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16. Abstract
The existing smoothness specifications of the Texas Department of Transportation (TxDOT) require certification of inertial profilers for ride quality assurance testing. Currently, inertial profilers are certified based on profile measurements collected on dense-graded hot-mix asphalt concrete sections. However, the same profilers are used to measure smoothness of asphalt, Portland cement concrete, and flexible base sections with distinctly different textures than the dense-graded asphalt surfaces on which these profilers were certified. TxDOT also uses inertial profilers to measure the smoothness of the state highway network as part of the department's annual pavement condition surveys to support pavement management applications. A significant percentage of this network consists of roads with seal coat surfaces and surface treatments. Since texture affects the international roughness index, there is a need to build additional sections to certify profilers over the range of textured surfaces on which they will be used. This project aims to enhance TxDOT's profiler certification program by building additional test sections at the Texas A&M Riverside Campus to include surfaces with different textures and smoothness levels. These new sections are expected to improve the validity and applicability of TxDOT's certification program, and also the accuracy of ride quality measurements.

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CONSTRUCTION OF NEW PROFILER CERTIFICATION TRACKS

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DISCLAIMER

The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented. The contents do not necessarily reflect the official views or policies of the Texas Department of Transportation (TxDOT) or the Federal Highway Administration (FHWA). This report does not constitute a standard, specification, or regulation, nor is it intended for construction, bidding, or permit purposes. The United States Government and the State of Texas do not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the object of this report. The engineer in charge of the project was Dr. Emmanuel G. Fernando, P.E. # 69614.

ACKNOWLEDGMENTS

The work reported herein was conducted as part of an implementation project sponsored by the Texas Department of Transportation and the Federal Highway Administration. The authors gratefully acknowledge the support and guidance of the project monitoring committee headed by Dr. Magdy Mikhail of the Maintenance Division of TxDOT. The authors also acknowledge the following individuals who ran inertial profile measurements in the preliminary tests conducted on the new profiler certification tracks: Todd Copenhaver, Phillip Hempel, and Benny Benningfield of the Pavement Preservation Section of TxDOT's Maintenance Division; Jonathon Keoughan of the Bryan Dynatest office; and James Porter Jr. of Duininck Bros. Finally, the authors thank John Wirth and Cody Tanner of the Pavement Preservation Section for collecting on-board sound intensity measurements on the new test track sections.

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CHAPTER 1. INTRODUCTION

The Texas A&M Transportation Institute (TTI) administers the Texas Department of Transportation's (TxDOT) profiler and operator certifications in support of the department's implementation of its Item 585 and SP247-011 ride quality specifications. The profiler certifications are conducted on an asphalt concrete test track built in 1999 along the east shoulder of runway 35C at the Texas A&M Riverside Campus. Figure 1 shows the location of the existing 11-ft wide test track, which runs from the intersection of Runway 35C and Taxiway 7 to a point about 2000 ft north of that junction. Since the construction of this test track, TTI has conducted profiler certifications for contractors and service providers in Texas, U.S. profile equipment manufacturers, the Federal Highway Administration, TxDOT and other state departments of transportation, and international consulting companies.

Figure 1. Existing Test Track Used for Inertial Profiler Certifications.

Currently, inertial profilers are certified based on profile measurements collected on dense-graded hot-mix asphalt concrete sections. However, the same profilers are used to measure smoothness of asphalt, Portland cement concrete, and flexible base sections with distinctly different textures than the dense-graded asphalt surfaces on which these profilers were certified. In addition, TxDOT uses inertial profilers to measure the smoothness of the state highway network, a large percentage of which consists of roads with seal coat surfaces and surface treatments or chip seals. Given that the existing smoothness specifications use the International Roughness Index (IRI) for ride quality assurance testing, and that certain textured surfaces affects IRI, there is a need to build additional sections to certify profilers over the range of textured surfaces on which they will be used.

The effect of surface texture on IRIs was initially reported by Karamihas and Gillespie (2002) in a study conducted for the American Concrete Paving Association. They conducted profile repeatability tests on four pavement sections consisting of:

- An asphalt concrete pavement with a fine-aggregate surface.
- A new longitudinally tined jointed concrete pavement.
- An existing jointed concrete pavement with a broomed finish.
- A new jointed concrete pavement with slightly variable transverse tining.

The researchers found that the longitudinally tined concrete pavement had the lowest repeatability in terms of the average cross-correlation coefficient determined from repeat runs. They explained that the slow drift of a height sensor with a narrow footprint into and out of the longitudinal grooves introduces significant content into the profile that would be misinterpreted as roughness.

In TxDOT project 0-4760, researchers from TTI and the University of Texas at Arlington conducted laboratory tests on specimens simulating different surface treatments. Based on analyzing the data from these tests, the researchers found a statistically significant relationship between the IRIs computed from single-point laser measurements, and surface texture as measured using the sand-patch test (Fernando, Walker, and Estakhri, 2008). They also found the IRIs based on the 19mm laser to be consistently lower than the corresponding IRIs from the single-point laser, with an average difference of about 5 inches/mile based on the laboratory test data.

Disparities in IRI measurements from different lasers were also reported in a number of recent investigations conducted for TxDOT. In 2009, TTI researchers working under the Texas Smoothness Initiative collected data with different lasers on various pavement surfaces to assess the expected differences in IRIs between profiles collected with the 3 KHz Roline laser, the 19mm laser, the single-point laser, and the Ames TriODS multi-point laser. On continuously reinforced concrete pavements (CRCP) with conventional transversely tined surfaces, the IRI differences were found to be significantly higher than 6 in/mile between the single-point and 19mm lasers, and between the single-point and the Ames TriODS, with higher IRIs from the single-point laser. On flexible pavement sections with permeable friction courses (PFC), the IRI differences were found to be significantly higher than 6 inches/mile between the single-point and Roline lasers, and between the single-point and TriODS.

More recently, Fernando and Walker (2013) reported results from comparative profile measurements collected with different lasers and the SurPRO 3500 reference profiler on a broad range of pavement surfaces that included dense-graded hot-mix asphalt (HMA), PFC, stone-matrix asphalt, transversely tined, carpet-dragged, and longitudinally tined CRCP, flexible base, and various surface treatments. Pairwise comparisons between IRIs from the different lasers and the SurPRO showed IRI differences of 3 inches/mile and higher, depending on the surface type. Clearly, there is a need to build additional sections to certify profilers over the range of textured surfaces on which they will be used.

This project aims to enhance TxDOT's profiler certification program by building additional certification sections at the Texas A&M Riverside Campus to include surfaces with different textures and smoothness levels. These new sections are expected to improve the validity and applicability of TxDOT's certification program, and also the accuracy of ride quality measurements. To accomplish the project objective, TTI researchers carried out the following tasks during this implementation project:

- Procured a site at the Riverside Campus on which to build new test tracks.
- Developed plans for construction of the proposed test tracks.
- Solicited bids and acquired the services of a contractor to build the new tracks.
- Performed preliminary tests to establish the initial reference profiles on the new test tracks, and verify the applicability of TxDOT's existing Tex-1001S certification requirements on the new pavement surfaces.

This report documents the construction of the new profiler certification tracks at the Riverside Campus.

CHAPTER 2. SITE PROCUREMENT

To support the expansion of the existing profiler certification facility, additional land space was needed at the Riverside Campus on which to build new test sections. The initial goal was to build a concrete test track that will complement the existing hot-mix asphalt test track along runway 35C. However, during a meeting with TxDOT, a member of the project monitoring committee recommended that chip seal sections be included in the proposed expansion. Consequently, the decision was made to include a second test track where these chip seal sections would be built. Working with TTI's Facilities, Safety and Support Services, the researchers looked at the available land space at the Texas A&M Riverside Campus and the current land use to identify areas where the proposed test tracks might be built.

IDENTIFICATION OF CANDIDATE SITES

Researchers considered a number of alternative locations on which to build the proposed test tracks within the Riverside Campus. Figure 2 shows one of the candidate locations considered during the project. This location is near the entrance gate to the Riverside Campus and has ample space for constructing new profiler certification tracks. The sandy soil at this site also provides a better foundation material for building the test tracks, compared to the clay soil that is predominantly found within the Riverside Campus. However, researchers did not get approval to use the available area to build the new test tracks as Texas A&M has other plans for using that area.

Researchers considered other alternative locations within the Riverside Campus. However, existing users of these locations stated that they cannot afford to lose land for their research. One option TTI explored is the field adjacent to the existing test track shown in Figure 1. However, a 2200 ft × 150 ft land strip at that location would take up a large piece of land in a pasture belonging to Vet Med Research Park. That pasture received funding for a project where Vet Med researchers will be placing a herd of horses that cannot have nose-to-nose contact due to the diseases they are working with. All their other pastures are contiguous to another pasture. Thus, they would not be able to isolate the horses.

Figure 2. Candidate Location near Entrance to the Riverside Campus.

Other sites researchers considered were the fields east and west of Bryan Road, and the field on the northwest side of the Riverside Campus. However, at the time researchers were exploring options for locating the test tracks, Texas A&M had already made plans to build a library on the west side of Bryan Road while Vet Med Research Park is using the east side of that road. The northwest side of the Riverside Campus is shared between the Animal Science Beef Cattle and Vet Med. Vet Med Research noted that they have lost a large amount of land at the Large Animal Hospital and in the Vet Med Research Park on campus. They now have to move animals back and forth from campus daily for teaching and research. They are short on pasture and are trying to increase their programs. Thus, they strongly feel that they cannot lose any more land. On the northwest side, Animal Science Beef Cattle and Vet Med are combining forces to utilize that area. They plan to clear land, add cross fences, and place a new entrance on the northwest side.

SELECTED SITE LOCATION

One other alternative that researchers considered was locating the new test tracks along Taxiway 7 of the Riverside Campus. Figure 3 shows this alternate location. To accommodate the proposed construction of new test tracks in this implementation project, the existing fence line at the site needs to be moved about 15 ft west of its current location, which will encroach into the existing pasture that Vet Med Research uses, and will thus require their approval. However, preliminary discussions with Vet Med Research suggested that they can accommodate this change. The alternate location along Taxiway 7 also provides existing concrete pavements that test vehicles can use as a lead-in and a lead-out to get up to speed and to decelerate. It is also near the existing test track along runway 35C. However, this location does not provide space for future growth, and the clay soil at the site will likely require chemical stabilization and a thicker pavement. Nevertheless, among the alternative locations considered within the Riverside Campus, Taxiway 7 provided the least conflict with existing users. Consequently, TTI proposed this site as the location to build new test tracks for inertial profiler certifications. The TTI Facilities Coordinator presented this proposal in a meeting of the Texas A&M Council on the Built Environment (CBE). The Council subsequently submitted its recommendation for the President of the University to approve use of the land space adjacent to Taxiway 7 to build new test tracks for inertial profiler certifications. Figure 4 shows the approval document signed by the Texas A&M University President. Having procured land on which to build new test tracks, the researchers proceeded with developing plans for construction of these tracks.

Figure 3. Approved Site along Taxiway 7 for Construction of New Test Tracks.

OFFICE OF THE VICE PRESIDENT
FOR ADMINISTRATION

TEXAS A&M UNIVERSITY

April 3, 2012

MEMORANDUM

TO: Dr. R. Bowen Loftin
President

SUBJECT: CBE Recommendation: Additional Land Space for TTI Profiler Facility at Riverside

At its March 6, 2012 meeting, the Council on the Built Environment reviewed the request from Texas Transportation Institute requesting additional land space on which to build new test sections to permit future growth. The section of land is 2,100 ft. long by 25 ft. wide along Taxiway 7. The north end of this location is currently utilized by TTI. The south end of the location will require moving the fence for a pasture belonging to the College of Veterinary Medicine. Sam Wigington, Director of Facilities for the College of Vet Med, has provided a letter supporting the request. The Profiler Certification Facility is receiving funding from TXDOT and is awaiting final site selection to release their funds to TTI.

DRsc reviewed the proposal and agrees it is in line with the draft of the Riverside Campus Plan. DRsc recommends the approval of the proposal.

TRsc reviewed the proposal and stated there are no technical issues or concerns. TRsc recommends approval.

CBE voted unanimously to recommend the President's approval for additional land space for the TTI Profiler Certification Facility at Riverside Campus.

4-3-12
Karan L. Watson — Date
Provost and Executive Vice President
for Academic Affairs
Co-Chair, Council of Built Environment

4.3.12
Rodney P. McClendon — Date
Vice President for Administration
Co-Chair, Council of Built Environment

Recommendation Approved:

R. Bowen Loftin
President

4/4/12
Date

cc: Council of Built Environment (CBE) members
Dr. Dennis Christiansen

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Figure 4. Approval Document for Use of Taxiway 7 Signed by University President.

CHAPTER 3. CONSTRUCTION PLANS FOR NEW TEST TRACKS

This chapter presents plans and specifications for construction of new continuously reinforced concrete pavement and flexible pavement test tracks at the Riverside Campus of Texas A&M University. Figure 3 shows the approved location for this construction. As illustrated in Figure 5, the test tracks will be built adjacent to each other with the CRCP track placed alongside the outermost lane of Taxiway 7. In consultation with the project monitoring committee, researchers developed plans to build 1-inch transversely tined, ½-inch transversely tined, and 1-inch longitudinally tined sections on the CRCP test track. On the flexible pavement test track, plans were developed to build a permeable friction course hot-mix asphalt section, and inverted prime, Grade 3, and Grade 4 chip seal sections.

To optimize the use of available funds, the plans include a number of alternates on which construction bids were solicited. This approach provided flexibility in selecting the combination of alternates that made the best use of available funds to construct new test tracks for inertial profiler certifications. For this construction, the scope of work was divided into two phases (see Table 1 and Table 2). For each phase, two alternates are presented. However, for each phase, only one alternate will be selected, depending on the bids received and the available budget. With the project engineer's approval, the plans allowed the selected contractor to perform Phase 1 and Phase 2 work items jointly, if such scheduling would enhance construction efficiency, particularly for those items that use the same resources. Prospective contractors were instructed to carefully review the plans and specifications provided in this chapter in preparing their bids. Contractors were also asked to submit bids for each alternate identified in Tables 1 and 2, itemized according to the work items shown, with the unit cost per item included in the bids.

In addition to the construction of test tracks in Phase I and Phase 2, researchers included an alternate third phase covering placement of access ramps to the test tracks. Contractors were also asked to submit bids for this Phase 3 work according to the plans and specifications given in this chapter.

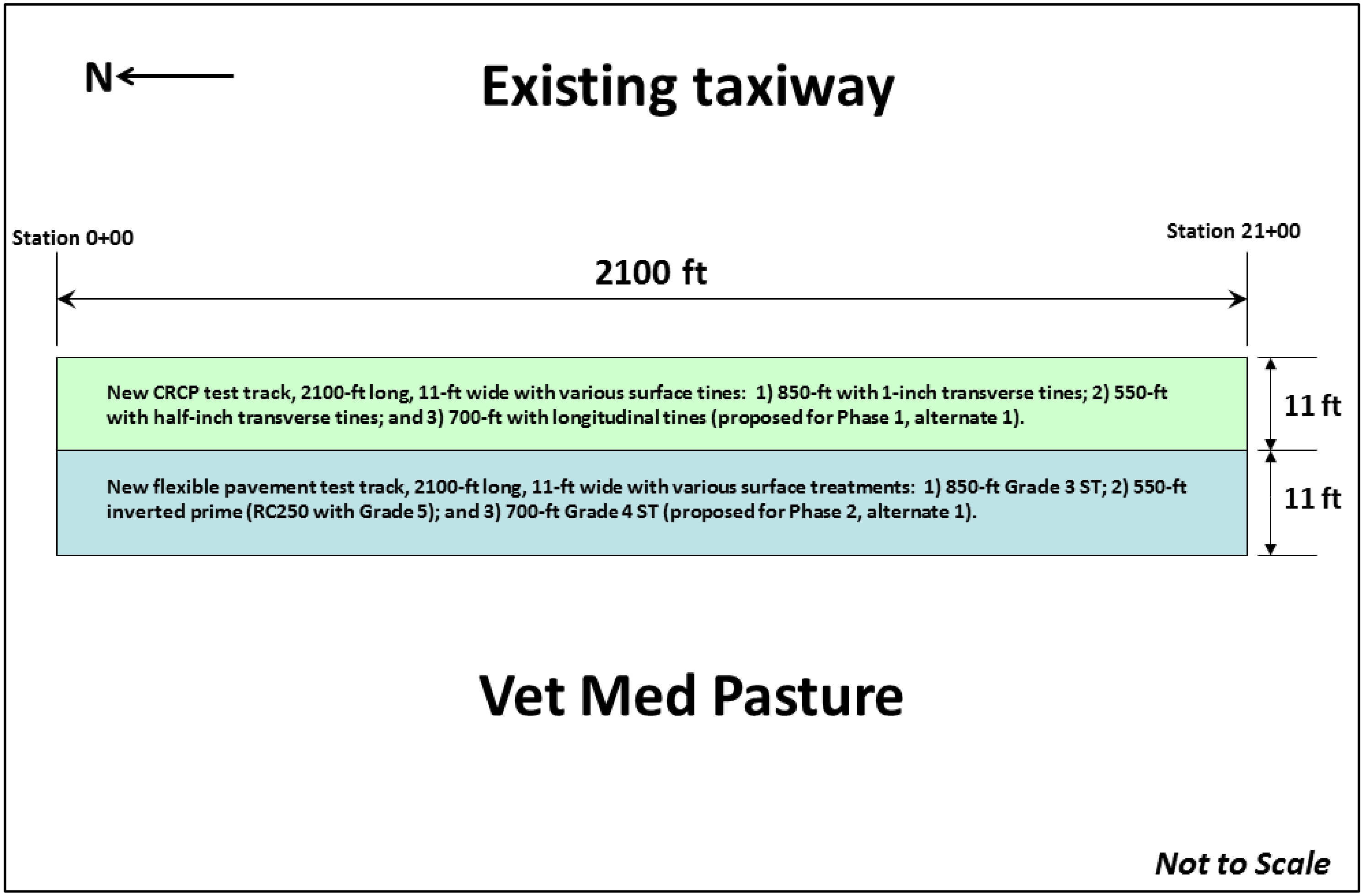

Figure 5. Plan View of Proposed New Test Tracks.

Table 1. Phase 1 Work Items.

Phase 1: Alternate 1, 2100-ft CRCP Test Track	
Work Item ID	Description
1-1a	Mobilization (to include a 2100-ft silt fence).
1-2a	Clear, grub, and haul off site existing vegetation over a 610 ft × 24 ft wide area.
1-3a	Excavate and remove 14 inches deep of existing materials over a 2100 ft × 13 ft wide area and haul off site.
1-4a	Lime stabilized existing soil 12 inches deep over a 2100 ft × 13 ft wide area.
1-5a	Place Grade 1, Type A flexible base 6 inches deep over a 2100 ft × 12 ft wide area.
1-6a	Place 2-inch Type C HMA base over a 2100 ft × 11 ft wide area.
1-7a	Place 6-inch thick CRCP slab over a 2100 ft × 11 ft wide area.
Phase 1: Alternate 2, 2000-ft CRCP Test Track	
Work Item ID	Description
1-1b	Mobilization (to include a 2100-ft silt fence).
1-2b	Clear, grub, and haul off site existing vegetation over a 610 ft × 24 ft wide area.
1-3b	Excavate and remove 14 inches deep of existing materials over a 2100 ft × 13 ft wide area and haul off site.
1-4b	Lime stabilized existing soil 12 inches deep over a 2100 ft × 13 ft wide area.
1-5b	Place Grade 1, Type A flexible base 6 inches deep over a 2100 ft × 12 ft wide area.
1-6b	Place 2-inch Type C HMA base over a 2000 ft × 11 ft wide area.
1-7b	Place 6-inch thick CRCP slab over a 2000 ft × 11 ft wide area.

Table 2. Phase 2 Work Items.

Phase 2: Alternate 1, 2100-ft Test Track of Surface Treatments	
Work Item ID	Description
2-1a	Excavate and remove 14 inches deep of existing materials over a 2100 ft × 11 ft wide area adjacent to Phase 1 excavation (Work Item 1-3a or 1-3b) and haul off site.
2-2a	Lime stabilized existing soil 12 inches deep over a 2100 ft × 11 ft wide area adjacent to Phase 1 lime treatment (Work Item 1-4a or 1-4b).
2-3a	Place Grade 1, Type A flexible base in two lifts: 1) 6-inch lift and 2) 7-inch lift from station 00+00 to 21+00 over a 12-ft wide area.
2-4a	Place Grade 3 surface treatment over an 850 ft × 11 ft wide area from station 00+00 to 08+50.
2-5a	Place inverted prime over a 550 ft × 11 ft wide area from station 08+50 to 14+00.
2-6a	Place Grade 4 surface treatment over a 700 ft × 11 ft wide area from station 14+00 to 21+00.
2-7a	Place Gr. 1, Type A flexible base 7 inches deep from station 20+00 to 21+00 over an 11-ft wide area at south end of CRCP track (OPTIONAL: to be executed only if Alternate 2 is selected in Phase 1).
2-8a	Place Grade 4 surface treatment from station 20+00 to 21+00 over an 11-ft wide area at south end of CRCP track (OPTIONAL: to be executed only if Alternate 2 is selected in Phase 1).
2-9a	Final clean-up after construction is completed.
Phase 2: Alternate 2, 2100-ft Surface Treatment + PFC Test Track	
Work Item ID	Description
2-1b	Excavate and remove 14 inches deep of existing materials over a 2100 ft × 11 ft wide area adjacent to Phase 1 excavation (Work Item 1-3a or 1-3b) and haul off site.
2-2b	Lime stabilized existing soil 12 inches deep over a 2100 ft × 11 ft wide area adjacent to Phase 1 lime treatment (Work Item 1-4a or 1-4b).
2-3b	Place Grade 1, Type A flexible base in two lifts: 1) 6-inch lift and 2) 7-inch lift from station 00+00 to 14+00 over a 12-ft wide area.
2-4b	Place Grade 1, Type A flexible base in two 6-inch lifts from station 14+00 to 21+00 over a 12-ft wide area.
2-5b	Place Grade 3 surface treatment over an 850 ft × 11 ft wide area from station 00+00 to 08+50.
2-6b	Place inverted prime over a 550 ft × 11 ft wide area from station 08+50 to 14+00.
2-7b	Place Grade 4 under seal over a 700 ft × 12 ft wide area from station 14+00 to 21+00.
2-8b	Place 1-inch permeable friction course on Grade 4 seal over a 700 ft × 11 ft wide area from station 14+00 to 21+00.
2-9b	Final clean-up after construction is completed.

PHASE 1 PLANS AND SPECIFICATIONS

Figure 6 shows the two alternates for constructing the CRCP test track in Phase 1. Figure 7 shows the cross-section for this test track while Figure 8 illustrates the reinforcement details for the slab. Plans and specifications for the Phase 1 construction are presented in this section.

