Dynamic Deflections to Determine Roadway Support Ratings

Final Report
Project HR-245

February 1983
Highway Division

Iowa Department of Transportation

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FINAL REPORT

FOR

IOWA HIGHWAY RESEARCH BOARD

PROJECT HR-245

DYNAMIC DEFLECTIONS TO DETERMINE ROADWAY SUPPORT RATINGS

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ABSTRACT

The Benkelman Beam structural test of flexible pavements was replaced in 1976 by dynamic deflection testing with a model 400 Road Rater. The Road Rater is used to determine structural ratings of flexible pavements. New pavement construction in Iowa has decreased with a corresponding increase of restoration and rehabilitation. A method to determine structural ratings of layered systems and rigid pavements is needed to properly design overlay thickness.

The objective of this research was to evaluate the feasibility of using the Road Rater to determine support values of layered systems and rigid pavements. This evaluation was accomplished by correlating the Road Rater with the Federal Highway Administration (FHWA) Thumper, a dynamic deflection testing device. Data were obtained with the Road Rater and Thumper at 411 individual test locations on 39 different structural sections ranging from 10" of pcc pavement and 25" of asphalt pavement to a newly graveled unpaved roadway. A high correlation between a 9000 pound Thumper deflection and the 1185 pound Road Rater deflection was obtained.

A Road Rater modification has been completed to provide 2000 pound load inputs. The basin, defined by four sensors spaced at 1 foot intervals, resulting from the 2000 pound loading is being used to develop a graph for determining relative subgrade strengths. Road Rater deflections on rigid pavements are sufficient to support the potential for this technique.

INTRODUCTION

Prior to 1976, Iowa DOT pavement structural testing was conducted using a Benkelman Beam to determine static deflection resulting from an 18000 lb. axle load. As part of Iowa Highway Research Board Project HR-178, "Pavement Deflection Study",[1] a model 400 Road Rater was purchased from Foundation Mechanics, Inc. It was evaluated and subsequently replaced the Benkelman Beam testing. The Road Rater is routinely used to determine structural ratings of asphalt pavements for secondary and primary roadways.

The current trend is a reduction of new construction and increased restoration or rehabilitation of older pavements. This often results in resurfacing acc and pcc pavements with either asphalt cement concrete or portland cement concrete. The determination of support values for these layered systems is complex. More research is also needed in determining structural ratings for rigid pavement.

The Federal Highway Administration has developed a pavement deflection test system named "Thumper".[2] The Thumper will apply loads, either static or dynamic, up to 9000 lbs. to a roadway surface and record the resulting deflections from sensors on that surface.

The system is mounted in a large front wheel drive van. When testing, the vehicle's air suspension system is deactivated and the rear of the van is raised on hydraulic jacks providing a stable platform from which to conduct the tests. A reference frame from which the sensors are suspended and a 12" diameter circular loadplate are lowered to the roadway surface. The load is then transmitted through the loadplate, and the sensors, located at loadpoint and 10 1/2", 15", 24", 36", and 48" from loadpoint parallel with the centerline, measure the resultant deflections.

OBJECTIVE

The objective of the project is to determine the feasibility of determining support values for rigid pavements and layered systems with the Road Rater by correlating it with a device which will apply loads up to 9000 lbs.

PROJECT DESCRIPTION

The Iowa DOT was advised by the FHWA that its research section was interested in a study to determine structural values using the Thumper. The Iowa DOT developed a work plan for testing and an agreement was made between the FHWA and the Iowa DOT for testing with the Thumper, the only cost to the Iowa DOT being lodging expenses incurred by the FHWA testing personnel.

A two week testing schedule in April 1982 was established, and testing was conducted at the predetermined locations by the Road Rater and then the Thumper.

The FHWA had retained Gilbert Baladi, PhD of Michigan State University to conduct the structural value determination study. Thumper data were to be utilized in determining subgrade moduli and support values. Unfortuantely, this study fell victim to funding restrictions, and Dr. Baladi was retained for only a short time after field test data were obtained. Due to manpower restrictions, complete data reduction was delayed until January 1983 and Dr. Baladi was not available to evaluate the data and provide expertise in determining subgrade moduli or support values.

IOWA DOT ROAD RATER PROGRAM

Flexible Pavements

Even though special rigid pavement studies had been conducted with the Benkelman Beam, its primary application was on flexible roadways. The Road Rater (Figure 1) replaced the Benkelman Beam and therefore the initial consideration was aimed at flexible pavement.

Figure 1 The Iowa DOT Model 400 Road Rater

A standard Road Rater procedure was established as Test Method No. Iowa 1009-A June 1977 (Appendix A).

