

### **Load Zoning Study, Elkhart County, Indiana**

More than 80% of all the roads in the nation pass through rural areas. Without them, the transport of goods and materials from farms, mines, factories and forests will be impossible. They also provide people living in rural areas with access to their jobs, schools, hospitals, clinics, markets and other attractions. Rural roads also provide city and suburban dwellers with access to beauty and recreational opportunities of the countryside. All of these affect road use and road maintenance. The transport of goods and materials substantially affect the condition of our roads, bridges and highways. Many of the rural roads are in bad conditions and Local agencies do not have sufficient funds to repair and rehabilitate roads to handle legal trucks. Thus Local agencies are forced to consider load zoning as an option to preserve the remaining life of their highways and roads. Limiting weight of trucks can also contribute to elimination of hazards from wide loads, reduces traffic congestion and traffic noise, preserves road surfaces and leads to safety benefits and improves mobility of motoring public and police and fire units.

### **Limiting Rural Access**

Elkhart County, Indiana has over 1100 miles of roads under its jurisdiction. Many pavements in Elkhart County are light pavement structures consisting of base, binder and a thin asphalt surface. As a result of heavy trucks and high traffic volumes on some roads, the Elkhart County Commissioners authorized the Engineering Division of the Department of Public Services to commission a study for load zoning of approximately 100 miles of roads frequently used by trucks. This engineering task was to evaluate the structural integrity and determine the load limit for each road.

### **Methodology**

Project level evaluation for engineering analysis to develop load zoning required collection of three (3) different types of data. Non-destructive study tools and technique of combining deflection testing data, ground penetrating radar data, and surface condition assessment data were selected for the purpose of the study. The following data were collected:

1. Structural Capacity data – The maximum load and number of repetitions a pavement can carry. This data would determine the pavement load carrying capacity and the number of projected trucks using the pavement and the remaining life of the pavement.
2. Ground Penetrating Radar data- a pulse echo method of measuring pavement layer thickness. This data would determine the thickness of surface, binder and base materials for calculating Structural Number of the pavement.
3. Surface Distress- damage to pavement surface. Pavements were surveyed to determine the type, severity and quantity of surface distress. This data would be used to compute rate of deterioration and to project future condition.

4. Roughness (ride quality data)- a measure of pavement distortion. This data would be used to estimate the ability of pavement to provide a comfortable ride to users.

Deflection testing

Nondestructive deflection testing of roads in Elkhart County was performed using Dynatest Model 8081 Heavy Falling Weight Deflectometer. The falling weight strikes a specially designed plate, transmitting the impulse force to the pavement to produce a half sine wave load pulse that approximates that of an actual wheel load. Testing was performed at two load levels of 10,000 and 16,000 lbs. Pavement surface deflections were measured at seven sensor locations: 0, 8, 12, 18, 24, 36 and 60 inches away from the center of the load plate. Tests were generally spaced 1,000 ft. in each lane. Tests were staggered by 500 ft. in each lane to provide an effective spacing of 500 ft. along the project length. In general, testing proceeded from west to east (Lane 1) and east to west (Lane 2) on east/west roads. Similarly, testing proceeded from south to north (Lane 1) and north to south (Lane 2) on north/south roads. Deflections testing results that were normalized to a 9,000-lbf load with charts illustrating the deflection profile along the project length of each road are shown in Figure 1.



**Deflection Measurements  
 Elkhart County, Indiana  
 Road Name: CR 52 - CR 3 TO SR 19**

Temp	Sta	MP	Lane	Load	Deflections in mils @ xx inches						
					0	8	12	18	24	36	60
43	0	0.000	1	9000	19.80	17.10	15.88	11.47	9.19	5.21	1.81
44	492	0.093	2	9000	30.24	22.80	19.66	11.64	8.09	3.85	1.42
42	1000	0.189	1	9000	19.06	15.60	14.87	9.76	7.65	4.25	1.58
44	1509	0.286	2	9000	22.89	18.91	16.47	11.64	8.98	4.68	1.93
43	2009	0.380	1	9000	21.17	18.35	16.12	12.17	9.72	5.74	2.29
44	2500	0.473	2	9000	27.20	22.37	18.01	12.16	8.63	3.73	0.79
43	3005	0.569	1	9000	24.67	21.61	19.45	13.05	10.22	5.38	1.79
44	3496	0.662	2	9000	19.07	16.83	14.99	11.60	9.39	5.48	2.18
43	4025	0.762	1	9000	24.58	19.60	16.34	10.87	7.85	3.79	1.56
44	4500	0.852	2	9000	28.85	23.00	18.85	12.74	9.03	4.06	1.23
44	5121	0.970	1	9000	32.79	26.39	21.84	14.06	10.10	4.90	1.93

