Airfield Pavement—Not Your Typical Highway Construction Project

Gary L. Mitchell P.E.
Vice President – Airports and Pavement Technology
American Concrete Pavement Association

Count on Concrete PAVEMENT

Airfield Pavements

- Aircraft Loading
  - Important to remember that one aircraft wheel load can easily exceed the total gross weight of many vehicles, including semi-tractor trailers.
  - Aircraft wheel loads are approaching 65,000-lbs and tire pressures can exceed 300 psi.

Airfield Concrete Pavements

- Pavements conforming to airfield concrete specifications are generally more challenging to construct than typical state highway pavements.
- Specification has evolved over the years to keep pace with operational characteristics required to support commercial aircraft traffic.
- High quality is desired and achieving quality is the responsibility of both Contractor and Engineer.

What Issues are Facing Airfields?

- Inconsistent construction and inspection
- Procurement/contracting limitations
- High costs of:
  - Shutdowns
  - Aircraft
- Increasing sensitivity to:
  - Operational readiness
  - Safety

What Problems Are We Trying to Minimize?

- **Cracking** – corner, longitudinal, transverse, material related.
- **Joint problems** – spalling, pumping, joint seal damage.
- **Surface defects** – scaling, popouts, map cracking.
- **Damage from Repairs** – lift-out chipping, coring, loose materials

FOD!

Popouts

D-Cracking

Corner Breaks

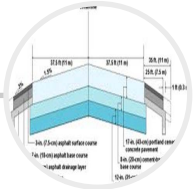
Weakened Surface

Joint Spalling

Sliver Spalling

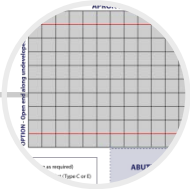
FOD Damage / Result

What Minimizes the Risk of Distress?

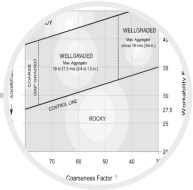


Thickness Design

Foundation Support



Joint Layout



Concrete Mixture Design

What Minimizes the Risk of Distress?

Stockpiling
& Mixing

Placing &
Consolidating

Finishing
& Curing

Jointing
& Sealing

Concrete Pavement Types

- Jointed Plain (JPCP)
  - Undoweled
  - Doweled
- Jointed Reinforced (JRCP)
- Continuously Reinforced (CRCP)

Nearly All Airfield Pavements!

Thickness and Strength

- Typical design strength – 650 psi flexural
- Typical design thickness – 15-20 inches
- FAARFIELD – FAA
- PCASE – Department of Defense

Airport Concrete Pavement Fundamentals (Some very different from highway pavements)

- Airport jointed concrete pavement typically has no distributed steel except special cases or odd-shaped panels.
- Doweling depends on standards & aircraft loads
- Both transverse and longitudinal joints may be doweled where required.
- No Tie Bars (exceptions)

Airport Concrete Pavement Fundamentals

- Runway, taxiway & apron paving require multi-lane paving.
- Fill-in lane paving requires special care not encountered on roadway paving.

Details…

In-pavement lights and dowels galore…

Qualifying Construction Materials

- Aggregates
  - Review State DOT records for performance history & certification
  - Use largest max. size consistent with placement requirements
  - Must meet project specs (typically ASTM C33)
    - Test for ASR
    - Test for F/T durability
  - Lead time required for test results

Deleterious Materials

- Major difference between Civil and Military airports
- FOD hazard increased – high performance aircraft
- 32 13 11 Supplementary report – page 58 and 59
- Requirements are mandatory for military airfields!
  - Waivers for USAF Bases by MAJCOM Engineer only
  - Significant cost increased is recognized
- Specifically enforced to reduce pop-outs (FOD)

Comparison of selected military UFGS 32 13 11 and ASTM C 33 Requirements

Deleterious Material	Test Standard	USAF/ Army Maximum %	Navy Maximum %	ASTM Maximum %
Clay lumps and friable particles	ASTM C 142	0.2	1.0	3.0
shale	ASTM C 295	0.1		
Material finer than 0.075 mm (No. 200 sieve)	ASTM C 117	0.5	1.0	1.0
Lightweight particles (SG < 2.0)	ASTM C 123	0.2	1.0	
Clay ironstone	ASTM C 295	0.1		
Chert and cherty stone	ASTM C 123/C 295	0.1		5.0
Claystone, mudstone, siltstone	ASTM C 295	0.1		
Shaly and argillaceous limestone	ASTM C 295	0.2		
Other soft particles	COE CRD-C 130	0.1		
Coal and lignite	ASTM C 123/C 295			0.5
Total deleterious substances exclusive of material finer than 0.0075 mm		1.0	3.0	
Sum of clay lumps, friable particles, and chert				5.0

ASR Test Methods

- C 295 – Petrographic Examination
- C 289 – Quick Chemical Test (False Negatives)
- C 277 – Mortar Bar Test (False Negatives)
- C 1260 – Accelerated Mortar Bar Test (Aggregate)
- C 1567 – Potential Alkali-Silica Reactivity of Combinations of Cementitious Materials and Aggregate (Aggregate Mortar Bar and not aggregate combination and SCM)
- C 1293 – Concrete Prism Test (CPT)

