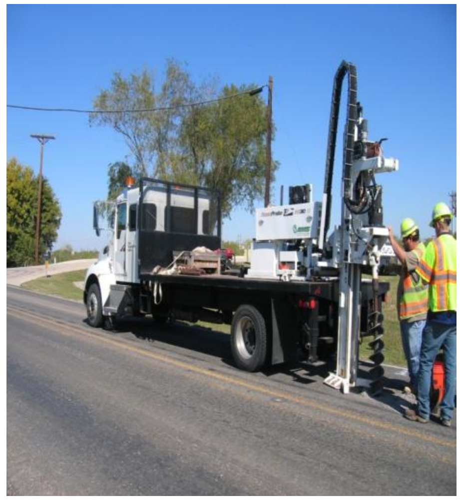


Full Depth Reclamation

Workshop Materials Study 0-6271-P2

PowerPoint Slides

FULL DEPTH RECLAMATION

Workshop Materials

PowerPoint Slides

By

Tom Scullion

Stephen Sebesta

Cindy Estakhri

Texas Transportation Institute

(979) 845-9913

t-scullion@tamu.edu

SECTION 1

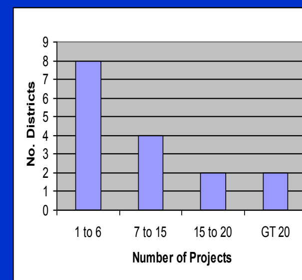
Full Depth Reclamation Workshop Materials
Study 0-6271-P2

Chapter 1 Introduction to FDR

Tom Scullion TTI

Full Depth Recycling in Texas

- 16 Districts used FDR
- Performance
  - 2/16 Excellent
  - 10/16 Good
  - 4/16 Fair/Poor
- Problems Exist
- Many Districts have limited experience



Objectives of Project 6271

- Develop Guidelines on
  - Project Evaluation and Design
  - Formulating a mix design
  - Controlling the construction process
  - Performing quality assurance
  - Bonding of the surface

    has led to construction delays and poor performance
- Implementation of best practices through
  - Workshops
  - Modified specifications or control procedures

Critical Steps in the FDR Process

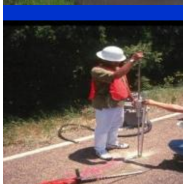
1. **Assembling Background Information**
2. **NDT Evaluation and Section Breakdown**
3. **Verifying Pavement Structure and Sampling**
4. **Laboratory Mix Design**
5. **Pavement Design**
6. **Special Considerations**
   1. **Use of Geogrids**
   2. **Ensuring Surface bonding**
   3. **Microcracking**
7. **Construction Quality Assurance**
8. **Feedback - addressing Performance problems**

Pavement Evaluation Tools

1) GPR thickness variability; identify major problem areas; sampling locations

2) DCP in-site strengths of lower layers

3) FWD Strength variability; subgrade stiffness entire project



Critical Steps in the FDR Process

1. **Assembling Background Information**
2. **NDT Evaluation and Section Breakdown**
3. **Verifying Pavement Structure and Sampling**
4. **Laboratory Mix Design**
5. **Pavement Design**
6. **Special Considerations**
   1. **Use of geogrids**
   2. **Ensuring Surface bonding**
   3. **Microcracking**
7. **Construction Quality Assurance**
8. **Feedback - Addressing Performance Problems**

FM 148 Lab Tests Results

Design Blend Percentages	
Existing RAP	50%
Existing Base	50%
Add Rock	0%

Compaction Properties	
Required Moisture	7.1
Max Dry Density	122.6

Sulfate Content (ppm)	
Medium	High
250	920

Sieve Analysis of Aggregate Base	
Sieve Size	% Passing
1 ¾˝	100
1 ¼˝	97.6
⅞˝	91.9
¾˝	81.9
⅜˝	61.6
#4	37.3
#40	18.0
#200	n/a

Performance Criteria				
	2%	3%	4%	Spec Limits
Dry Unconfined Compressive Strength (psi) @ 25°C (Tex-117-E)	138	198	240	175 psi min
Retained Unconfined Compression Strength (psi) @ 25°C (Tex-117-E)	148	220	301	Information Only
Retained Unconfined Compressive Strength (%) of dry strength	107%	111%	125%	100% min
Tube Suction Test Final Dielectric (Er) (Tex-144-E)		12		Information Only
Unconditioned Seismic Modulus (ksi) (ASTM D 4123)	531	841	1010	Information Only @ 7 days

Recommendations	
Cement Content	3%
Optimum Moisture Content	122.6

100% RAP@ 3% cement = 85 psi

Critical Steps in the FDR Process

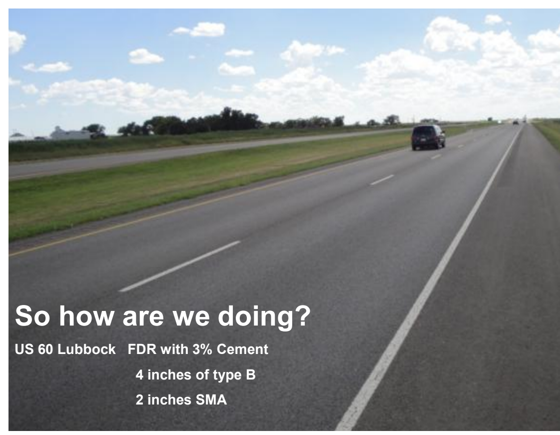
1. Assembling Background Information
2. NDT Evaluation and Section Breakdown
3. Verifying Pavement Structure and Sampling
4. Laboratory Mix Design
5. Pavement Design
6. Special Considerations
   1. Use of geogrids
   2. Ensuring Surface bonding
   3. Microcracking
7. Construction Quality Assurance
8. Feedback - Addressing Performance Problems

Pulverization (Road Mixed)

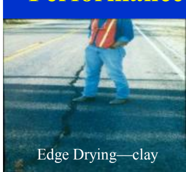
- Initial
  - 100% passing 2.5 in.
- After Mixing
  - Base
    - 100% pass 1.75 in.
    - 85% pass 0.75 in.
  - Subgrade
    - 60% pass No. 4

Time Limitation

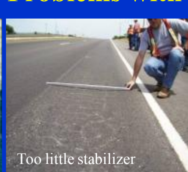
Compaction with 2 hours of adding cement



Performance Problems with FDR Projects



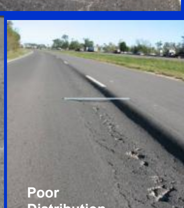
Edge Drying—clay



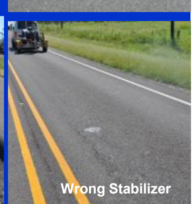
Too little stabilizer

Debonding

Too Much stabilizer



Poor Distribution



Wrong Stabilizer

SECTION 2

Chapter 2 Online Evaluation of Project Soil Conditions

SOIL PROPERTY	CONSEQUENCE
Plasticity index PI > 15	Avoid if at all possible do not mix soil into base. If unavoidable; consider lime as stabilizer
Plasticity index PI > 35	Experience has shown that stabilizer layers built on soils with high shrink swell potential can have problems with severe longitudinal cracks. Consideration should be given to incorporated geogrid into potentially problems sections
Sulfate Contents > 0.8%	Heaving problems have been documented with the use of cement and lime on sulfate rich soils. Follow TxDOT guidelines on dealing with sulfate, avoid incorporating these soils into bases
Organic Contents > 2%	Problems with permanently stabilizing these soils. Avoid using these soils in FDR design , follow TxDOT guidelines if these soils are to be treated

Using the Web Soil Survey

- http://websoilsurvey.nrcs.usda.gov/app/
- Press the green "start WSS" button
- Define the Area of Interest (AOI)
- Use Soil Map for soil series information
- Use the Soil Data Explorer for use limitations and soil properties
  - Maps are generated and can be printed or saved

Defining Area of Interest

Defining Area of Interest

- Use Area of Interest Interactive Map to zoom/pan to desired location
- Define area with rectangle or polygon
  - Polygon generally works best

Once at desired map location, activate rectangle or polygon AOI function to define the area of interest for investigation. The AOI is drawn in red.

