Perpetual Pavement Design and Sustainability

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TOPICS

- Sustainability of Asphalt Pavements
- Perpetual Pavements
- Design of Perpetual Pavements
- Benefits of Perpetual Pavements
- Research/Future Developments

Objectives

- Explain concept of perpetual pavements
- Discuss sustainability regarding pavement design and construction
- Identify sustainable practices for pavement design, construction and renewal
- Review applicable design methods
- Review recent and on-going research and case studies

Sustainability

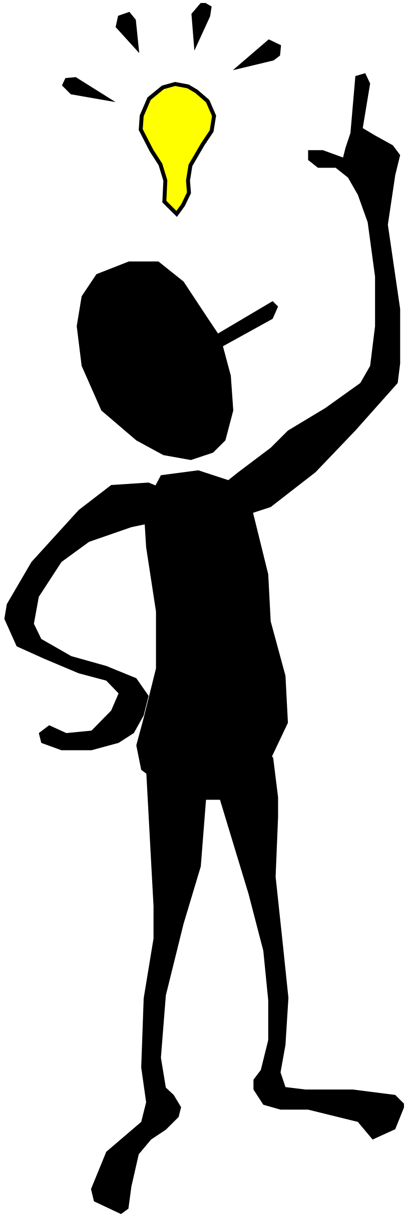
- Meeting the needs of the present without compromising the ability of future generations to meet theirs.
  - Conservation of resources (materials and energy)
  - Reduction of environmental impacts (GHG, carbon footprint, landfills, quarries, etc.)
- Growing awareness and demand from the public for sustainable practices.

Asphalt Pavements and Sustainability

- Lower energy consumption and green house gas emissions than concrete (COLAS, Robinette)
- Virtually 100% recyclable
  - Most recycled material in the US
  - Over 80% of old asphalt pavement reused
  - Reduces demand for new aggregates and binder
- *Beneficial* reuse of waste materials and by-products
  - Slags
  - Asphalt Shingles
  - Crumb rubber
  - Glass
  - Waste oils
  - Foundry sands

Asphalt Pavements and Sustainability

- Warm Mix Asphalt
  - Reduced fuel used for heating (15 to 30% reduction)
  - Reduced GHG
  - Construction benefits
- Porous Surfaces
  - Reduced noise (and need for noise walls), improved safety
  - Improved water quality
- Other benefits
  - Smooth → reduced vehicle maintenance, longer pavement life
  - Improved fuel efficiency
  - Reduced construction time → reduced user delay → reduced congestion, fuel usage, GHG
  - CO_2 sequestration



Perpetual Pavements

Recycling is great, but what is more sustainable than leaving the pavement in place?

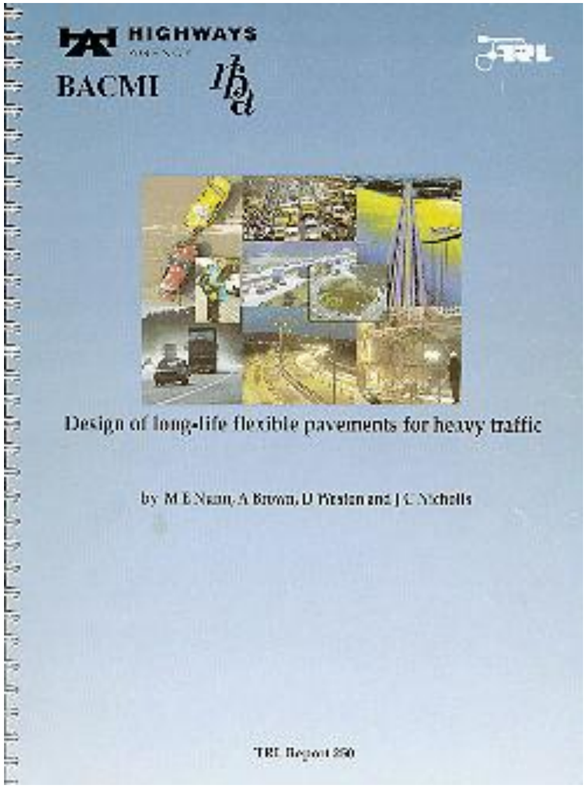
Perpetual = continuing or enduring forever

Perpetual Pavement

- Asphalt pavement designed to last over 50 years without requiring major structural rehabilitation and needing only periodic surface renewal.
  - *Full-depth pavement* – constructed on subgrade
  - *Deep-strength pavement* – constructed on thin granular base course
  - AKA *extended-life pavement* or *long-life pavement*

Concept

- Asphalt pavements with high enough strength will not exhibit structural failures even under heavy traffic.
- Distresses will initiate at the surface, typically in the form of rutting or cracking.
- Surface distresses can be removed/ repaired relatively easily,
  - Before causing structural damage,
  - Leaving most of pavement in place, performing well.



“The deterioration of thick, well constructed, fully flexible pavements is not structural, but occurs at the surface as cracking and rutting.”