Lead Time – ASR & F-T Testing

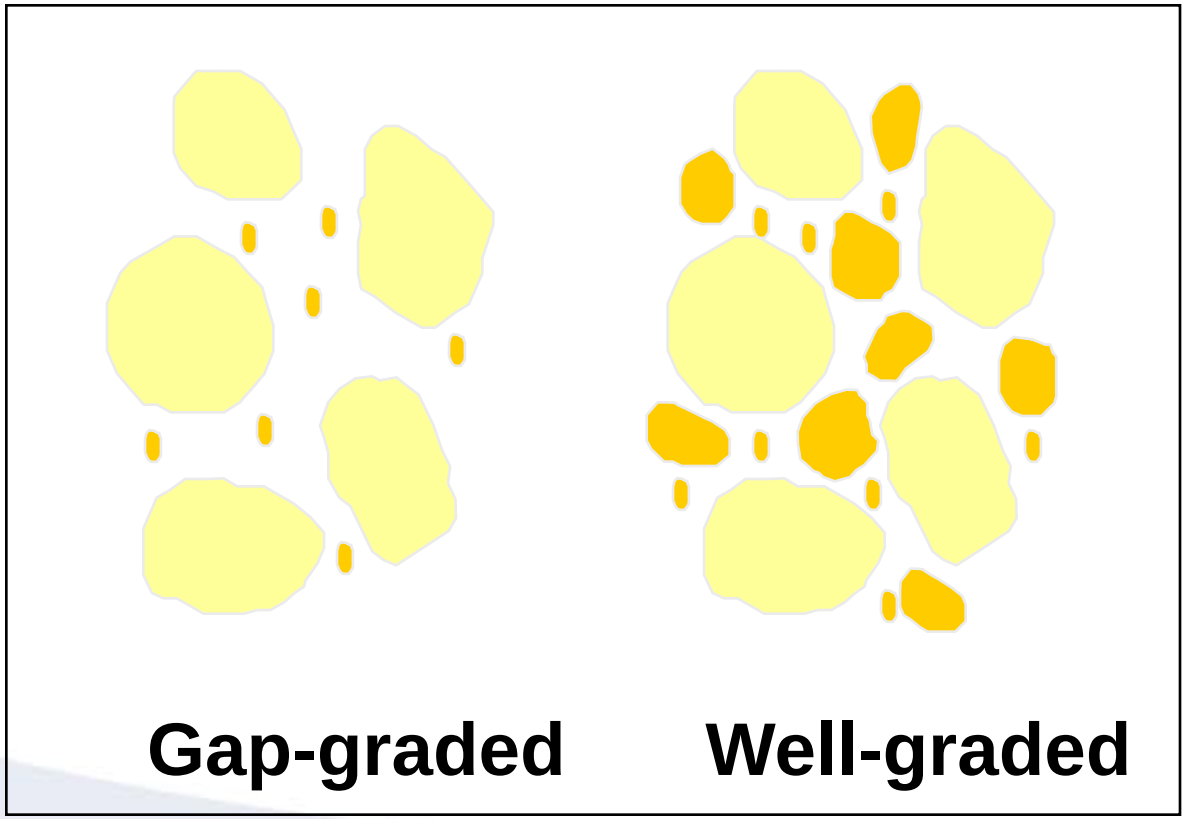
- ASTM C 1260 (ASR) - 30 days for testing.
  - Corp requires < 0.08% expansion at 28 days of soaking
  - FAA requires < 0.10% expansion at 28 days of soaking
- ASTM C 1293 (ASR) - 1 year to test aggregate for potential reactivity; 2 years to test effectiveness of mitigation measures.

1. About 60 days is available from contract award to start of work, so aggregate acceptance needs to be done within that time or before award.
2. ASTM C 1567 can be used to test the effectiveness of mitigation measures. Several combinations of cementitious materials can be tested simultaneously.

Diamond Grinding

- For Smoothness
- For High areas
- Area < 10% of lot
- Maximum ¼ inch depth
- Excess – remove and replace
- Re-texture or re-groove
- Thickness must still be met
- Grinding for rained on PCC

Aggregate Grading (Optimize)



Combined Aggregate Grading

- Proportioned for:
  - Workability
  - Finishibility
- Percent Combined Aggregate Retain

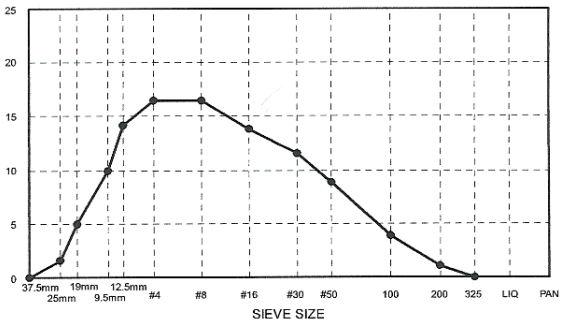


Figure 3.5 "Haystack" Particle Distribution for a Uniformly Graded Mixture

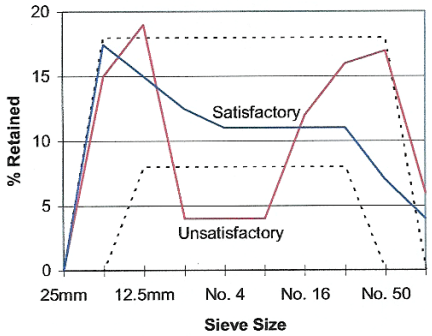
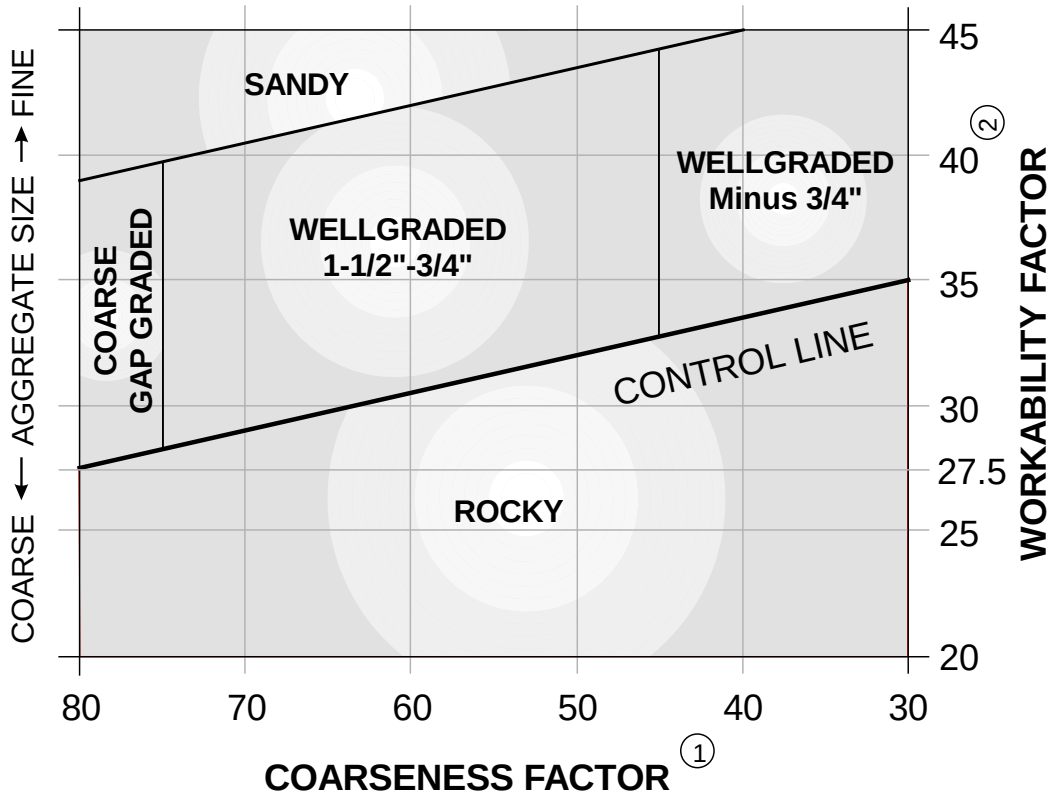


