California Research Partnered Pavement Research Program

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University of California, Berkeley

HVS Workshop

October 7-8, 2002

Significant Achievements

- Technology transfer – HVS and other
- Technical developments – AC and PCC
- Interaction with and support for Caltrans
- Flexibility/adaptability - durability
- Collaboration

Program Background

- Pre-CAL/APT program 1993
- California Accelerated Pavement Testing Program (CAL/APT)
  July 1, 1994 - June 30, 2000
- Partnered Pavement Research Center (PPRC)
  July 1, 2000 - June 30, 2004

California Accelerated Pavement Testing Program (CAL/APT)

- Research partners
  - Caltrans
  - UC Berkeley
  - Dynatest / CSIR, South Africa
- Caltrans-separate purchase of 2 HVS's from CSIR

CAL/APT / PPRC Program

- Three-pronged approach
  - analytical developments
  - laboratory test programs
  - HVS testing
- Field verification

Examples of Three - Pronged Approach

- Goal 1: fatigue performance, AC pavements
- Goal 3: long-life rigid pavement strategies
- I-710 study

Fatigue Performance, AC Pavements

- Laboratory fatigue studies
- HVS tests - two pavement sections
- Analysis - layered elastic and finite element

Performance of
Drained and Undrained Pavements
Under HVS Loading

Caltrans Accelerated Pavement Testing Project

Goal 1 objectives

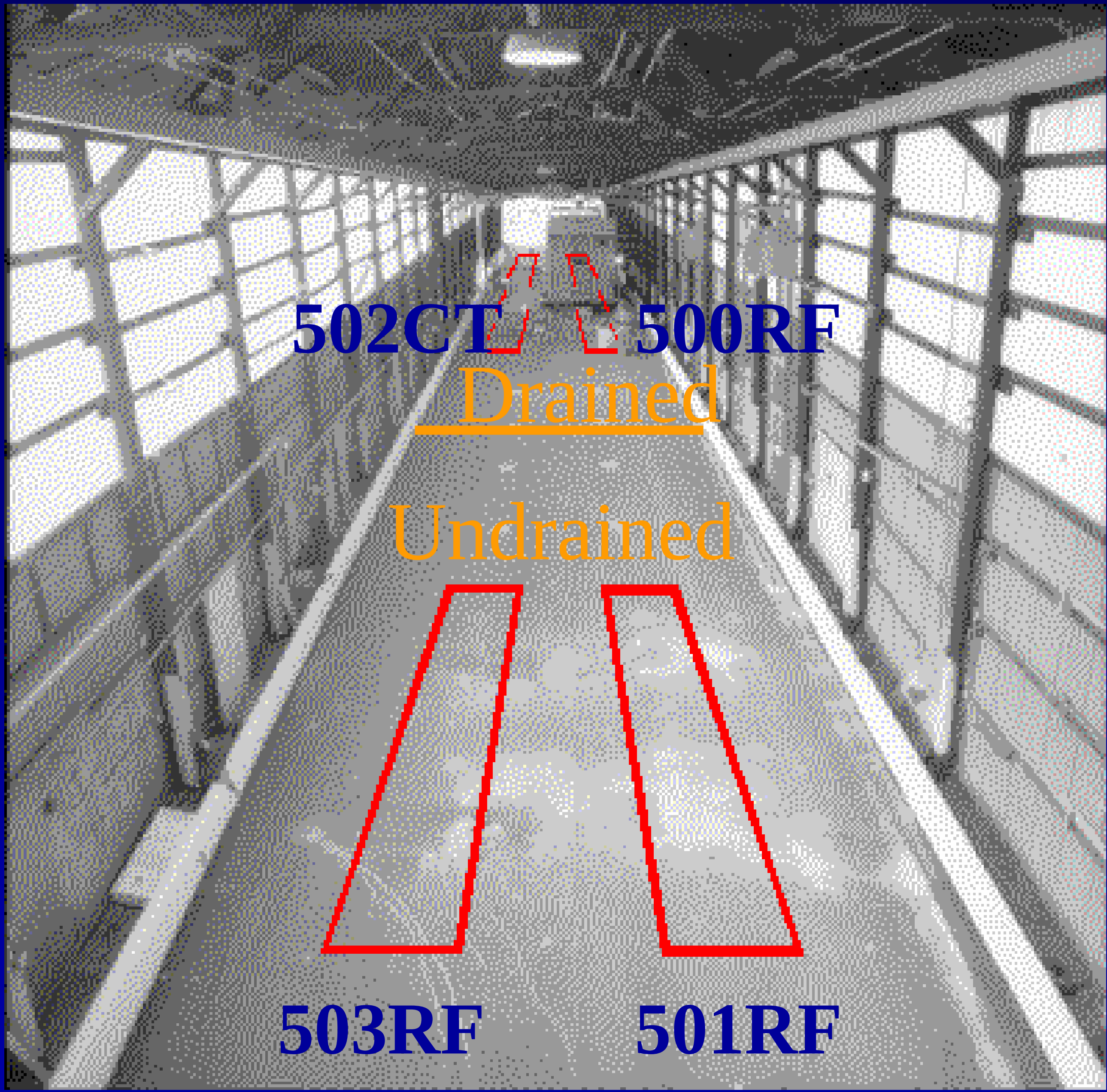
– determine fatigue, rutting performance of drained, undrained flexible pavement structures designed according to Caltrans pavement design procedure for one million ESALs

– determine failure mechanisms in layers at moderate temperatures

– evaluate design, materials, construction effects

Pavement Design and Construction

- Designs by Caltrans method:
  - subgrade R-value of 10
  - 1,000,000 ESALs (TI = 9)
- Construction:
  - commercial contractor
  - no tack coat between asphalt concrete lifts


502CT
500RF
Drained
Undrained
503RF
501RF

Construction Compaction
Air-Voids Contents

	500RF	501RF	502CT	503RF
AC top lift				
before	7.8	7.2	4.1	4.8
after	6.2	6.9	5.2	5.4
AC bottom lift				
before	4.4	5.6	2.4	4.4
after	3.7	6.3	2.2	4.6

Typical as constructed air-void contents for Caltrans are 8 to 10 %

Instrumentation and Measurements

- Multi-Depth Deflectometer (MDD)
  - at 2 m from each end, five depths
- Road Surface Deflectometer (RSD)
  - like Benkelman Beam, centerline, 200 mm off center
- Laser Profilometer
  - transverse profile every 0.5 m
- Thermocouples
  - two locations, 0, 50, 70, 137 mm depths

Environmental Control

- No surface water
- Groundwater at 4 to 5 m depth

	500RF	501 RF	502RF	503RF
Air Temperature	13-36	12-20	10-25	16-25
Avg Surface	24.7	18.9	20.8	20.3
Std Dev Surface	~ 4	1.4		1.7
Avg 70 mm	24.9	19.0	20.8	20.6
Avg 137 mm	24.9	19.1	21.0	20.7

HVS Loading

- Dual wheels
- Goodyear 10.00-20 bias-ply tires at 690 kPa
- Lateral wander 1 m
- 6.9 kilometers per hour, bi-directional loading
- 150,000 at 40 kN; 50,000 at 80 kN; 100 kN after
- 100 kN = 46.92 ESALs / pass

