2019 Nevada Transportation Conference

Percent Within Limits (PWL): Industry Perspective

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Presentation Overview

- Risk and Opportunity Associated with a Percent Within Limits (PWL) Specification
- Evolution of Specifications
- Overview of Percent Within Limits (PWL)
- Opportunities/Risks of a PWL Specification to a Contractor
- Critical Components of a PWL Based Specification
- Understanding Agency/Contractor Return on Investment

Evolution of Specifications

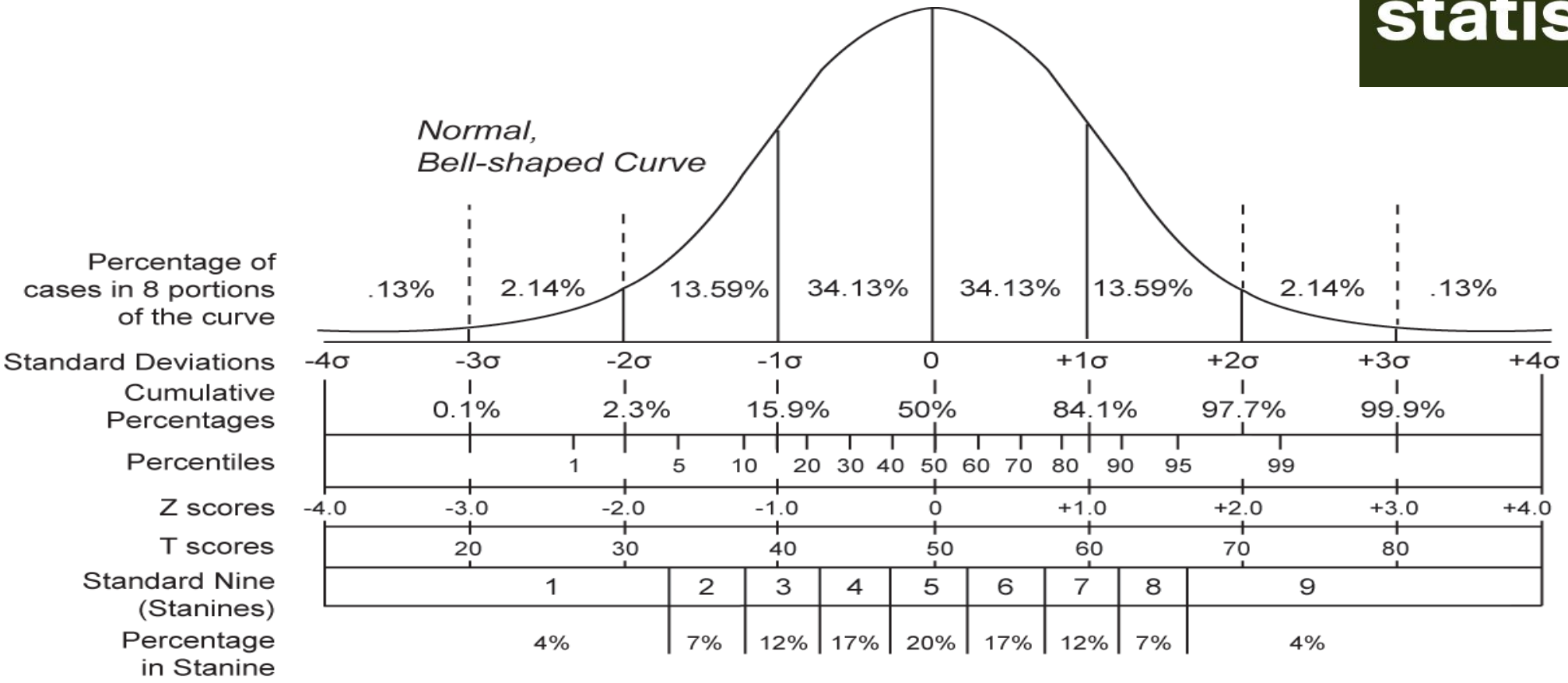
AASHO Road Test (Late 1950's)

- Basis of AASHTO Pavement Design Guide
- Collected "Real Time" Test Data and Quantified
  - **Variability of Material Properties**
  - **Variability of Construction Practices**

- AASHO Road Test Lessons Learned:
  - Specification Tolerances Must Recognize Total Variability of Materials Properties and Construction Practices
  - Specification Limits Must Apply Reasonable Risk to Both the **Seller** and **Buyer**

What is PWL?
Statistics – Ugh…

87.2% of people hate statistics.



Percent Within Limits Specification

What is It?

- Statistically Based Acceptance and Payment
- Assumes Material Production Test Data Follows a Normal Distribution (i.e. Bell Curve)
- Considers the Following For Acceptance:
  - Population Average and Standard Deviation (i.e. multiple samples)
  - Design Target and Specification Limits
- Rewards Being on Target and Being Consistent
- Acknowledges Level of Quality Different when Process is Off Target or Too Variable
- **Acceptance and Payment Adjusted Based on Proximity to Design Target and Variability**

