Perpetual Pavements

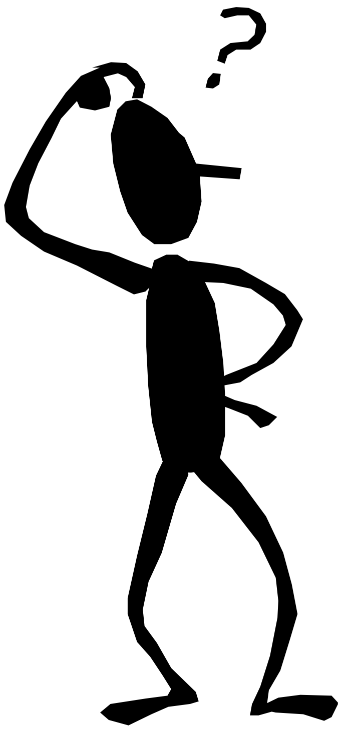
Rebecca S. McDaniel, PE, PhD
Technical Director
North Central Superpave Center
Purdue University

North Dakota Asphalt Conference, April 4, 2019

OBJECTIVES

- Define what perpetual pavements are.
- Explain the concept of perpetual pavements.
- Identify applicable design methods.
- Recognize suitable/unsuitable candidates.
- Consider potential benefits of perpetual pavements.

First



- What is a perpetual pavement?
  - Flexible pavement built to last indefinitely (>50 years).
  - Needing only occasional surface renewal.
  - New construction or existing pavement.

Existing Pavements

- Recognition that some existing pavements had lasted for 35 to 70 years.
- Minimal surface repair.
- Not intentionally designed to be perpetual.
- Asphalt Pavement Alliance coined term "perpetual pavements" ~2000.
- APA began awards program in 2001.
  - No more than 4 inches added thickness.
  - Overlays at least 13 years apart.
  - More than 126 awarded since 2001.

How Do They Last So Long?

- 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 and quickly,
  - Before causing structural damage,
  - Leaving most of pavement in place, performing well.

Flexible Pavements

- Made up of multiple, fairly thin layers.
- Pavement deflects under load.
- Each layer distributes load over larger area of layer below.
- Typically asphalt.
- Easily and routinely recycled.
- Typical lives 15-20 years (to first rehab).

What Can Go Wrong?

Rutting and Instability

- In asphalt layers or foundation.
- Poor mix design.
- Inadequate compaction.

Thermal Cracking (Top Down)

- Contraction at low temperatures.
- Typically transverse, sometimes block.
- Control by binder grade selection.

Reflective Cracking

- Also transverse, but bottom up.
- Over joints and cracks in lower layer (usually overlay over concrete).
- Crack and seat or rubblize concrete/ reclaim asphalt.

Longitudinal Cracking

- Construction or traffic related.
  - Paver segregation, joint construction.
  - Beginnings of fatigue cracking?

Moisture Damage

- Water enters pavement, disrupts bond.
- Drainage.
- Moisture resistant materials or antistrips.

Fatigue Cracking

- Alligator cracking.
- Excessive deflections – poor structure/foundation or high traffic.