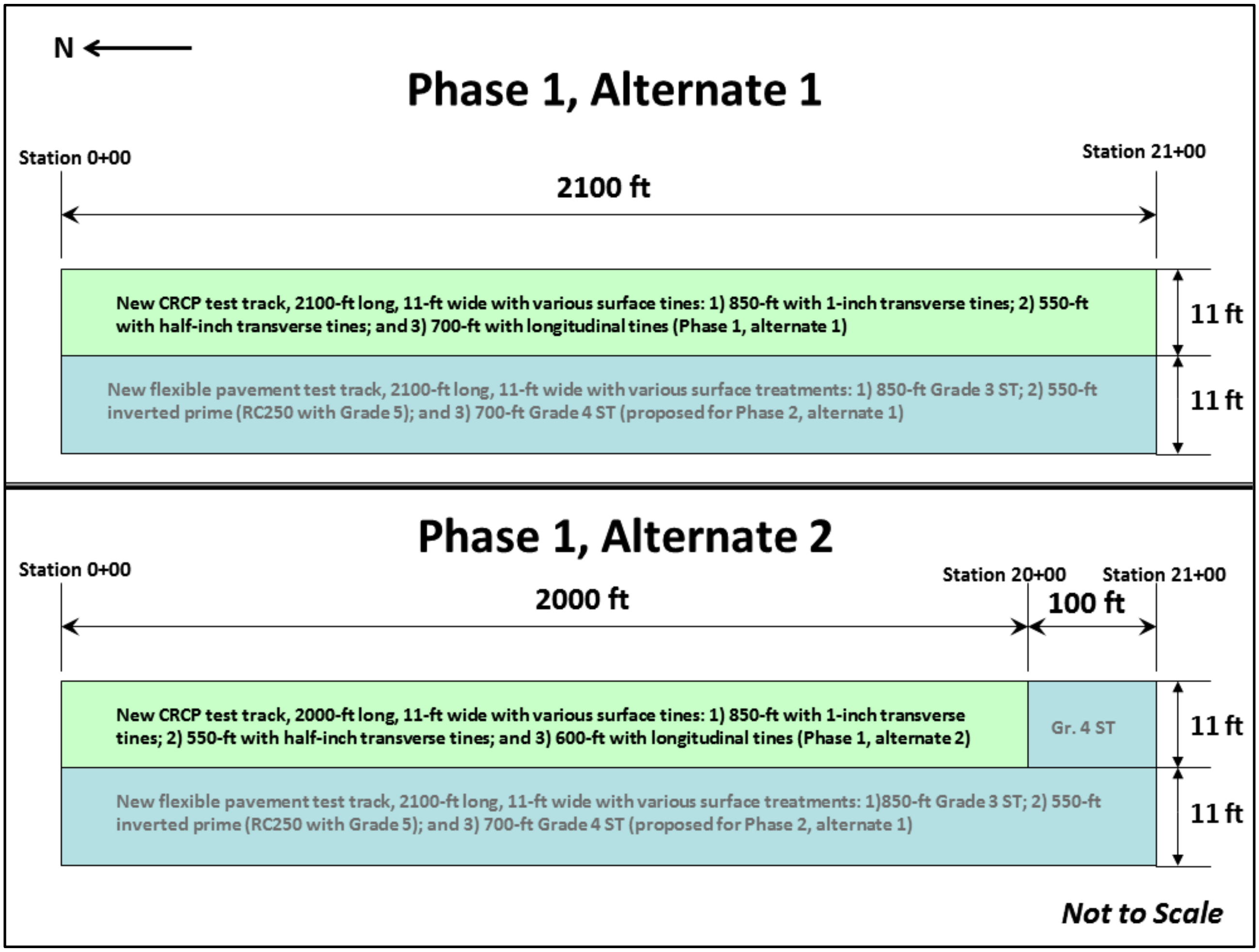

Figure 6. Plan View of Alternates for Construction of CRCP Test Track in Phase 1.

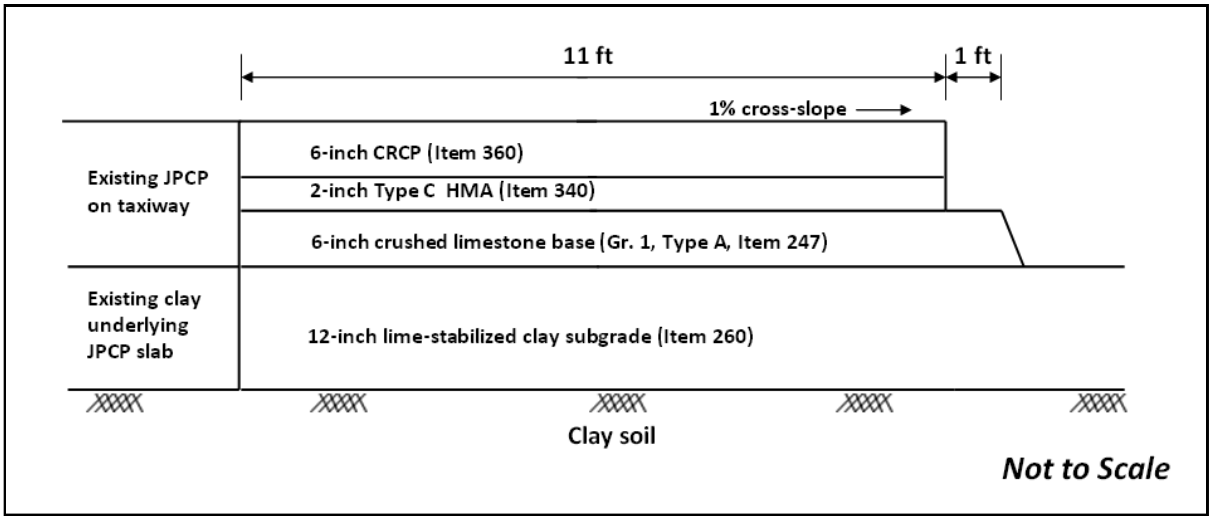

Figure 7. Typical CRCP Cross-Section.

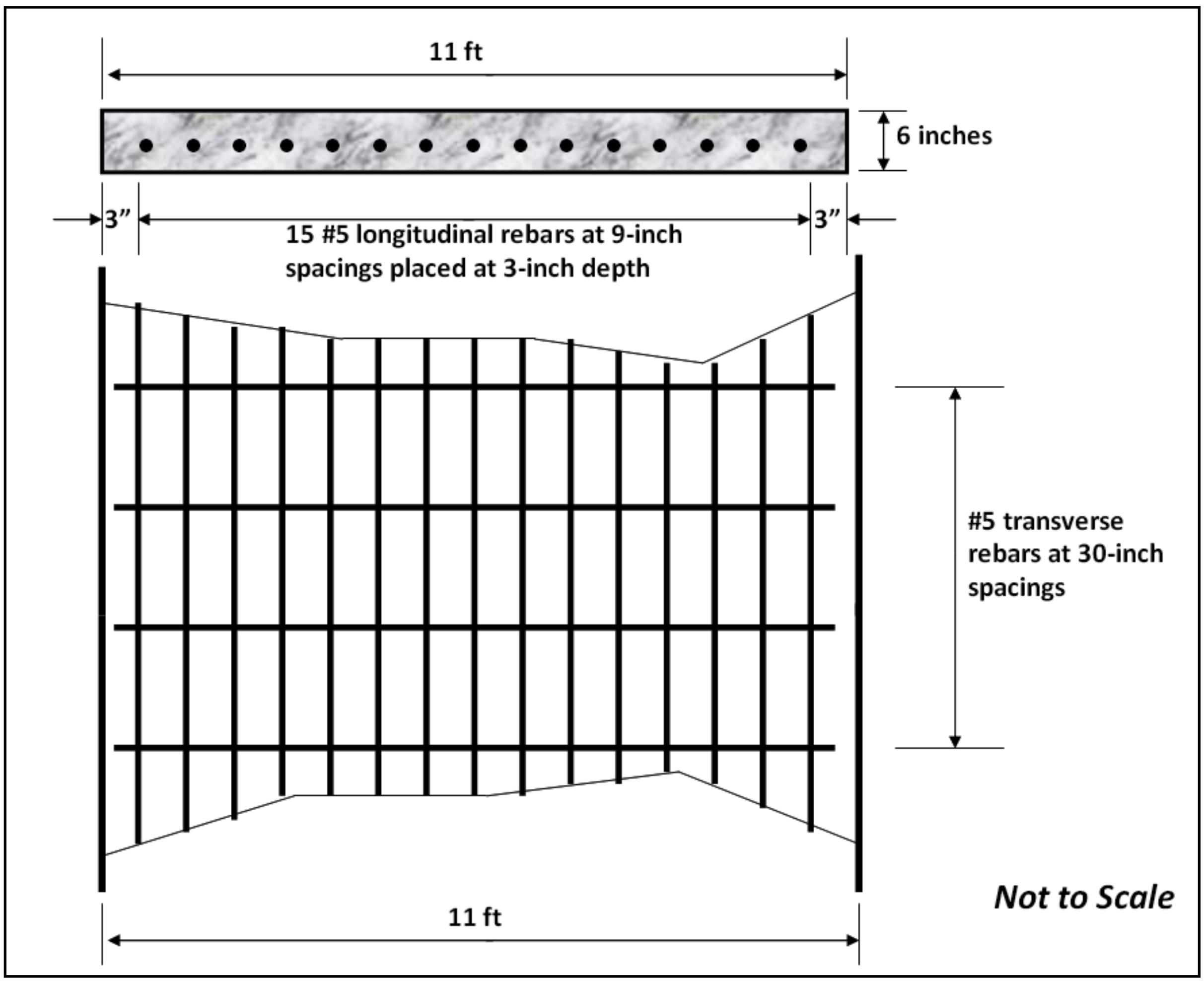

Figure 8. Concrete Slab Reinforcement Details.

Excavation and Removal of Existing Materials

The contractor shall excavate and remove existing materials at the site to a depth of 14 inches over an area 2100 ft long × 13 ft wide adjacent to Taxiway 7 (Work Item 1-3a or 1-3b). Unless otherwise directed by the project engineer, the contractor shall remove and haul salvaged materials from the Riverside Campus and dispose of these materials in accordance with federal, state, and local regulations.

Lime Stabilization

After performing Work Item 1-3a or 1-3b, the contractor shall lime stabilize the existing subgrade material adjacent to the taxiway to a depth of 12 inches over an area 2100 ft long × 13 ft wide in accordance with Item 260 of the TxDOT (2004) standards. Use quicklime for treating the subgrade and compact the material to at least 95percent of the maximum density as determined in accordance with TxDOT Test Method Tex-121-E. The project engineer will determine the density of the compacted subgrade after lime treatment in accordance with Tex-115-E. Acceptance of the compacted lime-treated section will be conducted in accordance with Item 260.4.E.2, *Density Control*. Grade the section such that the top of the CRCP test track after placement will be flushed with the existing taxiway along the longitudinal joint, and have a cross-slope of 1 percent as given in the CRCP typical cross-section shown in Figure 7.

Crushed Limestone Base

The contractor shall place flexible base on the lime-treated subgrade in accordance with Item 247 of the TxDOT (2004) standards. Use crushed limestone base classifying as Grade 1, Type A and provide documentation showing the material meets this classification per Item 247. The contractor may use Grade 1, Type A crushed limestone base that TxDOT has approved for use on a recent or ongoing project; or Grade 1, Type A crushed limestone obtained from a TxDOT-approved stockpile. Upon approval of the project engineer, the contractor shall place the crushed limestone base to provide a uniform compacted thickness of 6 inches over an area 2100 ft long × 12 ft wide (Work Item 1-5a or 1-5b). The contractor shall compact the flexible base using density control per Item 247.4.C.2, and grade the base such that the top of the CRCP test track after placement will be flushed with the existing taxiway along the longitudinal joint, and have a cross-slope of 1 percent as shown in Figure 7. The work performed and materials furnished in this section will be paid according to Item 247.6.A, *Flexible Base (Complete in Place)*.

Type C Hot-Mix Asphalt

The contractor shall place a 2-inch Type C HMA on top of the compacted flexible base over an area 2100-ft long × 11-ft wide under Work Item 1-6a of Table 1 or over an area 2000-ft long × 11-ft wide under Work Item 1-6b. Prior to placing the HMA, the contractor shall provide documentation showing that the material to be placed has gained TxDOT's approval on a recent or on-going Department project. The contractor may use a Type C mix that has already been approved for use and is being produced on an on-going TxDOT project.

Upon approval of the project engineer, the contractor will place the Type C mix to provide a uniform compacted thickness of 2 inches over the required area in accordance with Item 340. Apply a uniform tack coat over the flexible base at a rate of 0.10 gal/yd^2 prior to placing the Type C mix. Provide an adequate supply of HMA to place the Type C mix in one continuous operation over the required area. Use air-void control for compacting the mix.

Continuously Reinforced Concrete Slab

The contractor shall place a 6-inch thick continuously reinforced concrete slab on top of the compacted Type C HMA base in accordance with Item 360 over an area 2100 ft long × 11 ft wide under Work Item 1-7a of Table 1 or over an area 2000 ft long × 11 ft wide under Work Item 1-7b. Accurately place and secure into position all reinforcing steel. Figure 8 illustrates the reinforcement details for the concrete slab. Secure reinforcing bars at alternate intersections with wire ties or locking support chairs. Tie all splices with wire and provide a 30-inch overlap of rebars at splices. The CRC slab shall not be tied to the jointed plain concrete slabs of the adjacent taxiway.

The contractor shall provide an adequate supply of Class P concrete mix to place the 6-inch CRC slab in one continuous operation over the required area. The concrete mix shall have a 28-day compressive strength of 4400 psi. Texture the surface before the concrete has attained its initial set using a combination of carpet drag and metal tining to form sections with the tining patterns shown in Table 3. Include a line item in the bid proposal for an option to saw cut joints ⅛-inch deep at 5-ft intervals along the track as soon as sawing can be accomplished without damaging the pavement. Depending on the cost of this option and the available budget, a decision will be made on whether to include saw cutting with placement of the CRC slab in Work Item 1-7a or 1-7b.

The contractor shall place the CRC slab such that it is flushed with the existing taxiway along the longitudinal joint, and has a cross-slope of 1 percent. The ride quality of the finished pavement shall be measured in accordance with Item 585. The contractor shall first get the approval of the project engineer before performing quality assurance tests of concrete pavement smoothness. For areas that require corrective work by grinding, no grinding will be performed until after the project engineer gives approval to proceed with quality assurance tests.

Table 3. Surface Texturing of CRCP Test Track.

Tining Pattern	Limits of Tine		Length (ft)	Work Item ID
	From Station	To Station		
1-inch transverse tines	00+00	08+50	850	1-7a or 1-7b
½-inch transverse tines	08+50	14+00	550	1-7a or 1-7b
1-inch longitudinal tines	14+00	21+00	700	1-7a
1-inch longitudinal tines	14+00	20+00	600	1-7b

PHASE 2 PLANS AND SPECIFICATIONS

Figures 9 to 15 show the plans and specifications for construction of the flexible pavement test track in Phase 2. Figure 9 shows the two alternates being considered:

- Construction of a 2100-ft test track consisting of three surface treatments–a Grade 3, an inverted prime, and a Grade 4 (alternate 1).
- Construction of a 2100-ft test track consisting of two surface treatments–a Grade 3 and an inverted prime, and an asphalt concrete pavement section with a PFC surface (alternate 2).

The second alternate, with a PFC section, will be considered only if a 2100-ft CRCP test track is built in Phase 1 (alternate 1). If a 2000-ft CRCP test track is built (Phase 1, alternate 2), the flexible pavement test track will be constructed using alternate 1 in Phase 2 (see Figure 10). The following additional notes are provided to supplement the plans and specifications given in Figures 9 to 15 in connection with the Phase 2 construction of the flexible pavement test track.

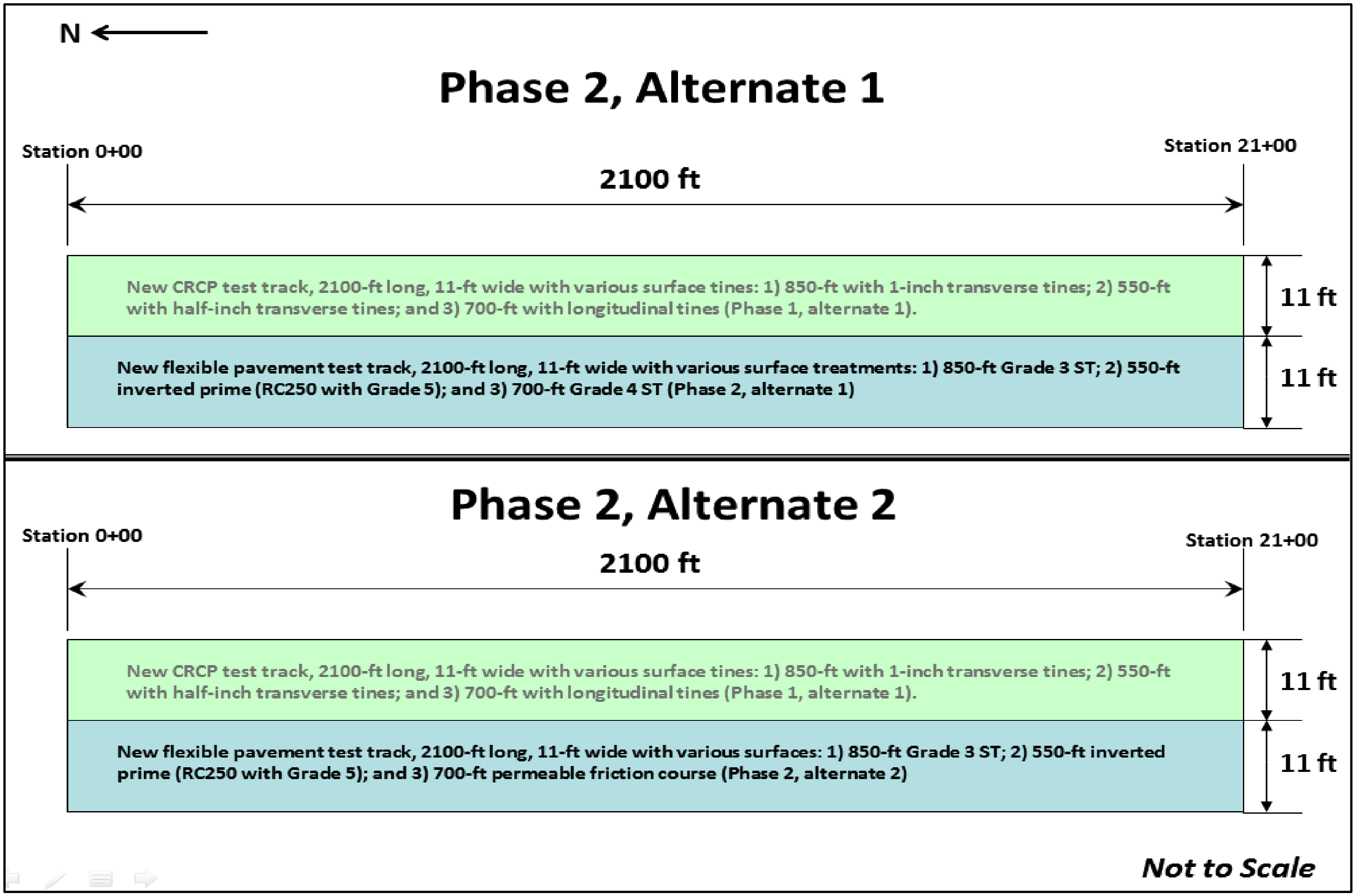

Figure 9. Plan View of Two Alternates for Construction of Flexible Pavement Test Track in Phase 2.

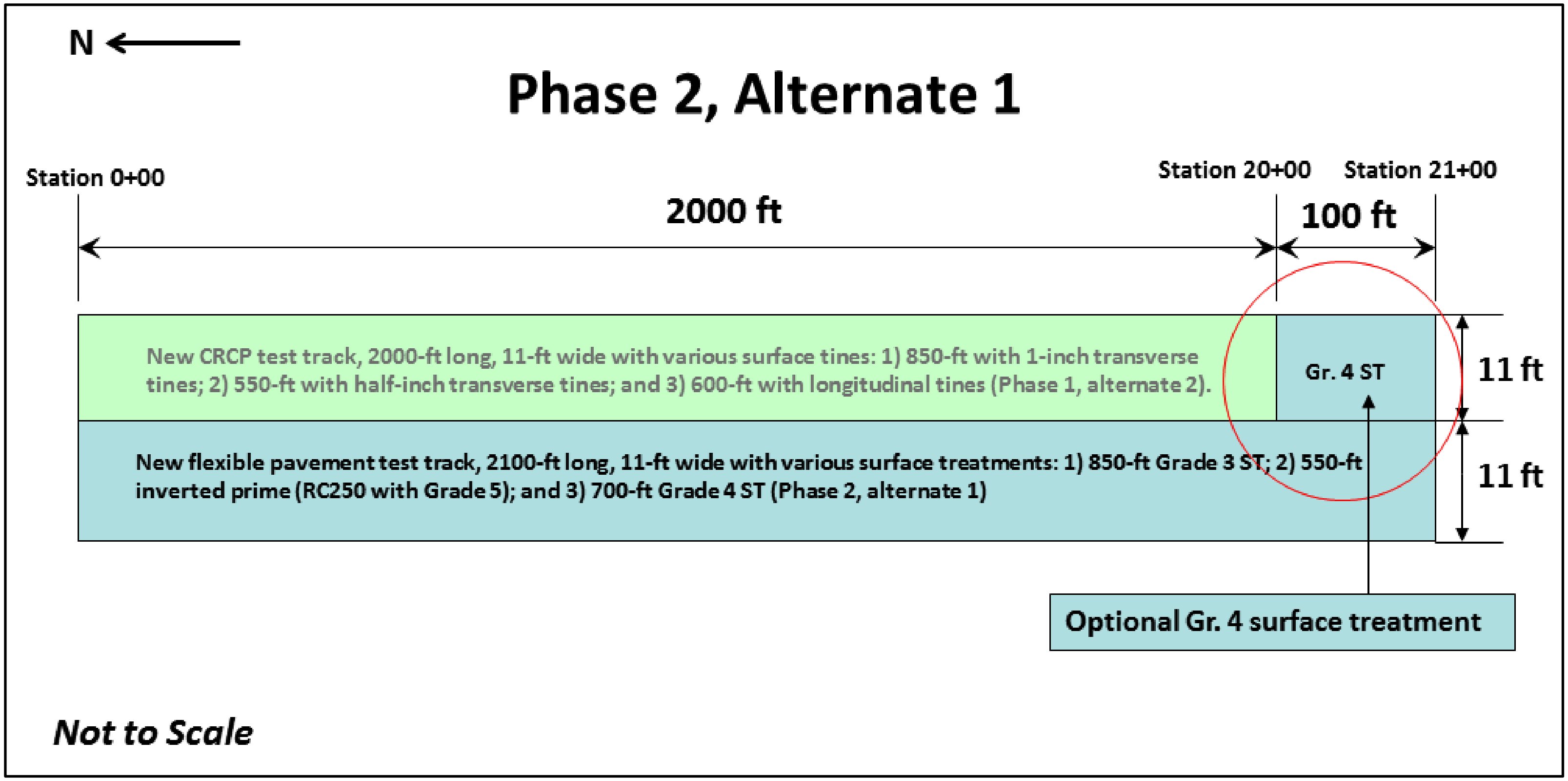

Figure 10. Plan View of Phase 2 Construction of Flexible Pavement Test Track Using Alternate 1, and Construction of Optional Grade 4 Surface Treatment at South End of 2000-ft CRCP Test Track Built under Phase 1, Alternate 2.

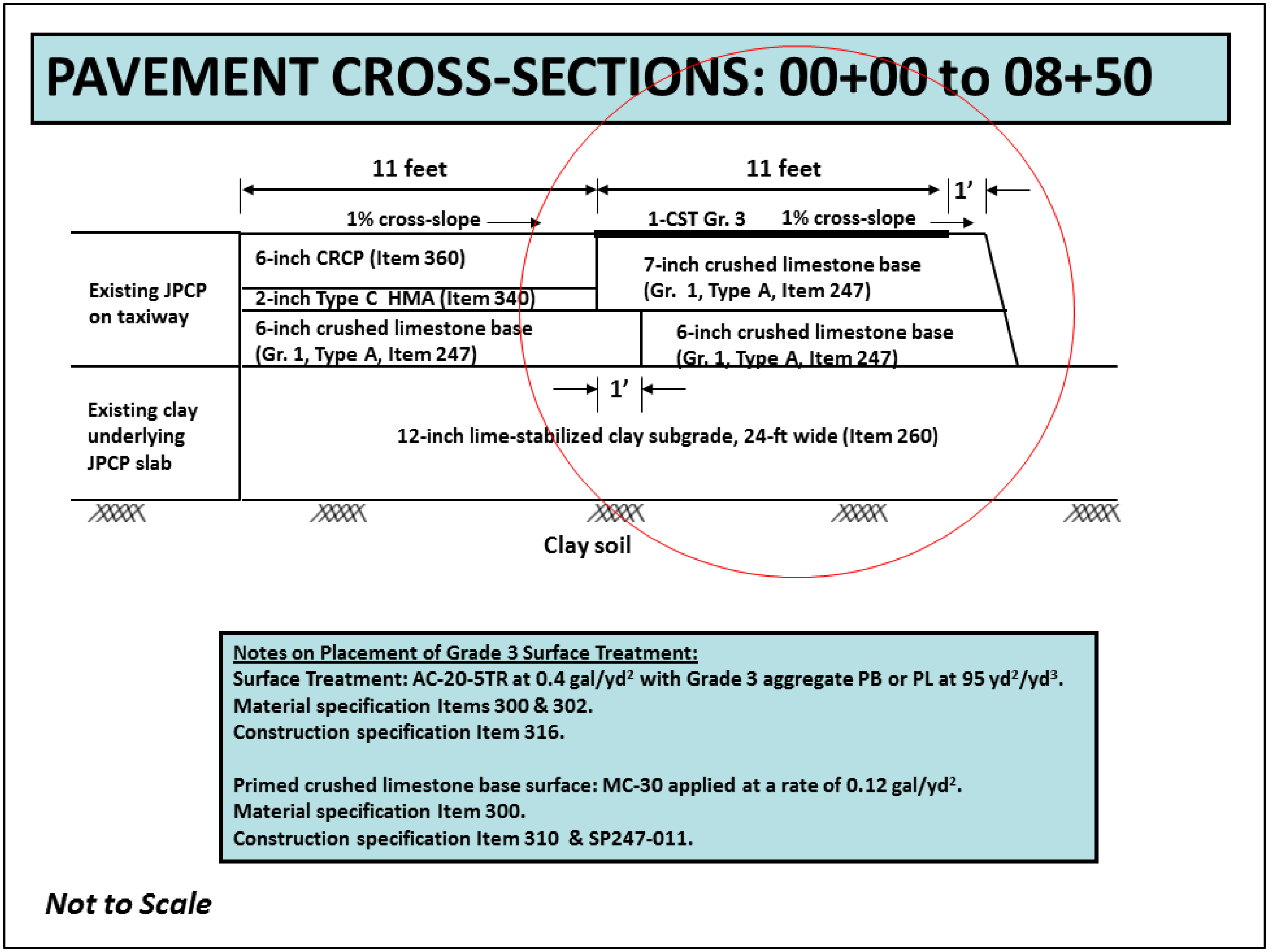

Figure 11. Typical Cross-Section of 850-ft Grade 3 Surface Treatment.

