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16. Abstract

The Texas Department of Transportation (TxDOT) employs the impact hammer method of sample compaction for laboratory preparation of road base and subgrade materials for testing. Serious concerns exist about the precision of the dry density obtained from this method. This report documents findings from efforts to improve the precision of Test Method Tex-113-E, TxDOT's impact hammer compaction method for aggregate base materials. First, a new sample finishing tool replaced the old finishing method. While data from this change indicated a slight improvement in precision, the change did not hold up to statistical tests of significance. Additionally, four unique variations of laboratory preparation with the impact hammer method were investigated. All four methods resulted in the same mean dry density of compacted test specimens. However, two of the methods clearly resulted in poorer test precision.

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INVESTIGATION OF METHODS FOR IMPROVED PRECISION OF TEST METHOD TEX-113-E

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Report 0-5135-1
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DISCLAIMER

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TABLE OF CONTENTS

Page

LIST OF FIGURES

Figure **Page**

LIST OF TABLES

Page

EXECUTIVE SUMMARY

The Texas Department of Transportation (TxDOT) employs the impact hammer method of sample compaction for laboratory preparation of road base and subgrade materials for testing. Serious concerns exist about the precision of the dry density obtained from this method. Disputes over appropriate field compaction targets or acceptance of field work occur when State and Contractor laboratories produce vastly differing dry densities of compacted specimens. The precision of the test needs improvement to minimize these occurrences. Alternatively, new methods that provide equal or improved precision while improving the correlation of laboratory-measured properties to field characteristics could be pursued.

This report documents findings from efforts to improve the precision of Test Method Tex-113-E, TxDOT's impact hammer compaction method for aggregate base materials. First, a new sample finishing tool replaced the old finishing method. While data from this change indicated a slight improvement in precision, the change did not hold up to statistical tests of significance. Additionally, four unique variations of laboratory preparation with the impact hammer compaction method were investigated. All four of these methods resulted in the same mean dry density of compacted test specimens. However, two of the methods clearly resulted in poorer test precision. The most precise methods both employed hand mixing the water into the aggregate, and hand placement of rock greater than 7/8 inch into the sample. Analysis of computed-axial tomography (CAT) data on test specimens showed that, visually, samples made without hand placement of the large rock had a more random and uniform distribution of rock particles and binder. However, subsequent image analysis of air void content and pore size with depth among the sample preparation variants tested did not confirm the visual interpretation; therefore, no test variant can be considered superior to another in terms of internal sample structure.

CHAPTER 1

IMPACT ON PRECISION FROM USING THE SLIDE HAMMER FINISHING TOOL

SUMMARY

TxDOT recently introduced a change in the sample finishing procedure in Tex-113-E, employing a schedule of blows with a slide hammer of specified mass from a specified drop height to the finishing tool. The slide hammer replaced the schedule of blows with a plastic mallet and the "firm blows" with a rawhide hammer. TxDOT evaluated this change to reduce the opportunity for test variation due to operator differences. From multiple compaction tests performed at multiple laboratories using both finishing methods, the change did appear to slightly improve the test precision. However, with the number of samples tested, the improvement was not sufficient enough to meet significance requirements for statistical tests.

FINISHING METHOD EXPERIMENTAL DESIGN

To investigate the impact of the proposed change in sample finishing methods, TxDOT sent pre-weighed, dried aggregate to numerous TxDOT and commercial laboratories. TxDOT prepared each sample in accordance with standard TxDOT testing methods, and TxDOT performed the moisture-density relationship for the aggregate before shipping out the material. Each laboratory therefore only had to mix in the appropriate amount of water to each pre-prepared specimen and compact the sample, finishing it with the appropriate finishing technique. With the rawhide hammer finishing method, TxDOT performed 42 tests, and private labs performed 11 tests. With the new slide hammer finishing tool, TxDOT performed 34 tests, and private labs performed 8 tests.

To conclude that precision significantly varies between data sets, the tabulated F-ratio must exceed the F-critical value. Given two data sets, dividing the larger variance by the smaller variance yields the F-ratio. The F-critical value was determined based upon a 95 percent confidence level and the appropriate degrees of freedom.

RESULTS

Table 1.1 shows the summary statistics and the information required to investigate the impact on precision from the new finishing method. The table displays analysis results for TxDOT labs only, private laboratories only, and for all labs combined. The mean dry density, expressed in pounds per cubic foot (pcf), did not differ regardless of lab employed or finishing method used. Within TxDOT labs, the change in finishing technique minimally impacted precision as indicated by the F-ratio very near 1.0. Within private labs only, the change in finishing method appears to improve precision as indicated by the 42 percent decline in variance of sample dry density. When pooling data from all labs together, the precision seems to slightly improve due to the influence of the private lab results. However, when subjected to statistical tests of significance, all the data sets indicate the new finishing method had no statistically significant improvement on precision. To become statistically significant, either more tests would be required (higher degrees of freedom), or the differences in variance must increase to raise the F-ratio above the critical value.

Table 1.1. Analysis of Impact on Precision from Different Sample Finishing Procedures.

	Only TxDOT Labs		**Only Private Labs**		**All Labs**	
	Rawhide	Slide Hammer	Rawhide	Slide Hammer	Rawhide	Slide Hammer
Mean (pcf)	128.5	129.0	130.9	130.5	129.0	129.3
StDev (pcf)	1.598	1.559	2.604	1.985	2.055	1.718
Min (pcf)	123.4	124.8	127.8	127.8	123.4	124.8
Max (pcf)	131.6	131.8	136.6	133.1	136.6	133.1
Count	42	34	11	8	53	42
Range	8.2	7	8.8	5.3	13.2	8.3
Variance	2.555	2.430	6.783	3.940	4.224	2.951
df	41	33	10	7	52	41
F-Ratio	1.05		1.72		1.43	
F-Critical	1.75		3.64		1.65	
Decision	**Fail to reject Ho**		**Fail to reject Ho**		**Fail to reject Ho**	

Note: Ho: Variances are equal

The collected data also provide an opportunity to investigate whether any specific lab produces more precise results. The results between TxDOT and private labs for a given sample finishing technique can be compared. Table 1.2 shows the results. With the rawhide hammer finishing method, the variability of results in private labs was 2.65 times the variability within TxDOT labs. Given the number of samples tested, this difference is not significant at the 95 percent confidence level. However, the F-critical value at the 90 percent confidence level is 2.13. The data indicate that at the 90 percent confidence level, private labs produce poorer precision than TxDOT labs when using the rawhide hammer finishing technique. In contrast, by changing to the slide hammer finishing technique, the variability in private labs improves to the point that no difference in precision exists between TxDOT and private labs.

Table 1.2. Comparison of Precision between TxDOT and Private Labs.

	Rawhide Finishing		**Slide Hammer Finishing**	
	TxDOT Labs	Private Labs	TxDOT Labs	Private Labs
Mean (pcf)	128.5	130.9	129.0	130.5
StDev (pcf)	1.598	2.604	1.559	1.985
Min (pcf)	123.4	127.8	124.8	127.8
Max (pcf)	131.6	136.6	131.8	133.1
Count	42	11	34	8
Range	8.2	8.8	7	5.3
Variance	2.555	6.783	2.430	3.940
df	41	10	33	7
F-Ratio	2.65		1.62	
F-Critical	2.66		3.36	
Decision	**Fail to reject Ho**		**Fail to reject Ho**	

Note: Ho: Variances are equal

CONCLUSIONS

The inter-laboratory testing comparing the rawhide hammer finishing technique to the new slide hammer finishing method shows:

- At the 90 percent confidence level, TxDOT lab results were more precise than private lab results with the rawhide hammer finishing technique.
- No difference in precision exists between TxDOT labs and private labs when using the slide hammer finishing method.
- The improvements in precision by switching to the slide hammer finishing method were not great enough, given the number of samples tested, to meet significance requirements for statistical tests.

Despite the lack of significant statistical evidence indicating improved precision by changing to the slide hammer finishing tool, TxDOT should still employ this finishing method for the following reasons:

- The schedule of blows with the slide hammer clearly eliminates opportunity for differences among multiple operators.
- Use of the slide hammer clearly appeared to be a step in the right direction. Using the slide hammer reduced the variability of data sets, particularly within private labs.
- Employing the slide hammer finishing technique improved the precision of results from private labs to equal the precision of results from TxDOT labs.

CHAPTER 2

EVALUATION OF ALTERNATIVE 113-E PROCEDURES

SUMMARY

After determining that the use of the slide hammer finishing tool should be implemented, the research team at TTI conducted additional testing with Spicewood Type A flex base to further evaluate means of improved precision from Test Method Tex-113-E. Four variants of Tex-113-E were used. The mean dry density did not differ between any of the methods used. However, two of the test variants clearly resulted in poorer test precision. The two most precise techniques both employed hand mixing of molding water into the aggregate and hand placement of aggregate retained on the 7/8 inch sieve. The only difference in the most precise methods was the number of lifts. One technique used four lifts, while the other variant used only three lifts. Everything else being equal, no difference in precision existed between specimens constructed with three or four lifts. To wrap up the investigation, CAT scans on specimens constructed with each of the finishing methods were used to investigate interspatial variability within the specimens. In general these tests showed no technique was superior in terms of the resultant internal sample structure.

DESCRIPTION OF EXPERIMENT

Before conducting testing, the research team determined the gradation for recombining test samples according to Test Method Tex-101-E Part II. Table 2.1 shows the results, and Figure 2.1 shows the moisture-density relationship determined according to Tex-113-E. The maximum dry density was 147.9 pcf at 5.7 percent water.

Table 2.1. Recombining Data for Spicewood Aggregate.

Sieve Size	Cumulative Percent Retained
1 ¾ inch	0
1 ¼ inch	2.6
7/8 inch	17.6
5/8 inch	31.8
3/8 inch	49.0
#4	65.5
Pan	100.0

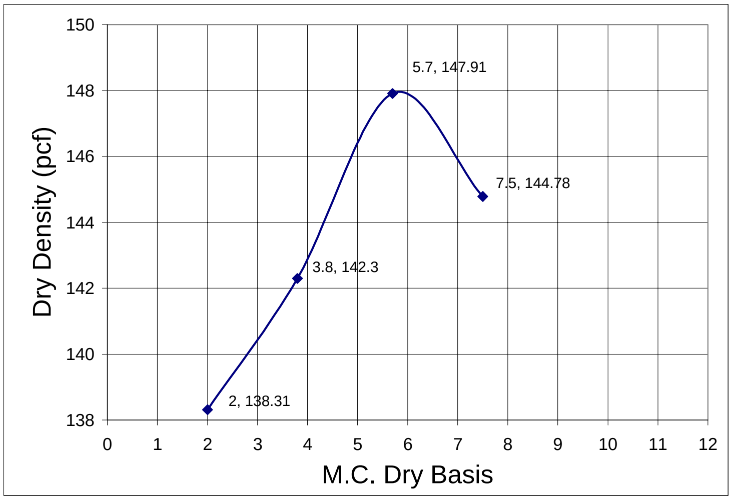


Figure 2.1. Moisture-Density Relationship for Spicewood Aggregate.

All four variants of Tex-113-E tested employed the same total compactive effort and the slide hammer finishing tool. However, techniques differed by number of lifts, hand placement of aggregate, and method of mixing in the molding water. Table 2.2 shows the key parameters of each of the four variants tested. For variant 2, which used only 3 lifts, the number of blows per lift was increased to 67 to maintain the same total compactive effort. Variant 4 differed from Variant 1 only in the method of mixing in the molding water. The research team mixed in the molding water with a mechanical mixer in the fourth technique, as Figure 2.2 shows.

Table 2.2. Parameters Used in Four Variants of Tex-113-E.

Tex-113-E Variant	Number of Lifts	Hand Placement of Aggregate > 7/8 inch	Method of Mixing in Molding Water
1	4	Yes	Hand
2	3	Yes	Hand
3	4	No	Hand
4	4	Yes	Mechanical Mixer

Figure 2.2. Mixing in Molding Water with a Mechanical Mixer.

The research team molded 24 test specimens with each of the test variants, for a total of 96 specimens. According to ASTM D 4855, 24 observations with each test variant will allow for statistically concluding that a difference in precision exists if one method is at least twice as precise as another. The research team computed the dry density of each specimen by using the measured dimensions of the specimen after molding and the oven-dry weight.

DRY DENSITY RESULTS

Table 2.3 shows the results of the testing and the summary statistics for each data set. The research team examined the data to answer two questions:

- Does any test variant result in a difference in mean sample density?
- Does any test variant have superior precision to the other preparation methods?

A simple analysis of variance (ANOVA) test examines whether the mean density of a data set differs from another. Table 2.4 shows the ANOVA result from the four data sets collected in the experiment. Since the F-ratio does not exceed the F-critical value, the data show no difference in mean density exists between the four Tex-113-E variants employed.

Table 2.3. Data for Evaluating Four Tex-113-E Variants.

	Dry Density Values for Four Tex-113-E Variants (pcf)			
Observation	Variant 1	Variant 2	Variant 3	Variant 4
1	146.0	146.5	146.8	146.9
2	146.8	146.9	147.1	147.0
3	146.9	146.3	147.3	147.4
4	146.9	147.0	147.4	146.4
5	146.5	146.0	147.3	146.8
6	147.0	146.7	146.9	145.7
7	147.0	147.4	148.2	147.2
8	147.3	146.7	146.9	147.1
9	147.0	146.9	145.3	145.7
10	146.5	146.8	145.2	147.2
11	147.0	147.0	147.0	146.7
12	146.7	147.1	146.6	146.6
13	145.5	146.9	146.2	147.3
14	147.1	147.2	147.2	145.2
15	147.1	146.4	146.0	147.2
16	146.3	147.3	147.1	146.0
17	146.7	146.8	145.6	146.7
18	146.8	146.6	144.9	147.3
19	147.1	147.3	146.7	146.6
20	146.9	145.4	145.1	146.5
21	146.8	147.2	147.6	147.1
22	147.3	146.1	147.7	147.9
23	147.1	146.7	147.5	145.8
24	147.2	146.3	146.8	147.5
Mean (pcf)	146.8	146.7	146.7	146.7
StDev (pcf)	0.416	0.471	0.901	0.671
Min (pcf)	145.5	145.4	144.9	145.2
Max (pcf)	147.3	147.4	148.2	147.9
Variance	0.1730	0.2215	0.8125	0.4499

Table 2.4. ANOVA Result from Four Variants of Tex-113-E.

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Variant 1	24	3523.81	146.825	0.1730094
Variant 2	24	3521.51	146.73	0.2214737
Variant 3	24	3520.33	146.68	0.8124609
Variant 4	24	3521.96	146.748	0.4498568

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F-crit*
Between Groups	0.26104	3	0.08701	0.2100789	0.88919	2.70359
Within Groups	38.1064	92	0.4142			
Total	38.3675	95				

After determining that all four variants of Tex-113-E tested result in the same mean specimen dry density, the research team proceeded with evaluation of precision of the methods. The F-ratio computed by dividing the larger variance by the smaller variance among the different sample preparation techniques provides the basis for determining if a difference in precision exists. Table 2.5 shows which test variants have significantly different precision. The data show that methods employed in variants 3 and 4 resulted in poorer precision than test variants 1 and 2. The research team believes poorer precision in test variant 3 resulted from the lack of separation of the aggregate greater than 7/8 inch. The reason for the reduced precision in test variant 4 is not known.

Table 2.5. F-Ratios for Examining Precision among Four Tex-113-E Variants.

Confidence level: 95%

	F	**F-crit**	**Different Precision?**
Variant 3/Variant 1	4.70	2.01	Yes
Variant 3/Variant 2	3.67	2.01	Yes
Variant 3/Variant 4	1.81	2.01	No
Variant 4/Variant 1	2.60	2.01	Yes
Variant 4/Variant 2	2.03	2.01	Yes
Variant 2/Variant 1	1.28	2.01	No

CAT SCAN RESULTS

To examine the internal sample structure of specimens compacted with each of the Tex-113-E variants, the research team performed computed-axial tomography tests on four specimens prepared with each test variant, for a total of 16 test samples. Scans on all specimens included five axial scans and three verticals scans. From these scans, the research team noted differences in internal sample structure between the four test variants. As a final analysis, one representative specimen from each test variant was submitted to the University of Texas for extensive CAT analysis where a transverse scan was collected every 0.5 mm throughout the sample profile. Following this data collection, Dr. Eyad Masad at TTI performed image analysis on the data.