$$\text{ESALs} = (100/40)^{4.2}$$

Summary of Response

Total load repetitions

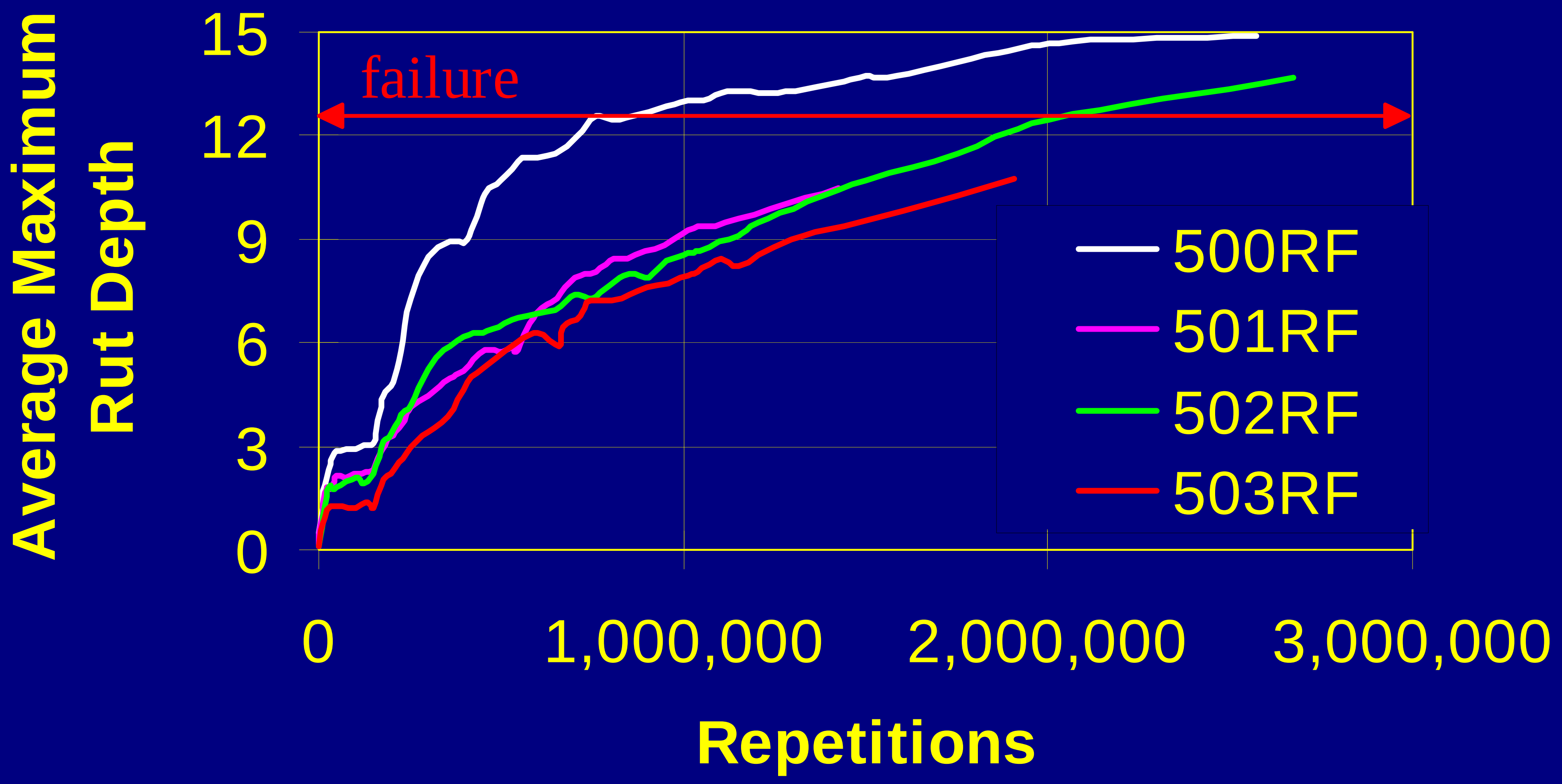
Permanent deformation

Fatigue cracking

Total Load Repetitions at Completion of Each Test Section

	Load Repetitions	ESALs (millions)
drained		
500RF	2,572,732	112.4
502CT	1,426,467	58.6
undrained		
501RF	2,673,589	117.1
503RF	1,911,823	81.4

Average Maximum Rut Depth vs Repetitions



Drained vs Undrained Structures (10^6 ESAL)

	500RF	502CT	501RF	503RF
Caltrans design estimate	1	1	1	1
Fatigue cracking (2.5 m/m^2)	55	91	34	34
Rutting (13mm)	41	100	109	129

Accelerated Pavement Testing Conclusions

- APT technology successfully transferred to California and applied to Caltrans pavement research
- Need to control temperature for APT on flexible pavements, and measure or control water
- Four test sections failed by fatigue, deflections, or rutting

Drained vs. Undrained Pavement Design Conclusions

- Different performance of drained (with ATPB) and undrained structures,
  performance ranking depends on failure criterion
- ATPB increases fatigue cracking life under dry conditions, similar unbound layer rutting and deflection performance
- ATPB may strip, lose stiffness
  recommend saturated test of both structures

Effects of Construction Variables Conclusions

- Good compaction of asphalt concrete lift resulted in long fatigue lives
  - bottom lift had 2.4 to 5.6 percent air-voids and never cracked
- Lack of tack coat and bonding resulted in cracking in upper lift first and shorter fatigue life than if bonded

Long-Life Rigid Pavement Strategies

Long-Life Rigid Pavement Strategies

- Remove and replace PCC slab
  - 200-225 mm (8-9 in.) slab adequate?
  - CTB in good enough condition?
- Remove and replace PCC slab and CTB
- Use fast setting hydraulic cement? Type III? other cements?
- Dowels, tied shoulders, wide lanes necessary?

Evaluation of Strategies

- Modeling
  - 2-D FEM for slab stresses
  - 3-D FEM for joint/dowel details (needs work)
  - include thermal, shrinkage stresses
- Laboratory testing
- Empirical performance modeling
- Accelerated pavement testing verification
- Construction productivity

Accelerated Pavement Testing: HVS on SR-14 near Palmdale

Pavement Instrumentation Before Placing Concrete

Dynamic Strain Gages

Length Change Gage (Carlson A-8)

Joint Deflection Measurement Device

Laboratory Testing of Candidate Concrete Materials

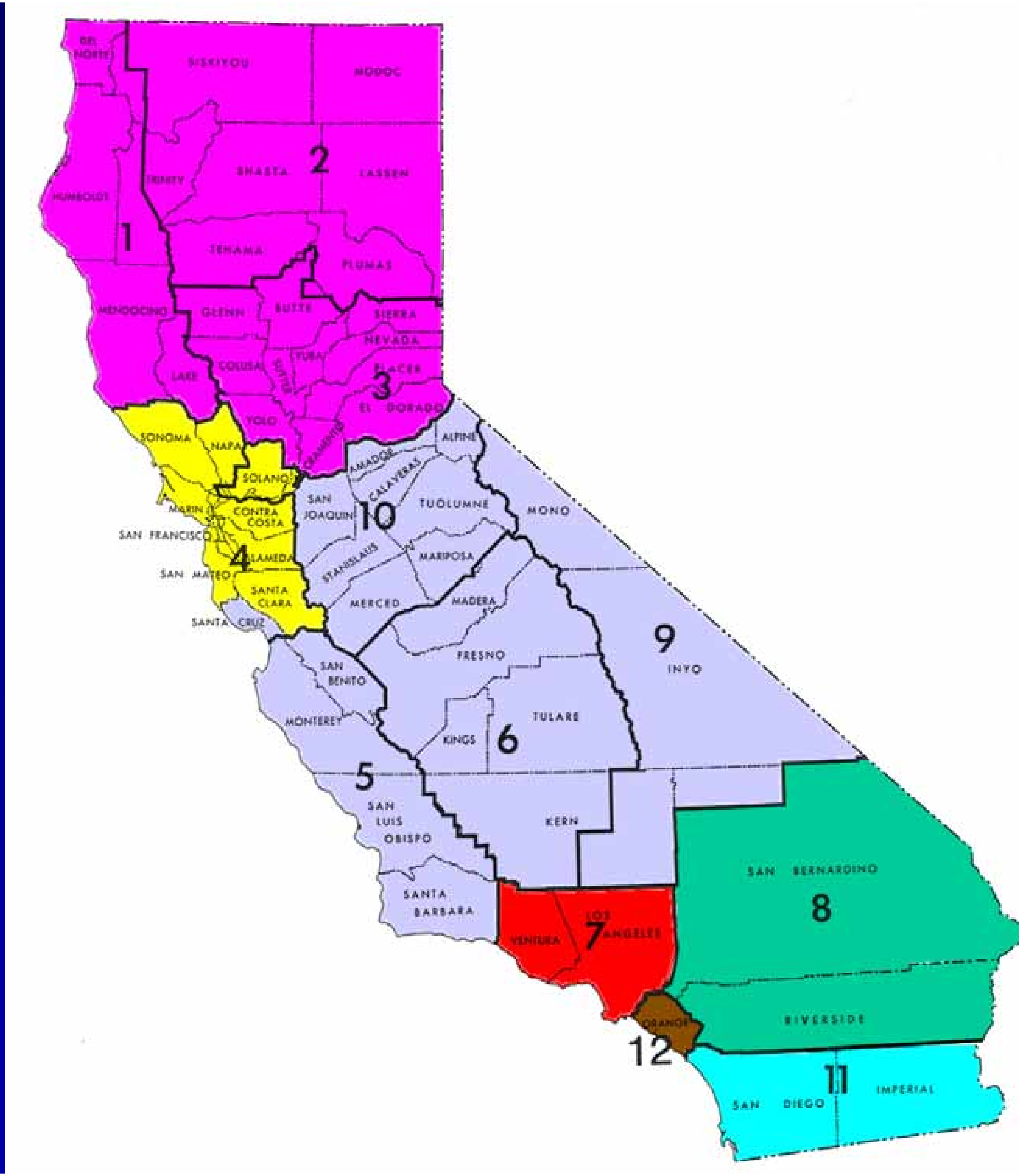
- Flexural strength
- Flexural fatigue (beams)
- Shrinkage, heat evolution, thermal expansion
- Durability
  - sulfate resistance
  - alkali aggregate reaction resistance
- Cement types: Type I/II; Type III (+aggregate effects); two Calcium Sulfo Aluminates (FSHCC); Calcium Aluminate

