Airfield Pavement Smoothness
Airport Pavement Workshop

Michael Gerardi
APR Consultants

APR CONSULTANTS
DRIVING SMOOTHNESS

Presentation Overview

- Why is Smoothness Important
- New Pavement Acceptance Criteria - (FAA AC 150/5370) – 16-Foot Straightedge and Profilograph
- Profiling Devices
- Pavement Roughness
- Existing Pavement Rejection Criteria (FAA AC 150/5380-9)
- Case Histories

APR CONSULTANTS
DRIVING SMOOTHNESS


Courtesy F. Seggie
The Primary Reason We Strive to Build and Maintain Smooth Pavements is to Minimize Aircraft Dynamic Response, and Maximize Aircraft Performance

FAA AC 150/5370-10F

Section 5 – P501 Rigid Pavements

- Smoothness (501-5.2) page 319
  - 16-Foot Straightedge (.25-inch)
  - California Profilograph (15 inch/mile)
- Grade Control
- Payment Schedule (per lot)

Airport Pavement Smoothness
The 16-Foot Straightedge

- Max Deviation ¼ - Inch for Final Surface
- Longitudinal Measurement Advancing not more than Half the Length of the Straightedge
- Deviations > ¼ - Inch but < ½ - Inch Will be Ground
- Deviations > than ½ - Inch, Pavement Shall be Replaced when Directed by the Engineer

APR CONSULTANTS
DRIVING SMOOTHNESS

Pavement Smoothness Assessment Using California Profilograph

- Two Passes Down Each Paving Lane
- One Pass on CL for Lanes Less than 20 Feet Wide
- 15 inches/mile Tolerance with a .2-inch Blanking Band
- Scallops Greater than .4-inch Must be Removed
- Re-Profile after Corrective Action

APR CONSULTANTS
DRIVING SMOOTHNESS

Pay Adjustment for Smoothness – Profilograph

b. Payment. Payment shall be made under:

Item P-501-8.1a Portland Cement Concrete Pavement—**[per cubic yard (cubic meter)] [per square yard (square meter)]**

c. Basis of adjusted payment for Smoothness. Price adjustment for pavement smoothness will apply to the total area of concrete within a section of pavement and shall be applied in accordance the following equation and schedule:

(Sq yds in section) x (original unit price per sq yds) x PFm =
= reduction in payment for area within section

Average Profile Index (Inches per mile) pavement strength rating			Contract Unit Price Adjustment
over 30,000 lb	30,000 lb or less	Short Sections	PFm
0 - 7	0 - 10	0 - 15	0.00
7.1 - 9	10.1 - 11	15.1 - 16	0.02
9.1 - 11	11.1 - 12	16.1 - 17	0.04
11.1 - 13	12.1 - 13	17.1 - 18	0.06
13.1 - 14	13.1 - 14	18.1 - 20	0.08
14.1 - 15	14.1 - 15	20.1 - 22	0.10
15.1 & up	15.1 & up	22.1 & up	corrective work required

P-501-35

APR CONSULTANTS DRIVING SMOOTHNESS

FAA AC 150/5370
APR's Experience with P-501

- Criteria
  - ¼ - Inch in 16 Feet or PI of 15 (inches / mile)
  - ½ - Inch Maximum Deviation to Design Grade
- Conservative from Aircraft Response Perspective
- Causes Disputes Regarding Pavement Acceptance
- Prompts the Question: Should the Decision to Repair be Made Case by Case?
- Do We want to Look at Different Pavements with Different Tolerances
  - Outer Lanes, Parking Ramps, etc.

Case History: Dispute Resolution

- AF Asphalt Runway Rehabilitation Project had Questionable PI Values Causing the Owner Concern
  - Higher PI Values were on the Outer Lanes
  - Aircraft Simulations Showed Aircraft Response was Acceptable
  - Decision was made to Accept the Pavement and the Runway was Opened

