Challenges in Concrete Pavement Design: Addressing Foundation Layer Limitations

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Benefits of Concrete Pavements

- Long life
- Provides good ride
- Requires little or no maintenance
- Provides more options for rehabilitation
- Able to withstand heavy traffic/loads
- Resilient pavement system
  - Foundation is the key
- In Texas, overall, excellent performance!

*Selecting the Right Concrete Pavement for the Right Situation– **Corey Zollinger, Cemex***

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Common Challenges in Concrete Pavement Design

- Inadequate Subgrade Support
- Drainage Issues
- Improper Stabilization Techniques
- Non-Uniform Layer Thickness
- Material Quality Variability
- Limited Geotechnical Data or Evaluation

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Concrete Pavement Design

- Consists of a systematic process to ensure the pavement structure performs efficiently under the expected traffic loads:
  1. Traffic Analysis
  2. Subgrade and Foundation Evaluation
  3. Slab Thickness Design
  4. Jointing and Reinforcing
  5. Concrete Material Selection
  6. Drainage Design
  7. Curing and Construction Considerations

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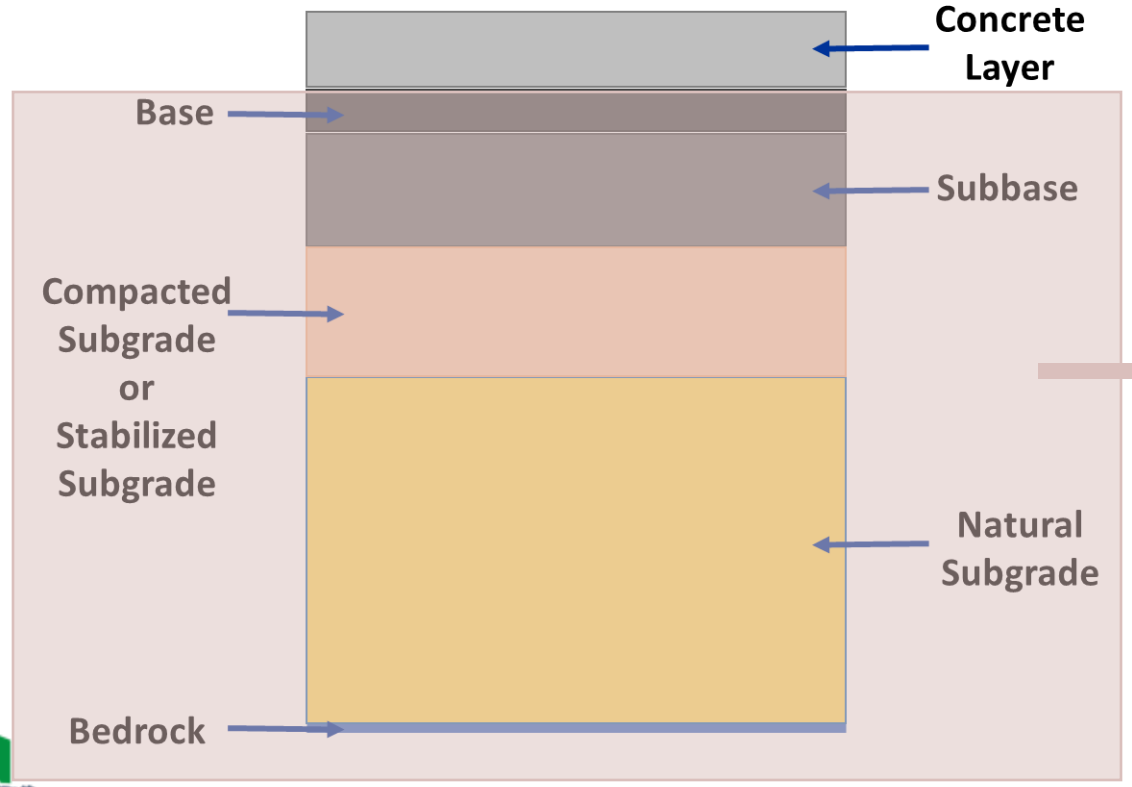
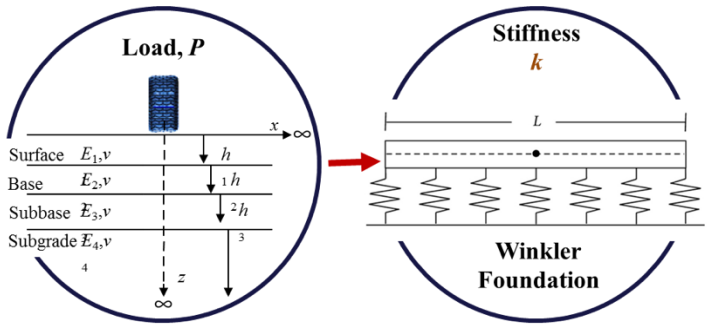
Concrete Pavement System





