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16. Abstract The Atlanta District has constructed six pavement sections since 1993 using hydrated fly ash as the flexible base material. This research project was initiated to evaluate and monitor performance and changes in material properties for these six pavements through the year 2001. Evaluation of performance shall be based on visual documentation, falling-weight deflectometer tests and compressive strengths of field cores. This report is intended to serve as an interim report documenting the performance evaluations conducted in the spring of 1997. This report covers the first annual evaluation in a series of five. Most of the hydrated fly ash test pavements are performing very well at this time. Two of the six pavements are exhibiting minor distress which might be attributable to deficiencies in the fly ash base material. Falling weight deflectometer testing revealed that there is variability in the moduli of these base materials which warrants investigation (i.e., weak spots and stiff spots within a single pavement section). Also, one pavement is considerably stiffer (overall) than the other five.			
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**FIELD PERFORMANCE EVALUATION OF HYDRATED,
FLY ASH BASES IN THE ATLANTA DISTRICT - YEAR 1**

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Research Report 2966-1
Research Study Number 7-2966

Research Study Title:
Durability of Surface Treatments as the Wearing Course
Placed on Crushed Fly Ash and Long-Term Performance
of Crushed Fly Ash for Flexible Base

Sponsored by the
Texas Department of Transportation

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TEXAS TRANSPORTATION INSTITUTE
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College Station, Texas 77843-3135

IMPLEMENTATION STATEMENT

This report covers the first annual evaluation of hydrated fly ash test pavements in the Atlanta District. It is recommended that the district continue to monitor these pavements for the next four years as planned in this study. The information presented in this report is not ready for implementation at this time.

DISCLAIMER

The contents of this report reflect the views of the authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of the Texas Department of Transportation (TxDOT) or the Federal Highway Administration (FHWA). This report does not constitute a standard, specification, or regulation, nor is it intended for construction, bidding, or permit purposes.

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SUMMARY

The objective of this report is to present the findings of the performance evaluations of six pavement sections constructed in the Atlanta District using hydrated fly ash as the base material. Hydrated fly ash is classified as a flexible base material; however, the fly ash is still active enough that the base gains strength after placement. This causes the material to behave more like a stabilized base; therefore, in this report, it is compared against stabilized bases.

This document covers the first evaluation which occurred in the spring of 1997. Annual evaluations are scheduled for the next four years. Performance evaluations were based upon visual pavement evaluations, falling weight deflectometer testing and compressive strength of field cores.

Visual evaluations reveal that, in general, the pavements are performing very well. However, one pavement is exhibiting alligator cracking in some isolated areas and another pavement is exhibiting slight levels of transverse (shrinkage) cracking.

Falling weight deflectometer (FWD) data is consistent with the distress (mentioned above) which is apparent on the surface. FWD data also indicates that there is variability in the material within a single pavement section and between different pavements. Some of the bases appear to be weaker than desired; however, they are performing quite well at this time. This may indicate that applying stabilized base criteria to this material may not be appropriate as will be determined by future performance.

The researchers recommend that the pavements continue to be monitored and that this year's evaluation program include the use of ground penetrating radar (GPR) to determine if there is water in these base materials that coincides with the "weak" spots. This might explain the variability in the FWD data.

BACKGROUND

Hydrated fly ash is produced by allowing powder fly ash (Class C) from coal power plants to cure with moisture. The hydrated (cured) fly ash becomes a stiff material that can be crushed to form a synthetic aggregate. When properly processed and compacted to optimum moisture content, the hydrated fly ash continues to gain strength after placement as a base material (1).

The Atlanta District constructed six pavement sections in 1993 through 1995 using hydrated fly ash as the flexible base material. This research project was initiated to evaluate and monitor performance and changes in material properties for these six pavements through the year 2001. Evaluation of performance shall be based on the following types of data:

- visual evaluations of surface distress,
- nondestructive field testing (falling weight deflectometer, as a minimum), and
- Compressive strength of field cores.

Table 1 provides a description of each of the six test sites and their locations.

Table 1. Test Site Descriptions

Roadway	County	Project Length	Location		Project Designation	Job Completion Date	Typical Pavement Cross-Section
			From	To			
LP 390	Harrison	4.0 km	US 59 in Marshall	0.5 km S. of SH 43	1575-05-005 STP 92(7)UM	12/10/93	Grade 4 Seal Coat 50 mm Type C Hot Mix MC-30 Prime 250 mm Fly Ash Base 200 mm Lime/FA Subgrade
IH 20 (FR)	Harrison	900 m	1.5 km E of Gregg Co. Line	1 km W. of Loop 281	0495-08-056 CC 495-8-56	7/13/94	50 mm Type C Hot Mix One-Course Surface Trt. MC-30 Prime 280 mm Fly Ash Base 200 mm Lime/FA Subgrade
SH 154	Upshur	600 m	0.16 km E. of US 259	0.8 km E. of US 259	0402-02-018 HES 000S(661)	6/8/93	Grade 4 Seal Coat One-Course Surface Trt. MC-30 Prime 165-330 mm FA Base
FM 1326	Bowie	120 m	4.8 km N. of US 82	4.9 km N.	1570-02 Maint. Forces	9/93	CRS-2p Grade 5 CRS-2p Grade 4 140 mm Fly Ash Base 50 mm asphalt concrete 125-175 mm Indeterminate (LRA or Black Base?)
FM 1520	Camp	2400 m	0.16 km E. of Picket Spring Branch	FM 1521	1232-03-09 A 1232-3-9	8/9/93	One-Course Surface Trt. MC-30 Prime 235 mm Fly Ash Base 200 mm Lime/FA Subgrade
FM 560	Bowie	700 m	Barkman Creek and Relief	700 m N.	1021-01-007 BR 90(241)	4/28/95	45-63 mm Hot Mix MC-30 Prime One-Course Surface Trt. 150-300 mm Fly Ash Base 0-150 mm Bank-Run RG

VISUAL CONDITION SURVEYS

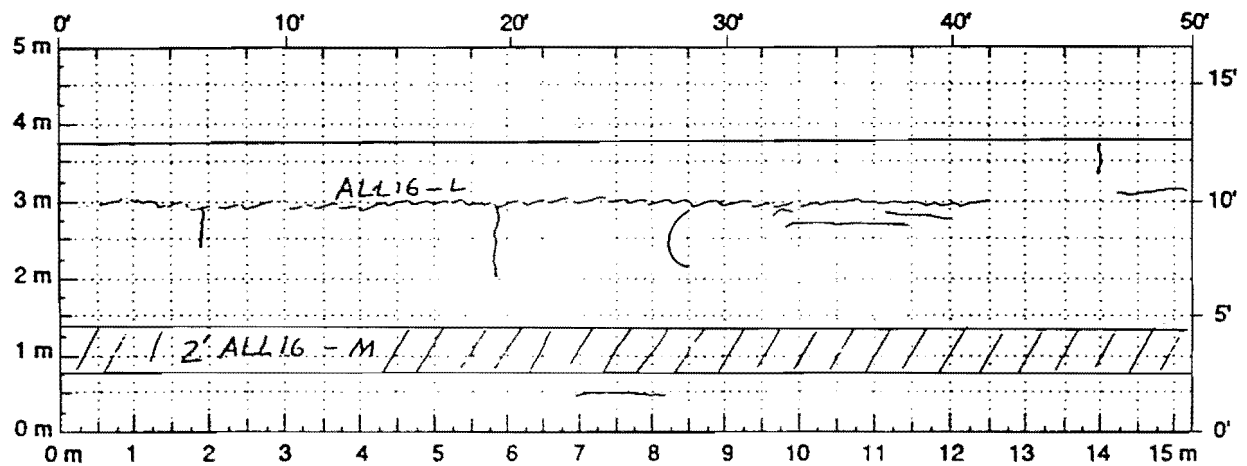
Visual condition surveys were performed on all six test pavements during the last week of April and first week of May in 1997. The manual survey was conducted in accordance with the procedures set up for a SHRP LTPP distress survey (2). In addition to measuring the quantity of each distress at each severity level, a map showing the location of crack-distress was also produced. Figure 1 shows an example of a completed form.

Loop 390

This project begins at US 59 in Marshall and extends to 0.5 km south of SH 43. The total length of the project is about 4.0 km. For visual condition surveys, the project was evaluated at 13 locations (60 m survey length per location) in the eastbound lane. There were three types of distress beginning to be evident on Loop 390: alligator cracking, a slight flushing of the seal coat surface, and rutting. Quantities of distress at each survey location are shown below in Table 2. A typical photograph of the alligator cracking is shown in Figure 2.

IH-20 Frontage Road

The IH-20 Frontage Road project begins 0.9 miles east of the Gregg Co. Line and continues eastward for 900 m. This pavement is in excellent condition. The only observed distress was a slight amount of raveling in the asphalt concrete surface. The project was evaluated at 3 locations (60 m length at each location) in the eastbound lane. The quantity of distress present at each location is shown in Table 3.



