AGGREGATES

Section 9 – Practice Problems

Practice Problems

- Aggregate Gradations (T-166)
- JMF
- Correlation of Testing Technicians for Aggregate Gradations
- Aggregate Pay Factor Calculations
- Need LL,PL, and PI. Practice problem on form T-166

Form T-166
(Rev. 05-05)

WYOMING DEPARTMENT OF TRANSPORTATION
MATERIALS TESTING LABORATORY
AGGREGATE ANALYSIS

☐ English ☐ Metric

TEST NUMBER _____ DATE _____
SUBMITTED BY _____ AT _____
SAMPLE I.D. _____ SAMPLED BY _____
PIT OR QUARRY _____ PROJECT # _____
QUANTITY (tons) _____ LOCATION _____
FOR USE AS _____ COUNTY _____

	WEIGHT (lbs or kg)	
	COARSE AGG.	FINE AGG.
Sample	= (E)	= (F)
After Wash		
Pass No. 200 [75µm]		
Pass No. 200 [75 µm], Pan		
Total Pass No. 200 [75µm]		

	Weight Retained (lbs or kg)	% Retained = (A or B / D) X 100
RETAINED No. 4 [4.75 mm] = (A)		= (H)
PASS No. 4 [4.75 mm]= (B)		= (I)
TOTAL , A + B = (D)		

SIEVE SIZE	WT RET	% RET = K X 100 / E	WT RET	% RET = P x 100 / F	% RET = R x I / 100
	=K	=L	=P	=R	=S
1 1/2" [37.5 mm]					
1" [25mm]					
3/4" [19 mm]					
1/2" [12.5 mm]					
3/8" [9.5 mm]					
No. 4 [4.75 mm]					
No. 8 [2.36 mm]					
No. 16 [1.18 mm]					
No. 30 [600 µm]					
No. 40 425 [µm]					
No. 50 [300 µm]					
No. 100 [150 µm]					
No. 200 [75 µm]					
Pass No. 200 [75 µm], Pan					
TOTAL					
FRACTURED FACES %	One or more		Two or more		
FLAT & ELONGATED %	1:5 Ratio				
FINENESS MODULUS: see M.T.M., Sect. 602.0:					

COMBINED AGGREGATE

% RET = L+S	% PASSING 100 - Σ (Z)		SPEC % PASSING
=Z	to 0.1 %	to 1 %	

WET WT (lbs or kg)	
DRY WT (lbs or kg)	
WET - DRY = MOISTURE	
% MOISTURE=(MOISTURE/ DRY WT)x100	

BLOWS = 28	Tin No.	Wet+Tare= AA	Dry + Tare= BB	Tare = CC	Moisture = AA - BB = DD	Dry Wt = BB - CC = EE	% MOISTURE (DD / EE) x 100	x Corr. Factor =	PLASTIC INDEX (PI) =LL - PL
LIQUID LIMIT (LL)									
PLASTIC LIMIT (PL)									

REMARKS 28 Blows=Correction Factor 1.014

TESTED BY _____

Practice Problem 1

Material	Crushed Gravel #1		Crushed Sand #2		Fine Sand #3		Filler		Combined Gradation	Target Value	Specification Limits
Percent Used		50%		25%		25%					
U.S. Sieves	Percent Passing	Percent Batch	Percent Passing	Percent Batch	Percent Passing	Percent Batch	Percent Passing	Percent Batch			
2"	100		100		100						100
1.5"	100		100		100						100
1"	100		100		100						100
3/4"	100		100		100						100
1/2"	100		100		100						100
3/8"	90		100		100						90-100
No. 4	42		100		100						60-75
No. 8	6		99		100						40-55
No. 16											
No. 30	1		20		93						20-35
No. 50			3		64						12-22
No. 100											
No. 200			1.0		28						4-10

