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16. Abstract

This report presents various edge failures, the methods used by districts to repair them, and the results of the repair. While there was no clear consensus on the best treatment of in-situ material for pavements with edge failures, the districts agreed that an up-front investigation should be conducted, samples should be obtained and tested, and widening the pavement contributes to a reduced risk of edge failure. Special treatments may be necessary when dealing with pavements that have no shoulders, steep front slopes, and/or subgrade soils of high plasticity.

Researchers found that geogrid reinforcement is beneficial to reducing longitudinal edge cracking, but will not totally eliminate edge cracking problems. Scarifying and reshaping the existing material with stabilization, combined with a flexible base overlay has shown good performance. Without a uniform cross section, simply widening the pavement can result in cracking problems at the longitudinal construction joint. This report also provides guidelines for repairing severe edge failures.

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DEVELOPING GUIDELINES FOR REPAIRING SEVERE EDGE FAILURES: TECHNICAL REPORT

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DISCLAIMER

This research was performed in cooperation with the Texas Department of Transportation (TxDOT) and the Federal Highway Administration (FHWA). The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of the FHWA or TxDOT. This report does not constitute a standard, specification, or regulation.

This report is not intended for construction, bidding, or permit purposes. The engineer in charge of the project was Tom Scullion, P.E. #62683.

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.

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CHAPTER 1: CURRENT EXPERIENCE ON REPAIRING EDGE FAILURES

This chapter documents key experiences from three TxDOT districts on repairing edge failures. These districts include Austin, Bryan, and Dallas; each district possesses significant experience with edge failures on pavements over soils with high plasticity index. While the Austin and Bryan Districts have obtained significant improvements using geogrid to reduce edge failures, the Dallas District reports less satisfaction with that approach. The Dallas District also has employed full-depth recycling using dual treatment of cement/asphalt emulsion with mixed results.

Although no clear consensus on the best treatment of in-situ material exists for pavements with edge failures, the information gathered does support consensus on the following items:

- A thorough up-front investigation using non-destructive tests such as ground-penetrating radar (GPR) and the falling weight deflectometer (FWD) should be conducted.
- Material samples should be obtained and tested in the laboratory.
- Special treatments may be necessary when dealing with pavements that have no shoulders, steep front slopes, and/or subgrade soils of high plasticity. These special treatments could include using geosynthetics between pavement layers, daylighting the base for better drainage, backfilling the pavement edge with compost to better stabilize the moisture content of the pavement layers, delaying placement of the final wearing surface, or using a final wearing surface designed for crack resistance.
- Widening the pavement contributes to a reduced risk of edge failures.

The remainder of this chapter presents more a detailed discussion of current practices and feedback from the Austin, Bryan, and Dallas Districts, and then concludes with other relevant information developed from TxDOT-sponsored activities.

AUSTIN DISTRICT

The Austin District's historical methods for treating edge failures include crack seals, level-ups, and full depth repairs. The district has also used some full depth reclamation (FDR) with stabilized layers and concluded such treatment cannot tolerate the large soil movements and oftentimes will crack over time, in some cases with more severity than the original condition. Therefore, in efforts to find better solutions, the Austin District began considering the following options:

- Take a flexible design approach, including techniques such as microcracking (when using cement treatment) to supply crack relief.
- Widen the pavement to add edge support and allow most movement (and any resultant distress) to occur in the shoulder.
- Use geosynthetics to provide reinforcement and separation to reduce crack propagation from the subgrade.
- Try to stabilize soil moisture fluctuations by using compost for backfill.

The Austin District recently completed two projects on SH 21 involving mitigation techniques for edge cracking. Figure 1 shows example cracking and steep front slopes typical of the SH 21 project. Figure 2 shows other pavements in the Austin District with severe edge failures.

Figure 1. Cracking and Steep Front Slopes on SH 21.

Figure 2. Edge Failures on Other Pavements in the Austin District.
Images courtesy of Mike Arellano.

Pavement Investigation and Planning

In the pavement investigation and design for the SH 21 projects, the district used site visits along with ground-penetrating radar for an initial project screening. Next, site testing including auguring and testing with the dynamic cone penetrometer (DCP) was used to confirm the pavement structure and check subgrade support and shoulder stability. After laboratory testing with the project materials to determine an FDR mixture design, typical sections were developed.

Typical Cross Sections of Completed Projects

Figure 3 presents the existing and proposed typical sections from the Austin District project on SH 21 from US 290 to FM 2440. Key elements from the plans included:

- Use of road-mixed cement treatment with a geogrid on top of the cement-treated layer.
- Placement of a flexible base course over the geogrid to provide additional protection from reflection cracks.
- Treatment of distress in the inside lines with full-depth pavement repair replacing with Type B mix.

These sections have been constructed. Figure 4 shows the geogrid placement on SH 21.

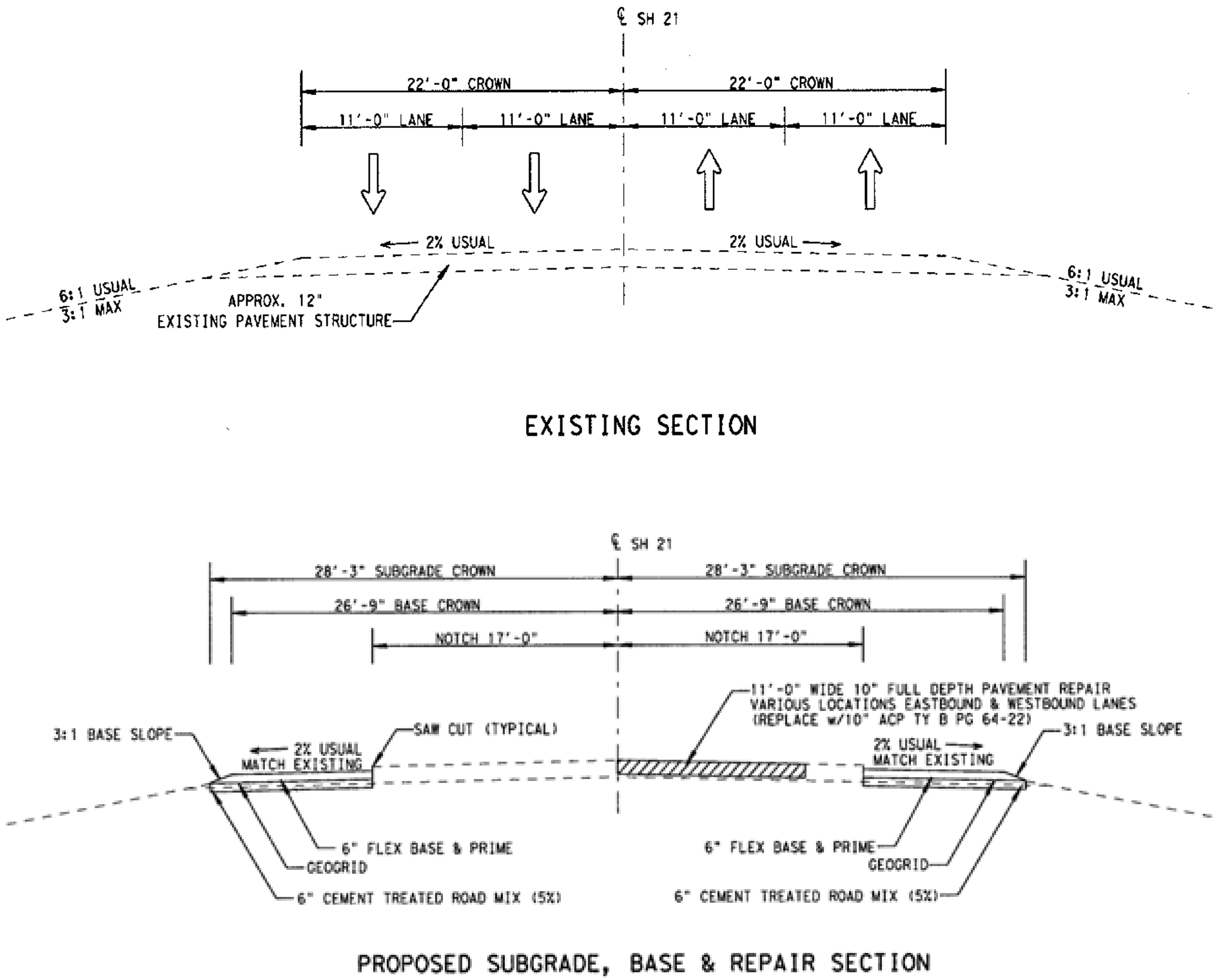

Figure 3. Existing and Proposed Sections on SH 21 from US 290 to FM 2440.

Figure 4. Geogrid Placement on SH 21.
Image Courtesy of Mike Arellano.

The Austin District also recently performed a project on SH 21 from US 290 to 0.8 mi east of FM 1441. The existing pavement had a lot of structure; however steep front slopes and soils with a plasticity index as high as 59 resulted in consistent maintenance requirements for cracking and roughness. Additionally, DCP profiles, illustrated in Figure 5, suggested a slip plane existed from about 24 to 28 inches from the pavement surface.

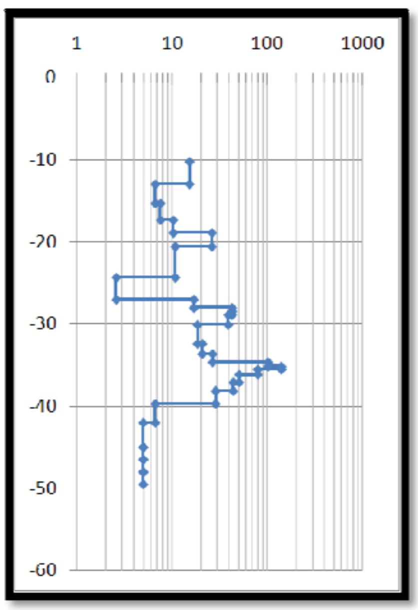

Figure 5. Slip Plane Evident in DCP Profile.

Figure 6 presents the typical existing section and the proposed double-geogrid section. Key elements from the plans included:

- The pavement would gain a 4 ft shoulder and the subgrade would be cut to a depth exceeding the depth of the weak zone observed in the DCP profiles.
- The widened pavement embankment included a mid-level geogrid.
- The cement treated base would be over a second geogrid; the plans also called for microcracking the cement treated base.
- The final surfacing would be a thin overlay mix designed using both the Hamburg and Overlay Test.