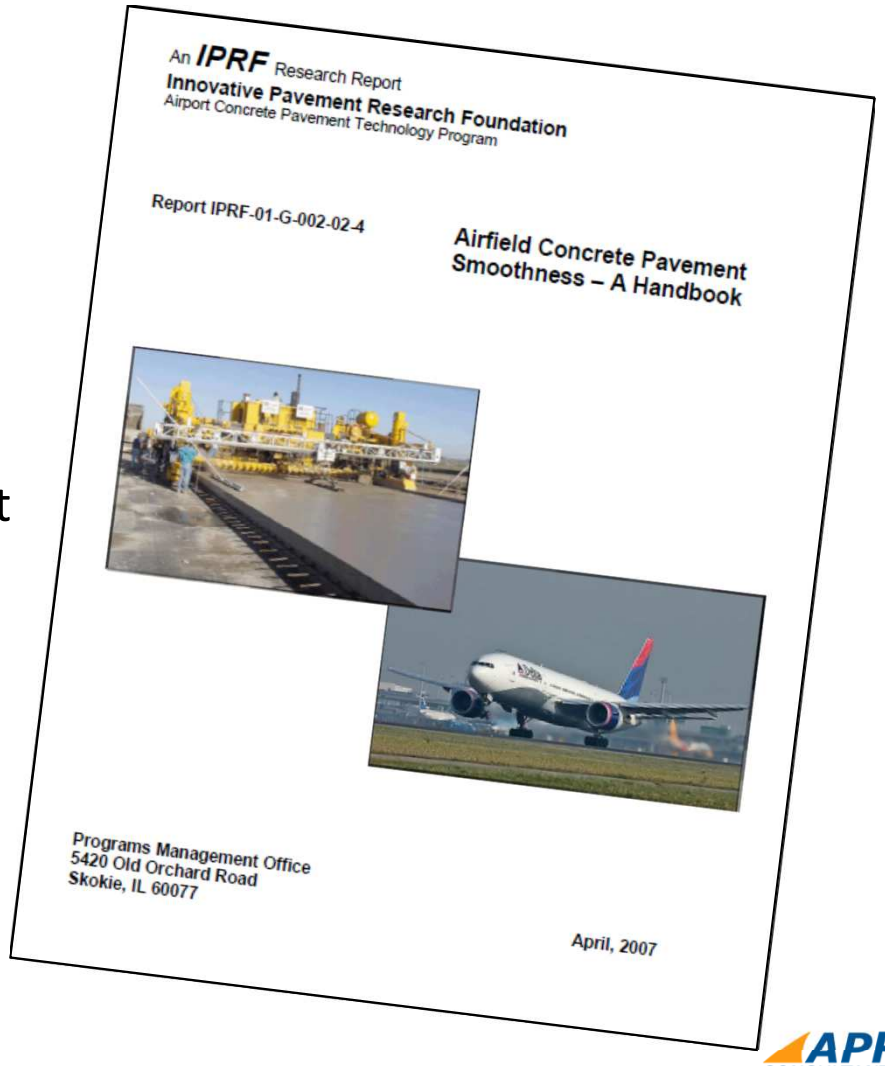
Grade Control

- ½ - Inch Max Deviation from Design
- Measure at 50-Foot Intervals or Less and at All Breaks in Grade
- Lateral Deviation Shall Not Exceed .10 Feet
- Vertical Deviation Shall Not Exceed .04 Feet
- Grade Control not Part of Pay Factor

APR CONSULTANTS
DRIVING SMOOTHNESS

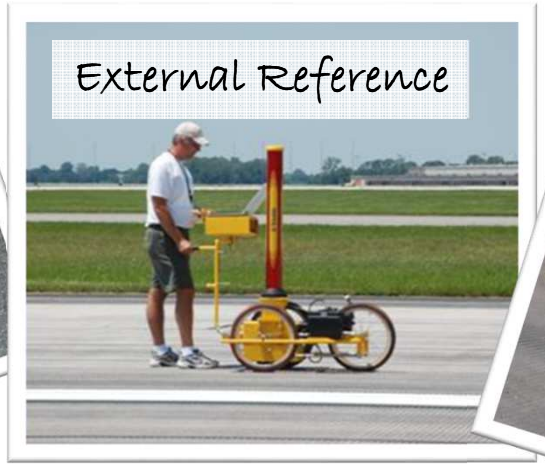
Profiling Devices

- IPRF 01-G-002-02-4
  - Can "*Off the Shelf*" Profilers be Used to Assess Airport Pavement Smoothness Using the P-501 Specification ¼ - Inch in 16 Feet?



APR CONSULTANTS
DRIVING SMOOTHNESS

Various Profiling Devices



- Walking Profilers
  - Sufficient Accuracy for Airfield Evaluation
  - Relatively Inexpensive
  - Can Track All Event Wavelengths
  - Collection Speed is Biggest Drawback
- "Flexible Data"

Various Profiling Devices

- Inertial Profilers
  - Van, Truck or ATV Mounted
  - Faster than Walking Type
  - Sub Millimeter Accuracy
  - Texture can Adversely Affect Ride Readings (Older Lasers)
  - Not as Repeatable as Walking Profilers
  - More Expensive
  - Difficulty Tracking Longer Wavelengths
  - Requires Acceleration Room

“Wet or Dry Profiler”

- Moves with or is Directly Mounted to the Paving Train
- Provides Immediate Feedback to the Paver
- Like Inertial Profilers, Difficult to Track Longer Wavelengths

APR CONSULTANTS
DRIVING SMOOTHNESS

Device Evaluation Summary

- All Device Types Tested *Have* the Required Accuracy to Assess Airport Pavements using the P-501
- Some Cannot Detect Grade Control
- Some are Slow to Operate
- Each Type has Advantages and Limitations