Practice Problem 2

Material	Bin #1		Bin #0		Bin #3		Filler		Combined Gradation	Target Value	Specification Limits
Percent Used		15%		40%		42%		3%			
U.S. Sieves	Percent Passing	Percent Batch	Percent Passing	Percent Batch	Percent Passing	Percent Batch	Percent Passing	Percent Batch			
2"											
1.5"	100										100
1"	90										90-100
3/4"	59		100								75-100
1/2"	4		67		100						55-90
3/8"											
No. 4			4		98						35-60
No. 8					75						20-45
No. 16											
No. 30											
No. 50					40		100				10-30
No. 100					21		96				5-18
No. 200					8.0		80				2-10

Practice Problem 3

Material	Bin #1		Bin #2		Bin #3		Filler		Combined Gradation	Target Value	Specification Limits
Percent Used											
U.S. Sieves	Percent Passing	Percent Batch	Percent Passing	Percent Batch	Percent Passing	Percent Batch	Percent Passing	Percent Batch			
2"											
1.5"	100						100				100
1"	79		100				100				90-100
3/4"											
1/2"	6		83				100				60-80
3/8"											
No. 4	2		4		100		100			43	25-60
No. 8			1		88		100			30	15-45
No. 16											
No. 30											
No. 50					27		100			11	3-18
No. 100											
No. 200					4.0		80			4.0	1-7

Table 1. Allowable Range of Standard Deviation for Tester Correlation

	Grading			
	Coarse		Fine	
Percent Retained	Maximum	Minimum	Maximum	Minimum
< 3%	3.00	0.39	0.60	0.21
3% - 10%	3.00	1.06	1.60	0.57
10% - 20%	4.70	1.66	2.70	0.95
20% - 30%	5.70	2.01	3.50	1.24
30% - 40%	6.90	2.44	4.00	1.41
>40%	9.00	3.18	5.20	1.41

- Use the coarse values unless the nominal maximum aggregate size is #4 or less, in which case use the fine values

Correlation Of Testing Technicians for Gradation

Example - #4:

Sampler: _____ **Contractor:** _____

Project: _____ **Location:** _____

Test Sieve Size: #200 **Date:** _____

Average % Passing #30 is 14.5%

Grading W - Coarse Gradation

$$t = \frac{|\bar{x}|}{\sqrt{\frac{s^2}{n}}}$$

Sample	Percent Passing Test Sieve WYDOT (A)	Contractor (B)	Difference (A) - (B)
A	3.20	3.17	
B	2.65	2.73	
C	3.16	2.95	
D	3.05	3.10	
E	2.98	3.02	
		Mean -x:	
Average Passing =		Std Dev - s:	
		Min SD:	
		Max SD:	
		SD Used:	
		t :	
		t > (t_{crit}=4.604):	

If $t > t_{crit}$, then the data sets are Significantly Different

If $t \leq t_{crit}$, then the data sets are Not Significantly Different

Is there directional bias?_____

Correlation Of Testing Technicians for Gradation

Example - #5:

Sampler: _____ **Contractor:** _____

Project: _____ **Location:** _____

Test Sieve Size: #200 **Date:** _____

Average % Passing #30 is 11.5%

Grading W - Coarse Gradation

$$t = \frac{|\bar{x}|}{\sqrt{\frac{s^2}{n}}}$$

Sample	Percent Passing Test Sieve WYDOT (A)	Contractor (B)	Difference (A) - (B)
A	3.30	2.70	
B	3.60	2.82	
C	3.53	2.79	
D	3.38	2.73	
E	3.63	2.89	
		Mean -x:	
Average Passing =		Std Dev - s:	
		Min SD:	
		Max SD:	
		SD Used:	
		t :	
		t > (t_{crit}=4.604):	

If $t > t_{crit}$, then the data sets are Significantly Different

If $t \leq t_{crit}$, then the data sets are Not Significantly Different

Is there directional bias?_____

Correlation Of Testing Technicians for Gradation

Example - #6:

Sampler: _____ Contractor: _____

Project: _____ Location: _____

Test Sieve Size: 3/8" Date: _____

Average % Passing 1/2" is 74.2%

Grading W - Coarse Gradation

$$t = \frac{|\bar{x}|}{\sqrt{\frac{s^2}{n}}}$$

Sample	Percent Passing Test Sieve WYDOT (A)	Contractor (B)	Difference (A) - (B)
A	52.8	47.3	
B	51.7	45.5	
C	53.6	46.3	
D	50.4	48.9	
E	52.2	45.9	
		Mean -x:	
Average Passing =		Std Dev - s:	
		Min SD:	
		Max SD:	
		SD Used:	
		t :	
		t > (t_{crit}=4.604):	