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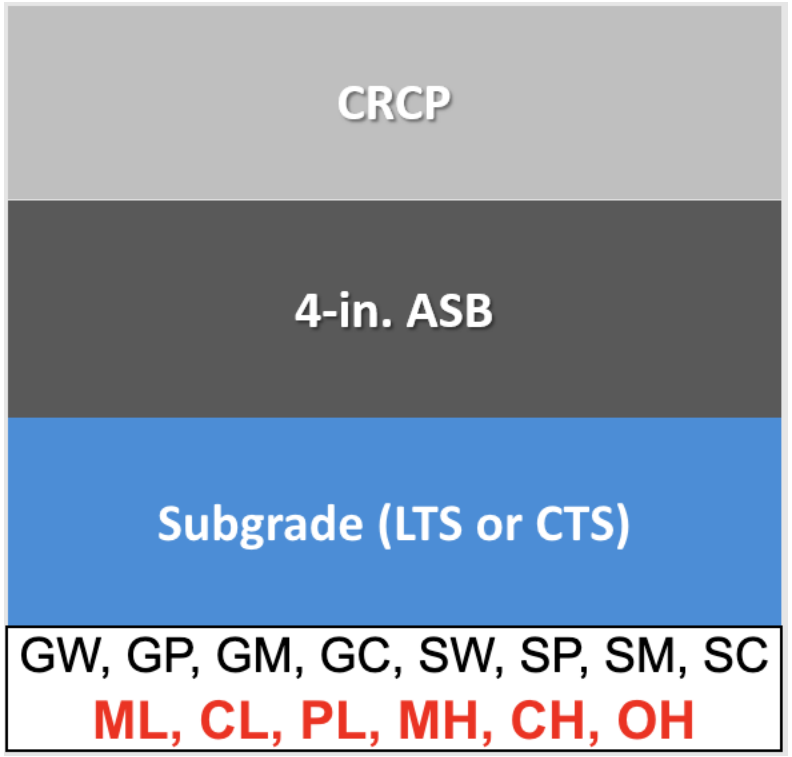
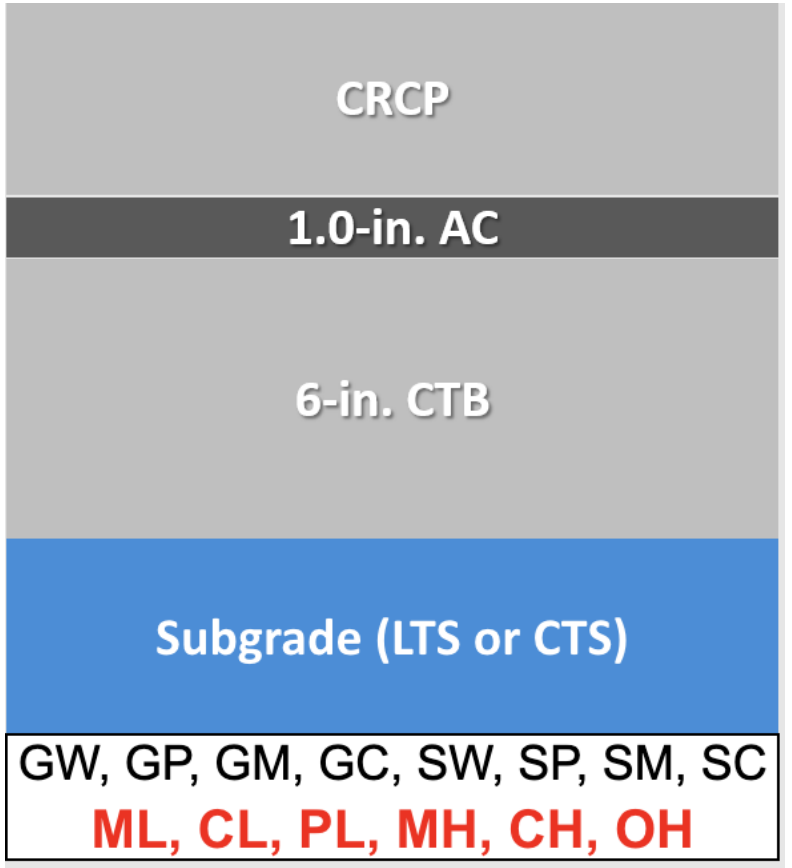
Supporting Layers