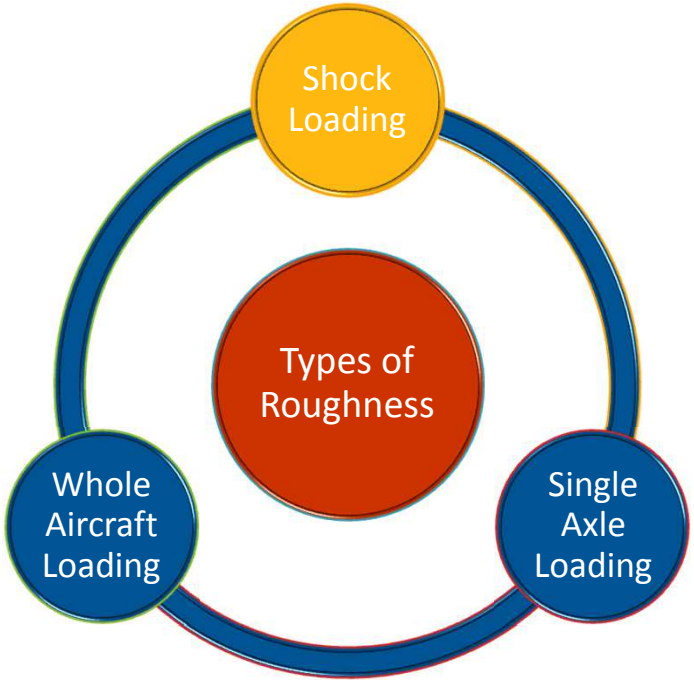
FAA Defined Roughness

- **Profile Roughness:**
  - *"The FAA defines profile roughness as surface profile deviations present over a portion of the runway that cause airplanes to respond in ways that can increase fatigue on airplane components, reduce braking action, impair cockpit operations, and/or cause discomfort to passengers."*

FAA AC 150/5380-9 , Page 1

Roughness Defined

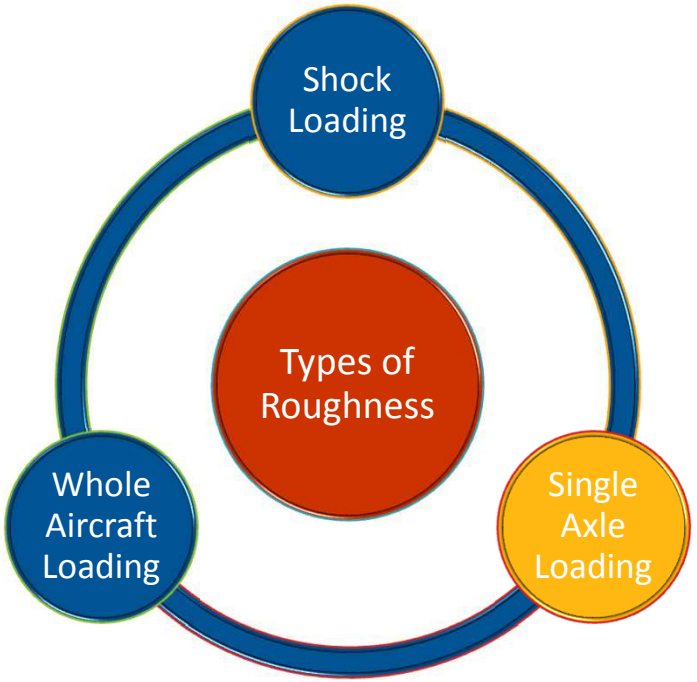
- Shock Loading
  - Short wavelength roughness that is too fast for the tires and suspension system to react. (rattles instruments, jars avionics)



APR CONSULTANTS
DRIVING SMOOTHNESS

Roughness Defined

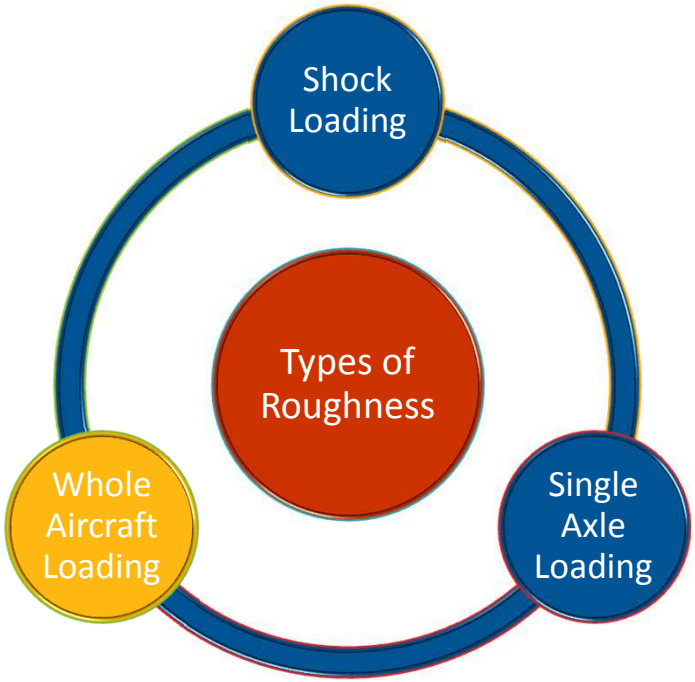
- Single Axle Loading
  - Short wavelength roughness that the tires and suspension system are capable of reacting to. (Increases O&S costs, passenger complaints)



