The Role of Design Innovation from Empirical to ME and Beyond

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Implementing Innovative Design
Tuesday 1.00 pm

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Why do we need to innovate in our design methods?

- Our goals change
  - Network demographics: where are our pavement in their life cycle?
  - Traffic changes: numbers, tires, axle loads, suspensions
  - Cost, smoothness, noise, environment
- Our circumstances change:
  - Funding levels and willingness of public to pay for roads
  - Public awareness of Cost, smoothness, noise, environment
  - Bitumen properties
  - Relative costs of materials
  - Climate
  - Workforce
- Our knowledge grows:
  - Mechanics, materials, management, statistical methods
  - Materials, construction and performance data
  - Lab testing capabilities, field testing capabilities
  - New materials, new construction machines and methods

Historical example: California empirical design method

- Goal in 1920s and 1930s, develop rational thickness design curves
  - O. J. Porter (State Highway Engineer 1928-1941): shear failure of soaked soils
  - Developed simple laboratory test

    California Bearing Ratio (CBR)
  - Correlated performance with subgrade CBR

APT: Stockton Runway Test Section

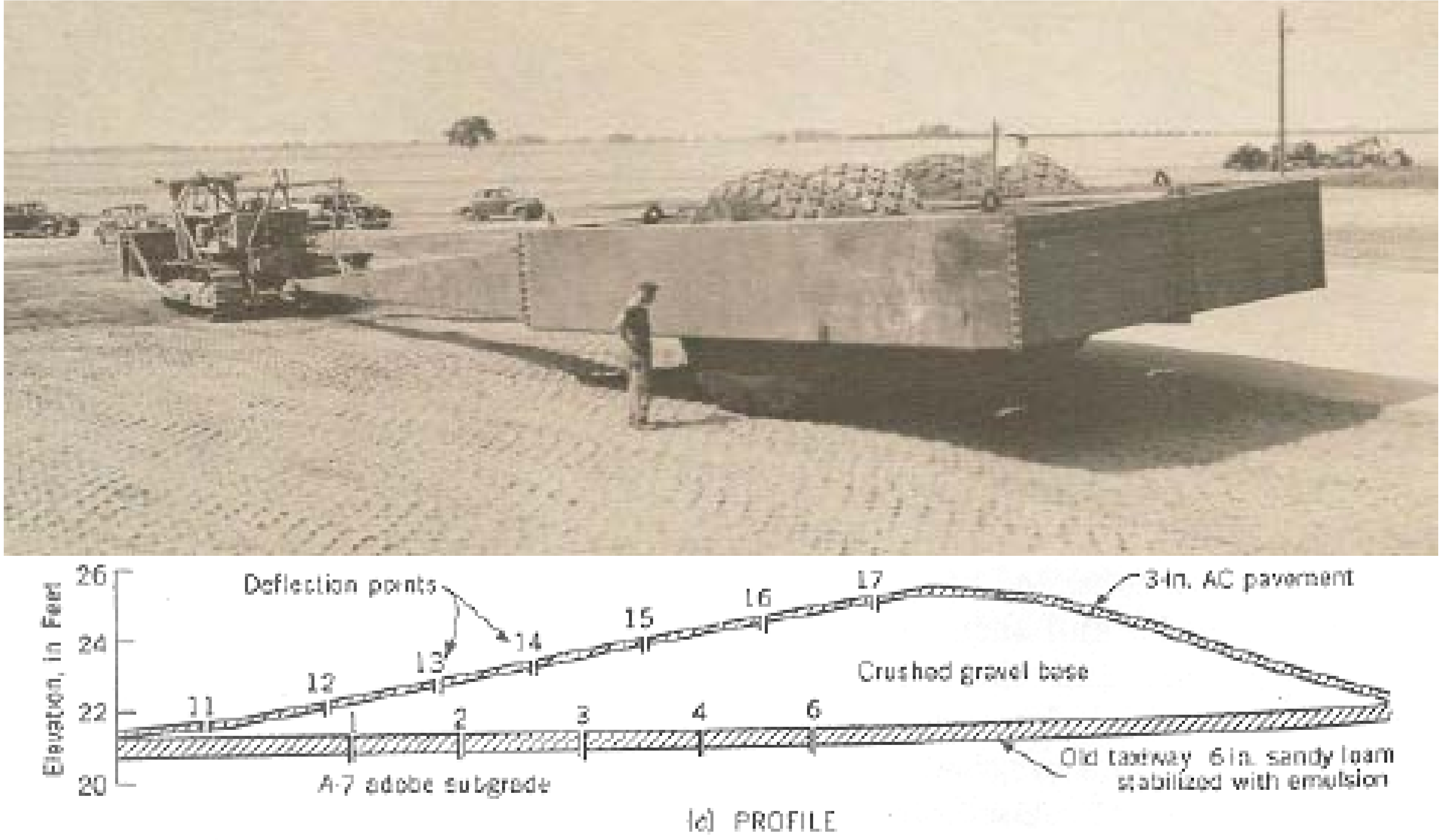


Fig. 13.—Stockton Runway Test Section

Continuous improvement 1940s to 1970s

- Brighton Test Track (1940-1943)
  - Design curves (1948)
- WASHO Road Test (1951- 1953)
  - Deflection test (Benkelman)
  - Wheel load factors
- Francis Hveem (Calif. DOT, 1942-1971)
  - Developed triaxial test device for design of soils and asphalt
  - Overlay design method (rehab) based on field sections
  - AASHO Road Test (1958-1960)
    - Compared pavement types
    - Performance vs axle loads (ESAL)
    - Ride quality parameter
    - Used to re-calibrate California designs

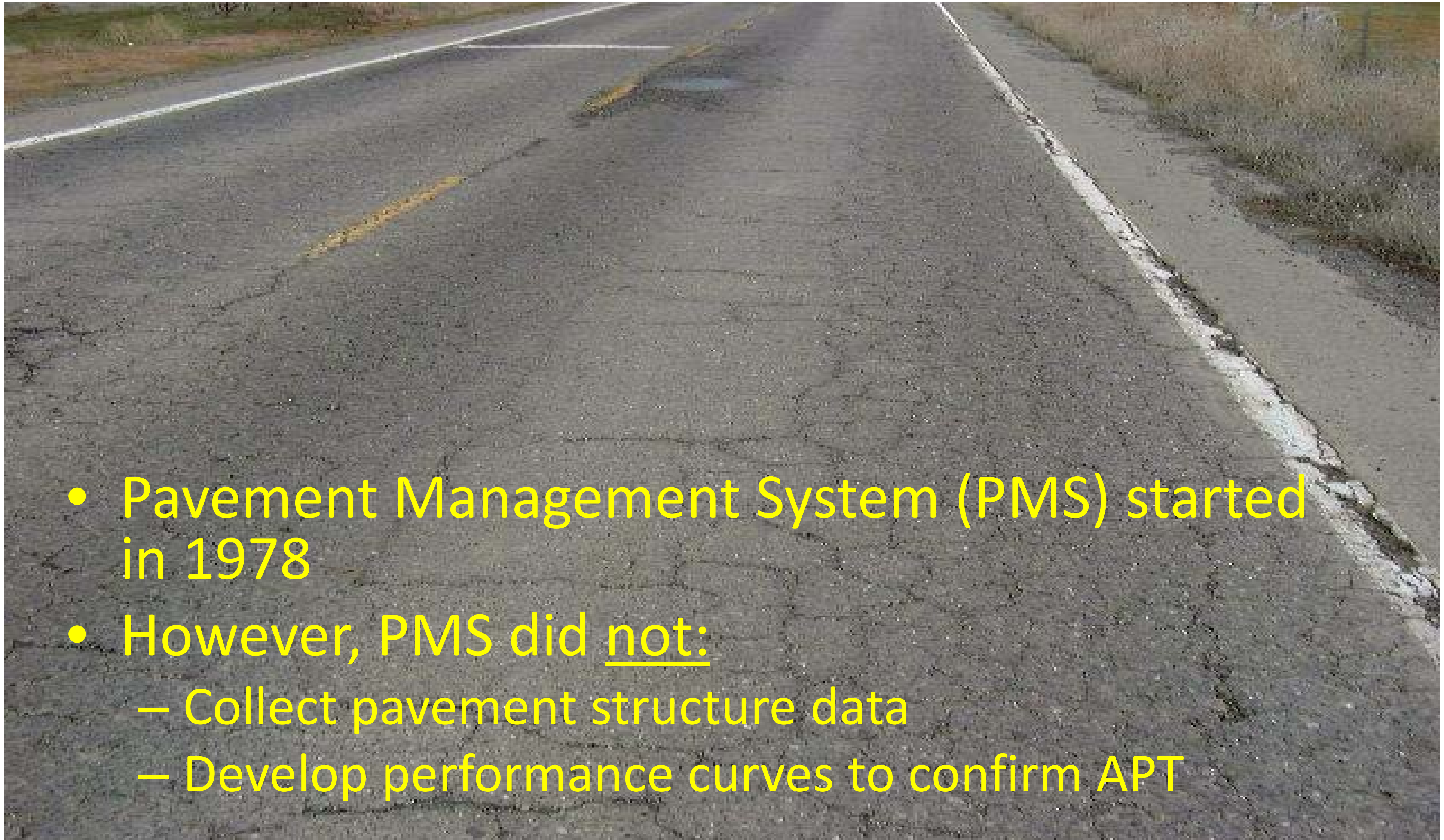
This evolution mostly stopped in USA after 1960s:

Why?

- Proposal to create satellite road tests around US after AASHO Road Test, didn't happen
- Perceptions:
  - High costs of research and development
  - "Problems have been solved"
  - Need to implement previous results
  - Difficulty implementing new research

- Research continued but little implementation
  - Link between research and implementation broken
  - Small, incremental changes
  - Less interest from young engineers
  - "Pavement engineering is cookbook"

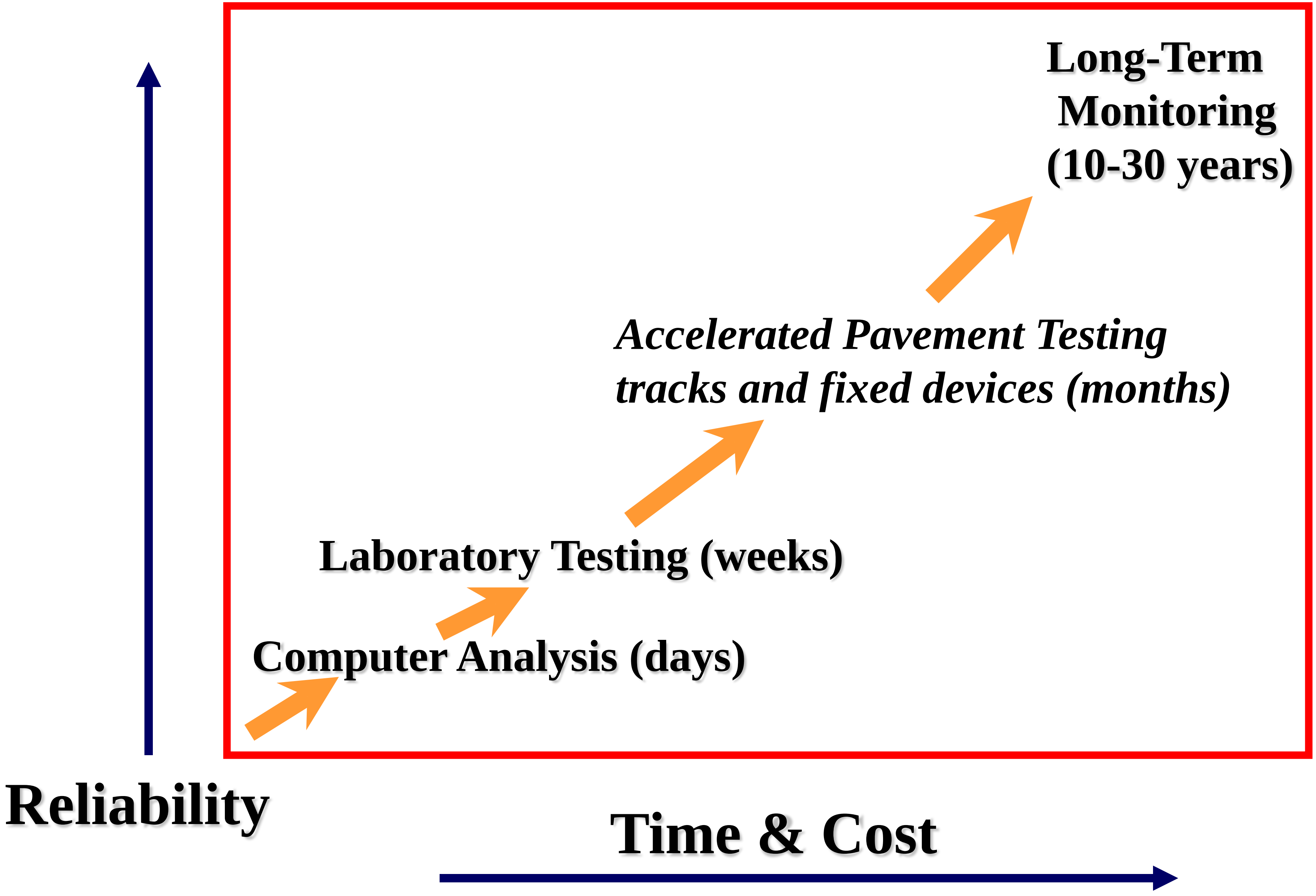
Responding to change: development of pavement management system



- Pavement Management System (PMS) started in 1978
- However, PMS did <u>not:</u>
  - Collect pavement structure data
  - Develop performance curves to confirm APT

Summary of historical example

- Connection of laboratory testing, APT and field observations
- Rapid checks and calibration of designs with APT
  - Fixed devices
  - Closed-circuit test tracks
- Quick implementation into standard practice
- Taking advantage of advances on many fronts
  - Materials, computers, testing ability, mechanics, statistics



Long-Term
Monitoring
(10-30 years)
Accelerated Pavement Testing
tracks and fixed devices (months)
Laboratory Testing (weeks)
Computer Analysis (days)
Reliability
Time & Cost

Why not rely only on observation of in-service pavements?

- Time
  - to build in-service pavement sections
  - to obtain performance measurements
- High risk of experimenting on network
- Difficulty collecting data over the service life
  - Traffic, climate, damage and performance
- Difficulty completing an experiment design
- Incompatibility of PMS, design method definitions
- However, we need to make better use of PMS data for feedback to our design methods
  - Location referencing over time
  - Compatibility of data (distress definitions for example)

New developments in California beginning in 2000

- New mechanistic design method
  - Development of new mechanistic design method
  - Process of continuous improvement re-established
  - Calibrated with California and other APT data
  - Issues with faster implementation still need work
- New PMS
  - Distress definitions tied to new mechanistic design and APT definitions
    - Crack length ratio for fatigue cracking
    - Same rutting definitions
  - Ground Penetrating Radar to fill missing as-builts
  - Implemented rigorous system of collecting as-builts
    - Next step is collection of QC/QA data
  - Developing PMS data to check design method

Improving design methods: study types

1. Identification and highlighting of deficiencies in current practices
2. Incorporation of new materials, designs, specifications or construction standards into method
3. Incorporation of data from performance related characterization instead of generic estimation