Figure 3.1 Percent Combined Aggregate Retained

USAF Constructability Chart



NOTES:

① **COARSENESS FACTOR =** $\frac{\text{\% RETAINED ABOVE 9.5mm SIEVE}}{\text{\% RETAINED ABOVE \#8 SIEVE}} \times 100$

② **WORKABILITY FACTOR =** % PASSING #8

Aggregate Proportioning Guide

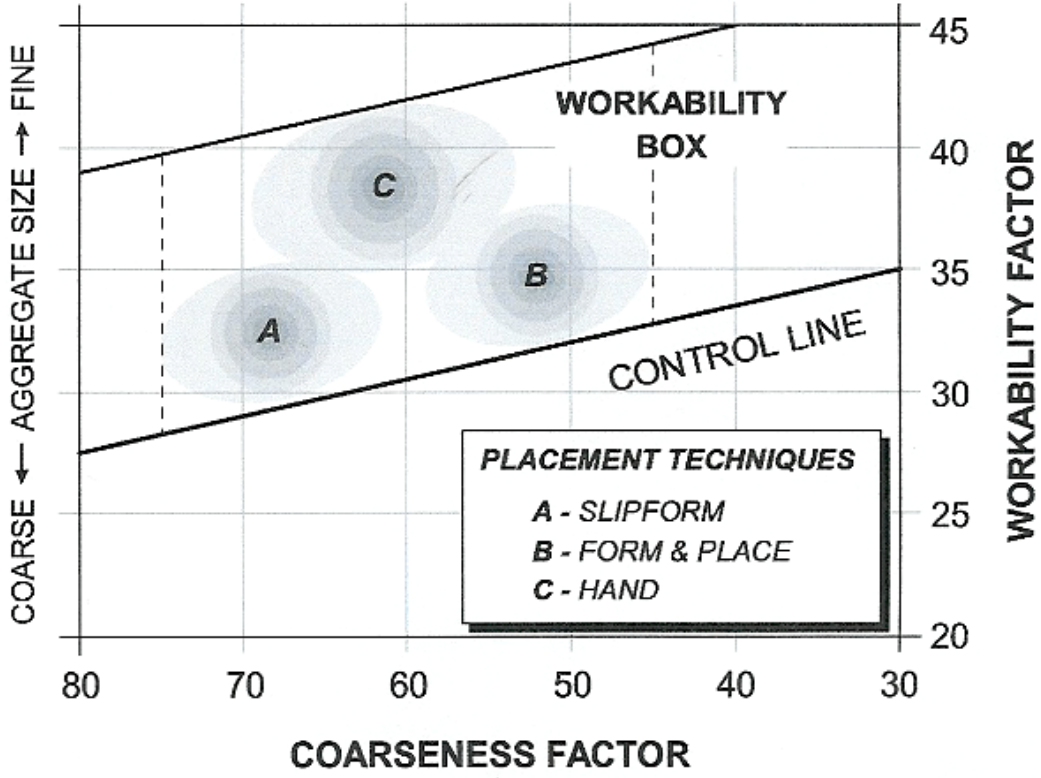
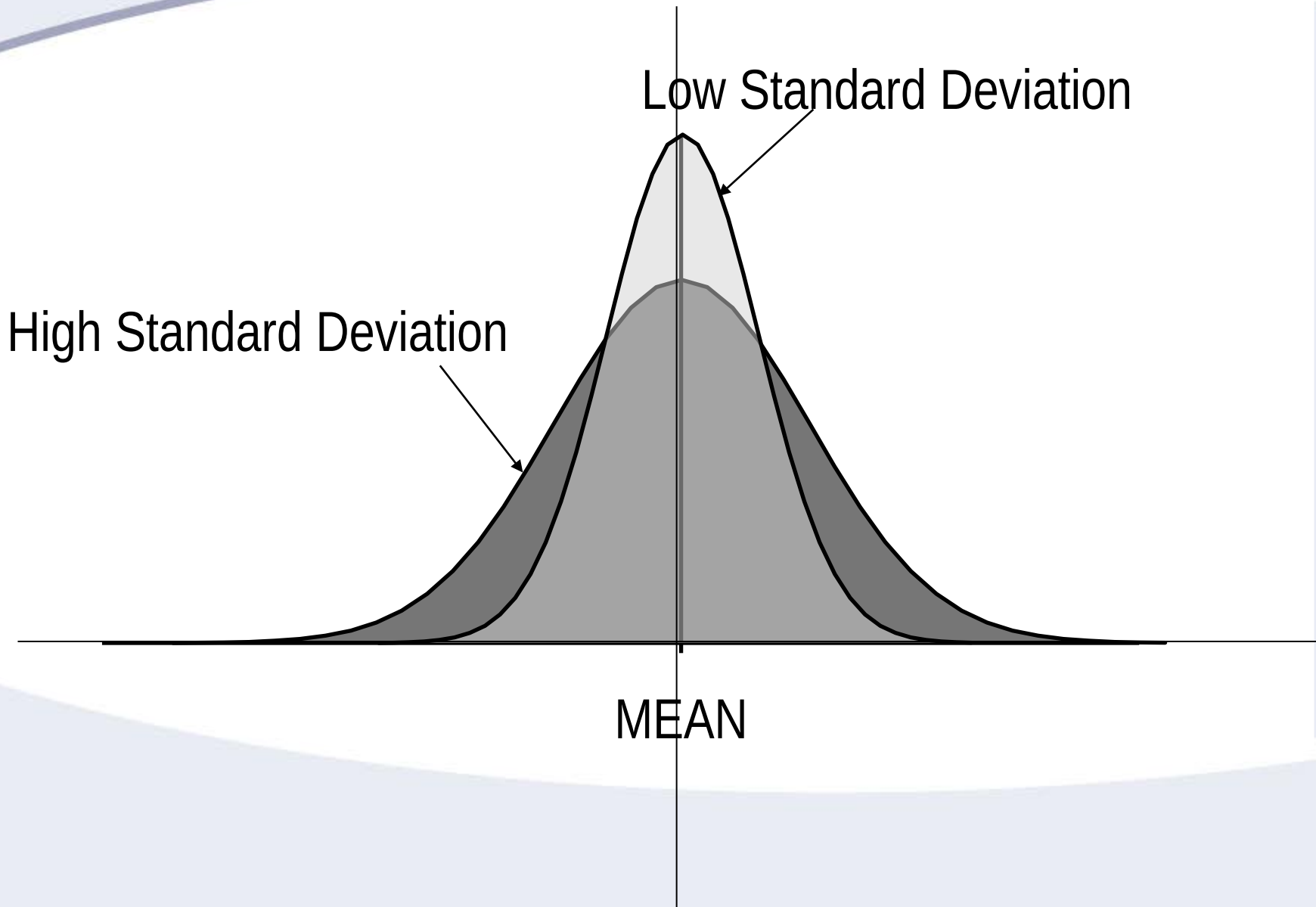