APR CONSULTANTS
DRIVING SMOOTHNESS

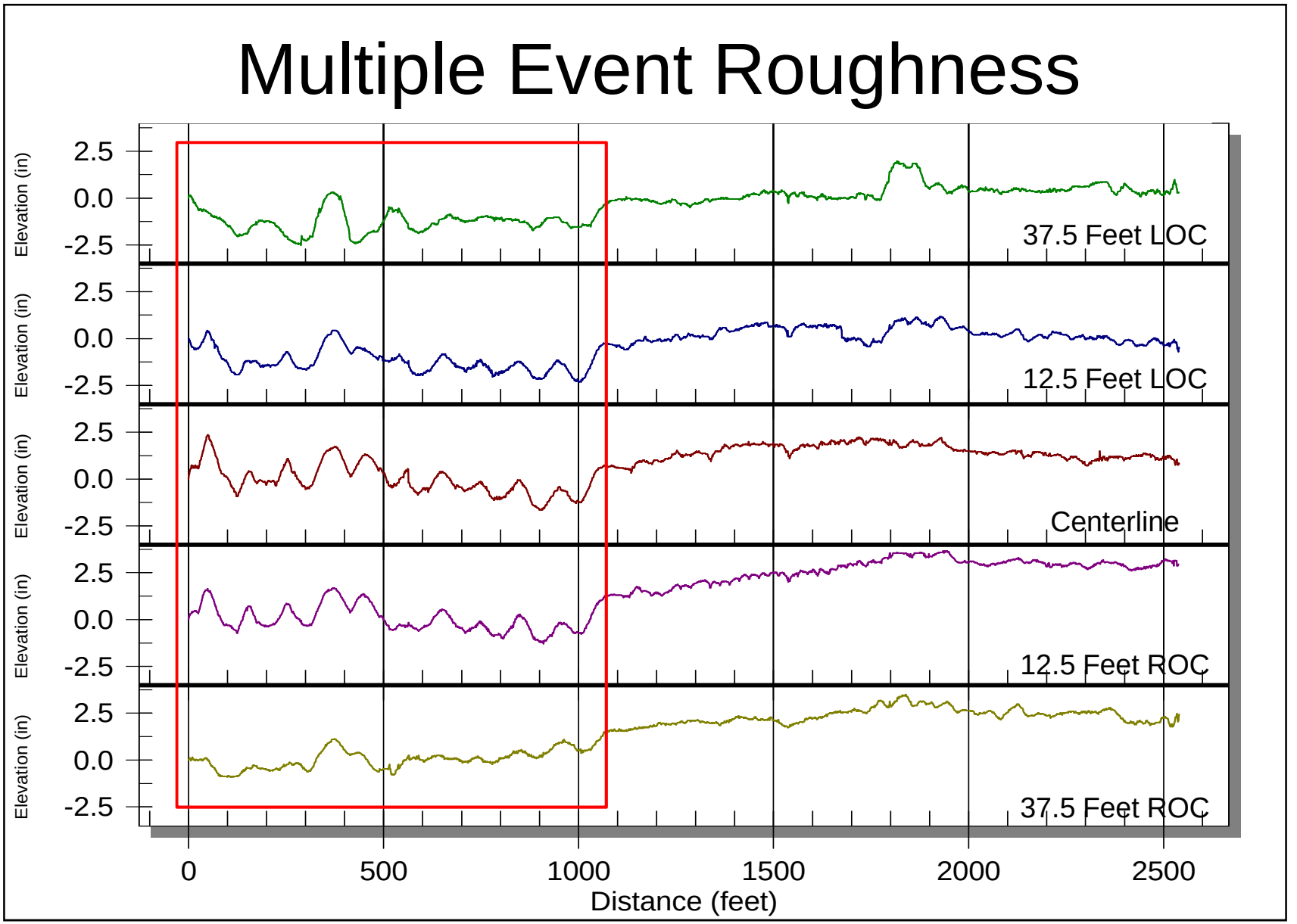
Roughness Defined

- Whole Aircraft Loading
  - Longer wavelength roughness that excites the whole aircraft (Aircraft fatigue damage, reduces braking ability, reduces pavement life) - Grade Control Issue



APR CONSULTANTS
DRIVING SMOOTHNESS

Multiple Event Roughness



Runway Roughness Evaluation: A Unique Problem

- Landing Gear Spacing up to 100 Feet
- Speeds Greater than 150 Knots
- Aircraft will Respond to Bumps 300 Feet Long or Longer
- Multiple Smaller Events in Succession can be Worse then One Large Event
- Struts are Primarily Designed for Landing Impact