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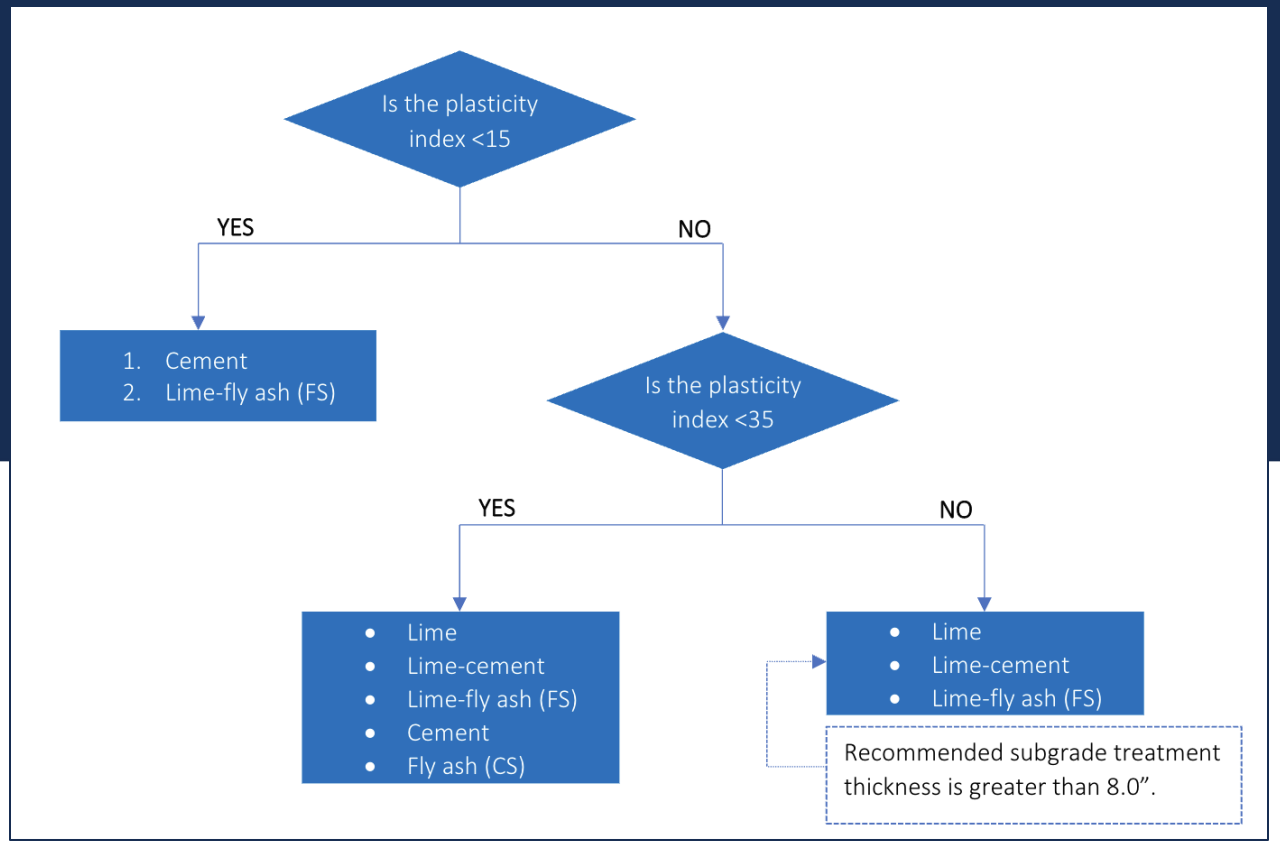
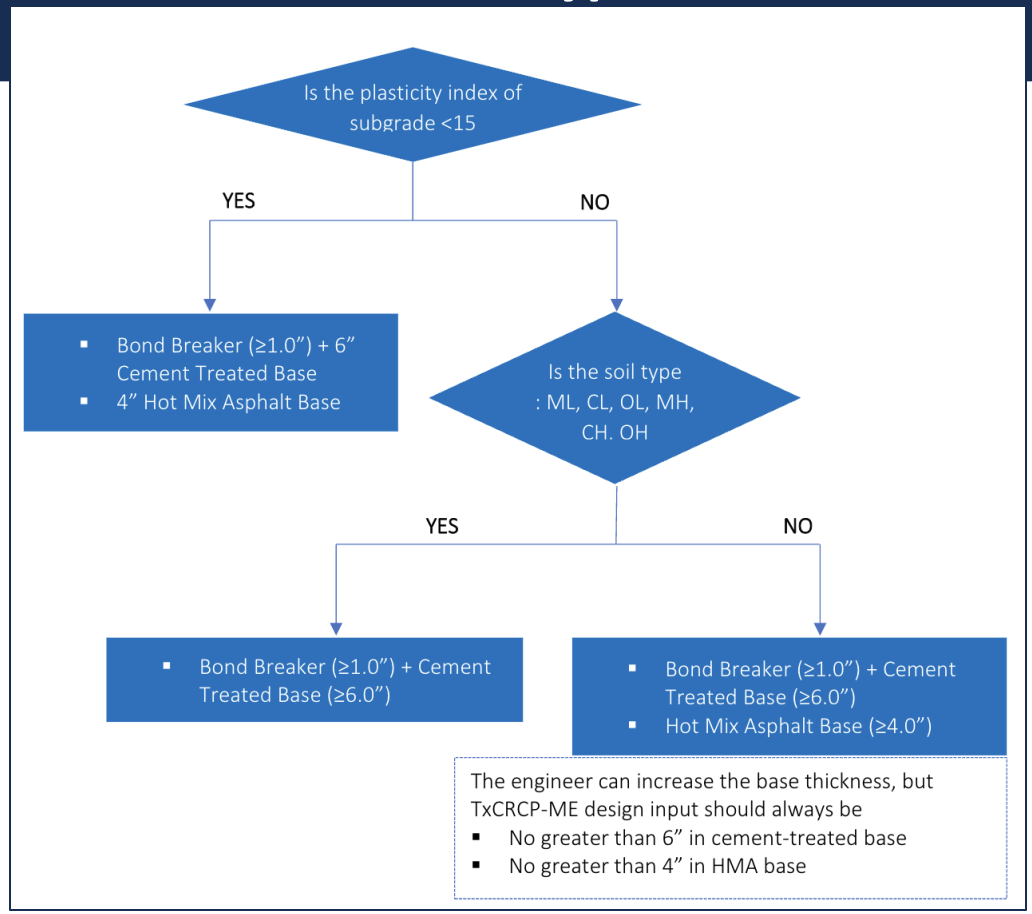


