Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA/TX-08/0-4687-2		

4. Title and Subtitle
FIELD EVALUATIONS AND GUIDELINES FOR RUBBLIZATION IN TEXAS

5. Report Date
September 2007
Published: December 2007

6. Performing Organization Code

7. Author(s)
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8. Performing Organization Report No.
Report 0-4687-2

9. Performing Organization Name and Address
Texas Transportation Institute
The Texas A&M University System
College Station, Texas 77843-3135

10. Work Unit No. (TRAIS)

11. Contract or Grant No.
Project 0-4687

12. Sponsoring Agency Name and Address
Texas Department of Transportation
Research and Technology Implementation Office
P. O. Box 5080
Austin, Texas 78763-5080

13. Type of Report and Period Covered
Technical Report:
September 2005-August 2007

14. Sponsoring Agency Code

15. Supplementary Notes
Project performed in cooperation with the Texas Department of Transportation and the Federal Highway Administration.
Project Title: Rubblization and Crack and Seat as Major Rehabilitation for Concrete Pavements
URL: http://tti.tamu.edu/documents/0-4687-2.pdf

16. Abstract

Rubblization is a unique means of rehabilitating concrete pavements by in-place conversion of the old concrete pavement into a useable base. Rubblization employs machinery that will break apart the concrete in place and leave pieces small enough that reflective cracking problems are significantly reduced or ideally eliminated. This report builds upon the previously published report 4687-1. This report presents a summary of several field investigations performed to evaluate projects' suitability for rubblization followed by construction and performance evaluations of two recently completed rubblization projects. Based on these experiences, this report presents a non-invasive field test procedure to evaluate projects, recommended thickness design procedures for rubblization projects, and a construction specification for conducting rubblization in Texas.

17. Key Words
Rubblization, Resonant Breaker, Multi Head Breaker

18. Distribution Statement
No restrictions. This document is available to the public through NTIS:
National Technical Information Service
Springfield, Virginia 22161
http://www.ntis.gov

19. Security Classif.(of this report)	20. Security Classif.(of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	98	

FIELD EVALUATIONS AND GUIDELINES FOR RUBBLIZATION IN TEXAS

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Report 0-4687-2
Project 0-4687
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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 views or policies of the Texas Department of Transportation or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation. The engineer in charge was Tom Scullion, P.E. (Texas, #62683).

ACKNOWLEDGMENTS

This project was made possible by the Texas Department of Transportation (TxDOT) in cooperation with the Federal Highway Administration. Special thanks must be extended to Darlene Goehl, P.E., for serving as the project director. The authors also extend their thanks to the Project Monitoring Committee: Bill Willeford, P.E.; Leo Betancourt, P.E.; Susan Chu, P.E.; and Andrew Wimsatt, P.E. Additionally, personnel in the Bryan, Beaumont, Childress, Lufkin, and Dallas Districts of TxDOT are acknowledged for their participation in identifying field sites for use in this project.

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EXECUTIVE SUMMARY

Rubblization is a unique means of rehabilitating concrete pavements by in-place conversion of the old concrete pavement into a useable base. Rubblization employs machinery that will break apart the concrete in place and leave pieces small enough that reflective cracking problems are significantly reduced or ideally eliminated. Texas has many miles of old jointed concrete pavements (JCP) needing rehabilitation, thus this project evaluated field projects and the rubblization process to develop guidelines for performing rubblization on Texas Department of Transportation (TxDOT) projects.

This report builds upon the previously published report 4687-1 and presents the final guidelines and recommended specifications for performing rubblization. Through a series of field investigations performed to evaluate projects' suitability for rubblization, presented in Chapters 1 through 5, followed by construction and performance evaluations of two recently completed rubblization projects, presented in Chapters 6 and 7, a non-invasive test procedure using visual observation, ground-penetrating radar (GPR), falling weight deflectometer (FWD), and dynamic cone penetrometer (DCP) testing was developed that can screen a project's suitability for rubblization. Although researchers fed the results from these field tests into a rubblization selection chart originally developed for the Illinois DOT (IDOT), field experiences encountered in this project led the research team to recommend two changes to the chart. First, the chart was made slightly more conservative, and second, the distinction between the alternative rubblization equipment was eliminated. Chapter 8 of this report presents the recommended procedure, pavement type selection process, and rubblization selection chart for evaluating projects.

TxDOT continues to nominate projects for rubblization as they seek to rehab older jointed concrete pavements. For overlay design purposes, results from this project indicate estimating the rubblized layer modulus as 5 percent of the concrete modulus prior to rubblization is reasonable. If rubblization is not feasible, options such as a flex base overlay or overlay with asphalt mixtures optimized for both cracking and rut resistance exist. When rubblization is selected as the rehab strategy, this project produced a draft construction specification, included as an appendix in this report, for TxDOT's use.

CHAPTER 1
INVESTIGATION OF FM 912 FOR RUBBLIZATION

SUMMARY

In efforts to identify potential rehabilitation strategies for FM 912 in Washington County, researchers conducted a field investigation in October 2005 to investigate if rubblization (RBBL) would be an option for the JCP pavement. The section investigated is from the intersection with SH 105 to FM 1155. Based upon GPR, FWD, and DCP results, the majority of the project is not suitable for rubblization. Most of the project has either a history of voids beneath the slabs, insufficient subgrade support, or both, for rubblization to be feasible. Two sections are marginally suitable for rubblization. These sections are from reference marker (RM) 628 + 0.557 to RM 628 + 0.826 and from RM 630.019 to 630.658. In sections not suitable for rubblization, a flexible base overlay should be considered.

RESULTS FROM FIELD INVESTIGATION

Based on the field investigation the structure on FM 912 consists of approximately 7 inches of JCP over the subgrade. Within the section, substantial cracking exists such as illustrated in Figure 1.1. The average joint spacing is 40 feet, and the average transverse crack spacing is 6 to 7 feet. To evaluate if the FM 912 project is suitable for rubblization, the Texas Transportation Institute (TTI) performed a field analysis using GPR, FWD, and DCP testing. Figure 1.2 illustrates representative GPR data from the project.

The GPR survey serves two primary purposes. First, the survey can identify locations of excessively wet subgrade or trapped water, both of which hinder the rubblization process. Second, the GPR survey can identify section breaks or changes in structure. In the GPR data, no locations of excessively wet subgrade were identified. The highest subgrade dielectric value was 7.3 (values above 10 can indicate excessively wet material). However, at the time of testing the weather had been dry for several months. From discussions with TxDOT personnel, portions of the FM 912 project have a history of developing voids underneath the slabs, particularly in the low-lying areas. While TxDOT reported that maintenance work had recently been performed on locations with voids, the GPR data still detected areas of voids beneath the slabs. Figure 1.3 illustrates GPR data where voids exist. Follow-up testing with the DCP at selected locations verified the existence of voids beneath the slab. In the southbound (SB) travel direction, evidence of intermittent voids in the GPR data exist from RM 629 + 0.108 to 629 + 0.513. In the northbound (NB) travel direction, evidence of intermittent voids beneath the slabs exist from RM 629 + 0.898 to 628 + 0.936.

Figure 1.1. Cracked Slabs on FM 912.

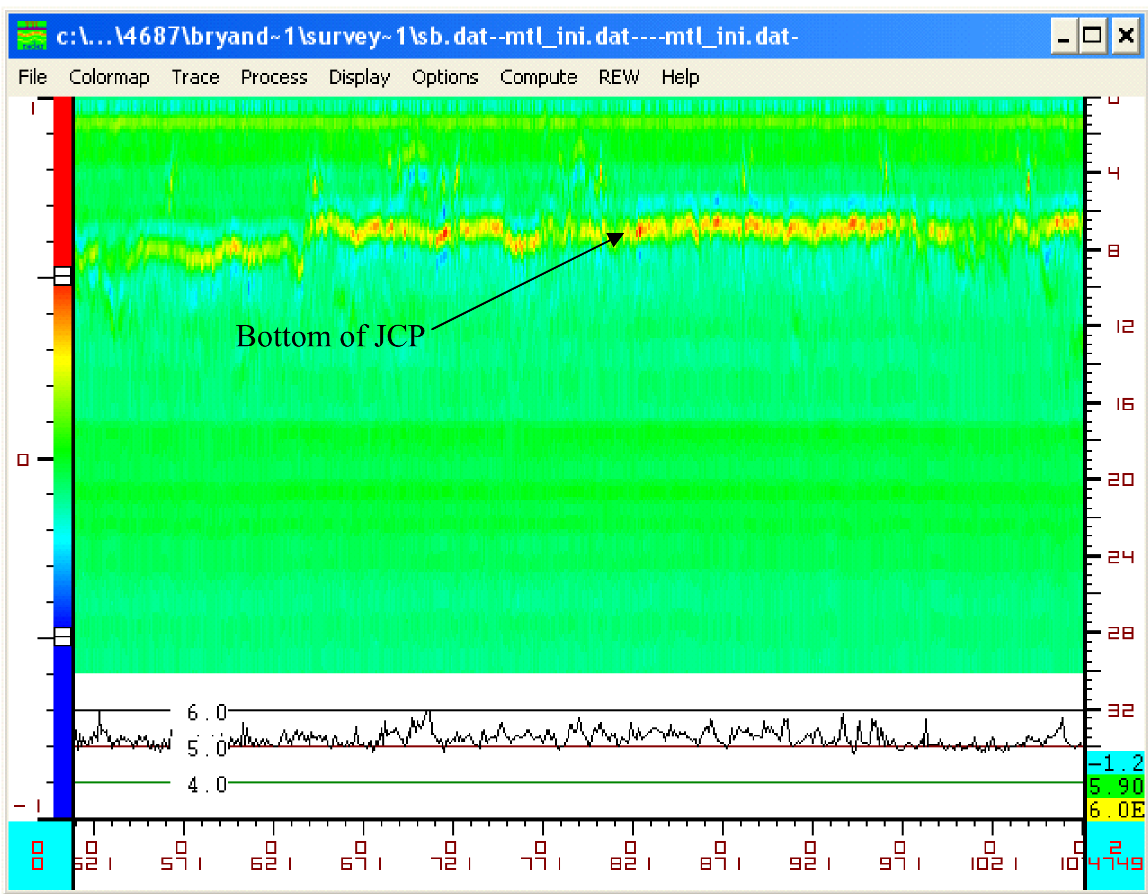


Figure 1.2. Representative GPR Data from FM 912.

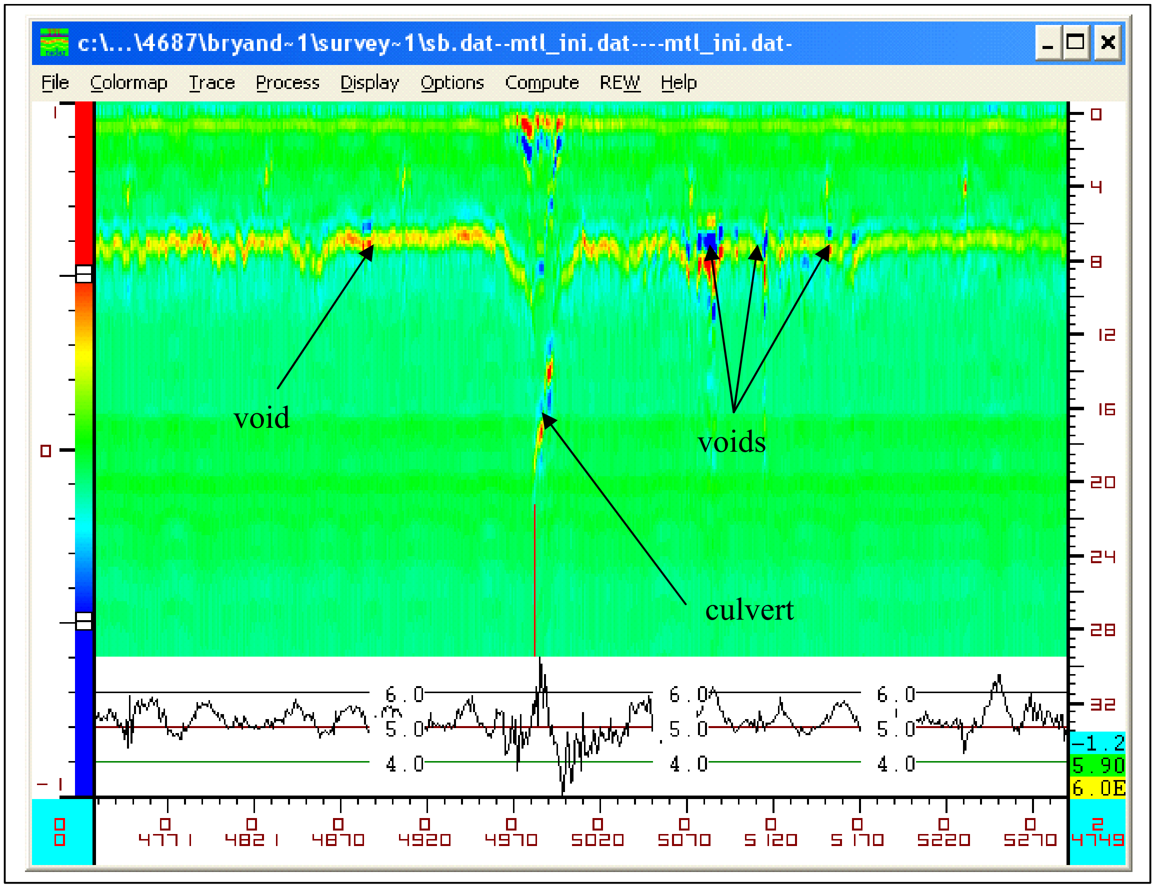


Figure 1.3. Voids beneath Slabs on FM 912.

Table 1.1 shows the FWD backcalculation results for the FM 912 project. After studying FWD results in the field, DCP tests were performed at selected locations to verify whether adequate subgrade support exists. Table 1.2 summarizes the DCP results as needed for application in the rubblization selection chart developed by Illinois DOT. The DCP data allow for evaluation of two governing parameters:

- *Support immediately beneath the slab*: If there is inadequate support immediately beneath the slab, rubblization may not be feasible. To evaluate the project for this parameter, the concrete thickness versus the California Bearing Ratio (CBR) of the base layer immediately beneath the slab is plotted. In instances where the DCP data did not reveal a clear layer distinction, a dummy base layer value of 6 inches was assigned.

- *Support at deeper depths into the subgrade*: Even if support is sufficient immediately beneath the slab for concrete breakage, weak soils deeper in the pavement can create problems. Shear failures can occur, particularly with the resonant breaker equipment due to the multiple passes required over the rubblized pavement to break the entire pavement width. To evaluate this parameter, the combined thickness of the concrete and base is plotted against the CBR value of the first 6 inches of subgrade.

Table 1.1. FWD Results for FM 912.

TTI MODULUS ANALYSIS SYSTEM (SUMMARY REPORT) (Version 6.0)

District:Bryan
County: Washington
Highway/Road: FM 912

MODULI RANGE (psi)

	Thickness(in)	Minimum	Maximum
Pavement:	7.5	340,000	5,000,000
Base:	0		
Subbase:	0		
Subgrade:	100.38	15,000	

Poisson Ratio Values
H1: v = 0.20
H2: v=0.00
H3: v=0.00
H4: v=0.40

Station	Load (lbs)	R1	R2	R3	R4	R5	R6	R7	SURF(E1)	BASE(E2)	SUBB(E3)	SUBG(E4)	Absolute ERR/Sens	Dpth to Bedrock
		Measured Deflection (mils)							Calculated Moduli Values (ksi)					
0	10,030	21.2	18.42	15.17	12.51	10.14	8.4	7.17	2323.1	0	0	2.6	3.59	300
0.052	10,320	9.5	8.79	7.53	6.28	5.11	3.96	3.06	5000	0	0	5.4	2.22	148.6 *
0.1	10,073	12.57	10.85	8.68	6.88	5.25	3.88	2.77	2785.4	0	0	5.6	2.15	117.9
0.145	10,177	7.78	6.73	5.28	3.98	2.84	2.02	1.39	3560.4	0	0	10.9	1.2	100
0.198	10,105	7.87	6.98	5.5	4.29	3.2	2.34	1.71	4118.5	0	0	9.3	1.46	115.7
0.243	10,165	10.51	9.8	8.4	7.07	5.81	4.63	3.67	4652.6	0	0	4.7	2.64	178.9 *
0.287	10,951	12.65	11.16	9.45	7.92	6.38	5.02	3.81	4372.1	0	0	4.4	1.74	140.7
0.337	9,855	12.21	10.89	9.15	7.79	6.5	5.3	4.15	4035.9	0	0	4	3.46	165.4 *
0.375	9,831	9.74	8.41	6.46	4.92	3.56	2.47	1.61	2712.1	0	0	8.6	1.4	93.3
0.406	10,570	17.78	13.96	9.91	6.82	4.5	2.83	1.66	972.4	0	0	7.5	2.57	89
0.406	11,055	14.43	11.3	7.99	5.61	3.7	2.3	1.31	1274	0	0	9.7	2.57	82.6
0.447	9,970	12.35	10.21	7.85	5.8	4.12	2.77	1.63	1919.8	0	0	7.7	1.91	85.6
0.487	10,046	8.5	7.22	5.56	4.2	3.06	2.17	1.5	3185.6	0	0	10.2	2.12	101.9
0.546	10,014	7.39	6.65	5.18	4.06	3.07	2.31	1.72	4534.5	0	0	9.5	2.23	121.3
0.595	9,994	7.85	7.03	5.61	4.39	3.31	2.41	1.74	4279.2	0	0	8.8	1.08	112.1
0.644	9,907	10.63	9.6	7.9	6.3	4.76	3.33	2	3313.3	0	0	6	0.92	84.4
0.699	10,053	9.75	8.57	6.69	5.15	3.86	2.82	2.09	3190.7	0	0	7.8	1.93	129.4
0.739	9,823	6.94	6.09	4.63	3.43	2.46	1.71	1.18	3565.3	0	0	12.4	1.41	99.5
0.792	9,899	8.98	8.39	6.82	5.41	4.04	2.84	1.85	3828.1	0	0	7.1	1.4	92.1
0.836	9,760	12.72	10.89	8.44	6.49	4.78	3.55	2.67	2272.9	0	0	6.2	2.6	147.5
0.846	9,807	15.14	12.02	8.82	6.37	4.41	2.85	1.74	1280.7	0	0	7.3	2.98	91.4
0.864	9,664	17.44	14.2	10.65	7.67	4.98	2.43	1.51	917.1	0	0	6.6	5.64	67.2
0.909	9,771	22.92	19.39	15.51	12.18	8.87	5.79	3.37	1220.6	0	0	3.5	2.2	91
0.959	8,953	21.72	20.14	18.33	17.79	17.52	17.74	18.26	1764.1	0	0	1.8	19.2	300.0 *
0.959	9,263	22.26	20.58	18.71	18.17	17.99	18.25	18.83	1738.6	0	0	1.7	19.8	300.0 *
0.99	9,942	11.57	9.19	6.49	4.3	2.44	1.69	1.2	1207.9	0	0	11.7	3.13	71.2
1.043	10,057	9.08	7.91	6.61	5.34	4.2	3.06	2.09	4471.8	0	0	6.8	1.46	98.5
1.096	9,851	10.61	9.22	7.32	5.64	4.15	2.88	1.84	2743.2	0	0	7.2	0.89	92.2
1.11	9,851	12.29	10.19	7.73	5.76	4.15	2.86	1.93	1964.5	0	0	7.6	2.59	104.2
1.145	9,720	7.64	6.41	4.86	3.65	2.67	1.92	1.32	3340.7	0	0	11.4	2.96	98.8
1.199	9,887	8.86	7.78	6.47	5.29	4.13	3.04	2.14	4579.4	0	0	6.7	1.26	104.1
1.247	10,546	14.78	12.02	9.33	6.94	4.96	3.44	2.16	1774.4	0	0	6.7	2.62	94.4
1.288	9,684	12.63	10.41	7.84	5.86	4.09	2.57	1.67	1687.4	0	0	7.7	1.76	87.8
1.355	9,255	29.28	4.4	3.72	3.33	2.9	2.55	2.2	504.3	0	0	16.8	53.05	300.0 *
1.355	9,064	33.78	27.29	21.02	16.48	12.78	9.82	7.4	871	0	0	2.2	5.39	179.1
1.356	9,561	18.06	15.76	12.86	10.47	8.13	6.03	4.32	2078.7	0	0	3.3	1.75	128.2
1.38	9,537	12.42	11.27	9.3	7.45	5.52	3.69	2.26	2589.5	0	0	5.1	2	89.1
1.382	9,783	12.28	11.12	9.09	7.25	5.47	3.88	2.77	2833.7	0	0	5.2	0.73	119.9
1.431	9,140	35.02	9.98	7.72	6.44	5.14	4.09	3.24	340	0	0	8.3	38.8	174.9 *
1.431	9,251	25.03	20.44	15.7	12.12	8.83	6.11	4.51	988.7	0	0	3.3	3.02	129.4
1.453	11,384	16.94	13.89	10.63	7.96	5.6	3.67	2.28	1570.3	0	0	6.5	1.81	93
1.496	9,775	10.3	9.43	7.74	6.3	4.98	3.9	3	4196.9	0	0	5.2	1.61	152.7
1.569	9,918	10.53	9.19	7.49	6.14	4.85	3.65	2.65	3897.3	0	0	5.7	2.18	116.6
1.627	10,081	10.53	9.06	7.18	5.7	4.39	3.29	2.39	3373.6	0	0	6.7	2.69	118.8
1.671	9,934	9.86	9.26	7.7	6.44	5.05	3.72	2.61	4531.5	0	0	5.3	1.38	104.2
1.71	9,644	17.81	6.24	4.98	3.98	3.16	2.5	1.96	894.7	0	0	13	31.23	152.1
1.71	9,684	20.84	15.8	11.38	8.17	5.73	3.96	2.85	904.8	0	0	5.5	5.62	124.9
1.76	9,752	11.17	9.8	7.72	5.93	4.39	3.34	2.57	2758.3	0	0	6.5	2.43	163.7
1.793	9,926	7.91	6.89	5.32	4.03	2.91	2	1.29	3354.6	0	0	10.6	1.02	88.8
1.837	9,497	21.72	5.75	4.95	4.1	3.24	2.52	1.94	449.6	0	0	15	42.32	133.3 *
1.837	9,243	27.37	21.35	15.32	10.77	6.78	3.77	2.54	519.6	0	0	4.4	2.75	79.1
1.861	9,843	8.4	7.15	5.47	4.16	2.98	2.1	1.43	3078.5	0	0	10.3	1.78	98.1
1.903	9,875	7.98	7.04	5.57	4.38	3.31	2.48	1.86	4201.1	0	0	8.7	1.96	127.6
1.998	9,763	13.81	12.73	10.69	8.96	7.01	5.31	3.52	3288.3	0	0	3.7	0.63	98.6
2.099	9,760	9.44	8.95	7.33	5.99	4.7	3.53	2.54	4457.7	0	0	5.6	0.91	113.8
2.2	9,831	9.45	8.57	6.91	5.53	4.17	2.94	1.81	3625.5	0	0	6.9	0.93	84.5
2.304	9,910	8.61	8.08	6.73	5.49	4.31	3.29	2.46	5000	0	0	6.2	0.84	127.9 *
2.396	9,954	10.7	9.22	7.01	5.23	3.64	2.24	1.12	2087.8	0	0	8.9	1.65	73.7
2.468	9,589	9.4	8.77	7.2	5.84	4.54	3.46	2.61	4302.7	0	0	5.7	0.93	137.1
2.596	9,716	8.72	7.73	5.93	4.43	3.13	2.17	1.48	2846.6	0	0	9.6	1.02	101.6
2.701	9,700	23.29	20.29	16.24	12.98	9.98	7.21	4.91	1468.6	0	0	2.9	1.81	116.8
Mean:		13.92	10.93	8.68	6.89	5.29	3.98	3	2714.8	0	0	7.1	5.23	107.9
Std. Dev:		6.66	4.66	3.77	3.31	3.06	3.03	3.14	1360.5	0	0	3.1	10.4	30.8
Var Coeff	(%):	47.82	42.66	43.45	48.02	57.9	76.12	104.52	50.1	0	0	43.9	198.59	28.6

Table 1.2. Summary DCP Results for FM 912.

DCP	Concrete Thickness (in)	Base Thickness (in)	CBR Values		Subgrade Modulus from FWD (ksi)	Location (RM)	Comment
			Base	Subgrade			
1	5.6	1.5	17.2	5.4	10.2	628.669	
2	6.7	6*	3.4	2.4	3.5	629.091	
3	6.5	6*	1.3	2.0	Not tested with FWD	629.145	Test location selected from GPR. DCP verified void beneath slab.
4	5.8	3.8	13.4	7.5	11.4	629.327	Within limits of intermittent voids
5	7.5	6*	0.6	4.2	4.1	629.457	Test location selected from GPR. DCP verified void beneath slab
6	6.8	8.2	7.9	3.4	3.7	630.180	
7	6.5	2.5	10.3	2.4	2.9	630.882	

*Assigned to 6 inches because not distinguishable in DCP data

Figure 1.4 shows this chart with the FM 912 data. Of particular attention in this graph are the data from DCP tests 1, 4, 6, and 7, because these are the only locations where the support immediately beneath the slab is sufficient to where rubblization may be feasible. The location represented by DCP 4 should not be rubblized because the section falls within the limits of the project where voids are occurring beneath the slab. Of the remaining locations 1, 6, and 7, the data show the portions of the project represented by tests 1 and 7 may not be suitable for rubblization because of the poor soil conditions a few inches below the bottom of the concrete. Only at location 6 do the data indicate the project is suitable for rubblization with minimal risk.

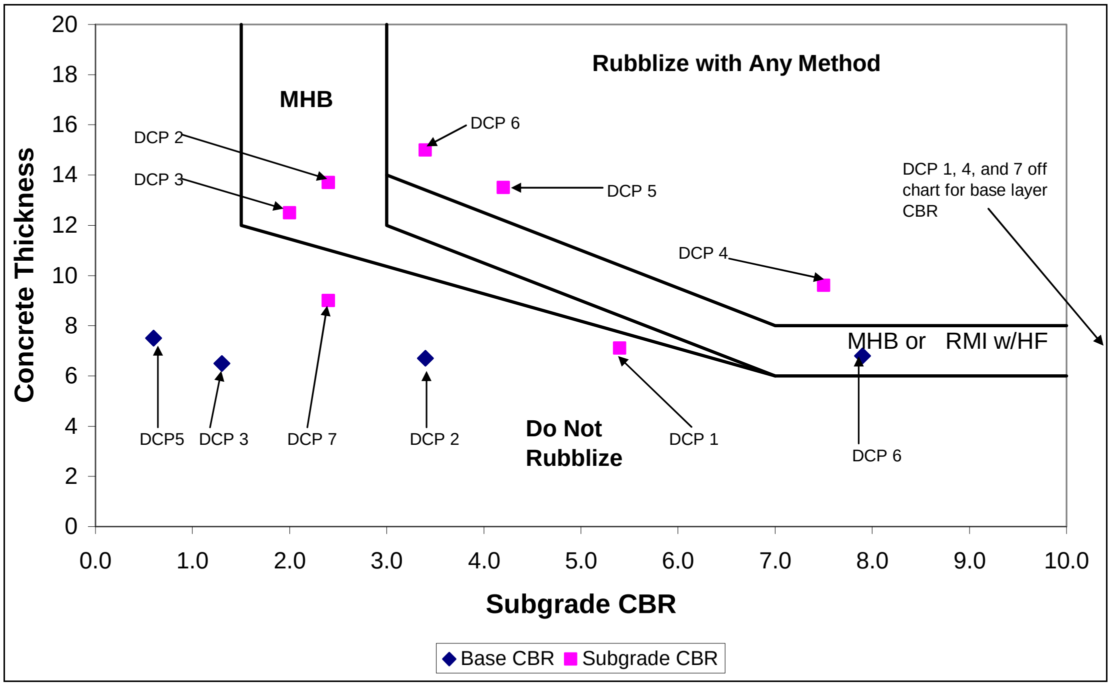


Figure 1.4. DCP Results from FM 912 on IDOT Rubblization Selection Chart.
Note: MHB = Multi-head breaker; RMI = Resonant Machines Inc; HF = High Flotation.