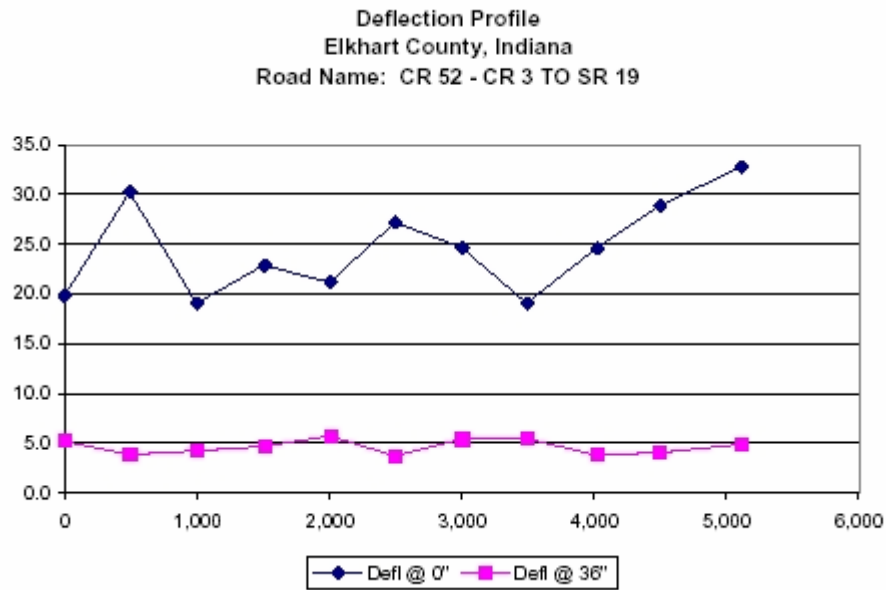


Figure 1

Data summary above lists the name of the roads, limits of the project, length, number of test points, average deflections measured at 0, 8, 12, 18, 24, 36 and 60 inches away from the center of the load plate,

Ground Penetrating Radar

To identify subsurface characteristics of the roads Ground Penetrating Radar (GPR) system was used to collect pavement layer thickness data. GPR pavement thickness data are accurate to within 3-15 percent of data obtained through conventional core samples (Maser 1996). Continuous radar data over 12" wide path on one hundred percent of pavement surface was collected and GPR data was reduced and coordinated with deflections. The data was acquired utilizing a short pulse radar with a center frequency of one Gigahertz. Position was determined by using a distance measuring device<sup>2</sup>. A typical output of radar image is given in Figure 2. Changes in color horizon indicate a change in structure, the thickness of each layer determined by



$$\text{Layer Thickness} = \frac{6 t_n}{\sqrt{E_n}}$$

Where  $t_n$  is the two way travel time in nanoseconds of the pulse in layer  $n$  and  $E_n$  is the dielectric constant of layer  $n$ .

Figure 3 is tabulated from reduced data and shows nominal layer thickness of flexible pavement cross section consisting of wearing surface, base course, subbase and compacted subgrade. Changes in the color horizons indicate a change in pavement structure.