Subgrade Treatment

Advancements in Soil-Cement Research: Findings and Applications – ***Ben Reese, Raba Kistner***

- Discuss results of cement treated high PI soils.

Base Type



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Impacts of Pavement Foundation
A FWD Case Study

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Cement Treated Subgrade (CTS) – Reduced Deflections

- Project completed in 2006: 8” CRCP, 4” HMA & 8” LTS or CTS
- Cores taken ~700’ apart
- Statewide average deflection for 8” slab = 3.4 mils
- **Increased HMA base thickness will not “bridge” weak soils**

C1: 4.7-mils

8.5-in. CRCP & 10-in. HMA

No signs of CTS & weak soil
SG modulus (DCP): 7.1 ksi

C7: 2.3-mils

8.2-in. CRCP +3.8-in. HMA + 12.0-in. CTS

Strong CTS & Soil
SG modulus (DCP): 12.6 ksi

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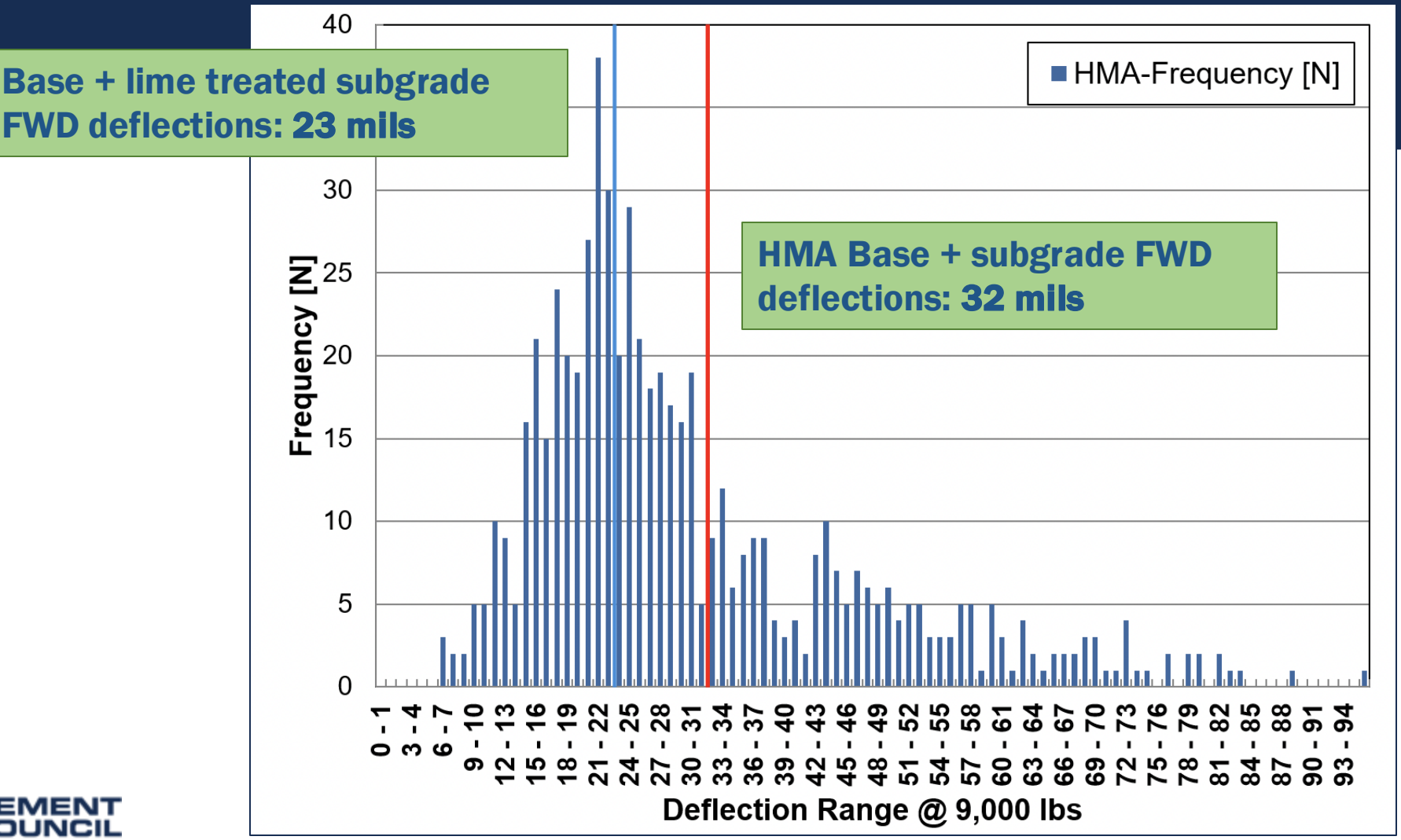
Deflection on HMA Base