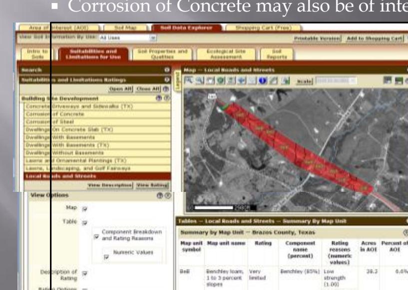
Survey Data – Soil Map and Soil Data Explorer

- Soil Map shows soil series present in AOI

- Soil Data Explorer is where to find
  - Suitabilities and Limitations for Use
  - Soil Properties and Qualities
  - Ecological Site Assessment
  - Soil Reports

Suggested Uses of Soil Data Explorer

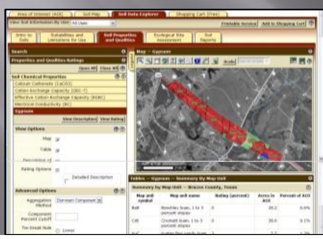
- Under Suitabilities and Limitations:
  - View rating for Local Roads and Streets
  - Corrosion of Concrete may also be of interest



In this example limitations for local roads and streets shown. 99.4% of AOI is very limited due to low strength and/or shrink-swell.

Suggested Uses of Soil Data Explorer

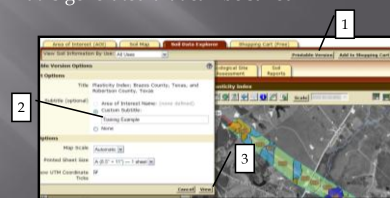
- Under Soil Properties and Qualities
  - In Soil Chemical Properties view rating for Gypsum
    - pH may also be of interest
  - In Soil Physical Properties view rating for Organic Matter and Plasticity Index
    - Surface Texture may also be of interest

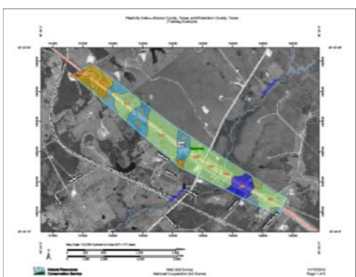


In this example ratings for Gypsum are shown. Some pockets with up to 3% Gypsum are indicated.

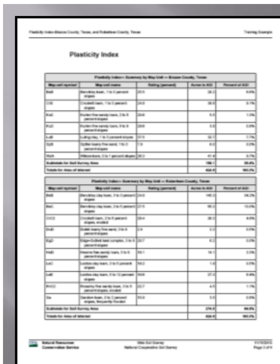
Saving Your AOI Output

- After viewing a rating, press the "Printable Version" button above the map
  - Insert any desired subtitles in the "Custom Subtitle" field
  - Press "View" in the Printable Version Options screen
  - A PDF format is generated that can be saved





Example PDF Report



SECTION 3

Chapter 3 Conditions Surveys and NDT

- What is a good FDR candidate
- Understand how NDT can help in the evaluation and design process
- Identify other issues
  - Failed culverts
  - Edge stability problems

FDR Candidates

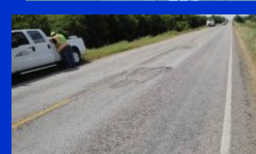
- Pavements with base problems
  - Inadequate thickness
  - Clay contamination
  - Loss of stabilized layer
- Pavements not structurally adequate
- Pavements with major edge failures
- Continuing and excessive maintenance

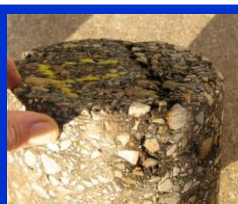
Good FDR Candidate 4-Lane Roadways-Simple Cases

2-4 Inches HMA 10-12 inches of base Fair subgrade

Rutting and Alligator in Wheel paths - major truck routes

Good FDR Candidates 2-Lane Roadways



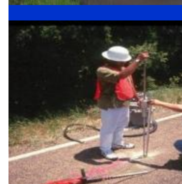


Not FDR Candidates

Problems restricted to HMA layer
Good FWD values
No base failures

Pavement Evaluation Tools

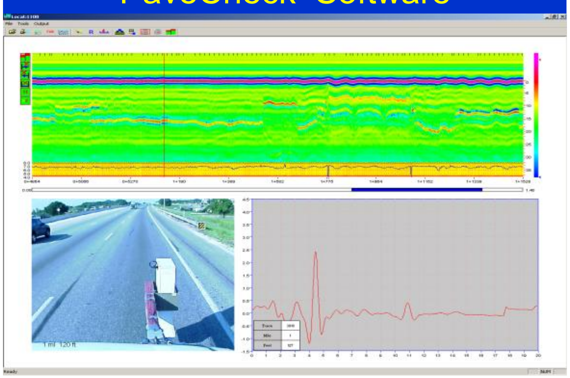
1) **GPR-thickness variability; identify major problem areas; sampling locations**
2) **DCP-in-site strengths of lower layers**
3) **FWD-strength variability; subgrade stiffness entire project**

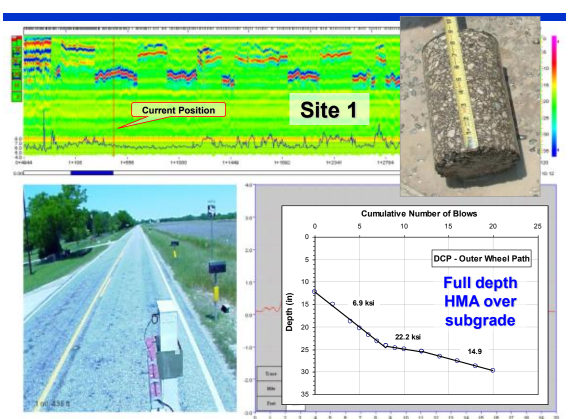


TxDOT's Ground Penetrating Radar Unit

- TTI's data acquisition and processing systems Integrated Video
- Data collected at highway speed (60 mph)
- Effective depth of penetration 20 ins
- TxDOT has 5 available units
- Measure layer thickness and locate subsurface defects

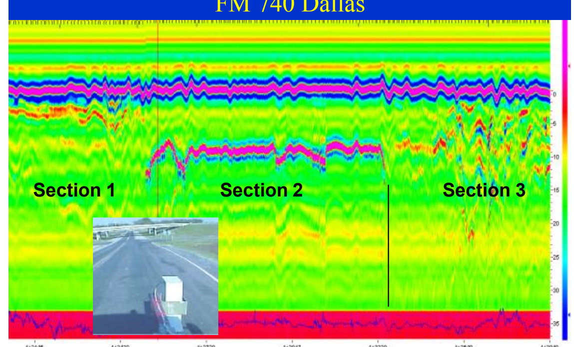
PaveCheck Software



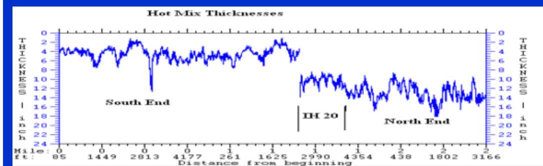


Section Breaks in FDR Candidate

FM 740 Dallas



Why Upfront Testing?