The Appendix presents all the collected CAT scans, and Figures 2.3a through 2.6b show scans from representative samples for each of the four test variants. In the scanning process, the X-ray source moves in a concentric circular path around the scan circle. X-ray attenuation data are gathered by stationary detectors located outside the path followed by the source. Due to the circular geometry of the CAT-scanner, there are artifacts that developed in the longitudinal scans. The dark areas in the middle of the specimens in the longitudinal scans are not low density areas but rather are artifacts of the scans. These samples are too large and dense for the X-rays to penetrate through the sample longitudinally, so the dark areas in the middle of the longitudinal scans are where the X-ray beam attenuated so much that the detectors could not receive data from this region. Evaluation of the visual CAT scan data shown in Figures 2.3a through 2.6b indicates:

- Specimens prepared with test variants 1 and 2 exhibit high-void interfaces between the bottom and second lift. This interface area contains a concentration of large aggregate.
- Specimens prepared with variant 2 (compacted in three lifts of 67 blows with hand placement of rock >7/8 inch) in general exhibited the most severe concentrations of voids.
- Specimens prepared with variant 3 (no hand placement of rock >7/8 inch) show the most uniformity throughout the sample profile in terms of even and random distribution of coarse aggregate and void areas.
- Specimens prepared with variant 4, which only differed from variant 1 in the method of mixing in the molding water, in general did not exhibit as severe internal sample structure variations as method 1 but were also not as homogeneous internally as specimens prepared with variant 3.

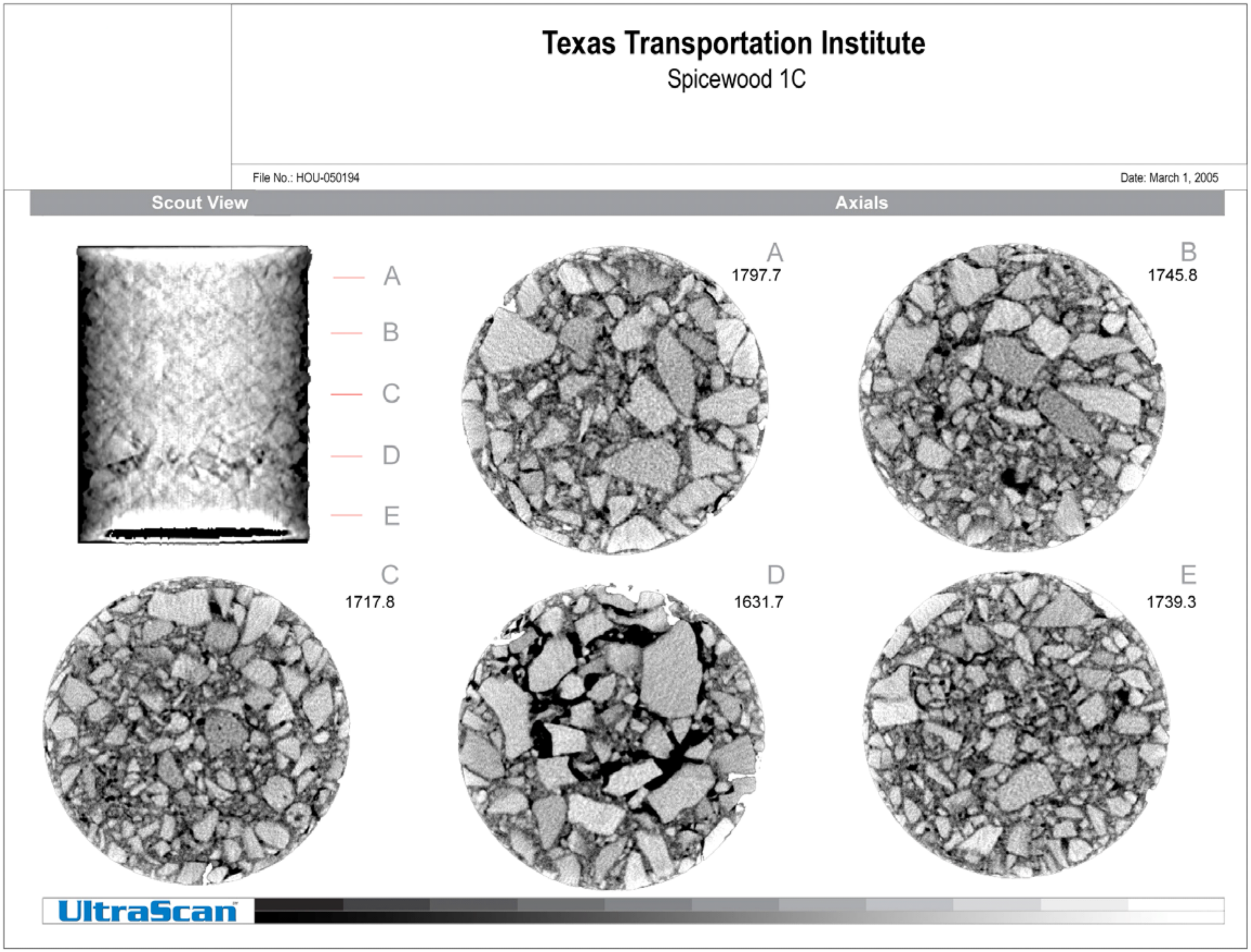


Figure 2.3a. Axial CAT Scans of Spicewood with Current Tex-113-E Compaction (Variant 1).

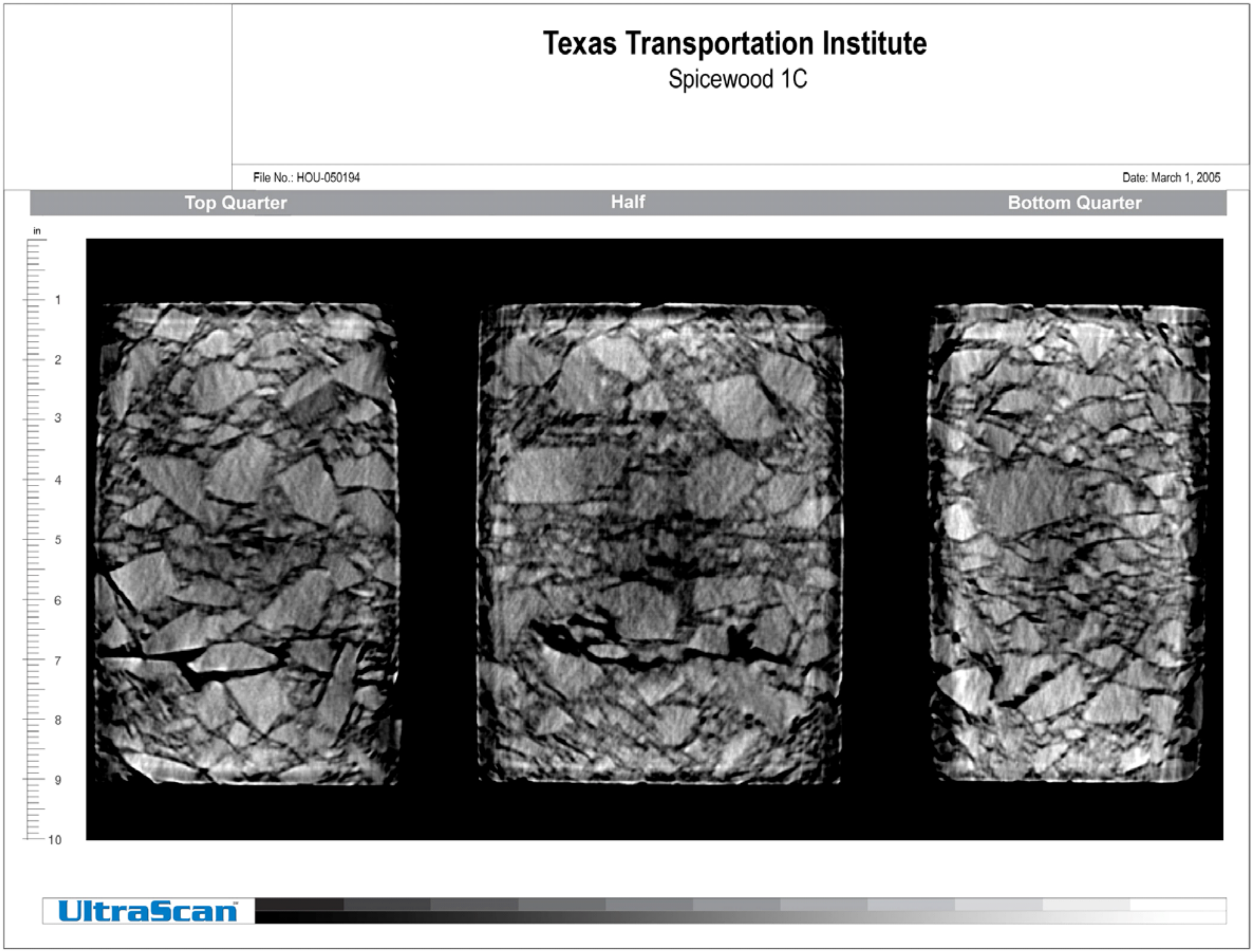


Figure 2.3b. Longitudinal CAT Scans of Spicewood with Current Tex-113-E Compaction (Variant 1).

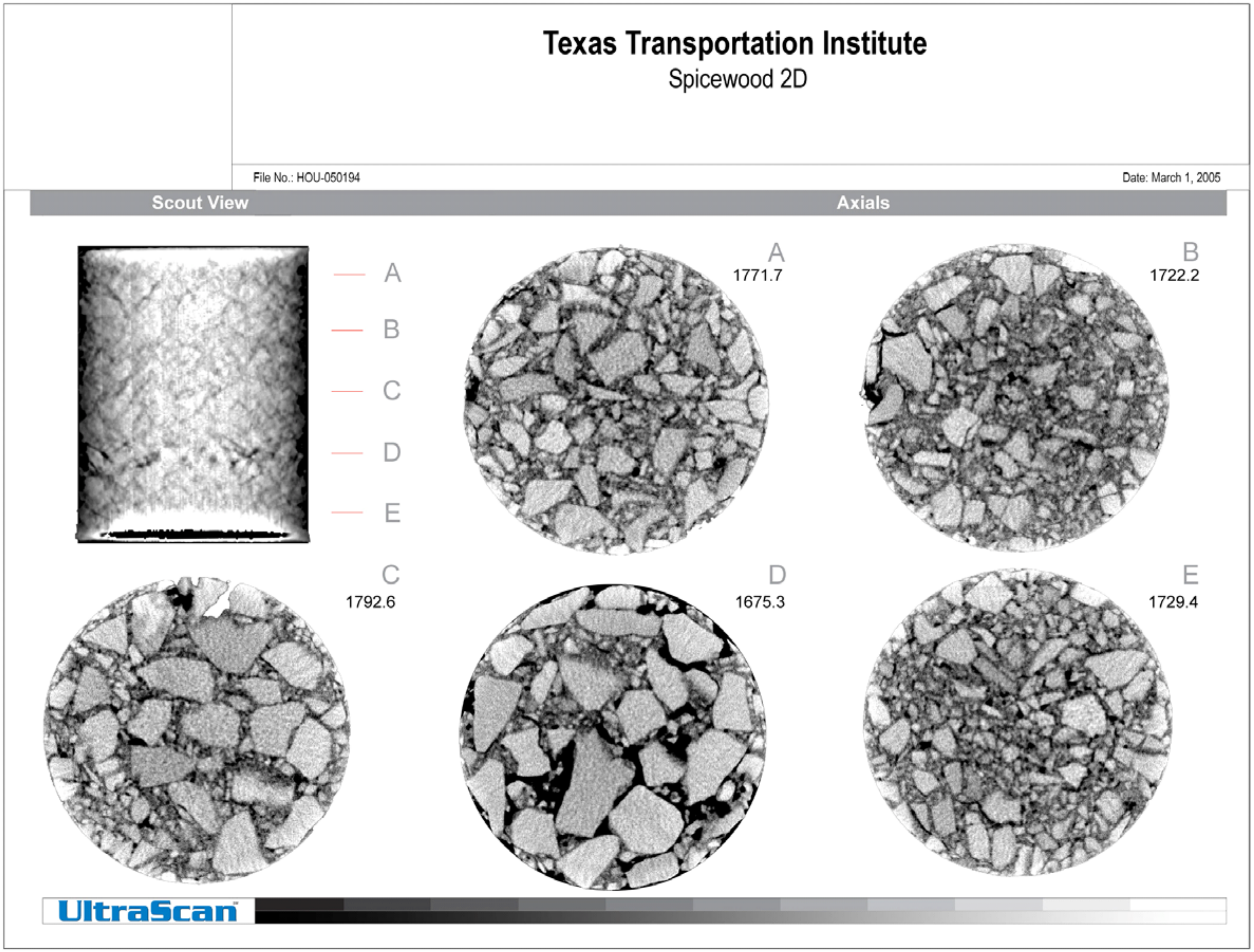


Figure 2.4a. Axial CAT Scans of Spicewood with Tex-113-E Variant 2 (Three Lifts of 67 Blows).

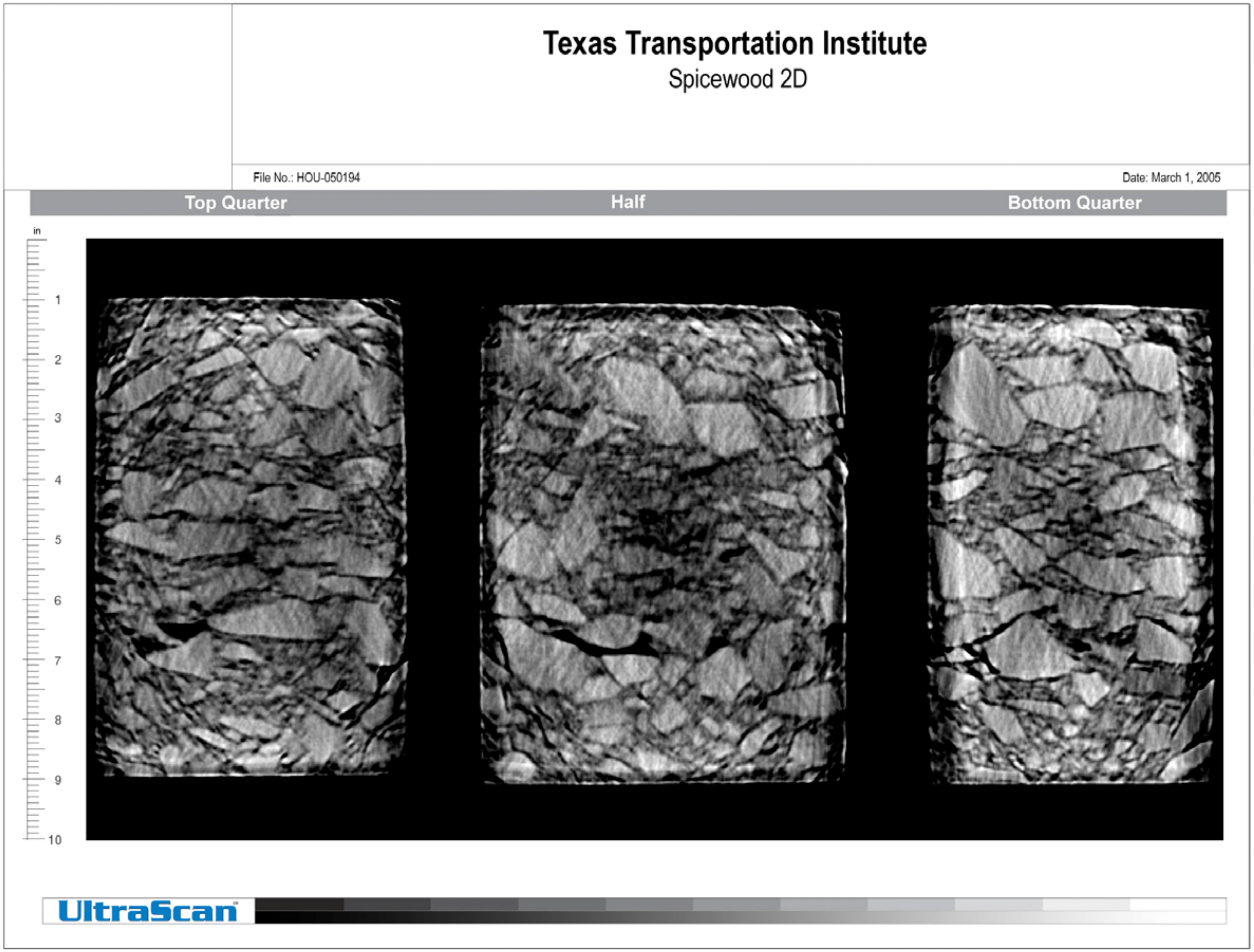


Figure 2.4b. Longitudinal CAT Scans of Spicewood with Tex-113-E Variant 2 (Three Lifts of 67 Blows).

