Percent Within Limits – The NDOT Story

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Outline

- What is Percent Within Limits (PWL)?

- How to calculate PWL?

- Why the need for PWL specifications?

- Development of PWL specifications

- Implementation of PWL specifications

- NDOT's current PWL specifications

- NDOT's final PWL specifications

What is PWL?

- PWL uses statistical analysis to determine the consistency and quality of a material produced by a contractor.

- PWL encourages contractors to produce consistent quality work by either rewarding them with incentives or penalizing them with disincentives.

- PWL is based upon established specification limits for a given material property.

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What is PWL? (Cont.)

- PWL: Percent Conforming

  ➤ Percentage of the lot falling above the LSL, beneath the USL, or between LSL and USL

  ❖ LSL: Lower Specification Limit

  ❖ USL: Upper Specification Limit
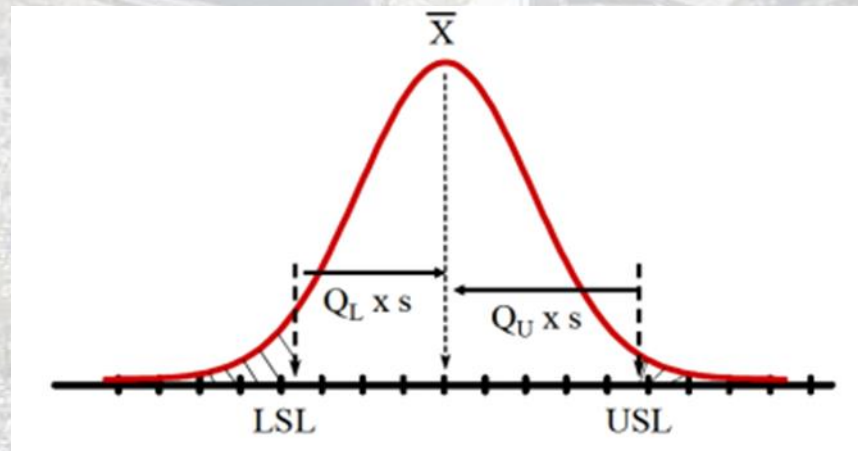
How to Calculate PWL?

1. Calculate sample mean for the lot

2. Calculate sample standard deviation of the lot

3. Calculate lower and upper quality indexes

4. Obtain upper PWL (PWL_U) and lower PWL (PWL_L) from PWL estimation table

5. Calculate Total PWL (PWL_T)

Example PWL Calculation

- The following asphalt content data was collected from a lot of HMA mix:

  ➢ AC_1 = 4.40%, AC_2 = 4.62%, AC_3 = 4.10%, AC_4 = 4.33%, & AC_5 = 4.86%

- The target asphalt content (AC_{Target}), LSL, & USL are specified as follows:

  ➢ AC_{Target} = 4.50%

  ➢ LSL = 4.10%

  ➢ USL = 4.90%

- What is the PWL_T for AC?

Example PWL Calculation (Cont.)

- Solution:

  ➢ The average AC is 4.46%

  ➢ The standard deviation is 0.29

  ➢ The lower and upper quality indexes are calculated as follows:

    ❖ Q_L = (4.46 – 4.10)/0.29 = 1.24

    ❖ Q_U = (4.90 – 4.46)/0.29 = 1.52

  ➢ The PWL values are obtained from the PWL estimation table as follows:

PWL Estimation Table for Sample Size *n = 5*

Q_L or Q_U	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	50.00	50.36	50.71	51.07	51.42	51.78	52.13	52.49	52.85	53.20
0.1	53.56	53.91	54.27	54.62	54.98	55.33	55.69	56.04	56.39	56.75
0.2	57.10	57.46	57.81	58.16	58.52	58.87	59.22	59.57	59.92	60.28
0.3	60.63	60.98	61.33	61.68	62.03	62.38	62.72	63.07	63.42	63.77
0.4	64.12	64.46	64.81	65.15	65.50	65.84	66.19	66.53	66.87	67.22
0.5	67.56	67.90	68.24	68.58	68.92	69.26	69.60	69.94	70.27	70.61
0.6	70.95	71.28	71.61	71.95	72.28	72.61	72.94	73.27	73.60	73.93
0.7	74.26	74.59	74.91	75.24	75.56	75.89	76.21	76.53	76.85	77.17
0.8	77.49	77.81	78.13	78.44	78.76	79.07	79.38	79.69	80.00	80.31
0.9	80.62	80.93	81.23	81.54	81.84	82.14	82.45	82.74	83.04	83.34
1.0	83.64	83.93	84.22	84.52	84.81	85.09	85.38	85.67	85.95	86.24
1.1	86.52	86.80	87.07	87.35	87.63	87.90	88.17	88.44	88.71	88.98
1.2	89.24	89.50	89.77	90.03	90.28	90.54	90.79	91.04	91.29	91.54
1.3	91.79	92.03	92.77	92.51	92.75	92.98	93.21	93.44	93.67	93.90
1.4	94.12	94.34	94.56	94.77	94.98	95.19	95.40	95.61	95.81	96.01
1.5	96.20	96.39	96.58	96.77	96.95	97.13	97.31	97.48	97.65	97.81
1.6	97.97	98.13	98.28	98.43	98.58	98.72	98.85	98.98	99.11	99.23
1.7	99.34	99.45	99.55	99.64	99.73	99.81	99.88	99.94	99.98	100.00