Foundation Mechanics, Inc., the manufacturer, recommended the use of a Mass displacement of 0.058" or 58 mils and a vibration frequency of 25 Hertz for testing flexible pavements. The manufacturer provided the following formulae to determine the peak to peak force output of the Road Rater:

$$F = 32.7 f^2 D$$

F is the peak to peak force output in pounds

f is the frequency of the loading in Hertz

D is the peak to peak displacement of the mass in inches.

The peak to peak output for standard flexible pavement testing is:

$$F = (32.7)(25)^2 (0.058)$$

$$= 1185 \text{ pounds}$$

This force has been satisfactory for evaluation of flexible pavements.

Due to problems with the front suspension, the Road Rater loading and sensing units were moved from the front to the rear of the van but the procedure remains unchanged.

A study of the relationship of the theoretical structural number to dynamic deflection was conducted on several roadways. A nomograph was developed to normalize all data to 80°F. These temperature adjusted deflections have exhibited a definite correlation with theoretical structural ratings.

Rigid Pavements

Recent California research(3) has shown that lighter dynamic testing devices can correlate well with heavier dynamic testing devices and can be used to evaluate stronger pavement sections. With this and other research as background, a decision was made to ascertain the potential of determining the structural capability of rigid pavements using the Iowa DOT Model 400 Road Rater. The manufacturer recommended an increased loading for rigid pavements. Modifications to accomplish this end were completed in the fall of 1982. The peak to peak output at a mass displacement of 0.068" and a frequency of 30 Hertz is:

$$F = (32.7)^2 (30)^2 (0.068)$$
$$= 2001 \text{ or } 2000 \text{ pounds}$$

This greater output was not available for collection of data at the time of the Thumper correlation in April 1982. An independent rigid pavement study in the fall of 1982 indicated a potential for determining structural ratings.

CORRELATION OF THE ROAD RATER AND THUMPER

Data Collection

The data for the correlation was obtained from April 19, 1982 through April 29, 1982 from 26 different roadway sections which are tabulated in Appendix B. Some of these roadways were research projects with variable structural characteristics, thus yielding 39 different structural sections.

The Road Rater was operated at a mass displacement of 0.058" and a frequency of 25 Hertz to obtain all correlation data. Tests were conducted in the outside wheel path. Test interval was normally 0.1 mile, but a shorter interval that would provide 10 individual tests was used for shorter sections. The Road Rater preceded the Thumper in obtaining deflection data. Deflection data was recorded for four velocity sensors placed at the load and at distances of 1, 2 and 3 feet from the load.

The Thumper (Figure 2) normally utilized a 9000 pound 1 cycle per second dynamic load at the same locations as the Road Rater. An oscillating trace on a strip chart was obtained at each location. At the fifth location of each series of 10 tests, deflections were determined for loadings of 3000, 6000 and 9000 pounds. In general, deflections at 9000 pounds were approximately three times those of the 3000 pound loading. The loading was reduced to 3000 pounds on the weakest paved and the unpaved roadways to yield readable traces. Traces were obtained from six sensors with one at the load and the other at 10 1/2", 15", 24", 36", and 48" from the load.