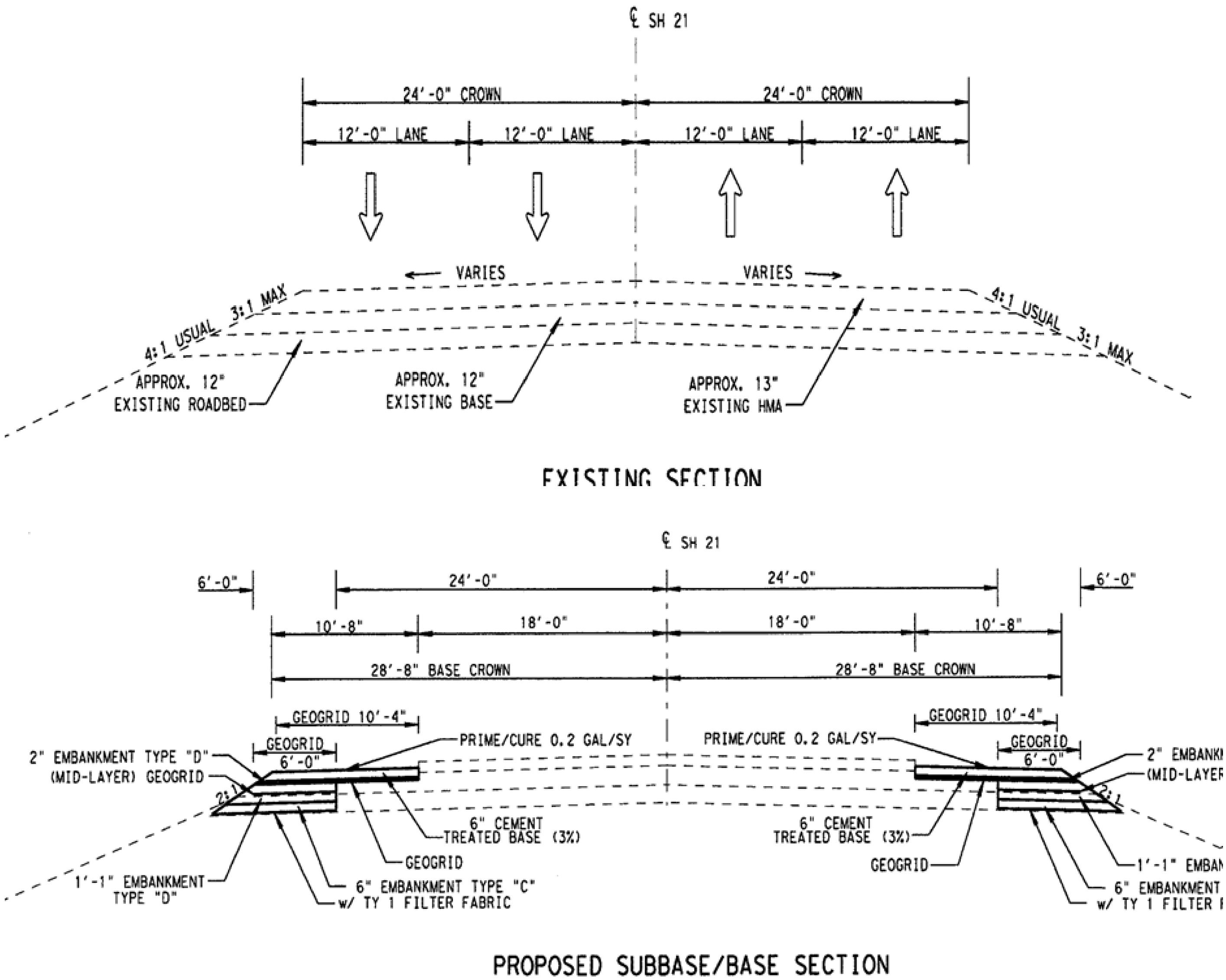

Figure 6. Existing and Proposed Double Geogrid Sections on SH 21.

BRYAN DISTRICT

The Bryan District has performed many miles of FDR generally in locations with high plasticity soils. The use of geogrids for reducing cracking due to highly plastic soils was first documented within TxDOT on projects in the Bryan District (*1*).

Pavement Investigation and Planning

With extensive project experience dealing with edge problems, the Bryan District's general testing and evaluation procedure includes:

- Perform non-destructive testing with GPR and the FWD to break the project into sections:
  - Use the online web soil survey to obtain initial estimates on subgrade properties for plasticity index, sulfate content, and soil organic matter.
  - Use the GPR to identify thickness variability, identify major problem areas, and select sampling locations.
  - Use the FWD to evaluate the strength variability and subgrade stiffness of the entire project.
- Verify the pavement structure and collect material samples:
  - Auger samples of the pavement for laboratory design tests.
  - Use the DCP to evaluate the strength of lower layers and the shoulder/front slope.

The goal of the Bryan District in treating pavements with edge failures is to identify the cause of the failure and select an appropriate strategy to address the root cause or at least minimize the chance or recurrent distress. The strategy often involves FDR with geogrid reinforcement, and the district makes a uniform pavement structure in the FDR process.

Typical Cross Sections of Completed Projects

Figure 7 illustrates a typical cross section for low volume roadway repair in the Bryan District. Based upon the soils tests, historical problem areas, and zones of weak subgrade detected in the FWD, the district will select limits of where to use geogrid reinforcement. The purpose of the geogrid is to minimize reflective cracking from the subgrade up through the pavement structure.

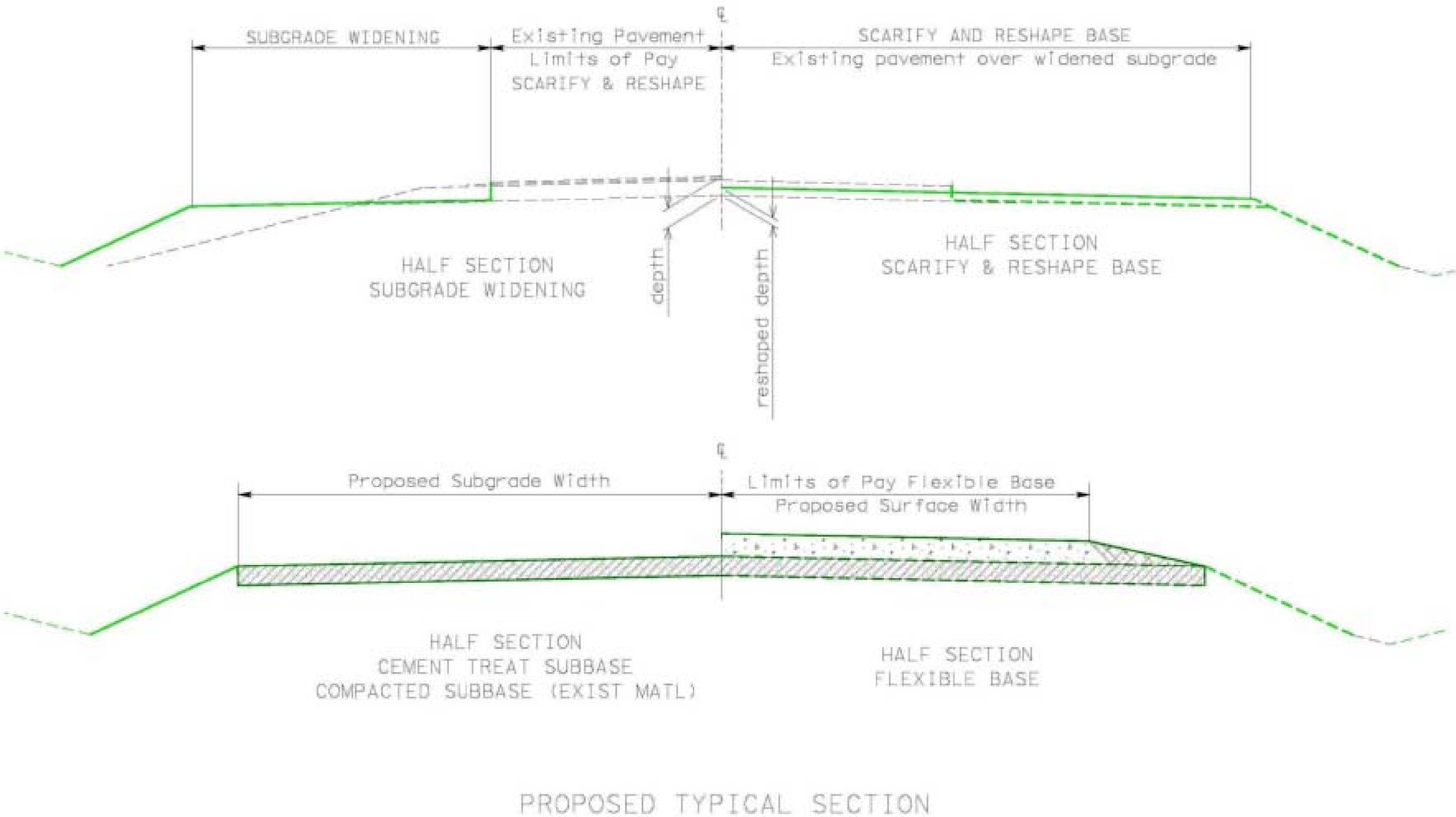

Figure 7. Typical Section for Low-Volume Roadway Repair in the Bryan District.

The first major test of using the FDR technique with geogrid reinforcement in the Bryan District occurred on FM 1915. Constructed in 1997, Figure 8 illustrates that in general the sections reinforced with the geogrid do not have as much cracking distress as the control sections.

Figure 8. FM 1915 Sections 5 and 16 Years after Repair.
Images Courtesy of Darlene Goehl.

The Bryan District also has one of the few well documented cases of edge repair of concrete pavement. The distress shown in Figure 9 occurred shortly after construction. The subgrade plasticity index ranged from 14 to 49. Figure 10 presents the typical existing section. Figure 11 presents the repair details, which used a continuously reinforced concrete pavement (CRCP) repair tied to the existing concrete pavement contraction design (CPCD). As Figure 12 illustrates, although the crack did recur, the crack severity is much less than before.

Figure 9. Edge Failure of Concrete Pavement.
Image Courtesy of Darlene Goehl.

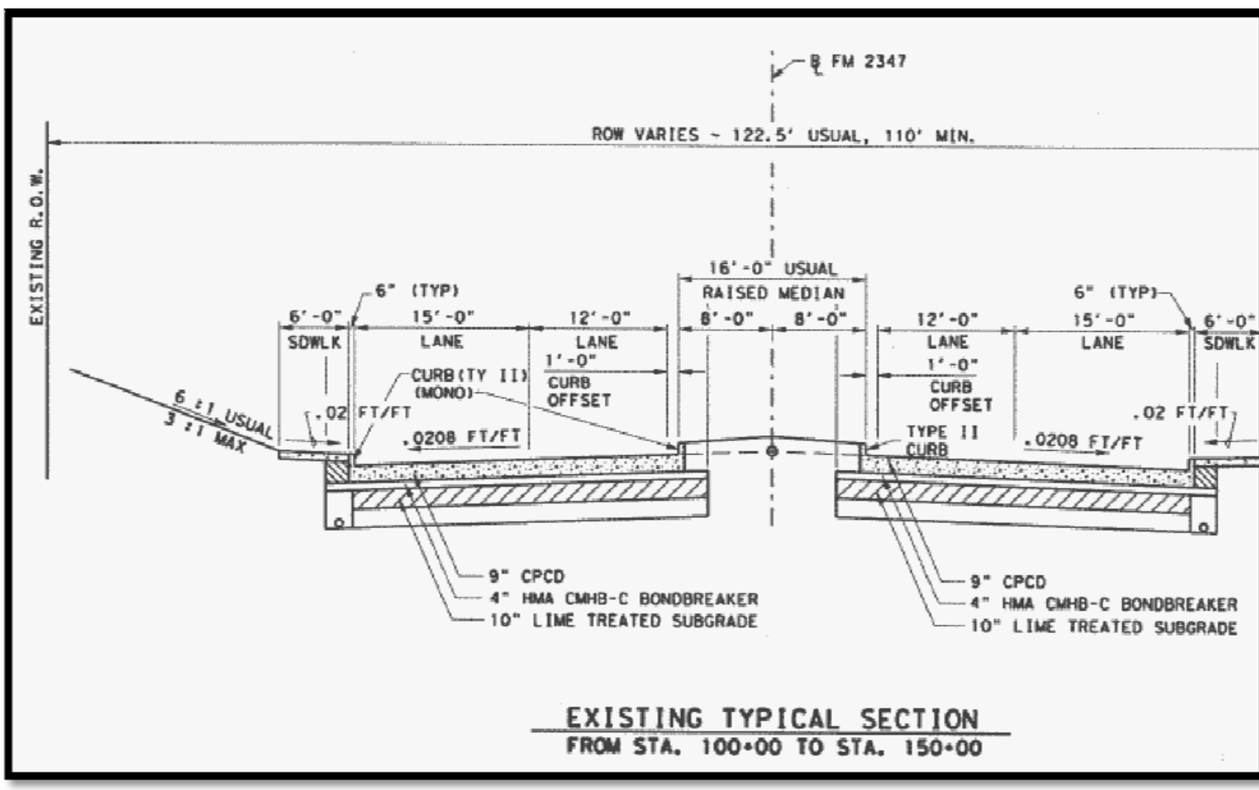

Figure 10. Typical Existing CPCD Section.