Comments: _____

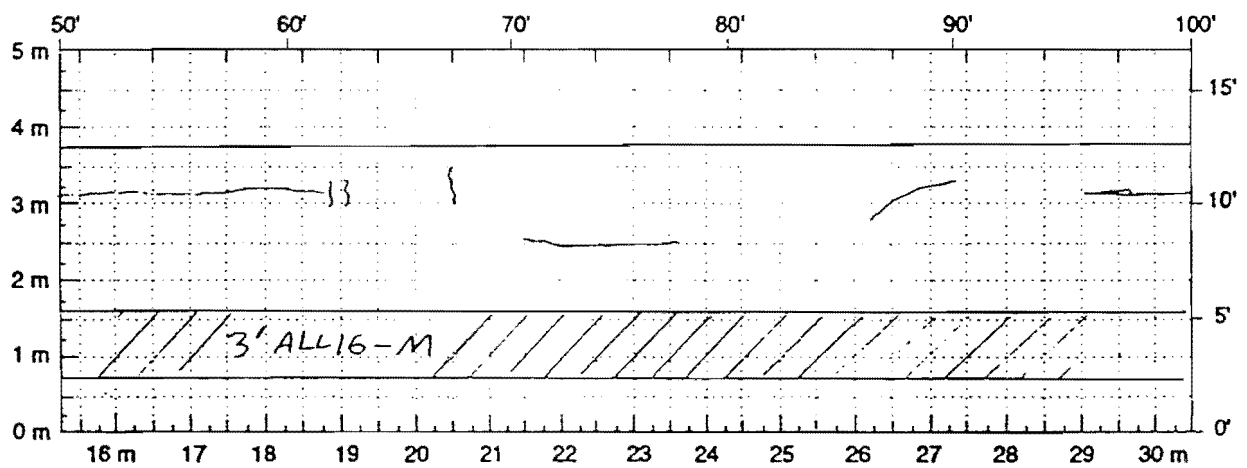


Figure 1. Example of Completed SHRP LTPP Condition Survey Form

Table 2. Loop 390 Distress (April 1997)

Location (each location represents a 60 m length)	Alligator Cracking, sq m	Flushing, sq m	Rutting, mm	
			Left Wheelpath	Right Wheelpath
1	0	0	0	0
2	0	0	0	0
3	0	0	2	2
4	0	0	3	2
5	0	0	4	4
6 (1st Coring Attempt Location)	56 (Slight)	56 (Slight)	11	12
7	93 (Slight)	112 (Slight)	13	13
8 (2nd Coring Attempt Location)	93 (Slight)	112 (Slight)	10	10
9	56 (Slight)	93 (Slight)	9	11
10	0	37 (Slight) 19 (Moderate)	4	5
11	0	56 (Slight)	3	3
12	0	0	5	4
13	0	0	0	2



Figure 2. Alligator Cracking on Loop 390

Table 3. IH 20 Frontage Road Distress (April 1997)

Location (each location represents a 60 m length)	Raveling, sq m
1 Core Location 1	4 (slight)
2 Core Location 2	5 (slight)
3 Core Location 3	4 (slight)

SH 154

This project is located in Diana beginning 0.16 km east of US 259 and extending to 0.8 km east of US 259. The entire length of this pavement was visually evaluated in the westbound lane. The primary distress of interest on this pavement is some slight transverse cracking. These cracks are beginning in the shoulder and most have not progressed all the way across the main lanes of travel; however, the cracks are very evenly spaced (every 3.5 to 4 m) and might be attributable to shrinkage of the fly ash base. A summary of the distress is shown in Table 4 below.

Table 4. SH 154 Distress (April 1997)

Location (beginning at east end of project)	Transverse Cracking in westbound lane, linear m	Longitudinal Cracking in westbound lane, linear m
0 - 60 m (1st core location)	1.8 (slight)	0
60 - 120 m	7.3 (slight)	0
120 - 180 m	3.6 (slight)	0
180 - 240 m	5.2 (slight)	0
240 - 300 m	2.4 (slight)	2.4 (slight)
300 - 360 m	11.6 (slight)	17.0 (slight)
360 - 420 m	1.8 (slight)	0
420 - 480 m	0	0
480 - 540 m	0	0
540 - 600 m	8.0 (moderate)	6.7 (moderate)

FM 1326

The FM 1326 project begins about 4.8 km north of US 82. It was constructed by district maintenance forces and is about 120 m in length. The entire length of pavement (both lanes) was evaluated visually. No distress of any kind was evident in the seal coat surface.

FM 1520

The FM 1520 project is located in Camp County and begins 0.16 km east of Pickett Spring Branch extending to FM 1521. Its total length is about 2400 m. This project was visually evaluated at eight locations as shown below in Table 5.

Table 5. FM 1520 Distress (April 1997)

Location (each location represents a 60 m length)	Flushing, sq m
1	93 (slight)
2	112 (slight)
3	140 (slight)
4 Core Location	30 (slight)
5	0
6	0
7	0
8	0

FM 560

The FM 560 project is located near Hooks and begins at Barkman Creek and Relief and extends north for 700 m. The primary distress evident on this pavement is a moderate amount of flushing in the wheelpaths. The surface treatment under the hot-mix overlay was constructed using a multi-grade asphalt (10W30) and appears to be flushing through the hot mix to the surface. There was also a very slight amount of cracking in the northbound lane. At about 457 m north of where the project begins (Barkman Creek), four transverse cracks appeared in the center of the northbound lane. Each crack was less than 1 m in length. There was also one longitudinal crack 1.5 m long. The project was evaluated at three locations (60 m length at each location) in the northbound lane. The quantity of distress present at each location is shown below in Table 6.

Table 6. FM 560 Distress (April 1997)

Location (each location represents 60 m in length)	Flushing, sq m	Longitudinal Cracking, linear m	Transverse Cracking, linear m
1 Core Location 1	93 (moderate)	0	0
2 Core Location 2	14 (moderate) 11 (slight)	1.5	3
3 Core Location 3	0	0	0

FIELD CORE AND FALLING WEIGHT DEFLECTOMETER DATA

Attempts were made to obtain three cores from each of the six test pavements. Laboratory staff from the Atlanta District performed the coring operations using district coring equipment. Water was used to cool the bit during the coring operations. It was not possible to obtain as many cores as desired because, in many cases, the cores were not retrievable. They broke into pieces when attempting to remove them from the pavement or core bit.

TTI performed unconfined compressive strength testing on the field cores. Plaster was used to cap the ends of the specimens prior to testing. For unconfined compressive strength, it is desirable to have a sample length (L) to diameter (D) ratio of at least 2. However, some of the cores were very short and L/D ratios varied from 0.76 to 2.2. Adjustment factors were used to facilitate comparing cores of different thickness as shown in Table 7 (Tex 418-A) .

Dynamic cone penetrometer (DCP) testing was attempted on three of the six hydrated fly ash test pavements. A DCP test consists of dropping an 8 kg hammer on a spike with graduated markings. The relationship between the number of blows and depth of penetration is plotted and slope generated. The California Bearing Ratio (CBR) is related to the DCP slope, and Texas Triaxial Classification ratings can be derived from CBR values. This test was performed on Loop 390, SH 154 and IH 20 frontage road. Penetration of the DCP through the hydrated fly ash bases was almost impossible. Penetration rates on all three pavements averaged 0.5 mm per blow of the DCP hammer. Correlations only exist for as little as 3 mm/blow and greater. The fly ash pavements had a very low penetration which would correspond to a very high CBR value of 100%+ and an excellent Texas Triaxial Classification of 1+. Since penetration of the DCP was almost negligible in the fly ash bases, this testing was not continued on the other three pavements.

At the time the pavements were visually evaluated, falling weight deflectometer (FWD) testing was also performed by the Atlanta District personnel. The FWD is a test which non-destructively measures stiffness and relative deflection of the various layers of a

pavement system. A load which simulates a truck load is applied to the pavement through a 305 mm diameter load plate. Pavement deflection is measured by geophones placed at various distances from the plate, yielding a “deflection bowl.” Deflection magnitudes and bowl shape are used to calculate stiffness and relative deflection of each layer. In general, the lower the deflection and higher the stiffness, the better the pavement’s ability to distribute and carry load without rutting and cracking. FWD deflections were measured at regular intervals along the length of each test pavement.

Moduli values of the pavement layers were calculated using the TTI Modulus Analysis System (Version 5.1). Results of the analysis are presented in Tables 8 through 14. Of particular interest for this project is the moduli values for the base (E2). TTI experience has shown that for stabilized bases, moduli values between 1000 and 3500 MPa are optimum in terms of field performance. Bases with moduli values between 3500 and 7000 MPa give variable field performance and values above 7000 MPa seem to be too stiff and exhibit transverse/shrinkage cracking. In Figures 3 through 8, the base moduli values are plotted for each test pavement.

Another parameter which should be noted is the ratio of the base to the subgrade ($E2/E4$). It is desirable (in stabilized bases) for this ratio to be greater than 3. Between 2-3 is marginal and below 2 is considered poor.

For subgrades, moduli values less than 28 are considered poor while good values are those greater than 110.

Below is a discussion of the FWD test results and the field core data.

Loop 390

No cores were obtained from this pavement. Multiple unsuccessful attempts were made at three locations along the length of the pavement, as well as transversely (between wheelpaths, in wheelpath and on shoulder).

FWD data shown in Table 8 and Figure 3 indicate that the base layer is weak in some areas which also happens to coincide with areas where alligator cracking is observed. Another concern here and on most of the other test pavements is the variability in moduli along the length of the pavement.

IH 20 Frontage Road

Three cores were obtained from this pavement but only two were tested as shown in Table 7 (one broke during sample preparation for testing). This pavement exhibited the highest compressive strength at an average of 8075 kPa.

The first four data points and last data point on the FWD (Table 9) show extremely high moduli values for the base material (seemingly uncharacteristic for this material). Therefore, researchers conclude that the data points at each end of the section are another type of pavement so these data points are excluded from Figure 4. The moduli values are not as variable on this pavement but are generally on the border or below that which is desired of at least 1000 MPa; however, this does not correlate with the high compressive strengths of the cores.

