Pavement Design

TTP Orientation Seminar
2011
What are Pavements?

- Engineered structures in contact with the earth's surface built to facilitate movement of people and goods
  - Pedestrians
  - Personal vehicles
  - Freight and freight handling
  - Trains and trams
  - Aircraft and spacecraft
Pavement Types

• Asphalt Concrete Surface
  – Granular bases
  – Subgrade

• Concrete Surface
  – Various bases
  – Subgrade

• Surface Treatment
  – Thin sprayed asphalt on granular bases

• Permeable Pavement
  – Open graded asphalt or concrete layers, open granular layers, on uncompacted subgrade
What are Pavements?
What are pavements?
What are pavements?
Why Build Pavements?

- Provide all-weather mobility for road users
Why Build Pavements?
Why Build Pavements?
Why Build Pavements?
Who are the Stakeholders?

• User
• Owner
• Builder
• Society
  – Internal
  – External
Pavement Life Cycle

• Infrastructure Life Cycle
  – Deployment
  – Maintenance
  – Rehabilitation
  – Reconstruction (Abandonment? Reuse?)

• Goal at all stages is greater efficiency
  – how is efficiency defined?
<table>
<thead>
<tr>
<th>Years</th>
<th>Infrastructure</th>
<th>Pavement Research</th>
</tr>
</thead>
<tbody>
<tr>
<td>1970-2050</td>
<td>Management</td>
<td>M &amp; R Scheduling, Condition Assessment</td>
</tr>
<tr>
<td>Years</td>
<td>Infrastructure</td>
<td>Pavement Research</td>
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<tr>
<td>1995-2025</td>
<td>Reconstruction</td>
<td>Reconstruction, Materials Optimization, Traffic Considerations, ReDesign</td>
</tr>
<tr>
<td>2010-2050</td>
<td>Sustainability</td>
<td>Materials ReUse, Vehicle/Pavement Interaction, New Materials, Information Technology Integration</td>
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</tbody>
</table>
Is There a Pattern?

Continued expansion of the system boundaries in which pavement problems are defined.
What Causes Pavement Distress?

• Traffic
• Environment
• Interaction of traffic/environment, construction quality, materials, design
California: 1912

Australia: 1914
Traffic Variables

Highways - it’s the trucks

- Loads
- Tire pressures
- Speeds
- Dynamics (interaction with roughness)
- Which are most important?
- One fully loaded truck pass causes same damage as about 5,000 passes of an SUV
Traffic

• Measurement of traffic
  – counts
  – load measurements

• Prediction of future traffic
  – growth factors for vehicle repetitions
  – will load limits change on highways?
  – are your loads controlled?
Big Truck - 1960
Australian for “truck”

“Road Train”
Local Government Pavement Design

• Some agencies
  – Standard cross sections and materials
  – Little or no construction inspection (particularly compaction)
  – No money for testing and analysis

• Other agencies
  – Design for particular traffic, environment, soils
  – Good construction inspection
  – Testing and analysis (is there a net cost savings?)

• Standard specifications and design methods
  – Greenbook (mostly in S. California)
  – Use of state specifications (much of N. California, joint powers financing, federally funded projects)
  – Use of consultants
What are Pavements Made Of? and will this change?

- Most pavements are made of engineered soils and processed rock
- Asphalt concrete is 85% aggregate by volume; 10% asphalt; some plastic, rubber modifiers
- Portland cement concrete is 70% aggregate by volume; 11% portland cement; up to 25% of cement replaced by fly ash; some steel

- Nearly all of these materials can be perpetually recyclable into the same infrastructure
Pavements: will the demand for them increase or decrease?

Pavements sorted by transportation mode

- Streets, roads, highways, freeways, parking
- Railroads, switching yards, intermodal yards
- Runways, taxiways, aprons
- Land-side port facilities, container yards
- Bike paths, sidewalks, other hardscape
What is the impact on pavements of efforts to improve sustainability?

• Vehicle fuel economy and fuel type will change
• Fuel type change impact on available materials?
• Fuel economy change impact on functional and structural requirements?
  – Smoothness requirements
    • Impacts on product life cycle and waste
  – Pneumatic tire loads and inflation pressures
  – Operating speeds and suspension systems
  – Repetitions
How can the environmental impact of pavements be reduced?