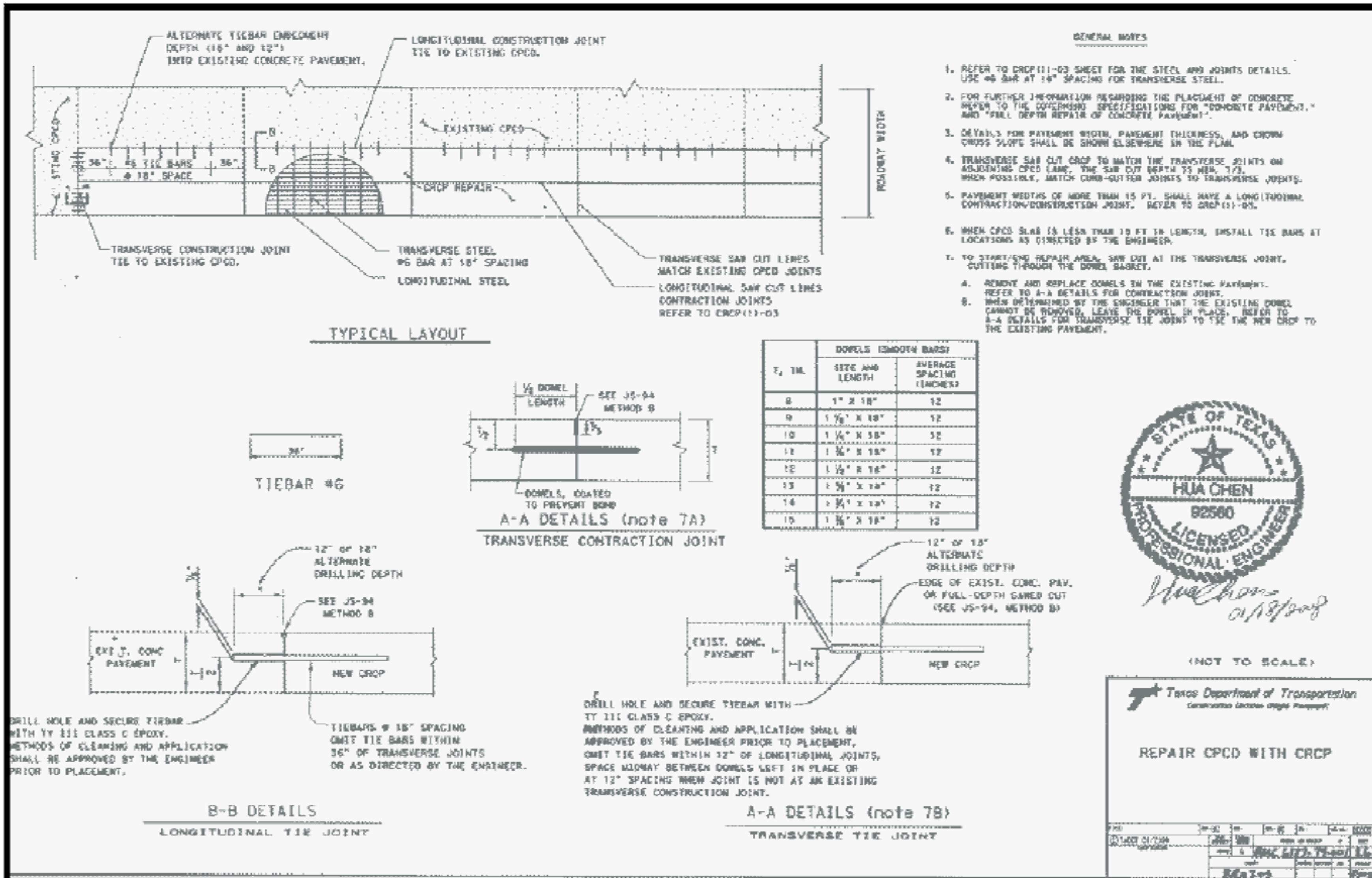

Figure 11. Details of Concrete Pavement Repair.

Figure 12. Concrete Pavement Edge Distress 7 Years after Repair.
Image Courtesy of Darlene Goehl.

DALLAS DISTRICT

Many FM roads over soils with high plasticity index exist in the Dallas District. Historically, distresses on such pavements have been treated with level-ups or thick HMA patches, and the edge failures generally recur in a short time frame. With a goal of minimizing edge failures and maintaining ride quality, the district has begun examining other repair approaches in recent years.

Pavement Investigation and Planning

Similar to the other districts, the Dallas District prefers to begin the pavement investigation with nondestructive testing such as GPR and FWD to screen the project and help select sample locations. Representative samples from sections identified are used in a laboratory mixture design, where the district has constructed sections using flexible base overlays, cement treatment, and dual treatment with cement and asphalt emulsion. Additionally, the district has constructed sections using a geogrid on top of the FDR mixture.

In the FDR mixture design, the recycled asphalt pavement (RAP) content is kept to 50 percent or less, and cement-treated mixtures targeted an unconfined compressive strength of 175 psi. The mixtures using dual treatment of cement with asphalt emulsion targeted an unconfined compressive strength of 150 psi.

Typical Cross Sections of Completed Projects

Figure 13 presents a typical cross section for projects in the Dallas District. Over the past years, the district has performed repairs on the following pavements:

- FM 549, FM 1827, FM 550, FM 148: FDR with geogrid and flex base overlay.
- FM 548, FM 740, FM 429: FDR with cement/emulsion and geogrid reinforcement.

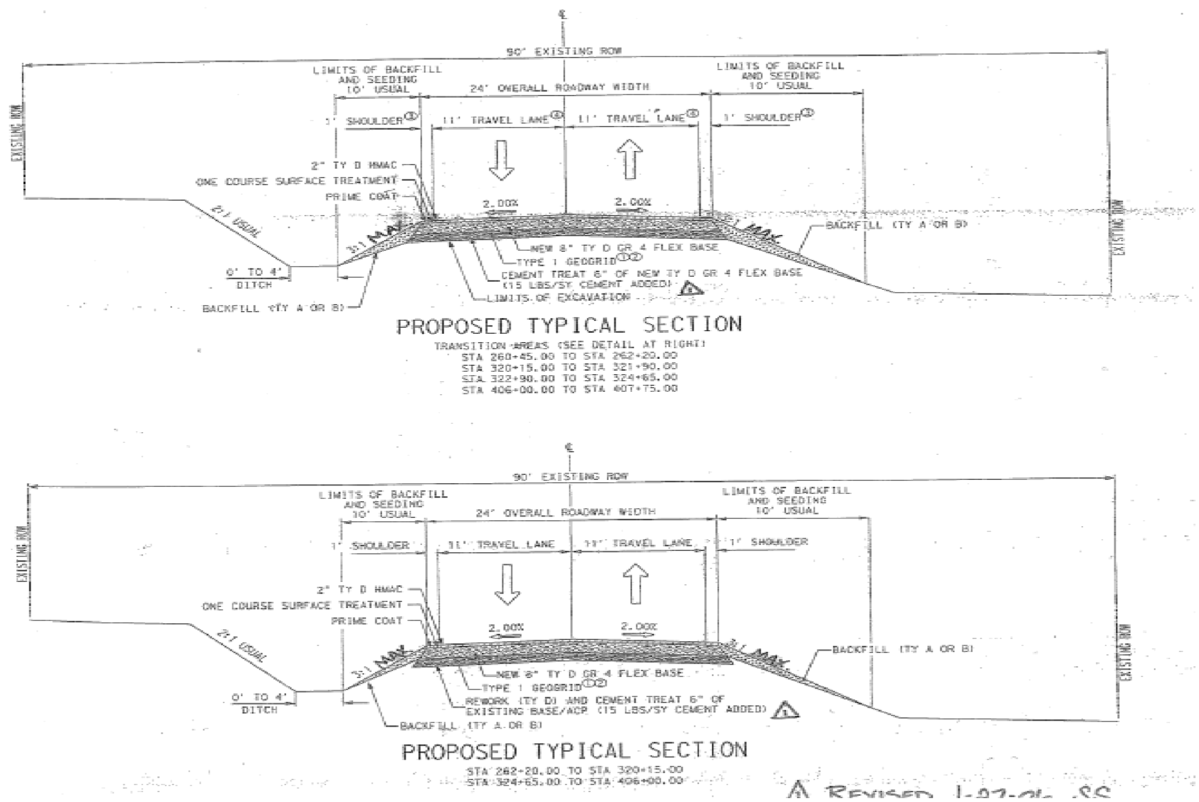

Figure 13. Typical Sections from Dallas District.

Figure 14 contrasts FM 549 and FM 1827, both after 3 years of service. While FM 549 has edge failures with roughness continuing to occur on the project, on FM 1827 the ride is still good although cracking has recurred.

Figure 14. FM 549 (Left) and FM 1827 (Right) after 3 Years of Service.

FM 550 and FM 148 both employed similar repair strategies. Figure 15 presents the repair sequence proposed for FM 148. Constructed in 2010, Figure 16 illustrates the constructed section tested met the structural design expectations.