APR CONSULTANTS
DRIVING SMOOTHNESS

The California Profilograph Relative to a Modern Commercial Aircraft

Boeing 777-200ER
Gear Spacing 84 feet 11 inches
Equates to 3.4 California Profilograph lengths

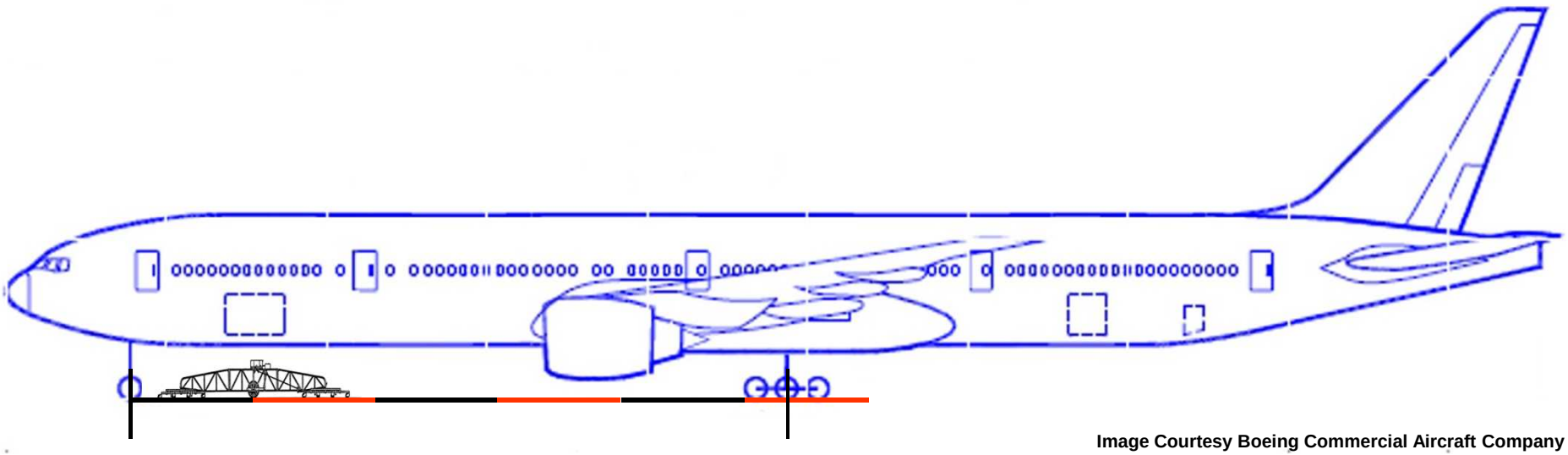
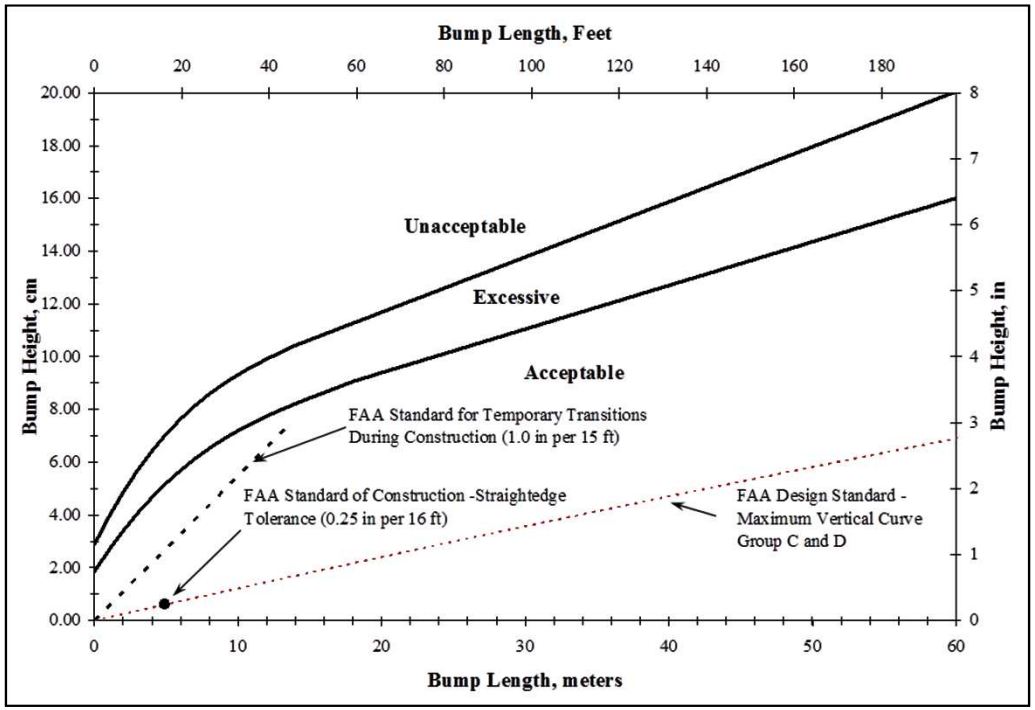