If $t > t_{crit}$, then the data sets are Significantly Different

If $t \leq t_{crit}$, then the data sets are Not Significantly Different

Is there directional bias?_____

Correlation Of Testing Technicians for Gradation

Example:

Sampler: _____ **Contractor:** _____

Project: _____ **Location:** _____

Test Sieve Size: _____ **Date:** _____

Average % Passing ____ is ____%

Grading ___ - _____ Gradation

$$t = \frac{|\bar{x}|}{\sqrt{\frac{s^2}{n}}}$$

Sample	Percent Passing Test Sieve WYDOT (A)	Contractor (B)	Difference (A) - (B)
A			
B			
C			
D			
E			
		Mean -$\bar{x}$:	
		Std Dev - s:	
		Min SD:	
		Max SD:	
		SD Used:	
		t :	
		t > (t_{crit}=4.604):	

If $t > t_{crit}$, then the data sets are Significantly Different

If $t \leq t_{crit}$, then the data sets are Not Significantly Different

Is there directional bias?_____

Table 113.1-1
Quality Level Analysis by the Standard Deviation Method

P_U or P_L percent Within Limits for Positive Values of Q_U or Q_L	Upper Quality Index Q_U or Lower Quality Index Q_L				
	n = 3	n = 4	n = 5	n = 6	n = 7
100	1.16	1.50	1.79	2.03	2.23
99		1.47	1.67	1.80	1.89
98	1.15	1.44	1.60	1.70	1.76
97		1.41	1.54	1.62	1.67
96	1.14	1.38	1.49	1.55	1.59
95		1.35	1.44	1.49	1.52
94	1.13	1.32	1.39	1.43	1.46
93		1.29	1.35	1.38	1.40
92	1.12	1.26	1.31	1.33	1.35
91	1.11	1.23	1.27	1.29	1.30
90	1.10	1.20	1.23	1.24	1.25
89	1.09	1.17	1.19	1.20	1.20
88	1.07	1.14	1.15	1.16	1.16
87	1.06	1.11	1.12	1.12	1.12
86	1.04	1.08	1.08	1.08	1.08
85	1.03	1.05	1.05	1.04	1.04
84	1.01	1.02	1.01	1.01	1.00
83	1.00	0.99	0.98	0.97	0.97
82	0.97	0.96	0.95	0.94	0.93
81	0.96	0.93	0.91	0.90	0.90
80	0.93	0.90	0.88	0.87	0.86
79	0.91	0.87	0.85	0.84	0.83
78	0.89	0.84	0.82	0.80	0.80
77	0.87	0.81	0.78	0.77	0.76
76	0.84	0.78	0.75	0.74	0.73
75	0.82	0.75	0.72	0.71	0.70
74	0.79	0.72	0.69	0.68	0.67
73	0.76	0.69	0.66	0.65	0.64
72	0.74	0.66	0.63	0.62	0.61
71	0.71	0.63	0.60	0.59	0.58
70	0.68	0.60	0.57	0.56	0.55
69	0.65	0.57	0.54	0.53	0.52
68	0.62	0.54	0.51	0.50	0.49
67	0.59	0.51	0.47	0.47	0.46
66	0.56	0.48	0.45	0.44	0.44
65	0.52	0.45	0.43	0.41	0.41
64	0.49	0.42	0.40	0.39	0.38
63	0.46	0.39	0.37	0.36	0.35
62	0.43	0.36	0.34	0.33	0.32
61	0.39	0.33	0.31	0.30	0.30
60	0.36	0.30	0.28	0.27	0.27
59	0.32	0.27	0.25	0.25	0.24
58	0.29	0.24	0.23	0.22	0.21
57	0.25	0.21	0.20	0.19	0.19
56	0.22	0.18	0.17	0.16	0.16
55	0.18	0.15	0.14	0.13	0.13
54	0.14	0.12	0.11	0.11	0.11
53	0.11	0.09	0.08	0.08	0.08
52	0.07	0.06	0.06	0.05	0.05
51	0.04	0.03	0.03	0.03	0.03
50	0.00	0.00	0.00	0.00	0.00