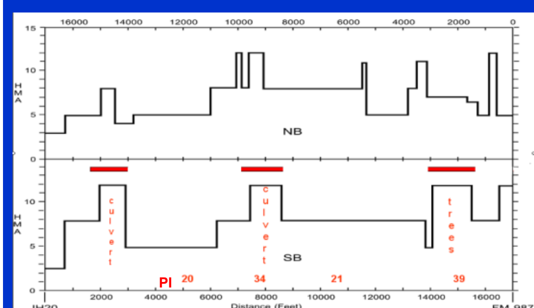
3 inches HMA 6 inches base

14 inches HMA 4 inches base

FM 148 Difficult Project

Thick HMA-many structural edge failures

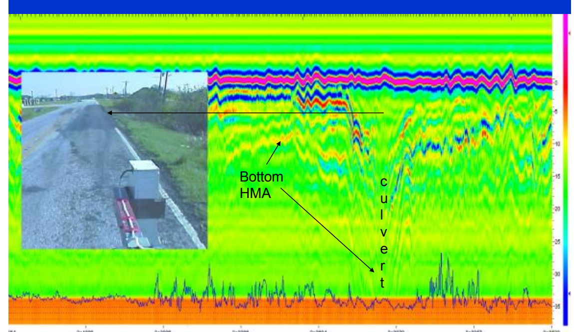
FM 148 HMA Thickness



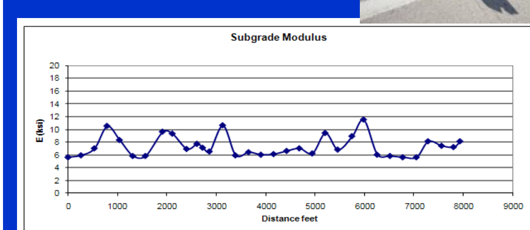
6 to 8 inches of Grade 2 base

Poor Subgrade – high pavement deflections

Identifying Failing Culverts



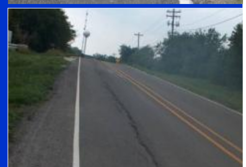
FWD testing is required to obtain subgrade modulus for pavement design

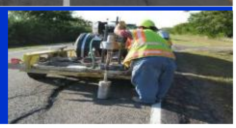


FDR Candidates

Tough Cases

- 9 inches HMA, 3 inches of base, PI 60 soils
- Lots of maintenance; variable HMA thickness
- No shoulders, lots of trees close to edge
- Traffic handling headache
- No foundation layer





SECTION 4

Chapter 4 Verification Coring and Sampling

- Understand what field testing is required for GPR verification
- How to obtain samples for lab testing
- Understand how to use the DCP to investigate pavement edge failures

Verification Coring and Sampling

- Sampling locations
  - Assigned based on the GPR data analysis
  - 2-4 sampling locations per road for thickness validation
  - 1-2 sampling locations per road for lab testing
- Amount of sampled material per site
  - Sufficient for laboratory testing: ~ 10 buckets
  - On-site pavement structure evaluation: ~ 1 core and one augur (bag samples of all layers)

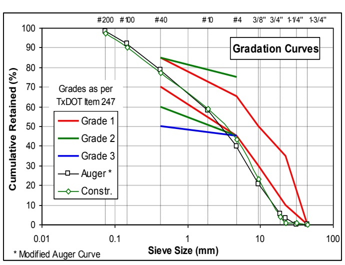
HMA Coring
Thickness Verification and Defect Detection

Material Sampling – Site 1

- Auguring base
- Shelby Tube sampling soils

Obtaining Samples for Lab Testing

- Milling machine (Best)
- 9 to 12 inch Augur (Good)
- Back Hoe

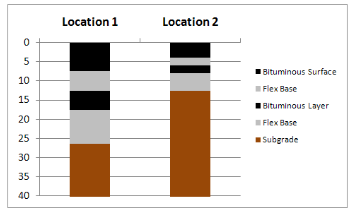


Material Sampling – Site 1

- Shelby Tube samples

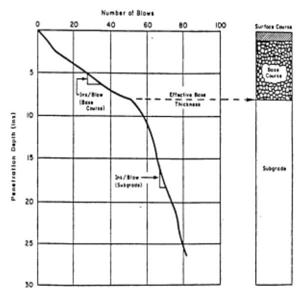
Thick HMA Sections > 4 ins
Keep HMA and Base Samples Separate

Mapping Project Variability



DCP Testing

Processing DCP Data



CBR = 292 / (PR) ** 1.12

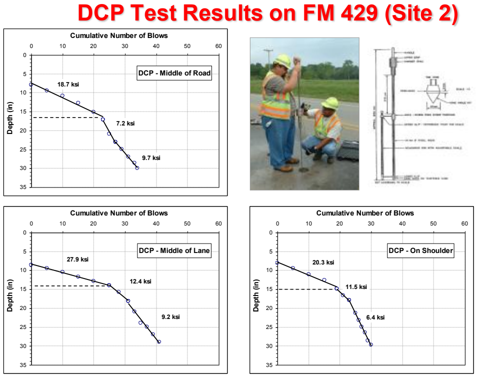
CBR California Bearing Ratio

PR Penetration rate mm/blow

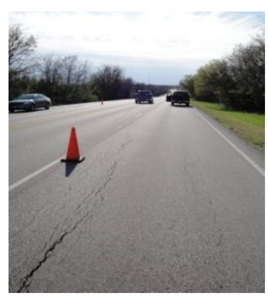
E = 2.54 * (CBR)** 0.64

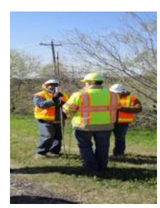
E modulus (ksi)

DCP Test Results on FM 429 (Site 2)

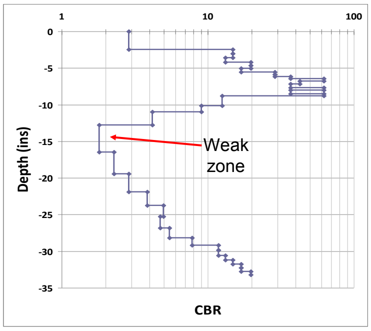


DCP on Shoulder where Edge Failures Occurring





Using the DCP to Identify Weak Layers on Shoulder



SECTION 5

Chapter 5 Laboratory Mix Design Procedures

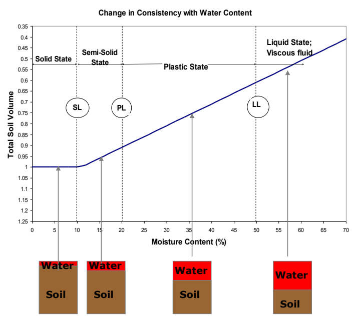
- Understand guidelines for determining if stabilization is required
- Be familiar with TxDOT guidelines on selecting stabilizer types
- Understand the steps required to select optimal stabilizer contents
- Be familiar with current TxDOT design criteria
- Understand what test can be run to ensure adequate surface bonding

FDR Option Selections Considerations

Objective	Base Thickening	Upgrade base to Class 1	Create a Stabilized Base
Used When	• Existing base is uniform • No widespread structural damage • Low to medium traffic • Medium to Good subgrade	• Low – moderate traffic • Subgrade > 10 ksi • Moisture not a concern	• Bridging over poor subgrade • Strengthening required • Low quality variable base/stripped HMA • Higher Rainfall • Early opening to traffic
Selection of Stabilizer	No Stabilizer added to the existing material. This is a base thickening project, where new untreated granular material is placed on top of existing.	Full Texas Triaxial test (117-E), add low levels of stabilizer Criteria after 10 days capillary rise 1) 45 psi at 0 psi confining 2) 175 psi at 15 psi confining	Use Prevailing TxDOT spec and Test Methods (120 E, 121 E, 127E, SS3066) • All tests should include a retained strength on moisture saturation
FPS 19 Moduli	70 ksi	100 ksi	150 ksi
	1) New base should be of higher or equal quality than existing, and 2) Blending of existing and new base strongly recommended to avoid trapping moisture in upper layer		1) Avoid cutting into high PI subgrade, if existing structure is thin then add new base before milling where needed 2) To avoid longitudinal cracking consider grids and flex base overlay where the PI subgrade soils > 35 3) Max RAP 50% 4) If lab strength > 350 psi then consider micro-cracking 5) Max Cement 4%, other stabilizer can be used

Basic Soil Moisture States

- **Solid State:**
  - **Soil stable under pressure**
- **Semi-Solid State:**
  - **Soil crumbles under pressure**
- **Plastic State:**
  - **Soil deforms and remains deformed under pressure**
- **Liquid State:**
  - **Soil flows under its own weight; Viscous Fluid**