Percent Within Limits (PWL) Specification

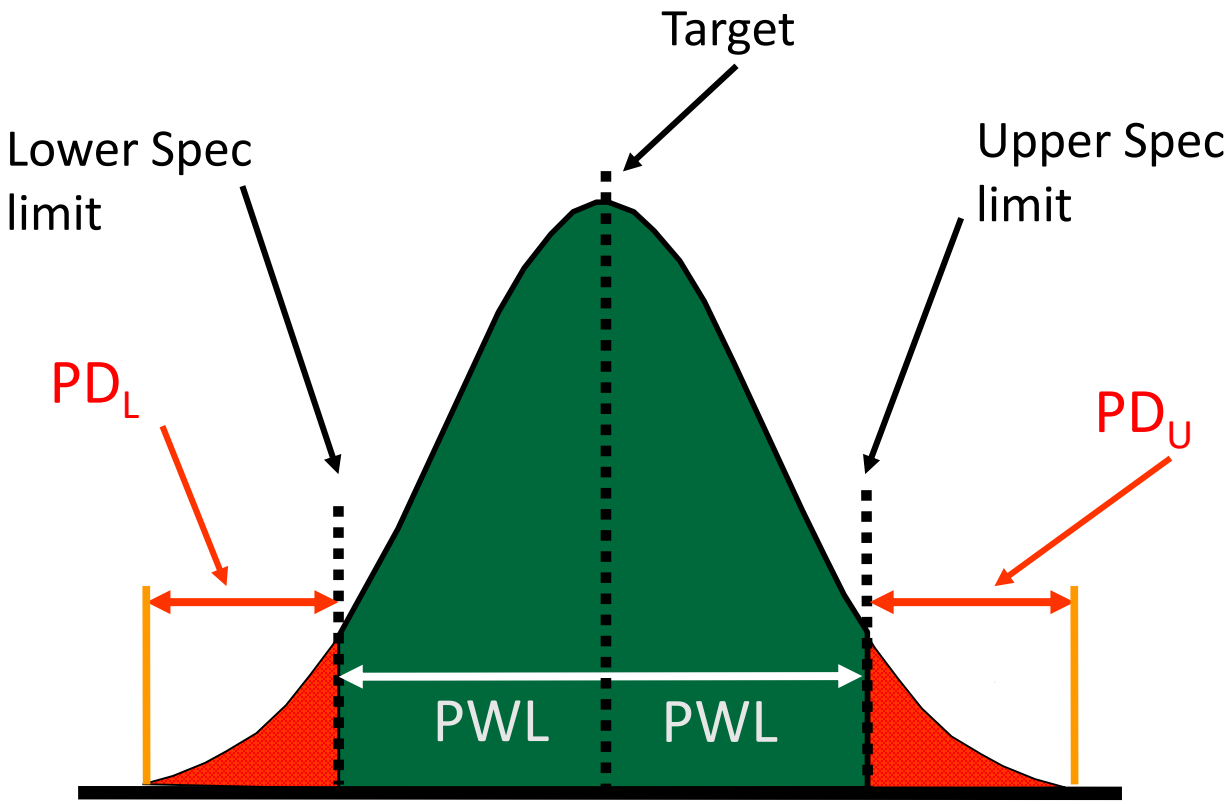
What is It?

PWL = Area of Distribution within Spec Limits

PD = Percent Defective

PWL = 100 - (PD_U + PD_L)

