PERPETUAL PAVEMENTS

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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.
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.
  - 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

Repeated Bending Leads to Fatigue Cracking
Perpetual Pavements

High Strain = Short Life

Low Strain = Unlimited Life

Strain

Unlimited Fatigue Life

70°

Fatigue 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

Climate

Materials

Structure

Iterations

Damage Accumulation

Response

Damage

Traffic

Distress
PAVEMENT DESIGN RESOURCES

- Perpetual Pavement Design Software [asphaltroads.org/PerRoad](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/](me-design.com/)
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.

SHRP2 Using Existing Pavements in Place …
**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.

SHRP2 Using Existing Pavements in Place …
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

- original profile
- weak asphalt layer
- shear plane
- original profile
- asphalt layer
- weak subgrade or underlying layer
**Design Thicknesses**

- Depend on existing pavement or base modulus, subgrade modulus and traffic.
- Higher pavement modulus $\rightarrow$ thinner lift.
- Higher subgrade modulus $\rightarrow$ somewhat thinner lift.
- Higher traffic $\rightarrow$ 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/Pages/256.aspx

- APA *Perpetual Asphalt Pavements: A Synthesis*

- Proceedings of International Conferences on Perpetual Pavements,
  https://www.ohio.edu/icpp/
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