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Pavement Design and Construction
DESIGN OVERVIEW

- Define Design
- What Information is Required?
- Where is information available?
- How is Information Used?
Design Type

• New Construction
  ◦ Asphalt Concrete
    • Conventional
    • Full Depth
    • Pervious/Permeable
  ◦ Portland Cement Concrete
    • Conventional
    • Pervious/Permeable
Design Type

- Resurfacing
  - Asphalt Concrete
    - Reflective crack control
    - Ride quality correction
    - Grade Modification
  - Portland Cement Concrete
    - Jointing Details
Design Type

- Rehabilitation
  - Reinforcement
  - Cold in-place recycling
  - Hot in-place recycling
  - Full Depth Reclamation
  - Partial Section Replacement
  - Vertical and Horizontal Realignment
  - Widening
SUSTAINABLE DESIGN

- Grade selection
- Median curb heights
- Wheel path location
- Surface drainage
- Material selection
- Future reinforcement
  - Wearing surface replacement
Pavement Design Components

Subgrade Soil Support

- Strength Criteria
  - R-value
  - CBR
  - Modulus

- Prevailing Conditions
  - Modification options
    - Lime Treatment
    - Cement Treatment
    - Emulsion Treatment
Pavement Design Components

Traffic Characterization

- **Trucks**
  - Statewide Average Weights
  - Location Specific Weights

- **Buses**
  - School bus
  - Scheduled transit buses
  - Bus Rapid Transit (BRT)

- **Automobiles**
Pavement Design Components

Design period

- 10 years
- 20 years
- Other
  - 25 years
  - 40 years
Pavement Design Components

Material Type

- Conventional Asphalt Concrete
  - Aggregate Size
  - Aggregate Shape
  - Binder Type

- Standard Specification Selection
  - Standard Specifications for Public Works Construction - Greenbook
  - Caltrans Standard Specifications
  - Superpave
Pavement Design Components

Material Type

- Portland Cement Concrete
  - Flexural Strength v Compressive Strength
  - Curing period
  - Plain v. Reinforced
    - Conventional Reinforcement
    - Fiber Reinforcement
Pavement Design Components

Material Type

- **Aggregate Base**
  - Crushed Aggregate Base
    - CAB - Greenbook
  - Recycled Aggregate Base
    - CMB/PMB – Greenbook
    - Class 2 - Caltrans
  - Stabilized Base
    - Cement Treated
    - Emulsion Treated
    - Lime/Flyash Treated
Subgrade Strength

- CBR, R-Value, Modulus
- CBR assumes degree of saturation
- R-value predicts most probable moisture condition
- Predates landscape islands, permeable pavements and urban run-off
Back to the Future

- 1960’s design impacted by the 70’s oil embargo
  - Increased axle loads
  - Increased tire pressures
  - Weight variances for bus axles
  - Tractor trailer buses
  - Larger trash and recycle trucks
  - Tag overload axles
Traffic Use

- Number of trucks
- Number of axles
- Axle weights
- Number of buses
- Future weight increases
- Future tire pressure increases
Axle Weight Impact

- ESAL = $((\text{axle load})/18,000)^{4.2}$

- 18,000 axle weight 1 ESAL

- 20,000 axle weight 1.6 ESAL
- 23,000 axle weight 2.8 ESAL
- 26,000 axle weight 4.6 ESAL
- 34,000 tandem axle 1.2 ESAL

- Automobile 0.0003 ESAL
Traffic Index - ESAL

ESAL = \((\text{AXLE LOAD/18,000})^{4.2}\)

Example 1

3 axle Truck  \(\frac{1}{2}\) Load

Front Axle  9,975 pounds

Rear Axle  11,638 pounds

\[ \text{ESAL}_{\text{front}} = \left(\frac{9,975}{18,000}\right)^{4.2} = 0.08 \]

\[ \text{ESAL}_{\text{rear}} = \left(\frac{11,638}{18,000}\right)^{4.2} = 0.16 \]

\[ \text{ESAL}_{\text{total}} = 0.08 + 2(0.16) = 0.40 \]
Traffic Index - ESAL

ESAL = \frac{(AXLE~LOAD/18,000)^{4.2}}{}

Example 1  3 axle Truck  Fully Loaded

Front Axle  12,500 pounds
Rear Axles  17,000 pounds each

ESAL_{\text{front}} = \frac{(12,500/18,000)^{4.2}}{} = 0.21

ESAL_{\text{rear}} = \frac{(17,000/18,000)^{4.2}}{} = 0.79

ESAL_{\text{total}} = 0.21 + 2(0.79) = 1.79
Traffic Index - ESAL

ESAL = \((AXLE \text{ LOAD}/18,000)^{4.2}\)

