OptiPave Overview – MCA Annual Conference

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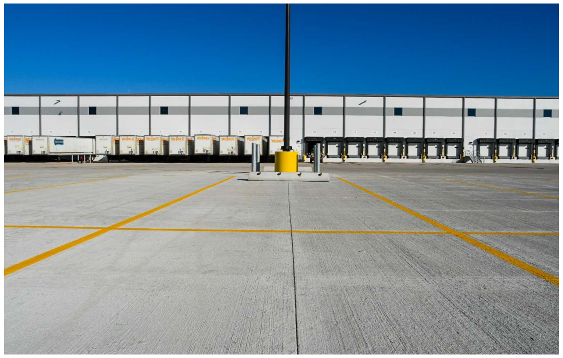
OptiPave® Value Proposition?

(also know as Short-Slab Design, or Pavement Panels with optimized geometry)

Optimized Concrete Pavement System that provides:

- Concrete pavement that can compete with asphalt on first cost.
- Lower Risk (advanced engineering, 20+ years of proven performance).
- Sustainable pavement alternate, opportunity for reduction in GHGs.



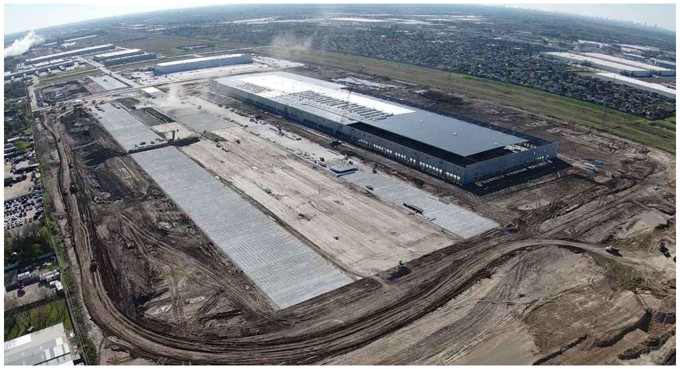
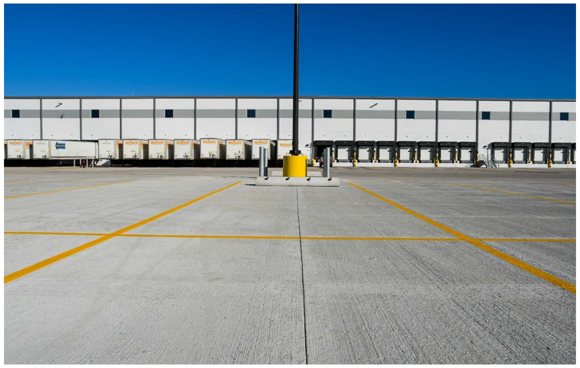
Cost

Performance

Sustainability

OptiPave® Project Savings

- $2.4 Million Savings on a 2.7M sq.ft industrial pavement, compared to heavily reinforced concrete pavement - TX
- $1.0 Million Savings on a 1.6M sq.ft industrial pavement, compared to asphalt pavement design - IL


TCPavements™ PAVEMENT INNOVATION

FORTA® CONCRETE FIBER

OptiPave® Clients

UNITED STATES COLD STORAGE®

UNITED STATES ARMY

UNITED STATES AIR FORCE

ALDI

MACGREGOR ASSOCIATES ARCHITECTS
ATLANTA • DALLAS

PCG Group of Companies

The Electric Company®
El Paso Electric

NorthPoint™ DEVELOPMENT

MERIT PARTNERS

THE HOME DEPOT

Coca-Cola®

HILLWOOD
A PEROT COMPANY®

NATIONAL PROPERTY HOLDINGS

THE WOOSTER® BRUSH COMPANY

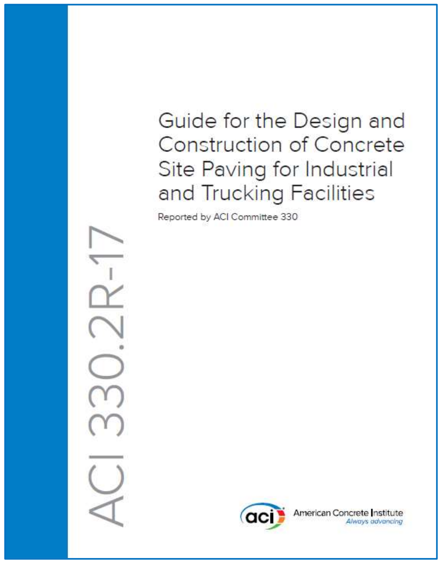
CK Childress Klein

PROLOGIS®

Theory behind OptiPave

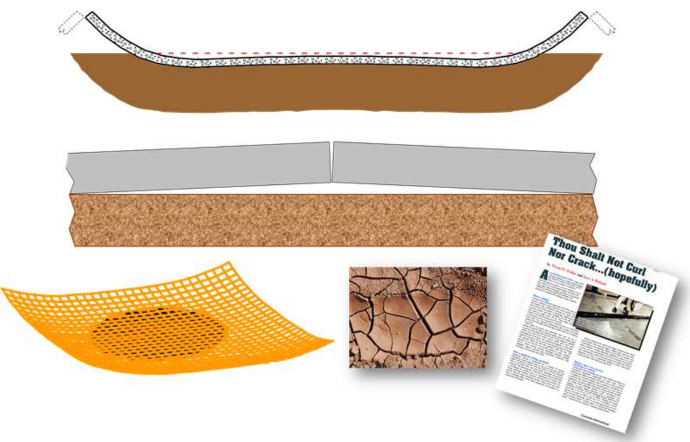
Chapter 4 – Pavement Design

- "It is imperative that the designer consider all factors that influence the performance of a concrete pavement. Such factors include truck traffic or other vehicular loads, patterns and frequencies, subgrade/subbase support, concrete strength, pavement panel thickness, joint spacing, joint stability (load transfer), the use of curbs and widened lanes, humidity and ambient effects (humidity and temperature)."
- Thickness is directly related to joint spacing, curling/ warping and load transfer…and CANNOT be designed independently!



- B.1.1 ACPA StreetPave™
- B.1.2 AASHTOWare Pavement ME
- **B.1.3 TCPavements® OptiPave™**
- B.1.4 ACPA AIRPave™

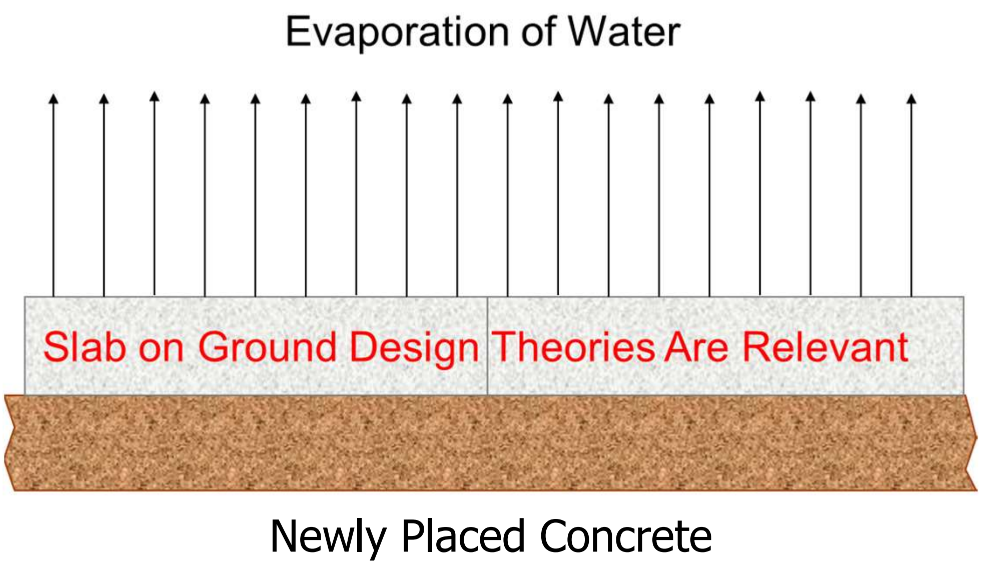
"All slabs [and pavements] curl"
Jerry Holland, Structural Services, Inc.

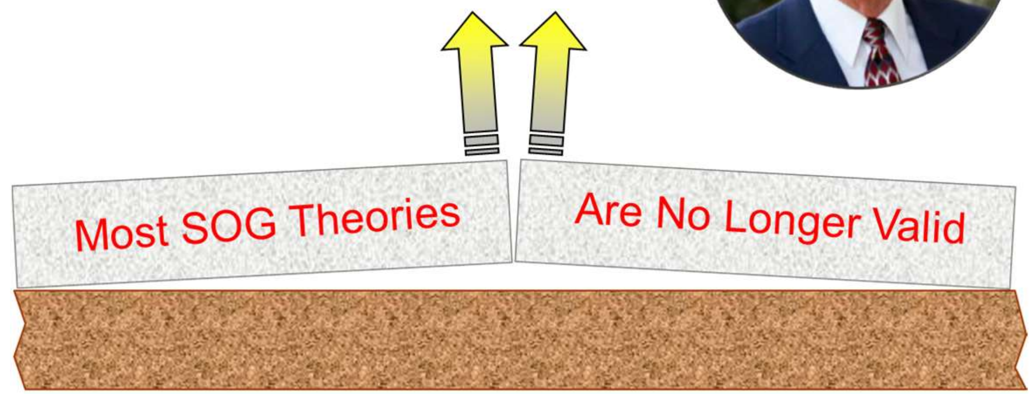


Let's take a closer look at the impact of curling & slab geometry

Curling of Concrete Pavements

During & After Drying:

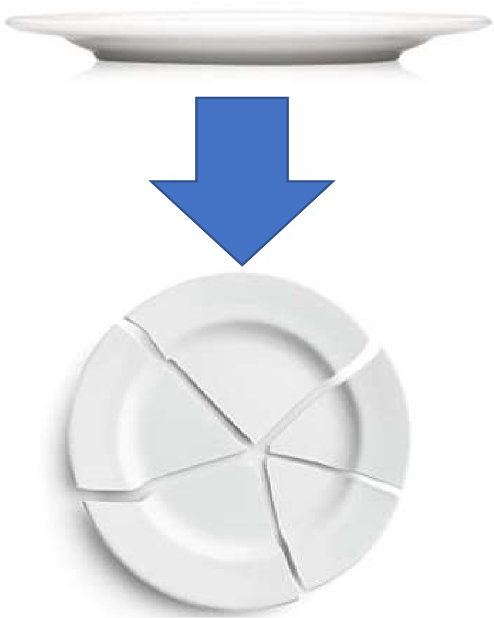




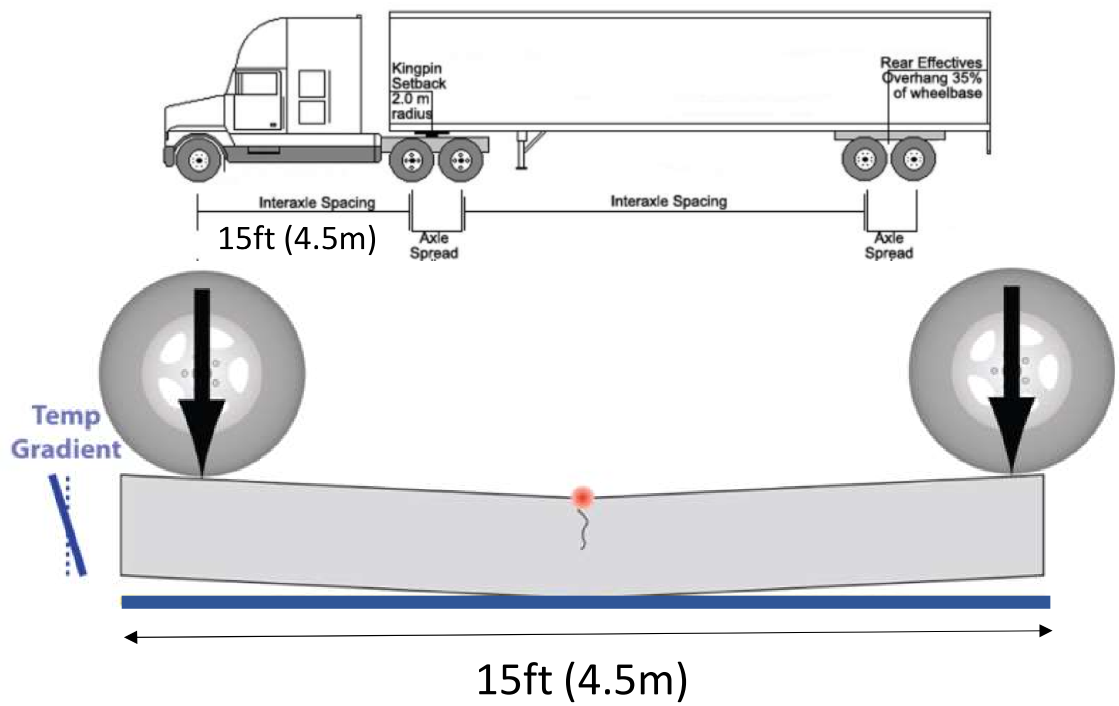
(Slide courtesy of Jerry Holland, P.E. Structural Services, Inc.)

Curling Induces Cracking Under Loading

Concrete slabs are curved like a plate



Cracks form when truck axles load opposite edges of the slab simultaneously.

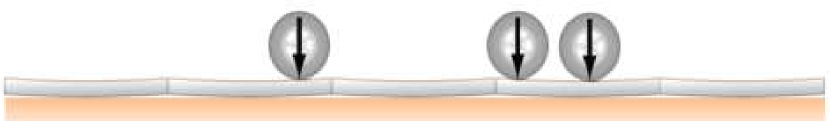


Optimized Slab Geometry

Conventional Design

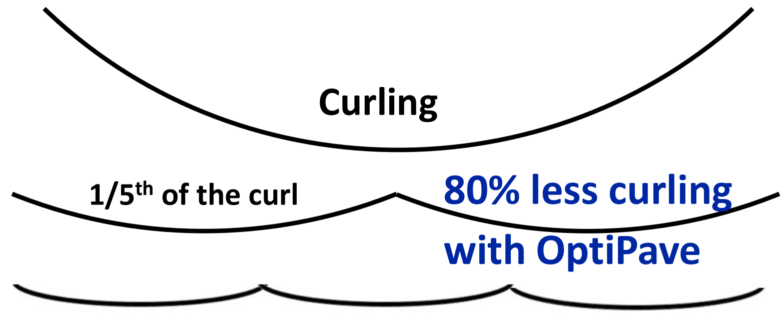
Thickness = 8” (200mm)
Slab Size = 15’ x 15’ (4.5m)

OptiPave Design



Thickness = 5.5” (140mm)
Slab Size = 6’ x 6’ (1.8m)

Graphic illustrates axle spacing of a standard 80kip U.S. legal limit 18-wheeler

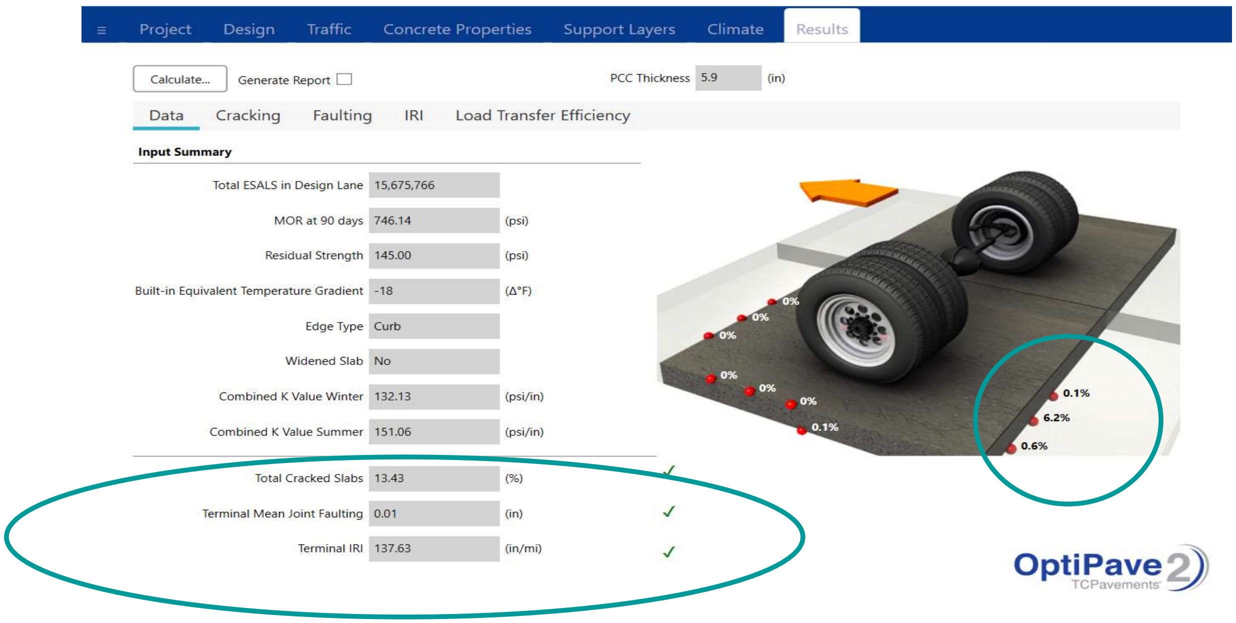


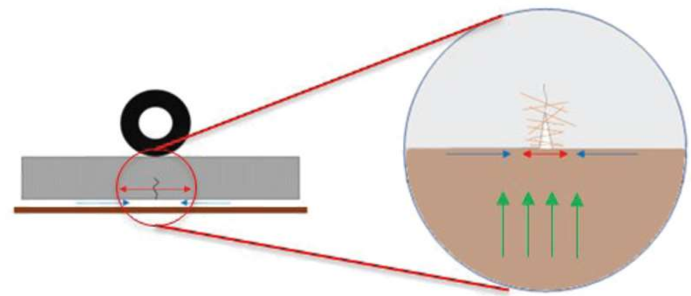
OptiPave reduces joint spacing to minimize curl and prevent both sides of the slab from being loaded at the same time.

This reduces stress, allowing slab thickness to be reduced for cost savings while maintaining reliable performance.

FORTA-FERRO® IN THE OPTIPAVE SYSTEM

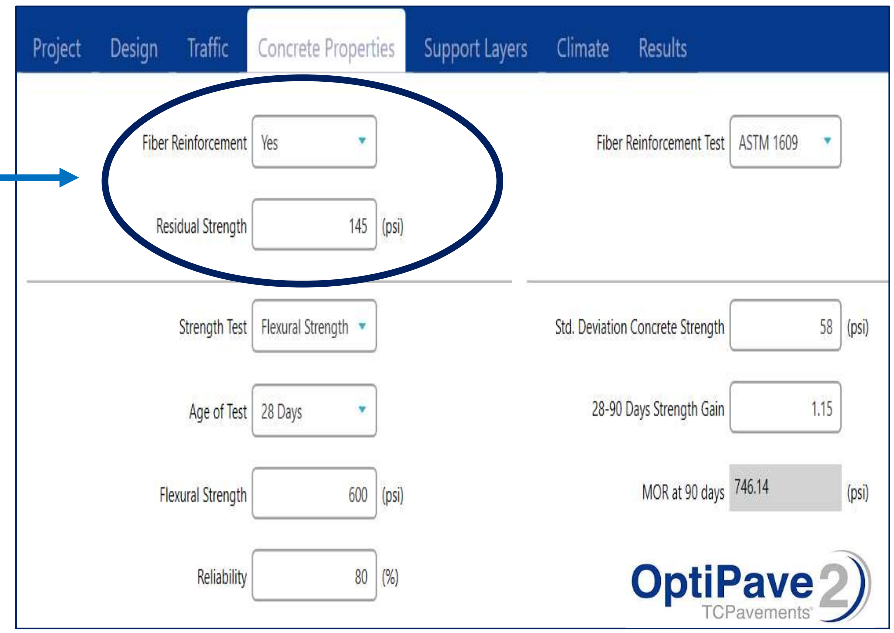
In the OptiPave System, FORTA-FERRO provides the residual strength required to restrain bottom-up cracks. The fibers act in tandem with the subgrade support, which provides confinement and friction while the fibers restrict the crack opening to redistribute forces. This heavy-duty macrosynthetic fiber can reduce pavement thickness, offers improved impact, abrasion resistance and provides maximum long-term durability; extending beyond the pavements design life.