Improving design methods: study types

4. Updating of traffic and climate considerations: tires, wheel or axle types, suspensions, loads
5. Improvement of consideration of uncertainty in materials, soil conditions, drainanage and especially construction in reliability calculations
6. Periodic recalibration with network data

Improving design methods: study types

7. Improvements in calculations methods for temperatures, moisture conditions, stress/strain/deformation, damage, distress

All of these require

- High level support
- Vision, effort, coordination
- Good, compatible data
- Documentation
- Critical review

A look ahead:
Materials characterization and modeling

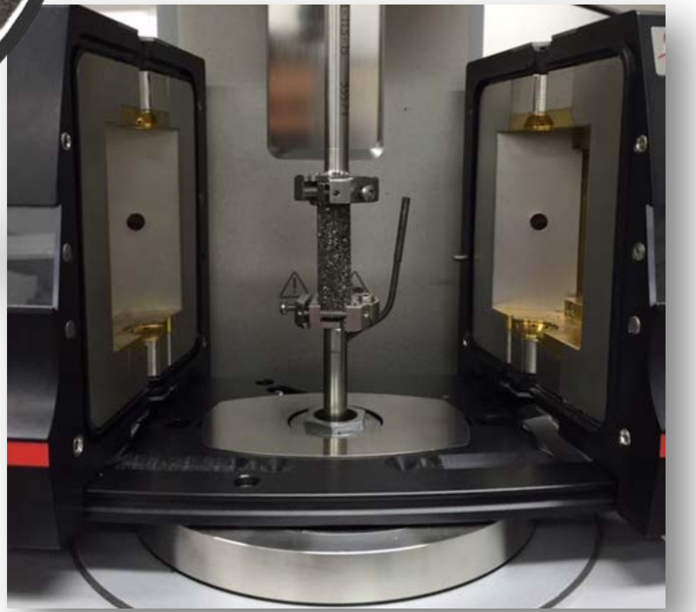
- Successes
  - Capabilities have increased at an exponential rate since 1990
  - Models and laboratory tests for most important properties
  - Dramatic reduction in need for empiricism
- Challenges to integration into specifications and practice
  - Speed often the issue more than cost
  - Importance of construction quality vs materials quality
  - Extend to new materials
  - Integrate into pavement design, specifications
  - Find young engineers interested and capable of using these advances in routine practice

Implementation of new knowledge in pavement design methods

- Are these advances being moved into pavement design?
  - Relationship of laboratory to in-place properties
  - Aging evolution of mix properties
  - Thixotropy, healing
  - Damage, fracture (other than Miner's Law), permanent deformation of asphalt and soils
  - Axle spectra, tire contact stresses, dynamic effects
  - Variability of all of above from construction methods and field condition and their effect on pavement reliability
  - Interaction of all of above and prediction of damage and distress
  - Preservation, recycling (plant and in-place) methods

Find ways to keep sophistication of testing and analysis, but make it faster and easier

- Where we can, make it
  - Smaller
  - Faster
- Without violating Representative Volume Element and other things we know



Strategic approach for improving pavement design

- Listen to stakeholders at top-level, and at other levels
- Develop strategic plan for improving design method
  - Set goals
  - Road map of projects to get to goals
  - Solve today and tomorrow's problems, don't focus on resolving yesterday's issues
- Avoid "not invented here" syndrome
  - Adapt as much as possible from elsewhere (it's cheaper), plus gives a broader range of ideas
  - Partner to get things done
- Document what is done and benchmark through international comment and review

Strategic approach for improving pavement design

- Fully capture the results
  - Mechanistic lab testing
  - Data quality control
  - Relational databases that can be mined years later
- Combine APT and field data between organizations as needed (must fully capture results)
- Have different types of people work on problems
  - Experimentalists
  - Mechanistic modelers
  - Empirical modelers
  - New insights from inherent conflicts between approaches, but must be manage to keep focus on results not methods
- Have strategies to move results into practice
- Continuous improvement

Questions?