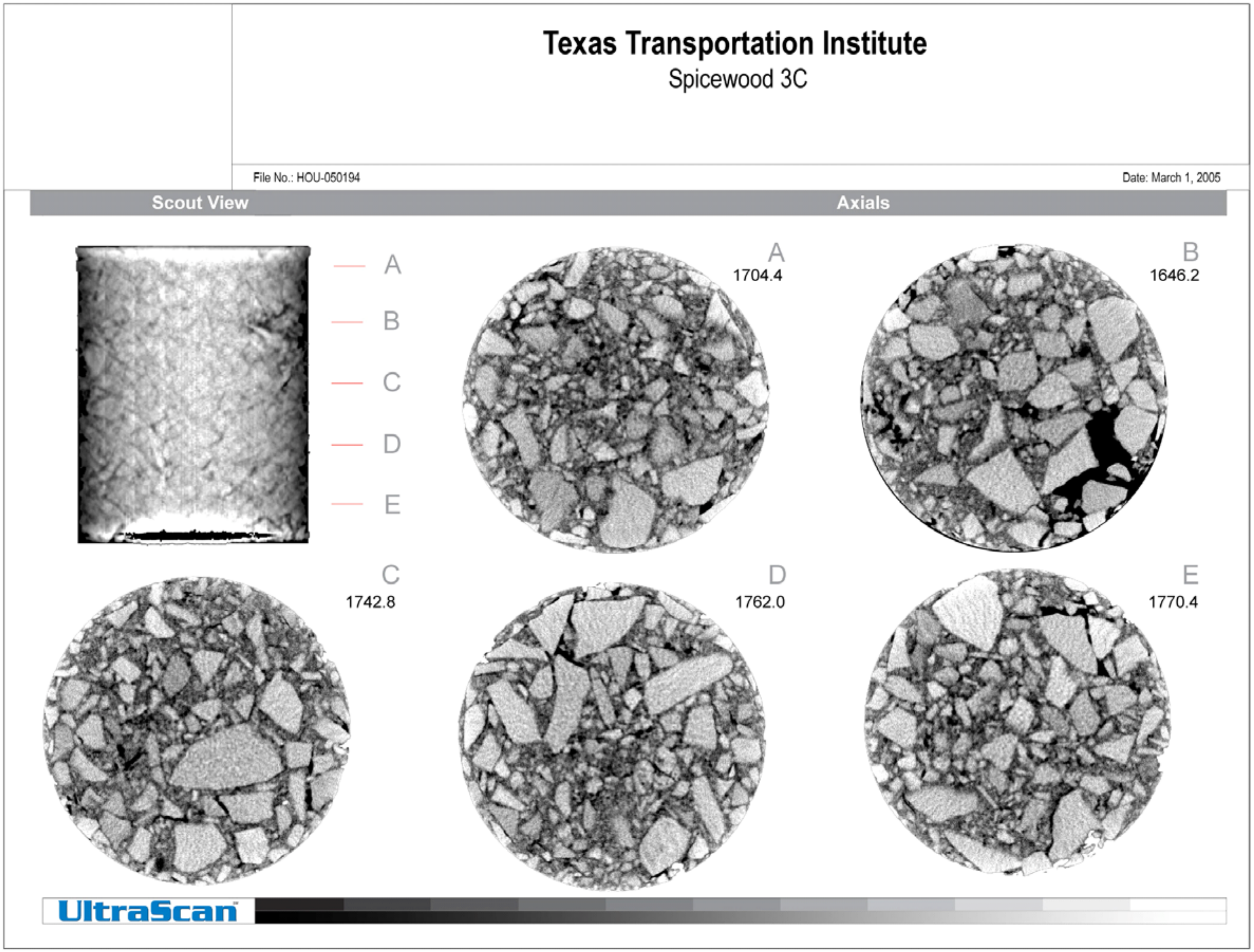


Figure 2.5a. Axial CAT Scans of Spicewood with Tex-113-E Variant 3 (No Hand Placement).

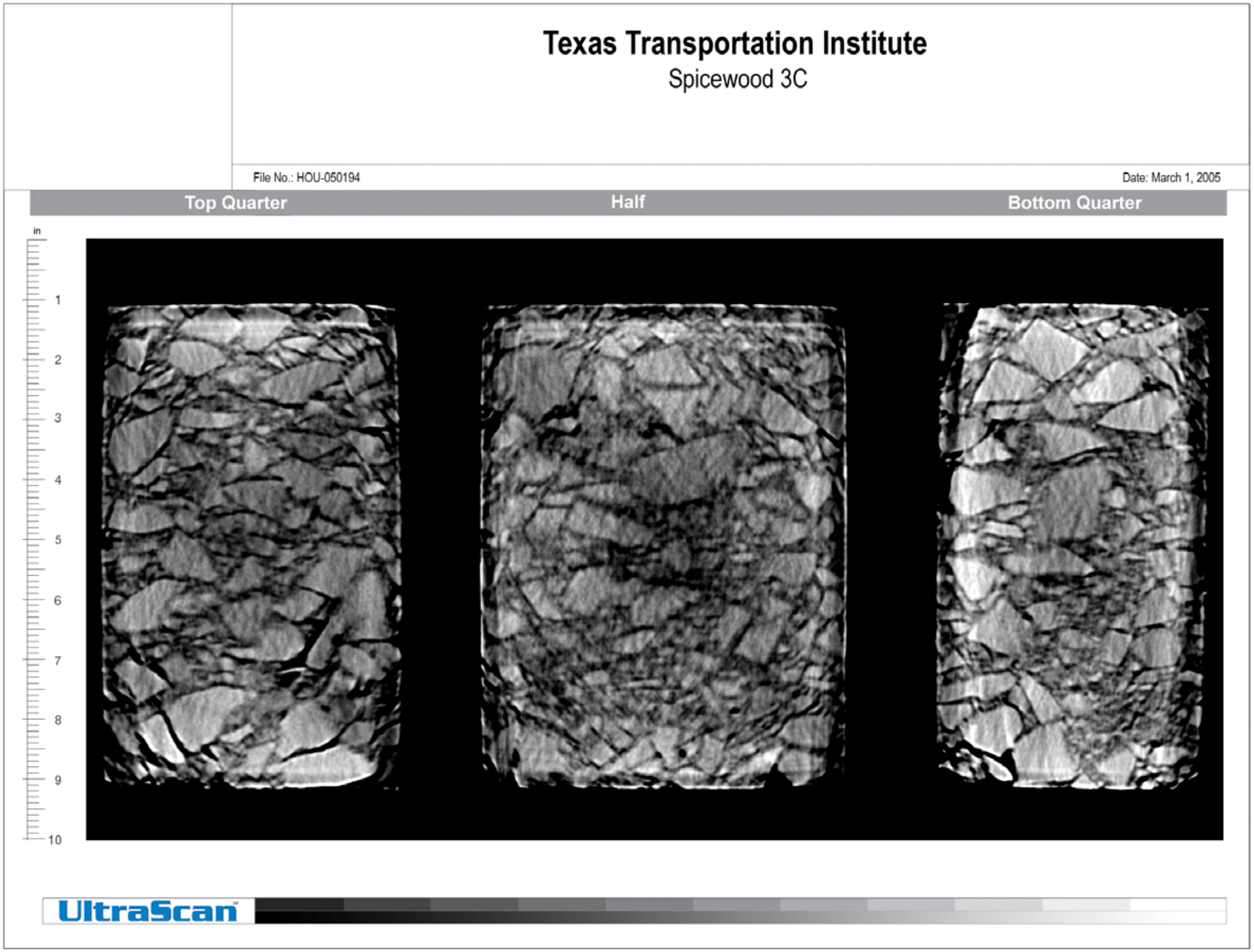


Figure 2.5b. Longitudinal CAT Scans of Spicewood with Tex-113-E Variant 3 (No Hand Placement).

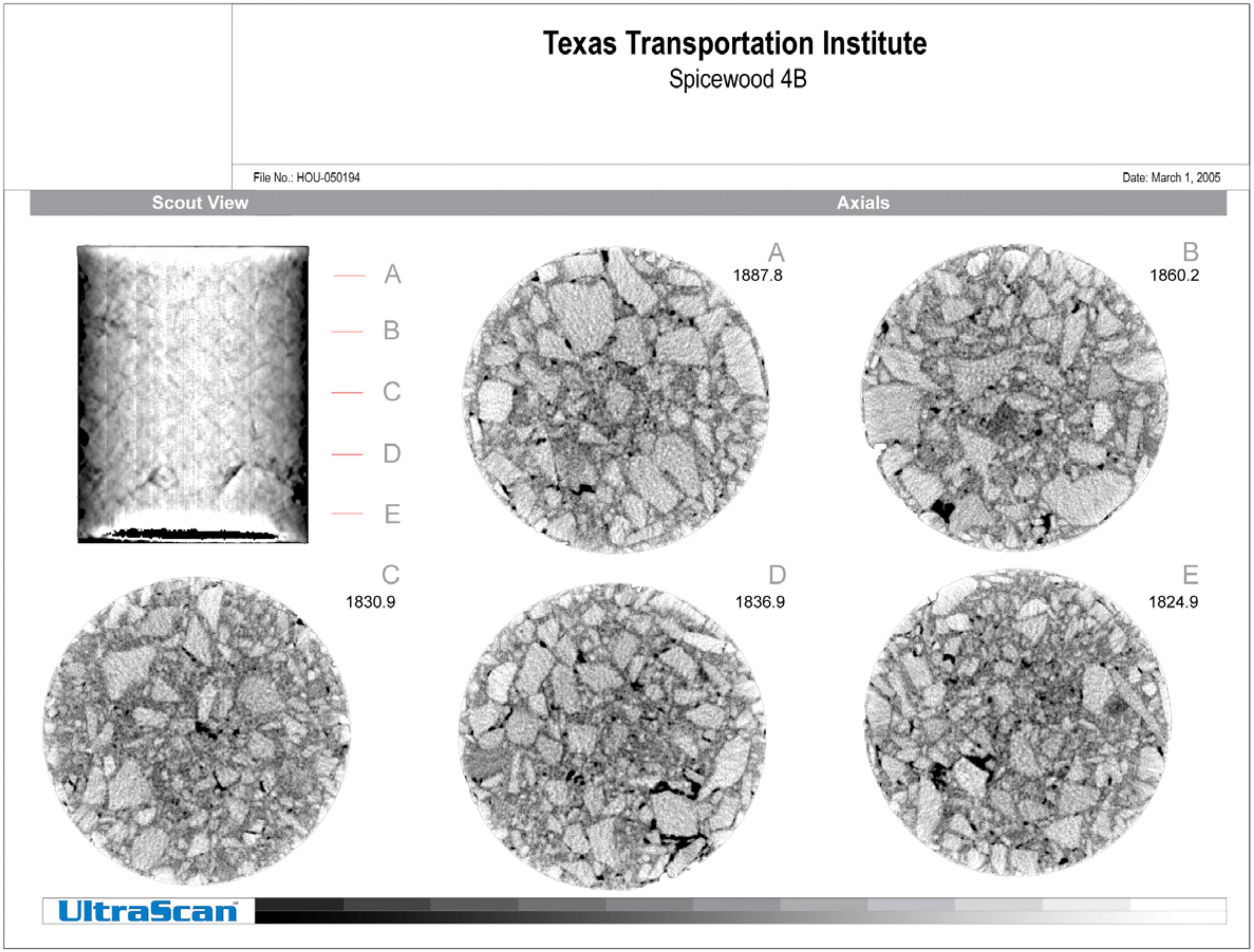


Figure 2.6a. Axial CAT Scans of Spicewood with Tex-113-E Variant 4 (Mechanical Mixing).

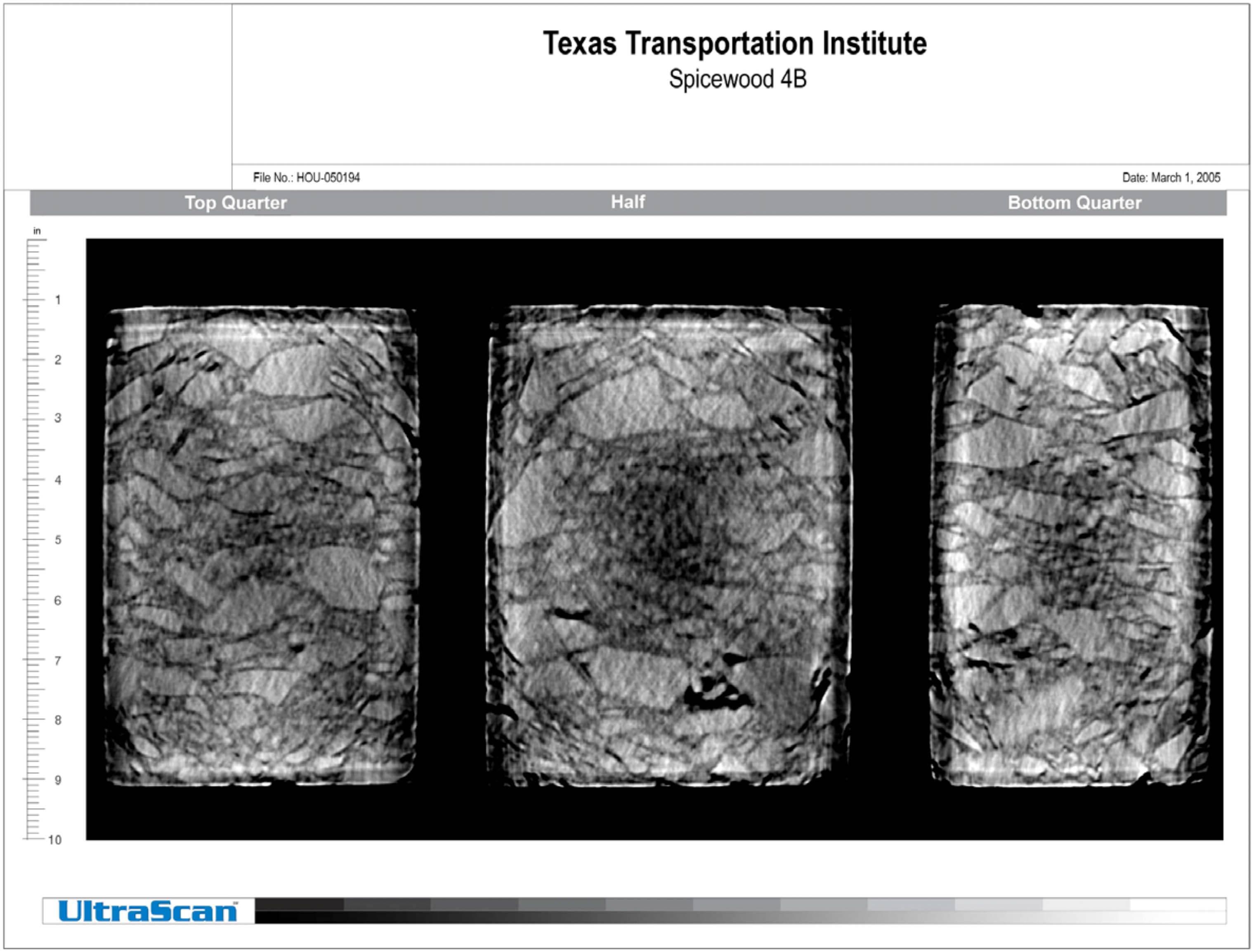


Figure 2.6b. Longitudinal CAT Scans of Spicewood with Tex-113-E Variant 4 (Mechanical Mixing).

Figures 2.7 and 2.8 show the percent air voids and air void size with depth for each of the specimens tested at the University of Texas. According to Dr. Masad, these data indicate:

- Specimens prepared with variant 4 (mixed with a mechanical mixer) exhibit less increases in percent air voids and air void size at the lower lift interface.
- No significant difference exists among specimens prepared with variants 1, 2, or 3.

From the CAT scan data, the visual and quantitative analysis contradict each other. From the visual scans, variant 3 (no hand placement) appeared to have the most uniform distribution of rock particles and binder. From the quantitative data, the only difference among any of the variants was the extent of the increase in air voids at the lowest lift interface. Due to the contradictory nature of the data, no evidence exists that any test variant is superior in terms of internal sample structure.

