December 15, 2006

Mr. Chris Brakke, P.E.
Pavement Design/Management Engineer
Office of Design
Iowa Department of Transportation
(515) 239-1882 telephone
Chris.Brakke@dot.iowa.gov

Subject: **Rolling Wheel Deflectometer (RWD) Results for the Iowa Department of Transportation (Iowa DOT).** ARA Project No. 16860.

Dear Mr. Brakke:

Applied Research Associates (ARA), Inc. appreciates the opportunity to submit the analysis of RWD testing performed on selected Iowa highways. This report summarizes the RWD device, testing program, and results.

It has been a pleasure for ARA to provide these services to you, and we look forward to your feedback regarding this innovative device. If you have any questions or comments, please feel free to contact us.

Sincerely,

Douglas A. Steele, P.E.
Senior Engineer

William R Vavrik, Ph.D., P.E.
Midwest Division Manager

Attachment

cc. Ms. Lisa Rold, FHWA IA Division
Mr. Thomas Van, FHWA, D.C.

TRANSPORTATION SECTOR
505 W. UNIVERSITY AVE. ■ CHAMPAIGN, IL 61820-3915
(217) 356-4500 ■ FAX: (217) 356-3088 ■ WWW.ARA.COM/TRANSPORTATION

FINAL REPORT

Rolling Wheel Deflectometer (RWD) Demonstration for the Iowa Department of Transportation (Iowa DOT)

Prepared for:

Iowa Department of Transportation

Prepared by:
Applied Research Associates, Inc.
Transportation Sector
505 West University Ave.
Champaign, IL 61820-3915
Tel. (217) 356-4500

December 15, 2006

TABLE OF CONTENTS

EXECUTIVE SUMMARY I

Activities Performed for Iowa DOT i
Findings i

ACKNOWLEDGEMENTS III

INTRODUCTION 1

RWD DESCRIPTION 2

Equipment 2
Measurement Methodology 2

TESTING PROGRAM 3

DATA PROCESSING AND FILTERING 5

Truck Speed and Speed Variation 5
Pavement Surface Temperature 7
Bridges and Intersections 7

RWD DEFLECTION RESULTS 8

Full-depth AC in Good Condition on I-80—Low and Uniform Deflections 8
Full-depth AC in Very Poor Condition on IA 146—Variable Deflections Due to Deterioration 8
5-in AC Pavement in Fair to Poor Condition on IA 175—High Deflections 8
Statistical Summary of All Roads Tested 12
FWD Comparison 13

POTENTIAL USES OF RWD DATA 15

APPENDIX A: Deflection Profiles

EXECUTIVE SUMMARY

The Rolling Wheel Deflectometer (RWD) is an innovative device to efficiently measure continuous pavement deflections at normal highway speeds. The never-before-available data it provides present many potential benefits to pavement managers and highway agencies, mainly by providing a measure of structural capacity for use in network-level pavement evaluation and management. This report summarizes a pilot study performed for the the Iowa DOT.

Activities Performed for Iowa DOT

- Applied Research Associates (ARA), Inc. performed RWD testing on 30 pavement sections, consisting of Interstate, U.S., and state routes. The majority of roads were two- and four-lane asphalt concrete (AC) pavements of variable thickness and condition.

- For each road, the RWD measured a continuous deflection profile in the outer wheelpath of the outer traffic lane, operating at normal highway speeds. ARA tested 278 lane-miles over a 3-day period from July 25-27, 2006.

- ARA used pavement structure information (e.g., layer types and thicknesses) provided by Iowa DOT, to validate deflection results and normalize deflections to a standard temperature. Specifically, the AC thickness is used in conjunction with pavement temperatures measured during field survey to normalize deflections to 68 ºF.

- A quality control process was followed to remove any non-representative RWD data due to truck and pavement factors, such as excessive truck bouncing due to bridge joints. Overall, a negligible amount of data (less than 0.5 percent) was excluded.

- RWD deflections averaged over 0.1-mi intervals were plotted for each highway to provide a deflection profile that showed the magnitude and variability of the pavements' structural response, as well as changes in pavement structure. A statistical summary was developed to show the mean deflections and representative deflections (i.e., mean plus 2 standard deviations, or 98th percentile deflection) for each road.

- FWD data was collected by Iowa DOT for each road at 0.5-mi intervals. The FWD was normalized to a standard temperature using the same techniques as those used with the RWD data, and the data were plotted on the RWD deflection profiles for comparison.

Findings

- The diverse pavement conditions produced mean deflections ranging from 3 to 18 mils, with the lower deflections generally occurring on the thicker, higher-volume interstate pavements, and higher deflections on the state routes. Deflections were reasonable for the pavement layer types and thicknesses tested.

- In addition to pavement thickness, pavement condition also had a large influence on deflection magnitude and variability. In general, pavements with higher distress amounts (e.g., fatigue cracking in the wheelpath), produced higher deflections─and more variable deflections─than

those in good condition. The RWD collected digital images of each roadway during testing, and several examples of these are included in the report.

- In terms of structural performance, the representative deflection (defined as the mean plus 2 standard deviations, or 98th percentile) is more appropriate than just the mean deflection in predicting future performance, as it takes into account the section's variability. This is important as it will be the weaker areas of pavement (i.e., areas of higher deflection) that show structural distress first. In terms of representative deflection, the values ranged from 5 to 23 mils. Deflection values in this range typically correspond to pavements with high to medium levels of structural capacity.

- When normalized to a standard temperature, the RWD and FWD showed very similar deflection profiles for each road. The mean RWD and FWD values for each road also correlated very well.

- The RWD is capable of good productivity, testing almost 300 lane-miles over a 3-day period. Productivity is determined primarily by the length and geographic distribution of test sites. On other projects where longer, more closely spaced test sites were chosen, the RWD has accomplished 200 to 300 lane-miles of testing per day.

- The RWD is a safe method for collecting highway structural data, as it does not require lane closures or interruptions to the highway users. The RWD blends with surrounding traffic, operating at prevailing highway speeds for tractor-trailer combinations, typically performed at 55 to 65 mph.

- In addition to deflections, the RWD also collected continuous digital images of each road tested. With additional effort, the RWD could be enhanced to collect inertial longitudinal profiles for use in calculating the International Roughness Index (IRI). The combination of pavement deflection, condition rating, and IRI would make the RWD a powerful single device for the collection of multiple PMS data types.

ACKNOWLEDGEMENTS

ARA would like to express our appreciation to the FHWA Office of Asset Management for their sponsorship and support of the RWD program. Specifically, we would like to recognize Mr. Thomas Van and Mr. Stephen Gaj for their continued leadership and support. In addition, we are appreciative to Mr. Michael Arasteh (FHWA Baltimore Resource Center) and Mr. Max Grogg (FHWA Iowa Division) for their input and support of the RWD program.

ARA is thankful to the FHWA Iowa Division office and the Iowa DOT for their assistance in coordinating and providing needed data for this pilot study. Specifically, we would like to recognize Ms. Lisa Rold (FHWA Iowa Division) and Iowa DOT personnel Mr. Chris Brakke and Mr. Jason Omundson for providing pavement structure and falling weight deflectometer (FWD) data.

INTRODUCTION

The Rolling Wheel Deflectometer (RWD) is an innovative device for the efficient, high-speed determination of highway pavement structural response. The current prototype was developed jointly by the Federal Highway Administration (FHWA) Office of Asset Management and Applied Research Associates (ARA), Inc. It uses four triangulation lasers mounted underneath the bed of a semi-trailer to measure a continuous deflection profile of the pavement when loaded by the trailer's 18-kip single axle load. The system has undergone extensive field testing, including pilot studies for numerous state highway agencies, including Texas, Indiana, Virginia, New Jersey, and Minnesota DOTs. Field testing has verified the RWD's capability to measure pavement deflections at highway speeds. Currently, ARA is .

In July 2006, ARA performed a field demonstration of the RWD for the Iowa Department of Transportation (Iowa DOT). Figure 1 shows overviews of several of the highways tested. This report details the testing program and RWD results.

Figure 1. Overviews showing the diverse range of pavements and conditions tested by the RWD, including I-35 (AC/CRCP), IA 146 (AC), and IA 21 (PCC whitetoppings).

RWD DESCRIPTION

Equipment

The RWD is comprised of a set of four triangulation lasers attached to an aluminum beam mounted on a custom designed 53-ft trailer. The trailer is sufficiently long to isolate the deflection basin produced by the RWD trailer's 18-kip, dual tire, single axle from deflections produced by the RWD tractor. Figure 2 shows an overview of the RWD truck, trailer, and laser mounting beam. In addition, the natural frequency of the trailer's suspension of 1.45 to 1.8 Hz is low enough that it does not couple with the high-frequency vibration of the 25.5-ft aluminum beam used to support the lasers. The beam uses a curved extension to pass under and between the dual tires, placing the rearmost laser approximately 6 inches rear of the axle centerline and 7 inches above the roadway surface, as shown in figure 2. The wheels have been spaced a safe distance from the laser and beam using custom lugs and a spacer.

Figure 2. Overview of the RWD and a close-up of laser D between the dual tires.

Measurement Methodology

The RWD utilizes a "spatially coincident" methodology for measuring pavement deflection. Three lasers placed forward of the loaded axle are used to define the unloaded pavement surface profile and a fourth laser (D) placed between the dual tires measures the deflected pavement surface. Deflection is calculated by comparing the undeflected pavement surface with the deflected pavement profile at the same location. This method was originally developed by the Transportation and Road Research Laboratory (TRRL) and furthered by Dr. Milton Harr at Purdue University.

At 55 mph, the RWD's 2-kHz lasers take readings approximately every 0.5 in, resulting in extremely large data sets. To make the data set manageable and to reduce the random error of individual readings, data are averaged over an interval suitable for pavement management purposes, typically at 0.1-mi (528-ft) intervals. At normal highway speeds, a 0.1-mi average contains approximately 60,000 individual laser readings.

TESTING PROGRAM

ARA performed testing on July 25-27, 2006 on roads selected by Iowa DOT. The roads consisted primarily of two- and four-lane asphalt concrete (AC) highways. Testing was performed in the outer traffic lane in both traffic directions. Table 1 summarizes the locations and typical pavement structures for the roads tested. A total of 278 lane-miles were tested over 3 days.

The RWD was operated by two people—a driver and a operator. During data collection the operator enters event markers that correspond to mile markers, bridges, changes in pavement surface type, and zones of significant acceleration/deceleration. These event markers are used during data processing to reference the RWD data and for filtering of outlier data due to localized events. In addition to deflection data, the RWD also records continuous digital images and GPS coordinates for each road. In general, the RWD tested at normal highway speeds (i.e., 55 mph), whenever conditions permitted.

Table 1. Summary of the test roads.

Road	RWD Section	Direction	From MM	To MM	Description	Typical Pavement Structure
I-35	i35nb1 i35sb1	NB/SB	24.31	33.04	Decatur county line north to US 34 interchange	4.5”AC, 8”CRCP
	i35nb2 i35sb2	NB/SB	33.04	42.85	US 34 interchange north to Warren county line	12.5-13.5”AC, 14”RSB
I-80	i80wb1	WB	49.71	55.33	Ramp junction IA 173 west to Pottawattamie county line	17”AC, 9”GSB
	i80wb2	WB	73.32	85.75	West ramp junction IA 25 west to Cass county line	10”AC, 12”RSB
	i80eb3	EB	85.75	99.21	West ramp junction IA 25 east to Dallas county line	11.5”AC, 12”RSB
	i80eb4 i80wb4	EB/WB	225.93	239.99	0.7 mile east of US 151 interchange east to WCL Coralville	7.5”AC, 14”ATB
	i80eb5 i80wb5	EB/WB	257.66	265.76	Wapsipinicon Creek bridge east to Cedar river bridge	10”AC, 16”ATB
US 63	us63nb us63sb	NB/SB	146.70	153.33	Tama county line north to junction IA 58	9”AC, 9”Rubblized PCC
IA 14	ia14nb ia14sb	NB/SB	106.04	111.57	1.5 mile south of junction IA 330 north to junction IA 96	13”AC, 6” GSB
IA 21	ia21nb ia21sb	NB/SB	45.55	52.72	East junction US 6 north to junction IA 212	Thin PCC whitetoppings
IA 141	ia141eb	EB	133.18	145.18	0.5 mile west of county road R30 east to Estate Hwy	12”AC, 7.5”GSB
IA 146	ia146nb1 ia146sb1	NB/SB	2.71	18.04	Mahaska county line north to 0.5 mile south of junction I-80	9.5”AC, 9”RSB
	ia146nb2 ia146sb2	NB/SB	29.99	40.72	Poweshiek county line north to junction county road E49	7.5-10”AC, 8-9”RSB
IA 175	ia175eb1 ia175wb1	EB/WB	145.65	153.66	North junction IA 17 east to south junction US 69	5”AC, 5”BTB
	ia175eb2 ia175wb2	EB/WB	158.95	172.41	Junction I-35 east to south junction US 65	3”AC, 4”CIP, 5”BTB
IA 210	ia210eb1 ia210wb1	EB/WB	1.93	4.36	Dallas county line east to just west of Des Moines river	6”AC, 8”RSB
	ia210eb2 ia210wb2	EB/WB	5.52	6.87	East of Des Moines river east to WCL of Madrid	6”AC, 8”RSB

Asphalt Concrete (AC), Portland Cement Concrete (PCC), Continuously Reinforced Concrete Pavement (CRCP), Rolled Stone Base (RSB), Asphalt-Treated Base (ATB), Bituminous-Treated Aggregate Base (BTB), Granular Subbase (GSB), Cold-Inplace-Recycled Asphalt (CIP)

DATA PROCESSING AND FILTERING

Data were processed in the office using proprietary RWD software. The software processes the raw RWD files to calculate and display the following parameters per sample unit (0.1-mi):

- RWD deflection and deflection deviation
- Truck speed and speed deviation.
- Pavement surface temperature.
- Linear referencing based on the Distance Measuring Instrument (DMI), GPS, and physical mile markers.
- Event markers, such as bridges, intersections, or other references.

A typical RWD raw data file of 40-mi length (approximately 1 Gb in size) is reduced to an HTML output file of minimal size, making the data set easily viewable and manageable.

The following sections present the quality control process followed to ensure valid RWD results. This process is used to eliminate outlier data due to either truck or pavement factors (e.g., excessive truck bouncing due to bridge joints) from the data set. Typically, a only a very small percentage of the data is removed (e.g., less than 0.5 percent).

Truck Speed and Speed Variation

Figure 3 shows the average truck speed for IA 146 between mile markers 2 and 16. In this case the truck speed was fairly constant, averaging 50 to 60 mph for the majority of the test run. The truck's acceleration can be seen at the beginning of the test run. Figure 4 displays the speed deviation within a 0.1-mi interval. A few outliers (i.e., deviations greater than 2 mph) can be seen. These correspond to the junction with F62, which required the RWD to slow down, prior to the merger.

Significant accelerating and decelerating of the RWD may cause excessive bouncing of the trailer, resulting in invalid laser readings at isolated locations. When this happens, the RWD deflections are reviewed to determine whether they have been influenced by the truck's bouncing. In this particular case, the truck speed deviations were not significant enough to have an influence on the resultant deflections; therefore, it was not necessary to eliminate outliers.

