Pavement Evaluation

Objectives

• Determine condition of existing pavements for use in planning or design
• Assess the ability of an existing pavement to support different types, weights, and volumes of aircraft
• Develop rehabilitation designs
• Determine pre-overlay repair needs
Pavement Evaluation Process

• Records Review
• Site Inspection
• Sampling and Testing
• Structural Analysis (FAARFIELD)
• Evaluation Report
• Applicable Advisory Circulars:
  – Pavement Evaluation, AC 150/5320-6E
  – Nondestructive Testing, AC 150/5370-11A
Records Review

- Construction data and history
- Design considerations and specifications
- Previous testing results
- Maintenance history
- Weather records
- Traffic data
Site Inspection

- Condition of pavement by visual inspection (PCI)
- Drainage conditions and drainage structures
- Frost action, swelling soils, materials-related distresses (MRD)
PCI Surveys

• Provide consistent methodology for measuring pavement condition
• Provide an indication of overall pavement condition
• Standard airfield PCI procedures:
  • AC 150/5380-6B
  • ASTM D 5340-04
• Used to determine SCI
Sampling and Testing

• Provide information on the thickness, quality, and general condition of pavement layers

• Level of effort based on type of evaluation
  – Project-level/design
  – Network-level/planning

• Consider availability of existing information
Sampling and Testing (cont.)

• Direct Sampling
  – Coring and boring
  – Dynamic cone penetrometer (DCP)

• Nondestructive Testing
  – Falling weight deflectometer (FWD)
  – Ground Penetrating Radar (GPR)
  – Infrared Thermography
  – Seismic and other methods
Pavement Coring

- Layer thicknesses
- DCP access
- Underlying condition
- Bonding conditions
- Materials sampling
Pavement Coring (cont.)

Do you have...this?
Pavement Coring (cont.)

...or this?
Soil Boring

- Drill rig
- Split-spoon sampling
- Standard penetration test

Photo Courtesy CME, Inc.
Microscopic Evaluation

What’s going on where you can’t see it?
Dynamic Cone Penetrometer

- Portable and fast
- Inexpensive
- Assess strength of underlying unbound layers
- Correlates to CBR
Nondestructive Testing

- In situ testing
- Minimal traffic disruption
- Minimizes need for destructive testing
Analysis of NDT Data to Estimate Layer Properties

• Evaluate deflection basins
• Select analytical sections
• Localized areas of weakness
• Subgrade modulus
• Layer moduli
Flexible Pavement Analysis

- Minimum input requirements
  - Layer thicknesses
  - Subgrade California Bearing Ratio (CBR)
    - Based on laboratory CBR testing – ASTM D 1883
    - FAARFIELD: $E_s = 1500 \times CBR$
  - Traffic data
Flexible Pavement Analysis (cont.)

• Layer properties
  – FAARFIELD layer properties
    • Correspond to FAA materials specifications (P-xxx)
  – Determined from sampling and testing
    • Use of “undefined” or “variable” layers for significantly different layer modulus values
## FAARFIELD – Flexible Pavement Analysis

<table>
<thead>
<tr>
<th>Airplane</th>
<th>Operating Weight, (lbs)</th>
<th>Annual Departures</th>
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<tbody>
<tr>
<td>A300</td>
<td>375,000</td>
<td>975</td>
</tr>
<tr>
<td>B737-900</td>
<td>174,700</td>
<td>35,175</td>
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<td>A380</td>
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<tr>
<td>B727-200</td>
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<tr>
<td>B737-400</td>
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<td>B747</td>
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<td>B757</td>
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<td>B-777</td>
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<td>DC8-60/70</td>
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<td>94</td>
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<td>DC9-30/40</td>
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<td>DC10</td>
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<td>542</td>
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<tr>
<td>MD11</td>
<td>621,000</td>
<td>52</td>
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FAARFIELD – Flexible Pavement Remaining Life

Existing structure

Updated traffic

Remaining Life
FAARFIELD – Flexible Pavement Traffic/Load

Existing structure

Increased volume

Remaining Life
FAARFIELD – Flexible Pavement Traffic/Load

Reduced weight

Remaining Life
Rigid Pavement Analysis

• Minimum input requirements
  – Layer thicknesses
  – Concrete flexural strength
    • Saw cut test beams...impractical.
    • Tensile splitting strength: \( R = 1.02(T) + 117 \)
    • Elastic modulus: \( R = 43.5 \left( \frac{E}{10^6} \right) + 488 \)
  – Modulus of subgrade reaction (k-value)
    • Historically based on plate bearing test...impractical.
    • FAARFIELD: \( E_s = 26 k^{1.284} \) or
      \( k = \left( \frac{1500 \times CBR}{26} \right)^{0.7788} \)
  – Traffic
Rigid Pavement Analysis (cont.)

