

Texas Demonstration Project: Continuously Reinforced Concrete Pavement on FM 1938

**Final Report
April 2015**



WAYS FOR LIFE
...on for the American Driving Experience.



U.S. Department of Transportation
Federal Highway Administration

FOREWORD

The purpose of the Highways for LIFE (HfL) pilot program is to accelerate the use of innovations that improve highway safety and quality while reducing congestion caused by construction. **LIFE** is an acronym for **L**onger-lasting highway infrastructure using **I**nnovations to accomplish the **F**ast construction of **E**fficient and safe highways and bridges.

Specifically, HfL focuses on speeding up the widespread adoption of proven innovations in the highway community. “Innovations” is an inclusive term used by HfL to encompass technologies, materials, tools, equipment, procedures, specifications, methodologies, processes, and practices used to finance, design, or construct highways. HfL is based on the recognition that innovations are available that, if widely and rapidly implemented, would result in significant benefits to road users and highway agencies.

Although innovations themselves are important, HfL is as much about changing the highway community’s culture from one that considers innovation something that only adds to the workload, delays projects, raises costs, or increases risk to one that sees it as an opportunity to provide better highway transportation service. HfL is also an effort to change the way highway community decision makers and participants perceive their jobs and the service they provide.

The HfL pilot program, described in Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) Section 1502, includes funding for demonstration construction projects. By providing incentives for projects, HfL promotes improvements in safety, construction-related congestion, and quality that can be achieved through the use of performance goals and innovations. This report documents one such HfL demonstration project.

Additional information on the HfL program is at [FHWA Highways for Life website](#).

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16. Abstract As part of a national initiative sponsored by the Federal Highway Administration (FHWA) under the Highways for LIFE program, the Texas Department of Transportation (DOT) was awarded a \$1,000,000 grant to demonstrate the use of proven, innovative technologies including non-woven geo-textile bond breaker between CRCP and cement-treated base, intelligent compaction of subgrade and base materials, optimized aggregate gradation for concrete pavement, improved concrete curing, texture and grooving of CRCP. This report documents deployment of innovations on the construction of FM 1938 in the cities of Southlake, Westlake and Keller, just north of Fort Worth, Texas. The project involved the construction of the new 2.6 mile freeway with six lanes from SH 114 to Dove Road and four lanes from Dove Road to Randol Mill Road. The purpose of the new roadway was to improve capacity and ease mobility on FM 1709. The construction of the FM 1938 project provided TxDOT with valuable insight to several aspects of the construction process. The use of optimized gradation showed potential cost savings through reduction in cement and pavement thickness requirements. The estimated cost savings with reduced cement requirements was about 60 cents per CY of concrete; however, the reduction in thickness could not be further reduced for this project due to the cover requirements for steel in the continuously reinforced design. The use of a non-woven fabric as a bond breaker was not considered an advantage on this project, especially given the use of continuous reinforcement. The installation was labor intensive and the use of the fabric did not result in any improved attributes. While intelligent compaction was not used under the pavement sections as originally planned, it did show promise as an evolving technology. The lithium based curing compounds were more expensive and requires additional research to determine its cost-benefits.			
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SI* (MODERN METRIC) CONVERSION FACTORS				
APPROXIMATE CONVERSIONS TO SI UNITS				
Symbol	When You Know	Multiply By	To Find	Symbol
LENGTH				
(none)	mil	25.4	micrometers	µm
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
AREA				
in ²	square inches	645.2	square millimeters	mm ²
ft ²	square feet	0.093	square meters	m ²
yd ²	square yards	0.836	square meters	m ²
ac	acres	0.405	hectares	ha
mi ²	square miles	2.59	square kilometers	km ²
VOLUME				
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft ³	cubic feet	0.028	cubic meters	m ³
yd ³	cubic yards	0.765	cubic meters	m ³
NOTE: volumes greater than 1000 L shall be shown in m ³				
MASS				
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
TEMPERATURE (exact degrees)				
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
ILLUMINATION				
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela per square meter	cd/m ²
FORCE and PRESSURE or STRESS				
lbf	poundforce	4.45	Newtons	N
lbf/in ² (psi)	poundforce per square inch	6.89	kiloPascals	kPa
k/in ² (ksi)	kips per square inch	6.89	megaPascals	MPa
DENSITY				
lb/ft ³ (pcf)	pounds per cubic foot	16.02	kilograms per cubic meter	kg/m ³
APPROXIMATE CONVERSIONS FROM SI UNITS				
Symbol	When You Know	Multiply By	To Find	Symbol
LENGTH				
µm	micrometers	0.039	mil	(none)
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
AREA				
mm ²	square millimeters	0.0016	square inches	in ²
m ²	square meters	10.764	square feet	ft ²
m ²	square meters	1.195	square yards	yd ²
ha	hectares	2.47	acres	ac
km ²	square kilometers	0.386	square miles	mi ²
VOLUME				
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m ³	cubic meters	35.314	cubic feet	ft ³
m ³	cubic meters	1.307	cubic yards	yd ³
MASS				
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
TEMPERATURE				
°C	Celsius	1.8C+32	Fahrenheit	°F
ILLUMINATION				
lx	lux	0.0929	foot-candles	fc
cd/m ²	candela per square meter	0.2919	foot-Lamberts	fl
FORCE and PRESSURE or STRESS				
N	Newtons	0.225	poundforce	lbf
kPa	kiloPascals	0.145	poundforce per square inch	lbf/in ² (psi)
MPa	megaPascals	0.145	kips per square inch	k/in ² (ksi)

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ABBREVIATIONS AND SYMBOLS

AASHTO	American Association of State Highway and Transportation Officials
AC	Asphalt Concrete
ACMM	ATEK Concrete Maturity Meter
ASTM	American Society for Testing and Materials
CBR	California bearing ratio
CRCP	Continuously Reinforced Concrete Pavement
dB	Decibel
DC	dielectric content
DCP	Dynamic cone penetrometer
DOT	Department of Transportation
EI	Effectiveness Index
FHWA	Federal Highway Administration
FWD	Falling weight deflectometer
HfL	Highways for LIFE
IC	Intelligent Compaction
IRI	International Roughness Index
mph	Miles Per Hour
OBSI	onboard sound intensity
OSHA	Occupational Safety and Health Administration
PBT	Plate bearing test
RH	Relative Humidity
RoW	Right-of-Way
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users
TTI	Texas Transportation Institute
TxDOT	Texas Department of Transportation
SHRP 2	Strategic Highway Research Program
SI	sound intensity

INTRODUCTION

HIGHWAYS FOR LIFE DEMONSTRATION PROJECTS

The Highways for LIFE (HfL) pilot program, the Federal Highway Administration (FHWA) initiative to accelerate innovation in the highway community, provides incentive funding for demonstration construction projects. Through these projects, the HfL program promotes and documents improvements in safety, construction-related congestion, and quality that can be achieved by setting performance goals and adopting innovations.

The HfL program - described in the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) - has provide incentives to a maximum of 15 demonstration projects a year. The funding amount may total up to 20 percent of the project cost, but not more than \$5 million. Also, the Federal share for a HfL project may be up to 100 percent, thus waiving the typical State-match portion. At the State's request, a combination of funding and waived match may be applied to a project.

To be considered for HfL funding, a project must involve constructing, reconstructing, or rehabilitating a route or connection on an eligible Federal-aid highway. It must use innovative technologies, manufacturing processes, financing, or contracting methods that improve safety, reduce construction congestion, and enhance quality and user satisfaction. To provide a target for each of these areas, HfL has established demonstration project performance goals.

The performance goals emphasize the needs of highway users and reinforce the importance of addressing safety, congestion, user satisfaction, and quality in every project. The goals define the desired result while encouraging innovative solutions, raising the bar in highway transportation service and safety. User-based performance goals also serve as a new business model for how highway agencies can manage the highway project delivery process.

HfL project promotion involves showing the highway community and the public how demonstration projects are designed and built and how they perform. Broadly promoting successes encourages more widespread application of performance goals and innovations in the future.

Project Solicitation, Evaluation, and Selection

FHWA issued open solicitations for HfL project applications in fiscal years 2006 through 2013. State highway agencies submitted applications through FHWA Divisions. The HfL team reviewed each application for completeness and clarity, and contacted applicants to discuss technical issues and obtain commitments on project issues. Documentation of these questions and comments was sent to applicants, who responded in writing.