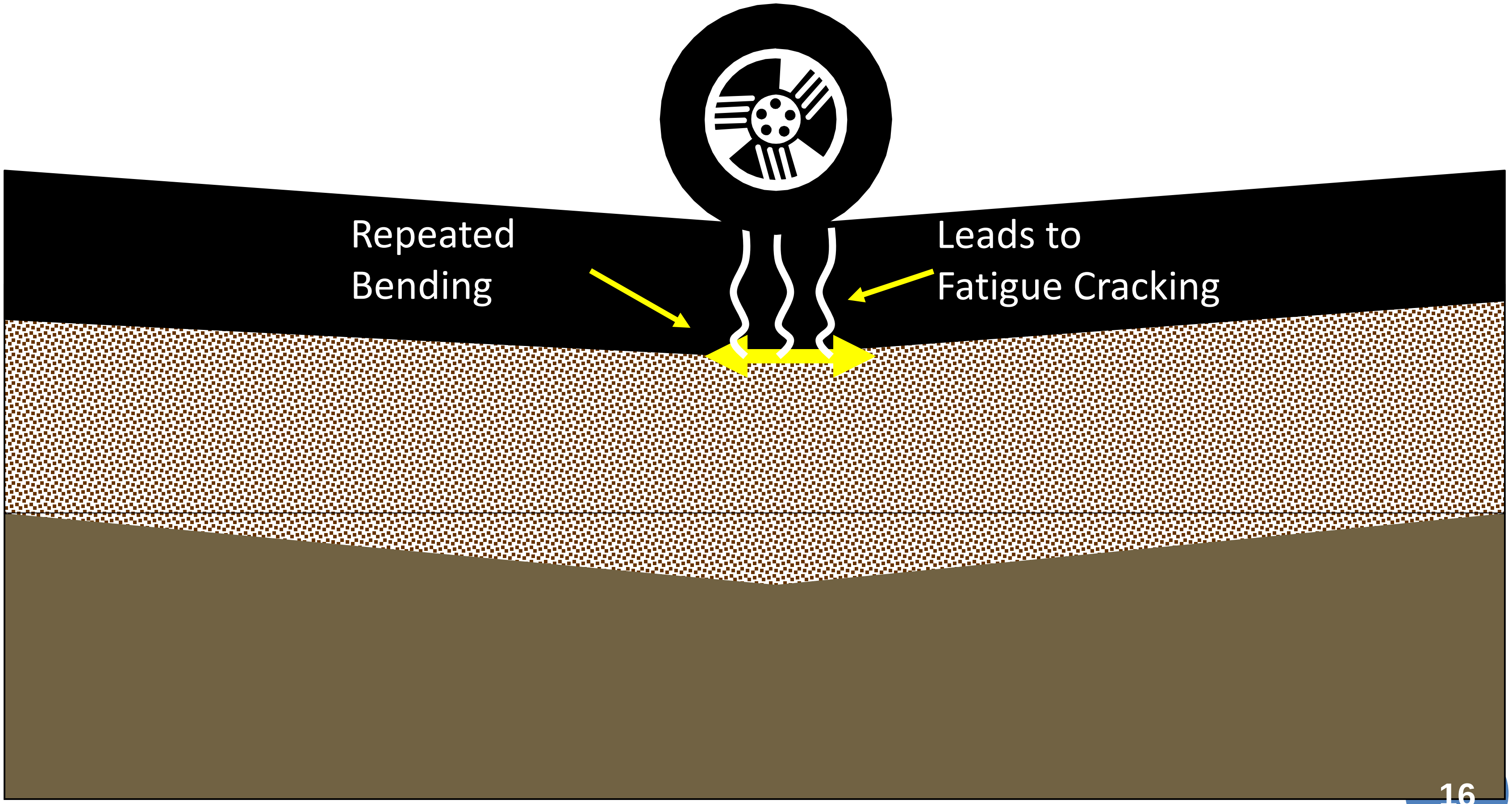
How Can We Achieve Long Life?

- Preventing fatigue cracking is key to long-life.
  - Rutting, cracking or moisture damage in lower layers can contribute to structural issues.
- Confine distress to surface layer(s).
  - Rutting – Proper material selection, mix design and production/construction.
  - Thermal cracking – appropriate binder selection for climate.