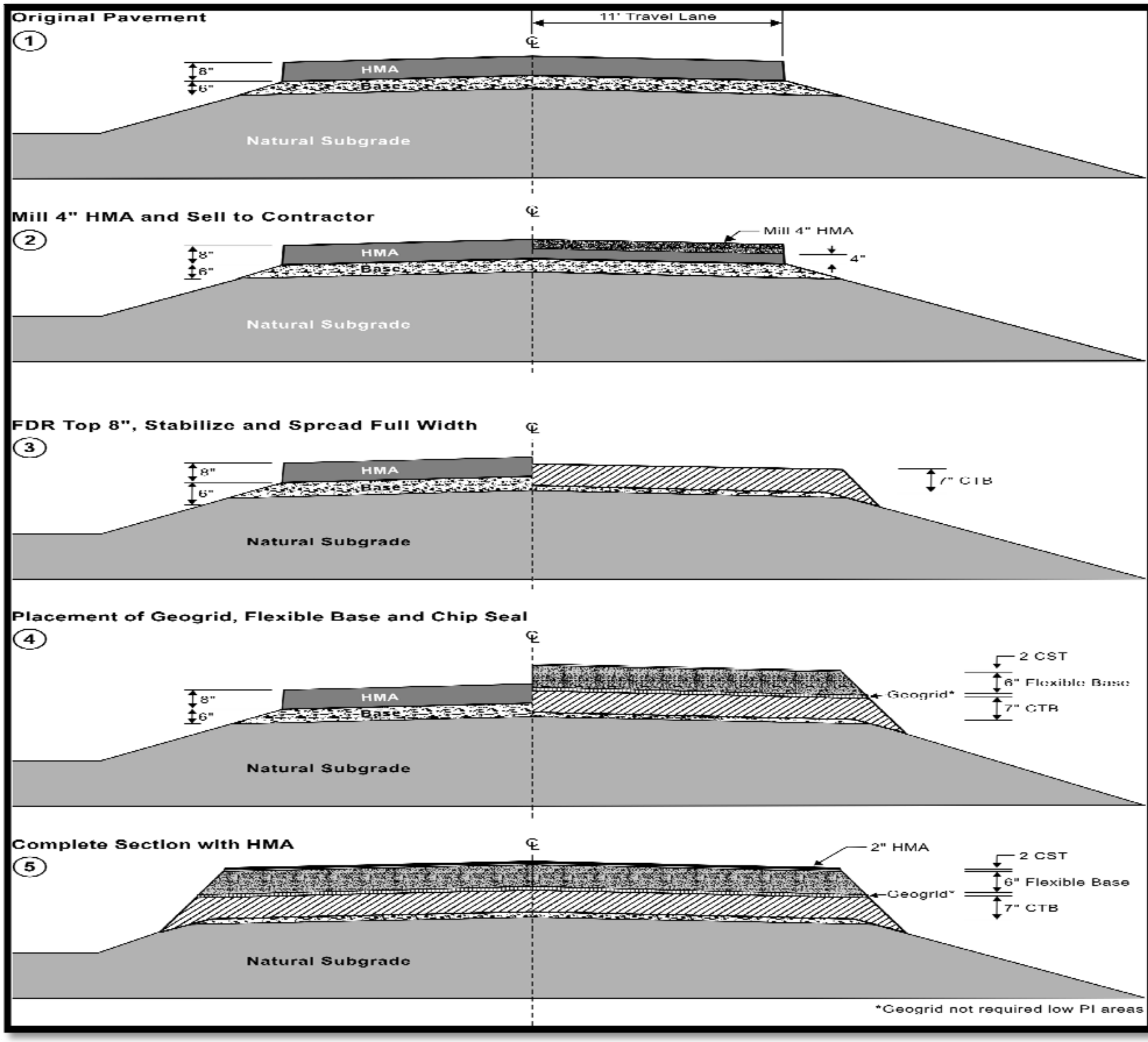

Figure 15. Repair Sequence for FM 148.

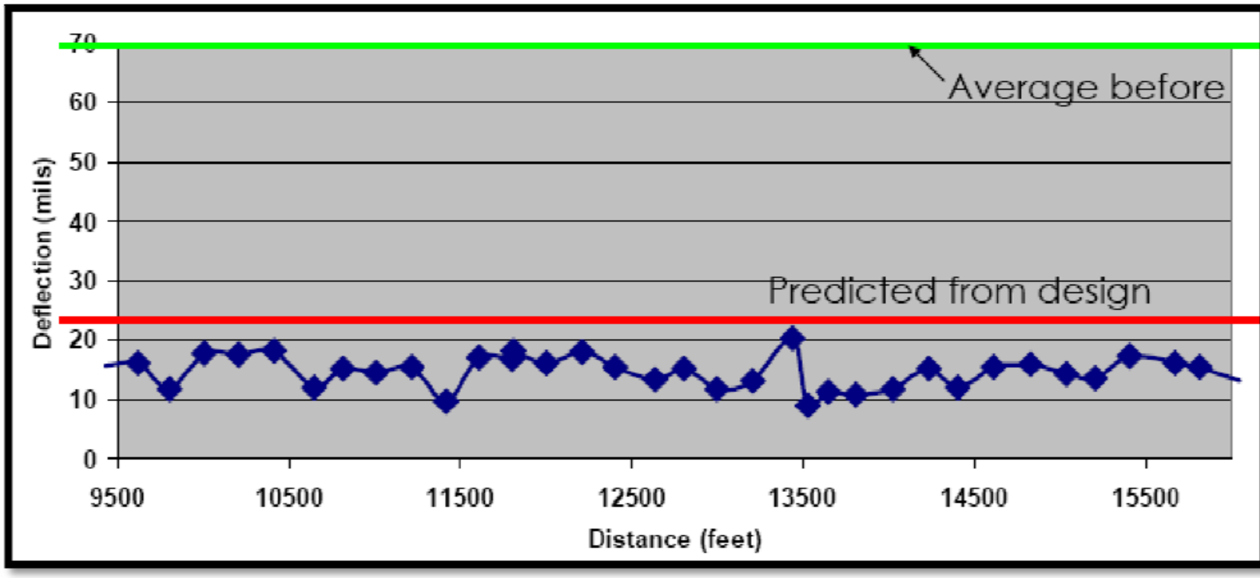

Figure 16. Post-Construction FWD Deflections on FM 148.

The Dallas District also constructed several projects where FDR employed dual treatment with cement and asphalt emulsion. The results were mixed, where on two projects, pavement distress recurred rapidly; on the third project, results were substantially improved. Figure 17 shows FM 429 and FM 548 after about 3 years of service, where distress has recurred on the former while the latter exhibited excellent overall condition.

Figure 17. Contrast of Performance on Projects with Cement/Asphalt Emulsion Treatment (L: FM 429; R: FM 548).

OTHER INFORMATION SOURCES

TxDOT Project 0-4573 (*2*) evaluated compost amendments to reduce shrinkage and pavement edge cracking. The work concluded that biosolids compost amendments could reduce shrinkage cracking of expansive soils and thus reduce pavement cracking and maintenance costs. The researchers also noted that biosolids compost amendments increase vegetation and could also potentially enhance landscaping.

Project 0-6589 (*3*) surveyed TxDOT districts where edge failures were largely attributed to plastic subgrades, a lack of pavement width, and environmental factors causing moisture fluctuations. About half of districts reported edge cracking recurred within one year after treatment. Project 0-6589 also surveyed six FM roads that had various treatments applied to address edge failures. The pavements included FM 1915, FM 2, FM 471, FM 734, FM 1293, and FM 787. From site visits and Pavement Management Information System (PMIS) data of these pavements, the researchers concluded the following regarding treatments for edge failures:

- Cement-treated bases showed the best performance.
- Geogrid reinforcement proved beneficial and its effectiveness increased when combined with subgrade stabilization.
- Overlay treatments showed adequate performance.
- Pavement widening showed great potential for improving performance.

Project 0-4396 (*4*) summarized TxDOT institutional knowledge for pavement edge maintenance. The primary cited cause of edge problems was the lack of shoulders, traffic type, and environmental conditions. Edge repair techniques reported included hand patching, reshaping shoulders, cutting edges, rebuilding edges, and road widening.

Project 0-4829 (*5*) characterized soil-geosynthetic interactions. From extensive testing, the project developed a test to characterize and compare the soil-geosynthetic interface using a stiffness parameter. The project also evaluated two field sections and concluded that the cracking performance of projects reinforced with geosynthetics was significantly better than the performance of the control.

CHAPTER 2: EXISTING PROJECT INFORMATION AND PERFORMANCE

This chapter documents the project information and current performance observations from FM 1712, FM 487, and FM 1600 in the Bryan District, and SH 21 in the Austin District. Additionally, the research team visited two county roads with known cracking problems. The existing project information and performance show the following:

- Geogrid reinforcement is beneficial to reducing longitudinal edge cracking. The use of geogrid reinforcement will not totally eliminate edge cracking problems.
- Scarifying and reshaping the existing material with stabilization, combined with a flexible base overlay, thus far is providing good performance where used on the pavements monitored in the Bryan District.
- Simply widening the pavement, without scarifying and reshaping the existing material to achieve a uniform cross section, can result in cracking problems at the longitudinal construction joint. Additionally, the cost increase to achieve a uniform cross section as opposed to simply performing a shoulder widening is generally minimal. Especially if cost competitive, full rehabilitation should be preferred over simply notching and repairing the edge.

FM 1712

Figure 18 presents the existing and proposed typical sections for FM 1712 from reference marker 406+1.604 to FM 487. The edge problems on this pavement were addressed by subgrade widening, scarifying, and reshaping the existing material followed by cement treatment to a depth of 8 inches, and then a 4 inch flexible base layer surfaced with a two course surface treatment. The Bryan District used Type D, Grade 2 flexible base for the new flexible base layer. Figure 19 shows representative images of the pavement's present condition. No distresses were observed.

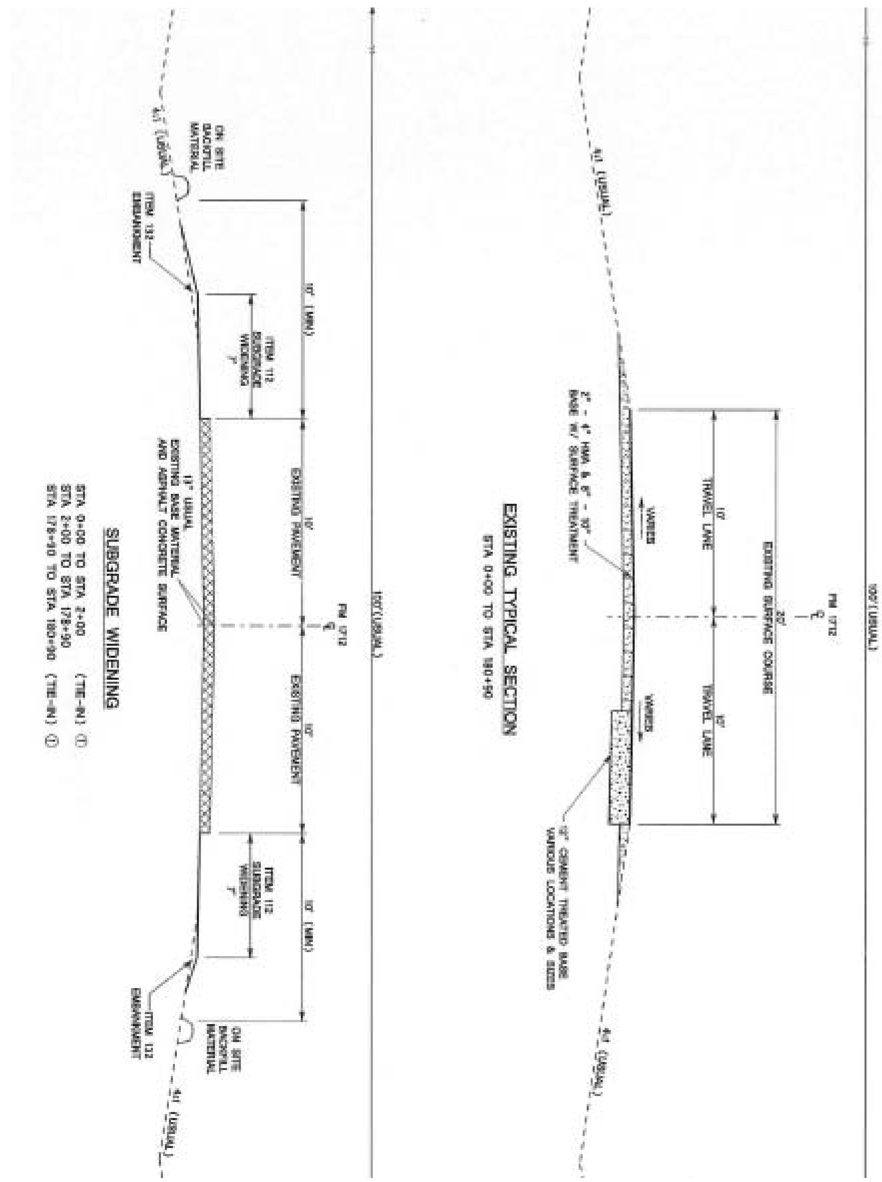

Figure 18. Existing and Proposed Sections for FM 1712.

