December 2, 2011

Steven R. Marvin, PE

Pavement Design and Construction

LaBelle Marvin

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

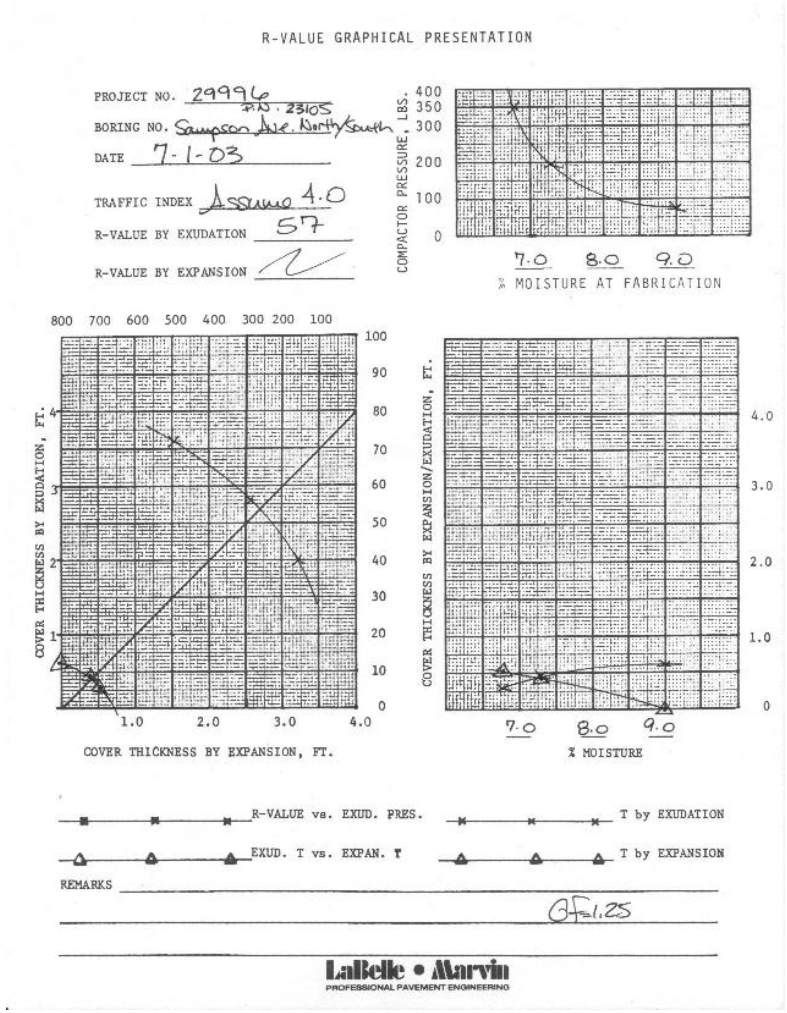
Material Type

- 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 = ((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

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

Example 1	3 axle Truck	½ Load	
	Front Axle	9,975 pounds	
	Rear Axle	11,638 pounds	
$ESAL_{front}$ =	$(9{,}975/18{,}000)^{4.2}$	=	0.08
$ESAL_{rear}$ =	$(11{,}638/18{,}000)^{4.2}$	=	0.16
$ESAL_{total}$ =	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

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

Example 1	2 axle Transit Bus	Fully Loaded	
	Front Axle	12,500 pounds	
	Rear Axle	23,000 pounds	
$ESAL_{front}$ =	$(12{,}500/18{,}000)^{4.2}$	=	0.21
$ESAL_{rear}$ =	$(23{,}000/18{,}000)^{4.2}$	=	2.79
$ESAL_{total}$ =	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