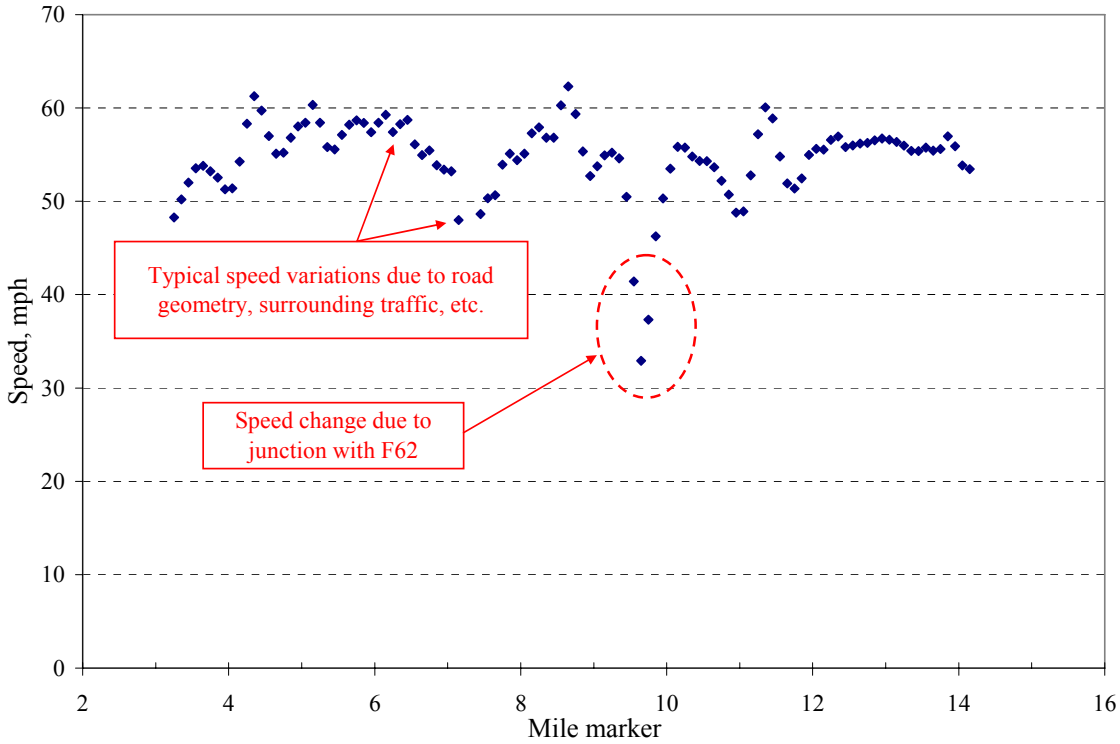


Figure 3. Average truck speed per 0.1-mi interval—IA 146, northbound.

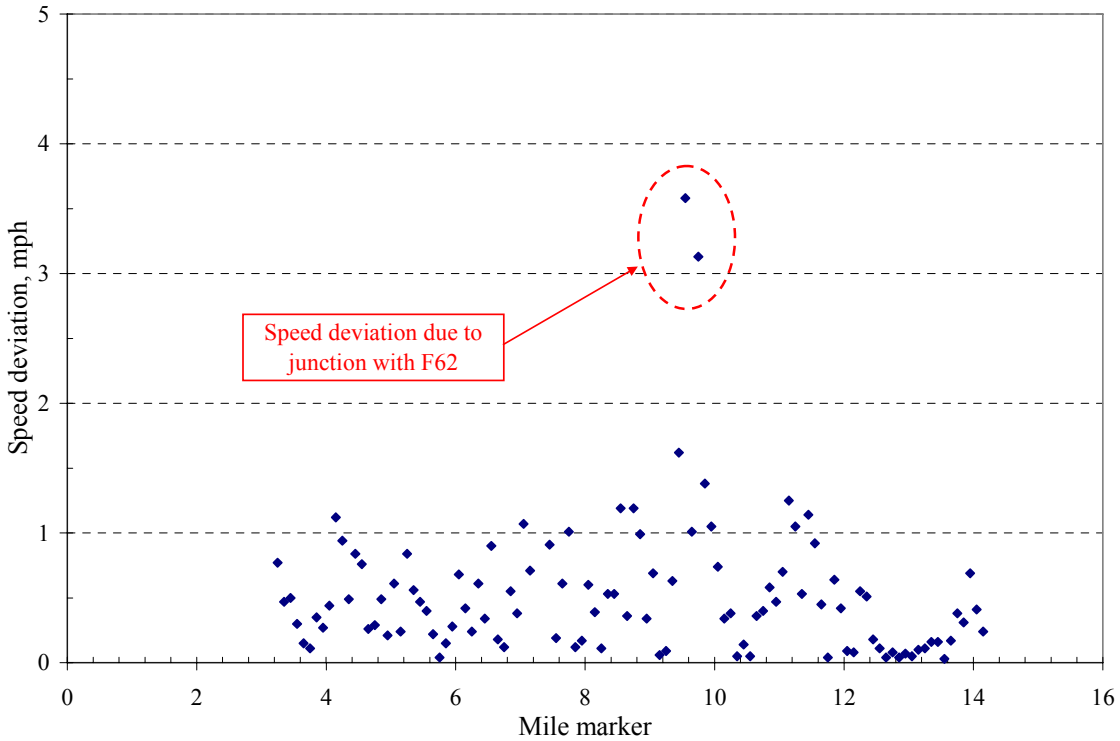


Figure 4. Truck speed deviation per 0.1-mi interval—IA 146, northbound.

Pavement Surface Temperature

The RWD collects pavement surface temperatures using an infrared thermometer. These temperatures, in conjunction with air temperature and AC layer thickness, are used to adjust the field deflections to a standard temperature of 68 ºF. The BELS3 method is used to predict the AC mid-depth temperature and the AASHTO 1993 method is used to correct the RWD maximum deflection, based on the predicted AC temperature.

Bridges and Intersections

Finally, deflections were reviewed with respect to pertinent events that were recorded in the data file through the use of markers. These events include bridges, changes in pavement type, areas of significant braking or acceleration, and other discrete events that may have affected isolated deflection readings. In cases where localized deflections were determined to coincide to the noted events, they were removed from the data set.

RWD DEFLECTION RESULTS

This chapter presents sample RWD deflection profiles for several Iowa highways, followed by a statistical summary of all the test roads. Detailed profiles for all roads tested are displayed in appendix A. Figures in this chapter show average RWD deflections calculated at 0.1-mi intervals, and the representative RWD deflection (i.e., mean plus 2 standard deviations) is shown in each figure. This corresponds to the 98th percentile (meaning 98 percent of the data is lower than this value) and it is considered more representative of expected pavement structural capacity than just the mean RWD deflection itself, as it also takes into account pavement variability. In other words, the weaker pavement areas (i.e., areas of high deflection) are the areas that are expected to show structural deterioration first.

Additionally , FWD data were collected by Iowa DOT at approximately 0.5-mi intervals for the same roads. FWD testing took place over a 1-week period immediately after RWD data collection, such that temperature and moisture conditions were very similar for both types of testing. FWD data were normalized to a standard temperature of 68 ºF using the same procedure as that used for the RWD, and are included in the RWD profiles. Overall, the RWD/FWD comparison was very good.

Full-depth AC in Good Condition on I-80—Low and Uniform Deflections

Figure 5 presents the RWD and a digital image taken of the I-80 eastbound section between mile markers 85 and 99. This high-volume pavement consists of 11.5 in of AC over a 12-in rolled stone base and is in excellent condition. Overall, the RWD deflections were very low and uniform, ranging from 3 to 7 mils, with a representative deflection of 6.4 mils. Both of these characteristics (low and uniform deflections) are desirable from a structural capacity point of view, and this pavement can be expected to have good structural performance for many years.

Full-depth AC in Very Poor Condition on IA 146—Variable Deflections Due to Deterioration

Figure 6 shows the RWD deflections and an overview of IA 146 between mile markers 30 and 41. The pavement consists of 7.5 to 10 in of AC over a 8 to 9 in rolled stone base. As can be seen, it presents significant deterioration, including transverse cracking, as well as fatigue cracking in both wheelpaths. Cracking is reflected in RWD deflections in two manners—higher variability and higher overall deflections. In this case, the deflections ranged from 4 to 17 mils, with a representative deflection of 16.4 mils. FWD deflections showed a similar magnitude and variability. Both the RWD deflections and visual conditions indicate that this road is in need of structural improvement. Based on the RWD deflections, placement of a medium-thick AC overlay (say 4 to 6 in) in conjunction with pavement milling may be a suitable treatment for increasing the pavement's structural capacity (i.e., lowering deflections) and restoring uniformity.

5-in AC Pavement in Fair to Poor Condition on IA 175—High Deflections

The RWD deflections and an image of IA 175 between mile markers 146 and 154 are presented in figure 7. The pavement consists of 5 in of AC over a 5-in bituminous treated base. As can be seen, the deflections are high and variable, with the majority of values ranging from 11 to 24 mils. The representative deflection of 23.0 mils reflects both the lower structural capacity of the relatively thin pavement section, as well as its deterioration from fatigue cracking in the wheelpath. Depending on the expected traffic level for this road, a combination of pavement milling and an AC overlay would likely be required to restore structural integrity and provide structural capacity for the future.

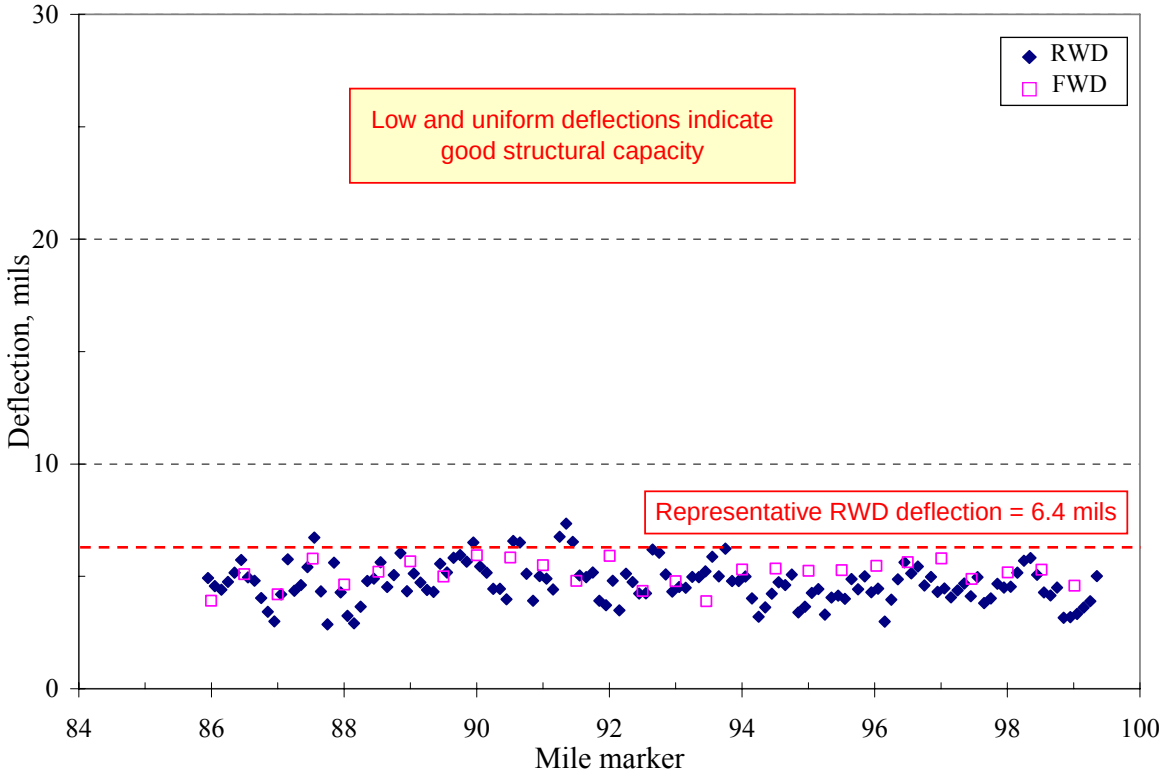


Figure 5. I-80, eastbound. Low and uniform deflections on a high-volume, full-depth AC section in excellent condition.

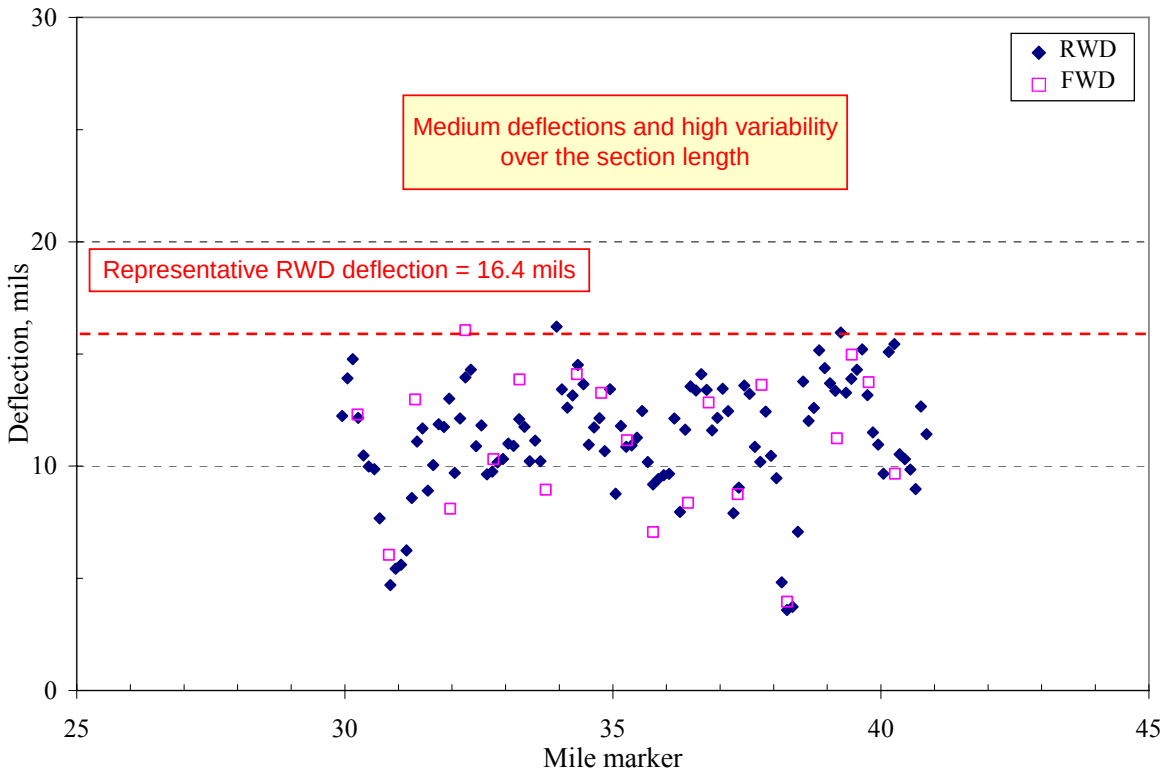


Figure 6. IA 146, northbound. Medium and variable deflections on full-depth AC with significant fatigue cracking.

