INSITU STABILIZATION of SOILS by INJECTION of HIGH-DENSITY POLYURETHANE: PRINCIPLES AND APPLICATIONS

aka Insitu Soil Stabilization by Injecting Polyurethane or ISSBIP

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URETEK™

AGENDA

- **FUNDAMENTALS**
  - **GOAL OF PRESENTATION**
  - **ISSBIP DEFINITION**
  - **ISSBIP TENETS**
- **OBSERVATIONS**
  - **ISSBIP: SOIL / POLYMER INTERACTION**
  - **ISSBIP ADVANTAGES**
  - **ISSBIP APPLICATIONS**

AGENDA (continued)

- **CASE STUDY:**
  STABILIZING BRIDGE APPROACHES AND DEPARTURES

- **SUMMARY / DISCUSSION**

FUNDAMENTALS

GOAL OF PRESENTATION

Provide essential information on ISSBIP to engineering professionals involved in evaluating insitu soil stabilization alternatives

ISSBIP DEFINITION

A process for stabilizing weak and/or poorly compacted soils insitu and leveling structures (including bridge approaches / departures) by injecting a specially-formulated polyurethane into the soils

ISSBIP DEFINITION

- ISSBIP Polyurethane Description
  - Low viscosity when introduced into the soil
  - 2-component: Resin & Hardener (1:1 by volume)
  - Exothermic chemical reaction between the two components creates CO2 gas which causes polymer expansion and creates pressure on the surrounding environment
  - Formulated to resist water intrusion into the reaction

ISSBIP DEFINITION

- ISSBIP Polyurethane Description
  - Rapid Cure –
    - Reaction complete in < 1 minute
    - Can support traffic after 20 minutes
    - Full strength in 24 hours
  - Rigid Structural Polyurethane created as the material cures
  - Installed density range – 3 to 20 pcf

ISSBIP DEFINITION

- ISSBIP Process Description
  - The heated components are introduced in the impingement gun and forced down the injection tube by air pressure
  - The low viscosity polymer flows easily into the voids and weak zones in the soil mass
  - As the reaction occurs, the expanding polymer compacts the surrounding soils; continued injection yields lift
  - Reaction mass necessary for compaction is achieved by
    1) weight of pavement and overlying soil
    2) stabilized mass in the upper elevations by employing a top-down injection pattern

ISSBIP TENETS

- Polymer is placed via an injection tube; “surgically” placed in the strata where stabilization is needed

- Multiple injection tubes are used to promote full coverage throughout the area being stabilized

- Injected substance is a two-component, high-density polyurethane characterized by rapid expansion and large volume increase created by chemical reaction between the components

- Movement is monitored at the surface during the injection process

OBSERVATIONS

ISSBIP SOIL / POLYMER INTERACTION

- Complex Issue
  - Governed by both soil and polymer properties
  - Can be further impacted by adjusting operational parameters (heat and injection pressure)

- Soil Properties – density, grain size, porosity, permeability, degree of saturation

- Polymer Properties – chemical composition and viscosity

- Operational Parameters – injection temperature, injection pressure, shot duration, and shot sequencing

ISSBIP SOIL / POLYMER INTERACTION – TRENDS

- Aggregate Bases/Subbases and Coarse Sand
  - Polymer Infiltration (binding)
  - Polymer Expansion (compacting)

- Saturated Fine Sands
  - Polymer expansion displaces the water and flowable soils
  - Polyurethane encapsulates the remaining soil and begins to “set up”