Table 113.1-2 Pay Factors

Pay Factor	Required Quality Level for a Given Sample Size n and Pay Factor				
	n = 3	n = 4	n = 5	n = 6	n = 7
1.05	100	100	100	100	100
1.04	90	91	92	93	93
1.03	80	85	87	88	89
1.02	75	80	83	85	86
1.01	71	77	80	82	84
1.00	68	74	78	80	81
0.99	66	72	75	77	79
0.98	64	70	73	75	77
0.97	62	68	71	74	75
0.96	60	66	69	72	73
0.95	59	64	68	70	72
0.94	57	63	66	68	70
0.93	56	61	65	67	69
0.92	55	60	63	65	67
0.91	53	58	62	64	66
0.90	52	57	60	63	64
0.89	51	55	59	61	63
0.88	50	54	57	60	62
0.87	48	53	56	58	60
0.86	47	51	55	57	59
0.85	46	50	53	56	58
0.84	45	49	52	55	56
0.83	44	48	51	53	55
0.82	42	46	50	52	54
0.81	41	45	48	51	53
0.80	40	44	47	50	52
0.79	38	43	46	48	50
0.78	37	41	45	47	49
0.77	36	40	43	46	48
0.76	34	39	42	45	47
0.75	33	38	41	44	46

- **Maximum Pay Factor**
  - **Base and Subbase – 1.00**
  - **Treated Base – 1.00**
  - **Plant Mix Pavement – 1.05**
  - **Plant Mix Wearing Course – 1.05**
  - **Seal Coat Aggregate – 1.05**
  - **PCCP – 1.00**

Pay Factor Worksheet #4

Aggregate Specification: Crushed Base Grading W **Test Value:** #4

Test Results: n = 5

Test Values: 44 45 58 65 66

Average Value: $\overline{x}$ = _____ **Standard Deviation:** s = _____ (σ_{n-1})

Upper Specification Limit, SL_U = _____

Lower Specification Limit, SL_L = _____

Upper Quality Index, $Q_U = \frac{SL_U - \overline{x}}{s}$ = _____ = _____

Percent Material Within SL_U P_U = _____ (From Table 113.1-1)

(If SL_U is not specified, P_U = 100)

Lower Quality Index, $Q_L = \frac{\overline{x} - SL_L}{s}$ = _____ = _____

Percent Material Within SL_L P_L = _____ (From Table 113.1-1)

(If SL_L is not specified, P_L = 100)

Quality Level = Percent Within Specification Limits

$QL = (P_U + P_L) - 100$ = _____ + _____ **-100 =** _____

Pay Factor = PF = _____ (From Table 113.1-2)

Minimum Pay Factor = _____

Max Pay Factor= _____

Pay Adjustment Factor = PAF

= Min Pay Factor - 1.00 = _____ **-1.00 =** _____

Pay Factor Worksheet #5

Aggregate Specification: PMP (1") **Test Value:** #30

Test Results: **n =** 5

Test Values: 13 18 15 22 16

Average Value: $\overline{x}$ = _____ **Standard Deviation:** s = _____ (σ_{n-1})

Upper Specification Limit, SL_U = _____

Lower Specification Limit, SL_L = _____

Upper Quality Index, $Q_U = \frac{SL_U - \overline{x}}{s}$ = _____ = _____

Percent Material Within SL_U P_U = _____ (From Table 113.1-1)

(If SL_U is not specified, P_U = 100)

Lower Quality Index, $Q_L = \frac{\overline{x} - SL_L}{s}$ = _____ = _____

Percent Material Within SL_L P_L = _____ (From Table 113.1-1)

(If SL_L is not specified, P_L = 100)

Quality Level = Percent Within Specification Limits

$QL = (P_U + P_L) - 100$ = _____ **+** _____ **-100 =** _____

Pay Factor = PF = _____ (From Table 113.1-2)