Because the DCP testing is spot-specific, researchers made efforts to use the FWD data to better partition the project into limits where rubblization may be an option. To accomplish this segmenting, a relationship between the FWD and CBR of the top 12 inches of subgrade was developed. For the concrete thickness on FM 912, a subgrade CBR of approximately 6.5 would be required according to the selection chart shown in Figure 1.4. From the relationship between the DCP and FWD data illustrated in Figure 1.5, the minimum backcalculated subgrade modulus should be at least 7 ksi.

To segment the project, the backcalculated subgrade modulus with distance is graphed in Figure 1.6. Segments 2 and 6 are marginally suited for rubblization. The average subgrade value exceeds (segment 2) or nearly meets (segment 6) the required minimum value. The DCP data from within these sections indicate they are marginally suitable for rubblization. The limits of these sections are from RM 628.557 to 628.826 and 630.019 to 630.658.

The first segment is not suitable for rubblization because the subgrade modulus is less than the required minimum value. Segments 3 through 5 should not be rubblized due to their proximity to locations where voids have occurred beneath the slabs.

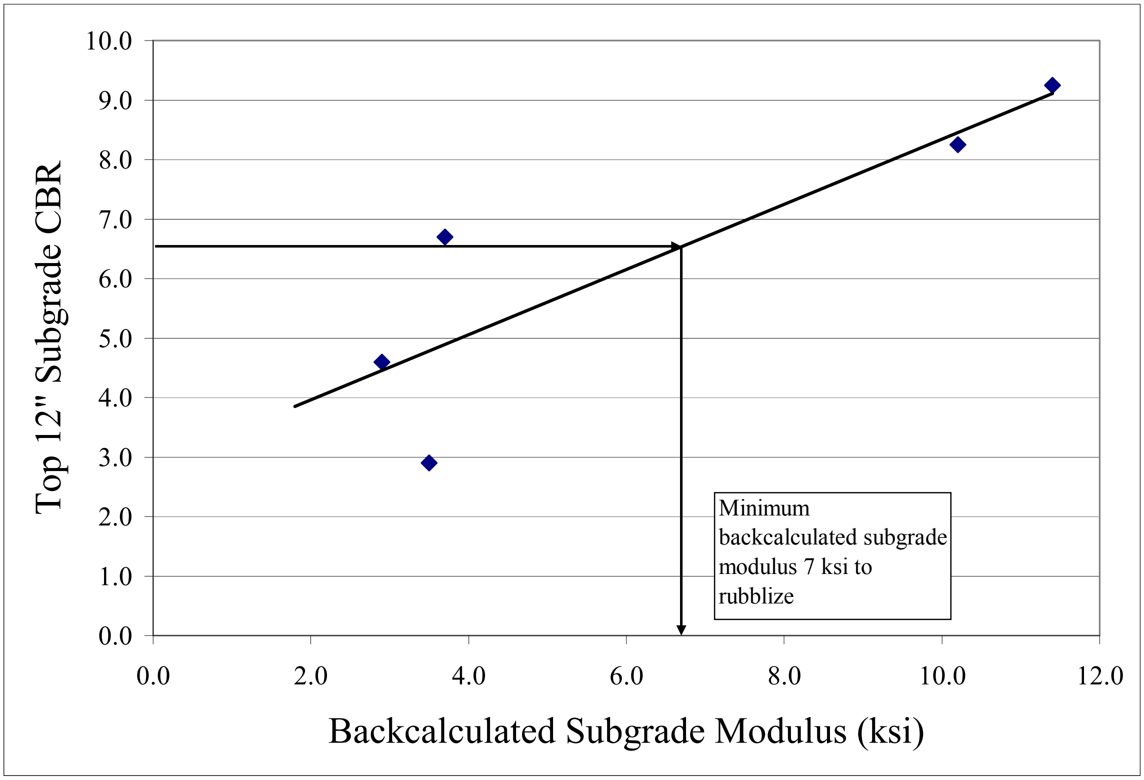
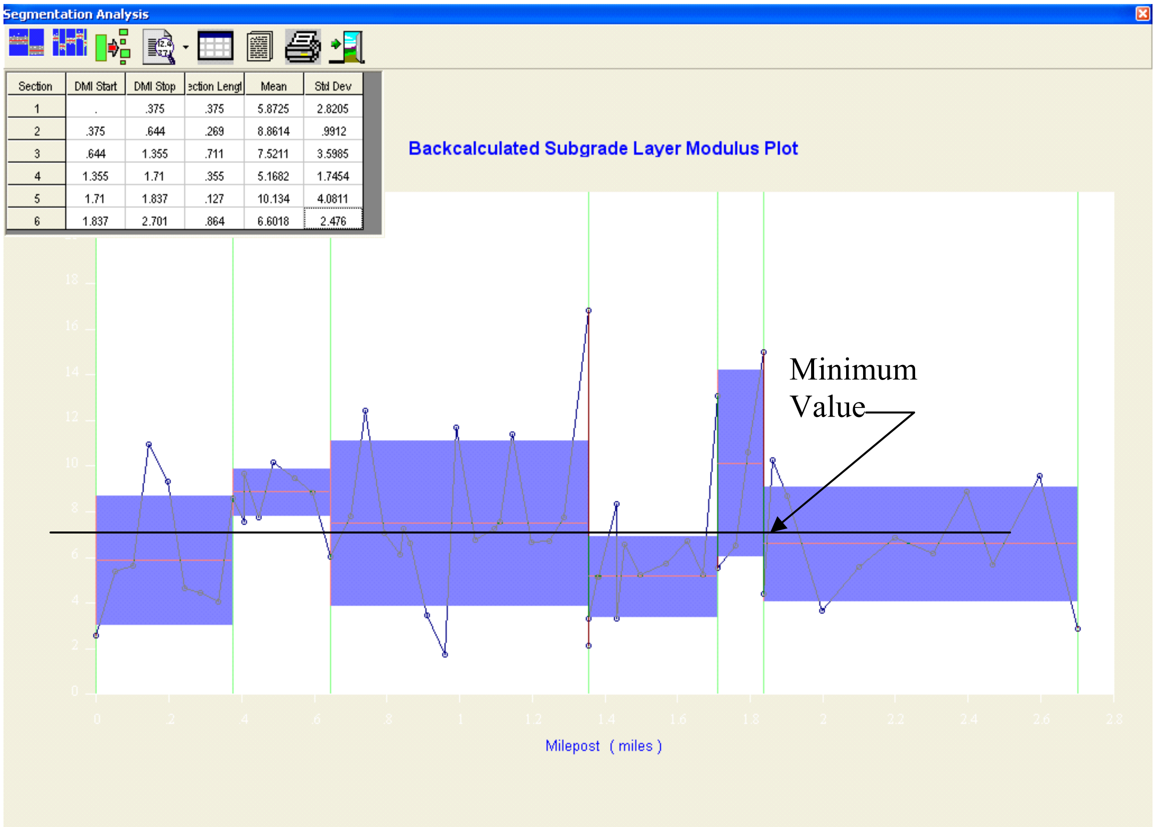


Figure 1.5. Relationship between DCP and FWD on FM 912.



Section	DMI Start	DMI Stop	ection Lengt	Mean	Std Dev
1	.	.375	.375	5.8725	2.8205
2	.375	.644	.269	8.8614	.9912
3	.644	1.355	.711	7.5211	3.5985
4	1.355	1.71	.355	5.1682	1.7454
5	1.71	1.837	.127	10.134	4.0811
6	1.837	2.701	.864	6.6018	2.476

Figure 1.6. FM 912 Backcalculated Subgrade Modulus with Distance (SB direction). Note: Milepost Zero is at RM 628 + 0.182

RECOMMENDATION

Based upon the results presented and discussed above, the majority of the FM 912 project should not be rubblized. Most of the project has either a history of voids beneath the slabs, insufficient subgrade support, or both. Two sections are marginally suitable for rubblization. These sections are from RM 628 + 0.557 to RM 628 + 0.826 and from RM 630.019 to 630.658. In sections not suitable for rubblization, a flexible base overlay should be considered.

CHAPTER 2
INVESTIGATION OF FM 1155 FOR RUBBLIZATION

SUMMARY

The JCP pavement evaluated for rubblization on FM 912 continues as FM 1155 in Washington County. The section investigated on FM 1155 is from the intersection with FM 912 to just past Park Road 12, where the JCP pavement ends. The investigation was begun at RM 631 on FM 912 then progressed northbound. Based upon GPR, FWD, and DCP results, the majority of the project is marginally suitable for rubblization. On one section, from 4550 to 5250 feet north of RM 631, the subgrade support is likely too poor to support rubblization operations.

RESULTS FROM FIELD INVESTIGATION

Based on the field investigation, the structure consists of approximately 7 to 8 inches of JCP over the subgrade. Figure 2.1 shows the pavement section looking northbound from RM 631 on FM 912.

Figure 2.1. JCP Pavement Tested for Suitability for Rubblization.

To evaluate whether the project is suitable for rubblization, TTI performed a field analysis using GPR, FWD, and DCP testing. Several sections of the project have asphalt concrete patches over the concrete. Table 2.1 shows the sections that exist based upon observation and GPR data. Figure 2.2 illustrates representative GPR data from the project where the structure consists solely of JCP. Figure 2.3 shows GPR data illustrating the transition from a location with asphalt concrete pavement (ACP) back to solely JCP.

Table 2.1. Sections on JCP Pavement Investigated.

Location North from RM 631 (Feet)	Pavement
0-360	JCP
360-700	~2.5 inch ACP over JCP (at culvert)
700-3446	JCP
3446-3875	~4 inch ACP over JCP (at culvert)
3875-4580	JCP
4580-5250	~7 to 9 inch ACP over JCP
5250-5520	JCP
5520-6545	~2.5 inch ACP over JCP
6545-7256	JCP
7256-8380	~2 inch ACP over JCP

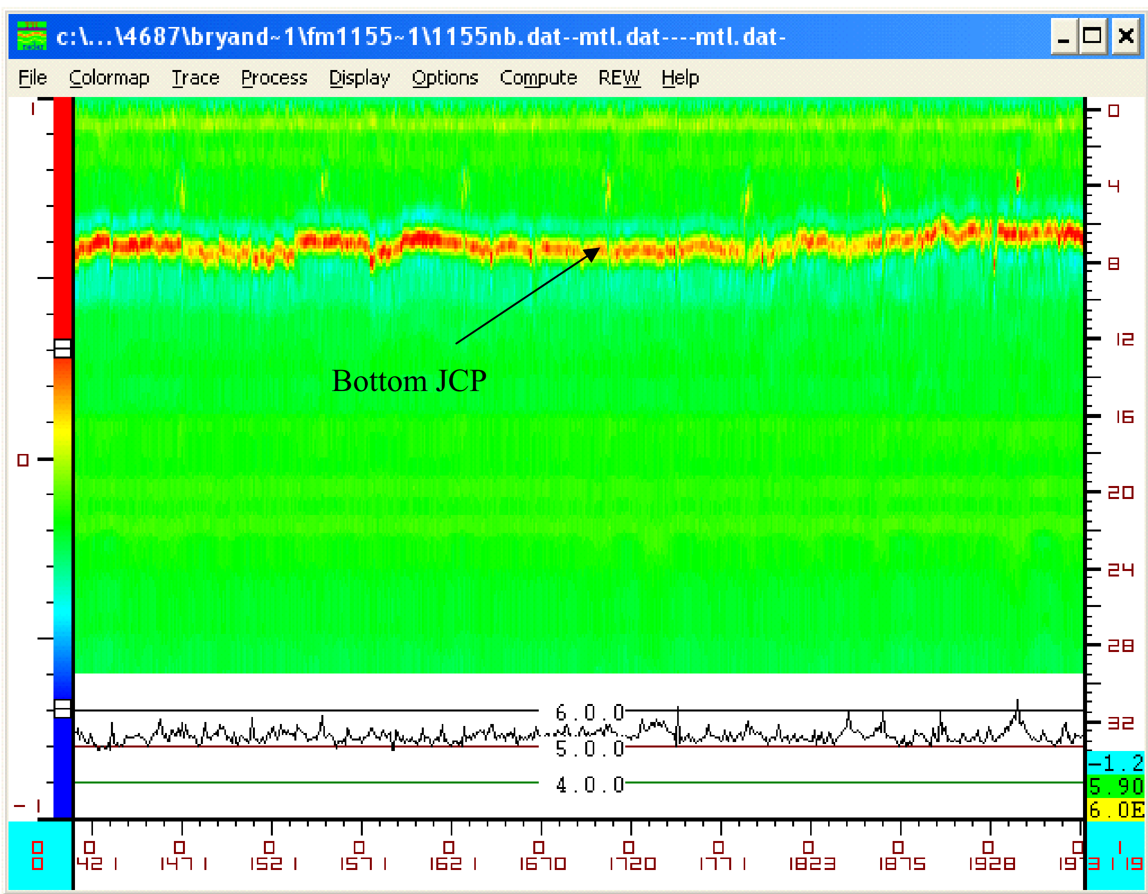


Figure 2.2. Representative GPR Data from JCP on FM 1155.

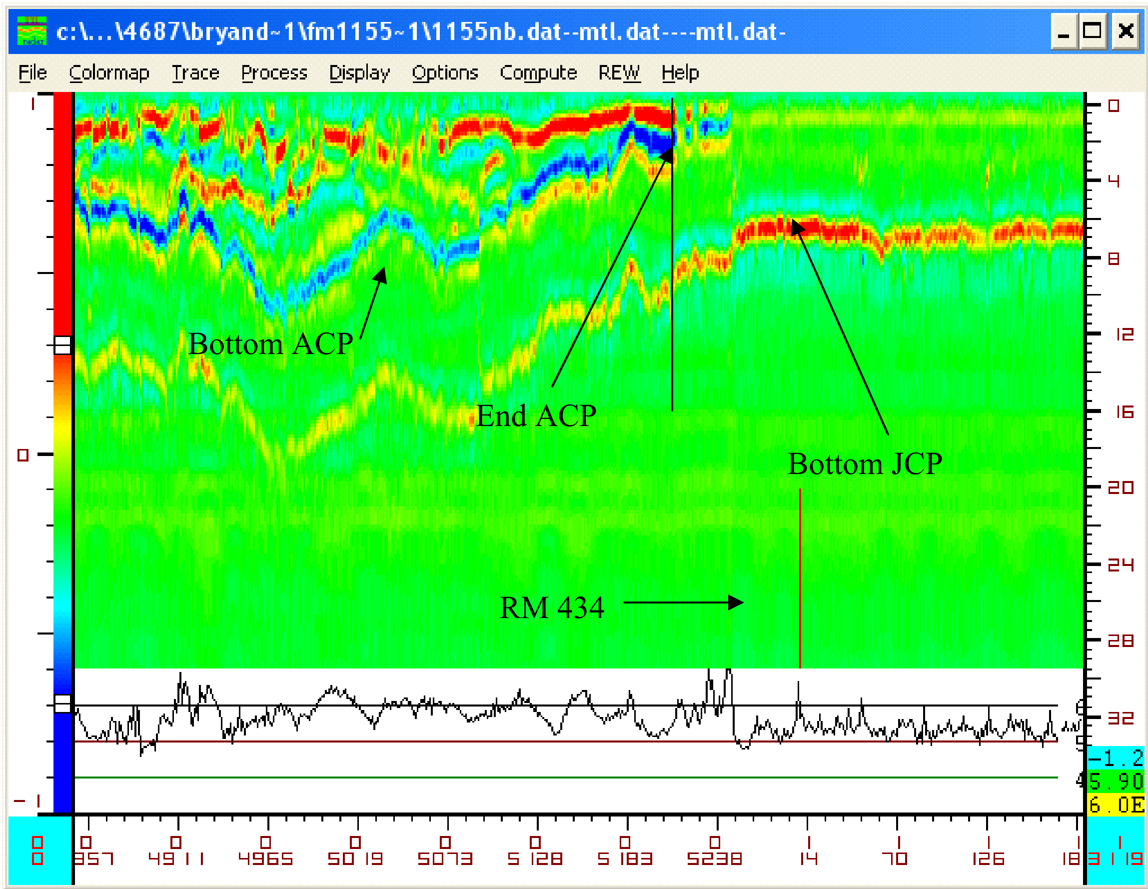


Figure 2.3. GPR Where ACP Exists over JCP on FM 912.

The GPR survey serves two primary purposes. First, the survey can identify locations of excessively wet subgrade or trapped water, both of which hinder the rubblization process. Second, the GPR survey can identify section breaks or changes in structure. In the GPR data, no locations of excessively wet subgrade were identified. The highest subgrade dielectric value was 8.7 (values above 10 can indicate excessively wet material). The only changes in structure seen were at locations where ACP has been placed on top of the JCP.

Table 2.2 shows the FWD backcalculation results for the locations with only JCP. Tables 2.3 and 2.4 show the FWD backcalculation results for the sections with ACP over JCP. The data in Table 2.4 reveal unusually low backcalculated base moduli values, indicating the JCP is severely deteriorated or possibly has been replaced with cement treated base (CTB). However, the GPR data from this section (an excerpt of which is in the left side of Figure 2.3) seem to indicate the JCP is still in place. A core should be taken within this section (between 4580 to 5250 feet north from RM 631) to verify the pavement structure.

Table 2.2. FWD Results for FM 1155 Sections with Solely JCP.

TTI MODULUS ANALYSIS SYSTEM (SUMMARY REPORT) (Version 6.0)

				MODULI RANGE (psi)				
District:	Bryan							
County:	Washington		Thickness (in)	Minimum	Maximum		Poisson Ration Values	
Highway/Road:	FM 1155 NB	Pavement:	7.50	1,000,000	5,500,000	5,500,000	H1:	v = 0.20
		Base:	0.00				H2:	v = 0.00
		Subbase:	0.00				H3:	v= 0.00
		Subgrade:	131.49 (by DB)	20,000			H4:	v= 0.40

Station	Load (lbs)	Measured Deflection (mils): R1	R2	R3	R4	R5	R6	R7	Calculated Moduli values (ksi): SURF(E1)	BASE(E2)	SUBB(E3)	SUBG(E4)	Absolute ERR/Sens	Dpth to Bedrock
0	9,152	7.26	6.35	5.17	3.97	2.96	2.2	1.71	3815.8	0	0	11.1	0.89	149.2
254	8,941	12.68	10.54	8.21	5.99	4.01	2.31	1.52	1274.5	0	0	8.7	4.08	78.6
753	8,969	8.09	7.01	5.87	4.66	3.59	2.7	2.11	3978.8	0	0	8.7	1.17	163.4
1002	9,048	6.4	5.69	4.56	3.5	2.59	1.87	1.43	4062.8	0	0	12.7	0.32	123
1250	9,021	6.74	5.61	4.35	3.09	1.98	1.06	0.58	2121.3	0	0	17.7	5.91	66.6
1500	8,894	6.94	6.23	5	3.78	2.74	1.92	1.46	3422	0	0	11.9	1.06	112.6
1754	9,176	9.67	8.3	6.81	5.21	3.7	2.56	2.11	2503.1	0	0	9.2	1.36	113.7
2002	8,897	9.09	7.75	6.08	4.61	3.32	2.4	1.76	2466.8	0	0	10	1.14	127.1
2256	8,874	7.67	6.98	5.76	4.54	3.4	2.49	1.88	3852.1	0	0	9.2	0.74	137.4
2496	9,040	9.28	8.63	7.31	5.79	4.3	3.03	2.17	3317.5	0	0	7.3	2.37	119.4
2752	9,033	6.2	5.52	4.5	3.48	2.56	1.87	1.42	4377.3	0	0	12.6	0.41	129.3
3006	9,084	7.99	7.1	5.76	4.42	3.25	2.37	1.89	3329	0	0	10.1	0.4	138.1
3260	8,953	10.67	9.76	8.44	6.9	5.44	4.17	3.24	3766.8	0	0	5.3	0.47	174.1
4000	9,052	8.89	8.39	7.33	6.13	4.89	3.72	2.9	5066.4	0	0	5.8	1.45	162.1
4251	8,977	7.19	6.58	5.44	4.34	3.28	2.47	1.97	4471.4	0	0	9.4	0.55	158.9
4528	8,905	7.21	6.5	5.39	4.28	3.32	2.54	2.04	4625.5	0	0	9.2	0.75	180.6
5250	9,116	8.98	8.08	6.96	5.63	4.31	3.11	2.3	3897.2	0	0	7.3	1.6	128.9
5502	8,798	9.81	8.83	7.29	5.5	4	3.06	2.38	2699.1	0	0	7.7	1.61	186.3
6629	8,766	9.15	8.43	7.21	5.91	4.72	3.69	2.99	4450.8	0	0	5.9	0.24	230.1
6750	8,719	9.02	8.11	6.66	5.05	3.63	2.44	1.63	2587.9	0	0	8.9	2.2	102.2
7000	8,921	9.15	8.63	7.34	5.93	4.54	3.28	2.33	3779.2	0	0	6.6	2.13	114.5
7257	8,937	9.98	8.81	7.18	5.58	4.19	3.06	2.29	2782.2	0	0	7.7	0.33	142.1
Mean:		8.55	7.63	6.3	4.92	3.67	2.65	2.01	3484	0	0	9.2	1.42	139
Std. Dev:		1.56	1.37	1.2	1.01	0.85	0.71	0.59	935.5	0	0	2.8	1.35	41.8
Var Coeff (%)		18.25	17.94	19.04	20.61	23.08	26.66	29.44	26.9	0	0	30.3	95.26	30.1

Table 2.3. FWD Results for FM 1155 Sections with Thin ACP over JCP.

TTI MODULUS ANALYSIS SYSTEM (SUMMARY REPORT) (Version 6.0)

		Thickness (in)	MODULI RANGE (psi) Minimum	Maximum		Poisson Ration Values	
District: Bryan							
County: Washington							
Highway/Road: FM 1155 NB	Pavement:	2.50	421,600	421,600	5,500,000	H1:	v = 0.35
	Base:	7.50	200,000	7,000,000		H2:	v = 0.20
	Subbase:	0.00				H3:	v= 0.00
	Subgrade:	290.00 (by DB)	20,000			H4:	v= 0.40

Station	Load (lbs)	Measured Deflection (mils): R1	R2	R3	R4	R5	R6	R7	Calculated Moduli values (ksi): SURF(E1)	BASE(E2)	SUBB(E3)	SUBG(E4)	Absolute ERR/Sens	Dpth to Bedrock
500	9,060	8.44	7.26	6.66	5.83	4.86	3.96	3.32	421.6	5657.5	0	8.2	1.51	300
3500	9,291	8.26	8.28	8.22	6.2	4.21	2.66	2.32	421.6	2394.9	0	10.8	11.78	150.4
3750	9,148	7.01	6.21	5.38	4.45	3.44	2.59	2.02	421.6	3926.1	0	13	2.05	300
6253	9,029	8.17	7.12	5.88	4.65	3.46	2.51	1.89	421.6	2102.2	0	13.2	1.96	300
6449	9,009	12.67	12.62	12.35	6.63	5.31	4.21	3.32	421.6	926.7	0	8	9.84	113.1
7452	8,917	7.84	6.46	5.13	3.93	2.89	2.13	1.68	421.6	1694.6	0	15.6	0.47	300
7758	9,052	7.06	6.33	5.32	4.28	3.25	2.39	1.81	421.6	3092.4	0	13.9	2.48	300
8009	9,128	6.41	6.39	5.44	4.39	3.38	2.54	2.01	421.6	4427.5	0	12.8	4.9	300
8249	8,850	7	6.63	5.73	4.65	3.54	2.62	2.07	421.6	3597.2	0	12.1	4.05	300
Mean:		8.1	7.48	6.68	5	3.82	2.85	2.27	421.6	3091	0	11.9	4.34	300
Std. Dev:		1.85	2.03	2.33	0.96	0.81	0.72	0.62	0	1475.8	0	2.5	3.93	117.8
Var Coeff (%):		22.87	27.21	34.93	19.19	21.11	25.4	27.33	0	47.7	0	21.3	90.55	44.2

Table 2.4. FWD Results for FM 1155 with Thick ACP over JCP.

TTI MODULUS ANALYSIS SYSTEM (SUMMARY REPORT) (Version 6.0)

		Thickness (in)	MODULI RANGE (psi) Minimum	Maximum		Poisson Ration Values	
District: Bryan							
County: Washington							
Highway/Road: FM 1155 NB	Pavement:	8.00	160,000	720,000	5,500,000	H1:	v = 0.35
	Base:	7.50	100,000	500,000		H2:	v = 0.20
	Subbase:	0.00				H3:	v= 0.00
	Subgrade:	144.80 (by DB)	20,000			H4:	v= 0.40

Station	Load (lbs)	Measured Deflection (mils): R1	R2	R3	R4	R5	R6	R7	Calculated Moduli values (ksi): SURF(E1)	BASE(E2)	SUBB(E3)	SUBG(E4)	Absolute ERR/Sens	Dpth to Bedrock
4753	8,925	14.81	13.13	10.88	8.6	6.34	4.34	3.22	633.7	100	0	5.1	3.62	118.4
5000	9,096	11.08	9.05	7.38	5.87	4.52	3.53	2.89	496.4	300.1	0	7.1	0.63	248
Mean:		12.95	11.09	9.13	7.24	5.43	3.94	3.06	565.1	200	0	6.1	2.13	160.3
Std. Dev:		2.64	2.88	2.47	1.93	1.29	0.57	0.23	97.1	141.5	0	1.4	2.11	56.7
Var Coeff (%):		20.37	26.01	27.11	26.7	23.7	14.6	7.64	17.2	70.7	0	23.4	99.4	35.4

After studying FWD results in the field, researchers performed DCP tests at selected locations to verify whether adequate subgrade support exists. These data are used in the rubblization selection chart developed by the Illinois DOT. The DCP data allow for evaluation of two governing parameters:

- *Support immediately beneath the slab*: If there is inadequate support immediately beneath the slab, rubblization may not be feasible. To evaluate the project for this parameter, the concrete thickness versus the CBR of the base layer immediately beneath the slab is plotted. In instances where the DCP data did not reveal a clear layer distinction, a dummy base layer value of 6 inches was assigned.

- *Support at deeper depths into the subgrade*: Even if support is sufficient immediately beneath the slab for concrete breakage, weak soils deeper in the pavement can create problems. Shear failures can occur particularly with the resonant breaker equipment due to the multiple passes required over the rubblized pavement to break the entire pavement width. To evaluate this parameter, the combined thickness of the concrete and base is plotted against the CBR value of the first 6 inches of subgrade.

Table 2.5 summarizes the DCP results for use in the Illinois DOT rubblization selection chart. Figure 2.4 shows the DCP data in this chart. The DCP data, in conjunction with the IDOT criteria, indicate:

- The location at DCP 1 is of questionable suitability for rubblization due to marginal support immediately beneath the slab.
- The locations represented by DCP tests 2, 3, and 4 are suitable for rubblization.
- At the location of DCP 5, support is inadequate for rubblization; the concrete may not break. Additionally, due to the poor support, even if the concrete does break, if the resonant breaker was used, the multiple passes may result in shear failure of the subgrade.
- At the locations of DPC 6 and 7, the project is marginally suitable for rubblization. This is because although reasonable support exists immediately beneath the slab, the subgrade quality quickly deteriorates with depth. Again, depending on equipment used, shear failure in the subgrade could occur from loading stresses from the construction equipment.

Table 2.5. Summary DCP Results for FM 1155.