ISSBIP SOIL / POLYMER INTERACTION – TRENDS

- Layers with Silts and Clay Size Particles

  - Polymer infiltrates the weak lenses in these layers

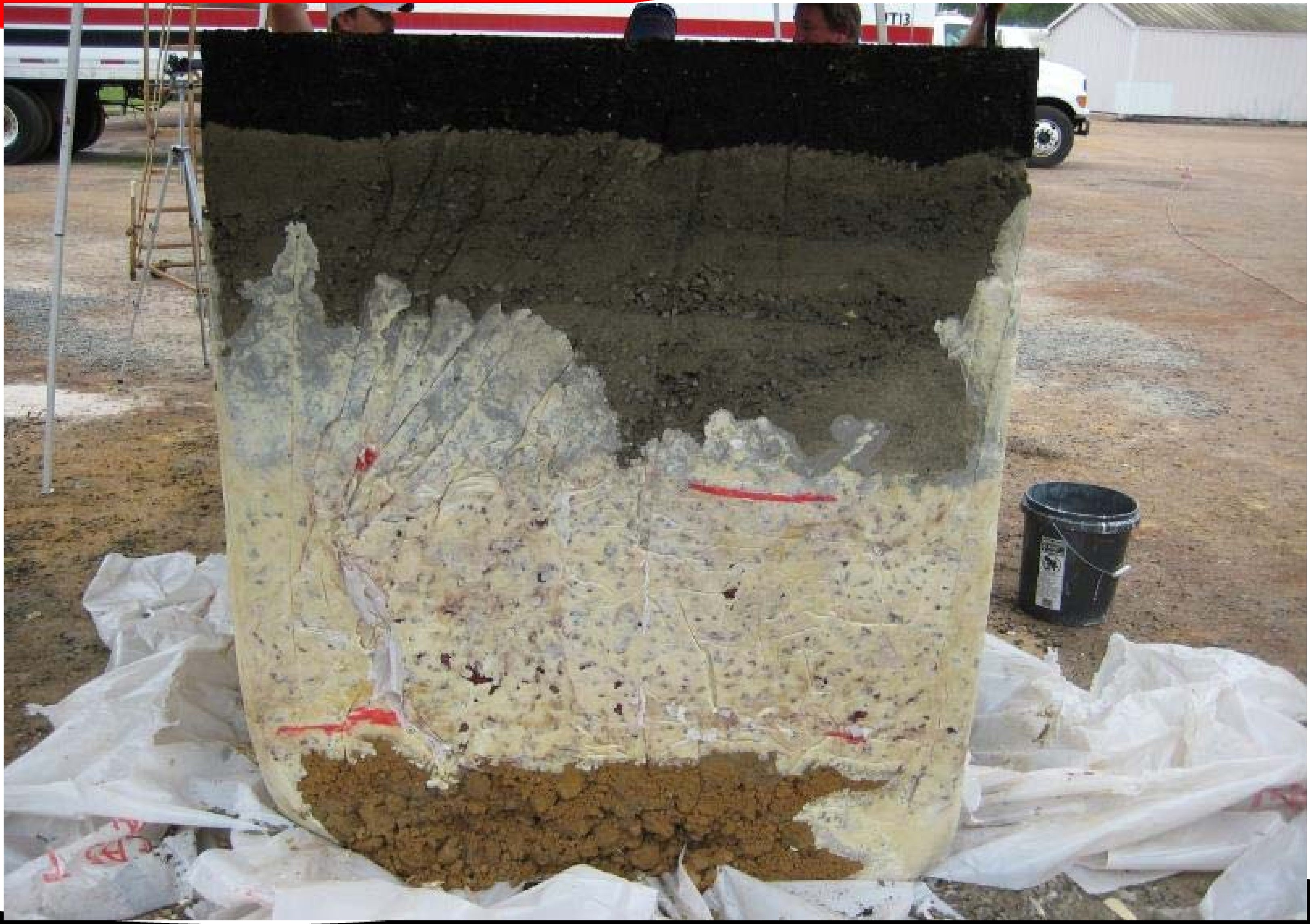
  - Polymer begins to expand – encapsulating and compacting the surrounding soils

ISSBIP SOIL / POLYMER INTERACTION – TRENDS

- Organic Soils
  - When operating in soft soils, the polymer reaction time is accelerated so the polymer spends little time moving laterally
  - The rapid reaction time causes the polyurethane to form a vertical shear wall within the soft soil mass
  - By designing the injection pattern, these walls can be shaped into an interconnected series of confinement cells capable of supporting loads