SURFACE RENEWAL

- Every 15-20 years.
- Quick.
- Cost effective.
- Repair surface distresses before they become structural.
  - Mill and fill
  - Thin overlay
- Keep most of pavement in place

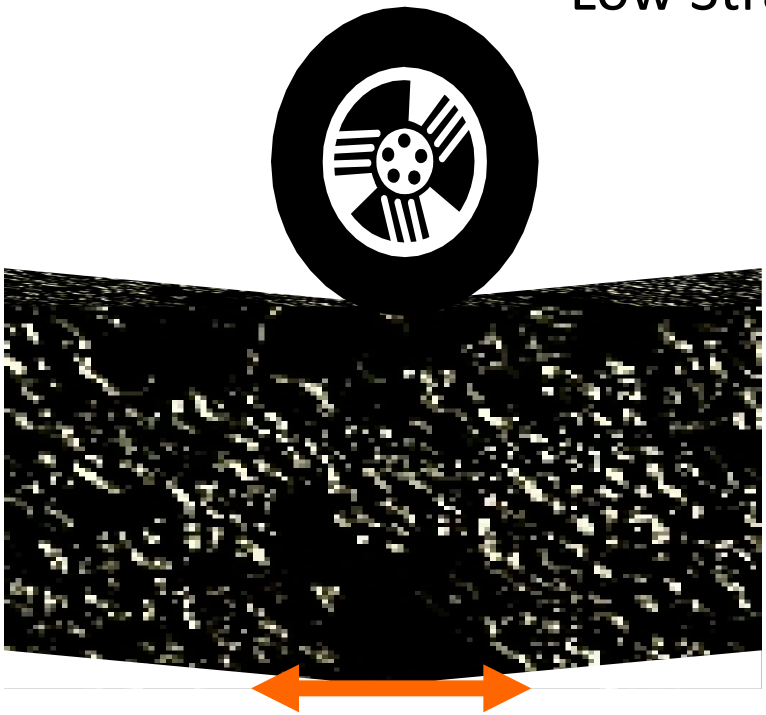
Fatigue Cracking

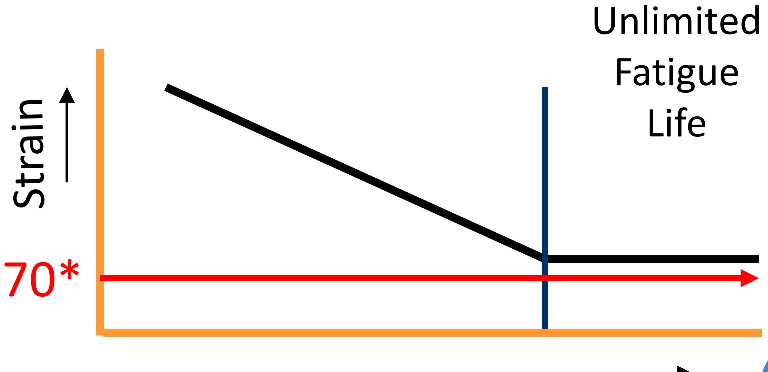


Perpetual Pavements

High Strain = Short Life

Low Strain = Unlimited Life





Fatigue Endurance Limit (FEL)

- 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/Pavement ME

Perpetual Pavement Features

- Each layer designed to resist specific distresses.
- Base – resist fatigue and moisture damage.
  - Thick enough conventional base; lower voids, rich bottom base; high modulus/stiff base.
- Intermediate/binder – durable and rut resistant.
- Surface – resistant to surface initiated distresses (top-down cracking, rutting, other).