TRL Report 250, 1997
Nunn, Brown, Weston & Nicholls

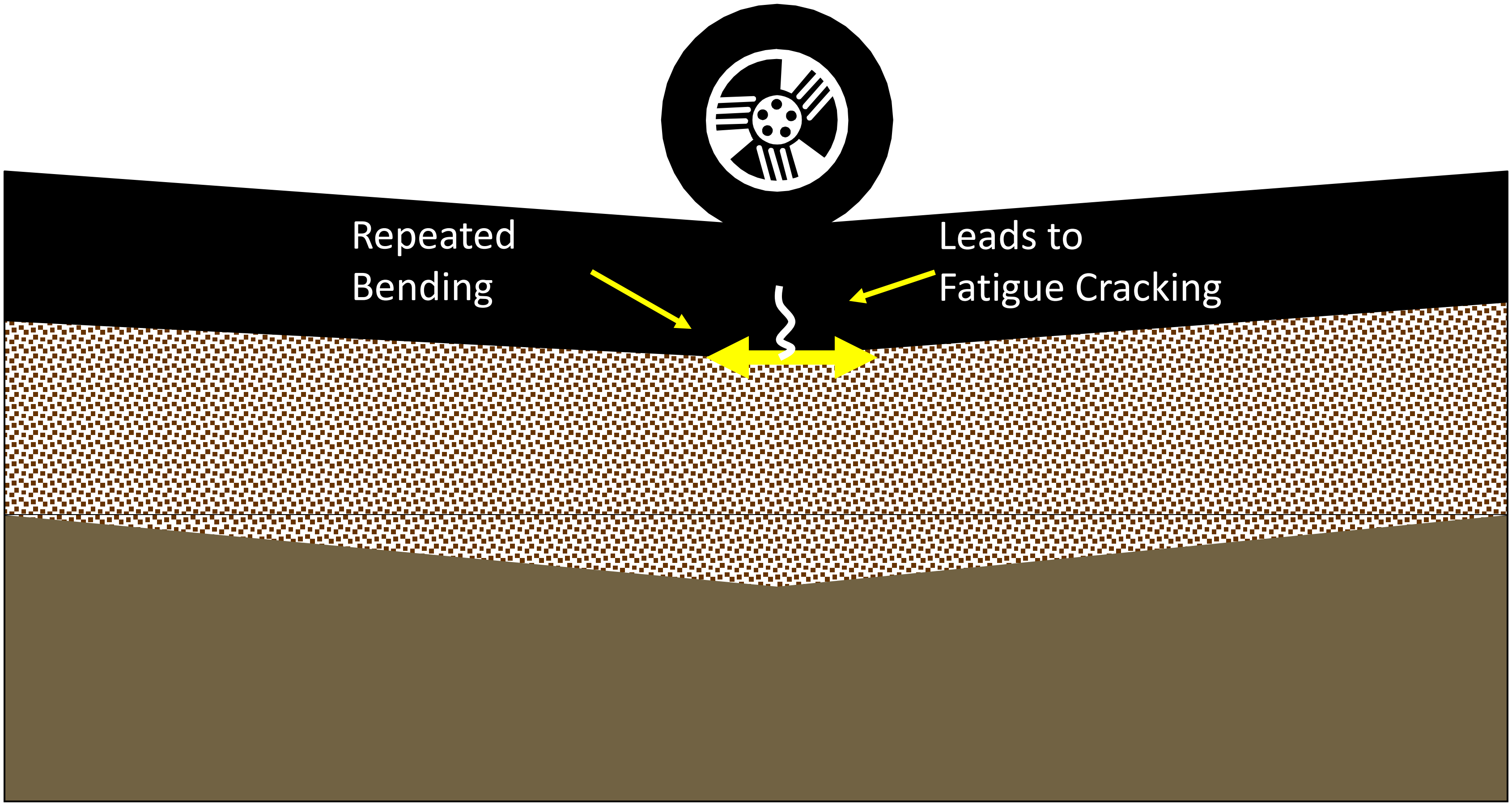
Design of Long-Life Flexible Pavements for Heavy Traffic

http:\\www.trl.co.uk

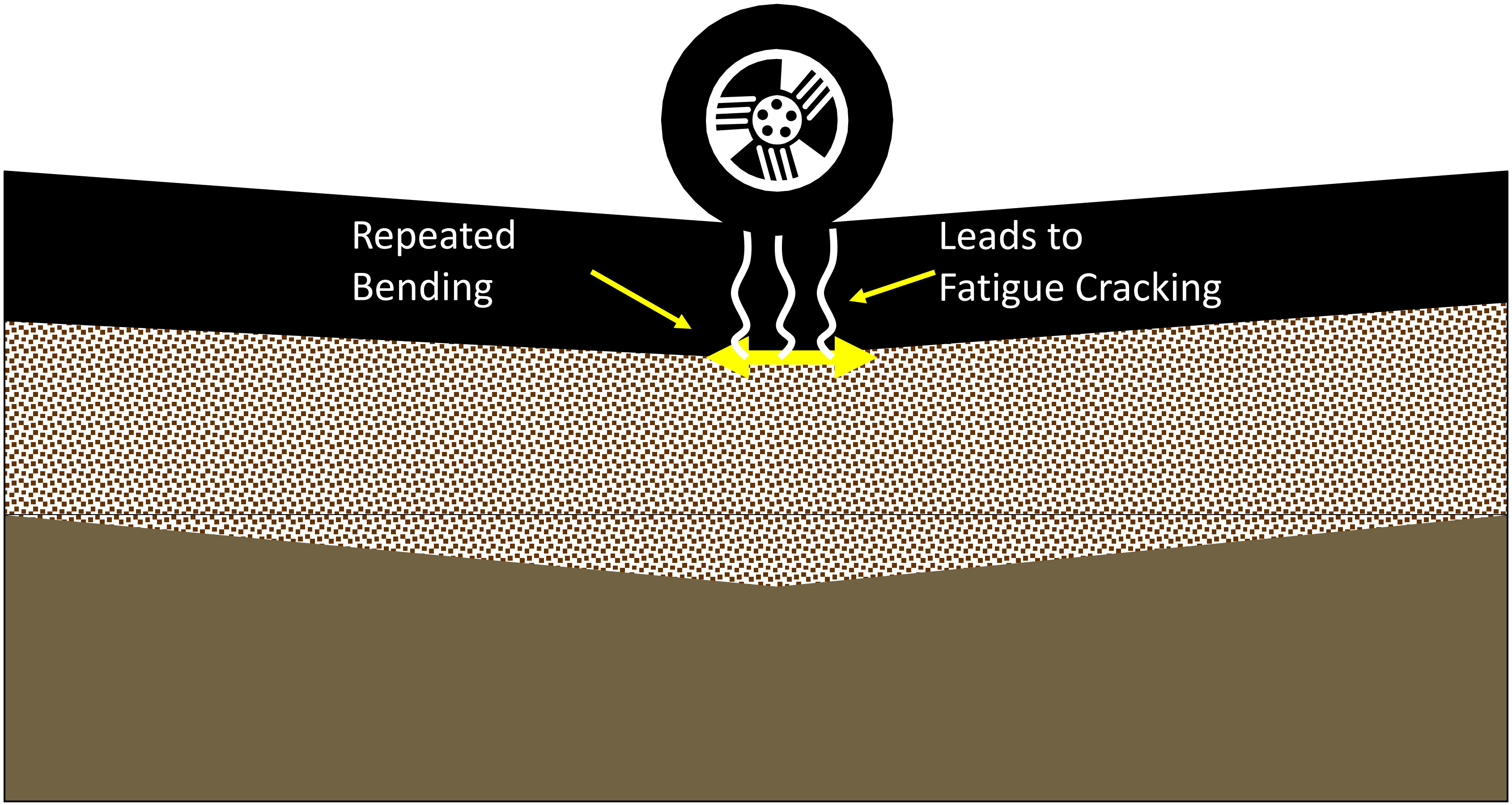
Perpetual Pavement Features

- Three layer system
- Each layer designed to resist specific distresses
- Base – designed to resist fatigue and moisture damage, to be durable
- Intermediate/binder – designed for durability and stability (rut resistance)
- Surface – designed to resist surface initiated distresses (top-down cracking, rutting, other)