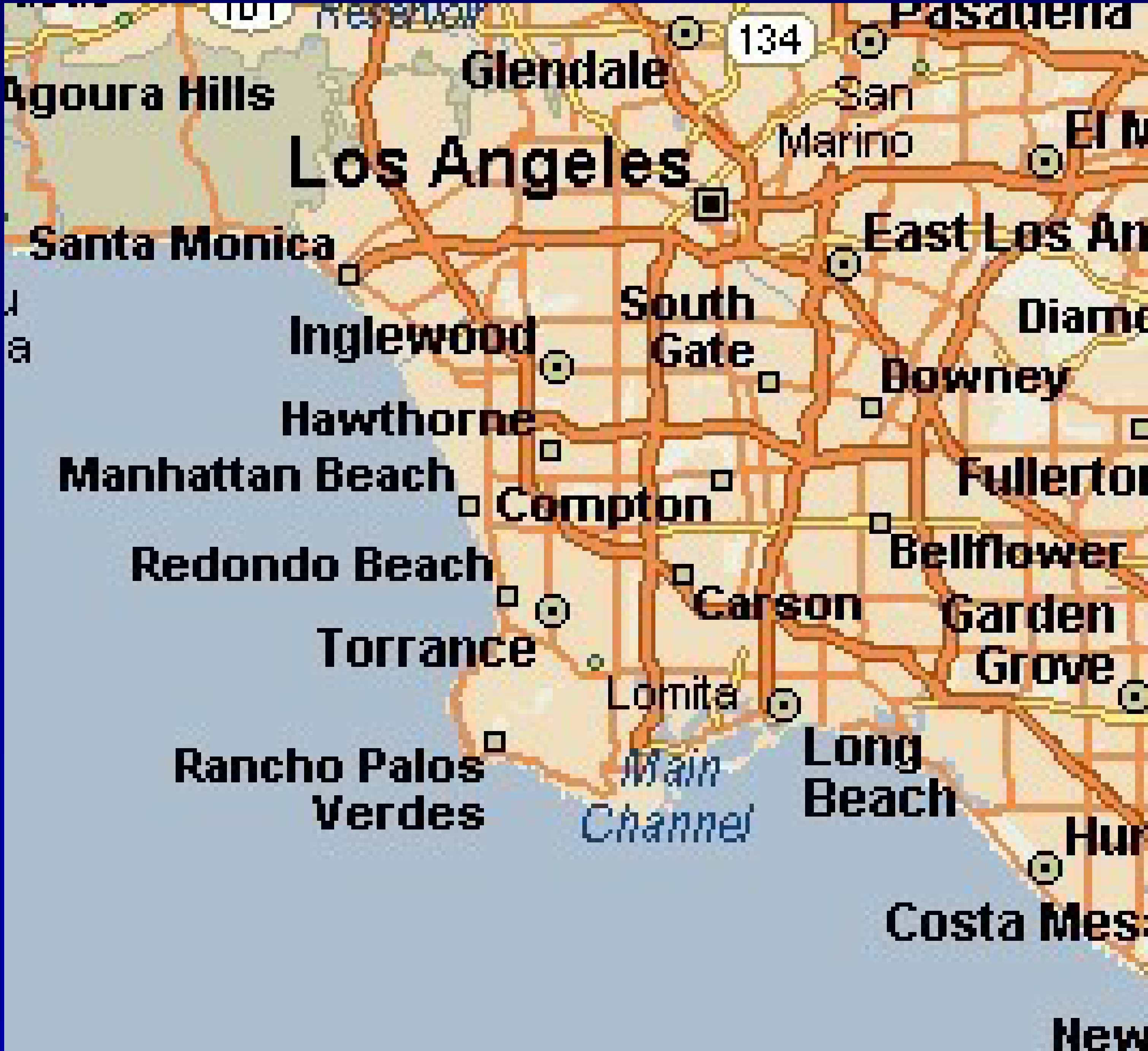
Top-Down Thermal/Shrinkage Cracking at Palmdale (*Section 11*)

Long-Life Pavement Rehabilitation
I-710 Project

I-710 Study

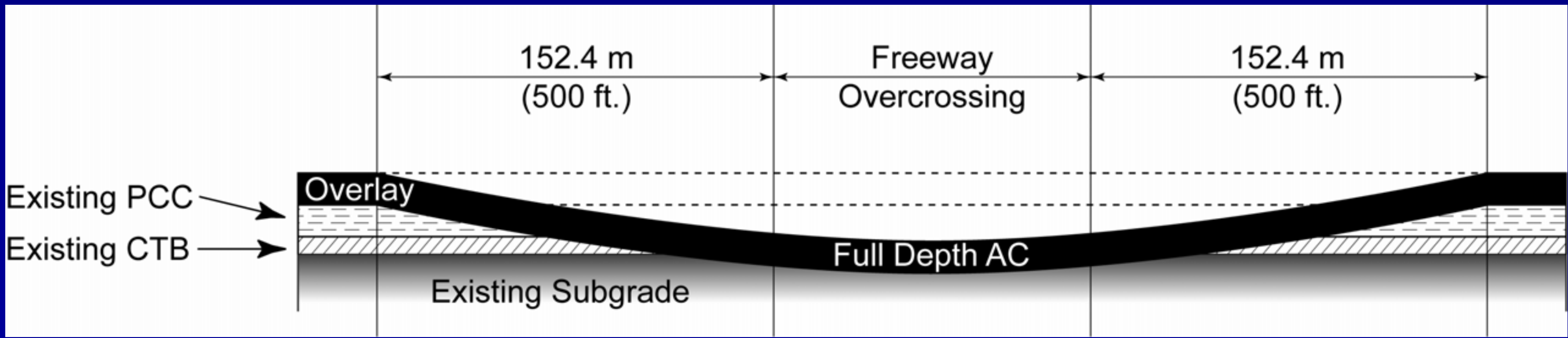
- Laboratory / field FWD testing
- Pavement analyses (layered elastic, FEM)
- HVS testing


DEL NORTE
SISKIYOU
MODOC
1
2
TRINITY
SHASTA
LASSEN
HUMBOLDT
TEHAMA
PLUMAS
MENDOCINO
GLENN
BUTTE
SIERRA
NEVADA
LAKE
COLUSA
SUTTER
YUBA
PLACER
3
YOLO
EL DORADO
SACRAMENTO
SONOMA
NAPA
SOLANO
AMADOR
ALPINE
CALAVERAS
MARIN
CONTRA COSTA
SAN JOAQUIN
10
TUOLUMNE
MONO
SAN FRANCISCO
4
ALAMEDA
STANISLAUS
MARIPOSA
SAN MATEO
SANTA CLARA
MERCED
MADERA
SANTA CRUZ
9
FRESNO
INYO
SAN BENITO
TULARE
MONTEREY
KINGS
6
5
SAN LUIS OBISPO
KERN
SAN BERNARDINO
SANTA BARBARA
8
VENTURA
LOS ANGELES
7
ORANGE
RIVERSIDE
12
11
SAN DIEGO
IMPERIAL