Figure 3.3 Workability Box Within Aggregate Proportioning Guide

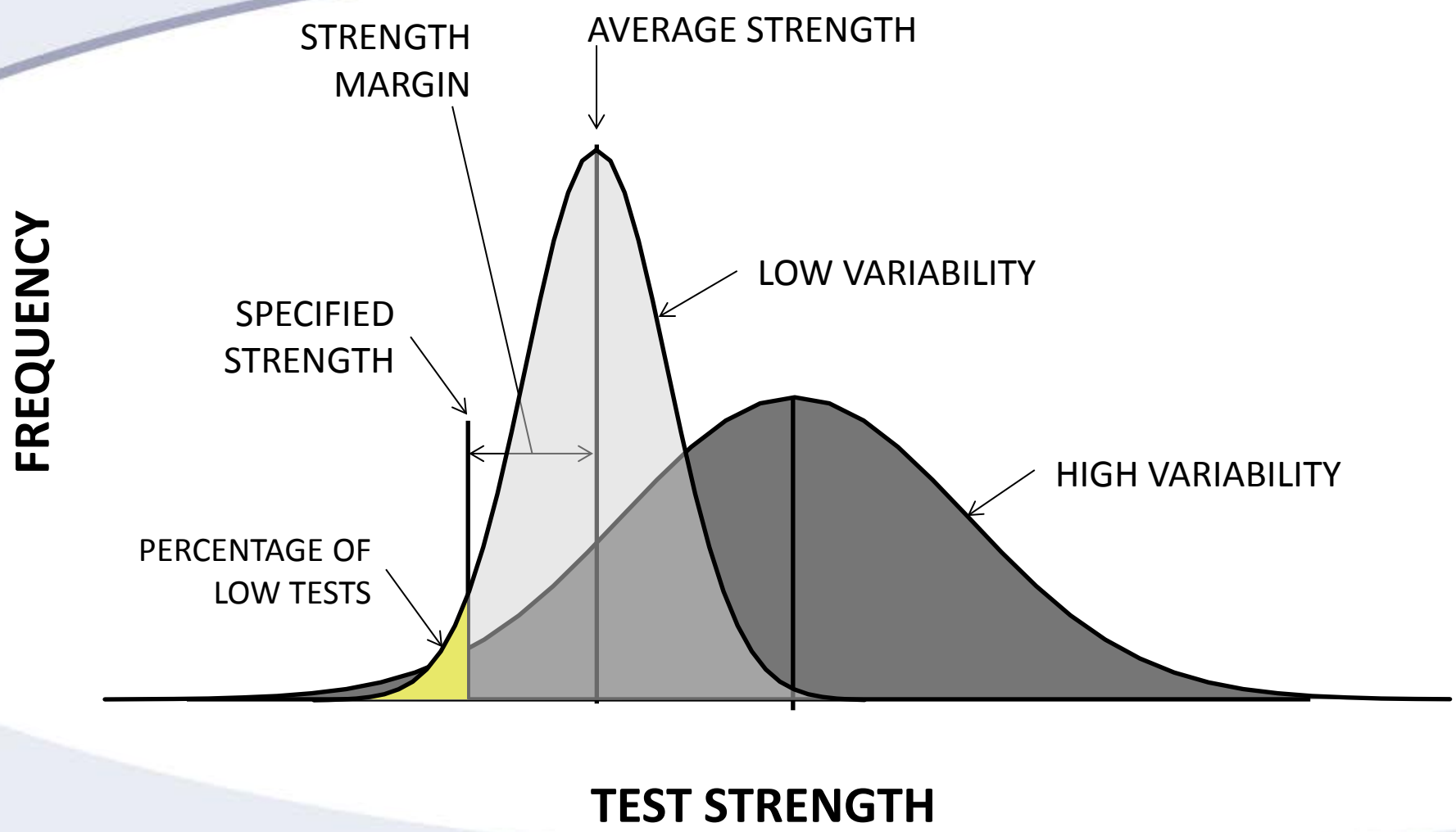
Statistical Quality Control Concepts

- Test are estimates
- Variation expected
  - Material
  - Errors in Sampling
- Random Sampling
- Two Measures define Quality
  - Average
  - Variation (or standard deviation)