PHOTOGRAPHS

Stabilization of Aggregate Subbase



Excavation Revealing ISSBIP-Stabilized Sand

Excavating Native Soil to Expose Crater Repair – Note Polymer Veins

Intact Extraction of Stabilized Crater Repair

Forensic Excavation of ISSBIP-Stabilized Peat Deposit

The constructed structure was removed to expose the injected foam

ISSBIP ADVANTAGES

- Fast: can withstand traffic in 20 minutes; achieves full strength within 24 hours
- Reduced Disruption: Minimally Invasive Process
- Predictable: Highly Controlled Expansion
- Accuracy: Precision Alignment of Faulted Slabs

ISSBIP ADVANTAGES

- Lightweight: Provides strength (with minimal weight) to the already distressed soil
- Great utility: a single process which can solve multiple problems
- Permanent: Impervious to Water and Most Chemicals
- Eco-Friendly: Environmentally Benign Material; NSF 61 Certified (can use around potable water)

ISSBIP APPLICATIONS

- Settled or Poorly-supported Transportation Assets
  - Bridge Approaches and Departures
  - Asphalt, Concrete, and Composite Pavements
    - Airfields (runways, taxiways, aprons)
    - Roadways
  - Dips or Faulted Joints
  - Railroads
- Leaking Underground Drainage Systems
- Settled or Poorly-supported Structures

CASE STUDY

STABILIZING BRIDGE APPROACHES AND DEPARTURES

CASE STUDY – DESCRIPTION

- STABILIZING SOILS ON BOTH THE EAST AND WEST ENDS OF A BRIDGE ON US 80 OVERPASSING FM 548
- FORNEY, TEXAS
- JANUARY 2013

CASE STUDY – DATA REVIEW

- PHOTOGRAPHS FROM SITE VISIT
- DCP RESULTS
- CONSULTANT'S GEOTECHNICAL REPORT AND SUPPLEMENT

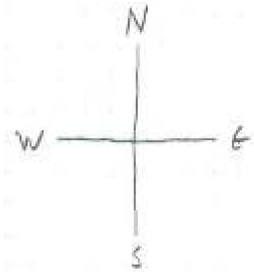
distressed pavement at interface of asphalt & concrete pavement
(Northeast quadrant - looking North from median)

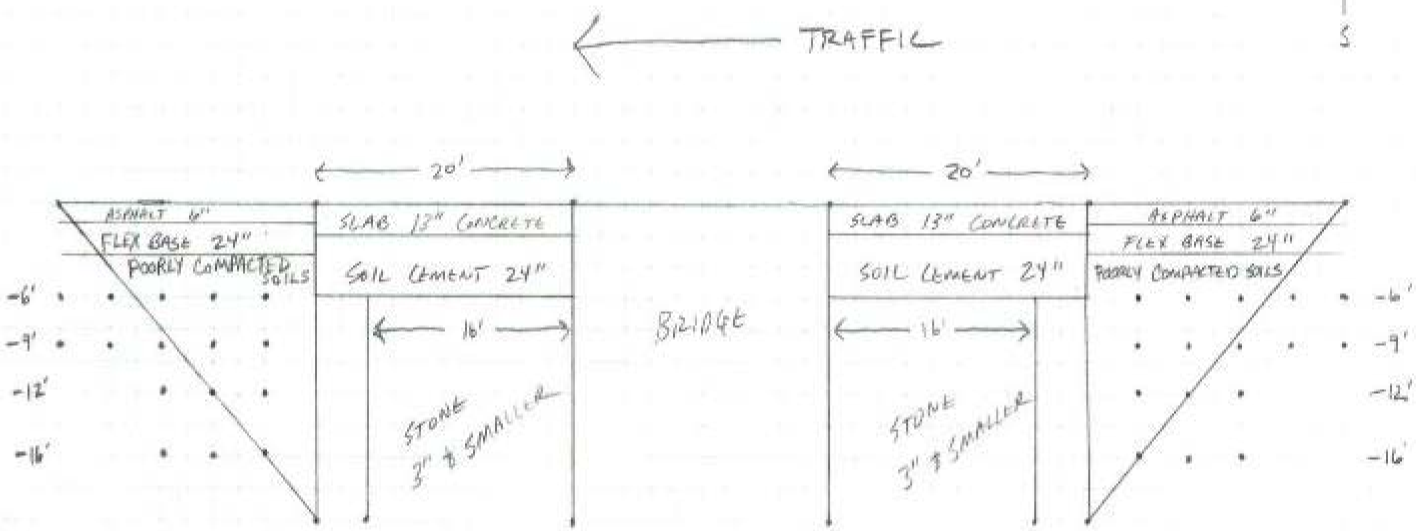
distressed pavement at interface of asphalt & concrete pavement
(Northwest quadrant - looking North from median)

