# *Permeable Pavement Overview*

Meeting of CCPIC
City of Berkeley
City of Davis
City of Martinez

6 April 2018

# Permeable Pavement Team and Sponsors

- Contributors to published work presented:
  - David Jones, Hui Li, Rongzong Wu, Erol Tutumleur (UIUC), Masoud Kayhanian, Lin Chai, Ting Wang, Bruce Campbell, Erik Dennemen, UCPRC lab & HVS crews
- Work sponsored by:
  - Concrete Masonry Association of California and Nevada
  - Interlocking Concrete Pavement Institute
  - California Department of Transportation

# Permeable Pavement for Stormwater Management

- Impervious pavement in urban areas contributes to
  - Water pollution (*oil, metal, etc*.)
  - Reduced groundwater recharge
  - Increased risk of flooding
  - Local heat island effect (*less evaporation*)


- Gaps to be filled
  - Designs for heavy vehicles
  - Cost and environmental impact comparisons
  - Other obstacles to successful use and implementation

# Permeable Pavement Studies by UCPRC

- Goal:  Mechanistic based design methods for heavy vehicle applications, fill other gaps
- Studies by UCPRC
  - Caltrans Study (2008-2010)
    - Hydraulic and structural design method and tables for permeable concrete and asphalt pavements
    - Not yet validated with traffic
  - CMACN / ICPI Study (2013-2014)
    - Design method and tables for PICP
    - Validated with Heavy Vehicle Simulator
  - Caltrans Study (underway)
    - Survey of experience and knowledge regarding permeable pavements

# General Concept
# Shoulder or Traveled Way

**Permeable surface**

**(Interlocking Conc Pavers, HMA-O or PCC-O or PCC with holes)**

***Fatigue (except for pavers)***

**Granular reservoir layer**

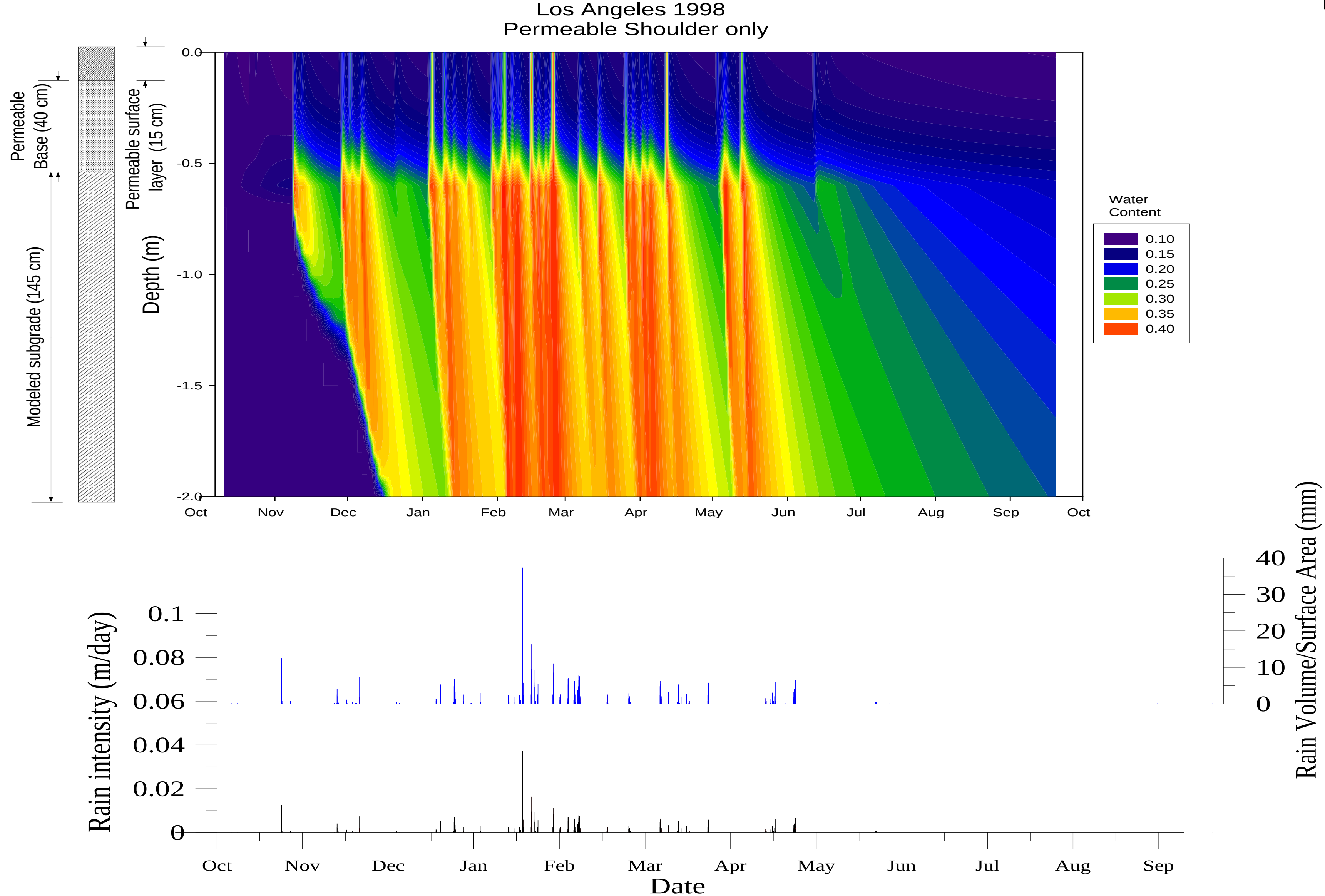
***Rutting (Shear Stress/Strength Ratio)***