SH 154

With indications of what appears to be shrinkage cracking, one would expect this pavement to be the stiffest of the six. This is true in terms of FWD data (Table 10). Base moduli values along the pavement exceed 7000 MPa in some locations. Also note the variability in the moduli values as shown in Figure 5. Average compressive strength of the three field cores was 4090 kPa.

FM 1326

One core was obtained from FM 1326 which could be tested and its compressive strength was 3902 kPa. FWD data (Table 11 and Figure 6) indicate some weak spots in the base layer but also some variability.

FM 1520

Three cores were obtained from FM 1520 with an average compressive strength of 5147 kPa. FWD data on this pavement also indicates that there are some weak areas where the moduli values drop below the minimum desired value of 1000 MPa, and again, there is variability along the length of the pavement (Table 12 and Figure 7).

FM 560

Three cores were obtained from FM 560 with an average compressive strength of 3359 kPa. The base on this pavement has two different thicknesses along its length: 24 cm and 16 cm. Because of the difference in thicknesses, two separate FWD analyses were performed as shown in Table 13. Results from both analyses, however, were combined for Figure 8. The data point at station 96.3 is not shown in Figure 8 because it appears that it may not be representative. Moduli values for this pavement do not appear to be as variable as on some of the others; however, the values are lower than the desired minimum of 1000 Mpa.

Table 7. Unconfined Compressive Strength of Field Cores**District :** Atlanta**Material :** Hydrated Fly Ash**Test :** Unconfined Compressive Strength, and Moisture Content

Sample ID	Sample Date	Sample Dimensions					Load Adjustment Factor	Failure Load		Failure Disp. in.	Failure Stress	
		Diameter		Height		L/D		Actual	Adjusted		psi	kPa
		in	mm	in	mm	Ratio		lbs	lbs			
154-1	4/23/97	6	152.4	13.19	335	2.20	1.000	16367	16367	0.1055	579	3991
154-2	4/23/97	6	152.4	11.25	286	1.88	1.000	21989	21989	0.078	778	5362
154-3	4/23/97	6	152.4	11	279	1.83	1.000	11963	11963	0.0705	423	2917
IH20-1	4/23/97	6	152.4	5.59	142	0.93	0.845	38257	32327	0.085	1353	9328
IH20-2	4/23/97	6	152.4	5.59	142	0.93	0.845	27979	23642	0.1125	990	6822
IH20-3	4/23/97	6	152.4	5.62	143	0.94	0.848		0		0	0
1520-1	4/23/97	6	152.4	5.62	143	0.94	0.848	22729	19275	0.0695	804	5542
1520-2	4/23/97	6	152.4	4.56	116	0.76	0.784	18542	14537	0.0705	656	4521
1520-3	4/23/97	6	152.4	9.09	231	1.52	0.961	22058	21198	0.142	780	5378
560-1	5/1/97	6	152.4	5.56	141	0.93	0.845	15967	13492	0.086	565	3893
560-2	5/1/97	6	152.4	9.19	233	1.53	0.962	14013	13481	0.0795	496	3417
560-3	5/1/97	6	152.4	9.44	240	1.57	0.965	13806	13323	0.0715	488	3366
1326-1	5/1/97	6	152.4	5.72	145	0.95	0.852	16003	13635	0.062	566	3902

Note :

No adjustment for L/D between 1.8 and 2.2

c/s area (in²) : 28.27

Adjustment Factors

L/D : 1.75 1.50 1.25 1.00 0.75*

Factor : 0.98 0.96 0.93 0.87 0.78

* Extrapolated

Table 8. FWD Data Analysis - Loop 390

TTI MODULUS ANALYSIS SYSTEM (SUMMARY REPORT)

(Version 5.1)

District: 19
 County: 103
 Highway/Road: LP0390

Pavement: 5.08
 Base: 25.40
 Subbase: 20.32
 Subgrade: 387.35

Thickness (cm)

MODULI RANGE (MPa)

Minimum Maximum
 1,379 1,379
 207 3,448
 34 3,448
 103

Poisson Ratio Values

H1: = 0.35
 H2: = 0.30
 H3: = 0.25
 H4: = 0.40

Station (m)	Load (N)	Measured Deflection (μ):							Calculated Moduli values (MPa):				Absolute ERR/Sens	Dpth to Bedrock (m)
		R1	R2	R3	R4	R5	R6	R7	SURF(E1)	BASE(E2)	SUBB(E3)	SUBG(E4)		
0.000	57,477	286.00	188.98	108.46	64.26	41.40	30.23	21.59	1379	2231.2	127.6	223.4	5.11	47.32
0.030	58,429	246.38	145.80	93.47	60.71	40.89	27.18	20.83	1379	2429.1	314.4	230.3	0.56	45.48
0.061	57,633	391.67	250.70	130.81	73.66	49.28	36.32	27.69	1379	1283.2	100.0	191.7	6.74	37.81
0.091	54,915	481.58	360.43	233.43	152.15	98.81	69.09	53.59	1379	1717.5	44.1	97.9	3.46	52.56
0.122	54,119	396.75	238.00	121.92	65.79	46.23	39.12	30.99	1379	981.8	129.6	183.4	8.58	30.82
0.152	56,045	480.06	321.06	145.54	80.01	53.34	37.85	31.50	1379	921.9	63.4	179.3	9.75	33.71
0.183	59,790	286.00	190.25	133.86	101.09	75.69	56.90	43.18	1379	2186.4	1148.0	120.7	2.03	78.69
0.213	57,441	441.45	234.95	122.94	76.96	56.39	44.20	33.53	1379	767.4	236.5	166.9	6.63	90.71
0.244	59,367	537.72	279.40	144.78	90.68	61.72	48.01	39.37	1379	630.2	167.5	151.7	4.65	70.19
0.274	53,269	821.44	478.28	260.60	154.18	99.82	71.88	55.63	1379	434.4	53.1	84.8	4.38	53.93
0.305	54,702	540.26	338.07	212.60	132.33	87.38	60.20	42.16	1379	923.9	87.6	98.6	1.96	57.61
0.335	52,437	914.91	457.45	277.37	166.12	103.63	73.41	55.63	1379	311.7	81.4	73.8	2.01	44.29
0.366	55,515	461.01	238.76	131.32	82.30	57.91	43.69	37.08	1379	700.5	222.7	154.4	4.14	91.44
0.396	56,859	658.11	347.98	157.23	112.52	89.41	72.64	53.09	1379	414.4	219.3	108.9	11.63	55.19
0.427	57,050	438.40	208.03	110.49	72.64	57.40	46.48	38.61	1379	627.4	437.8	168.9	7.99	91.44
0.457	55,142	511.56	277.11	144.02	91.19	63.50	45.21	37.34	1379	664.0	143.4	142.0	4.67	66.39
0.488	54,808	457.71	213.87	91.95	56.39	41.66	35.56	27.69	1379	564.0	197.9	213.7	8.81	35.27
0.518	65,924	279.65	159.26	89.66	63.75	47.24	35.05	26.16	1379	1747.9	690.9	233.7	5.33	69.96
0.549	60,902	232.16	131.32	83.06	57.91	40.39	33.02	26.92	1379	2124.3	857.7	236.5	4.04	81.57
0.579	56,396	451.87	284.99	184.91	124.21	83.82	60.71	45.97	1379	1163.9	187.5	103.4	1.94	66.58
0.610	59,897	306.58	215.14	136.14	90.42	63.50	43.18	31.50	1379	2803.5	147.6	160.0	2.71	50.79
0.640	63,326	375.16	126.75	65.28	43.69	32.51	24.89	19.05	1379	624.0	1021.1	341.3	5	10.97
0.671	58,024	220.47	107.19	70.36	49.02	36.58	26.42	19.30	1379	1593.4	1579.0	274.4	1.76	10.97
0.701	49,577	328.17	188.98	87.12	60.71	48.26	38.35	32.00	1379	912.9	327.5	180.0	11.5	67.32
0.734	45,921	544.83	335.03	157.73	83.82	55.37	43.69	34.54	1379	557.1	55.8	131.7	9.18	29.83
Mean:		443.48	252.73	139.70	88.14	61.21	45.72	35.31	1379	1172.8395	345.4395	170.3085	5.38	52.61
Std. Dev:		170.69	96.77	56.39	34.04	21.34	14.99	11.18	0	721.217	399.91	64.1235	3.17	43.88
Var Coeff (%)		38.47	38.24	40.33	38.61	34.68	32.56	31.5	0	61.5	100	37.6	58.91	83.41

Table 9. FWD Data Analysis - IH 20 Frontage Road

TTI MODULUS ANALYSIS SYSTEM (SUMMARY REPORT) (Version 5.1)

District:	19			MODULI RANGE (MPa)		
County:	103		Thickness (cm)	Minimum	Maximum	Poisson Ratio Values
Highway/Road:	IH0020	Pavement:	5.08	1,379	1,379	H1: = 0.35
		Base:	27.94	690	41,370	H2: = 0.35
		Subbase:	20.32	138	4,827	H3: = 0.25
		Subgrade:	127.00		103	H4: = 0.40