FORTA-FERRO® in OptiPave

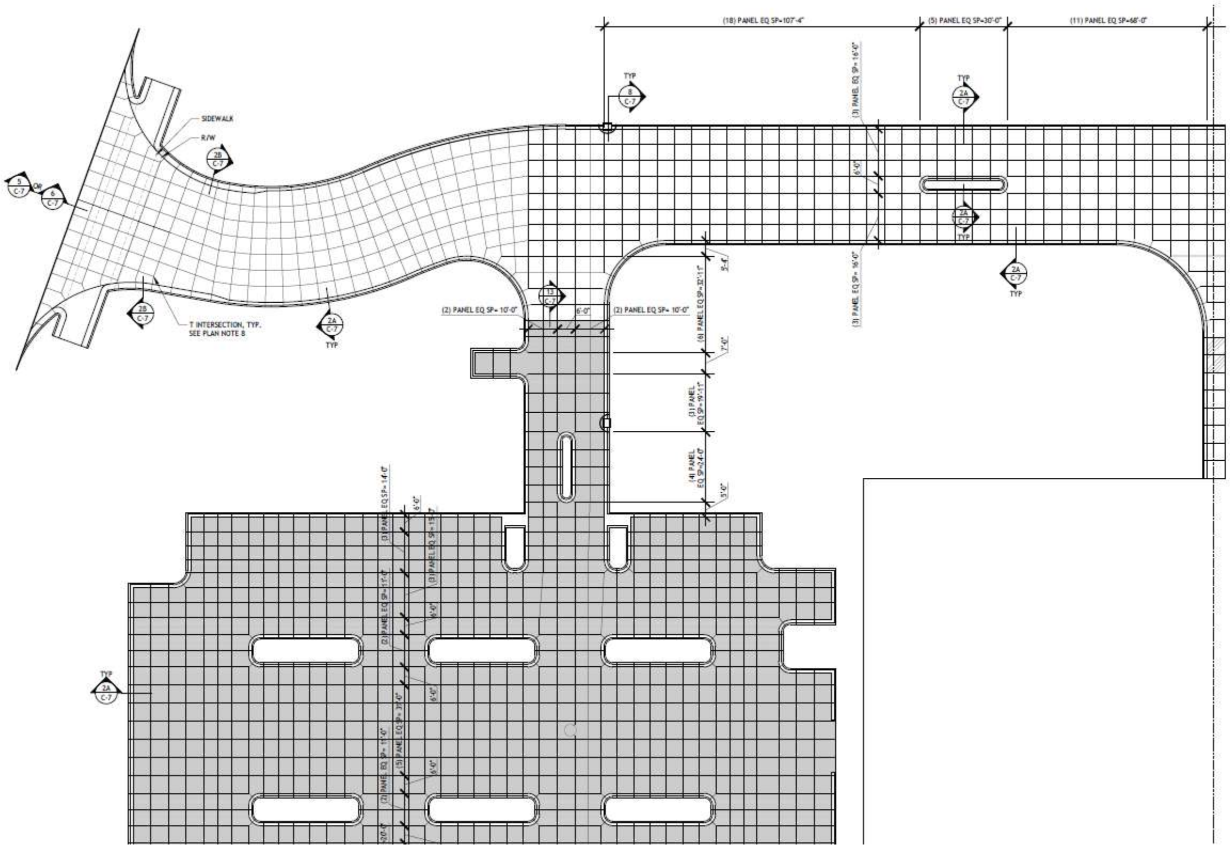
- **Macro Synthetic Fiber:**
  - Blend of Heavy-Duty Monofilament & Fibrillated Fiber
  - Copolymer & Polypropylene
- **Typical Dosage: 4.0 lb./yd³ (2.4 kg/m³)**
  - 145psi (1MPa) residual strength
- **Fiber Length: 2 ¼" (54mm)**



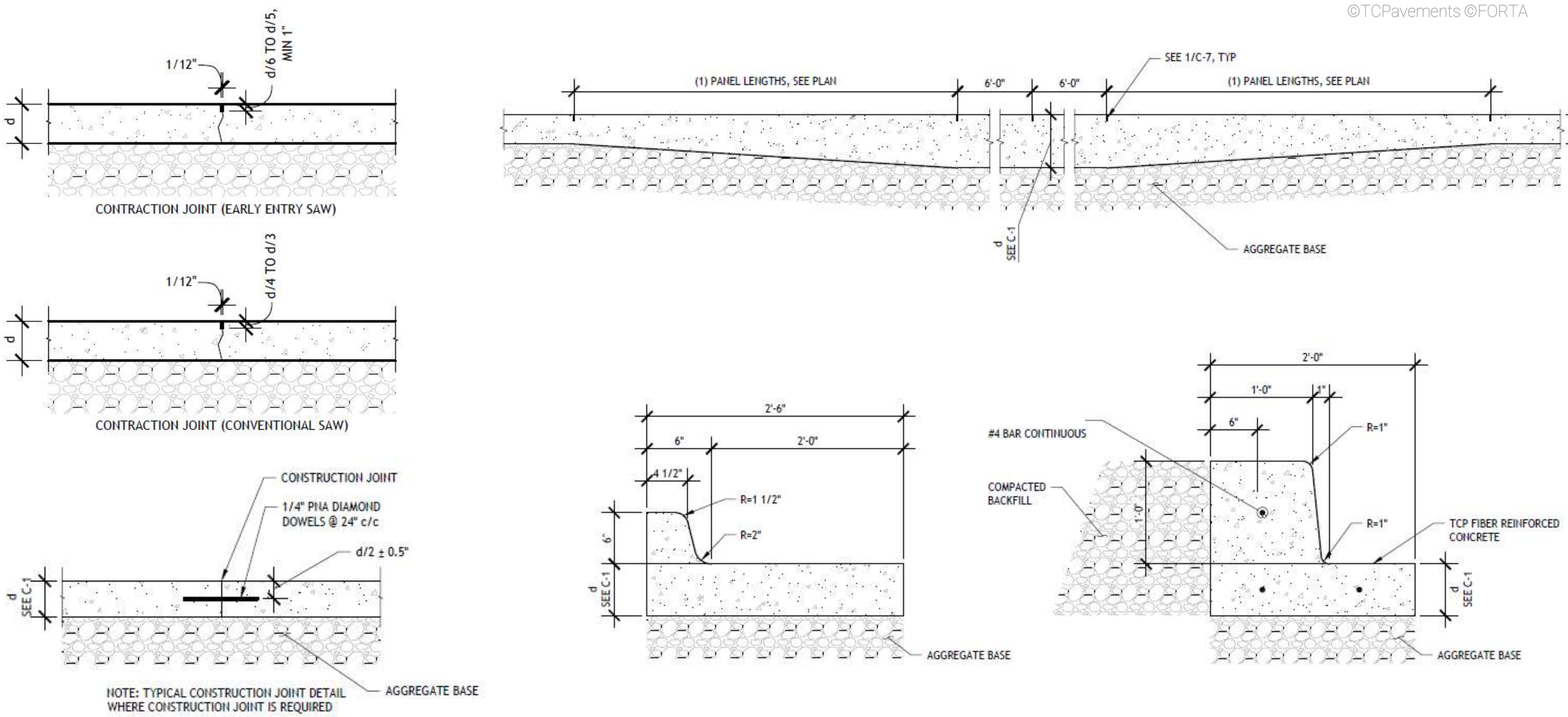
Testing at University of Illinois

Significance of Fiber Reinforcement

Joint Layout and Detail Examples



Joint Layout and Detail Examples



Joint Treatment Options

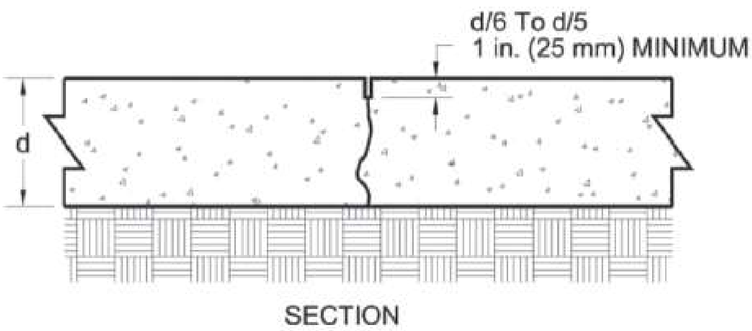


Fig. 4.4.2.3a—Contraction joint (early-entry saw).

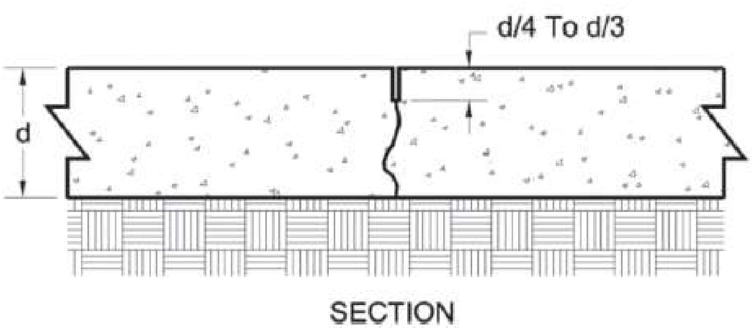
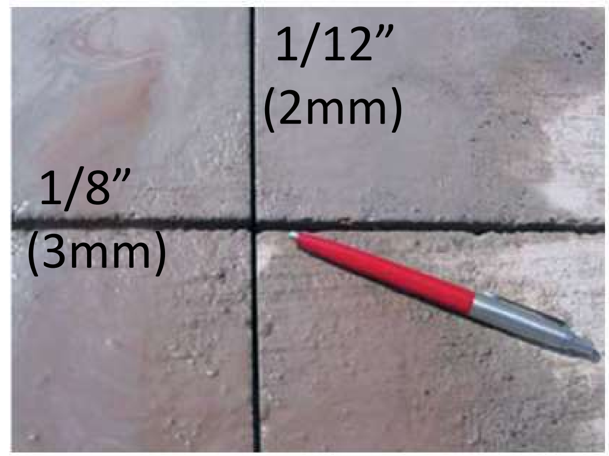
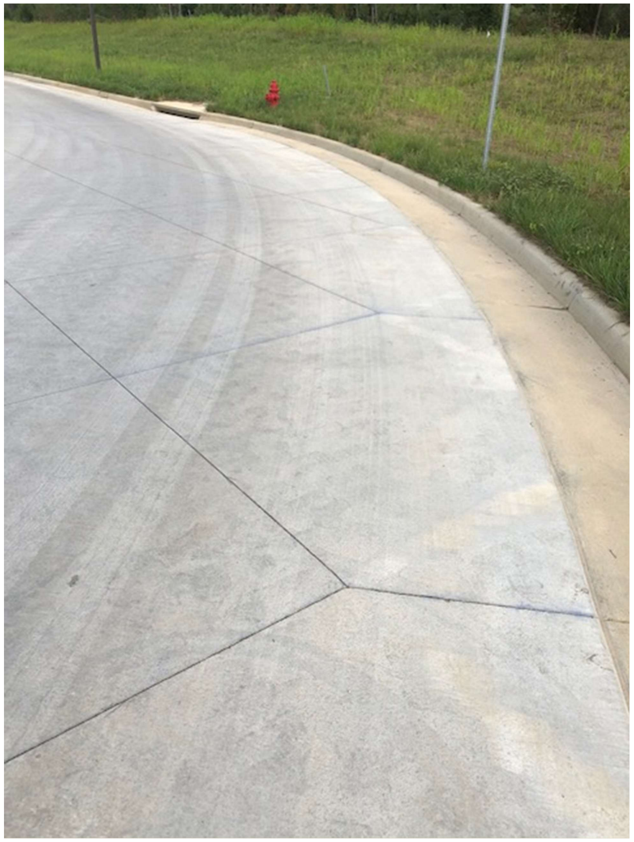
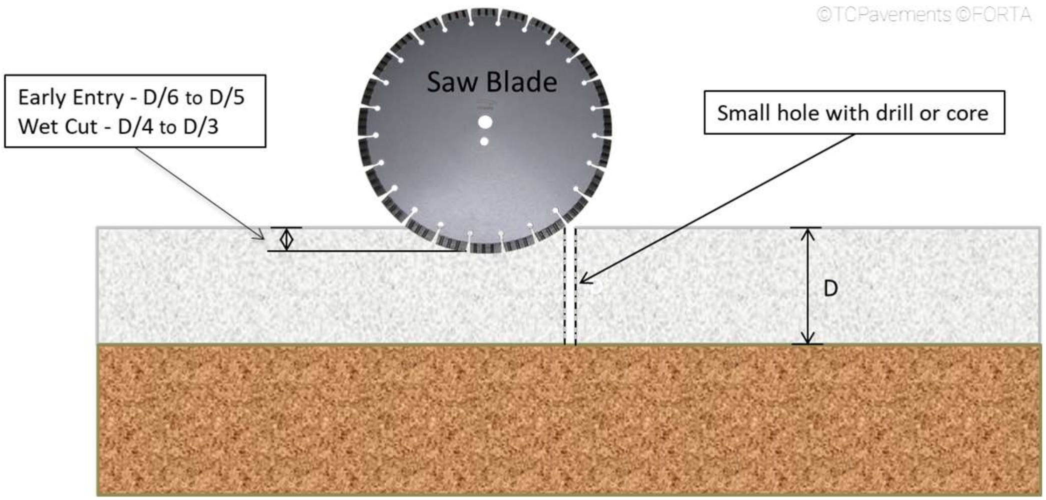


