Federal Aviation Administration

FAA 40-Year Life Pavement Extension R&D

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Origins of 20-Year Design Life

• Early CBR method for airports (1940’s) did not explicitly consider traffic.
  – “Full” (100%) thickness was considered to be adequate for about 5,000 coverages of wheel passes from a B-36 bomber.
  – Designers assumed that a pavement adequate for 5000 coverages would support traffic indefinitely.

• Dick Ahlvin (Origin of Developments for Structural Design of Pavements, 1991):
  “The ‘Capacity’ or ‘Zone of Interior’ (ZI) design criteria were accepted as representing a 5,000 coverage use life (nominally 20 years).” (my emphasis)
Channelized Aircraft Traffic

- B-47 aircraft introduced 1951-53.
  - “Bicycle” gear; much better centerline control vs. B-36.
  - Less wander led to early flexible pavement failures.
  - Forced recognition that, in general, pavements sufficient for 5000 coverages would not provide 20 years service.

- New designs applied “percent of thickness”:
  \[ \%t = 0.23 \log C + 0.15 \]
Timeline – FAA Design Procedures

- **1964 – AC 150/5320-6**
  - Design charts for “capacity operations” of critical aircraft.
  - No explicit consideration of traffic in design procedure.

- **1978 – AC 150/5320-6C**
  - New design charts.
  - Annual departures are taken to occur over a 20-year life.

- **1995 – AC 150/5320-16**
  - LEDFAA 1.2 introduced.
  - Program accepts design life other than 20 years, but 20 years remains standard.
Extended Pavement Life Initiative

• In 2011 the FAA Airports organization (ARP) identified as a core activity: "doubling the expected life of runways at large hub airports from the current standard of 20 years to 40 years."

• Large hub airport: Enplanes at least 1% of the US national total (includes passengers on connecting flights).
  – 29 large hub airports.
  – 68% of all enplanements in 2008.
  – 33.8% of all NPIAS costs 2011-2015.
Why Go Past 20 Years?

• Longer service periods will translate into life cycle cost savings to the FAA.
  – Fewer major interventions = fewer eligible costs.
  – Avoid expensive delays/downtime due to reconstruction.

• Evidence exists that many airport pavements built to current standards already provide useful life in excess of 20 years.

• Challenges:
  – Need to establish a pavement life definition that is realistic and meaningful over 40 years.
  – May require changes to the FAA’s current funding rules.
20-Year Design and the FAA’s Airport Funding Mechanism

- Airport Improvement Program (AIP) funds eligible capital projects at US NPIAS airports.
- From the AIP Handbook: “The reconstruction, rehabilitation, pavement overlays, or major repairs of facilities and equipment are defined as eligible capital costs generally considered permanent with a 20-year life expectancy.”
- Thus, the expectation of 20 year life is embedded in the FAA’s funding structure,
- But …
What Is Life?

• Some different kinds of pavement life:
  – Design life
  – Structural life
  – Functional life
  – Service life
  – Operational life
  – Economic life
  – “Useful” life

• What airport operators mean by “life” is often quite different than design engineers.
Structural Life vs. Functional Life

• **Structural Life**
  - Applies only to the ability of the pavement structure to support the forecast aircraft loads.
  - Failure characterized by fatigue cracks, shear flow.
  - FAA NAPTF testing is mostly focused on structural life.

• **Functional Life**
  - Considers non-structural distresses such as low friction, surface rutting and distortion, etc., that can impact safety of aircraft operations.
Pavement Condition Index (PCI)

- **ASTM standard based on visual survey data.**
  - PCI lumps together structural and functional distresses into a single index.
  - But fails to consider other factors (e.g., ride quality deterioration) that may trigger replacement.
  - ASTM D5340-10 defines component distresses.

- **Structural Condition Index (SCI).**
  - Attempts to extract the structural damage component from the PCI by defining a limited set of “load-related” distresses.
  - Currently no accepted definition for flexible pavements.
  - FAA rigid pavement structural failure corresponds to SCI 80.
Design vs. Operational Life

• Failure is keyed to structural distresses.
  – Subgrade rutting for flexible pavements.
  – Extensive structural cracking for PCC.

