Composite Pavements: Design, Construction, and Benefits

Michael I. Darter & Derek Tompkins
Pavement Research Research Institute
University of Minnesota
1. History of Composite Pavements
2. Critical Issues for Composite Pavements
   • Design
   • Construction
3. SHRP2 R21 Composite Pavements
• All pavements are “composite” since they consist of layers of different materials bonded together.

• Types of pavements generally called “Composite” Pavements:
  – AC/PCC (new construction)
  – PCC/PCC (“wet-on-wet”)
• North American urban areas, US States, & Canadian Provinces have built AC/PCC for many years
• European usage with AC/CRCP is common on major freeways
• New AC/JPCP composite pavements built by NJ, WA, WI, and Ontario in the past on major highways
• New AC/JPCP and CRCP on lane addition projects
• Urban areas such as Columbus, OH; NYC and adjoining boroughs; Wash. D.C.; and City of Toronto
• Construction of AC/CRCP on major European highways: Holland, Austria, Germany, France, Italy, and UK
  – Relatively thin AC layer (2-3 in) over relatively thin CRCP
• Considerable AC/Roller Compacted Concrete has been built in various locations (e.g., Columbus, OH; Spain)
PCC-over-PCC
Composite Pavements

- PCC / PCC composite pavements used frequently in Europe
- State-of-the-art construction expertise & equipment resides in Europe

High quality smaller-sized aggregates

Lower-cost local aggregates
First concrete pavement built in the U.S. (1891 in Ohio) was a two-lift composite pavement.
European countries: Germany, Austria, Belgium, Netherlands, and France.
- PCC/PCC built mainly to provide a cap of high quality aggregate concrete over a thicker layer of lower quality local aggregates or recycled concrete
- Some projects included porous concrete as the top layer

US applications (Detroit freeway, 1993), though not as numerous as those of Europe, have resulted in useful research results.
Two Layer Concrete With Exposed Aggregate

• Permanent high skid resistance
• Low development of noise
• Long term life

⇒ Exposed aggregate surface
• Quality of the AC mixture is critical. The most critical issues include permanent deformation, stripping of asphalt, de-bonding with the PCC, and reflection cracking.

• Functional performance of the AC surfacing ideally also provides low noise, high friction, reduced splash and spray, and smoothness.

• The ability of the AC surfacing to bond securely and have full friction with the PCC slab surface.
Critical Issues for AC/PCC: Rapid renewal

Ability to remove and replace the AC surfacing rapidly and reliably
Critical Issues for AC/PCC: Reflection cracking

Needed: A reflection cracking solution for JPCP or RCC
AC over PCC (NYC experiment)

12th Annual MN Pavement Conf
14 Feb 2008

Pavement Research Institute
Department of Civil Engineering
Possible solution: ‘Saw and Seal’ joints in the AC surfacing over joints in JPCP or RCC
Example 1: Saw and Seal

15+ year old Saw & Seal transverse joints
Example 2: Saw and Seal

Sawing missed joint
Design of the JPCP or RCC slab is critical. The key factors include thickness, joint spacing, load transfer at joints, slab width/shoulders, PCC coefficient of thermal expansion, PCC strength/modulus, and base course.

Slab should be designed to have low fatigue damage over the entire analysis period so that fatigue cracking will not develop.
Design to Minimize Fatigue Damage and Cracking

Jointed Plain Concrete Pavement

Continuous Reinforced Concrete Pavement

Concrete Slab (no transverse joints)
Transverse cracks
Rebar Spacing
Base
Subgrade
Continuous Longitudinal Steel

Surface Texture
Longitudinal joint
Transverse joint
Surface smoothness
Slab Thickness
Concrete materials
Dowel bars
Tiebars
Subgrade
Subbase or base

12th Annual MN Pavement Conf
14 Feb 2008

Pavement Research Institute
Department of Civil Engineering
• Development of construction guidelines and QA procedures are also critical, both for composite AC/PCC and PCC/PCC pavements.
To develop a consistent, systematic approach to performing highway renewal that:

- is rapid
- causes minimum disruption
- produces long-lived facilities

**SHRP 2 Renewal Goal**
Two strategies show great promise for providing strong, durable, safe, smooth, and quiet pavements that require minimal maintenance

1. Surfacing of new portland cement concrete (PCC) layer with high quality asphalt concrete (AC) layer(s), and

2. Relatively thin, high-quality PCC surface atop a thicker, less expensive PCC layer.
AC over PCC

HMA Upper Lift
(HMA, PMA, SuperPave)

PCC Lower Lift
(JPCP, CRCP, RCC)
AC over PCC

Slab Cracked Sensitivity Analysis

Slab Cracked (%)

JPCP Thickness (in)

- AC 0 in
- AC 1.5 in
- AC 3.0 in
PCC over PCC

PCC Upper Lift
(Exp Aggr, Porous, High Strength, etc.)

PCC Lower Lift
(Recycled/Low Quality Materials, etc.)

H1, E1

H2, E2
Effect of E2 Modulus on Slab Cracking (H1=3, H2=6.5 in)

- H1 = 3 in
- E1 = 4.4 Mpsi
- H2 = 6.5 in
- E2 varies

Percent Slab Cracking vs. E2 Modulus, Mpsi

Graph showing the decrease in percent slab cracking as E2 modulus increases from 1 to 4 Mpsi.
Effect of H1 & E2 On Slab Cracking
(H2 = 6.5 in Constant)

- H1 = Varies
- E1 = 4.4 Mpsi
- H2 = 6.5 in
- E2 = Varies

Percent Slab Cracking

Thickmess H1 Top PCC Layer, in

0 100

3.5 Mpsi

3.2 Mpsi

3.5 Mpsi

4.4 Mpsi

E2 = 2.85 Mpsi
Composite Pavement Surfaces

Exposed Aggregate Surface

Porous Asphalt Surface
Motivation for SHRP2 R21: Composite Pavements

• The structural and functional performance of these two types of composite pavements is not well understood or documented.

• Models for predicting the performance of these pavement systems need to be developed for use in design, pavement management, and life-cycle cost analysis (LCCA).

• Construction techniques, guidelines, and specifications are limited and insufficient.
Goals of R21 Project

• Focus on new AC/PCC and new PCC/PCC composite pavement systems to:
  – Determine the behavior and identify critical material and performance parameters
  – Develop and validate mechanistic-empirical performance models and design procedures that are consistent with the Mechanistic-Empirical Pavement Design Guide (MEPDG)
  – Develop recommendations for construction specifications, techniques, and quality management procedures for adoption by the transportation community.
SHRP2 R21 Project Team

• PI: Mike Darter, PRI
• Applied Research Associates, Inc.
  – Co-PI: Harold Von Quintus
• Minnesota DOT & MnROAD
• University of Minnesota
  – Co-PI: Lev Khazanovich, UMN Civil Engineering
• University of California at Davis
  – Co-PI: John Harvey, UCPRC
• University of Pittsburg
• International Consultants
SHRP2 R21 and Minnesota Pavement Research

- $4 Million in FHWA funding over 48 months
- Over half of funding to the State of Minnesota (Mn/DOT and UMN)
  - UMN will investigate modeling and accelerated loading, Mn/DOT will implement experimental design in MnROAD test sections
- R21 is an opportunity to bring more federal attention to quality and depth of research in Minnesota
Benefits

• Long life PCC surfacing
• Rapid renewal of AC surfacing
• Surface characteristics
• Use local aggregates lower PCC slab
• Long life PCC slab, no fatigue cracking
• Utility repair
• Lower life cycle costs