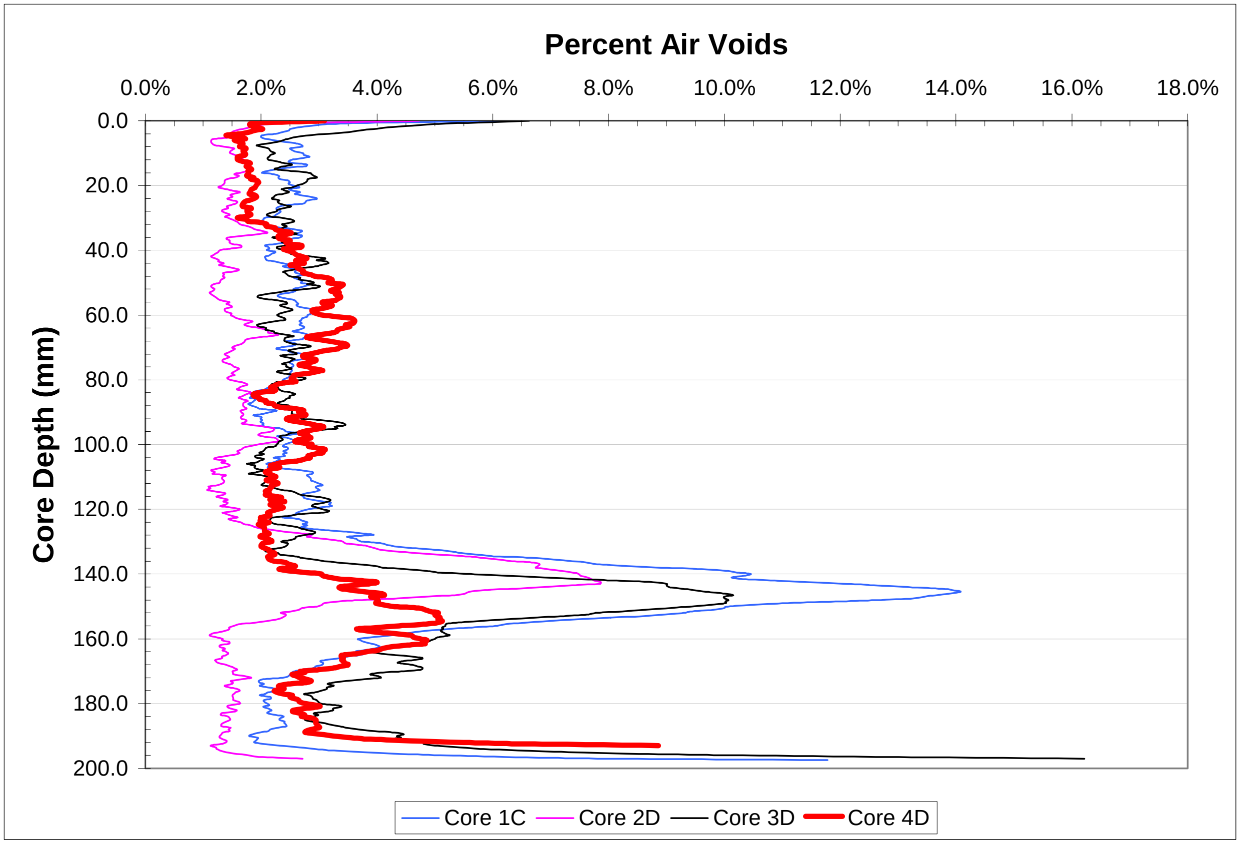


Figure 2.7. Percent Air Voids with Core Depth from CAT Scans.

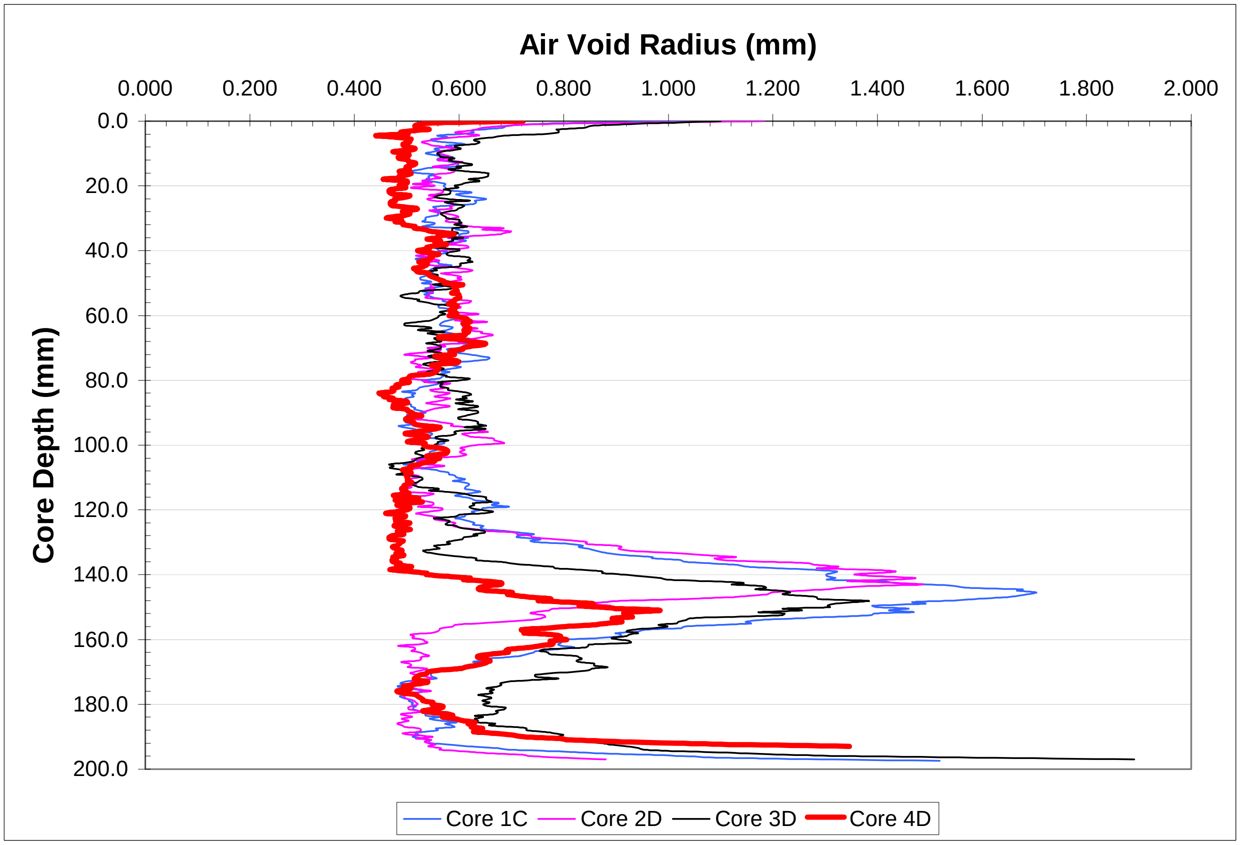


Figure 2.8. Air Void Radius with Core Depth from CAT Scans.

CONCLUSIONS

Of the Tex-113-E variants examined, data show two techniques offer the best precision for bulk sample dry density in Tex-113-E style compaction. These two methods differ only according to the number of lifts used.

- Mix the molding water into the aggregate by hand.
- Separate the wetted aggregate over the 7/8 inch sieve before molding.
- Hand place the aggregate retained on the 7/8 inch sieve.
- Compact the specimen in either four lifts of 50 blows or three lifts of 67 blows.
- Finish the specimen with a schedule of blows from the slide hammer finishing tool.

The research team believes the techniques described above which yield the best precisions in terms of sample bulk dry density do not represent a random distribution of particles such as would be expected in the field. However, CAT scan analysis performed on the specimens does not confirm the superiority of any technique. Therefore, if the desire is to obtain the most precision of the specimen molded dry density, no justification currently exists to abandon the separation of the 7/8 inch rock.

CHAPTER 3

CONCLUSIONS AND RECOMMENDATIONS

SUMMARY

The first phase of this research project studied several aspects of TxDOT Tex-113-E style laboratory sample preparation in efforts to identify the most precise methods for constructing laboratory test specimens. Efforts focused on evaluating the impact of a new finishing tool and evaluation of the precision offered by four different variants of Tex-113-E compaction.

CONCLUSIONS AND RECOMMENDATIONS REGARDING TxDOT IMPACT HAMMER COMPACTION

The data collected and analyzed support the following conclusions regarding TxDOT impact hammer style compaction:

- The new slide hammer finishing tool did not offer a statistically significant improvement in precision of the dry density of laboratory-compacted specimens.
- The new slide hammer finishing tool did, however, improve the precision of private labs to equal that of TxDOT labs.
- Of the four variants of Tex-113-E employed in the lab, two variants clearly resulted in the best precision. Both of these methods employed hand mixing of the water with the aggregate and separation and hand placement of aggregate retained on the 7/8 inch sieve. The methods varied only according to the number of lifts used.
- Visual analysis of CAT scan data collected on specimens constructed with each of the four Tex-113-E variants indicated differences in sample structure existed among the methods. In particular, the "mix and dump" method seemed to exhibit a more random and uniform orientation of rock particles and binder. However, image analysis did not confirm these observations, and therefore no justification currently exists to abandon the separation of the 7/8 inch rock.

Based upon these observations, the research team offers the following recommendations:

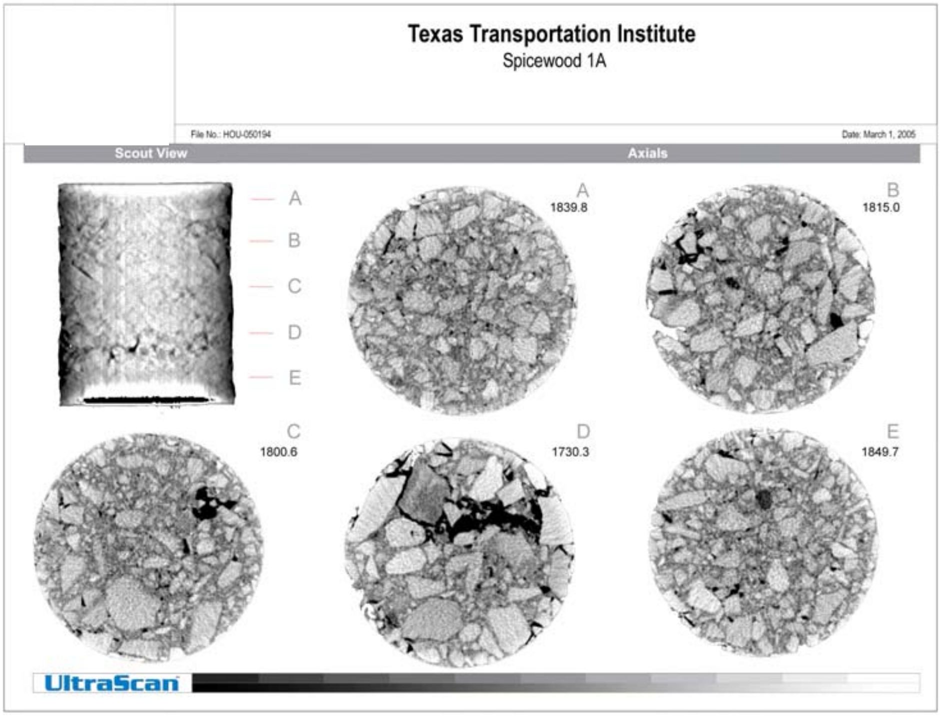
- Continue use of the slide hammer finishing tool instead of the schedule of blows with the rawhide hammer. In particular, make it a requirement of private labs performing work for TxDOT construction projects to employ the slide hammer finishing technique.
- Continue Tex-113-E compaction with the following basic procedure for optimum precision:
    - Mix the molding water into the aggregate by hand.
    - After the required setting period, separate the wetted aggregate over the 7/8 inch sieve before molding.

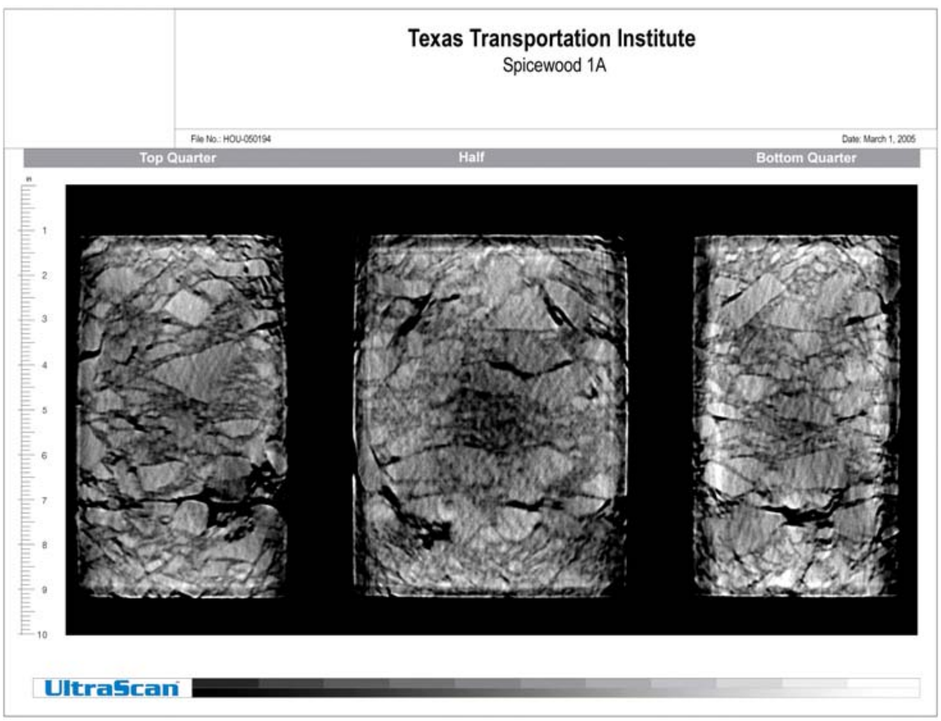
- Separately place the aggregate retained on the 7/8 inch sieve in the middle of the passing 7/8 inch fraction for each lift.
- Compact the specimen in four lifts of 50 blows.
- Finish the specimen with the prescribed schedule of blows from the slide hammer finishing tool.

At this stage of the project, following these recommendations will ensure TxDOT achieves the best precision in terms of sample bulk dry density. A future phase of this project will study differences in test results between specimens constructed with impact hammer compaction versus specimens constructed with new, alternative lab compaction techniques.

APPENDIX

CAT SCANS OF SPECIMENS WITH FOUR TEX-113-E VARIANTS


Texas Transportation Institute
Spicewood 1A
File No.: HOU-050194
Date: March 1, 2005
Scout View
Axials
A
B
C
D
E
A
1839.8
B
1815.0
C
1800.6
D
1730.3
E
1849.7
UltraScan


Texas Transportation Institute
Spicewood 1A
File No.: HOU-050194
Date: March 1, 2005
Top Quarter
Half
Bottom Quarter
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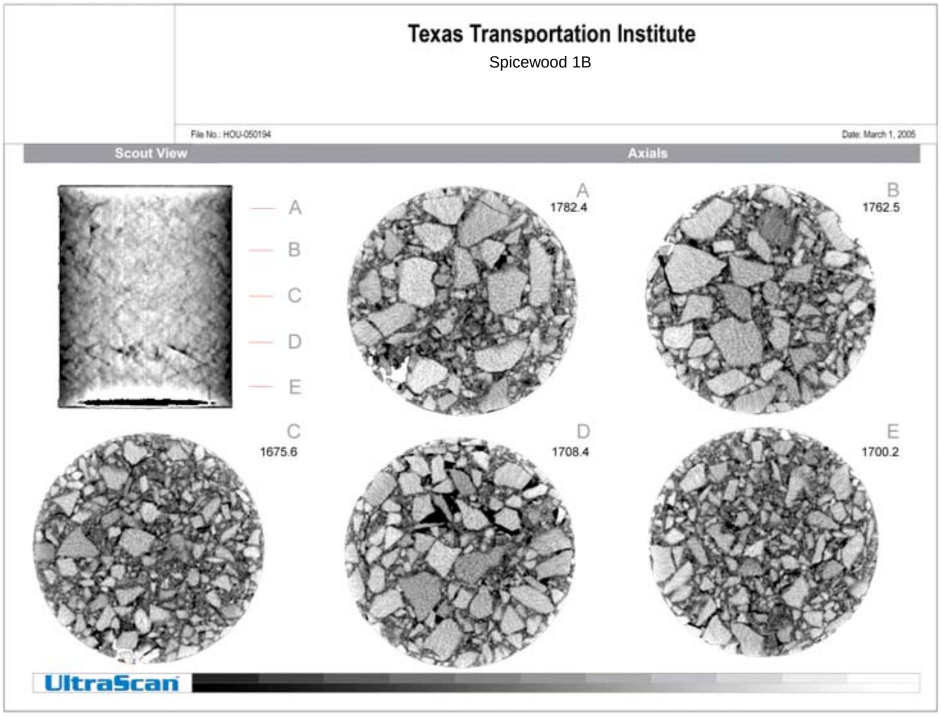
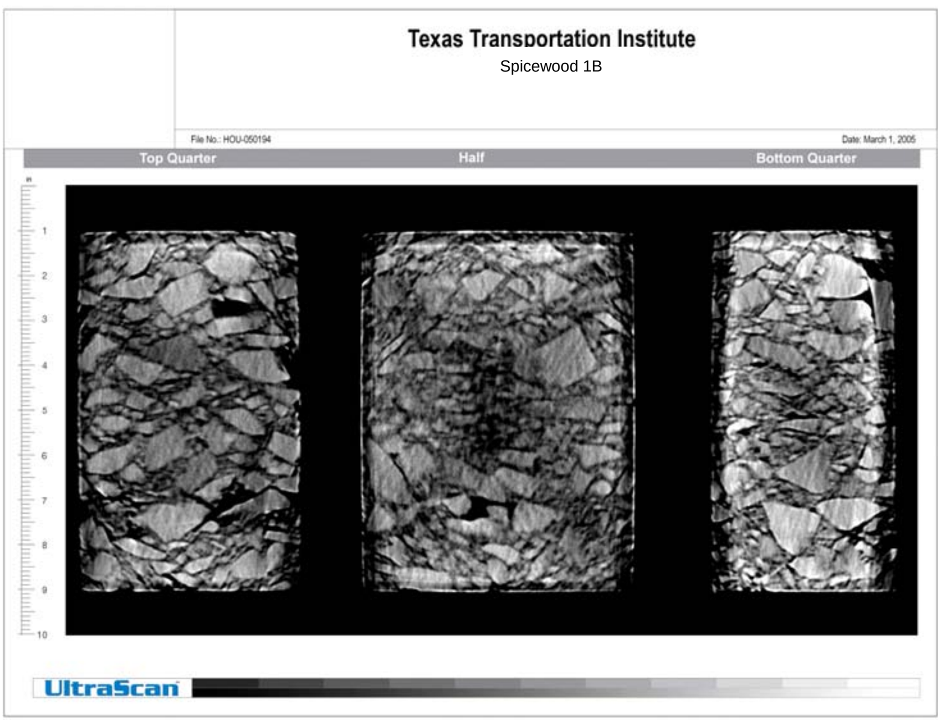
10
UltraScan