Image Courtesy Boeing Commercial Aircraft Company

APR CONSULTANTS
DRIVING SMOOTHNESS

FAA AC 150/5380-9 - Boeing Bump Index



- **Acceptable** – Minor Impact on Aircraft Fatigue Damage and Minimal Passenger Discomfort
- **Excessive** – Pavement Repair Recommended. Immediate Closure Not Required
- **Unacceptable** – Immediate Closure of the Affected Pavement

APR CONSULTANTS
DRIVING SMOOTHNESS

FAA AC 150/5380-9

APR's Real-World Experience Thus Far

- Airports are Concluding if they Pass the Boeing Bump Index (BBI), Their Pavement is OK
- BBI Does not Consider Multiple Bumps, Aircraft Type or the Velocity of Encounter.
- This AC is Not Being Interpreted as Intended by the FAA
  - Puts an "OK" Stamp on Marginal or Unacceptable Pavements

APR CONSULTANTS DRIVING SMOOTHNESS

FAA Guidance for Measuring the Runway Profiles

- Longitudinal Lines of Survey
  - Measure Centerline and 10 Feet and/or 17.5 Feet Left & Right of the Centerline (17.5 feet is for wide body operations)
- Survey Interval
  - .25-Meter (0.82 feet) Minimum

Flexible Data

- Measuring the Initial with a Profile Walking Profiler
  - Complies with FAA Advisory Circulars
    - 16-Foot Straightedge
    - California Profilograph
  - Provides Further Analysis Options
    - Aircraft Simulation
    - Dispute Resolution
  - Provides a True Profile for Use in Pavement Management
    - Tracking Differential Settlement