The project selection panel consisted of representatives of the FHWA's Offices of Infrastructure, Safety, and Operations; the Resource Center Construction and Project Management Team; the Division offices; and the HfL team. After evaluating and rating the applications and

supplemental information, panel members convened to reach a consensus on the projects to recommend for approval. The panel gave priority to projects that accomplish the following:

- Address the HfL performance goals for safety, construction congestion, quality, and user satisfaction.
- Use innovative technologies, manufacturing processes, financing, contracting practices, and performance measures that demonstrate substantial improvements in safety, congestion, quality, and cost-effectiveness. An innovation must be one that the applicant State has never or rarely used, even if it is standard practice in other States.
- Include innovations that will change administration of the State's highway program to more quickly build long-lasting, high-quality, cost-effective projects that improve safety and reduce congestion.
- Will be ready for construction within 1 year of approval of the project application. For the HfL program, FHWA considers a project ready for construction when the FHWA Division authorizes it.
- Demonstrate the willingness of the applicant department of transportation (DOT) to participate in technology transfer and information dissemination activities associated with the project.

HfL Project Performance Goals

The HfL performance goals focus on the expressed needs and wants of highway users. They are set at a level that represents the best of what the highway community can do, not just the average of what has been done. States are encouraged to use all applicable goals on a project:

- **Safety**
 - Work zone safety during construction—Work zone crash rate equal to or less than the preconstruction rate at the project location.
 - Worker safety during construction—Incident rate for worker injuries of less than 4.0, based on incidents reported via Occupational Safety and Health Administration (OSHA) Form 300.
 - Facility safety after construction—At least twenty percent reduction in fatalities and injuries in 3-year average crash rates, using preconstruction rates as the baseline.
- **Construction Congestion**
 - Faster construction—At least fifty percent reduction in the time highway users are impacted, compared to traditional methods.
 - Trip time during construction—Less than 10 percent increase in trip time compared to the average preconstruction speed, using 100 percent sampling.
 - Queue length during construction—A moving queue length of less than 0.5 mile (mi) (0.8 kilometer (km)) in a rural area or less than 1.5 mi (2.4 km) in an urban area (in both cases at a travel speed 20 percent less than the posted speed).

- **Quality**
 - Smoothness—International Roughness Index (IRI) measurement of less than 48 inches per mile.
 - Noise—Tire-pavement noise measurement of less than 96.0 A-weighted decibels (dB (A)), using the onboard sound intensity (OBSI) test method.
- **User Satisfaction**
 - User satisfaction—An assessment of how satisfied users are with the new facility compared to its previous condition and with the approach used to minimize disruption during construction. The goal is a measurement of 4-plus on a 7-point Likert scale.

THE TEXAS HIGHWAYS FOR LIFE DEMONSTRATION PROJECT

During 2010, the Texas Department of Transportation (TxDOT) began construction of a 2.6 mile pavement on new alignment along a section of FM 1938. The work was completed during 2012. The new pavement project consists of six lanes from SH 114 to Dove Road and four lanes from Dove Road to Randol Mill Road. The purpose of the new roadway was to improve capacity and ease mobility on FM 1709. TxDOT joint ventured the project with the cities of Southlake, Westlake, and Keller. The pavement type was continuously reinforced concrete pavement (CRCP). As part of the construction project, TxDOT, with support from FHWA’s HfL program, evaluated several technologies to achieve a longer lasting CRCP. These technologies are:

1. Improved base type for CRCP – four base types were evaluated. One test feature included the use of a non-woven geo-textile bond breaker between the concrete and the cement-treated base to speed up construction and reduce construction related costs.
2. Optimized aggregate gradation for the paving concrete – two aggregate gradations were evaluated. One gradation was the standard TxDOT gradation, and the other was an optimized gradation. The optimized aggregate gradation was used to reduce concrete drying shrinkage that would lead to tight cracks which provide a more durable and better performing CRCP.
3. Improved Concrete Curing – three curing compounds were evaluated. The use of water-based lithium curing compound was included to help mitigate the development of plastic shrinkage cracking.
4. Improved surface texture – four methods for providing surface texture were evaluated to identify a more durable and safe pavement surface that is also less noisy.
5. Intelligent compaction - use of intelligent compaction was evaluated for the base and subgrade to allow for real-time correction in the compaction process.

REPORT SCOPE AND ORGANIZATION

This report documents TxDOT’s HfL demonstration project, which involved the construction of the new 2.6 mile freeway (FM 1938) from SH 114 to Randol Mill Road in the cities of Southlake, Westlake and Keller, just north of Fort Worth, Texas. The report is organized as follows:

- Project Overview and Lessons Learned
- Project Details
- Data Acquisition and Analysis
- Technology Transfer
- References

The report presents project details relevant to the HfL program, including safety, construction congestion and user satisfaction. HfL performance metrics and economic analysis lessons learned are also discussed along with innovative methods of public involvement and technology transfer.

PROJECT OVERVIEW AND LESSONS LEARNED

PROJECT OVERVIEW

The HfL project undertaken on FM 1938 was a cooperative effort between TxDOT and Tarrant County, the North Central Texas Council of Governments and the cities of Keller, Southlake and Westlake. The primary focus was to provide a more direct connection between State Highway 114 and Keller Parkway with greatly expanded capacity and increased access. The project replaced an existing narrow two-lane facility built in the 1950s with a 2.6 mile roadway consisting of a 6-lane segment from SH 114 to Dove Road, and a 4-lane section from Dove Road to Randol Mill Road at the South termini. The project was constructed on new alignment. Improved access was developed at all intersections and extensive enhancements were provided to match the surrounding landscape.

Project Innovations

Several innovations were included in this project covering many aspects of construction. They include:

1. Optimized aggregate gradation for the paving concrete – two aggregate gradations were evaluated. One gradation was the standard TxDOT gradation, and the other was an optimized gradation. The optimized aggregate gradation was used to reduce concrete drying shrinkage that would lead to tight cracks which provide a more durable and better performing CRCP.
2. The use of intelligent compaction for the subgrade to allow for real-time correction in the compaction process.
3. Improved base type for CRCP – four base types were evaluated with respect to compaction control and erodability. A non-woven geo-textile bond breaker between the concrete and the cement-treated base was also used to speed up construction which also reduced construction related costs.
4. Improved Concrete Curing – three curing compounds were evaluated. The use of water-based lithium curing compound was included to help mitigate the development of plastic shrinkage cracking.
5. Improved surface texture – four methods for providing surface texture were evaluated to identify a more durable and safe pavement surface that is also less noisy.

Figure 1 shows the layout of the project test features. The HfL project features were incorporated in four primary test sections, between Sta. 98+23 to Sta. 205+00, as shown in Figure 1 and detailed below:

1. Section 1 – Sta. 98+23 to Sta. 115+00
 - a. 9 in. CRCP
 - b. 2 in. AC interlayer, Type B
 - c. 8 in. cement treated subgrade
2. Section 2 – Sta. 115+00 to Sta. 132+00
 - a. 9 in. CRCP
 - b. 1 in. AC interlayer, Type D

- c. 6 in. cement stabilized base
 - d. 8 in. cement treated subgrade
- 3. Section 3 – Sta. 132+00 to Sta. 160+00
 - a. 9 in. CRCP
 - b. Non-woven geotextile
 - c. 6 in. cement stabilized base
 - d. 8 in. cement treated subgrade
- 4. Section 4 – Sta. 160+00 to Sta. 205+00
 - a. 9 in. CRCP
 - b. 4 in. AC, Type B
 - c. T treated subgrade (8 in. cement treated or 8 in. lime treated, 18 in. lime treated)

The test features were located within the four test sections as follows:

- 1. Aggregate gradation features
 - a. Optimized gradation, three aggregates – Sta. 175+00 to Sta. 190+00
 - b. Standard concrete (Class P) with Gr-3 or GR-4 coarse aggregate (ASTM C33) – Sta. 190+00 to Sta. 205+00
- 2. Embankment (subgrade) compaction features
 - a. Intelligent compaction – Sta. 98+23 to Sta. 160+00
 - b. Density control, Type D – Sta. 160+00 to Sta. 205+00
- 3. Concrete/stabilized base interface features
 - a. Non-woven geotextile bond-breaker – Sta. 132+00 to Sta. 160+00
 - b. 1 in. AC interlayer – Sta. 115+00 to Sta. 132+00
- 4. Concrete curing features
 - a. Lithium based, TxDOT supplied – Sta. 98+23 to Sta. 115+00
 - b. Lithium based, Contractor supplied – Sta. 115+00 to 160+00
 - c. Type II – Sta. 160+00 to Sta. 205+00
- 5. Surface texture features
 - a. Longitudinal tining, spaced at 1 in. – Sta. 98+23 to Sta. 115+00
 - b. Carpet drag only – Sta. 115+00 to Sta. 132+00
 - c. Transverse tining, spaced at ½ in. – Sta. 132+00 to Sta. 160+00
 - d. Transverse tining, spaced at 1 in. – Sta. 160+00 to Sta. 205+00