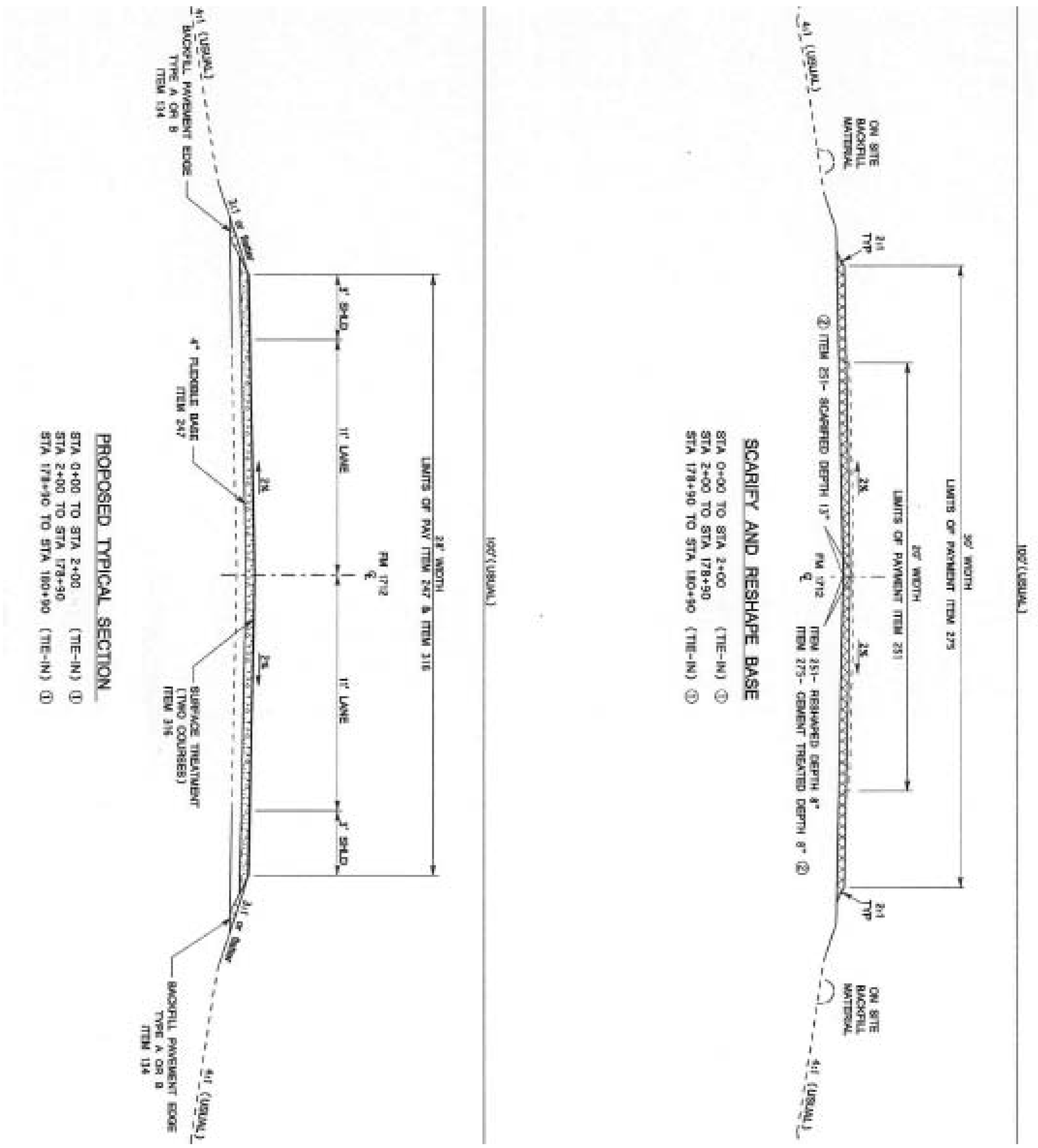

Figure 18. Existing and Proposed Sections for FM 1712 (Cont.).

Figure 19. Representative Condition of FM 1712.

Figure 19. Representative Condition of FM 1712 (Cont.).

FM 487

Figure 20 presents the existing and proposed typical sections for FM 487 from FM 1712 to reference marker 590+0.016. FM 487 was widened by adding shoulders alongside the existing pavement. The shoulders were constructed with Type D Grade 2 flexible base.

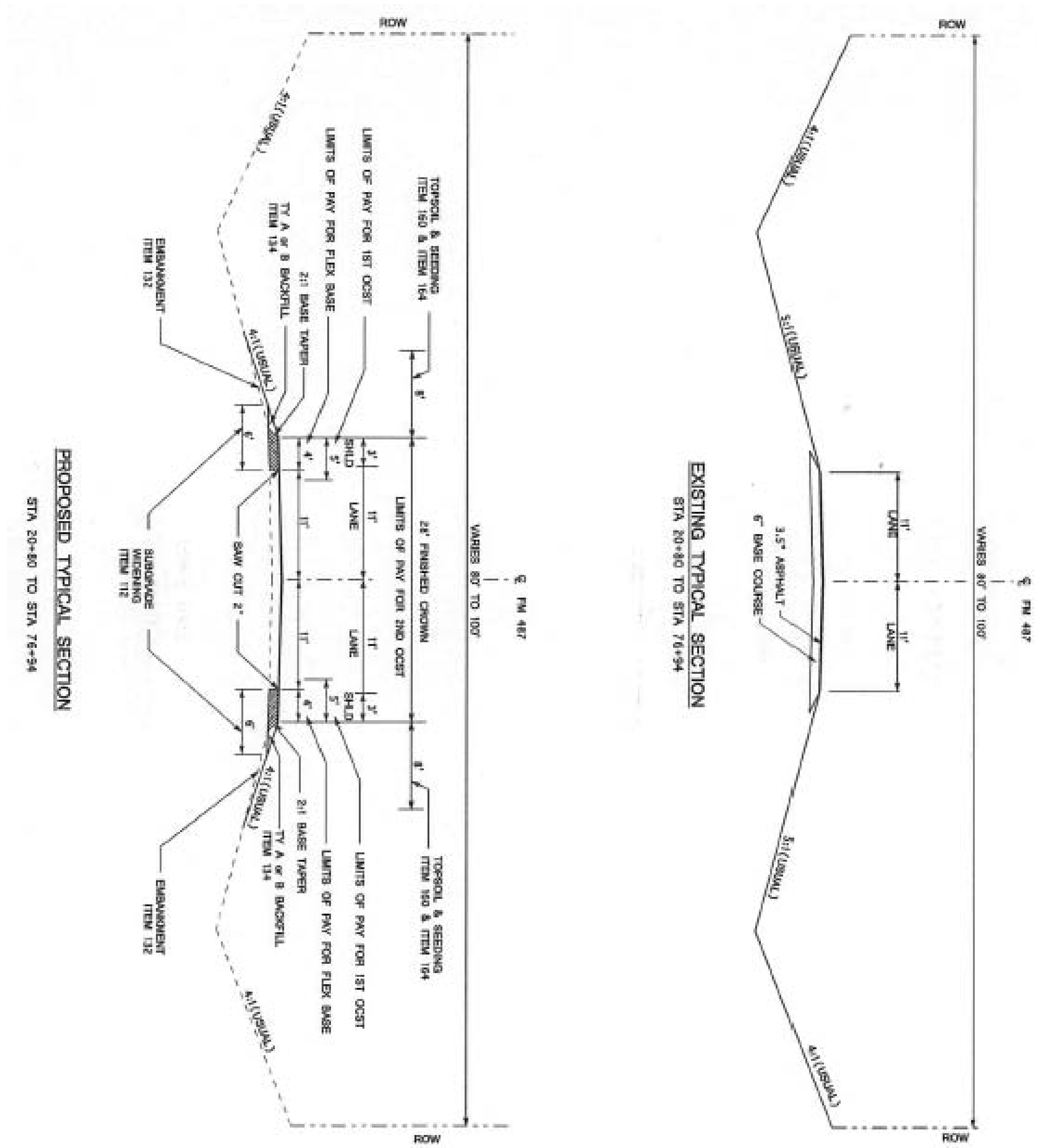

Figure 20. Existing and Proposed Sections for FM 487.

Figure 21 shows current conditions on FM 487. Problems exist at the longitudinal construction joint between the added shoulder and the existing pavement. In many locations a crack exists at the joint, resulting in pumping of fines and initiation of additional cracking in the vicinity. Several locations already exist where surface patches have been applied at the joint and shoulder.

Figure 21. Representative Condition of FM 487.

Figure 21. Representative Condition of FM 487 (Cont.).

Figure 21. Representative Condition of FM 487 (Cont.).

FM 1600

Figure 22 presents the existing and proposed typical sections for FM 1600 from reference marker 400+1.700 to reference marker 404+1.205. This section was widened by full depth recycling of the existing pavement and placement of new flexible base. Type D Grade 2 flexible base was used for the new 4 inch flexible base layer. Cement stabilization of the existing roadbed was performed to an 8 inch depth.

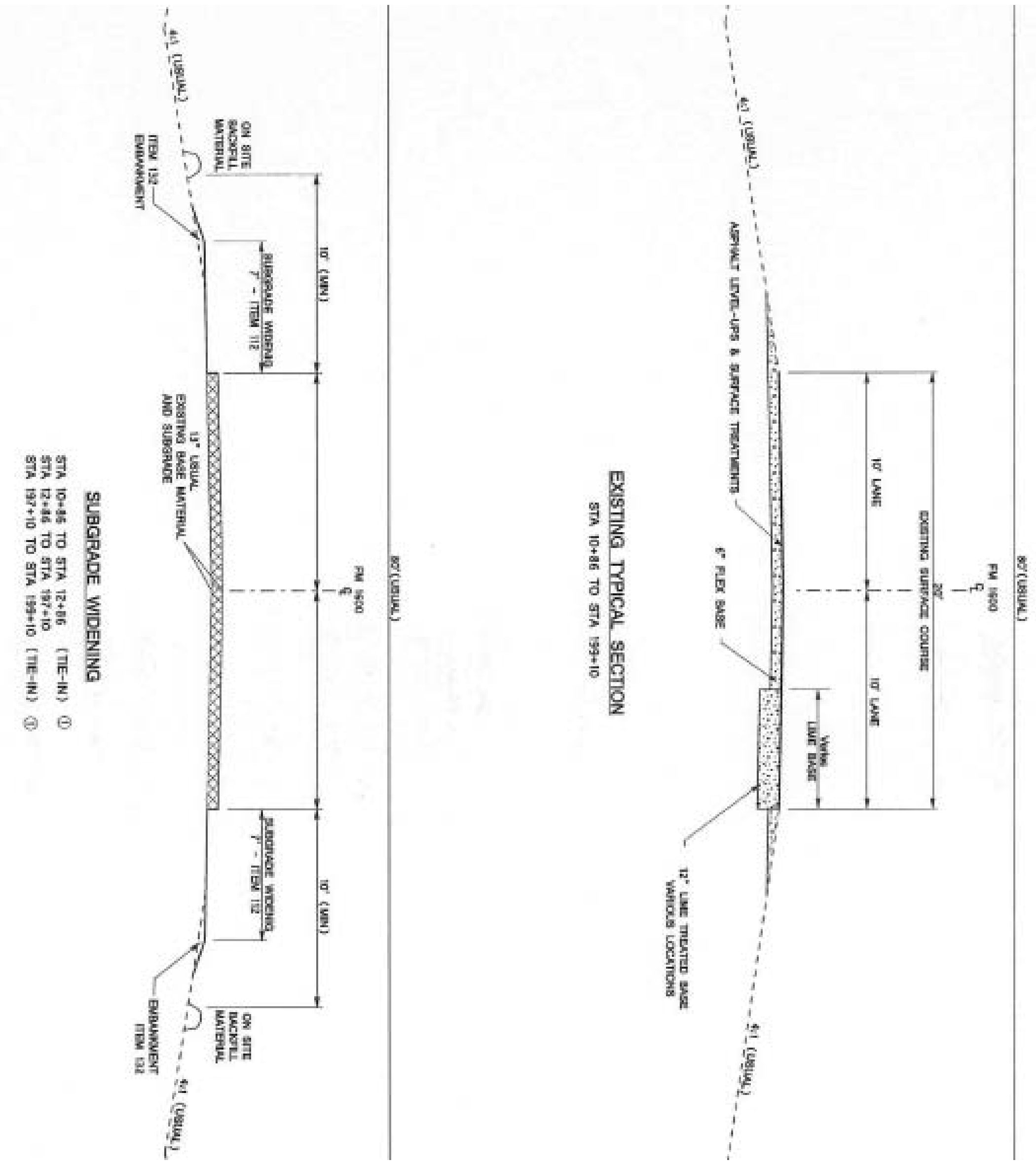

Figure 22. Existing and Proposed Sections for FM 1600.