**Optional permeable 15 cm PCC-O subbase**

**Lightly compacted subgrade**

***Rutting (Shear Stress/Strength Ratio)***

# Caltrans Study: Hydraulic profile of water content for LA area: permeable shoulder



# Caltrans Studies: LCCA, LCA

- LCCA
  - *Realcost* for LCCA
  - BMP costs from Caltrans reports
  - Permeable pavement costs from Teichert
  - 40 year analysis, discount rates, agency costs
- LCA
  - Framework produced for future LCAs
- Field measurements of clogging on older projects
  - Concrete only

# Caltrans Studies:
# Key Findings:  LCCA

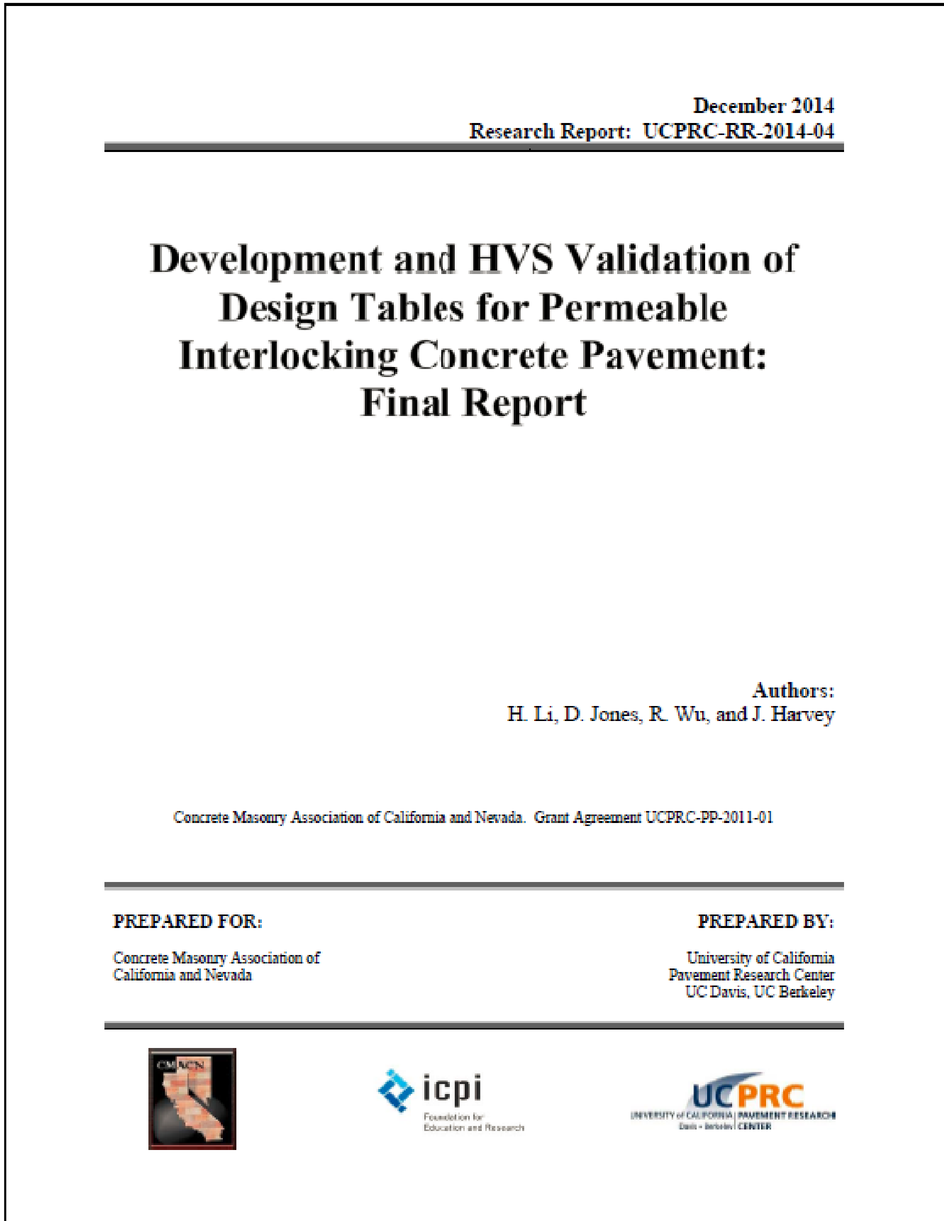
- Shoulder Retrofit of Impermeable Road
  - Drains two lanes
    - 0.75 x cost of lowest cost BMP
  - Drains three or more lanes
    - 0.5 x cost of lowest cost BMP
- Maintenance yard/parking lot
  - Same cost as lowest cost BMP
  - 0.15 x cost of highest cost BMP