Minimum Pay Factor = _____

Max Pay Factor= _____

Pay Adjustment Factor = PAF

= Min Pay Factor - 1.00 = _____ **-1.00 =** _____

Pay Factor Worksheet #6

Aggregate Specification: PMP(3/4") **Test Value:** #4

Test Results: n = 5

Test Values: 58 41 48 68 65

Average Value: $\overline{x}$ = _____ **Standard Deviation:** s = _____ (σ_{n-1})

Upper Specification Limit, SL_U = _____

Lower Specification Limit, SL_L = _____

Upper Quality Index, $Q_U = \frac{SL_U - \overline{x}}{s}$ = _____ = _____

Percent Material Within SL_U P_U = _____ (From Table 113.1-1)

(If SL_U is not specified, P_U = 100)

Lower Quality Index, $Q_L = \frac{\overline{x} - SL_L}{s}$ = _____ = _____

Percent Material Within SL_L P_L = _____ (From Table 113.1-1)

(If SL_L is not specified, P_L = 100)

Quality Level = Percent Within Specification Limits

QL = (P_U + P_L) -100 = _____ + _____ **-100 =** _____

Pay Factor = PF = _____ (From Table 113.1-2)

Minimum Pay Factor = _____

Max Pay Factor= _____

Pay Adjustment Factor = PAF

= Min Pay Factor - 1.00 = _____ **-1.00 =** _____

Pay Factor Worksheet #7

Aggregate Specification: PMWC **Test Value:** #4

Test Results: **n =** 6

Test Values: 25 51 34 57 29 42

Average Value: $\bar{x}$ = _____ **Standard Deviation:** **s** = _____ (σ_{n-1})

Upper Specification Limit, SL_U = _____

Lower Specification Limit, SL_L = _____

Upper Quality Index, $Q_U = \frac{SL_U - \bar{x}}{s}$ = _____ = _____

Percent Material Within SL_U P_U = _____ (From Table 113.1-1)

(If SL_U is not specified, P_U = 100)

Lower Quality Index, $Q_L = \frac{\bar{x} - SL_L}{s}$ = _____ = _____

Percent Material Within SL_L P_L = _____ (From Table 113.1-1)

(If SL_L is not specified, P_L = 100)

Quality Level = Percent Within Specification Limits

QL = (P_U + P_L) -100 = _____ **+** _____ **-100 =** _____

Pay Factor = PF = _____ (From Table 113.1-2)

Minimum Pay Factor = _____

Max Pay Factor= _____

Pay Adjustment Factor = PAF

= Min Pay Factor - 1.00 = _____ **-1.00 =** _____

Pay Factor Worksheet #8

Aggregate Specification: PMP (1") **Test Value:** #4

Test Results: **n =** 5

Test Values: 48 59 52 46 58

Average Value: $\overline{x}$ = _____ **Standard Deviation:** **s =** _____ (σ_{n-1})

Upper Specification Limit, SL_U = _____

Lower Specification Limit, SL_L = _____

Upper Quality Index, $Q_U = \frac{SL_U - \overline{x}}{s}$ = _____ = _____

Percent Material Within SL_U P_U = _____ (From Table 113.1-1)

(If SL_U is not specified, P_U = 100)

Lower Quality Index, $Q_L = \frac{\overline{x} - SL_L}{s}$ = _____ = _____

Percent Material Within SL_L P_L = _____ (From Table 113.1-1)

(If SL_L is not specified, P_L = 100)

Quality Level = Percent Within Specification Limits

$QL = (P_U + P_L) - 100$ = _____ **+** _____ **-100 =** _____

Pay Factor = PF = _____ (From Table 113.1-2)

Minimum Pay Factor = _____

Max Pay Factor= _____

Pay Adjustment Factor = PAF

= Min Pay Factor - 1.00 = _____ **-1.00 =** _____

Pay Factor Worksheet

Aggregate Specification: _____ **Test Value:** _____

Test Results: **n =** _____

Test Values: _____

Average Value: $\bar{x}$ = _____ **Standard Deviation:** **s =** _____ (σ_{n-1})