For Q_L = 1.24
PWL_L = 90.28

PWL Estimation Table for Sample Size *n = 5*

Q_L or Q_U	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	50.00	50.36	50.71	51.07	51.42	51.78	52.13	52.49	52.85	53.20
0.1	53.56	53.91	54.27	54.62	54.98	55.33	55.69	56.04	56.39	56.75
0.2	57.10	57.46	57.81	58.16	58.52	58.87	59.22	59.57	59.92	60.28
0.3	60.63	60.98	61.33	61.68	62.03	62.38	62.72	63.07	63.42	63.77
0.4	64.12	64.46	64.81	65.15	65.50	65.84	66.19	66.53	66.87	67.22
0.5	67.56	67.90	68.24	68.58	68.92	69.26	69.60	69.94	70.27	70.61
0.6	70.95	71.28	71.61	71.95	72.28	72.61	72.94	73.27	73.60	73.93
0.7	74.26	74.59	74.91	75.24	75.56	75.89	76.21	76.53	76.85	77.17
0.8	77.49	77.81	78.13	78.44	78.76	79.07	79.38	79.69	80.00	80.31
0.9	80.62	80.93	81.23	81.54	81.84	82.14	82.45	82.74	83.04	83.34
1.0	83.64	83.93	84.22	84.52	84.81	85.09	85.38	85.67	85.95	86.24
1.1	86.52	86.80	87.07	87.35	87.63	87.90	88.17	88.44	88.71	88.98
1.2	89.24	89.50	89.77	90.03	90.28	90.54	90.79	91.04	91.29	91.54
1.3	91.79	92.03	92.27	92.51	92.75	92.98	93.21	93.44	93.67	93.90
1.4	94.12	94.34	94.56	94.77	94.98	95.19	95.40	95.61	95.81	96.01
1.5	96.20	96.39	96.58	96.77	96.95	97.13	97.31	97.48	97.65	97.81
1.6	97.97	98.13	98.28	98.43	98.58	98.72	98.85	98.98	99.11	99.23
1.7	99.34	99.45	99.55	99.64	99.73	99.81	99.88	99.94	99.98	100.00

For Q_U = 1.52
PWL_U = 96.58

Example PWL Calculation (Cont.)

- Solution:

  - The PWL values obtained from the PWL estimation table as follows:

    - PWL_L = 90.28

    - PWL_U = 96.58

  - PWL_T = 90.28 + 96.58 – 100 =

  86.86% or 87%

WAKE UP

courtesy of John

Why the Need for PWL Specifications?

- Nationwide push by FHWA to utilize PWL specifications

- NDOT specifications prior to PWL did not adequately address failing Hot Mix Asphalt (HMA) gradations.

- NDOT desired a specification ensuring the contractor provides not only a quality mix but a consistent one as well.

Development of PWL Specifications

- University of Nevada research project (2010)

  ➢ Three phase project

    ❖ Phase 1 – Review of existing PWL specifications

    ❖ Phase 2 – Develop the specifications for NDOT

    ❖ Phase 3 – Implement the specifications

Development of PWL Specifications (Cont.)

- Created a PWL committee

  ➢ Committee was comprised of members from NDOT, UNR, FHWA, the contracting community, & the consulting community

  ➢ Met on several occasions over the course of the research project and through the drafting of the final specifications

Implementation of PWL Specifications

- Year 1

  - Implement PWL specifications on 3 contracts (1 per District) with 25,000 tons or greater of HMA (dense-grade)

    - Contracts 3621, 3636, & 3628

  - $PWL_{Overall}$ = 70 to receive 100% pay

  - Contractor received 5% incentive on every lot for Contract 3636 – No disincentive

Implementation of PWL Specifications

- Year 1

  ➢ Contractor received an incentive on 80 percent of the lots for contract 3621 and 100% pay for remaining lots – No disincentive

  ➢ Contract 3628 will begin this June.

Implementation of PWL Specifications (Cont.)