PWL Then Converted to $ with Pay Adjustment Table



PWL Specifications

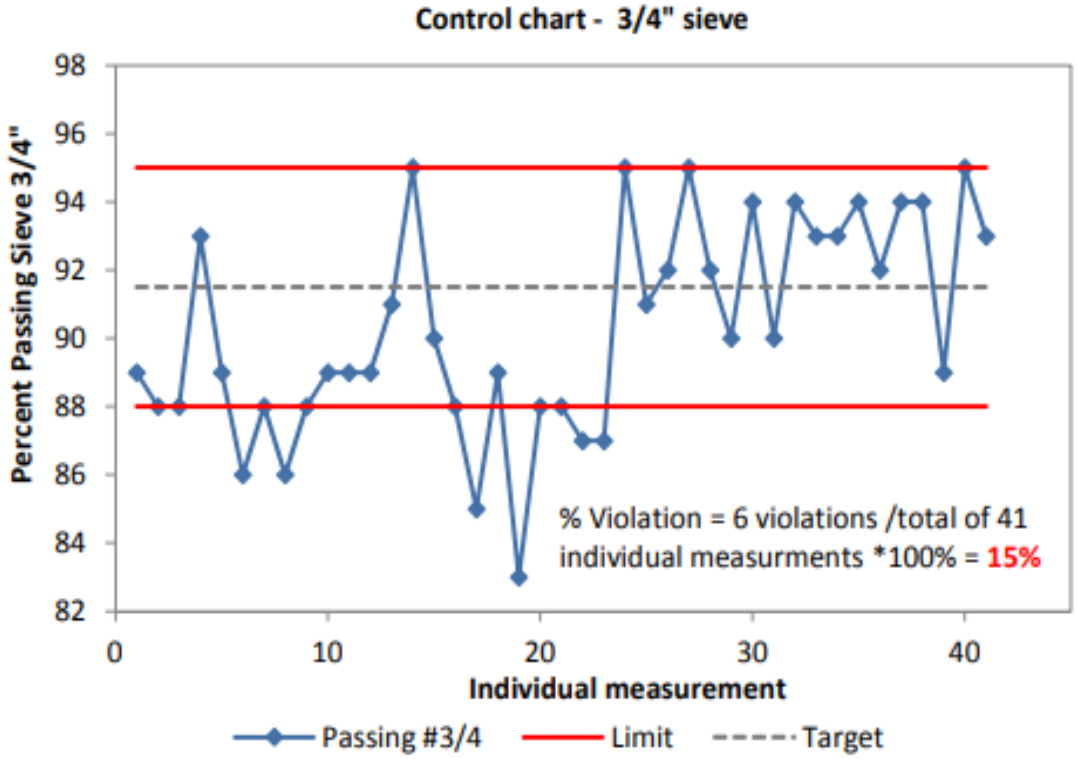
General

- Not All PWL Specifications Are the Same
  - Mechanics of Statistical Calculations Are the Same But Acceptance/Payment Processes Differ
- Acceptance and Payment Differences
  - Contractor Data For Acceptance/Payment with Agency Statistical Check
  - Agency Data Acceptance/Payment but Require Contractor Data Be Submitted
  - Agency Data Acceptance/Payment Only Require Contractor Data For Dispute Process
- For This Presentation
  - General Discussion of What We Have Learned From Experiences in Multiple States
  - Focus on HMA PWL Specifications

Percent Within Limits vs. Other Acceptance Criteria

What's The Difference?

- Conformance to Specification Acceptance Criteria
  - Non Statistically Based Acceptance
  - Considers Only Specification Limits Only For Acceptance
    - Between Limits = Acceptance
  - Individual Sample Measure
  - Level of Quality Assumed to Be The Same for All Tests within Specification Limits
  - **Acceptance and Full Pay Awarded for Being in Anywhere with Specification Band**



PWL Specification Signals a Significant Change in Opportunity/Risk to a Contractor

- Not Business as Usual
- Being In Specification is No Longer Good Enough
- Requires Operational Planning
  - Those Who Do Not Prepare Often Struggle On Initial PWL Projects
- May Require Changes to:
  - Production Equipment
  - Products
  - Laboratory Facilities and Equipment
  - Quality Control Staff

Opportunities/Advantages

PWL Specifications

Key Opportunities/Advantages

- PWL Acceptance Criteria is Best Tool to Quantify Quality
  - Considers - TV, Spec Limits, Average, Variability
- QC/QA with PWL Acceptance
  - Transfer of Responsibility/Risk from Agency to Material Producer/Contractor for Quality
- Opportunity for Producer/Contractor to Control Processes
- Opportunity to Be Compensated for Quality Provided
- Opportunity for Producer/Contractor to Refine Processes and Build Technical Competency

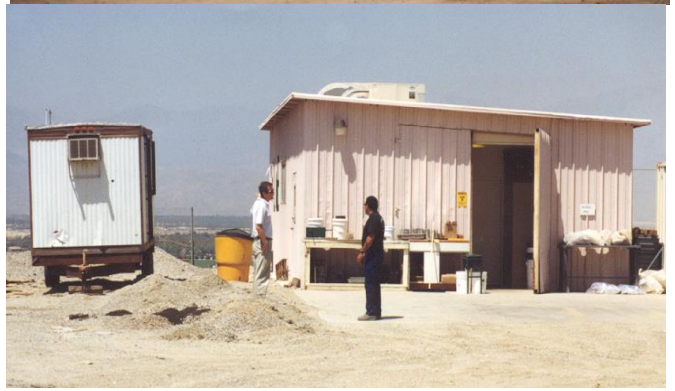
Opportunities/Advantages

Transfer of Responsibility With QC/QA

- Take Greater Role in Design and Acceptance Testing
  - Perform Own Mix Designs with Agency Verification Process
  - QC Data Used as Part of Acceptance and In Some Locations Payment

- Led to Investments In:
  - Facilities
  - Equipment
  - Technical Personnel
  - Laboratory AASHTO Accreditation (14 AASHTO Accredited Laboratories)

- **Outcome**
  - **Improved Materials Quality**
  - **Increased Technical Competency**



Before QC/QA Specifications (early 2000's)

After QC/QA Specifications (2019)

Opportunities/Advantages

Compensated for Quality

- Incentives/Disincentives – Pay Factors
- All Businesses Strive to Maximize Profits
- Driver for Improved Quality

Opportunities/Advantages

Refine Processes and Build Technical Competency

- Preparation for Future Contracting Practices
  - Construction Manager at Risk (CMAR)
  - Design/Build
  - Design/Build/Maintain
  - Warranty

- Complimentary Benefits
  - Materials Optimization for Cost and Quality
  - Development of Byproduct Uses

Risk Points/Disadvantages

Risk Points/Disadvantages

Lack of Knowledge of Risk in Specifications

- Applies to Both Industry and Agency
- Risk and Payment Changes with:
  - Lot and Sublot Size
  - Samples and Tests per Lot and Sublot
  - Sampling Location
  - Test Methods and Test Method Options
  - Acceptance Limit Changes
  - Specification Limit Changes
  - Pay Factor Equations, Weights and Variables
  - …
- Full Risk Impact of PWL Spec Often Only Understood During/After First Projects