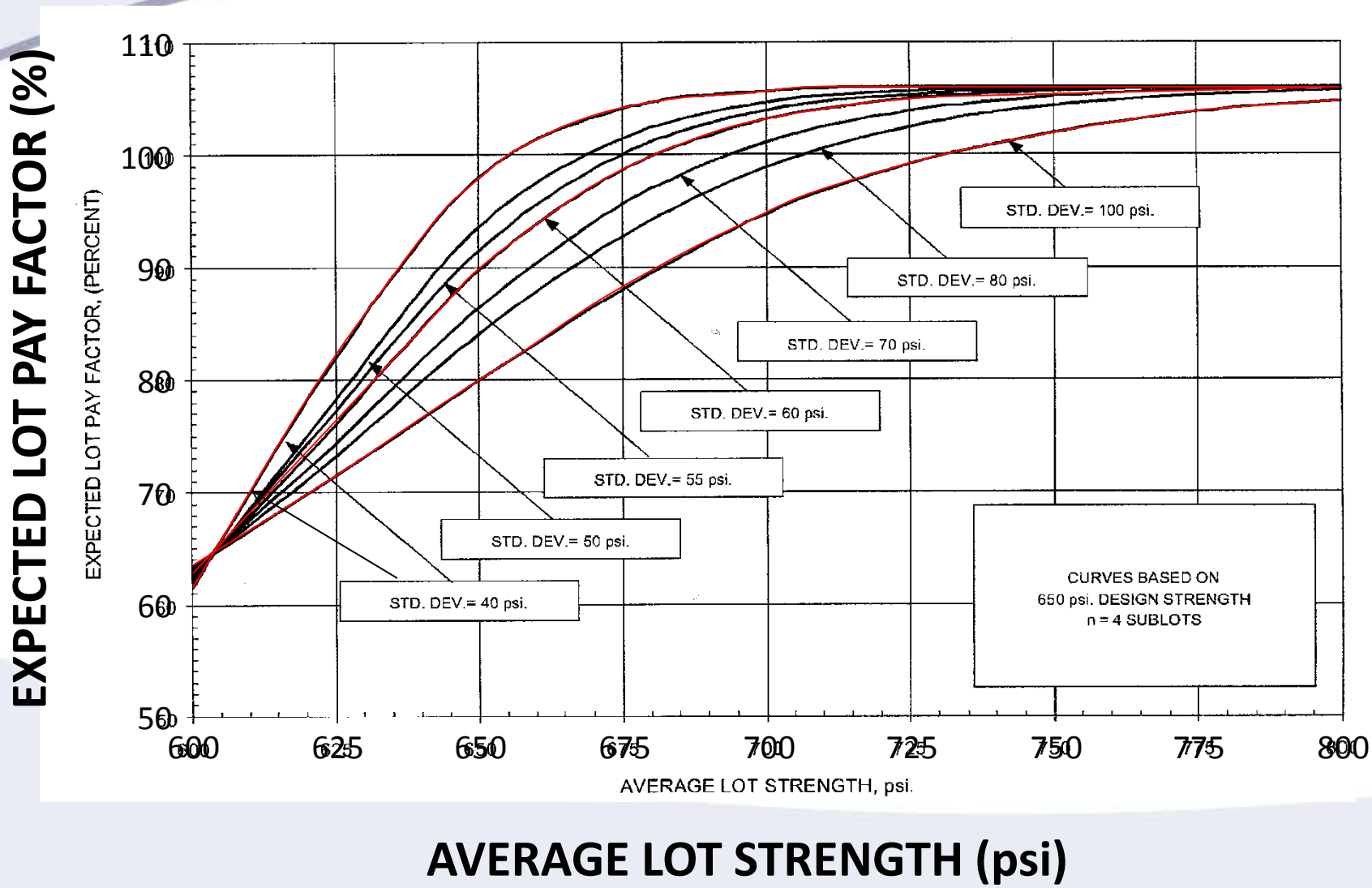
Minimizing Problems = Reducing Variability