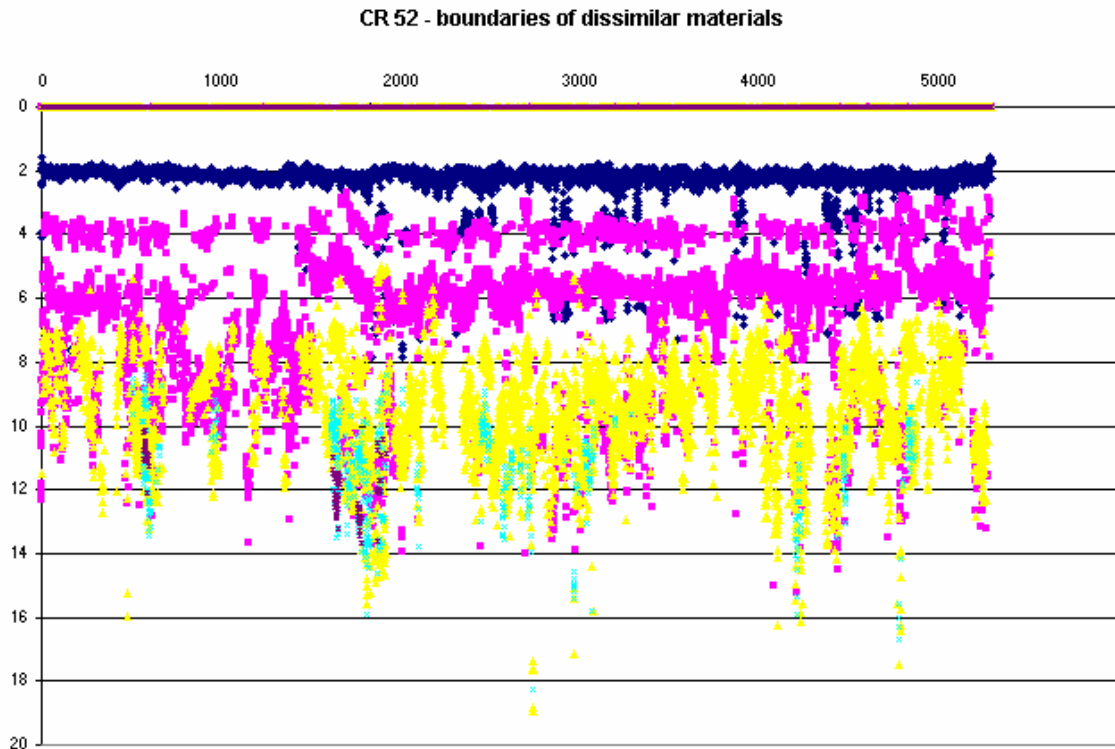


Figure 2

Location	d1 Layer depth	d2 Layer depth	d3 Layer depth
0	3.8	5.6	9.4
512	4	7	9.5
1040			8.4
1570	3.8	5.3	8.3
2090	3.8	5.6	8.8
2601	3.9	5.4	9.2
3126	3.7	5.4	8.5
3637	4	5.5	7.7
4188	4.1	5.5	9.4
4682	3.9	5.9	10.9
5328	3.4	5.3	10.9

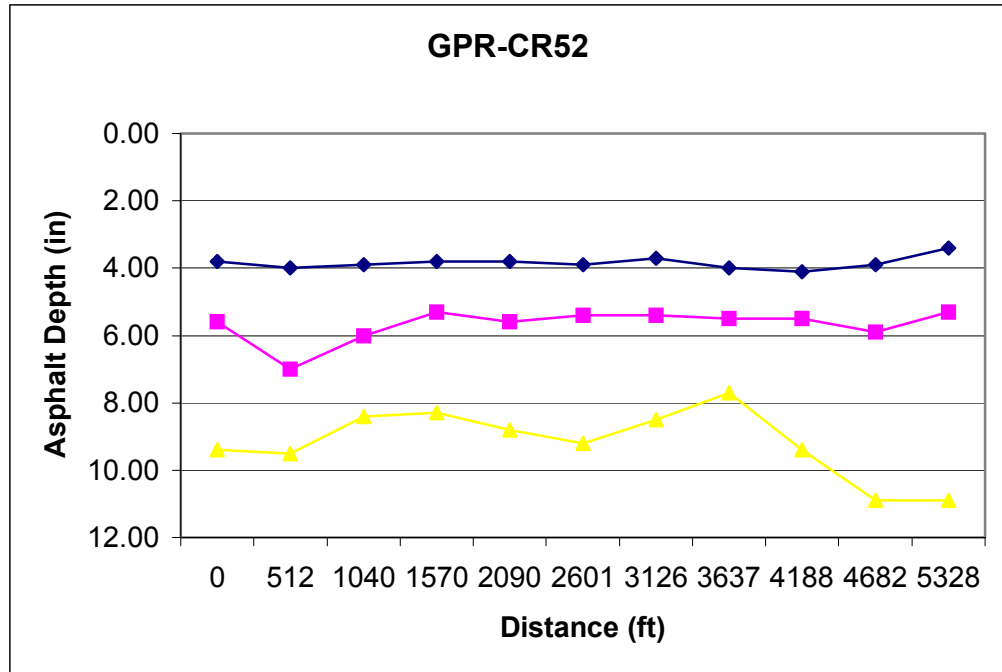


Figure 3

Pavement Distress Data

Distress images of pavement surface were collected on high resolution video. Pavement surface of both lanes were recoded using twin cameras focused and covering both lanes. Automated analysis of the images affected by shadows from trees or other anomalies were manually interpreted by reviewing the images for type severity and quantity of individual distress types. Lasers were used to collect other data such as International Roughness Index and Ride Number. Condition information which describes the current condition of pavement segments was based on subjective analysis of reduced distress data.