Risk Points/Disadvantages

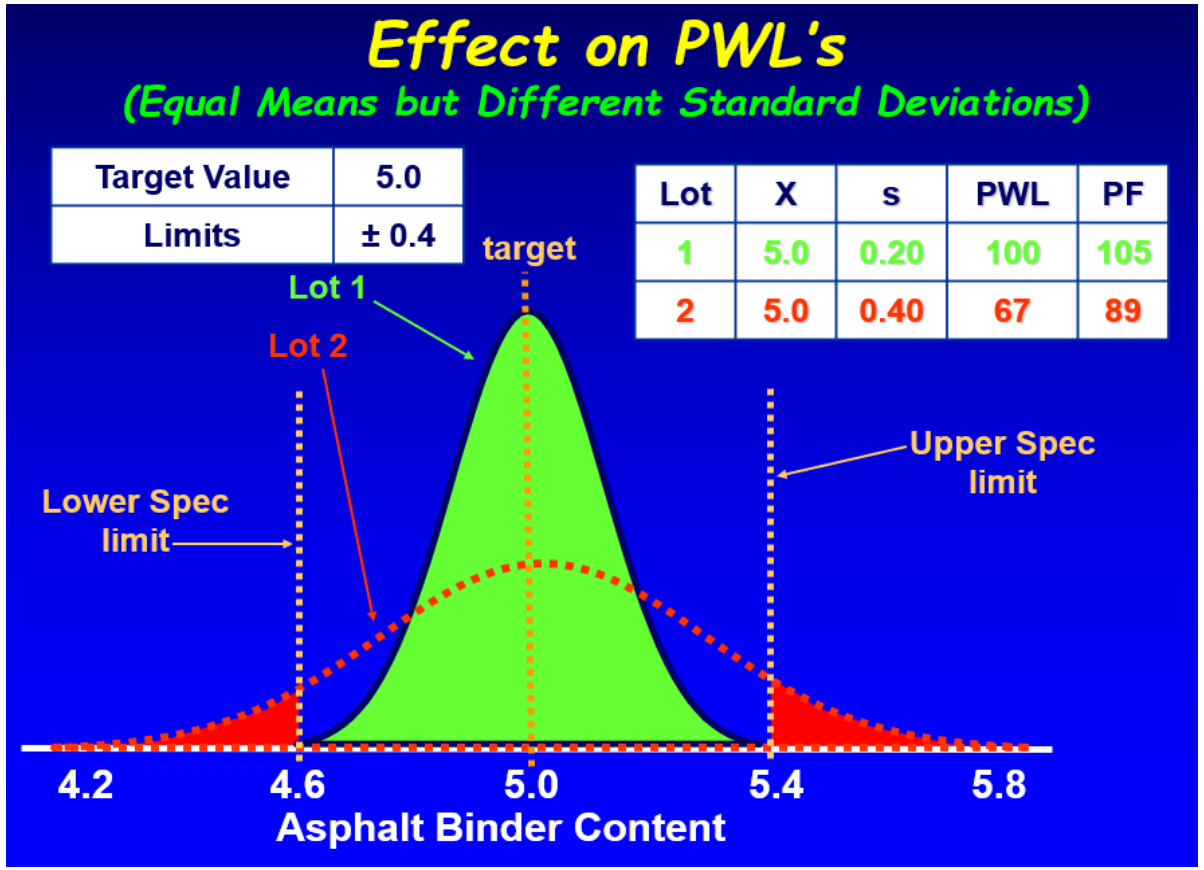
Not Being Prepared for the Change

- A Contractor Must have a PWL Implementation Plan That Considers:
  - Evaluation of Existing Mixes – Are Changes Required to Achieve Desired Level of Bonus?
  - Operational Changes that Cost $$$
  - Laboratory Facilities, Equipment and Accreditation
  - Quality Control Staff
  - PWL Specification Training Within Organization

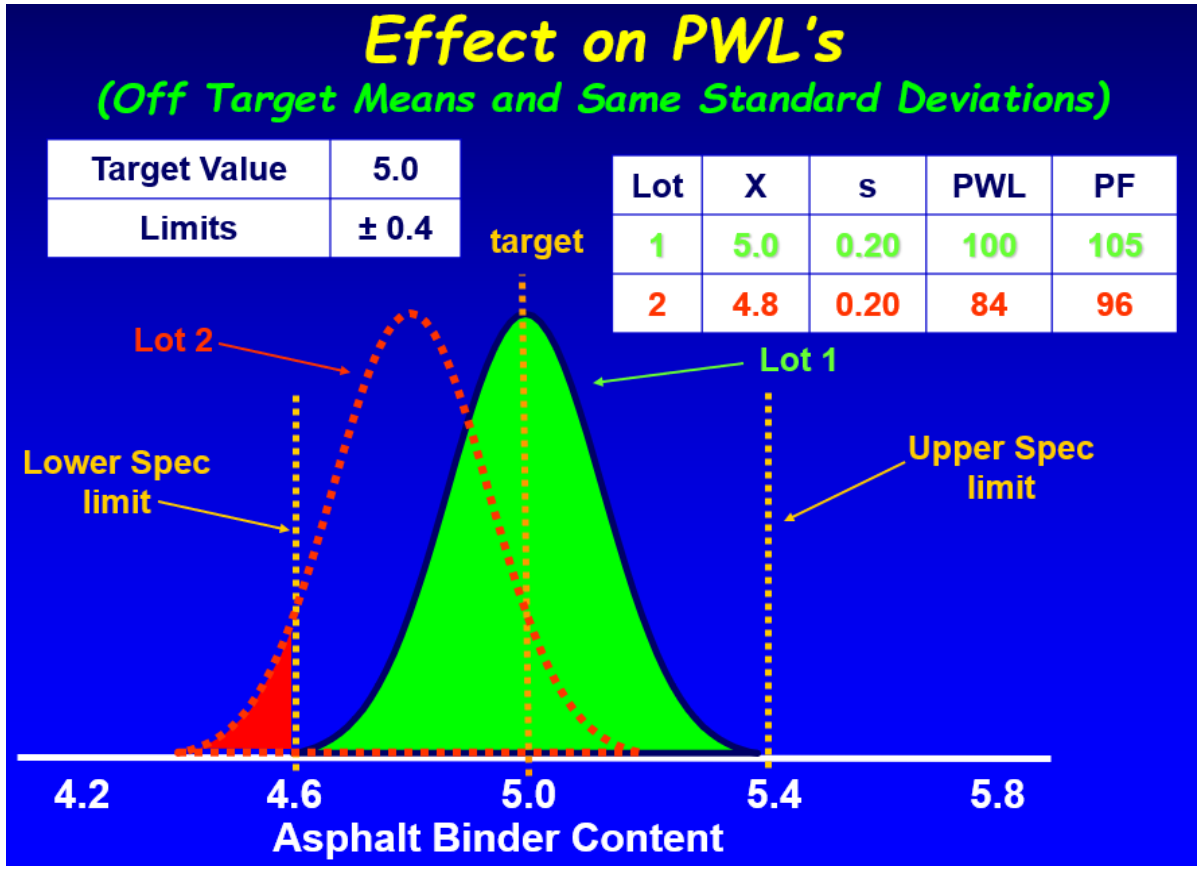
- This Can Be a Big Opportunity Also!!!