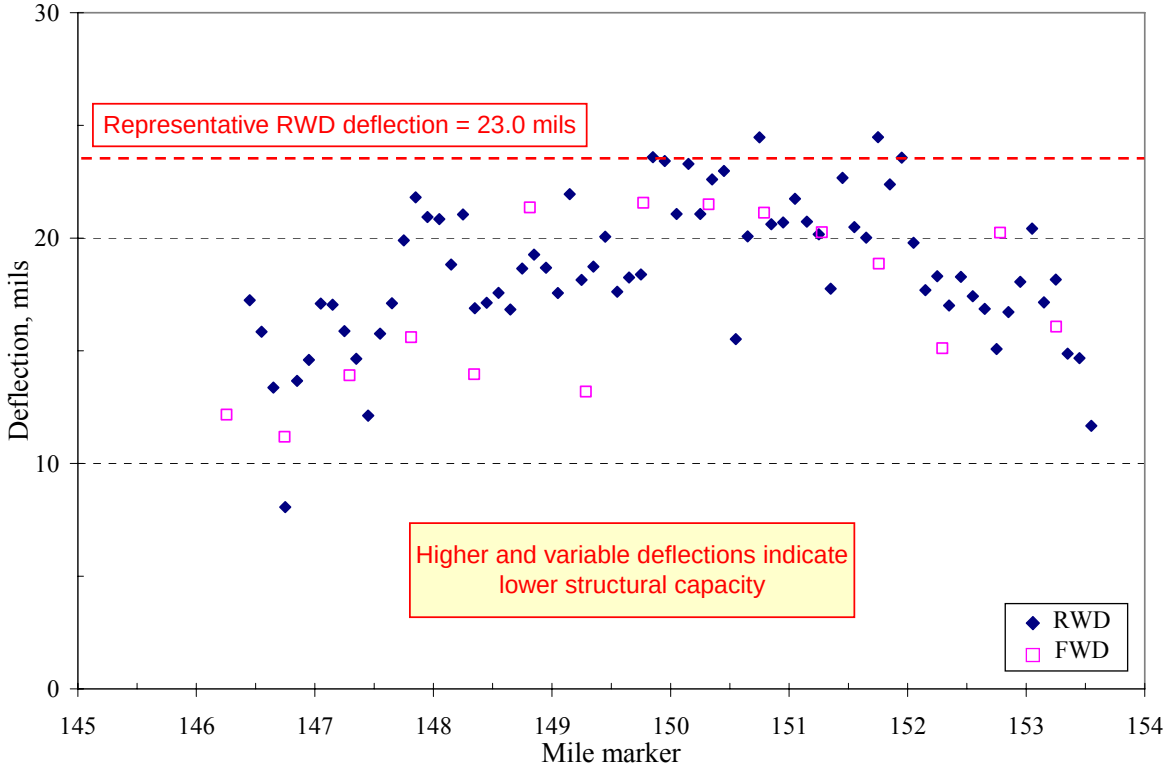


Figure 7. IA 175, eastbound. High deflections on a 5-in AC pavement with fatigue cracking in the wheelpath.

Statistical Summary of All Roads Tested

Figure 8 presents a statistical summary for all 30 pavement sections tested. For each section, the mean deflection and a range representing +/- 2 standard deviations is displayed. Therefore, the higher the mean value, the weaker the pavement structure. Likewise, the wider the vertical band, the higher the variability in deflections. In general, it is desirable to have pavements with low deflections and good uniformity (i.e., low standard deviations). The data show that mean deflections ranged from 3 to 18 mils, with the lower deflections generally occurring on the thicker, higher volume interstate pavements, as expected.

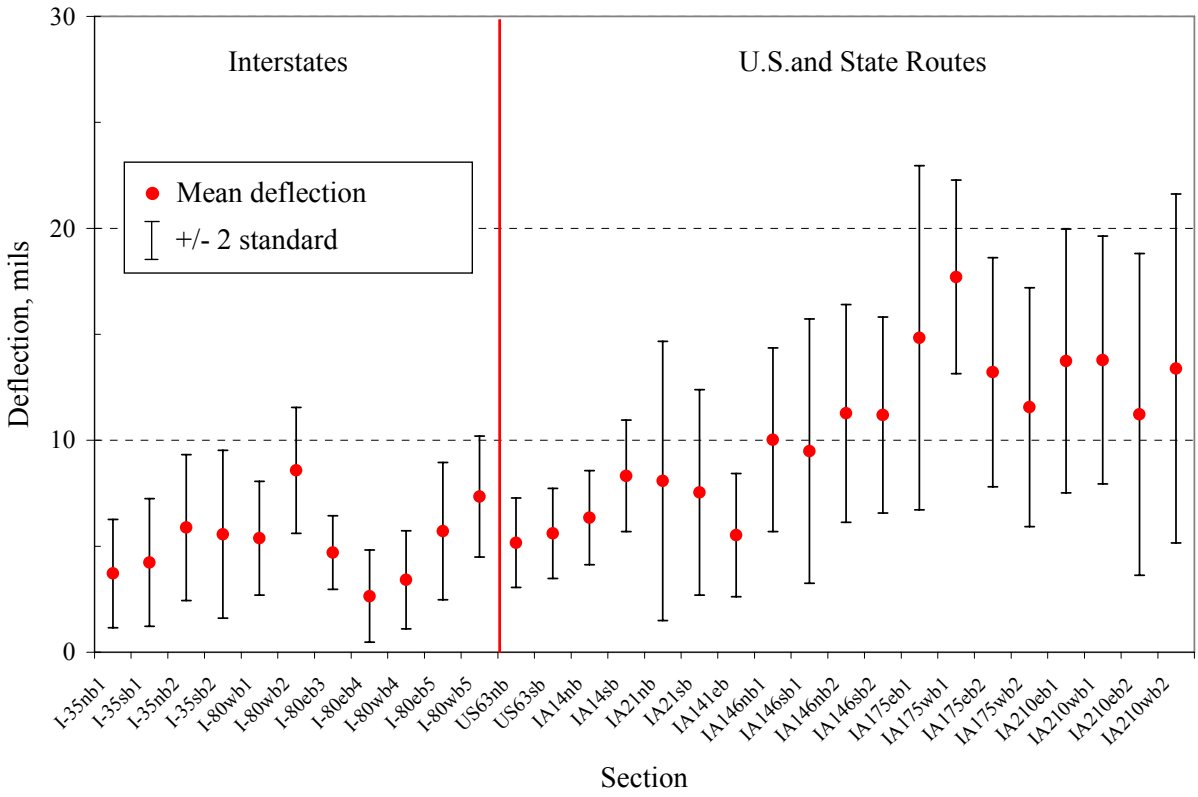


Figure 8. Diverse pavement conditions produced a wide range of deflections and variability.

From a pavement performance point of view, the upper limit of pavement deflections is actually more indicative of expected performance than mean values, as the weaker pavement areas are expected to show structural distress first. Therefore, by defining the section's representative deflection as its mean plus 2 standard deviations (i.e., the 98th percentile), we also account for section variability. Figure 9 displays the 30 pavement sections ordered by their representative deflection, lowest to highest. The values ranged from 5 to 23 mils. Subjective ratings describing the structural capacity of each deflection level (e.g., low, medium, and high) have been applied.

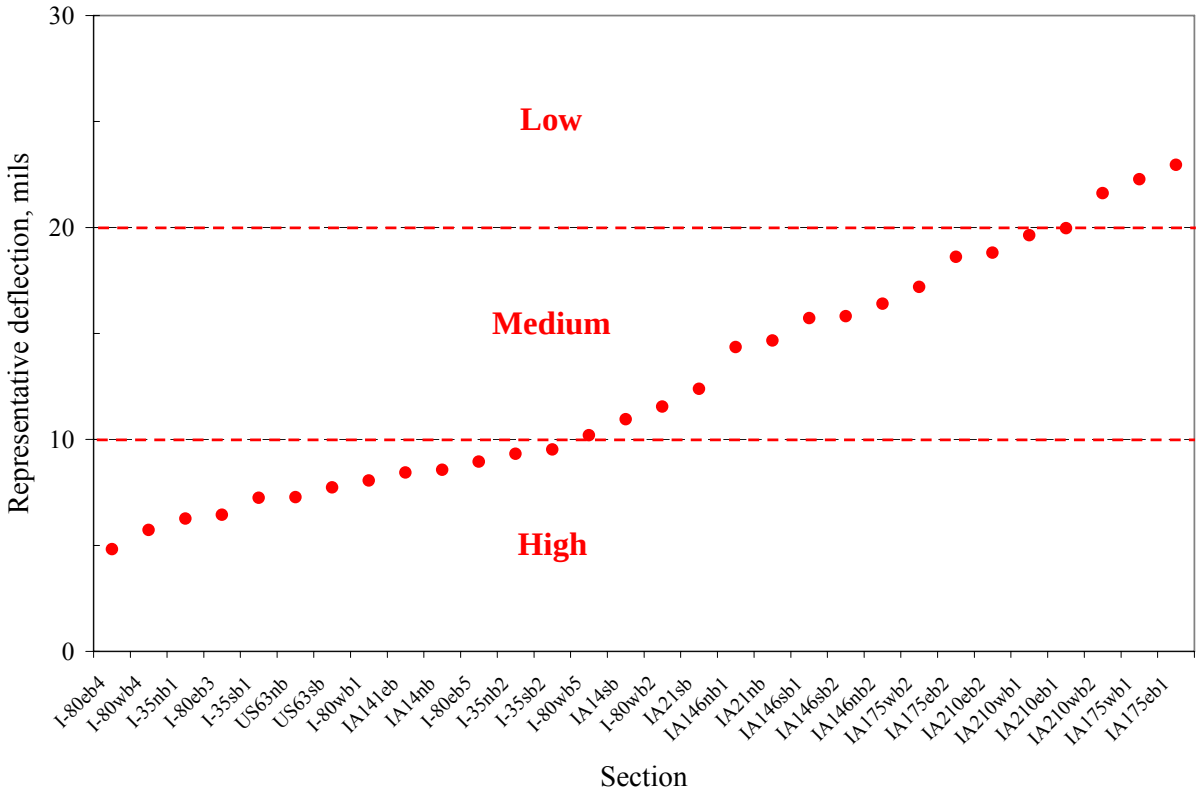


Figure 9. The structural capacity of each section can be characterized by its representative deflection.

FWD Comparison

FWD deflection data was provided by Iowa DOT, collected over a 1-week period following RWD testing. Data was collected at 0.5-mi intervals over all 30 pavement sections included in the study. Both FWD and RWD data were normalized to a standard temperature of 68 ºF. Figure 10 presents the comparison of data, which shows that the two devices correlated very well.

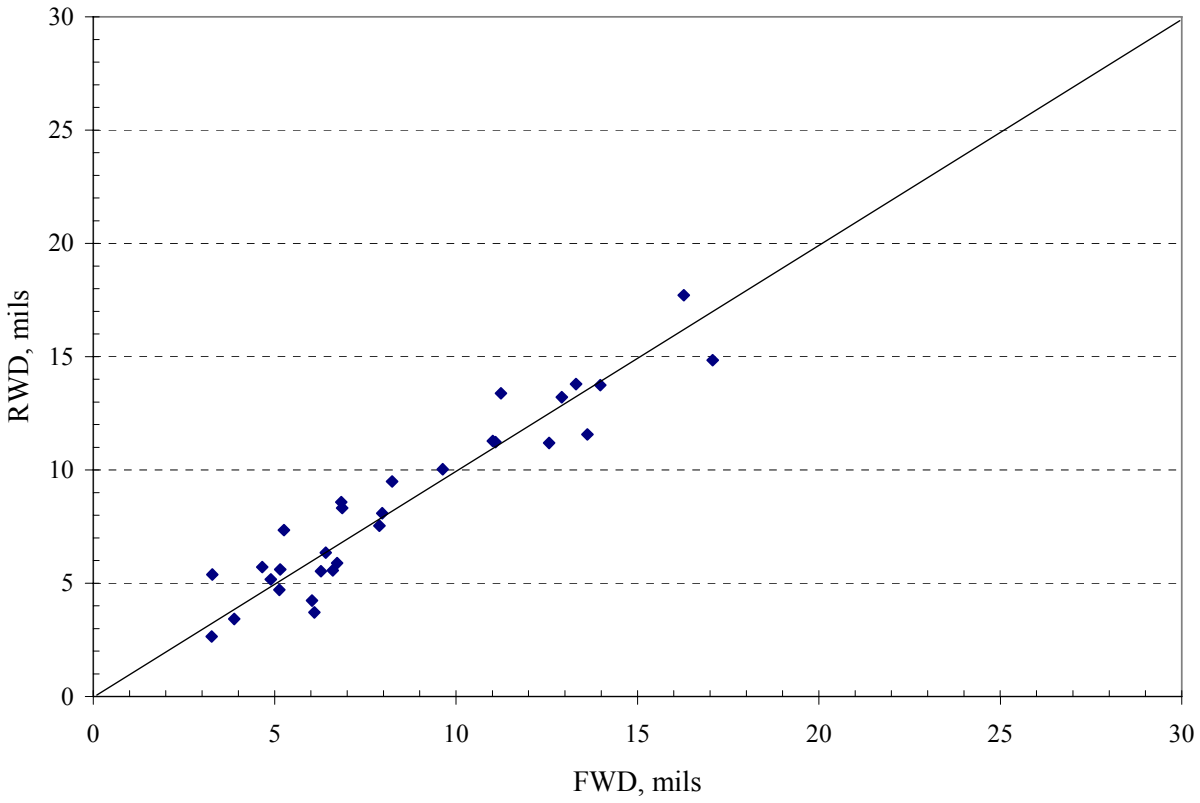


Figure 10. The RWD and FWD data showed similar trends.

POTENTIAL USES OF RWD DATA

The RWD provides an efficient means of collecting continuous pavement deflections over a large number of roads, thereby providing pavement structural capacity data not previously available for network-level evaluation and management. As this data has become available, the methods and techniques to use this information in pavement management are also being developed. Several manners of incorporating RWD data into pavement management practices include:

- **Treatment matrices**: This was recently performed on an RWD-based pavement management implementation for Champaign County, IL. RWD data were used in conjunction with visual condition ratings to determine when pavement maintenance and rehabilitation should be performed and appropriate strategies for individual pavement sections (for example, maintenance, surface treatments, overlays, or reconstruction).