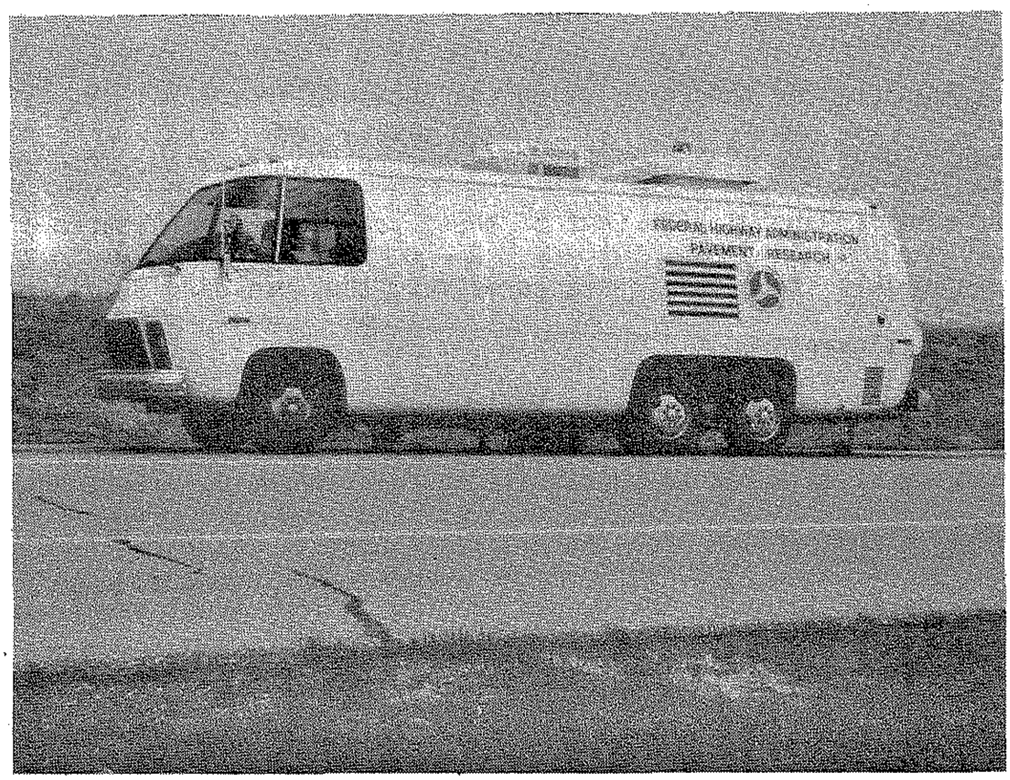


Figure 2 The FHWA Thumper

Data Reduction and Evaluation

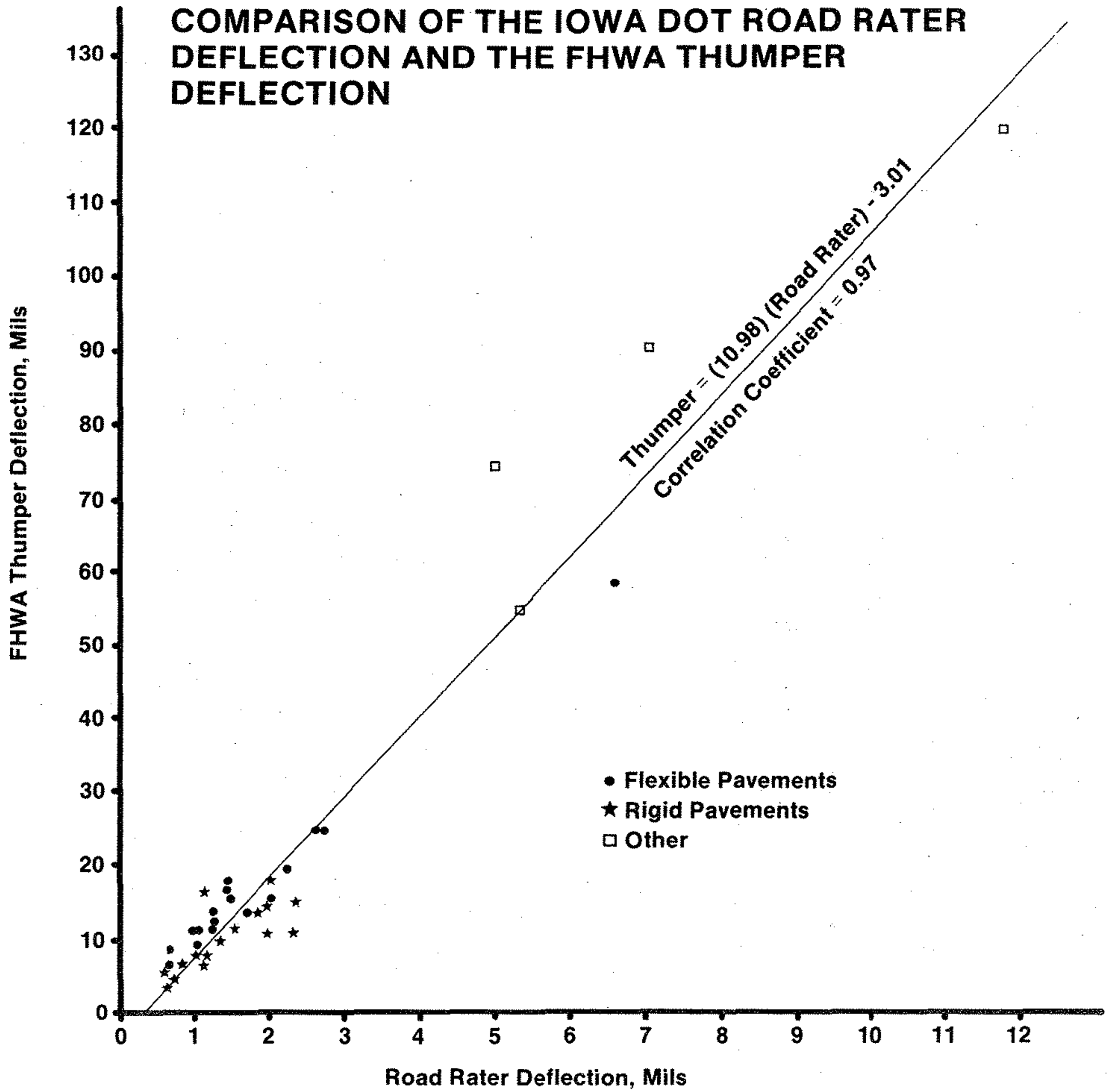
The deflection in mils was determined for the sensor at the load for each individual Road Rater Test. The data for deflection at the 1, 2 and 3 foot intervals is available but was not reported or used in this correlation. The average Road Rater deflection and standard deviation of all data for each structural section were calculated and are given in Appendix B. These averages are provided as a better evaluation of the different structural sections but were not used in any correlations. The only Road Rater deflections used in the correlation were those where a comparitive Thumper deflection at the same location was available.