• Layer properties
  – FAARFIELD material properties
    • Correspond to FAA materials specifications (P-xxx)
  – Determined from sampling and testing
    • Adjustment of flexural strength
    • Use of “undefined” and “variable” layers for significantly different layer modulus values
FAARFIELD – Rigid Pavement Remaining Life

Existing structure

Updated traffic

Remaining Life
FAARFIELD – Rigid Pavement Traffic/Load

Existing structure

Increased volume

Remaining Life
Evaluation Reporting

- Summary of evaluation tasks
- Summary of results
  - Planning purposes
  - Project design purposes
  - Pavement strength
    - Allowable load/capacity
    - PCN
Overlay Considerations
Why do we have premature failures?

• ________________________
• ________________________
• ________________________
• ________________________
• ________________________
• ________________________
• ________________________
• ________________________
• ________________________
Limitations and Effectiveness of HMA Overlays

What limits the effectiveness of HMA overlays?

• _________________________
• _________________________
• _________________________
• _________________________
• _________________________
HMA Overlay Selection to Correct Deficiencies

Thin Overlay

- Surface Defects

Thick Overlay

- Structural Defects
Limitations and Effectiveness of HMA Overlays

How can we improve our overlays?

- Pre-overlay treatments
- Better materials and practices
- Sound engineering judgment
- More funding (not likely)
Pre-overlay Treatment and Repair

- Dependent upon:
  - Type of overlay
  - Structural adequacy of existing pavement
  - Existing types of distress
  - Future traffic
  - Physical constraints
  - Cost
To Repair or Not to Repair?
Types of Pre-overlay Treatments

• Localized repair (patching)
• Surface leveling
• Drainage improvements
• Reflection crack control
Localized Repair

Repair Cost

Overlay Cost

% Area Repaired
Localized Repair (cont.)

There is a trade-off between the amount of pre-overlay repairs for optimal performance and overlay thickness.
Surface Leveling

• Purpose
  – Rut filling
  – Restore cross slope
  – Improve longitudinal profile

• Method
  – Cold milling
  – Leveling course
Drainage Improvements

• Drainage survey
• Identify moisture / drainage related distresses
• Develop solutions that address moisture problems
Reflection Cracking

- Appears on surface above underlying joints and cracks
- Caused by movement at joints and cracks
  - Low temperatures
  - Traffic loads
- Initiates at bottom of HMA overlay and propagates upward
Thermal Stress in HMA Overlay

- Lower temperatures
  - Overlay
    - Higher temperatures
  - Old pavement
    - Higher temperatures
  - Joint or crack
- Higher temperatures
  - Subgrade Soil

Thermal stress
Shearing and Bending Stresses in HMA Overlay

Tip of the joint or working crack

AC overlay

Void

Old PCC pavement

AC bending stress

Stress at the tip of the crack

Shearing stress
Reflection Crack Control
Design Issues

• Rate of propagation through overlay
• Number of reflected cracks
• Rate of deterioration of reflected cracks
• Amount of water that can infiltrate through the cracks
Reflection Crack Control Measures

- Large stone (>1 inch) binder mix
- Fabrics
- Stress-relieving interlayers
- Crack-arresting interlayers
- Pre-overlay repairs
- Fractured slab techniques
- Sawing and sealing joints
- Increased overlay thickness
Crack Control Effectiveness

- Delay the occurrence of cracking
- Reduce the number of cracks
- Control the crack severity
- Provide other benefits
  - Reduce overlay thickness
  - Enhance waterproofing capabilities
Fabrics

• Woven or non-woven synthetic materials
• Provide restraint to resist crack formation
• Most effective with smaller joint movements
  – Longitudinal joints
  – Differential vertical movements between 3 and 8 mils
Fabrics

