Design and Construction of Concrete Overlay

Course Number: CE-02-111

PDH: 13

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Module 1: Part I—Analytical Studies and Field Testing

Learning Objectives

By the end of this section, you will be able to:

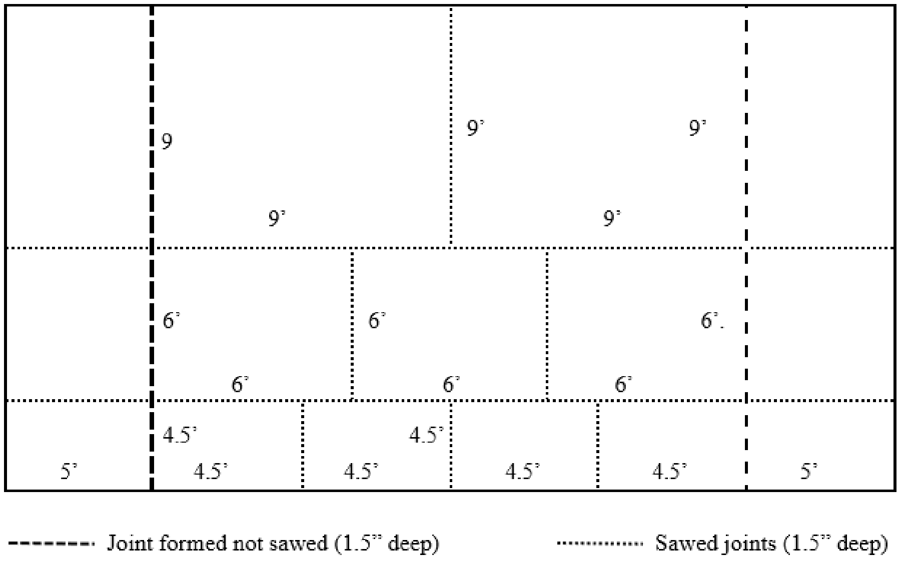
- **Evaluate** the structural impact of interface bonding, joint spacing, and widening unit dimensions on composite pavement performance.
- **Identify** appropriate finite element modeling techniques for 3-D analysis of thin PCC overlays (whitetopping).
- **Determine** the necessity of positive load transfer mechanisms, such as tie bars, to maximize the benefits of pavement widening.

Executive Summary: Analytical and field studies of Iowa Highway 13 demonstrate that maintaining a robust bond between pavement layers and ensuring effective load transfer at widening units are the most critical factors for reducing system stress and deflection. Temperature-induced curling can produce stresses significantly higher than wheel loads, making mechanistic modeling essential for long-term durability.

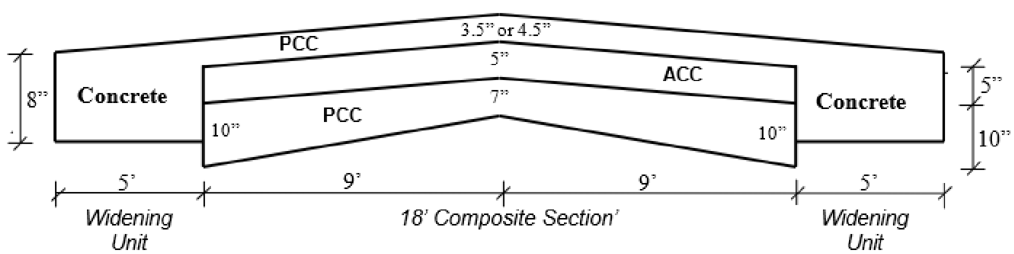
Background

Resurfacing hot mix asphalt (HMA) with thin Portland Cement Concrete (PCC) overlays, or **whitetopping**, provides several advantages over conventional asphalt resurfacing. It significantly reduces time and delays associated with maintenance and offers proven durability and lower life-cycle costs.

In Iowa, many original pavement systems reached their design life by the 1970s and were continually resurfaced with asphalt. Whitetopping presents an attractive, lower-cost alternative to continued asphalt rehabilitation. Key research including the 1994 Iowa County project and the 2002 Iowa Highway 13 (IA 13) project has demonstrated the viability of this method.



(a) Plan – Various joint spacing configuration



(b) Pavement cross-section

Figure 1. Schematics of the composite pavement (not to scale)

Finite Element Modeling Techniques

To investigate performance, 3-D finite element models are required to account for varying thicknesses, cross-slopes, and widening units that 2-D programs cannot handle.

Modeling of Concrete and Asphalt Layers

- **Solid Elements: SOLID45** 8-node brick elements are utilized.
- **Extra Displacement Functions:** These are included to correct for parasitic shear and allow the element to accurately represent bending effects without the extreme computational burden of higher-order elements.

Interface and Foundation Modeling

- **Interface Elements:** Surface-to-surface contact pairs (**TARGE170** and **CONTA174**) model the interaction between layers.
- **Friction Model:** Based on **Coulomb friction**, where sliding occurs when shear stress exceeds sliding resistance.