Fig. 4.4.2.3b—Contraction joint (conventional saw).

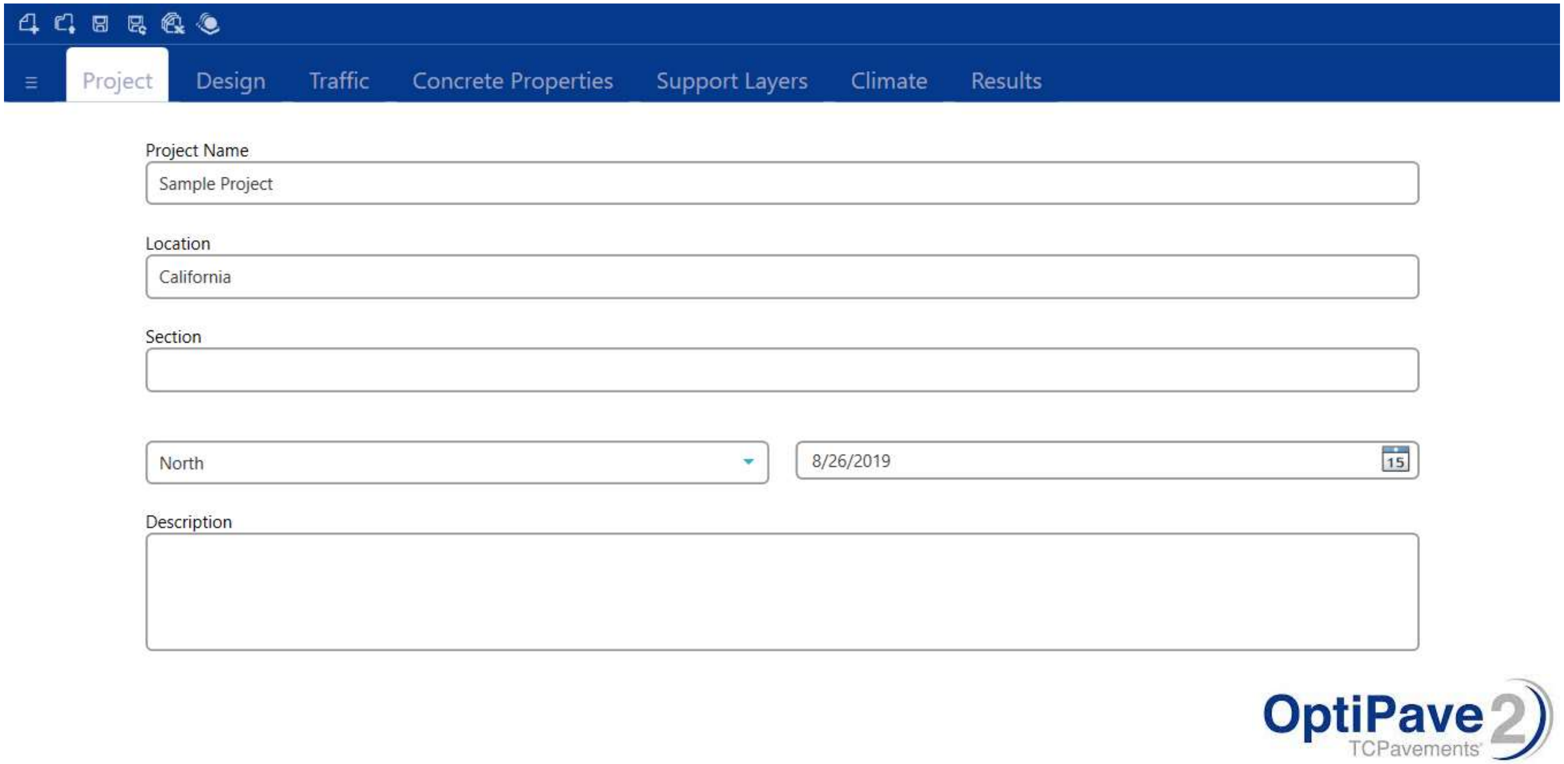


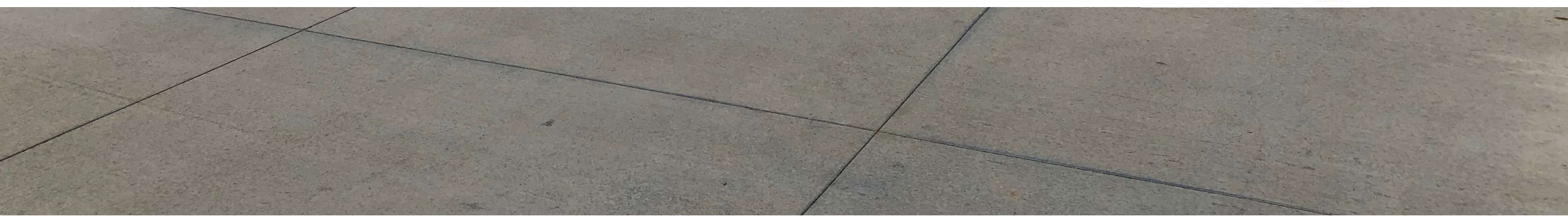
Dog-Leg Joints and T-Joints





OptiPave 2 TCPavements Example



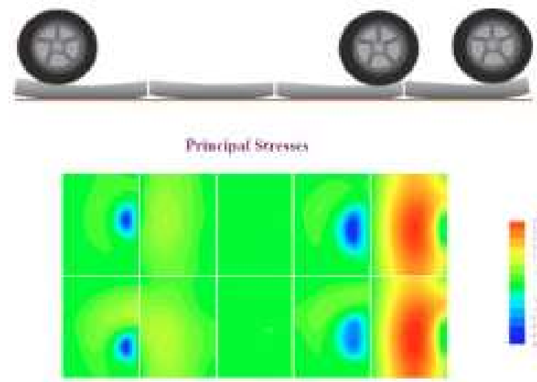


TCPavements™
PAVEMENT INNOVATION

FORTA®
CONCRETE FIBER

≡ Project | Design | Traffic | Concrete Properties | Support Layers | Climate | Results

Design Life	20	(years)
Joint Spacing	6	(ft)
PCC Thickness	5.9	(in)
Compute Thickness	☑	
Edge Type	Curb	
Widened Slab	No	
Doweled Joints	No	
Lateral Drain	No	
Pavement-Base Interface Model	Unbonded	
Initial IRI	99	(in/mi)



Percentage of Cracked Slabs	15	(%)
Terminal IRI	217	(in/mi)
Mean Joint Faulting	0.2	(in)
Design Reliability	85	(%)

OptiPave2 TCPavements

≡ Project | Design | Traffic | Concrete Properties | Support Layers | Climate | Results

Traffic Input

Truck Traffic Classification: ACI 330

Truck Traffic Group: CATEGORY D

Annual Traffic Growth: 0 (%)

Analysis Method: Load Spectra

Advanced Options: ☑

Lateral Traffic Wander

Mean Wheel Location (From the Lane Marking): 18 (in)

Traffic Wander Standard Deviation: 10 (in)

Category A	Car parking areas and access lanes
Category B	Shopping center entrance and service lanes; city and school buses parking areas and interior lanes; Truck parking areas
Category C	Entrance and exterior lanes; Truck parking areas
Category D	Truck parking areas

Load Spectra

Two-way Average Annual Daily Truck Traffic: 250

Percentage of Trucks in Design Direction: 100 (%)

Percentage of Trucks in Design Lane: 100 (%)

Percentage of Traffic During Summer: 50 (%)

OptiPave 2 TCPavements

Project | Design | Traffic | **Concrete Properties** | Support Layers | Climate | Results

Fiber Reinforcement: Yes
Residual Strength: 145 (psi)
Fiber Reinforcement Test: ASTM 1609

Strength Test: Flexural Strength
Age of Test: 28 Days
Flexural Strength: 600 (psi)
Reliability: 80 (%)
Advanced Options ☑

Std. Deviation Concrete Strength: 58 (psi)
28-90 Days Strength Gain: 1.15
MOR at 90 days: 746.14 (psi)

Type of Aggregate	Coefficient of Thermal Expansion (10^{-6}/°F)
Granite	4.0-5.0
Basalt	3.3-4.4
Limestone	3.3
Dolomite	4-5.5
Sandstone	6.1-6.7
Quartzite	6.1-7.2
Marble	2.2-4