Load Zoning Analysis/ Methodology

Criteria for load limit recommendation were based on cumulative damage caused the repetition to failure of a standard 18 kip equivalent single axel loads (ESAL) to the pavement. By calculating the remaining life of pavement structure under 10,50,100 or more trucks per day and comparing it to the pavement life desired by the Local agency a load limit is discerned or established<sup>1</sup>.

AASHTO pavement design equation below was used to determine the number of 18 Kip ESAL's<sup>2</sup>:



Figure 5 summaries remaining life in years based on application of various truck loading scenarios per day for 312 days per year. The cumulative concept of remaining life permits accounting of damage caused by different axel loads. The scenarios include remaining life for 10,50,100 and 200 trucks per day for four types of legal loads (delivery truck, type 3 truck, type 3S2 truck and type 3-3 truck). Weight limit recommended is based on analysis of two hundred 18-kip ESAL's (fifty 18 Kip plus fifty 22-Kip axles plus ten 48-Kip axle weights) and desired life expectancy .

Equivalent 18000 ESAL'S:		1.78			2.54			3.82			4.30
				type 3 unit			type 3S2 unit			type 3-3 unit	
	312 days/year		312 days/year		312 days/year		312 days/year				
Remaining life	Load Limit	Remaining life	Load Limit	Remaining life	Load Limit	Remaining life	Load Limit	Remaining life	Load Limit		
trucks/ day	years	lbs.	years	lbs.	years	lbs.	years	lbs.	years	lbs.	
10	79.75	35000	55.91	50000	37.12	72000	32.99	80000			
50	15.95	35000	11.18	50000	7.42	72000	6.60	80000			
100	7.98	35000	5.59	50000	3.71	72000	3.30	80000			
200	3.99	35000	2.80	50000	1.86	72000	1.65	80000			

Type of Axels	Weight (lbs.)	No. of Axels	Equivalency factor	No. of 18 k ESAL's
Single	18000	50	1.00	50
Single	22000	50	2.18	109
Tandem	48000	10	4.17	42
			Total Axels=	201
			Remaining life years	7.06
			Load Limit	

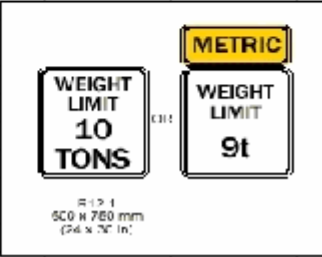
  


Figure 5

Condition Assessment

The purpose of condition survey is to determine engineering and functional condition of the pavement. Thus, surface distress and structural capacity data and drainage information were used in determining the pavement condition. Roughness and ride quality data were considered to measures the functional condition of the pavement and were not used for load zoning. Figure 6 summaries the listing of roads in the study, distresses and condition.

Condition Survey table lists the name of the roads, limits of the project, length, road image ID file, distresses, severity, maximum extent, rutting, geometry and Pavement Condition Index (PCI). The Pavement condition Index PCI may be used to identify timing of maintenance and rehabilitation as well as funds needed in the pavements management process.

Pavement Evaluation 2002  
**Establishing Load Limits for County Roads**

By: Jerry H. Mohajeri, P.E.