DCP Test Location	Concrete Thickness (in)	Base Thickness (in)	CBR Values		Subgrade Modulus from FWD (ksi)	Location (feet north from RM 631 on FM 912)	Comment
			Base	Subgrade			
1	7.5	6*	5.5	3.8	8.2	500	~ 2.5" ACP over JCP
2	8.5	6*	66	133.0	12.7	1002	
3	7.4	4.3	15.5	7.5	10.1	3006	
4	7.0	6*	15.8	12.6	5.3	3260	
5	7.0	6*	3	2.6	7.1	5000	~ 8" ACP over JCP**
6	7.1	5.9	9.0	2.2	8.9	6750	
7	7.4	4.1	8.5	2.4	7.7	7257	

*Assigned to 6 inches because no clear base layer boundary observed in DCP data

**FWD indicates JCP either severely deteriorated or perhaps replaced with CTB

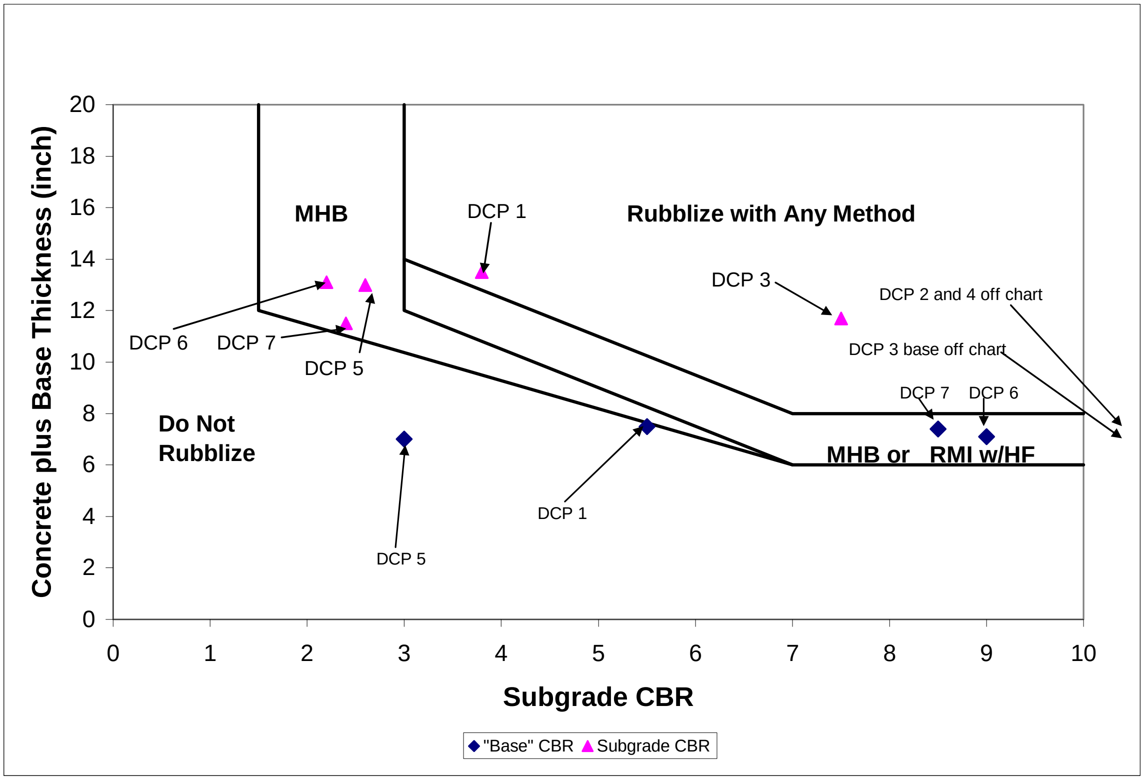


Figure 2.4. DCP Results from FM 1155 on IDOT Rubblization Selection Chart.

Because the DCP testing is spot-specific, efforts were made to use the FWD data to better partition the project into limits where rubblization may be an option. To accomplish this segmenting, the minimum recommended subgrade CBR that would enable the concrete to be broken was read from Figure 2.4. For the concrete thickness on FM 1155 (~7.5 inches), a subgrade CBR of approximately 6 would be required. Next, a relationship between the FWD and average CBR of the top 12 inches of subgrade was evaluated as shown in Figure 2.5. With all the data, a poor fit exists. When the two outliers are trimmed, as shown in Figure 2.6, a better fit exists. The data in Figure 2.5 indicate a minimum backculated modulus of approximately 7.5 is needed; the trimmed data in Figure 2.6 indicate a backcalculated subgrade modulus of approximately 8.5 is necessary. The two methods of analysis are in reasonable agreement with each other, and it seems reasonable that for analysis purposes, the minimum required backcalculated subgrade modulus can be estimated as approximately 8.

Figure 2.7 shows the backcalculated subgrade modulus with distance for the project. Using the approximate minimum subgrade CBR of 8, rubblization may not be feasible for approximately one third of the project. With the FWD analysis in conjunction with the DCP analysis, the greatest risk of encountering problems if rubblization is attempted exists between 4580 to 5250 feet north of RM 631 on FM 912.

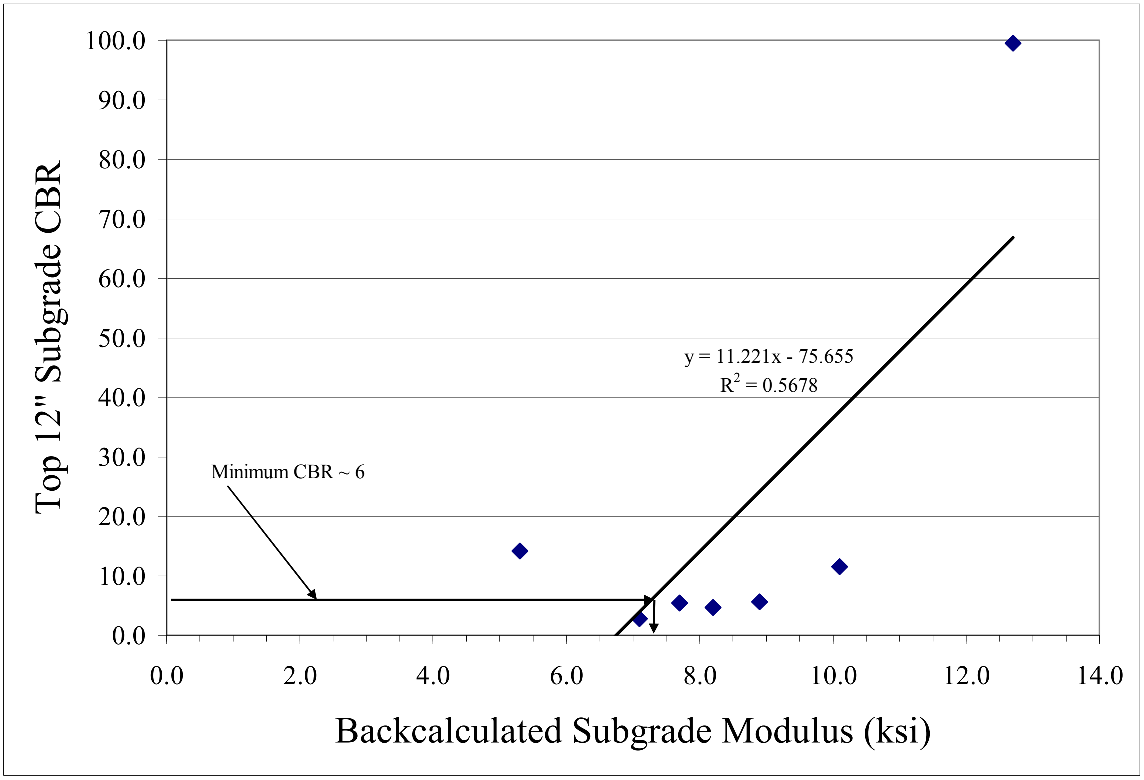


Figure 2.5. Subgrade CBR vs. Subgrade Modulus for FM 1155.

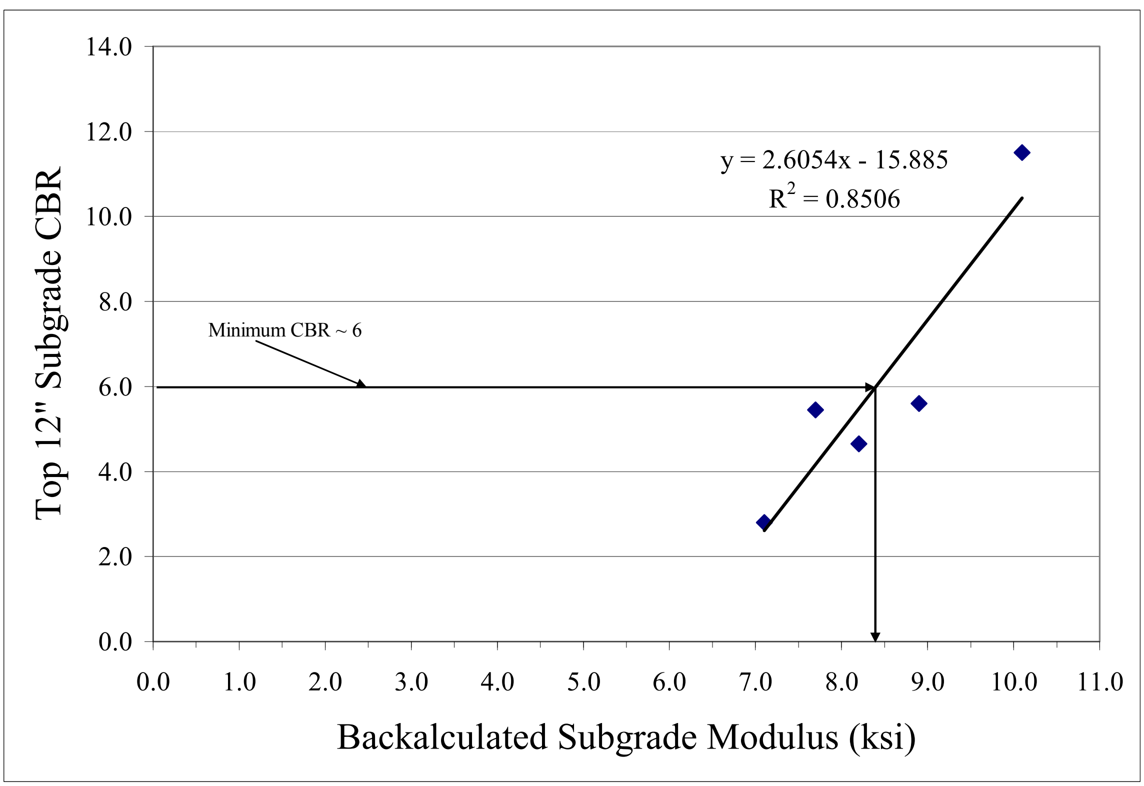


Figure 2.6. Subgrade CBR vs. Subgrade Modulus with Trimmed Data for FM 1155.

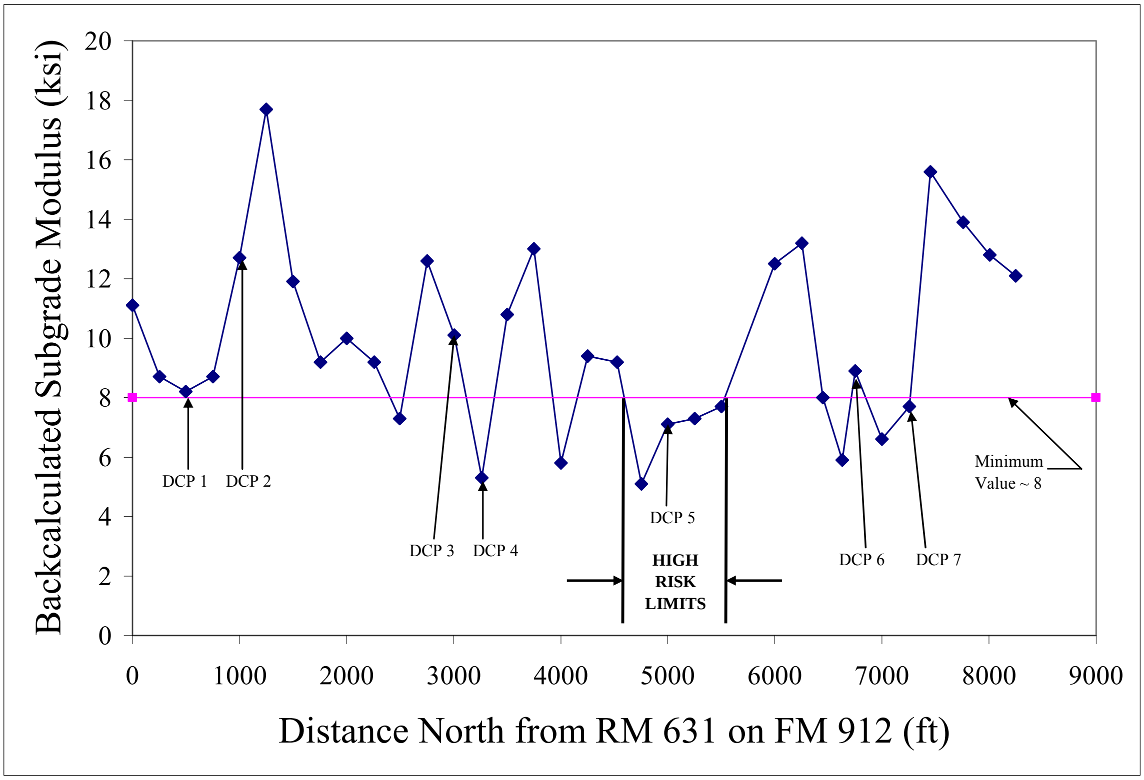


Figure 2.7. FM 1155 Backcalculated Subgrade Modulus with Distance (NB direction). Note: Zero Distance is at RM 631 on FM 912.

RECOMMENDATION

Based upon the results presented and discussed above, the majority of the JCP on FM 1155 is of marginal suitability for rubblization. Using RM 631 on FM 912 as the zero distance point, the data indicate the following:

- The first 1000 feet are of questionable suitability for rubblization.
- From 1000 to 4550 feet, the project should be suitable for rubblization.
- From 4550 to 5250 feet, the subgrade support is likely too poor to support rubblization operations. A core should be taken at 5000 feet to verify the pavement structure.
- From 5250 feet to the end of the JCP, the project is marginally suitable for rubblization.
- Given the soil conditions, the multi-head breaker likely is the safest equipment to use if rubblization is attempted.

CHAPTER 3
INVESTIGATION OF LOOP 288 FOR RUBBLIZATION

SUMMARY

In efforts to identify potential rehabilitation strategies for Loop 288 in Denton, researchers conducted a field investigation in November 2005 to investigate if rubblization would be an option for the JCP pavement. The section investigated is between FM 428 and US 380. Based upon GPR, FWD, and DCP results, the pavement is an excellent candidate for rubblization. Additionally, a subsequent forensic investigation in January 2006 revealed the cause of the cracking in the pavement is due to a construction problem. The pavement did not crack at the saw-cuts as designed.

RESULTS FROM FIELD INVESTIGATION

The section under investigation on Loop 288 was accepted in December 1987. According to plans the structure consists of:

- 9 inch continuously placed contraction design (CPCD) concrete,
- approximately 440 lb/sy (~4 inches) asphalt-stabilized base, and
- approximately 17 inches embankment with top 8 inches stabilized with 4 percent lime.

Within the section, substantial longitudinal cracking exists, such as illustrated in Figure 3.1. To evaluate if the Loop 288 project is suitable for rubblization, TTI performed a field analysis using GPR, FWD, and DCP testing. Figure 3.2 illustrates representative GPR data from the project. The GPR data could not distinguish the bottom of the lime-treated subgrade (LTS); however, the thicknesses observed in the GPR data for the concrete and asphalt-stabilized base (ASB) layers correspond well with the plan thicknesses.

The GPR survey serves two primary purposes. First, the survey can identify section breaks. Second, the GPR survey can identify locations of excessively wet subgrade or trapped water, both of which hinder the rubblization process. In the survey, the signal from the LTS was lost at locations of slab replacement. From discussions with area office personnel, it is believed the change in signal is due to undercutting the subgrade and placement of hot-mix asphalt beneath the new slabs. Figure 3.3 shows one of the section breaks at a location of slab replacement. No non-typical GPR traces were seen other than at locations of slab replacements. The GPR data did not indicate any locations of excessive moisture, which, if present, can hinder rubblization activities.

Figure 3.1. Pavement Distress on Loop 288.

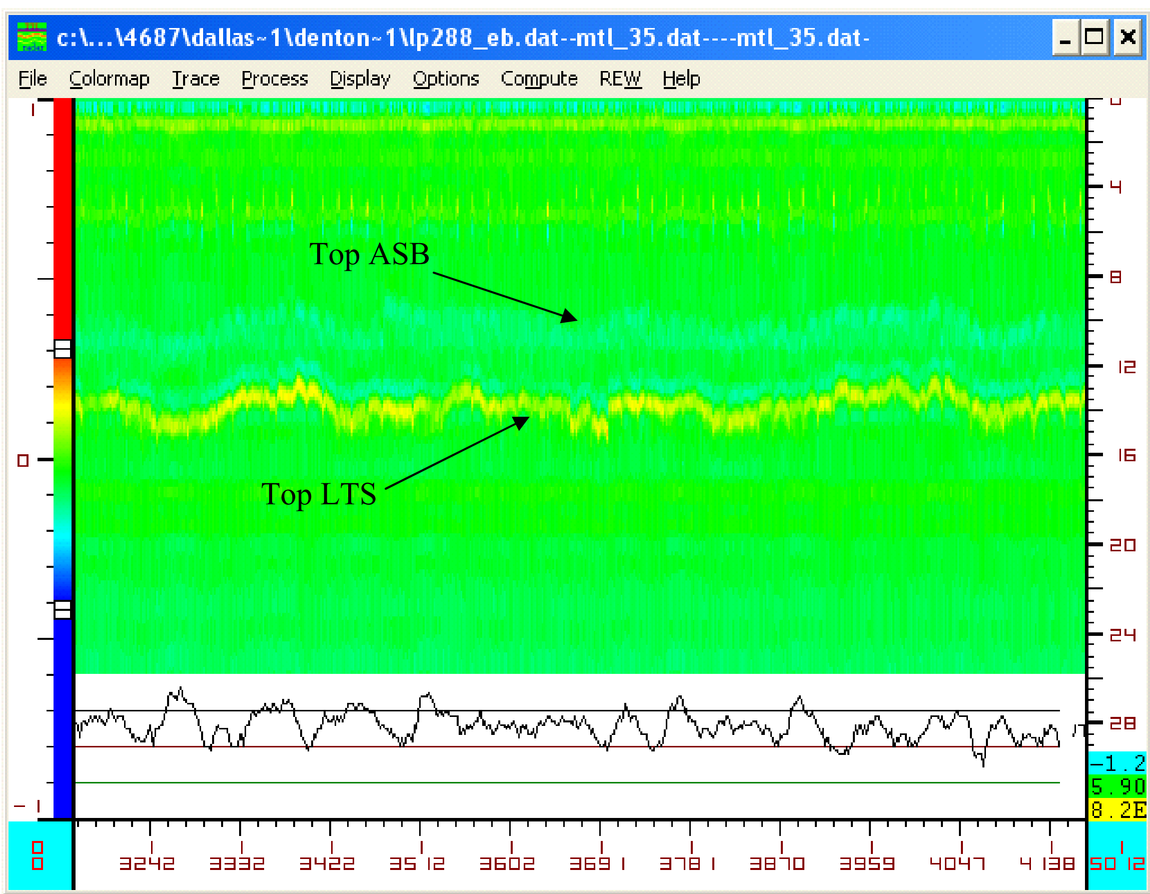


Figure 3.2. Representative GPR Data from Loop 288.

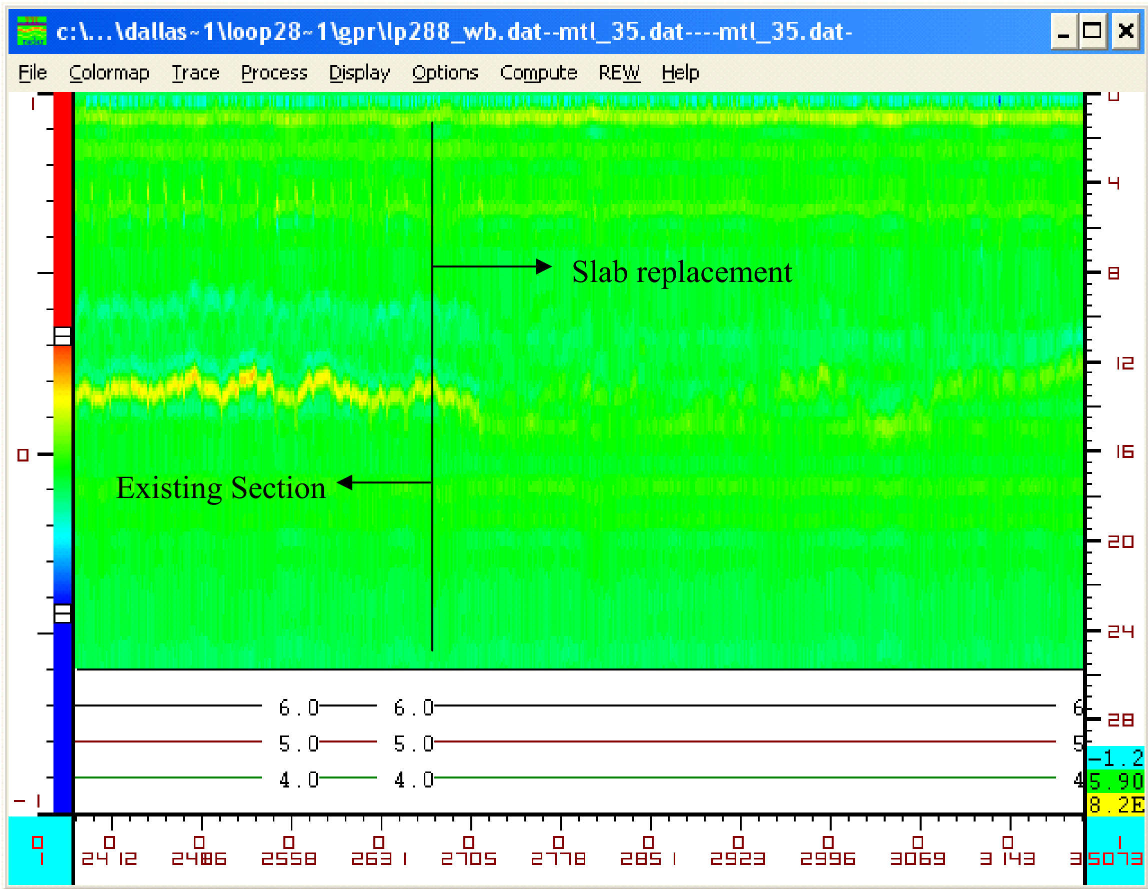


Figure 3.3. Section Break at Location of Slab Replacement in Westbound Travel Direction.

Tables 3.1 and 3.2 show the FWD backcalculation results for the Loop 288 project. Current thinking suggests a minimum value of 10 ksi for the subgrade modulus in order for rubblization to be an option. As evidenced by the data in Tables 3.1 and 3.2, nearly all the backcalculated subgrade moduli values exceed this minimum. However, verification with DCP testing is still necessary to ensure adequate soil support exists. After studying FWD results in the field, TTI selected several locations to perform DCP tests at the project site. Researchers performed DCP tests only conducted in the eastbound (EB) travel direction. Table 3.3 summarizes the DCP results. The results show the condition of the lime layer was excellent, and the untreated embankment and native subgrade soil were good. The Illinois DOT developed a rubblization selection chart to aid in evaluating a project's suitability for rubblization. This chart uses the CBR of the top 12 inches of subgrade (divided into two 6 inch layers) along with the combined concrete and base thickness as an indicator of the project's suitability for rubblization. Figure 3.4 shows this chart, and as evidenced by the data in Table 3.3, the CBR values of the subgrade were typically greater than 10, off the scale of the IDOT chart. Therefore, based on existing guidelines, this project is suitable for rubblization.

Table 3.1. FWD Results for Loop 288 EB.

TTI MODULUS ANALYSISI SYSTEM (SUMMARY REPORT) (Version 6.0)

District:18 (Dallas)
County: 61 (Denton)
Highway/Road: sl0288

		MODULI RANGE (psi)		Poisson Ratio Values
	Thickness(in)	Minimum	Maximum	
Pavement:	9.00	2,000,000	8,000,000	H1: v = 0.2
Base:	4.00	50,000	1,000,000	H2: v=0.35
Subbase:	0.00			H3: v=0.00
Subgrade:	118.93 (by DB)	15,000		H4: v=0.4

Station	Load (lbs)	R1	R2	R3	Measured Deflection (mils) R4	R5	R6	R7	SURF(E1)	BASE(E2)	Calculated Moduli Values (ksi) SUBB(E3)	SUBG(E4)	Absolute ERR/Sens	Dpth to Bedrock
0	9,656	4.32	3.79	3.11	2.36	1.71	1.32	0.88	3465.6	201.5	0	18.3	1.63	85.7
317	9,712	2.7	2.5	2.2	1.82	1.53	1.24	1.04	8000	457.7	0	19.8	4.36	300.0 *
666	9,664	2.39	2.22	1.93	1.59	1.32	1.11	0.91	8000	561.7	0	23.8	5.29	142.6 *
952	9,752	2.64	2.39	2.06	1.67	1.34	1.07	0.83	8000	750.6	0	21.5	0.98	110.6 *
1196	9,668	3.83	3.6	3	2.33	1.82	1.42	1.08	5393.2	166	0	16.4	1.94	117.7
1956	9,692	3.11	2.89	2.57	2.15	1.8	1.48	1.2	8000	983.1	0	14.4	1.28	142.5 *
2411	9,696	3.2	3	2.64	2.16	1.78	1.46	1.14	8000	364.6	0	15.7	1.98	120.7 *
2420	9,704	3.59	3.45	2.88	2.29	1.81	1.44	1.11	6050	365.2	0	15.8	2.04	120.1
2744	9,819	2.89	2.67	2.32	1.94	1.61	1.34	1.07	8000	533.7	0	17.9	3.66	125.6 *
2985	9,672	3.2	2.96	2.57	2.13	1.75	1.48	1.19	8000	354.4	0	15.9	2.24	137.2 *
2994	9,644	3.14	3.21	2.64	2.1	1.65	1.36	1.09	7829.8	217.7	0	16.5	3.47	143.4
3318	9,565	3.96	3.83	3.23	2.56	1.98	1.63	1.28	5217.3	428.5	0	13.8	2.76	137.2
3620	9,668	4.04	3.72	3.06	2.39	1.87	1.52	1.23	4462.4	442.9	0	15.7	2.27	164.9
3910	9,672	2.54	2.28	2.02	1.72	1.44	1.24	1.03	8000	413.2	0	22.2	7.3	149.4 *
4228	9,628	3.98	3.82	3.44	3	2.59	2.34	2.05	8000	542.1	0	9.4	3.68	300.0 *
4503	9,652	2.68	2.48	2.22	1.85	1.53	1.3	1.06	8000	457.7	0	19.6	5.19	141.9 *
4789	9,672	3.35	3.14	2.75	2.29	1.91	1.56	1.28	7879.6	876.8	0	13.3	0.81	159.4
5139	9,620	5.48	5.01	4.22	3.35	2.65	2.07	1.57	3459.8	334.4	0	11	1.11	125.1
5429	9,597	2.93	2.63	2.2	1.77	1.39	1.15	0.91	6251.3	860.8	0	20.4	1.83	124.8
5779	9,648	2.31	2.05	1.72	1.37	1.09	0.91	0.74	8000	1000	0	26.4	2.17	136.7 *
6097	9,617	2.54	2.4	2.07	1.69	1.36	1.15	0.93	8000	561.7	0	21.2	3.31	135.9 *
6107	9,632	3.07	2.95	2.37	1.82	1.39	1.14	0.91	6564.6	102.3	0	21.3	3.42	300
6430	9,708	2.74	2.46	2.15	1.77	1.42	1.24	0.99	8000	561.7	0	20.3	2.95	300.0 *
6716	9,720	3.23	3.03	2.53	2.04	1.65	1.39	1.14	7849.8	353.1	0	16.6	2.3	161.8
7094	9,656	3.15	2.91	2.48	1.99	1.59	1.25	0.97	7346	332.9	0	18	0.99	118
7289	9,732	2.6	2.34	1.98	1.59	1.27	1.04	0.83	8000	713.2	0	22.7	1.46	126.5 *
7624	9,692	2.61	2.38	2.07	1.69	1.39	1.09	0.87	8000	561.7	0	21.5	2.48	125.9 *
7631	9,783	3.17	3.03	2.39	1.84	1.4	1.07	0.83	5813.9	105.2	0	22.6	2.31	120.5
8224	9,668	2.81	2.53	2.17	1.75	1.44	1.14	0.93	8000	561.7	0	20.1	1.06	148.2 *
8513	9,803	3.16	3.06	2.69	2.27	1.91	1.61	1.34	8000	413.2	0	14.7	4.08	171.0 *
8889	9,672	2.74	2.54	2.1	1.61	1.24	0.96	0.71	7259.2	114.9	0	24.7	1.95	98.9
9205	9,605	2.35	2.43	2.04	1.62	1.29	1.07	0.83	8000	654.9	0	22.6	4.38	113.1 *
9212	9,720	2.37	2.28	1.95	1.56	1.26	0.98	0.79	8000	654.9	0	24.3	2.73	134.0 *
9528	9,656	4.89	4.47	3.74	2.96	1.87	1.59	1.29	3332.6	95.6	0	15.4	5.07	81.4
Mean:		3.17	2.95	2.52	2.03	1.62	1.33	1.06	7064	473.5	0	18.6	2.78	131.9
Std. Dev:		0.73	0.68	0.56	0.45	0.35	0.3	0.26	1507.2	244.8	0	4.1	1.49	35.8
Var Coeff (%):		23.18	22.98	22.27	22.06	21.33	22.61	24.59	21.3	51.7	0	21.8	53.75	27.2

Table 3.2. FWD Results for Loop 288 WB.