satisfactory performance at interface of asphalt & concrete pavement
(Southwest quadrant - looking South from median)

settlement at interface of concrete shoulder & asphalt shoulder
(Southeast quadrant - looking South from median)

PROFILE OF WESTBOUND LANES (US 80 @ FM 548)

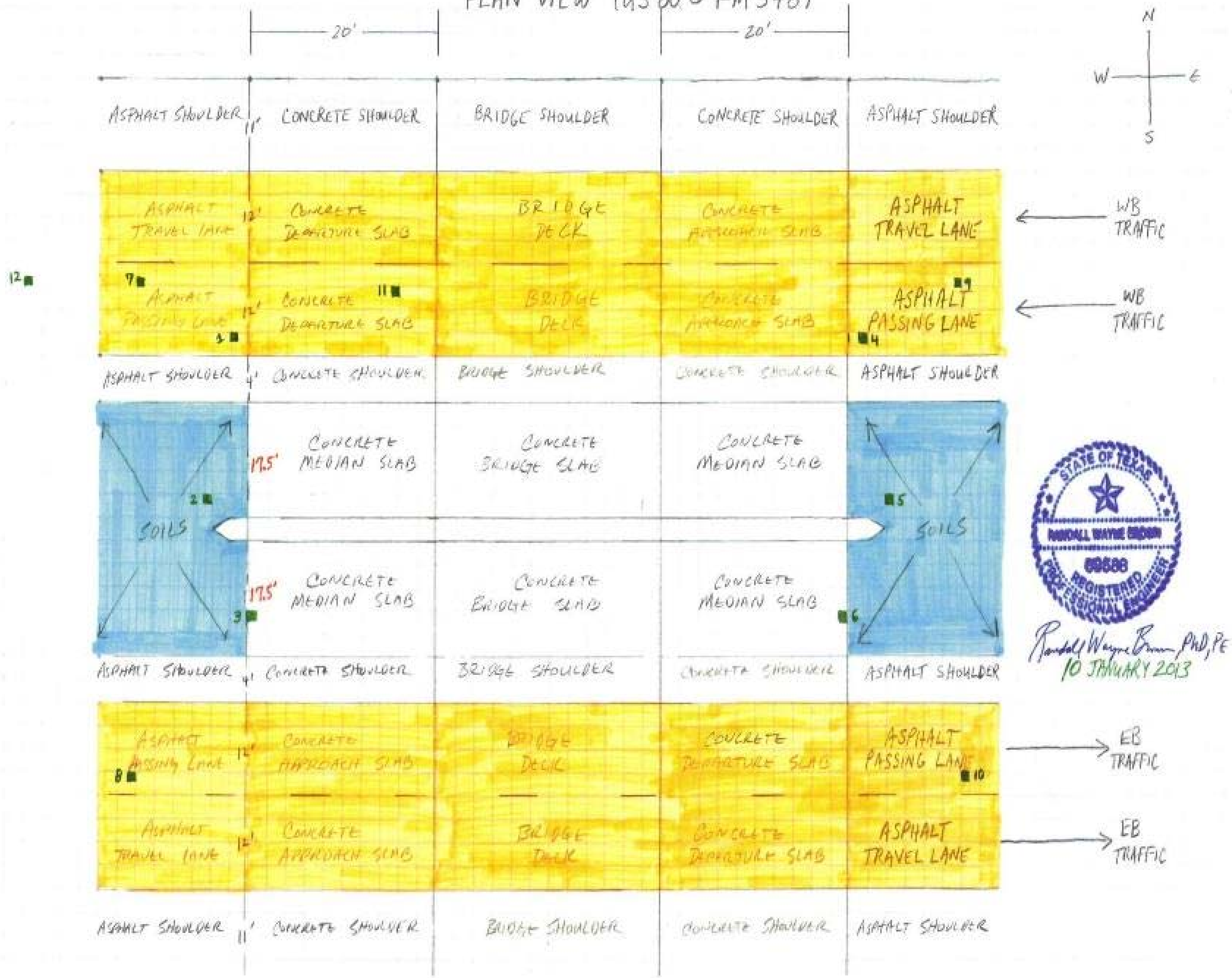




STATE OF TEXAS
RANDALL WAYNE BROWN
89588
REGISTERED
PROFESSIONAL ENGINEER

Randall Wayne Brown, PhD, PE
10 JANUARY 2013

PLAN VIEW (US 80 @ FM 548)



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12 TX 01 021 Forney TX DCP Totals

Depth in Feet	DCP 1	DCP 2	DCP 3	DCP 4	DCP 5	DCP 6	DCP 7	DCP 8	DCP 9	DCP 10	DCP 11	DCP 12
1.64	17	33	35	7	26	2	30	32	20	15	14	11
1.97	15	58	30	16	24	6	27	24	36	21	20	13
2.30	23	56	38	19	43	8	18	16	16	24	15	10
2.62	21	67	42	15	33	9	16	4	17	27	11	7
2.95	15	39	45	8	31	13	7	8	28	25	8	6
3.28	5	30	39	2	19	16	8	5	31	8	4	5
3.61	3	34	33	1	37	12	4	5	23	4	3	4
3.94	2	38	37	1	34	15	5	6	26	4	3	6
4.26	1	41	17	2	29	14	4	4	14	4	7	11
4.59	1	12	13	2	24	9	4	4	11	1	1	12
4.92	1	17	7	2	17	5	5	4	12	3	3	8
5.25	2	11	12	1	5	3	11	6	15	5	2	8
5.58	1	2	11	1	5	4	10	5	13	1	15	3