Texas Transportation Institute
Spicewood 1B
File No.: HOU-050194
Date: March 1, 2005
Scout View
Axials
A
B
C
D
E
A 1782.4
B 1762.5
C 1675.6
D 1708.4
E 1700.2
UltraScan


Texas Transportation Institute
Spicewood 1B
File No.: HOU-050194
Date: March 1, 2005
Top Quarter
Half
Bottom Quarter
in
1
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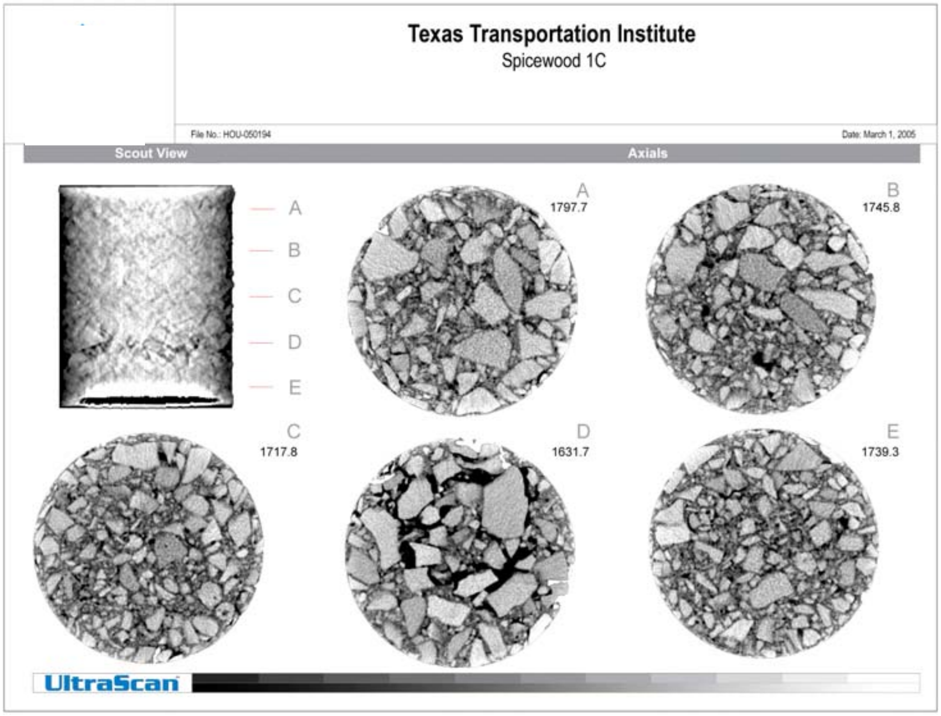
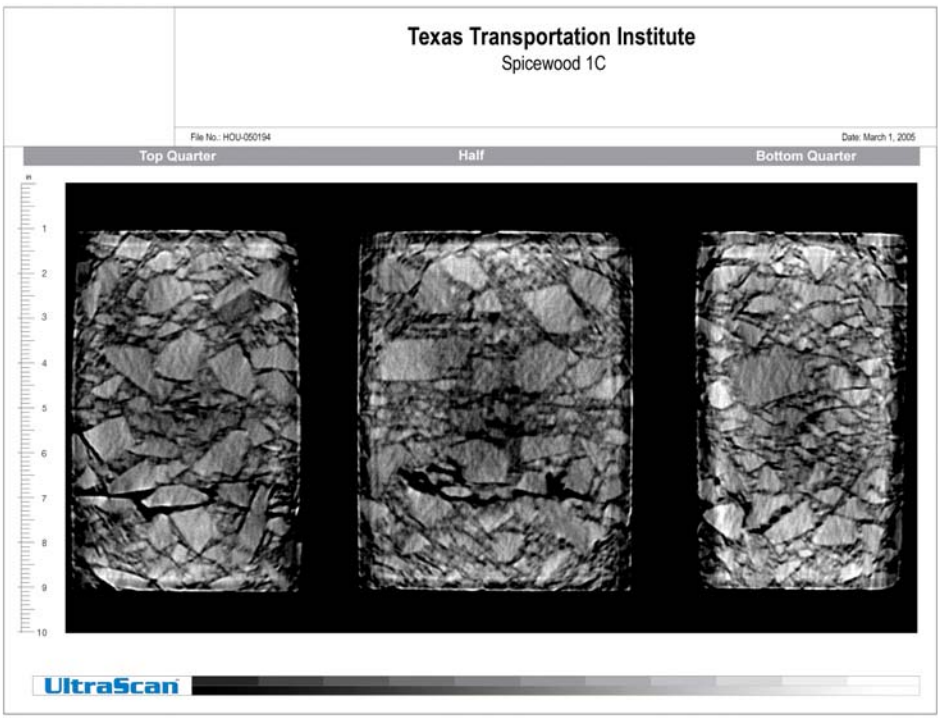
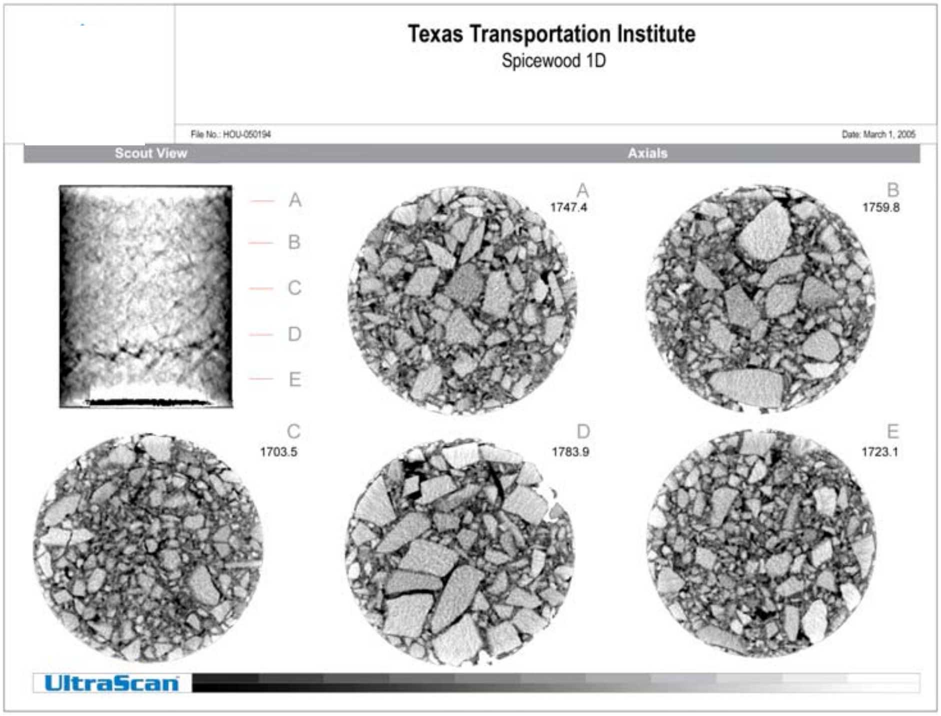
UltraScan


Texas Transportation Institute
Spicewood 1C
File No.: HOU-050194
Date: March 1, 2005
Scout View
Axials
A
B
C
D
E
1797.7
1745.8
1717.8
1631.7
1739.3
UltraScan


Texas Transportation Institute
Spicewood 1C
File No.: HOU-050194
Date: March 1, 2005
Top Quarter
Half
Bottom Quarter
UltraScan


Texas Transportation Institute
Spicewood 1D
File No.: HOU-050194
Date: March 1, 2005
Scout View
Axials
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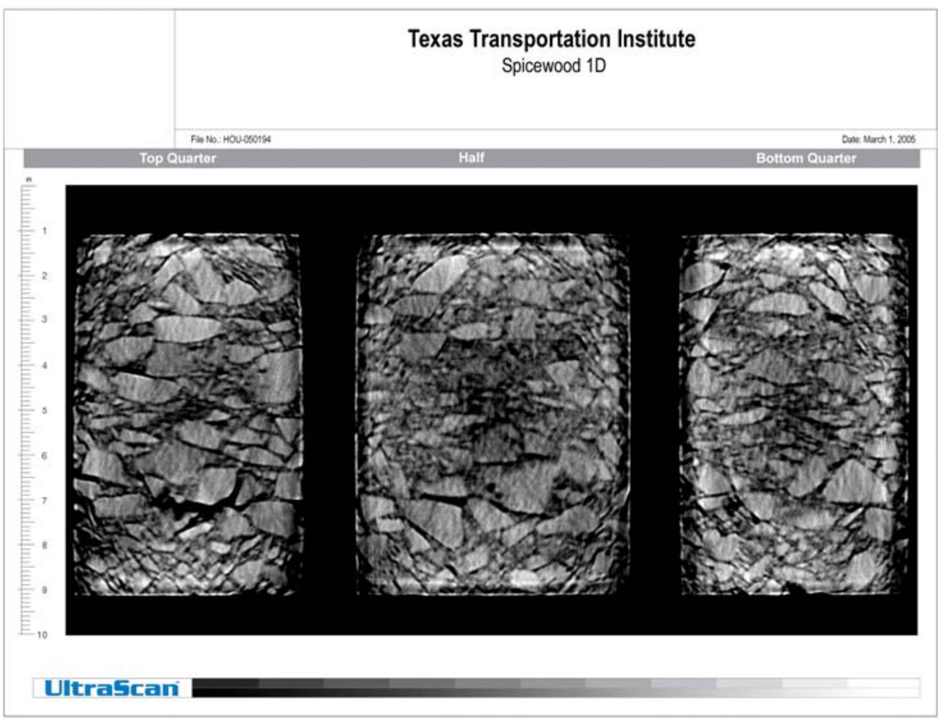
B
C
D
E
A 1747.4
B 1759.8
C 1703.5
D 1783.9
E 1723.1
UltraScan


Texas Transportation Institute
Spicewood 1D
File No.: HOU-050194
Date: March 1, 2005
Top Quarter
Half
Bottom Quarter
in
1
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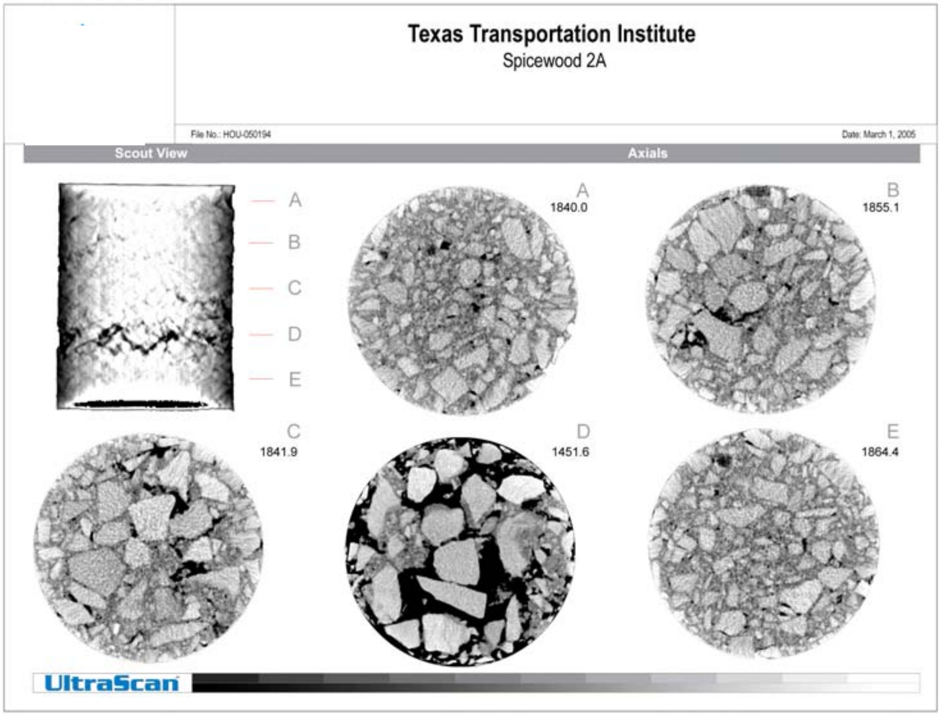
UltraScan


Texas Transportation Institute
Spicewood 2A
File No.: HOU-050194
Date: March 1, 2005
Scout View
Axials
A
B
C
D
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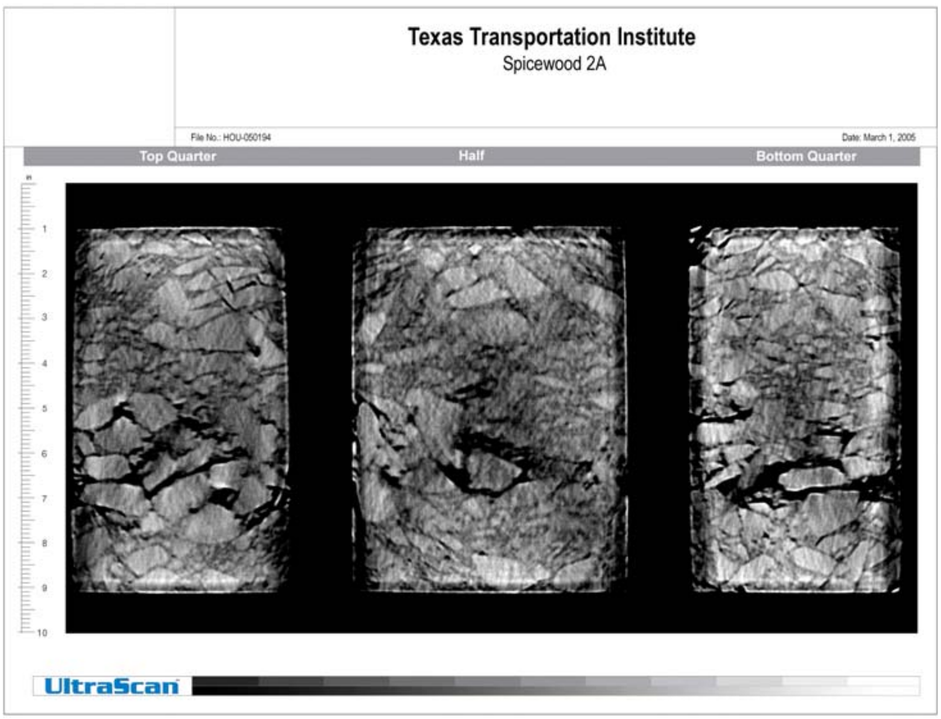
B
1855.1
C
1841.9
D
1451.6
E
1864.4
UltraScan