Production Team Training Example

Understanding Targets and Variability



Impact of Being More Variable



Impact of Being Off Target

Risk Points/Disadvantages

Laboratory Accreditation

- Accreditation Matters
  - Round Robin Studies Confirm Reduced Variability in Data From Accredited Labs
  - Recognized by Many Agencies Requiring Design Labs Be Accredited

- Does a Double Standard for Accreditation Exist?
  - Non Design Labs Typically Not AASHTO Accredited But Perform Significant Amount of Acceptance Testing
  - What is Impact on Mix Design Verification and Production Acceptance/Payment?

AASHTO ACCREDITATION PROGRAM

Critical Components of a PWL Based Specification

- Contractor Participation in Design and Production Acceptance Processes
- Risk Based Specification Limits
- Test Turnaround Timelines
- Dispute Resolution Process
  - Including Outlier Identification and Re-Testing Provisions

Contractor Participation in Design and Production Acceptance Processes

- Increased Contractor Participation in Material Design/Testing is Important Part of Assuming Additional Risk
  - Mix Design
    - Agency Transfers Risk to Contractor and Have Contractor Perform the Design
    - Contractor Assumes Risk of a “Good” Design
    - Contractor Develops Mix Design to Meet Agency Requirements
    - Agency “Verifies” Mix Design on Lab or Field Produced Material
  - Production Acceptance
    - Contractor Data Required and Considered in Acceptance Process

- Without Increased Participation – Will Contractor Capabilities/Quality Improve?

Risk Based Specification Limits

- Define *Acceptable and Unacceptable* Material Quality

- Must Incorporate All Sources of Variability
  - Function of $(S^2_T) = S^2_{sampling} + S^2_{testing} + S^2_{material/construction}$

- Specification Limits Basis:
  - Acknowledge Sampling and Testing Variability in Spec Limit Development
  - Review Historical Data to Understand Overall Variability
  - Consider Buyers and Sellers Risk