Coefficient of Thermal Expansion (10^{6}): 5.56 (1/°F)
Ultimate Shrinkage (365 days): 600 (microstrain)
Air Content: 3 (%)
Water-Cement Ratio: 0.45
Advanced Options ☑

Modulus of Elasticity: 3,800,000 (psi)
Concrete Unit Weight: 150 (pcf)
Poisson Ratio: 0.15

OptiPave 2
TCPavements

≡ Project | Design | Traffic | Concrete Properties | Support Layers | Climate | Results

Number of Layers 2

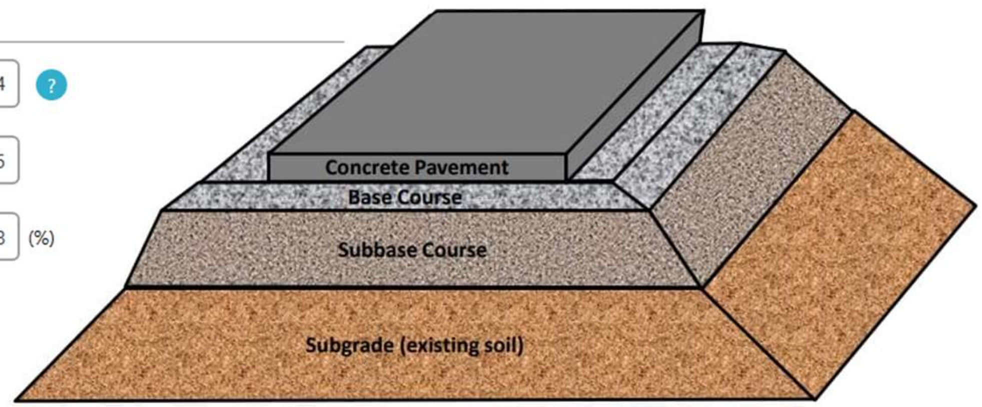
	Type of Soil	Rm Winter (psi)	Rm Summer (psi)	Poisson Ratio	Thickness (in)
Base	A-1-a	28000	28000	0.35	4
2nd Layer	CTB	21000	21000	0.35	12
Subgrade	A-1-a	5000	6000	0.35	

Base Properties

Erodibility index: 4 ?

Base/slab friction coefficient 0.65

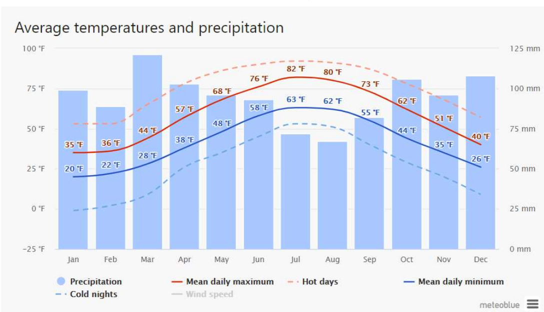
Passing #200 sieve (%) Base Material 8 (%)

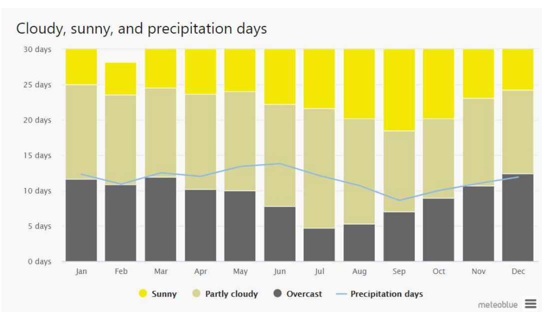


OptiPave2 TCPavements

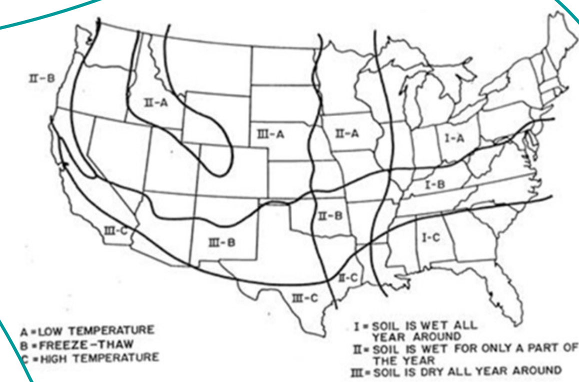
≡ Project | Design | Traffic | Concrete Properties | Support Layers | **Climate** | Results

meteoblue
weather close to you





Country	Generic	
Zone	Dry Non-freeze	
Built-in Equivalent Temperature Gradient	-18	(Δ°F) ?
Mean Air Winter Temperature	46	(°F)
Mean Air Summer Temperature	96	(°F)
Concrete Setting Temperature	104	(°F)
Average Annual Number of Rainy Days	60.5	
Base Freezing Index	5	(%)



OptiPave 2
TCPavements

TCPavements™ PAVEMENT INNOVATION

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≡ Project | Design | Traffic | Concrete Properties | Support Layers | Climate | Results

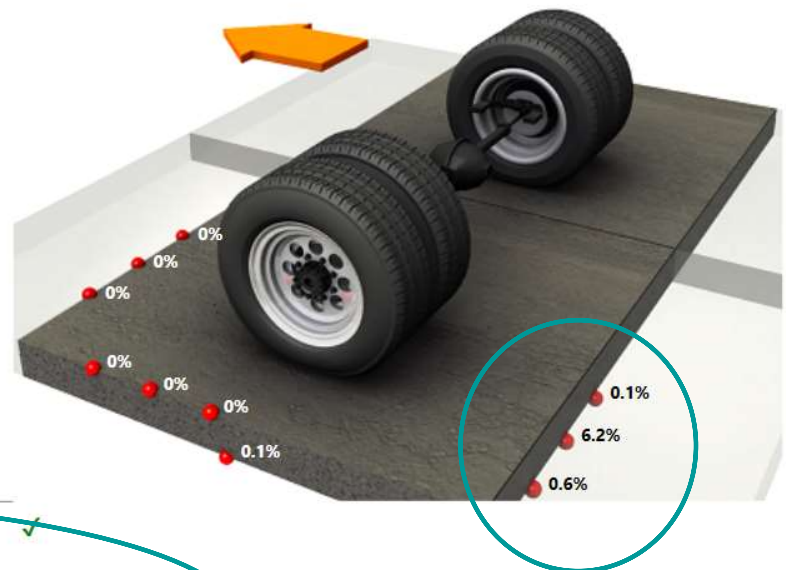
Calculate... Generate Report ☐ PCC Thickness 5.9 (in)

Data | Cracking | Faulting | IRI | Load Transfer Efficiency

Input Summary

Total ESALS in Design Lane	15,675,766	
MOR at 90 days	746.14	(psi)
Residual Strength	145.00	(psi)
Built-in Equivalent Temperature Gradient	-18	(Δ°F)
Edge Type	Curb	
Widened Slab	No	
Combined K Value Winter	132.13	(psi/in)
Combined K Value Summer	151.06	(psi/in)

Total Cracked Slabs	13.43	(%)	✓
Terminal Mean Joint Faulting	0.01	(in)	✓
Terminal IRI	137.63	(in/mi)	✓

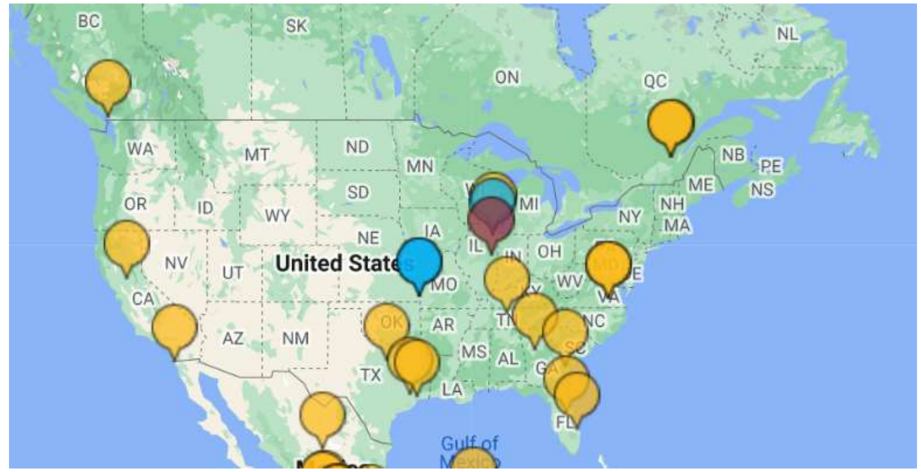


OptiPave 2 TCPavements

OptiPave™ Case Studies

TCPavements™

http://www.tcpavements.cl/eng/proyectos



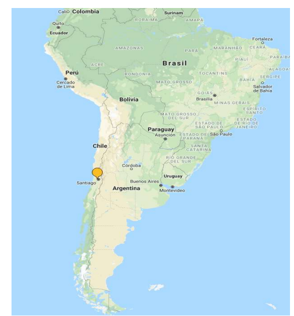
OptiPave™
TCPavements™

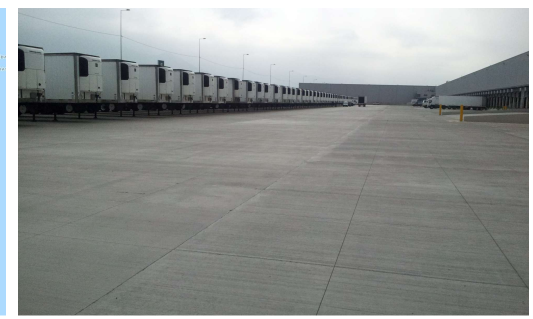
CASE STUDIES

Walmart, Lo Aguirre

Walmart, Lo Aquirre

- Thickness = 6”
  - with 6ft joint spacing
  - with 6” granular base
- Traffic = 10M ESALs
  - (Approximately 500 trucks/day, single/double/triple axle)
- Constructed in 2011
- Santiago, Chile
- 600,000 ft2





Walmart - Main Entrance and Access Road

OptiPave cut Walmart's costs by 12% on this project.

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Walmart - Adopts TCP

In 2018, Walmart built another distribution center in Santiago, choosing TCP as its pavement solution – 1.5M ft^2 of pavement.