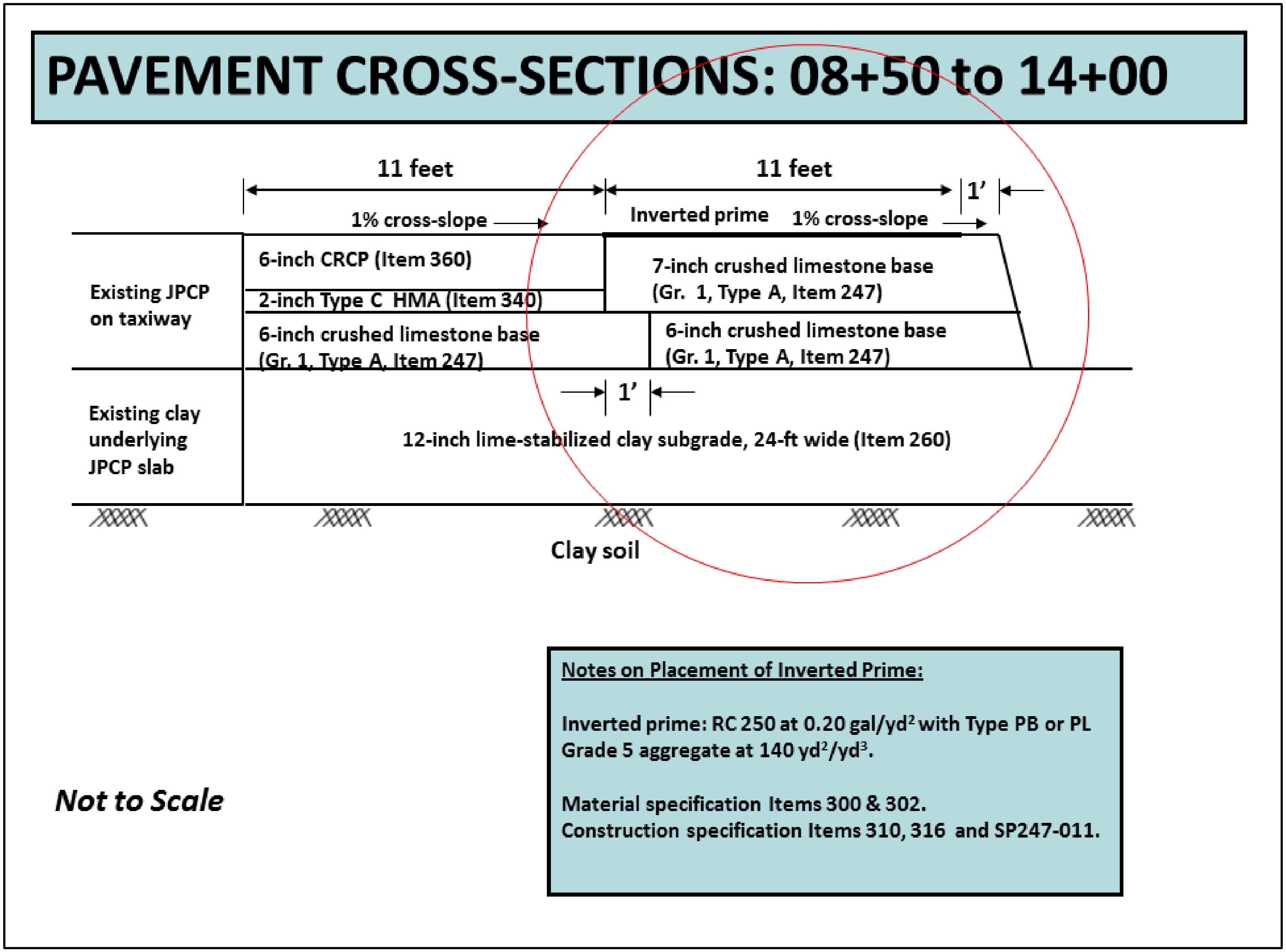

Figure 12. Typical Cross-Section of 550-ft Inverted Prime Section.

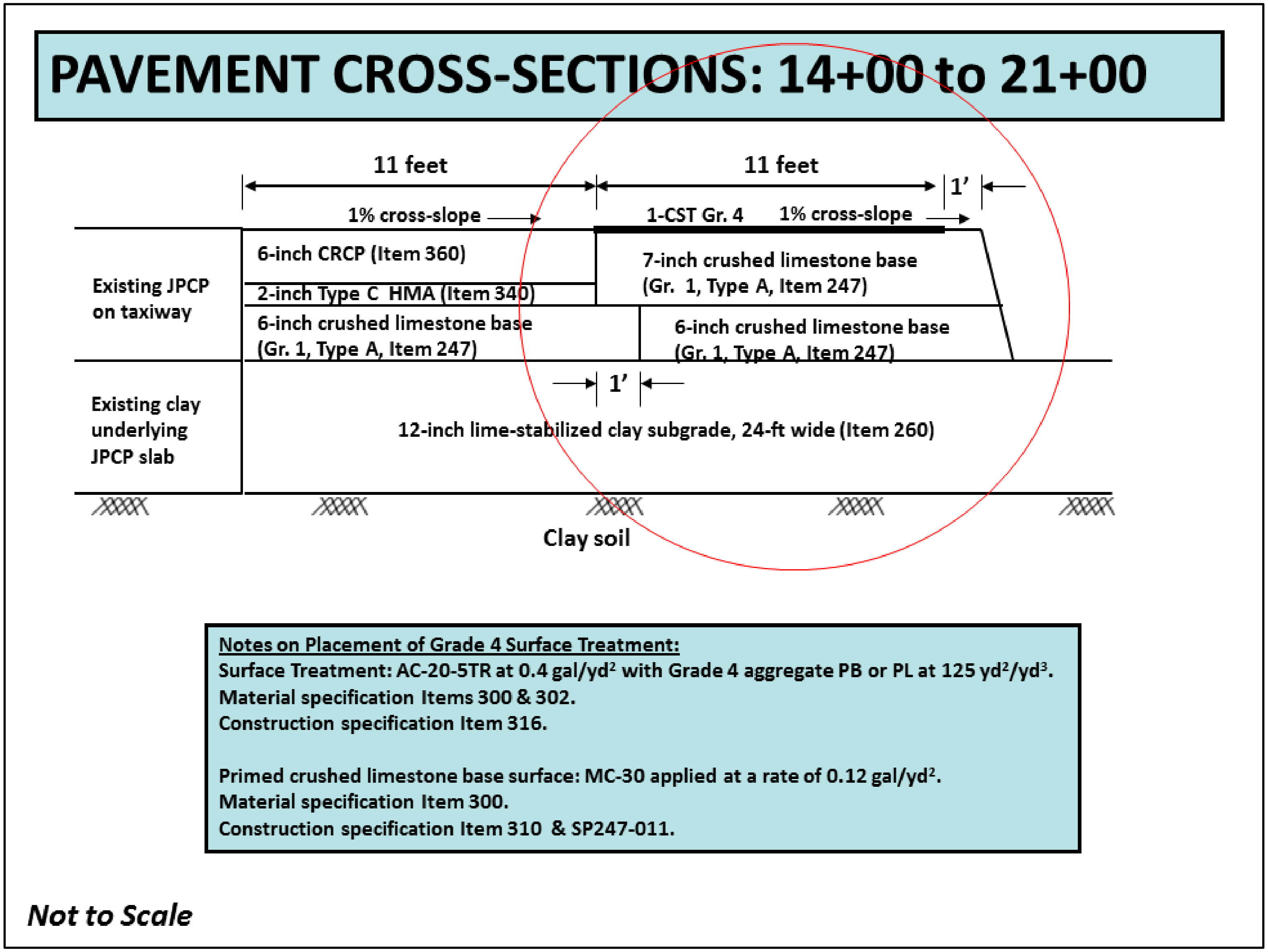

Figure 13. Typical Cross-Section of 700-ft Gr. 4 Surface Treatment (Phase 2, Alt. 1).

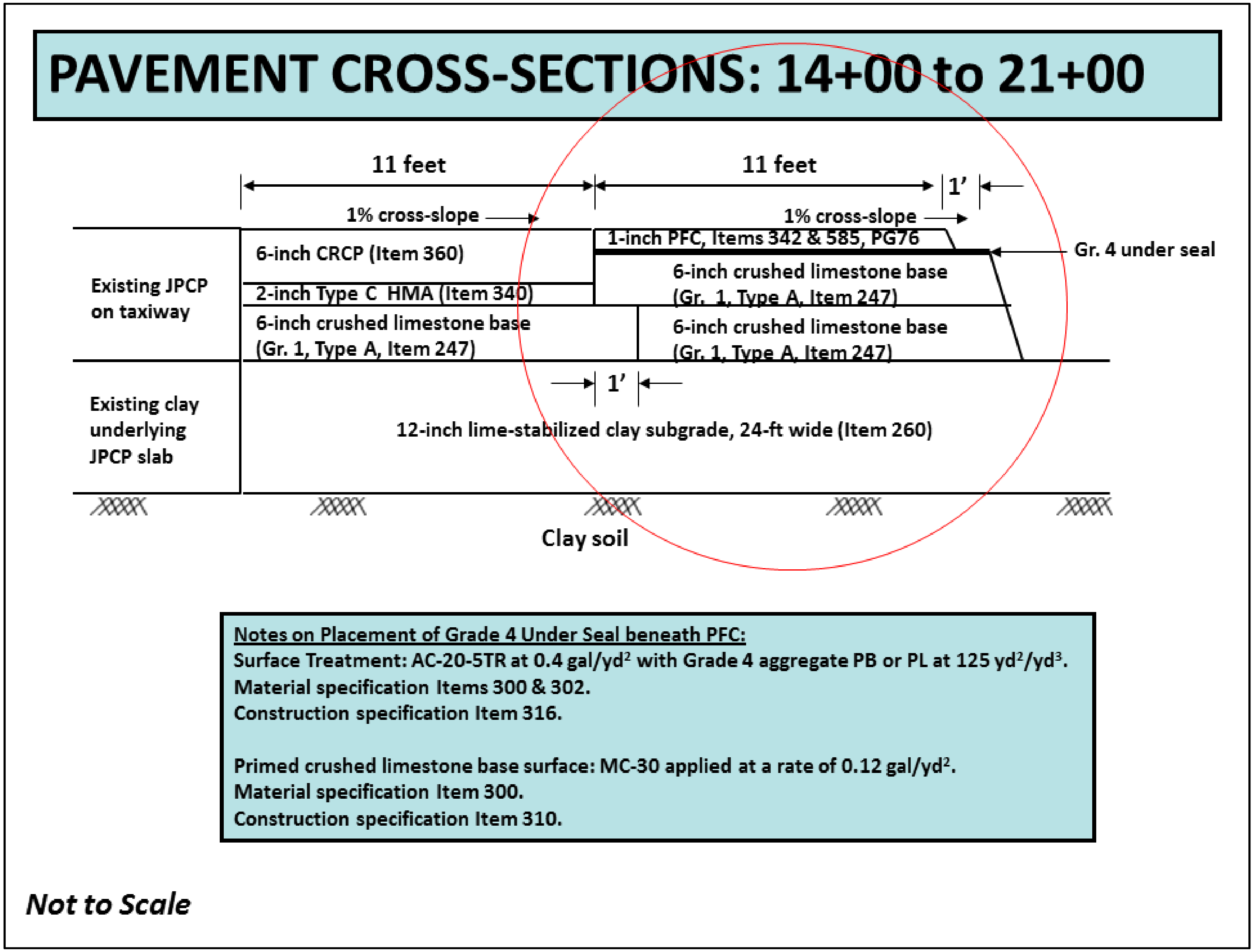

Figure 14. Typical Cross-Section of 700-ft PFC Section (Phase 2, Alternate 2).

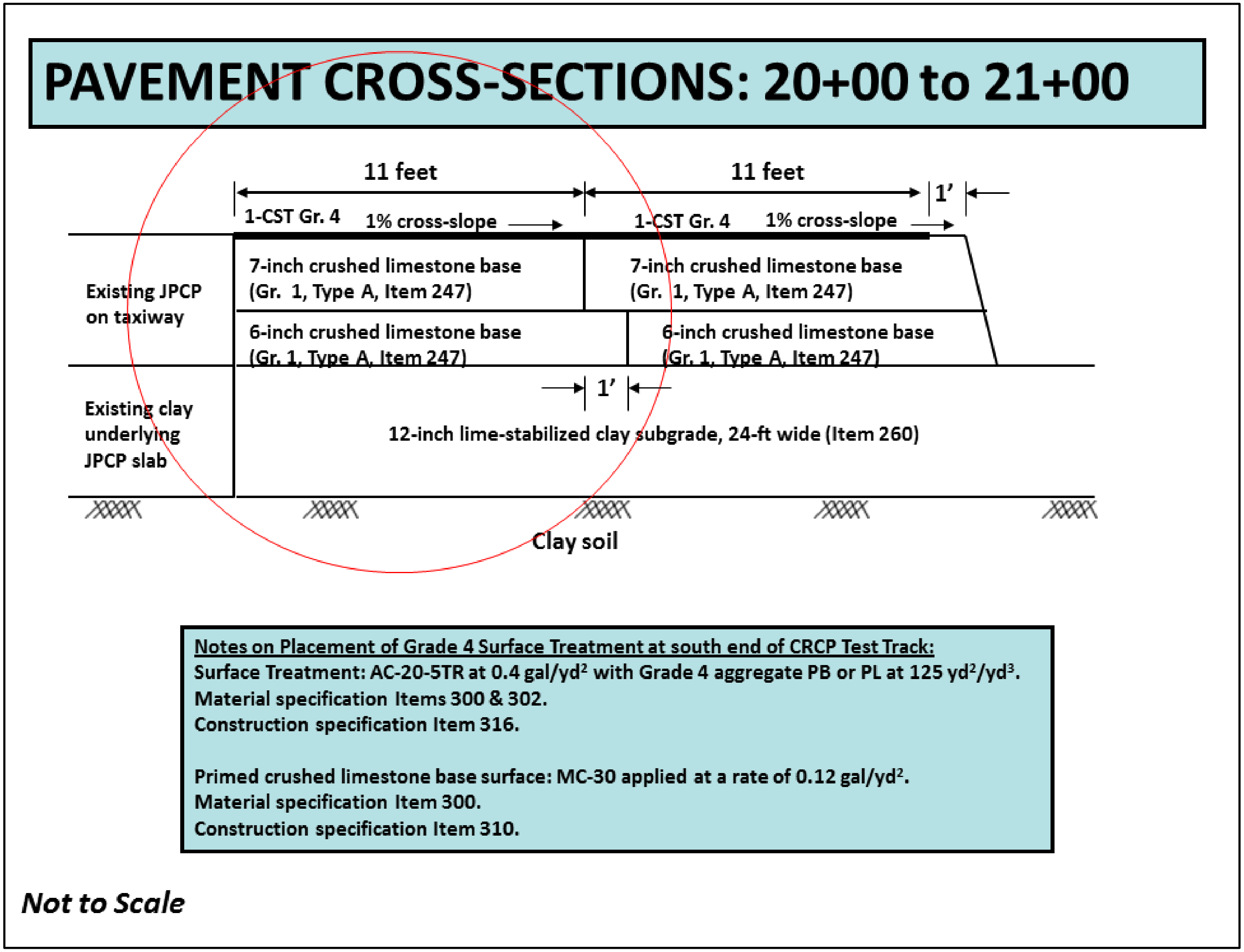

Figure 15. Typical Cross-Section of Optional 100-ft Grade 4 Surface Treatment at South End of CRCP Test Track.

Excavation and Removal of Existing Materials

The contractor shall excavate and remove existing materials at the site to a depth of 14 inches over an area 2100 ft long × 11 ft wide adjacent to the Phase 1 excavation. With the project engineer's approval, the contractor may perform this excavation in conjunction with Work Item 1-3a or 1-3b if this coordination will enhance construction efficiency. Unless otherwise directed by the project engineer, the contractor shall remove and haul salvaged materials from the Riverside Campus and dispose of these materials in accordance with federal, state, and local regulations.

Lime Stabilization

After performing Work Item 2-1a or 2-1b, the contractor shall lime stabilize the existing subgrade material adjacent to the Phase 1 lime treatment to a depth of 12 inches over an area 2100 ft long × 11 ft wide in accordance with Item 260. Use quicklime for treating the subgrade and compact the material to at least 95 percent of the maximum density as determined in accordance with TxDOT Test Method Tex-121-E. The project engineer will determine the density of the compacted subgrade after lime treatment in accordance with Tex-115-E. Acceptance of the compacted lime-treated section will be conducted in accordance with Item 260.4.E.2, *Density Control*. Grade the section such that the top of the flexible pavement test track after placement will be flushed with the CRCP track along the longitudinal joint, and have a cross-slope of 1 percent as given in the typical cross-sections shown in Figures 11 to 15. With approval from the project engineer, the contractor may perform this lime stabilization (Work Item 2-2a or 2-2b) in conjunction with Work Item 1-4a or 1-4b if this coordination will enhance construction efficiency.

Crushed Limestone Base

The contractor shall place flexible base on the lime-treated subgrade in accordance with Item 247. Use crushed limestone base classifying as Grade 1, Type A and provide documentation showing the material meets this classification per Item 247. The contractor may use Grade 1, Type A crushed limestone base that TxDOT has approved for use on a recent or ongoing project, or Grade 1, Type A crushed limestone obtained from a TxDOT approved stockpile. Upon approval of the project engineer, the contractor shall place the crushed limestone base in accordance with the applicable Work Items in Table 2 (Work Items 2-3a, 2-7a, 2-3b, and 2-4b) and the plans and specifications given in Figures 11 to 15. The contractor shall compact the flexible base using density control per Item 247.4.C.2, and grade the base such that the top of the flexible pavement test track will be flushed with the CRCP test track along the longitudinal joint, and have a cross-slope of 1 percent. The ride quality of the finished flexible base will be measured using SP247-011 prior to placement of the surface treatments for the Grade 3, inverted prime, and Grade 4 sections on the flexible pavement test track. The work performed and materials furnished to place the flexible base will be paid according to Item 247.6.A, *Flexible Base (Complete in Place)*.

Surface Treatments

The contractor shall place surface treatments on top of the compacted flexible base in accordance with the applicable Work Items in Table 2 (Work Items 2-4a, 2-5a, 2-6a, 2-8a, 2-5b, 2-6b, and 2-7b), and the plans and specifications given in Figures 11 to 15.

Permeable Friction Course

For placing the PFC section under alternate 2 of Phase 2, the contractor shall use a PFC mix that TxDOT has approved for use on a recent or ongoing project. The contractor shall provide documentation that the PFC has received TxDOT's approval prior to placing the mix on the flexible pavement test track. For the sake of cost-effectiveness, it is recommended that the contractor use a TxDOT-approved PFC mix that is being placed on an ongoing TxDOT project.

The contractor shall build the PFC section in accordance with the drawing and specifications given in Figure 14. The compacted PFC surface shall be flushed with the adjacent CRCP test track along the longitudinal joint, and have a cross-slope of 1 percent. After placement of the PFC, the ride quality of the finished surface shall be measured using Item 585. For areas that require corrective work, no grinding will be performed until after the project engineer gives approval to proceed with the quality assurance testing of pavement smoothness.

PHASE 3 PLANS AND SPECIFICATIONS FOR ACCESS RAMPS

This section provides plans and specifications for an alternate third phase covering placement of access ramps at the north and south ends of the test tracks built in Phase 1 and

Phase 2. Depending on the cost of this alternate and the available budget, a decision will be made on whether to proceed with construction of the access ramps in the contract to be awarded.

Table 4 and Table 5 present the work items for placement of the access ramps at the north and south ends of the test tracks, respectively. Figure 16 illustrates the north access ramp while Figure 17 shows the south access ramp.

Figures 18 to 20 show typical cross-sections and specifications for placement of the access ramps. The south access ramp shall be built using alternate 1 (with a Grade 4 surface treatment) if Phase 2 was completed using alternate 1. Otherwise, if Phase 2 was completed using alternate 2 (with the PFC section), the south access ramp shall be built using alternate 2 (with a two-course surface treatment). The following additional notes are provided to supplement the plans and specifications shown in Figures 18 to 20.

Lime Stabilization

The contractor shall lime stabilize the existing subgrade material within the access ramp to a depth of 12 inches in accordance with Item 260. Use quicklime for treating the subgrade and compact the material to at least 95 percent of the maximum density as determined in accordance with TxDOT Test Method Tex-121-E. The project engineer will determine the density of the compacted subgrade after lime treatment in accordance with Tex-115-E. Acceptance of the compacted lime-treated section will be conducted in accordance with Item 260.4.E.2, *Density Control*. Grade the section such that the top of the surface treatment will be flushed with the existing taxiway, the CRCP, and flexible pavement test tracks; and have a cross-slope of 1 percent as given in the typical cross-sections shown in Figures 18 to 20.

Crushed Limestone Base

The contractor shall place flexible base on the lime-treated subgrade in accordance with Item 247. Use the same Grade 1, Type A crushed limestone base placed on the test tracks built in Phase 1 and Phase 2. The contractor shall compact the flexible base using density control per Item 247.4.C.2, and grade the base such that the top of the surface treatment will be flushed with the existing taxiway, the CRCP, and flexible pavement test tracks; and have a cross-slope of 1 percent as given in the typical cross-sections shown in Figures 18 to 20. The work performed and materials furnished to place the flexible base will be paid according to Item 247.6.A, *Flexible Base (Complete in Place)*.

Table 4. Work Items for Placement of North Access Ramp.

Work Item ID	Description
3-N1	Excavate and remove 14-inch deep of existing materials within an 862 ft^2 area designated as North Access Ramp in Figure 13. Haul salvaged materials from the Riverside Campus and dispose of these materials in accordance with federal, state, and local regulations.
3-N2	Lime stabilize existing soil 12 inches deep within the 862 ft^2 North Access Ramp area.
3-N3	Place Grade1 Type A flexible base in two lifts: 1) 6-inch lift; and 2) 7-inch lift within the North Access Ramp area.
3-N4	Place Grade 3 surface treatment within the North Access Ramp Area.

Table 5. Work Items for Placement of South Access Ramp.