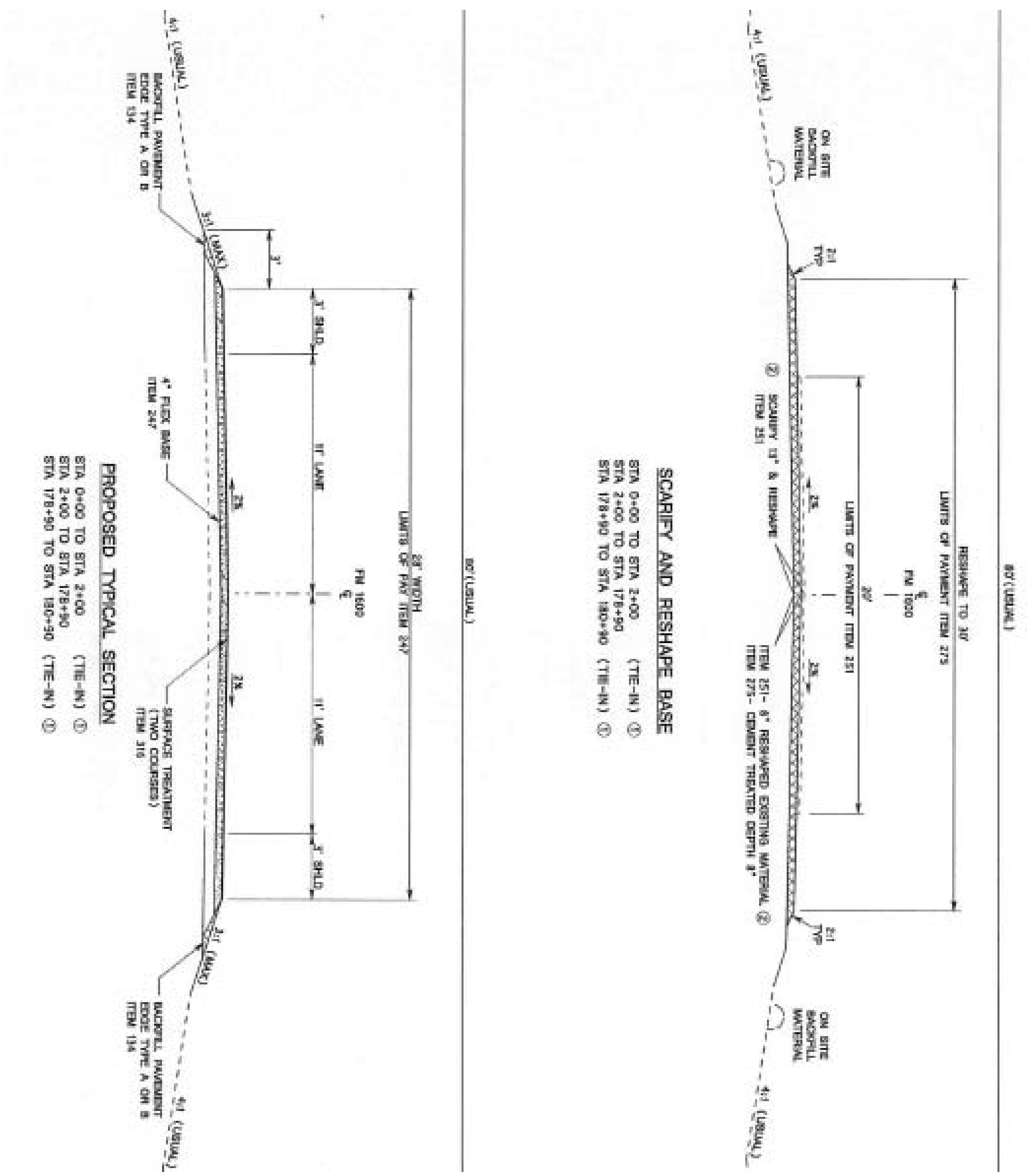

Figure 22. Existing and Proposed Sections for FM 1600 (Cont.).

Figure 23 shows the representative current condition of the majority of the project, which shows no distress. However, localized edge distress exists near reference marker 404. Figure 24 illustrates the edge failure, where steep front slopes exist and longitudinal cracking and settlement have occurred at the pavement edge.

Figure 23. Representative Condition on FM 1600.

Figure 24. Localized Edge Distress on FM 1600.

SH 21

Figure 25 presents the existing and proposed typical sections for SH 21 from US 290 to 0.8 mi. east of FM 1441. This pavement exhibited steep front slopes, poor ride, and indications of slope failures. The proposed section included two layers of geogrid reinforcement, and the cement-treated layer included microcracking and the Austin District's Item 275/276 notes. The Appendix presents those notes.

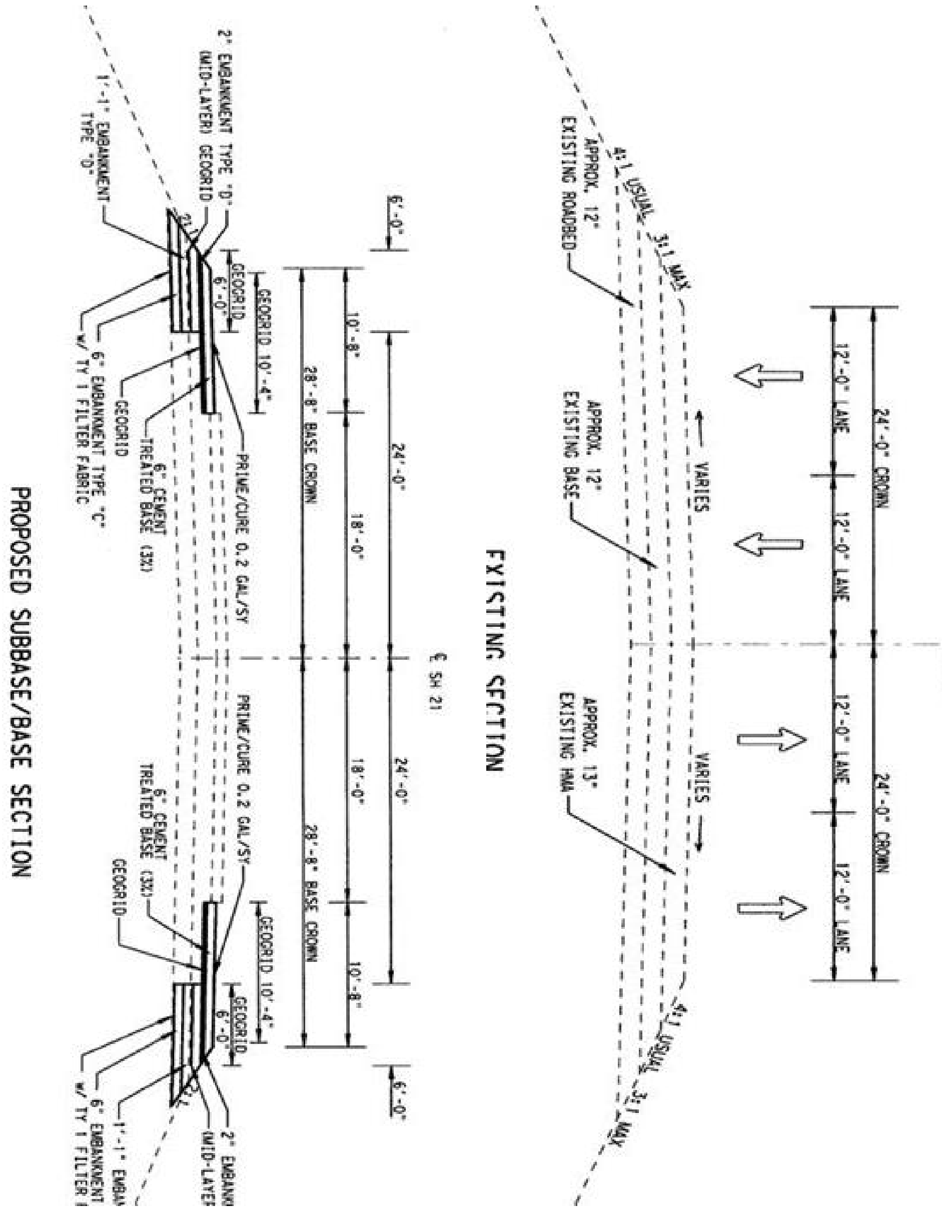

Figure 25. Existing and Proposed Sections for SH 21.

Currently, the section on SH 21 appears to be performing well with the exception of one crack shown in in Figure 26. Based on the distance of the crack from the pavement edge, it is uncertain whether the geogrid reinforcement extends under the pavement to the location of the crack.

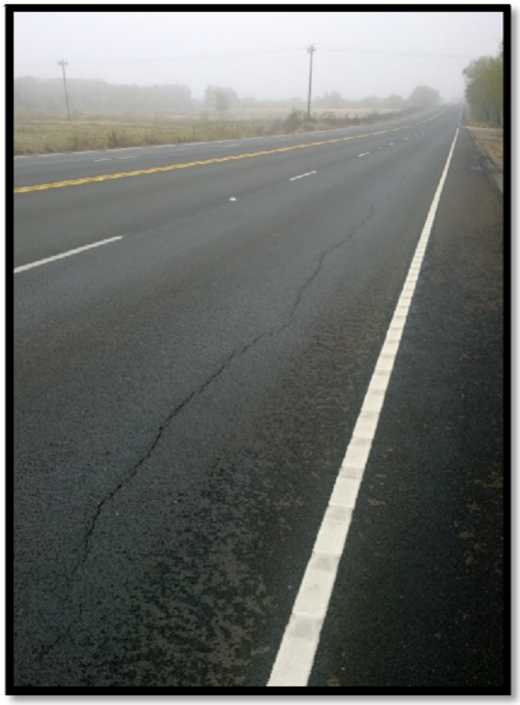

Figure 26. Longitudinal Crack on SH 21.