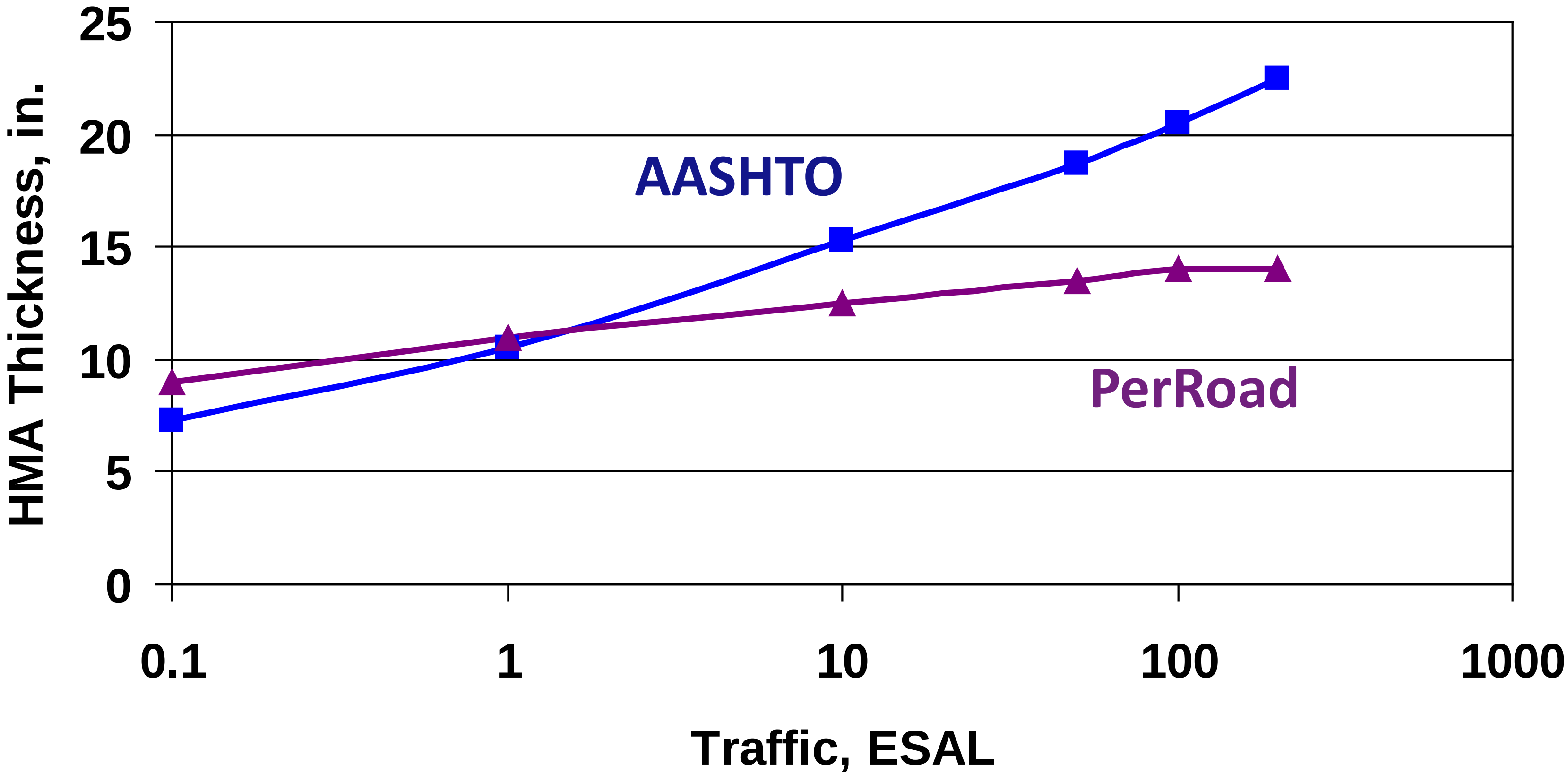
Perpetual Pavement Design Options

- New construction
  - Design and build to be perpetual.
- Stage construction
  - Plan for added thickness at later date.
- Make existing pavements perpetual.
  - Where structure is adequate or nearly so
  - SHRP2 report, *Using the Existing Pavement in Place and Achieving Long Life*
  - Existing asphalt or concrete pavements