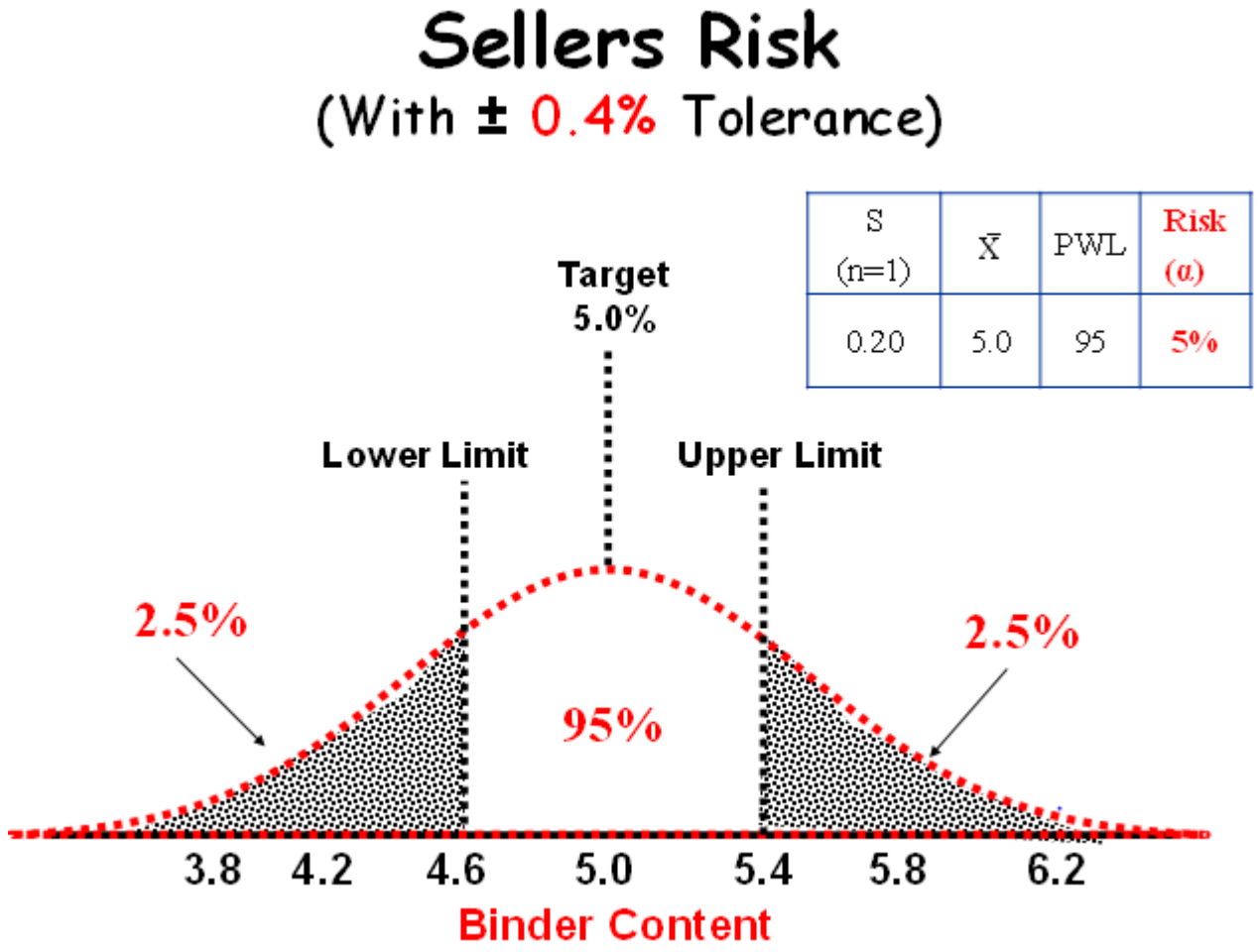
Risk Based Specification Limits

Buyer's Risk β = Risk of Accepting "Bad" Material

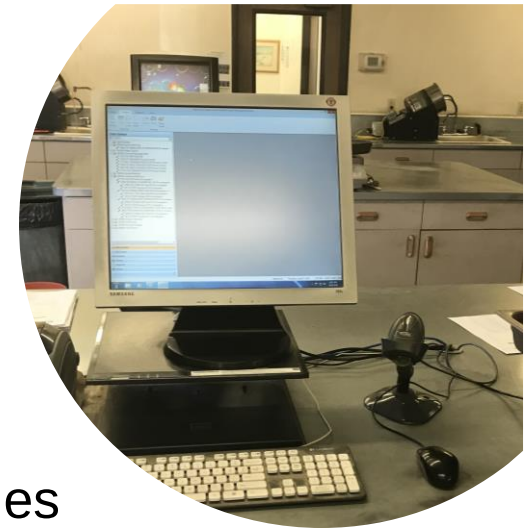
Seller's Risk α = Risk of Rejecting "Good" Material

FHWA Recommended Seller's Risk (α): 5.0% Max.

- Typically 2s About the Mean



Test Turnaround Timelines and Data Management



- Timely Test Data Critical for PWL Specification
  - Data Required for Timely Plant Changes/Process Changes
  - PWL Process Requires Proactive Plant Changes to Achieve Bonus
  - Use of Testing Software Critical with Automated Data Reporting Capabilities

- QC vs. QA Testing
  - Often Differences Exist Between the QC and QA Results
  - Need to Understand and Quickly Resolve Between Lab Differences
  - Highest Risk – Start of Project

Proactive Information Dissemination

Right Information, Right Level of Detail, Right Person at the Right Time

Automated Sample Specific Email Alerts

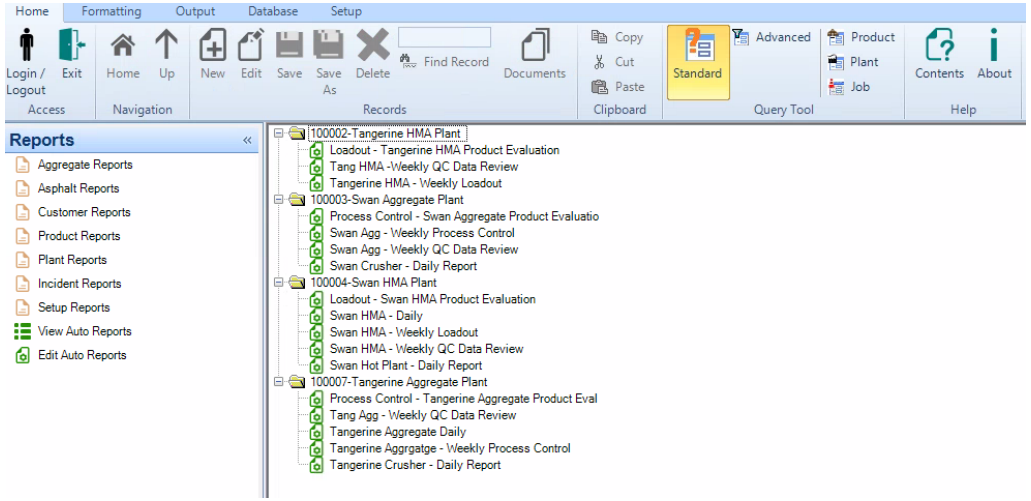
From: Benkovich, Teilhard
Sent: Monday, May 21, 2018 2:05 PM
To:
Subject: StonemontQC Email Alert