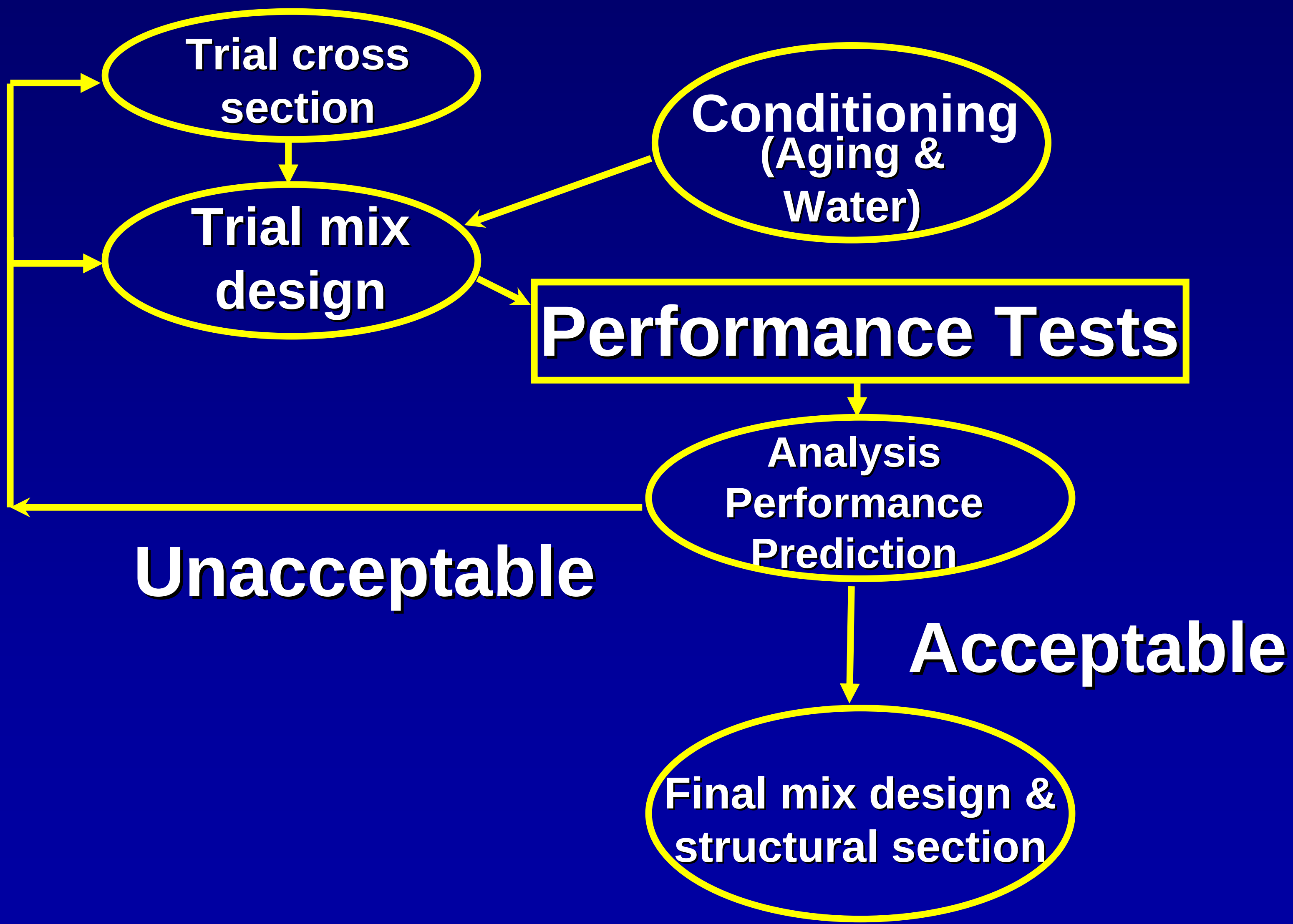


134
Glendale
Agoura Hills
San
Marino
Los Angeles
Santa Monica
South
Gate
Inglewood
Downey
Hawthorne
Manhattan Beach
Compton
Bellflower
Redondo Beach
Carson
Garden
Grove
Torrance
Lomita
Long
Beach
Rancho Palos
Verdes
Main
Channel