TxDOT also evaluated additional features as follows:

- 1. Cement stabilized base features
 - a. Lower strength, 7-day compressive strength of 250 psi – Sta. 115+00 to Sta. 123+00 and Sta. 145+00 to Sta. 160+00
 - b. Standard strength, 7-day compressive strength of 600 psi – Sta. 123+00 to Sta. 145+00
- 2. Cement treated subgrade features
 - a. Higher cement content, 7-day compressive strength of 430 psi – Sta. 98+23 to Sta. 106+00
 - b. Lower cement content, 7-day compressive strength of 200 psi – Sta. 106+00 to Sta. 205+00

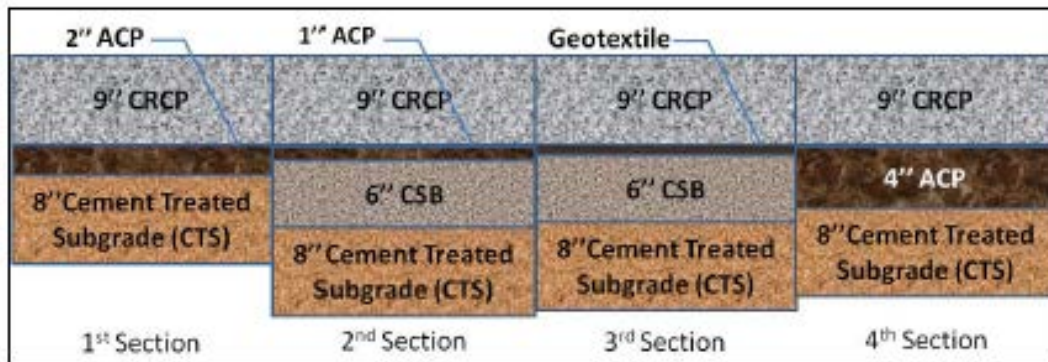


Figure 1. Details of the sections incorporating test features.

The test features were selected for evaluation on the HfL project to allow TxDOT to assess the best practices for the test items of interest and to provide first-hand experience with the performance of the selected test features.

HfL PERFORMANCE GOALS

The successful implementation of an HfL project is assessed with respect to how safety, construction congestion, quality, and user satisfaction were addressed during the construction of the project. On most HfL projects, data are collected before, during, and after construction where appropriate, to demonstrate that the featured innovations can be deployed while simultaneously meeting the HfL performance goals in these areas. For the Texas CRCP project, because the project was constructed along a new alignment and new right-of-way (RoW), many of the HfL performance metrics did not apply, and only the worker safety during construction goal could be assessed as discussed below:

1. Safety

- a. **Work Zone Safety** - Because this project was constructed on new RoW, there was no impact to the safety of the public during construction.
 - b. **Worker Safety during Construction**—No worker injuries occurred during construction, which exceeded the goal of less than a 4.0 rating on the OSHA 300 form.
2. **Construction Congestion/Trip time/Queue Length-** Because all construction took place along a new RoW, there was no impact to existing traffic movements or trip times within the construction area. Therefore, no traffic impact study was conducted.

3. Quality

- a. **Smoothness** – Due to the low speed nature of the final roadway, no smoothness goal was established for this project. However, the standard TxDOT specification for smoothness was included in the contract. The standard specification requires a maximum International Roughness Index (IRI) limit of 95 inches per mile, with a pay penalty for IRI numbers above 75 inches per mile and a bonus for IRI numbers below 60 inches per mile. The IRI results for this project, as measured

by TxDOT, averaged about 92 inches per mile, with no segments receiving a bonus and several requiring grinding to achieve the maximum allowed value of 95 inches per mile. The higher than expected values are attributed to the numerous short sections that were paved on the project. While no further testing was done after the bump grinding, the pavement is expected to be satisfactory with respect to smoothness due to the low speed limit at this location.

- b. **Noise** – With a proposed speed limit of only 40 miles per hour (mph) for the completed project, the HfL goal for noise was not included in the evaluation. However, TxDOT did conduct extensive testing on the project using their noise measuring equipment. Several texture types were included on this project, with the resulting noise levels ranging from 94 to 100.9 dB.
 - c. **Durability** – Several innovations included in this project are expected to improve the durability and performance of the final project.
 - i. The use of optimized aggregate gradation improves concrete workability and results in fewer issues with slipform paving concrete placement and finishing. Another significant advantage with the use of optimized aggregate gradation is that less cement is necessary to obtain the desired concrete characteristics.
 - ii. The use of intelligent compaction technology resulted in better control over the compaction of the subgrade (embankment material), resulting in improved overall quality. The ability to make real time corrections to the subgrade compaction process translates into a more uniform paving platform and thus a longer lasting and durable pavement.
 - iii. The use of the non-woven geo-textiles rather than conventional asphalt bond breakers between cement stabilized bases and CRCP was not considered effective as it resulted in longer undesirable crack spacing.
4. **User satisfaction** - The project was constructed on new RoW and therefore had no impact on the public during construction. No user satisfaction survey was conducted. Increased public satisfaction is expected to result from shortened travel distances and times along the new corridor. Also, the public satisfaction will be enhanced over the long-term because the new pavement is expected to provide a longer service life without requiring frequent lane closures to perform repair and rehabilitation treatments.

ECONOMIC ANALYSIS

No economic analysis was performed because alternative pavement types were not considered, and the test section features were pre-determined.

LESSONS LEARNED

Overall, the FM 1938 project was a success. Many of the innovations have shown promise, however additional research is required to adequately assess the results.

- The use of optimized gradation for Portland cement concrete shows particular promise. Testing showed that significantly less cement is required to achieve the design strength. In this case, the cement content was reduced to achieve the desired compressive strength, resulting in a significant cost savings.

- There were additional advantages to the optimized gradation concrete mix. While the mix as delivered appears very dry, it finishes very well. A sharp vertical edge is created behind the paver with very little slump. The contractor reported that finish labor was reduced and that the surface was easier to texture.
- The use of a non-woven fabric as a bond breaker was not considered an advantage on this project, especially given the use of continuous reinforcement. From the contractor perspective, it was labor intensive to apply initially. The fabric was easily damaged during steel installation. In areas where steel was cut, the fabric melted and repair under the steel mat was difficult. It also does not seem to work well for projects using staged construction. Rain on the exposed material resulted in silt and mud covering the surface and again this was very labor intensive to remove. The use of fabric as a bond breaker may be suitable for use on jointed pavements, but is considered a disadvantage under CRCP, where shorter consistent crack spacing is desired.
- While intelligent compaction was not used under the pavement sections as originally planned, it did show promise as an evolving technology. It provided a more complete picture of the entire area being worked, resulting in decreased labor and reduced testing. In this case, it was found that a footed roller did not provide good results using the available instrumentation. A switch to a smooth roller was required. It was noted that in order to achieve reliable results the equipment needs to be calibrated to local soils before construction.
- The use of several different curing compounds was investigated on this project. At temperatures below 45 degrees, the application of the lithium based curing compound increased dry times dramatically and prevented longitudinal joint sawing in some cases up to 2 days. The lithium based compounds were also significantly more expensive, requiring additional research to determine if the cost is justified.
- While the tining and texture techniques employed were not necessarily new, experience reinforced the need to control tine pressure and spacing to achieve a good surface texture. Additional testing is needed to determine the best surface texture to provide good friction and a quiet surface. Conclusions

The TxDOT gained good experience with the innovations used on this project. Many of the procedures, especially the use of optimized aggregate in PCP and intelligent compaction, appear ready for implementation in future TxDOT projects.

PROJECT DETAILS

PROJECT BACKGROUND

The focus of the FM 1938 HfL project was to provide a more direct north/south connection between State Highway 114 and FM 1709 (Keller Parkway). The 2.2 mile project (Figure 2) shortens the length of the connector by 1 mile at a cost of approximately \$16 million. The project provides improved access at all intersections along the route and extensive enhancements to match the surrounding landscape. Due to the higher cost of RoW in this area, about \$1.1 million per acre, every effort was made to minimize the footprint of the project. TxDOT owns only 1 foot of RoW outside the shoulder edge, with the City acquiring an additional 8 feet of RoW.

The project was a cooperative effort between TxDOT and Tarrant County, the North Central Texas Council of Governments and the cities of Keller, Southlake and Westlake. The existing two lane corridor (Figure 3), Precinct Road, was replaced with a six lane facility from SH 114 to Dove Road and a four lane divided facility from Dove Road to Randol Mill road at the South termini.