- Overlay
- Fabric
- Stress concentration
- Old pavement
- Horizontal opening
- Vertical differential Movement
- Subgrade Soil
Fabric Application
Stress-Absorbing Interlayers

• Dissipates movements and stresses
• Ineffective for working cracks or large movement
• SAMI
  – Spray application of rubber or polymer-modified asphalt
  – Seating of aggregate chips
• Proprietary materials available (band-aids)
Stress-Absorbing Interlayers

Overlay

Membrane

Old pavement

Stress concentration

Horizontal opening

Vertical differential Movement

Subgrade Soil
Stress-Absorbing Interlayers
Crack Arresting Interlayers

Overlay

Old pavement

Crack arresting layer 20 - 30% voids

Subgrade Soil
Fractured Slab Techniques

- Crack and seat (JPCP)
- Break and seat (JRCP)
- Rubblization (JPCP, JRCP, CRCP)
- FAA Engineering Brief No. 66, Rubblized Portland Cement Concrete Base Course (incorporates P-215 specification)
Rubblization

• Rubblize when
  – MRD is prevalent
  – Freeze-thaw damage has occurred

• Slab breaking methods
  – Multiple head breakers
  – Resonant pavement breaker
Rubblization

• Seating
  – Multihead breaker
    • 2 passes with 10-ton “Z” grid vibratory steel drum roller
    • 1 pass with a 25-ton pneumatic tire roller
    • 1 pass with a smooth steel wheel vibratory roller
  – Resonant breaker
    • 3 passes with a smooth steel wheel vibratory roller with a 10-ton minimum weight
Rubblization

• Miscellaneous
  – Install edge drains 2 weeks prior to rubblizing
  – Remove any existing HMA
  – Pieces should be no larger than 3 inches above reinforcement, 8 inches below
  – Steel must be debonded from PCC
  – Process eliminates reflection cracking
Crack & Seat

- Feasible option when:
  - Extensive joint faulting exists
  - MRD is prevalent
  - Voids are present beneath the slabs
Crack & Seat

• Cracking Methods
  – Guillotine cracking machine
  – Modified pile or drop hammer
  – Other equipment types that crack full depth
Crack & Seat

• Seating
  – Roll with 50-ton pneumatic roller
  – Complete 4 or 5 passes
  – Roll near the time of paving

• Miscellaneous
  – Install edge drains prior to cracking slabs
  – Remove any existing HMA prior to cracking
Crack & Seat

• Miscellaneous – continued
  – For plain jointed PCC, pieces should be smaller than 36 inches square
  – For reinforced PCC (break and seat), smaller than 24 inches square
  – Advisory Circular does not mention crack and seat
  – Model in same manner as rubblized layer

• Significantly reduces reflection cracking
Other HMA Overlay Considerations

- Milling before new HMA overlay
  - Match grades
  - Remove existing HMA in poor condition
  - Remove existing HMA prior to crack and seat, or rubblizing

- Increased overlay thickness delays the occurrence of reflection cracking
  - Cracks propagate about 1 inch per year
  - Reduces temperature fluctuations in underlying pavement
PCC Overlay Construction Considerations

- Type of overlay
- Pre-overlay repairs
- Surface preparation
- PCC placement
- Curing
- Joint locations and sawing
PCC Overlay Types

• PCC/PCC
  – Bonded
  – Partially bonded (not a standard FAA design)
  – Unbonded

• PCC/HMA
  – Conventional whitetopping (unbonded)
  – Bonded whitetopping
Fully Bonded PCC Overlays

- Pre-overlay repairs
  - Full-depth repair of deteriorated slabs/joints
  - Partial-depth repair of spalled joints
  - Stabilization of rocking slabs

Existing pavement needs to be in good condition before overlay is placed
Fully Bonded PCC Overlays

• Surface preparation
  – Need to ensure strong bond to elicit monolithic behavior
  – Mechanical preparation is typically required (shotblasting or sandblasting)
  – Surface MUST be clean; sweeping/airblowing the surface
Fully Bonded PCC Overlay

• Surface preparation (continued)
  – Bonding agent may be required
    • Typically a neat cement slurry
    • Epoxy bonding agents are available
    • Overlays have been done without bonding agents
Bonded PCC Overlays

• Curing
  – Very important due to high surface area to volume ratio
  – Liquid curing compounds commonly used