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Case Studies

Ruta 60 Ch Camino

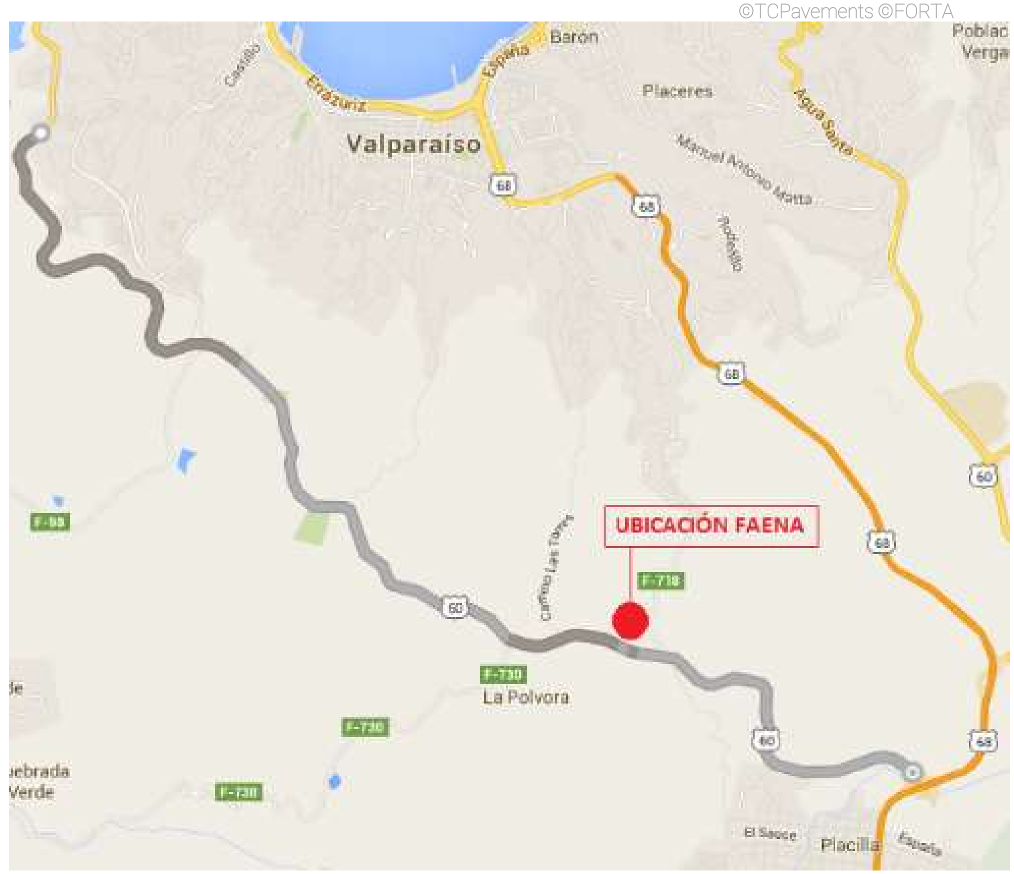
La Pólvora, Chile

Ministerio de Transportes y Telecomunicaciones

Ruta 60 Ch Camino La Pólvora, Chile

- Thickness = 9”
  with 6ft joint spacing
  with macrosynthetic fibers
- Traffic = **189M ESALs**
- Constructed in 2016

Ruta 60 Ch Camino La Pólvora, Chile



Ruta 60 Ch Camino La Pólvora, Chile

Length (Km)	30
Width (m)	14
	420,000 m2

	Unidad	Asphalt Espesor	Asphalt TOTAL	Traditional Concrete Espesor	Traditional Concrete TOTAL	OptiPave Espesor	OptiPave TOTAL
HCV con Fibra	m3		USD -		USD -	0.21	USD 11,459,418
HCV	m3		USD -	0.33	USD 15,928,657		USD 0
Asfalto Carpeta de rodado	m^3	0.07	USD 4,704,000		USD -		USD 0
Asfalto 2 Categoria (2 capas)	m^3	0.14	USD 8,232,000		USD -		USD 0
Remoción material	m^3	0.81	USD 3,300,448	0.15	USD 611,194		USD 0
Sub-Base estabilizada CBR 40%	m^3	0.45	USD 3,969,000		USD -		USD 0
Base estabilizada CBR 60%	m^3		USD -	0.15	USD 1,638,000		USD 0
Base estabilizada CBR 80%	m^3	0.15	USD 1,827,000		USD -		USD 0
Imprimacion	m^2	1	USD 420,000		USD -		USD 0
Riego Liga	m^2	2	USD 840,000		USD -		USD 0
Colocacion H°	m2		USD -	1	USD 3,360,000	1	USD 3,360,000
Membrana de curado	m^2		USD -	1	USD 336,000	1	USD 336,000
Geotextil	m^2		USD -	1	USD 336,000	1	USD 336,000
Corte Hormigon	m		USD -	0.28	USD 70,560	0.85	USD 214,200
Royalty TCP Patente	m^2		USD -			1	USD 756,000
		Total solucion en Asfalto	USD 23,292,448	Total Hormigón Tradicional	USD 22,280,411	Total OptiPave	USD 16,461,618

	Costs	Savings
Savings (compared with Asphalt)	**USD 6.830.830**	**41%**
Savings (compared with traditional concrete pavement)	USD 5.818.793	35%

North American Projects

Dinwiddie County, VA (2017)

Traffic: 3M ESALs

(Approximately 80 trucks/day, over 20-years)

Thickness: 5.5”

- **600psi flexural strength**
- **Forta-Ferro® macrosynthetic fibers**
- **6ft joint spacing**
- **6” granular base**

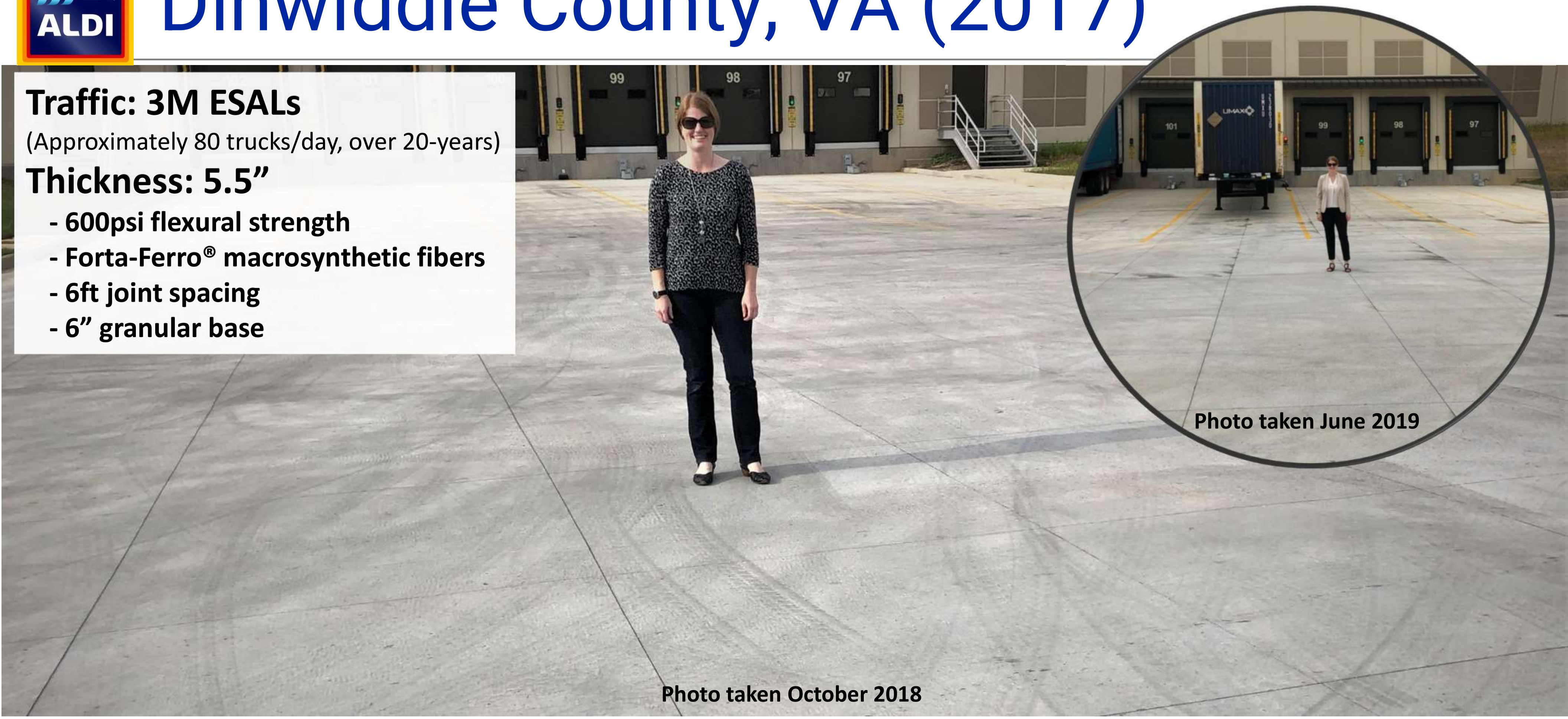


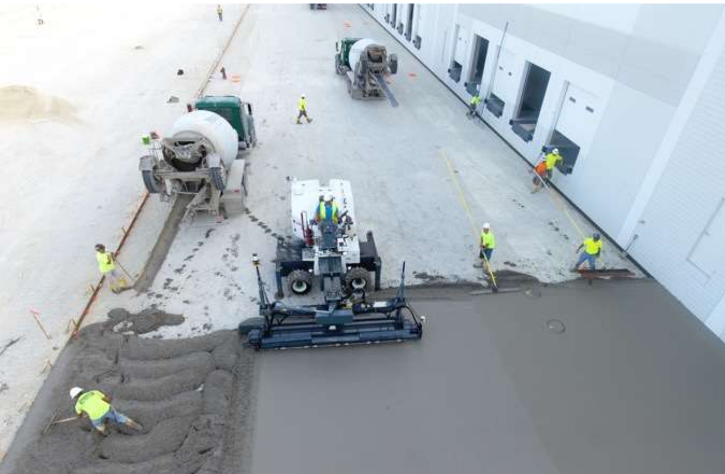
Photo taken October 2018

Photo taken June 2019

Atlanta, GA (2019)

Atlanta, GA – 2019
Size: 270,000 ft^2
Traffic: 23M ESALs
(Approximately 250 trucks/day, over 50-years)
Thickness: 5.5”
- **650psi flexural strength**
- **Forta-Ferro® macrosynthetic fibers**
- **5ft joint spacing**
- **4” granular base**

PROLOGIS® Lockport, IL (2020)



Traffic: 6M ESALs

(Approximately 150 trucks/day, 20-years)

Thickness: 6.0”

- **580psi flexural strength**
- **Forta-Ferro® macro fibers**
- **6ft joint spacing**
- **6” granular base**

PROLOGIS®

Nashville, TN (2021)