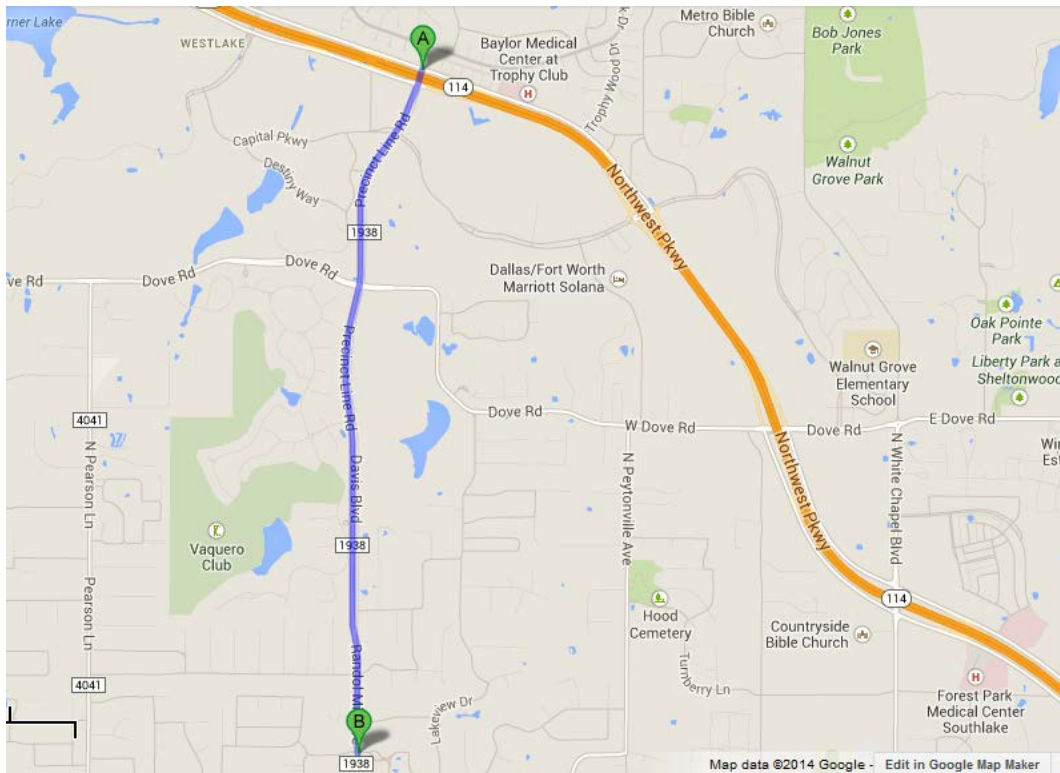


Figure 2. General Project Location



Figure 3. Existing Two-Lane Facility, Precinct Road (Courtesy TxDOT)

The existing facility carried about 5,400 vehicles per day prior to construction. When completed, the new facility (Figure 4) is predicted to carry more than 12,000 vehicles per day, providing increased mobility far into the future.



Figure 4. New Four- and Six-Land FM 1938

PROJECT TEST FEATURES DETAILS

The details on following HfL specific test features are presented as follows:

1. Optimized aggregate gradation
2. Intelligent compaction
3. Geotextile interlayer
4. Lithium-based curing
5. Surface texture techniques

Information presented here is based on the project report prepared for TxDOT (Zollinger et al, 2013) and observations and limited data analysis performed by ARA staff. Although the project included evaluation of many other design/construction features, this report addresses only the five features listed above.

OPTIMIZED AGGREGATE GRADATION

The concept of optimized aggregate gradation for paving portland cement concrete is not new. However, it has not been commonly used by the pavement construction industry in Texas, even though TxDOT has had a specification for optimized aggregate gradation in place since 2004. Optimized aggregate graded concrete relies on aggregate strength and stone on stone contact to develop strength, using a minimum amount of cement paste to bind the mixture. The result is a mix that has increased workability and strength with reduced drying shrinkage and water demands. A cost savings is realized from a reduction in cementitious material required.

For the FM 1938 project, the goal was to demonstrate that a concrete mixture with optimized aggregate gradation can provide a concrete with better workability for slipform paving while also meeting other TxDOT specified requirements for paving concrete using less cementitious material. As discussed, the pavement on this project consisted of 9- inch CRCP placed over different support conditions. A variety of bases and bond breakers were included for comparison. A control section using the standard Class P concrete on 4-inches of AC base with a treated subgrade was also included.

Several methods were investigated to arrive at an optimum aggregate gradation. The methods evaluated included the following:

1. Maximum density of aggregates, based on the 0.45 power chart
2. Optimizing fineness modulus
3. Optimizing specific surface area of aggregates
4. Shilstone method
5. Percent retained graph
6. Aggregate dry pot unit weight
7. Packing modulus

Mixture Proportioning

The main goal of the concrete mixture proportioning is to reduce the cementitious material content and obtain a concrete with desirable workability and specified properties. A total of eighteen aggregate gradations were evaluated using combinations of two aggregates (coarse and fine) or three aggregates (coarse, intermediate, and fine). The gradations of the three aggregates are shown in Figure 5. The eighteen concrete mixtures evaluated and the test results for each mixture are given in Table 1.

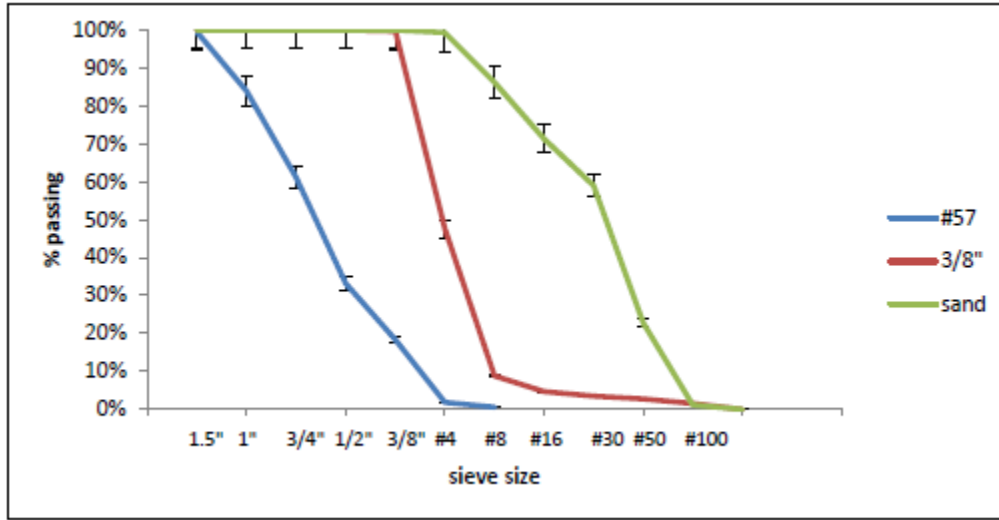


Figure 5. Aggregate Gradations

Based on the analysis of the test results, the following two mixtures were selected:

1. Optimized gradation mixture – using 4.5 bags of cementitious materials (35% flyash) and three aggregates. The sieve analysis of the optimized aggregate is shown in

3. Table 2.
 - a. Cement – 275 pcy
 - b. Flyash – 148 pcy
 - c. Aggregate
 - i. Grade 3 coarse aggregate – 1,627 pcy
 - ii. 3/8 in. intermediate aggregate – 467 pcy
 - iii. Sand – 1,266 pcy
 - iv. Water – 190 pcy

The concrete properties were as follows:

- Slump – 0.75 in.
- 7-day compressive strength – 3,600 psi
- 28-day compressive strength – 5,300 psi

4. Standard mixture - using 4.75 bags of cementitious materials (35% flyash) and two aggregates.
 - a. Cement – 290 pcy
 - b. Flyash – 156 pcy
 - c. Aggregate
 - i. Grade 3 coarse aggregate – 1,941 pcy
 - ii. Sand – 1,395 pcy
 - iii. Water – 192 pcy

The concrete properties were as follows:

- Slump – 0.75 in.
- 7-day compressive strength – 4,280 psi
- 28-day compressive strength – 6,080 psi

The sieve analysis of the optimized aggregate is shown in Table 2.

For each mixture, the design water/cement ratio was 0.45, the target 28-day compressive strength was 4,400 psi, and the design air content was 4.5 percent. The results in the field for both mixtures exceeded the design 28-day compressive strength. It should be noted that obtaining higher concrete strength in the field compared to the design compressive strength is not desirable because the design of steel reinforcement in CRCP is based on the design concrete strength. Obtaining higher concrete strength in the field can result in longer spaced transverse cracking, which is not desirable for long-term performance of CRCP.

