TTI: 0-7027

Texas A&M Transportation Institute

Workshop Guide: Rapid Mix Design of Cement-Treated Base

Product 0-7027-P3

Cooperative Research Program

TEXAS A&M TRANSPORTATION INSTITUTE
COLLEGE STATION, TEXAS

sponsored by the
Federal Highway Administration and the
Texas Department of Transportation
https://tti.tamu.edu/documents/0-7027-P3.pdf

Texas A&M Transportation Institute

Lives, Time and Resources

Workshop Guide: Rapid Mix Design of Cement-Treated Base

Product 0-7027-P3

by

Ross Taylor, Texas A&M Transportation Institute
Stephen Sebesta, Texas A&M Transportation Institute

Project 0-7027
Project Title: Accelerating Mix Designs for Base Materials

August 2023

Table of Contents

Background

Current Method

- Current method is Tex-120-E
- Requires unconfined compressive strength (UCS) testing of each cement content in triplicate
- Each specimen ~20 lb of material
- Minimum 1 week test turnaround time for strength testing alone
- Particularly for road-mix applications, covering anticipated materials variability can add up to requiring large amounts of sample

Representative Tex-120-E Specimens

Objectives of Rapid Method

Objectives of Rapid Mix Design Method

- Reduce the testing burden
- Use less materials
- Produce mix design results faster
- Use with materials for both plant- and road-mix projects
- Harmonize mix design approach, to the extent reasonable, across stabilizer types

Cement-treated base specimen for rapid mix design

Method Harmonization

Test Method Harmonization

- Switch to 4×2 indirect tensile (IDT) strength test specimen
  - Materials for 1 traditional 6×8 specimen will yield 6 specimens for IDT strength testing
- Accelerate curing schedule
  - 72-hr cure at elevated temperature to reduce test turnaround time
  - Tex-122 and Tex-134-E (for emulsion and foamed asphalt) use similar test specimen and curing schedule

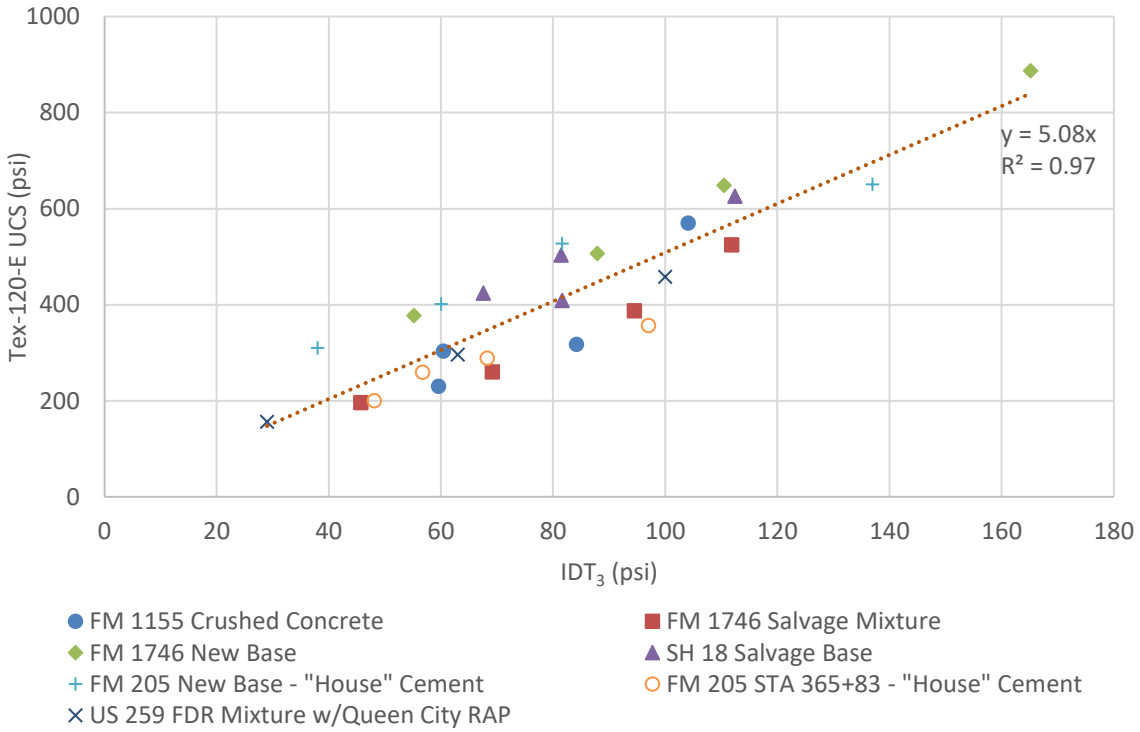
6 IDT Strength Specimens vs. 1 UCS Specimen