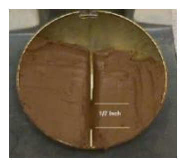


PI Calculation

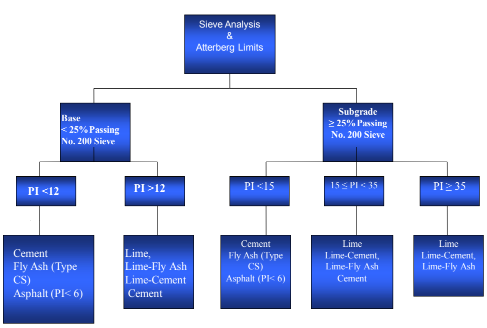
- **Plastic Limit – PL (Tex-105-E)**
  - **Lowest moisture content at which the soil can be rolled into threads 1/8th inch in diameter without the soil breaking into pieces**
- **Liquid Limit – LL (Tex-104-E)**
  - **Lowest moisture content at which a 0.5 inch groove of soil begin to flow together**
- **Plasticity Index – PI (Tex-106-E)**
  - **Range or difference between the LL and PL**
  - **PI = LL - PL**

Plastic Limit Test

Liquid Limit Test



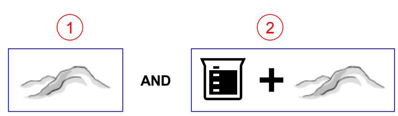
TxDOT's Stabilization Selection Guidelines (2006)



Laboratory Assessment of the Material

- Laboratory performance evaluation
- Mix design recommendations

- Design methodologies
  1. Cement treatment
  2. Emulsion only or Dual emulsion-cement treatment



Design Methodology 1

- Cement treatment
  - Ordinary portland cement, Type I
  - 2, 3, and 4% by weight of total dry solids
  - 7 days of moist cure (25 C and 100% R.H.)
- Tests and criteria

Unconfined Compressive Strength	≥ 300 psi (Class L)*
	≥ 175 psi (Class M)*
Tube Suction dielectric value, ε	Report
UCS after Tube Suction	≥ 100% 7D UCS_{Dry}
UCS after Dunk Test	≥ 100% 7D UCS_{Dry}
Seismic Modulus	Report

* TxDOT Item 276 specification; Test method Tex-120-E

Design Methodology 2

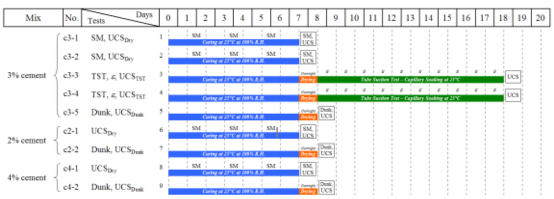
- Emulsion-cement treatment
  - 4% of emulsion, 65% residue
  - Ordinary portland cement, Type I
  - 0, 1, or 2% of cement
  - 2 days of hot cure (60 C) + 1 day cooling
- Tests and criteria

Unconfined Compressive Strength	≥ 150 psi *
Tube Suction dielectric value, ε	Report
UCS after Tube Suction	≥ 80% UCS_{Dry}
UCS after Dunk Test	≥ 80% UCS_{Dry}
Seismic & Resilient Moduli	Report

* TxDOT Special Specification No. 3066

Timeline 1

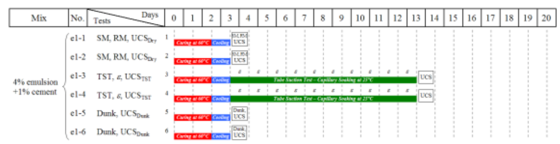
- Cement treatment
  - Duration: about 3 weeks



Notation: ***c3-4*** = "c" – cement, "3" – 3% cement by weight, "4" – fourth sample.

Timeline 2

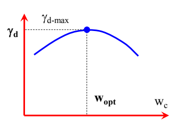
- Emulsion-cement treatment
  - Duration: about 2 weeks



Notation: ***e1-6*** = "e" – emulsion, "1" – 1% cement by weight, "6" – sixth sample.

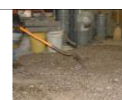
Sample Preparation and Characterization

- All material is spread out and air-dried overnight
- Material characterization
  - Atterberg limits analysis
  - Particle size analysis
  - Moisture-density relationship



- Specimen fabrication
  - TxDOT Test Method Tex-113-E
  - ∅ 6" by 8" samples
  - 4 layers, 10 lb hammer, 18 inch drop, 50 blows per layer
- Laboratory protocol…

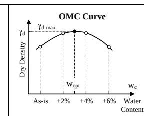
A. Preparation of the Base Material for Testing

Day 1	1. Thoroughly mix the material originating from a single sampling location, spread it out on the floor, and let air-dry overnight.		
Day 2	2. Collect representative samples of the air-dried material to determine: • The baseline (air-dried) moisture content of the virgin material; • The particle size gradation of the virgin material; • Plasticity index of the virgin material. 3. Prepare material batches (~ 8,000 g) by adding the desired amount of water and thoroughly mixing.		
Day 3	4. Cover and seal each batch with foil. 5. Weigh each covered batch and record the mass in order to monitor the weight loss due to involuntary water evaporation. 6. Let the batches sit overnight (12 hours). 7. Weigh each batch to check for the possible water loss. Replenish the evaporated moisture.		

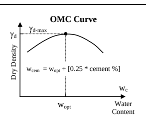
B. Compaction of the Base Material Specimens

Day 1	1. Prepare the base material according to **(A)**. 2. If necessary, mix additives into the batches, following the additive-specific mixing procedures. 3. Set-up lab equipment to compact the base specimens according to the Tex-113-E procedure. 4. Weigh an empty 6" × 8.5" mold; record its mass.		
–	5. Compact the 6" × 8" specimens in 4 layers using the standard compaction effort (Tex-113-E): 10-lb hammer, 18-in drop, 50 blows/layer. 6. Scarify the surface of each internal layer with a spatula to facilitate bonding between the compacted layers. 7. Finish off the final surface of each specimen using 10 firm blows of a rawhide hammer.		
–	8. Weigh the compacted specimen in the mold and record their combined mass. 9. Extrude the compacted specimen from the mold using the hydraulic press. 10. Determine the height of each specimen using a ruler to the nearest 0.05 inch.		

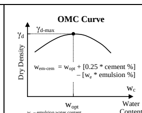
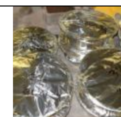
C. Determination of the Optimum Moisture Content of the Base Material

Day 1	1. Prepare the base material according to **(A)**. Namely, prepare four batches (8,000 g) by adding the following amounts of water to the base material: • As-is (air-dried, no additional water); • +2% (160 g) tap water; • +4% (320 g) tap water; • +6% (480 g) tap water. 2. Compact the specimens according to **(B)**.		
–	3. Label and weigh the empty drying bowls. 4. Place the compacted specimens into the corresponding labeled drying bowls, break them to promote drying, and weigh along with the bowls. 5. Place the bowls holding the wet broken-up specimens into the oven adjusted at 85°C (185°F). The lower than recommended drying temperature of 110°C (Tex-113-E) is suggested due to the presence of the RAP in the base material.		
Day 4	6. After approx. three days of drying (weekend), record the stabilized weight of each drying bowl. 7. Use the collected data to construct the OMC curve and determine: • Optimum moisture content; • Maximum dry density; • Original (as-is) moisture content of the base material after air-drying.		<u>Determine:</u> OMC (w_{opt}) % $\gamma_{dry\text{-max}}$ lb/ft^3 Original water %

D. Preparation of the Cement Stabilized Base Specimens

–	1. Determine the OMC of the base material according to **(C)**. 2. Adjust the OMC value: • For the original (as-is) water content; • For inclusion of cement. 3. Prepare the base material batches according to **(A)**, using the adjusted optimum moisture content.		
Day 1	4. Calculate the desired amount of cement, defined as a percent of the total dry solids. 5. Weigh out cement and thoroughly mix it into the wetted base material. 6. Compact the cement-base mix according to **(B)**.		
Day 8	7. Place the compacted specimen on the porous stone, wrap into a plastic bag, and cover with another porous stone. 8. Move the specimens into a climate chamber set at 25°C (77°F) and 100% relative humidity. 9. Cure the specimens in the chamber for 7 days.		