APR CONSULTANTS
DRIVING SMOOTHNESS

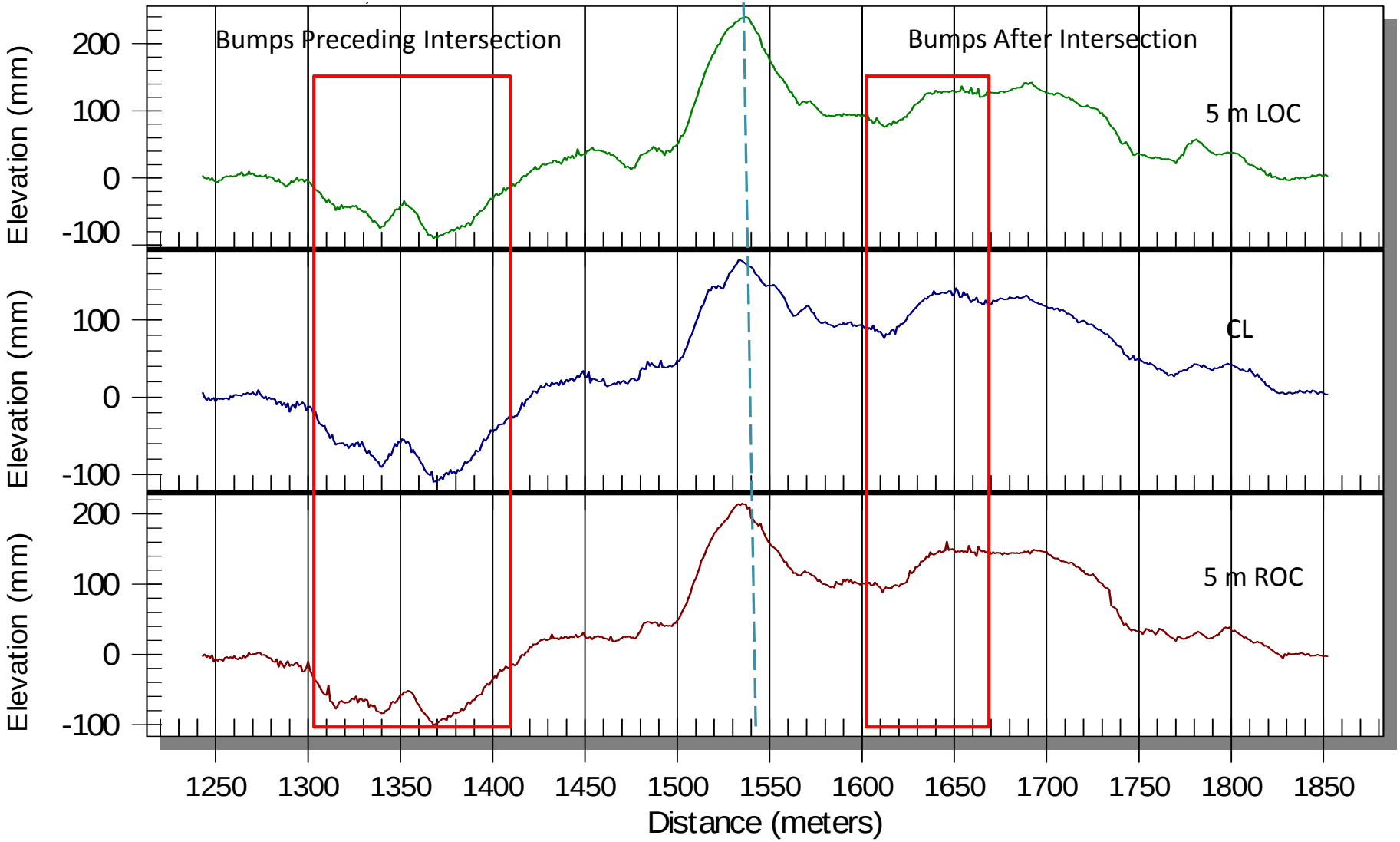
Case Studies

- Pilot Reported Roughness
  - Combining Recorded Aircraft Response with Aircraft Simulation
- Differential Settlement
  - Change Happens


• Toronto International (YYZ) Runway Intersection Before Repairs
• Boeing 777 Onboard FDM System Recorded Nz Values Above .7G, Yet BBI was “Acceptable”
©2011 Google - Imagery ©2011 DigitalGlobe, First Base Solutions, GeoEye, Map data ©2011 Google - Terms of Use

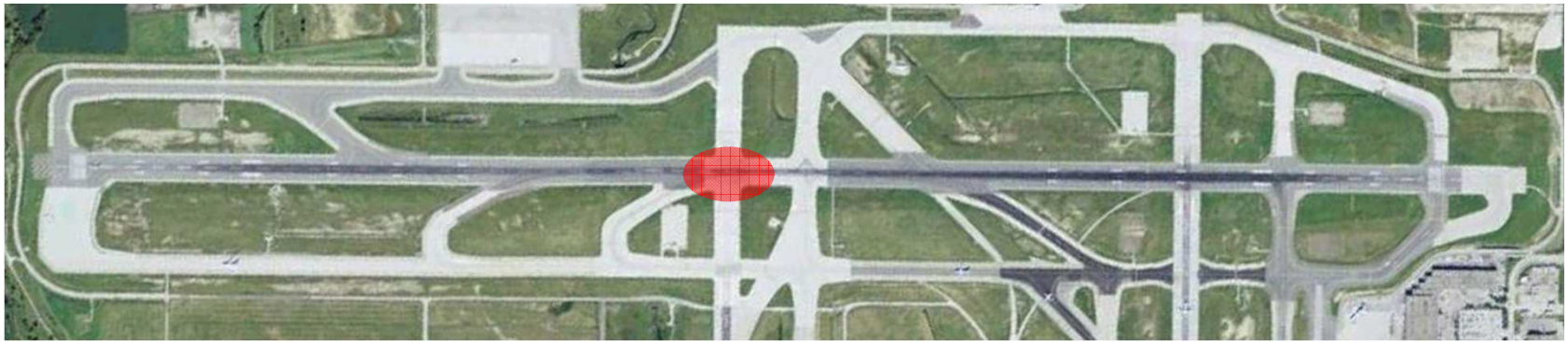
Intersection Showing Crown for Drainage

Bumps before and after intersection



Probable Causes of Pilot Complaints

- Located in the Middle Affecting Takeoffs in the Both Directions
- Aircraft Velocity is High
  - Longer Wavelengths
  - Harder to Detect
- Multiple Events in Both Directions
- Undulations Prevent Effective Dampening of Aircraft Response
- Point of Rotation Increases Main Gear Loading



APR CONSULTANTS
DRIVING SMOOTHNESS

Preventable Action – Evaluate the Design

- Design Constraints can Cause Unacceptable Roughness
  - Vertical Curves
  - Tying into Existing Elevations
  - Patching
- Intersecting Runways
  - Crowns are Bumps (Increases Aircraft Sink Speed)
  - Optimize Drainage and Roughness
  - Minimize the Impact on the Primary Runway

Differential Settlement on Airport Pavements – Change Happens

- Large Amounts of Fill Material have Potential for Differential Settlement
- Unstable Soils and Clays
- Tunneling - Vehicular, Utility, Other…
- Seasonal Impact - Rains, Freeze/Thaw Cycle