IDT Strength & UCS Relationship

- A relationship exists between IDT strength and Tex-120-E UCS
- Non-material-specific relationship for cement-treated base materials

$$UCS = 5.1 * IDT_3$$

UCS = Tex-120-E unconfined compressive strength, psi
IDT_3 = Accelerated cure indirect tensile strength, psi



UCS vs. IDT Strength for Cross Section of Materials

Accelerated Method

Overview, Advantages, and Procedural Steps

Overview of Procedure

- Compact 6 4×2 IDT strength test specimens at each treatment rate
- Cure 72 hours at 104°F
  - For cement stabilization, cure in air- and watertight container or bag
- Condition 24 hours by submersion in water
- Perform IDT strength test after conditioning

IDT Strength Specimens

Advantages of New Procedure

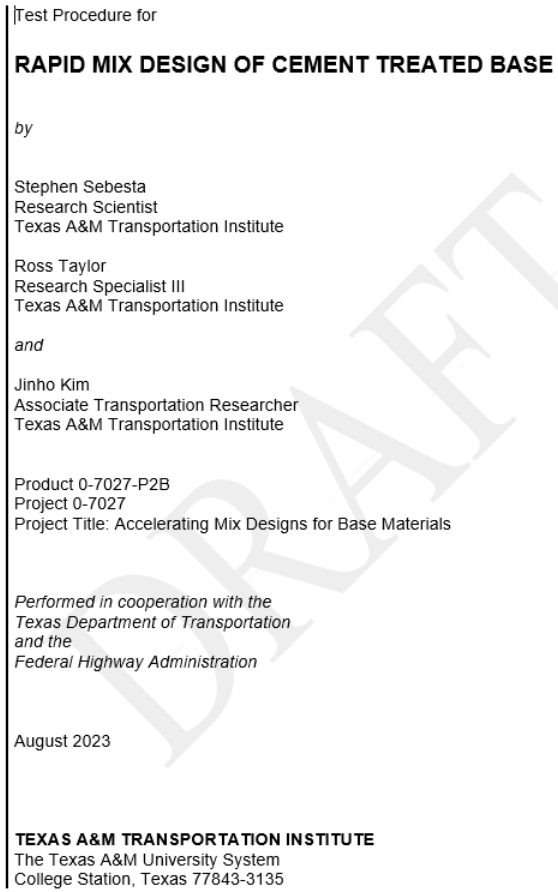
- Decrease material sample quantities
- Speed up test turnaround time
- Harmonize test scope with other treatment methods for base materials

Test	Quantity & Dimension of Test Specimen	Material Required (lb)*	Test Turnaround Time (Days)*
Tex-120-E	9 - 6×8	180	7
Accelerated Design Method for Cement	18 - 4×2	54	4
Tex-122-E & Tex-134-E	18 - 4×2	54	4

*Note: Material required and test turnaround time for strength test specimen only.

Rapid Mix Design of Cement-Treated Base – Proposed Tex-120-E Part III

- Material sampling and preparation
- Moisture density curve
- Mixture design
  - Sample preparation
  - Treatment
  - Compaction
  - Curing
  - Conditioning
  - Testing
- Reporting



Test Procedure for

RAPID MIX DESIGN OF CEMENT TREATED BASE

by

Stephen Sebesta
Research Scientist
Texas A&M Transportation Institute

Ross Taylor
Research Specialist III
Texas A&M Transportation Institute

and

Jinho Kim
Associate Transportation Researcher
Texas A&M Transportation Institute

Product 0-7027-P2B
Project 0-7027
Project Title: Accelerating Mix Designs for Base Materials