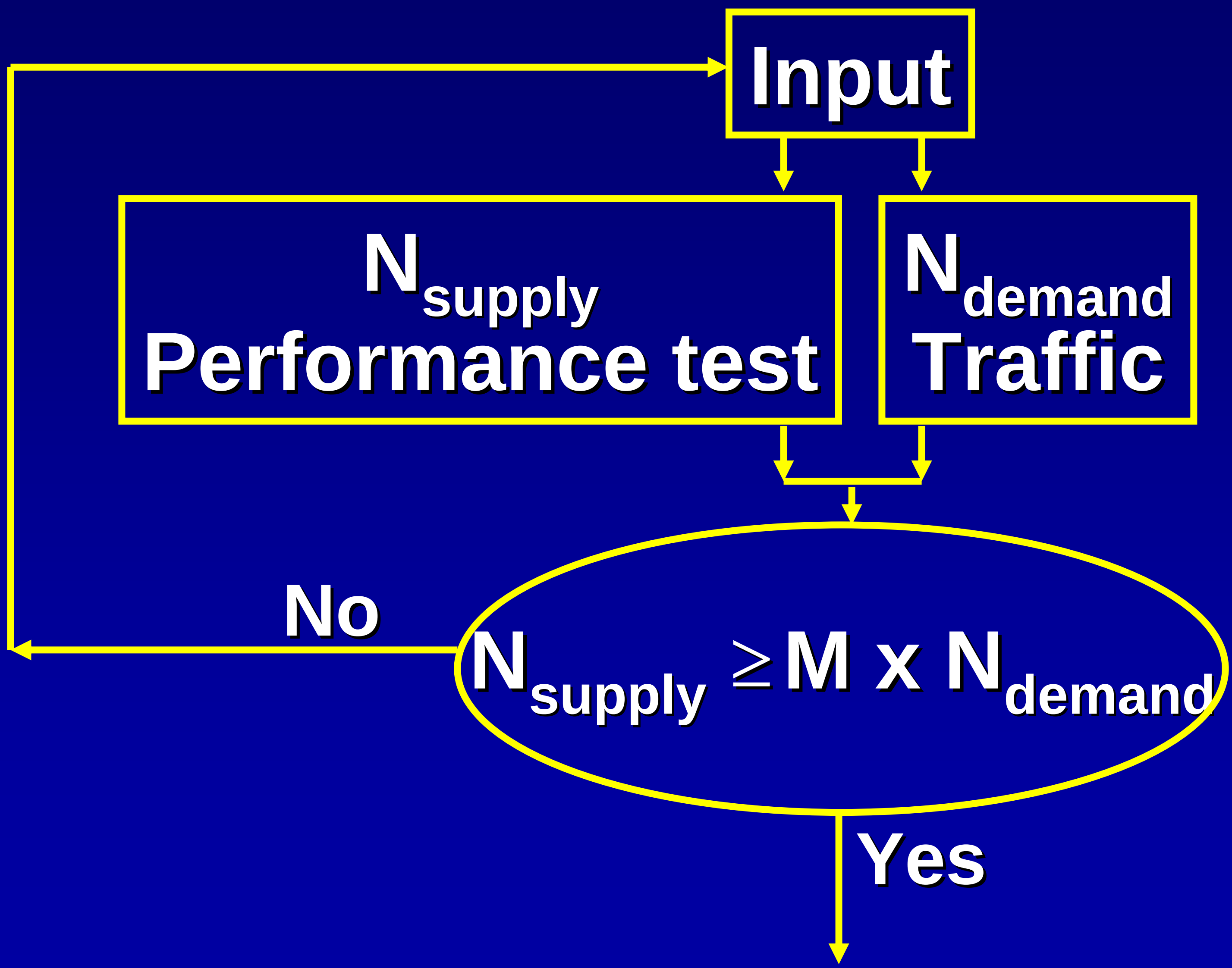
Section Profile



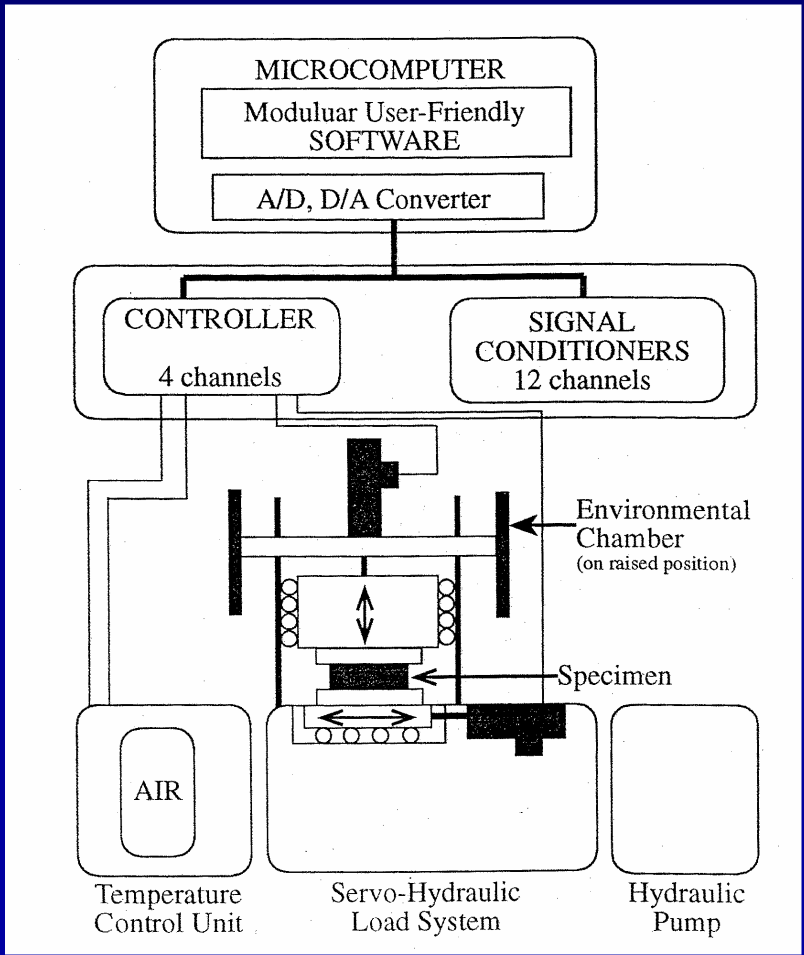
Design & Analysis



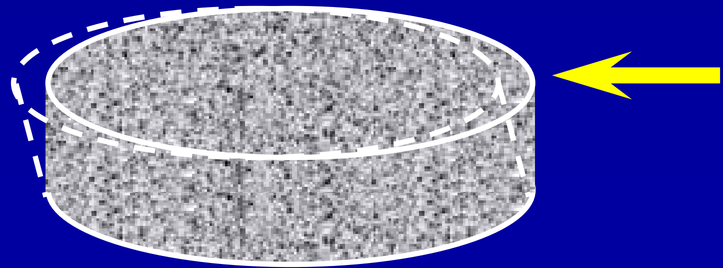
Final Mix Design - Rutting



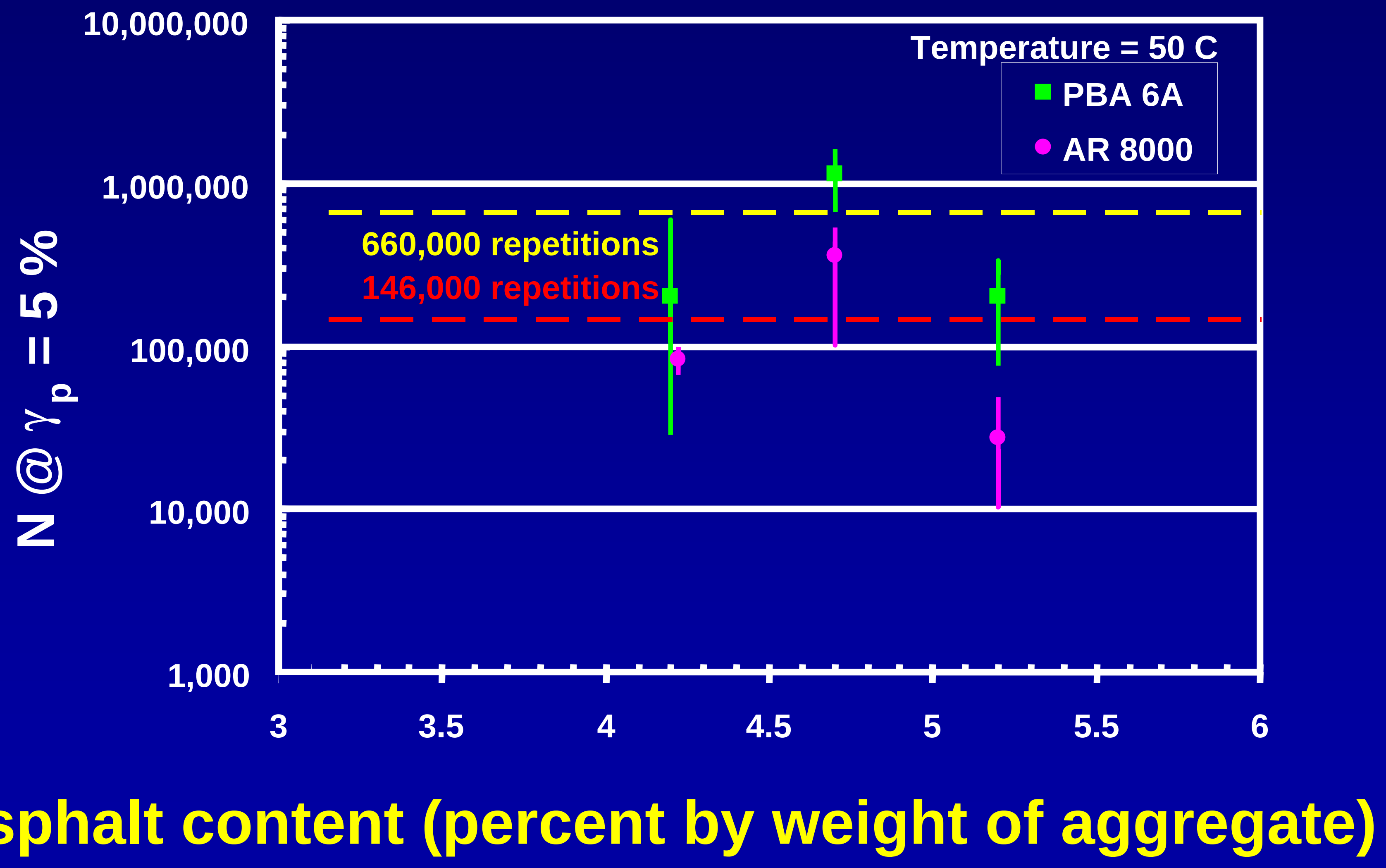
Shear Test


MICROCOMPUTER
Moduluar User-Friendly
SOFTWARE
A/D, D/A Converter
CONTROLLER
4 channels
SIGNAL
CONDITIONERS
12 channels
Environmental
Chamber
(on raised position)
Specimen
AIR
Temperature
Control Unit
Servo-Hydraulic
Load System
Hydraulic
Pump