Table 1. Mixture Proportions Evaluated and Test Results.

Mix #	Binder (sacks)	Fly Ash %	Percentage of Aggregate			w/c	Add Mixture		Dry U.W. (b/ft ³)	Slump (in)	Box Test	Concrete Unit Wt. (b/ft ³)	AIR%	Comp. (psi)	
			G3	3/8"	Sand		Type	oz/cwt						7 day	28 day
1	4.73	35%	46%	16%	38%	0.41	Daracem 55	11.9	11.9	0.25	Pass	148.6	2%	5239	6974
2	5	35%	45%	17%	38%	0.41	Daracem 55	4.5	4.5	0	Pass	148.8	5%	4711	6560
3	5	35%	45%	17%	38%	0.41	WRDA 35	6.2	6.2	0.5	Pass	147.2	5.5%	4187	5964
4	5	35%	45%	17%	38%	0.41	WRDA 35	5.1	5.1	0.25	Pass	147.4	5%	4058	6021
5	4.75	35%	45%	17%	38%	0.43	Daracem 55	1.9	1.9	.5"	Fail	149.7	4.1%	4507	6378
6	4.75	35%	45%	17%	38%	0.45	Daracem 55	6.3	6.3	1.5"	Pass	148.8	4.6%	4152	5473
7	4.75	35%	45%	17%	38%	0.45	Daracem 55	6.3	6.3	1.5"	Pass	149.4	1.5%	5066	7554
8	4.75	35%	45%	17%	38%	0.45	MIRA 110	5.6	5.6	1"	Pass	148.4	4.2%	3248	4928
9	4.73	35%	48%	14%	38%	0.45	MIRA 110	4.0	4.0	1.25"	Pass	149	3.9%	3235	5052
10	4.5	35%	48%	14%	38%	0.45	Daracem 55	6.0	6.0	.75"	Pass	148.5	4.4%	3624	5299
11	4.25	35%	48%	14%	38%	0.45	Daracem 55	10.4	10.4	.5"	Fail	150.1	4.3%	4743	5785
12	5	35%	57%	0%	43%	0.41	Daracem 55	7.5	7.3	0.25	Fail	148.4	5.0%	4814	7228

Table 1. Mixture Proportions Evaluated and Test Results.

Mix #	Binder (sacks)	Fly Ash %	Percentage of Aggregate			w/c	Add Mixture		Dry U.W. (b/ft ³)	Slump (in)	Box Test	Concrete Unit Wt. (b/ft ³)	AIR%	Comp. (psi)	
			G3	3/8"	Sand		Type	oz/cwt						7 day	28 day
13	5.5	35%	59%	0%	41%	0.41	Daracem 55	4.5	4.5	1	Fail	148.2	5%	4797	6553
14	4.7	31%	60%	0%	40%	0.45	Daracem 55	3.3	3.3	4.5	Pass	148.3	4.8%	3240	4553
15	5.2	30%	61%	0%	39%	0.45	Daracem 55	3.2	3.3	7.25	Fail	143.4	7.5%	4369	5871
16	5	35%	58%	0%	42%	0.43	Daracem 55	7.7	7.8	1"	Pass	148.2	4.5%	4157	6131
17	4.75	35%	58%	0%	42%	0.43	Daracem 55	10.0	10.0	3/4"	Pass	148.1	4.8%	4279	6083
18	4.5	35%	58%	0%	42%	0.43	Daracem 55	13.3	13.4	1.5	Pass	142.3	8.6%	3902	5627

Table 2. Sieve Analysis of Optimized Aggregate for FM 1938.

SIEVE ANALYSIS

Sieve Size	Sieve Size (in)	Coarse Agg. 1 % Passing	Coarse Agg. 2 % Passing	Intermediate Agg. 1 % Passing	Intermediate Agg. 2 % Passing	Fine Agg. 1 % Passing	Fine Agg. 2 % Passing	Combined % Passing	Combined Cumulative % Retained	Combined % Retained
2 1/2 in	2.500	100	100			100		100.0	0.0	0.0
2 in	2.000	100	100			100		100.0	0.0	0.0
1 1/2 in	1.500	99.4	100			100		99.7	0.3	0.3
1 in	1.000	83.9	100			100		92.7	7.3	7.1
3/4 in	0.750	61.2	100			100		82.3	17.7	10.4
1/2 in	0.500	33.2	100			100		69.5	30.5	12.8
3/8 in	0.375	18.4	99.6			100		62.7	37.3	6.8
No. 4	0.187	1.8	47.6			99.3		46.1	53.9	16.7
No. 8	0.093	0.6	8.8			86.2		34.0	66.0	12.0
No. 16	0.047		4.7			71.3		27.5	72.5	6.5
No. 30	0.024		3.5			59		22.7	77.3	4.8
No. 50	0.012		2.8			22.8		9.0	91.0	13.7
No. 100	0.006		1.6			1.1		0.7	99.3	8.3
No. 200	0.003							0.0	100.0	0.7
Pan	0.000							0.0	100.0	0.0
Percent of Total Agg.		45.60%	17.00%	0.00%	0.00%	37.40%	0.00%	100.00%		

Summary

Based on observations at the construction site, the mixture with the optimized aggregate gradation provided excellent workability and finishing characteristics. While the mixture appeared dry as delivered, the mixture provided a stable vertical edge behind the paver and little finishing was required to restore the edge. Figure 6 shows the optimized aggregate gradation mixture in front of the slipform paver.



Figure 6. Optimized Aggregate Mix Placed in Front of Paver (Courtesy TxDOT)

INTELLIGENT COMPACTION

Intelligent compaction (IC) technology was used to aid in the construction of the subgrade embankment on this project. While IC technology has been used before, it is not commonly used at the project level in Texas. IC provides continuous real time data to aid in the compaction of soils. Through a computer interface installed on the compaction equipment, IC uses sensors mounted to the roller drum to equate displacements of the roller to material properties such as stiffness or penetration. Feedback from the computer allows the operator to adjust the amplitude, frequency, or speed of the roller to provide a more consistent compaction operation and achieve real-time corrections in the compaction process

The Process

The instrumented roller package used for the IC study was developed at the Texas Transportation Institute (TTI). The roller package is installed on a roller and includes the following:

1. GPS distance measurement sensor
2. An accelerometer which measures the vibratory response. Lower vibrator amplitude readings indicate that the subgrade is weaker in those areas.

3. A computer with a live display

The roller drum response in terms of the roller vibrator amplitude was correlated with several subgrade stiffness testing procedures. These procedures included the following:

1. Dynamic cone penetrometer (DCP)
2. Falling weight deflectometer (FWD)
3. Plate bearing test (PBT)

Results

IC technology proved very sensitive to variations in moisture content and sandy soils encountered on FM 1938. The IC package was effective in locating areas of weak support in the subgrade soil. However, the correlation with California Bearing Ratio (CBR), determined from DCP values, was rather weak in one area. It appears that the IC package can be used for proof-rolling but not for determining stiffness characteristics, until additional field testing is performed.

NON-WOVEN GEO-TEXTILE BOND BREAKERS

As part of the HfL project, the use of non-woven geo-textiles as a bond breaker between the base course and the CRCP was investigated as an alternative to the use of AC interlayer. The successful application of a geotextile as a bond breaker would reduce construction time and lead to cost savings. At the FM 1938 project, a standard non-woven geotextile was used at test section 3, between Sta. 132+00 to Sta. 160+00. The adjoining test sections using traditional AC layers as a bond breaker allowed comparison of the two interlayer techniques. The use of the geotextile interface layer under the CRCP was considered based on the findings of successful use of this practice in Germany and in the US, as detailed in Rasmussen et al (2009). It should be noted that the successful use in Europe and in the US was for jointed concrete pavement projects and not CRCP projects.

Constructability Issues

The geotextile fabric was laid down using standard placement procedures related to fabric overlap and nailing requirements. A view of the installed geotextile fabric is shown in Figure 7.

There were several constructability issues associated with the use of fabric on the FM 1938 project. The fabric was labor intensive to install and repair of damaged areas was difficult, especially after placement of the reinforcing steel. Workers burned holes at many locations while cutting steel rods driven through the fabric to provide lateral stability of the steel mat during paving. Also, a sudden rain storm deposited mud on the fabric, as shown in Figure 8. Cleaning of the fabric with steel in place was extremely time consuming and resulted in additional damage to the material.