HMA Base + lime treated subgrade (LTS) FWD deflections: 23 mils



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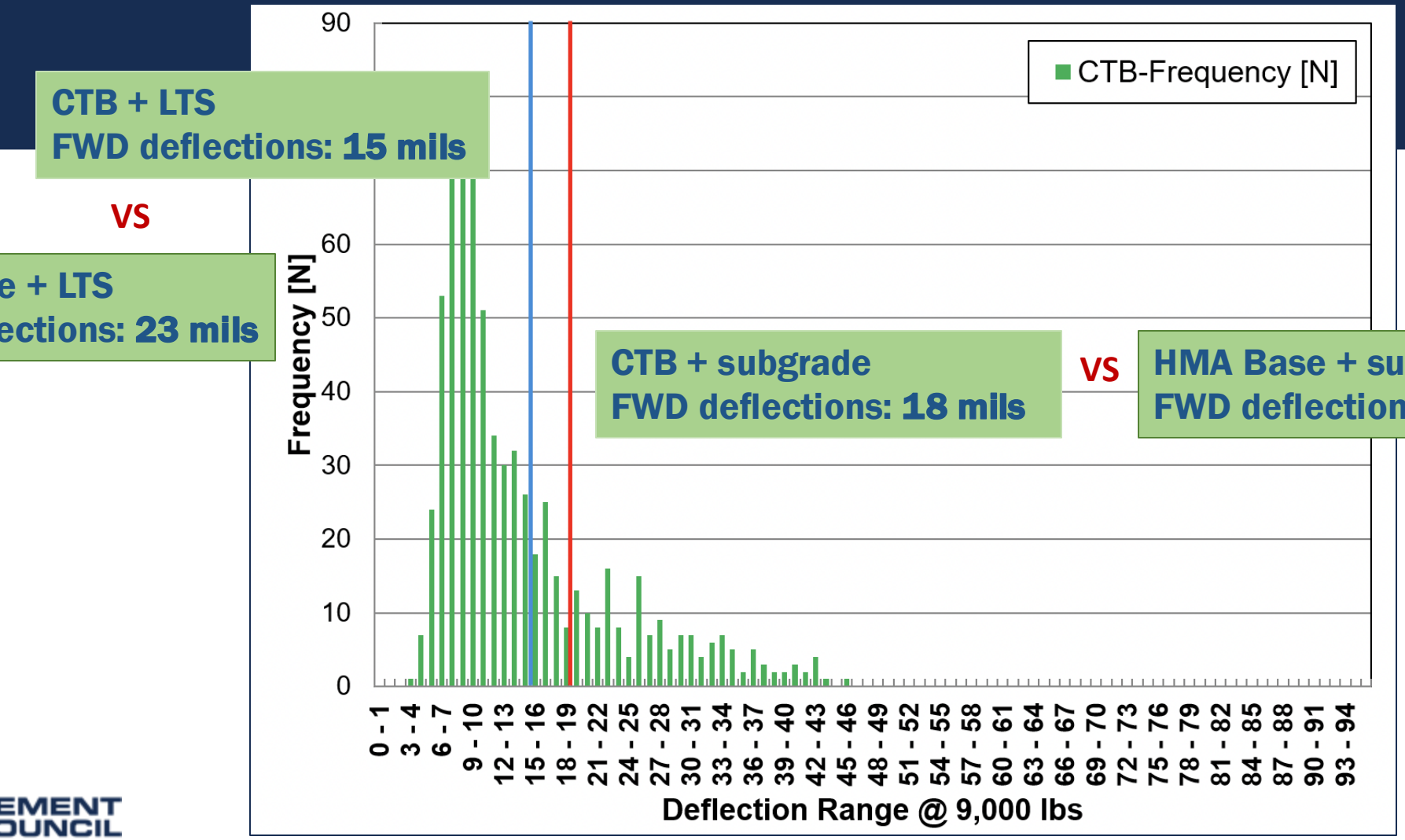
Deflection on Cement Treated Base

CTB + LTS
FWD deflections: 15 mils

VS

HMA Base + LTS
FWD deflections: 23 mils



CTB + subgrade
FWD deflections: 18 mils

VS

HMA Base + subgrade
FWD deflections: 32 mils

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Single axle load

Demonstrating the Benefits of Base and Soil Stabilization – A Finite Element Analysis

