 100-98% = EXCEL. 2. 97-90% = SUPER. 3. 89-80% = GOOD 4. 79-65% = AVER. 5. 64-50% = POOR 6. 50%-LESS= FAIL		1-2-3-4						1-2-3-4						1-2-3-4				1-2-3-4				1-2-3-4						1 = LESS THAN 5% 2 = 5% TO 15% 3 = 15% TO 30% 4 = 30% OR MORE		
		CRACKING						DISTORTION						RAVELING				SURFACE ROUGHNESS				BASE FAILURE			RUT DEPTH					
RATING INTERVAL (MI.)	CONDITION RATING (%)	LONGITUDINAL	TRANSVERSE	RANDOM	BLOCK	ALLIGATOR	CRACKING	MINOR BLEEDING	INTER. BLEEDING	MAJOR BLEEDING	SHOVING	CORRUGATING	DISTORTION	MINOR	INTERMEDIATE	MAJOR	RAVELING	SMOOTH	MOD. ROUGH	ROUGH	SURFACE ROUGH	MODERATE	SEVERE	BASE FAILURE	0.1 or 0.2 INCH	0.3 or 0.4 INCH	0.5 or GREATER	PATCH FT^2	COMMENTS	
3.2	62	X					2							X			2								X	X	X		over 1"	
3.4	60	X		X		X	2	X					1	X			2								X	X	X		over 1"	
3.6	70	X					1							X			1								X	X				
3.8	64	X					1							X			1								X	X				
4.0	62	X	X			X	2							X			1								X	X	X			
4.2	62	X	X				2	X					1	X			1								X	X	X			
4.4	64	X	X				1							X			1								X	X	X			
4.6	70	X					1							X			1								X	X				
4.8	70	X	X				2	X					1	X			1								X	X				
5.0	70	X					1	X					1	X			1								X	X				
5.2	70	X					1							X			1								X	X				
5.4	64	X					1							X			1								X	X	X			
5.6	69	X					1		X				1	X			1								X	X				
5.8	69	X					1		X				1	X			1								X	X				
6.0	70	X					1							X			1								X	X				
6.2	60	X					1							X			2								X	X				

APPENDIX C

Selected Rut Measurements

The table below contains rut depth measurements from areas specifically selected for annual comparisons. For most sections, a spot was selected which was judged, by visual inspection, to be severely rutted. A few sections exhibited rutting that was considered to be about average for the project. Measurements were taken at the selected spot and at 3 m (10 ft) intervals in both directions. Each section averaged about 30 m (100 ft) in length.

SECTION	YEAR											
NOBLE CO	1993			1994			1995			1996		
IN INCHES	high	low	avg	high	low	avg	high	low	avg	high	low	avg
N-1	0.5	0.4	0.4	0.5	0.4	0.4	0.6	0.4	0.5	0.9	0.4	0.6
N-2	0.6	0.4	0.5	0.6	0.4	0.5	0.6	0.5	0.5	0.6	0.5	0.5
N-3	0.5	0.3	0.4	0.5	0.4	0.4	0.5	0.4	0.4	0.5	0.4	0.5
N-4	1.0	0.4	0.6	1.2	0.4	0.7	1.2	0.4	0.7	1.2	0.4	0.7
N-5	0.8	0.4	0.6	0.8	0.5	0.7	0.8	0.5	0.7	1.0	0.7	0.8
N-6	0.4	0.3	0.4	0.4	0.4	0.4	0.5	0.4	0.4	0.5	0.4	0.4
N-7	0.6	0.4	0.5	0.6	0.4	0.5	0.6	0.5	0.5	0.7	0.5	0.5
GARFIELD CO	1993			1994			1995			1996		
G-1	0.3	0.2	0.2	0.3	0.2	0.3	0.3	0.3	0.3	0.4	0.3	0.3
G-2	0.4	0.2	0.3	0.4	0.2	0.3	0.8	0.3	0.4	0.8	0.3	0.4
G-3	0.5	0.4	0.4	0.5	0.4	0.5	0.6	0.4	0.5	0.6	0.4	0.5
G-4	0.6	0.4	0.5	0.6	0.4	0.5	0.6	0.4	0.5	0.7	0.4	0.5