Traffic: 3.7M ESALs

(Approximately 150 trucks/day, over 20-years)

Thickness: 5.5”

- **580psi flexural strength**
- **Forta-Ferro® macrosynthetic fibers**
- **6ft joint spacing**
- **6” granular base**

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Houston, TX (2021)

Traffic: ~4.0M ESALs
Size: 2.7M sq.ft.
Thickness: 5.5” (14cm)

- 580psi (4.0MPa) flexural strength
- with macrosynthetic fibers
- 6ft (1.8m) joint spacing
- 8” (20cm) cement treated base

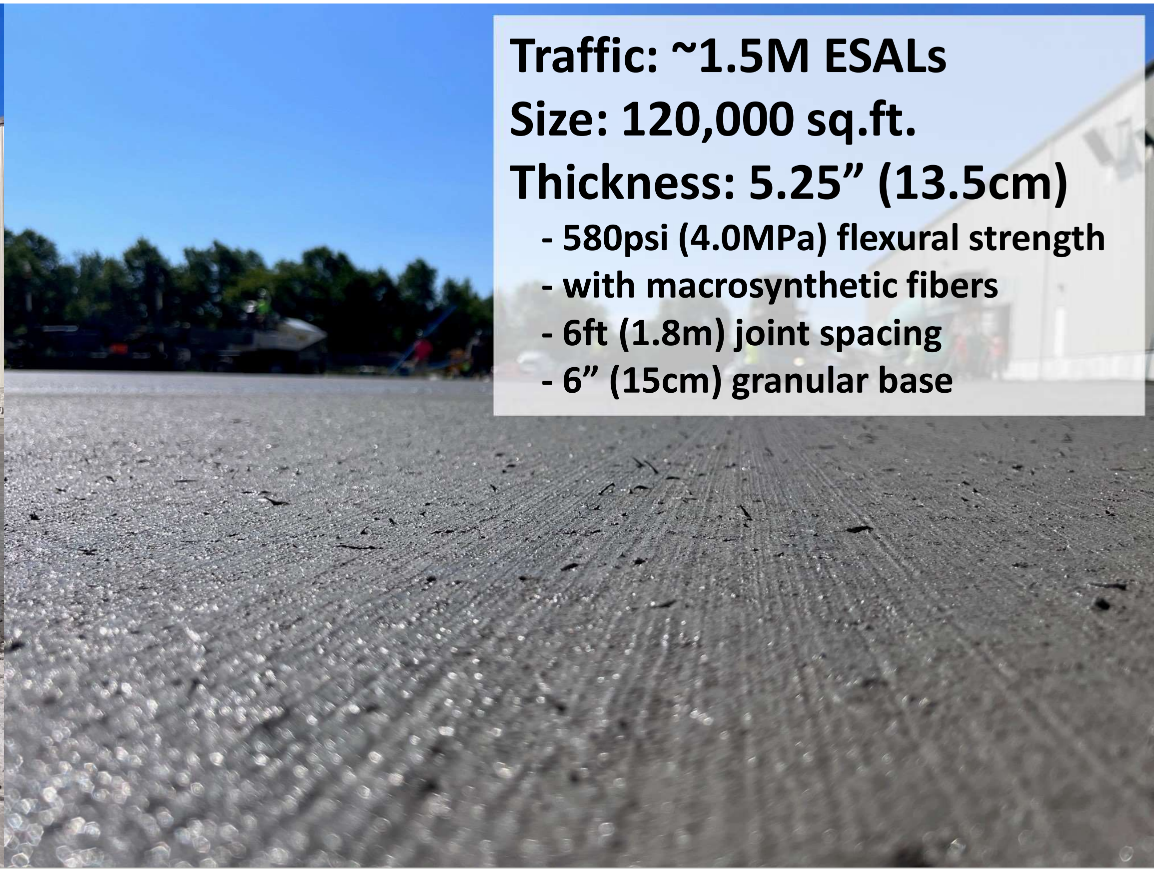
$2.76M savings by using OptiPave

Military Roadway, OK (2021)

Thickness: 7.0” (18cm)

- 580psi (4.0MPa) flexural strength
- with macrosynthetic fibers
- 6ft (1.8m) joint spacing
- 9” (23cm) granular base

Presidential Container - Middletown, NY (2021)



Traffic: ~1.5M ESALs

Size: 120,000 sq.ft.

Thickness: 5.25” (13.5cm)

- 580psi (4.0MPa) flexural strength
- with macrosynthetic fibers
- 6ft (1.8m) joint spacing
- 6” (15cm) granular base

Wooster, OH (2022)

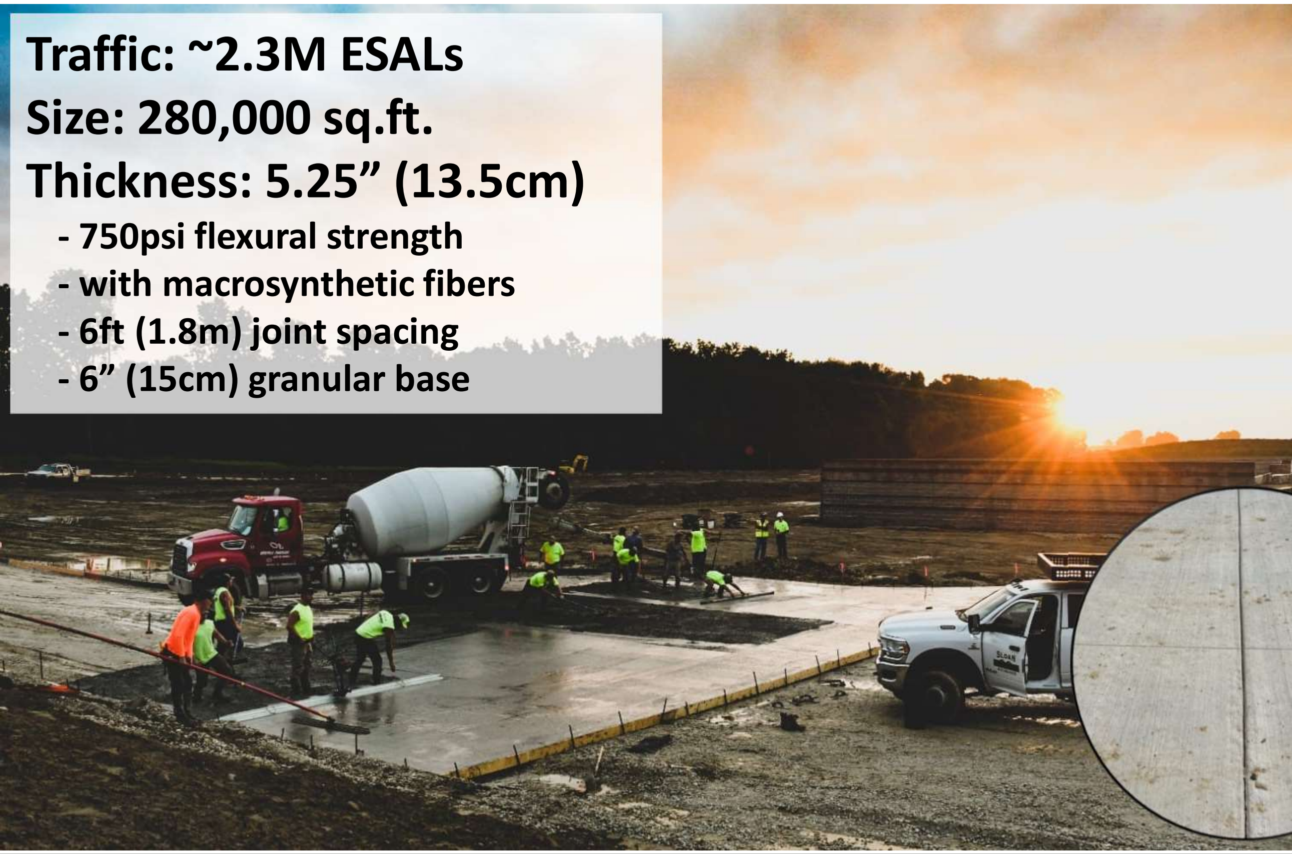
THE WOOSTER BRUSH COMPANY

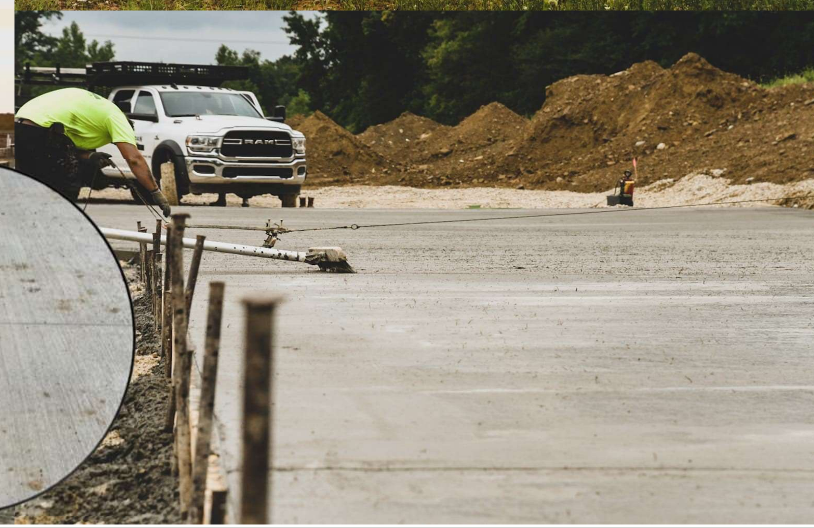
Traffic: ~2.3M ESALs

Size: 280,000 sq.ft.

Thickness: 5.25” (13.5cm)

- 750psi flexural strength
- with macrosynthetic fibers
- 6ft (1.8m) joint spacing
- 6” (15cm) granular base





OptiPave™

TCPavements™

URBAN ROADWAY EXAMPLES

Punta Arenas, Chile

Thickness

4”

Traffic

200,000 ESALs

Year built

2008

Image taken Nov’18

Valdivia, Chile

Thickness
3.5”

Traffic
50,000 ESALs

Year built
2012

Size: 172,000 ft2

Santiago, Chile

Thickness

4.5 "

Traffic

200,000 ESALs

Year built

2013

U-TCP Project.

Placed without base.