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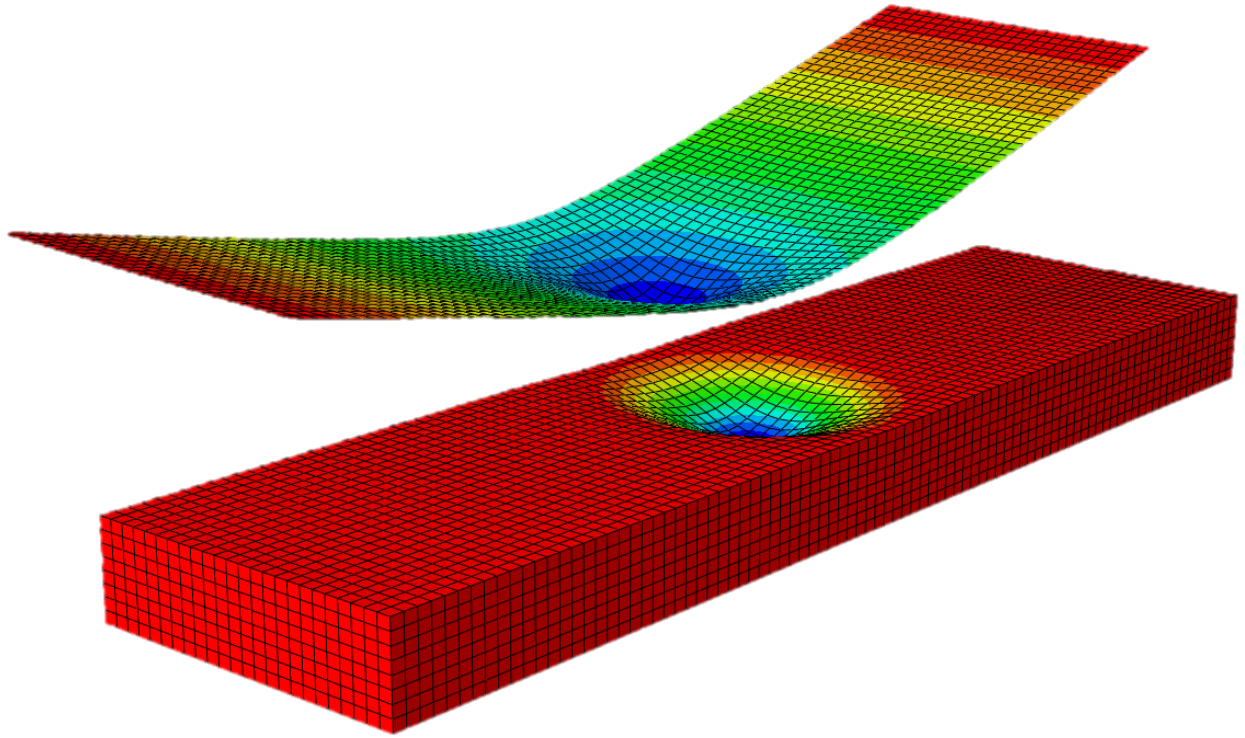

