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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

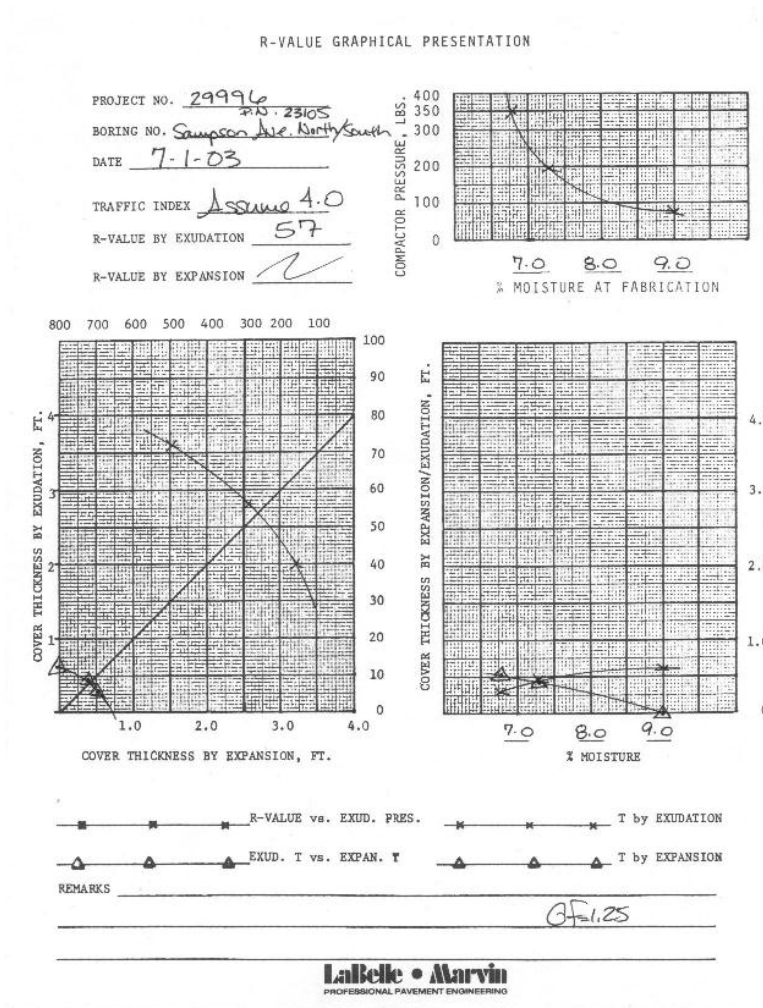
## Material Type

- **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

# R-value strength example





# 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

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

Example 1

3 axle Truck

½ Load

Front Axle

9,975 pounds

Rear Axle

11,638 pounds

$$\text{ESAL}_{\text{front}} = (9,975/18,000)^{4.2} = 0.08$$

$$\text{ESAL}_{\text{rear}} = (11,638/18,000)^{4.2} = 0.16$$

$$\text{ESAL}_{\text{total}} = 0.08 + 2(0.16) = 0.40$$

# Traffic Index - ESAL

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

Example 1

3 axle Truck Fully Loaded

Front Axle 12,500 pounds

Rear Axles 17,000 pounds each

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

$$ESAL_{rear} = (17,000/18,000)^{4.2} = 0.79$$

$$ESAL_{total} = 0.21 + 2(0.79) = 1.79$$

# Traffic Index - ESAL

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