The FHWA evaluated the traces from the Thumper data and provided the millimeters of trace deflection. Deflections from all six sensors were provided for the first half of the data. Upon notification that only the deflection at the load was to be used for the correlation and to complete the data reduction with limited manpower, only the deflection at the load was determined for the last half of the data. Deflection at some individual test locations, generally on weaker structures, could not be determined because the trace went "off the strip chart" or was "too noisy" (too eratic) for interpretation. Deflections were provided for 411 individual test locations. All 3000 pound Thumper data were normalized to 9000 pounds by multiplying resultant deflections by a factor of 3.

A graphical plot of the average deflections for each structural section (figure 3) did not exhibit any significant curvature of the data points. A linear correlation program was therefore used for all comparisons. The data point for structural section 12B was excluded from the correlations as the graphical plot showed it to vary sub-

FIGURE 3

COMPARISON OF THE IOWA DOT ROAD RATER DEFLECTION AND THE FHWA THUMPER DEFLECTION



stantially from all other data.

A correlation coefficient of 0.94 (r^2 = 0.88) resulted when the 410 individual deflections were used. The linear relationship was:

Thumper = (9.88) (Road Rater) - 1.18

When the average deflection for each of 37 structural sections was used (Figure 3), the correlation coefficient was 0.97 (r^2 = 0.94) with the following relationship:

Thumper = (10.98) (Road Rater) - 3.01

The average deflections from the 17 flexible pavements yielded a correlation coefficient of 0.99 (r^2 = 0.97) with a relationship of:

Thumper = (8.43) (Road Rater) + 1.94

A correlation coefficient of 0.75 (r^2 = 0.56) was obtained from the 16 rigid pavement sections with the following relationship:

Thumper = (5.31) (Road Rater) + 2.68

The correlation coefficient is much lower for rigid pavements than for flexible pavements or for the combination of rigid and flexible pavements and unpaved sections. The Road Rater deflections were the results of the load input used for flexible pavements. The correlation may have been better had the heavier load input modification been completed.

DETERMINATION OF SUBGRADE SUPPORT VALUES

The correlation of the Road Rater to the Thumper supports the potential of the Road Rater for determining support values. The data obtained from this research are not presently adequate for this purpose. This research has increased confidence in the Model 400 Road Rater for determining structural rating, subgrade moduli and subgrade support values. Based on this research, a study to determine subgrade support values using the 0.068" mass displacement and 30 Hertz frequency, yielding a 2000 pound load input, has been initiated.

The plans are to use the deflection basin defined by four sensors in the same manner as Louisiana[4] to determine subgrade characteristics. Louisiana determines relative subgrade strength (E_s) from the Dynaflect deflections and the graph of Figure 4.