South Access Ramp Alt. 1: Grade 4 Surface Treatment	
Work Item ID	Description
3-S1a	Excavate and remove 14-inch deep of existing materials within a 2071 ft^2 area designated as South Access Ramp in Figure 14. Haul salvaged materials from the Riverside Campus and dispose of these materials in accordance with federal, state, and local regulations.
3-S2a	Lime stabilize existing soil 12-inch deep within the 2071 ft^2 South Access Ramp area shown in Figure 14.
3-S3a	Place Grade1 Type A flexible base in two lifts: 1) 6-inch lift; and 2) 7-inch lift within the South Access Ramp area.
3-S4a	Place Grade 4 surface treatment within the South Access Ramp Area.
South Access Ramp Alt. 2: Grade 4 over Grade 3 Two-Course Surface Treatment (2-CST)	
Work Item ID	Description
3-S1b	Excavate and remove 14-inch deep of existing materials within a 2071 ft^2 area designated as South Access Ramp in Figure 14. Haul salvaged materials from the Riverside Campus and dispose of these materials in accordance with federal, state, and local regulations.
3-S2b	Lime stabilize existing soil 12-inch deep within the 2071 ft^2 South Access Ramp area shown in Figure 14.
3-S3b	Place Grade 1 Type A flexible base in two 6-inch lifts within the South Access Ramp area.
3-S4b	Place the Grade 4 over Grade 3 two-course surface treatment within the South Access Ramp area.

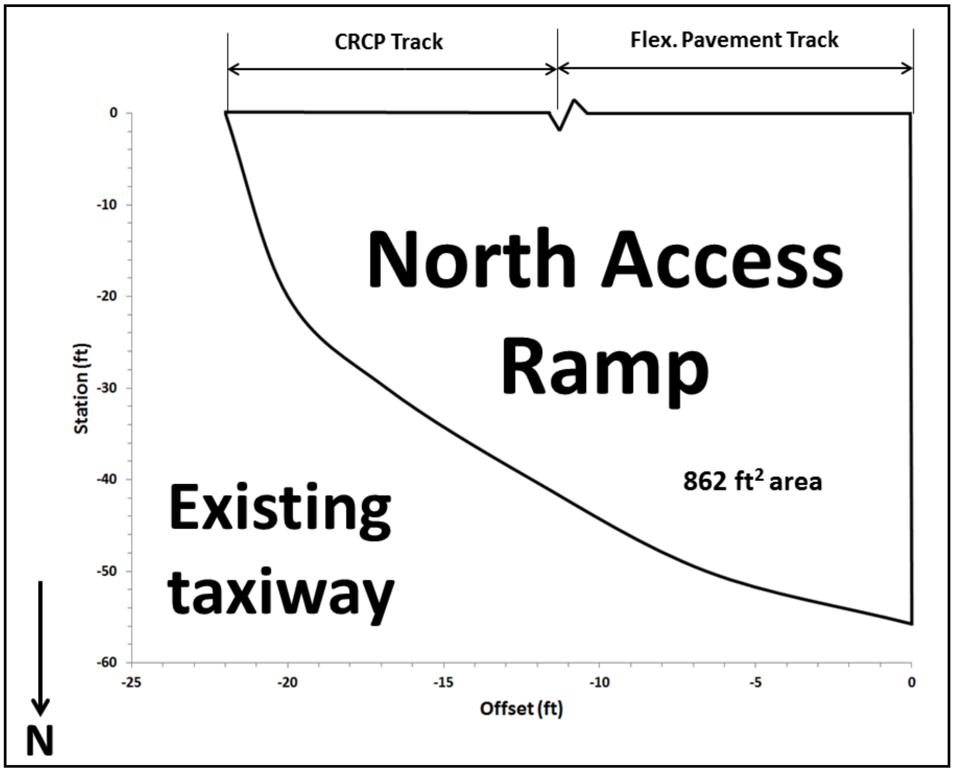

Figure 16. North Access Ramp for Test Tracks.

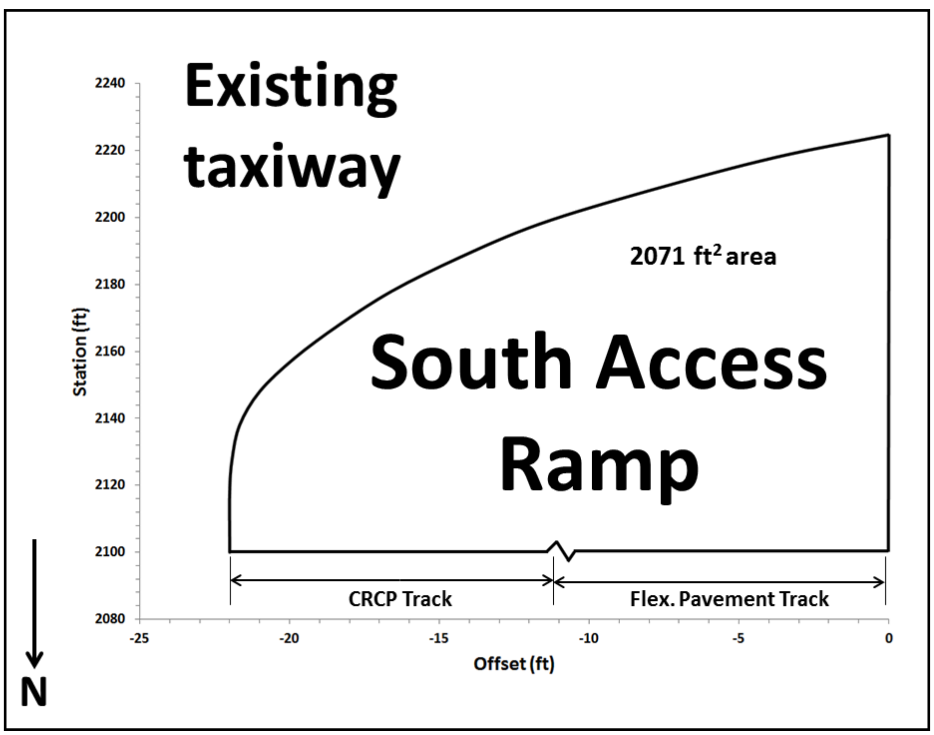

Figure 17. South Access Ramp for Test Tracks.

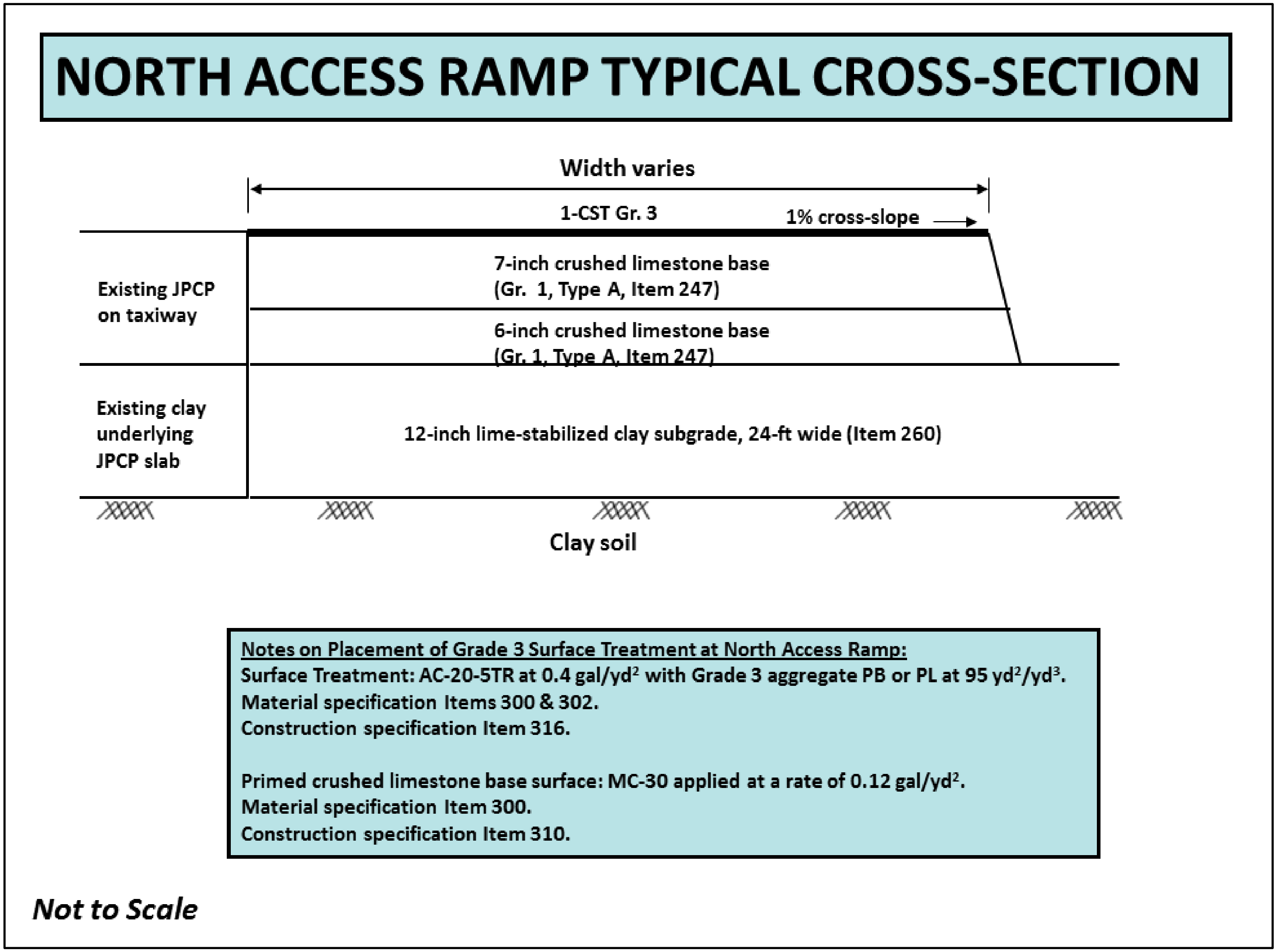

Figure 18. Typical Cross-Section of Grade 3 Surface Treatment at North Access Ramp.

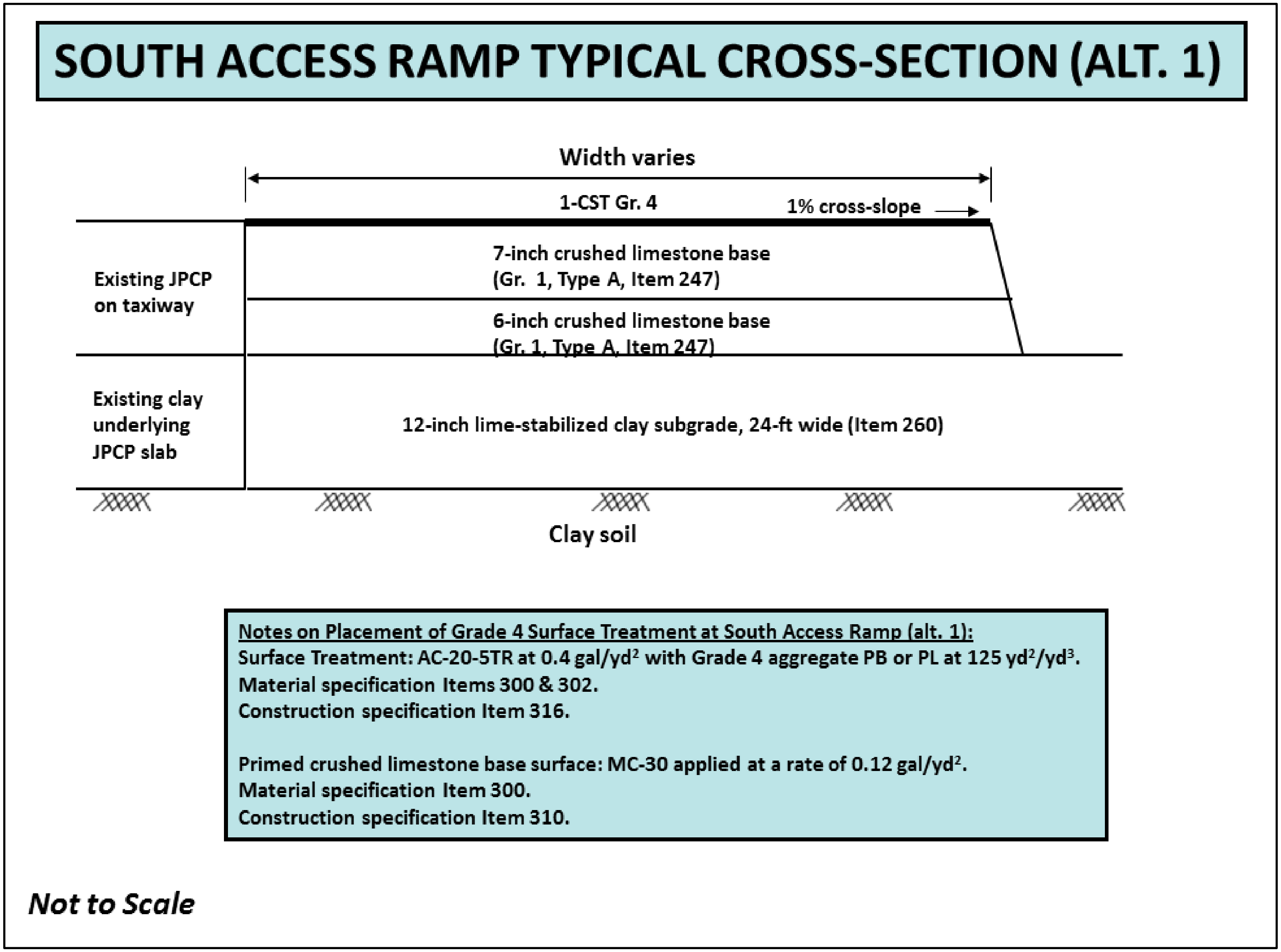

Figure 19. Typical Cross-Section of Grade 4 Surface Treatment at South Access Ramp (Alternate 1).

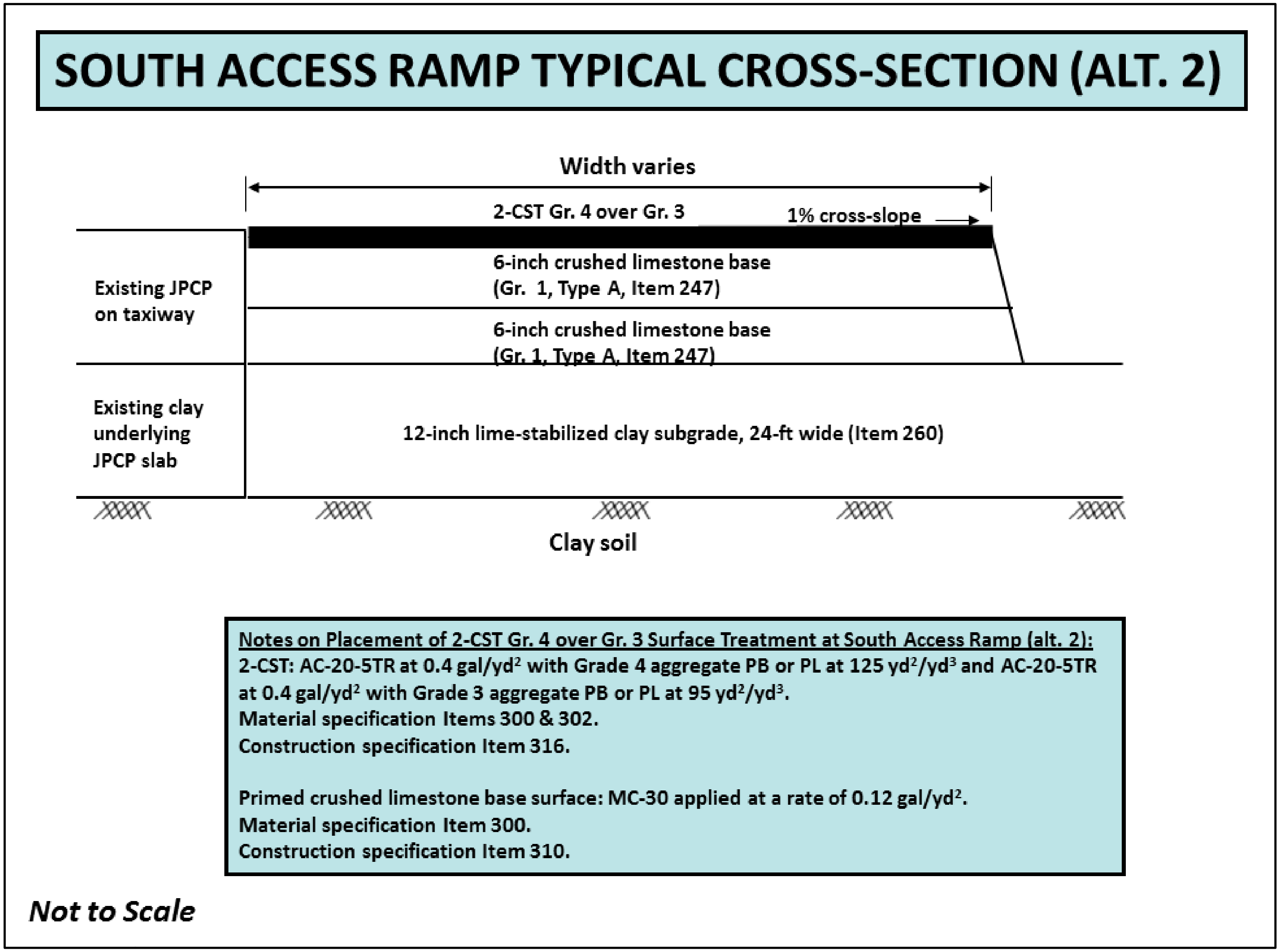

Figure 20. Typical Cross-Section of Grade 4 over Grade 3 Two-Course Surface Treatment.

CHAPTER 4. CONSTRUCTION OF NEW TEST TRACKS

This chapter documents the construction of the CRCP and flexible pavement test tracks at the Riverside Campus. Plans for this construction were previously presented in Chapter 3. To optimize the use of available funds, the plans included several alternates on which bids were solicited. Based on the bids received, the decision was made to proceed with construction of the new test tracks using alternate 1 for Phase 1 and alternate 2 for Phase 2. Figure 21 illustrates the selected alternates. Construction of the new test tracks proceeded in the following sequence:

1. Removal of existing vegetation.
2. Excavation and removal of existing materials.
3. Lime stabilization of clay soil at site.
4. Placement of 6-inch flexible base.
5. Placement of Type C hot-mix asphalt concrete (HMAC) for CRCP test track.
6. Placement of CRCP slab.
7. Placement of additional flexible base for flexible pavement test track.
8. Placement of surface treatments specified in the plans.
9. Placement of PFC section.
10. Final clean-up after construction.

The following sections describe the above sequence of construction in more detail.

REMOVAL OF EXISTING VEGETATION

Construction of the new test tracks began on September 4, 2012. The contractor first cleared and grubbed existing vegetation found within the limits of the construction site. Figure 22 shows the north end of the site where the contractor began clearing existing vegetation to make way for the new test tracks. The contractor loaded vegetation removed from the site on trucks and hauled them off the Texas A&M Riverside Campus for disposal. He then placed a 2100-ft silt fence along the west boundary of the construction site before proceeding with the next stage of construction.

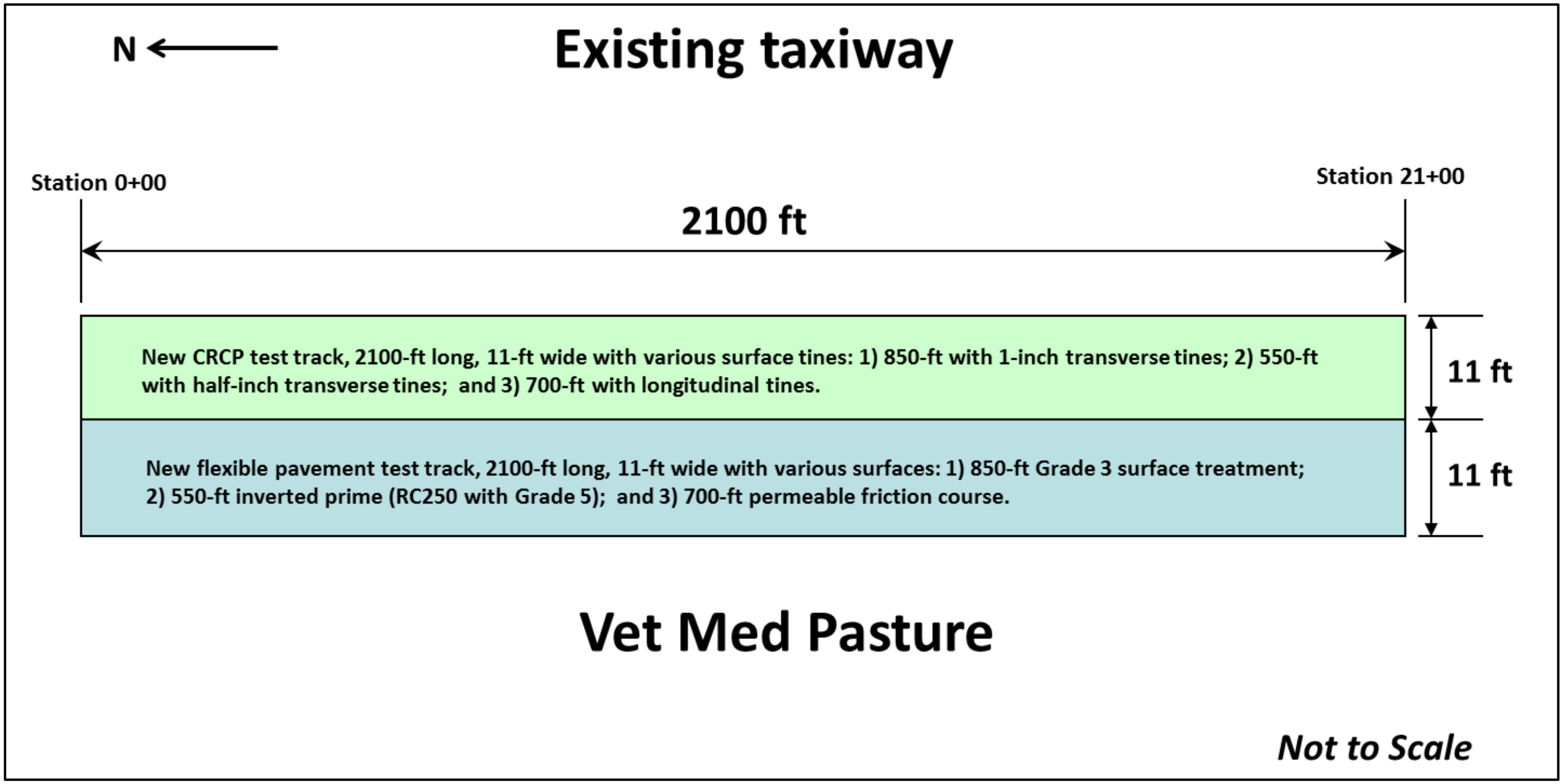

Figure 21. Pavement Sections Comprising New Test Tracks.