Station (m)	Load (N)	Measured Deflection (μ):							Calculated Moduli values (MPa):				Absolute ERR/Sens	Dpth to Bedrock (m)
		R1	R2	R3	R4	R5	R6	R7	SURF(E1)	BASE(E2)	SUBB(E3)	SUBG(E4)		
128.930	48,603	80.52	59.94	47.75	36.83	28.19	21.59	16.76	1379	33087.0	410.3	100.0	1.34	10.97
201.778	50,654	66.80	47.75	36.83	28.70	22.61	17.53	13.97	1379	41370.0	317.9	146.2	2.73	7.32
271.882	48,728	118.62	95.76	72.64	52.58	38.10	27.43	20.57	1379	14551.9	337.9	82.1	2.28	67.29
305.714	47,740	83.82	60.96	47.24	36.83	28.70	22.86	18.29	1379	29822.3	188.2	111.0	2.06	10.97
365.760	47,438	234.70	131.57	86.61	63.25	48.51	36.32	27.69	1379	1135.6	4574.1	56.5	5.5	80.32
427.025	49,666	186.18	95.76	61.21	47.50	38.61	30.73	26.67	1379	5814.6	333.0	111.0	18.97	91.44
487.375	49,048	208.53	137.41	93.98	69.85	52.07	40.13	31.50	1379	1930.6	2953.8	53.1	5.79	91.44
617.830	49,560	322.58	190.50	91.19	61.47	48.51	36.83	28.96	1379	762.6	1321.8	69.6	13.87	91.44
670.560	47,949	254.00	136.14	72.90	52.83	40.39	33.02	28.19	1379	897.7	3213.1	75.8	11.19	91.44
731.520	48,799	306.07	181.86	90.93	59.69	46.48	37.34	30.99	1379	817.7	1396.2	69.6	13.38	91.44
793.394	45,654	338.84	195.58	109.73	71.88	50.55	36.58	28.96	1379	737.8	926.7	58.6	8.01	73.05
853.440	47,687	274.57	139.45	80.26	56.64	42.42	31.75	24.89	1379	814.3	2689.7	72.4	8.39	90.58
914.400	51,165	233.17	107.95	54.61	30.99	21.59	16.26	12.70	1379	981.2	2029.2	147.6	11.64	7.32
958.901	48,781	312.67	153.42	68.58	36.32	25.15	19.81	17.78	1379	714.3	747.4	121.4	16.6	10.97
1021.080	47,705	67.56	40.39	26.67	18.29	13.46	10.67	9.40	1379	18706.1	753.6	285.5	6.76	4.88
Mean:		205.99	118.36	69.34	48.26	36.32	27.94	22.61	1379	10143.2	1479.7	104.1	8.57	21.65
Std. Dev:		99.57	51.05	23.62	16.26	12.19	9.14	7.37	0	14034.8	1328.0	58.6	5.54	23.52
Var Coeff (%):		48.29	43.24	33.87	33.46	33.6	32.94	32.24	0	100.0	89.8	56.7	64.63	108.66

Table 10. FWD Data Analysis - SH 154

TTI MODULUS ANALYSIS SYSTEM (SUMMARY REPORT) (Version 5.1)

District: 19
County: 230
Highway/Road: SH0154

Pavement: Thickness (cm) 1.27
Base: 33.02
Subbase: 0.00
Subgrade: 508.00

MODULI RANGE (MPa)

Minimum Maximum
1,379 1,379
103 10,343
0 0
103

Poisson Ratio Values

H1: = 0.35
H2: = 0.30
H3: = 0.25
H4: = 0.40

Station (m)	Load (N)	Measured Deflection (μ):							Calculated Moduli values (MPa):				Absolute ERR/Sens	Dpth to Bedrock (m)
		R1	R2	R3	R4	R5	R6	R7	SURF(E1)	BASE(E2)	SUBB(E3)	SUBG(E4)		
30.480	43,426	1057.15	557.02	212.60	115.82	75.95	55.63	43.69	1379	185.5	0.0	79.3	13.27	21.37
60.960	46,909	854.20	403.86	100.58	29.72	29.46	28.70	23.88	1379	202.0	0.0	162.7	38.19	7.32
91.440	42,296	1359.92	647.70	201.17	78.74	56.90	54.86	39.88	1379	118.6	0.0	86.2	20.61	17.05
121.920	58,696	210.31	169.16	121.67	88.90	71.12	52.58	42.16	1379	4967.2	0.0	156.5	3.63	82.88
148.133	60,337	160.53	124.71	96.27	70.36	53.59	40.64	32.26	1379	7175.6	0.0	206.9	2.51	91.44
182.880	58,184	157.23	133.35	107.70	73.41	63.25	51.05	41.40	1379	8825.6	0.0	167.5	5.47	91.44
213.360	59,986	131.32	128.52	82.80	65.53	51.56	40.39	30.48	1379	10071.5	0.0	208.9	6.85	73.65
243.840	58,411	161.29	135.64	108.46	83.82	66.29	51.82	39.88	1379	9149.7	0.0	158.6	2.47	84.73
275.844	53,852	254.00	137.67	109.73	82.55	65.79	51.31	44.96	1379	3106.2	0.0	164.8	10.7	91.44
304.800	57,335	196.60	102.62	54.61	37.59	28.70	24.38	19.05	1379	2514.6	0.0	323.4	11.1	10.97
335.280	54,208	216.15	153.67	122.17	95.00	73.66	55.88	45.47	1379	4956.8	0.0	140.0	3.34	91.44
372.466	55,796	218.69	162.81	120.65	88.39	67.31	53.09	42.93	1379	4305.2	0.0	153.1	3	91.44
396.240	55,124	185.17	149.35	120.40	92.20	72.39	56.13	45.97	1379	6933.6	0.0	138.6	1.63	91.44
426.720	52,122	201.93	190.25	153.92	114.55	84.07	63.50	49.02	1379	5859.4	0.0	107.6	5.78	90.79
458.724	56,841	95.25	74.93	62.48	49.78	61.47	42.93	39.88	1379	10342.5	0.0	286.8	18.69	55.17
488.290	51,325	196.34	168.40	134.87	103.63	79.50	60.96	48.01	1379	6092.4	0.0	115.8	2.33	91.44
518.160	55,249	238.51	175.01	121.41	78.74	60.20	45.47	35.81	1379	2943.5	0.0	164.1	4.25	91.44
548.640	55,689	227.08	163.83	115.82	84.58	63.75	49.02	37.59	1379	3642.6	0.0	162.0	3.62	84.33
579.120	54,595	262.89	195.33	135.13	93.98	70.61	53.59	41.40	1379	2824.9	0.0	140.7	3.46	91.20
609.600	51,962	366.52	245.62	154.94	105.16	75.69	58.67	46.48	1379	1446.6	0.0	117.2	4.26	91.44
637.946	57,477	358.39	201.42	124.71	83.06	56.64	41.66	32.51	1379	1385.2	0.0	159.3	4.16	69.80
Mean:		338.58	210.57	121.92	81.79	63.25	49.28	39.12	1379	4621.7	0.0	162.0	8.06	65.08
Std. Dev:		330.71	146.30	37.59	22.35	14.22	9.91	7.87	0	3242.7	0.0	57.9	8.73	84.94
Var Coeff (%)		97.71	69.46	30.8	27.33	22.41	20.12	19.96	0	70.2	0.0	35.8	108.27	130.50

Table 11. FWD Data Analysis - FM 1326

TTI MODULUS ANALYSIS SYSTEM (SUMMARY REPORT) (Version 5.1)

District: 19
County: 32
Highway/Road: FM1326

Thickness (cm)
Pavement: 1.27
Base: 13.97
Subbase: 20.32
Subgrade: 243.33

MODULI RANGE (MPa)

Minimum Maximum
1,379 1,379
138 5,516
28 1,241
103

Poisson Ratio Values

H1: = 0.35
H2: = 0.30
H3: = 0.35
H4: = 0.40

Station (m)	Load (N)	Measured Deflection (μ):							Calculated Moduli values (MPa):				Absolute ERR/Sens	Dpth to Bedrock (m)
		R1	R2	R3	R4	R5	R6	R7	SURF(E1)	BASE(E2)	SUBB(E3)	SUBG(E4)		
0.000	46,677	1117.35	565.91	241.30	123.19	84.84	67.82	56.13	1379	446.8	83.4	63.4	8.6	27.16
15.240	51,979	410.21	299.21	166.12	97.28	60.20	42.42	32.51	1379	4499.7	289.6	96.5	4.2	40.39
30.480	53,394	373.13	285.50	191.01	108.71	73.15	50.80	36.83	1379	5516.0	544.0	83.4	4.86	41.78
45.720	51,962	370.08	279.40	169.67	108.97	76.71	57.91	41.91	1379	3295.8	817.7	85.5	5.68	91.44
61.265	50,832	460.25	293.88	150.11	88.14	57.66	42.42	33.78	1379	2029.9	320.6	106.9	4.8	50.93
76.200	51,819	557.28	373.13	214.38	122.17	77.98	57.40	45.47	1379	2106.4	287.5	77.2	3.67	42.83
91.135	49,964	567.94	358.90	187.96	99.82	61.72	45.47	36.07	1379	1820.3	199.3	88.9	3.21	29.99
106.680	46,748	1085.60	578.87	268.22	123.70	74.68	54.36	41.40	1379	624.7	64.8	62.7	3.39	22.12
121.920	44,364	1882.90	667.51	170.69	92.71	71.12	56.64	46.23	1379	155.1	33.1	78.6	14.14	19.33
Mean:		758.19	411.48	195.58	107.19	70.87	52.83	41.15	1379	2277.4	293.0	82.7	5.84	33.48
Std. Dev:		510.79	150.62	38.86	13.72	9.14	8.38	7.37	0	1849.2	253.0	14.5	3.52	13.86
Var Coeff (%):		67.35	36.81	19.83	12.7	12.92	15.89	18.08	0	81.2	86.2	17.4	60.2	41.38