# Caltrans Studies: Structural Design

- Scope
  - Base/reservoir/permeability design for three regions
  - HMA-O/PCC-O/Cast PCC slab for two regions
  - With and without PCC-O subbase below reservoir
- HMA-O
  - Three part process
    - Determine base/reservoir thickness based on subgrade permeability & rainfall
    - Determine HMA thickness
    - Check subgrade stress to subgrade strength ratio
- PCC-O and Concrete Slabs with Holes
  - Two part process
    - Determine base/reservoir thickness
    - Determine PCC-O thickness for given slab length

# ICPI Study

- Study approach
  - Literature review
  - Field testing
  - Test track design
  - Test track construction
  - Accelerated load testing
  - Data Analysis
  - Design method & tool
  - Design tables
  - Final report
    - includes interim reports


December 2014
Research Report: UCPRC-RR-2014-04

**Development and HVS Validation of Design Tables for Permeable Interlocking Concrete Pavement: Final Report**

Authors:
H. Li, D. Jones, R. Wu, and J. Harvey

Concrete Masonry Association of California and Nevada. Grant Agreement UCPRC-PP-2011-01

PREPARED FOR:
Concrete Masonry Association of California and Nevada

PREPARED BY:
University of California
Pavement Research Center
UC Davis, UC Berkeley

# ICPI Study: Mechanistic approach

- Distress
  - Unbound layer rutting
- Approach
  - Shear stress to shear strength ratio (SSR) at top of layer
  - 0.3 ≤ SSR ≤ 0.7
- Required inputs
  - Unbound layer stiffness, strength, and other mechanical properties
  - Obtained from lab and field testing

$$Shear\ Stress\ Ratio\ (SSR) = \frac{\tau_f}{\tau_{max}}$$

$$\tau_f = \frac{\sigma_1 - \sigma_3}{2} cos\phi = \frac{\sigma_d}{2} cos\phi$$

$$\tau_{max} = c + \sigma_f tan\phi$$

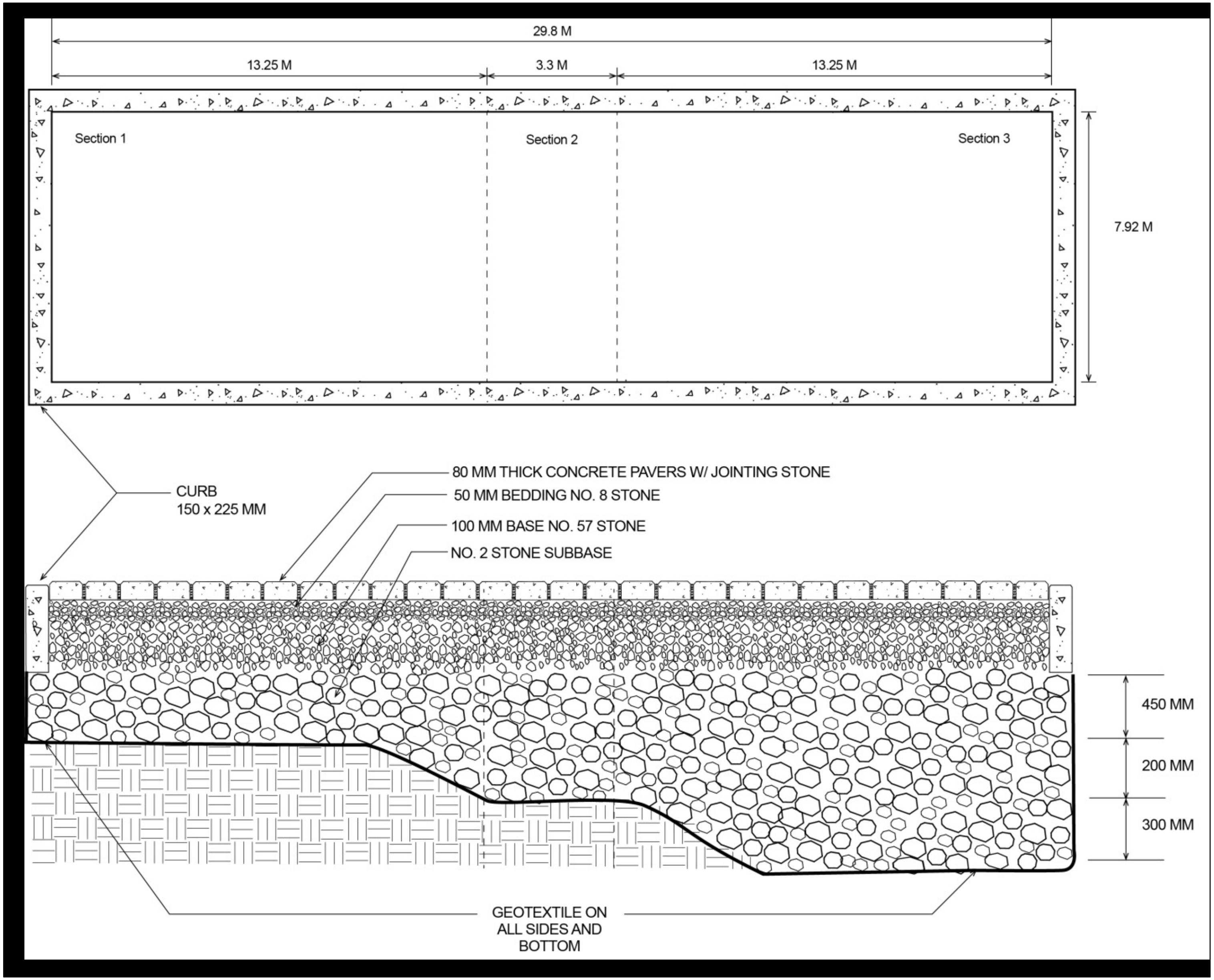
$$\sigma_f = \frac{\sigma_1 + \sigma_3}{2} - \frac{\sigma_1 - \sigma_3}{2} sin\phi = \frac{\sigma_d + 2\sigma_3}{2} - \frac{\sigma_d}{2} sin\phi$$