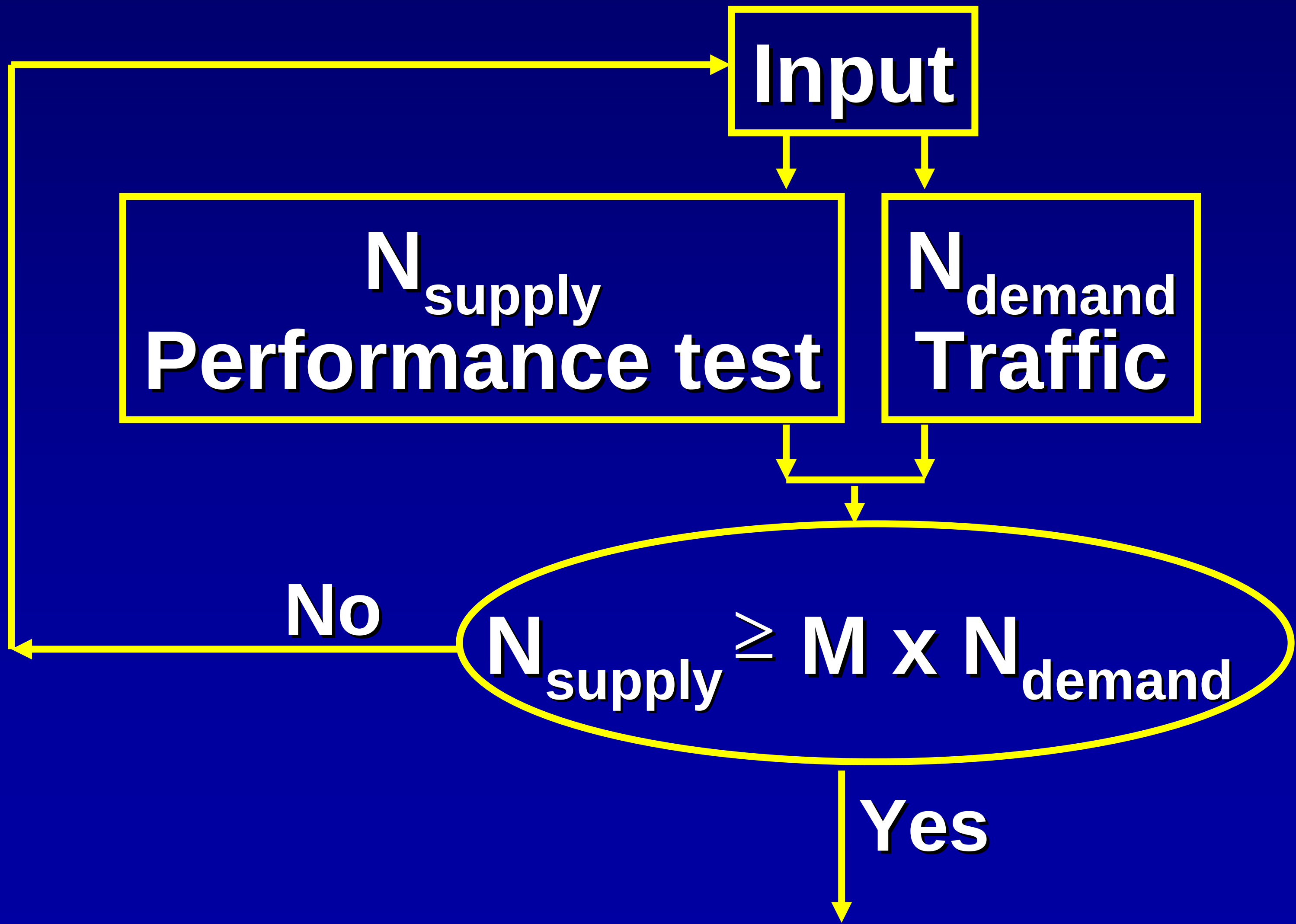

COX & SONS



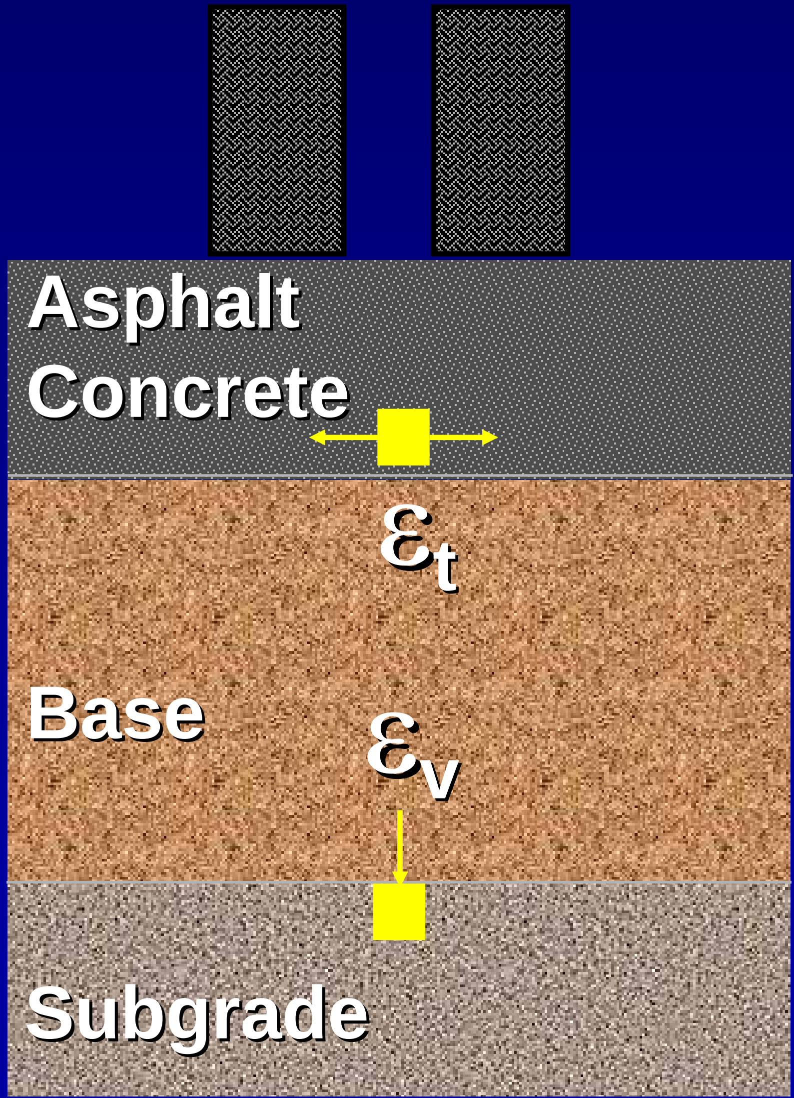
Design Binder Content



Thickness Design - Fatigue Analysis



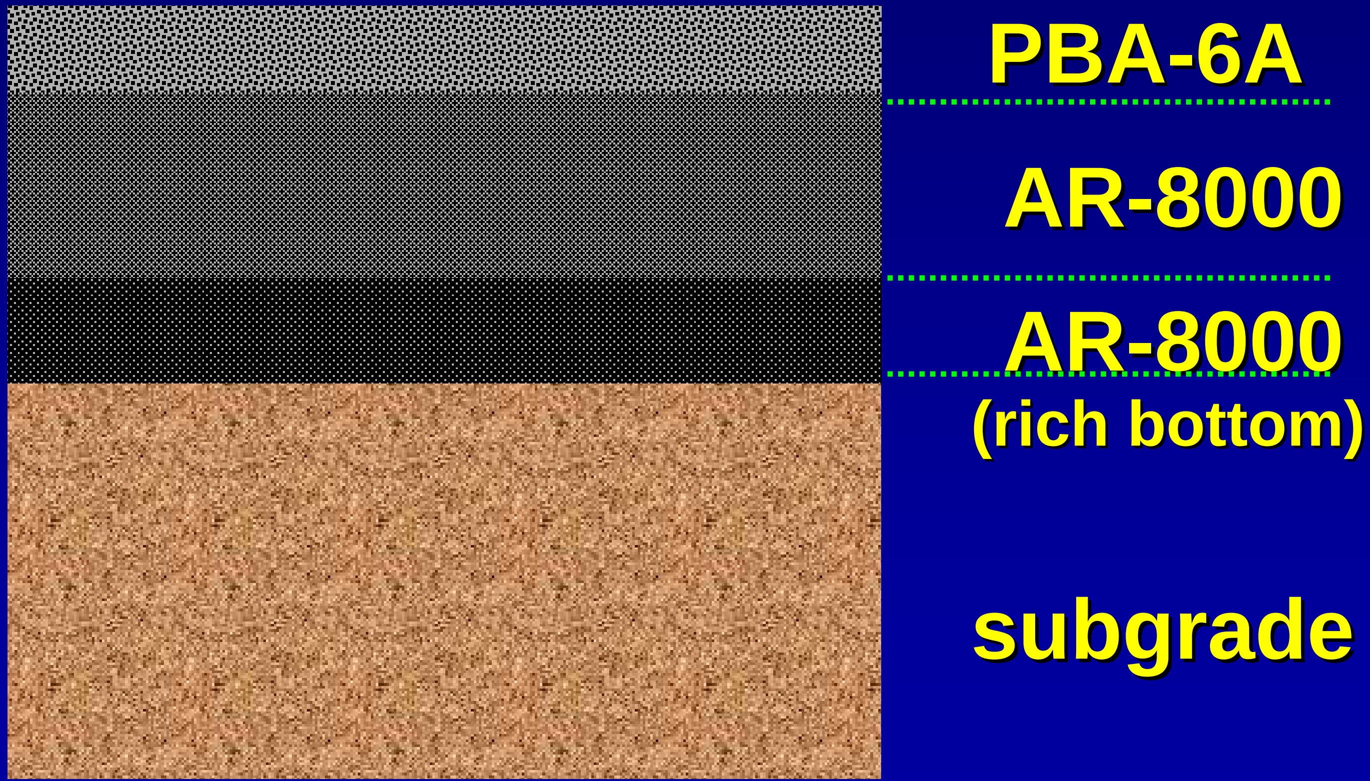
Design Considerations