Fatigue Cracking



Fatigue Cracking

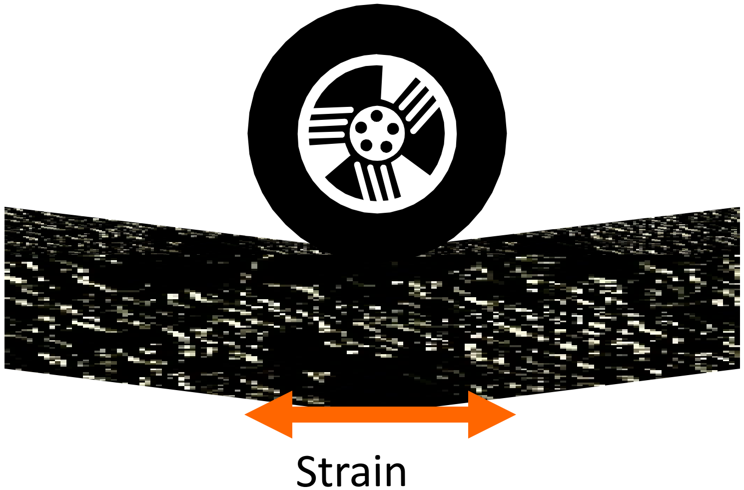


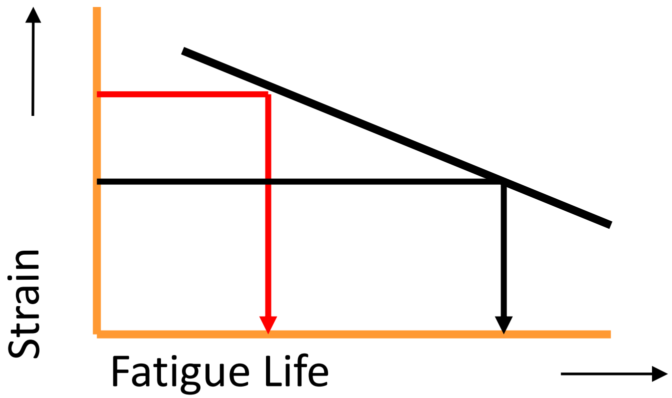
Fatigue Cracking

Fatigue Theory

High Strain = Short Life

Low Strain = Long Life





Extrapolations of loads from AASHO Road Test

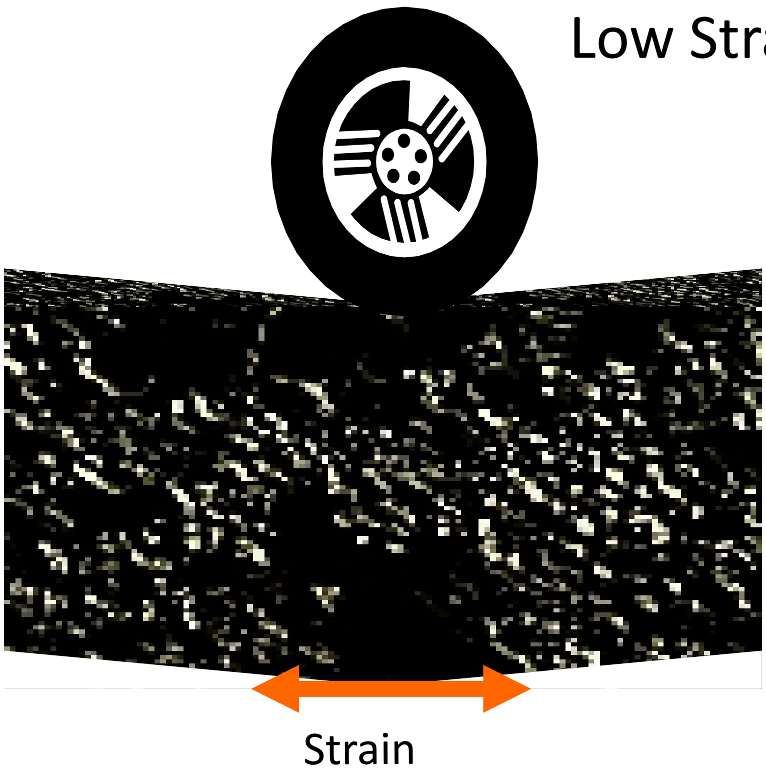
Extrapolation of Fatigue

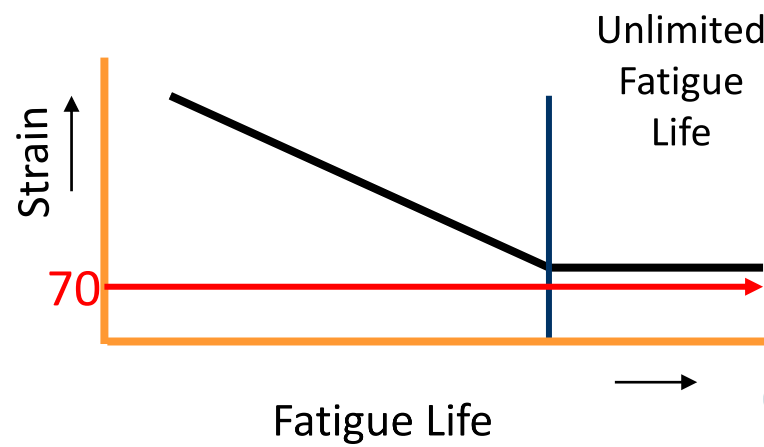
- Higher traffic leads to thicker pavements
- Pavements may be over-designed
  - Over-conservative
  - Unnecessary expense
  - Not sustainable
  - Example - Indiana pavements over-designed by 1.5 to 4.5 inches using 1993 AASHTO Guide (Huber et al., 2009)