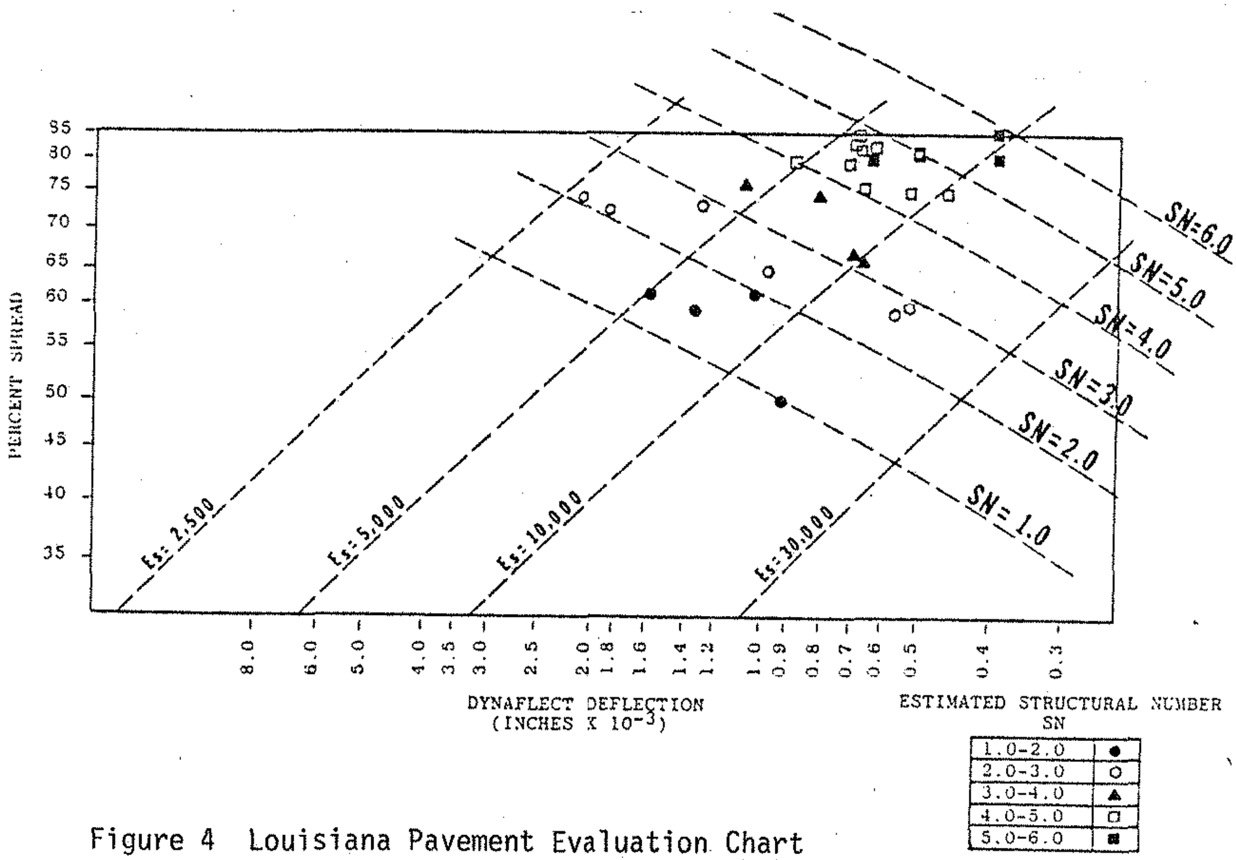


Figure 4 Louisiana Pavement Evaluation Chart

A preliminary graph to determine subgrade support values has been developed, by the Iowa Department of Transportation, but is not sufficiently supported by data to verify its accuracy.

CONCLUSIONS

From this research it can be concluded that:

1. The deflections from the 1185 pound Road Rater dynamic loading correlate very well with the 9000 pound Thumper dynamic deflections.
2. Road Rater deflections on rigid pavements are sufficient to indicate that it can be used to determine subgrade support values.

RECOMMENDATIONS

Research should be continued to develop and prove the use of Road Rater deflections and the basin defined by four sensors to determine subgrade support values.

ACKNOWLEDGEMENT

Research Project HR-245 was supported by the Iowa Highway Research Board and the Iowa Department of Transportation. Funding for this project was $251 from the Primary Research Fund and $224 from the Secondary Road Research Fund.

The FHWA participated in this research by providing the Thumper and personnel to operate it. Special appreciation is extended to FHWA personnel Gilbert Baladi, Bill Bralove and L. R. Staunton for their effort, extra long days of testing and data reduction.

The Iowa D.O.T. Road Rater testing was under the direction of Charles Potter and the Special Investigations personnel. Charles Potter put forth special effort in the evaluation and interpretation of Road Rater data and conducted the initial efforts in using the deflections to determine subgrade support ratings.

REFERENCES

1. Heins, Douglas - Dynamic Deflections for Determining Structural Rating of Flexible Pavements, Iowa Department of Transportation, 1979

2. McMahon, T. F. and May, R. W. - Solving the Mysteries of Pavement Deflections With "Thumper" pp 121-125 Public Roads, Vol 42 No. 4 March 1979.

3. Roberts, Donald V. "Evaluation of the Cox Deflection Devices" FHWA-CA-TL-3150-77-14, Caltrans, June 1977.

4. Kinchen, R. W. & Temple, W.H. "Asphalt Concrete Overlays of Rigid and Flexible Pavements" Final Report, Louisiana Highway Research FHWA/LA-80/147, October 1980

Appendix A

Method of Test for Determining Pavement Deflection Using the Road Rater

Test Method No. Iowa 1009-A
June 1977

IOWA DEPARTMENT OF TRANSPORTATION
HIGHWAY DIVISION

Office of Materials

METHOD OF TEST FOR DETERMINING PAVEMENT DEFLECTION
USING THE ROAD RATER

Scope

The Road Rater is an electronically controlled, hydraulically powered unit mounted on the front of a van type vehicle. The unit inputs a dynamic force into the pavement and measures the movement of the surface using velocity sensors. This velocity is integrated to show displacement which is referred to as pavement deflection which is a measure of structural adequacy. The pavement deflection data can be used to predict the performance of the surface, the probable maintenance required, and the resurfacing needed to restore the surface to required structural capability.