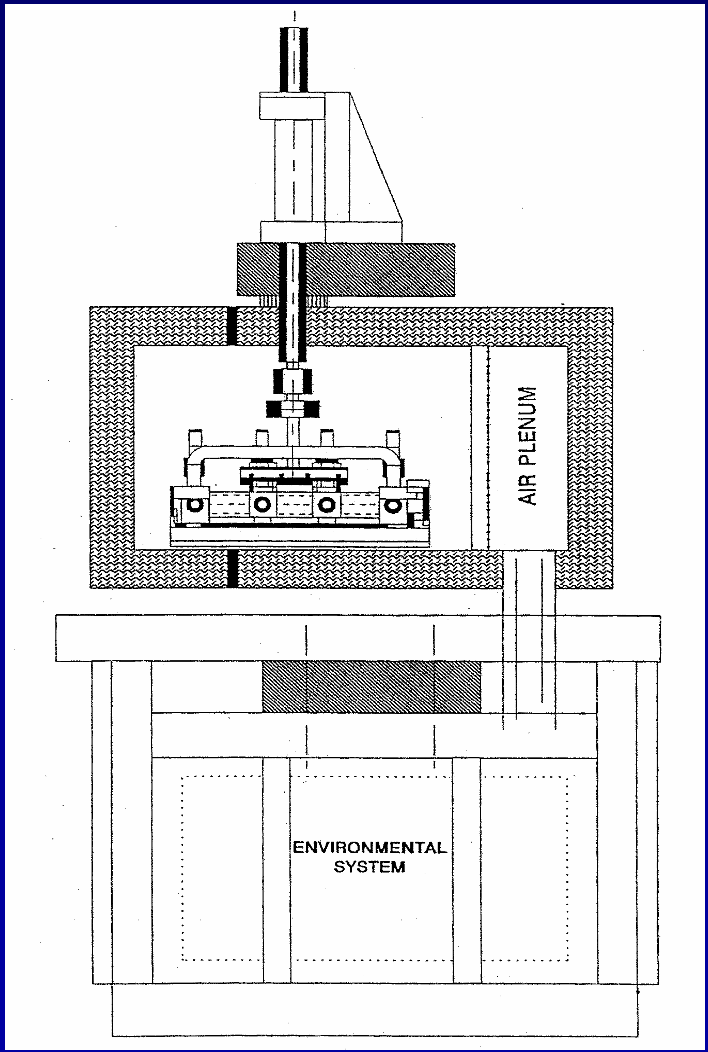
Input

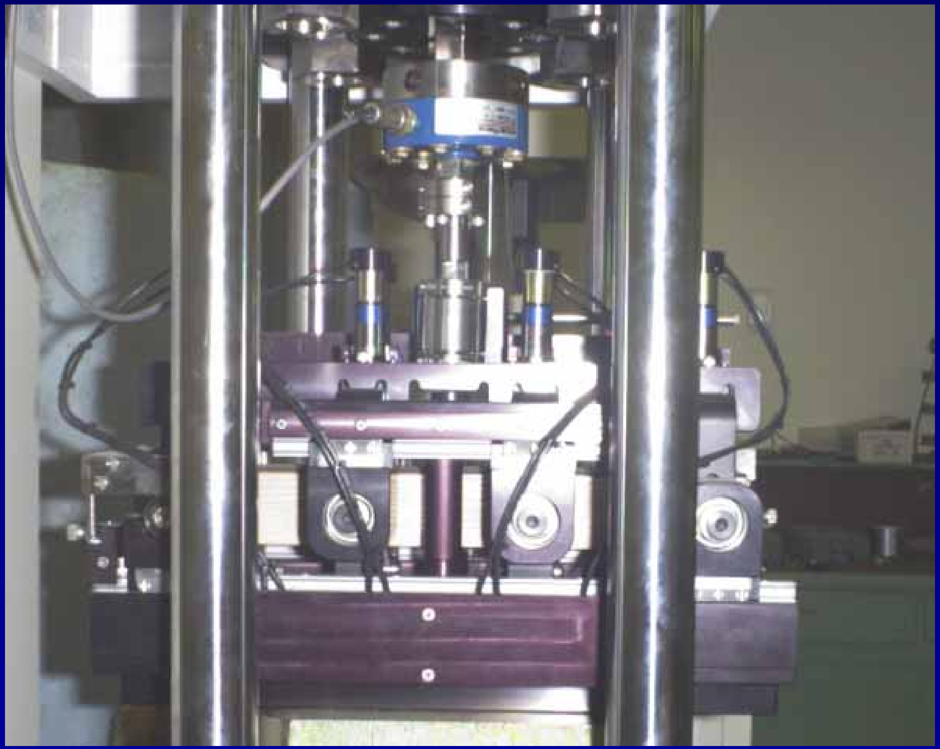
- Structural section (full-depth)
- Traffic (200 million ESALs)
- Environment (T = 20°C)
- Trial mixes & pavement section