- Understand the pavement life cycle
- Identify environmental costs
- Consider environmental costs in decision-making
- Identify how to reduce environmental costs considering interactions with other systems
- Determine how to make new methods standard practice
Some basic good practices

• Minimize the annual use of new materials
  – Perpetual reuse
  – Make materials/pavements last longer
  – Thinner pavements

• Reduce the environmental costs of new materials and recycling
  – Local materials
  – Reduce energy needs
  – Low-impact materials

• Reduce the delay associated with construction
Caltrans Funded UCPRC Research

Sustainability Issues:
- Nonrenewable fuel depletion
- Greenhouse gas emissions
- Global climate change
- Local air quality

Projects:
- Modified Binders
- Deep In Situ Recycling
  - Foamed asphalt
  - Pulverization
- Warm Mix Asphalt
Deep In-Situ Recycling

- Cracked AC repeated overlays
- Granular layers
- Subgrade

Grind

- New AC Overlay
- Recycled Layer
- Remaining Granular Subgrade

Currently developing project selection, mix design and construction guidelines
New pulverization and in-place stabilization equipment
Warm mix asphalt

• Additives to asphalt concrete
  – reduce temperature for effective compaction of asphalt concrete

• Advantages:
  – Better compaction in cold weather
  – Reduced energy costs
  – May reduce emissions

• Possible disadvantages:
  – May increase risk of rutting, moisture damage
Asphalt paving with conventional mix
Same project with Warm Mix Asphalt
Caltrans Funded UCPRC Research

Sustainability Issues:
  – Congestion
  – Low mobility
  – Fatalities and injuries

Projects: CA4PRS
  – Faster construction from innovative scheduling;
    • Shorter closures
    • Less traffic delay
    • Fewer accidents
Los Angeles Basin Freeway Network

Los Angeles

Riverside

San Bernardino

Santa Monica

San Fernando Valley

Ports of LA, Long Beach

Orange County

Los Angeles Basin Freeway

Concrete pavements to be rebuilt 2000-2015
Project lengths 2 to 50 km
I-710 Traffic Detour Plan - Simulation Boundary
Simulation Before Construction
## I-710 Reduction of Pavement Thickness Using Mechanistic Design

<table>
<thead>
<tr>
<th>Conventional design</th>
<th>Mechanistic design</th>
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<tbody>
<tr>
<td>535 mm thick asphalt concrete</td>
<td>75 mm PBA-6a</td>
</tr>
<tr>
<td>8 % air-voids, same mix design throughout</td>
<td>125 mm, 5 % air-voids, AR-8000</td>
</tr>
<tr>
<td></td>
<td>75 mm, Rich Bottom</td>
</tr>
</tbody>
</table>
CA4PRS: Case Study on I-15 Devore Reconstruction Project
<table>
<thead>
<tr>
<th>Construction Scenario</th>
<th>Schedule Comparison</th>
<th>Cost Comparison ($M)</th>
<th>Max. Peak Delay (Min)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total Closures</td>
<td>Closure Hours</td>
<td>User Delay</td>
</tr>
<tr>
<td>One Roadbed Continuous (24/7)</td>
<td>2</td>
<td>400</td>
<td>5.0</td>
</tr>
<tr>
<td>72-Hour Weekday Continuous</td>
<td>8</td>
<td>512</td>
<td>5.0</td>
</tr>
<tr>
<td>55-Hour Weekend Continuous</td>
<td>10</td>
<td>550</td>
<td>10.0</td>
</tr>
<tr>
<td>10-Hour Night-time Closures</td>
<td>220</td>
<td>2,200</td>
<td>7.0</td>
</tr>
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Caltrans Funded UCPRC Research

Sustainability Issues:
  – Life Cycle Analysis

Projects:
  – Long-life pavement design
  – Comparison of life cycle environmental costs for 20, 40 and 100 year pavement design lives using PaLATE
CO$_2$ Payback Period
Using Life Cycle Analysis

• Savings are not immediately realized
  – Payback ~30-45 years in the future
• Future is highly uncertain
  – Technological advancements
  – Uncertain demand
• What’s the right analysis period?