Procedure

A. Apparatus

1. Road Rater (Figure 1)
2. Air Pressure Gauge
3. Temperature equipment (Raytek Infrared gun or thermocouple)
4. Safety Support Vehicles

B. Test Record Form

Original data is recorded on a data processing input form (see example on Page 4). If available the following data should be recorded:

1. The numeric designation of the county
2. The highway system: P-primary, S-secondary, I-interstate
3. The state or county route designation
4. Beginning and ending milepost on the primary system or mileage designation on the secondary system.
5. Direction of the lane being tested
6. Pavement Type: PC-Portland cement concrete, AC-Asphaltic concrete, SC-seal coat
7. Date tested: May 4, 1977 - 050477
8. Time: When testing begins based on a 24 hr. clock
9. Lab Number and Year Built
10. Observer: The person operating the Road Rater
11. Weather: Cl-cloudy, S-sunny, PC-partly cloudy, C-clear
12. History by year and structural rating
13. The location (by milepost or odometer), range (Road Rater console selection), sensor 1 (per cent of meter), sensor 2 and remarks (an identification of a complete remark shown at the bottom).
14. Remarks should include: lane designation on multilane roadways, air and surface temperatures, fixed references and unusual conditions.

C. Test Procedures

1. Determination of testing frequency

a. A minimum of 30 individual tests shall be obtained per test section when inventorying. A minimum of 50 individual tests are needed for special evaluation of a given roadway.

1. Under 8 miles adjust spacing to obtain a minimum of 30 tests.

2. For test sections greater than 8 miles in length a minimum of 4 tests shall be made for each two-lane mile.

3. Tests of adjacent lanes shall be staggered and evenly spaced to obtain a maximum representation of the roadway.

b. Testing frequency shall be as noted or as directed by the engineer for special test sections.

2. Preparation prior to testing

a. Open overhead engine compartment vent.

b. Check engine oil level.

c. Start the engine and allow to run for a five minute warm-up period.

d. Check air pressure in the two upper air springs with a good tire air pressure gauge. Add air if required to bring the spring pressure to 50±5 psi.

e. Check air pressure in the six center air springs. This check must be made with the small valve that separates the two sets of air springs in the open position (clockwise to open). Add air as may be required to bring this pressure to 40±5 psi. Close the small valve (counter-clockwise) until finger-tight.

f. Install the channel that holds the sensors in the recess at the base of the foot. Lock the channel in place with set screws. For normal operation, only sensor No. 1 and No. 2 will be used. Secure the electrical connections to the recepticles designated for No. 1 and No. 2.

g. On the console (figure 2) within the vehicle place the power switch to "monitor". Hold the function switch to "elevate". Hold the movement switch in the "raise" position until the elevator cylinders are "full up" against the stops.

h. With the unit in the "full up" condition lift the upper lock rings on the elevator cylinders and remove the two sets of mechanical locking tubes.

i. With the power switch to "monitor" and the function switch held to "elevate", hold the movement switch to "lower" until the unit has been lowered sufficiently to elevate the van. Maintain these switch positions until no motion is evident (allow about 5 seconds).

j. With the function switch held to "elevate" and the movement switch held to "lower", read the system hydraulic pressure on the gauge. The pressure should be 600+25 psi.

k. Set the frequency control at 25 Hertz.

Figure 1

The Road Rater

l. Place the function switch to vibrate and set meter No. 4 to read 58 by adjusting with the "level" control.

m. Observe the reading on Meter No. 1.

n. Repeat steps g. i, l and m to check the repeatability of the setting.

o. Raise the unit to the "full up" position.

p. Stop the engine and check the level of hydraulic oil in the reservoir. Use clean "Aero-shell Fluid 4" to bring the level to between 1 and 2 inches from the top of the reservoir.

3. Testing Operation

a. With the engine running, position the Road Rater foot over the outside wheel track at the predetermined longitudinal location.

b. Place the vehicle in the "park position".

c. Lower the unit sufficiently to elevate the van, maintain the switch positions for about 5 seconds until no motion is evident.

d. With the power switch in "monitor" and the function switch in "vibrate" verify a 58 per cent reading on meter No. 4.

e. Select a range that will yield a reading between 50 and 100 on meter No. 1.

f. Record the lane, milepost, range and readings for sensor #1 and #2. Note any changes in surface type.

g. Raise the unit and proceed to the next test location.

4. After testing operation

a. When traveling between testing locations assure that the elevator cylinders remain in the up position. If traveling more than 2 miles without testing, engage the mechanical locking tubes and "lower" the unit to secure them.

b. Upon completion of testing, remove the channel holding the sensors.

D. Precautions

1. Do not move the vehicle with the unit in the down position. A red light on the console indicates that the testing unit is too low to travel.

2. Before moving onto the traveled portion of the roadway, insure that all traveling safety is as required by the Traffic Engineering layout. Be sure that the required signs are in position and that all warning lights are functioning.