APR CONSULTANTS
DRIVING SMOOTHNESS

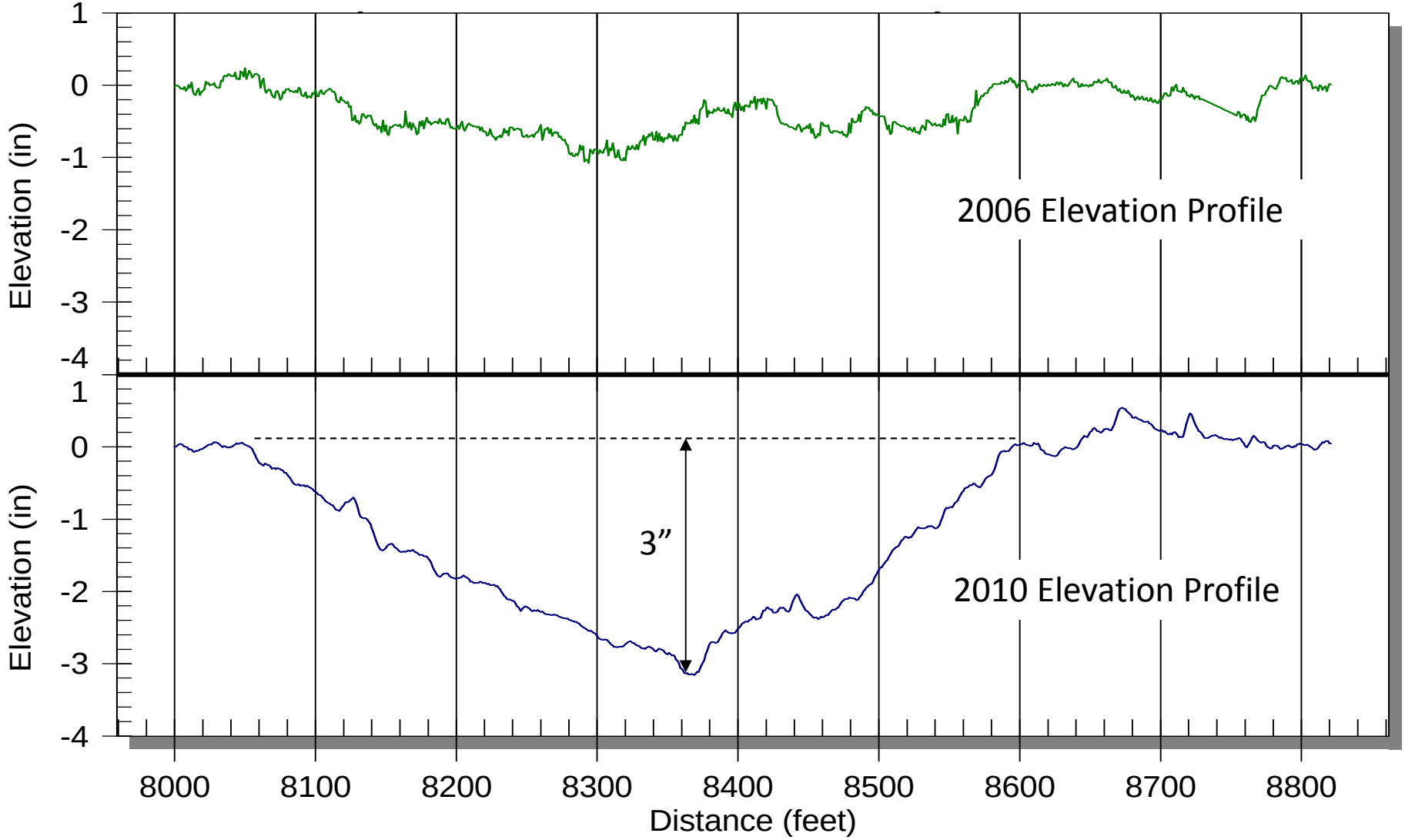
Measure a Baseline Profile For Future Reference

- Pavements Settle with Time, Traffic and Climate
- Measure Baseline True Profile (MSL) Before Pavement Opens to Traffic
  - Profile Data is a Deliverable
  - Used for Smoothness Acceptance
- Track Differential Settlement Periodically by Comparing MSL Profiles
- New PMS Tool; Non Destructive Test of Pavement's Structural Integrity

APR CONSULTANTS DRIVING SMOOTHNESS

Differential Settlement

New PCC Runway with Deep Fill



Conclusions

- P-501, when Grade Control is Achieved, Produces Acceptable Pavement from a Ride Quality Perspective
  - Current Acceptance Standards are Conservative for Ride Quality
  - Consider Alternative Limits for Outer Lanes and Ramps
- Many New Devices can assess New Pavement for Initial Smoothness
  - Use Devices to Measure *"Flexible Data"*
  - Satisfies FAA and Provides Data for Other Uses

APR CONSULTANTS
DRIVING SMOOTHNESS

Conclusions

- Roughness is Different than Smoothness
  - FAA has taken First Step to Help Airports Identify / Quantify Roughness
- We Know that as Pavements Age, Profile Changes
  - Develop One Comprehensive Method Using Flexible Data
    - Acceptance Profile Becomes Baseline for Use Throughout Pavement's Life in Pavement Management

The End

APR CONSULTANTS
DRIVING SMOOTHNESS