5.90	1	2	9	1	4	2	9	4	16	5	25	4
6.23	1	3	1	1	3	5	11	4	12	4	28	2
6.56	1	2	2	3	4	7	6	4	15	4	23	3
6.89	1	4	1	2	2	6	11	3	10	5	22	2
7.22	1	4	2	1	1	9	14	3	8	5	15	4
7.54	1	3	10	2	2	7	11	4	6	4	11	4
7.87	1	2	3	2	6	13	9	3	4	6	10	4
8.20	1	2	2	1	3	18	8	6	5	5	16	4
8.53	1	5	1	1	6	15	9	3	6	7	22	3
8.86	2	7	9	1	5	4	7	3	3	9	21	4
9.18	2	2	8	1	5	4	6	4	2	8	23	3
9.51	2	2	2	1	3	2	7	5	9	20	31	4
9.84	3	2	2	2	4	1	6	5	7	23	36	4
10.17	1	4	6	2	5	1	4	5	5	17	32	4
10.50	0.5	6	3	3	5	3	4	9	5	14	29	2
10.82	0.5	4	3	1	3	3	3	6	7	11	35	5
11.15	0.5	2	2	1	5	5	2	5	6	9	26	3
11.48	0.5	5	5	1	6	9	4	4	5	7	25	3
11.81	0.5	3	17	1	6	6	3	7	5	4	42	3
12.14	0.5	6	8	1	5	4	2	7	5	8	59	4
12.46	0.5	3	5	1	6	2	4	3	5	7		5
12.79	0.5	4	11	0.5	4	4	5	2	3	9		2
13.12	0.5	6	19	0.5	5	4	4	4	18	8		1
13.45	0.5	7	18	0.5	3	4	4	5	16	6		5
13.78	0.5	8	7	0.5	3	3	2	4	11	3		5
14.10	0.5	4	9	0.5	2	4	3	2	9	4		6
14.43	0.5	8	23	2	8	6	3	2	7	5		4
14.76	2	5	18	1	6	8	6	3	10	4		4
15.09	2	3	2	0.5	6	6	7	3	9	6		6
15.42	3	9	2	0.5	5	3	8	2	10	5		9
15.74	4	8	1	0.5	5	4	7	2	12	7		11
16.07	4	19	4	0.5	8	5	6	1	11	4		13
16.40	5	10	3	0.5	4	4	5	0.6	8	5		15
16.73	6	3	3	0.5	3	14	4	0.6	9	8		22