Sample Information	
Plant	100186- Plant #1
Product	1817-3/4" AGGREGATE BASE
Sample Id	1851358776
Sampled Date	5/21/2018 7:59:00 AM
Sampled By	Ty Benkovich
Sample Type	Process Control
Sample Method	Stockpile
Sample Location	West Plant
Ledge	134B - 1" and 3/4" PMA w/ agg base
Sample Notes	PRODUCTION 5/21/18
User	tbenkovich

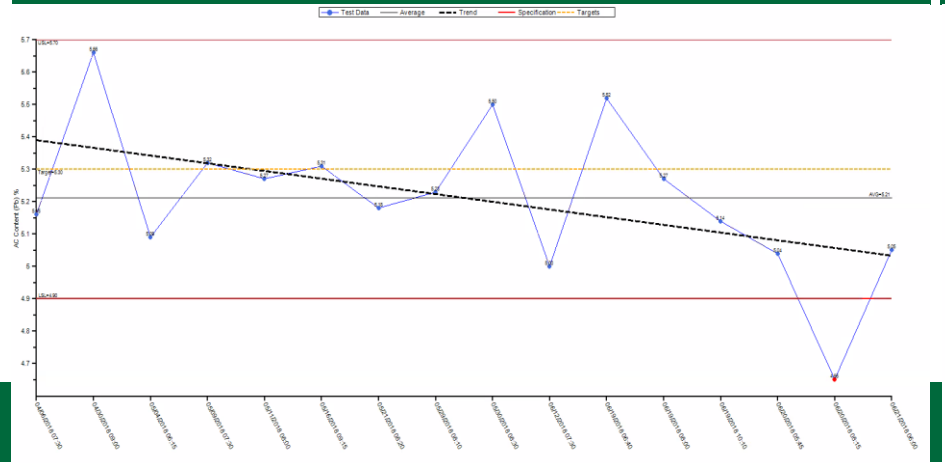
Gradation Test Failure - Type2, Class B (2012)

Sieve	Mass Retained	% Passing	Specifications	Targets	Comment
1"	0.00	100	100-100		
3/4"	48.10	98	90-100		
1/2"	467.20	77			
3/8"	260.70	65			
#4	501.80	42	35-65		
#8	359.60	26			
#10	35.60	24	25-53		Fail
#16	101.80	20	15-40		
#30	100.40	15			
#40	44.40	13	12-28		
#50	48.10	11			
#100	67.40	8			
#200	38.60	6.3	2-10		
PAN	10.60	0.0			

Automated Summary Reporting



Control Charts



Statistical Summary Reports

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Sample Id	Date	AC Content (Pb) (%)	Specimen Mass (g)	Specimen Thickness (in)	Air Voids (Va) (%)	Vtotal (%)	Absorption (Asphalt) (%)	SPGR (Compacted,Gmb)	Spgr (Effective, Gse)	SPGR (Max, Gmm)	Density (Relative) (%)	Unit Wt (Compacted) (lb/ft3)	Unit Wt (Max) (lb/ft3)
1806954198	04/06/2018 07:30	5.16	1176.6	2.462	5.0	0.120	0.31	2.357	2.693	2.482	95.0	146.7	154.6
1816628351	04/30/2018 09:00	5.66	1184.3	2.469	4.4	0.132	0.28	2.356	2.695	2.465	95.6	146.7	153.4
1949783582	06/04/2018 06:15	5.09	1217.6	2.602	6.6	0.116	0.32	2.314	2.680	2.475	93.4	144.0	154.1
1951697511	05/09/2018 07:30	5.32	1219.8	2.594	6.8	0.120	0.39	2.310	2.694	2.478	93.2	143.8	154.3
1851357891	05/11/2018 08:00	5.27	1213.0	2.567	6.0	0.120	0.46	2.338	2.702	2.486	94.0	145.5	154.8
1709315668	05/16/2018 09:15	5.31	1219.5	2.549	4.9	0.123	0.22	2.368	2.709	2.490	95.1	147.4	155.0
1486992342	05/21/2018 08:20	5.18	1202.0	2.526	5.4	0.120	0.22	2.358	2.705	2.492	94.6	146.8	155.2
1478535197	05/29/2018 08:10	5.23	1201.4	2.482	4.8	0.121	0.36	2.362	2.695	2.482	95.2	147.0	154.4
1886037192	05/30/2018 08:30	5.60	1206.2	2.533	5.0	0.126	0.44	2.340	2.685	2.464	95.0	145.6	153.4
1536175826	06/12/2018 07:30	5.00	1197.2	2.502	5.7	0.115	0.20	2.350	2.697	2.492	94.3	146.2	155.2
1584052079	06/19/2018 06:40	5.52	1219.8	2.562	4.4	0.127	0.14	2.350	2.681	2.460	95.6	146.3	153.2
1667657298	06/19/2018 08:00	5.27	1210.2	2.562	4.9	0.121	0.28	2.344	2.674	2.464	95.1	145.8	153.4
1991024109	06/19/2018 10:10	5.14	1209.8	2.526	4.7	0.119	0.18	2.364	2.688	2.480	95.3	147.2	154.4
1596150320	06/20/2018 05:45	5.04	1220.5	2.530	4.6	0.117	0.13	2.370	2.691	2.486	95.4	147.6	154.8
1093338125	06/20/2018 08:15	4.65	1198.9	2.480	3.6	0.109	0.13	2.392	2.666	2.480	96.4	148.9	154.4
1536175433	06/21/2018 06:00	5.05	1208.0	2.520	3.8	0.117	0.16	2.358	2.650	2.452	96.2	146.8	152.6