Benchley and Mumford County Roads

Brazos County officials recently embarked on trying geogrid reinforcement on problem county roads near Benchley, TX. Figure 27 shows construction of the geogrid section on Benchley Dr. in 2013. Figure 28 shows extensive cracking currently exists in the section without geogrid, while Figure 29 and Figure 30 show that the section with grid reinforcement has improved performance but is not totally crack free. The geogrid sections were constructed with a lime treated subgrade, geogrid, 6 inches of Grade 1 flex base, and then a two course surface treatment.

Figure 27. Construction of Geogrid Section on Benchley Dr.

Figure 28. Section on Benchley Dr. without Geogrid.

Figure 29. Representative Section on Benchley Dr. with Geogrid.

Figure 30. Longitudinal Crack Observed in Section on Benchley Dr. with Geogrid.

Figure 31 shows the current condition of Mumford Rd. reconstructed without geogrid in 2011. Substantial cracking exists, along with significant surface patching.

Figure 31. Current Condition of Mumford Rd.

Costs of Edge Widening versus Reconstruction

Visits to the Bryan District discussing treatment of edge failures revealed that pavement sections could be scarified and reshaped to achieve a uniform cross section for very similar costs as just notching and repairing or widening the edge. Figure 32 presents average costs that suggest that as long as surface treatments are the wearing surface, reconstruction is quite cost competitive. Based on results in the Bryan District, the field performance of sections suggests scarifying/reshaping/reconstructing the pavement to achieve a uniform section achieves better performance than notching and widening. These findings match observations in project 0-6748 (*6*), which stated:

> Some districts have found that the cost of constructing a full-depth reclamation of the entire roadbed is from 15 to 22 percent higher than constructing a narrow widening section on each side of the roadway. Though slightly more expensive, full-depth reclamation results in total rehabilitation of the roadway and eliminates the widening joint lines and potential variability in material stiffness and moisture contents, which improves construction quality and pavement performance.

The findings suggest that, especially if costs are competitive, full rehabilitation should be preferred over simply notching and repairing the edge.

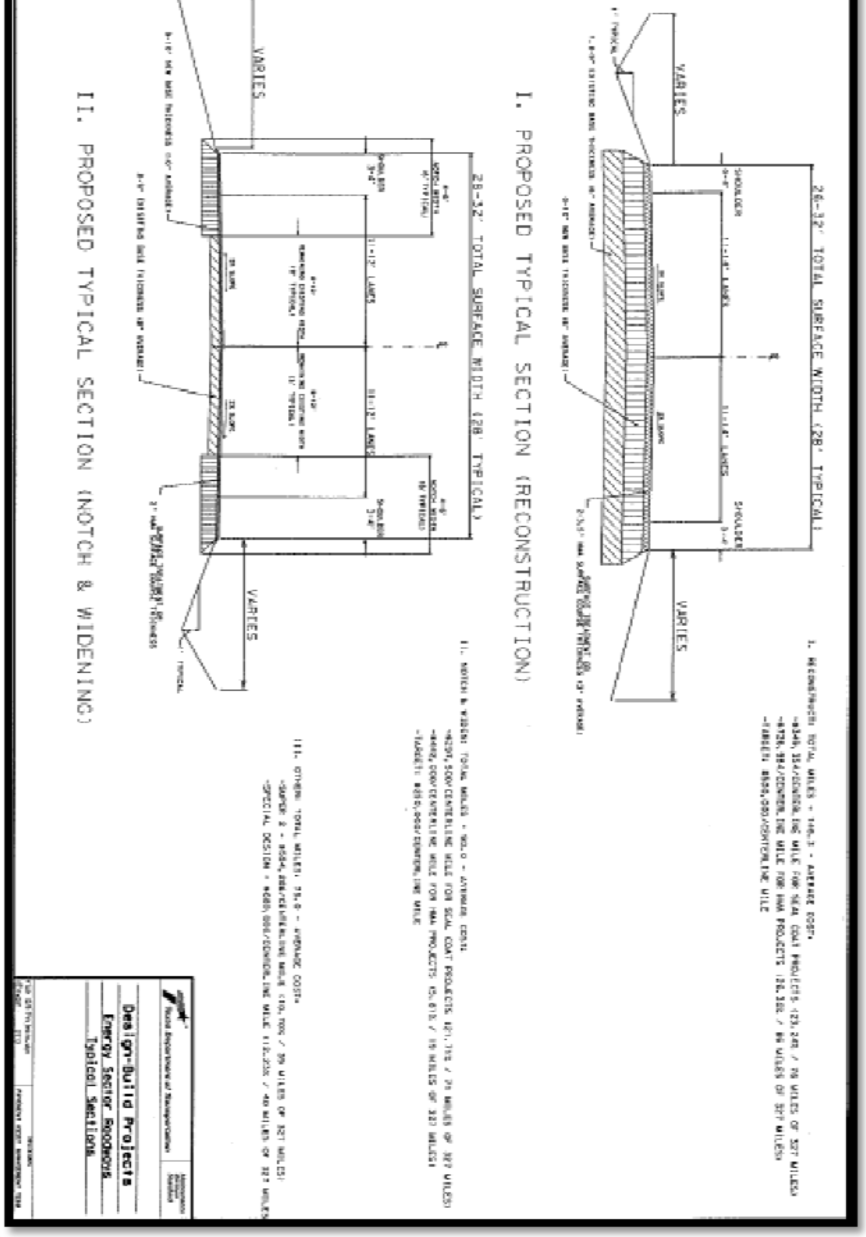

Figure 32. Statewide Summary of Rehabilitation versus Notch and Widening Costs.

CHAPTER 3: GUIDELINES FOR REPAIRING SEVERE EDGE FAILURES

GUIDELINES FOR REPAIRING SEVERE EDGE FAILURES

Based on the documented experience on repairing edge failures, and the existing project information, this chapter presents the recommended steps to evaluate and design repairs for pavements with edge failures. Key components of these steps include:

- A site visit and understanding of the project history.
- Characterizing the existing structure, obtaining roadway samples, and appropriate laboratory materials tests.
- Sound mixture and pavement design.

Step 1: Evaluate Project History

- Evaluate visually the current pavement condition including the types of distresses and likely causes of distresses. Typically the primary distress will be longitudinal cracking with or without faulting. Project specific issues could include:
  - Narrow pavement width.
  - Lack of edge support.
  - Steep front slopes.
  - Soils with high plasticity index, typically greater than 35.
  - Trees or other major vegetation close to the pavement edge.

  Other factors that could contribute to edge failures include abnormal climate conditions such as drought, superheavy loads, and sudden surges in traffic like in energy development-impacted areas.
- Obtain and review plans for preliminary information on the existing pavement structure.
- Use the Web Soil Survey at http://websoilsurvey.nrcs.usda.gov/app/ to review the subgrade soil types likely to be encountered.

Step 2: Characterize Existing Pavement Structure with NDT

If long sections of pavement are impacted by edge failures, perform non-destructive testing (NDT) to determine the pavement structure, identify section breaks, and select locations for focused pavement structure verification and material sampling:

- GPR should be conducted on all projects; FWD should be conducted if structural deficiencies are suspected or if measurement of the subgrade modulus is needed.
- Note existing drainage problems.
- Analyze the GPR and FWD surveys to identify section breaks in the existing pavement and determine the in-situ modulus values.

Step 3: Verify Pavement Structure and Obtain Material Samples

- If long sections of pavement were surveyed with NDT, use the NDT survey analysis as guidance to select focused verification and sampling locations.
  - In the absence of NDT analysis, perform a boring at intervals at most 0.5 mi. apart, and use soil survey maps and historical plans to select any additional focused boring locations.
- *Verification* locations should be selected at locations of non-typical GPR signature to verify the pavement structure and aid in interpreting the GPR signal. Verification locations are not used to generate materials for laboratory testing. Perform only one boring at verification locations and include the subgrade in the boring.
- *Sampling* locations should be selected from places with the typical pavement structure as based on GPR. Sampling locations serve to both verify the pavement structure and generate materials for laboratory testing. Multiple borings take place at sampling locations to generate sufficient quantities of materials for use in laboratory testing. At least one boring at sampling locations should go into the subgrade to fully validate the interpretation of the GPR signal at that location and enable collection of subgrade samples for laboratory testing.
- At each verification location perform the following:
  - Collect a DCP profile from within the pavement.
  - Move approximately 2 ft off the pavement edge and collect a DCP profile to a depth of interest as determined by the Engineer, which will typically be between 2 and 5 ft.
  - If sufficient hot mix asphalt (HMA) is present, collect a pavement core to verify the condition of the HMA.
  - Collect material samples to verify the pavement structure.
  - Collect subgrade soil samples for plasticity index, sulfates, and organic tests.
- At the sampling location(s) perform the following:
  - Collect a DCP profile.
  - Move approximately 2 ft off the pavement edge and collect a DCP profile to a depth of interest as determined by the Engineer, which will typically be between 2 and 5 ft.
  - If sufficient HMA is present, collect a pavement core to verify the condition of the HMA.
  - Collect material samples to verify the pavement structure down to the subgrade.
  - Collect subgrade soil samples for plasticity index, sulfates, and organic tests.
  - Use an auger to excavate existing materials that will be used in laboratory mixture design and maintain separate samples of RAP, flexible base, and subgrade.
    - Based on district preferences and availability of stabilization agents, most lab tests focus on a cement-based stabilization design. For this series of tests, the amount of material collected among all the sampling locations combined should be at least 15 five-gallon buckets of material.
    - An additional 10 five-gallon buckets of material is required to perform a laboratory emulsion-series with two different emulsion levels.
    - If lime or lime-fly ash treatment is being considered, an additional 5 five-gallon buckets of material is required for each level of lime or lime-fly ash treatment under consideration.

Step 4: Perform Mixture Design

If long sections of pavement exist with edge failures, a mixture design should be performed to determine the optimal method of using the in-situ materials:

- Use TxDOT's *Guidelines for Modification and Stabilization of Soils and Base for Use in Pavement Structures* to determine the appropriate additive for treatment. Availability and cost of additive can be determining factors but are secondary to performance.
- For laboratory testing, reconstitute RAP and base materials in proportions representative of field conditions. However, limit RAP to no more than approximately 50 percent of the mixture for design purposes.
    - If substantial particle breakdown is suspected beyond that produced in the field sampling program, consider increasing the amount of fine sands (passing the #40 and retained on the #200) in the reconstituted laboratory mixture 10 percent and decreasing the amount of coarse aggregate in the reconstituted laboratory mixture by 10 percent.
- Perform Tex-117-E strength tests if considering options with no stabilization.
- For stabilization options, use appropriate TxDOT Test Procedures to select the optimum stabilizer contents.
    - Cement treatment is the most commonly investigated option. Cement content is based on the demonstrated strength and durability characteristics and includes satisfying the following criteria in Table 1.

Table 1. Laboratory Requirements for Cement Treatment.

Test	Spec Limits
Unconfined Compressive Strength (psi) (Tex-120-E)	175 min*
Retained Strength after Moisture Conditioning (Tex-120-E, 10 day capillary soak)	80% of 7-day Unconfined Compressive Strength

*Some Districts reduce this requirement to 150 psi.

- Emulsion treatment, with or without a small percentage of cement, has become a somewhat popular option to provide increased strength while retaining some flexibility. Table 2 presents the recommended criteria for emulsion treatment, which primarily follow Wirtgen-recommended design procedures.