Upper Specification Limit, SL_U = _____

Lower Specification Limit, SL_L = _____

Upper Quality Index, $Q_U = \frac{SL_U - \bar{x}}{s}$ = _____ = _____

Percent Material Within SL_U **P_U =** _____ (From Table 113.1-1)

(If SL_U is not specified, P_U = 100)

Lower Quality Index, $Q_L = \frac{\bar{x} - SL_L}{s}$ = _____ = _____

Percent Material Within SL_L **P_L =** _____ (From Table 113.1-1)

(If SL_L is not specified, P_L = 100)

Quality Level = Percent Within Specification Limits

QL = (P_U + P_L) -100 = _____ **+** _____ **-100 =** _____

Pay Factor = PF = _____ (From Table 113.1-2)

Minimum Pay Factor = _____

Max Pay Factor= _____

Pay Adjustment Factor = PAF

= Min Pay Factor - 1.00 = _____ **-1.00 =** _____

Atterberg Limits

TOTAL								WET WT (lb)	
FRACTURED FACES %	One or more		Two or more					DRY WT (lb)	
FLAT & ELONGATED %	1.5 Ratio							WET - DRY = MOISTURE	
FINENESS MODULUS: see M.T.M., Sect. 602.0:								% MOISTURE=(MOISTURE/ DRY WT)x100	

BLOWS = = 28	Tin No.	Wet+Tare= AA	Dry + Tare= BB	Tare = CC	Moisture = AA - BB = DD	Dry Wt = BB - CC = EE	% MOISTURE (DD / EE) x 100	x Corr. Factor =		PLASTIC INDEX PI =LL - PL
LIQUID LIMIT (LL)	jvt	148.38	142.38	121.46						
PLASTIC LIMIT (PL)	x38	141.21	138.74	123.57						

TOTAL								WET WT (lb)	
FRACTURED FACES %	One or more		Two or more					DRY WT (lb)	
FLAT & ELONGATED %	1.5 Ratio							WET - DRY = MOISTURE	
FINENESS MODULUS: see M.T.M., Sect. 602.0:								% MOISTURE=(MOISTURE/ DRY WT)x100	

BLOWS = = 23	Tin No.	Wet+Tare= AA	Dry + Tare= BB	Tare = CC	Moisture = AA - BB = DD	Dry Wt = BB - CC = EE	% MOISTURE (DD / EE) x 100	x Corr. Factor =		PLASTIC INDEX PI =LL - PL
LIQUID LIMIT (LL)	r33	160.34	154.21	122.62						
PLASTIC LIMIT (PL)	44S	150.90	147.25	123.84						

Atterberg Limits

TOTAL								WET WT (lb)		
FRACTURED FACES %	One or more		Two or more					DRY WT (lb)		
FLAT & ELONGATED %	1.5 Ratio							WET - DRY = MOISTURE		
FINENESS MODULUS: see M.T.M., Sect. 602.0:								% MOISTURE=(MOISTURE/ DRY WT)x100		
BLOWS = = 20	Tin No.	Wet+Tare= AA	Dry + Tare= BB	Tare = CC	Moisture = AA - BB = DD	Dry Wt = BB - CC = EE	% MOISTURE (DD / EE) x 100	x Corr. Factor =		PLASTIC INDEX PI =LL - PL
LIQUID LIMIT (LL)	5x3	155.56	149.66	123.65						
PLASTIC LIMIT (PL)	8-3	140.16	137.88	124.75						

TOTAL								WET WT (lb)		
FRACTURED FACES %	One or more		Two or more					DRY WT (lb)		
FLAT & ELONGATED %	1.5 Ratio							WET - DRY = MOISTURE		
FINENESS MODULUS: see M.T.M., Sect. 602.0:								% MOISTURE=(MOISTURE/ DRY WT)x100		
BLOWS = = 31	Tin No.	Wet+Tare= AA	Dry + Tare= BB	Tare = CC	Moisture = AA - BB = DD	Dry Wt = BB - CC = EE	% MOISTURE (DD / EE) x 100	x Corr. Factor =		PLASTIC INDEX PI =LL - PL
LIQUID LIMIT (LL)	A-2	181.08	162.76	122.62						
PLASTIC LIMIT (PL)	8-1	190.46	179.68	124.38						