E. Preparation of the Base Specimens Stabilized with the Emulsion-Cement Mix

–	1. Determine the OMC of the base material according to **(C)**. 2. Adjust the OMC value: • For the original (as-is) water content; • For inclusion of cement; • For water contained in emulsion. 3. Prepare the base material batches according to **(A)**, using the adjusted optimum moisture content.		
Day 1	4. Transfer the prepared base material into the bucket of an electrical mixer. 5. Calculate and weigh an appropriate amount of cement, defined as a percent by mass of the total dry solids. 6. Add the weighed cement to the base material in the mixer and mix thoroughly.		
–	7. Shake the bottle containing emulsion first. 8. Calculate and weigh an appropriate amount of emulsion, defined as a percent by mass <u>in addition</u> to the total dry solids. 9. Pour the weighed emulsion into the mixer in addition to the blend of the base material and cement.		

E. Preparation of the Base Specimens Stabilized with the Emulsion-Cement Mix - CONTINUED

–	10. Mix for no more than 60 ± 10 seconds. 11. Place the loose mixture into a bowl. 12. Move the blended specimens into an oven and cure at 60°C (140°F) for 30 minutes. Do not mix during curing.		
–	13. Compact the cured mixtures according to **(B)**. 14. Place the compacted specimens on the porous stones.		
Day 3 Day 4	15. Move the specimens into a climate chamber set at 60°C (140°F). 16. Cure the specimens in the chamber for 48 hours (2 days). 17. Remove the specimens from the hot chamber and cool them at 25°C (77°F) for 24 hours (1 day), but not more than 48 hours (2 days).		

Unconfined Strength

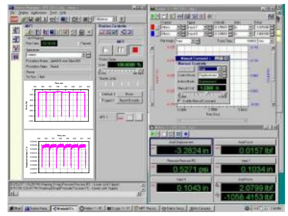
- Unconfined Compressive Strength

Seismic Modulus Test

- Free-Free Resonant Column
- Correlation with Young's modulus

Resilient Modulus Test

- Test method: AASHTO T 307
  - Unconfined sample at 23 C
  - 200 cycles at 35 psi
  - 0.1 sec load & 0.9 sec unload



- Correlation with Young's modulus

Dunk Test

- Accelerated moisture susceptibility test
  - 4-hour period of full submerging @ 25 C
  - Unconfined compressive strength test at the end
  - $UCS_{Dunk} \geq 80\%\ UCS_{Dry}$
- Conditioning of the cement treated samples
  - After curing, overnight drying is required @ 60 C
  - Followed by at least 2 hours of cooling
- Emulsion-cement samples
  - No additional conditioning

Tube Suction Test

- Extended moisture susceptibility test
  - 240-hour (10-day) period of capillary soak @ 25 C
  - Unconfined compressive strength test at the end
  - $UCS_{TST} \geq 100\%\ UCS_{Dry}$
- Sample conditioning: identical to Dunk Test

Current TxDOT Design Strength Requirements

Laboratory Requirements for Lime Treatment.

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

*After moisture conditioning per Tex-121-E over 10 days

Laboratory Requirements for Cement Treatment.

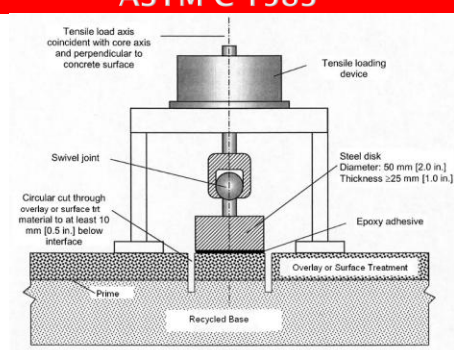
Test	Spec Limits
Unconfined Compressive Strength (psi) @ 77°F (Tex-120-E)	175 min
Retained UCS (psi) @ 77°F after Tube Suction Test	100% min
Tube Suction Test Final Dielectric (Er) and moisture content (%) (Tex-144-E)	For Information Only
Unconditioned Seismic Modulus (ksi) (Draft TxDOT Method)	For Information Only Tested at 7 days

Laboratory Requirements for Emulsion Treatment.

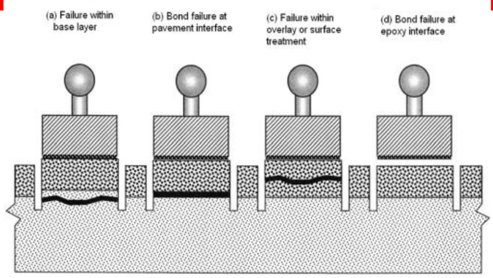
Test*	Spec Limits
Unconfined Compressive Strength (psi) (SS3066)	150 min
Indirect Tensile Strength (Tex-226-F)	> 50 psi
Tube Suction Test Final Dielectric (Er) (Tex-144-E)	< 10
Unconfined Compressive Strength after the Tube Suction Test	≥ 80% Dry UCS
Seismic Modulus	Report

*All tests are preceded by 2 days curing at 60 °C and 1 day cooling

Direct Tensile Bond Test ASTM C-1583



Possible Failure Modes



All 4 failure modes found in current studies

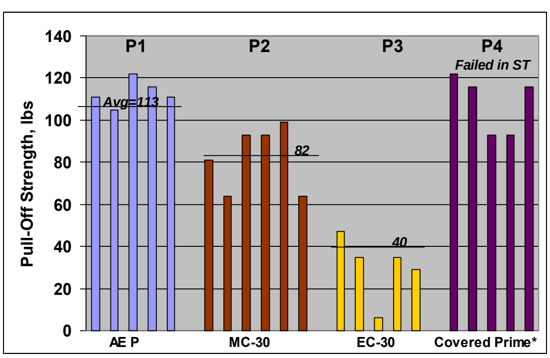
Sample Preparation

Oven Cure Primed Sample for 3 days at 110ºF

Tests Performed on Grade 5 Surface Treatment

MC-30 Prime, Grade 5 ST
Mean Tensile Strength = 133 lb,
Std Dev = 28 lb

No Prime, Grade 5 ST
Mean Tensile Strength = 49 lb,
Std Dev = 12 lb



SECTION 6

Chapter 6 Pavement Design

- FPS Input values
- When to add new base
- Methods of handling project variability
- Methods of minimizing shrinkage cracking
- Methods of minimizing edge cracking
- Adding lateral support to pavement edge

FPS 19 Recommended Design Moduli Values for FDR Projects

Stabilizer Type	Field Moduli Range	Design Modulus (ksi)	Design Poissons Ratio
Emulsion	100 - 300	100	0.30
Lime	60 - 200	75	0.30
Cement	100 - 600	150	0.25
Fly Ash	70 - 300	75	0.30

FPS and Triaxial Check Design Values

Table – Design Method A

Materials Description	FPS Design Modulus Values	Poisson Ratio	Cohesiometer Value for TR. Check
Existing Material (including subgrade)	Backcalculated from FWD	0.40	na
Existing Pavement Sacrified, Reshaped	3 Times Subgrade Modulus	0.35	na
Stabilized			
Existing/Subgrade a) Most Granular Base (75% more base) b) Blend Subgrade & Base (50 – 75% base) c) Mostly Subgrade (<50% base)	a) 100 ksi b) 65 ksi c) 35 ksi	0.30 0.30 0.35	a) 800 b) 650 c) 300
Stabilized RAP/Existing Base; Max 50/50 Blend a) Cement b) Lime c) Emulsion d) Fly Ash	a) 150 ksi b) 75 ksi c) 100 ksi d) 75 ksi	a) 0.25 b) 0.30 c) 0.30 d) 0.30	a) 1000 b) 300 c) 300 d) 300
New Flexible Base over Stabilized Layer	70 ksi	0.35	na

Note: Subject to Change

Extract from a Typical Design Report

I recommend reworking the existing material and widening the existing pavement to at least 24 feet then adding enough additional material to treat a 10" thick blend of existing and new material with 3% cement by weight.