Findings

The constructability and the short-term performance of the geotextile section (Section 3) was compared with the standard CRCP of Test Section 2, that incorporated an AC interlayer. Details of the two test sections are given below:

1. Section 2 – Sta. 115+00 to Sta. 132+00
 - a. 9 in. CRCP
 - b. 1 in. AC interlayer, Type D
 - c. 6 in. cement stabilized base
 - d. 8 in. cement treated subgrade
2. Section 3 – Sta. 132+00 to Sta. 160+00
 - a. 9 in. CRCP
 - b. Non-woven geotextile
 - c. 6 in. cement stabilized base
 - d. 8 in. cement treated subgrade

Figure 7. Non-Woven Geo-Textile Fabric Placement

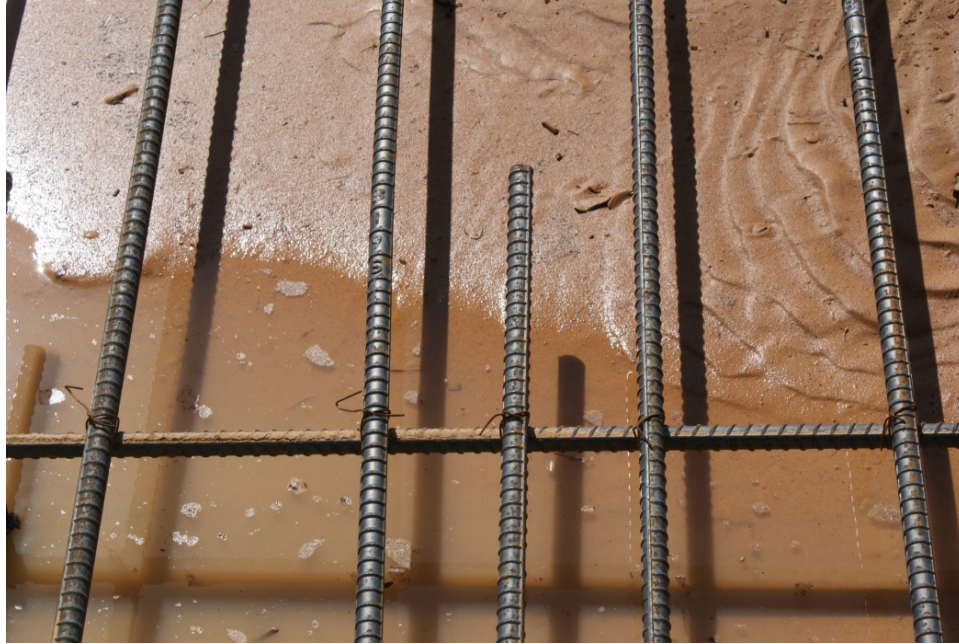


Figure 8. Non-Woven Geo-Textile Fabric after Rain Storm

With respect to assessment of the short-term performance of the above two sections, the following metrics were compared:

1. Transverse crack spacing
2. Deflections, under falling weight deflectometer (FWD) loading
3. Slab curling and concrete stresses (using sensors installed at time of concrete placement)

Comparison of the section constructed using the non-woven geo-textile fabric to the control section using the traditional 1 inch AC interlayer indicated the following:

1. There was not much difference in crack spacing between the two sections as shown in Figure 9 below. However, the geotextile fabric section did have a larger amount of cracking that was greater than 10 ft. The larger crack spacing is attributed to the lower frictional resistance between the concrete and the fabric. Also, the geotextile fabric section exhibited larger variations in crack spacing.
2. There was a significant difference in deflection between the two sections based on FWD testing. The deflection of the fabric section was measured at 3.2 mils under a 9,000 pound load, compared to a deflection of only 1.4 mils for the 1 inch AC section.
3. There was less vertical displacement (curling) of the slab in the fabric section when compared to the 1-inch control section, resulting in less pavement stress. The curling measurements are shown in Figure 10.

Based on the data, the use of non-woven geo-textiles under CRCP was considered of questionable value when compared to traditional (AC interlayer) methods of providing a bond breaking interlayer.

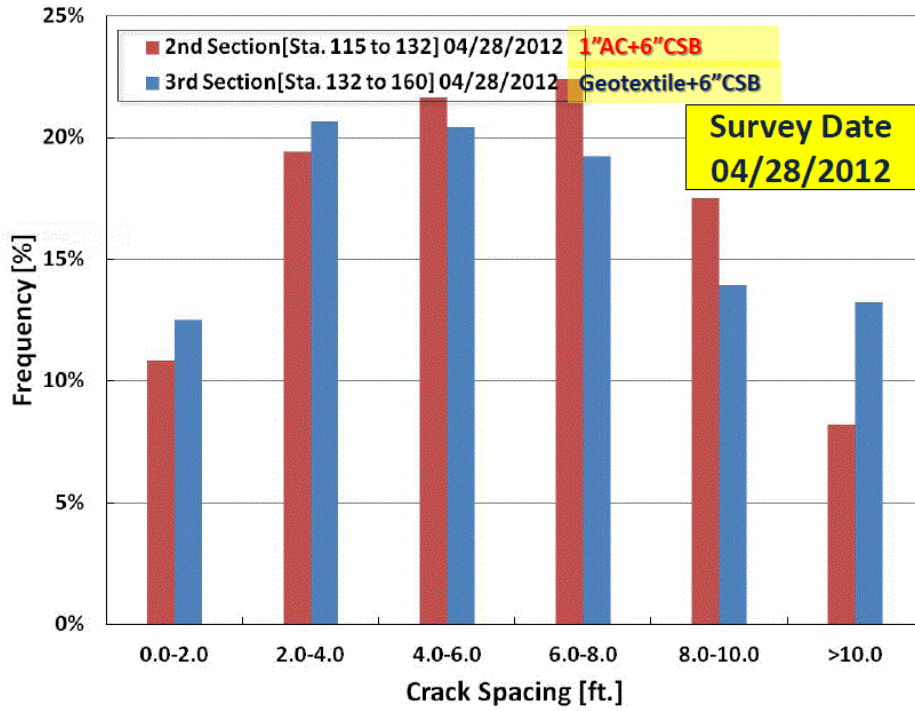


Figure 9. Crack Spacing Survey (Courtesy Texas Tech University).

Daily Vertical Movement

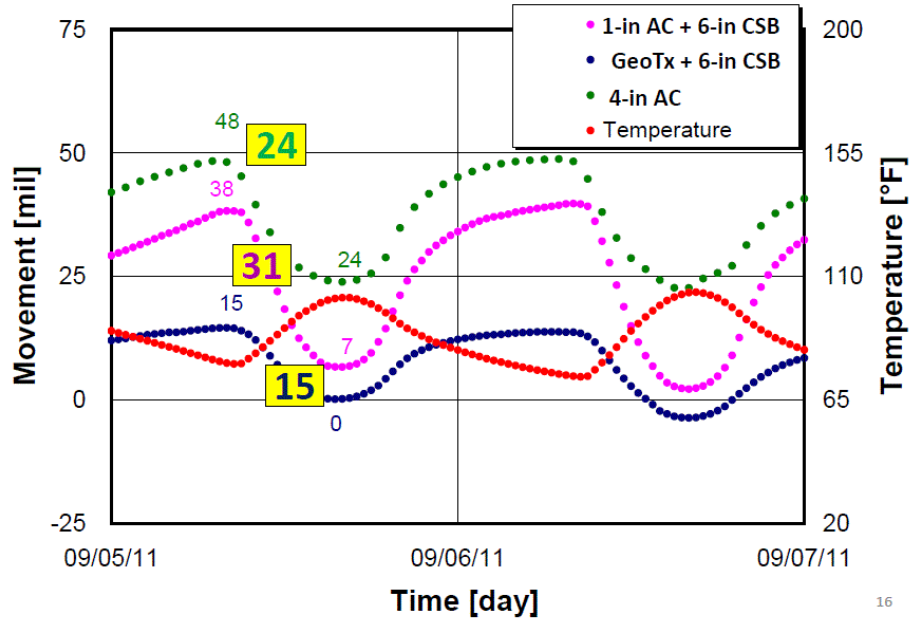


Figure 10. Slab deflections of section using fabric interlayer compared to traditional methods.

IMPROVED CONCRETE CURING METHODS OF CRCP

Another innovation employed on this HfL project was the use of lithium based curing compounds. Curing has long been recognized as an important process in constructing durable concrete pavements. Curing of concrete is defined as the maintenance of adequate moisture and temperature conditions to allow the development of required physical properties. Curing should be initiated as soon as possible after placing the concrete to prevent excessive water loss and drying of the surface. Curing compounds work by sealing the concrete surface and reducing the rate of moisture loss. Poor curing practices can result in excessive curling, early age cracking, surface deterioration, low early strengths, and reduced durability. Most of the damage caused by poor curing is irreversible. Most highway agencies specify use of curing compounds that meet the requirements of ASTM C 309 or AASHTO M 148.