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17.06	4	4	1	2	5	16	7	0.6	11	7		18
17.38	4	5	2	0.5	3	15	6	0.6	12	7		15
17.71	6	7	3	0.5	7	19	7	0.6	13	6		13
18.04	5	7	3	3	6	23	5	1	11	7		17
18.37	7	4	3	3	5	21	3	3	16	6		19
18.70	6	12	3	3	6	27	7	8	19	7		22
19.02	4	20	3	3	7	29	4	9	9	8		26
19.35	3	6	1	2	4	36	3	8	12	6		21
19.68	9	4	7	5	3	33	5	7	10	9		19
20.01	6	3	8	4	3	31	4	7	13	7		24
20.34	5	3	1	4	3	29	8	6	11	5		29
20.66	7	3	1	3	2	40	7	6	10	5		32
20.99	8	3	1	3	6	34	5	5	12	4		27
21.32	7	3	1	5	5	33	5	7	15	5		24
21.65	9	2	1	4	4	35	7	9	12	6		21
21.98	11	2	1	3	4	39	8	8	10	10		28
22.30	13	3	7	2	4	36	7	7	10	9		19
22.63	10	2	10	4	3	41	7	4	27	8		26
22.96	21	5	13	7	3	28	6	2	24	6		27
23.29	27	6	6	5	5	33	5	6	31	7		
23.62	29	4	32	6	6	29	6	9	28	7		
23.94	39	4	35	6	5	23	5	8	21	6		
24.27	87	8	26	7	4	25	5	9	19	6		
24.60	91	9	29	7	4	31	6	7	20	5		
24.93		8	37	7	4	30	7	6	27	5		
25.26		10	31	3	7	31	7	7	29	6		
25.58		9	43	6	6	29	9	8	25	5		
25.91		10	38	6	9	27	5	6	26	6		
26.24		8	47	7	9	29	6	6	23	5		
26.57		11	42	6	8	34	5	5		6		
26.90		11	48	6	7	37	4	8		5		
27.22		10	39	7	5	26	4	9		5		
27.55		9	45	7	5	28	6	7		4		
27.88		11		9	6	37	5	10		5		
28.21		13		8	6	41	6	9		6		
28.54		8		8	8	47	7	10		6		
28.86		12		9	8	50	8	10		7		
29.19		15		8	7		7	8		11		
29.52		18		9	6		6	11		13		
29.85		21		10	7		7	9		11		
30.18		19		11	7		11	12		12		
30.50		26		13	8		14	13		12		
30.83		21		11	10		16	17		16		
31.16		37		15	10		24	14		13		
31.49		48		17	9		26	16		16		
31.82		41		21	12		23	14				
32.14		46		19	17		38					
32.47		59		24	19		33					
32.80		86		28	14							

CASE STUDY – FINDINGS

- NON-UNIFORM SLAB SUPPORT FOR THE APPROACH AND DEPARTURE SLABS LED TO SETTLEMENT

- MIGRATION OF FINES FROM THE COMPACTED SOIL ZONE INTO THE STONE ZONE RESULTED IN VOIDING, REDUCTION IN SUPPORT, AND DISTRESSES