TTI MODULUS ANALYSISI SYSTEM (SUMMARY REPORT) (Version 6.0)

District:18 (Dallas)
County: 61 (Denton)
Highway/Road: sl0288

MODULI RANGE (psi)

	Thickness(in)	Minimum	Maximum	Poisson Ratio Values
Pavement:	9.00	2,000,000	8,000,000	H1: v = 0.2
Base:	4.00	50,000	1,000,000	H2: v=0.35
Subbase:	0.00			H3: v=0.00
Subgrade:	118.93 (by DB)		15,000	H4: v=0.4

Station	Load (lbs)	Measured Deflection (mils) R1	R2	R3	R4	R5	R6	R7	Calculated Moduli Values (ksi) SURF(E1)	BASE(E2)	SUBB(E3)	SUBG(E4)	Absolute ERR/Sens	Dpth to Bedrock
0	9,851	2.35	2.29	1.97	1.61	1.32	1.07	0.86	8000	561.7	0	27	4.42	128.0 *
513	9,617	2.74	2.61	2.28	1.87	1.59	1.3	1.06	8000	561.7	0	20.6	3.32	146.9 *
1046	9,605	2.26	2.13	1.75	1.34	1.06	0.85	0.68	8000	373.4	0	31.8	2.71	130.6 *
1380	9,632	3.49	3.15	2.6	2.02	1.58	1.24	0.96	5566.6	102.2	0	21.7	1.41	122.2
2003	9,609	2.68	2.39	2	1.61	1.3	1.03	0.84	6859.5	774.3	0	25.3	1.01	144.2
2590	9,620	2.62	2.41	2.09	1.76	1.44	1.21	0.99	8000	701.1	0	22.5	3.03	139.4 *
2985	9,640	2.31	2.07	1.74	1.41	1.12	0.95	0.79	8000	1000	0	28.6	1.98	300.0 *
3514	9,652	1.96	1.89	1.57	1.26	1.03	0.87	0.71	8000	134	0	36.6	7.49	134.3 *
4256	9,624	2.38	2.13	1.8	1.44	1.17	0.94	0.76	7800.4	1000	0	27.7	1.13	133.3 *
4529	9,573	2.98	2.78	2.43	2.03	1.61	1.37	1.04	8000	561.7	0	18.6	1.79	300.0 *
5001	9,620	2.4	2.24	1.93	1.57	1.29	1.06	0.85	8000	561.7	0	26.5	3.29	127.3 *
5489	9,700	8.98	8.38	7.11	5.68	4.48	3.58	2.75	2181.8	207.5	0	7.2	1.54	154
6019	9,696	2.48	2.3	1.96	1.57	1.29	1.06	0.88	8000	571.3	0	25.8	2.48	163.6 *
6505	9,644	2.57	2.48	2.1	1.7	1.38	1.17	0.94	8000	701.1	0	22.8	2.72	132.6 *
7009	9,605	3.17	2.94	2.56	2.11	1.76	1.43	1.15	8000	562.7	0	17.2	0.91	138.7 *
7507	9,565	2.49	2.47	2.17	1.78	1.52	1.22	0.99	8000	114.5	0	24.1	6.9	140.4 *
7949	9,744	2.49	2.26	1.95	1.62	1.25	1.11	0.83	8000	561.7	0	26.3	3.27	300.0 *
8572	9,617	2.69	2.52	2.12	1.68	1.31	0.98	0.7	7748.7	119	0	25.8	1.61	88.3
9028	9,557	3.96	3.7	3.11	2.49	2.06	1.65	1.36	5368.4	473.3	0	15.3	1.42	186.3
Mean:		3	2.8	2.38	1.92	1.56	1.27	1.01	7343.4	507.5	0	23.8	2.76	153.6
Std. Dev:		1.52	1.42	1.2	0.96	0.75	0.6	0.45	1489.1	276	0	6.4	1.83	42.2
Var Coef (%):		50.68	50.64	50.43	49.72	48.32	46.95	45.09	20.3	54.4	0	26.9	66.41	27.5

Table 3.3. Summary DCP Results from Loop 288.

Hole	Subgrade CBR 0-6"	Subgrade CBR 6-12"	Native Subgrade CBR (>30" beneath surface)	Subgrade Modulus from FWD (ksi)	Location (feet east from FM 428)
1	61.0	7.2	5.9	15.7	2411
2	45.2	31	18.9	13.8	3318
3	>100	14	19.7	9.4	4228
4	>100	14.8	13.0	11	5139
5	>100	>100	6.2	22.7	7289
6	non-penetrable by DCP	11.2	8.2	24.3	9212

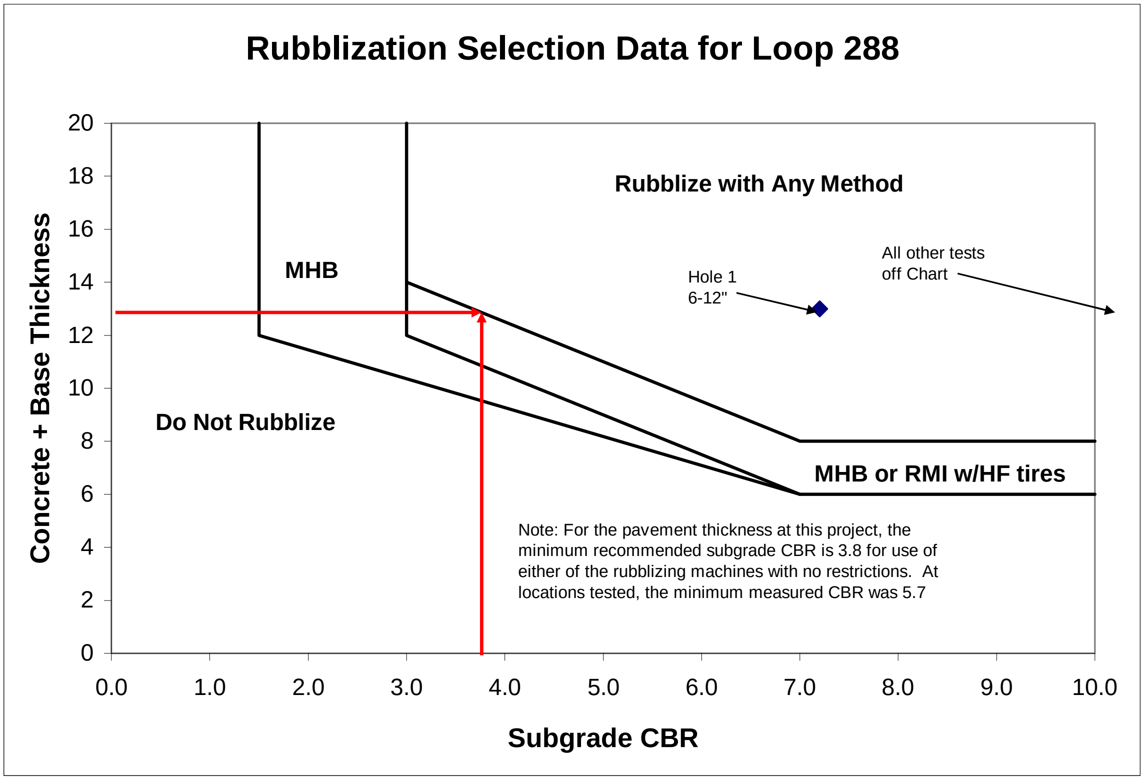


Figure 3.4. DCP Results from Loop 288 on IDOT Rubblization Selection Chart.

CAUSE OF PAVEMENT DISTRESS

In an effort to determine the cause of the distress on Loop 288, a forensic investigation was conducted in January 2006. Two cores were taken as illustrated in Figure 3.5. The first core, shown in Figure 3.6, was collected 4230 feet east of FM 428 and was taken directly over the sawcut at the outside shoulder. This core revealed the concrete did not crack as intended at the sawcut. The second core, collected 4320 feet east of FM 428 and taken from directly over a longitudinal crack, revealed that the cracking is confined to the concrete layer. Figures 3.7 and 3.8 show that the ASB is not cracked where there is a longitudinal crack in the concrete. Therefore, based upon this investigation, researchers concluded the primary cause of distress on Loop 288 is due to a construction problem: the concrete did not crack at the sawcuts as designed.

In the course of the forensic investigation, the Atterberg limits of the embankment and native subgrade were measured, and both soils were also checked for soluble sulfates. The plastic index (PI) of the embankment was 17, and the PI of the native subgrade was 25. In both soils, no soluble sulfates were detected.

Figure 3.5. Preparing to Core over Longitudinal Crack on Loop 288.

Figure 3.6. Core over Saw Cut on Loop 288.
Note that the concrete did not crack at the sawcut.

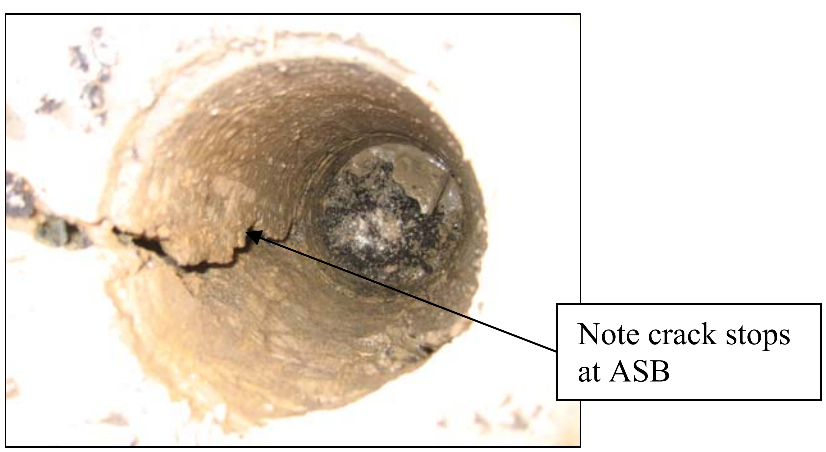


Figure 3.7. Coring Hole over Longitudinal Crack.

Figure 3.8. Core Collected over Longitudinal Crack.
Note the cracking is confined to the concrete layer.

RECOMMENDATION

Based upon the results presented and discussed above, the Loop 288 project between FM 428 and US 380 is suitable for rubblization. Due to the pavement structure, the resonant machine may be a better method to rubblize this pavement. A forensic investigation revealed the primary cause of distress in the pavement is due to construction problems: the pavement did not crack at the saw-cut joints as designed, resulting in uncontrolled cracking in the concrete layer.

CHAPTER 4
INVESTIGATION OF LOOP 12 FOR RUBBLIZATION

SUMMARY

In efforts to identify potential rehabilitation strategies for Loop 12 between Jim Miller Road and US 175 in the Dallas TxDOT District, TTI conducted a field investigation to evaluate whether rubblization would be an option for the JCP pavement. Based upon GPR, FWD, and DCP results, the project is suitable for rubblization. The project has sufficient concrete thickness and subgrade support to adequately support rubblization activites with either of the two primary rubblizers (RMI and MHB). The only potential concern observed was a few locations of wet subgrade. Testing at these locations still revealed suitable subgrade support exists. However, it is possible that the vibrating action of the RMI machine could pump water; therefore, if rubblization is pursued using the RMI equipment, consideration should be given to installing edge drains prior to rubblization.

RESULTS FROM FIELD INVESTIGATION

Based on the field investigation the structure consists of approximately 1 to 2.5 inches of HMA over approximately 10 inches of JCP pavement. Figure 4.1 illustrates the general pavement condition. To evaluate if the project is suitable for rubblization, TTI performed a field analysis using GPR, FWD, and DCP data. Figure 4.2 shows the GPR data from the EB travel direction. Figure 4.3 shows a typical single GPR trace used to estimate pavement layer thicknesses and dielectric values.

The GPR survey serves two primary purposes. First, the GPR survey can identify section breaks or changes in structure. Second, the survey can identify locations of excessively wet subgrade or trapped water, both of which hinder the rubblization process. As Figure 4.2 shows, the structure appears consistent throughout the project limits. In the GPR data, the subgrade dielectric values ranged from 6.8 to 12.1 with an average value of 9.0. Values greater than 10 typically indicate excessively wet material. The subgrade dielectric value exceeded 10 in a few sections of the project, as Figure 4.4 illustrates. DCP at selected locations verified the existence of wet subgrade beneath the JCP as Figure 4.5 illustrates. Although the GPR data were collected in August 2004 and the DCP testing performed in February 2006, there appears to be reasonable agreement between the locations of high dielectric values and the observance of wet soil in the DCP tests.

Figure 4.1. Representative Pavement Condition on Loop 12.

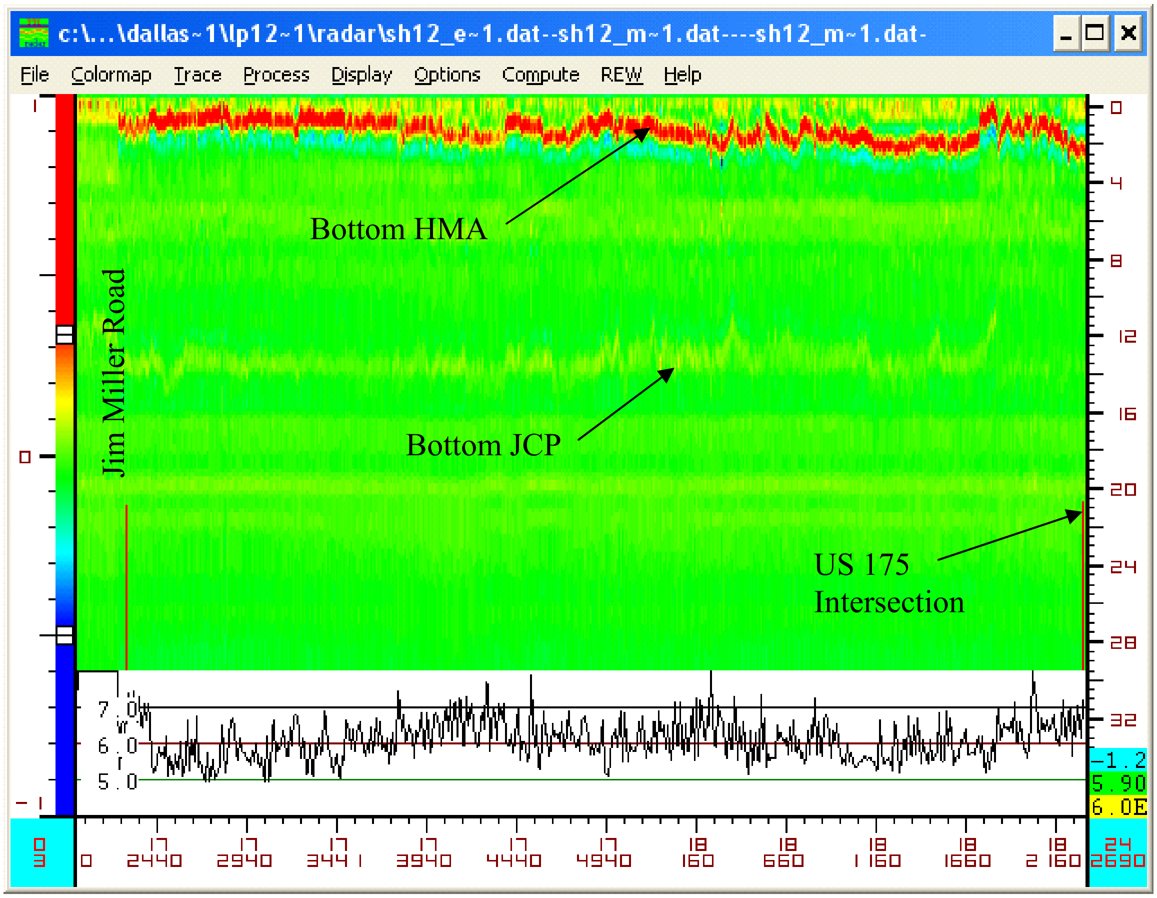


Figure 4.2. GPR Data on Loop 12 EB.

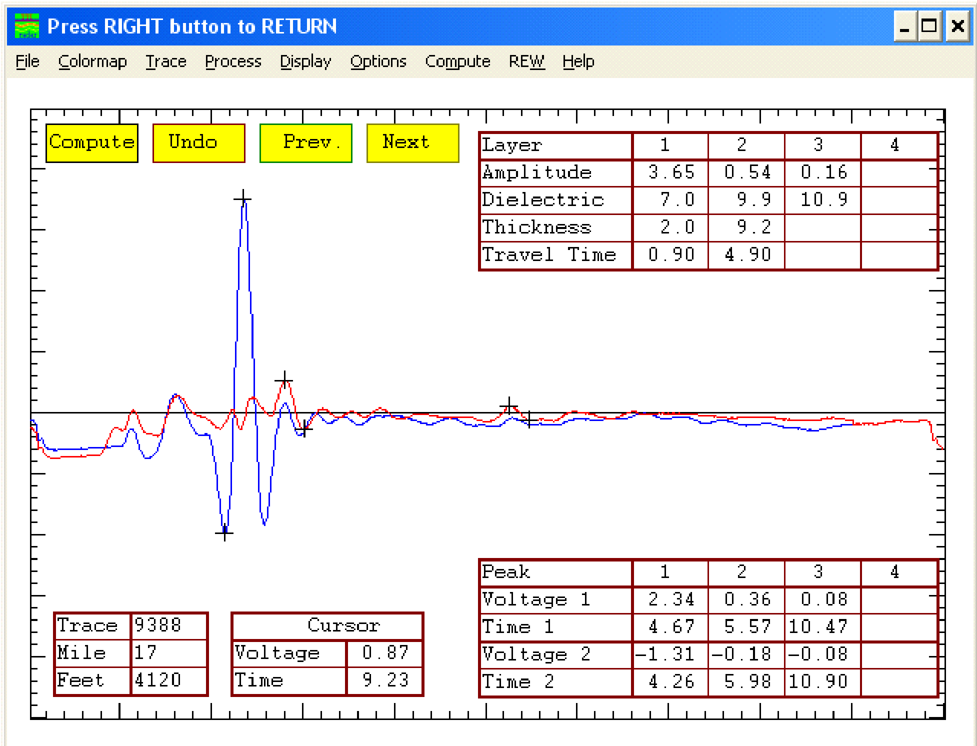


Figure 4.3. Example GPR Trace from Loop 12.

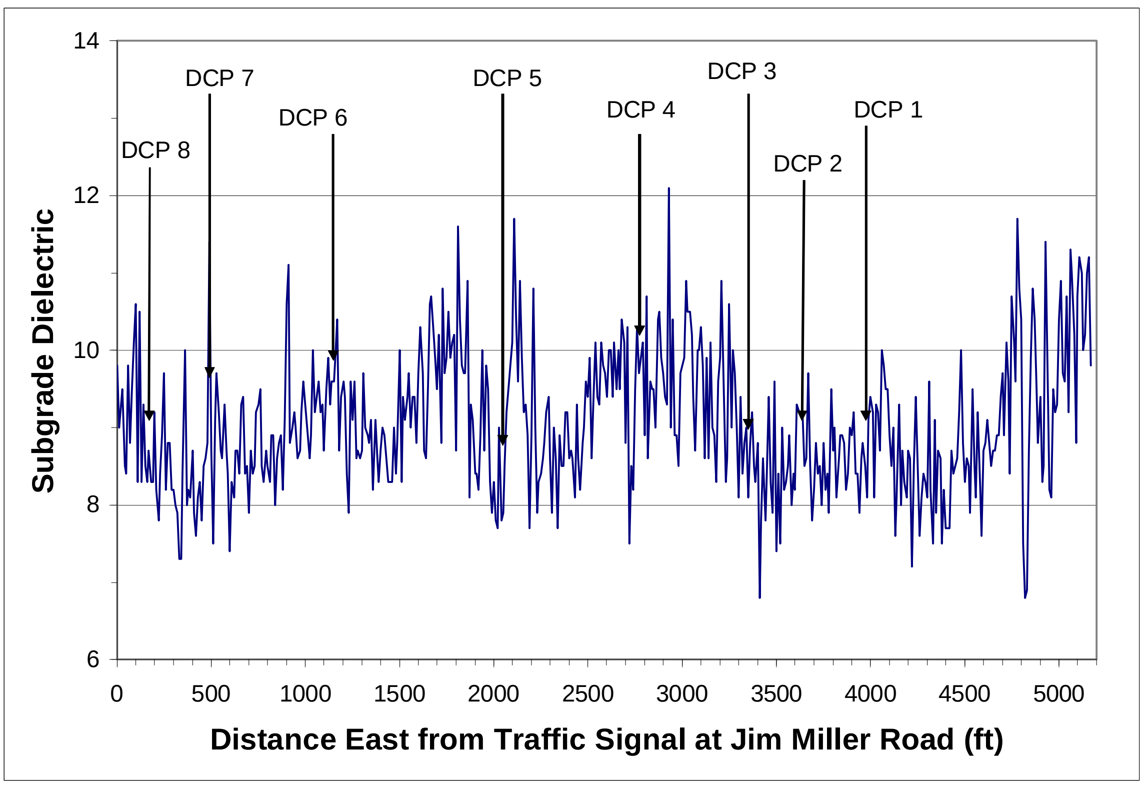


Figure 4.4. Sugrade Dielectric Value on Loop 12 Project.
Note: Soil at DCP 4 and DCP 6 visibly wet on DCP rod when tested with DCP.

Figure 4.5. Wet Subgrade Soil on DCP Rod after Test at Location DCP 6.

Table 4.1 shows the FWD backcalculation results for the FM 912 project. From prior experience, typically a minimum subgrade modulus value between 10 and 15 is needed for the subgrade to support rubblization. The FWD data only revealed a few locations of subgrade moduli at the low end of this criteria range. However, the correlation between stiffness and bearing capacity is not always very reliable, so spot testing with the DCP is performed to verify if adequate subgrade support exists. Based upon the FWD results, DCP test locations were chosen to represent the spectrum of observed subgrade moduli values. Table 4.2 summarizes the DCP results.

The Illinois DOT developed a rubblization selection chart to aid in evaluating a project's suitability for rubblization. This chart uses the CBR of the top 12 inches of subgrade (divided into two 6-inch layers) along with the combined concrete and base thickness as an indicator of the project's suitability for rubblization. Figure 4.6 shows this chart with the Loop 12 data. In all cases, the data indicate that rubblization with any method should be feasible. Little concern exists regarding the ability of the pavement to support rubblization activities.

Table 4.1. FWD Results for Loop 12.

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TTI MODULUS ANALYSIS SYSTEM (SUMMARY REPORT) (Version 6.0)

District:18 (Dallas)
County :57 (DALLAS)
Highway/Road: sl0012

	Thickness(in)	MODULI RANGE(psi) Minimum	Maximum	Poisson Ratio Values
Pavement:	2.00	663,400	663,400	H1: v = 0.35
Base:	10.00	2,000,000	7,000,000	H2: v = 0.20
Subbase:	0.00			H3: v = 0.00
Subgrade:	288.00(by DB)	20,000		H4: v = 0.40

Station	Load (lbs)	Measured Deflection (mils): R1	R2	R3	R4	R5	R6	R7	Calculated Moduli values (ksi): SURF(E1)	BASE(E2)	SUBB(E3)	SUBG(E4)	Absolute ERR/Sens	Dpth to Bedrock
6.000	9,823	4.10	3.67	3.17	3.54	2.07	1.65	1.35	663.4	3724.0	0.0	22.3	1.71	300.0
334.000	9,791	3.05	2.98	2.63	2.90	1.74	1.46	1.20	663.4	6728.3	0.0	24.2	3.88	300.0
647.000	9,716	2.80	2.61	2.31	2.51	1.63	1.39	1.17	663.4	7000.0	0.0	27.2	3.09	300.0 *
978.000	9,787	2.65	2.56	2.29	2.43	1.65	1.37	1.15	663.4	7000.0	0.0	28.6	5.28	300.0 *
1308.000	9,736	5.92	6.06	5.70	5.14	4.40	3.74	3.18	663.4	7000.0	0.0	7.8	5.19	300.0 *
1612.000	9,752	5.60	5.45	4.91	5.19	3.43	2.91	2.37	663.4	4217.3	0.0	11.6	2.59	300.0
1947.000	9,819	3.07	3.03	2.76	2.88	2.00	1.71	1.44	663.4	7000.0	0.0	22.3	5.18	300.0 *
2251.000	9,879	4.13	4.06	3.65	4.11	2.67	2.24	1.87	663.4	6551.0	0.0	14.8	2.88	300.0
2572.000	9,811	2.72	2.42	2.13	2.34	1.50	1.27	1.08	663.4	7000.0	0.0	30.7	2.59	300.0 *
2897.000	9,771	2.37	2.22	2.02	2.13	1.51	1.29	1.10	663.4	7000.0	0.0	33.1	7.98	300.0 *
3219.000	9,760	2.90	2.68	2.31	2.59	1.43	1.11	0.85	663.4	4844.6	0.0	32.5	3.39	300.0
3535.000	9,807	3.33	3.28	2.90	3.20	1.93	1.62	1.27	663.4	6233.2	0.0	21.7	3.92	300.0
3854.000	9,787	4.01	3.70	3.32	3.51	2.24	1.81	1.44	663.4	4929.0	0.0	19.5	2.52	300.0
4173.000	9,748	3.34	3.09	2.76	2.95	1.83	1.56	1.27	663.4	6184.5	0.0	23.1	2.56	300.0
4494.000	9,728	6.83	6.46	5.85	6.56	3.91	3.13	2.53	663.4	2393.1	0.0	11.1	2.82	300.0
4796.000	9,831	3.74	3.66	3.30	3.51	2.34	1.97	1.59	663.4	7000.0	0.0	17.1	2.70	300.0 *
Mean:		3.79	3.62	3.25	3.47	2.27	1.89	1.55	663.4	5925.3	0.0	21.7	3.64	300.0
Std. Dev:		1.29	1.29	1.21	1.23	0.90	0.75	0.63	0.0	1453.3	0.0	7.7	1.58	0.0
Var Coeff(%):		34.13	35.77	37.37	35.38	39.63	39.76	40.55	0.0	24.5	0.0	35.6	43.26	0.0

Note: Distances are west from Shell Station at US 175.

Table 4.2. Summary DCP Results for Loop 12.