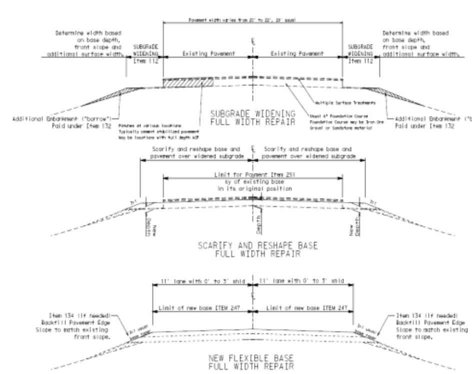
Cement	Cement	Treat	Cement trt	Hot Mix	2" lift
$/ton	$/sy	$/sy	total $/sy	$/ton	$/sy
$ 110.00	$ 1.55	$ 3.30	$ 4.84	$ 61.00	6.71

Note: Cost is based on Houston District 12 month average low bids for Construction.

Est. Unit Weight	125	pounds per cubic foot	rate placed	3.125	pounds/sf
Percent cement	3	percent	rate placed	0.0141	tons/sy
Treatment width	12	feet	Length per ton	53	feet

When to Place New Base over Treated Layer

- Thin pavement structure over poor subgrade – treated layer to be a foundation/subbase layer
- Concerns about edge drying cracking – flex base overlay will reduce cracking
- ADT more than 2000
- Inadequate depth of cover over subgrade from Texas Triaxial design
- Raising the pavement to improve drainage



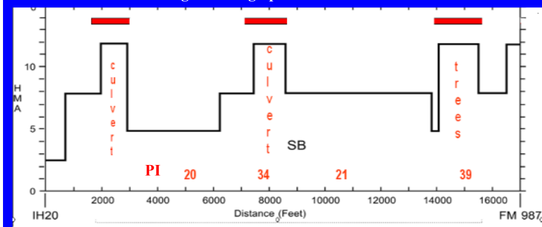
SEQUENCE OF WORK FOR FULL WIDTH REPAIR

Additional Considerations in the Design Process

- Handling project thickness variability
  - Add new base over existing
  - Milling depth requirements
- Special Considerations
  - Micro-cracking
  - Use of Geogrids
  - Widening to add lateral support

FM 148 HMA Thicknesses

Existing 6 to 8 inches of Grade 2 base
Poor Subgrade – high pavement deflections



1. No more than a 50/50 RAP Base Blend
2. Avoid cutting into subgrade
3. Recycling depth 8 inches

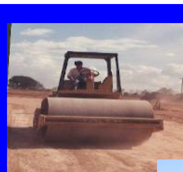
Design Recommendations Incorporated into Plans

From - To (feet)	Treatment
0 - 700	2 inch overlay only (new construction)
700 - 1800	Mill 4 inches of HMA the FDR 8 ins + base overlay
1800 - 3000	Mill 6" HMA add 4" new base; FDR 8" + Geogrid + base overlay
3000 - 6000	FDR 8" + base overlay
6300 - 7200	Mill 4 inches of HMA the FDR 8 ins + base overlay
7200 - 8900	Mill 6" HMA add 4" new base; FDR 8" + Geogrid + base overlay
8900 - 14000	Mill 4 inches of HMA the FDR 8 ins + base overlay
14000 - 15600	Mill 6" HMA add 4" new base; FDR 8" + Geogrid + base overlay
15600 - 16700	Mill 4 inches of HMA the FDR 8 ins + base overlay
16700 - end	2 inch HMA over only (intersection new construction)

Use of Micro-Cracking or Early Trafficking to Reduce Shrinkage Cracking Extent and Severity

- Early traffic or
- Heavy vibratory steel wheel roller after 1 - 3 days
- Little long-term loss in strength
- reduction in amount and severity of cracks

Micro-Cracking



- 12 ton vibratory roller
- 1 – 2 days after placement
- Creep speed
- High amplitude
- 2 – 4 passes
- During set up test after 2 passes
- Wet section after cracking

Control Testing

- Number of passes required to get a 40% reduction in stiffness
- Stop after 2 and test

- Humboldt Geo-gauge
- Falling Weight Deflectometer
- PFWD
- Seismic
- Anything that will tell you if you have broken the slab

Micro-Cracking Influence on Crack Severity

Low cost – No long-term damage to slab – lots of benefit

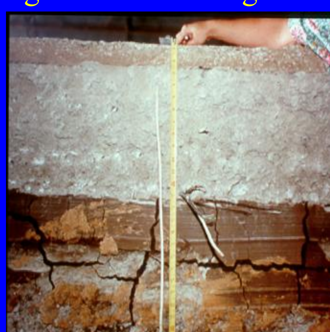
Wet Cured

Micro-cracked

Minimizing Longitudinal Cracking Problems Edge Drying Problem

Causes of Longitudinal Cracking

- Subgrade Shrinkage associated with:
  - PI > 35
  - Trees near edge
  - Summer droughts
  - Stiff bases

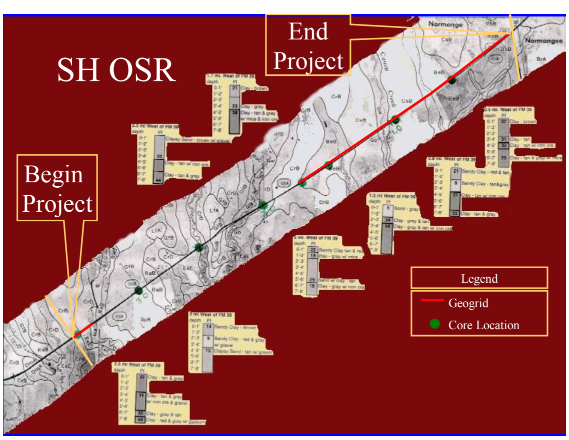


Current Bryan District Design Approach

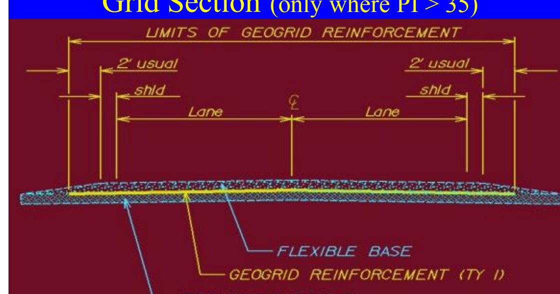
Darlene Goehl (2002)

- Define the limits of potential problem areas based on:
  - Soil borings at 0.5 mile intervals
  - Cross-reference to USDA maps
  - Analysis of structural strength data (FWD)
  - Drive section/input from Maintenance forces
- Combine all the information to define the limits of Geogrid reinforcement
- Geogrid introduces a slip plane to intercept cracks

SH OSR



Grid Section (only where PI > 35)



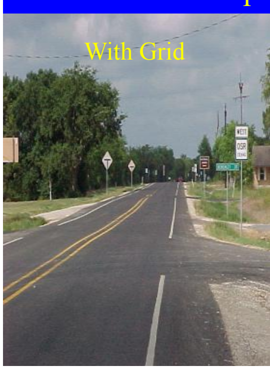
Slides from Darlene Goehl, Lab Engineer Bryan District

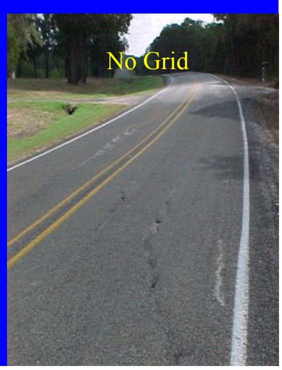
Geogrid material passes TxDOT DMS 6240 - need high junction strength to withstand construction (Tensar/Tenex products have performed well)