Effects of Variability

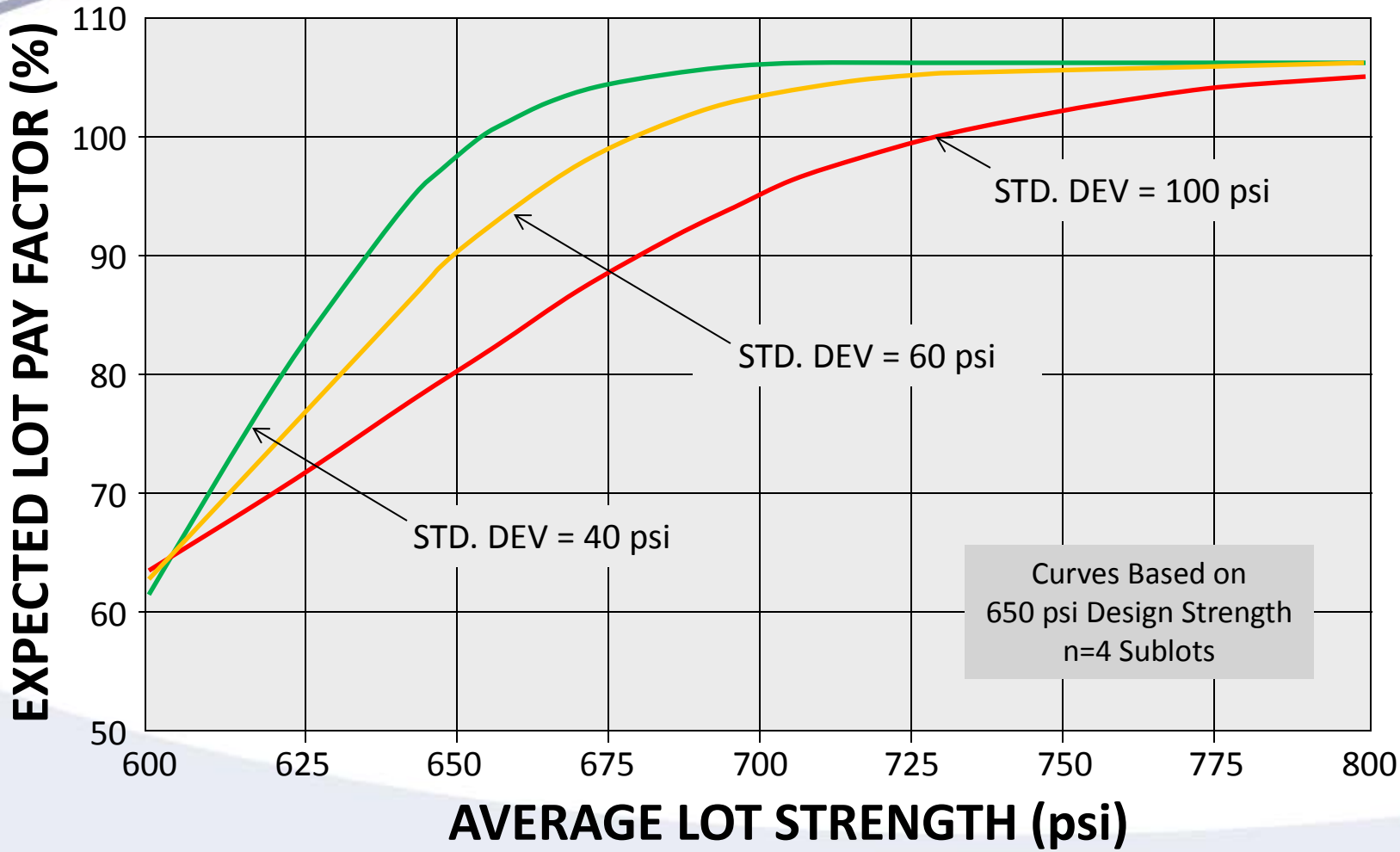


Effects of Variability



AVERAGE LOT STRENGTH (psi)

Effects of Variability



Acceptance Criteria and Design Relationship

- Construction Specification purpose
- Design Intent and AQL Relationship
- Design assumes 1 Standard Deviation
- AQL is established at 90 PWL
- RQL=AQL-1 Standard Deviation

$$
\begin{aligned}
RQL &= AQL - 34.1\ \% \\
&= 90 - 34.1 \\
&= 55\ PWL
\end{aligned}
$$

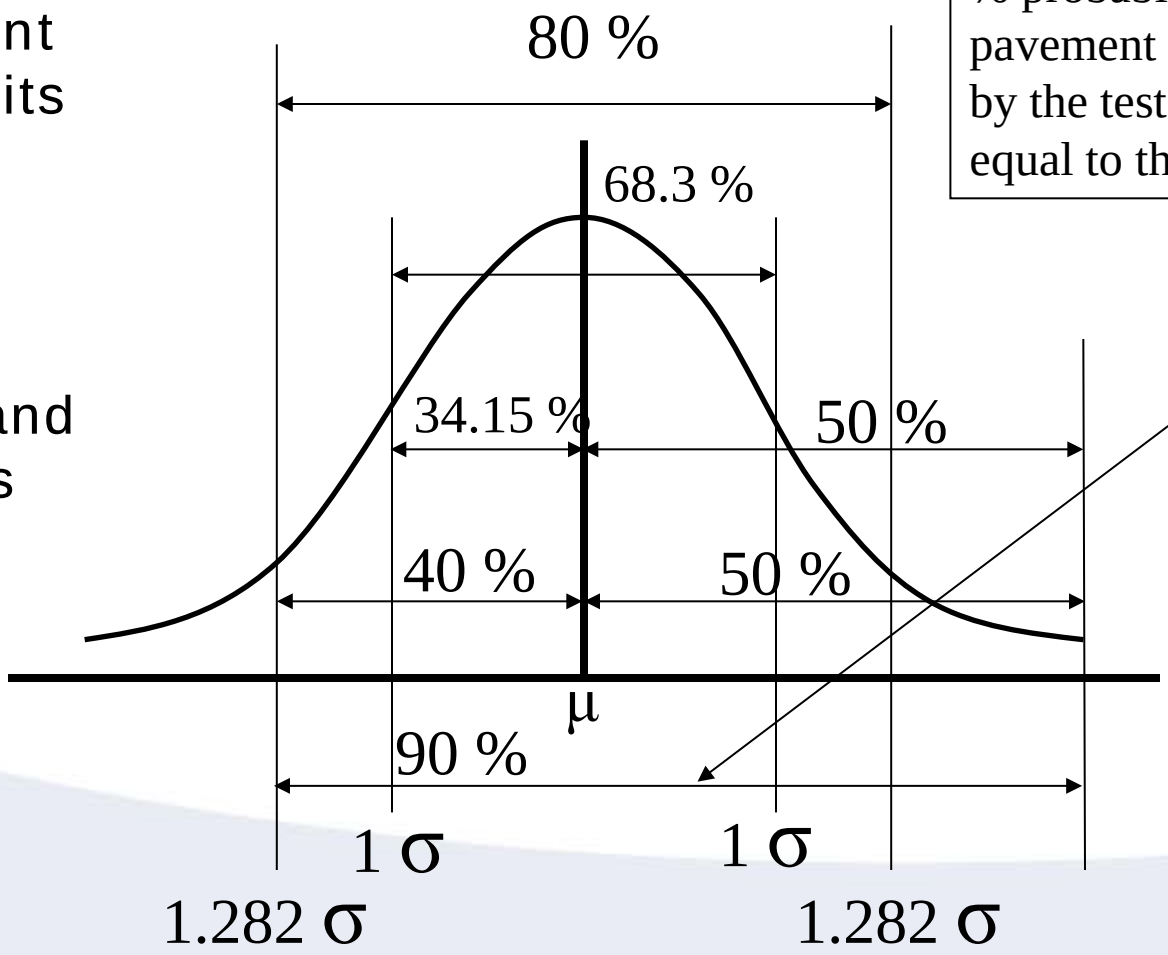
Design intent is met

Acceptable vs. Unacceptable

- Acceptable Quality Level (AQL)
  - Minimum requirement for full pay
- Rejectable Quality Level (RQL)
  - Minimum requirement at reduced pay
- AQL and RQL can be related to total area under the normal probability density curve
- Quality Index
- 1.282 standard deviation = 90 PWL
- Lower tolerance limit = 93% of the design strength