Perpetual Pavements Sound Expensive

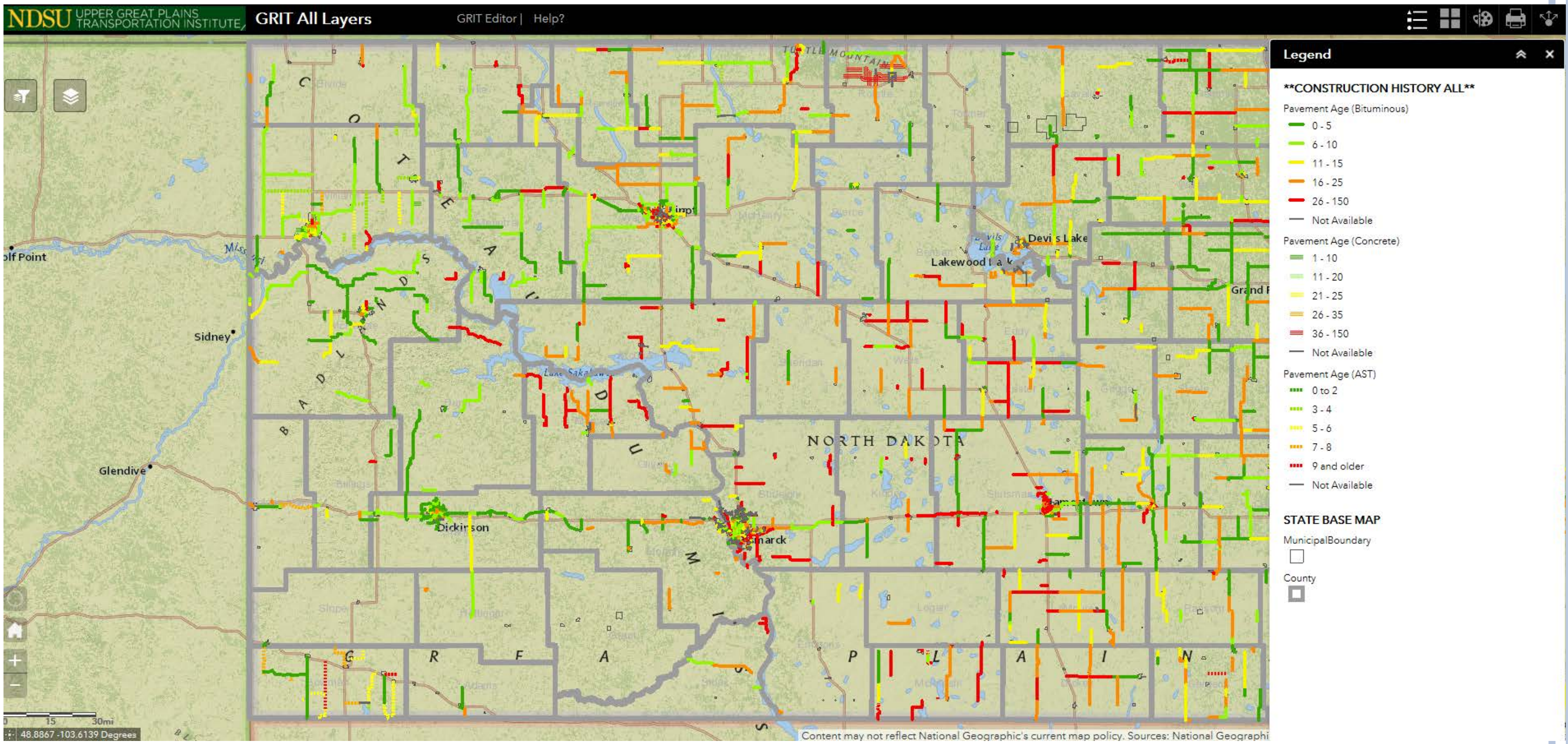
- Not necessarily.
- Pavement thickness may be comparable to or even less than conventional.
- Existing pavements may be or could become perpetual.
- Costs for later rehabilitation are lower.
- User delay costs are lower.
- Safety is improved.

Perpetual Pavement vs. Conventional Design



Mechanistic design can be thinner and less expensive!