Grid Placement

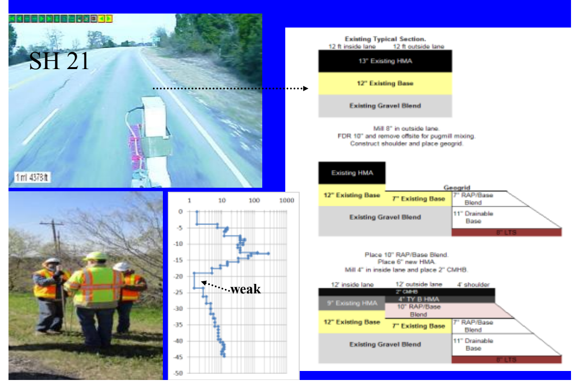
Adding Flexible Base

Old Spanish Road





Adding Lateral Support by Shoulder Widening



SECTION 7

Chapter 7 Construction Specifications
Existing TxDOT Specifications

- Item 260 Lime Road Mixed
- Item 275 Cement Road Mixed
- Item 265 Fly Ash Road Mixed
- SS 3066 Asphalt Emulsions
- SS 3158 Foamed Asphalt (1993)

Typical Field Construction Sequence

Pulverization (Road Mixed)

- Initial
  - 100% passing 2.5 in.
- After Mixing
  - Base
    - 100% pass 1.75 in.
    - 85% pass 0.75 in.
  - Subgrade
    - 60% pass No. 4

Time Limitation

Compaction with 2 hours of adding cement

Grading Requirements
All Stabilizers

- After shaping, before mixing
  - Pulverize existing material so that 100% passes a 2.5 inch sieve

- After Mixing

	Base	Subgrade
Sieve Size	**% Pass**	**%Pass**
1 ¾ in.	100	100
¾ in.	85	85
No. 4	-	60

Application - Road Mixed

- Dry Placement
  - Bring Soil to OMC
  - Apply Cement or Lime
- Slurry
  - Continuous Agitation
  - Apply < 2 hrs of adding water

Calculation of Application Rates

- Length of treatment

Est. Unit Weight	125	pounds per cubic foot	rate placed	3.125	pounds/sf
Percent cement	3	percent	rate placed	0.0141	tons/sy
Treatment width	12	feet	Length per ton	53	feet

Application of Stabilizers
(new in 2004 spec book)

	Dry	Slurry
Cement	x	x
Lime	x	x
Fly Ash	x	

Childress Fly Ash Base Performance

- Materials treated either sand/gravel or caliche
- Design use Tex 127 E to select Fly Ash content, spec says UCS at least 100 psi (some Districts prefer 175 psi at 15 psi confining)
- Priming Sand/gravel – straight AC-5 or CRS-1P
- Priming Caliche rework top 1 inch treat with dilute MS 2 emulsion
- One course surface treatment before final surfacing
- Design thickness with FPS 19
- Used on major roads US 287 – excellent performance
- Back calculated modulus 200 – 300 ksi
- Details Ron Hatcher – heavy involvement on each project
- Caution – good subgrades in District – light rainfall

Compaction

- QC/QA system
  - Target 95% proctor
  - No more than 1 in 5 test fail

Sheep's Foot for Initial Compaction
Steel Wheel for Finishing

Walking out of stabilized base

Mellowing + Compaction Requirements

	Mellowing Time	Compaction Time	Density 115-E
Cement	None	2 hours after application	95%
Lime (Hydrated)	1–4 days	After mellow	95% first 98% next
Lime (Quick)	2–4 days	After mellow	95% first 98% next
Fly Ash	None	6 hours after application	95% first 98% next

Multiple lifts with cement not recommended because of bonding problems

Curing

- 3 days sprinkling
  - Maintain no more than 2% below OMC
- Asphalt Membrane
  - 0.1 to 0.2 gals sq yd

Curing Requirements
(membrane curing as alternative)

	Sprinkling (Item 2040)
Cement*	3 days
Lime PI < 35	2 days
Lime PI > 35	5 days
Fly Ash	1 day 2 days drying before tack coat

*** Spec says no traffic – conflicts with micro-cracking option**

Road Mixed Asphalt Treatment

- Coats non-plastic base particles to achieve a level of water proofing
- Typically used with granular and non-plastic material, like base course (PI < 6)

- Can be a one pass operation
- Not used widely in Texas
- Emulsions work very well in Amarillo
- Humidity/rainfall/clay contaminated problems in East Texas
- Few Foamed asphalt since failure in Wichita Falls

Highway 20 Colusa California

Highway 20, State of California

20 lane miles reconstructed & repaved in 20 days

Emulsion Treated Bases
Good Performance

- Contractor (Brown and Brown- John Huffman) design based on indirect tensile strength
- US 287 "treat top 8 inches of new base with CSS-1 emulsion, then 4 inches of type D and 2.5 inches of Type D"
- FWD Results
  - 2% 44 ksi (first project- performance problems)
  - 4% 360 ksi (excellent early)
  - 6% 275 ksi (excellent early)
- District contacts Tom Nagel (Construction), several more projects planned

2002 Foamed Asphalt Warranty Project
(Wichita Falls, Forensic Investigation after 1 Year)

Recycling project! Did not have the 10 inches of granular material on entire project – in some places mixed high PI clay with base

Strength Testing

- During Construction /Quality Control
  - Various stiffness devices
    - Stiffness changes rapidly in early days
  - Intelligent compaction systems
    - Strongly influenced by support
- After Construction/Quality Assurance
  - Feedback to designers
  - Different rates of strength gain with time

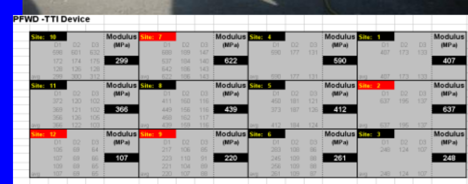
Alternative Base Testing Devices





Device	Benefits	Drawbacks
PFWD	• Portable • Linkable to design values • Provides rapid results • Already adopted for acceptance testing by some agencies	• May not correlate 1:1 with FWD • Selection of target value may require calibration strip • Requires supplementary moisture content test
DCP	• Simple, rugged and portable • Already adopted for acceptance testing by some agencies • Inexpensive	• Requires supplementary moisture content test • Selection of target value may require calibration strip
PSPA	• Linkable to laboratory test results and design values • Portable • Provides rapid results	• Load impulse very small • Susceptible to errors if surface cracks exist • Requires supplementary moisture content test
Instrumented Rolling	• Tests during compaction – results available immediately upon completion of rolling • Provides full coverage results	• Link to surface layer properties questionable • Not widely available • Equipment is costly • Requires calibration strip
FWD	• TxDOT's standard pavement assessment tool • Linkable to design values • Provides rapid results	• May not be available for every project • Equipment is costly • Requires supplementary moisture content test • Stiffness partially dependent on quality of support

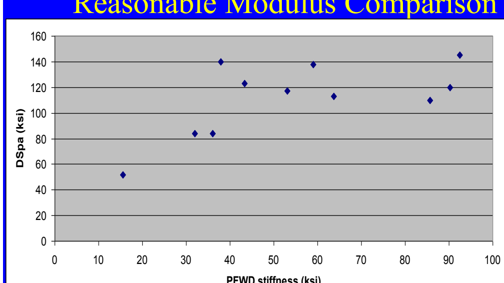
Comparison of Different Devices


PFWD -TTI Device

Site		D1	D2	D3	Modulus (MPa)
10		598	601	632	299
		172	174	175	
		128	126	128	
	avg	299	300	312	
7		688	189	147	622
		537	184	140	
		642	186	143	
	avg	622	186	143	
4		590	177	131	590
	avg	590	177	131	
1		407	173	133	407
	avg	407	173	133	
11		372	120	102	366
		369	121	102	
		356	126	105	
	avg	366	122	103	
8		411	160	116	439
		449	156	116	
		458	162	117	
	avg	439	159	116	
5		450	181	121	412
		373	187	126	
	avg	412	184	124	
2		637	195	137	637
	avg	637	195	137	
12		105	69	64	107
		107	69	66	
		109	69	65	
	avg	107	69	65	
9		217	106	85	220
		223	110	91	
		221	104	89	
	avg	220	107	88	
6		283	108	86	261
		245	109	88	
		256	109	88	
	avg	261	109	87	
3		248	124	107	248
	avg	248	124	107	