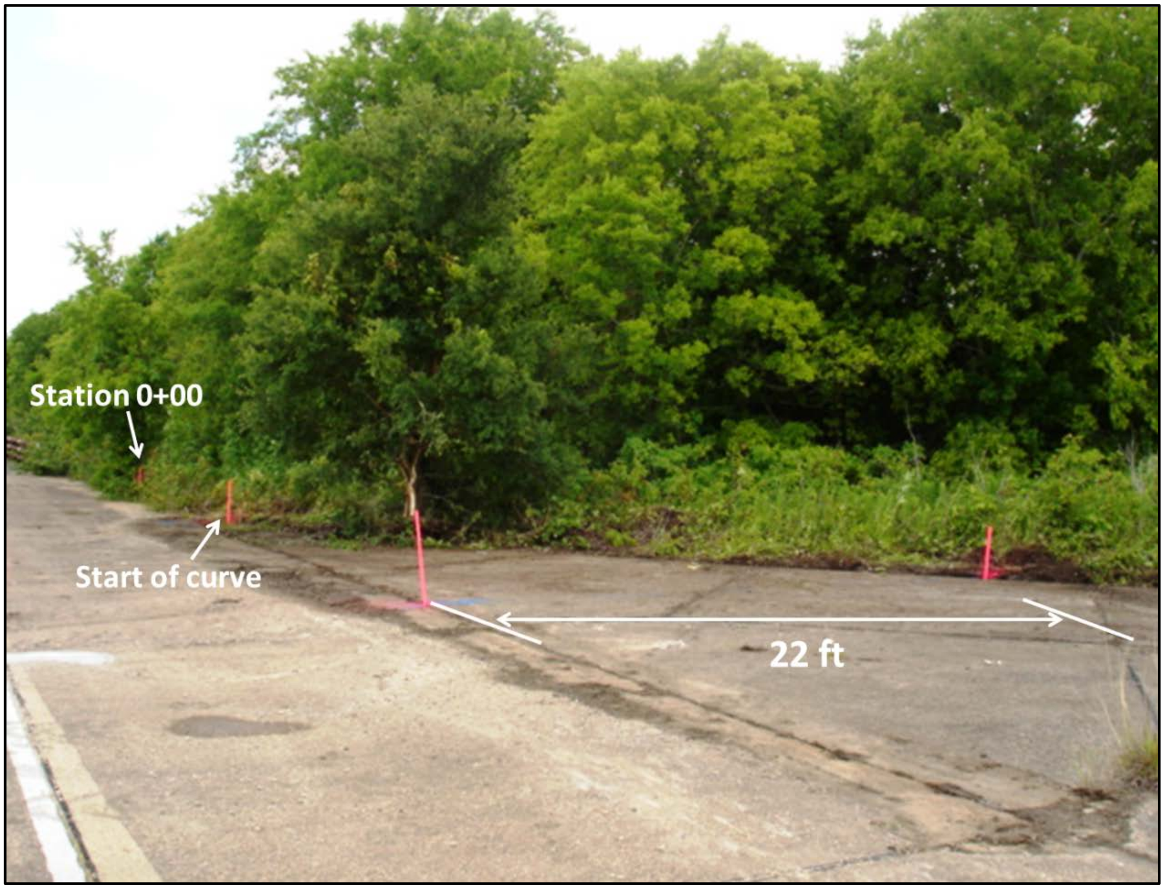

Figure 22. Picture Showing Vegetation at North End of Construction Site.

EXCAVATE AND REMOVE EXISTING MATERIALS

To make room for placing new pavement sections for profiler certifications, the contractor excavated to a 14-inch depth and removed existing materials over an area approximately 2200 ft long × 24 ft wide. Test sections previously placed on earlier TxDOT research projects were removed from the site during this stage of construction. All materials removed from the site were loaded on trucks and hauled off the Riverside Campus for disposal.

In addition, other items required special attention. One such item was an old utility box found at around station 1+50 after the contractor cleared the site of vegetation. This utility box, illustrated in Figure 23, contained cables that might have been used for power or communication at a time when the Riverside Campus was an active U.S. Army airfield base. The contractor removed the utility box and filled the hole after TTI Facilities ascertained with Texas A&M's Utilities and Energy Management (UEM) that this action can be taken.

Figure 23. Utility Box Found within Construction Site.

Another item uncovered during excavation was an old manhole at around station 13+00. TTI Facilities requested Utilities and Energy Management to visit the site and inspect the manhole. UEM found that the manhole can be safely removed, so the contractor pulled the manhole out and filled the hole.

The contractor also found a 3-inch water line at around station 14+50 that conveyed water to the adjacent pasture. Since this water line was at a depth of about 6 inches below subgrade, the line had to be lowered to permit the contractor to lime stabilize the existing subgrade to a depth of 12 inches. UEM subsequently got a contractor to lower the water line to a depth of 30 inches below the subgrade.

LIME STABILIZATION

TTI technicians used Part III of TxDOT Test Method Tex-121-E to determine the minimum lime content for stabilizing the clay soil at the construction site. This test is based on determining the minimum percent of lime needed for the soil-lime mixture to attain a pH of 12.4 at which cation exchange occurs. TTI technicians ran tests on samples of the clay material taken at three different locations along the site. From these tests, the minimum lime content was found to vary from 2.8 to

3.4 percent (see Figures 24 to 26). Based on these results, the contractor decided to use 4 percent lime to stabilize the clay soil, requiring about 117 tons of pebble quicklime.

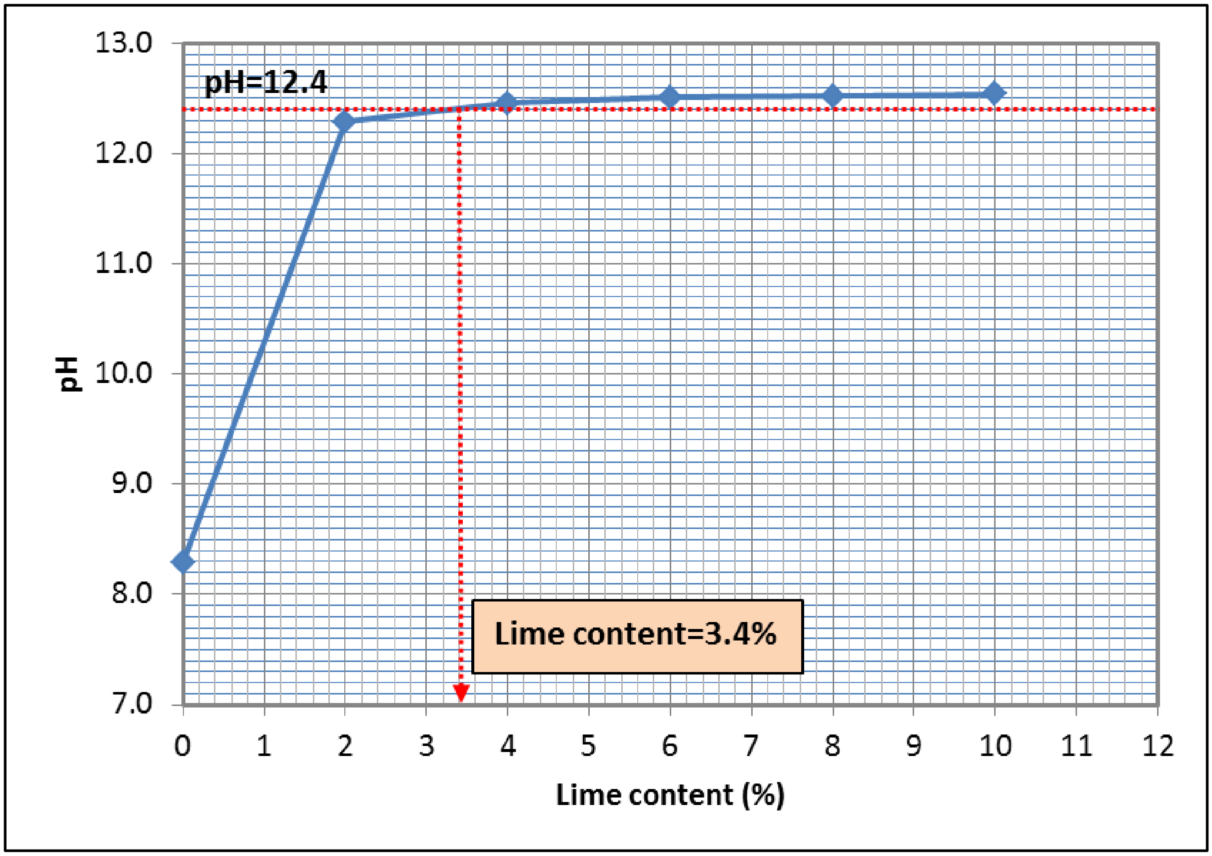

Figure 24. Tex-121-E Test Results Using Clay Samples from Station 4+25.

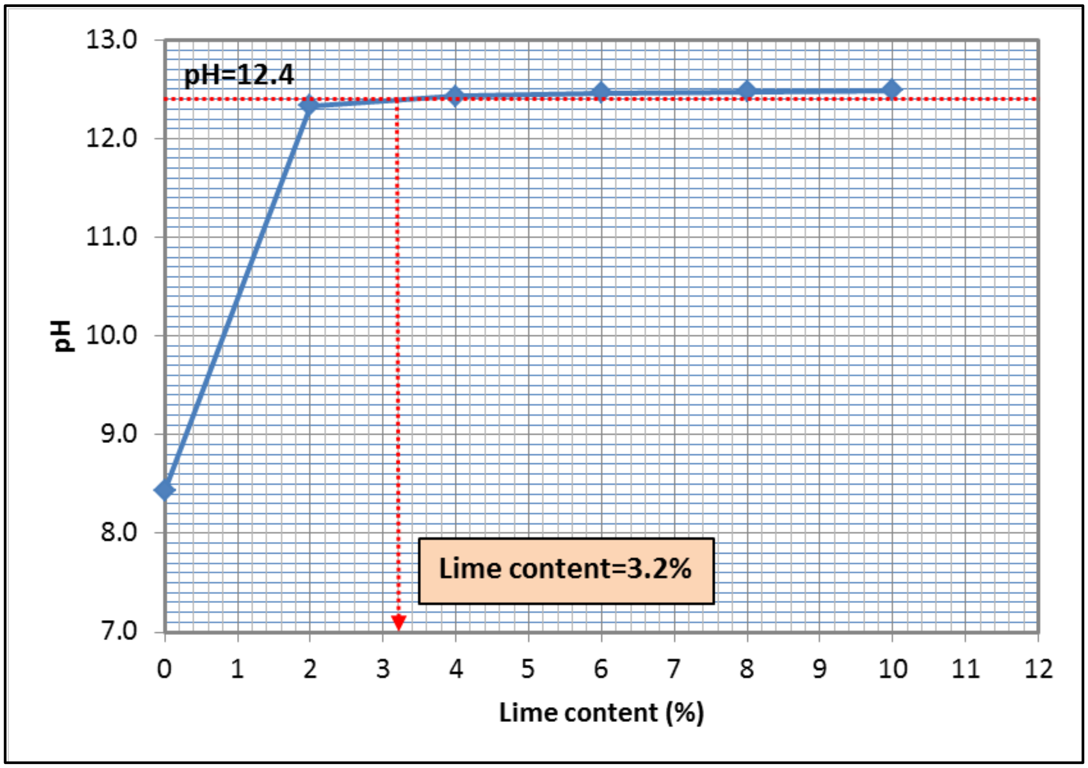

Figure 25. Tex-121-E Test Results Using Clay Samples from Station 11+25.

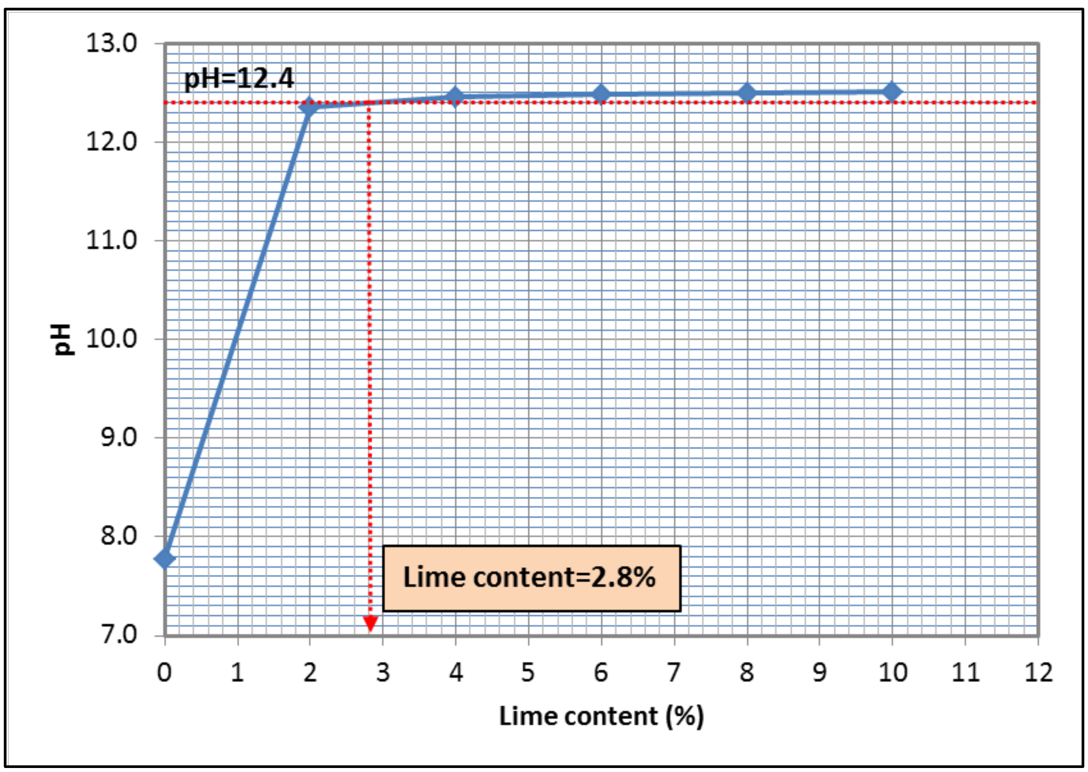

Figure 26. Tex-121-E Test Results Using Clay Samples from Station 17+50.

Pneumatic tanker trailers delivered the lime in windrows. The contractor then used a motor grader to spread pebble quicklime on the surface of the subgrade to be stabilized. Water was then added to hydrate the lime. The contractor then started mixing the soil with lime using a Caterpillar SS250 soil stabilizer. During this process, the contractor added water as necessary to achieve complete hydration and thorough mixing of the soil, water, and lime. Figure 27 illustrates the type of mixer that he used.

Figure 27. Equipment Used to Mix Soil with Lime.

After the initial mixing, the contractor allowed the soil-lime mixture to cure for two days. He then continued mixing soil, lime, and water until he got the gradation of the mixture to pass in accordance with the gradation requirements in Item 260. The contractor then compacted the lime-stabilized soil in two 6-inch lifts using a sheepsfoot roller to get at least 95 percent of maximum density as specified in the plans.

To verify compaction, TTI technicians measured densities in accordance with TxDOT Test Method Tex-115-E. For this purpose, samples of the soil-lime mixture were taken at two different locations to determine the moisture-density curves shown in Figure 28 and Figure 29. The corresponding maximum densities were then used to check the level of compaction achieved at different stations along the job site. Table 6 summarizes the results from these density tests. As shown, the contractor met the density required in the plans.

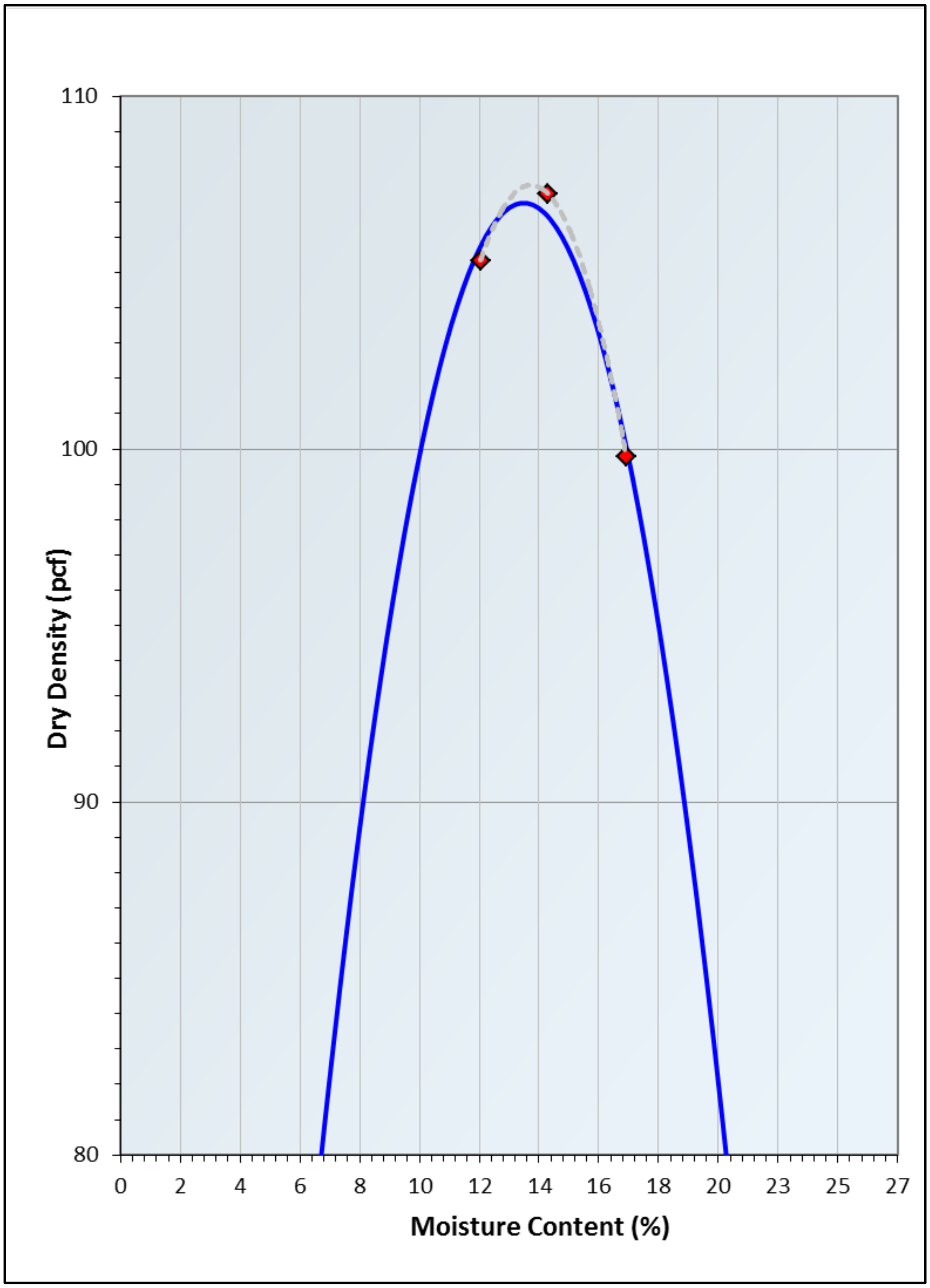

Figure 28. Moisture-Density Curve for Soil-Lime Mixture Sampled at Station 2+00.

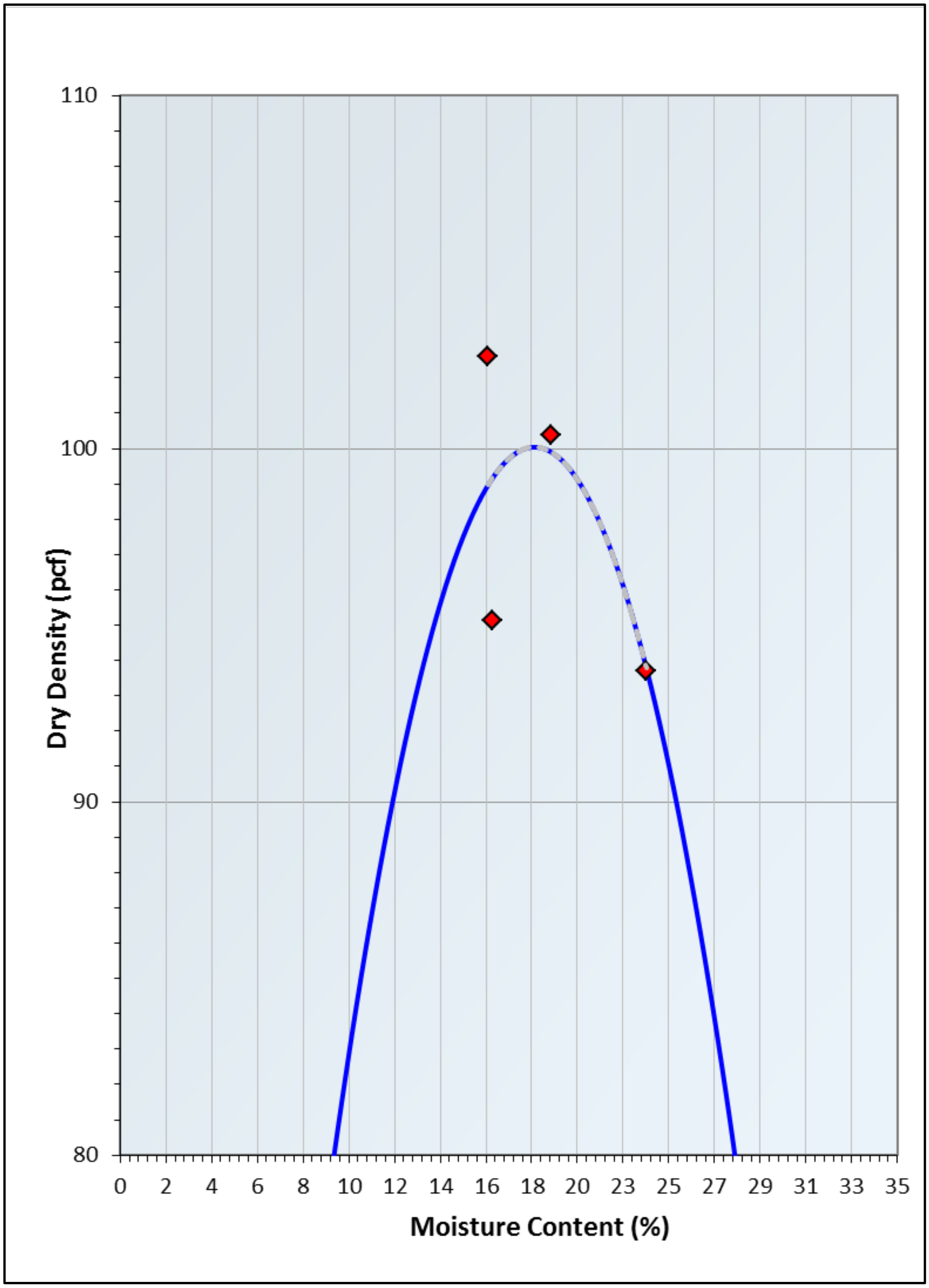

Figure 29. Moisture-Density Curve for Soil-Lime Mixture Sampled at Station 12+00.

Table 6. Summary of Density Measurements on Lime-Stabilized Subgrade.

Station	Dry Density (pcf)	Moisture (%)	Compaction (%)
1+75	103.1	16.6	96.4
3+75	103.4	16.6	96.6
5+75	107.3	13.9	100.3
7+75	110.5	10.3	103.3
11+00	96.0	17.8	96.0
13+00	101.1	14.1	101.1
15+00	99.98	14.7	99.98
17+00	107.4	13.2	107.4
19+50	110.5	9.0	110.5

PLACE 6-INCH FLEXIBLE BASE

The plans called for the contractor to place crushed limestone base classifying as Grade 1, Type A, and allowed the use of base material from a recent or ongoing TxDOT project, or from a TxDOT-approved stockpile. The contractor provided documentation from the Waco District laboratory that showed test results on samples of Type A base material from Killeen Crushed Stone. Table 7 summarizes the results from the gradation, moisture-density, and triaxial tests that the Waco District Laboratory performed. Based on these results, approval was given for the contractor to use the same material to build the new test tracks.

The contractor delivered the base material on site with belly dump trucks and spread the material using a motor grader. He then proceeded to mix water with the crushed limestone base and continued this process until the material was ready for compaction. For placement, the plans required the contractor to compact the flexible base using density control in accordance with Item 247.4.C.2, which required compaction to at least 100 percent of maximum density.

The contractor compacted the flexible base in sections using an 84-inch steel wheel vibratory roller. After he completed a section, TTI technicians took density measurements in accordance with Tex-115-E to check the base compaction at different stations. This process continued until the first 6 inches of flexible base was placed throughout the length and width of the test tracks to be built. Table 8 summarizes the results from these density tests. The data show that the contractor met the required minimum density of 100% on the flexible base.

Table 7. Summary of Test Results on Crushed Limestone Base from Waco District.

Particle Size Analysis (Tex-110-E)			
Sieve Size	**Cumulative % Retained**	**Grade 1 Limits**	**Within Master Grading?**
2″	0.0	–	–
1–¾″	0.0	0	Yes
1–½″	0.0	–	–
⅞″	23.5	10–35	Yes
⅜″	49.5	30–50	Yes
#4	61.9	45–65	Yes
#40	78.8	70–85	Yes
Moisture-Density Data			
Maximum dry density (pcf)	131.3		
Optimum moisture content (%)	8.8		
Triaxial Test Data (Tex-117-E)			
Compressive Strength (psi)		**Minimum Strength (Grade 1)**	
At 0 psi lateral pressure	44.7	45	
At 15 psi lateral pressure	216.6	175	
Flexible Base Classification			
Triaxial class	1.0		
Internal friction angle	56.7°		
Cohesion (psi)	9.8		

Table 8. Summary of Density Measurements on Initial 6 Inches of Flexible Base.