DCP Test Site	Subgrade CBR		Subgrade Modulus from FWD (ksi)	Location (feet west from Shell at US 175)
	0-6"	6-12"		
1	15.2	15.2	28.6	978
2	10.2	17.3	7.8	1308
3	10.1	6.9	11.6	1612
4	7	9.2	14.8	2251
5	16.7	20.5	33.1	2897
6	12.6	8.5	19.5	3854
7	10.3	6.4	11.1	4494
8	23.3	22.6	17.1	4796

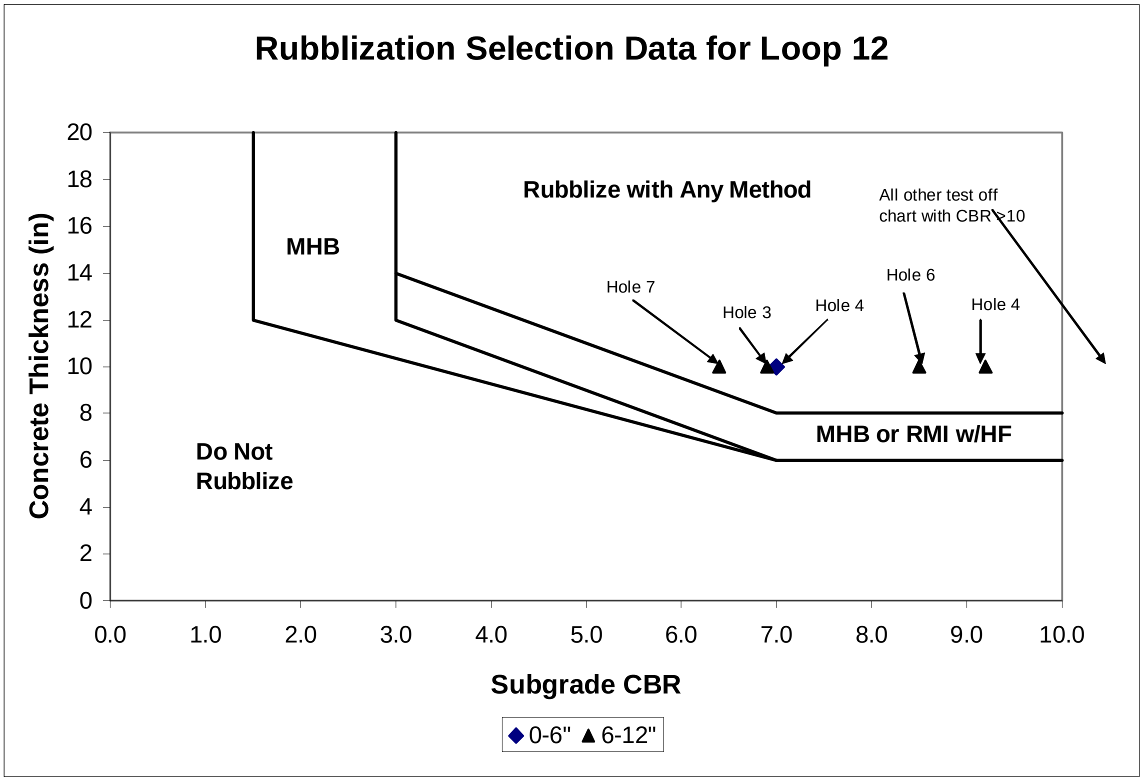

Figure 4.6. DCP Results from Loop 12 on IDOT Rubblization Selection Chart.

RECOMMENDATION

Based upon the results presented and discussed above, the Loop 12 project between Jim Miller Road and US 175 is suitable for rubblization with either the resonant machines or multi-head breaker equipment. The only potential concern observed was a few locations of wet subgrade. Testing at these locations still revealed suitable subgrade support exists. However, it is possible that the vibrating action of the RMI machine could pump water; therefore, if rubblization is pursued using the RMI equipment, consideration should be given to installing edge drains prior to rubblization.

CHAPTER 5
CONSTRUCTION AND PERFORMANCE OF US 83 FROM FM 3256 IN COTTLE COUNTY

SUMMARY

The Childress District rubblized approximately 0.9 miles of US 83 from FM 3256 northward in 2003. Monitoring of the section reveals good performance from the pavement, with the rubblized layer retaining a relatively uniform and low moisture level. Results show the average modulus of the rubblized layer continues to increase with time. Originally 114 ksi within one year of rubblization, this value was 200 ksi after two years. Currently the average rubblized base modulus is 323 ksi.

SURVEY RESULTS

The latest survey at this site took place in April 2007 with GPR and FWD. Figure 5.1 shows the site in April 2007. Visually the section still appears in excellent condition.

Figure 5.1. US 83 from FM 3256.

Figure 5.2 illustrates example GPR data from the section, and Figure 5.3 shows the rubblized layer dielectric values along the project. Often in the GPR, the interface between the rubblized layer and subgrade is not distinguishable, indicating the materials have similar dielectric values. The results in Figure 5.3 are similar to those obtained when the section was two years old. The rubblized layer dielectrics show good uniformity with occasional spikes, and the level of the values indicate low moisture levels in the material.

Figure 5.2 . Example GPR Data on US 83 from FM 3256.

Note: black line in GPR pattern is top of rubblized layer.

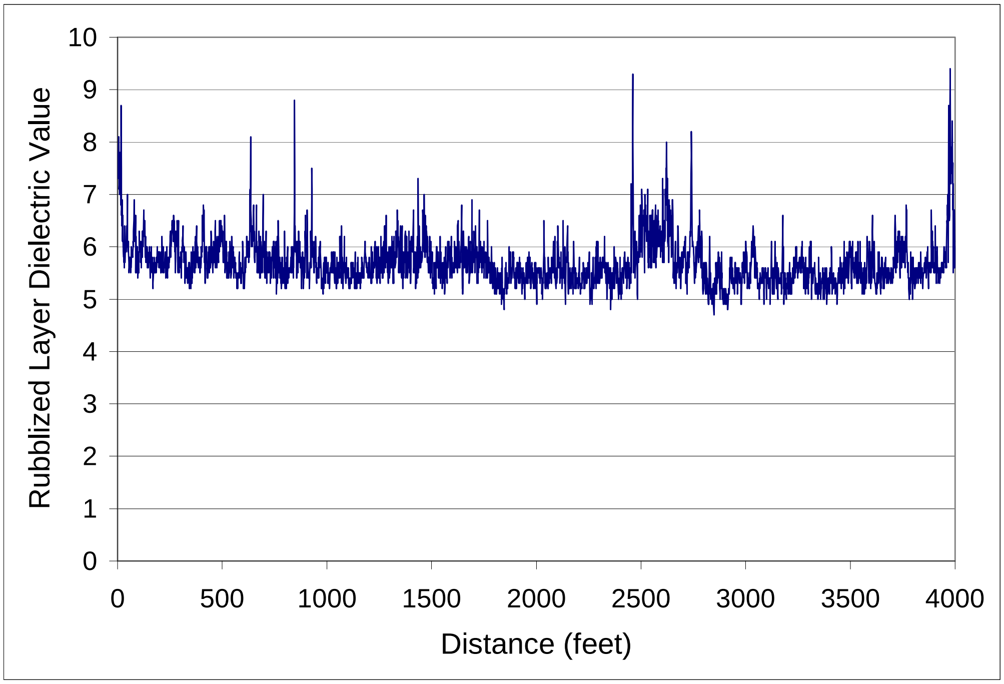

Figure 5.3. Rubblized Layer Dielectrics for US 83 from FM 3256.

Table 5.1 shows the FWD backcalculations from April 2007. Von Holdt and Scullion presented the prior data sets in TTI report 0-4517-3. Figure 5.4 shows the average backcalculated modulus for each of the test occasions. The data show a consistent subgrade modulus with time. The rubblized layer modulus, originally approximately 4 percent of the pre-fractured modulus, shows a trend of increasing modulus with time. This increase is likely due to self-cementing properties of the rubblized layer. Figure 5.5 contrasts the mean, standard deviation, and coefficient of variation of the rubblized layer results. The data indicate the base modulus may not uniformly stiffen, as indicated by the slight increase in the coefficient of variation in the most recent FWD test results.

Table 5.1. FWD Results for US 83 from FM 3256.

TTI MODULUS ANALYSIS SYSTEM (SUMMARY REPORT) 6.0)

District:25 (Childress)			MODU RANGE(psi)					
County	:51	(COTTLE)	Thickness(in)	Minimum	Maximum		Poisson	Values
Highway/Road:	US0062		Pavem 8	340,000	1,040,000	H1:	v	0.35
			Base: 8	50,000	2,000,000	H2:	v	0.35
			Subbas 0			H3:	v	0
			Subgra 121.45	DB)	5,000	H4:	v	0.4

Station	Load (lbs)	R1	R2	R3	R4	R5	R6	R7	SURF(E1)	BASE(E2)	SUBG(E4)	Absolute ERR/Sens	Dpth to Bedrock	
		Measured Deflection (mils):							Calculated Moduli Values (ksi):					
0	10,900	8.14	6.67	5.35	4.11	3.12	2.39	1.85	950.8	313.6	11.3	0.93	146.7	
101	11,412	8.24	6.7	5.3	4.03	3.08	2.28	1.76	944.8	301.4	12.3	0.6	138	
202	10,570	7.76	6.7	5.2	3.92	2.87	2.15	1.61	1040	206.2	12.4	1.99	127.2	*
301	11,670	7.92	6.33	4.96	3.8	2.85	2.14	1.62	886.9	346.2	13.6	0.83	126.3	
500	10,486	6.83	5.6	4.6	3.63	2.83	2.2	1.72	940.1	525.6	11.6	0.7	145.5	
603	10,153	6.76	6.22	5.02	3.95	3.07	2.37	1.87	1040	166.6	12.3	9.18	160	*
702	10,276	8.42	6.72	5.35	4.11	3.18	2.44	1.88	640.6	384.3	10.6	1.13	145.5	
800	10,093	8.6	6.91	5.41	4.1	3.06	2.31	1.78	759.5	246.2	10.9	0.98	148.5	
900	10,002	8.2	7.1	5.61	4.3	3.32	2.54	2	1040	247.4	9.7	1.51	169.9	*
1402	10,669	7.09	5.93	4.58	3.46	2.6	1.96	1.52	1040	232.3	14.2	2.41	143.9	*
1500	10,304	7.99	6.88	5.26	3.92	2.86	2.13	1.65	1040	161.2	12.3	2.17	149.2	*
1600	10,153	7.05	5.6	4.45	3.47	2.68	2.06	1.61	689.3	518.8	12.3	1.12	146.5	
1700	10,375	8.7	7.02	5.34	4.03	2.96	2.25	1.72	802.7	212.7	11.7	1.6	140.5	
1802	10,355	7.3	6.49	5.02	3.75	2.92	2.13	1.62	1040	284.2	11.7	2.18	130.5	*
1900	10,896	11.23	6.7	5.22	3.95	2.96	2.22	1.73	340	267.9	13.2	6.2	151.2	*
2003	9,930	7.63	6.22	4.89	3.73	2.8	2.14	1.64	899.4	277.8	11.6	1.13	139.9	
2100	10,594	9.85	6.38	4.91	3.67	2.71	2.07	1.58	340	339.3	13.6	3.76	137.1	*
2200	10,022	7.41	6.16	4.79	3.61	2.64	1.97	1.49	1040	221.3	12.5	1.14	131.8	*
2300	9,950	7.17	6.18	4.82	3.69	2.82	2.18	1.62	1040	305.5	11.3	1.85	121.3	*
2401	10,268	7.49	6	4.72	3.6	2.72	2.04	1.57	1040	194.7	13.4	3.08	140.1	*
2800	10,340	7.8	5.18	3.94	2.93	2.1	1.61	1.23	340	514.8	16.9	2.42	160.2	*
3001	10,320	6.82	5.22	3.85	2.8	2.03	1.56	1.19	693.4	306	17.1	2.51	130.9	
3101	10,399	6.96	4.65	3.5	2.6	1.91	1.45	1.16	340	723	18.9	2.34	148.6	*
3200	10,022	5.69	4.43	3.11	2.08	1.4	0.99	0.74	1040	148.3	24.1	2.37	108.2	*
3301	10,336	8	4.52	3.31	2.38	1.65	1.3	0.91	340	314.8	22	5.76	124	*
3400	9,644	4.97	4.16	3.21	2.47	1.84	1.51	1.15	1040	573.5	16.5	3.03	205.8	*
3500	9,700	7.25	5.61	4	2.81	2.02	1.45	1.1	762.7	168.1	16.6	1.98	119.9	
3602	10,101	4.36	3.8	2.76	2	1.49	1.18	0.94	1040	517.3	22.6	4.54	150.9	*
3801	10,773	7.23	3.31	2.47	1.85	1.42	1.09	0.91	340	472.3	29.4	12.02	140.3	*
3901	9,593	6.26	5.39	4.22	3.21	2.36	1.79	1.35	1040	327.5	13.1	1.86	126.3	*
4000	9,827	7.24	5.43	3.9	2.72	1.87	1.41	1.1	656.4	187.7	17.6	2.43	127.1	
Mean:		7.50	5.81	4.49	3.38	2.52	1.91	1.47	812.47	322.79	14.75	2.77	141.35	
Std. Dev:		1.28	1.00	0.86	0.71	0.57	0.43	0.34	268.76	142.27	4.56	2.51	17.88	
Var Coeff(%):		17.01	17.27	19.24	20.94	22.74	22.58	22.82	33.08	44.08	30.88	90.76	12.65	

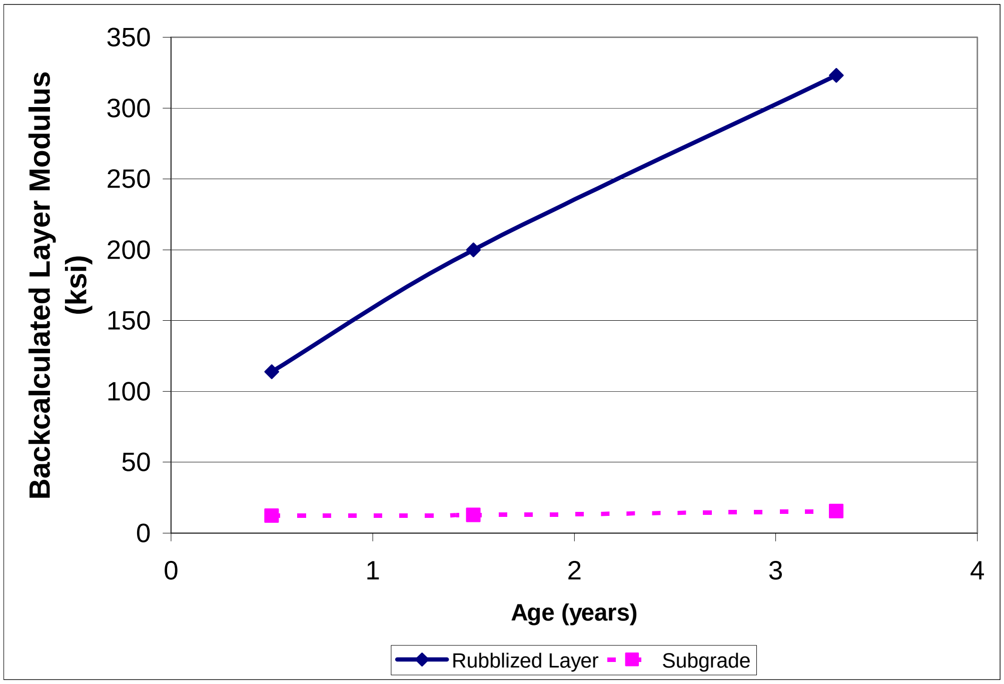

Figure 5.4. Average Pavement Layer Modulus with Time for US 83 from FM 3256.

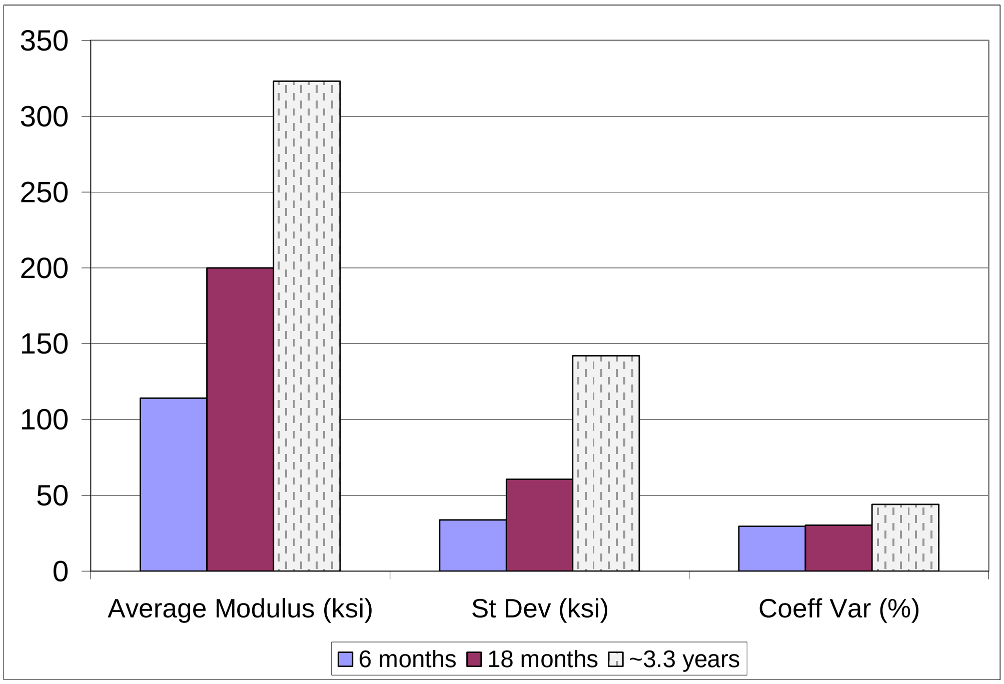

Figure 5.5. Statistical Measures for Rubblized Layer Modulus on US 83 from FM 3256.

CONCLUSIONS

This rubblization project continues to exhibit good performance, and the presence of moisture does not appear to be a problem in the rubblized layer despite frequent heavy rains in the months leading up to this latest survey. FWD data show the rubblized layer modulus initially averaged 114 ksi, or approximately 4 percent of the pre-fractured modulus, and through time increased to 323 ksi. This trend of increasing modulus with time should be studied on other rubblization projects. Studying other projects will assist with selecting a reasonable design value for use in the project planning stage.

CHAPTER 6
CONSTRUCTION AND PERFORMANCE OF US 70

SUMMARY

In the summer of 2006, the Childress District rubblized a portion of the westbound travel direction of US 70 in Foard County starting at FM 267. A pre-construction site investigation conducted in the fall of 2005 concluded that although the section was suitable for rubblization, the collected data were spot specific, so a chance existed for areas to exist between test locations where problems could occur. The pre-construction investigation recommended the district estimate 10 to 20 percent of the project would require removal and replacement. Unfortunately, stability problems were discovered during the paving operation. Although only approximately 5 percent of the rubblized section had problems, most of the rubblized concrete was removed and rubblization abandoned due to the unfortunate timing of when the problem was discovered. Approximately 3000 feet of rubblized concrete remained in place. Problems arose on the project because the unstable areas were not detected prior to paving. This project highlighted the importance of re-evaluating the project screening phase, the rubblization operation, the enforcement of specifications, and the crucial role of proof rolling. In the rubblized section that TxDOT retained, the average rubblized layer modulus was 138 ksi approximately eight months after construction.

RESULTS FROM PRE-CONSTRUCTION INVESTIGATION

To evaluate if the US 70 project was suitable for rubblization, TTI performed a field analysis using GPR, FWD, and DCP testing. Figure 6.1 illustrates representative GPR data from the project between FM 267 and Crowell. An analysis of the GPR data indicated an average ACP thickness of 7.44 inches and an average JCP thickness of 7.9 inches. These thicknesses match well with the plans provided by the Childress District, shown in Figure 6.2. Additionally, TTI reviewed the GPR data for signs of excessively wet subgrade, indicated by high layer 3 dielectric values, since a wet subgrade hinders the rubblization process. The GPR data did not indicate any locations of excessively wet subgrade soil. Typical subgrade dielectric values ranged from 5 to 8. In the GPR data, some instances existed of significant negative reflections in the ACP layer, which oftentimes indicate problems such as stripping in the ACP; however, if the JCP is to be rubblized the ACP must be removed, so these sites of potential ACP defects were not investigated further.

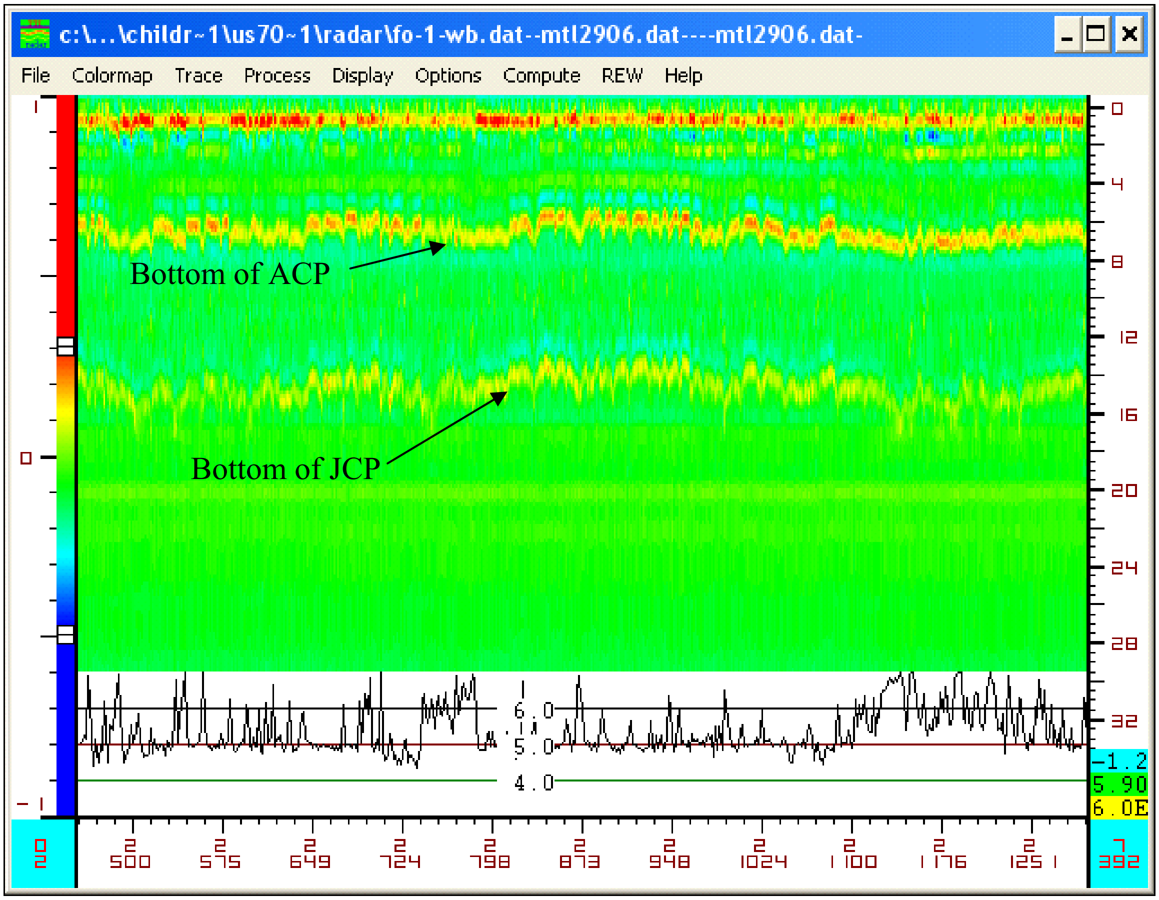

Figure 6.1. Representative GPR Data on US 70 in Foard County.

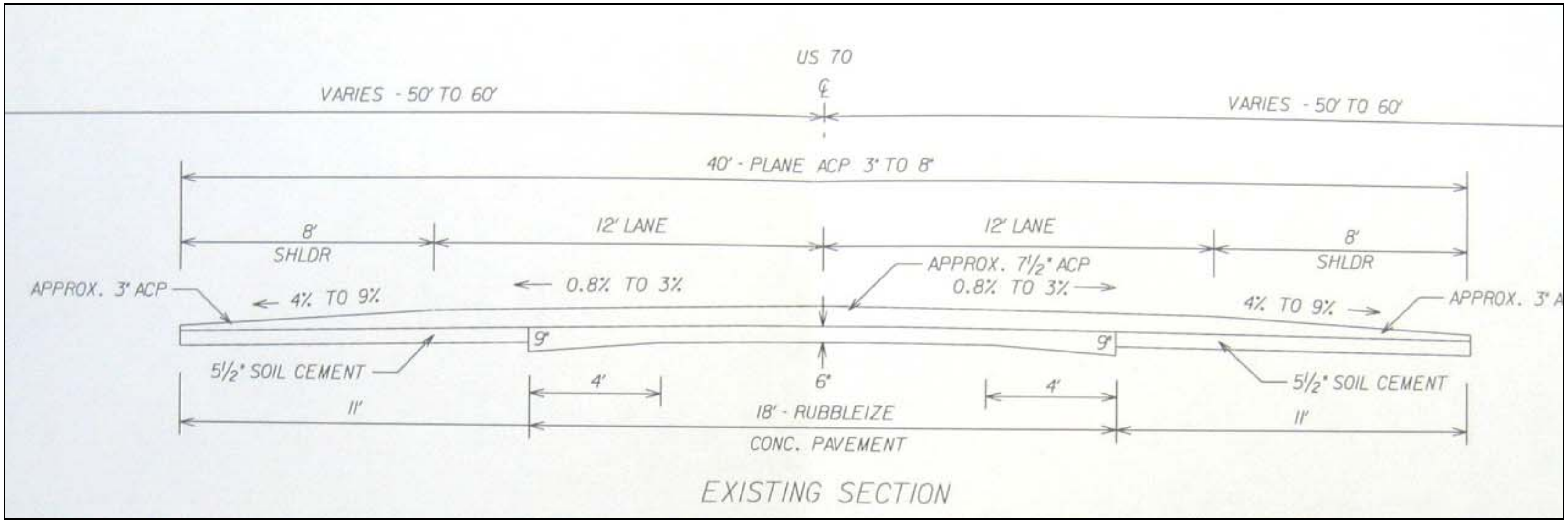

Figure 6.2. Typical Existing Section on US 70 in Foard County.

RESULTS FROM FWD AND DCP TESTING

Table 6.1 shows the FWD backcalculation results for US 70 from FM 267 to Crowell. Layer thicknesses of 7.5 inches were used for both the ACP and JCP based upon GPR and plan sheets. Additionally, since other states' experience indicates the top 12 inches of subgrade is most crucial for rubblizing success, a 12-inch dummy subbase layer was used, and a fixed depth to bedrock value of 240 inches was input into Modulus 6.0. After studying FWD results in the field, TTI selected several locations to perform DCP tests at the project site. These tests represented some of the softest and stiffest subgrade locations along the length of the project and are summarized in Table 6.2. Combined, the FWD and DCP data complete the information necessary to analyze the suitability of the project for rubblization.

For rubblization, two critical issues are drainage and support beneath the slab. The GPR data already indicated trapped moisture was not a problem. To evaluate support beneath the slab, researchers used the IDOT rubblization chart. Figure 6.3 shows the data from US 70 on this chart, which indicates the project is generally suited to rubblization, with a slight risk of problems at the location of test number 3.

Table 6.1. FWD Results for US 70 from FM 267 to Crowell.