Texas Transportation Institute
Spicewood 2A
File No.: HOU-050194
Date: March 1, 2005
Top Quarter
Half
Bottom Quarter
in
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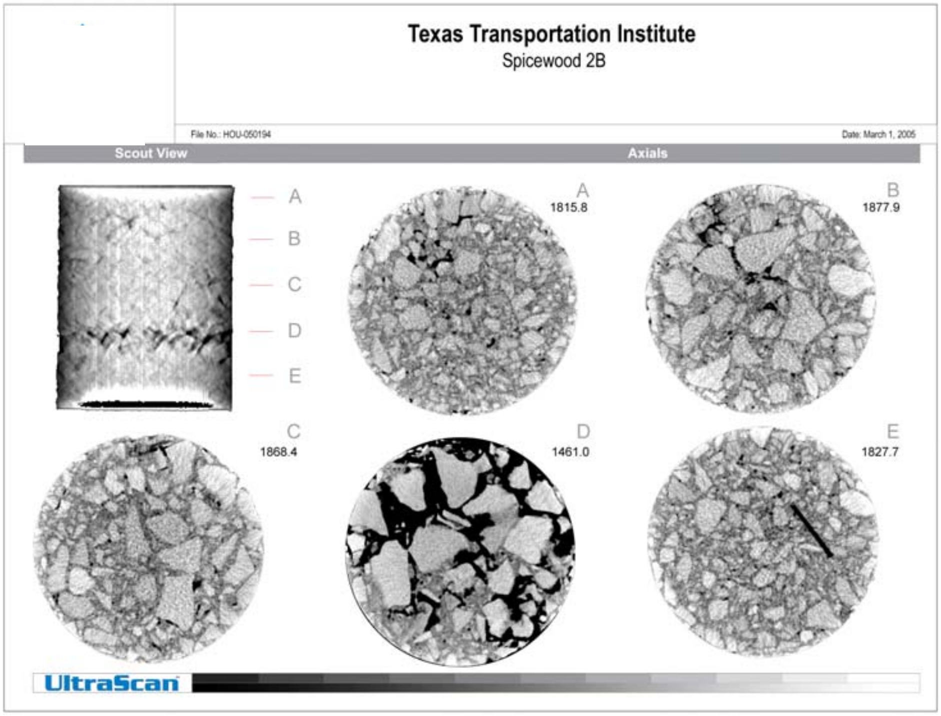
UltraScan


Texas Transportation Institute
Spicewood 2B
File No.: HOU-050194
Date: March 1, 2005
Scout View
Axials
A
B
C
D
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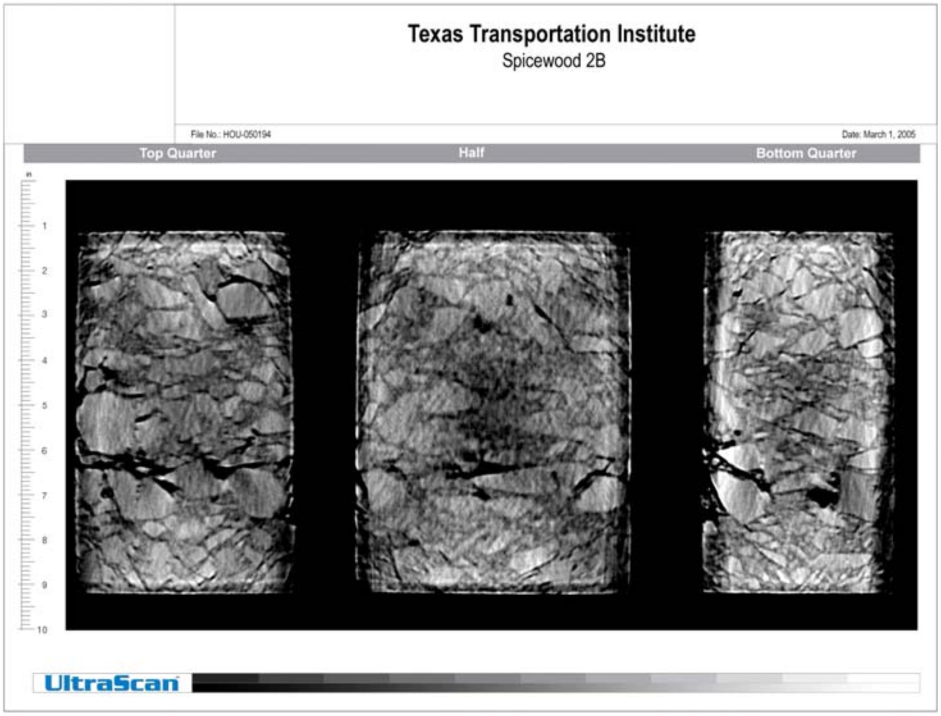
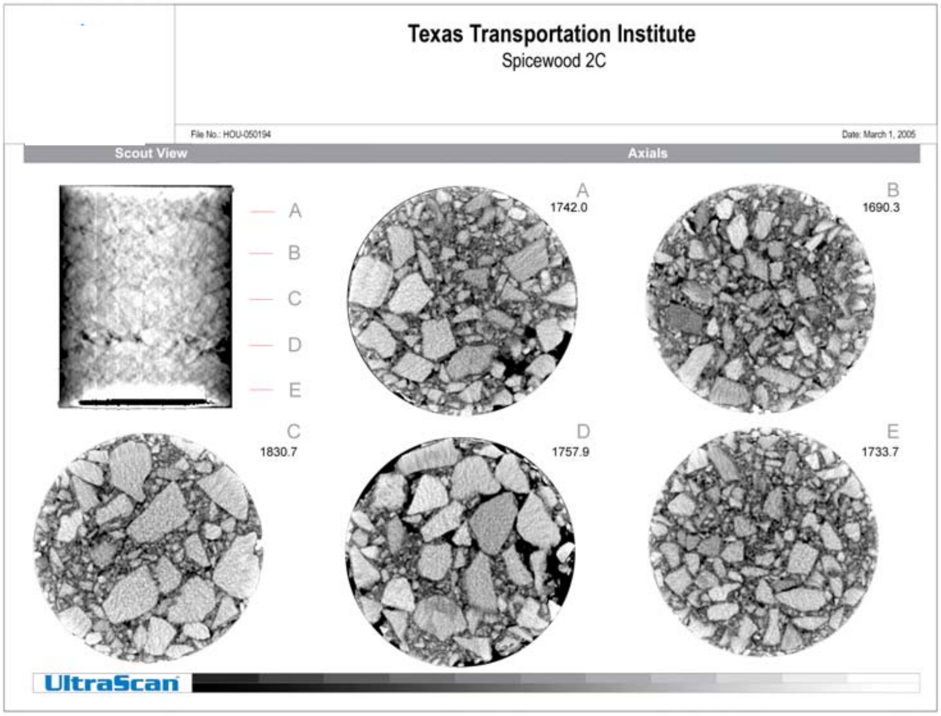
B
1877.9
C
1868.4
D
1461.0
E
1827.7
UltraScan


Texas Transportation Institute
Spicewood 2B
File No.: HOU-050194
Date: March 1, 2005
Top Quarter
Half
Bottom Quarter
UltraScan


Texas Transportation Institute
Spicewood 2C
File No.: HOU-050194
Date: March 1, 2005
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Axials
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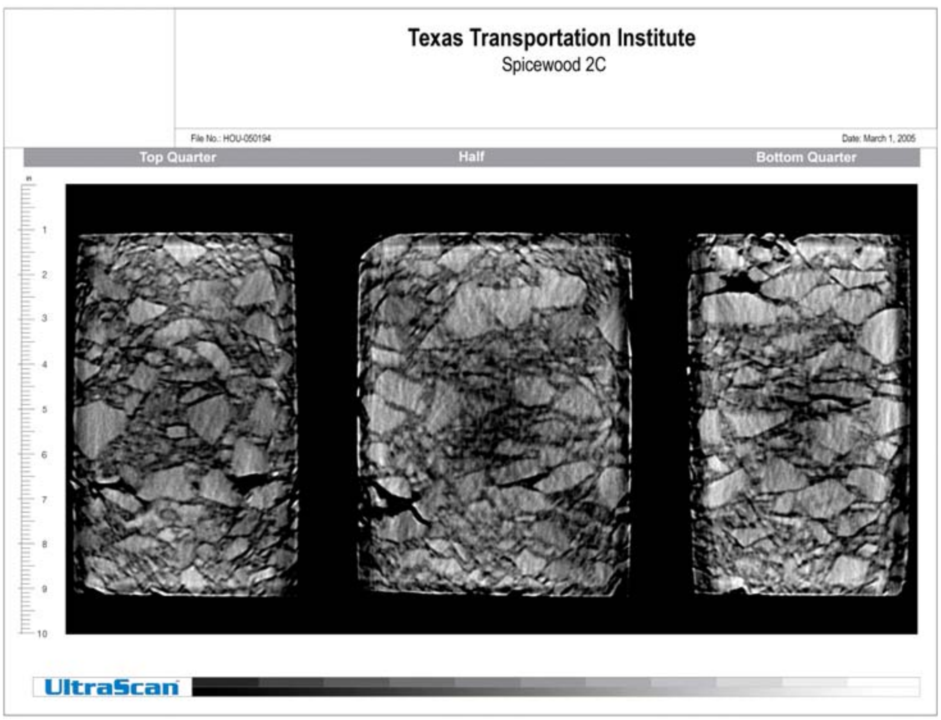
B
C
D
E
A 1742.0
B 1690.3
C 1830.7
D 1757.9
E 1733.7
UltraScan


Texas Transportation Institute
Spicewood 2C
File No.: HOU-050194
Date: March 1, 2005
Top Quarter
Half
Bottom Quarter
in
1
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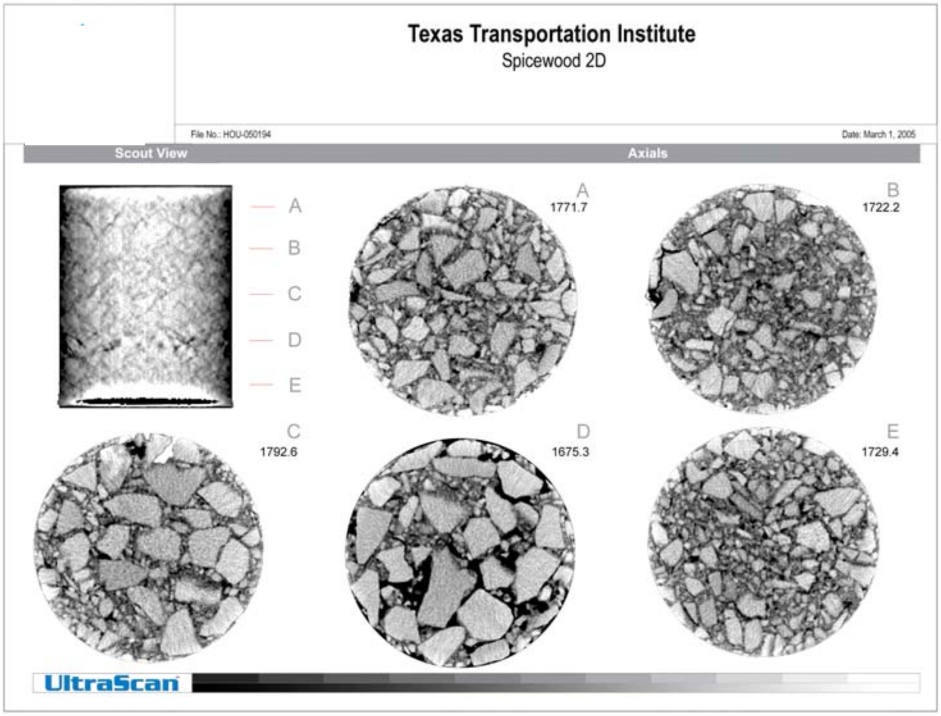
UltraScan


Texas Transportation Institute
Spicewood 2D
File No.: HOU-050194
Date: March 1, 2005
Scout View
Axials
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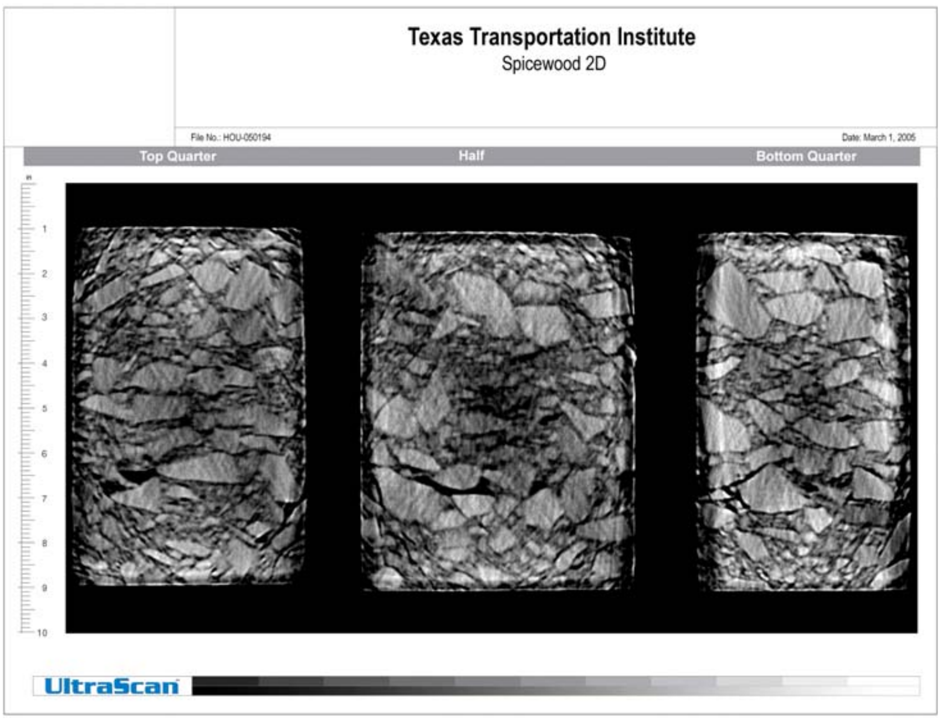
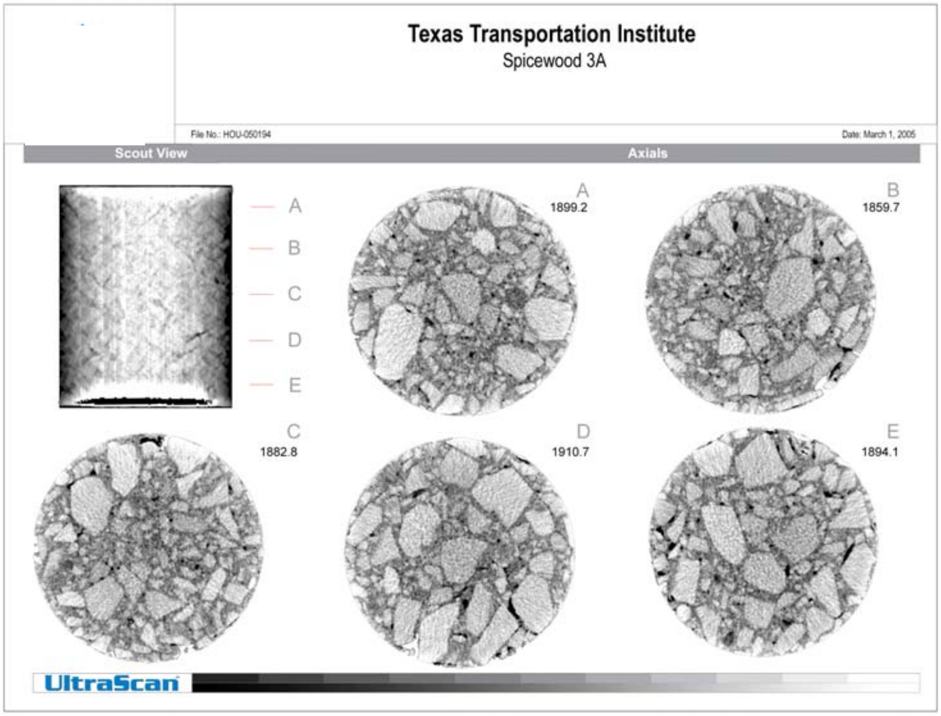
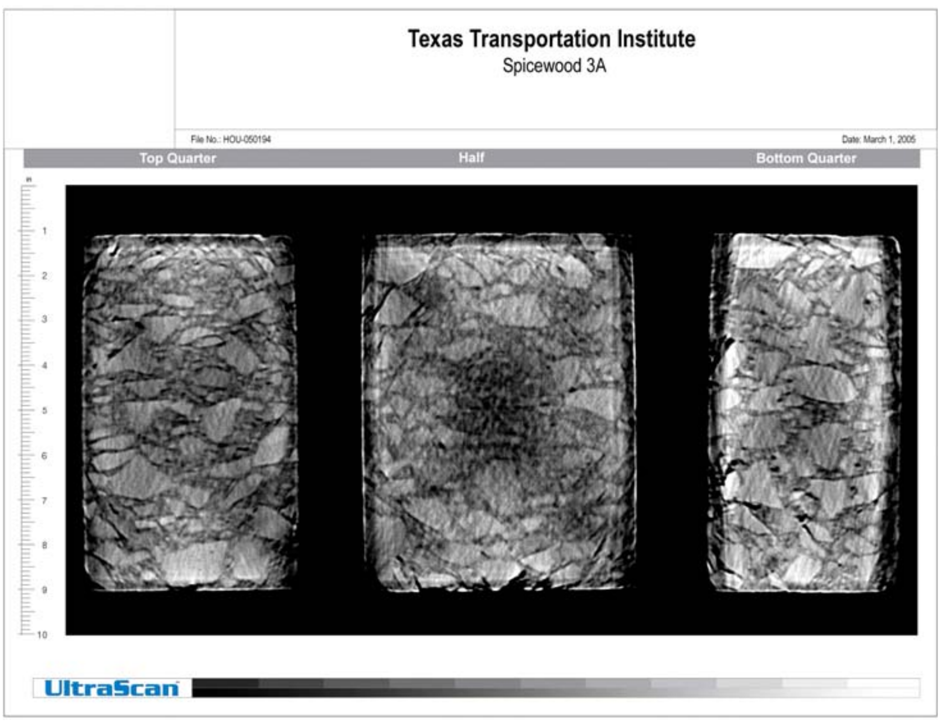
B
C
D
E
A 1771.7
B 1722.2
C 1792.6
D 1675.3
E 1729.4
UltraScan