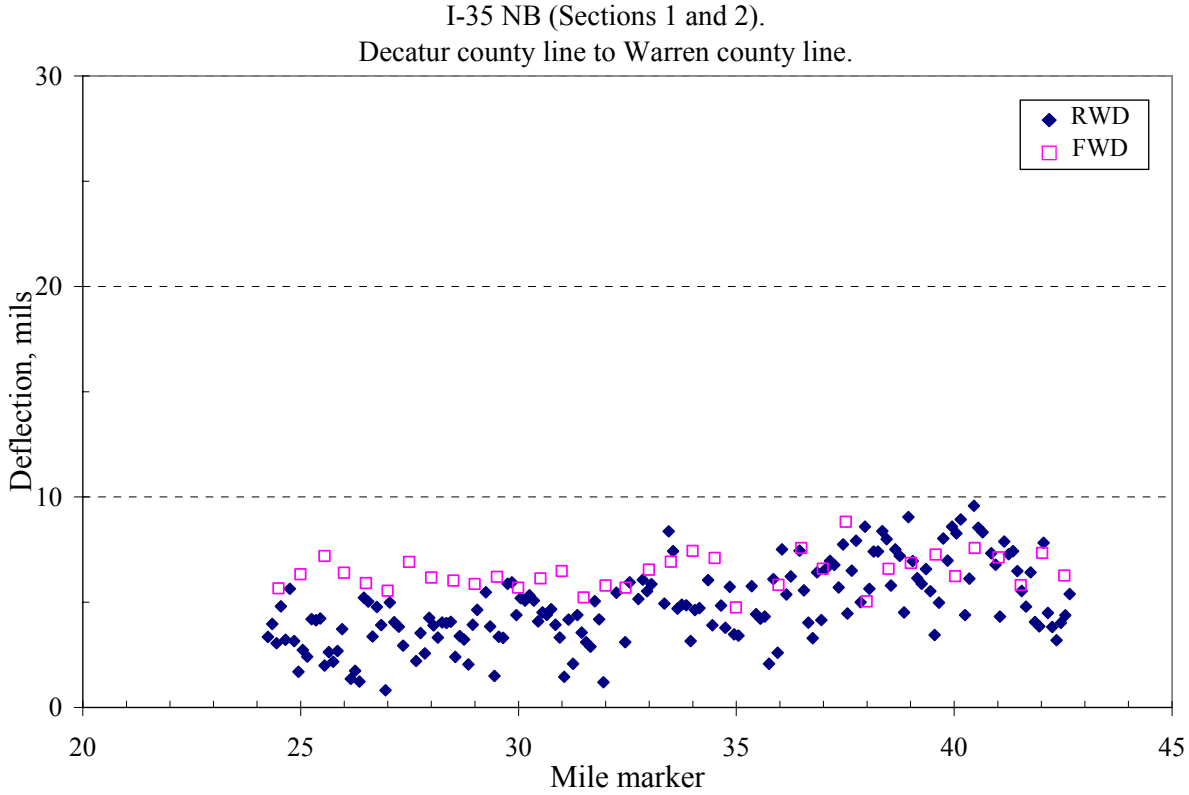
- **Pavement preservation:** There is interest from state agencies in using the RWD to identify which roads are suitable candidates for pavement preservation (i.e., maintenance and surface treatments), as opposed to those that require structural improvement. Obviously, if a road lacks structural adequacy, then pavement preservation is not an effective expenditure of funds. The RWD could be used to establish threshold deflection values for when pavement preservation is appropriate, given a specific traffic level.

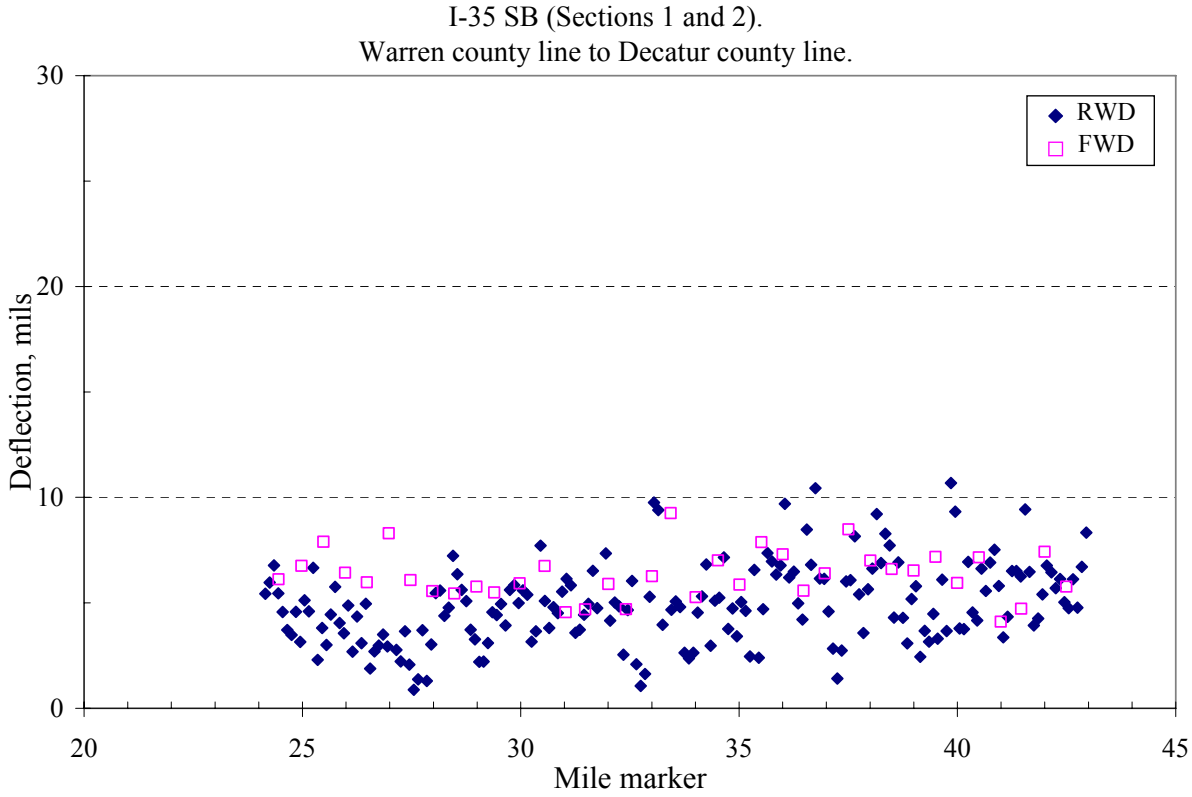
- **RWD-based structural ratings:** Structural ratings can be applied to different deflection levels to describe a road's structural capacity. For example, deflections from 0 to 10 mils, 10 to 20 mils, and 20 to 30 mils represent pavements with High, Medium, and Low structural capacities, respectively. These ratings could be customized for each agency and other factors, such as traffic level.

The data collected as part of this study, along with Iowa DOT's pavement management experience, present an excellent opportunity to develop these methodologies.

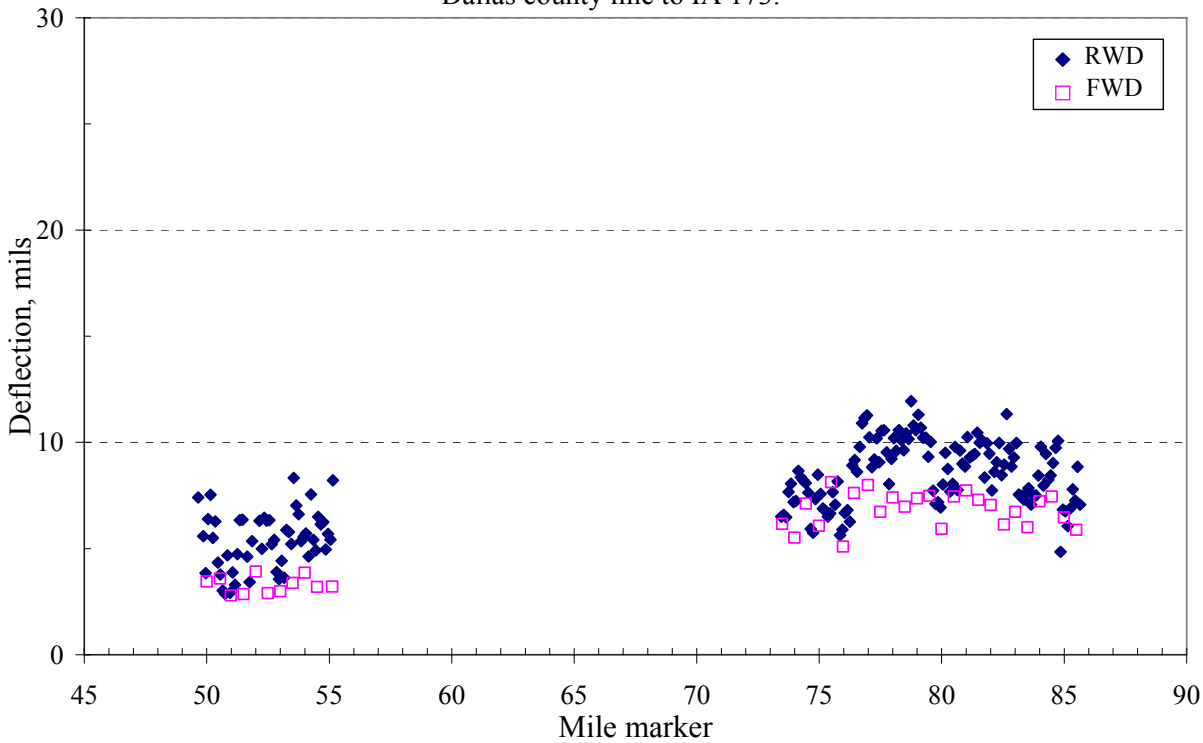
APPENDIX A

RWD Deflection Profiles

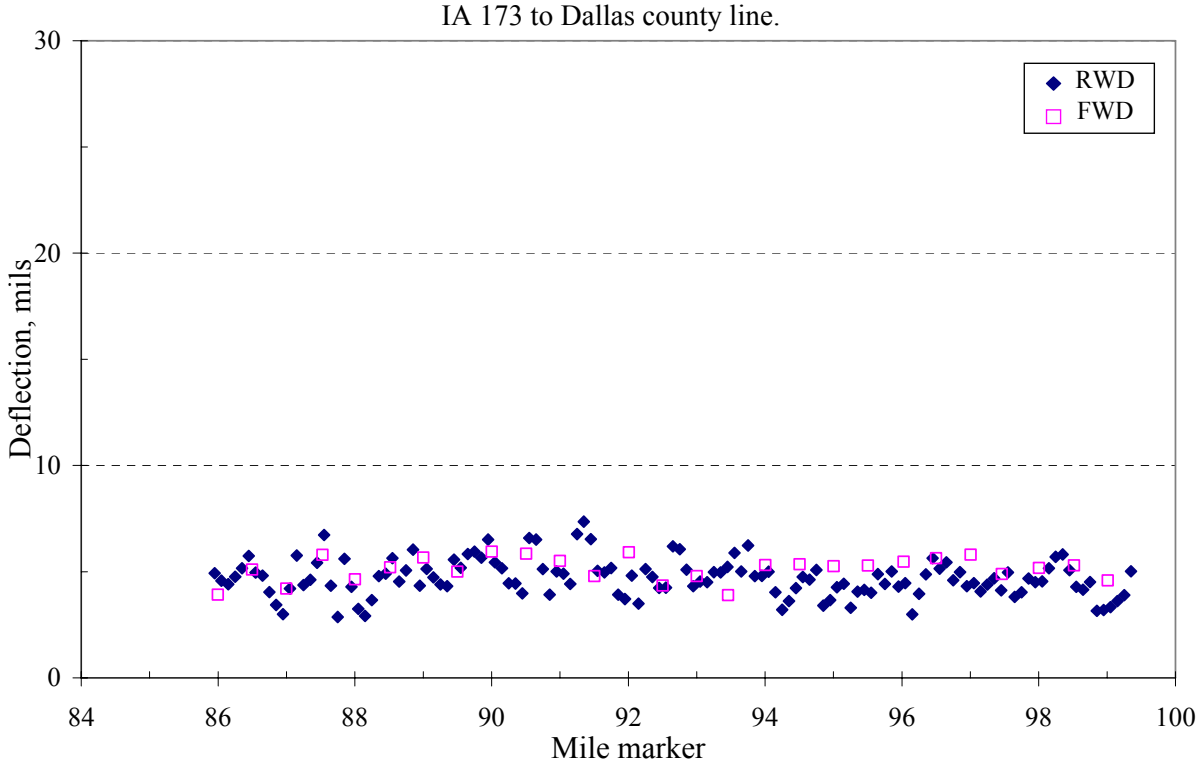

I-35 NB (Sections 1 and 2).
Decatur county line to Warren county line.
RWD
FWD
Deflection, mils
Mile marker
0
10
20
30
20
25
30
35
40
45

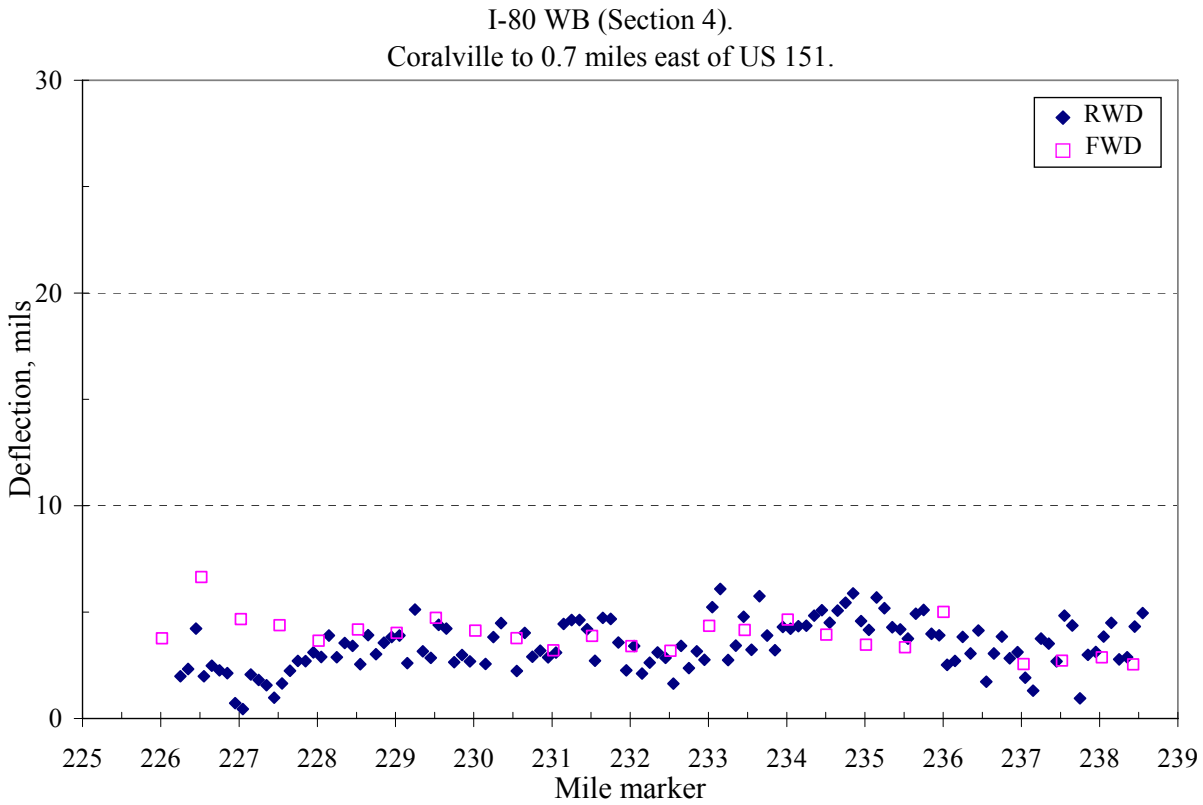

I-35 SB (Sections 1 and 2).
Warren county line to Decatur county line.
RWD
FWD
Deflection, mils
Mile marker
0
10
20
30
20
25
30
35
40
45