Performed in cooperation with the
Texas Department of Transportation
and the
Federal Highway Administration

August 2023

TEXAS A&M TRANSPORTATION INSTITUTE
The Texas A&M University System
College Station, Texas 77843-3135

Product 0-7027-P2B contains complete steps for procedure

Material Sampling & Preparation

- Sampling
  - Minimum 1 gallon of cement
  - Minimum 200 lb of in-place roadway material
    - When the RAP layer is greater than 2 in., separate RAP and base materials
  - When testing stockpile material, sample a minimum of 200 lb
- Preparation
  - Prepare material in accordance with Tex-101-E, Part II
  - Sieve sizes used:
    - 1-3/4", 1-1/4", 7/8", 5/8", 3/8", No. 4, No. 40, Pan (or passing No. 40).

Example Aggregates of Different Sizes

Moisture-Density Curve

- Determine the optimum moisture content and maximum dry density in accordance with Tex-113-E
- Material for moisture-density (M-D) curve is treated with 3% cement
  - Different rate may be directed to use in M-D curve

Example M-D Curve
Specimen after Compaction

Mixture Design – Sample Preparation

- Select a minimum of 3 cement contents
- Produce an 18-lb sample for each cement content
- Replace any aggregate retained on the 7/8" sieve with equivalent material retained on the 5/8" sieve
  - Aggregate replacement maintains reasonable maximum aggregate size relative to smaller-diameter test specimen
- Adjust the moisture content for each cement content
- Both aggregate replacement and moisture adjustment are automatically calculated in new Tx120p3 template
- After adding water to sample, cover and allow to stand for 18-24 hours

TEXAS DEPARTMENT OF TRANSPORTATION

IDT Weigh-Up

Refresh Workbook

MIXTURE DESIGN PROPERTIES					
Max Dry Density, (pcf)	123.5				
Optimum Moisture Content, (%)	6.9%				
Tex-113-E Cement Content, (%)	2.0%				
	Mixture 1	Mixture 2	Mixture 3	Mixture 4	
Cement Content, (%)	2.0%	3.0%	4.0%	6.0%	

SAMPLE WEIGH-UP								
Sample Type		4x2 IDT		Aggregate Weight		18.000		
Material	Salvage Base 1		Flexible Base (Stockpile)					
Description	SB-2		Marble Falls stockpile 642					
Sieve Sizes	Portion, (%)	75.0%	Portion, (%)	25.0%	Portion, (%)		Portion, (%)	
	Individual Weight		Individual Weight		Individual Weight		Individual Weight	
	Modified Gradation, (lb)		Modified Gradation, (lb)		Modified Gradation, (lb)		Modified Gradation, (lb)	
1 3/4	0.000		0.000					
1 1/4	0.000		0.000					
7/8	0.000		0.000					
5/8	0.851		1.152					
3/8	1.472		0.797					
#4	1.836		0.761					
#40	3.497		1.265					
Pan	5.846		0.527					
Total	0.000		0.000					

SAMPLE WEIGHTS					
	Mixture 1	Mixture 2	Mixture 3	Mixture 4	
Weight Dry Aggregate, (lb)	18.000	18.000	18.000	18.000	
Water, (lb)	1.267	1.326	1.385	1.507	
Cement, (lb)	0.360	0.540	0.720	1.080	
Single Sample Wet Weight, (lb)	1.920	1.920	1.920	1.920	

Mixture Design – Treatment Application

- Reweigh wetted sample after standing time and replace evaporated water
- Place sample into mechanical mixer or mixing pan
- Add cement uniformly and mix thoroughly
- After mixing cement into sample, do not allow the mixture to stand for any period of time
- Immediately start the compaction process

Adding Cement into Material for Mixing Using a Mechanical Mixer

Mixture Design – Trial Specimen Compaction

- Estimate the weight for a trial specimen using the M-D curve
  - Template provides a starting weight to achieve 100% density
- Compact a trial specimen
- Adjust the specimen weight if the specimen is not 2 ± 0.1 in. height
  - Template provides height adjustment calculation