	AC Content (Pb) (%)	Specimen Mass (g)	Specimen Thickness (in)	Air Voids (Va) (%)	Vtotal (%)	Absorption (Asphalt) (%)	SPGR (Compacted,Gmb)	Spgr (Effective, Gse)	SPGR (Max, Gmm)	Density (Relative) (%)	Unit Wt (Compacted) (lb/ft3)	Unit Wt (Max) (lb/ft3)
Count	16	16	16	16	16	16	16	16	16	16	16	16
Mean	5.21	1206.6	2.528	5.0	0.120	0.26	2.352	2.688	2.477	95.0	146.4	154.2
St Dev	0.238	12.88	0.0415	0.89	0.0053	0.109	0.0203	0.0151	0.0122	0.89	1.28	0.78
Target	5.3			5.6								

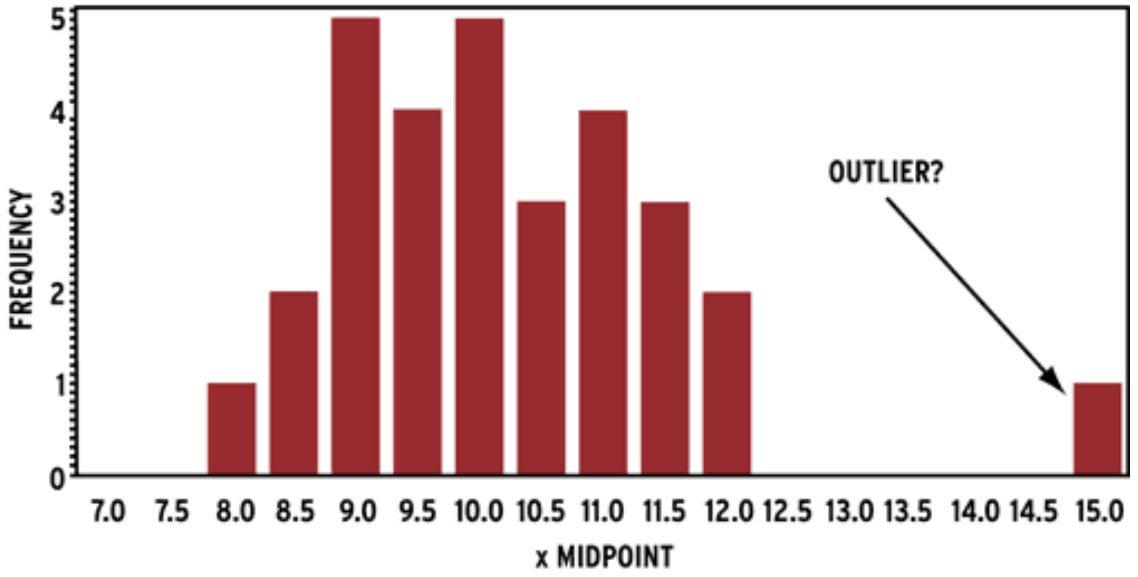
Dispute Resolution
Best Practice

- Process Needs to Be Well Defined
- Consider both QC and QA Data
- Utilize Independent 3rd Party Resolution Testing Labs Mutually Agreed Upon
- Utilize a Simple Process as to Promotes Timely Resolution of Issues

Dispute Resolution

Outlier Detection and Re-Testing

- Need for Outlier Definition – "*Wacky or Flyer*"
- Need for Outlier Detection Tool
  - ASTM E178 or some other criteria
- Need Re-test Provision – Test whole sample or individual test? Split or independent sample…
  - Just Because Something Is Out of Specification, Does Not Mean It Should be Re-Tested



Return on Investment (ROI)

Contractor

- Return on Investment (ROI)
  - Investment Made to Improve Quality and Increase Bonus Payment
    - Facilities, Equipment, Technical Personnel

- Assume Reasonable Return on Investment
  - Significant Capital Investments Required
  - Bonuses Must Exceed Investments
  - Must Consider Long Analysis Period
  - Specification Must be Steady-State

Return on Investment (ROI)

Agency

- Does Bonus Payout Result in Sufficient Increased Quality/Performance?
- Are Expenditures Within the Context of Quality and Consequence of Failure
  - Identify and Optimize Agency Expenditures on Items with Greatest Consequence of Failure (e.g. Bridge Deck vs. Frontage Road)

Summary

- PWL Specifications Provide Both an Opportunity and Increased Risk to a Contractor
- As Part of a Contractor Assuming More Risk, Agencies Typically Transfer Additional Responsibilities to the Contractor (i.e. mix design, use of QC Data in acceptance process)
- Contractors Must Prepare and Evaluate Impact to “Current” Operations
  - Budget for Changes to Facilities, Equipment, Staff and Operations
  - Those Who Do Not Prepare Will Struggle
- Specification Limits Must be Developed Considering Both Buyers and Sellers Risk
- Return on Investment – Well Designed PWL Specification
  - Contractor – Achievable Bonus Must Be Sufficient to Cover Initial Investments
  - Agency – Increased Level of Quality and Performance to Justify Bonus

Thank You

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