Geographical Roadway Inventory Tool (GRIT)

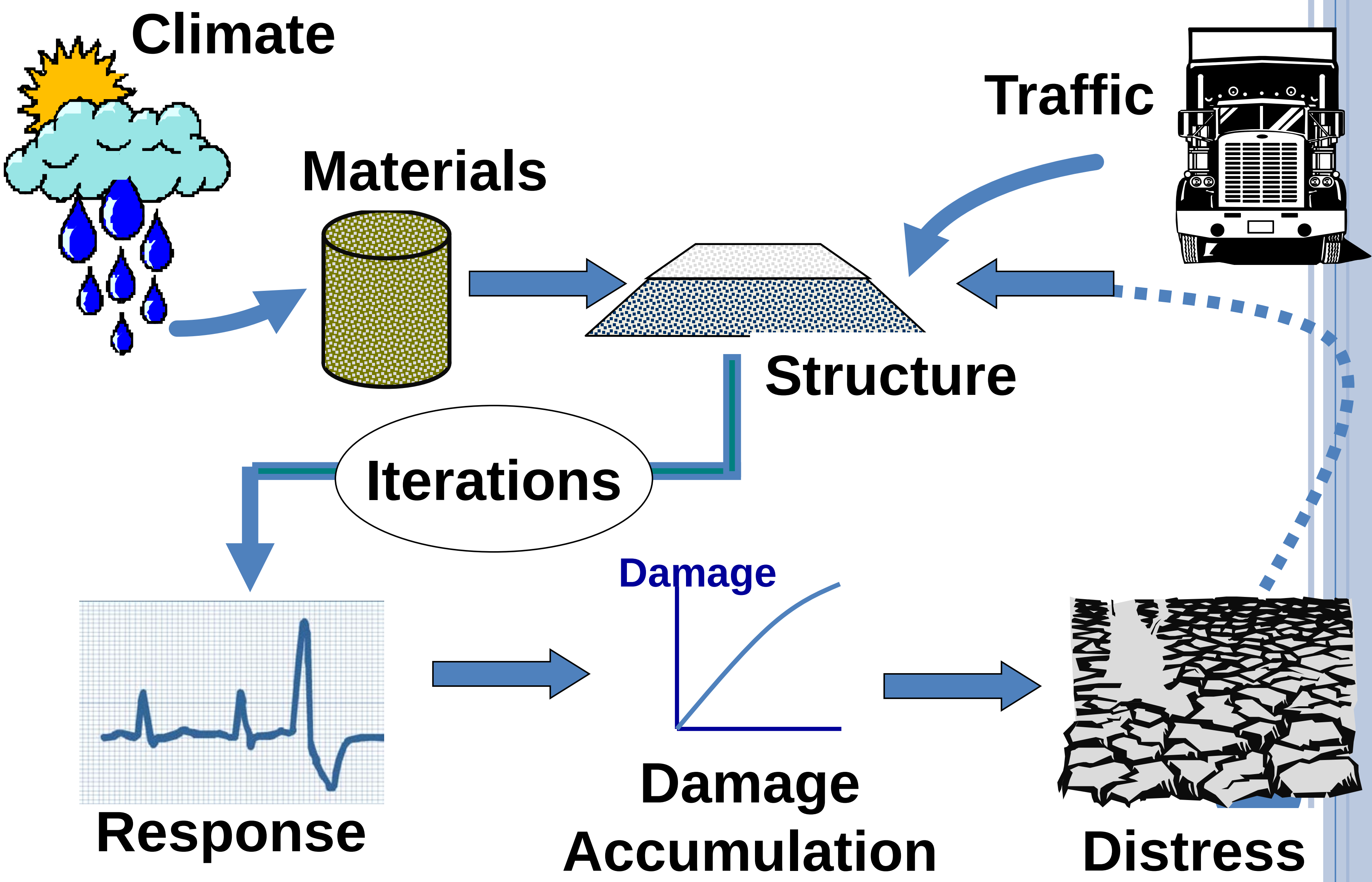


ORANGE 16-25 years; RED >26 years

Pavement Design Methodologies

- Empirical
  - Statistical models from road tests (AASHO)
  - AASHTO 1993
- Mechanistic-Empirical (M-E)
  - Calculation of pavement responses, i.e., stresses, strains, deformations
  - Empirical pavement performance models
  - Pavement ME, PerRoad, PerRoad Xpress
- Mechanistic – not there yet.