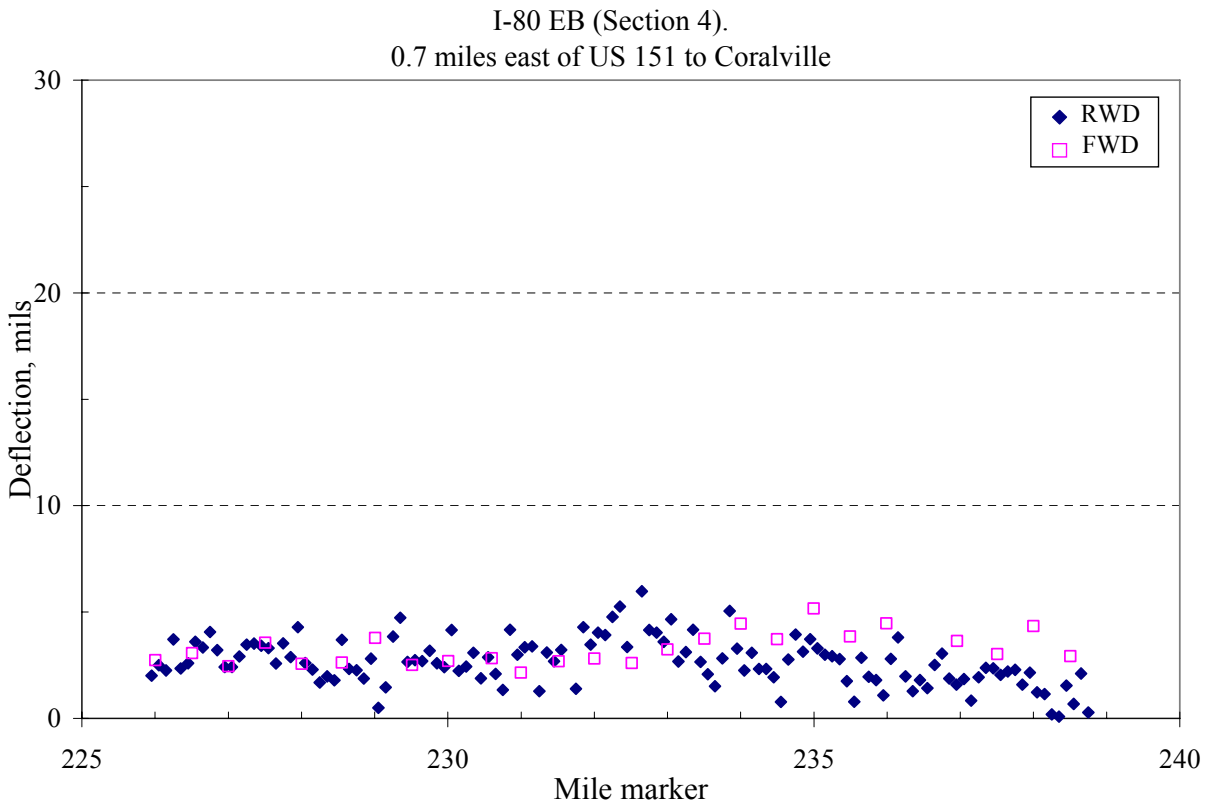
I-80 WB (Sections 1 and 2).
Dallas county line to IA 173.

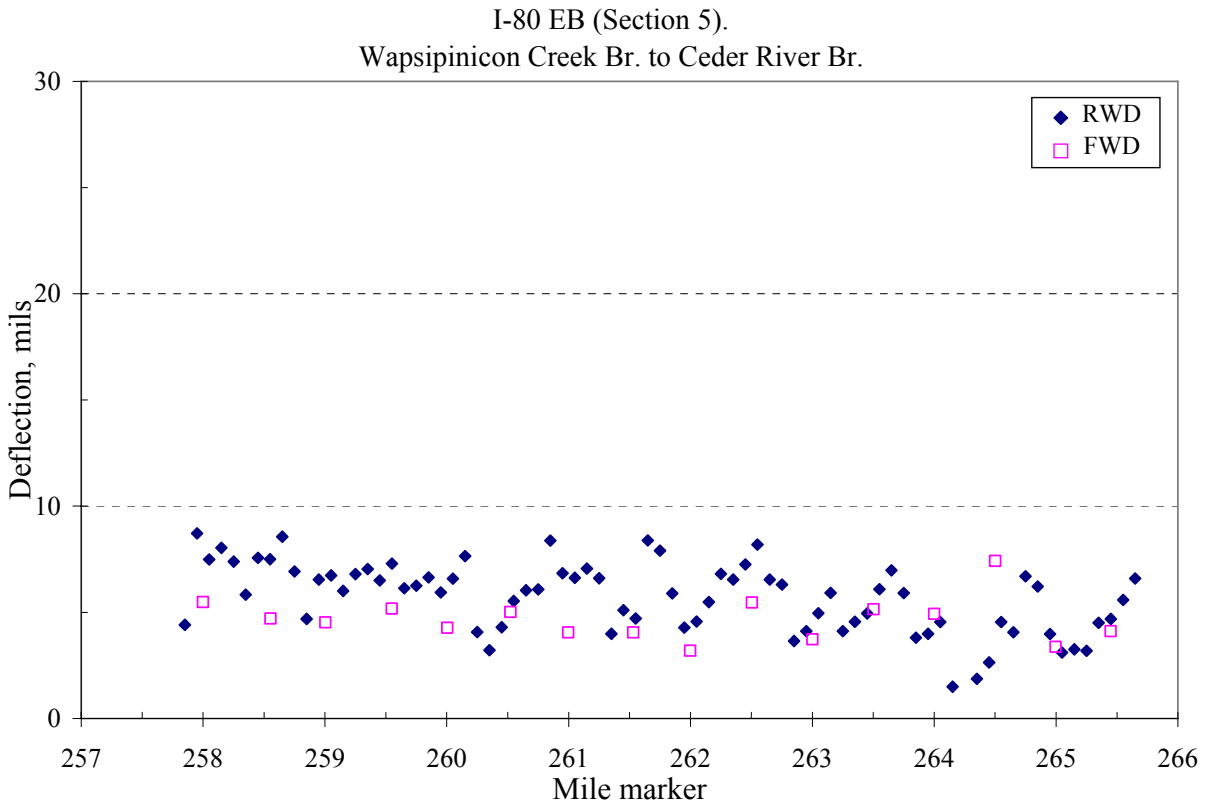


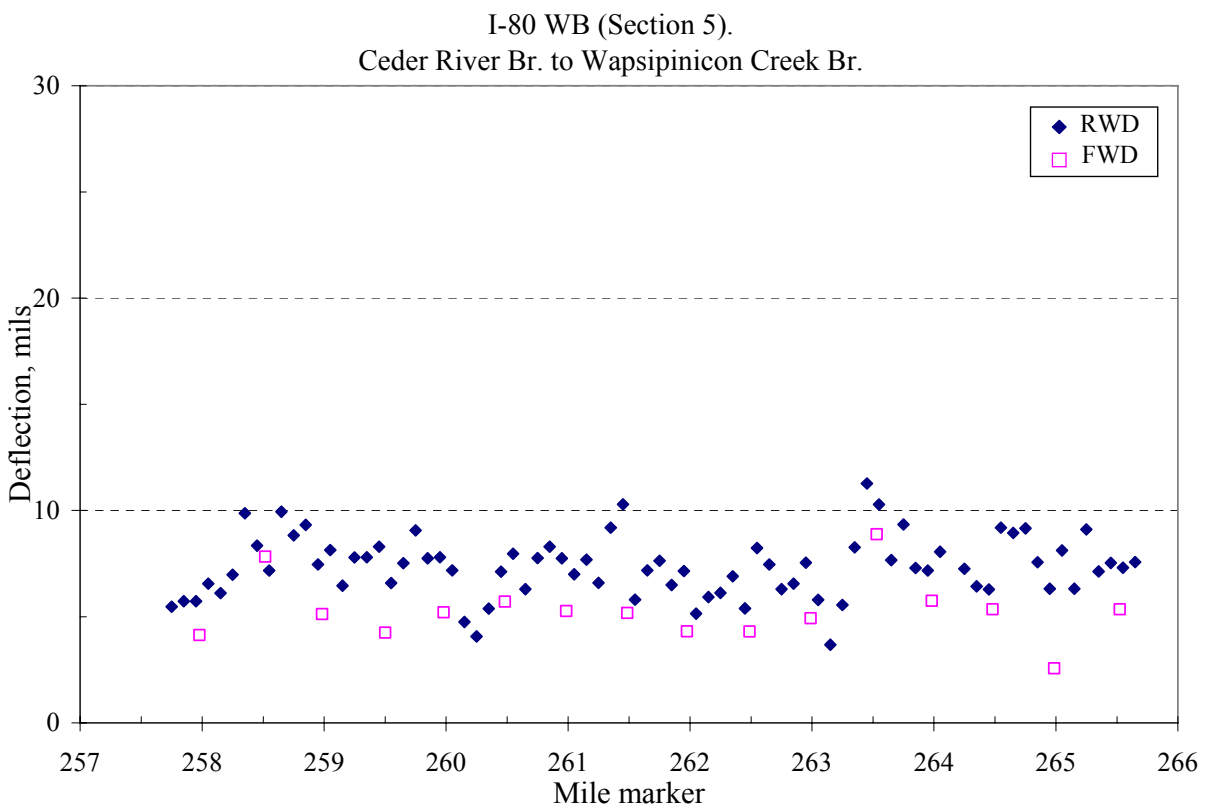
I-80 EB (Section 3).
IA 173 to Dallas county line.



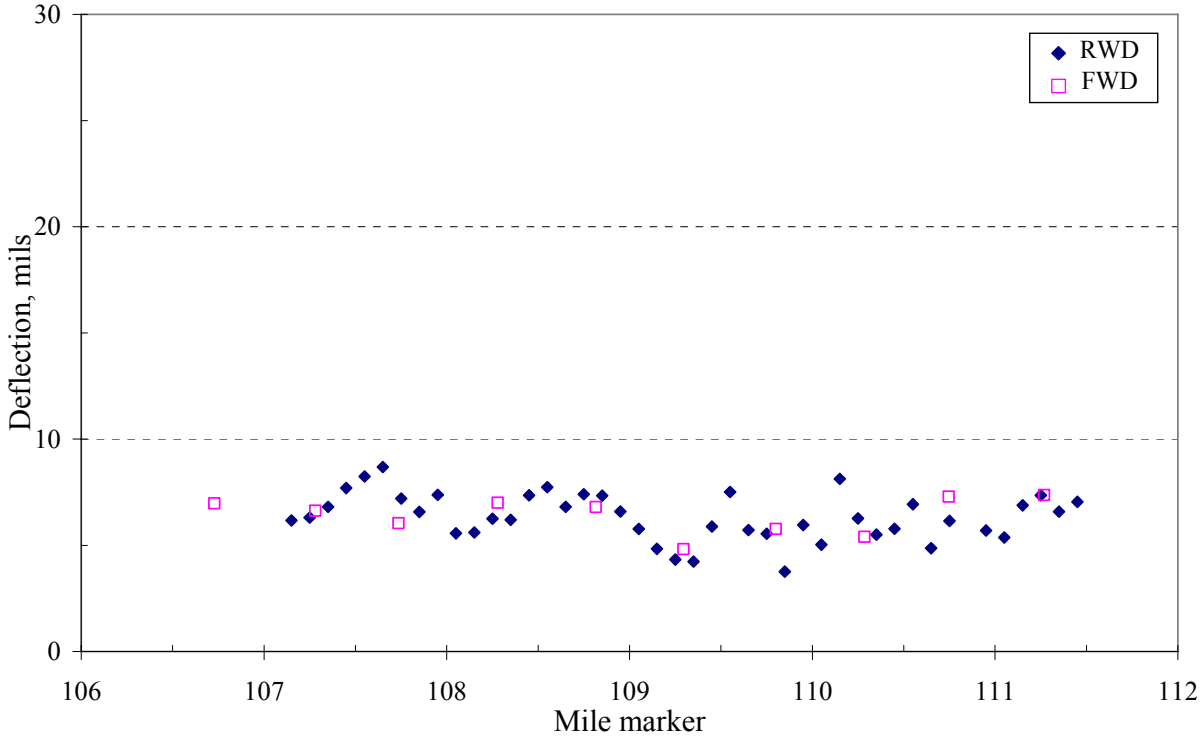

I-80 WB (Section 4).
Coralville to 0.7 miles east of US 151.
RWD
FWD
Deflection, mils
30
20
10
0
225
226
227
228
229
230
231
232
233
234
235
236
237
238
239
Mile marker


I-80 EB (Section 4).
0.7 miles east of US 151 to Coralville
RWD
FWD
Deflection, mils
30
20
10
0
225
230
235
240
Mile marker

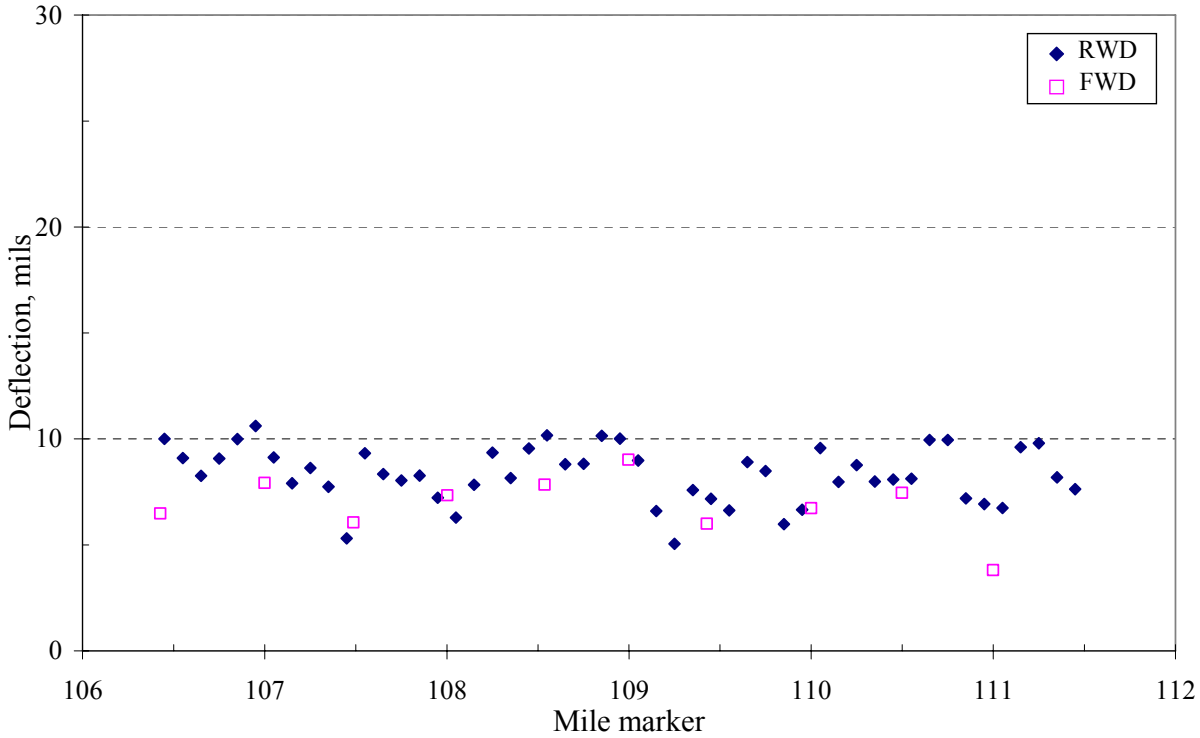

I-80 EB (Section 5).
Wapsipinicon Creek Br. to Ceder River Br.
RWD
FWD
Deflection, mils
30
20
10
0
257
258
259
260
261
262
263
264
265
266
Mile marker