Standard Normal Probability Distribution

FAA Currently uses Percent Within Limits (PWL) concepts based on random sampling and pay factors



Sample Test value in this range means there is a 90 % probability that the pavement lot represented by the test is greater than or equal to the specifications

Table 1: Acceptance Criteria, Item P-401 and Item P-501

	Quality Levels		*Tolerance Limits*	
Item P-401	AQL	RQL	Lower limit	Upper Limit
Mat Density	90 PWL	55 PWL	96.3 %	N/A
Air Voids	90 PWL	55 PWL	2 %	5%
Item P-501	AQL	RQL	Lower limit	Upper limit
Strength	90 PWL	55 PWL	93 % of design	N/A
Thickness	90 PWL	55 PWL	Plan – ½ inch	N/A

Table 2: Pay Factor Adjustment Schedule

PWL	*Lot Pay Factor*
96 and above	106
90 to 96	PWL + 10
75 to 90	0.5 PWL + 55
55 to 74	1.4 PWL – 12
Below 55	Reject

Runway Roughness Evaluation: A Unique Problem

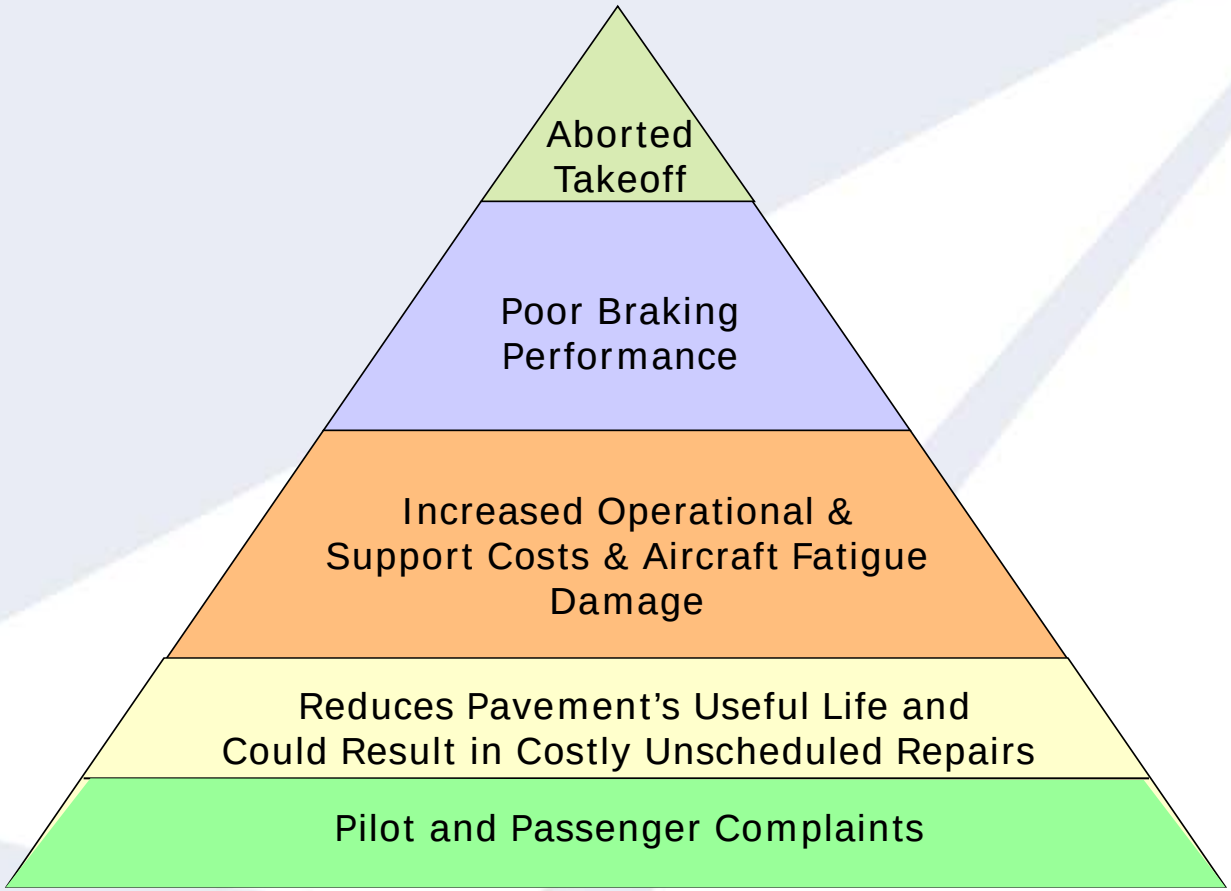
- Landing Gear Spacing of nearly 100 Feet
- Speeds up to 150 Knots
- Aircraft will Respond to Bumps 300 Feet Long or Longer
- Multiple Bumps in Succession; Non-Linear Effect
- Struts are Primarily Designed for Landing Impact

What is Smooth?

How smooth is smooth?

- Shock
  - Sharp Change in Elevation
  - Suspension system cannot absorb the energy
- Short Wavelengths
  - Bump (in 16 feet)
  - Suspension system can react too
- Long Wavelengths
  - Deviations from grade control or interaction with crown
  - Aircraft Responds as a whole

Why Be Concerned About Runway Roughness?



How do you measure smooth?