Table 12. FWD Data Analysis - FM 1520

TTI MODULUS ANALYSIS SYSTEM (SUMMARY REPORT) (Version 5.1)

District: 19
County: 32
Highway/Road: FM1520

Pavement: 1.27
Base: 25.40
Subbase: 20.32
Subgrade: 373.89

Thickness (cm)

MODULI RANGE (MPa)

Minimum Maximum
1,379 1,379
138 2,758
28 1,034
103

Poisson Ratio Values

H1: = 0.35
H2: = 0.30
H3: = 0.25
H4: = 0.40

Station (m)	Load (N)	Measured Deflection (μ):							Calculated Moduli values (MPa):				Absolute ERR/Sens	Dpth to Bedrock (m)
		R1	R2	R3	R4	R5	R6	R7	SURF(E1)	BASE(E2)	SUBB(E3)	SUBG(E4)		
183.185	59,474	478.03	258.57	124.97	105.66	82.04	55.63	47.24	1379	983.2	323.4	133.8	12.39	91.44
365.760	54,595	381.51	224.79	129.29	91.19	67.31	43.69	38.86	1379	1303.8	326.8	134.5	4.85	42.28
609.600	46,379	1399.79	781.05	305.82	160.27	106.93	83.06	71.88	1379	215.1	27.6	66.9	11.01	24.08
731.520	57,424	549.66	262.64	146.81	87.88	67.06	43.69	43.94	1379	695.7	235.1	142.7	5.33	59.02
914.705	52,989	405.38	304.04	195.33	114.30	70.10	48.01	36.32	1379	2491.9	31.0	162.7	3.02	39.44
1097.280	52,864	798.83	415.04	203.71	111.51	83.82	64.01	57.15	1379	472.3	82.1	106.2	7.46	34.10
1269.492	55,231	426.72	157.99	78.23	54.86	35.81	28.70	21.84	1379	797.8	289.6	220.6	15.23	91.44
1463.345	59,029	616.20	291.08	166.12	99.31	86.61	74.17	59.18	1379	672.3	229.6	123.4	12.74	58.94
1645.920	60,813	986.28	629.92	266.19	138.43	87.12	51.82	42.42	1379	567.5	27.6	135.8	7.89	28.25
1828.800	53,536	367.79	250.70	163.32	104.90	70.36	48.01	33.78	1379	2222.3	100.0	130.3	0.6	53.04
1996.745	54,452	230.12	147.32	109.98	80.77	61.72	47.50	38.10	1379	2758.0	581.2	153.8	9.37	91.44
2195.170	51,063	406.40	233.68	135.38	87.38	62.23	43.18	36.32	1379	1132.8	213.7	134.5	3.24	56.95
2379.878	50,498	610.87	390.40	223.01	125.48	75.69	51.31	35.31	1379	1006.0	37.9	120.0	1.38	37.91
2560.320	53,678	287.53	171.70	121.16	83.82	57.91	41.40	28.19	1379	1838.9	768.8	131.7	2.94	49.32
Mean:		567.44	322.83	169.16	103.38	72.39	51.82	42.16	1379	1225.2	233.7	135.1	6.95	50.50
Std. Dev:		312.93	181.86	63.25	26.42	16.76	13.97	13.21	0	795.7	220.6	33.1	4.64	22.25
Var Coeff (%):		55.14	56.35	37.43	25.56	23.20	27.00	31.17	0	64.9	94.3	24.5	66.78	44.07

Table 13. FWD Data Analysis - FM 560

TTI MODULUS ANALYSIS SYSTEM (SUMMARY REPORT) (Version 6.1)

District: 19
County: 32
Highway/Road: FM0560

Pavement: 5.08
Base: 16.51
Subbase: 15.24
Subgrade: 690.63

Thickness (cm)

MODULI RANGE (MPa)

Minimum Maximum
1,379 1,379
138 2,758
28 1,034
103

Poisson Ratio Values

H1: = 0.35
H2: = 0.30
H3: = 0.35
H4: = 0.40

Station (m)	Load (N)	Measured Deflection (μ):							Calculated Moduli values (MPa):				Absolute ERR/Sens	Dpth to Bedrock (m)
		R1	R2	R3	R4	R5	R6	R7	SURF(E1)	BASE(E2)	SUBB(E3)	SUBG(E4)		
30.480	45,089	828.04	543.81	323.85	208.28	149.10	111.51	87.63	1379	654.3	90.3	56.5	2.96	91.44
96.317	48,639	138.43	121.16	106.43	89.92	75.18	60.71	49.02	1379	6895.0	4826.5	155.1	15.42	91.44
137.160	46,557	709.68	444.25	258.06	167.89	116.84	85.34	67.82	1379	729.5	106.2	74.5	1.88	91.19
184.709	45,565	627.38	413.51	280.92	186.18	123.70	88.65	68.83	1379	1043.9	179.3	66.9	1.55	65.40
231.038	43,995	700.79	448.31	280.16	179.07	119.89	85.34	65.28	1379	800.5	97.9	66.9	0.4	71.45
274.320	44,929	438.40	296.93	204.72	136.91	94.23	66.29	50.80	1379	1769.9	300.6	89.6	1.15	65.25
320.345	44,258	455.42	257.81	158.75	109.47	81.03	62.48	49.53	1379	654.3	600.6	108.9	3.27	91.44
365.760	44,311	364.49	201.42	117.86	80.26	60.96	49.28	41.40	1379	861.9	604.7	148.2	4.87	91.44
Mean:		532.89	340.87	216.41	144.78	102.62	76.20	59.94	1379	1676.2	850.8	95.8	3.94	87.29
Std. Dev:		225.04	144.02	81.79	47.75	29.72	20.07	14.99	0	2140.2	1620.3	37.9	4.85	21.85
Var Coeff (%)		42.23	42.25	37.78	32.96	28.84	26.34	25.11	0	100.0	100.0	39.8	123.07	25.02

District: 19
County: 32
Highway/Road: FM0560

Pavement: 5.08
Base: 24.13
Subbase: 8.89
Subgrade: 505.97

Thickness (cm)

MODULI RANGE (MPa)

Minimum Maximum
1,379 1,379
138 2,758
28 1,034
103

Poisson Ratio Values

H1: 3/4 = 0.35
H2: 3/4 = 0.30
H3: 3/4 = 0.35
H4: 3/4 = 0.40

Station (m)	Load (N)	Measured Deflection (μ):							Calculated Moduli values (MPa):				Absolute ERR/Sens	Dpth to Bedrock (m)
		R1	R2	R3	R4	R5	R6	R7	SURF(E1)	BASE(E2)	SUBB(E3)	SUBG(E4)		
411.480	44,613	278.89	179.32	118.87	81.79	61.21	49.02	40.39	1379	1406.6	1586.5	130.3	3.88	91.44
457.200	44,983	342.65	229.62	149.35	103.63	76.71	58.42	48.01	1379	1307.3	705.4	102.7	3.75	91.44
503.225	45,036	490.73	268.73	141.99	91.69	69.09	53.34	41.66	1379	550.2	213.7	119.3	6.34	91.44
549.859	45,089	312.67	137.92	58.67	43.69	39.62	33.27	29.21	1379	615.0	1262.5	245.5	14.33	32.24
594.055	44,275	413.51	225.04	118.87	75.18	52.83	41.15	33.78	1379	690.2	146.9	148.2	4.18	91.44
640.080	45,232	425.96	238.51	139.70	87.38	60.96	45.72	36.07	1379	759.8	171.0	131.0	2.55	90.93
685.495	43,906	720.09	397.76	189.99	103.38	74.93	67.82	35.05	1379	351.6	35.2	98.6	8.53	33.57
Mean:		426.47	239.52	131.06	83.82	62.23	49.78	37.85	1379	811.5	588.8	139.3	6.2	65.29
Std. Dev:		148.59	81.79	39.88	20.57	12.95	11.43	6.10	0	395.1	616.4	49.6	4.1	40.94
Var Coeff (%)		34.82	34.15	30.42	24.54	20.96	22.84	16.27	0	48.7	100.0	35.8	65.74	62.71