I-80 WB (Section 5).
Ceder River Br. to Wapsipinicon Creek Br.
RWD
FWD
Deflection, mils
30
20
10
0
257
258
259
260
261
262
263
264
265
266
Mile marker

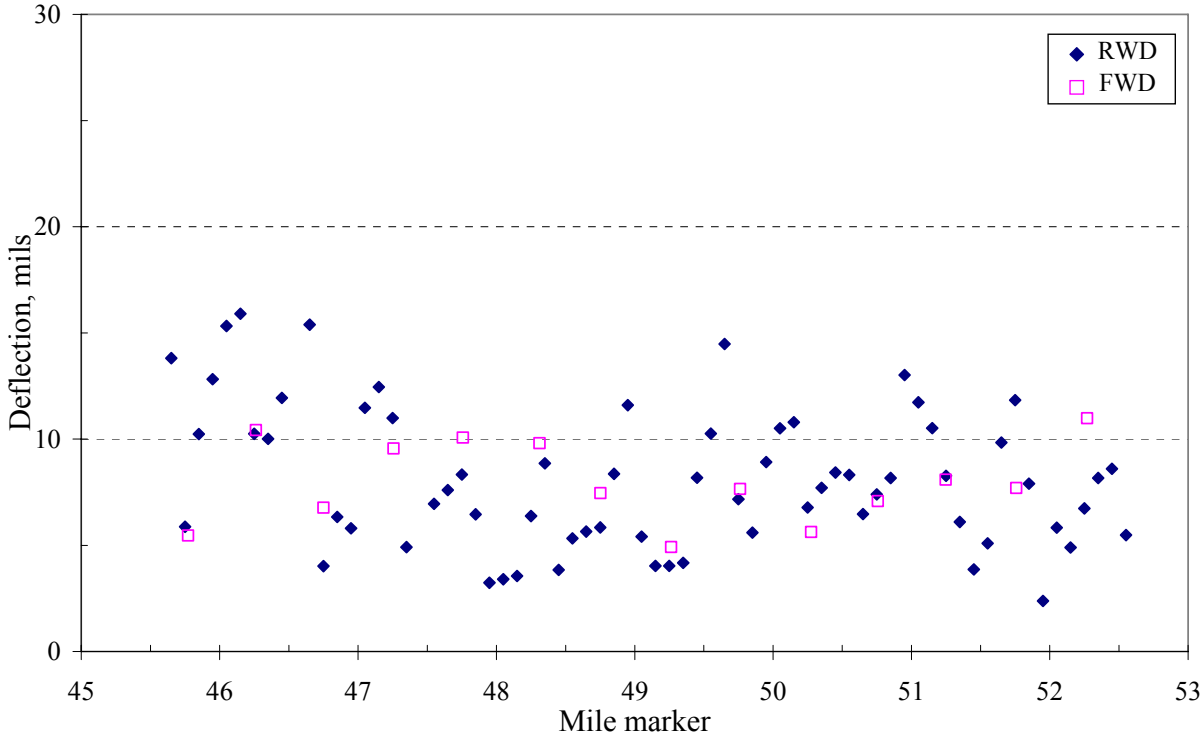
IA 14 NB.
1.5 miles south of IA 330 to IA 96.



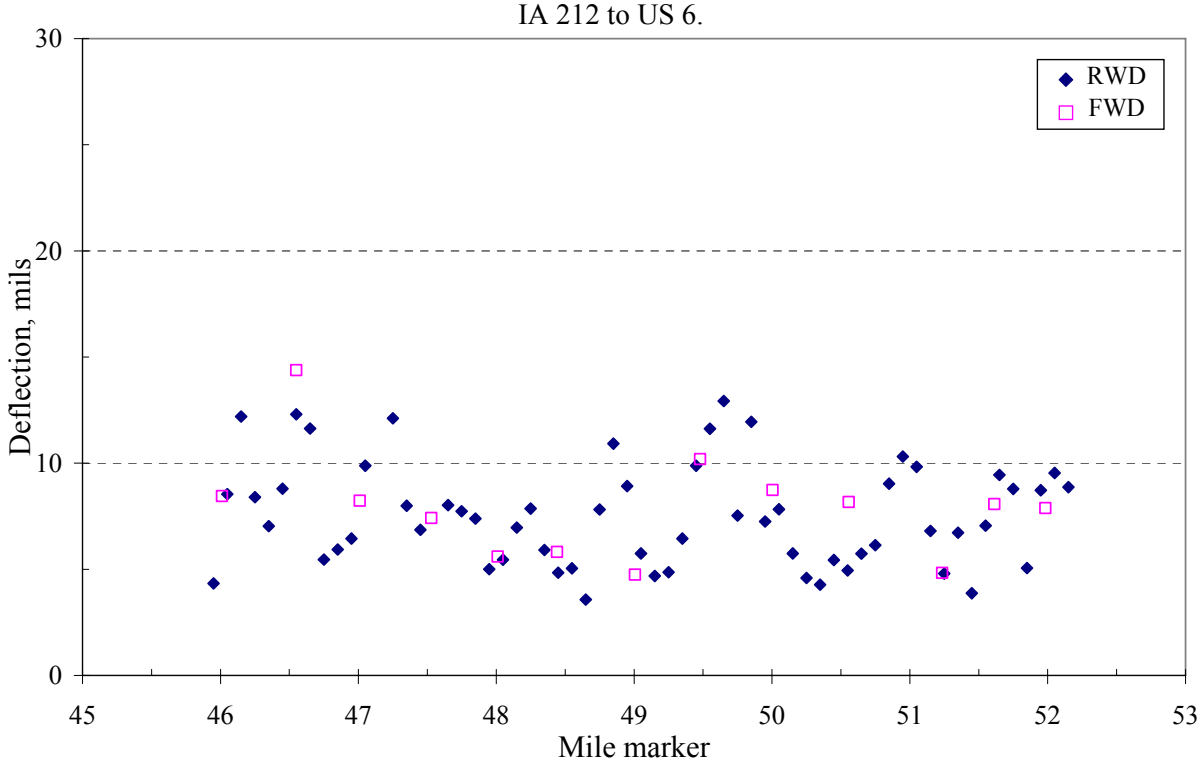
IA 14 SB.
IA 96 to 1.5 miles south of IA 330.



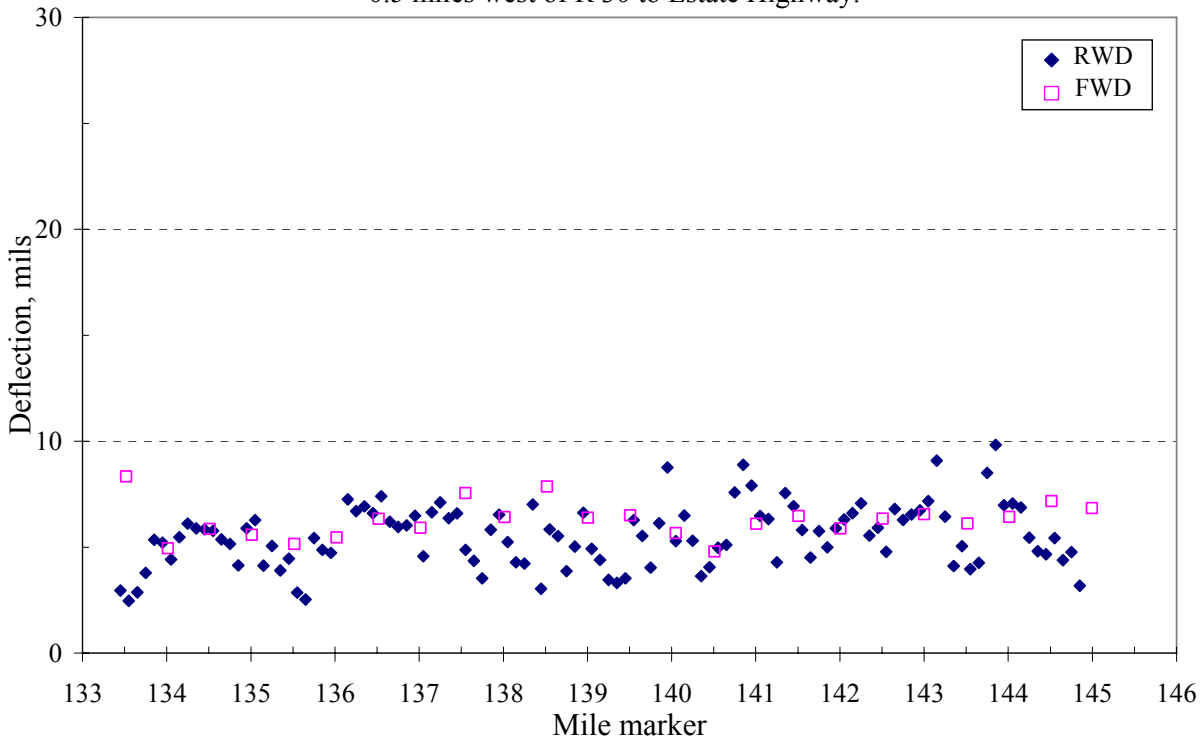
IA 21 NB.
US 6 to IA 212.



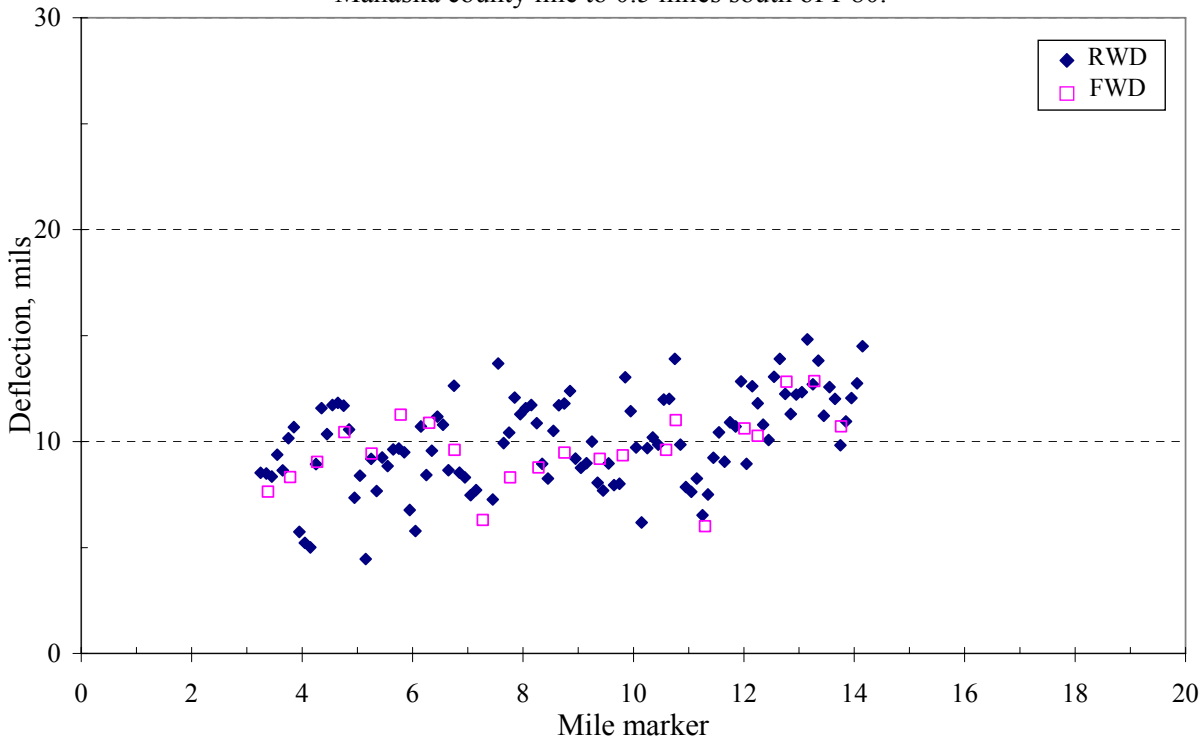
IA 21 SB.
IA 212 to US 6.



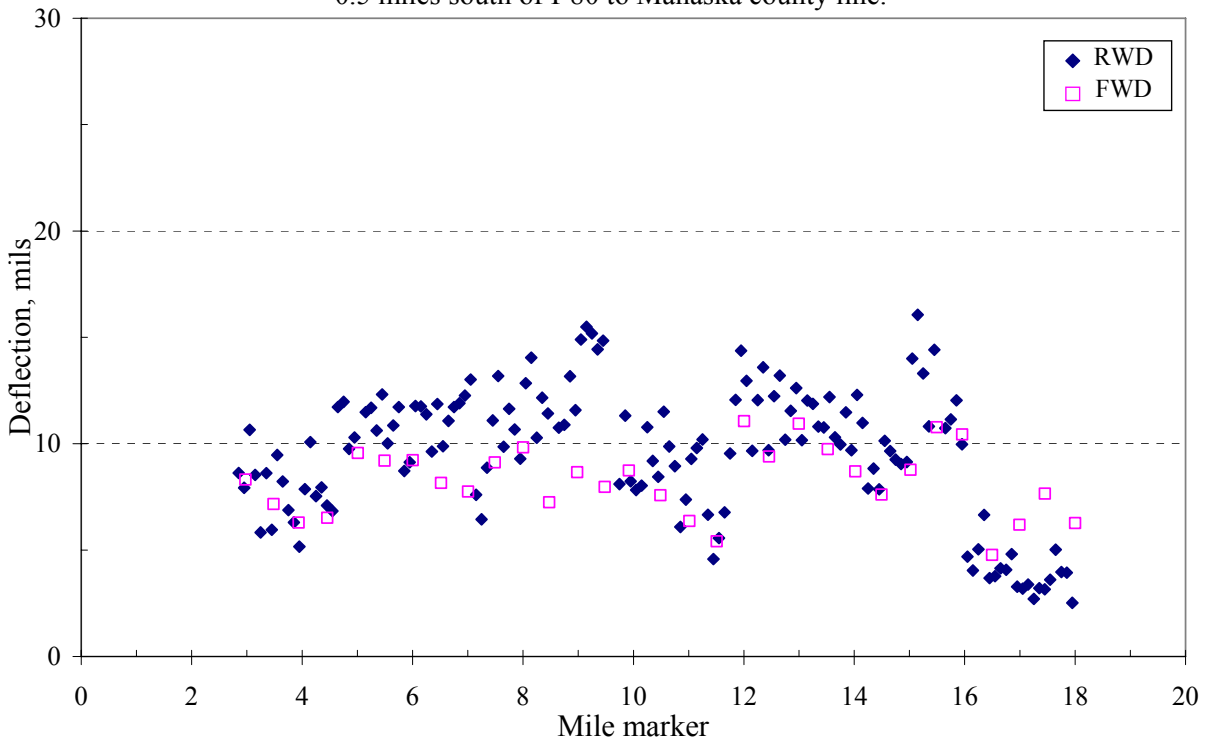
IA 141 EB.
0.5 miles west of R 30 to Estate Highway.