Condominium Alto Bulnes

Thickness

3.5”

Traffic

50,000 ESALs

Year built

2016

Av. Los Álamos, Perú

Thickness
5”

Traffic
200,000 ESALs

Year built
2013

Located in Villa Salvador

Huancayo, Perú

Thickness
4”

Traffic
200,000 ESALs

Year built
2015

Size: 226,000 ft2

Road Exchange – Trujillo, Perú

Thickness

4.7”

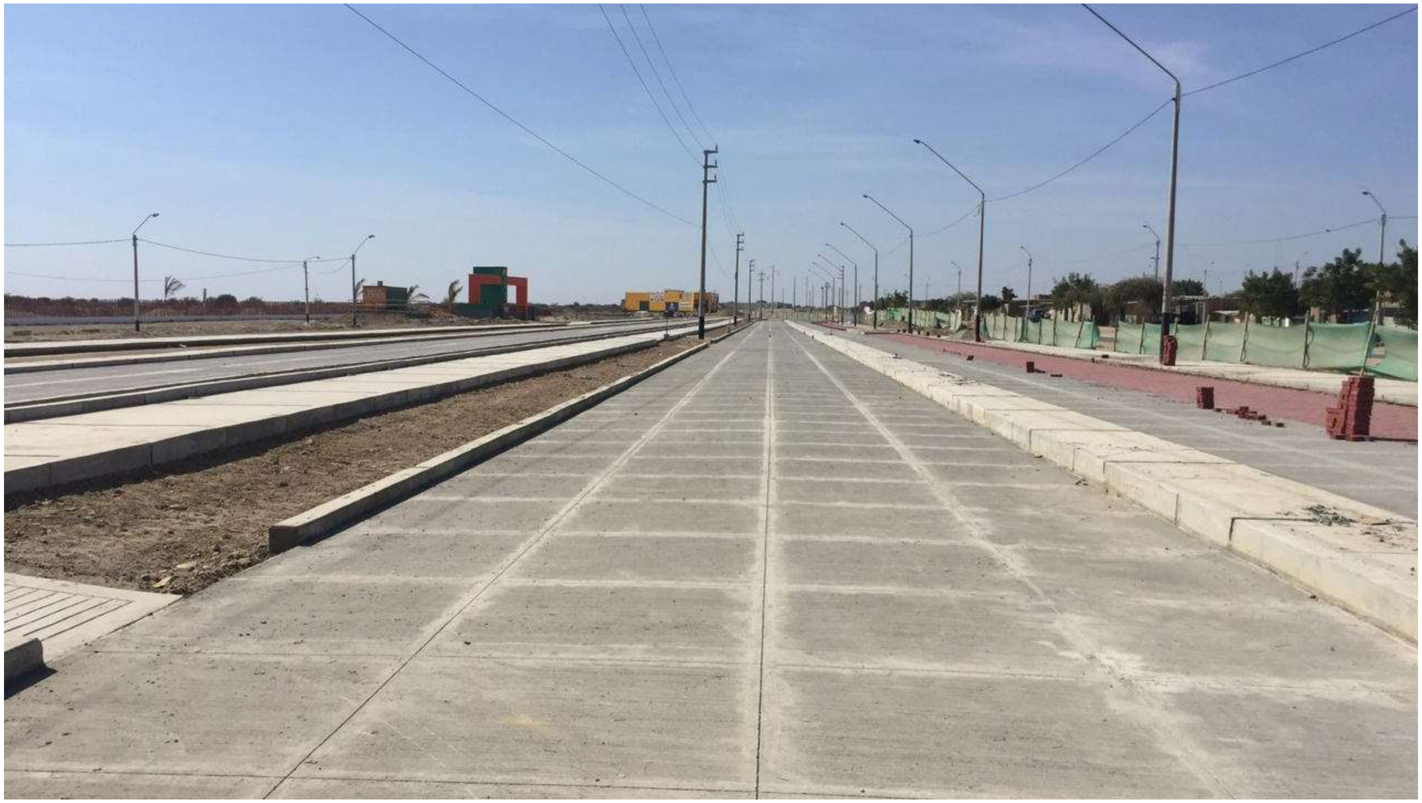
Traffic

1,000,000 ESALs

Year built

2015

Aguilar Santisteban, Piura



Thickness
5.5”

Traffic
15,000,000 ESALs

Year built
2018

Size: 900,000 ft2

Sanchez Cerro Street, Piura

Thickness

5.5”

Traffic

14,000,000 ESALs

Year built

2018

Size: 323,000 ft2

Credit: Guillaume Lemieux – CQI, CANADA

Ciment Québec

Stanstead, Québec CANADA

Ciment Quebec Terminal – Stanstead, QC

Constructed in 2018

TCPavements™ PAVEMENT INNOVATION

FORTA® CONCRETE FIBER

Ciment Québec

CONSTRUCTION
Oct. 26, 2018

OPEN to TRAFFIC
Oct. 31, 2018

Apr. 4, 2019

Nov. 20, 2019







Lessons Learned

- Good looking skid resistant surface
- Quick turnover vs traditional approach
- 46% cost reduction
  - OptiPave Design ($23,900)
  - Original Design ($35,000)
- 52% GHG reduction

Project Name	Impacts	Unit	Materials & Equipment	Transport	Total	% of Reduction
Stanstead - Optipave	Global Warming Potential	kg CO2 eq	11 249	3 770	15 019	52.3%
Stanstead – Traditionnal Design	Global Warming Potential	kg CO2 eq	19 976	2 894	22 870	

*Simulations made using PavementLCA developed by the Athena Institute

Sustainable Pavements:
What Role Can Design Play?

Sustainable Pavements need to demonstrate:

- Economic value
- Reduced environmental impact
- Reduced social impact



Things to Think About with OptiPave

- **When Optimizing our Concrete Pavement Designs, we can…**
  - reduce cost, GHG emissions and increase productivity
  - eliminate the need for steel reinforcement & dowels (in most cases)
  - allow for more flexible maintenance
    - smaller slabs allow for simple & effective utility repairs
- **Improved long-term performance will provide additional sustainability benefits throughout the life of the pavement.**
- **With improved end-of-life options, including concrete overlays, additional long-term benefits are possible.**

Concrete Pavement Life Cycle Environmental Assessment & Economic Analysis: A Manitoba Case Study

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Manitoba Infrastructure Case Study

1. 11.02 km project with 2-lanes and shoulders
2. 10 different concrete pavement alternatives evaluated
   - Economic LCCA (MIT CSHub without uncertainty)
   - Environmental LCA (Athena Pavement LCA Tool)
3. Looked at different concrete mixtures, designs, and M&R strategies
4. Compared to current "business as usual" base case over 50-year period

The Ten Alternatives

Case #	Case description	Analysis rationale
Base	355 kg cementitious, 15% fly ash, 0% slag, 276 t steel , regular M&R	Impacts of past practice
1	355 kg cementitious, 20% fly ash, 0% slag, 276 t steel, regular M&R	Effect of additional fly ash
2	355 kg cementitious, 15% fly ash, 25% slag, 276 t steel, regular M&R	Effect of slag/ternary mix, if used
3	307 kg cementitious, 15% fly ash, 0% slag, 276 t steel, regular M&R	Effect of reduced cementitious material (tarantula optimization)
4	355 kg cementitious, 15% fly ash, 0% slag, 126 t steel, regular M&R	Effect of reduced steel
5	307 kg cementitious, 20% fly ash, 0% slag, 276 t steel, regular M&R	Combined effect of reduced cementitious and increased fly ash
6	307 kg cementitious, 20% fly ash, 0% slag, 126 t steel, regular M&R	Combined effect of reduced cementitious and steel, and increased fly ash (new spec.)
7	307 kg cementitious, 15% fly ash, 25% slag, 126 t steel , regular M&R	Combined effect of new spec. and slag/ternary mix, if used
8	307 kg cementitious, 15% fly ash, 25% slag, 126 t steel , extended M&R	Effect of extended M&R
9	355 kg cementitious, 15% fly ash, 0% slag, 0 steel, TCP, regular M&R	Effect of short concrete panel (TCP)
10	307 kg cementitious, 15% fly ash, 25% slag, 0 steel, TCP, extended M&R	Effect of reduced cementitious, TCP, ternary mix and extended M&R

250 mm JPCP (10”)

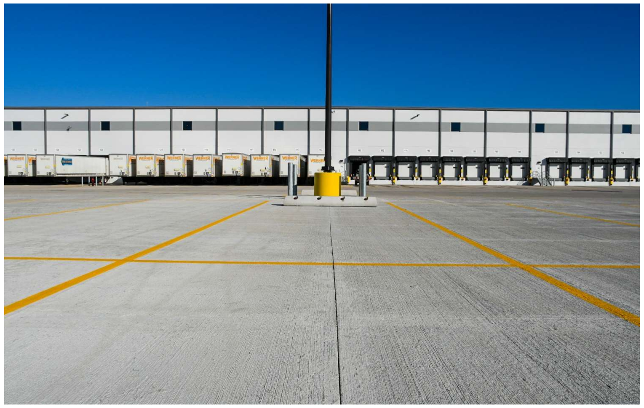
200 mm JPCP (7.5”)

Analysis Results

- **This study demonstrates that the transportation sector can have a significant impact on the reduction of environmental impacts by adopting sustainable material, design, construction and maintenance practices.**
  - 5% reduction in GHG emissions, and 3% reduction in total life cycle cost with the adoption of the new concrete mix design and dowel/tie bar configurations.
  - 6% reduction in GHG emissions, and 11% reduction in total life cycle cost with the adoption of a short slab (OptiPave) design.
  - 16% reduction in GHG emissions, and 18% reduction in total life cycle cost with the use of ternary concrete mix, using a short slab (OptiPave) design and extending the pavement service life by five years.

Final Remarks

OptiPave Summary



- Short Panel Joint spacing: 5’ (1.5m) - 8’ (2.4m)
- No Rebar; No Dowels *(only at construction joints)*
- Min & Max Saw Cut Depth
  - Using 1/12” (2mm) saw blades
  - Joints are left Unsealed
- Potential for significant reduction in GHGs
- Smooth Surface with 80% less curling
- Mechanistic + Empirical design method with 20+ years of proving performance

Thickness = 6.5” (160mm)
Slab Size = 6’ x 6’ (1.8 x 1.8m)

OptiPave® Team (US)

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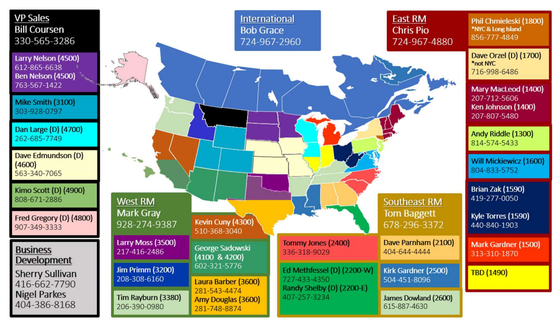

+ 29 field reps

TCPavements® PAVEMENT INNOVATION

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