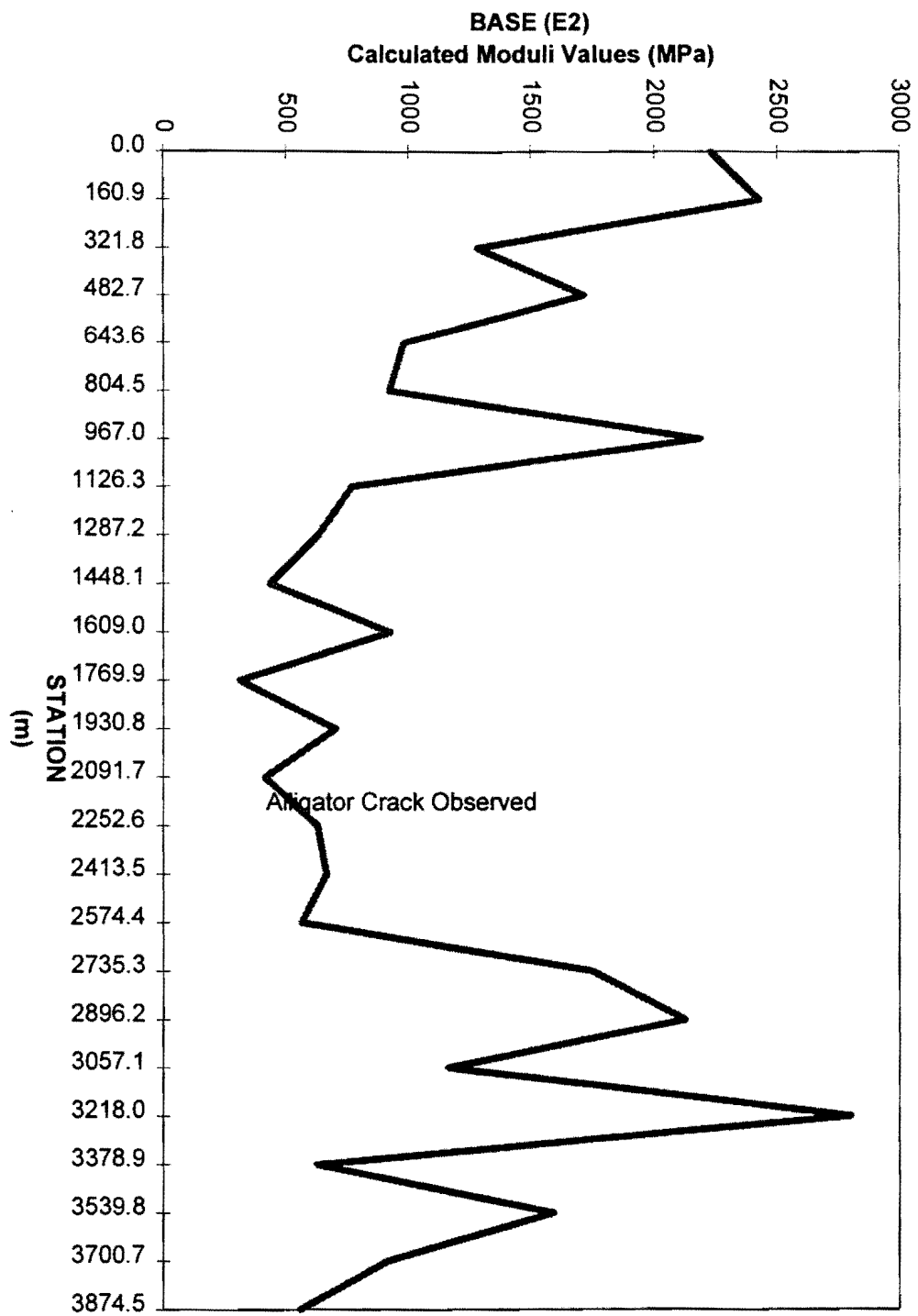


Figure 3. Base Moduli Values for Loop 390

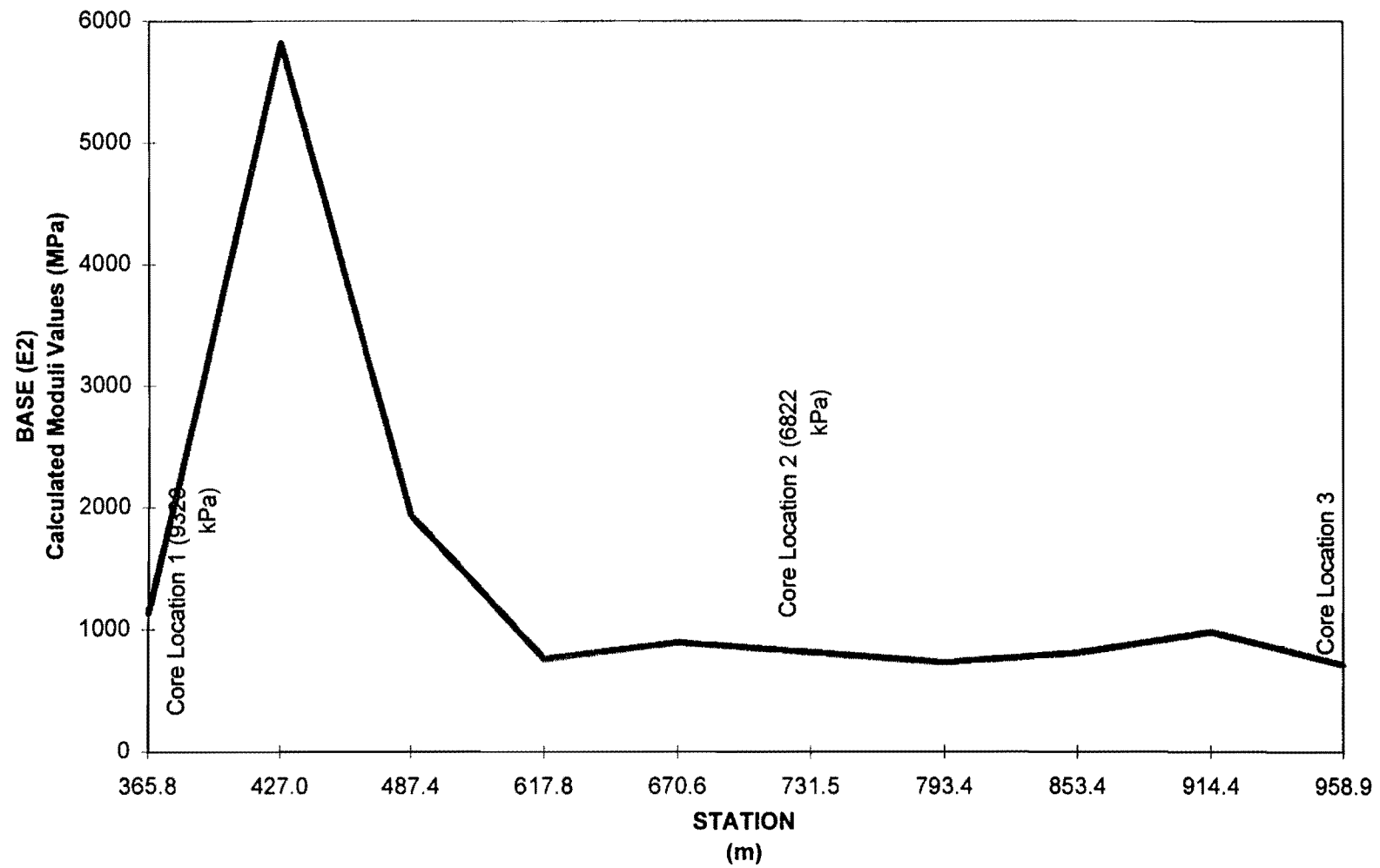


Figure 4. Base Moduli Values for IH 20 Frontage Road

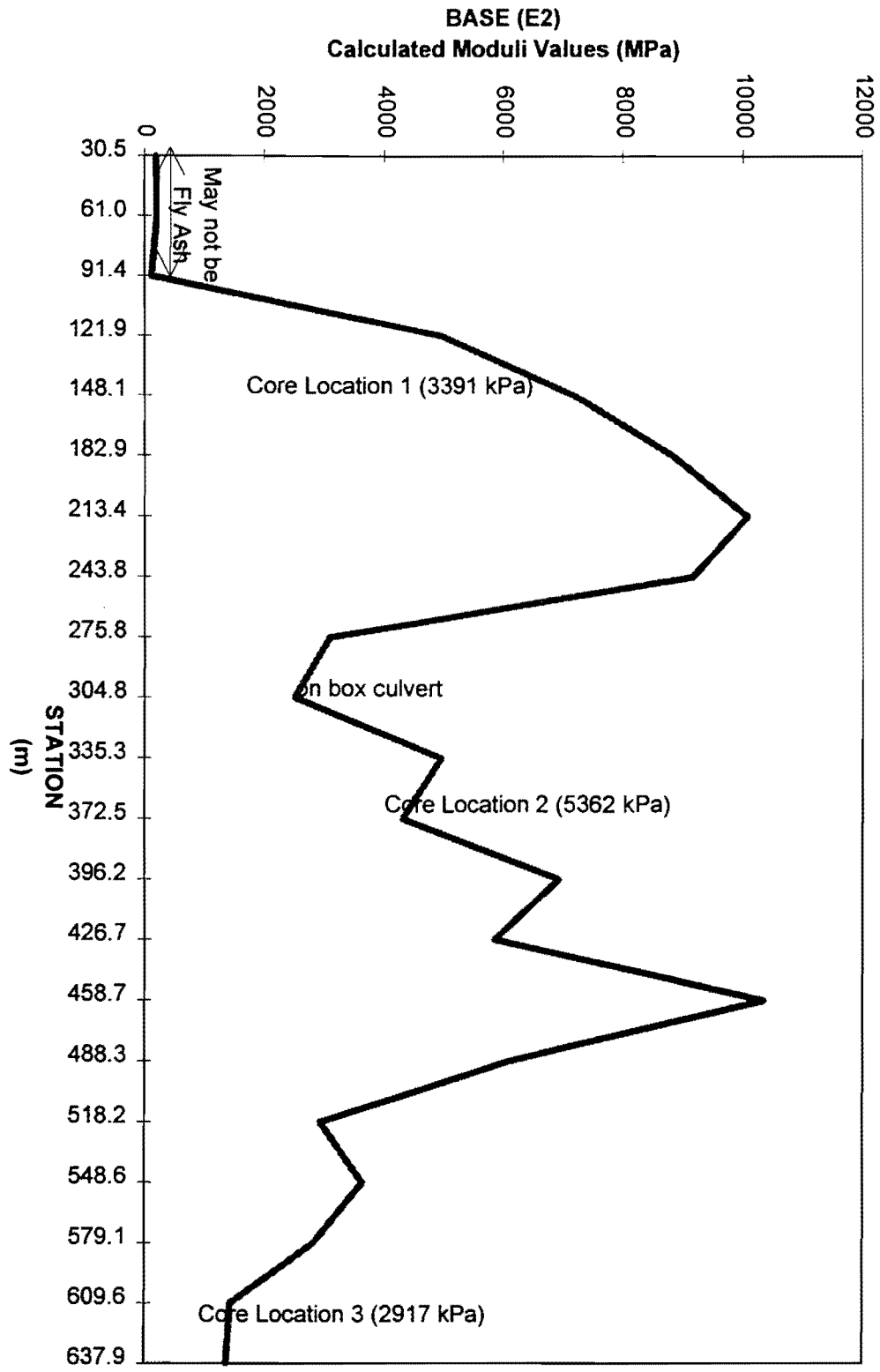


Figure 5. Base Moduli Values for SH 154

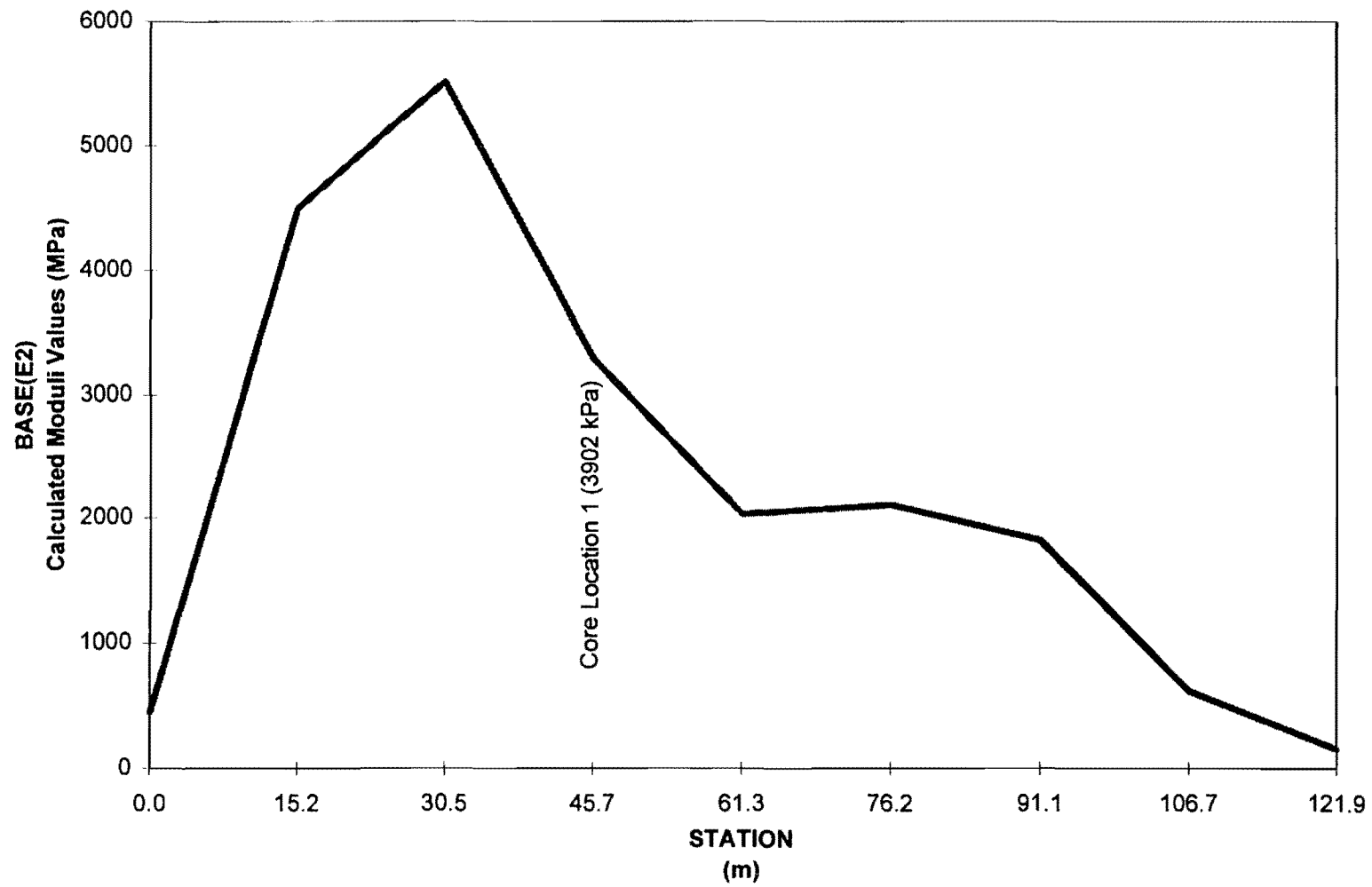


Figure 6. Base Moduli Values for FM 1326

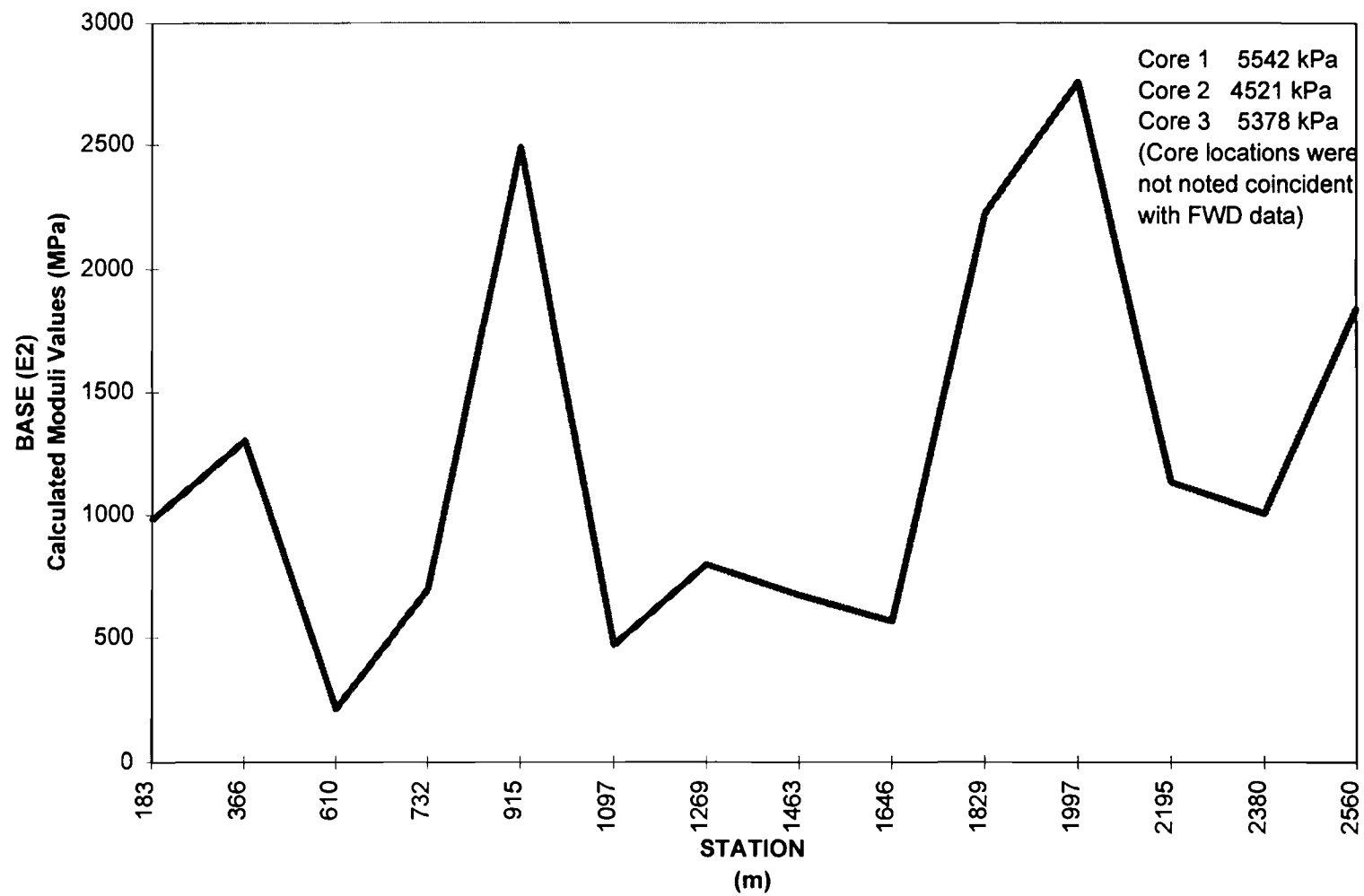


Figure 7. Base Moduli Values for FM 1520

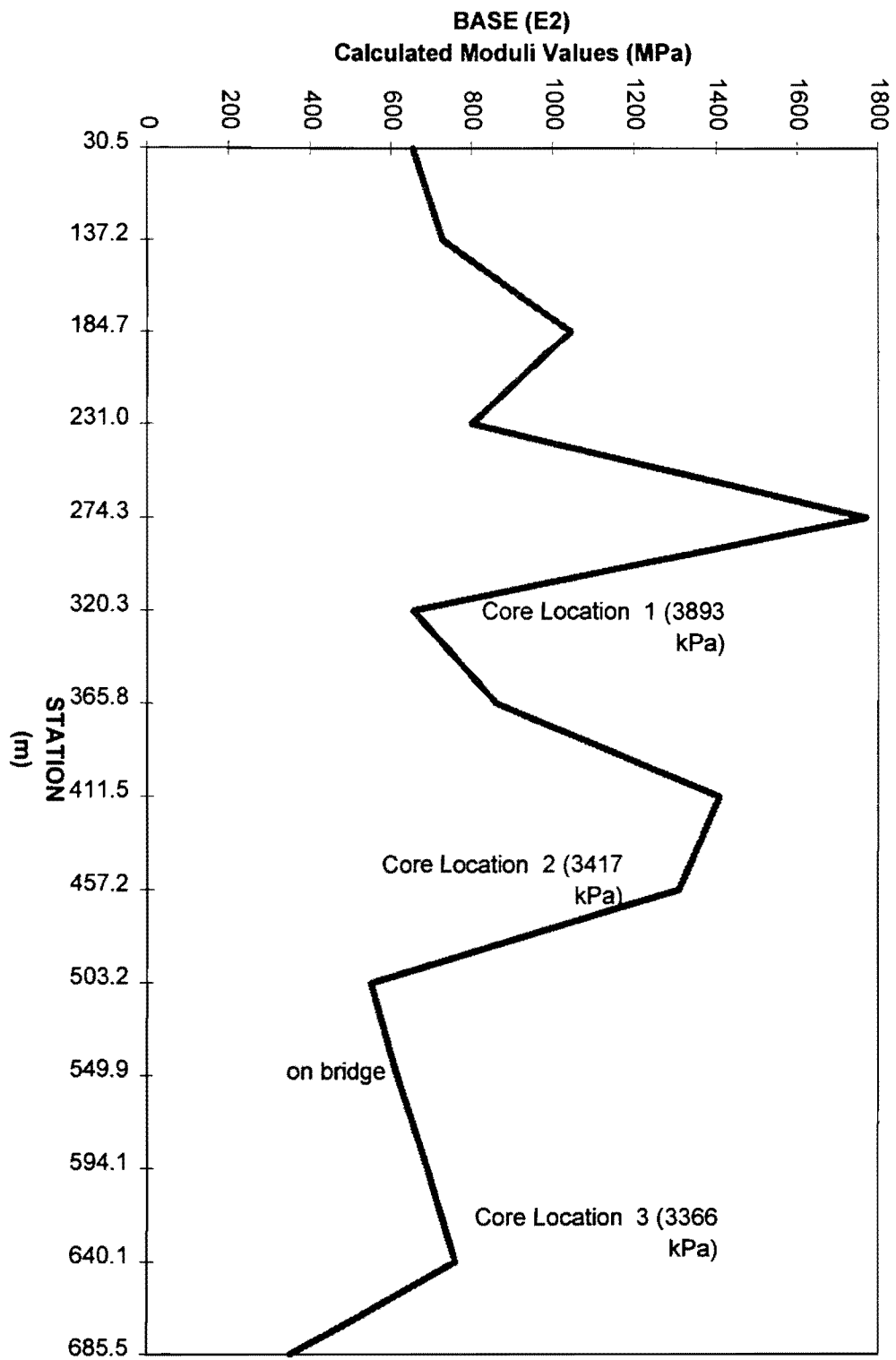


Figure 8. Base Moduli Values for FM 560

SUMMARY

- Most of the hydrated fly ash test pavement are performing very well at this time. Those pavements which have distress are in isolated areas and the distress is not affecting the serviceability of the roadway.
- Two of the six hydrated fly ash test pavements are exhibiting distress which might be attributable to deficiencies in the fly ash base material. Loop 390 is exhibiting a small amount of alligator cracking in an area where the FWD data indicates the base is weak. SH 154 is exhibiting transverse cracking (which appears to be from shrinkage of the base) and the FWD data indicates this pavement is excessively stiff.
- While four of the test pavements are not exhibiting any base-related distress, some of the FWD data indicate that the bases are weaker than that typically desired of a stabilized material (as weak as the section of Loop 390 where alligator cracking is observed).