Fatigue Theory for Thick Pavements

High Strain = Short Life

Low Strain = Unlimited Life

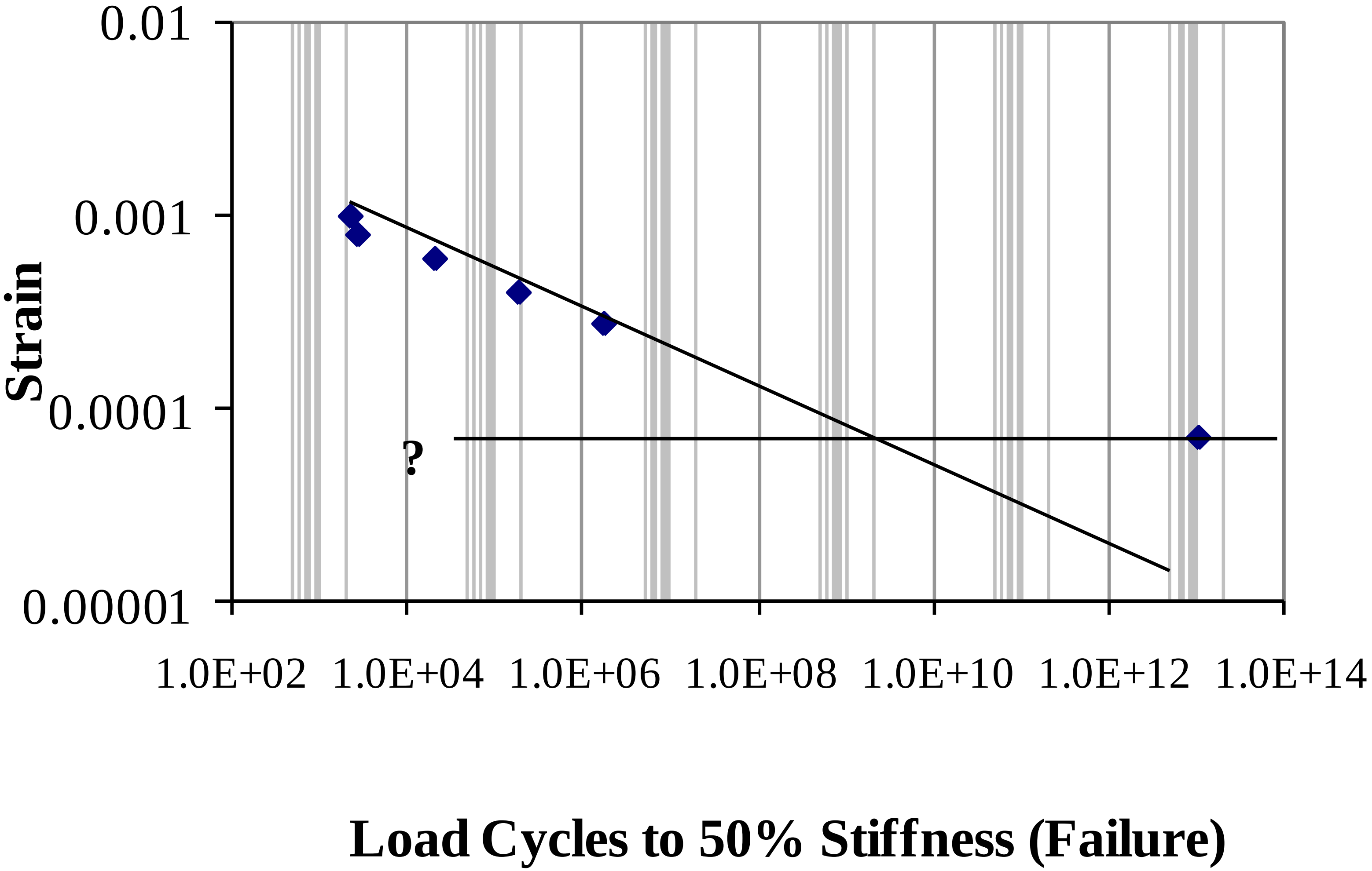


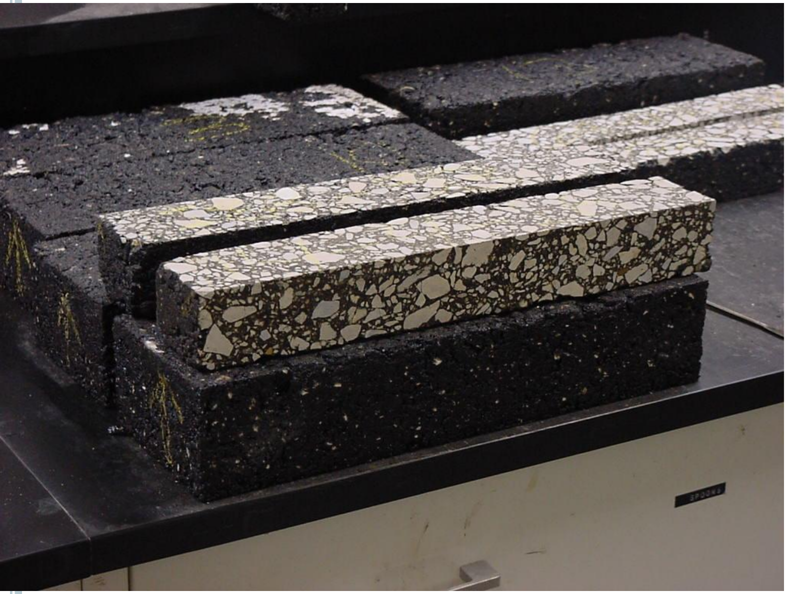


Fatigue Endurance Limit

- Strain level below which fatigue damage does not occur
  - 500 million loads over 40 years, Prowell et al., 2010
- Varying levels have been reported
  - 70 µЄ – Monismith and McClean, 1972
  - 150-200 µЄ – Mishizawa et al., 1996
  - 70-100 µЄ conservative – Willis, 2009
  - 75-200 µЄ – Prowell, et al., 2010
  - 100-250 µЄ – MEPDG
- Validating an Endurance Limit, NCHRP 9-44A