- Straightedge
- California Profilograph
- Lightweight Profilers
- Wet/Dry Profilers
- Contact Profilers

Existing Smoothness Indices

- Profile Index (PI)
- International Roughness Index (IRI)
- Ride Number (RN)

No relationship exist between the IRI and RN to the straightedge measurements

No correlation exist between profiler measurements and straightedge measurements

FAA AC 150/5370-10G (P-501)

- Criteria
  - 0.25-Inch in 12 Feet or PI of 5-7 (in/mile)
  - 0.5-Inch Max Deviation from Established Grade
- Profile Index 7 to 15 inches per mile (with penalties)
- Difficult to Meet 100% of the Time
- Conservative from Aircraft Response Perspective
- Causes Unnecessary Disputes Regarding Pavement Acceptance
- Unnecessary Grinding
- Led to IPRF/FAA Research Project

Evolution of Airport Pavement Smoothness Assessment California Profilograph

PI of 5-7 Inches/Mile is Conservative

Misapplication and Misinterpretation of the Profilograph Specification

- Low PI = smooth
- Requiring low PI (e.g. 4”per mile)
- Low PI apron—phased project
- Short Sections
- Tying to existing pavement
- Using existing is measurements
- Effects of speed

What is the goal for smoothness?

FAA Advisory Circular 150/5380-9
(Based of Boeing Bump Criteria)

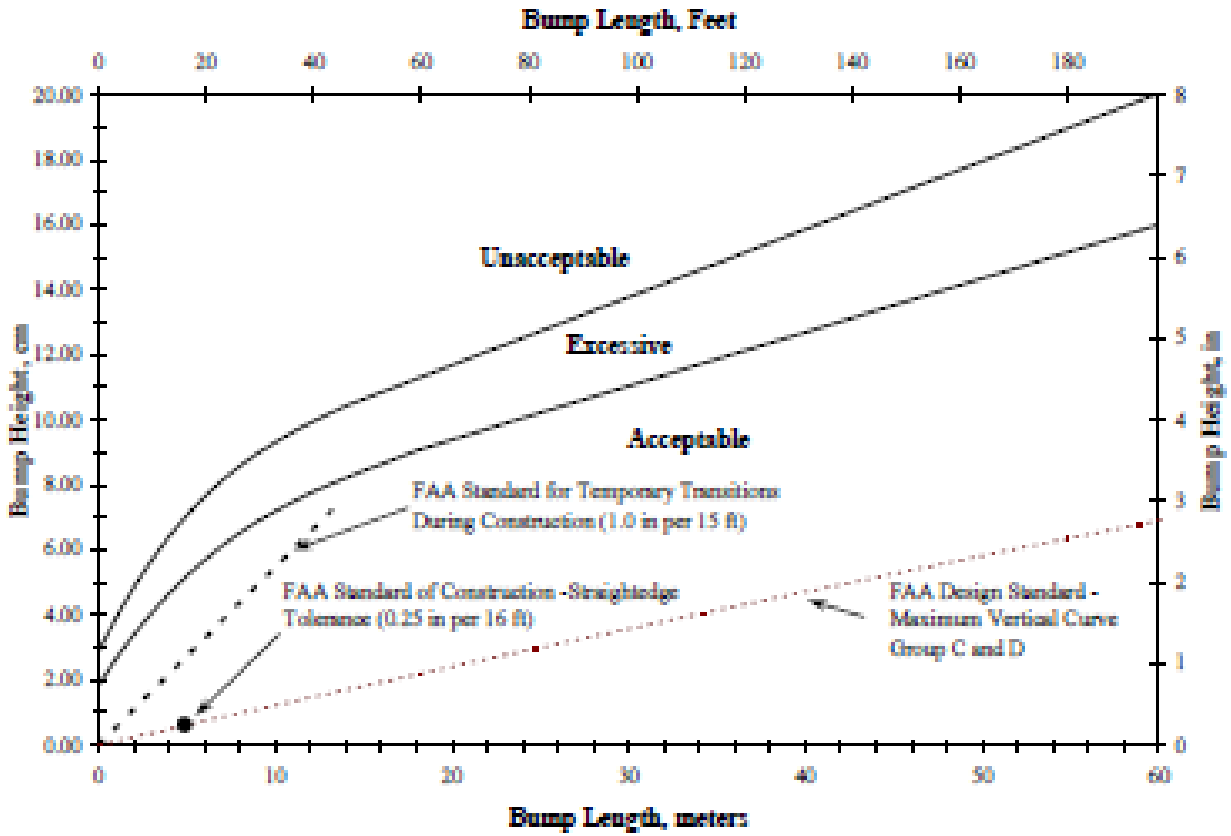


FIGURE 2-3. SINGLE EVENT BUMP - ROUGHNESS ACCEPTANCE CRITERIA

Runway Grooving

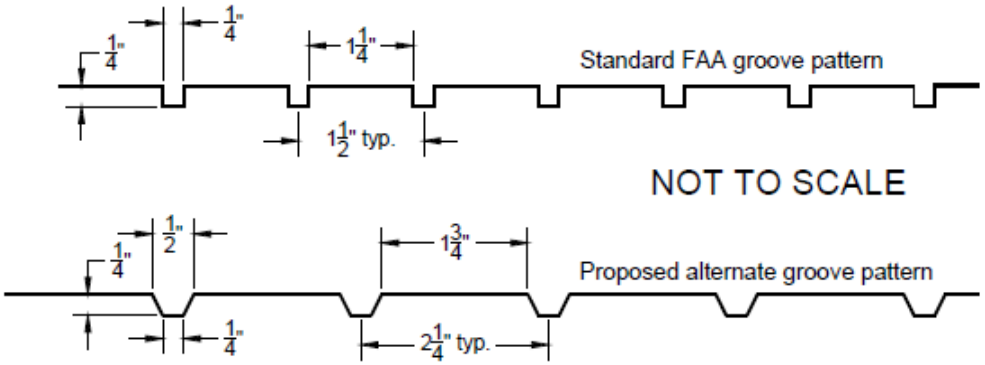


Figure 1. Standard and Trapezoidal-Shaped Groove Configurations

Airfield Pavement—Not Your Typical Highway Construction Project

Gary L. Mitchell P.E.
Vice President – Airports and Pavement Technology
American Concrete Pavement Association

Count on Concrete PAVEMENT

Summary /Discussion