- Concern is warranted regarding the fly ash material variability as exhibited in moduli values from FWD data. There is variability along a single pavement length, as well as between different pavements (i.e., SH 154 is much stiffer overall than any other pavement). This variability is evident in Figure 9. Reasons for this variability are unknown but should be investigated. The material may have been inconsistent in its *as-received* condition, or the effect of the fly ash as a stabilizer may be deteriorating over time (perhaps due to water infiltrating the base in certain areas).
- Hydrated fly ash is a new material and is different from other stabilized base materials. Given this fact, it may not be appropriate to apply FWD criteria to this material as the researchers are attempting to do in this report. The moduli values for some of these pavements appear to be low when compared with criteria for stabilized bases; however, for this material and its respective traffic conditions, these values may be acceptable (since the pavements are performing very well). This will be evident as performance is monitored over the next four years with successive FWD testing.

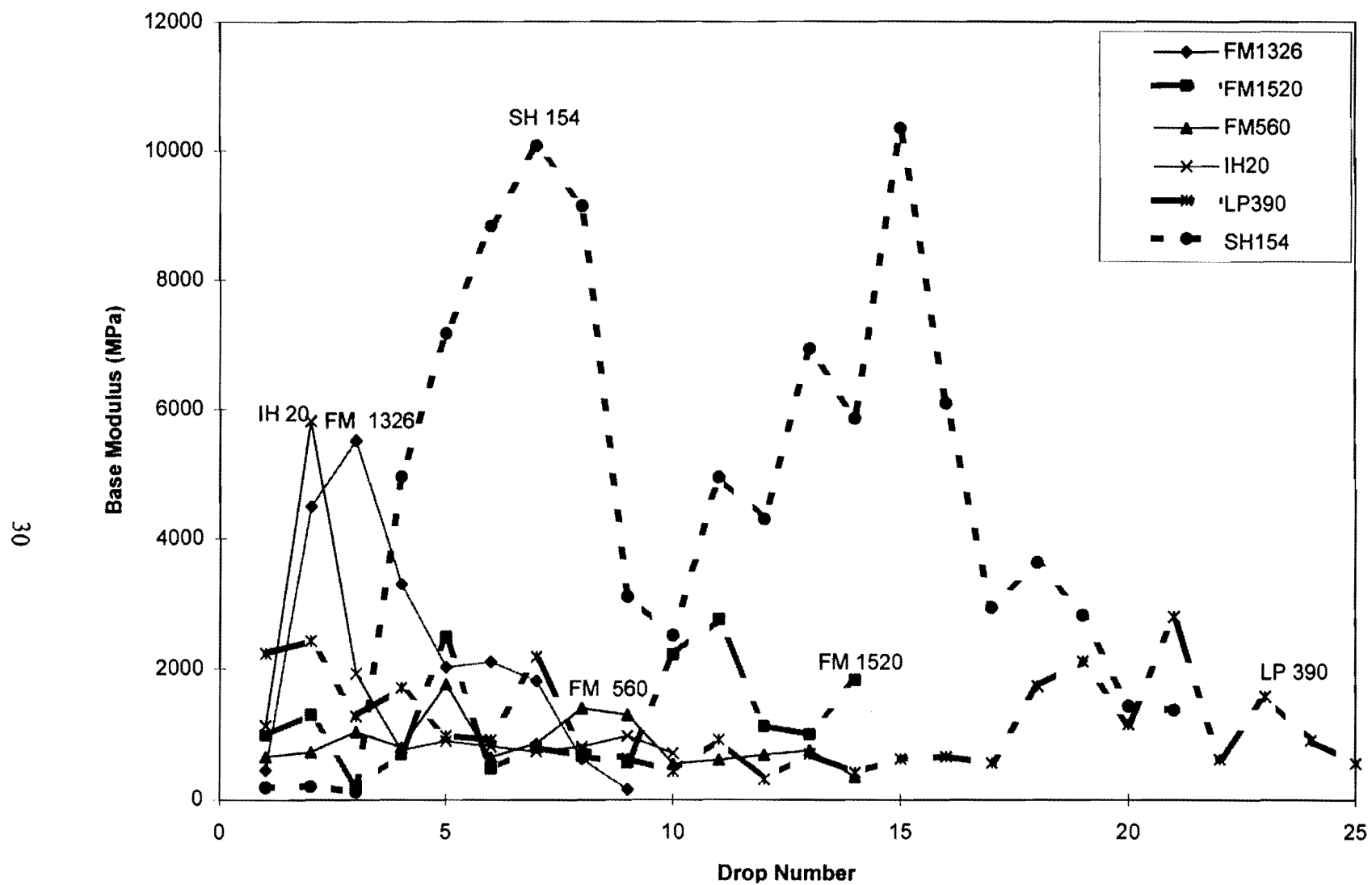


Figure 9. Base Moduli Values for All 6 Pavement Sections.

RECOMMENDATIONS

Overall, the hydrated fly ash test pavements are performing very well; however, some of the data as discussed above is worthy of concern. The researchers recommend that the Atlanta District continue the current course of action: monitoring the performance of these pavements over the next few years. FWD data collection should continue as a part of the monitoring program since it provides a non-destructive tool to watch for changes that may be occurring in the base yet are not manifested on the surface.

It is also recommended that this year's monitoring program employ the use of ground penetrating radar (GPR) on all six test pavements. It is possible that the reason for the moduli variation in the base materials is due to the presence of water in the base which is causing a *weakening* of that layer. If so, this will be revealed through GPR. This additional work will not require any new allocation of research funds.

REFERENCES

1. Nash, P. T., P. Jayawickrama, S. Senadheera, J. Borrelli, and A. Ashek Rana, 1995. *Guidelines for Using Hydrated Fly Ash as a Flexible Base*, Research Report 0-1365-1F, College of Engineering, Texas Tech University, Lubbock.
2. *Distress Identification Manual for the Long-Term Pavement Performance Project*, 1993. Report SHRP-P-338, Strategic Highway Research Program, National Research Council, Washington, D.C.