Texas Transportation Institute
Spicewood 2D
File No.: HOU-050194
Date: March 1, 2005
Top Quarter
Half
Bottom Quarter
UltraScan


Texas Transportation Institute
Spicewood 3A
File No.: HOU-050194
Date: March 1, 2005
Scout View
Axials
A
B
C
D
E
A
1899.2
B
1859.7
C
1882.8
D
1910.7
E
1894.1
UltraScan


Texas Transportation Institute
Spicewood 3A
File No.: HOU-050194
Date: March 1, 2005
Top Quarter
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Bottom Quarter
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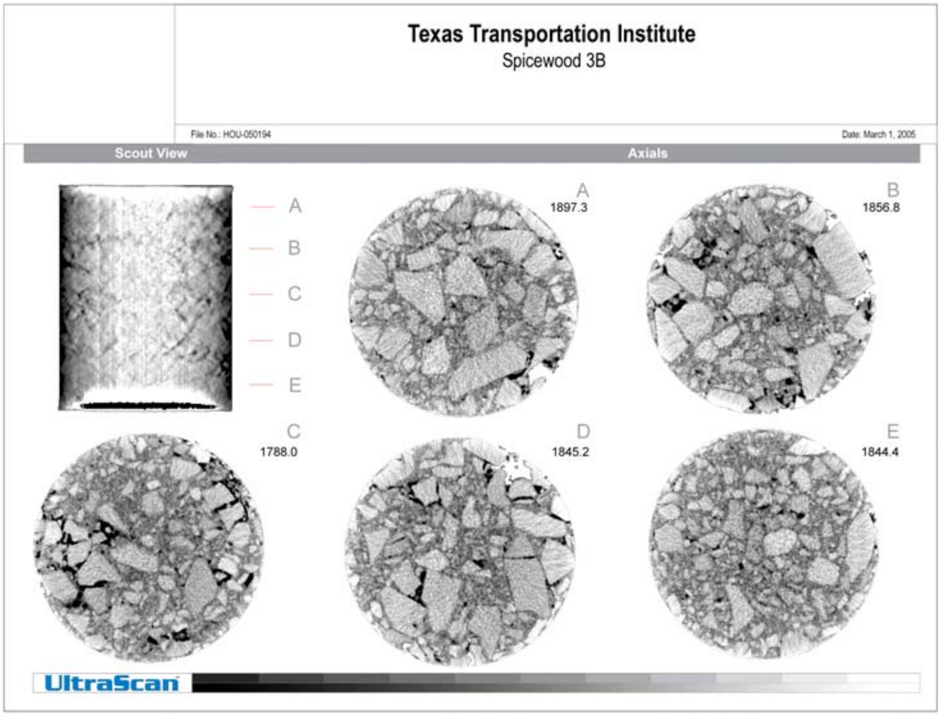
Texas Transportation Institute
Spicewood 3B
File No.: HOU-050194
Date: March 1, 2005
Scout View
Axials
A
B
C
D
E
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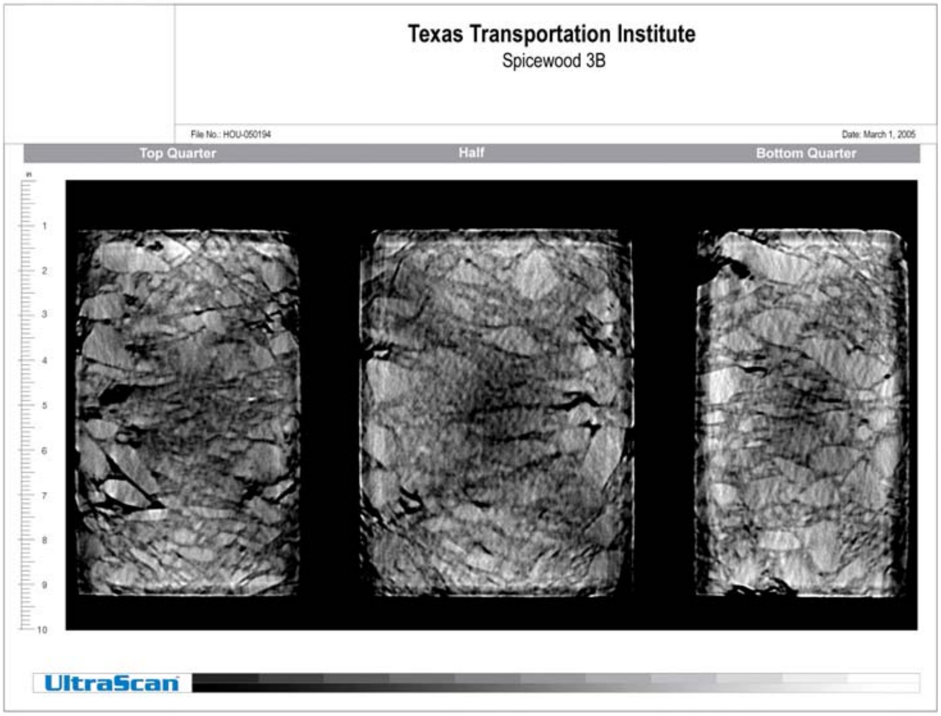
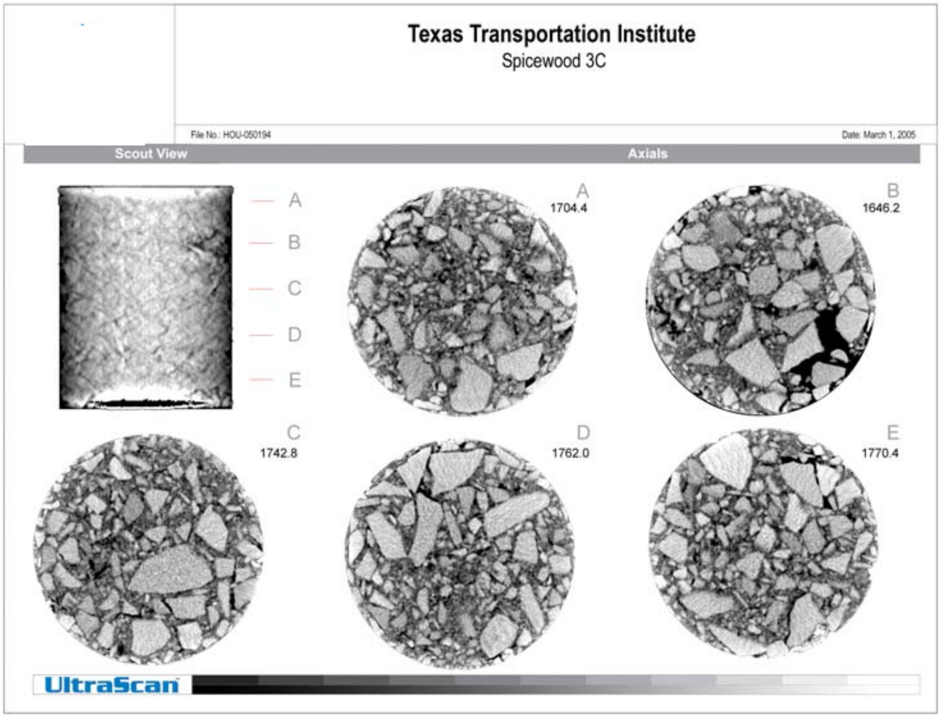
C
1788.0
D
1845.2
E
1844.4
UltraScan


Texas Transportation Institute
Spicewood 3B
File No.: HOU-050194
Date: March 1, 2005
Top Quarter
Half
Bottom Quarter
UltraScan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Spicewood 3C
File No.: HOU-050194
Date: March 1, 2005
Scout View
Axials
A
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C
D
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1646.2
C
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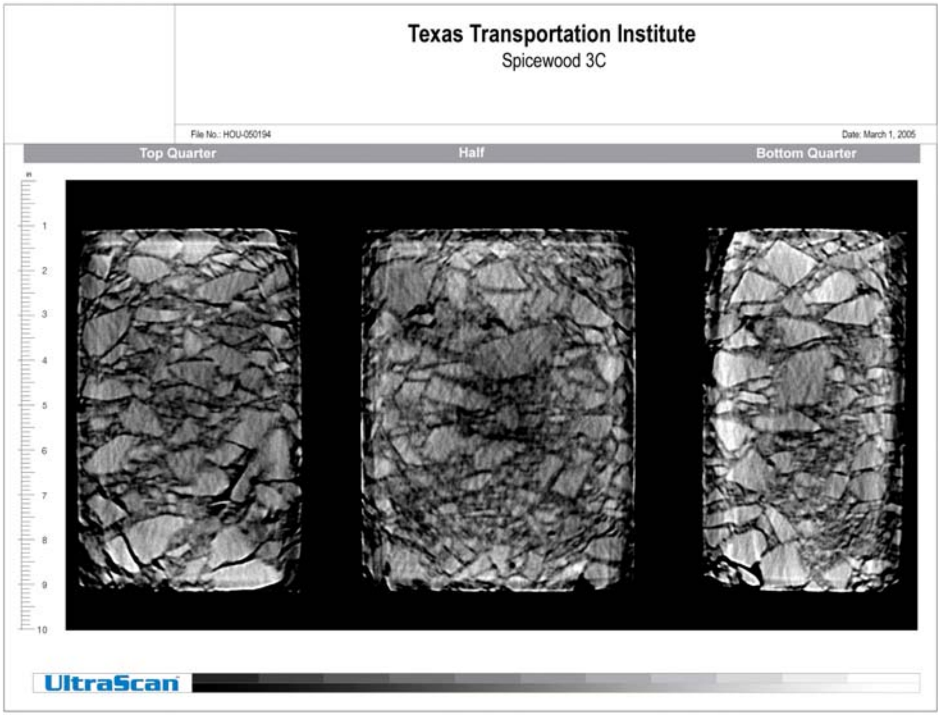
D
1762.0
E
1770.4
UltraScan


Texas Transportation Institute
Spicewood 3C
File No.: HOU-050194
Date: March 1, 2005
Top Quarter
Half
Bottom Quarter
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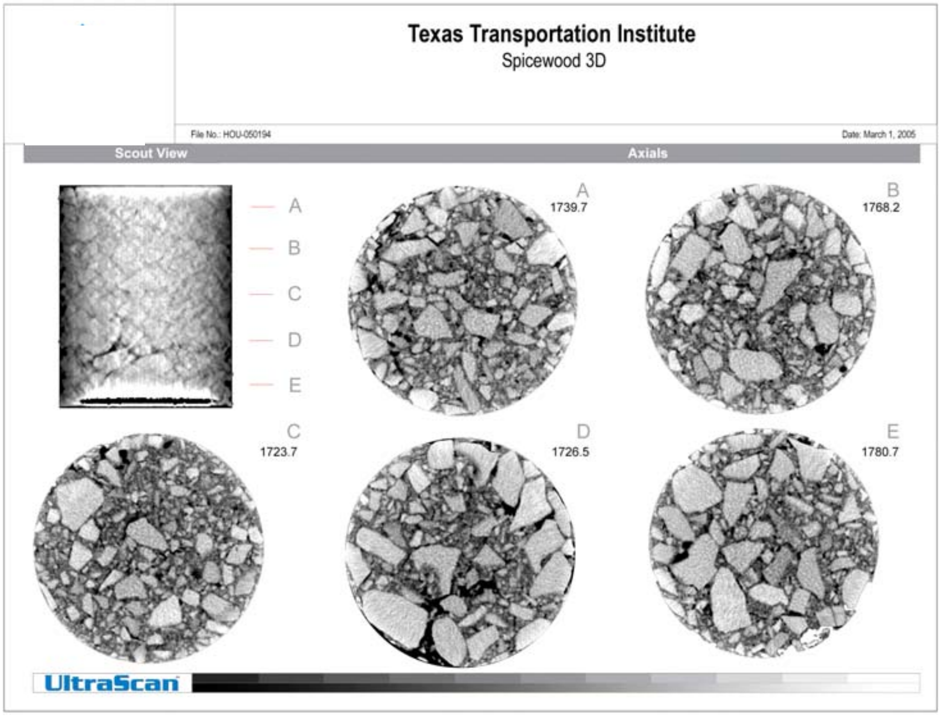
UltraScan


Texas Transportation Institute
Spicewood 3D
File No.: HOU-050194
Date: March 1, 2005
Scout View
Axials
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B
C
D
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1768.2
C
1723.7
D
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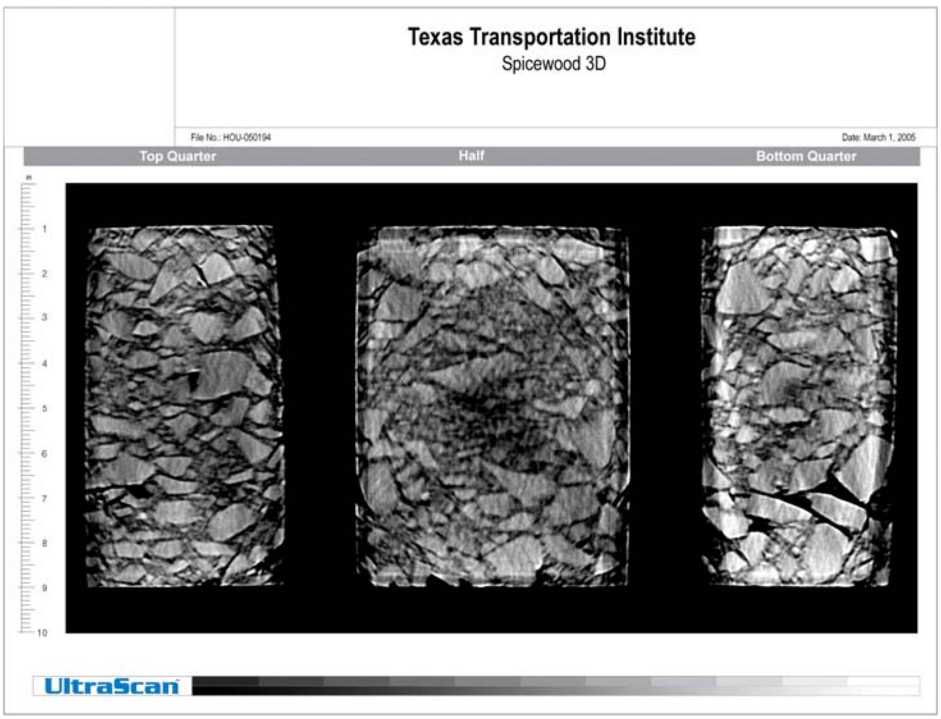
UltraScan


Texas Transportation Institute
Spicewood 3D
File No.: HOU-050194
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Top Quarter
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Bottom Quarter
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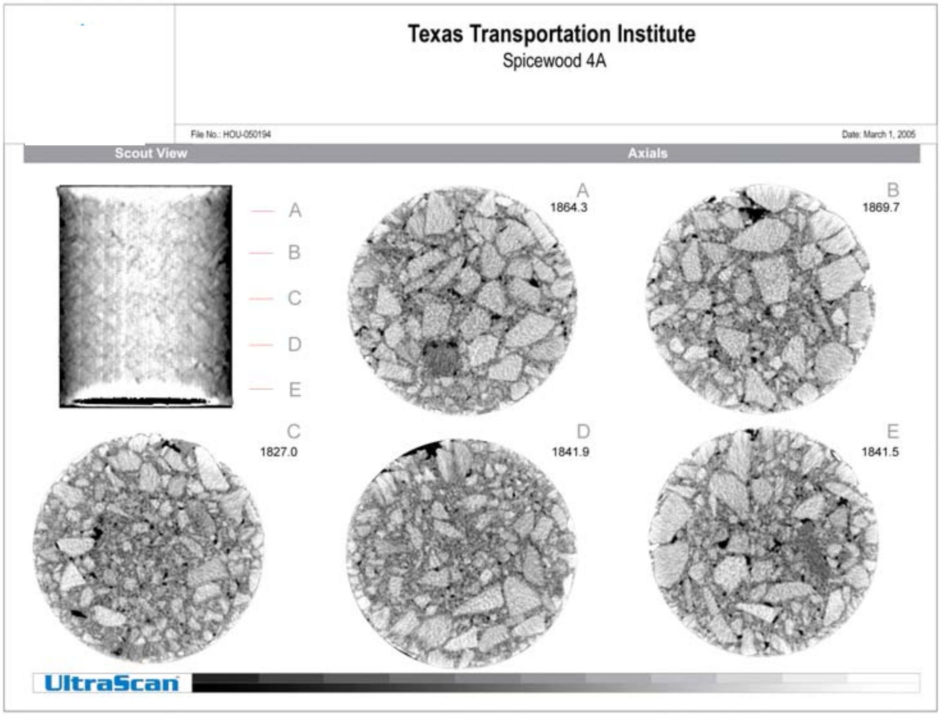
UltraScan