M–E Design Process



Pavement Design Resources

- Perpetual Pavement Design Software asphaltroads.org/PerRoad
  - PerRoad 4.4
    - M-E framework requiring multiple inputs
    - High volume roadways
  - PerRoadXpress 1.0
    - Simplified
    - Low to medium volumes
- Pavement ME me-design.com/
  - AASHTOWare software

SUITABLE CANDIDATES – EXISTING ASPHALT

For overlay or mill and fill

- No or limited full depth cracking.
  - Repair limited full depth cracking.
  - Mill to remove surface cracking.
- Good foundation/subgrade.
  - No structural issues.
- No stripping in lower layers.
  - Remove upper layers if stripped.
- Adequate drainage.

Suitable Candidates – Existing Asphalt

- Asphalt pavements with deeper distresses.
  - Moisture damage, deep block cracking, >15% fatigue cracking.
  - Reclaim existing asphalt layers (CIR, HIR, FDR).
  - Smooth and compact.
  - Disadvantage – now counts as base, not asphalt layer; requires thicker overlay.

SHRP2 *Using Existing Pavements in Place* …

Suitable Candidates – HMA over Concrete

- Good foundation/subgrade.
- Adequate drainage.
- No pumping.
- Risk of reflective cracking – could crack and seat or rubblize.

- Over CRCP
  - Good bond between asphalt and concrete.
  - Absence of or few repaired major defects.

UNSUITABLE CANDIDATES

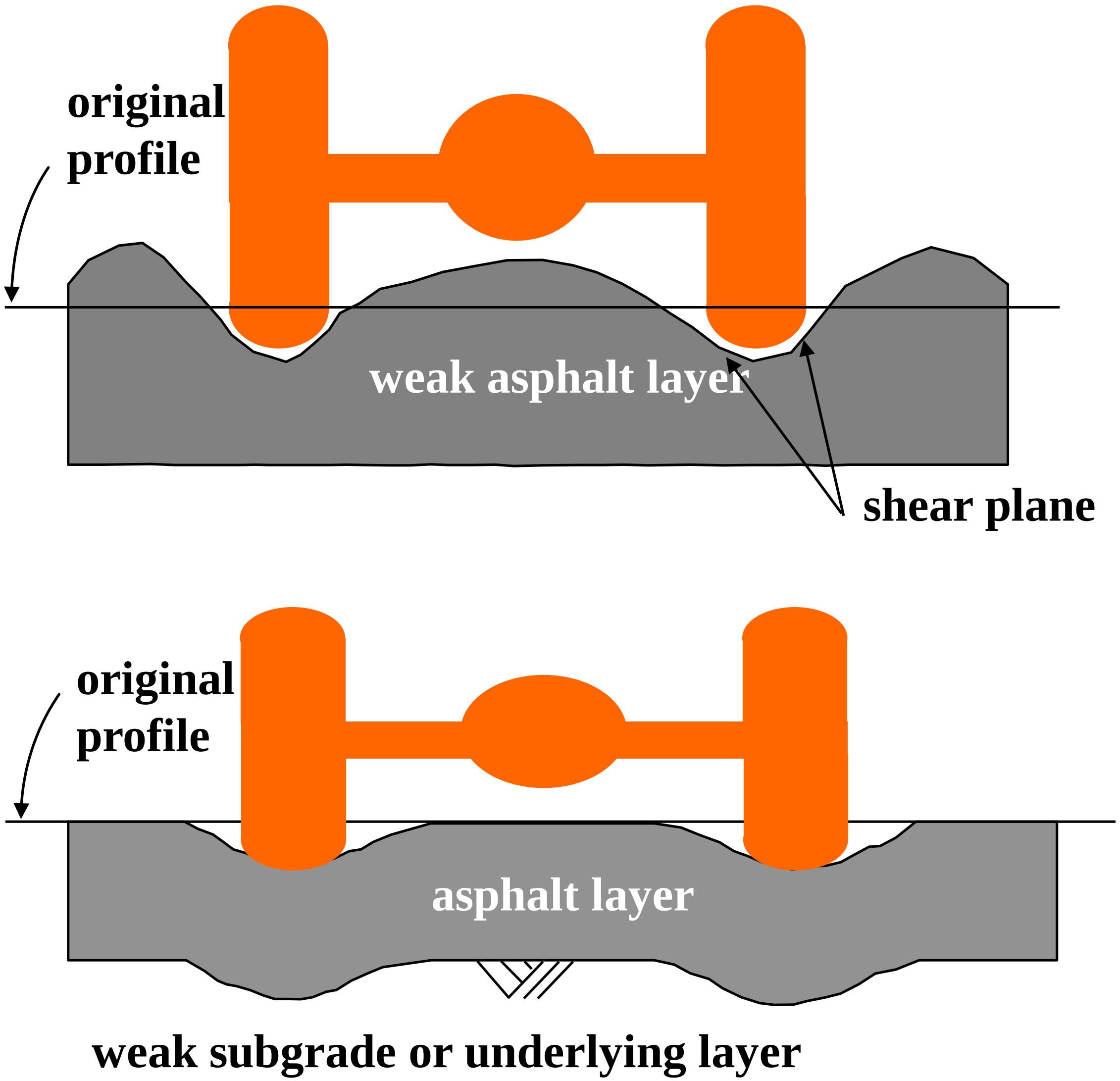
Making existing pavements perpetual may not be best choice:

- If deep problems (cracking, rutting, moisture damage) are too extensive.
  - Reclamation may be less cost effective (thicker overlay).
- If there are subgrade problems requiring repair.
- If there is risk of reflective cracking.
  - Cracking and seating or rubblizing increases cost.

Is It Structurally Sound?

- Ideally, evaluate with cores or trenches, FWD, DCP.
- No evidence of stripping (cores).
- No wide ruts/evidence of deformation in lower layers.
- No or limited alligator cracking.

Rough Suggestion of Structural Issue



Design Thicknesses

- Depend on existing pavement or base modulus, subgrade modulus and traffic.
- Higher pavement modulus → thinner lift.
- Higher subgrade modulus → somewhat thinner lift.
- Higher traffic → thicker lift.

SHRP2 *Using Existing Pavements in Place* …

Range of Total Design Thicknesses

- 5.5 in. for low-medium traffic with strong subgrade and existing pavement stiffness/ modulus.
- 14 in. for very high traffic with low base and pavement moduli.
- Subtract depth of asphalt in place (minus milled pavement) from total design thickness to get thickness of new asphalt

SHRP2 *Using Existing Pavements in Place …*

BENEFITS OF PERPETUAL PAVEMENTS

Sustainability/Environmental Benefits

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

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.

Perpetual Asphalt Pavements

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

NRRA

- National Road Research Alliance (NRRA) – Upper Plains Transportation Institute joined
- North Dakota DOT and NDSU are partners
- NRRA Pavement Workshop 2019
- MSP, May 21-23, 2019
- Flexible and rigid pavements, preservation, geotech, intelligent construction, rejuvenators, and more.

Useful References

- SHRP2 *Using Existing Pavements in Place and Achieving Long Life,* http://www.trb.org/Publications/Blurbs/171517.aspx
- TRB Circular 503, *Perpetual Bituminous Pavements*, 2001, http://www.trb.org/Publications/Pages/256.aspx
- APA *Perpetual Asphalt Pavements: A Synthesis*
- Proceedings of International Conferences on Perpetual Pavements, https://www.ohio.edu/icpp/

Rebecca S. McDaniel

Technical Director
North Central Superpave Center
Purdue University
West Lafayette, IN
765/463-2317 ext 226
rsmcdani@purdue.edu

Lyles School of Civil Engineering
150 YEARS OF GIANT LEAPS
PURDUE UNIVERSITY