TTI MODULUS ANALYSIS SYSTEM (SUMMARY REPORT) (Version 6.0)

District:25	(Childress)		MODULI RANGE (psi)		
County: 97	(FOARD)		Thickness(in)	Minimum Maximum	Poisson Ratio Values
Highway/Road: us0070		Pavement:	7.5	60,000 800,000	H1: v = 0.3
		Base:	7.5	100,000 10,000,000	H2: v=0.2
		Subbase:	12	5,000 50,000	H3: v=0.40
		Subgrade:	240.00 (user input)	15,000	H4: v=0.4

Station	Load (lbs)	Measured Deflection (mils) R1	R2	R3	R4	R5	R6	R7	Calculated Moduli Values (ksi) SURF(E1)	BASE(E2)	SUBB(E3)	SUBG(E4)	Absolute ERR/Sens	Dpth to Bedrock	
0.045	11,988	5.32	4.44	3.91	3.35	2.73	2.26	1.78	1052	3584.8	7.8	19.8	0.46	123.5	
0.101	11,094	10.28	6.3	5.77	4.89	3.87	3.13	2.43	167	5503.4	7.3	13.2	1.59	135.3	
0.201	11,523	8.97	5.64	4.89	3.99	3.14	2.56	1.98	203.6	4853.3	6.1	19	0.82	131.4	
0.214	11,293	9.55	5.72	5	4.12	3.24	2.62	2.04	170.4	5210.9	5.7	18	0.72	135.8	
0.302	10,951	9.48	5.37	4.76	3.94	3.09	2.48	1.88	153.8	4976.1	16.5	16	1.03	119	
0.4	10,864	8.97	5.22	4.52	3.74	2.98	2.28	1.8	168.2	4481.6	15.8	17.2	0.9	142.5	
0.5	10,824	8.16	5.78	5.15	4.33	3.48	2.84	2.19	296.2	3395.3	33.1	13.1	0.94	128.5	
0.6	11,392	9.25	5.3	4.56	3.8	3.06	2.57	1.98	163.1	4843.2	50	15.6	0.86	122.9	*
0.702	10,951	11.5	6.67	5.77	4.78	3.81	3.07	2.41	129.3	3953.2	13.1	13	0.38	148.5	
0.8	10,987	8.28	5.35	4.91	4.15	3.34	2.68	2.14	234.1	4756.2	46.1	13.7	1.69	152	
0.9	10,633	10.91	5.85	5.12	4.28	3.36	2.69	2.07	120.5	3740.9	42.5	13.7	0.99	128.5	
1	11,452	12.55	7.07	5.96	4.88	3.75	2.9	2.22	123.7	2184.3	33.4	13.9	0.82	131.4	
1.101	10,737	10.77	6.04	5.24	4.33	3.49	2.81	2.25	129.3	3730.1	38	13.3	0.27	165.2	
1.2	10,919	9.8	5.78	4.81	4.01	3.24	2.7	2.09	149.9	4821.1	16.2	15	1.6	128.3	
1.3	11,126	10.59	6.33	5.5	4.63	3.65	2.86	2.13	151.4	4592.5	5.7	15.6	0.61	112.1	
1.403	11,015	8.78	5.01	4.39	3.69	2.98	2.38	1.93	165.1	6214.4	16.8	16.5	0.41	162.6	
1.503	11,448	9.28	5.26	4.54	3.77	3.02	2.45	1.9	161.9	4542.3	46.2	16.2	0.34	127.1	
1.6	11,639	9.41	5	4.37	3.61	2.91	2.36	1.9	148.7	6104	34.2	17.7	0.39	156.3	
1.701	11,241	12.13	7.06	5.8	4.73	3.62	2.91	2.22	132.7	1571.2	47.2	13.5	0.79	129.1	
1.801	10,816	11.04	6.05	5.29	4.33	3.36	2.65	2.04	127	3028.3	37.7	14.3	1.21	133.5	
1.9	10,935	9.8	5.44	4.7	3.92	3.15	2.53	1.96	142.7	4291.5	43.7	15	0.25	128.6	
2	11,484	9.73	4.83	4.29	3.59	2.93	2.37	1.97	131.1	7235.2	43.6	17	0.46	196.7	
2	12,163	9.4	4.64	4.25	3.09	2.94	2.41	1.79	139.7	9670.7	38.6	18.4	3.88	300	
2	10,769	8.66	4.8	4.38	3.77	2.93	2.44	2.02	161.2	6195.6	48.8	14.9	1.83	300	
2.003	11,488	9.18	5.07	4.46	3.54	2.93	2.43	1.96	158	5064.2	49.8	16.8	1.34	171.8	
2.202	10,963	10.18	5.69	5.08	4.28	3.46	2.79	2.19	139.7	4970	40.3	13.3	0.85	139.1	
2.417	10,919	11.44	7.17	6.27	5.22	4.13	3.34	2.59	152.6	3542.6	11	12.1	0.63	141.7	
2.614	10,963	11.86	6	5.19	4.3	3.39	2.7	2.13	107	3512.1	50	14.4	0.68	147.6	*
2.802	10,403	10.43	6.79	5.97	4.98	3.94	3.17	2.46	175.3	3368.3	11.5	12	0.79	141.9	
3.003	12,306	11.02	6.75	6.12	5.14	4.11	3.07	2.5	177.5	4230.8	12.5	14.1	2.43	133.4	
3.207	11,158	8.33	5.2	4.7	3.84	3.09	2.43	1.87	214.6	5756.6	5.7	18.7	0.97	128.5	
3.401	11,730	9.1	5.42	4.78	4	3.06	2.4	1.84	188.5	5278.8	6.1	20.2	1.36	120.6	*
3.6	10,089	8.6	5	4.33	3.48	2.65	2.06	1.5	169.4	2792.3	29.5	17.3	1.36	106.5	
3.814	11,837	8.78	4.9	4.28	3.51	2.75	2.13	1.66	178.2	4983.9	22.6	20.2	0.97	129.3	
4.009	10,439	13.07	8.52	7.66	6.34	4.96	3.7	2.82	148.8	2327	5.1	10.7	2.24	142.4	
4.016	11,865	7.91	4.8	4.03	3.16	2.41	1.84	1.33	236.4	2945.4	20.7	23.8	0.58	100.7	
4.203	10,641	9.78	6.17	5.35	4.37	3.43	2.65	1.98	181.3	3072.3	11.8	14.9	0.82	118.6	
4.406	11,499	7.87	5.01	4.35	3.55	2.77	2.22	1.73	241.5	4962.6	7.3	21.6	0.74	131.8	
4.602	10,963	9.74	5.93	5.03	4.04	3.04	2.28	1.66	176.4	2951.2	6.1	20.2	0.95	107.9	*
4.804	10,403	8.56	7.44	6.26	5.05	3.93	3.08	2.27	1100	369.5	10.1	12	1.32	119.3	*
5.004	9,835	9.18	4.67	3.98	3.15	2.39	1.83	1.35	128.6	3076.4	30.7	19.8	1.04	110.9	
5.216	10,030	10.33	5.88	5.09	4.08	3.05	2.43	1.95	135	2604.8	19.1	15.2	1.4	180	
5.406	10,117	10.36	6.33	5.53	4.45	3.41	2.62	2.02	154.8	2571	10.5	14.4	1.34	142.6	
5.606	11,166	7.32	5.69	4.91	4.1	3.22	2.57	1.96	513.9	2340.3	5.4	17.8	0.59	120.4	*
5.806	10,955	9.53	6.75	6.13	5.11	4.07	3.28	2.51	262	3683.7	5.2	13.1	1.27	132.4	
5.984	10,657	7.1	4.99	4.42	3.62	2.82	2.23	1.7	338.4	3761.6	6	20	1.13	122	*
Mean:		9.61	5.76	5.04	4.15	3.28	2.61	2.02	217.4	4166.2	23.3	16	1.04	132.3	
Std. Dev:		1.47	0.87	0.76	0.65	0.5	0.38	0.3	197.4	1581.2	16.3	2.9	0.65	23.3	
Var Coeff(%):		15.29	15.01	15	15.63	15.19	14.66	15.06	90.8	38	70.1	18.4	62.12	17.6	

Table 6.2. Summary DCP Results from US 70 in Foard County.

Hole	Subgrade CBR 0-6"	Subgrade CBR 6-12"	Subgrade Modulus from FWD (ksi)	Location
1	9.1	9.8	7.3	0.101 miles west of FM 267
2	11.6	9.1	15.8	0.4 miles west of FM 267
3	8.5	5.2	11	2.417 miles west of FM 267
4	10.7	11.9	5.1	4.009 miles west of FM 267
5	12.8	12.6	30.7	5.004 miles west of FM 267

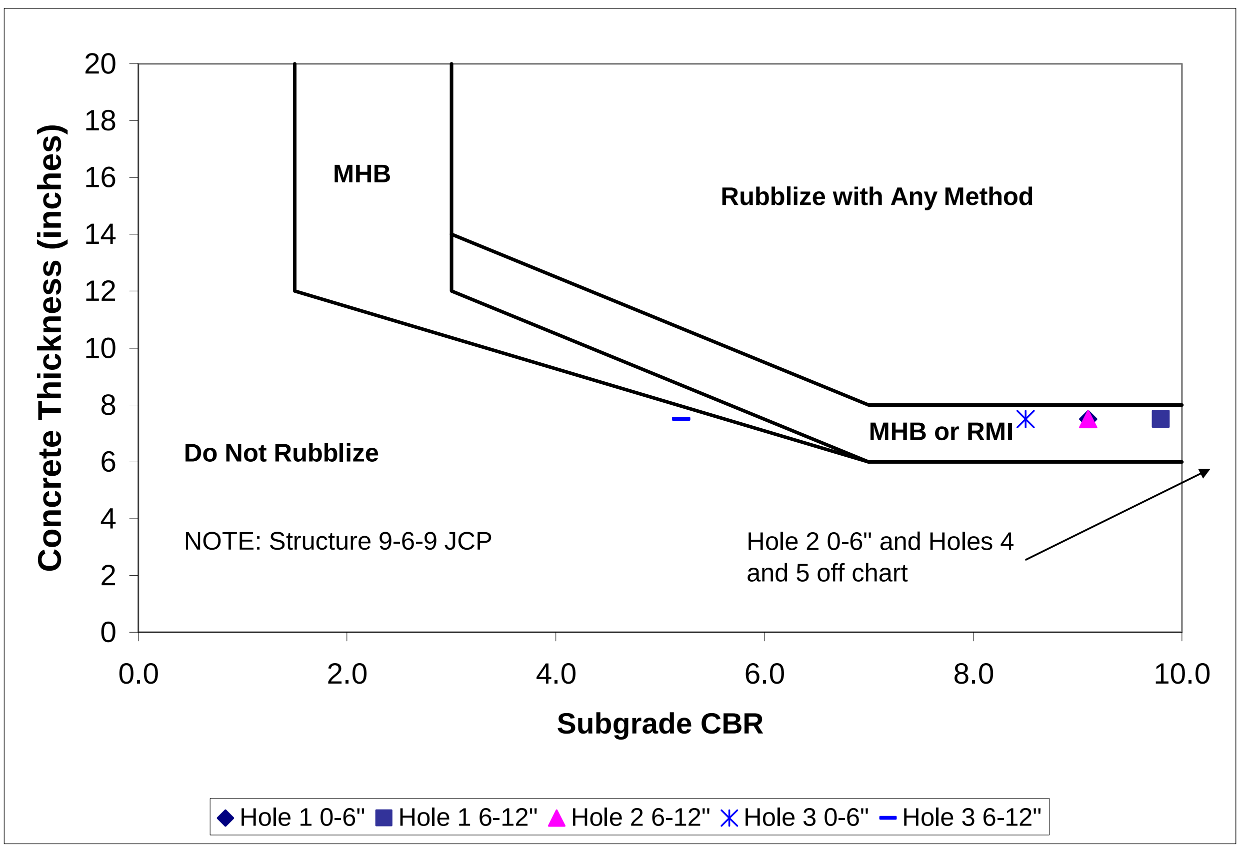

Figure 6.3. DCP Results for US 70 from FM 267 to Crowell.

RECOMMENDATION FROM PRE-CONSTRUCTION INVESTIGATION

Based upon the pre-construction survey, the research team concluded the data collected indicate the section was suitable for rubblization. However, the collected data are spot specific, so a chance existed that some areas between test locations could experience problems. From experience, 10 to 20 percent of the project is normally estimated to require removal and replacement.

CONSTRUCTION NOTES

In August 2006, the contractor initiated rubblization, and the TTI research team visited the construction site to observe operations. The existing slab length was 40 feet, and most slabs contained two to four transverse cracks in them. Figure 6.4 shows the existing concrete slabs after removal of the HMA by milling.

Figure 6.4. Existing Concrete Slabs on US 70 in Foard County.

The multiple head breaker machine rubblized the existing JCP, as Figure 6.5 shows. Figure 6.6 illustrates the typical surface view and cross section of the rubblized layer. Figure 6.6 shows how the multiple head breakage pattern produced a layer of small particles, typically less than 3 inches, overlaying a layer of fractured concrete with larger particle sizes, typically around 8 to 15 inches in size.

Figure 6.5. Multiple Head Breaker on US 70 in Foard County.

Figure 6.6. Surface and Cross Section Views of Rubblized JCP on US 83.

At the project startup, the only problem noted was that the longitudinal reinforcing steel was not being consistently debonded, and the particle sizes at the reinforced edge were larger than specifications allow. The contractor and the engineer worked together until both were satisfied with the rubblizer's operation.

Duininck Brothers constructed the HMA overlays on top of the rubblized pavement. Unfortunately, although project personnel report that proof rolling was performed, the paving train found unstable locations during the course of HMA compaction. Figure 6.7 shows one of these locations. The contractor reported these failures occurred while the vibratory rollers were operating on the HMA.

Figure 6.7. Failure on US 70 Encountered during Paving.

Figure 6.8 shows the proposed mechanism of these failures. Essentially, during operation of the vibratory compactors, the large rubblized particles dislodged and rotated to where they protruded through the HMA.

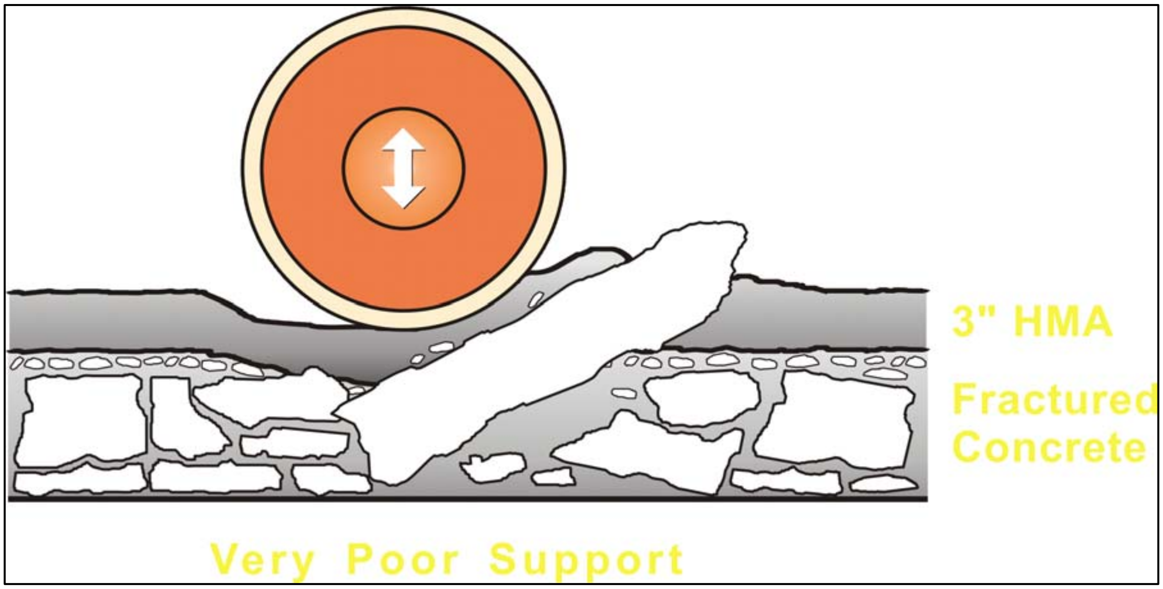

Figure 6.8. Mechanism of Failure on US 70.

A review of the project following the occurrence of the failures revealed the following contributing factors:

- Wet / weak subgrade was not detected in the project pre-screening evaluation. This project highlights the weakness of the spot test nature of the pre-screening tests. Additionally, the GPR survey did not indicate wet subgrade areas. The thickness of the HMA cover when the GPR was performed could have contributed to this lack of detection.
- Large, out of spec, particle sizes did not trigger action during inspection of the rubblization process. Figure 6.9 shows the large particle sizes removed from one of the failure areas. Because particles cannot be broken down as small by rubblization when poor subgrade support exists, not meeting particle size specification indicates a weak spot may exist. Stricter enforcement of the particle size specification could have helped avoid the failures encountered on this project.
- The construction process itself may pump water. The rubblization process and compaction of HMA produce vibrations that could pump water to the bottom of the concrete, contributing to even poorer subgrade conditions.
- Proof rolling did not detect weak spots. Although TxDOT reports proof rolling was conducted, the wheel loads apparently were not high enough or the process was not monitored sufficiently.

Figure 6.9. Out of Spec Particle Sizes at Failure Location.

FOLLOW-UP SURVEY RESULTS

In April 2007 a follow-up survey was conducted on the westbound section starting at the US 70 sign just west of FM 267 and ending at RM 444. Figure 6.10 shows the section, and Figure 6.11 shows example GPR data from the site. From GPR the typical HMA thickness is 12.5 inches. Figure 6.11 shows the transition from the rubblized section to the full-depth HMA. FWD data were collected on the section in April 2007. Modulus 6.0 performed FWD backcalculations using 12.5 inches for the HMA thickness and 7.5 inches for the rubblized layer thickness. Table 6.3 shows the output. At the time of testing, the age of the section was approximately 11 months, and the average rubblized layer modulus was 138 ksi, or 3.3 percent of the pre-fractured PCC modulus. The standard deviation of the rubblized layer modulus was 92 ksi, which results in a coefficient of variation of approximately 67 percent.

Figure 6.10 Rubblized Section on US 70 WB.

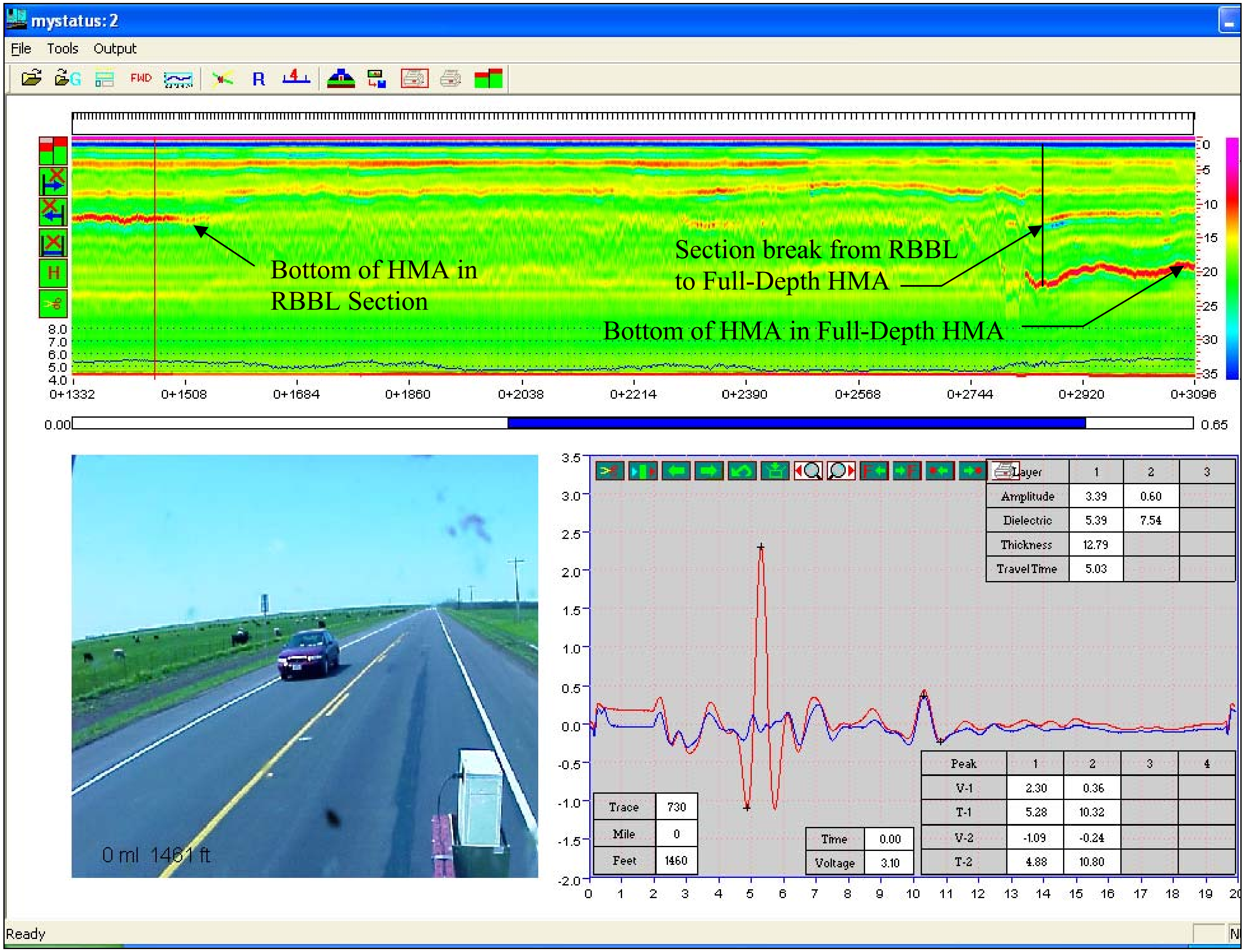

Figure 6.11. Example GPR on US 70 in Foard County.

Table 6.3. FWD Output for US 70 in April 2007.

TTI MODULUS ANALYSIS SYSTEM (SUMMARY REPORT) (Version 6.0)

District:25	(Childress)		MODULI RANGE (psi)		
County:		Thickness(in)	Minimum	Maximum	Poisson Ratio Values
Highway/Road:	US0070	Pavement: 12.5	340,000	1,040,000	H1: v = 0.35
		Base: 7.5	25,000	500,000	H2: v = 0.35
		Subbase: 0			H3: v = 0
		Subgrade: 123.59 (by DB)	5,000		H4: v = 0.4

Station	Load (lbs)	Measured Deflection (mils) R1	R2	R3	R4	R5	R6	R7	Calculated Moduli Values (ksi) SURF(E1)	BASE(E2)	SUBB(E3)	SUBG(E4)	Absolute ERR/Sens	Dpth to Bedrock
0	11,070	8.21	6.94	5.6	4.4	3.39	2.6	2.07	858.8	57.2	0	10.6	0.9	171.9
100	11,078	8.8	6.94	5.63	4.41	3.37	2.62	1.98	594.3	122.1	0	10.6	0.77	129.3
200	10,923	8.06	6.9	5.69	4.51	3.51	2.66	2.06	973.6	43.2	0	10	0.64	145
300	11,213	9.19	7.67	6.26	4.91	3.87	2.89	2.19	789.9	51.3	0	9.5	0.53	134.3
400	10,987	7.71	7.09	5.8	4.57	3.55	2.73	2.12	1040	44.8	0	9.7	2.06	148.7
501	10,927	7.39	6.53	5.38	4.3	3.39	2.61	2.05	1040	80	0	9.9	1.29	152.6
600	10,713	7.35	6.37	5.24	4.15	3.22	2.5	1.96	1040	52.7	0	10.5	1.06	152.5
700	10,371	8.08	6.69	5.47	4.36	3.44	2.65	2.08	950	30.1	0	9.9	1.14	155.8
801	11,055	7.62	6.19	5.15	4.14	3.29	2.56	2.03	783.8	167.5	0	10.4	0.29	158
900	11,074	7.75	6.22	5.13	4.1	3.2	2.5	1.93	727.1	160.1	0	10.8	0.48	136.2
1001	10,912	6.91	6.29	5.26	4.22	3.35	2.6	2.06	1040	102	0	10.1	2.16	159.6
1101	10,224	7.85	6.3	5.28	4.24	3.36	2.64	2.05	648.4	184.9	0	9.3	0.45	144.6
1200	10,228	7.44	5.99	4.93	3.92	3.04	2.34	1.8	732.4	124.9	0	10.7	0.31	136.2
1301	10,852	6.72	5.66	4.61	3.62	2.74	2.09	1.58	1040	56.3	0	12.9	0.79	123.1
1400	10,908	6.61	5.41	4.36	3.4	2.62	1.99	1.57	927	95.7	0	13.7	0.66	150.8
1500	10,463	6.56	5.63	4.63	3.66	2.84	2.16	1.69	1040	82.9	0	11.7	1.06	146.3
1600	10,570	6.77	5.76	4.71	3.7	2.88	2.18	1.69	1040	62.3	0	11.9	0.75	140.3
1700	10,435	7.1	5.76	4.74	3.73	2.88	2.17	1.67	851.8	89.9	0	11.8	0.2	135.9
1801	10,689	7.57	5.53	4.59	3.68	2.87	2.21	1.72	455.3	347.2	0	11.6	0.39	138.4
1901	10,340	6.91	5.41	4.48	3.57	2.76	2.19	1.69	667.5	213.2	0	11.6	0.77	133.9
2001	10,848	5.66	4.87	4	3.17	2.58	1.95	1.46	1040	206.8	0	13.1	1.67	113.4
2201	10,562	6.88	5.11	4.22	3.38	2.66	2.07	1.58	515.8	371.1	0	12.2	0.33	123.6
2400	10,526	6.3	5.29	4.42	3.57	2.86	2.26	1.8	1034.8	170.4	0	11	0.61	155.8
2600	10,912	7.39	5.85	4.74	3.75	3	2.31	1.82	657.5	204.3	0	11.5	0.77	150.9
2700	10,852	6.76	5.5	4.56	3.67	2.95	2.32	1.83	829	221.2	0	11.2	0.52	147.3
2802	10,566	8.23	6.32	5.27	4.21	3.31	2.61	2.02	511.5	246.8	0	9.8	0.63	141.4
Mean:		7.38	6.09	5.01	3.97	3.11	2.4	1.87	839.6	138	0	11	0.82	143.6
Std. Dev:		0.79	0.69	0.55	0.43	0.33	0.26	0.21	194.7	92	0	1.1	0.51	13.3
Var Coeff (%):		10.7	11.27	11.04	10.85	10.75	10.71	11.02	23.2	66.6	0	10.4	62.1	9.3

CONCLUSIONS

Although only approximately 5 percent of the area of the rubblized pavement had problems, this project created a unique opportunity for learning due to the timing of the discovery of problems. First, during the pre-screening project evaluation, closer attention may be needed to spot test areas based on the visual inspection. Second, the fact that the nature of spot tests means problem areas may be missed cannot be forgotten. Additionally, if thick HMA is present, a follow-up GPR survey should be considered after the HMA has been milled but prior to rubblization to again investigate for high dielectric subgrades. Next, particle size specifications should be more strictly enforced since the success in meeting the size specification is at least partially dependent on foundational support. Finally, particularly with the MHB equipment, closer care in proof rolling is needed to make sure weak spots are identified prior to the arrival of the paving train.

CHAPTER 7
CONSTRUCTION AND PERFORMANCE OF US 83 IN COTTLE COUNTY FROM THE KING COUNTY LINE

SUMMARY

In the summer of 2006, the Childress District rubblized the southbound travel direction of US 83 in Cottle County from approximately 6.3 miles north of the King County line to the county line. This project employed the resonant breaker machine. A pre-construction investigation conducted in September 2005 indicated locations existed where the concrete had already been removed, and a sizeable percentage of the remainder of the project was of questionable suitability for rubblization. Based upon the construction records, approximately 20 percent of the rubblized concrete required removal and replacement due to instability after rubblization. As of April 2007, the section is still closed to traffic, and the final surfacing has not been placed yet. The current HMA thickness is approximately 6.5 inches, and the average modulus of the rubblized PCC layer is 154 ksi. Ongoing monitoring of the project site should continue tracking the performance and layer moduli through time.

RESULTS FROM PRE-CONSTRUCTION INVESTIGATION

To evaluate if the US 83 project was suitable for rubblization, TTI performed a field analysis using GPR, FWD, and DCP testing. Figure 7.1 illustrates representative GPR data from the project. An analysis of the GPR data indicated an average ACP thickness of 3.5 inches and a typical JCP thickness of 8.6 inches. In portions of the project, the GPR data also showed what appears to be a fill layer of varying thickness beneath the slabs, ranging in thickness from 2 to 6 inches.

Since a wet subgrade hinders the rubblization process, TTI reviewed the GPR data for signs of excessively wet subgrade, indicated by high subgrade dielectric values. The GPR data did not indicate any locations of excessively wet subgrade soil. Typical subgrade dielectric values ranged from 4.4 to 5.6.

In the GPR data, two clear section breaks are evident. These sections of different structure are from 3.18 to 3.44 miles and from 4.22 to 4.82 miles north of the King/Cottle County line. Figure 7.2 shows an example of one of the section breaks.