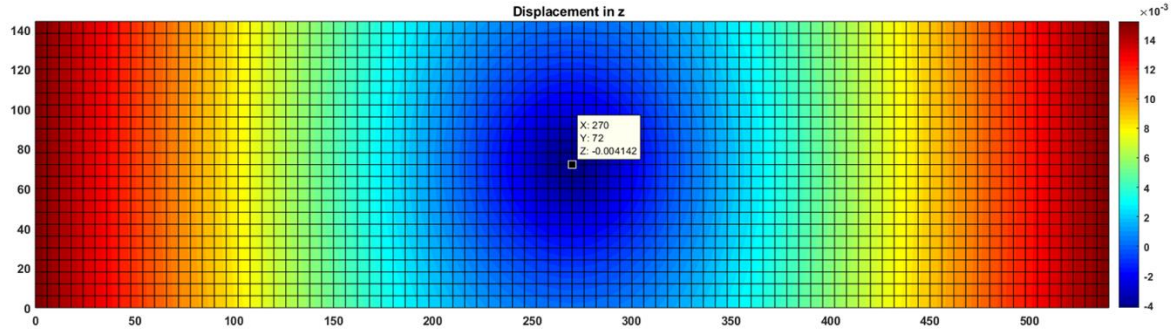

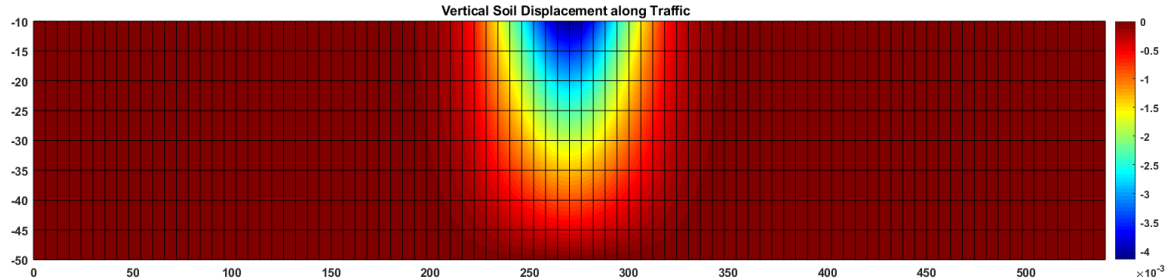

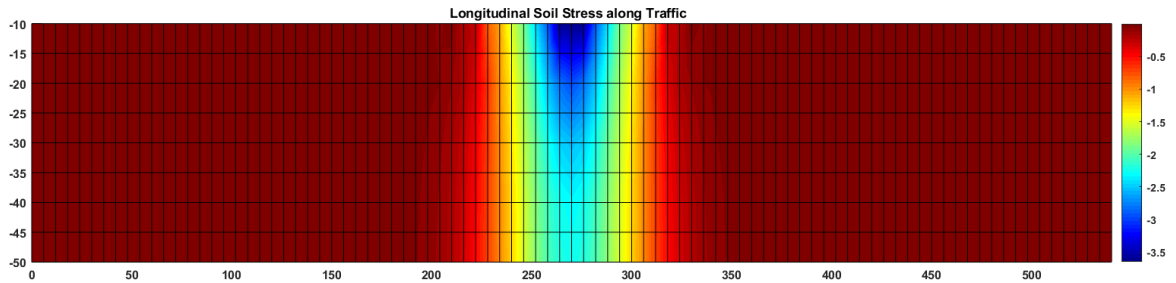

Finite element modeling is a powerful tool for analyzing concrete pavement performance, allowing engineers to simulate stresses, deflections, and cracking behavior under various loading and environmental conditions.

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4-in. HMA Base vs 6-in. CTB

- HMA Base

Layer*	Thickness (in.)	Modulus (ksi)	Poisson's Ratio
CRCP	12	5,000	0.15
HMA Base	4	500	0.35
Embankment Type C	8	15	0.35
Existing Subgrade	200	8	0.40

- CTB

Layer*	Thickness (in.)	Modulus (ksi)	Poisson's Ratio
CRCP	12	5,000	0.15
HMA Bond Breaker	1	400	0.35
CTB	6	750	0.20
Embankment Type C	8	15	0.35
Existing Subgrade	200	8	0.40

Maximum Pavement Responses

Location	HMA Base	CTB	
Stress at the Bottom of CRCP (psi)	104	99	5% ↓
Strain at the Top of Subgrade (με)	51*	49*	4% ↓

* Results in compression

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LTS vs CSS – Example 1

- Lime Treated Subgrade (LTS)

Layer	Thickness (in.)	Modulus, *E* (ksi)	Poisson's Ratio, ν
CRCP	12	5,000	0.15
HMA	4	400	0.35
LTS	8	**35**	**0.35**
Subgrade	200	6	0.45

- Cement-Stabilized Subgrade (CSS)

Layer	Thickness (in.)	Modulus, *E* (ksi)	Poisson's Ratio, ν
CRCP	12	5,000	0.15
HMA	4	400	0.35
CSS	8	**200**	**0.25**
Subgrade	200	6	0.45

Maximum Pavement Responses

Location	LTS	CSS	
Stress at the Bottom of CRCP (psi)	106	102	4% ↓
Strain at the Top of Subgrade (με)	48*	36	25% ↓

* Results in compression

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LTS vs CSS – Example 2

- Lime Treated Subgrade (LTS)

Layer*	Thickness (in.)	Modulus (ksi)	Poisson's Ratio
CRCP	11.5	5,000	0.15
HMA Bond Breaker	1	400	0.35
CTB	6	500	0.20
LTS	12	24	0.30
Existing Subgrade	200	8	0.40

- Cement-Stabilized Subgrade (CSS)

Layer*	Thickness (in.)	Modulus (ksi)	Poisson's Ratio
CRCP	11.5	5,000	0.15
HMA Bond Breaker	1	400	0.35
CTB	6	500	0.20
CSS	12	200	0.25
Existing Subgrade	200	8	0.40

Maximum Pavement Responses

Location	LTS	CSS	
Stress at the Bottom of CRCP (psi)	212	196	7.5% ↓
Strain at the Top of Subgrade (με)	180*	124*	31% ↓

* Results in compression

Design Recommendations

- CTB vs HMA base
  - Increasing the HMA thickness will not “bridge” weak soils.
- Highly recommend subgrade treatment
  - **Always test** to ensure you select the most adequate treatment and to determine % content.
- Design for a better foundation
  - If the base underneath the concrete slab does not provide good support, long term pavement performance will be severely compromised, **regardless of the concrete slab thickness**.

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