Station	Dry Density (pcf)	Moisture (%)	Compaction (%)
2+00	135.9	8.7	103.5
4+00	135.9	7.9	103.5
6+00	135.5	7.9	103.2
8+00	135.6	8.7	103.3
10+00	139.7	7.3	106.4
12+00	132.7	9.1	101.1
14+00	137.0	5.9	104.3
16+00	133.5	6.6	101.7
18+00	134.5	6.3	102.4
20+00	134.6	7.1	102.5
21+40	137.1	8.0	104.4

PLACE TYPE C HMAC

The plans called for placing a 2-inch Type C mix beneath the CRCP test track. For this purpose, the contractor was given the option to use a Type C mix that TxDOT has already approved. He selected this option, and provided TTI with documentation showing test results for the Type C mix he planned to use. This material is a Knife River mix identified as KRCHC01-J64-R. It is a Hanson C mix with Jebro PG 64-22 binder, 1 percent lime, and 20 percent recycled asphalt pavement (RAP).

Table 9 shows the combined gradation for the mix while Table 10 summarizes results from the aggregate quality tests. Table 11 provides information about the bins where samples were collected to run the aggregate quality tests reported in Table 10. The mix design resulted in an optimum binder content of 4.8 percent, with a voids-in-mineral aggregate (VMA) of 14.0 percent, and a ratio of recycled to total binder content of 16.7 percent. The Type C mix also passed the Hamburg wheel test from communications with the Bryan District.

The contractor applied a tack coat on the flexible base prior to placing the Type C mix. This work was done on a Saturday weekend (October 27, 2012). Due to weather delays, the contractor was not able to place the mix until 4 days later. Figure 30 shows the primed flexible base that covered the area where the CRCP test track would be placed. This picture was taken at the north end of the job site.

Table 9. Combined Gradation for Type C Mix.

Sieve Size	Cumulative % Passing	Gradation Limits for Type C Mix		Within Limits?
		Lower	Upper	
1″	100.0	100	100	Yes
¾″	99.8	95	100	Yes
⅜″	84.9	70	85	Yes
#4	56.5	43	63	Yes
#8	35.6	32	44	Yes
#30	21.0	14	28	Yes
#50	13.1	7	21	Yes
#200	5.3	2	7	Yes

Table 10. Results of Aggregate Quality Tests.

Test Name	Test Method	Spec. Min. or Max.	Spec. Limit	Bin #1	Bin #2	Bin #3	Bin #4	Bin #5	Bin #6
Stockpile									
Decantation	Tex-217-F	Max.	1.5	0.2	0.3	0.3			
Deleterious material	Tex-217-F	Max.	1.5	0.0	0.0	0.0	0.0	0.0	0.0
Surface aggregate classification	Tex-438-A, Tex-612-J	As shown on plans		B	B	B	B		
Magnesium sulfate soundness	Tex-411-A	Max.	30	23	23	23	23		
LA abrasion	Tex-410-A	Max.	40	29	29	29	29		
Crushed faces count	Tex-460-A	Min.	85	100	100	100			
Flat & elongated	Tex-280-F	Max.	10	0.0	2.0	2.0			
Fine Aggregate									
Bar linear shrinkage	Tex-107-E	Max.	3				0.0	1.0	
Combined Aggregate									
Sand equivalent	Tex-203-F	Min.	45	94	94	94	94	94	

Table 11. Information on Bins Used for Aggregate Quality Tests.

Bin No.	Aggregate Source	Aggregate Pit	Sample ID
1	Limestone_Dolomite	Servtex	C Rock
2	Limestone_Dolomite	Servtex	D Rock
3	Limestone_Dolomite	Servtex	F Rock
4	Limestone_Dolomite	Servtex	Washed Screenings
5		River Bend	Sand
6		Austin White Lime	Hydrated Lime

Figure 30. Tack Coat Applied to Flexible Base.

The contractor used a Blaw-Knox PF-875 track-mounted paver/finisher to place the Type C mix. Figure 31 shows a photograph of this equipment, taken at the south end of the job site where the contractor started placing the mix. The contractor used a steel wheel roller to compact the mix behind the paver (see Figure 32). He then used a pneumatic tire roller to compact the mix further, and get the required density. The contractor took nuclear density measurements as the mix was being placed to verify the level of compaction from his rolling operation. In this regard, the plans specified air-void control to compact the mix in accordance with Item 340.4.H.1.

After the contractor finished placing the mix, TTI technicians took cores at different stations to verify the as-built air voids. Table 12 summarizes the air voids determined from the laboratory tests done on cores. The results labeled "box" identify air voids on cores taken at locations where the contractor took nuclear density measurements. At these locations, the contractor drew a box where the nuclear density gauge was placed. TTI technicians later took cores at these locations. The results given in Table 12 verified that the contractor achieved the level of compaction specified in the plans.

Figure 31. Paving Machine Used to Place Type C Mix.

Figure 32. Steel Wheel Roller Used to Compact Type C Mix.

Table 12. Summary of Densities and Air Voids from Laboratory Tests on Cores.

Station	Air Voids (%)		Average Air Voids (%)	Within 5% to 9% Air Voids Band
	Sample 1	Sample 2		
3+50	6.0	6.0	6.0	Yes
5+25 (box)	7.1			Yes
9+00	8.4	8.0	8.2	Yes
9+00 (box)	8.6			Yes
12+00 (box)	5.9			Yes
20+30	6.7	4.6	5.7	Yes
20+30 (box)	5.7			Yes

PLACE CRCP TEST TRACK

The plans called for placing a 6-inch CRCP over the 2-inch Type C base using Class P concrete mix with a minimum 28-day compressive strength of 4400 psi. Transit Mix produced the Class P mix was produced by Transit Mix at the company's Independence Avenue plant in Bryan, Texas. Table 13 shows the concrete mix design that Transit Mix provided, while Table 14 shows the coarse and fine aggregate gradations. Around the time the Class P mix was produced, it was being used on two projects along SH30 and FM1791 in Walker County.

Table 13. Class P Concrete Mix Design.

Material Type	Source Supplier	Description	Sp. Grav.	Design Qty.	Material in TxDOT's MPL[1]?
Cement	Capitol–San Antonio	ASTM C-150 (Type I)	3.15	368 lb	Yes (DMS-4600)
Fly Ash	MRT–Gibbons Creek	ASTM C-618 (Class C)	2.63	192 lb	Yes (DMS-4610)
Fine Aggregate	Little River–Maysfield	ASTM C-33 (sand, concrete)	2.63	1258 lb	Yes (CRSQC[2])
Coarse Aggregate	Capitol–Marble Falls	ASTM C-33 (#57 limestone)	2.79	1924 lb	Yes (CRSQC)
Admixture (air entraining)	BASF	ASTM C-260 (MB AE-90)			Yes (DMS-4640)
Admixture (water-reducing)	BASF	ASTM C-494 (Pozzolith® 80)			Yes (DMS-4640)
Water	Water Utility	ASTM C-1602	1.00	29 gal	
			Total	3984 lb	
Air Content	4.5% ±1.5%	Designed unit weight (pcf)	148.4		
Slump	5.0″ ± 1.5″	Designed water-cement ratio	0.43		

[1]Material Producer List
[2]TxDOT Concrete Rated Source Quality Catalog

Table 14. Coarse and Fine Aggregate Gradations of Class P Concrete Mix.

Sieve Size	Cumulative % Passing	ASTM C33 Limits[1]	Within Limits?
Coarse Aggregate			
1-½″	100.0	100	Yes
1″	95.1	95–100	Yes
½″	48.2	25–60	Yes
#4	4.3	0–10	Yes
#8	2.0	0–5	Yes
Fine Aggregate[2]			
3/8″	100	100	Yes
#4	99.8	95–100	Yes
#8	87.5	80–100	Yes
#16	64.9	50–85	Yes
#30	42.2	25–60	Yes
#50	16.2	5–30	Yes
#100	2.4	0–10	Yes
#200	0.6[3]	0–3	Yes

[1]Coarse aggregate gradation limits are for size no. 57 stone
[2]Fine modulus is 2.87 (within ASTM C33 limits of 2.3 and 3.1)
[3]Percent passing #200 sieve determined by decantation

The contractor set up forms and reinforcement on the Type C base prior to pouring concrete for the CRCP test track. The forms were made of 2 × 6 (nominal size) 16-ft boards placed on each side of where the slab would be. Figure 33 illustrates a segment of the form placed along the west side of the Type C base. The form placed along the west side was supported on wooden braces as shown in this figure, with the bottom part of the brace nailed to the Type C base. The contractor tied form segments as illustrated in Figure 34.

On the east side, the contractor nailed 2 × 6 16-ft boards on the existing concrete slabs of Taxiway 7, as illustrated in Figure 35. This figure also shows the stringline that the contractor set up to ensure proper alignment. The contractor's surveyor took elevation measurements to guide the placement of the form on each side of the track.

Once the forms were in place, the contractor began laying out the CRCP reinforcement according to the details given in Figure 8 of Chapter 3. A TTI technician monitored this work, and verified that the reinforcement was placed according to the plans. Figure 36 shows the reinforcement that the contractor placed before the concrete was poured for the CRCP test track.

Figure 33. Form along West Side of Type C Base to Place CRCP.

Figure 34. Joint between Form Segments on West Side of Type C Base.

Figure 35. Placement of Form along East Side of Type C Base.

Figure 36. Reinforcement Placed for CRCP Test Track.

The contractor scheduled placement of the concrete for the CRCP test track on November 9, 2012. He had his crew and equipment on the job site at midnight that day. TTI technicians were also at the site to monitor the work. The contractor initially sprayed the concrete forms with a releasing agent to facilitate removal of the forms after the concrete was placed. Figure 37 shows the contractor placing his vibrating screed on the form when the concrete pour began. This picture was taken at the south end of the track where the contractor started pouring concrete.

Figure 37. Vibrating Screed Used to Place the Concrete Mix.

The vibrating screed was propelled forward using two cable and hand crank systems at each end of the vibrating screed. Each cable was hooked onto a rebar and two crew members turned the crank to move the screed forward, checking as they did that the screed remained flat and aligned with the form. As the concrete was poured ahead of the vibrating screed, crew members used concrete placers to manually spread the wet concrete uniformly within the area of the pour. As the mix was spread, other crew members vibrated the mix.

Behind the vibrating screed, the contractor had a crew with bull floats finishing the concrete to get a smooth surface. In addition, another crew was removing segments of the form along the east side of the track. The crew cut the concrete nails holding the 16-ft boards onto the adjacent slabs, and then lifted the boards off the edge of the concrete. Another crew then placed fresh concrete mix, and used hand trowels to get a smooth finish at these edges. As the concrete mix was being placed, the contractor applied an evaporative retardant (Monofilm ER) to reduce moisture loss, and help the finishing process. This particular retardant is on TxDOT's DMS-4650 approved list.

About two hours into the concrete pour, the contractor began carpet dragging and tining the concrete surface. Texturing was accomplished manually by dragging a carpet and a tining bar along the surface (see Figures 38 and 39). Figure 39 shows the tining bar the contractor used to longitudinally tine the concrete surface between stations 14+00 and 21+00. A similar method was used to place the ½-inch and 1-inch transverse tines.

Figure 40 shows a close-up view of the change from the longitudinally tined section to the half-inch transversely tined section. This photograph was taken at station 14+00. Figure 41 shows the change from the half-inch to the one-inch transversely tined section at station 8+50. The contractor placed 1-inch tines as illustrated in Figure 42. As may be observed in the figure, it was already morning when this picture was taken. The entire process of placing the CRCP—from the time the concrete pour began to the time the concrete was completely tined—took about 12 hours. The contractor imprinted 09-11-12 (dd-mm-yy) as the date of concrete placement at the northwest corner of the CRCP test track.

During the concrete pour, samples of the concrete mix were taken at different times to mold specimens for compressive strength testing. The Terracon laboratory at College Station performed compressive strength tests at 7 and 28 days after receiving the concrete specimens. Table 15 summarizes the results from tests done on concrete mix samples taken during placement. As shown, the average compressive strength at 28 days met the minimum requirement of 4400 psi specified in the plans.

After the CRCP was placed, the contractor put chalk marks at 5-ft intervals in preparation for saw cutting the slab. The saw cuts were intended to control the development of transverse cracks in the CRCP. The contractor assigned a two-person crew to saw cut the pavement. The cuts made were about ¾-inch deep, and were sealed.

Figure 38. Concrete Surface Textured with Carpet Drag.

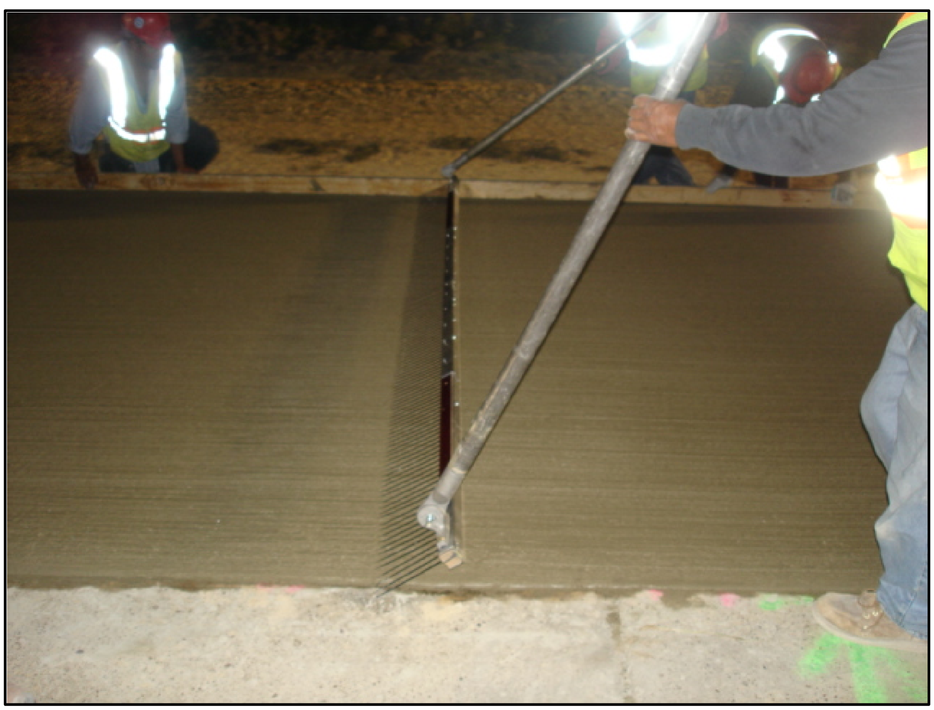

Figure 39. Concrete Surface Textured with Longitudinal Tines.

Figure 40. Change from Longitudinal Tines to ½-inch Transverse Tines.

Figure 41. Change from ½-inch to 1-inch Transverse Tines.

Figure 42. Concrete Surface Texture with 1-inch Transverse Tines.

Table 15. Test Results on Concrete Mix Samples Taken during Placement.

Measurement Variable	Sample #1	Sample #2	Sample #3
Sample Date	11/09/2012	11/09/2012	11/09/2012
Sample Time	1:12am	5:00am	8:31am
Slump (inches)	5½	5½	6¼
Air Content (%)	3.9	3.5	3.1
Concrete Temp. (°F)	70	73	76
Ambient Temp. (°F)	63	63	65
Compressive Strength (psi)			
1. 7-day	4440	4680	4260
2. 28-day[1]	6550	6980	6540

[1]Average compressive strength of three 28-day specimens

PLACE ADDITIONAL FLEXIBLE BASE

After placing the CRCP, the contractor began work on the flexible pavement test track. The contractor took out the forms along the west side of the CRCP track, and cleared the area of debris from the concrete placement. He then had base material delivered to the site to place beside the CRCP test track, and at the north and south access ramps. The plans called for placing 7 inches of flexible base from the north access ramp to station 14+00, and 6 inches of base from this station to the south access ramp.

The contractor used the same material and followed the same process in placing additional flexible base as was done for the initial 6-inch placement described previously in this chapter. TTI technicians took density measurements to check the base compaction after the contractor completed placing the material. Table 16 summarizes the results from the density tests.

Table 16. Density Measurements on Flexible Base for Flexible Pavement Test Track.

Station	Dry Density (pcf)	Moisture (%)	Compaction (%)
0+20	134.9	7.2	102.7
2+20	134.4	7.0	102.4
4+20	137.6	8.2	104.8
4+20	138.4	7.4	105.4
6+20	130.1	10.2	99.1
8+20	136.0	6.3	103.6
10+20	130.8	9.6	99.6
12+20	131.6	9.3	100.2
14+20	130.7	6.4	99.5
16+20	131.3	8.7	100.0
18+20	131.9	9.5	100.5
20+20	132.0	8.6	100.5

The plans also called for checking the ride quality of the flexible base where the Grade 3 and inverted prime sections would be placed. These sections cover the first 1400 ft of the flexible pavement test track. The contractor spent much time trying to meet the ride quality requirement of TxDOT SP247-011. After placing the CRCP, the contractor found that he had limited space to use equipment with automated grade controls to achieve the required smoothness on the flexible base, and be within 125 inches/mile on the average IRI. Thus, corrections had to be done manually. TTI project staff assisted the contractor in this process by providing profile measurements and suggesting areas where corrective work should be made. This process required a lot of iterations as can be inferred from Figure 43, which plots the average IRIs with the number of profile runs made to check the ride quality of the flexible base. Most of the work was spent on the first 528 ft of the project. After the 26th profile test, the research supervisor deemed the average IRIs to be acceptable. This decision was based on the overall weighted average of the IRIs, which was determined to be 125 inches/mile. With this work behind him, the contractor proceeded to place the surface treatments shown in the plans.

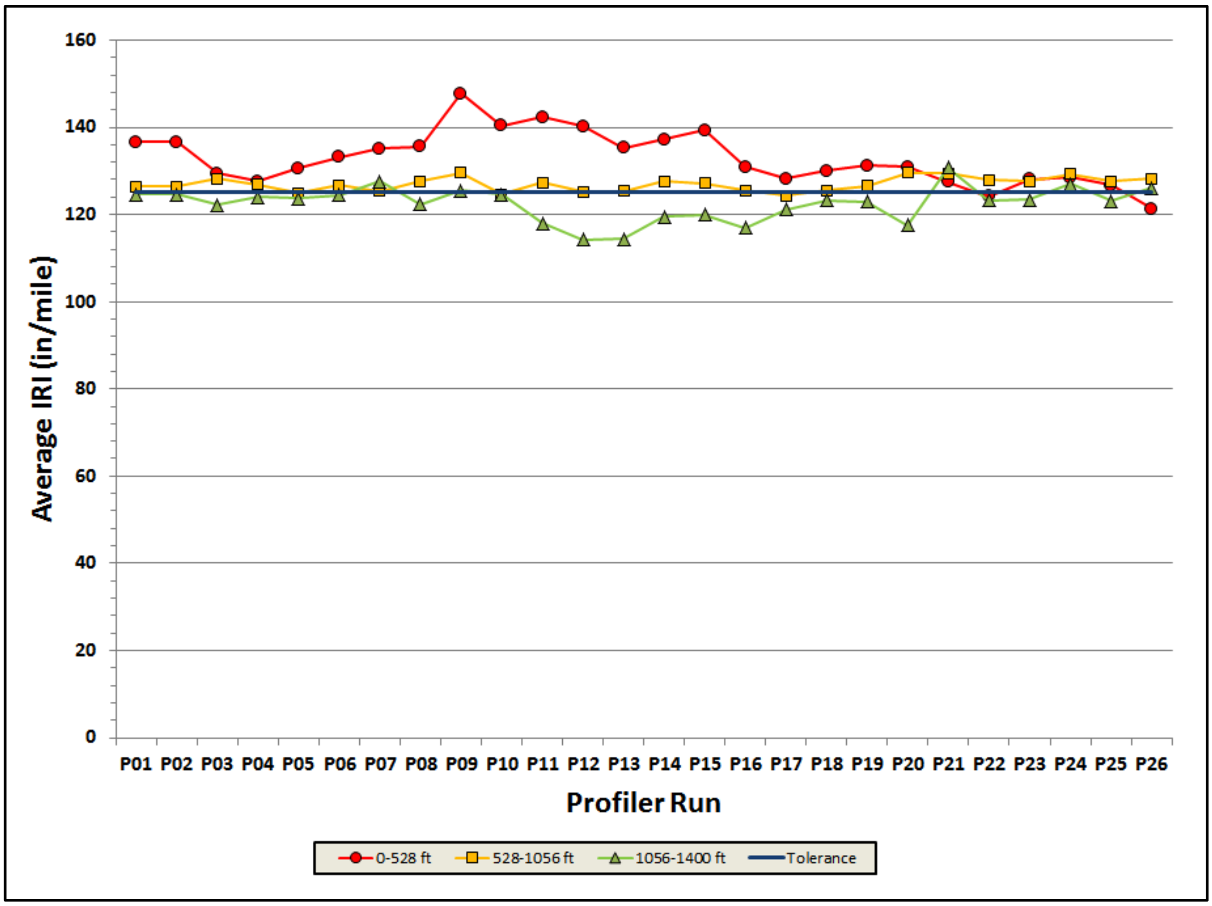

Figure 43. Results from Profile Tests to Check Ride Quality of Flexible Base.

PLACE SURFACE TREATMENTS

The prime contractor hired a subcontractor to place the following surface treatments included in the plans:

- Grade 3 on the north access ramp, and from station 0+00 to 8+50 of the flexible pavement test track.
- Inverted prime from station 8+50 to 14+00.
- Grade 4 from station 14+00 to 21+00 (underseal for the PFC section).
- Grade 4 over Grade 3 two-course surface treatment on the south access ramp.

Prior to placing the surface treatment, the contractor primed the flexible base with MC-30 asphalt in accordance with the plans. The prime coat was allowed to cure for a week before the surface treatments were placed.

The subcontractor hired to place the surface treatments avoided tracking the flexible base wheel paths when he applied the asphalt and aggregates. He was concerned about affecting the profile of the flexible base. Thus, he used the CRCP to place the surface treatments. Figure 44 illustrates how the subcontractor applied the asphalt on the flexible base. His operator drove the distributor truck such that the driver-side tires were on the CRCP, and the right side tires were between the wheel paths of the flexible base. Asphalt was then applied on the base over a 10-ft width. The distributor truck was then driven on the concrete to shoot asphalt over the remaining 1 ft of flexible base (see Figure 45).

Figure 44. Asphalt Sprayed on Flexible Base for Surface Treatment.

Figure 45. Finishing Asphalt Application on Flexible Base for Surface Treatment.

The plans called for the contractor to use RC250 for the inverted prime, and AC-20-5TR for the other surface treatments. However, AC-20-5TR was not available at the time the surface treatments were to be placed. Thus, permission was given for the contractor to use AC-15P in lieu of AC-20-5TR.

The subcontractor initially placed the inverted prime. To place the Grade 5 aggregate, he drove his chip spreader on the CRCP, and applied aggregate over half the width of the inverted prime section as illustrated in Figure 46. He then positioned the chip spreader so that the equipment straddled the concrete and the inverted prime section, and applied Grade 5 aggregate on the other half of the inverted prime section as illustrated in Figure 47. Thus, he did not drive his chip spreader on the wheel paths of this section.

Since the spreader tires that were on the inverted prime did not pick up aggregates with this method of placement, the subcontractor decided to check if he can use the same method to place the Grade 3 and Grade 4 surface treatments. Thus, he positioned his chip spreader at the start of the Grade 3 section such that the left side tires were on the concrete, and the right side tires were between the wheel paths of the flexible base. He then started spreading Grade 3 aggregates over the full-width of the flexible base, checking if the right side tires were going to peel off aggregates as the spreader moved forward. He found that the aggregates were sticking with the asphalt. Thus, he placed the Grade 3 and Grade 4 sections in this manner, which sped up his operation.

At no time did the subcontractor's equipment drive over the wheel paths of the flexible base sections placed alongside the CRCP. The only areas where his equipment drove over the wheel paths were on the north and south access ramps. At the south access ramp, his chip spreader did peel off about a 10-ft long strip of the Grade 3 course, which wrapped around the tires exposing the flexible base. Figure 48 shows the strip where the Grade 3 course peeled off. The subcontractor had his crew patch up this area before placing the Grade 4 on top of the Grade 3. The subcontractor used a 9-wheel pneumatic tire roller to seat the aggregates.