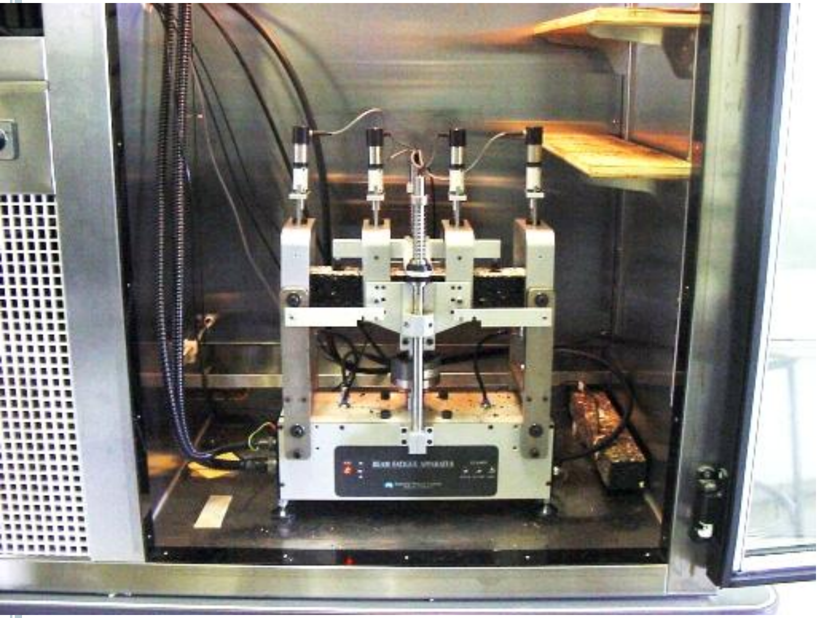
Traditional Fatigue Plot

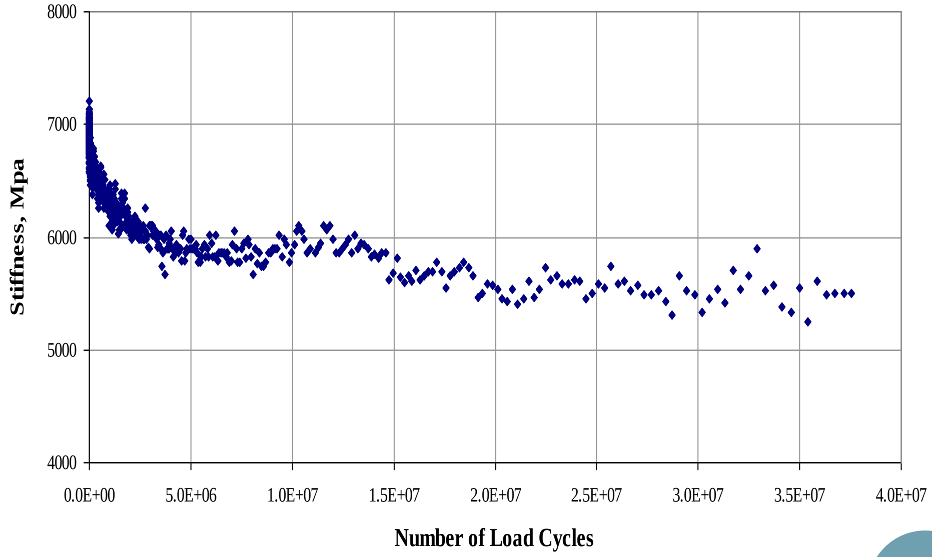




Measuring Fatigue

- Beam Fatigue
  - ASTM D7460-10
- Other protocols





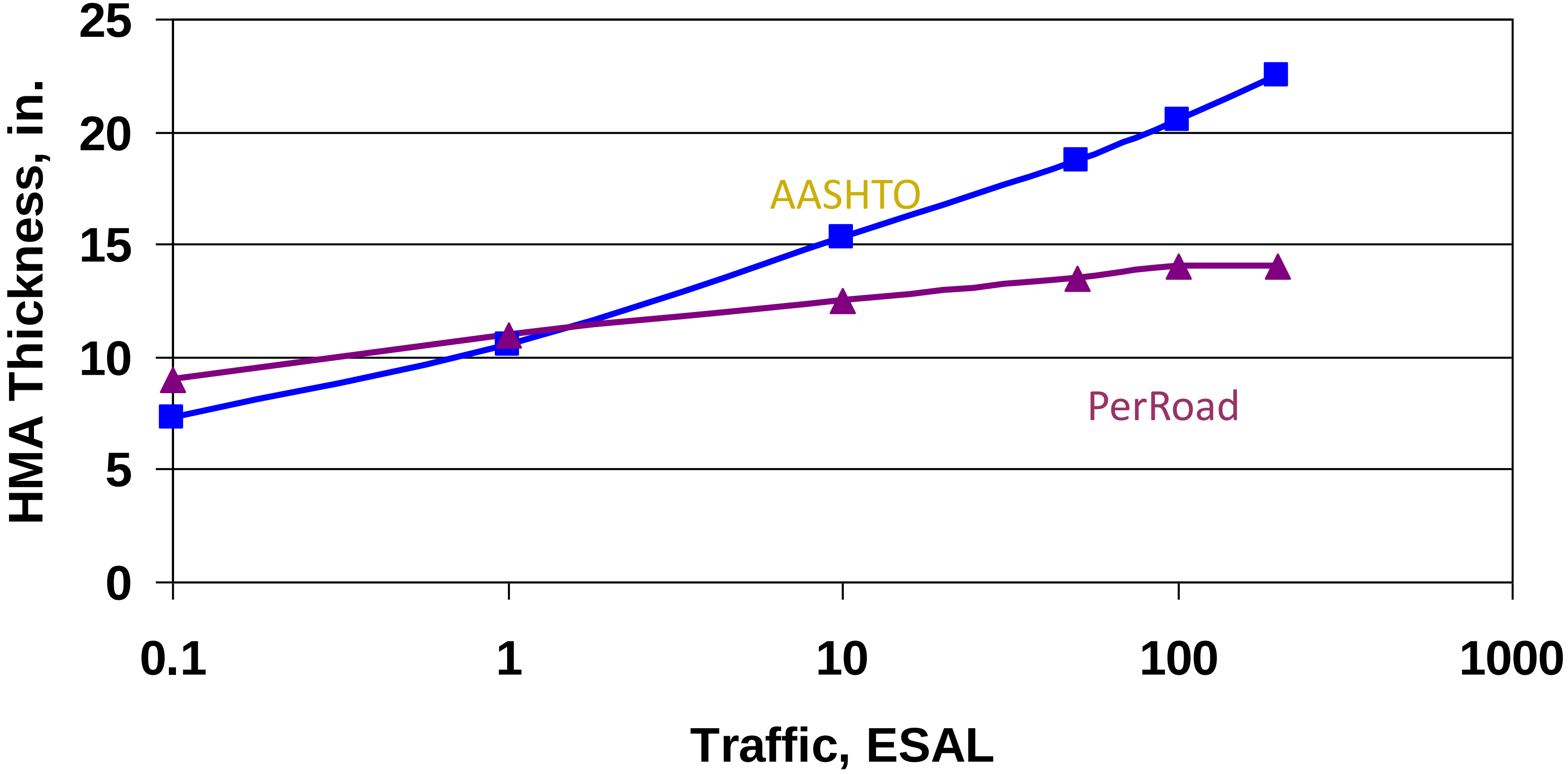
Design of Perpetual Pavements

- Limit strains at bottom of asphalt layer
  - Thick enough (>200mm) – but not too thick
- Fatigue resistant materials in lower layers
- Rutting and cracking resistant materials in surface layers
- Mechanistic-empirical approach best