ROAD NAME	FROM	TO	LENGTH (ft)	LENGTH (miles)	Image ID	Distresses	Severity	Max. % Cracking	Rutting	Geometry	Condition Index PCI
CR7	CR4	STATE LINE	8,690	1.65	JPG63-64	Alligator Crk ,Block Crk, & Edge Crks	L	20		Good	75
CR3	CR16	OLD 33	2631	0.50	JPG65	Reflec. Crk	L				84
CR 3	CR 18	CR 24	4,666	0.88	01JPG	Reflec. Crk	L				90
CR 17	US 20	CR 18	2,450	0.46	14JPG	Sealed Block Crk	L	40		Excellent	90
CR 111	US 20	MISHAWA KA RD	2,413	0.46	07JPG	Alligator Crk ,Block Crk, & Edge Crks	M	50		Fair	54
CR 13	CR 18	RAILROA D	7,612	1.44	09JPG	Block Crk	L				90
CR 17	CR 18	CR 45	13,925	2.64	10-12JPG	Alligator Crk ,Block Crk, & Edge Crks	M	40		Fair	63-94
CR 31	CR 34	CR 46	31,289	5.93	56-61JPG	Alligator Crk ,Block Crk, & Edge Crks	L	20		Fair	58-88
CR 3	WAKARU SA LIMITS	CR 46	12,753	2.42	22JPG	Block Crk	L			Good	85-87
CR 146	CR 46	ASH ROAD	11,652	2.21	25-26JPG	Alligator Crk ,Block Crk, & Edge Crks	L	20			73-78
CR 29	SR 15	CR 56	37,322	7.07	3948-JPG	Alligator Crk ,Block Crk, & Edge Crks	L	20		Curves	57-79
E. CO. LINE ROAD	US 6	CR 56	7,268	1.38	55JPG	Alligator Crk ,Block Crk, & Edge Crks	L	20			78
CR 43	US 33	CR 56	5,210	0.99	54JPG	Block Crk	L				80
CR 22 (WAYNE ST)	US 20	SR 13	1,720	0.33	28-31JPG	Alligator Crk ,Block Crk, & Edge Crks	L	10		Curves	80
CR 18	ELKHART CITY LIMITS	CR 17	15,001	2.84	08-13JPG	Alligator Crk ,Block Crk, & Edge Crks	M	20		Good	60-93
CR 24	CR 3	CR 105	8,289	1.57	03JPG	Reflec. Crk	L				85-90
CR 28	ASH RD	CR 17	46,535	8.81	07-15.jpg	Alligator Crk ,Block Crk, & Edge Crks	M	50	medium level ruts	Good	45-95
CR 30	SR 19	CR 17	35,041	6.64	16JPG	Alligator Crk ,Block Crk, & Edge Crks	L	10			60-80
CR 34	GOSHEN CITY LIMITS	CR 39	32,000	6.06	63-67JPG	Reflec. Crks & alligator Crks	L	10			77-80

<b>CR 40</b>	SR 119	ELKHART RIVER	30,000	5.68	75-80JPG	Block Crk	L					<b>90-95</b>
<b>CR 40</b>	SR 15	SR 13	36,254	6.87	68-74JPG	Alligator Crk ,Block Crk, & Edge Crks	L	30	medium level ruts	Narrow		<b>74-80</b>
<b>CR 142</b>	CR 11	SR 15	30,733	5.82	30-37JPG	Alligator Crk ,Block Crk, & Edge Crks	M	40	medium level ruts			<b>49-65</b>
<b>CR 46</b>	CR 3	SR 19	5,076	0.96	29JPG	Alligator Crk ,Block Crk, & Edge Crks	L					<b>73</b>
<b>CR 50</b>	CR 3	SR 19	5,100	0.97	27JPG	Alligator Crk ,Block Crk, & Edge Crks	M	40	medium level ruts			<b>58</b>
<b>CR 52</b>	SR 19	CR 3	5,121	0.97	28JPG	Alligator Crk ,Block Crk, & Edge Crks	M	40				<b>60</b>
<b>CR56 -CO LINE)</b>	CR 29	CR 43	23,493	4.45	49-53JPG	Alligator Crk ,Block Crk, & Edge Crks	L	20	medium level ruts			<b>75-79</b>
			Total	80.00								

### Load Limit Summary – Recommendation

Using data collected, summarized in methodology phases 1 and 2, analysis of pavement surface condition and comparison of the remaining life to a life expectancy of 10 years, load zoning recommendations were suggested. Figure 7 summaries load zoning recommendations to Elkhart County, Indiana.

Of approximately 80 miles of roads, which were posted as “No Trucks”, 12 miles were rated for “5 TON” load zoning and 33 miles were rated for “10 TON” load zoning. To improve and upgrade these roads, appropriate asphalt overlay design was recommended. The remaining study mileage comprising 40% of total are under consideration for removal of load zoning by County pending analysis of truck traffic study by County.

The total cost of moving goods by truck has two cost components: the public cost, associated with maintenance, rehabilitation and reconstruction of the road network; the private cost of acquiring, operating and maintaining trucks<sup>1</sup>.

