The Phase One I-710 Freeway Rehabilitation Project: Initial Design to Performance After Six Years of Traffic

Meeting with Caltrans District 4 Staff
Oakland, CA 6/04/2010
I-710 Project - Partnered Effort (most recent participants)

• **Caltrans**
  - T. Bressette, W. Farnbach, C. Suszko

• **Industry**
  - J. St. Martin,

• **University of California PRC**
  - C. Monismith
I-710 Project - Partnered Effort
(some earlier participants)

- **Caltrans**
  - K. Herritt, R. Doty, J. Dobrowolski, S. Shatnawi
- **Industry**
  - L. Nawrocki, J. Copley, R. Smith, D. Chapman
- **University**
  - J. Harvey, F. Long
Presentation

- Mix designs
- Structural section designs
  - full-depth AC
  - overlay on cracked and seated PCC
- Aspects of construction
- Some lessons learned
- Phase II structures
Rehabilitation of Interstate - 710

- Full-Depth Asphalt Concrete replacement under overpasses
- Overlay of PCC (cracked-seated)
Design & Analysis

Trial cross section

Trial mix design

Conditioning (Aging & Water)

Performance Tests

Analysis Performance Prediction

Unacceptable

Acceptable

Final mix design & structural section
Long-Life Asphalt Pavement

- QC/QA specifications
- Polymer modified binders
- Improved aggregate requirements
- Modified mix design method
Trial Mix Design

- San Gabriel aggregate
- Binders
  - Conventional: AR-8000
  - Polymer modified: PBA-6a*
- Hveem Stabilometer—to establish range of binder contents
Trial Mix Design

- Range of binder contents
  - 4.2 - 5.7% (by wt of aggregate)
- Conventional dense-graded mix, Caltrans specs.
- All crushed materials
Final Mix Design - Rutting

Input

\[ N_{\text{supply}} \]

Performance test

\[ N_{\text{demand}} \]

Traffic

\[ N_{\text{supply}} = M \times N_{\text{demand}} \]

No

Yes
Shear Test
\( N_{\text{demand}} - (PBA-6A) \)

- **Design ESALs - first five years**
  - \( 30 \times 10^6 \) ESALs

- \( N_{\text{demand}} = 660,000 \)
  - \( M \times \text{Design ESALs} \times \text{TCF} \times \text{SF} \)
    - \( M = 5 \)
    - \( \text{TCF} = 0.116 \)
    - \( \text{SF} = 0.04 \)
Temperature = 50°C

Asphalt content (percent by weight of aggregate)

- N @ γ_p = 5%
  - 660,000 repetitions
  - 146,000 repetitions

Design Binder Content
HVS Rutting Study
Rutting Study Layout

- 25 m section
- 33 tonnes AC
- 4 m
- Placed on jointed PCC
- 3 m
- 150 mm
- K-barrier on one side of section
Mix Performance Evaluation

- 38-mm ARHM-GG
- 62-mm ARHM-GG
- 75-mm DGAC AR-4000
- 76-mm PBA-6A

½ inch rut depth

< 20,000 reps

~ 170,000 reps

HVS Load Applications
Thickness Design - Fatigue Analysis

1. **Input**
   - $N_{\text{supply}}$
   - Performance test
   - $N_{\text{demand}}$
   - Traffic

2. **Decision Check**
   - $N_{\text{supply}} \geq M \times N_{\text{demand}}$

3. **Outcome**
   - **Yes**
   - **No**
Design Considerations

- Fatigue in asphalt concrete
- Deformation in unbound layers
- Subsequently, design checked by CalME
Design Considerations

Asphalt
Concrete
Base
Subgrade

$\varepsilon_{t}$
$\varepsilon_{v}$
Input

- Structural section (full-depth)
- Traffic (200 million ESALs)
- Environment (T = 20°C)
- Trial mixes & pavement section
Input

- Reliability (M=5)
- $f(\text{traffic estimate & testing variability})$
- Performance criterion
  - wheel path cracking $\leq 10\%$
Trial Pavement Sections

PBA-6A*
AR-8000
AR-8000 (rich bottom)
subgrade
Fatigue
Fatigue Test Results

Mean Strain vs. Nf:

- AR-8000, 4.7% AC, 6% AV
- AR-8000, 5.2% AC, 3% AV
- PBA-6A, 4.7% AC, 6% AV
- PBA-6A, 5.2% AC, 3% AV
Fatigue

\[ N_{\text{supply}} \geq M \times N_{\text{demand}}? \]

*Check vertical subgrade strain!!!*

*(controlled total thickness)*
Final Design

AR-OGFC
PBA-6A (4.7%)
AR-8000 (4.7%)
(subrich bottom)

6% air voids
6%
3%

25 mm
75
150
75

subgrade
Overlays

- Asphalt Concrete
- Fabric
- Leveling Course
- Jointed PCC
- Cement treated Base
- Subgrade

Layer Thicknesses:
- 30 mm
- 150 mm
- 200 mm
- 150 – 250 mm
Calculated Configuration