Design Programs

- PerRoad
  - David Timm, NCAT/Auburn, Asphalt Pavement Alliance
  - *PerRoad 3.5* – ME approach
  - *PerRoad Express* – for low to medium volume roads and parking lots
  - www.asphaltroads.org/PerpetualPavements
- MEPDG
- Others

Perpetual Pavement versus Conventional Design

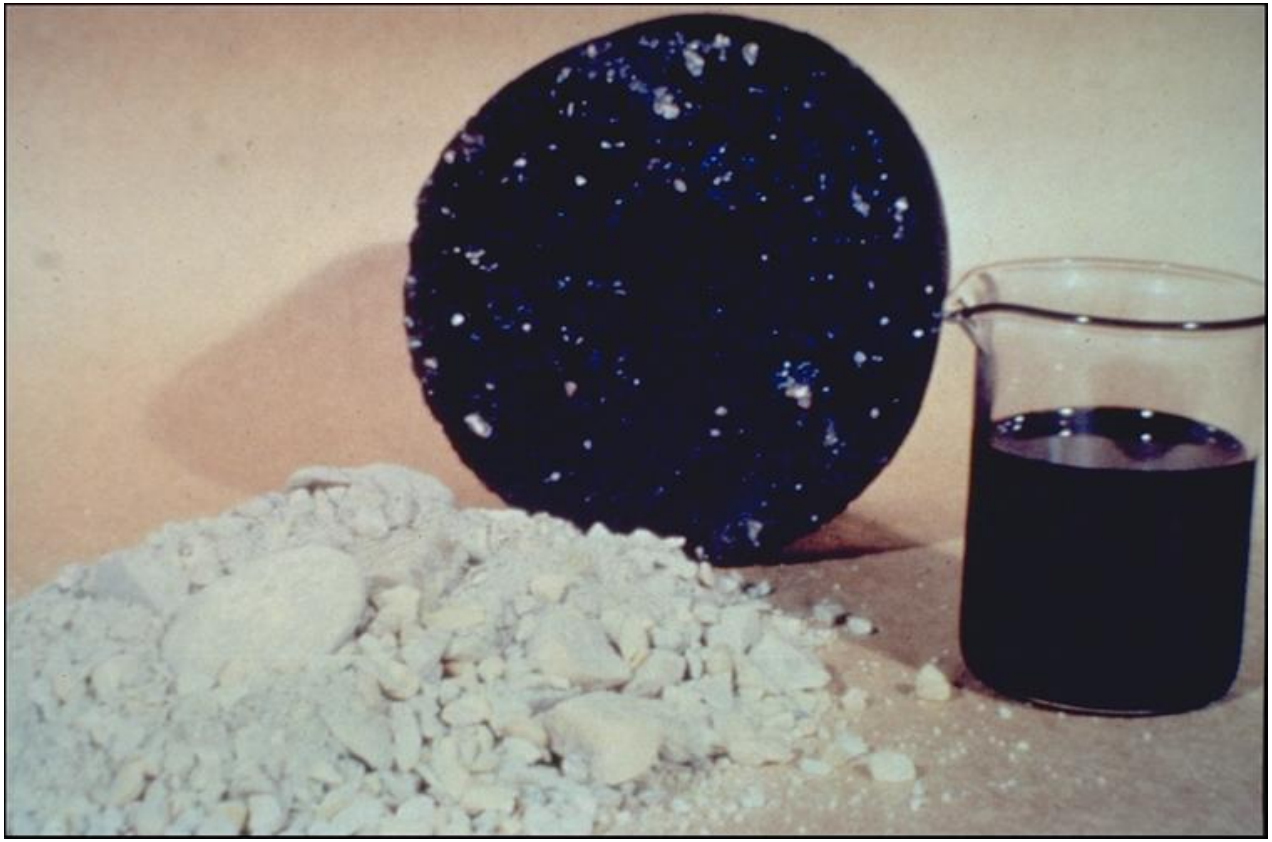


Design Options

- Stage construction
  - Plan for added thickness
- Make existing pavements perpetual with overlays
  - New Jersey example
- Low to medium volume roadways
- Rubblized concrete pavement foundation

Components of HMA Pavements

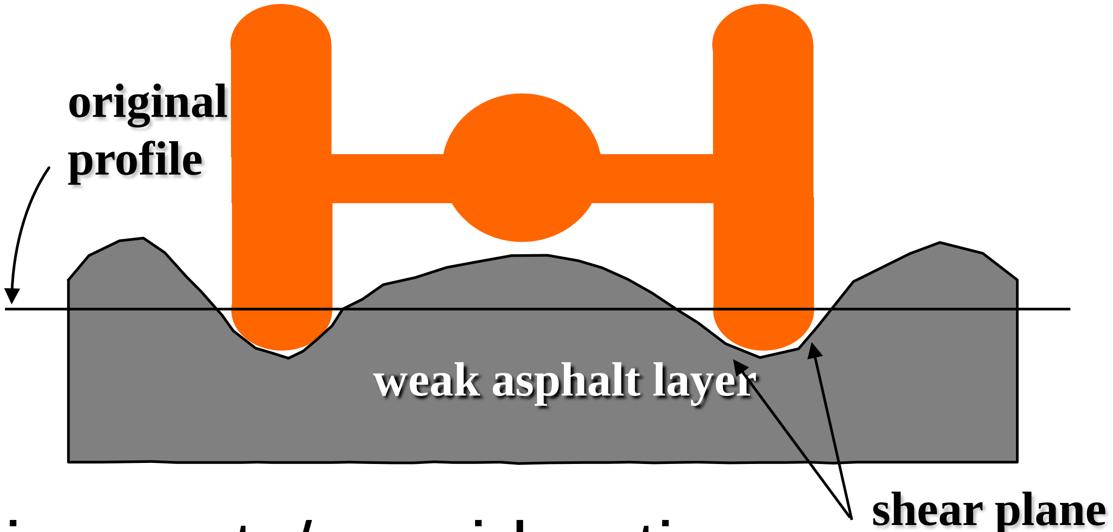
- Aggregates (~95% by weight or ~85% by volume)
- Asphalt Cement (~5% by weight or ~15% by volume)



Can include recycled asphalt pavement (RAP).