• Joints
  – Must match those in underlying slab
  – Sawcut must be within ½ inch
  – Full-depth sawcuts for less than about 6 inches
  – Intermediate joints may be sawed to control cracking when base slabs are large
Bonded PCC Overlay Performance

• Mixed performance

• Key factors affecting performance:
  – Appropriate use  
    (pavement not too far deteriorated)
  – Adequate pre-overlay repairs
  – Effective bond
  – Timely and effective joint sawing
Unbonded PCC Overlays

• Repairs
  – Limited pre-overlay repair required
  – Slabs do not act monolithically

• Separator Layer
  – Separator layer required
  – Generally 1- to 2-inch HMA layer is placed
Unbonded PCC Overlays (cont.)

- **Surface Preparation**
  - Use a tack coat on the existing PCC
  - There is no minimum leveling course depth except that required by maximum aggregate size in HMA
  - Use a bond breaker between HMA and new PCC (two coats of paraffin-based curing compound works)
Unbonded PCC Overlays (cont.)

• Curing
  – PCC placement, finishing, and curing are the same as conventional PCC paving

• Joints
  – Conventional joint sawing operations
  – Jointing can be done independently of pattern in underlying slab
Unbonded PCC Overlay Performance

• Generally good performance

• Key factors affecting performance:
  – Adequate separator layer
  – Adequate structural design

• Matching grades is one of key considerations
Conventional Whitetopping

- PCC overlay placed directly on existing HMA pavement
- Designed as a new pavement considering the HMA pavement as a stabilized base course (*assumes no bonding between PCC and HMA*)
- Can be used on HMA pavements in FAIR to POOR condition
Conventional Whitetopping

• Repairs
  – Localized repair of failed areas

• Surface Preparation
  – Milling may be used to remove surface deterioration and to maintain elevations
Conventional Whitetopping

• Curing
  – PCC placement, finishing, and curing are the same as conventional PCC paving

• Joints
  – Conventional joint sawing operations
  – Similar jointing considerations as for unbonded PCC overlays
Conventional Whitetopping Performance

- Good to excellent performance
- Some partial bonding occurs, which may contribute to performance
- Uniform support and effective joint design required
Bonded Whitetopping

• Thin PCC overlays (4 to 8 inches) bonded to HMA surface
• Applications:
  – Aprons/ramps
  – Taxiways and runways (light traffic)
Bonded Whitetopping Projects

- Spirit of St. Louis Airport, MO (1995)
- New Smyrna Beach Airport, FL (1997)
- Centennial Airport, CO (1998)
- Savannah-Hardin County Airport, TN (2000)
- Fernandina Beach Airport, FL (2003)
- Williamsburg County Airport, SC (2004)

Not used under heavy aircraft applications
Miscellaneous Considerations

• Slab considerations (not for fully bonded overlay)
  – Any slab greater than 20 feet long, or odd shaped slabs, must be reinforced
  • Reinforcement should be a minimum of 0.05 percent in each direction
  • Functionally, #4 rebar on 12-inch centers each way at mid-slab works fine
  • Limit slab length to 20 feet whenever possible
Miscellaneous Considerations

– Ratio of slab length to width should not exceed 1.25. If ratio is exceeded, the slab is “odd” shaped and should be reinforced

– Check maximum slab size
  • Slab maximum dimension in inches should be less than or equal to 5 times the radius of relative stiffness of the slab

– See table 3-16 for maximum joint spacings
Radius of Relative Stiffness

\[ l = \left( \frac{Eh^3}{12k(1 - \mu^2)} \right)^{\frac{1}{4}} \]

where:

- \( l \) is the radius of relative stiffness, inches
- \( E \) is the PCC modulus of elasticity, typically 4,000,000 psi
- \( h \) is the slab thickness, inches
- \( \mu \) is Poisson’s Ratio for PCC, typically 0.15
- \( k \) is modulus of subgrade reaction, psi/in
Radius of Relative Stiffness, Example Calculation

– Available information
  • Unbonded overlay, 14 inches thick
  • k-value on existing pavement is 2,600 psi/in
  • Maximum slab dimension is 24.49 x 5, or 122 inches (10.2 feet)

\[
l = \left( \frac{4,000,000 \times 14^3}{12 \times (1 - 0.15^2) \times 2,600} \right)^{\frac{1}{4}} = 24.49
\]
Questions?