Example 1

2 axle Transit Bus  
Fully Loaded

Front Axle  
12,500 pounds

Rear Axle  
23,000 pounds

\(\text{ESAL}_{\text{front}} = \frac{12,500}{18,000}^{4.2} = 0.21\)

\(\text{ESAL}_{\text{rear}} = \frac{23,000}{18,000}^{4.2} = 2.79\)

\(\text{ESAL}_{\text{total}} = 0.21 + 2(2.79) = 5.81\)
Vehicle Comparison

- 1 Full Bus = 10,000 automobiles
- 1 Articulated Bus = 19,000 automobiles
- 1 10 Wheeler = 6,000 automobiles
Traffic Index

\[ TI = 9 \left( \frac{ESAL}{1,000,000} \right)^{1.19} \]

- 50 \( \frac{1}{2} \) full 3 axle trucks/day 24/7/365 for 20 years

\[ ESAL = (50)(7)(365)(20)(0.40) = \]

- 10 Year Design Period

TI 8.5
Traffic Index

- 1 Trash truck/week, 20 years
  
  TI 4.5

- Add Green Waste Truck & Recyclables
  
  TI 5.0
New Section Design

- R-Value + Traffic Index

- $T = 0.0032(100 - R)TI$
Resurfacing/Rehabilitation Design Components

Pavement/Section Condition

- Visual Condition
  - Cracking
  - Surface Wear
  - Distortion
Resurfacing/Rehabilitation Design Components

Pavement/Section Condition

- Construction History
  - Original As-built Sections
  - Widening/Realignment
  - Resurfacing
  - Utility Construction/Access

- Section Verification
  - Pavement Coring
  - Ground Penetrating Radar
Resurfacing/Rehabilitation Design Components

Pavement/Section Condition

- **Layer Fatigue**
  - Estimated Values
  - Component analysis
  - In-place strength testing

- **Effective Strength**
  - Deflection Based Component Analysis
Resurfacing/Rehabilitation Design Components

Pavement/Section Condition Requirements

- **Layer Fatigue/Cracking**
  - Reflection Crack Mitigation
    - Pavement Interlayer's
    - Cold In-Place Recycling
    - Hot In-Place Recycling

- **Pavement Rutting/Shoving**
  - Partial Section Replacement
  - Mixture Modification
Pavement Design Components

Material Type

• Stabilized Base
  ○ Cement Treated
  ○ Emulsion Treated
  ○ Lime/Flyash Treated

• Full Depth Reclamation
  ○ Cement Treated
  ○ Emulsion Treated
  ○ Lime/Flyash Treated
CONDITION ASSESSMENT

- Visual Condition Survey
  - Observed Defect
  - Severity of Defect
  - Frequency of Defect

- Estimated impact of Defects
  - Ride conditions
  - Reflection crack potential
  - Structural implications
CONDITION ASSESSMENT

- Pavement Management

- History Documentation
  - Original As-built plans
  - Maintenance Records
  - Capital Improvement projects
  - Widening/realignment records
  - Utility access records
CONDITION ASSESSMENT

• Layer Fatigue
  ◦ Estimated Values
    • Pavement Management Reports
    • Arbitrary Component Analysis Estimates
  ◦ Measured Values
    • Falling Weight Deflectometer
      • Test Method 356
      • Condition Specific Reinforcement Requirement
CONDITION ASSESSMENT

- Collateral Constraints
  - Crown Height
  - Cross Slope
  - Median Curbs
  - Median Gutters
  - Storm Water Hydraulics
CONDITION ASSESSMENT

Falling Weight Deflectometer
Pavement Strength Testing...

Pavement Coring Services
Forensic Investigations
Materials Testing...

Engineering
Rehabilitation Alternatives
Project Specifications
Expert Witness
Planning and Scheduling

Ground Penetrating Radar (GPR)
Pavement Measuring Testing...