Table 2. Recommended Laboratory Requirements for Emulsion Treatment.

Property	Test Procedure	Criteria
Min Indirect Tensile strength[1]	Tex 226-F	45 psi
Strain at Break in IDT	Tex 226-F	Report
Min (wet) IDT[2]	Tex 226-F	30 psi
Tensile Strength Ratio		70%[4]
Min Unconfined Compressive Strength[3]	Tex 117-E, Part II	Report

1) Average of three specimens air dried overnight then oven dried at 104°F for 3 days.
2) Average of three specimens 24 hours under water.
3) Average of three specimens subjected to 10 days capillary moisture absorption before conducting UCS.
4) Average rainfall < 20 in./yr: > 50%.
   Average rainfall 20–40 in./yr: > 60%.
   Average rainfall > 40 in./yr: > 70%.

- o Fly ash and lime-fly ash are used in some districts for stabilization. Table 3 shows the lab requirements for these mixtures.

Table 3. Laboratory Requirements for Fly Ash and Lime-Fly Ash Treatment.

Test	Spec Limits
Unconfined Compressive Strength (psi)* (Tex-127-E)	150 min as subbase; Similar to cement treatment for base course
Unconfined Compressive Strength (psi)**	200 psi

*After conditioning per Tex-127-E over 17 days.
**After 6 days benchtop curing per project 0-5223 recommendations; not currently in TxDOT practice.

- o Lime-treated mixtures can be appropriate for materials of elevated plasticity index and are tested in accordance with Tex-121-E. Table 4 shows the strength requirements for lime treatment.

Table 4. Laboratory Requirements for Lime Treatment.

Test	Spec Limits
Unconfined Compressive Strength (psi) (Tex-121-E Part I)*	50 psi min as subbase; 150 psi for final course of base construction

*After conditioning per Tex-121-E over 17 days.

Step 5: Perform Pavement Design

Performance data suggest edge failures should be treated by scarification and reshaping of the entire lane width to achieve a uniform pavement cross section, because simply notching and repairing the edge can result in premature distress at the longitudinal construction joint:

- Use the materials' properties measured in the lab and the traffic information in FPS 19W to perform pavement design and economic evaluations. Perform the Texas Triaxial design check in FPS to make sure the design adequately protects the subgrade.
- Include in the design recommendations any additional considerations:
  - If possible, narrow pavements should be widened to a minimum of 28 ft.
  - If using cement-treated base, consider incorporating microcracking to reduce shrinkage cracking the treated base.
  - For sections with project-specific issues such as high plasticity index subgrades, steep front slopes, or trees close to the pavement edge, consider using geogrid reinforcement with a flexible base overlay to reduce the risk of future edge cracking.
  - Specialized materials such as low-fines bases or surface mixes designed with the Overlay Test can also be included to reduce the risk of recurring problems.

Figure 33 shows a typical section not including geogrid, while Figure 34 presents a typical section including geogrid.

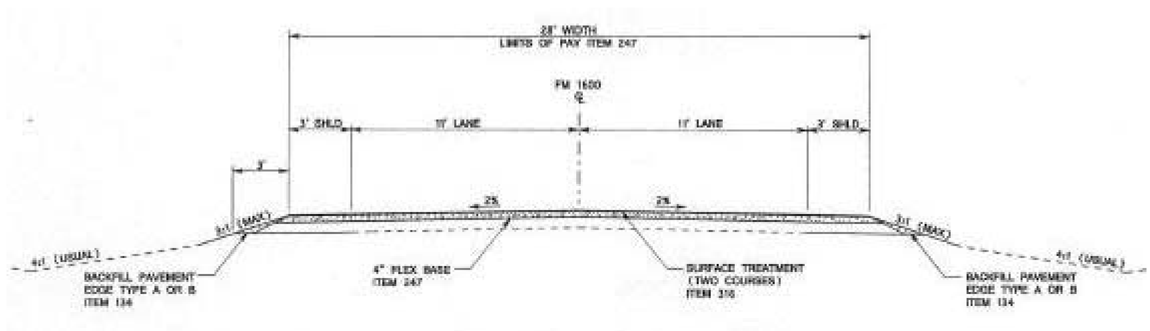

Figure 33. Typical Section Not Including Geogrid.

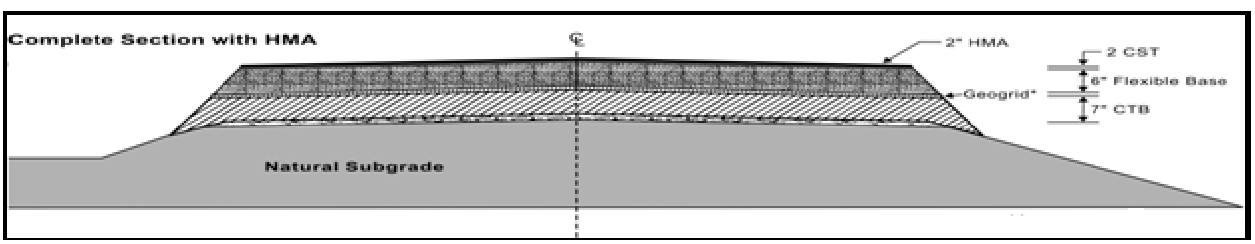

Figure 34. Typical Section Including Geogrid.

APPENDIX. AUSTIN DISTRICT ITEM 275/276 NOTES

ITEM 275 – CEMENT TREATMENT (ROAD-MIXED)

The Engineer will designate a target cement content and optimum moisture content necessary to produce a stabilized mixture that meets the strength requirements and moisture susceptibility requirements shown in Table 5. The Contractor shall furnish the Engineer with representative samples of cement to be used in production of the cement treated base.

If the existing asphalt pavement materials are reclaimed and incorporated into the road-mix to be cement treated, no more than 50 percent RAP can be incorporated into the road-mix. Do not incorporate underlying subgrade, unless approved otherwise. If the road-mix material is contaminated with subgrade, the road-mix must be removed and replaced with a suitable material, as approved by the Engineer.

Table 5. Requirements for Cement Treatment (Item 275).

Description	**Minimum**	**Maximum**
Cement Content (by dry weight of base)	2%	5%
	Test Method	**Requirement**
7-Day Unconfined Compressive Strength (min.)[1]	Tex-120-E, Part I	150 psi
Retained Strength after Moisture Conditioning (min.)	Tex-120-E, Part I (10 day capillary soak)	80% of 7-Day Unconfined Compressive Strength

1. Meet the unconfined compressive strength after addition of stabilizer.

Final compaction must be obtained within 2 hours after water is incorporated into the cement/road-mix material.

(Blind Note: Use the following notes when microcracking is implemented.)

Once final compaction is obtained, wet cure the finished cement treated base for a period of 24 to 48 hours. During this time, but not sooner than 24 hours, roll the finished course with a vibratory roller to induce microcracking.

Roll with a TY C vibratory roller with a static weight equal to or more than 12 tons. The vibratory drum will not be less than 20 inches wide. Roll at a speed of 2 mph, vibrating at maximum amplitude, and make 2 to 4 passes with 100 percent coverage exclusive of the outside 1 ft of the surface crown, unless otherwise directed by the Engineer. Additional passes may be required to achieve the desired crack pattern as directed by the Engineer. The Contractor shall notify the District Laboratory 72 hours before the microcracking begins.

After completion of the microcracking, wet cure the section for a period of 48 hours, unless approved otherwise. Wet cure in accordance to Item 276.4.E. "Curing."

ITEM 276 – CEMENT TREATMENT (PLANT-MIXED) (FLEXIBLE PAVEMENT)

Furnish Class N Cement Treated Base

The Engineer will designate a target cement content and optimum moisture content necessary to produce a stabilized mixture that meets the strength requirements and moisture susceptibility requirements shown in Table 6. The Contractor shall furnish the Engineer with representative samples of the materials to be used in production of the cement treated base.

Table 6. Requirements for Cement Treatment (Item 276).

Description	Minimum	Maximum
Cement Content (by dry weight of base)	2%	5%
	Test Method	**Requirement**
7-Day Unconfined Compressive Strength (min.)[1]	Tex-120-E, Part I	200 psi (Flexible Pavement) 450 psi (Rigid Pavement)
Retained Strength after Moisture Conditioning (min.)	Tex-120-E, Part I (10 day capillary soak)	100% of 7-Day Unconfined Compressive Strength
Expansion[2]	ASTM C 1567	0.10% (maximum)

1. Meet the unconfined compressive strength after addition of stabilizer.
2. Required when using crushed concrete or other material that contains cement. Provide the certified test report signed and sealed by a licensed professional engineer. This may be waived by the Engineer when the material has a known performance history based on previous ASTM C 1567 or ASTM C 1260 tests.

If the cement treated base fails these requirements, a different flexible base source will be required. The Engineer may accept a mixture design from the Contractor that is performed in accordance with Test Method Tex-120-E, Part I and meets the moisture susceptibility requirement shown above.

Final compaction must be obtained within 2 hours after water is incorporated into the cement/road-mix material.

(Blind Note: Use the following notes when microcracking is implemented.)

Once final compaction is obtained, wet cure the finished cement treated base for a period of 24 to 48 hours. During this time, but not sooner than 24 hours, roll the finished course with a vibratory roller to induce microcracking.

Roll with a TY C vibratory roller with a static weight equal to or more than 12 tons. The vibratory drum will not be less than 20 inches wide. Roll at a speed of 2 mph, vibrating at maximum amplitude, and make 2 to 4 passes with 100 percent coverage exclusive of the outside 1 ft of the surface crown, unless otherwise directed by the Engineer. Additional passes may be required to achieve the desired crack pattern as directed by the Engineer. The Contractor shall notify the District Laboratory 72 hours before the microcracking begins.

After completion of the microcracking, wet cure the section for a period of 48 hours, unless approved otherwise. Wet cure in accordance to Item 276.4.E. “Curing.”

REFERENCES

1 Scullion, T. and Syed, I. "In-Place Engineering Properties of Recycled and Stabilized Pavement Layers." Texas Transportation Institute, College Station, TX, December 1998.

2 Puppala, A., Intharasombat, N., and Qasim, S. "The Effects of Using Compost as a Preventive Measure to Mitigate Shoulder Cracking: Laboratory and Field Studies." Technical Report 0-4573-2, The University of Texas at Arlington, Arlington, TX, October 2004.

3 Dessouky, S., Oh, J., Yang, M, Ilias, M., Lee, S., Freeman, T., Bourland, M., and Mien, J. "Pavement Repair Strategies for Selected Distresses in FM Roadways. " Report FHWA/TX-11/0-6589-1. The University of Texas at San Antonio, San Antonio, TX, June 2012.

4 Lawson, W.D. and Hossain, S. "Best Practices for Pavement Edge Maintenance." PSR 0-4396-S, Center for Multidisciplinary Research in Transportation, Texas Tech University, Lubbock, TX, May 2004.

5 Zornberg, J.G., Ferreira, J.A., and Roodi, G.H. "Geosynthetic-Reinforced Unbound Base Courses: Quantification of the Reinforcement Benefits." Report FHWA/TX-13/5-4829-01-2. Center for Transportation Research, The University of Texas at Austin, Austin, TX, August 2013.

6 Burton, M., Smit, A., Trevino, M., Prozzi, J., and Murphy, M. "Best Practices for Flexible Pavement Structure Widening: Workshops. " Product 0-6748-P2, Center for Transportation Research, The University of Texas at Austin, Austin, TX, July 2013.