CASE STUDY – FINDINGS

- CROSS-SLOPE and LONGITUDINAL SLOPE LED TO RUNOFF COLLECTING IN THE NW QUADRANT (WB DEPARTURE AREA) LEADING TO SATURATED CONDITIONS

- GEOTECHNICAL CONSULTANT FOUND SOIL UNDER WB LANES WAS WEAKER THAN UNDER EB LANES

CASE STUDY – FINDINGS

- GEOTECHNICAL CONSULTANT CONCLUDED THERE WAS CREEP DEFORMATION OF THE EMBANKMENT

- GEOTECHNICAL CONSULTANT SAID IT WAS "DIFFICULT TO ASCRIBE THE ACTUAL CAUSE OF PAVEMENT SETTLEMENT TO ANY ONE FACTOR IN THIS CASE"

CASE STUDY – TREATMENT

- ESTABLISHED A GROUT CURTAIN BETWEEN THE COMPACTED SOIL ZONE AND ROCK ZONE TO PRECLUDE THE MIGRATION OF FINES

- STABILIZED SUPPORT SOILS AND LIFTED SLABS THAT ARE EXHIBITING SETTLEMENT

CASE STUDY – TREATMENT

- STABILIZED SOILS SUPPORTING PAVEMENTS EXHIBITING DISTRESS

- STABILIZED THE ASPHALT SHOULDER PAVEMENT IN THE NW QUADRANT (WB DEPARTURE AREA) TO REDUCE WATER INFILTRATION INTO THE SUPPORT SOILS

CASE STUDY – TREATMENT

- STABILIZED THE BACKFILL SOILS IN THE RETAINED ZONE OF THE WB LANES (NW and NE QUADRANTS)

- INJECTION DEPTHS/ PATTERN VARIED BASED ON:
  - OBJECTIVE SOUGHT
  - SOIL CONDITIONS
  - MAGNITUDE OF DISTRESS

CASE STUDY – SUMMARY

- **EXECUTED: 11-28 JANUARY 2013 (16 days of actual injection)**
- **COST OF PROJECT: $190,349**
- **2-YEAR WARRANTY; NO CALL BACKS IN YEAR ONE**
- **URETEK USA PERSONNEL PERFORMED A ROUTINE “ONE YEAR ANNIVERSARY” INSPECTION ON 4 FEBRUARY 2014**

SUMMARY / DISCUSSION

ISSBIP SUMMARY

- Fixes the problem by stabilizing the soils and increasing the stiffness of the weak layers in order to better support the load
- Fixes the symptom of the problem by lifting the settled pavement or structure to the desired grade
- Completed with minimal downtime

THANK YOU

FOR

YOUR TIME

MICHIGAN CONTACTS

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TIMELINE

- **17 Jul 2012 – Geotechnical consultant releases first report on problems with this bridge system (still under warranty)**
- **10 Aug 2012 – Initial Reconnaissance Visit by URETEK USA Regional Manager**
- **15 Aug 2012 – Site Visit by URETEK Engineering personnel**

TIMELINE

- 20 Aug 2012 – Initial Remediation Plan and Proposal published by URETEK USA

- 5 Sep 2012 – Geotechnical consultant publishes supplemental report

- 23 Sep 2012 – Supplement to Remediation Plan published by URETEK USA

TIMELINE

- **20-21 Dec 2012 – Dynamic Cone Penetrometer (DCP) testing executed by URETEK USA**
- **10 Jan 2013 – Site Visit and DCP data review with involved parties**
- **11 Jan 2013 – Final Remediation Plan and Proposal published by URETEK USA**

TIMELINE

- **11- 28 Jan 2013 – Stabilization of Soils in the Bridge System using ISSBIP**

  (16 actual injection days within this timeframe)

- **4 Feb 2013 – Inspection by URETEK USA personnel (1-year anniversary)**