# ICPI Study:  Test sections

**Surface:  80 mm interlocking concrete paver**
**Bedding layer:  50 mm ASTM #8 aggregate**
**Base layer:  100 mm ASTM #57 aggregate**
**Subbase layer:  Varying thickness ASTM #2 aggregate**
**Subgrade soil:  Silty clay, compacted after excavation**

| Subbase Thickness | Shear Stress Ratio (SSR) | Calculated (mm) | | As-Built |
|---|---|---|---|---|
| | | Dry | Wet | |
| **Thin** | 0.8 | 450 | 650 | 450 |
| **Medium** | 0.5 | 800 | 950 | 650 |
| **Thick** | 0.2 | 1,350 | 1,450 | 950 |

# ICPI Study:  Cross sections



2003
38°32'04.15" N 121°47'37.50" W elev 19 m eye alt 275 m
Google earth

# ICPI Study: Instrumentation

- Aggregate size limited options
- Stress (pressure cell)
  - Top of base
  - Top of subgrade
- Deformation (profiler + dipsticks)
  - Surface
  - Top of base
  - Top of subgrade
- Deflection (RSD)
- Water level
  - Manual and automated

# ICPI Study: Testing conditions

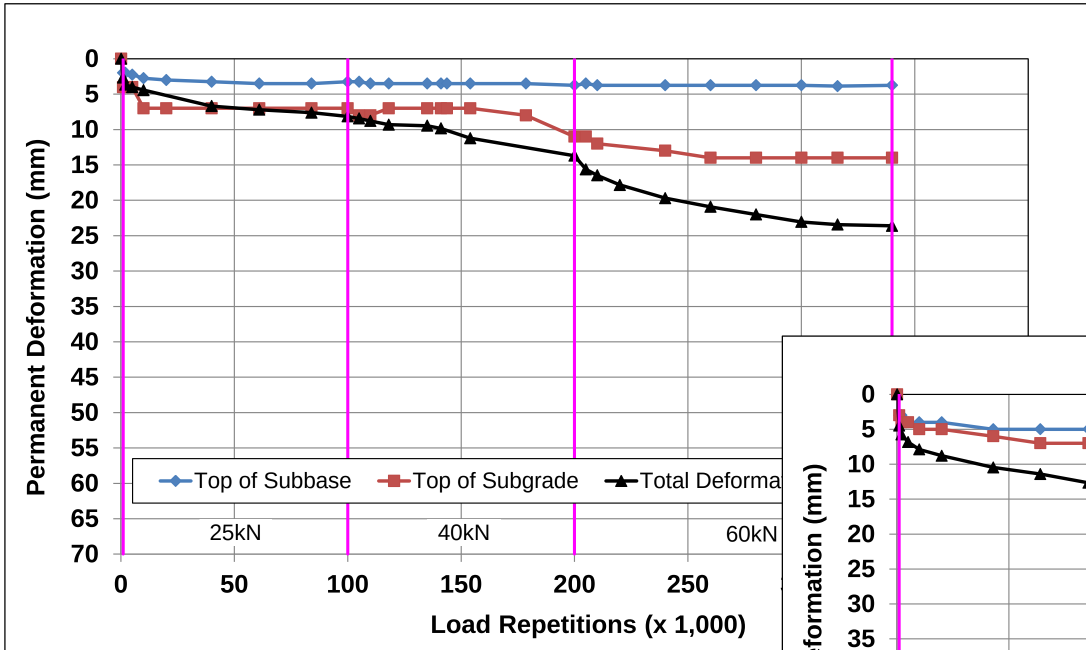
- Extended HVS (13m) used to test all sub sections together
  - Bidirectional trafficking with wander
  - Wheel load range from 25kN to 80kN
- Three testing conditions
  - Dry
  - Wet: water table maintained at the top of the subbase
  - Drained: Wet subgrade, no water in the subbase
  - All testing at ambient temperature
- Failure criteria
  - >25 mm of surface rut