On this project, sections of CRCP were cured using the following three methods:

1. Lithium based, TxDOT supplied – Sta.98+23 to Sta. 115+00
2. Lithium based, Contractor supplied – Sta. 115+00 to 160+00
3. Type II, resin-based – Sta. 160+00 to Sta. 205+00 (control section)

The lithium based curing compounds used are a water based product that uses the reaction between lithium silicate and cement to produce additional cementitious gel at the surface of the concrete. This increased gel layer reduces the ability for moisture to escape during the concrete hydration process and minimizes shrinkage cracking, typically, plastic shrinkage cracking.

The Process

For the FM 1938 project, the curing effectiveness was determined using the ATEK Concrete Maturity Meter (ACMM). This device measures the relative humidity (RH) at the concrete surface over time as an indication of curing effectiveness. A view of the device is shown in Figure 11.

As part of the FM 1938 HfL project, a laboratory study was conducted to assess the effect of the curing compound application rate (120 ft²/gallon versus 220 ft²/gallon) and the concrete water/cement (w/c) ratio (0.40 versus 0.43). Samples were prepared and the RH measurements and moisture loss at the concrete surface were recorded for the three test sections for three days using the ACMM. Also, the dielectric constant (DC) was measured at the concrete surface as an indication of the water content inside the hardened concrete at the surface. The ACMM data were used to compute the Effectiveness Index (EI) for each sample. Also, after three days, samples from the concrete surface (top ¾ in.) were tested for their abrasion strength.



Figure 11. The ATEK ACMM
(Source: Sun, 2013)

Findings

The laboratory study resulted in the following observations:

1. Samples with the higher w/c ratio (0.43) always had a higher percentage of moisture loss than samples with lower w/c ration (0.40).
2. At the same w/c ration, a higher curing application rate was not always effective in limiting evaporation compared to samples with a lower application rate. This indicates that a rate of 220 ft²/gallon was high enough to maintain the moisture at a level similar as that experienced with a rate of 120 ft²/gallon
3. The abrasion test data indicate that the samples made the higher application rate lost less weight and exhibited a better curing quality than the samples made with the lower application rate.

The field testing at FM 1938 resulted in the following observations:

1. The cracking pattern was similar for the lithium curing compounds and Type 2 curing compound, as shown in Figure 12.

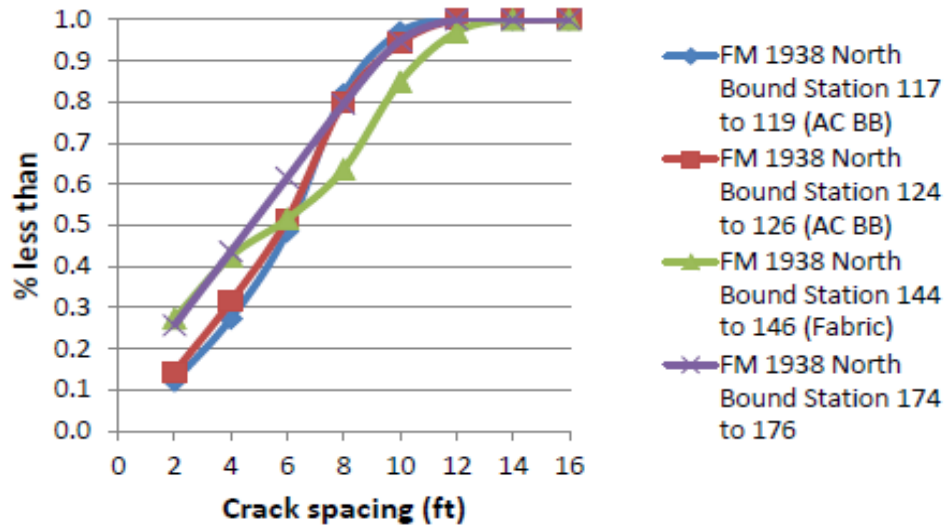


Figure 12. Cracking pattern at the FM 1938 demonstration project

IMPROVED TEXTURING TECHNIQUES FOR CRCP

Surface texture is a critical end product requirement for concrete pavements. Surface texture affects the risk of wet-weather accidents and impacts tire/pavement surface characteristics. In the US, transverse tining was the surface of choice for many decades. In recent years many highway agencies in the US have migrated to use of longitudinal tining. TxDOT has been investigating surface texture methods for concrete pavements that effectively meet the needs with respect to safety (reduce wet weather accidents) and noise (reduce noise levels away from the vehicle and in the vehicle). The following surface texture methods were studied at the FM 1938 project.

1. Longitudinal tining, spaced at 1 in. – Sta. 98+23 to Sta. 115+00 (see Figure 13)
2. Carpet drag only – Sta. 115+00 to Sta. 132+00 (see Figure 14)
3. Transverse tining, spaced at ½ in. - Sta. 132+00 to Sta. 160+00 (see Figure 15)
4. Transverse tining, spaced at 1 in. - Sta. 160+00 to Sta. 205+00 (see Figure 16)



Figure 13. Typical texture of longitudinally tined surface.



Figure 14. Typical texture of carpet drag surface.



Figure 15. Typical texture of 1/2 inch transversely tined surface.

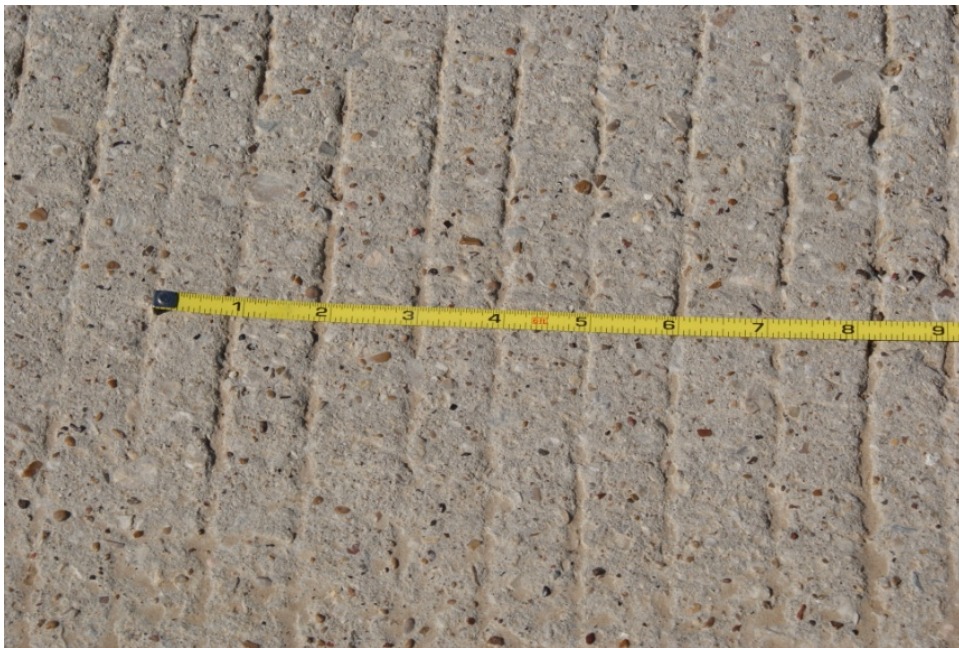


Figure 16. Typical texture of 1 inch transversely tined surface.

Noise Related Testing

Noise testing was performed by TxDOT using the on board sound intensity (OBSI) method. The TxDOT OBSI setup is shown in Figure 17. The data from the OBSI testing, collected at 45 mph, are summarized in Figure 18. The transverse tined section with ½ in. spacing (Section 2) had the lowest noise level. However, Section 3 with longitudinal tining had not been opened to traffic at the time of noise testing. The results are considered typical for concrete pavements and were considered acceptable for this project given the relatively low projected speed limit of 45 mph.