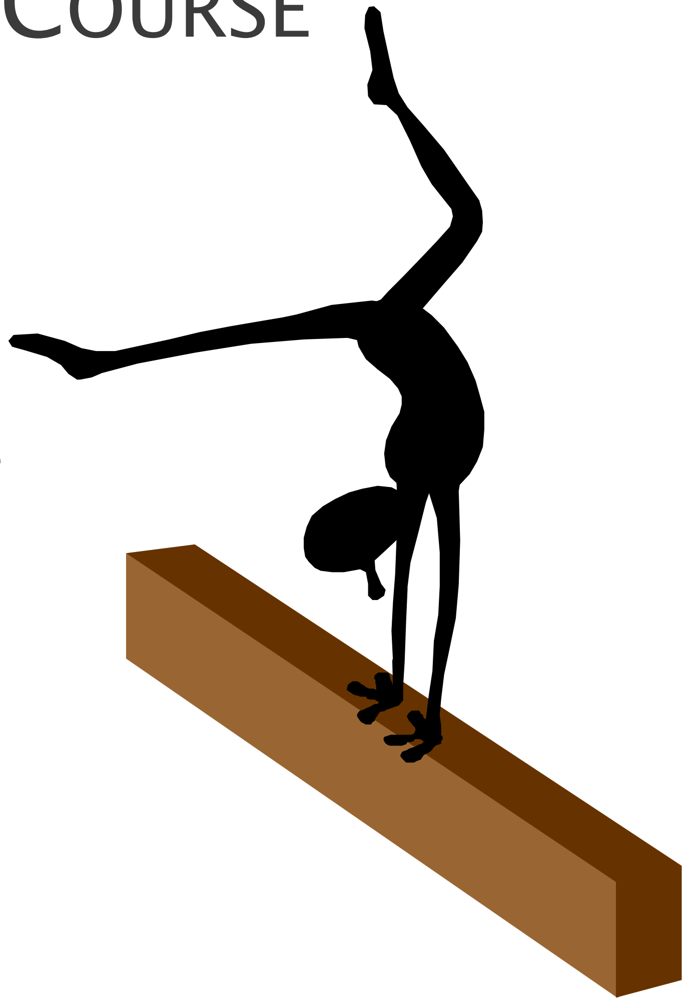
Surface/Wearing Course

- High quality HMA, SMA or OGFC (38-75 mm)
- Rut resistant
  - Aggregate interlock
  - PG grade
- Crack resistant
  - PG grade
  - polymer, fibers
- High friction
- Other local requirements/considerations



Intermediate/Binder Course

- Stability
  - Stone-on stone contact
  - Angular aggregate
  - High temperature PG grade
- Durability
  - Proper air void content
  - Moisture resistant



Base Course

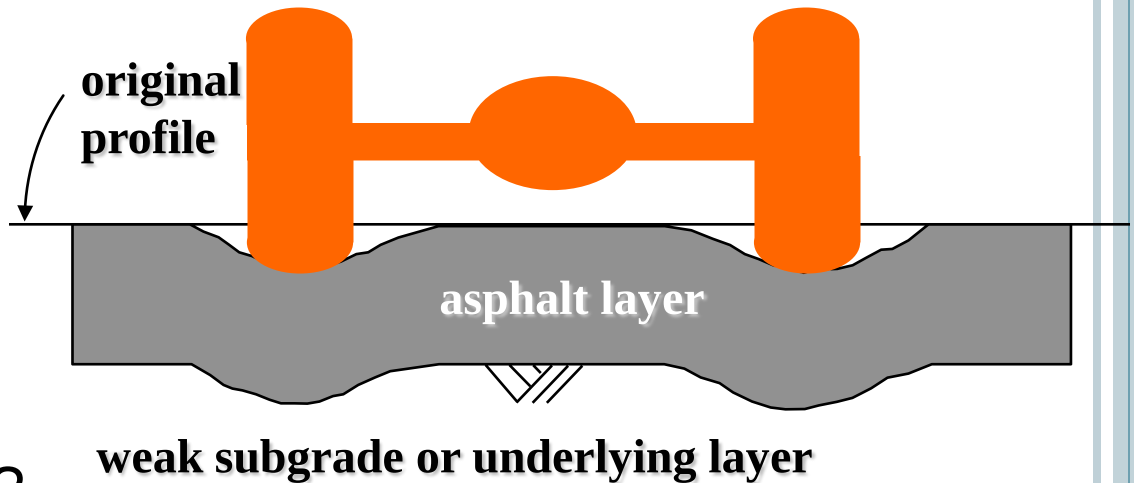
- Resistant to fatigue cracking
  - Higher binder content → lower voids, higher density → durability and fatigue resistance
    - Rich bottom bases – designed at 2-3% air voids
  - Binder grade
  - Fine gradation
  - Moisture resistant

Base Course

- Alternate – stiff base of adequate thickness to reduce strain
  - Hard binders
  - High modulus mixes – hard binder and high binder content
    - Stiffness reduces strains in subgrade (at equal thickness)
    - High binder content improves compaction, reduces fatigue

Foundation

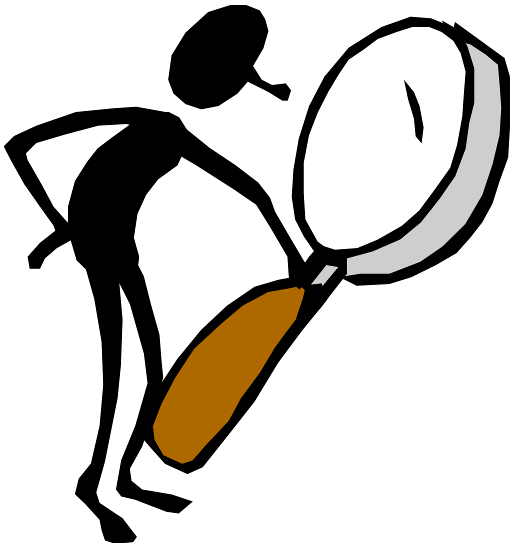
- Working platform during construction and support over service life
  - CBR ≥ 5%
  - Mr ≥ 7000 psi
  - Proof rolling
  - Stabilization
  - Positive drainage
  - Frost penetration?
  - Intelligent compaction?