Figure 46. Chip Spreader Applying Grade 5 on Inside Half of Inverted Prime Section.

Figure 47. Chip Spreader Applying Grade 5 on Outside Half of Inverted Prime Section.

Figure 48. Strip of Grade 3 Course that Peeled Off at South Access Ramp.

PLACE ONE-INCH PERMEABLE FRICTION COURSE

For placing the PFC section, the plans called for the contractor to use a PFC mix that TxDOT has approved for use on a recent or ongoing project. The contractor placed a PFC mix that was used on a TxDOT project along SH6 in Robertson County in July 2012 under CSJ 0049-06-060. Communications with the Bryan District identified the mix as KRC-164-2 that Knife River had produced and placed. It is a PFC mix with Martin PG 76-22 binder, 1 percent lime, and 0.3 percent fiber.

Table 17 shows the combined gradation for the mix while Table 18 summarizes results from the aggregate quality tests. Table 19 provides information about the bins where samples were collected to run the aggregate quality tests reported in Table 18. The mix design used 50 as the design number of gyrations. Using a target density of 80 percent, and the design gradation in Table 17, the mix design resulted in an optimum binder content of 6.3 percent.

The contractor placed the PFC mix over the Grade 4 underseal between stations 14+00 and 21+00. He used a steel wheel roller to compact the mix. Figure 49 shows the PFC section after placement.

SMOOTHNESS TESTING OF CRCP TEST TRACK AND PFC SECTION

In accordance with the construction plans, researchers conducted inertial profile measurements to check the pavement smoothness on the new CRCP test track and PFC section. Because of the longitudinally tined CRCP section, all profile measurements were made with a Roline laser profiling module. Researchers used the measured profiles to compute continuous IRIs at 528-ft intervals along the CRCP test track and PFC section.

The research team met with the contractor to present the results from the ride quality assurance tests. These results showed the need for corrective work to improve the ride quality on the CRCP test track and PFC section. During the meeting, the research team provided contact information for a couple of contractors that do pavement grinding. The contractor subsequently had the CRCP test track ground, which significantly improved the smoothness on the track to acceptable levels based on IRI measurements made with the SurPRO reference profiler. The contractor also had the surface re-tined after grinding.

On the PFC section, not much improvement could be made because grinding as a method of correction does not work well on this open-graded mix. Instead, the contractor performed corrective work at defect locations by heating and planing the surface at those locations. Most of the corrections were made on the east wheel path of this section, where the contractor was able to reduce the IRI by about 55 inches/mile.

FINAL CLEAN-UP

After construction, the contractor removed his barricades and equipment from the Riverside Campus. He also broomed the new test tracks and the adjacent taxiway.

Table 17. Combined Gradation for PFC Mix.

Sieve Size	Cumulative % Passing	Gradation Limits for Type C Mix		Within Limits?
		Lower	Upper	
¾″	100.0	100	100	Yes
½″	81.0	80	100	Yes
3/8″	45.7	35	60	Yes
#4	7.7	1	20	Yes
#8	3.9	1	10	Yes
#200	1.8	1	4	Yes

Table 18. Results of Aggregate Quality Tests on PFC Mix.

Test Name	Test Method	Spec. Min. or Max.	Spec. Limit	Bin #1	Bin #2
Stockpile					
Decantation	Tex-217-F	Max.	1.5	0.2	0.3
Deleterious material	Tex-217-F	Max.	1.0	0.0	
Surface aggregate classification	Tex-438-A, Tex-612-J	Min.	A	A	B
Magnesium sulfate soundness	Tex-411-A	Max.	20	AQMP[1]	AQMP
LA abrasion	Tex-410-A	Max.	30	AQMP	AQMP
Crushed faces count	Tex-460-A	Min.	95	100	100
Flat & elongated	Tex-280-F	Max.	10	4.0	1.0
Fine Aggregate					
Bar linear shrinkage	Tex-107-E	Max.	3	N/A	N/A
Combined aggregate					
Sand equivalent	Tex-203-F	Min.	45	100	

[1]Aggregate Quality Monitoring Program

Table 19. Information on Bins Used for Aggregate Quality Tests on PFC Mix.

Bin No.	Aggregate Source	Aggregate Number	Sample ID
1	Capital	Brownlee	Grade 4
2	Hansen	Perch Hill	C Rock

Figure 49. PFC Section Adjacent to Longitudinally Tined CRCP Section.

CHAPTER 5. PRELIMINARY TESTING AT NEW TEST TRACKS

This chapter documents the work researchers conducted to collect reference profiles and run preliminary tests to verify the applicability of the existing TxDOT Tex-1001S certification requirements on the new CRCP and flexible pavement test tracks. Figure 50 shows the new test tracks built along Taxiway 7 of the Riverside Campus. Figure 51 to Figure 56 show pictures of the pavement surface on each of the test sections. After construction, researchers collected reference profile measurements on these sections, and tested a number of inertial profilers equipped with different lasers to verify the applicability of TxDOT's current profiler certification requirements on the new pavement surfaces. The tests performed are presented in this chapter.

Figure 50. New Test Tracks for Profiler Certifications.

Figure 51. One-inch Longitudinally Tined CRCP Section.

Figure 52. Half-inch Transversely Tined CRCP Section.

Figure 53. One-inch Transversely Tined CRCP Section.

Figure 54. Permeable Friction Course Section.

Figure 55. Inverted Prime Section.

Figure 56. Grade 3 Chip Seal Section.

REFERENCE PROFILE MEASUREMENTS

Reference profile measurements were collected using the SurPRO 3500 profiler illustrated in Figure 57. This reference profiler is a product of the Federal Highway Administration (FHWA) pooled fund study TPF-5(063), which conducted an evaluation that assessed the accuracy and repeatability of profiles collected with three different systems provided by equipment developers who participated in that study. Based on the results, FHWA recommended using the SurPRO for evaluating profile measurements collected with inertial profilers. The SurPRO 3500 is the same profiler used to collect reference data on the existing profiler certification track that TTI maintains.

Figure 57. Instrument Used to Measure Reference Profiles.

Researchers made three repeat runs to determine the wheel path profiles on each test section. Prior to making these runs, researchers laid out the wheel paths on both test tracks. These wheel paths were then delineated with paint dots placed at 5-ft intervals. Researchers then profiled each wheel path using the SurPRO, and tied the reference profile elevations to a common benchmark using rod and level measurements collected at 190-ft intervals on each wheel path. Reference profiles were collected at 1-inch intervals.

Researchers evaluated the repeatability of the measurements from repeat runs based on the point-to-point variability of the measured elevations as well as the cross-correlations of IRI filtered profiles. In this analysis, the point-to-point variability is determined by computing the standard deviation of the measured elevations from repeat runs station-by-station. Researchers then used the average of the standard deviations to assess the repeatability of the unfiltered elevation profiles from repeat runs. Table 20 summarizes the profile repeatability statistics from this analysis. The average standard deviations are all within 10 mils, indicating very good repeatability between elevation measurements from repeat runs on the CRCP test track.

Researchers also evaluated the repeatability of the IRIs computed from the unfiltered SurPRO data as well as the repeatability of the IRI filtered profiles. In this analysis, the standard deviations of the IRIs and the cross-correlations between IRI filtered profiles were determined. The statistics given in Table 21 show excellent repeatability of the IRIs computed from repeat runs. It is observed that the IRI standard deviations are all within 1 inch/mile. This repeatability is also reflected in the cross-correlation statistics summarized in Table 22, which shows cross-correlations of 97 percent or better from pairwise comparisons of IRI filtered profiles.

In a similar manner, researchers evaluated the repeatability of the reference profiles collected on the flexible pavement test track. The results from this analysis are summarized in Tables 23 to 25. Table 23 shows that the repeatability of the unfiltered PFC reference profiles is comparable to the repeatability of the reference profiles collected on the CRCP sections, with average standard deviations of about 10 mils on both wheel paths. On the chip seal sections, the average standard deviations range from 11 to 19 mils, with higher standard deviations on the right wheel path, particularly on the inverted prime section. Nevertheless, these statistics are well within the range of values characteristic of repeatable profiles.

Table 20. Repeatability of Unfiltered Reference Profiles Collected on CRCP Test Track.

Section	Average standard deviation (mils)	
	Left Wheel Path	Right Wheel Path
1-inch longitudinally tined	9.51	9.52
½-inch transversely tined	9.12	9.66
1-inch transversely tined	9.90	9.75
Entire CRCP track	9.57	9.65

Table 21. Repeatability of IRIs Computed from Unfiltered Reference Profiles Collected on CRCP Test Track.

Section	IRI standard deviation (inch/mile)	
	Left Wheel Path	Right Wheel Path
1-inch longitudinally tined	0.44	0.61
½-inch transversely tined	0.75	0.46
1-inch transversely tined	0.36	0.25
Entire CRCP track	0.25	0.40

Table 22. Repeatability of IRI Filtered Profiles Based on Cross-Correlation.

Section	Average Cross-Correlation (%)		Minimum Cross-Correlation (%)		Maximum Cross-Correlation (%)	
	LWP	RWP	LWP	RWP		RWP
1-inch longitudinally tined	98	98	97	97	98	99
½-inch transversely tined	98	98	98	98	99	99
1-inch transversely tined	99	99	98	98	99	99
Entire CRCP track	99	98	98	98	99	99

Table 23. Repeatability of Unfiltered Reference Profiles Collected on Flexible Pavement Test Track.

Section	Average standard deviation (mils)	
	Left Wheel Path	Right Wheel Path
Permeable friction course	9.61	9.56
Inverted prime	11.83	19.29
Grade 3 chip seal	10.79	12.71
Entire PFC-Chip Seal Track	10.67	13.40

Table 24. Repeatability of IRIs Computed from Unfiltered Reference Profiles Collected on Flexible Pavement Test Track.

Section	IRI standard deviation (inch/mile)	
	Left Wheel Path	Right Wheel Path
Permeable friction course	0.25	0.25
Inverted prime	0.26	0.51
Grade 3 chip seal	0.61	0.40
Entire PFC-Chip Seal Track	0.15	0.29

Table 25. Repeatability of IRI Filtered Profiles on Flexible Pavement Test Track Based on Cross-Correlation.

Section	Average Cross-Correlation (%)		Minimum Cross-Correlation (%)		Maximum Cross-Correlation (%)	
	LWP	RWP		RWP	LWP	RWP
Permeable friction course	99	100	99	99	100	100
Inverted prime	99	99	99	98	99	99
Grade 3 chip seal	99	99	99	99	100	100
Entire PFC-Chip Seal Track	99	99	99	99	99	99

With respect to IRI repeatability, the computed indices from repeat runs show excellent agreement as measured by the standard deviations of the IRIs computed from the unfiltered SurPRO reference profiles. The IRI standard deviations given in Table 24 are all within

1 inch/mile. This IRI repeatability is also consistent with the high cross-correlations between IRI filtered profiles shown in Table 25. In summary, the statistics presented verify the excellent agreement between the reference data from repeat runs made on the CRCP and flexible pavement test tracks.

PRELIMINARY TESTING OF INERTIAL PROFILERS

After measuring the reference profiles on both test tracks, and verifying their repeatability, researchers collected data from a number of profiling systems equipped with three types of lasers. Two of these systems are TxDOT profilers equipped with conventional single-point lasers. The other profiler was made available by the Bryan Dynatest office, and is equipped with Roline lasers that project a 100mm-wide footprint. The remaining profiling system is one that was assembled at TTI. This system has a pair of single-point lasers, but for the purpose of this preliminary testing, researchers replaced one of the single-point lasers with a Selcom 19mm laser. All profiling systems were current in their profiler certifications at the time of testing on the CRCP and the PFC-Chip Seal test tracks. However, since the TTI profiler had one of its single-point lasers replaced with the 19mm laser, researchers ran this system on the existing test track and verified that the channel with the 19mm laser produced profiles that met the existing Tex-1001S profiler certification requirements. Prior to testing, all participants were informed that results from the preliminary tests would not affect their current profiler certifications. Instead, the data would be used only to check TxDOT's existing profiler certification standards on the new sections. All runs were made in the northbound direction along each test track, with the operators providing test data over the entire track.

Results from CRCP Tests

Tables 26 to 29 present the test statistics determined from runs made on the CRCP sections. The test results on the CRCP sections show that only the Roline laser passed (i.e., met all Tex-1001S profiler certification requirements) on the 1-inch longitudinally tined CRCP section. Table 27 shows that the standard deviations of the IRIs computed from wheel path profiles collected with the single-point and 19mm lasers exceed the 3.0 inches/mile threshold on IRI repeatability of the existing test method. In addition, Table 29 shows that the IRIs from the same lasers do not meet the IRI accuracy tolerance of 6 inches/mile, with the average IRIs computed from the test profiles being much higher than the corresponding reference IRIs by the magnitudes of the differences shown in Table 29.

Researchers note that on the 1-inch longitudinally tined section, the single-point and 19mm laser footprints run in and out of the grooves in an irregular manner, generating features in the profile data that inflate the IRI statistics. The Roline laser measures the elevations across the surface along its 100mm footprint. The elevation readings are then processed using the laser's internal tire-bridging filter to produce a bridged value at the given station. This capability reduces profile measurement errors on longitudinally tined surfaces.

On the ½-inch and 1-inch transversely tined CRCP sections, Tables 26 to 29 show that the single-point and 19mm lasers met all of the existing Tex-1001S profiler certification requirements. Surprisingly, the Roline laser did not pass on the ½-inch transversely tined section, where the average IRI computed from the test profiles exceeded the IRI accuracy tolerance of 6 inches/mile on the right wheel path. Researchers note that the Roline laser was oriented perpendicular to the direction of travel on all test runs. While the laser was measuring elevations across the longitudinal tines, the laser footprint was going in and out of the grooves on the transversely tined sections just like the single-point and 19mm laser footprints. However, the Roline laser with its wider footprint measures more of the road surface at any given station compared to the single-point and 19mm lasers. The surface features of the ½-inch transversely tined surface coupled with how the line scan tracked those features during testing could explain the higher IRIs.

Table 26. Profile Repeatability on CRCP Sections.

Section	Profiler/Laser	Average Standard Deviation (mils)[1]	
		LWP	RWP
1-inch Longitudinally Tined	3209H/single-pt.	34	37
	3287G/single-pt.	34	39
	04-172/Roline	6	6
	TTI/19mm	18	22
½-inch Transversely Tined	3209H/single-pt.	17	18
	3287G/single-pt.	17	18
	04-172/Roline	6	7
	TTI/19mm	8	7
1-inch Transversely Tined	3209H/single-pt.	18	15
	3287G/single-pt.	15	15
	04-172/Roline	7	5
	TTI/19mm	7	7

[1]Not to exceed 35 mils per TxDOT Test Method Tex-1001S (results in red exceed specified tolerance).

Table 27. IRI Repeatability on CRCP Sections.

Section	Profiler/Laser	Standard Deviation (inch/mile)[2]	
		LWP	RWP
1-inch Longitudinally Tined	3209H/single-pt.	9.15	9.89
	3287G/single-pt.	9.70	12.69
	04-172/Roline	0.14	0.65
	TTI/19mm	3.15	4.29
½-inch Transversely Tined	3209H/single-pt.	0.66	1.16
	3287G/single-pt.	0.83	2.52
	04-172/Roline	0.24	0.46
	TTI/19mm	0.51	1.81
1-inch Transversely Tined	3209H/single-pt.	1.11	0.68
	3287G/single-pt.	1.37	1.51
	04-172/Roline	1.35	0.40
	TTI/19mm	0.62	0.62

[2]Not to exceed 3.0 inches/mile per TxDOT Test Method Tex-1001S

Table 28. Profile Accuracy on CRCP Sections.

Section	Profiler/Laser	Average Difference (mils)[3]		Average Absolute Difference (mils)[4]	
		LWP	RWP	LWP	RWP
1-inch Longitudinally Tined	3209H/single-pt.	−0.40	−0.32	17	16
	3287G/single-pt.	−0.16	0.71	14	15
	04-172/Roline	−1.17	−0.23	11	11
	TTI/19mm	−0.73	0.39	14	13
½-inch Transversely Tined	3209H/single-pt.	−0.61	−0.57	20	23
	3287G/single-pt.	−0.28	0.43	11	12
	04-172/Roline	−0.89	−0.43	14	14
	TTI/19mm	−1.47	0.15	17	18
1-inch Transversely Tined	3209H/single-pt.	0.66	−0.06	27	23
	3287G/single-pt.	0.69	−0.26	8	9
	04-172/Roline	0.90	0.74	11	10
	TTI/19mm	1.93	0.06	23	17

[3]Must be within ±20 mils per TxDOT Test Method Tex-1001S

[4]Not to exceed 60 mils per TxDOT Test Method Tex-1001S

Table 29. IRI Accuracy on CRCP Sections.

Section	Profiler/Laser	Difference between Averages of Test and Reference IRIs (inch/mile)[5]	
		LWP	RWP
1-inch Longitudinally Tined	3209H/single-pt.	42.97	44.07
	3287G/single-pt.	43.75	52.75
	04-172/Roline	1.63	5.01
	TTI/19mm	20.04	19.22
½-inch Transversely Tined	3209H/single-pt.	2.95	3.51
	3287G/single-pt.	2.46	5.39
	04-172/Roline	4.09	9.24
	TTI/19mm	2.98	3.32
1-inch Transversely Tined	3209H/single-pt.	5.25	5.05
	3287G/single-pt.	3.42	4.4
	04-172/Roline	5.54	4.87
	TTI/19mm	5.27	3.97

[5]Absolute difference not to exceed 6 in/mile per TxDOT Test Method Tex-1001S
Positive difference indicates higher IRI from profiler relative to reference, and vice-versa

There is evidence from test data that the ½-inch transverse tines affected the Roline measurements on the right wheel path. Figure 58 compares the IRI filtered profile from one of the runs on the CRCP track with the corresponding IRI filtered reference profile along the same interval. The IRI filtered profiles are observed to track each other quite well up to about 390 ft of the measured interval. Thereafter, the IRI filtered Roline profile shows more deviations from the IRI filtered reference profile. Researchers note that the pavement surface changes from 1-inch longitudinal tines to ½-inch transverse tines at about 390 ft on the chart. Within the first 390 ft, the cross-correlation between the IRI filtered profiles is 95 percent. If the cross-correlation is determined over the whole test interval, the cross-correlation drops to 84 percent.

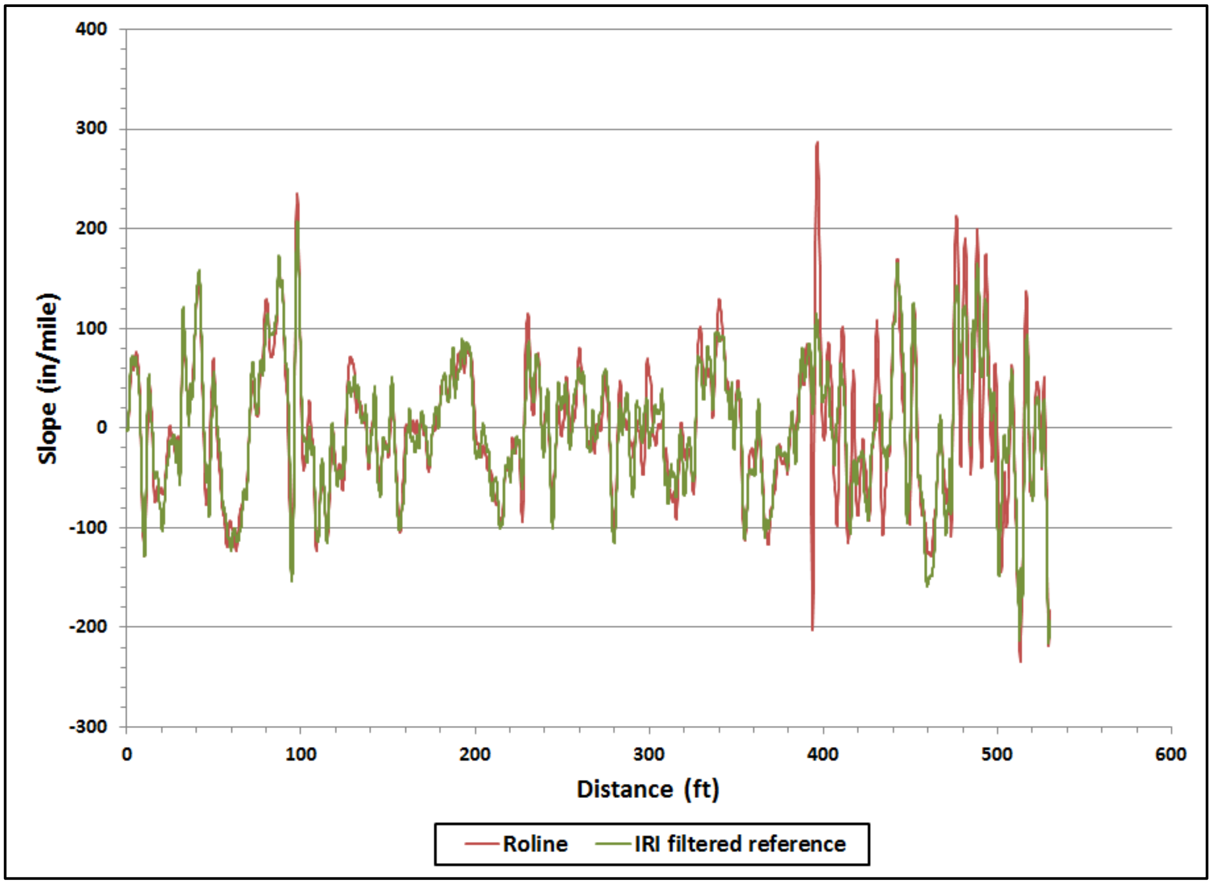

Figure 58. Comparison of IRI Filtered Profiles on a Section of CRCP Test Track.

On the ½-inch transversely tined section, the Roline laser, as configured, failed to meet the IRI accuracy tolerance specified in Tex-1001S. Table 29 shows that on the right wheel path of this section, the IRI from the test profiles is about 9 inches/mile higher than the reference IRI. Note that the SurPRO reference profiler bridges over the transverse tines. In contrast, the Roline (as well as the 19mm and single-point lasers) run in and out of the tines during testing. Researchers recommend additional tests at different Roline footprint orientation angles to determine the optimal setup that gives a better match with the reference data on both longitudinally tined and transversely tined surfaces.

While the Roline laser footprint orientation can be varied to bridge across tines, the same cannot be said with the 19mm and single-point lasers. Although the test data from these lasers met Tex-1001S profiler certification requirements, there is a question as to whether the comparisons with reference data on the transversely tined sections can be further improved, particularly with respect to IRI accuracy. Researchers conducted a preliminary investigation that involved using a smoothing filter on the test profiles collected with these lasers.

The smoothing filter researchers investigated was developed on another TxDOT project by Dr. Roger Walker of UT Arlington. At one time, Dr. Walker proposed implementing the filter on TxDOT's profilers. However, due to concerns with the potential impact this change would have on the historical data stored in TxDOT's Pavement Management Information System (PMIS) database, the department decided not to implement this smoothing filter.

Researchers note that at the time this change was considered, there was no reference profiler. Since then, one has been developed with which measurements made with inertial profilers can be verified. Considering this technological change, researchers included a preliminary assessment of this smoothing filter on the 19mm and single-point test profiles collected on the CRCP transversely tined sections. Tables 30 to 33 summarize the results from this analysis. These tables compare the test statistics with and without the use of the smoothing filter. It is observed from Table 33 that the smoothing filter significantly improves the accuracy of the IRIs determined from the test profiles relative to the reference values. Researchers note that the results presented are preliminary, and that more tests and analysis of data from PMIS surveys are necessary before a recommendation can be made on whether to implement this smoothing filter on TxDOT's profilers. This preliminary assessment was included here to solicit further discussions within TxDOT on this subject.

Table 30. Comparison of Profile Repeatability Statistics on Transversely Tined CRCP Sections with and without Smoothing.