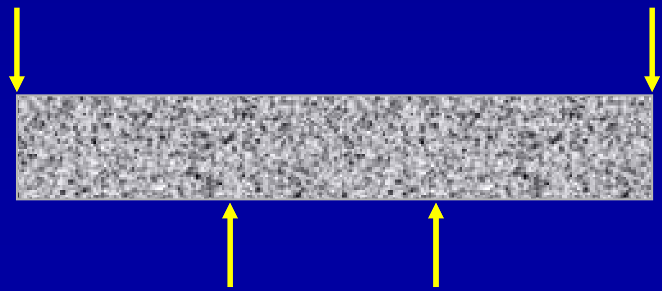
Trial Pavement Sections



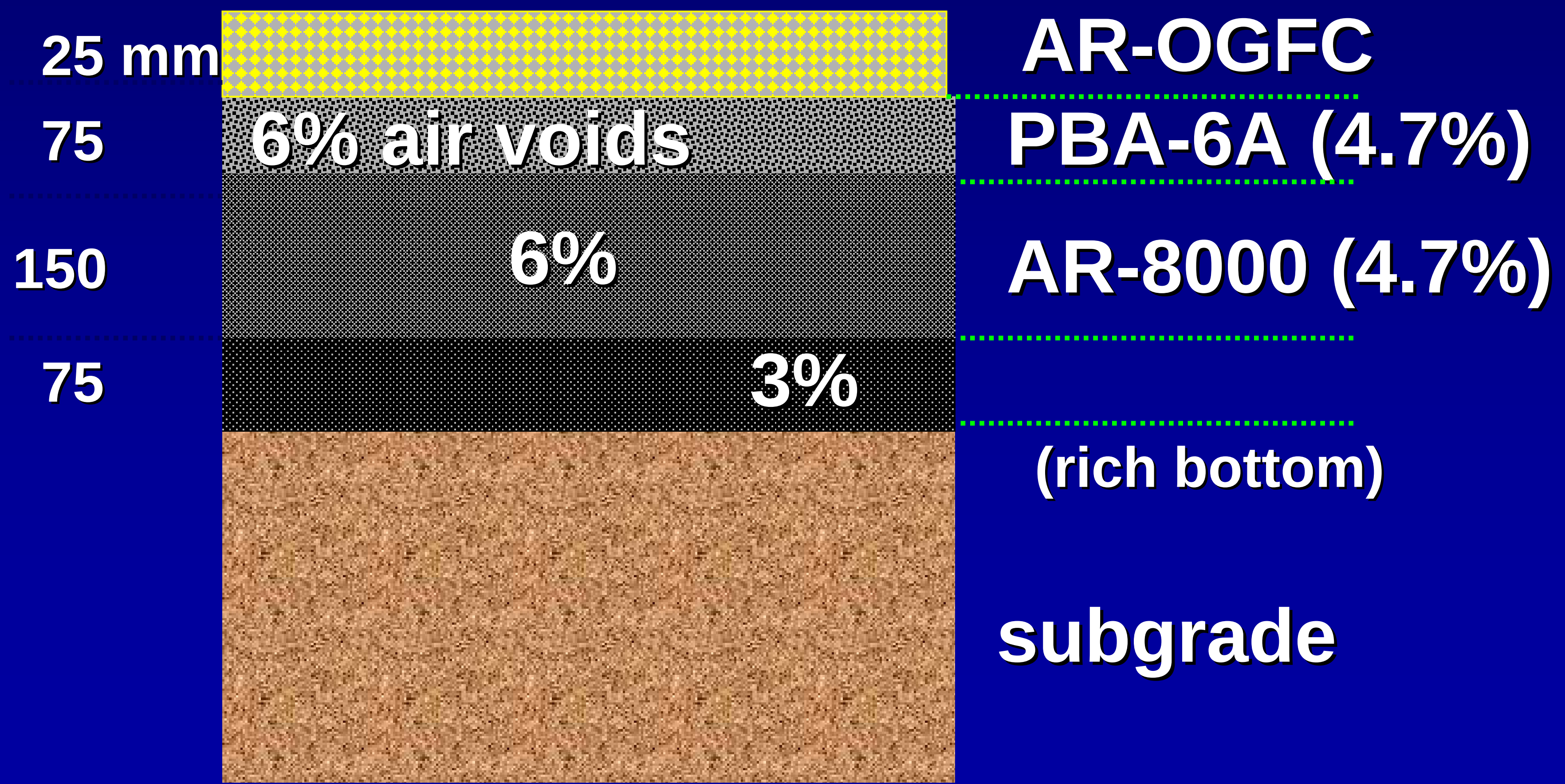
Fatigue Test





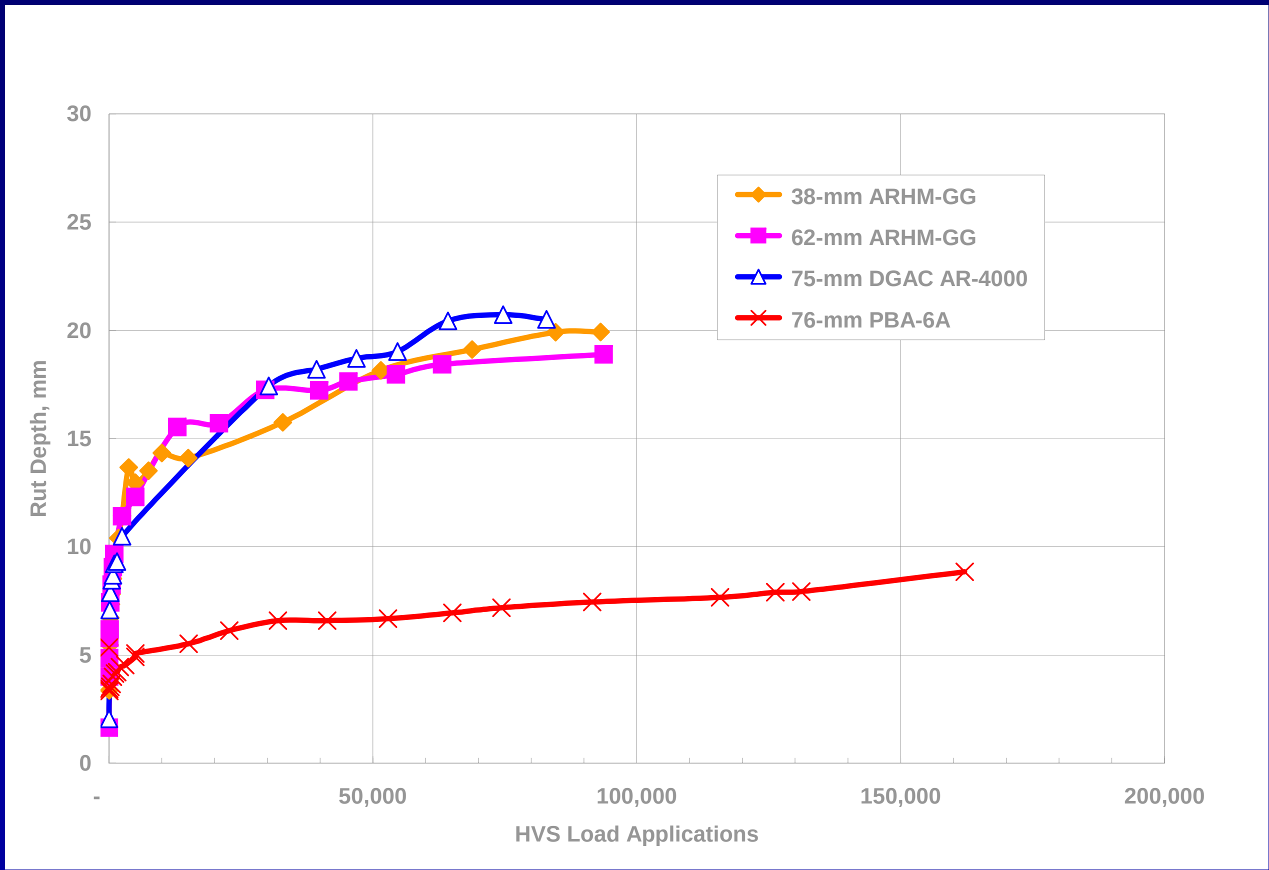


Final Design



HVS Rutting Study

CAL/APT Evaluation



Program Contributions

- Impact of asphalt construction technology on asphalt pavement performance
- Concrete pavement long life strategies
- Impact of environment on concrete pavement performance
- Introduction, development and validation of new technologies within Caltrans
- Pavement constructability
- Established productive APT and laboratory testing programs for Caltrans

Impact of Asphalt Construction Technology on Asphalt Pavement Performance

- AC mix compaction
  - effect on pavement life
  - relationship to mix design
  - field control
- Use of tack coats in multiple lift AC construction

Concrete Pavement Long-Life Strategies

- Fast setting hydraulic cement concrete (FSHCC)
  - established do’s and don’ts for usage
  - established data base of properties
    - mechanical-strength, stiffness, fatigue
    - durability-ASR, sulfate resistance
- Importance of dowels
- Control of slab lengths
- Construction productivity-urban rehabilitation

Environmental Impacts on Concrete Pavement Performance

- Importance of concrete shrinkage and curling effects on performance in desert and central valley (California)
- Longitudinal cracking-identification of causes
- Establishment of environmental regions for concrete pavement design purposes

New Technologies for Caltrans - Introduction, Development and Validation

- Introduction of South African technologies, e.g.
  – DCP, improved chip seal design, foamed asphalt
- Mechanistic-empirical design, AC and concrete pavements
- Long-life pavement design
  – rich bottom AC
  – shear and fatigue tests for AC
- Validation of Caltrans thickness design for ARHM-GG in overlays

Pavement Constructability - Urban Rehabilitation

- Productivity - concrete and AC pavement
  - computer program, CA4PRS
- Impacts of traffic (included in CA4PRS)

Productive APT and Laboratory Testing Capabilities

- Partnership with Dynatest and CSIR
- Extensive test of concrete pavements
- Laboratory test facilities
  - asphalt concrete - mechanical properties
  - soils and aggregate - mechanical properties
  - cement and concrete - mechanical properties, durability

Program Results

- Dissemination
  - reports to Caltrans (also posted on web site)
    - (including 1 to 2 page summaries)
  - papers in technical journals
    - TRB, AAPT, ISAP, CAPSA
  - technology transfer, UCB/ITS publications
  - short courses
  - special seminars throughout California

Program Results

- Implementation
  - direct interaction with Caltrans and Industry
    - e.g. long-life pavement task group for I-710 freeway rehabilitation
  - working directly with Caltrans on items such as:
    - DCP
    - concrete maturity
    - pavement constructability

Program Results

- Measures of efficacy
  - HVS productivity
  - Economic analyses; David Gillen et al
    - implementation of improved design and rehabilitation procedures
    - improved construction procedures;
      - compaction
      - use of tack coats

Significant Problems and Issues

- Institutional issues
- Implementation of results
- Communication among Caltrans programs
- Data bases
- Construction quality control/assurance
- Education/training - construction and maintenance sectors

Problems - Implementation

- Reports, papers, short courses not enough
- Next step?
  - e.g preparation of draft documents;
    - standard specs. (new)
    - special provision (new)
    - manual and guide changes and new documents
    - software
    - test methods (new)

Program Costs

- PPRC budget - $5,000,000/year (Caltrans)
- HVS operation costs
  - HVS1 - RFS ~$800,000/year
  - HVS2 - Palmdale (other field sites), ~$1,200,000/year
- Laboratory operations

Program Costs

- Subcontracts
  - Symplectic
  - University of Illinois
  - University of Washington/University of Maine
  - Tech. University of Vienna
  - other

Collaboration Activities

- Recent examples
  - WSDOT: dowel retrofit study
  - SPTC
  - U. Of Illinois: M-E concrete pavement design
- Initial collaboration with CSIR key to program success

Collaboration Activities

- Suggestions
  - sharing of data
  - early collaborative planning
  - pooling efforts directed to specific problems
  - consortium?

APT Program Keys

- Adequate funding commitments for
  - long term operations
  - data analysis and presentation of results of investigations

APT Program Keys

- Long term goals
  - don't limit to product and pass/fail testing
  - must have at least 2 or 3 long term goals underway

APT Program Keys

- Strategic plan
  - developed by program management
  - input from:
    - customers
    - operation staff
    - analyses staff
    - resource providers
  - amenable to modification as project progresses

APT Program Keys

- Trust among team managers/directors
  - knowledgeable staff
  - working together

APT Program Keys

- Partnering
  - purpose - maximize results
  - build on work of others
  - share results
  - will enhance progress

Significant Achievements

- Technology transfer – HVS and other
- Technical developments – AC and PCC
- Interaction with and support for Caltrans
- Flexibility/adaptability - durability
- Collaboration