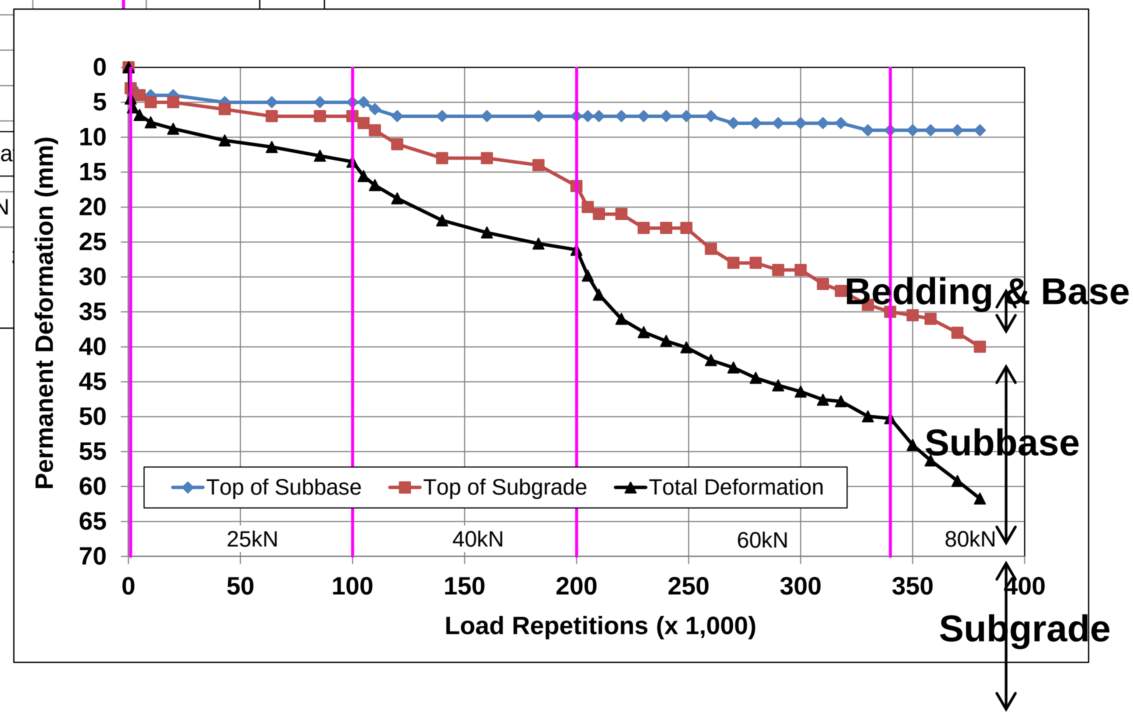
# ICPI Study: HVS testing

# ICPI Study:  HVS testing

# HVS Results:  450 mm

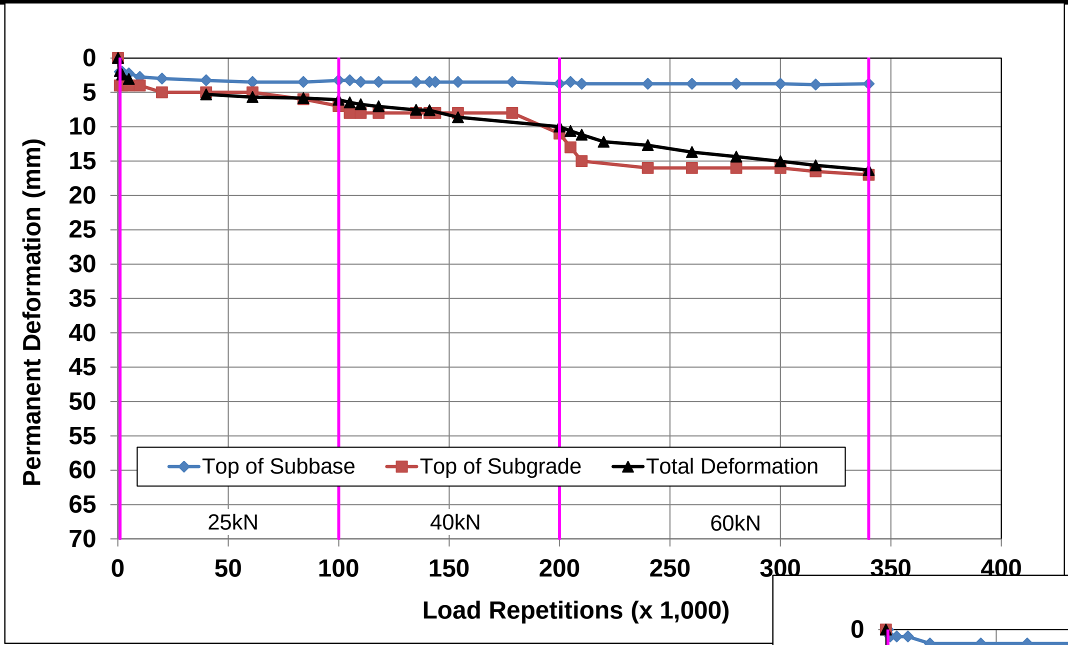
**Dry**



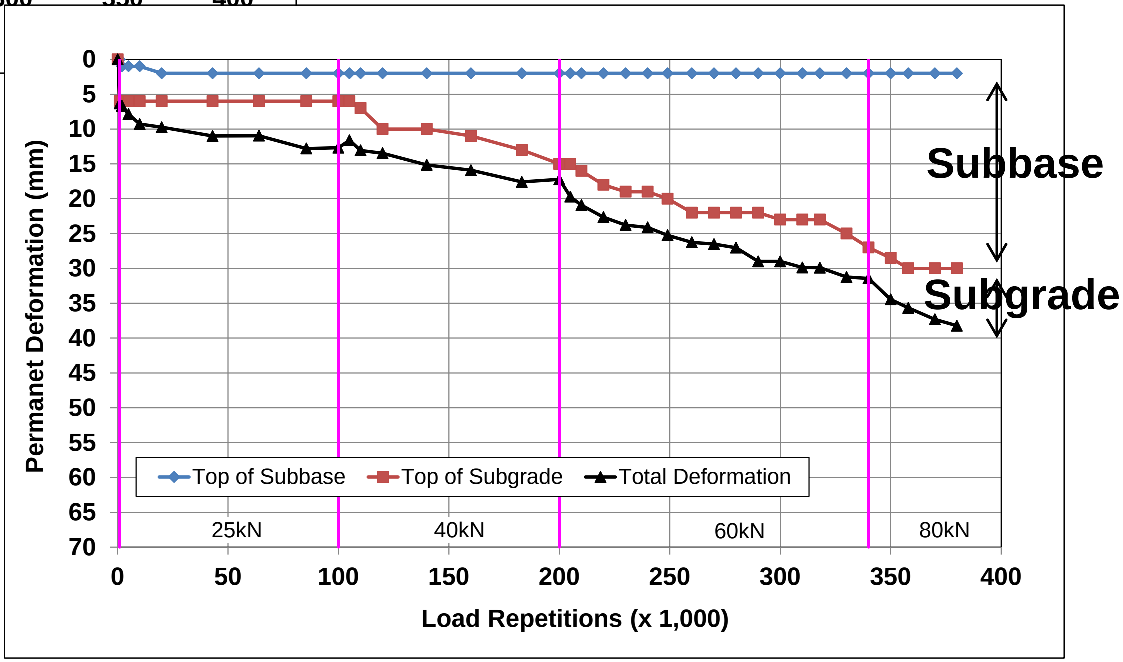




**Wet**

# HVS Results: 950 mm




Dry




Wet

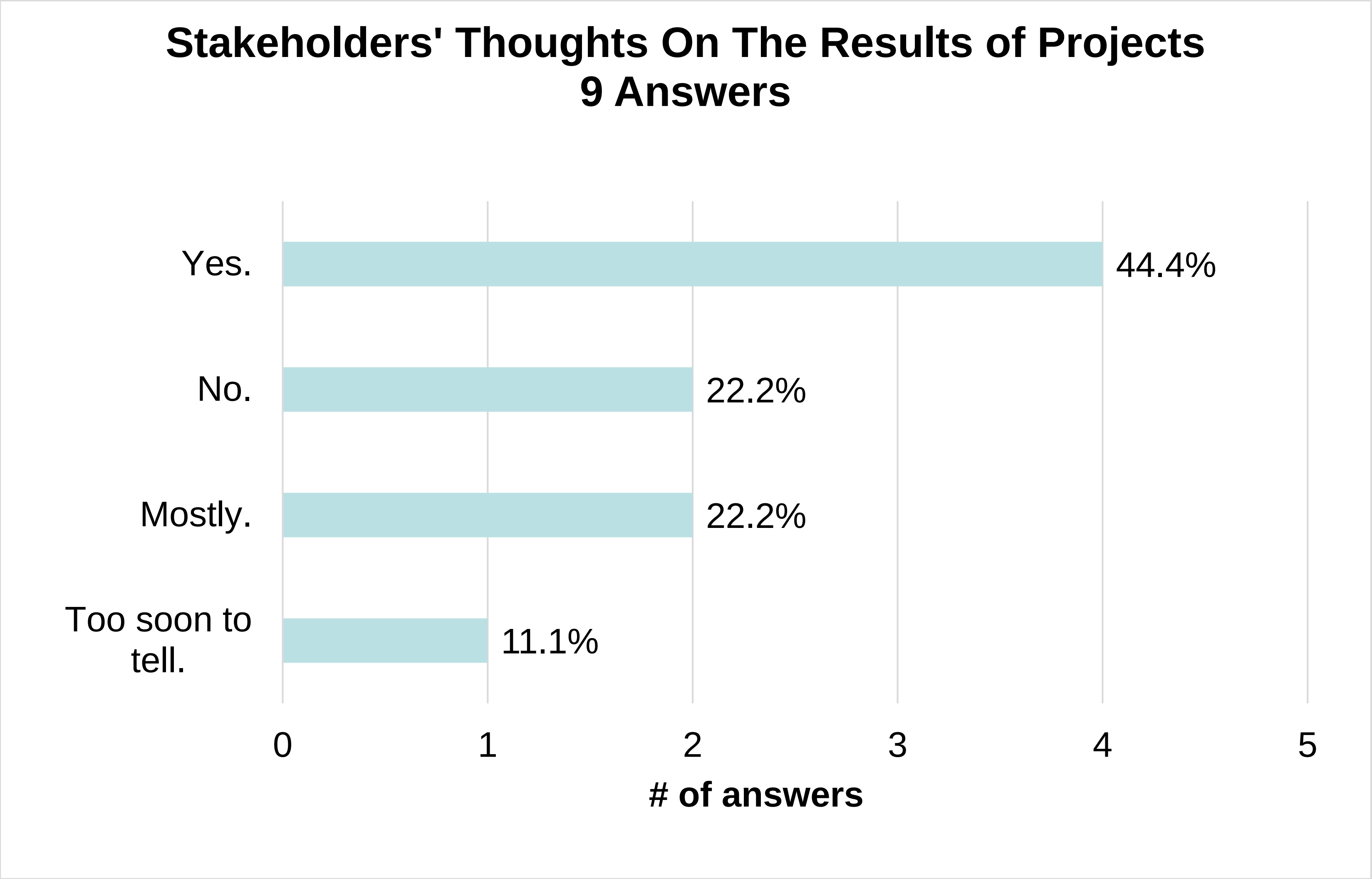
# ICPI Study: APT conclusions & use

- Conclusions:
  - Most rutting in top of subbase when wet at very high loads (close to 2x legal limit)
    - Adjust bedding layer design
  - Subgrade rutting diminished by increased subbase (reservoir) thickness
- Rutting models
  - Incremental-recursive models for each layer
  - Laboratory test data and layer elastic theory
  - Shear stress/strength ratio (SSR)

# ICPI Study: Design tool

- Design tool developed (*Excel*® spreadsheet)
  - Number of days with water in the subbase
  - Material properties
  - Traffic and load spectra
- Tool used to validate ICPI design tables
  - Less conservative than current ICPI for dry conditions
  - Slightly more conservative for very wet conditions