3. Read the Road Rater "Owners Manual Operations and Maintenance Guide" before operating the unit.

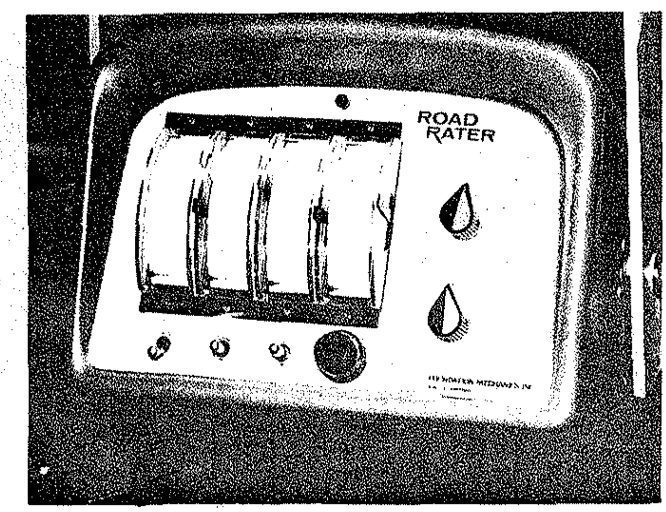


Figure 2

The control console of the Road Rater showing the selection controls and display meters.

OFFICE OF MATERIALS
ROAD RATER TESTS

SHEET NO. ___ (79)

1 COUNTY ___ (2) HIGHWAY SYS. ___ (4) ROUTE ___ (5) BEGINNING MP ___.___ (9) ENDING MP ___.___ (14) DIRECTION ___ (19)

PAVEMENT TYPE ___ (22) DATE TESTED ___ (24) TIME ___ (30) LAB NUMBER RR ___ (35) - ___ (38) YEAR BUILT ___ (40)

OBSERVER ___ (42) WEATHER ___ (59) ___ (64) SR ___ (66) ___ (69) SR ___ (71) ___ (74) SR ___ (76)

1	LOCATION (2)	RANGE (8)	READING SENSOR1 (10)	READING SENSOR2 (12)	REMARKS (14)	LOCATION (18)	RANGE (24)	READING SENSOR1 (26)	READING SENSOR2 (28)	REMARKS (30)	LOCATION (34)	RANGE (40)	READING SENSOR1 (42)	READING SENSOR2 (44)	REMARKS (46)	77
2																0.1
2																0.2
2																0.3
2																0.4
2																0.5
2																0.6
2																0.7
2																0.8
2																0.9
2																1.0
2																1.1
2																1.2

REMARKS

STMP-SURFACE TEMPERATURE *PINT*-PRIMARY INTERSECTION *SINT*-SECONDARY INTERSECTION *DINT*-INTERSECTION W/DRIVEWAY *XX*-OTHER