- **Foundation:** A **Winkler foundation** (liquid foundation) is used, represented by a thin layer of plate elements (**SHELL63**) placed beneath the bottom PCC layer.

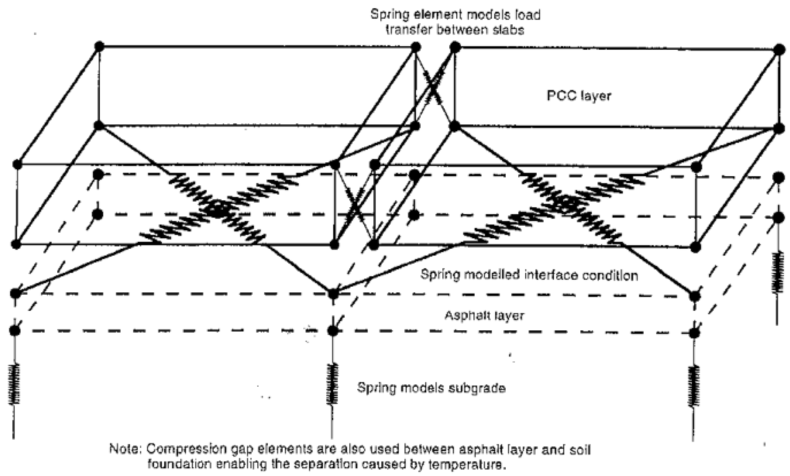


Figure 2. 3-D finite element model (Wu et al. 1998)

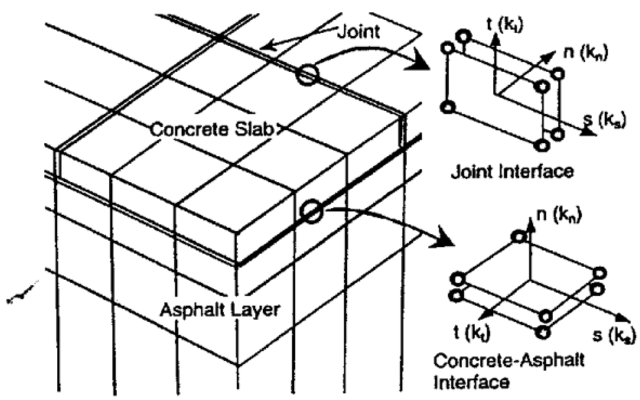


Figure 3. Interface elements (Nishizawa et al. 2003)

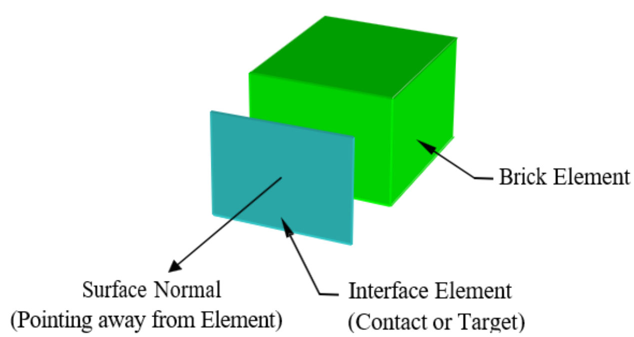


Figure 4. Orientation of interface element

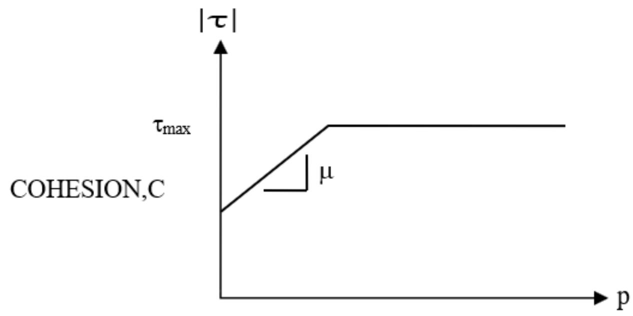


Figure 5. Friction model

Modeling of Iowa Highway 13

The IA 13 model length was 72 ft to ensure at least one truck load could be placed while maintaining panel edge boundaries for various joint configurations (4.5 ft, 6 ft, and 9 ft).

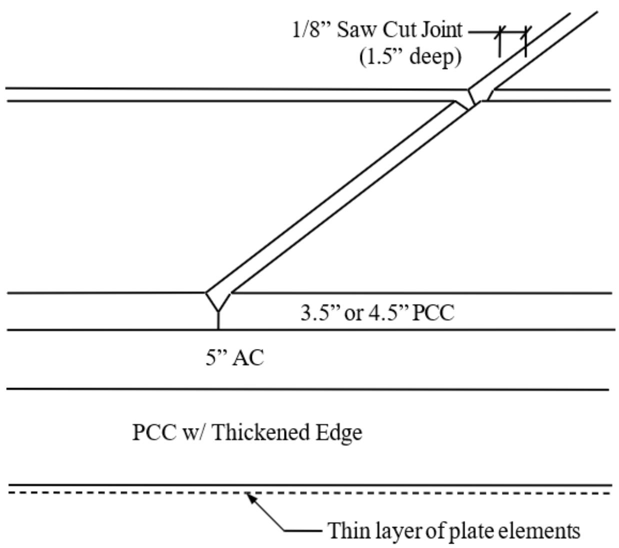


Figure 6. Finite element model details (not to scale)