# Caltrans Survey of Local Agencies (underway)



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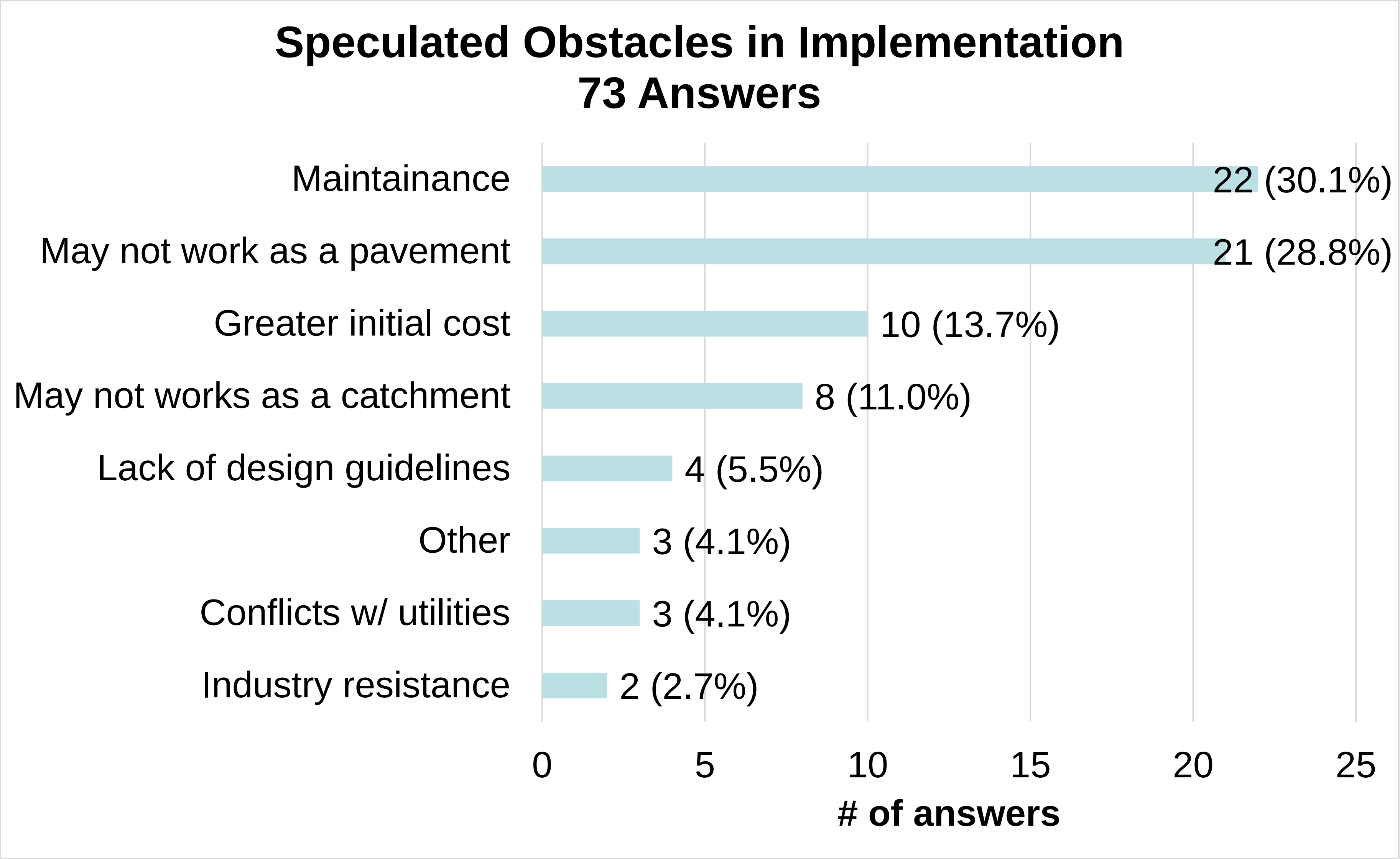
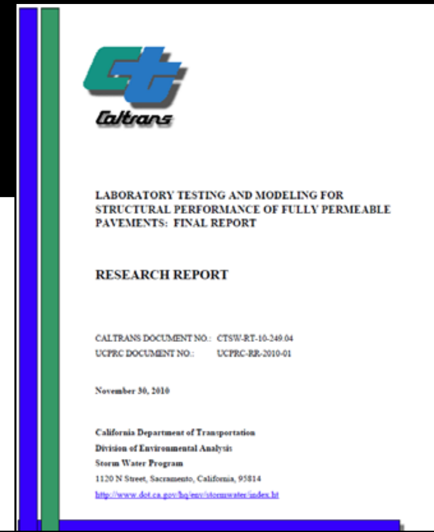


# Getting the Permeable Pavement Results

- Pervious Concrete and Porous Asphalt for Heavy Traffic
  - Preliminary permeable pavement designs that can be tested in pilot studies under typical California traffic and environmental conditions
  - http://www.ucprc.ucdavis.edu/PDF/UCPRC-RR-2010-01.pdf
- Permeable Interlocking Concrete Pavement for Heavy Traffic
  - Design method and validation results
  - Being incorporated into ICPI and ASCE designs
  - http://www.ucprc.ucdavis.edu/PDF/UCPRC-RR-2014-04.pdf



Caltrans

LABORATORY TESTING AND MODELING FOR STRUCTURAL PERFORMANCE OF FULLY PERMEABLE PAVEMENTS: FINAL REPORT

RESEARCH REPORT

CALTRANS DOCUMENT NO.: CTSW-RT-10-249.04
UCPRC DOCUMENT NO.: UCPRC-RR-2010-01

November 30, 2010

California Department of Transportation
Division of Environmental Analysis
Storm Water Program
1120 N Street, Sacramento, California, 95814
http://www.dot.ca.gov/hq/env/stormwater/index.ht

# Questions?