Seismic – PFWD – Humboldt -DCP

Reasonable Modulus Comparison



Seismic vs P FWD

Comparison of E values in Day 3

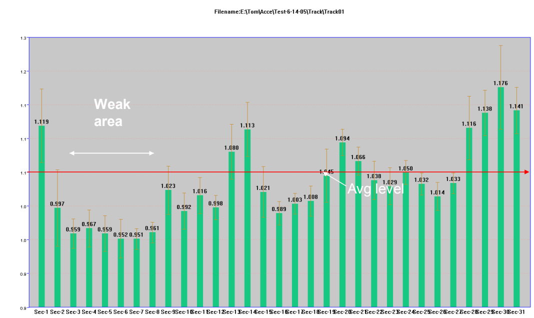
Location	PFWD (ksi) (subgrade ksi)	Seismic (ksi)	DCP (ksi)
2	92 (11 ksi)	145	65
7	90 (12 ksi)	120	73
9	31 (6 ksi)	84	43
12	15 (4.5 ksi)	52	30

Seismic from lab design at 3 days 600 to 800 ksi

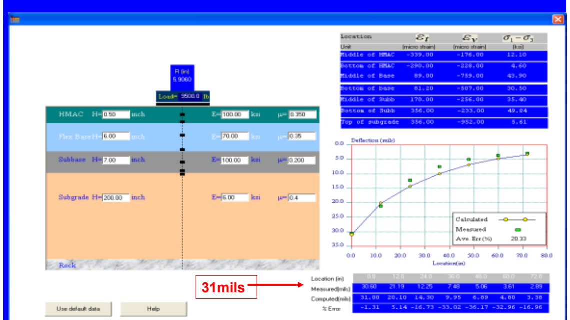
Validation Testing

- Can be done, but difficult to set criteria
- FWD can be used to compare to design assumptions
- PSPA compare to lab values
  - Field values around 25% lab
- Issues
  - When to test – stiffness changing rapidly
  - Moisture conditions – curing underway

Instrumented Roller 100% Coverage Average Deflection per 40 ft Interval



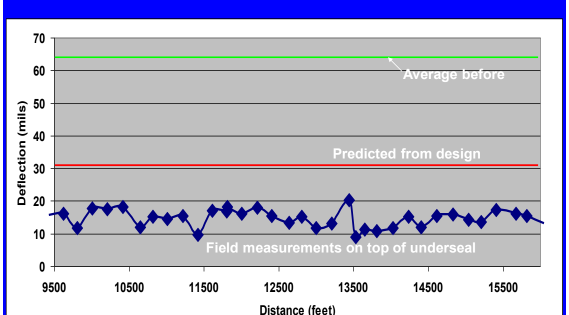
Quality Assurance Testing Predicting Acceptable Pavement Deflections



Construction Underway Sept 2010

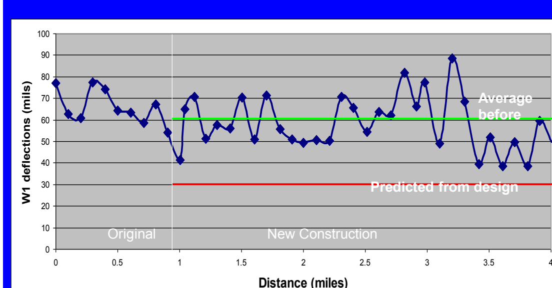
Structural Evaluation of FM 148

FWD 9000 lb maximum deflection



FWD Maximum Deflection Values Shortly after Construction

Limits based on poor subgrade (5 ksi) min flex base (30 ksi) and 2 inches HMA

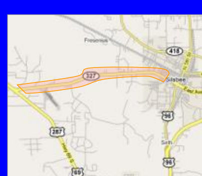


Poor performing section

Questions ???

Summary of Project

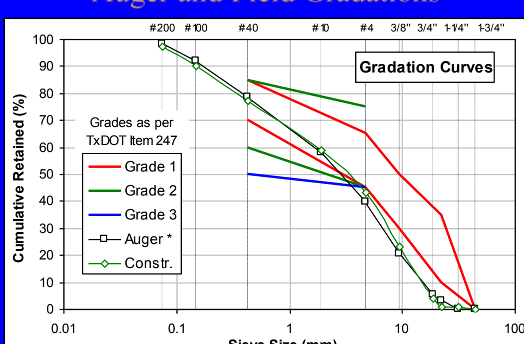
- ~ 5″existing ACP blended w/5″ existing base
- ACP pulverized w/milling machine then blended w/base by rotomill in October 2008
- Cement slurry application (4%) initiated in November 2008



Gradation Investigation

- Auger versus Field construction Investigated
- Auger sampling technique extremely close to field production

Auger and Field Gradations

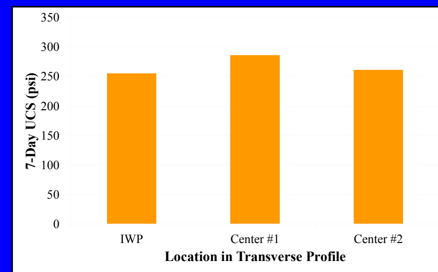


Application of Cement Slurry

- Produced by concrete plant and hauled in concrete trucks
- Each truck spread in two batches with a custom spreader box over a length of ~ 211′
- Concerns with uniformity of cement application rate across transverse profile
  - Field-molded samples from wheelpath and center for 7-day UCS
  - PFWD on 2-day old section along both transverse and longitudinal profiles

Slurry Application

Strength Results



PFWD Results Investigating Transverse vs Longitudinal Variability

- 8 measurements taken along centerline at 100′ intervals
- 6 measurements taken across lane width at one station
- Variability of longitudinal versus transverse results evaluated

PFWD Analysis of Variability

Measurement Orientation	Average E1 (Mpa)	Standard Deviation (s)	Test Statistic	Coefficient of Variation (%)	Test Statistic
Longitudinal	1633	349	2.35	21.4	2.53
Transverse	989	534		54.1	

•Test statistic = (larger variability/smaller variability)
•F-critical value for # tests = 2.88 for 90% confidence
•Data suggest no difference in variance or coefficient of variation between longitudinal and transverse E1 modulus values

Setting Micro-cracking Pattern

- Used PFWD before and after 2 passes at 8 different stations to evaluate E1 Modulus
- Target = at least 40% reduction in average value
- 2 passes achieved 41% reduction
  - Recommended 3 passes to ensure target gets consistently met

Conclusions from SH 327

- Auger samples used for lab mix design matched well with field construction
- Cement slurry application, after bugs worked out, seemed to work reasonably well
  - No evidence of greater variability across lane width as compared to variability with longitudinal distance
- 3 passes with roller recommended for micro-cracking

Fly Ash Basics

What is fly ash?

- ✯Fine residue from combustion of coal, by-product of a coal-fired electrical generation plant
- ✯80% of fly ash produced is disposed, 20% reclaimed
- ✯Cementing characteristics vary widely with source – test each source with project base materials

Types of fly ash

- ✯Type F
  - ✯ Produced from bituminous or anthracite coal (East Texas, Eastern US)
  - ✯ Pozzolonic - in presence of water will combine with available lime to produce cementitious material
  - ✯ Light to dark gray color
- ✯Type C
  - ✯ Produced from subbituminous or ignite coal (Wyoming)
  - ✯ Both pozzolonic and cementitious - forms cementitious material by adding water
  - ✯ Tan or buff color

SH 87 Beaumont Summary

- One 1 core in 6 solid
- Back calculated modulus of base 40 to 70 ksi
- Concerns about delayed compaction in high rainfall areas
- Not appropriate if need to traffic section early

Highway 20 Colusa California

CIR with Foamed Asphalt

Typical condition of pavement prior to Foam Recycling

2001 Traffic, > 5000 vpd, 20% Heavy Trucks

Recycling Results

Construction July 2001

April 2004