TRIAL SAMPLE INFORMATION	
Sample Type:	4x2
Single Sample Weight, (lb)	1.920
Trial Sample Height, (in)	2.11
Corrected Sample Weight, (lb)	1.820

- Superpave gyratory compactor compaction parameters
  - 2-in. (50.8-mm) height
  - Do not exceed 200 gyrations
  - Unheated 4-in. (100-mm) diameter mold
  - 600-kPa compaction pressure
  - 30 gyrations per minute
  - 1.25° compaction angle

Mixture Design – IDT Specimen Compaction

- Compact 6 total specimen that meet height tolerance
- Record for each specimen:
  - Weight after molding, lb
  - Height, in.
- After compaction, seal each specimen in an air- and watertight bag or container

Extruding a 4×2 IDT Strength Test Specimen

Mixture Design – Curing

- Cure sealed test specimens at 104 ± 5°F for 72 ± 2 hours
- After curing, remove specimens from sealed containers

Cement-Treated Specimens Sealed in Zip-Top Bags for Curing during Mixture Design

Mixture Design – Moisture Conditioning

- Place each specimen in a container large enough to completely submerge the specimen
- Fill the container with water to 0.5 to 1 in. above the top of the specimen
- Soak each specimen for 24 hours ± 15 minutes

Soaking Specimens

Mixture Design – IDT Strength Testing

- IDT strength test in accordance with Tex-226-F
  - 2 in. per minute loading rate
- Record peak load, lb
- Calculate and report IDT strength

$$IDT = \frac{2 * F}{3.14 * h * d}$$

IDT = Indirect tensile strength, psi
F = Total applied vertical load at failure, lb
h = Height of specimen, in.
d = Diameter of specimen, in.

	TEST SPECIMEN INFORMATION				IDT TEST DATA: Tex-226-F			
	Sample Number	Weight After Molding, (lb)	Height, (in)	Wet Density, (lb/ft3)	Conditioning	Max Load, (lb)	IDT Strength, (psi)	Average, (psi)
Mixture 1	1	1.886	2.030	127.8	Wet	847.9	66.48	70
	2	1.889	2.040	127.3		813.2	63.44	
	3	1.889	2.030	128.0		906.8	71.09	
	4	1.886	2.020	128.4		1006.2	79.28	
	5	1.884	2.030	127.6		998.5	78.28	
	6	1.889	2.010	129.2		800.9	63.42	
Mixture 2	1	1.883	2.010	128.8	Wet	1481.4	117.30	116
	2	1.885	2.030	127.7		1384.6	108.55	
	3	1.880	2.010	128.6		1654.7	131.02	
	4	1.882	2.010	128.8		1322.1	104.69	
	5	1.886	2.010	129.0		1583.7	125.40	
	6	1.874	2.010	128.2		1397.2	110.63	
Mixture 3	1	1.882	2.020	128.1	Wet	1920.8	151.34	135
	2	1.872	2.020	127.4		1731.0	136.38	
	3	1.872	2.020	127.4		1532.3	120.73	
	4	1.882	2.010	128.8		1808.7	143.22	
	5	1.882	2.010	128.8		1843.4	145.96	
	6	1.883	2.010	128.8		1405.6	111.30	
Mixture 4	1	1.885	2.010	129.0	Wet	1950.7	154.46	154
	2	1.888	2.000	129.8		1898.9	151.11	
	3	1.882	2.010	128.8		2004.4	158.71	
	4	1.883	2.020	128.2		1975.6	155.66	
	5	1.887	2.000	129.7		1888.8	150.31	
	6	1.879	2.010	128.5		1934.6	153.18	

Reporting

- Report the type of cement used
- Report to the nearest 0.1:
  - Design cement content
  - Gradation of aggregate blend
  - Maximum dry density
  - Optimum moisture content
- Report to the nearest whole number:
  - Average IDT strength for moisture-conditioned test specimen
  - Percentage of each material used
- Template has inputs for
  - Minimum IDT strength
  - Treatment depth