- Year 2 (Current)

  ➢ Implementation on all contracts with 25,000 tons or greater of HMA (dense-grade)

  ➢ $PWL_{Overall}$ = 80 to receive 100% pay

Implementation of PWL Specifications (Cont.)

- Year 3 and beyond

  ➢ Implementation on all contracts with 25,000 tons or greater of HMA (dense-grade)

  ➢ $PWL_{Overall}$ = 90 to receive 100% pay

Current NDOT PWL Specifications

- PWL is used as project control on HMA (dense-grade) for the following properties:

  - Bitumen ratio

  - Aggregate gradation

  - In-place density

- PWL for bitumen ratio and aggregate gradation will be based upon a sublot of 1,000 tons or end of day, whichever comes first.

Current NDOT PWL Specifications (Cont.)

- The number of in-place density tests for each sublot is determined based upon Subsection 402.03.06 of the Standard Specifications.

  - ➤ Frequency of in-place density tests are based upon square yards of compacted pavement

    - ❖ Number of in-place density tests representing 1,000 ton sublot

Current NDOT PWL Specifications (Cont.)

- The size of a lot for bitumen ratio and aggregate gradation will be based upon 5,000 tons or five sublots, whichever comes first and the corresponding number of in-place density tests.

Current NDOT PWL Specifications (Cont.)

- Gradation Percentage within Limits ($PWL_{Gradation}$) is based upon four sieves

  - These sieves include 1/2 - Inch(Type 2C) or 3/8 – Inch (Type 2), No. 4, No. 10., & No. 200.

    - Selection of sieves were based upon prior UNR research project titled "Impact of Construction Variability on Pavement Performance"

Current NDOT PWL Specifications (Cont.)

- Gradation Percentage within Limits ($PWL_{Gradation}$) is based upon four sieves.

  - Different weight factors were assigned to each sieve.

    - ½ inch for Type 2C   10%
    - 3/8 inch for Type 2   10%
    - No. 4   35%
    - No. 10   35%
    - No. 200   20%

Current NDOT PWL Specifications (Cont.)

- PWL$_{Gradation}$ is determined by the following:

    ➢ PWL$_{Gradation}$ = (0.10)PWL$_{1/2 \text{ or } 3/8}$ + (0.35)PWL$_{#4}$ + (0.35)PWL$_{#10}$ + (0.20)PWL$_{#200}$

    ➢ The PWL value for each sieve is based upon one lot.

Current NDOT PWL Specifications (Cont.)

- Weigh factors are used when calculating the Overall Percentage within Limits ($PWL_{Overall}$).

  - ➢ The following are the weigh factors for aggregate gradation, bitumen ratio, & in-place density:

    - ❖ Aggregate Gradation   25%

    - ❖ Bitumen Ratio   33%

    - ❖ In-Place Density   42%

Current NDOT PWL Specifications (Cont.)

- PWL$_{Overall}$ is determined by the following:

  - PWL$_{Overall}$ = (0.25)PWL$_{Gradation}$ + (0.33)PWL$_{Bitumen\ Ratio}$ + (0.42)PWL$_{In-Place\ Density}$

  - Contractor is to cease production if the PWL for two consecutive lots is less than 60 for any one of the measured properties

    - Contractor to evaluate available information and determine likely cause or causes of problem and propose change for NDOT's approval

Current NDOT PWL Specifications (Cont.)

- The Pay Factor (PF) for each lot of plantmix is determined by the following:

  - $PF = 60 + (0.5 \times PWL_{Overall})$

    - ❖ PF cannot exceed 105%

    - ❖ IF a lot has a PWL < 60 for any one of the measured properties, contractor is not eligible for a PF over 100%

Current NDOT PWL Specifications (Cont.)

- The Pay Factor (PF) for each lot of plantmix is determined by the following:

  - ➤ PF = 60 + (0.5 X $PWL_{Overall}$)

    - ❖ Contractor is required to remove material with a PF < 90% at own expense

      - ○ Material may be allowed to remain in place, with NDOT approval, at the corresponding pay factor

Current NDOT PWL Specifications (Cont.)

- The Progress Pay Adjustment (PPA) for each lot is determined by the following:

PPA = $\left(\frac{PF-100}{100}\right)$ x L x C

Where: PF = Pay Factor

L = Tonnage amount per lot

C = Bid price per ton of plantmix

Final NDOT PWL Specifications

- Same as current specifications except for the following:

  ➢ Contractor is to cease production if the PWL for two consecutive lots is less than 70 for any one of the measured properties

  ➢ PF = 55 + (0.5 X $PWL_{Overall}$)

  ➢ IF a lot has a PWL < 70 for any one of the measured properties, contractor is not eligible for a PF over 100%

THANK YOU

Questions