Section	Profiler/Laser	Average Standard Deviation (mils)[1]			
		No smoothing		W/ smoothing	
		LWP	RWP	LWP	RWP
½-inch Transversely Tined	3209H/single-pt.	17	18	16	17
	3287G/single-pt.	17	18	17	17
	TTI/19mm	8	7	7	6
1-inch Transversely Tined	3209H/single-pt.	18	15	17	14
	3287G/single-pt.	15	15	14	14
	TTI/19mm	7	7	7	6

[1]Not to exceed 35 mils per TxDOT Test Method Tex-1001S

Table 31. Comparison of IRI Repeatability Statistics on Transversely Tined CRCP Sections with and without Smoothing.

Section	Profiler/Laser	Standard Deviation (inch/mile)[2]			
		No smoothing		W/ smoothing	
		LWP	RWP	LWP	RWP
½-inch Transversely Tined	3209H/single-pt.	0.66	1.16	0.65	1.13
	3287G/single-pt.	0.83	2.52	0.77	2.38
	TTI/19mm	0.51	1.81	0.50	1.72
1-inch Transversely Tined	3209H/single-pt.	1.11	0.68	1.06	0.66
	3287G/single-pt.	1.37	1.51	1.36	1.44
	TTI/19mm	0.62	0.62	0.62	0.52

[2]Not to exceed 3.0 in/mile per TxDOT Test Method Tex-1001S

Table 32. Comparison of Profile Accuracy Statistics on Transversely Tined CRCP Sections with and without Smoothing.

Section	Profiler/Laser	Average Difference (mils)[3]				Average Absolute Difference (mils)[4]			
		No smooth		W/ smooth		No smooth		W/ smooth	
		LWP	RWP	LWP	RWP	LWP	RWP	LWP	RWP
½-inch Tines	3209H/single-pt.	−0.61	−0.57	−0.19	−0.15	20	23	20	22
	3287G/single-pt.	−0.28	0.43	0.14	0.85	11	12	11	11
	TTI/19mm	−1.47	0.15	−1.01	0.61	17	18	16	17
1-inch Tines	3209H/single-pt.	0.66	−0.06	1.09	0.37	27	23	27	23
	3287G/single-pt.	0.69	−0.26	1.12	0.17	8	9	8	9
	TTI/19mm	1.93	0.06	2.39	0.52	23	17	23	16

[3]Must be within ±20 mils per TxDOT Test Method Tex-1001S
[4]Not to exceed 60 mils per TxDOT Test Method Tex-1001S

Table 33. Comparison of IRI Accuracy Statistics on Transversely Tined CRCP Sections with and without Smoothing.

Section	Profiler/Laser	Difference between Averages of Test and Reference IRIs (inch/mile)[5]			
		No smoothing		W/ smoothing	
		LWP	RWP	LWP	RWP
½-inch Transversely Tined	3209H/single-pt.	2.95	3.51	1.89	1.92
	3287G/single-pt.	2.46	5.39	1.39	3.75
	TTI/19mm	2.98	3.32	2.39	2.40
1-inch Transversely Tined	3209H/single-pt.	5.25	5.05	4.40	4.11
	3287G/single-pt.	3.42	4.40	2.58	3.43
	TTI/19mm	5.27	3.97	4.88	3.53

[5]Absolute difference not to exceed 6 in/mile per TxDOT Test Method Tex-1001S
Positive difference indicates higher IRI from profiler relative to reference, and vice-versa

Researchers also conducted preliminary tests to check the effect of temperature on profile measurements collected on the CRCP test track. Slab movement due to temperature variations affect profile measurements on jointed concrete pavements. Since TxDOT primarily builds concrete pavements that are continuously reinforced, the effect of temperature variations should be less but could still be significant. For the purpose of checking the performance of inertial profilers on these pavements, it is necessary to consider the effect of slab movement due to temperature variations. If the effect is significant, the inertial and reference profile measurements should be made at close to the same prevailing temperature conditions. Thus, as part of the preliminary tests, researchers collected inertial profile measurements at hourly intervals over a day's period. Using TTI's inertial profiler equipped with single-point lasers, they collected 10 sets of measurements from 8am to 5pm, which is when most profiler certifications are scheduled on the existing test track. Measurements were collected on a typical Texas summer day. Table 34 shows the range in air and surface temperatures measured during the testing period.

At each hour, researchers made 10 runs on the CRCP test track. They then computed the IRIs from the measured inertial profiles and determined the standard deviations and averages of the IRIs for each hourly set of data. Table 35 shows that the mean IRIs and standard deviations varied over a narrow range during the 10-hour period of test.

Researchers did an analysis-of-variance (ANOVA) test to check the hypothesis that the mean hourly IRIs are the same. Since the data were collected in a time sequence, they first did a residual analysis and verified that the computed IRIs were not affected by the order in which the measurements were taken. This finding is illustrated in Figure 59 and Figure 60, which show that the residuals fluctuate randomly about 0 with no perceptible correlation between the residuals and the measurement sequence.

Tables 36 and 37 present the results of the analysis-of-variance on the hourly IRIs. For both the ½-inch and 1-inch transversely tined CRCP sections, the ANOVA results indicate that the mean hourly IRIs are the same at a 95 percent confidence level. There is no apparent effect of temperature, which is consistent with the results previously presented. While this finding is encouraging from the point of view of collecting reference profiles for certification testing of inertial profilers on the CRCP test track, more tests over time and under different seasons or prevailing weather conditions need to be conducted to ascertain the effect of temperature on CRCP profile measurements.

Table 34. Measured Temperatures at Hourly Profile Testing.

Time	Air Temperature (°F)	Surface Temperature (°F)
0800	81	87
0900	84	90
1000	89	97
1100	95	101
1200	96	106
1300	93*	111
1400	98	116
1500	102	117
1600	102	120
1700	102	118

*Wind picked up

Table 35. Range in Means and Standard Deviations of IRIs from Hourly Profile Measurements.

Section	Wheel Path	Average IRI (inch/mile)			IRI Standard Deviation (inch/mile)		
		Min.	Max.	Range	Min.	Max.	Range
½-inch Transversely Tined	Left	63.5	64.8	1.3	0.80	1.57	0.77
	Right	56.0	56.9	0.9	0.78	1.15	0.37
1-inch Transversely Tined	Left	50.8	51.3	0.5	0.65	1.20	0.55
	Right	58.5	59.0	0.5	0.61	1.19	0.58

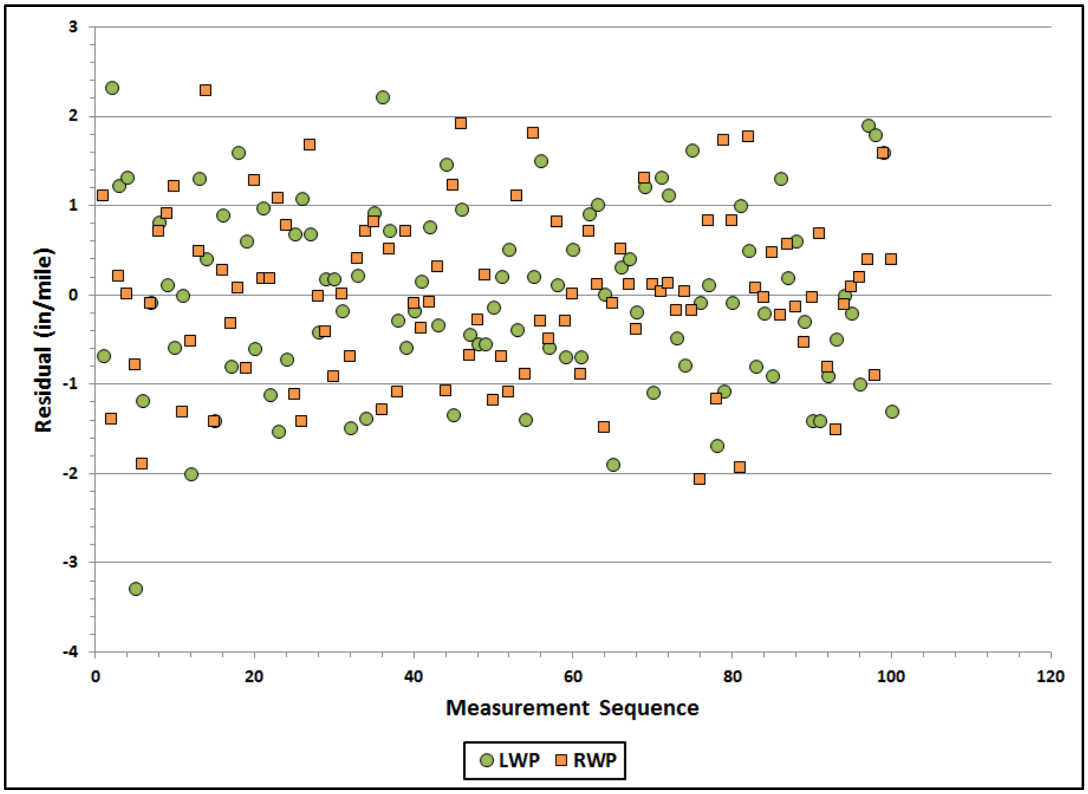

Figure 59. Results of Residual Analysis on ½-inch Transversely Tined Section IRIs.

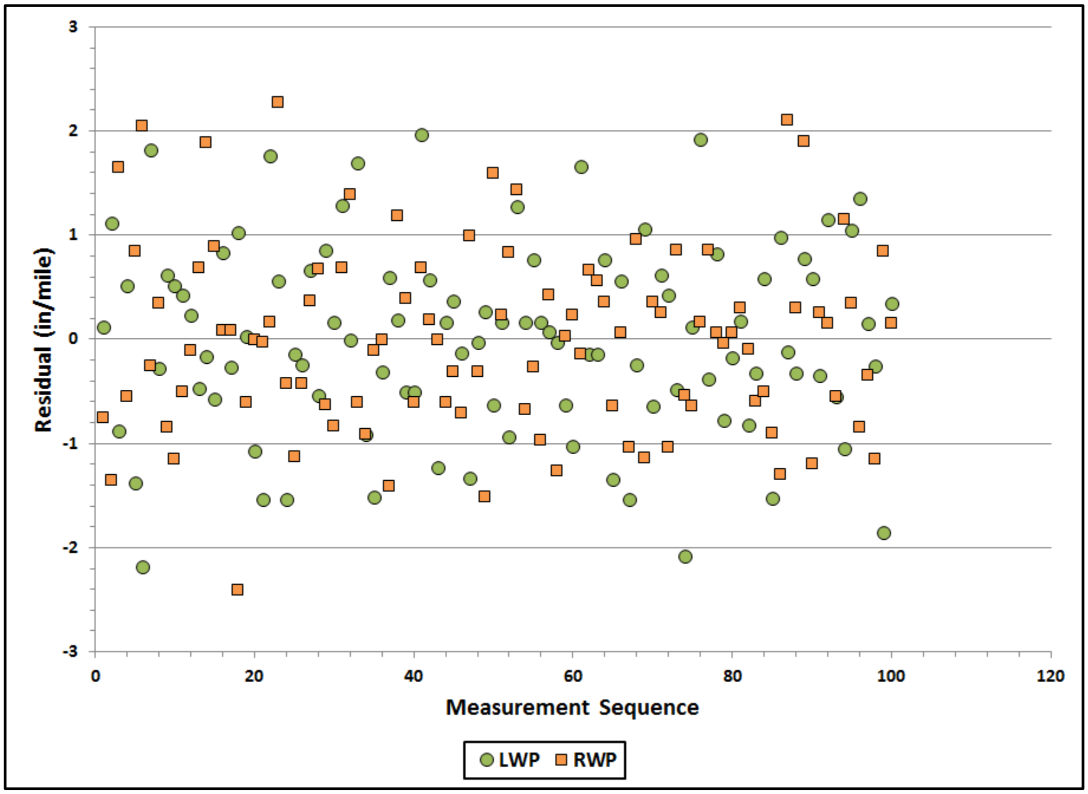

Figure 60. Results of Residual Analysis on 1-inch Transversely Tined Section IRIs.

Table 36. ANOVA Results Based on Hourly IRIs for ½-inch Transversely Tined CRCP Section.

<table>
<tr><th rowspan="2">Source</th><th colspan="2">Sum of Squares</th><th colspan="2">Degrees of Freedom (df)</th><th colspan="2">Mean Square</th><th colspan="2">F-statistic</th></tr>
<tr><th>LWP</th><th>RWP</th><th>LWP</th><th>RWP</th><th>LWP</th><th>RWP</th><th>LWP</th><th>RWP</th></tr>
<tr><td>Between samples</td><td>19.690</td><td>7.571</td><td>9</td><td>9</td><td>2.188</td><td>0.841</td><td rowspan="2">1.847</td><td rowspan="2">0.903</td></tr>
<tr><td>Within samples</td><td>106.626</td><td>83.835</td><td>90</td><td>90</td><td>1.185</td><td>0.931</td></tr>
<tr><td>Totals</td><td>126.316</td><td>91.406</td><td>99</td><td>99</td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td colspan="9">For α = 0.05, the critical F value is 1.99 at $df_1 = 9$ and $df_2 = 90$. Since the F-statistic for each wheel path is less than 1.99, the null hypothesis that the mean hourly IRIs are equal cannot be rejected.</td></tr>
</table>

Table 37. ANOVA Results Based on Hourly IRIs for 1-inch Transversely Tined CRCP Section.

<table>
<tr><th rowspan="2">Source</th><th colspan="2">Sum of Squares</th><th colspan="2">Degrees of Freedom (df)</th><th colspan="2">Mean Square</th><th colspan="2">F-statistic</th></tr>
<tr><th>LWP</th><th>RWP</th><th>LWP</th><th>RWP</th><th>LWP</th><th>RWP</th><th>LWP</th><th>RWP</th></tr>
<tr><td>Between samples</td><td>3.675</td><td>3.079</td><td>9</td><td>9</td><td>0.408</td><td>0.342</td><td rowspan="2">0.445</td><td rowspan="2">0.390</td></tr>
<tr><td>Within samples</td><td>82.513</td><td>79.007</td><td>90</td><td>90</td><td>0.917</td><td>0.878</td></tr>
<tr><td>Totals</td><td>86.188</td><td>82.086</td><td>99</td><td>99</td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td colspan="9">For α = 0.05, the critical F value is 1.99 at $df_1 = 9$ and $df_2 = 90$. Since the F-statistic for each wheel path is less than 1.99, the null hypothesis that the mean hourly IRIs are equal cannot be rejected.</td></tr>
</table>

Results from Tests on PFC and Chip Seal Sections

Tables 38 to 41 present the Tex-1001S test statistics determined from runs made on the PFC and chip seal sections. The only profilers that met Tex-1001S certification requirements are TxDOT's 3287G profiler with the single-point lasers, and the Dynatest profiler with the Rolines, which passed certification on the PFC section. On the chip seal sections, none of the profilers passed TxDOT's current requirements. On these sections, Table 42 identifies the test criteria where the profilers failed to meet specifications.

All profilers failed IRI repeatability on these sections, and this problem was primarily confined to the left wheel path. Even the Roline laser with its tire-bridging filter failed to meet IRI repeatability on the chip seal sections. Table 42 also shows problems in meeting Tex-1001S profile and IRI accuracy requirements. With respect to profile accuracy, only the Roline laser met the existing criteria on both chip seal sections. With respect to IRI accuracy, all lasers failed in one or both sections. More tests are needed to determine the nature of these problems in order to recommend appropriate criteria and a test protocol for certifying inertial profilers on the chip seal sections.

Researchers note that, in practice, no ride quality assurance testing is done on Grade 3 chip seals. Chip seal projects are normally let under TxDOT's flexible base ride specification (SP247-011), where ride quality assurance testing is done on the unstabilized flexible base prior to placement of the chip seal. The exception is the inverted prime, which is normally placed as a temporary wearing surface. Inverted prime surfaces undergo ride quality assurance testing under SP247-011. Thus, the inverted prime section is expected to be used for certifying inertial profilers but the Grade 3 chip seal section is expected to be used only by TxDOT in its annual profiler maintenance program. This maintenance is done prior to the PMIS data collection season, during which time TxDOT brings its profilers to the Texas A&M Riverside Campus for certification.

Table 38. Profile Repeatability on PFC and Chip Seal Sections.

Section	Profiler/Laser	Average Standard Deviation (mils)[1]	
		LWP	RWP
Permeable Friction Course	3209H/single-pt.	31	29
	3287G/single-pt.	29	22
	04-172/Roline	10	12
	TTI/19mm	15	14
Inverted Prime Chip Seal	3209H/single-pt.	39	38
	3287G/single-pt.		
	04-172/Roline	22	19
	TTI/19mm	27	28
Grade 3 Chip Seal	3209H/single-pt.	32	34
	3287G/single-pt.		
	04-172/Roline	18	17
	TTI/19mm	23	21

[1]Not to exceed 35 mils per TxDOT Test Method Tex-1001S

Table 39. IRI Repeatability on PFC and Chip Seal Sections.

Section	Profiler/Laser	Standard Deviation (inch/mile)[2]	
		LWP	RWP
Permeable Friction Course	3209H/single-pt.	5.20	2.51
	3287G/single-pt.	2.83	1.33
	04-172/Roline	2.81	0.75
	TTI/19mm	2.15	1.56
Inverted Prime Chip Seal	3209H/single-pt.	10.76	4.17
	3287G/single-pt.		
	04-172/Roline	9.74	2.51
	TTI/19mm	3.09	2.25
Grade 3 Chip Seal	3209H/single-pt.	12.82	2.08
	3287G/single-pt.		
	04-172/Roline	12.31	1.94
	TTI/19mm	5.78	1.32

[2]Not to exceed 3.0 inches/mile per TxDOT Test Method Tex-1001S

Table 40. Profile Accuracy on PFC and Chip Seal Sections.

Section	Profiler/Laser	Average Difference (mils)[3]		Average Absolute Difference (mils)[4]	
		LWP	RWP	LWP	RWP
Permeable Friction Course	3209H/single-pt.	2.43	0.67	34	35
	3287G/single-pt.	2.14	2.41	24	23
	04-172/Roline	−2.95	−3.35	21	23
	TTI/19mm	0.98	−3.33	33	36
Inverted Prime Chip Seal	3209H/single-pt.	2.74	3.75	72	57
	3287G/single-pt.				
	04-172/Roline	−0.69	2.39	47	43
	TTI/19mm	5.98	7.50	72	83
Grade 3 Chip Seal	3209H/single-pt.	7.43	2.41	93	71
	3287G/single-pt.				
	04-172/Roline	4.41	1.23	50	43
	TTI/19mm	4.53	−3.42	85	77

[3]Must be within ±20 mils per TxDOT Test Method Tex-1001S
[4]Not to exceed 60 mils per TxDOT Test Method Tex-1001S

Table 41. IRI Accuracy on PFC and Chip Seal Sections.

Section	Profiler/Laser	Difference between Averages of Test and Reference IRIs (inch/mile)[5]	
		LWP	RWP
Permeable Friction Course	3209H/single-pt.	2.20	3.33
	3287G/single-pt.	2.82	5.07
	04-172/Roline	0.95	1.58
	TTI/19mm	11.00	1.97
Inverted Prime Chip Seal	3209H/single-pt.	8.02	6.50
	3287G/single-pt.		
	04-172/Roline	5.33	5.76
	TTI/19mm	13.04	3.82
Grade 3 Chip Seal	3209H/single-pt.	3.01	7.20
	3287G/single-pt.		
	04-172/Roline	3.22	6.80
	TTI/19mm	15.79	6.01

[5]Absolute difference not to exceed 6 inches/mile per TxDOT Test Method Tex-1001S
Positive difference indicates higher IRI from profiler relative to reference, and vice-versa

Table 42. Test Criteria Where Profilers Failed on Chip Seal Sections.

	Profiler/Laser	Test Criteria*			
		Profile Repeatability	IRI Repeatability	Profile Accuracy	IRI Accuracy
Inverted Prime	3209H/single-pt.	X	X	X	X
	04-172/Roline		X		
	TTI/19mm		X	X	X
Grade 3	3209H/single-pt.		X	X	X
	04-172/Roline		X		X
	TTI/19mm		X	X	X

*Cells marked with X identify criteria where profiler failed to meet specifications.

SUPPLEMENTAL MEASUREMENTS

TTI researchers also collected texture data with a 64 KHz texture laser and computed the mean profile depth (MPD) on each section of the new test tracks. In addition, TxDOT collected on-board sound intensity (OBSI) measurements. Table 43 summarizes the MPDs determined on each wheel path and the A-weighted noise levels from the OBSI measurements.

Table 43. Summary of Texture and Noise Measurements on New Test Tracks.

Section	Mean Profile Depth (mm)		A-weighted Noise Level (dBA)
	LWP	RWP	
1-inch Longitudinally Tined	0.591	0.575	101.2
½-inch Transversely Tined	1.961	1.918	101.4
1-inch Transversely Tined	1.848	1.795	103.1
Permeable Friction Course	3.055	2.045	103.1
Inverted Prime Chip Seal	1.686	1.908	103.5
Grade 3 Chip Seal	1.570	1.199	105.3

CHAPTER 6. SUMMARY OF FINDINGS AND RECOMMENDATIONS

This project aimed to build additional sections for certifying inertial profilers over a broader range of textured surfaces on which these profilers are used in practice. The project met this objective with the construction of two new test tracks. The new CRCP test track includes 1-inch longitudinally tined, ½-inch transversely tined, and 1-inch transversely tined sections, while the new flexible pavement test track consists of a permeable friction course, an inverted prime, and a Grade 3 chip seal section. After construction, researchers collected reference profile measurements on these sections, and tested a number of inertial profilers equipped with different lasers to verify the applicability of TxDOT's current profiler certification requirements on these pavement surfaces. The findings from these preliminary tests are summarized as follows:

- The reference profiles collected from three repeat runs on the CRCP and PFC-Chip Seal test tracks showed excellent repeatability.
- Only the Roline laser passed (i.e., met all Tex-1001S profiler certification requirements) on the 1-inch longitudinally tined CRCP section. Profilers equipped with single-point and 19mm lasers failed to meet Tex-1001S IRI repeatability and IRI accuracy requirements on this section.
- On the ½-inch and 1-inch transversely tined CRCP sections, the single-point and 19mm lasers met all of the existing Tex-1001S profiler certification requirements. However, the Roline laser, as configured, failed to meet the IRI accuracy tolerance specified in Tex-1001S. Researchers note that the Roline laser was oriented perpendicular to the direction of travel on all test runs, and the test data showed evidence that the ½-inch transverse tines affected the Roline measurements along the right wheel path.
- The preliminary assessment of a smoothing filter to reduce the effect of transverse tines on 19mm and single-point test profiles showed significant improvements in IRI accuracy when this filter is applied to the profile data collected on the CRCP transversely tined sections.
- The statistical analysis of single-point profiles collected at hourly intervals on the transversely tined CRCP sections showed no significant difference in the mean hourly IRIs at a 95 percent confidence level. The effect of temperature on CRCP profile measurements was not evident over the duration of the test.

- Two profilers—one equipped with single-point lasers and the other with Roline lasers—met Tex-1001S certification requirements on the PFC hot-mix section.
- On the chip seal sections, none of the profilers passed certification under Tex-1001S. All profilers failed IRI repeatability on these sections. Based on profile accuracy, only the Roline laser met the existing criteria on both chip seal sections. With respect to IRI accuracy, all lasers failed in one or both sections.

Given the above findings from the preliminary tests conducted in this project, the following recommendations are made:

- Researchers recommend additional tests at different Roline footprint orientation angles to determine the optimal setup that gives a better match with the reference data on both longitudinally tined and transversely tined surfaces. This evaluation should include examining the raw scan data for drop-offs at different orientation angles.
- Once the optimal Roline setup has been determined from tests performed on the CRCP track, researchers recommend verifying the applicability of using the same setup on the hot-mix test sections.
- Researchers also recommend further investigations to determine the applicability of using the smoothing filter on single-point and 19mm laser measurements collected on transversely tined concrete pavements. This effort should also include an analysis of PMIS ride data to assess the potential impact of using this filter on historical ride quality performance trends in the PMIS database.
- Researchers recommend further testing under different seasons or prevailing weather conditions to ascertain the effect of temperature on CRCP profile measurements. These tests are needed to determine when reference profile measurements should be collected to certify inertial profilers on the CRCP test sections.
- To recommend appropriate criteria and a test protocol for profiler certifications on the chip seal sections, additional tests are needed to determine why none of the profilers pass Tex-1001S certification requirements on these sections.

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