MATERIAL GRADATION: Tex-101-E - Part II				
Material	Salvage Base 1	Flexible Base (Stockpile)		
Description	SB-2	Marble Falls stockpile 642		
Sieve Sizes	% Retained	% Retained	% Retained	% Retained
1 3/4	0.0%	0.0%		
1 1/4	1.1%	4.8%		
7/8	1.7%	9.5%		
5/8	3.5%	11.3%		
3/8	10.9%	17.7%		
#4	13.6%	16.9%		
#40	25.9%	28.1%		
Pan	43.3%	11.7%		
Total	100.0%	100.0%		

DESIGN SUMMARY: Tex-120-E - Part III			
Optimum Moisture Content, (%)	6.9%	Salvage Base 1, (%)	75%
Maximum Dry Density, (pcf)	123.5	Flexible Base (Stockpile), (%)	25%
Tex-113-E Cement Content, (%)	2.0%		
Selected Mixture Design	Mixture 1		
Cement Content, (%)	2.0%	Target IDT (conditioned), (psi)	43
☐ Lock Selected Design		Average IDT (conditioned), (psi)	82

QUANTITY ESTIMATOR		
Treatment Depth, (in)	10.0	
Treatment Rate Cement	(lb/SY)	18.53

Selecting Minimum IDT Strength

- Minimum IDT strength can be determined from the district's historic minimum UCS requirements

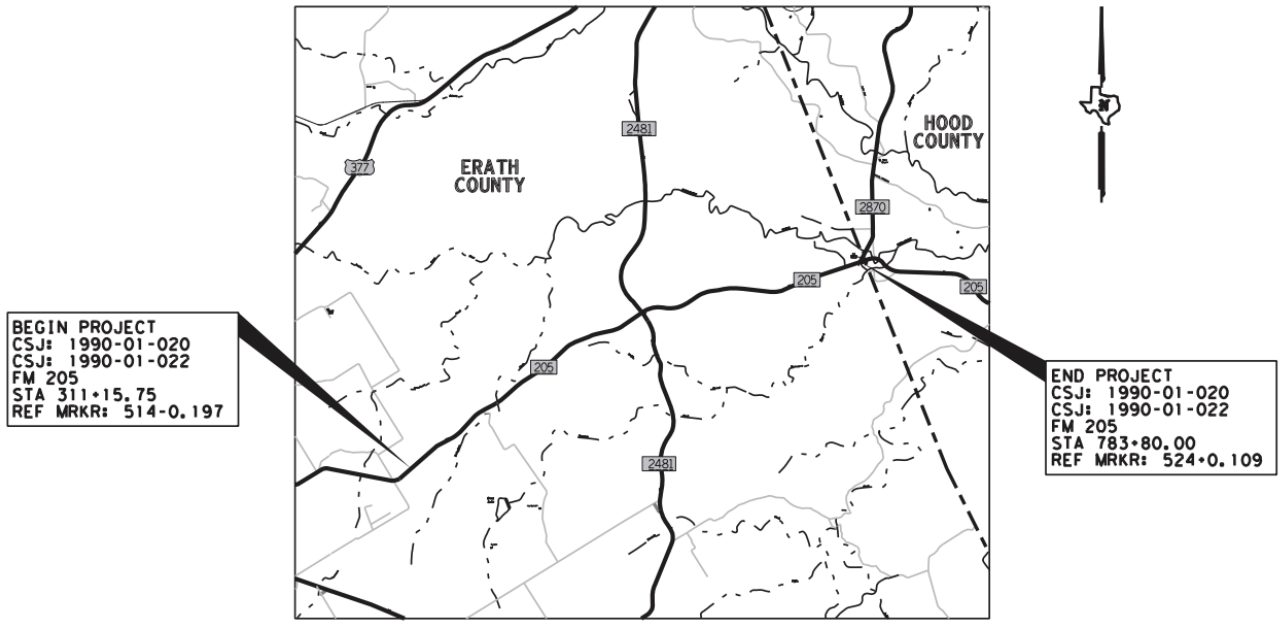
Accelerated Mix Design Thresholds by Historic UCS Targets

Tex-120-E UCS (psi)	Accelerated Cure IDT Strength Minimum (psi)
175	34
220	43
300	59
500	98