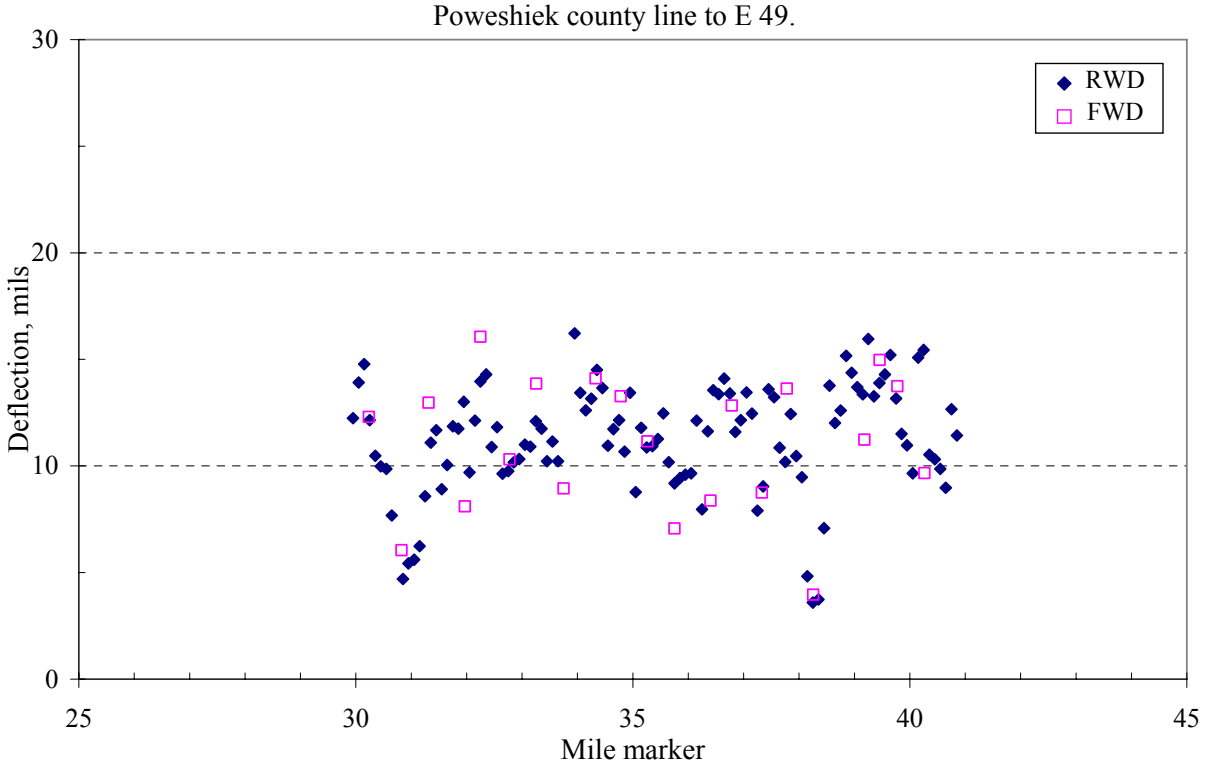
IA 146 NB (Section 1).
Mahaska county line to 0.5 miles south of I-80.



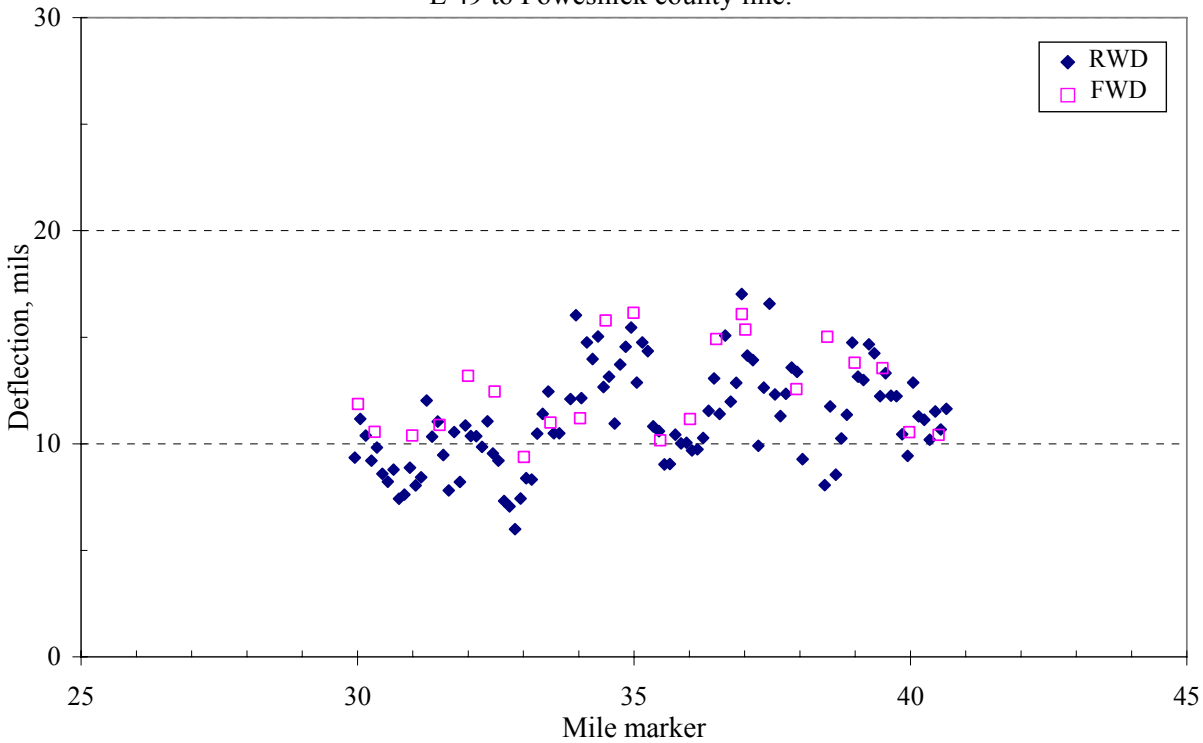
IA 146 SB (Section 1).
0.5 miles south of I-80 to Mahaska county line.



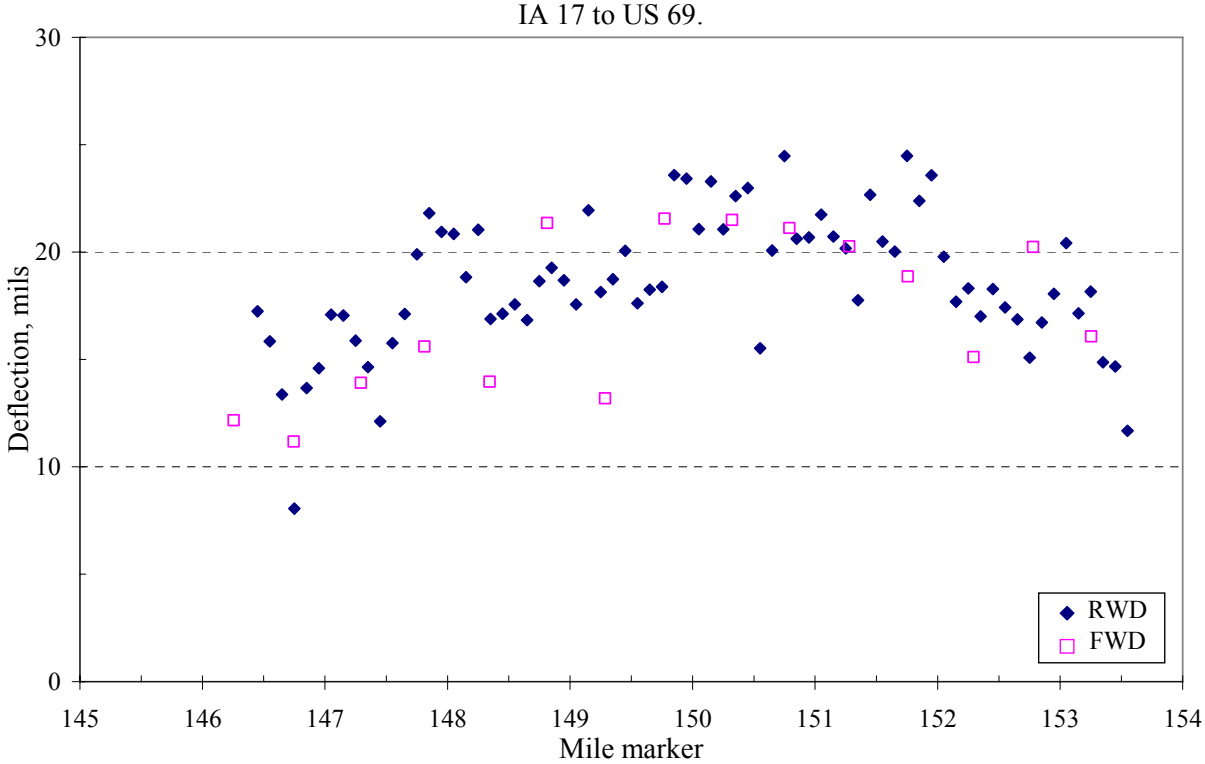
IA 146 NB (Section 2).
Poweshiek county line to E 49.



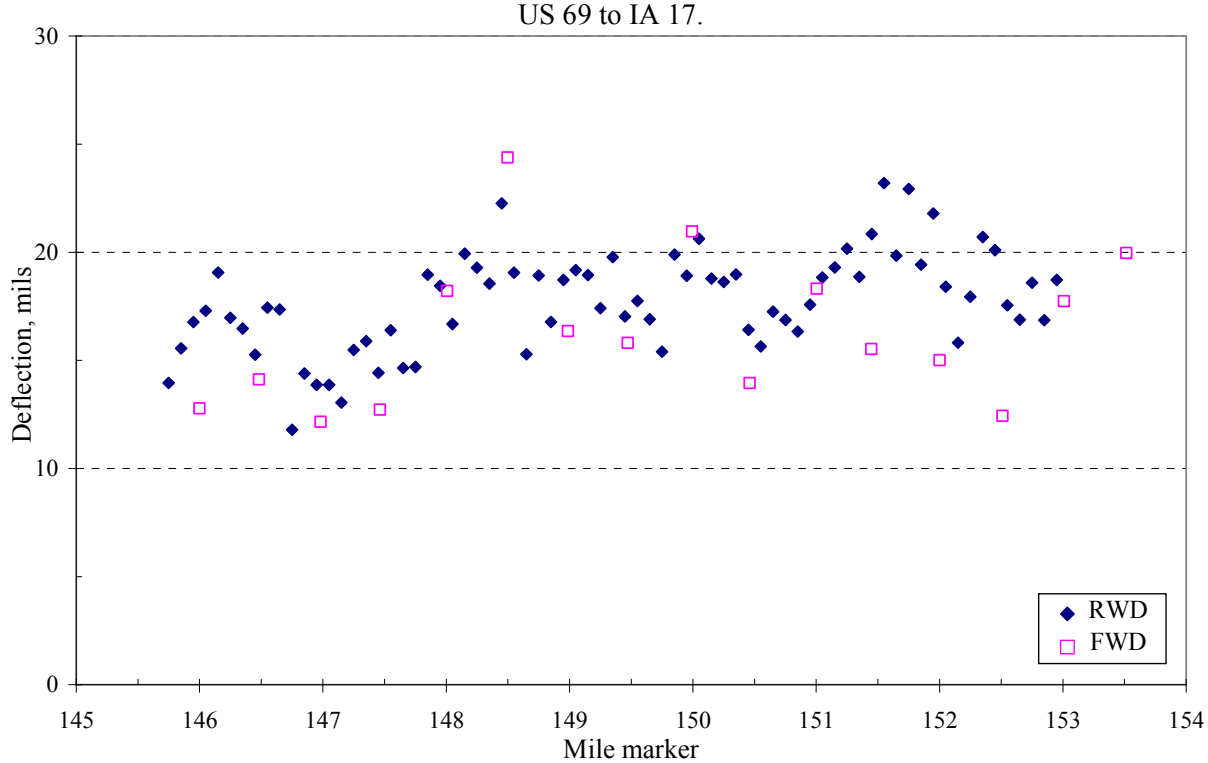
IA 146 SB (Section 2).
E 49 to Poweshiek county line.



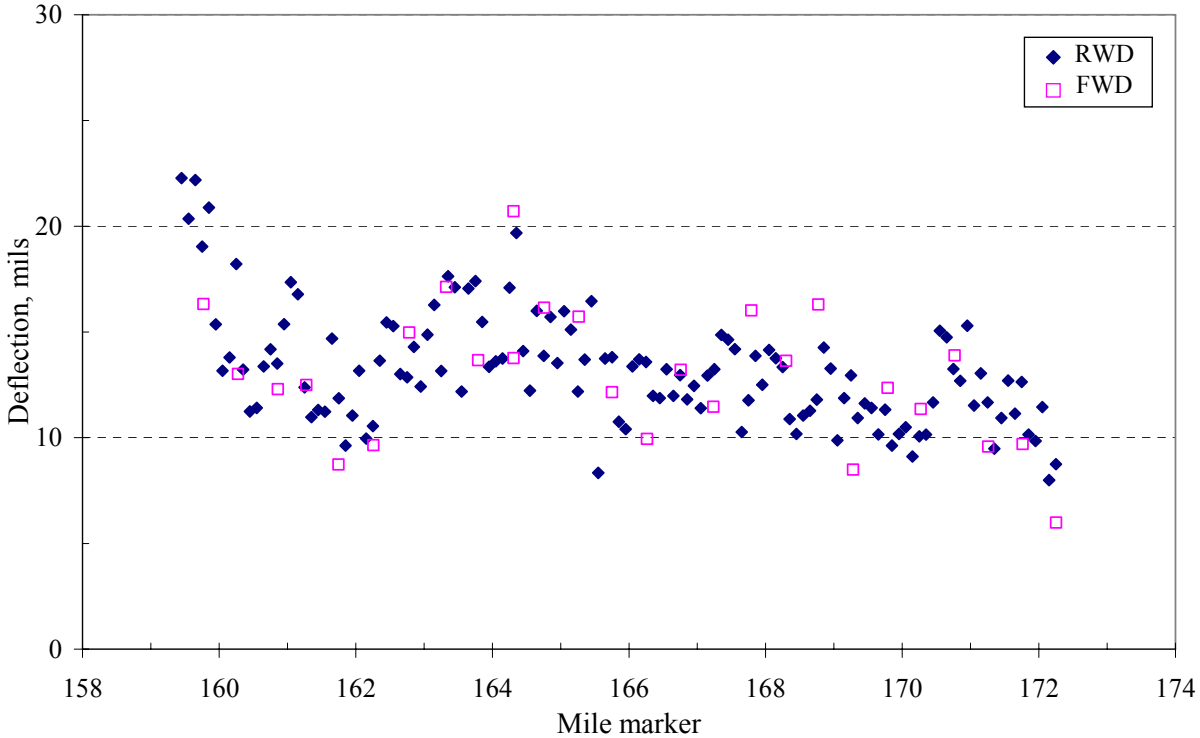
IA 175 EB (Section 1).
IA 17 to US 69.