Texas Transportation Institute
Spicewood 4A
File No.: HOU-050194
Date: March 1, 2005
Scout View
Axials
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D
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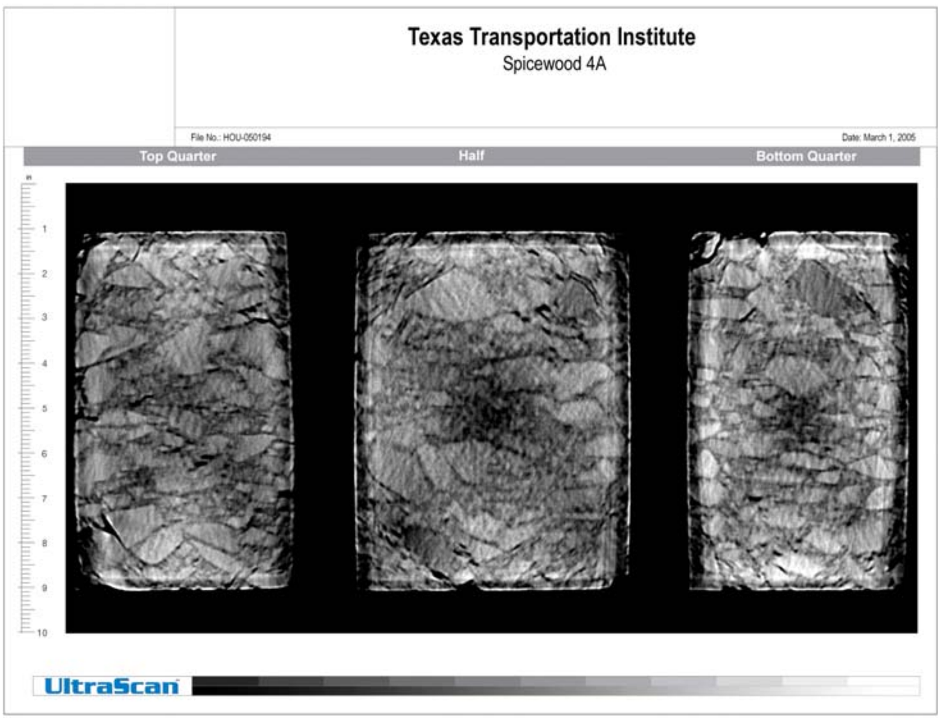
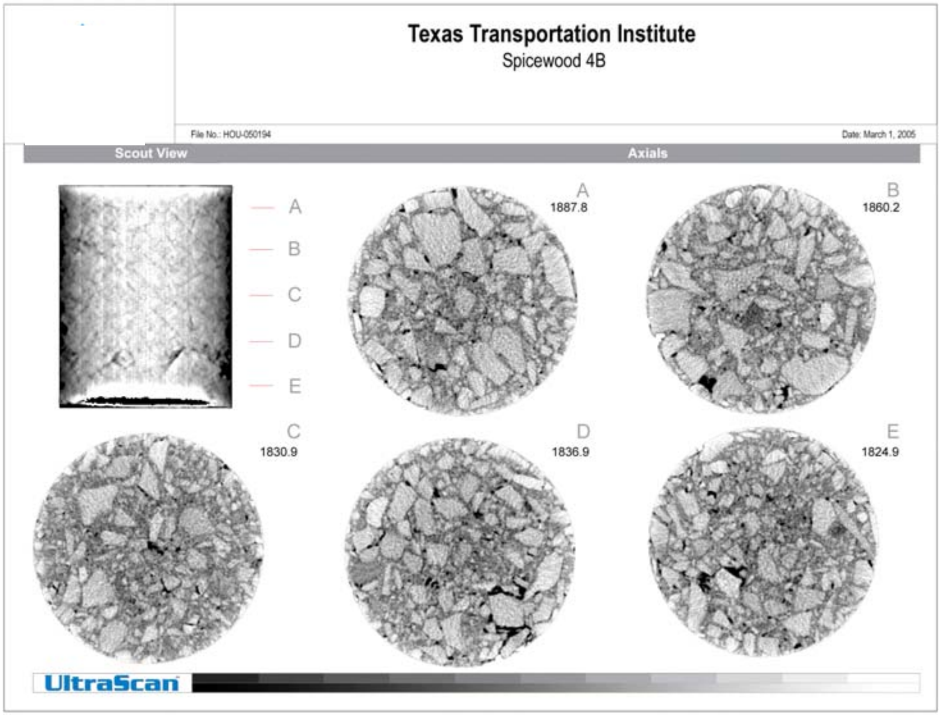
1841.5
UltraScan


Texas Transportation Institute
Spicewood 4A
File No.: HOU-050194
Date: March 1, 2005
Top Quarter
Half
Bottom Quarter
UltraScan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Spicewood 4B
File No.: HOU-050194
Date: March 1, 2005
Scout View
Axials
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C
D
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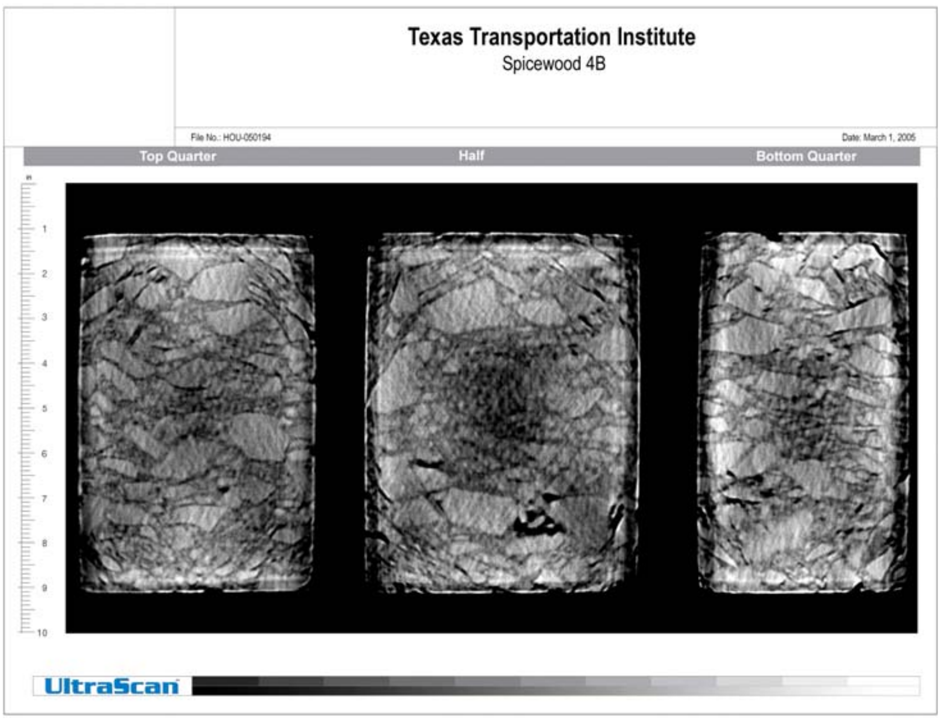
Texas Transportation Institute
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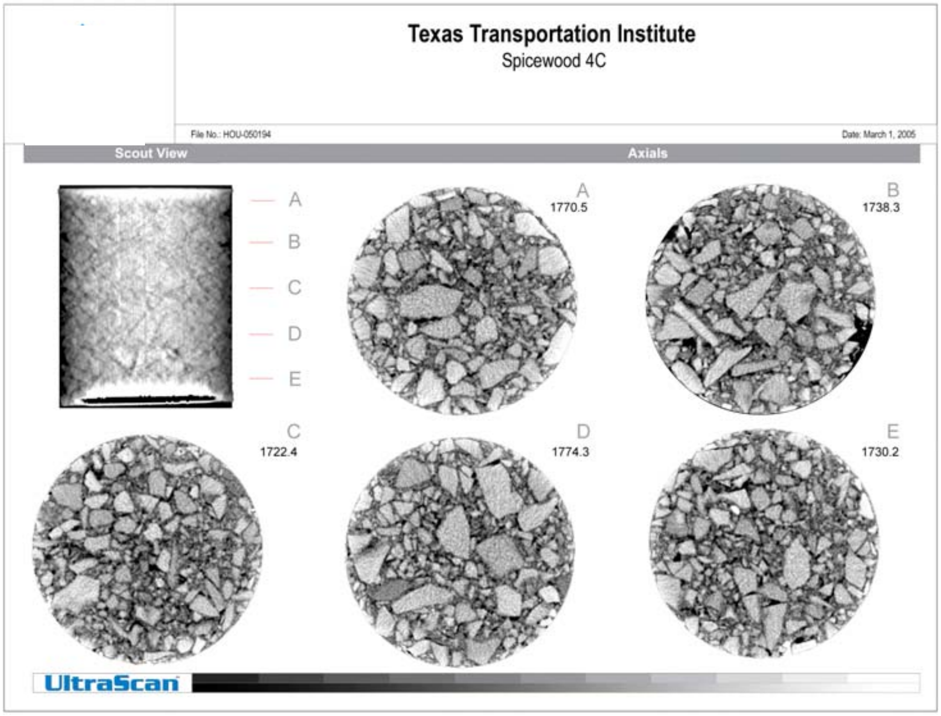
File No.: HOU-050194
Date: March 1, 2005
Top Quarter
Half
Bottom Quarter
UltraScan


Texas Transportation Institute
Spicewood 4C
File No.: HOU-050194
Date: March 1, 2005
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D
1774.3
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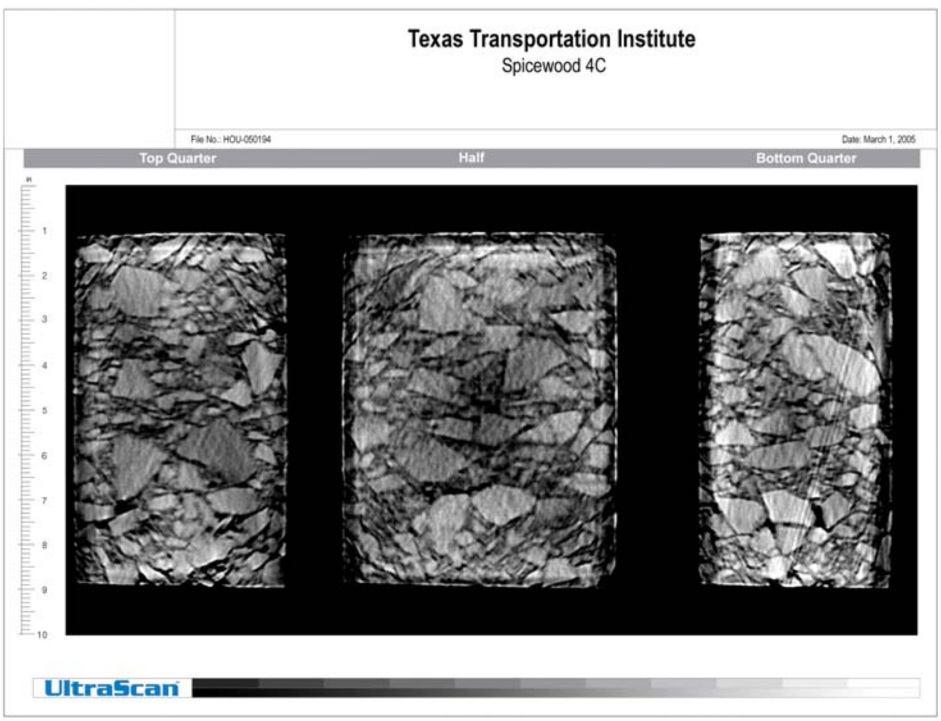
1730.2
UltraScan


Texas Transportation Institute
Spicewood 4C
File No.: HOU-050194
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Top Quarter
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Bottom Quarter
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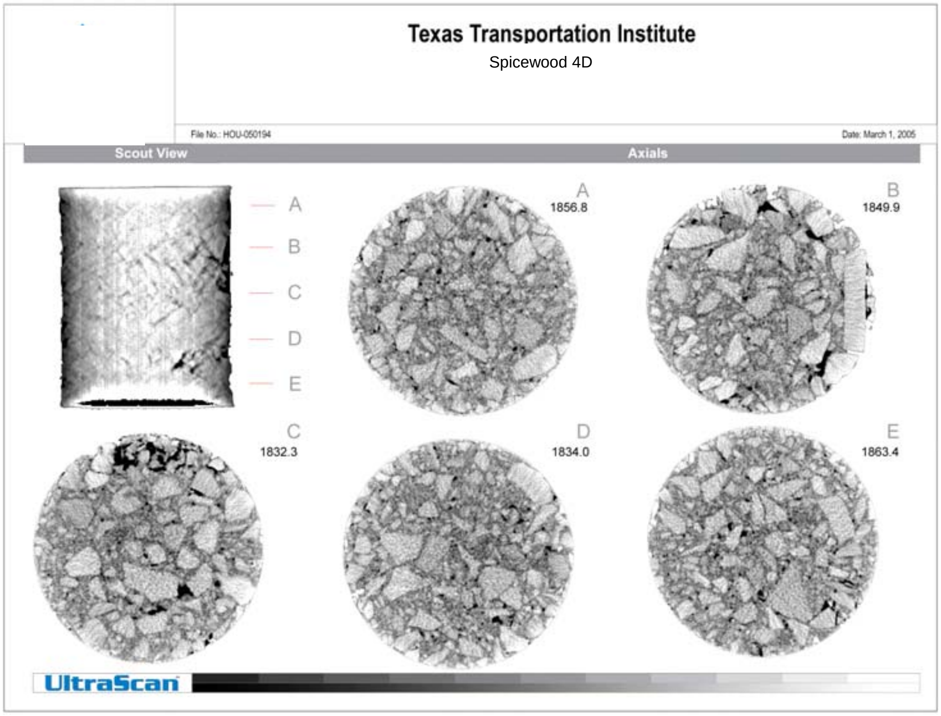
UltraScan


Texas Transportation Institute
Spicewood 4D
File No.: HOU-050194
Date: March 1, 2005
Scout View
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D
E
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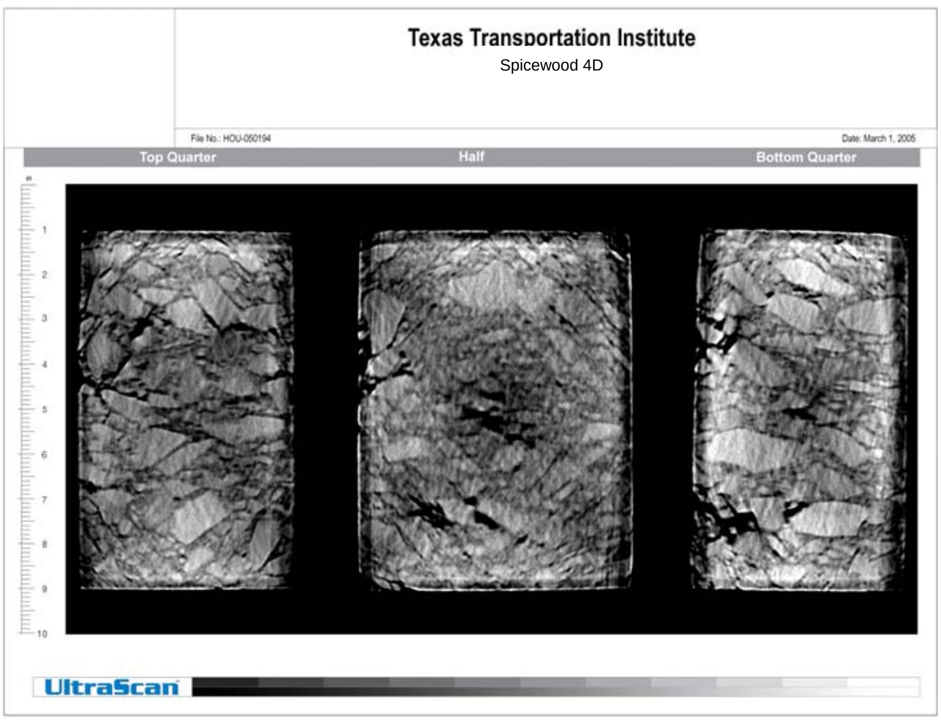
C 1832.3
D 1834.0
E 1863.4
UltraScan


Texas Transportation Institute
Spicewood 4D
File No.: HOU-050194
Date: March 1, 2005
Top Quarter
Half
Bottom Quarter
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UltraScan