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

- 50 ½ 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

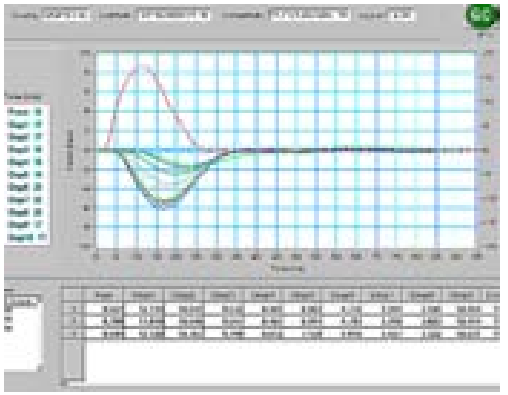
CONDITION ASSESSMENT

- Pavement Management

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

CONDITION ASSESSMENT

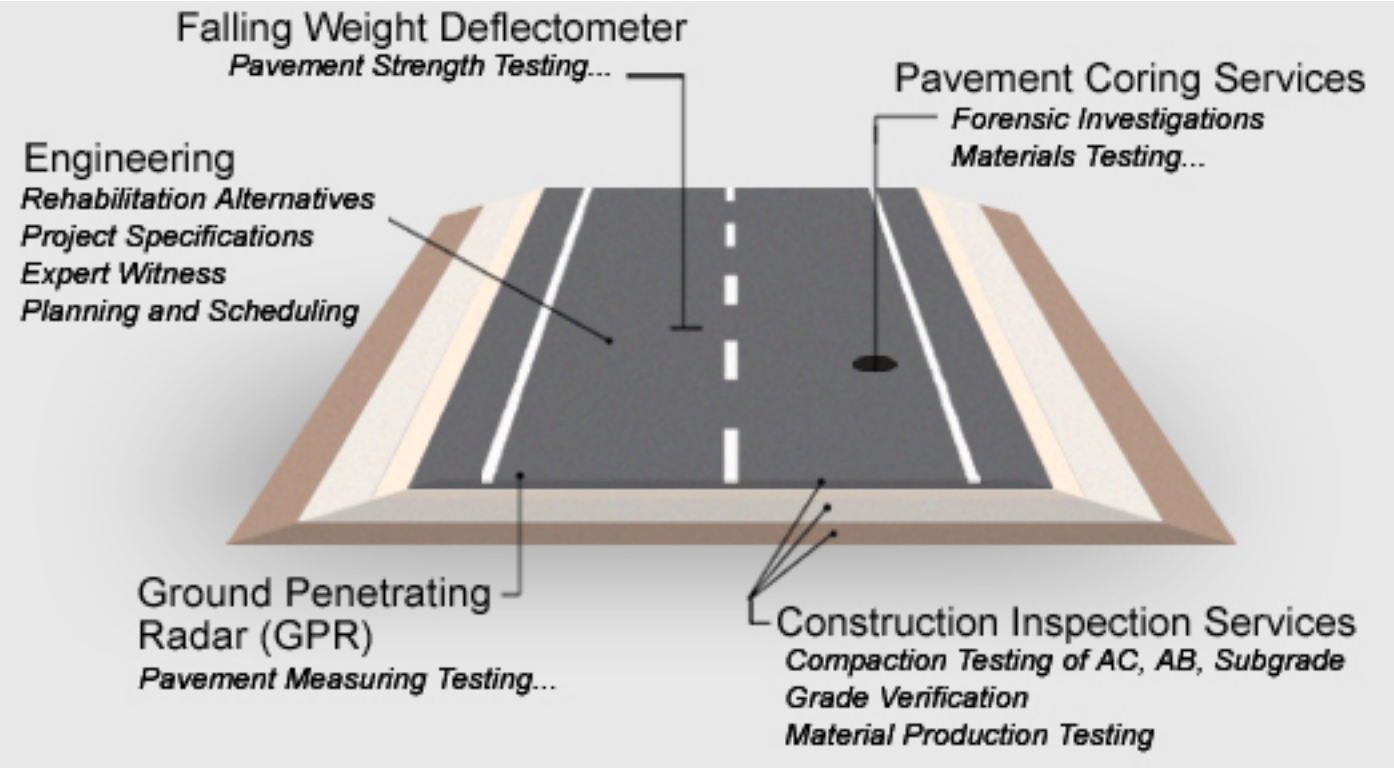
- Layer Fatigue
  - Estimated Values
    - Pavement Management Reports
    - Arbitrary Component Analysis Estimates
  - Measured Values
    - Falling Weight Deflectometer
      - Test Method 356
        - Condition Specific Reinforcement Requirement



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
  - Section400

- Two most popular binder types PG 64-10and 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

Steve Marvin

smarvin@labellemarvin.com

714-546-3468

www.labellemarvin.com