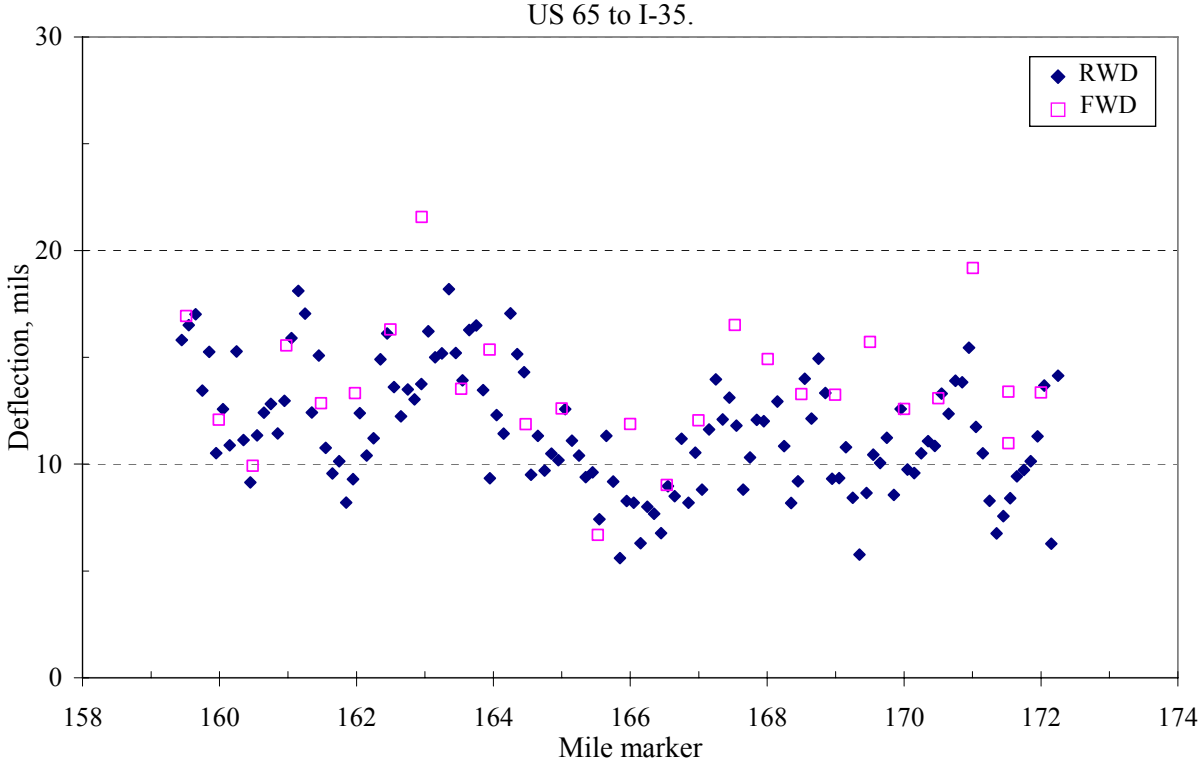
IA 175 WB (Section 1).
US 69 to IA 17.



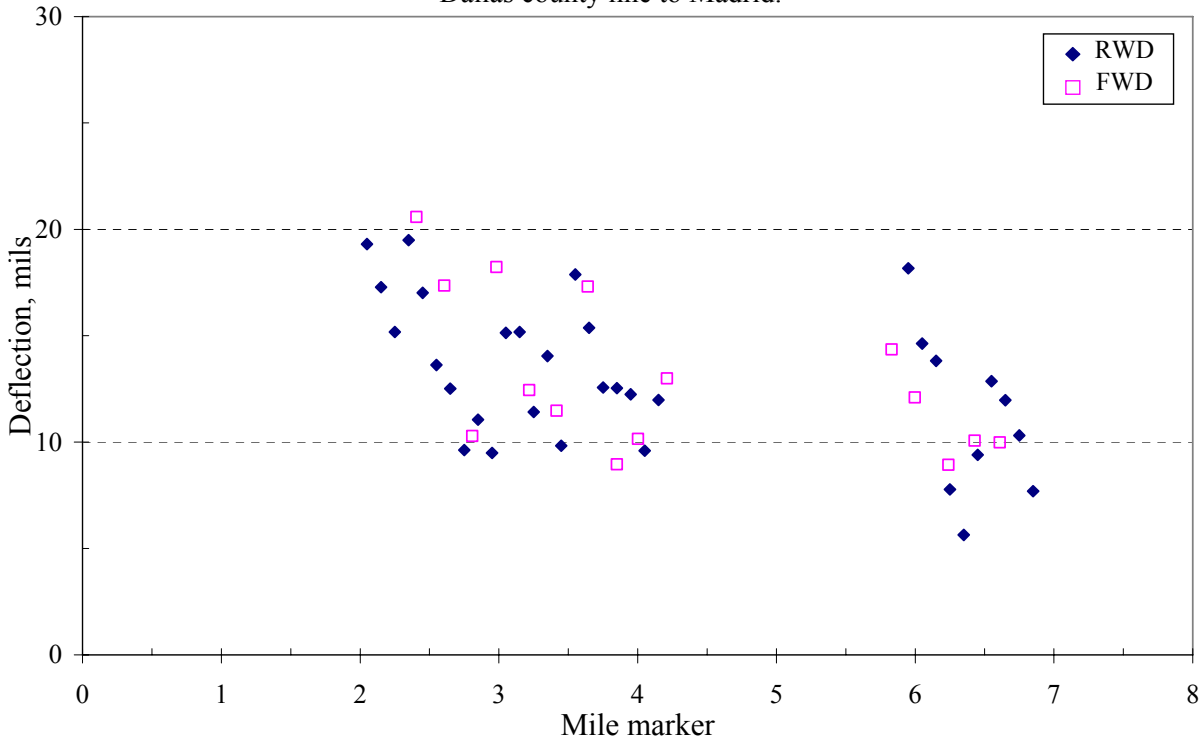
IA 175 EB (Section 2).
I-35 to US 65.



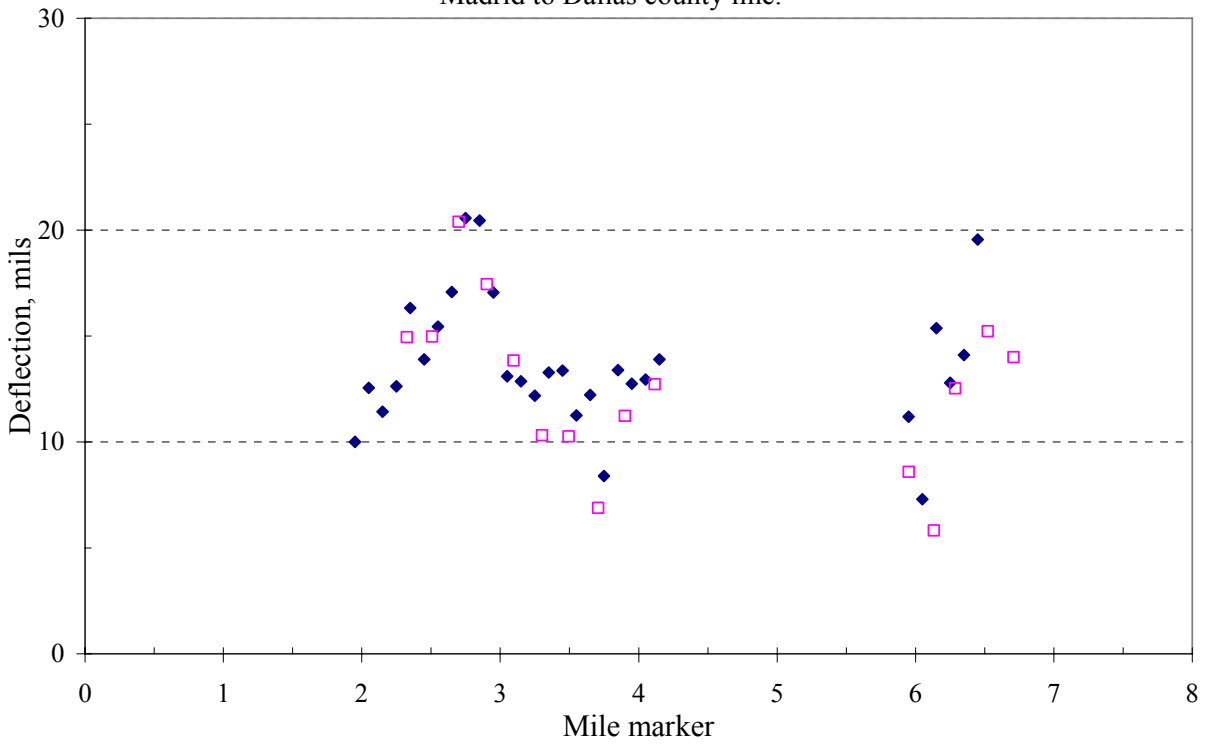
IA 175 WB (Section 2).
US 65 to I-35.



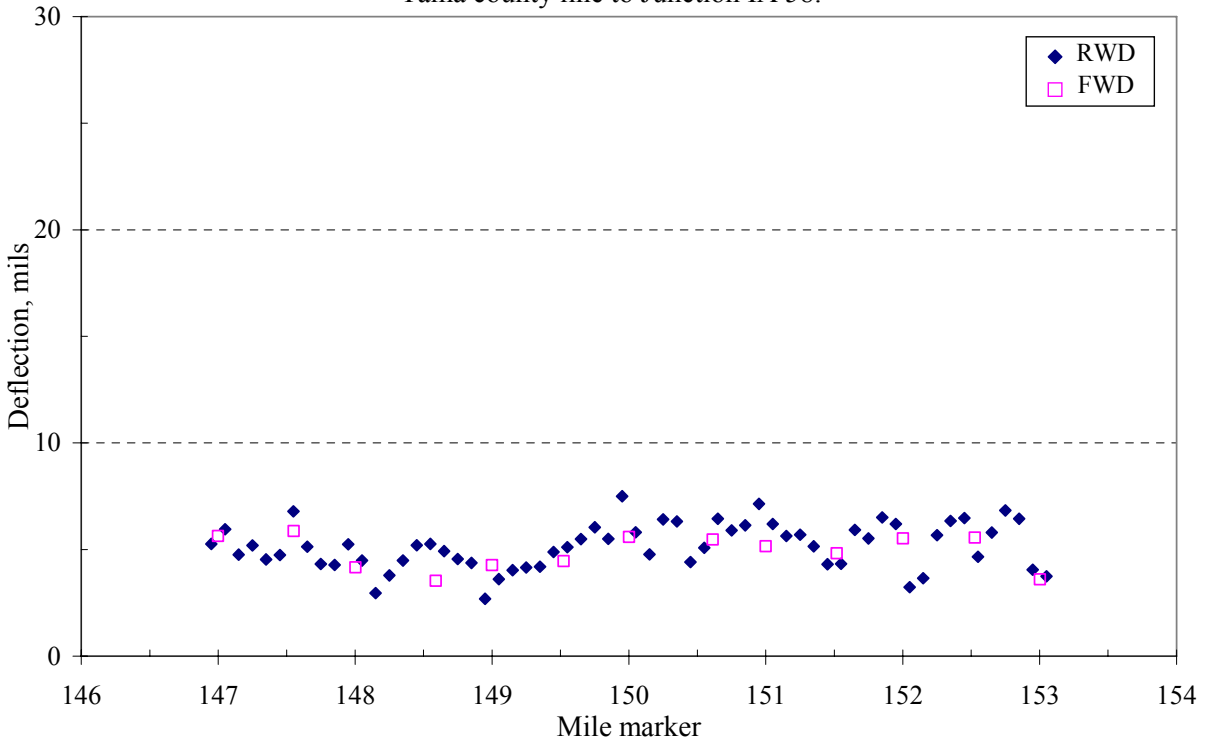
IA 210 EB.
Dallas county line to Madrid.

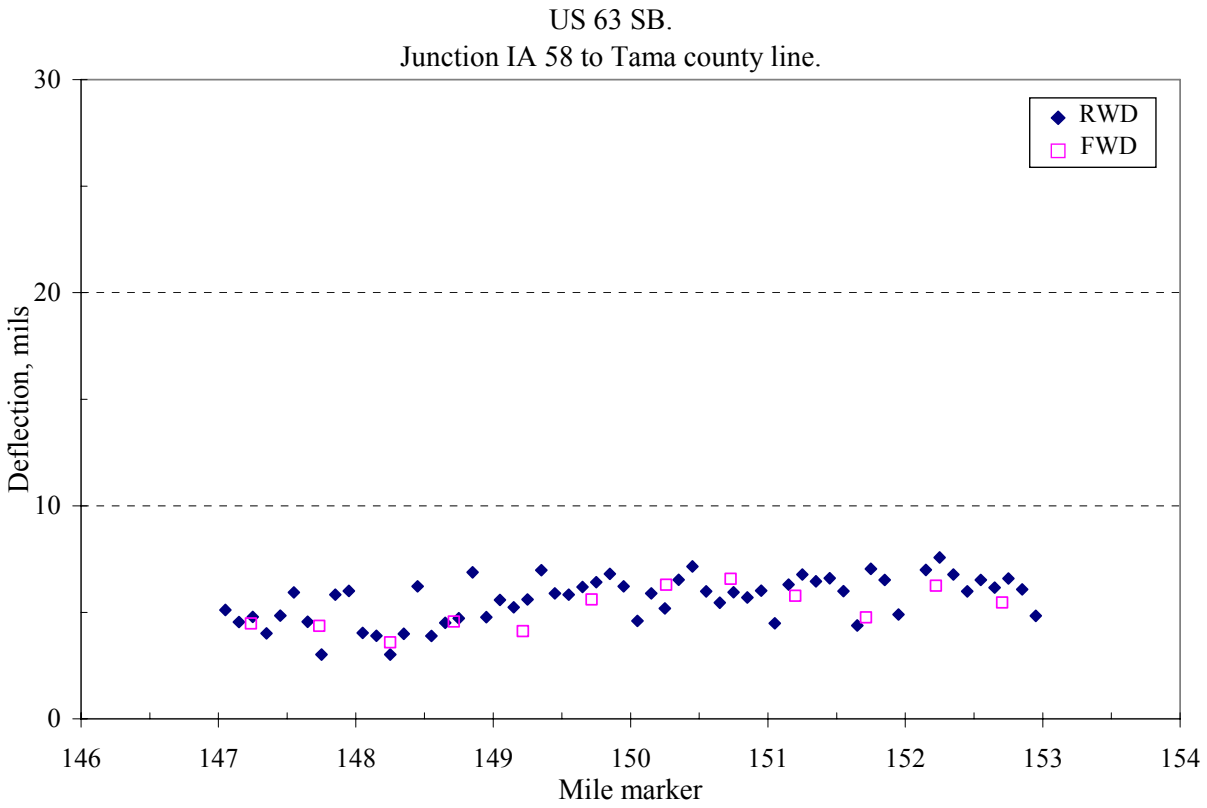


IA 210 WB.
Madrid to Dallas county line.



US 63 NB.
Tama county line to Junction IA 58.




US 63 SB.
Junction IA 58 to Tama county line.
RWD
FWD
Deflection, mils
30
20
10
0
146
147
148
149
150
151
152
153
154
Mile marker