Construction Inspection Services
Compaction Testing of AC, AB, Subgrade
Grade Verification
Material Production Testing
Asphalt Concrete Materials

- SSPWC includes 14 Conventional Asphalt Concrete Mixes
  - Section 203-6
  - Section 400

- Two most popular binder types PG 64-10 and PG 70-10 (previously AR4000 and AR 8000 – previously 85-100 and 60-70)
Asphalt Concrete Materials

- Caltrans
- Old Standard Specification
  - Eight (8) conventional asphalt concrete gradations
  - Type A and Type B Aggregate
  - A total of 32 different mixes
- New Standard Specification
  - Type A and Type B Aggregate
  - Type C Asphalt Concrete
Asphalt Concrete Materials

Asphalt Rubber Hot Mix

- Greenbook
  - Class B, C and D

- Caltrans
  - Gap Grade
  - Open Graded
Asphalt Concrete Materials

Additional Variables

- Performance Grade Bonders
  - Full range 35+ grades

- Polymer Modified Binders
  - Specialty Applications
Material Selection

- Over 100 mixes available
- Material must be consistent with use
- Expectations should match reality
- Mix design v. Blend Sheet
- QA/QC
Material Selection

- Engineers focus on intent
- Engineers view the mid-point of the specification as a target
- Contractors focus on the letter of the specification
- Inspection QC/QA must sort out the differences
Asphalt Concrete Production

- Batch Plant
- Drum Drier Plant
- Recycled asphalt concrete
  - Cold In-place recycling
  - Central Place Cold Recycling
  - Hot In-Place recycling
Placement

- Hand placement
- Skip loader/spreader bar
- Paving machine
  - Truck propelled
  - Self propelled
    - Tamping screed
    - Vibrating screed
Placement

- Thickness control
  - Grade tolerances
    - Aggregate base
    - Asphalt concrete
  - Thickness loss during compaction
Placement

- Temperature
  - Impacts placement thickness
  - Impacts surface tolerances
  - Impacts surface appearance
  - Impacts roller patterns
Placement

- Hand work
  - Lute design
  - Lute use
  - Balancing joint
  - Texture changes
Compaction

- Roller types
  - Rubber tire
  - Steel wheel
    - Static
    - Vibratory
  - Sizes - typical
    - 3-5 ton
    - 5 -8 ton
    - 10-12 ton
    - 12-15 ton
Compaction

- Paving Machine
  - 78 – 80%
- Breakdown Rolling
  - 91-93%
- Intermediate Rolling
  - 94-96%
- Finish Rolling
  - 95-96%
Minimum needs for Inspection

- Plans
  - Thickness(s)
  - Site documentation

- Specifications
  - Mix design
  - Grade tolerances
  - Compaction requirements
Critical Elements

• Grade tolerances
  ◦ Subgrade uniformity
    • Rough grade is +/- 0.10’
    • Acceptable subgrade is +/- 0.04’ w/AB or +/- 0.02’ w/o AB
  ◦ Aggregate Base
    • Acceptable grade is +/- 0.02’
  ◦ Asphalt Concrete
    • Acceptable finish grade is +/- 1/8” in 10’ – Greenbook
    • Acceptable finish grade is +/- 0.01’ in 12’ – Caltrans
      • Profilograph and/or ride tolerances in transition
  ◦ Section Thickness is result
Critical Elements

- Mix type compliance
  - Spec mixes v. non-spec mixes
  - Mix Design v. Mix Blend Sheet
  - Field Inspection verification
  - Batch plant verification
  - Laboratory verification
Critical Elements

- Production Rates
  - Segregation
    - Screed capabilities
    - Width of placement
    - Hand work
    - Equipment placement
  - Jointing detail
    - Overlapping
    - Rolling capabilities
      - Thickness
      - Temperature
      - Roller speed
  - Start and stop
    - Cold zones
Design Summary

- Grade tolerances
  - Thickness is result
- Mix type compliance
  - Spec mixes v. non-spec mixes
- Production rates
  - Segregation
  - Start and stop
- Hand work techniques
  - Segregation
- Rolling techniques
  - Speed
  - Patterns
Construction Summary

- Grade tolerances
- Mix type compliance
- Production rates
- Hand work techniques
- Rolling techniques
CONTACT INFORMATION

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