Elkhart County has information as result of this study to fairly and equitably balance the public and private costs of moving good. The pavement life desired represents a reasonable expectation of life based on County’s road maintenance budget. Its hoped that the condition analysis process will help to determine those sections of pavement requiring maintenance and rehabilitation before none restorable deterioration set in. This study will also assist in the determination and design of cost- beneficial corrective measure and avoiding costly over design. By continuous field examination and testing

program, Elkhart County performs their work efficiently and the load limits established for axel weights allow different load scenarios (truck types) without undue burden to the public or the trucking industry.

Elkhart County will be implementing load zoning for of county roads upon completion of traffic studies by County Engineering Department. This study assist's the County in establishing maintenance and rehabilitation treatments and costs for up grading structurally deficient roads and it impacts county's Pavement Management Process.

Load Limit Recommendation

ROAD	FROM	TO	PCI PAVEMENT CONDIT'N INDEX	SN STRUCTURAL NUMBER	18 KIP ESAL'S CAPACITY	REMAIN LIFE BASED ON 200-18K ESAL'S/DAY	SUGESTED LOAD LIMIT (TONS) BASED ON 200-18K ESAL'S/DAY
<b>CR 7</b>	STATE LINE	CR 4	75	2.23	1506134	24	LEGAL LOADS
<b>CR 3</b>	CR 16	OLD US 33	84	1.68	378301	6	10 TONS
<b>CR 3</b>	CR 18	CR 24	90	2.3872	1407511	22	LEGAL LOADS
<b>CR 17</b>	US 20	CR 18	90	2.6517	4382594	70	LEGAL LOADS
<b>CR 111</b>	US 20	MISHAWAKA RD	54	2.3358	967355	15	8-16 TONS
<b>CR 13</b>	CR 18	RAILROAD	90	2.1517	700899	11	8-16 TONS
<b>CR 17</b>	CR 18	CR 45	63-94	1.7464	394749	6	10 TONS
<b>CR 31</b>	CR 34	CR 46	58-88	2.2515	1101081	17	LEGAL LOADS
<b>CR 3</b>	WAKARUSA C L	CR 46	85-87	2.6136	1617694	25	LEGAL LOADS
<b>CR 146</b>	CR 46	ASH ROAD	73-78	2.2745	650759	10	10 TONS
<b>CR 29</b>	SR 15	CR 56	57-79	2.5809	1538389	24	LEGAL LOADS
<b>EAST COUNTY LINE ROAD</b>	US 6	CR 56	78	1.9211	363712	5	5 TONS
<b>CR 43</b>	US 33	CR 56	80	1.9086	199377	3	5 TONS
<b>CR 22</b>	US 20	SR 13	80	1.8663	434109	6	10 TONS
<b>CR 18</b>	ELKHART C L	CR 17	60-93	2.3709	1132394	18	LEGAL LOADS
<b>CR 24</b>	CR 3	CR 105	85-90	1.658	187400	13	8-16 TONS
<b>CR 28</b>	ASH RD	CR 17	45-95	2.2225	420874	6	10 TONS
<b>CR 30</b>	SR 19	CR 17	60-80	1.8655	365448	5	10 TONS
<b>CR 34</b>	GOSHEN C L	CR 39	77-80	2.1707	820536	13	8-16 TONS
<b>CR 40</b>	SR 119	TURKEY CREEK	90-95	2.2087	882378	14	8-16 TONS
<b>CR 40</b>	SR 15	SR 13	74-80	2.1914	594736	9	8-16 TONS

<b>CR 142</b>	CR 11	SR 15	49-65	2.0196	326527	5	5 TONS
<b>CR 46</b>	CR 3	SR 19	73	1.585	111284	2	5 TONS
<b>CR 50</b>	CR 3	SR 19	58	2.0707	265365	4	5 TONS
<b>CR 52</b>	CR 3	SR 19	60	2.1312	442599	7	10 TONS
<b>CR 56</b>	CR 29	CR 43	75-79	1.9442	361470	5	10 TONS

Figure 7

Acknowledgements

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Among them:

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Rick L. Pharis, P.E. (Elkhart County Engineer)

References

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2. Symphony 1.1™ Worksheet Solutions for the 1985 AASHTO Pavement Design Equations by Gary Owns and John P. Hallin, US Department of Transportation, Federal Highway Administration Region 10, Portland Oregon.