Traffic loads applied statically
symmetrical boundaries

250 mm

p = 725 kPa

AC

Cracks
@ 1 m
Finite Element Mesh

~ 12,000 elements, NIKE2D
Finite Element Mesh
Close-Up in Vicinity of Crack

Pavement traffic load
s = 1.00E+00
time = 1.00E+00

0.1 inches
Bending Strains in Mix just above Fabric

BENDING STRAIN (us)

DISTANCE FROM CENTER (ft)
Composite Overlay

Final overlay thickness

25 mm OGFC

225 mm

75 mm PBA-6A

125 mm AR-8000

Broken and seated PCC

Fabric

225 mm
Full-Depth AC Comparisons

- The Asphalt Institute
- United Kingdom
- Australia
- Asphalt Pavement Alliance-U.S.
Perpetual Pavement Design Concepts

1.5 - 3” SMA, OGFC or Superpave

Zone Of High Compression

High Modulus Rut Resistant Material 4.5 - 6”

Max Tensile Strain

Flexible Fatigue Resistant Material 3 - 4”

Pavement Foundation
Construction Specifications

- Performance requirements based on shear and fatigue testing
- More stringent compaction requirements
- Tack coat between layers
  - Asphalt cement (AR-4000)
Construction

- Six stages
- Stages 1 and 2 preliminary to rehab. of trafficked sections
- Stages 3-6 - rehab. of trafficked sections in 8 - 55 hr. weekend closures (vs. 10 originally planned)
- Use of CA4PRS (construction management program)
Construction

- **Stages 3 - 6**
  - Traffic closure
  - Crack, seat, and overlay (CSOL)
  - Full depth AC construction (FDAC)
  - Traffic opening
Placement of Leveling Course
Installation of Pavement Fabric
Placement of PBA-6A* Mix
Digout and Placement of Aggregate Base – Working Platform
Rich Bottom Layer Construction
Some Lessons Learned

- Pre-bid conference mandatory for all potential bidders.
- For projects of this importance, a “partnering” meeting at the outset is mandatory.
  - Partnering on the technical aspects extremely important!
Some Lessons Learned (cont.)

- For new test procedures included in Special Provisions, insure that all involved groups perform tests and analyze resulting data the same way:
  - equipment calibration essential
  - preliminary testing of comparable specimens
Some Lessons Learned (cont.)

- Improved specification requirements based on statistical considerations desirable
- For QC/QA activities adequate staffing imperative (large quantities of materials, up to 15,000 tonnes per weekend)
Some Lessons Learned (cont.)

• Timely QA results required
• Human resources - 3 to 5 weekend closures in a row maximum; if more required, allow 1 to 2 weekend interval
Some Lessons Learned (cont.)

• In digout areas (FDAC):
  ▪ Exploratory testing imperative
  ▪ Exact location of underground utilities
Some Lessons Learned (cont.)

• **Contingency plan important**
  - Digout areas - working platform; materials easily accessible
  - Standby HMA plant(s)

• **Meteorologist for contractor**
  (construction in digout areas)
Performance Evaluation

- FWD Deflection testing (2003 through 2008)
- Back calculation of layer moduli and strains in HMA layers using MLEA
- Condition surveys
- Longitudinal and transverse profile measurements
- Noise measurements
- Laboratory testing of cores (RSST-CH) and slabs (Fatigue)
Performance Evaluation

- Non-destructive HWD tests
  - 11/03, NB and SB
  - 9/04, NB; 2/5, SB
  - 12/05, NB; 2/06, SB
NB Lane 3 – Layer Moduli

I-710 Northbound Lane 3 Full Depth Sections - Layer Moduli with Time

Year Tested

Section 1 AC
Section 3 AC
Section 5 AC
Section 1 Base
Section 3 Base
Section 5 Base

Modulus (MPa)
<table>
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<tr>
<th>Section</th>
<th>NB</th>
<th>SB</th>
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<tr>
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<td>16</td>
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Rut Depth Measurements

SB Lane 3

Rutting (mm)

- Left WP
- Right WP

Station (m)

0+00 5+00 10+00 15+00 20+00 25+00 30+00 35+00 40+00 45+00

0 3 6 9 12 15

12.5 mm

12.5 mm
Rut Depth Measurements

NB Lane 3

Rutting (mm)

Left WP
Right WP

12.5 mm

Station (m)

0+00 10+00 20+00 30+00 40+00
I-710 Traffic
I-710 Traffic
I-710, Phase II

- Modifications
  - Design traffic: \(-330 \times 10^6\) ESALs
  - Thickness of HMA base layer
    \([\text{PG 70-10 (AR-8000)}]\) increased
  - Surface course: RAC-G instead of RAC-O
Concluding Thoughts

- Implementation of New Technology for Mix & Structural Design
- Strict Attention To Pavement Construction
- Constructability Considerations - Use of CA4PRS
- Successful partnering - agency, contractor and academia.
- Paving performing as expected.
Summary

• Implementation of SHRP developed technology
• Strict attention to pavement construction
• Constructability considerations; (CA4PRS)