CONSTRUCTION

- Conventional equipment and procedures
- Attention to detail/quality
- Compaction critical
  - Starting with foundation and including all layers
  - Density and air voids
- Avoid segregation
- Ensure good bonding between layers

Performance Monitoring



- Monitor pavement distresses
  - Thermal cracking
  - Minor surface rutting
  - Top-down fatigue
  - Raveling or functional problems
- Repair surface distresses before they become structural
  - Mill and fill
  - Thin overlay

Surface Renewal

- Repair surface distresses before they become structural
  - Mill and fill
  - Thin overlay
- Quick
- Cost effective

Performance and Case Studies

- Asphalt Pavement Alliance Perpetual Pavement Awards
  - Pavements more than 35 years old
  - No more than 4 inches added thickness
  - Overlays at least 13 years apart
  - More than 69 awarded to date!

New Jersey I–287

- Original construction in 1968
  - No rehab for over 26 years
- 10” of HMA on 8” crushed stone base on 10” of sand subbase
- Heavy traffic
  - 110,000 ADT in 1993 with 22% trucks
  - 20-year ESALs = 50 million
  - Slow, congested traffic

Fee; Rowe

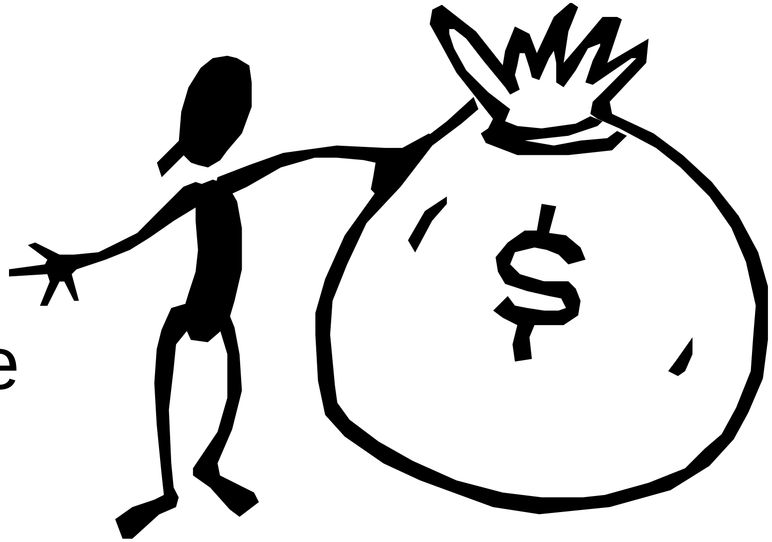
I-287 Rehabilitation

Mill 3” and Overlay with 4”

After rehab structural capacity = 69 million ESALs

“indeterminate pavement life” with surface renewal.

I-287 Economics



- Total rehab cost estimate
  - $429,000 per lane mile
  - No user costs included

- Perpetual pavement cost estimate (mill and fill)
  - $139,000 per lane mile
  - Faster construction → less delay, lower user costs

Case Studies: Ohio Study of Flexible Pavements

- Examined performance on 4 Interstate routes
  - HMA Pavements - Up to 34 Years without Rehabilitation or Reconstruction
  - "No significant quantity of work . . . for structural repair or to maintain drainage of the flexible pavements."

Case Study – Red Hill Valley Parkway

- 1997, Hamilton, Ontario
- Expected traffic up to 90,000 vehicles per day
- Environmentally sensitive area
- Perpetual Pavement vs. conventional
  - Reduced total CO_2 emissions
  - Reduced life cycle energy consumption
  - Somewhat higher emissions and energy for materials processing for initial construction
  - Much lower for later maintenance

Red Hill Valley Parkway

- 20 year Deep Strength design
  - 30 million ESALs
  - Total thickness 760 mm
  - 140 mm HMA, 150 granular base, 450 subbase
- 50 year Perpetual Pavement design
  - 90 million ESALs
  - Total thickness 760 mm
  - 120 mm HMA, 80mm Rich Bottom mix, 150 mm granular base, 370 mm subbase
- Life cycle costs favored Perpetual Design

Other Case Studies

- Washington State – I-90 (Mahoney)
  - No section required structural repair
  - Ages ranged from 23 to 35 years
  - Time to first resurfacing from 12 to 18.5 years
- Kansas Interstates (Romanoschi; Cross and Parsons)
  - Low strains in flexible pavements on US 75
  - Asphalt pavements more economical than PCC over 40 year life

Projects to Watch

- I-710 in California – perpetual pavement design constructed in 2003 with very heavy traffic (200 million ESALs!)
- Marquette Interchange in Wisconsin – instrumented pavement under heavy traffic
- I-695 around Baltimore – 175,000 vehicles per day

Benefits of Perpetual Pavements

Economics

- Lower life cycle costs
- Reduced user delays and costs
- No structural repairs means lower cost rehab
- Little to no added thickness preserves curb and gutter elevations, overhead clearance

Benefits of Perpetual Pavements

Sustainability/Environmental Benefits

- Better use of resources
- The ultimate in recycling
- Reduced CO_2 emissions
- Reduced energy consumption

Research/Future Developments

- NCHRP 9-44A, *Validating the Endurance Limit*
- NCHRP 9-44B, expected, field validation
- Intelligent Compaction potential
- Warm Mix Asphalt in Perpetual Pavements
  - Further reductions in energy, emissions
  - Compaction aid → better durability
  - Reduced binder aging → less thermal cracking, less fatigue, more RAP potential

Perpetual Asphalt Pavements

- Sustainable pavement lasting more than 50 years with periodic surface renewal
- Environmental and societal benefits
- Economical
- Design tools available
- Experience on different traffic roads in different climates and condition
- Conventional construction
- *History of successful use*

Credits/Important References

- Dr. Marvin Traylor, Illinois Asphalt Pavement Association (for use of slides and information)

- TRB Circular 503, *Perpetual Bituminous Pavements*, 2001
- *Perpetual Asphalt Pavements: A Synthesis*, 2010, AsphaltRoads.org
- TRL 250, *Design of Long-Life Flexible Pavements*, Nunn et al., 1997,www.trl.co.uk
- *Perpetual Pavement on Red Hill Valley Parkway*, Uzarowski and Moore, 2005, www.ohmpa.org

Important References

- *Energy, Emissions, Material Conservation, and Prices Associated with Construction, Rehabilitation, and Material Alternatives for Flexible Pavement,* Robinette and Epps, TRB 2010
- Huber, Andrewski and Gallivan, *Design and Construction of Highways for Very Heavy Trucks*, Proceedings, International Conference on Perpetual Pavements, 2009.
- Fee, *Perpetual Pavements: From Concept to Implementation*, Rocky Mountain Asphalt Conference, 2003, www.rmaces.org

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