Example 1

2 axle Transit Bus Fully Loaded

Front Axle 12,500 pounds

Rear Axle 23,000 pounds

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

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

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

# Vehicle Comparison

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

# Traffic Index

$$TI = 9(ESAL/1,000,000)^{.119}$$

- 50 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

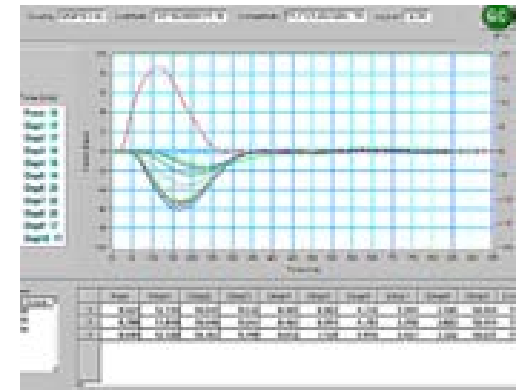
- Layer Fatigue

- Estimated Values

- Pavement Management Reports
- Arbitrary Component Analysis Estimates

- Measured Values

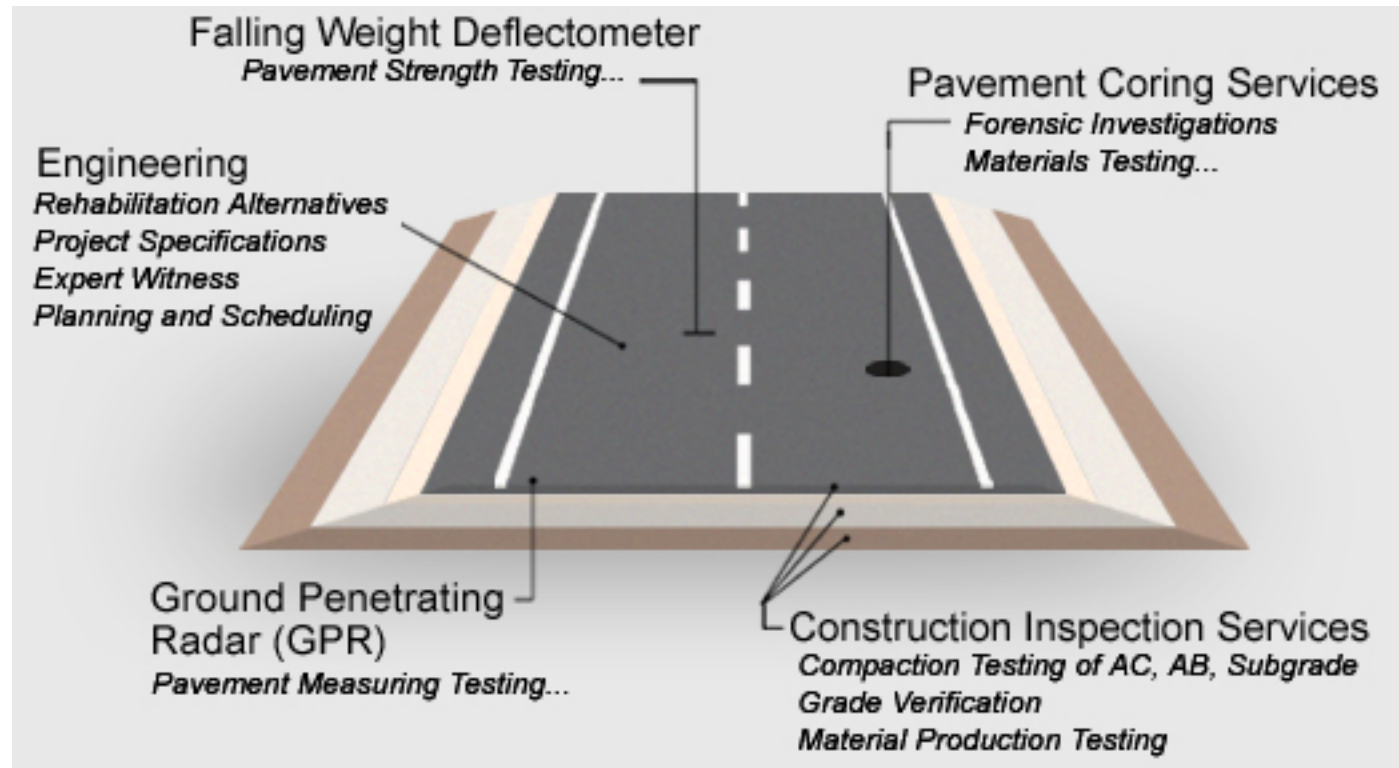
- Falling Weight Deflectometer
  - Test Method 356
    - Condition Specific Reinforcement Requirement



# CONDITION ASSESSMENT

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

# CONDITION ASSESSMENT





# 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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