1	2	6	77
3			0.1
3			0.2
3			0.3
3			0.4

APPENDIX B ROAD RATER AND THUMPER CORRELATION DATA

Dynamic Defelction in Mils

Section Number	Route Number	Location	Structure	All Road Rater Testing: No. of Tests	All Road Rater Testing: Avg.	All Road Rater Testing: Std. Der.	FHWA Thumper Valid Tests: No. of Tests	FHWA Thumper Valid Tests: Avg.	FHWA Thumper Valid Tests: Std. Der.	Comparitive Road Rater Testing: No. of Tests	Comparitive Road Rater Testing: Avg.	Comparitive Road Rater Testing: Std. Der.
1	I-80	MP 259-265	9" AC over 16" ATB	20	0.67	0.15	19	8.76	1.60	19	0.67	0.15
2	I-80	MP 198-199	10" PCCP over 4" GB No Drains	15	2.11	0.31	9	14.28	0.53	9	1.96	0.22
3	I-80	MP 184-198	10" PCCP over 4" GB Drains	15	1.84	0.41	14	13.57	2.27	14	1.87	0.41
4	I-80	MP 113-117	8" mesh reinforced CRCP over 4" GB	10	1.30	0.42	8	9.88	1.92	8	1.33	0.47
5	I-80	MP 93-97	10" PCCP over 5.25" AC over 24" GB	10	0.60	0.14	8	5.85	1.17	8	0.60	0.15
6	I-80	MP 64-70	3" AC over 10" PCCP over 4" GB	10	0.63	0.09	8	6.91	0.98	8	0.65	0.09
7	Ia. 25	U.S.6 to Guthrie Center	5½" AC over 8" GB	20	1.71	0.32	20	13.31	2.31	20	1.71	0.32
8	Ia. 4	Panora to Ia. 141	10" AC over 11" GB	20	1.99	0.46	16	15.14	2.68	16	2.03	0.49
9	Greene Co. Rd. E 57	Ia. 25 to Gr. Co. Rd. P14	6" PCCP	10	2.01	0.34	8	10.75	3.35	8	1.98	0.32
10	Boone Co. Rd. E 57	Gr. Co. line to Berkley	7"-5"-7" PCCP over 2½" AC over 4" GB	10	1.03	0.27	10	7.92	1.58	10	1.03	0.27
11	Ia. 144	Rippey to Grand Junction	Sealcoats over 5" GB	20	5.70	1.11	11	54.52	13.00	11	5.30	0.80
12A	Greene Co. Rd. E 57	Ia. 4 to Farlin	4½" mesh rein. PCCP	2	2.37	0.47	2	15.00	2.12	2	2.37	0.47
12B			4½" Non-rein. PCCP	2	3.80	1.56	1	16.50	---	1	4.90	---
12C			5½" Non-rein. PCCP	3	2.32	0.85	3	10.30	1.35	3	2.32	0.85
12D			6" Non-rein. PCCP	5	1.55	0.44	5	11.36	5.63	5	1.55	0.44
13	Greene Co. Rd. E 18	Ia. 144 to Gr. Co. Rd. P46	6" PCCP	20	2.00	0.45	19	17.96	4.35	19	2.03	0.45
14	Story Co. Rd. R 38	Lincoln Way northerly in Ames	8"-7"-8" PCCP	20	1.13	0.20	18	6.39	0.91	18	1.13	0.21
15A	Story Mortenson Rd.	In west Ames	Coherex Stabilized Grade	10	7.48	2.69	4	90.50	32.39	4	7.19	2.64
15B			Gravel Roadway	10	13.30	3.29	---	---	---	---	---	---
15C			Fiber Stabilized Grade	10	13.17	4.40	3	120.30	52.24	3	11.73	7.02
16	Story Co. Rd. E 63	Ia. 210 to Cambridge	2" AC over 6" GB over 4" SAS	20	2.56	0.55	9	24.56	8.37	9	2.72	0.66
16A			2½" AC over Sealcoats over 6" GB over 4" SAS	9	5.57	1.49	6	58.08	11.95	6	6.55	1.41
17	Story Co. Rd. S 14	Ia. 210 to Nevada	6" AC over 6" GB over 4" SAS	20	2.29	0.57	16	19.08	3.78	16	2.23	0.59
18	Story Co. Rd. E 29	I-35 to Story Co. Rd. S 14	6" AC over 6" GB over 4" SAS	20	2.66	0.89	18	24.46	6.41	18	2.61	0.93
19	I-35	MP 113-116	8" CRCP over 4" GB	20	1.17	0.19	20	7.90	1.38	20	1.17	0.19
20	Story Co. Rd. E 23	U.S. 69 Easterly	New Graveled Grade	10	6.54	3.24	2	74.45	19.16	2	5.03	0.53
21	I-35	MP 151-155	8" CRCP over 4" ATB	20	0.79	0.09	17	6.88	1.58	17	0.81	0.08
22	I-35	MP 155-161	8" CRCP over 4" CTB	20	0.64	0.12	18	3.98	0.91	18	0.63	0.13
23A	U.S. 218	Osage Northerly	6½" AC over 10"-7"-10" PCCP	10	0.99	0.30	10	11.16	3.89	10	0.99	0.30
23B			4" AC over 3½" BSRL over 10"-7"-10" PCCP	10	1.02	0.20	10	11.09	2.81	10	1.02	0.20
23C			4" AC over 2½" BSRL over 10"-7"-10" PCCP	10	1.24	0.23	10	13.76	2.78	10	1.24	0.23
24	U.S. 30	Cedar Rapids Bypass	9.5" PCCP over 4" CTB	10	0.71	0.17	10	4.70	0.50	10	0.71	0.17
25A	Ia. 64	Wyoming to Monmouth	3" AC over 8" ATB Fabric in ATB	10	1.48	0.17	10	15.49	2.36	10	1.48	0.17
25B			3" AC over 9" ATB No Fabric	10	1.44	0.09	10	16.45	2.35	10	1.44	0.09
25C			3" AC over 8" ATB Fabric under ATB	10	1.45	0.25	10	17.91	3.82	10	1.45	0.25
25D	Ia. 64	U.S. 151 to Wyoming	3" AC over 8" ATB	10	1.27	0.18	10	12.27	1.66	10	1.27	0.18
25E			3" AC over 8" ATB Higher AC in ATB	10	1.24	0.17	9	11.24	1.35	9	1.24	0.18
25F			3" AC over 8" ATB Sugar Creek AC	10	1.06	0.22	10	9.28	1.80	10	1.06	0.22
26	U.S. 151	Cascade to U.S. 61	9" PCCP	20	1.16	0.25	20	16.38	3.67	20	1.16	0.25

AC-Asphalt Concrete ATB-Asphalt Treated Base PCCP-Portland Cement Concrete Pavement
GB-Granular Base SAS-Soil Aggregate Subbase CRCP-Continous Reinforced Concrete Pavement
CTB-Cement Treated Base BSRL-Bituminous Stress Relief Layer