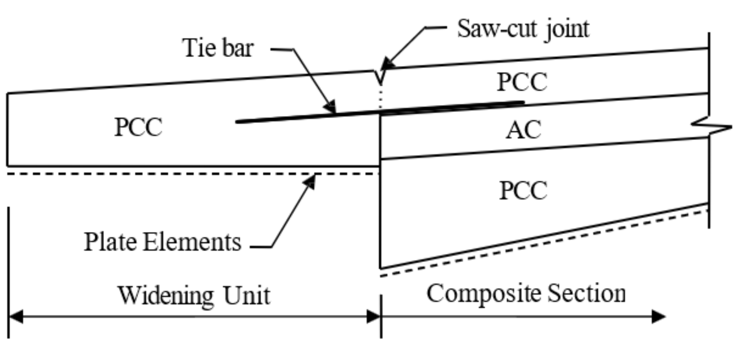


Figure 7. Location of tie bars (not to scale)

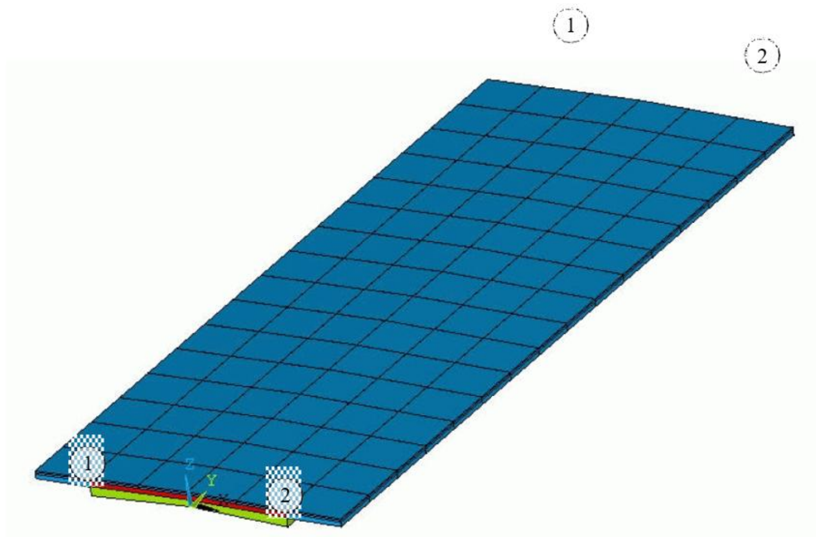


Figure 8. Sample composite pavement model

Field Investigation and Model Verification

Verification involved comparing FEM results with known solutions and field data from **Falling Weight Deflectometer (FWD)** tests and strain gages.

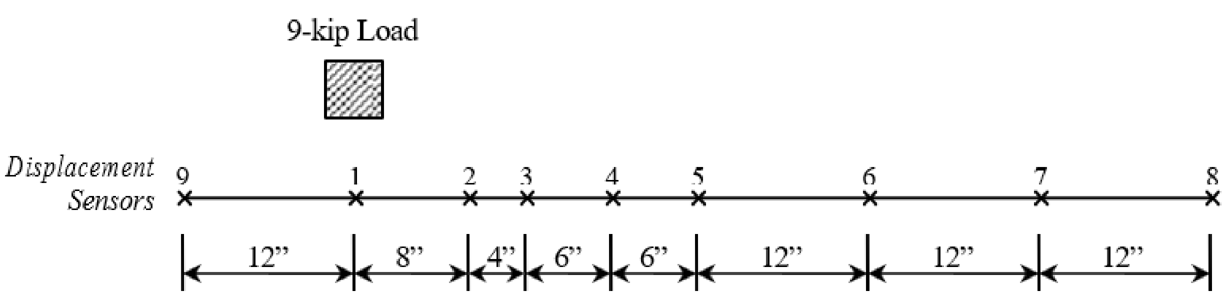


Figure 9. Schematic of FWD deflection sensors

Table 1: Breakdown of maximum deflection data from FWD test: 3.5" whitetopping pavement

	Max Deflection (in)								
	Scarify			HMA Stress Relief			Patch		
Fiber Type	4.5 x 4.5	6 x 6	9 x 9	4.5 x 4.5	6 x 6	9 x 9	4.5 x 4.5	6 x 6	9 x 9
No Fibers	0.00412	0.00495	n/a	0.00520	0.00369	n/a	0.00595	0.00518	n/a
Fiber Type A	n/a	n/a	n/a	0.00452	0.00526	n/a	0.00568	0.00641	n/a
Fiber Type B	0.00556	0.00442	n/a	0.00500	0.00433	n/a	0.00445	0.00531	n/a
Fiber Type C	n/a	0.00567	n/a	n/a	n/a	0.004472	n/a	0.00560	n/a