• FAA does consider non-structural distresses in its thickness design, but only indirectly.
  – **Experience**: Designs that satisfy structural design criteria also provide operational life of 20 years.
  – No confidence that this correlation extends to 40 years.
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FAA 2004 Operational Life Study

- Evaluated field data from 30 airports in 10 U.S. states.
  - 15 million m² (161 million square ft.).
  - Rigid and flexible.
  - Grouped by feature, age & size.
- Concluded that flexible and rigid pavements designed to FAA standards provided in excess of 20 years of structural life (SCI > 80).
- “While the structural performance of flexible and rigid pavements were comparable, a difference in functional performance was noted.”
Developing a Natural Pavement Life Definition

• Define a new metric $DL$ ("distress level").
  – Represents some combination of pavement distress indexes.
  – “Mega-Index” – May include both SCI and some combination of functional indexes (friction, roughness, etc.).
  – Assume $DL$ is on a numerical scale of 1 – 100.

• A pavement has reached the end of its useful life when $DL$ decreases below a lower threshold value ($DL_{lower}$) and cannot be restored to an upper threshold value ($DL_{upper}$) with probability $p$ of remaining above the lower threshold for a period of 10 years or more.

• The value of $p$, the upper and lower thresholds, and the specific component indexes, need to be determined.

• Acknowledgment: Dr. Gordon Hayhoe (retired).
Why A New Definition?

- This definition explicitly recognizes that useful life includes both structural (structural distresses in PCI, HWD) and non-structural (other PCI distresses, friction, roughness, etc.) components.
- Also recognizes that DL can be restored by periodic interventions, and the pavement can continue to function, but eventually there is a point of diminishing returns (at which point the pavement is truly “failed”).
  - Agrees more with what airport owners/operators think of as pavement life.
  - Note that ordinary maintenance work (e.g., rubber removal on the keel) would not be considered a restoration for the purpose of this definition.
- Can be used in conjunction with life cycle analysis to compute life cycle costs. In contrast, the structural definition of life is not adequate for LCCA.
Maintenance Activities Affecting Life

• **Major maintenance activities associated with the 40-year life cycle include:**
  – Surface grinding and/or milling to restore profile.
  – Surface treatments to restore friction (milling, seal coat, etc.)
  – Groove restoration.
  – Pavement preservation techniques.
  – Individual slab replacement / dowel bar retrofit.
  – Joint seal replacement.

• **These activities may be effective in restoring the DL as defined in the previous slide.**
40-Year Pavement Life Extension

- Runway data collection.
  - 4-year project - in year 3.
  - Construction and performance data on medium- and large-hub runway pavements.
  - Field data collection.
- FAA PAVEAIR database development (PA40).
- Performance/pavement life model development.
40-Year Life – Runway Data Collection

All Airports

• Design and construction data (with costs).
• Maintenance activities and costs.
• Pavement performance data. PCI, friction, roughness, groove condition, etc. Not limited to current fields in FAA PAVEAIR.
• Traffic history (aircraft type, history, weight).

Field Data

• PCI (visual survey).
• Heavy Falling-Weight Deflectometer (HWD).
• Material samples (concrete and asphalt) for laboratory characterization. Sample testing will be done at the NAPTF lab.
• Longitudinal roughness profiles (SurPRO) & FAA portable profiler (if feasible).
• Grooving (longitudinal texture) data.
• Laser imaging by FAA (if feasible).
Year 1 Airport Locations

Large Hub
- SEA
- TUS
- IAH
- CMH
- IAD
- BOS
- LGA

Medium Hub
- SEA
- TUS
- IAH

Site designated for field data collection
Year 2 Airport Locations

- **Large Hub**: SFO, LAX, ORD, BWI, MCO, DCA, GSO, IND
- **Medium Hub**: Site designated for field data collection
- **Small Hub**: SFO, LAX

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Year 3 Proposed Locations with Climatic Zones

[Map showing proposed locations with climatic zones marked with stars for Large Hub, Medium Hub, and Small Hub, and circles for sites designated for field data collection.]
Data Collection Activities

Groove Profiling

Pavement Imaging

Heavy-Weight Deflectometer

Field Core Testing
Field Data Collection – April 2013

Runway at Medium-Hub U.S. Airport
30+ Years Old
FAA PAVEAIRC Implementation

• Data collected falls into 2 categories:
  – Exists in current FAA PAVEAIRC (e.g., PCI, certain maintenance activities).
  – Not in the current version of FAA PAVEAIRC.