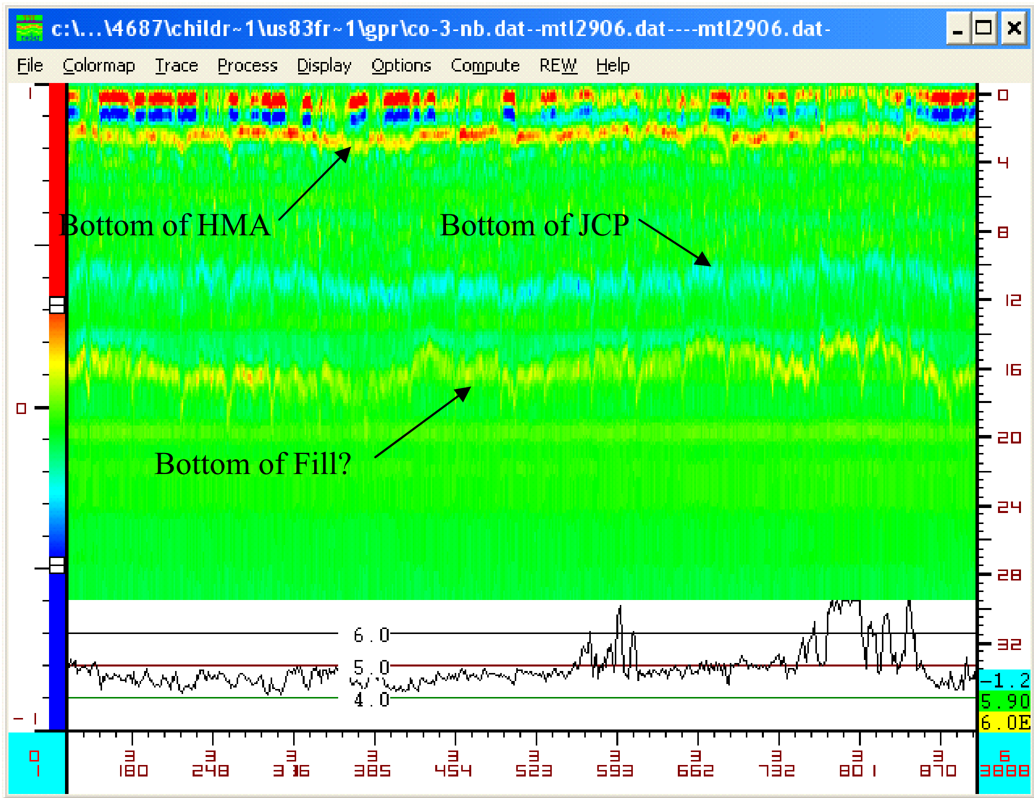

Figure 7.1. Representative GPR Data on US 83 in Cottle County.

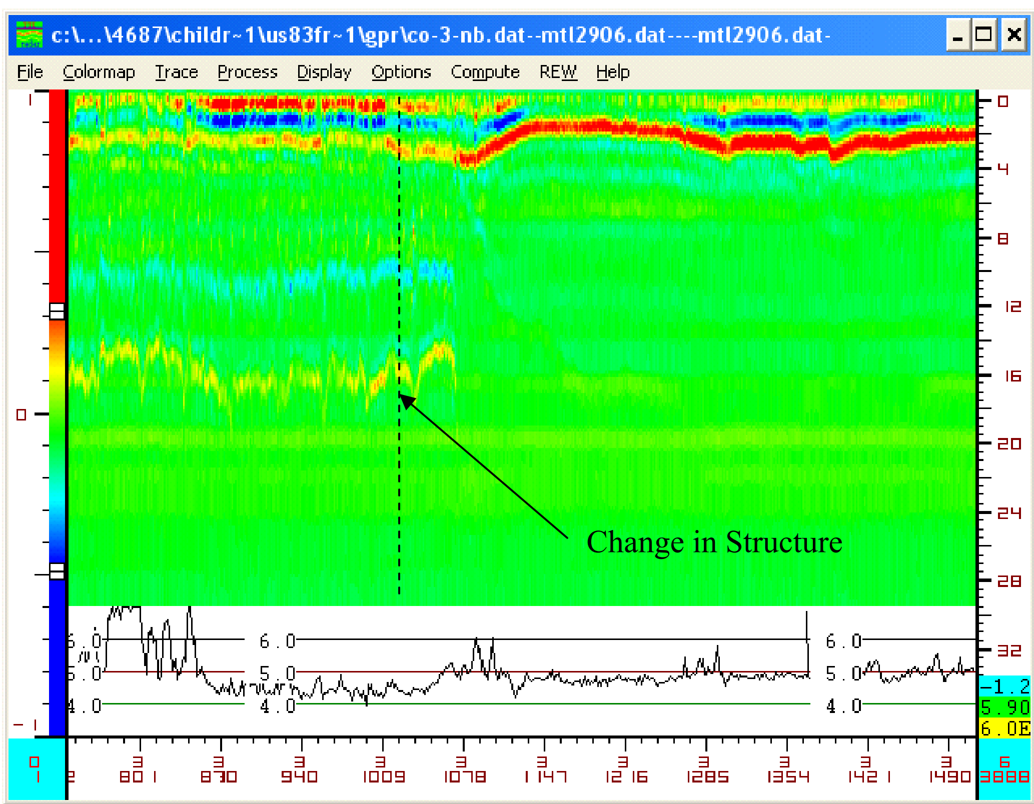

Figure 7.2. Representative Section Break in GPR Data on US 83 Northbound.

RESULTS FROM FWD AND DCP TESTING

Table 7.1 shows the FWD backcalculation results for US 83 from the King/Cottle County line to just south of County Road 240. Layer thicknesses of 3.5 inches were used for the ACP and 8.0 inches for the JCP. Additionally, since other states' experience indicates the top 12 inches of subgrade is most crucial for rubblizing success, a 12-inch dummy subbase layer was used, and a fixed depth to bedrock value of 240 inches was input into Modulus. After studying FWD results in the field, TTI selected several locations to perform DCP tests at the project site. Table 7.2 summarizes the DCP results for use in the IDOT rubblization selection chart. This chart uses the CBR of the top 12 inches of subgrade (divided into 6-inch layers) along with combined concrete and base thickness as an indicator of the project's suitability for rubblization. Combined, the FWD and DCP data complete the information necessary to analyze the suitability of the project for rubblization and show the following:

- The FWD data confirm the existence of different structures seen in the GPR data. Based on GPR, these sections are from 3.18 to 3.44 and 4.22 to 4.82 miles north of the King/Cottle County lines. In these sections, the FWD backcalculations have high errors per sensor, and the backcalculated base moduli are in the range of a flexible base as illustrated in Figure 7.3. In the GPR data, only the bottom of the surfacing could be seen in these sections, so other records or coring may be necessary to identify the structure of these sections.
- The DCP data, when plotted on the IDOT rubblization selection chart, indicate the project is of marginal suitability for rubblization. The data are plotted on the IDOT chart in Figure 7.4. These data show that the locations represented by Holes 1 and 3 are in the "gray area" of suitability. At Hole 1, the top 6 inches of subgrade are outside the rubblization zone, but the next 6 inches are in the suitability zone. Hole 3 shows the top 6 inches of subgrade are very good, but the next 6 inches of subgrade are poor. Problems rubblizing may occur at these locations and locations with similar soil properties.
- From the IDOT chart, assuming a concrete + base thickness of 8 inches for this project means the subgrade CBR value should be 6 or higher to have confidence in the feasibility of rubblizing the project with either the MHB or RMI.
- Figure 7.5 shows the relationship between the subgrade CBR and backcalculated subgrade modulus for the top 12 inches of soil for this project. From this relationship, the subgrade modulus should be 10 or higher to confidently pursue rubblization of the entire project with either rubblization method. A review of the FWD data reveals 57 percent of the observations for the first 12 inches of subgrade are below 10 ksi.

Table 7.1. FWD Results for US 83.

TTI MODULUS ANALYSIS SYSTEM (SUMMARY REPORT) (Version 6.0)

District:25 (Childress)
County:
Highway/Road: us0083

MODULI RANGE (psi)	Thickness(in)	Minimum	Maximum	Poisson Ratio Values
Pavement:	3.50	50,000	1,300,000	H1: v = 0.3
Base:	8.00	50,000	5,000,000	H2: v=0.2
Subbase:	12.00	5000	50000	H3: v=0.40
Subgrade:	240.00 (User Input)	15,000		H4: v=0.4

Station	Load (lbs)	Measured Deflection (mils) R1	R2	R3	R4	R5	R6	R7	Calculated Moduli Values (ksi) SURF(E1)	BASE(E2)	SUBB(E3)	SUBG(E4)	Absolute ERR/Sens	Dpth to Bedrock	
0.016	10,387	8.18	6.35	5.54	4.62	3.68	3.03	2.38	219.5	3727.3	49.8	11.7	0.83	300	
0.201	10,308	6.33	5.64	4.93	3.94	3.04	2.44	1.97	1285.3	2662.9	5.6	17.4	1.25	300	
0.404	9,327	11.98	8.42	6.74	5.18	3.71	2.7	1.89	103.4	1463.2	8.1	13	0.81	210.7	
0.611	9,624	8.4	7.45	6.11	4.65	3.24	2.27	1.55	757.3	1044.5	5	16.4	4.01	193.2	*
0.803	9,803	6.84	6.31	5.47	4.54	3.59	2.94	2.39	1103	2903.9	7.6	12.4	1.46	300	
1.004	9,756	9.66	7.58	6.17	4.87	3.67	2.76	2.06	234	1736	13.2	12.9	0.32	297.9	
1.009	9,259	12.1	7.84	6.37	4.96	3.7	2.7	1.99	74.2	1837.3	11.6	12.5	0.44	273.3	
1.204	9,696	8.35	6.09	5	3.94	2.97	2.27	1.72	174.9	2038.2	34.5	14.9	0.53	300	
1.398	9,656	5.7	5.48	4.83	3.94	3.04	2.44	1.83	1300	3403	5.1	15.5	3.31	300	*
1.604	9,545	8.78	6.67	5.48	4.33	3.24	2.35	1.65	199.1	2271.4	7.4	15.8	0.89	214	
1.804	9,446	8.36	6.59	5.57	4.47	3.42	2.63	2.02	258.2	2189.3	23.4	12.6	0.81	300	
2.011	10,582	7.87	6.37	5.45	4.38	3.33	2.52	1.86	358.2	3177.1	5.4	17.6	1	277.3	
2.204	9,466	8.35	6.39	5.42	4.43	3.39	2.61	1.97	200.8	2717.9	21.3	12.8	0.81	300	
2.405	10,761	7.22	5.39	4.54	3.7	2.88	2.28	1.8	202.7	4943.5	7	19.7	0.39	300	
2.611	10,240	6.73	4.87	4.21	3.51	2.41	1.96	1.56	208.5	4432.6	6.8	22.5	2.53	300	*
2.8	10,526	5.96	4.89	4.11	3.36	2.64	2.03	1.6	501.2	3622.6	31	18.3	0.37	300	
3.006	10,431	6.68	5.88	5.04	4.09	3.17	2.49	1.94	1068.5	2707	5.2	17.4	0.74	300	
3.205	10,745	19.21	11.65	5.61	3.05	1.95	1.57	1.23	350.1	70.5	10.1	23.5	6.06	117.3	*
3.398	10,725	23.55	9.6	3.1	1.81	1.28	1.03	0.89	100.6	100.6	10.5	33.5	18.97	53	*
3.598	10,610	7.45	6.41	5.4	4.35	3.4	2.58	1.95	1272	1605	10	15.3	0.74	300	
3.798	10,200	7.25	6.4	5.76	4.36	3.3	2.52	1.92	1044.7	1928.5	5	16.4	2.63	300	*
3.998	9,696	10.44	9.95	6.3	4.93	3.83	2.96	2.3	1207.8	352.6	12.6	12.1	5.27	300	*
4.199	10,606	6.57	5.45	4.87	4.07	3.18	2.59	1.84	532.5	5000	5.2	17.1	1.38	226.1	*
4.404	10,034	26.87	13.66	5.92	3.7	2.49	1.93	1.51	79.3	54.4	11.3	18.1	5.91	140	*
4.604	10,133	26.59	11.6	4.8	3.04	2.23	1.79	1.44	64.3	50	24.1	16.7	18.24	103.9	*
4.802	9,593	31.85	15.05	4.33	2.38	1.78	1.59	1.33	50	50	11.8	16.7	33.64	47.9	*
4.999	11,070	6.75	5.24	4.55	3.63	2.54	2	1.65	379.8	3339.9	12.1	21.5	2.49	300	
5.204	10,018	6.85	5.82	5	4.09	3.2	2.54	1.94	637.1	2736.6	22.2	13.9	0.64	300	
5.405	9,994	6.91	6.18	5.27	4.26	3.29	2.59	2.02	1127.7	2195.1	6.2	15.3	1.18	300	
5.417	9,398	13.34	5.41	4.57	3.7	2.85	2.22	1.72	50	1200	50	16	7.33	300	*
5.606	9,672	8.33	6.23	5.03	3.9	2.94	2.29	1.77	234.1	1350	48.2	14.7	0.45	300	
5.806	10,483	11.26	6.67	5.3	4.07	3	2.28	1.73	70.4	2740.8	6.3	19.9	0.74	300	
6	9,549	9.84	7.57	6.24	4.89	3.58	2.73	2.11	203.6	1727.1	11.1	13	0.84	300	
6.2	9,700	7.35	6.38	5.37	4.32	3.24	2.59	1.99	1278.2	1446.7	6.7	14.9	1.16	300	
6.398	11,027	5.8	5.27	4.85	4.06	3.05	2.16	1.77	1300	3599.9	5.7	19.1	4.96	250.9	*
6.569	9,426	11.44	8.56	7.13	5.38	3.87	2.86	2.09	153.8	1519.1	5	13.3	1.21	259.6	*
Mean:		10.7	7.26	5.29	4.08	3.06	2.37	1.82	510.7	2165.1	14.5	16.5	3.73	249.8	
Std.	Dev:	6.55	2.42	0.8	0.74	0.59	0.43	0.31	463.4	1352.3	13	4.2	6.69	200.3	
Var	Coeff(%):	61.25	33.4	15.05	18.02	19.22	18.01	16.91	90.7	62.5	89.7	25.3	179.23	80.2	

Table 7.2. Summary DCP Results from US 83.

Hole	Base+Concrete Thickness (inches, from GPR and DCP)	Subgrade CBR 0-6"	Subgrade CBR 6-12"	Subgrade Modulus from FWD (ksi, 12" dummy layer and 240" depth to bedrock)	Location
1	9.4	3.1	5.0	7.6	0.803 mi N of County Line
2	10.4	9.8	33.2	31.0	2.8 mi N of County Line
3	6.9	10.4	3.9	11.1	6.00 mi N of County Line

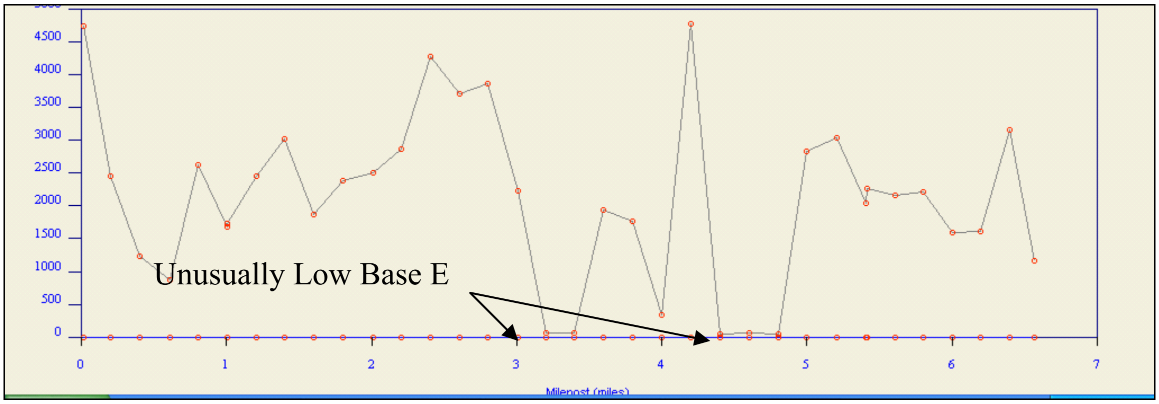

Figure 7.3. Base Modulus with Distance for US 83 Northbound.

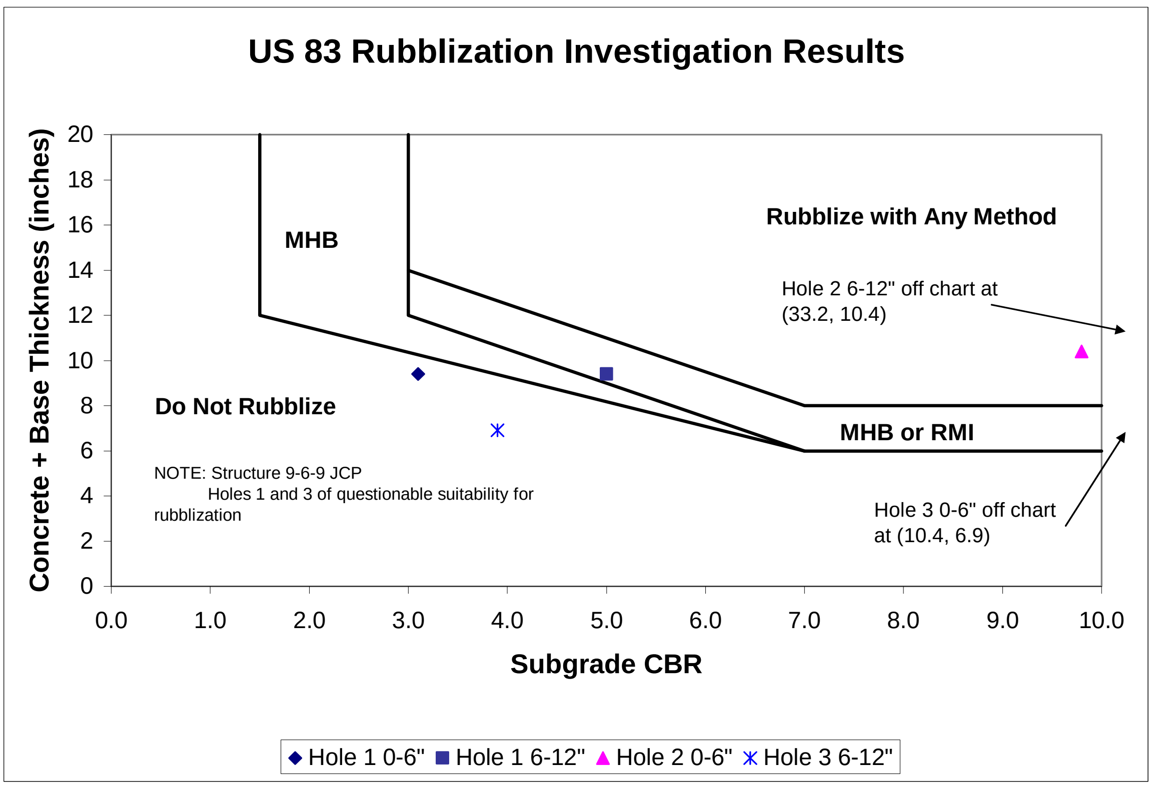

Figure 7.4. DCP Results from US 83 on IDOT Rubblization Selection Chart.

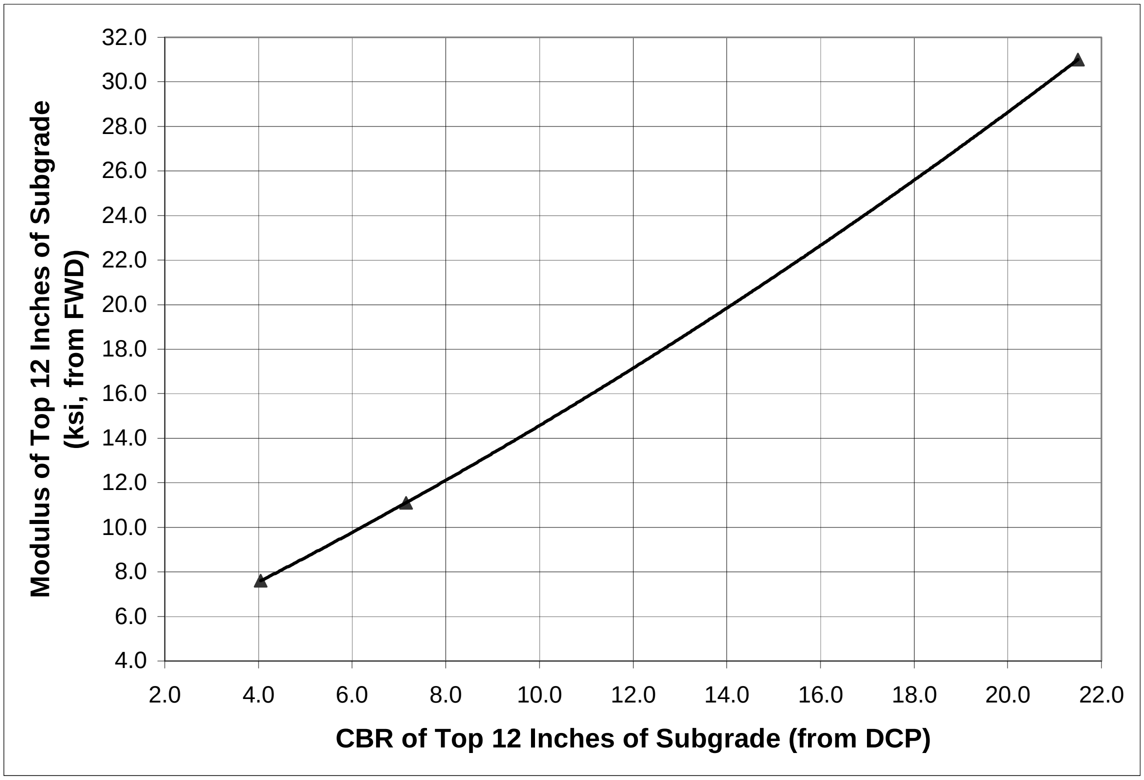

Figure 7.5. Relationship between Subgrade Modulus and CBR on US 83.

RECOMMENDATION FROM PRE-CONSTRUCTION INVESTIGATION

Based upon the pre-construction investigation, the rubblization recommendations on US 83 in Cottle County include:

- Different structures exist from 3.18 to 3.44 and 4.22 to 4.82 miles north of the King/Cottle County lines. Records should be checked or coring performed at these locations to identify the structure. Field data suggest the concrete slabs have been removed.
- Based on existing rubblization guidelines and collected DCP and FWD, the majority of the project is of questionable suitability for rubblization. Prior work indicates the top 12 inches of subgrade are the most crucial. At this project, the condition of the top 12 inches of subgrade are highly variable. More than 50 percent of the project is of questionable suitability for rubblization.

CONSTRUCTION NOTES

In July 2006, the TTI research team visited the construction site to observe operations. The existing slab length was 40 feet, and most slabs contained two to four transverse cracks in them. Figure 7.6 shows a typical existing concrete slab.

Figure 7.6. Existing Concrete Slabs on US 83 from King/Cottle County Line.

The resonant machine device rubblized the existing JCP, as Figure 7.7 shows. Figure 7.8 illustrates the typical surface view and cross section of the rubblized layer. Proof rolling, as Figure 7.9 shows, aided the inspector in determining limits of instability for removal. Although the rubblizer successfully fractured the concrete on the entire project, locations requiring removal typically exhibited abnormally large particle sizes, as Figure 7.10 illustrates. In some cases, the rubblizer created large ruts in the pavement, serving as its own proof roller and indicating the need for removal and replacement. Figure 7.11 shows one such location of significant rutting in the rubblized layer from the RMI machine.

Figure 7.7. Resonant Breaker on US 83 from King/Cottle County Line.

Figure 7.8. Surface and Cross Section Views of Rubblized JCP on US 83.

Figure 7.9. Proof Rolling on US 83 from King / Cottle County Line.


Figure 7.10. Large Particle Sizes Excavated from Removal Location.

Figure 7.11. Rutting in Rubblized Layer from Resonant Breaker.

The survey of the site by TTI prior to construction highlighted two locations where the concrete pavement appeared to have already been replaced. Additionally, at several locations non-destructive test (NDT) data suggested rubblization likely would encounter problems due to the subgrade. Milling off the old HMA overlay revealed that the concrete indeed had been previously removed in two sections. Figure 7.12 shows one of these locations. Additionally, Figure 7.13 shows how the predictions of marginal locations in the pre-construction evaluation matched quite well with the locations that were removed and replaced due to instability.

Figure 7.12. Location of Prior Concrete Removal on US 83 from King / Cottle County Line.

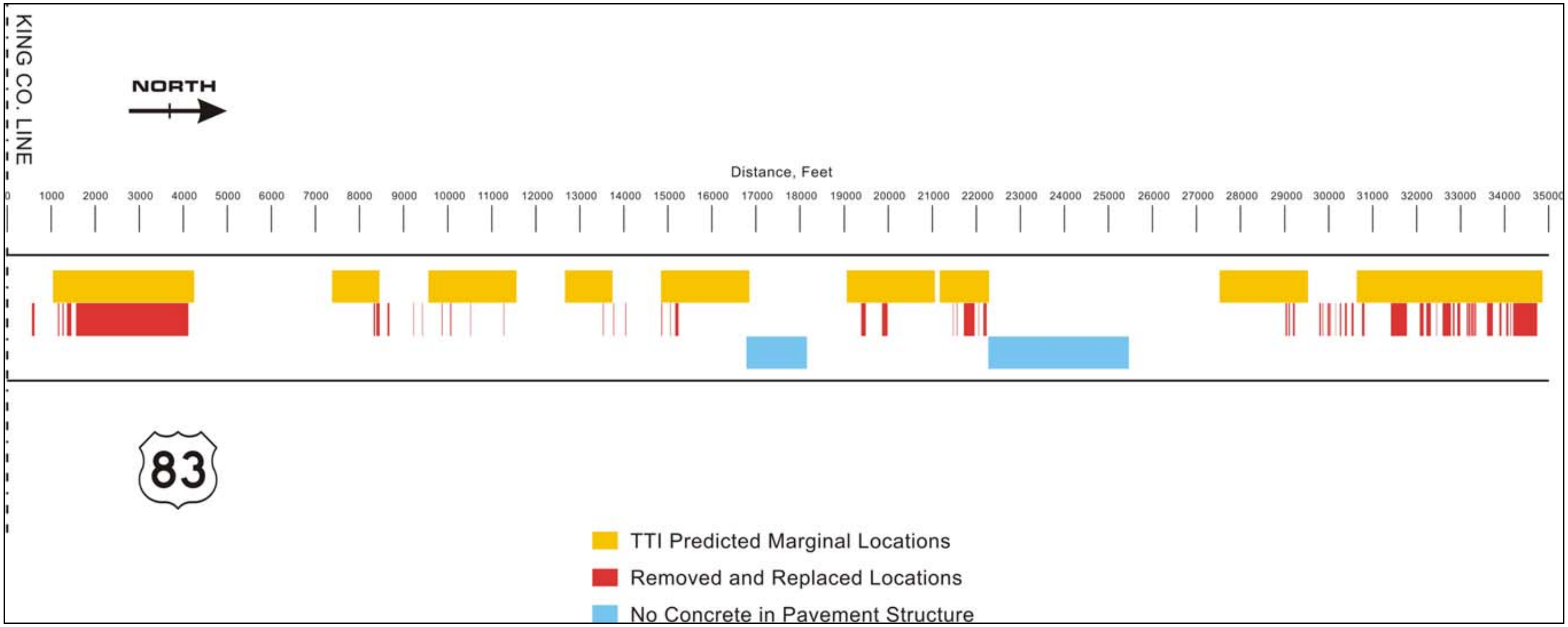

Figure 7.13. Comparison of NDT Predictions and Field Construction.

Jordan Paving constructed the HMA overlays on top of the rubblized pavement. According to their personnel, they did not encounter any problems placing the mix on top of the rubblized JCP. Figure 7.14 shows the paving operation.

Figure 7.14. Paving Operation on US 83 from King / Cottle County Line.