Figure 17. TxDOT OBSI Setup

Tire/Pavement Noise Sound Intensity - OBSI (45)
 FM 1938 Near Westlake, TX 5/30/2012
 Research Project 5-6037-01 Test Site, Rigid Pavement

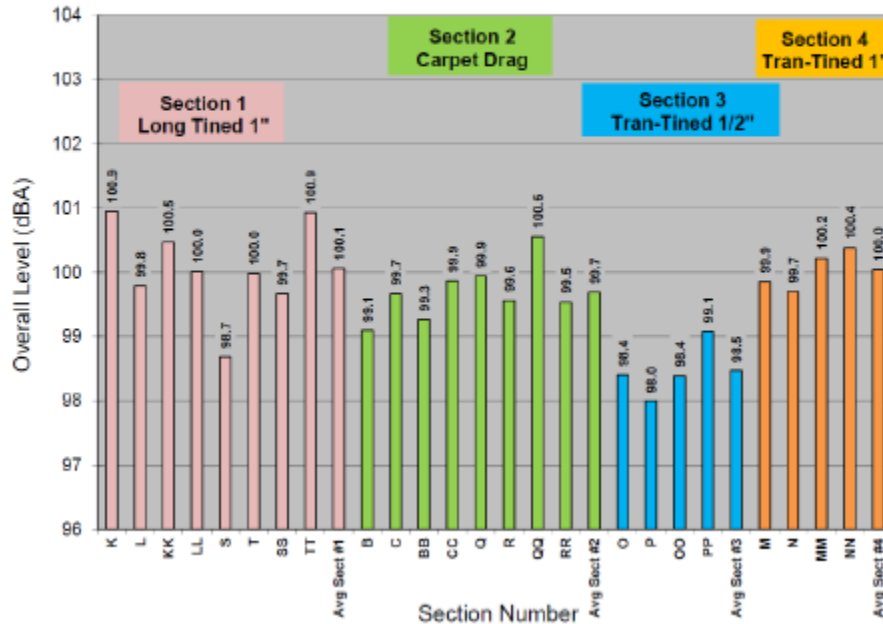


Figure 18. OBSI Data from FM 1938 HfL Project.

Friction (Skid) Testing

TxDOT collected skid resistance data using a smooth tire. The results are as follows:

1. For Section 2 (carpet drag), two tests were conducted and both tests resulted in value of 23. This is considered a low value.
2. For Section 2 (transverse tining at 1/2 in. spacing), two tests were conducted and test results were 44 and 46.
3. For Section 3 (transverse tining at 1 in. spacing), two tests were conducted and both tests resulted in value of 50.

Smoothness Testing

In addition to noise testing, TxDOT conducted smoothness testing on all sections. Overall, the results for this project averaged about 92 inches per mile, with no segments receiving a bonus and several requiring grinding to achieve the maximum allowed value of 95 inches per mile. The higher than expected values are attributed to the numerous short sections that were paved on the project. While no further testing was done after the grinding, the pavement is expected to be satisfactory with respect to smoothness due to the low speed limit at this location.

DATA ACQUISITION AND ANALYSIS

Data on safety, traffic flow, quality, and user satisfaction were collected before, during, and after construction to determine compliance with the HfL performance goals where appropriate. The primary objective of acquiring these types of data was to quantify the project performance, provide an objective basis on which to determine the feasibility of the project innovations, and demonstrate that the innovations can be used to do the following:

- Achieve a safer work environment for the traveling public and workers.
- Reduce construction time and minimize traffic interruptions.
- Produce a high-quality project and gain user satisfaction.

In the case of FM 1938, many of the goals were not considered relevant, due to the low speed nature of the final project and the fact that the construction took place on new RoW, resulting in no impact to the public with respect to congestion, travel time, or safety. This section discusses how TxDOT met the specific HfL performance goals related to this project.

SAFETY

Because the project was constructed on new RoW, there was no impact to the safety of the public during construction. No worker injuries occurred during construction, which exceeded the goal of less than a 4.0 rating on the OSHA 300 form.

CONSTRUCTION CONGESTION/ TRIP TIME/QUEUE LENGTH

Because all construction took place on new RoW there was no impact to existing traffic movements or trip times within the construction area. No measurements were taken in this area.

TRAFFIC STUDY

No impact to the public occurred as a result of the construction of this project; therefore, no traffic study was done.

QUALITY

Smoothness

Due to the low speed nature of the final roadway, no smoothness goal was established for this project. However, the standard TxDOT specification for smoothness was included in the contract. The standard specification requires a maximum limit of 95 inches per mile, with a pay penalty for numbers above 75 inches per mile and a bonus for numbers below 60 inches per mile. The first results for this project as measured by TxDOT, averaged about 92 inches per mile, with no segments receiving a bonus and several requiring grinding to achieve the maximum allowed value of 95 inches per mile. The higher than expected values are attributed to the numerous short sections that were paved on the project. While no further testing was done after the grinding, the

pavement is expected to be satisfactory with respect to smoothness due to the low speed limit at this location.

Noise

With a proposed speed limit of only 45 mph for the completed project, no HFL goal for noise was included. However, the TxDOT did perform noise testing on the project using their own equipment. Several textures were included on this project, with the resulting noise levels ranging from 94 to about 101 dB.

Durability

Several innovations included in this project are expected to improve the durability and performance of the final project, as noted below:

- The optimized aggregation gradation is one way to help control cracking in the CRCP. Another advantage is the reduction of cement paste, resulting in less drying shrinkage and less overall cracking.
- The use of intelligent compaction technology should also result in increased pavement durability and overall quality. The ability to make real time corrections to the compaction process should translate into a more uniform paving platform and thus a longer lasting and durable pavement.
- The use of non-woven geo-textiles rather than conventional asphalt bond breakers between cement stabilized bases and CRCP pavements did not result in any benefit and negatively impacted the crack spacing development.
- The use of lithium based curing technique did not result in any significant benefit compared to standard Type 2 curing
- The use of longitudinal texturing techniques did not show any improvement over the traditional transverse tining technique, based on early age testing. **USER SATISFACTION**

The project was constructed on new RoW and therefore had no impact on the public during construction. No satisfaction survey was conducted. Increased public satisfaction is expected to result from shortened travel distances and times along the new corridor once completed.

TECHNOLOGY TRANSFER

To promote further interest and use of the innovations included in this project, TxDOT, in conjunction with the FHWA, sponsored a one day showcase. The showcase was held May 1, 2012 at the Dallas/Ft. Worth Marriott Solana, in the City of Westlake. The event featured presentations by the FHWA, TxDOT, the project contractor, and representatives from several universities and consulting firms. The presentations were followed by a field trip to the project to observe paving with optimized aggregate concrete and a trip to the batch plant.



Figure 19. Showcase participants at the job site.



Figure 20. Placement of rebar assembly.



Figure 21. Participants visiting the batching plant.

Approximately 86 people attended the showcase from TxDOT, FHWA, local agencies, the construction and consulting industries, and academia. The program included the following:

1. Opening comments provided by Brian Barth, Deputy District Engineer for TxDOT in the Fort Worth District.
2. An overview of the Highway for LIFE program given by Sal Deocampo, District Engineer, FHWA –Texas division.
3. A national perspective on concrete pavement innovation was given by Suneel Vanikar, the Concrete Team Leader from FHWA.
4. An overview of the FM 1938 project outlining the specific goals and objectives of this project along with a discussion each individual innovation was discussed by representatives of the DOT, consultants, contractors and academia.
 - a. Instrumented roller study – Andrew Wimsatt
 - b. Non-woven geotextile bond breakers – Mike Darter
 - c. The use of geotextiles in CRCP – Moon Won
 - d. Improved curing of CRCP – Dan Zollinger
 - e. FM 1938 noise, texture and profile data – German Claros
 - f. Construction highlights - Stan Allen, Project manager, Ed Bell Construction
 - g. Lessons learned during the construction of the FH 1938 project - John Poskey, Project Manager, TxDOT

ECONOMIC ANALYSIS

A key aspect of HfL demonstration projects is quantifying, as much as possible, the value of the innovations deployed. This entails comparing the benefits and costs associated with the innovative project delivery approach adopted on an HfL project with those from a more traditional delivery approach.

CONSTRUCTION COSTS

Among the five innovations deployed on this project, only the use of optimized gradation has resulted in tangible cost savings to the agency. With the use of optimized gradation, TxDOT saved 15 lbs of cement per cubic yard of concrete mix. The immediate cost savings with the use of optimized gradation are presented as follows:

Cost of cement per metric ton in 2011 dollars = \$ 89.50 (Geological Survey 2005)

Cost savings with 1 CY of concrete = 15 lbs * \$ 89.50/ton = 60.9 cents

Potential cost saving per lane mile (9 in. thickness) = \$1,050

The applications of other innovations are expected to contribute to performance improvements of the in-service pavement such as improved density of subgrade with IC and reduced crack growth with lithium-based concrete curing methods. While these performance improvements may contribute to agency cost savings in the long-term, the benefits associated with these innovations cannot be readily monetized. Hence no detailed economic analysis was conducted for this project.

USER COSTS

Since this project involved the construction of a new roadway alignment, the presence of work zone did not adversely impact the existing traffic operations in terms of motorist delay, detour and safety risks. Hence, an analysis of work zone road user costs and benefits was not conducted for this project.

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 - Tyler Ley, Oklahoma State University
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