• All collected data for the 40 year project will be stored in a dedicated, standalone FAA PAVEAIRC implementation ("PA40").
  – Data are anonymized.
  – No PA40 databases are accessible from the public FAA PAVEAIRC implementation.

• Enhanced functionality in PA40.
PA40 – PAVEAIR Databases

- **Enhanced Functionality**
- **Fields for:**
  - HWD data, raw profile data, groove geometry data.
  - Computed roughness indexes (ProFAA) and groove characteristics (ProGroove)
  - Traffic data.
  - Climate data.
  - Structural layers and material properties.
- **Coordinate with FAA PAVEAIR development.**
PA40 Organization Concept

Network

AIRPORT

Branch

RUNWAY

Section

SECTION OF RUNWAY OR SHOULDER

Level

Data Type/File

Index

Climate Zone

Annual Rainfall

Weather Data

Mean High/Low Temperatures

Freezing/Thawing Degree Days

Local Work Type/Cost Data

Network

Branch

Section

Shaded area: Functionality in current FAA PAVEAIR

Functionality being added

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Developing New Performance Models

New performance models relate design inputs to distress index $DL$ and/or its individual component indexes.

**Current Design Procedures:**

- **Inputs**
  - Structural Layers
  - CBR or $k$-value
  - Aircraft Traffic
  - Concrete Strength (rigid)

- **Output**
  - Passes to structural failure*

*defined as 2.5 cm upheaval for flexible pavements or 50% of slabs cracked for rigid pavements

**40-Year Design:**

- **Inputs**
  - Everything to the left, plus …
  - Age, Climatic Data
  - Soil/Material Properties
  - Maintenance Data
  - Airport Feature (runway, apron, etc.)

- **Outputs**
  - Passes to structural failure, plus …
  - Roughness index prediction
  - Surface friction prediction
  - Other functional indexes
Economic Life

- Limited FAA guidance now.
- AC 150/5320-6E, Appendix 1, suggests that the analysis period for LCCA should be the same as the design life (i.e., 20 years).
- AAPTP Report 06-06 (2011) recommended use of a longer analysis period.
  - 40 years for new construction
  - 30 years for rehabilitation/overlays
  - Only about half of airport projects surveyed used 20 years for the LCCA analysis period.

**Performance Curve**

Analysis Period = Time period over which initial and future costs associated with alternative pavement strategies are evaluated.

(AAPTP Report 06-06, ARA, 2011)
Key Elements of LCCA-Based Design Procedures

• Consideration of multiple design alternatives over an extended analysis period.
• Structural design as one element within a larger economic framework.
• Design-time access to cost, performance, and other non-structural data.
• Accept and plan for future interventions (e.g., mill-and-fill operations, groove restoration, etc.) to achieve the desired operational life.
• Initial costs must be balanced against the costs of programmed maintenance, planned future rehabilitation, and other future factors, ideally resulting in the optimal design choice.
Standardizing LCCA Inputs

- Need to limit the ability of end users to manipulate life cycle cost inputs to favor a predetermined outcome.
- Key to a reliable design procedure.
- Provides a uniform basis on which to evaluate designs requesting FAA funds.
Design Strategies Incorporating Future Overlays

• Allow for projected surface replacements or overlays during the overall design period.
  – Base structure has a design life of 20 or 40 years (depending on the requirements).
  – Upper or surface layer may have a functional life that is considerably less than the design period.
  – Therefore, overlay design (HMA-on-flexible or HMA-on-rigid) becomes a more significant element within the LCCA-based design procedure.

• Upgraded overlay design models need to consider:
  – Deterioration of base structure under forecast traffic.
  – Degradation of material properties (over 40 years).
    • Current model assumes all materials have “new” properties.
  – Reflection cracking as a failure mode.
Integrated Design Procedures

ProFAA
Roughness Evaluation

BAKFAA
Structural Evaluation

COMFAA
PCN/Load Rating

FAA PAVEAIR
Web-Based PMS

Output: Optimal 40-Year Design

AirCost
Life-Cycle Cost Analysis for Airport Pavements

FAARFIELD
Thickness Design

New LCCA Procedures

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Thank You! ¡Muchas Gracias!

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