FOLLOW-UP SURVEY RESULTS

In April 2007 TTI conducted a follow-up survey including GPR and FWD on the southbound section. Based upon reported locations of removal and replacement, this survey focused on the section from station 1743 to 1653 in an attempt to avoid locations of concrete pavement removal. The section has not been opened to traffic yet. Figures 7.15 and 7.16 show the section at stations 1743 and 1653, respectively.


Figure 7.15. Looking North on US 83 SB from STA 1743.

Figure 7.16. Looking South on US 83 SB from STA 1653.

Figure 7.17 shows example GPR data from the section. From the GPR data the typical HMA thickness ranges between 6 and 7 inches. Likewise, the rubblized layer thickness also ranges between approximately 6 and 7 inches. Additionally, Figure 7.17 shows two short full depth repair locations. Based on the measured layer thicknesses with GPR, Modulus 6.0 performed FWD backcalculations using 6.5 inches for both the HMA and rubblized layer thicknesses. Table 7.3 shows the output. At the time of testing, the age of the section was approximately nine months, and the average rubblized PCC modulus was 154 ksi, or 7 percent of the pre-fractured PCC modulus. The standard deviation of the rubblized layer modulus was 83 ksi, which results in a coefficient of variation of approximately 54 percent.

Figure 7.17. Example GPR on US 83 from King / Cottle County Line.

Table 7.3. FWD Output for US 83 from King / Cottle County Line in April 2007.

TTI MODULUS ANALYSIS SYSTEM (SUMMARY REPORT) (Version 6.0)

District:25	(Childress)			MODULI RANGE (psi)		
County: 51	(COTTLE)	Thickness(in)		Minimum	Maximum	Poisson Ratio Values
Highway/Road:	US0083	Pavement	6.5	50,000	500,000	H1: v = 0.35
		Base:	6.5	50,000	500,000	H2: v = 0.35
		Subbase:	0			H3: v = 0
		Subgrade: 98.56 (by DB)		5,000		H4: v = 0.4

Station	Load (lbs)	R1	R2	R3	R4	R5	R6	R7	SURF(E1)	BASE(E2)	SUBB(E3)	SUBG(E4)	Absolute ERR/Sens	Dpth to Bedrock
		Measured Deflection (mils)							Calculated Moduli values (ksi)					
298	10,089	17.31	12.97	8.59	5.71	3.94	3	2.39	269.7	164.1	0	7.6	5.63	128.7
594	9,672	15.39	10.85	6.78	4.28	2.79	2.04	1.51	263.7	126.5	0	10.1	5.47	96.3
891	10,892	15.89	11.35	7.05	4.39	2.85	2.04	1.57	330.7	115	0	11	5.13	94.1
1486	10,653	15.43	11.56	7.88	5.39	3.77	2.82	2.15	279.5	265.2	0	8.4	4.91	137.4
1782	9,589	16.39	11.67	7.07	4.43	2.98	2.26	1.8	253.2	112.3	0	9.4	6.87	108.6
2081	10,109	13.96	9.98	6.66	4.61	3.26	2.48	1.98	199.7	431.8	0	9.4	5.91	143.5
2674	9,851	12.9	9.48	6.13	4.11	2.85	2.2	1.75	301.7	243.7	0	10.3	6.36	123.7
2971	10,236	14.79	10.53	6.65	4.29	2.89	2.12	1.65	276.8	166.9	0	10.5	5.64	108.2
3862	10,459	16.57	11.76	7.4	4.85	3.33	2.55	2.02	224.6	187	0	9.4	6.66	119.8
4456	10,081	20.24	13.89	8.59	5.62	3.94	3.02	2.41	160	155.6	0	7.8	7.86	140.7
4755	10,073	18.59	13.87	8.38	5.66	3.59	2.87	2.19	278.3	102.2	0	8	7.13	84.7
5051	10,467	20.26	14.05	8.16	5	3.22	2.53	2.08	218.3	81.4	0	9.2	7.55	91.4
5942	9,962	20.03	13.46	8.06	4.99	3.45	2.65	2.15	160	119.7	0	8.7	8.27	129
6239	10,065	23.78	16.55	9.88	6.13	4.1	3.06	2.4	169.1	80	0	7.2	6.99	108.1
6537	10,030	21.33	15.06	9.2	5.78	3.83	2.86	2.25	197.7	91.8	0	7.7	6.29	104.2
6834	9,891	20.71	14.22	8.02	4.9	3.29	2.59	2.09	182.4	80.5	0	8.7	8.89	105.9
7725	10,741	20.33	12.68	7.55	4.74	3.22	2.49	2.01	160	121.5	0	10	8.71	114.9
8616	10,884	15.89	10.24	6.03	3.7	2.39	1.76	1.38	199.6	147	0	13.2	6.69	90.5
8913	11,448	18.74	11.82	6.63	3.89	2.56	1.95	1.57	175.5	107.1	0	12.8	8.4	92.1
9000	11,285	18.62	10.96	6.77	4.36	2.97	2.28	1.8	160	176.1	0	11.7	9.37	115.2
Mean:		17.86	12.35	7.57	4.84	3.26	2.48	1.96	223.0	153.8	0.0	9.6	6.9	111.9
Std. Dev:		2.83	1.87	1.04	0.69	0.49	0.39	0.31	54.4	82.9	0.0	1.7	1.3	17.7
Var Coeff (%):		15.86	15.13	13.69	14.18	14.88	15.60	15.99	24.4	53.9	0.0	17.6	19.0	15.9

CONCLUSIONS

This project illustrates numerous observations regarding the process of selecting and constructing a rubblization project. First, the methods outlined in TTI report 0-4687-1 worked quite well for evaluating the project, as evidenced by the general match between predicted marginal locations (developed prior to construction) and actual limits of needed removal and replacement encountered during construction. Second, particle sizes from rubblization that do not meet specifications indicate poor foundational support in the pavement system. Third, the RMI machine serves quite well as a first line of proof rolling due to the heavy wheel loads and the number of repeat passes required over a section to rubblize the full lane width. Finally, the generalized recommendation of estimating the rubblized layer modulus to be 5 percent of the pre-fractured PCC modulus appears reasonable. However, efforts to monitor this section through time should continue to determine if the rubblized layer stiffens with age. This phenomenon has been observed on other rubblization projects and could impact decisions in selecting design values.

CHAPTER 8
NON-INVASIVE TEST PROCEDURE FOR EVALUATING PROJECTS

SUMMARY

Based upon a review of factors influential on the success of rubblization, a review of other DOT procedures and the results obtained during field testing and construction of the projects previously described, this chapter presents a non-invasive test procedure for evaluating projects. This procedure involves visual field inspection, GPR, FWD, and DCP data collection and analysis. A slightly modified version of the Illinois rubblization selection chart then provides a basis for evaluating if the pavement can support construction traffic after rubblization.

PROCEDURE

The procedure recommended uses information on pavement structure, pavement condition (distress and structural properties), and subgrade condition (bearing capacity and moisture condition). For a thorough analysis of the project, this plan includes reviews of plans, a visual site assessment, and surveys with ground-penetrating radar, falling weight deflectometer, and dynamic cone penetrometer. The GPR survey can be used to estimate pavement layer thicknesses, identify changes in the pavement structure, and detect locations of wet subgrade. The FWD provides data to evaluate the structural condition of the pavement layers. For jointed concrete pavements, the FWD also provides data to evaluate joint transfer efficiency. The DCP data serve for validation of the subgrade conditions. Use the following steps to evaluate a project:

- Plans: Collect and review plan sheets from the project to identify the existing pavement structure. Identify important parameters such as: existence of any treated subgrade layers, presence and thickness of base (if any), thickness of concrete pavement, thickness of any overlays, and presence of any pavement widening with non-uniform construction.
- Visual Condition Survey: Review the project for the overall level of and type of distresses present. Examine and note the location of any maintenance treatments where the structure may be different. Look for low-lying areas or areas with poor drainage where subgrade conditions may be poor.
- GPR: Perform a GPR survey over the entire project, collecting data at 1 foot intervals. Use Colormap to analyze the GPR data to estimate pavement layer thicknesses, locate limits of potential section breaks in the pavement structure, and identify locations where the subgrade may be excessively wet. For increased reliability, survey the section again prior to rubblization but after the contractor mills off all HMA.
- FWD: Collect FWD data on the project at 0.2 mile intervals, or at intervals sufficient to obtain at least 30 drops on the project, whichever is less. Collect the drops in the center of the concrete slabs. If the project is jointed concrete, randomly collect joint transfer tests to aid in evaluating the joint transfer efficiency. Process the FWD data with Modulus 6.0.
- DCP: From the FWD data, identify the locations with the highest and lowest deflections at the outermost deflection sensor. Perform DCP tests at these locations. Test a

minimum of two locations of high outer sensor deflection with the DCP. Test at least one location with low outer sensor deflection with the DCP. Estimate the thickness of the base layer from the DCP data, and use the Corps of Engineers equation to convert the DCP penetration rate to CBR. Determine the CBR and thickness of the base layer. If the DCP data do not clearly detect a base layer, then use the CBR of the first 6 inches beneath the concrete as a "dummy" base layer (many older concrete pavements in Texas do not have a base beneath them). Determine the CBR of the first 6 inches of subgrade.

PAVEMENT TYPE SELECTION PROCESS

The collection of the pavement evaluation data allows the project to be analyzed for its suitability for rubblization. Performing the following steps enables making this determination:

- Evaluate the DCP data using an adaptation of the IDOT rubblization selection chart (shown in Figure 8.1) as follows:
    - Plot the concrete thickness versus the CBR of the base. These data are used to gauge whether the concrete will rubblize, since sufficient support beneath the slab is crucial for satisfactory breakage.
    - Plot the combined thickness of the concrete and base versus the CBR of the subgrade. Use a "dummy" base layer of 6 inches if the DCP data do not distinguish a base layer. These data are used to evaluate whether the subgrade can support construction traffic after rubblization.
- If all the data points fall in the zones that indicate rubblization is feasible, the project should be suitable for rubblization.
- If all the data points fall in the "Do Not Rubblize" zone of the chart, rehabilitation options other than rubblization should be considered.
- If some, but not all, of the data points fall in the "Do Not Rubblize" zone, certain portions of the project may not be suitable for rubblization. More analysis, interpretation, and judgment are required. Typically in Texas these instances are encountered on the older (pre-1960) concrete pavements with little to no identifiable base present. Perform additional analysis as follows:
    - Determine the average CBR of the first 12 inches beneath the concrete.
    - From the rubblization selection chart, determine the minimum CBR necessary to support rubblization for the known concrete thickness at the project. Do this by starting on the Y-axis at the known concrete thickness, then project horizontally until intersecting the boundary where rubblization is feasible. At this intersection, project down to the X-axis, and read the minimum subgrade CBR required.
    - Form a relationship between the subgrade modulus and CBR by graphing the average CBR of the first 12 inches beneath the concrete versus the subgrade modulus. Input the minimum CBR necessary into this relationship to determine the anticipated minimum subgrade modulus needed. Typically this modulus value ranges between 10 and 15 ksi.
    - Graph the subgrade modulus with distance for the project. Where the modulus does not exceed the minimum subgrade modulus needed, a risk exists that the project may not rubblize. At this point the data must be reviewed on a case-by-

case basis and a judgment made as to where, if at all, rubblization should be attempted.

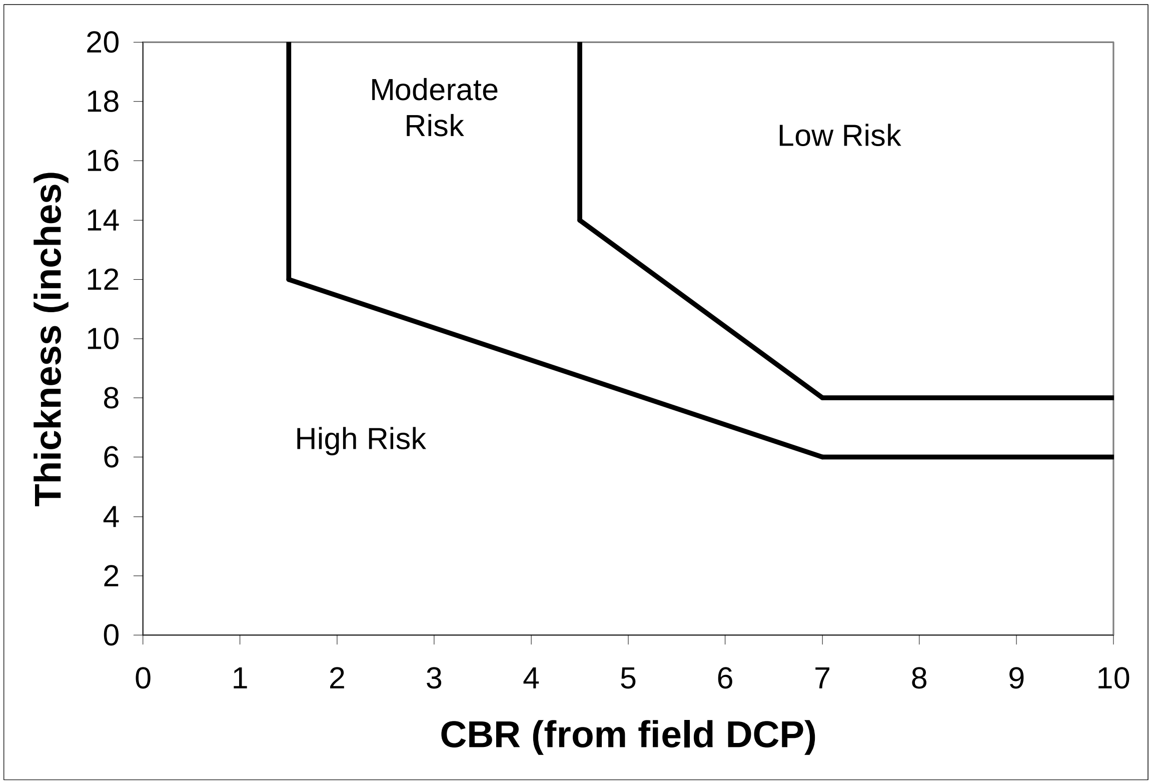

Figure 8.1. Proposed Rubblization Selection Chart.

PROPOSED RUBBLIZATION SELECTION CHART

The original IDOT selection chart, used in the project screenings presented in Chapters 1 through 4 of this report, worked reasonably well for evaluating projects and matching field construction experiences. However, from the experiences on the US 70 and US 83 projects, the researchers concluded that the distinction between rubblization equipment should be eliminated from the chart. The original philosophy behind the equipment distinction is the fact that the load from the MHB equipment stays on the unbroken concrete; therefore, this machine could be used to rubblize in poorer soil conditions. Field experience in Texas showed, however, that because of the nature of operation of the MHB, soft spots may be missed, which then fail under construction traffic during paving. The RMI, on the other hand, serves well as its own proof roller, and one would much rather discover weak foundation areas during rubblization rather than during paving. Because of these experiences, the researchers recommend the chart use risk rather than equipment for the various zones.

The second change the research team proposes to the selection chart is to make the chart slightly more conservative. Using the methods outlined in the previous "Pavement Type Selection Process" section, test location 3 on US 83 would plot at (3.9, 12.9), and fall into the "rubblize with any method" zone using the original IDOT boundaries. However, during field construction this location required full depth removal and replacement. Figure 8.1 shows the proposed rubblization selection chart incorporating the recommended modifications for use with the procedure described above.

NOTES TO PROCEDURE

Although use of these procedures provides a rather complete view of the project, all tests are spot tests, with the exception of GPR. Therefore, the possibility exists that problem locations can be missed between spot test locations. Closer sampling frequencies and special attention to visual site surveys such as locations of standing water, stock tanks, etc., can reduce the likelihood of overlooking a problem location.

CHAPTER 9
CONCLUSIONS AND RECOMMENDATIONS

SUMMARY

This project evaluated several JCP projects for their suitability for rehabilitation by rubblization. A framework for analyzing a project's suitability using visual observation, GPR, FWD, and DCP assists in making an informed decision regarding rehab options. If rubblization is feasible, either one of the rubblizers should perform acceptably. However, extra care to employ proof rolling should be used when using the MHB for rubblization. If rubblization is not feasible, options such as a flexible base overlay or an overlay using crack and rut resistant mixes exist.

CONCLUSIONS REGARDING THE MHB AND RMI

Experience in this project with the MHB and RMI machines show that both devices can acceptably rubblize the concrete pavement. However, the Texas experience indicates the distinction between machines is unnecessary in the rubblization selection chart. Therefore, the researchers propose the chart shown previously in Figure 8.1. Additionally, while proof rolling is recommended prior to overlay regardless of which machine is used for rubblization, proof rolling especially is crucial when the MHB rubblizes the concrete. This is because the wheel loads of the MHB stay on the unbroken concrete during operation. In contrast, the RMI traverses the rubblized section many times to complete one lane width; therefore, to an extent, the RMI machine serves as its own proof roller. As a minimum use a medium pneumatic roller with a ground contact pressure of at least 85 psi for proof rolling.

The break patterns produced by the two machines differ. The MHB produces larger particle sizes deeper in the concrete layer and flat, elongated particles at the top. These top particles are then broken down with the special Z-grid roller. In contrast the RMI process appears to produce a relatively uniform break pattern through the depth profile of the concrete layer. Figure 9.1 shows cross sections of the rubblized layer produced by each machine.

Figure 9.1. Cross Section of Rubblized Layer from MHB (left) and RMI (right).

RECOMMENDATION FOR PAVEMENT THICKNESS DESIGN

To perform a mechanistic-based pavement design, the modulus value of the rubblized layer is needed. Prior literature and projects in Texas both indicate the JCP modulus after rubblization averages approximately 5 percent of the concrete modulus prior to rubblization. Therefore, project designers should use 5 percent of the backcalculated pre-rubblization concrete modulus to estimate the rubblized layer modulus for use in the pavement design. The rubblized layer may be incorporated into a new flexible or rigid pavement facility.

If a rigid (concrete) pavement overlay is to be placed over the rubblized layer, at least 4 inches of asphalt concrete pavement or asphalt stabilized base will need to be placed on top of the rubblized layer before the rigid overlay is placed. The thickness of the rigid pavement overlay is calculated using the new rigid pavement thickness design procedure in the 1993 AASHTO Guide for Design of Pavement Structures. Chapter 8 of the TxDOT Pavement Design Manual (revised October 2006) describes the procedure and inputs that TxDOT designers use for new rigid pavement thickness design. This manual can be downloaded at: ftp://ftp.dot.state.tx.us/pub/txdot-info/gsd/manuals/pdm.pdf.

RECOMMNEDATIONS FOR HMA OVERLAY MIX DESIGN

When rubblization is not an option, major advances in crack- and rut-resistant HMA overlay design exist. The mixes should meet the Hamburg test requirement set forth by TxDOT 2004 Standard Specifications Item 341 and pass the overlay test requirements shown in Table 9.1 below. A good option is to use a 1 inch level up of a crack-attenuating mix (CAM) followed by a conventional surface mix. TxDOT Text Method Tex-242-F describes the Hamburg test, and Test Method Tex-248-F describes the overlay test.

Table 9.1. Cracking Requirements for Overlay Mixes.

Mix Type	Minimum Number of Cycles to Failure
Type C, D	300
RBL or CAM	750

APPENDIX
CONSTRUCTION SPECIFICATIONS FOR RUBBLIZATION

Rubblizing Concrete Pavement

1. **Description.** Rubblize and compact concrete pavement.

2. **Materials.** Furnish materials of uniform quality that meet the requirements of the plans and specifications. Notify the Engineer of the proposed material sources and of changes to material sources. The Engineer may sample and test project materials at any time throughout the duration of the project to assure specification compliance.

   A. **Flexible Base.** Furnish material of the type and grade shown on the plans and conforming to the requirements of Item 247, "Flexible Base" or Special Specification, "Engineered Flexible Base."

3. **Equipment.** Provide machinery, tools, and equipment necessary for the proper execution of the work. Provide either a Type I or Type II rubblizer and necessary rollers for proof rolling and compacting the rubblized pavement, unless otherwise shown on the plans.

   A. **Type I Rubblizer.** Provide a self-contained, self-propelled, resonant frequency breaker, capable of producing low-amplitude, 2000 lb blows, at a rate not less than 44 Hz.

   B. **Type II Rubblizer.** Provide a self-contained, self-propelled, multiple-head breaker, with each hammer independently adjustable, and capable of rubblizing a width of up to 13 ft. in one pass.

   C. **Roller-Vibratory.** Provide a Drum (Type C) roller, with a static weight ≥ 10 tons, meeting the requirements of Item 210, "Rolling."

   D. **Roller-Medium Pneumatic.** Provide a roller conforming to the requirements of Item 210, "Rolling."

   E. **Roller-Heavy Pneumatic.** Provide a roller conforming to the requirements of Item 210, "Rolling."

   F. **Roller-Z Grid Vibratory.** When rubblizing with Type II equipment, furnish a steel wheel, self-propelled vibratory roller, with a minimum weight of 10 tons, and a Z-pattern cladding bolted transversely to the surface of the drum.

   G. **Concrete Saw.** When rubblizing is required adjacent to concrete pavement to be retained, furnish a concrete saw capable of sawing a vertical cut full depth through the concrete pavement in a single pass.

4. **Construction.** Prepare, rubblize, compact, and proof roll concrete pavement. Operate equipment in a manner that will not damage the base, underground utilities, drainage structures, and other facilities on the project. Repair damaged facilities. Alternate breaking methods may be used in areas of identified underground utilities and drainage structures if approved. If required elsewhere in the plans, construct the pavement drainage systems at least two weeks prior to rubblization.

   A. **Preparatory Work.** Before rubblization, complete the following:

- Remove all material overlaying the concrete pavement. Material removed will remain property of the Department unless otherwise shown on the plans. Transport and stockpile the removed material at locations shown on the plans or as directed. Remove in accordance with Item 105, "Removing Stabilized Base and Asphalt Pavement," except measurement and payment.
- Before rubblizing a section, cut full-depth saw cut joints at any locations shown on plans to protect facilities that will remain in place.
- Adjustments or additions to the pavement adjacent to the concrete must be complete to the elevation of the top of the concrete pavement to be rubblized. Perform this work in accordance with pertinent bid items.
- Reconstruct adjacent shoulders and adjacent ramp areas prior to rubblization, when shown on the plans. Perform this work in accordance with pertinent bid items.

B. Rubblization and Compaction. Use a Type I or Type II rubblizer to completely de-bond any reinforcing steel and rubblize the existing concrete pavement. Use other types of rubblizing equipment only if shown on the plans or approved by the Engineer.

Table 1. Rubblization Requirements.

Location	Largest Particle Dimension	Allowable Percentage Exceeding
Top half of slab or above reinforcing steel[1]	3 in.	40
	6 in.	0
Bottom half of slab or below reinforcing steel	9 in.	25
	12 in.	0

1. Any particle greater than 6 inches in largest dimension remaining on the pavement surface shall be reduced to an acceptable size or removed. Fill area with flexible base and compact.

Cut off any projecting reinforcing steel below the rubblized surface. Dispose of removed steel in an approved manner.

1. **Type I Rubblization.** Begin rubblization at a free edge or previously broken edge and work transversely toward the other edge. In the event the rubblizer causes excessive deformation of the pavement, the Engineer may require high flotation tires with tire pressures less than 60 psi. Any displaced areas shall be considered non-conforming and treated as described above. Reduce any particle greater than 6 inches in largest dimension remaining on the pavement surface to an acceptable size or remove and fill the area with flexible base. Compact by seating rubblized pavement with the following rolling pattern:
   - one pass from a vibratory roller, followed by at least one pass with the pneumatic roller,
   - followed by at least two more passes with the vibratory roller.
   - The rolling pattern may be changed as directed.

2. **Type II Rubblization.** Unless otherwise directed, rubblize the entire lane width in one pass. Provide a screen to protect vehicles from flying particles as directed. Reduce any particle greater than 6 in. in largest dimension remaining on the pavement surface to an acceptable size or remove and fill the area with flexible base. Compact by seating the pavement with the following rolling pattern:

   - a minimum of four passes with the Z-grid vibratory roller,
   - followed by four passes with a vibratory roller,
   - and by at least two passes from a medium weight pneumatic roller.
   - The rolling pattern may be changed as directed.

C. **Verification of Rubblization Process**. Before full production begins, the Engineer will select approximately 200 linear ft. of one lane width to verify the rubblization operation. The contractor shall rubblize the test section, using the section to adjust equipment. From within this test section, the Engineer and Contractor shall agree upon a test pit location. At the test pit, excavate a 4 ft. square test pit. Verification testing of particle size distribution will be by the Engineer. Additional test pits may be required during the project to confirm ongoing compliance with the particle size specification. Replace excavated material with flexible base and compact. The Engineer may waive density control testing.

   If the rubblized material from the test pit does not meet specifications, another test strip shall be conducted and tested. Should this pit also fail, rubblization operations shall be suspended until the Contractor demonstrates to the satisfaction of the Engineer that specifications can be met, at which time the Engineer shall allow the Contractor to conduct another test strip.

D. **Proof Rolling.** Unless otherwise shown on the plans, perform proof rolling of the rubblized areas using a heavy pneumatic roller in accordance with Item 216, “Proof Rolling.” Unless otherwise directed by the Engineer, load the heavy pneumatic roller to an approximate weight of 25 tons. Increase the roller weight up to 50 tons when directed by the Engineer.

E. **Localized Repair.** Repair areas identified by the Engineer as unstable or non-uniform in accordance with Item 351, “Flexible Pavement Structural Repair,” except measurement and payment. Excavate repair areas to a depth of 18 inches from the surface of the concrete pavement. Use flexible base, as shown on the plans, to replace excavated material. The Engineer may waive density control testing. If unsuitable material is encountered below the 18 inches of excavated material, take corrective measures as directed.

F. **Finishing.** After completion of proof rolling and repairs, place the next successive course on the rubblized area before opening to all traffic. Cease operations if rain occurs after rubblization but before placing of the next course has been completed. Resume operations only after the Engineer has determined that the rubblized area is dry and stable. After rainfall remove natural soil from edges of the pavement area to facilitate drainage from the rubblized areas, when directed by the Engineer. Restore soil to former condition when directed.

1. Avoid unnecessary trafficking of construction equipment on the rubblized pavement.

2. Restrict public traffic on the rubblized pavement, except at Engineer-approved access points. When public traffic is permitted by the Engineer on the rubblized concrete, use traffic control methods that conform to requirements shown on the plans or as directed to minimize damage to the rubblized section.

3. Monitor the surface of the rubblized section for any reinforcing steel that may migrate to the top and cut off any projecting reinforcing steel below the rubblized surface.

5. Measurement. This Item will be measured as follows:

A. Rubblization. Rubblization will be measured by the square yard of surface area rubblized in place.

B. Repair of Localized Areas. Repair of localized material by the square yard of repaired area as defined by the Engineer. In areas where material is excavated, as directed, to depths greater than those specified on the plans, measurement will be made by dividing the actual depth of such area by the plan depth and then multiplying this figure by the area in square yards of work performed. Calculations for each repaired area will be rounded up the nearest 1/10 sq. yd. At each repair location, the minimum area for payment purposes will be 1 sq. yd.

6. Payment.

A. Rubblization. The work performed and materials furnished in accordance with this Item and measured as provided under "Measurement" will be paid for at the unit price bid for "Rubblizing Concrete Pavement" of the type specified. This price is full compensation for removal, transportation and stockpiling of surface materials removed, rubblizing and compacting concrete pavement, saw-cutting required locations, cutting, removing and disposing of exposed reinforcing steel, conducting required test pits, repairing any damaged facilities, removing and replacing soil at pavement edges to facilitate drainage, materials, equipment, labor, tools, and incidentals.

Proof rolling will be paid for in accordance with Item 216, "Proof Rolling."

B. Repair of Localized Areas. The work performed and materials furnished in accordance with this Item and measured as provided under "Measurement" will be paid for at the unit price bid for "Pavement Structure Repair." This price is full compensation for cutting and removing reinforcing steel in the repair area; removing, hauling, spreading, disposing of, and stockpiling existing pavement structure; removing objectionable or unstable material; furnishing and placing materials; maintaining completed section before surfacing; applying tack or prime coat; hauling, sprinkling, spreading, and compacting; and equipment, labor, tools, and incidentals.