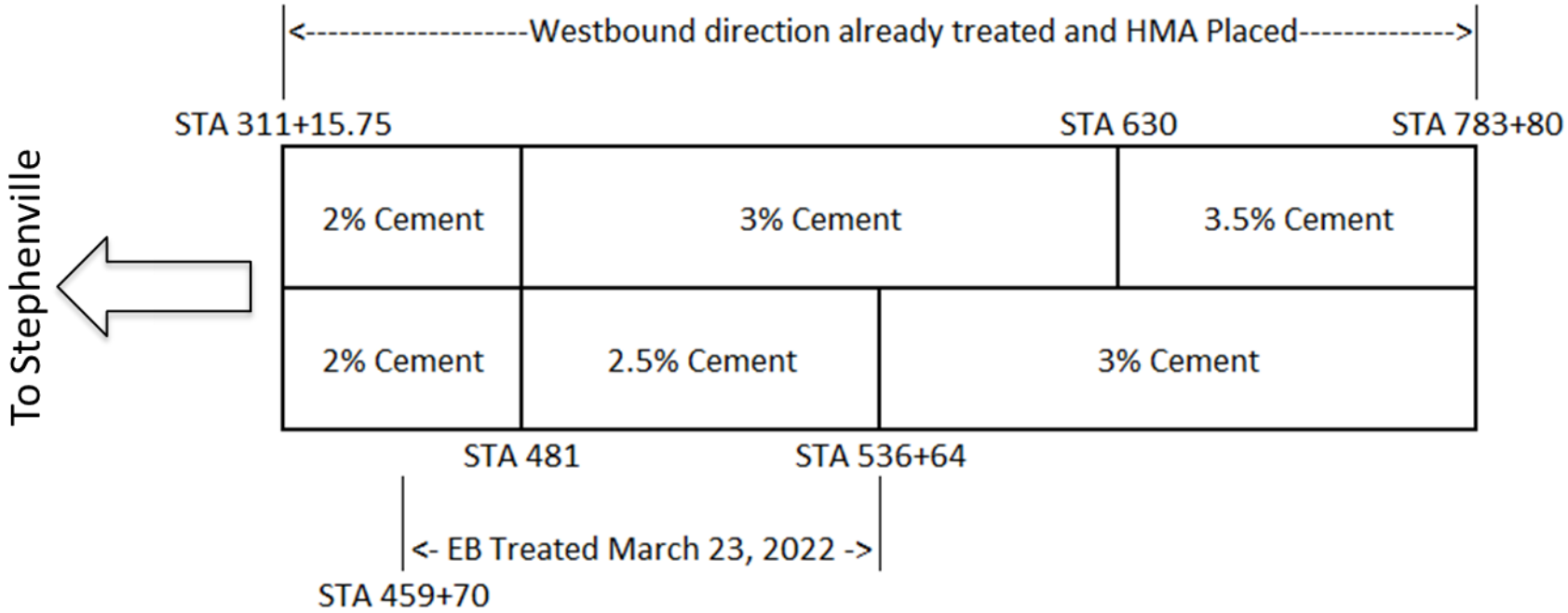
Example Field Project Results

Field Project – FM 205

- Collected materials for small-sample mix design research
- Reduced cement rate incorporated into test section in eastbound direction
- As-built falling weight deflectometer (FWD) collected



Layout of Field Treatments – FM 205 in March 2022



General process reported by contractor:

- Day 1: pre-pulverize and correct cross slope
- Day 2: cement treat
- Day 3: finish treated base
- Day 4: place seal coat
- Day 5: place 1st lift of HMA

Cement Treatment March 23, 2022
STA 536+64 to 459+70

FWD Survey on As-Built August 2, 2022

Summary FWD results in EB Test Sections

Start STA	End STA	% Cement	AVG Deflection (mils)	AVG base E (ksi)
311.15	481	2	7.92	538
481	536.64	2.5	7.94	377
536.64	630	3	7.35	319
630	783.8	3	7.49	541

Average Base Modulus 300+ ksi for All Treatment Rates

Questions

Questions and Contacts

Stephen Sebesta
979-317-2297
s-sebesta@tamu.edu

Ross Taylor
979-317-1224
ross-taylor@tti.tamu.edu

Jinho Kim, Ph.D.
979-317-2324
jinho-kim@tti.tamu.edu