Appendix D

Field Nomenclature, Technical Information, Formulas and Measurement Techniques

MONTANA
DEPARTMENT OF
TRANSPORTATION

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Appendix D
Table of Contents

Appendix D contains, diagrams, figures, formulas, data and example calculations project managers, inspectors and experienced personnel may find useful as a daily technical reference guide. Appendix D is also helpful for newer personnel as a training supplement.

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Soil Classification Nomenclature

Unified Soil Classification	AASHTO Classification	Soil Type
GW	A-1-a	GRAVEL – well graded
GP	A-1-a	GRAVEL – poorly graded
GM	A-1-b	GRAVEL – silty
GC	A-2-6 A-2-7	GRAVEL – clayey
SW	A-1-b	SAND – well graded
SP	A-3	SAND – poorly graded
SM	A-2-4 A-2-5	SAND – silty
SC	A-2-6 A-2-7	SAND – clayey
ML	A-4	SILT – inorganic SILT – sandy
CL	A-6 Lean Clay	CLAY – inorganic
OL	A-4	SILT – organic
MH	A-5	SILT – inorganic
CH	A-7	CLAY – inorganic Fat Clays
OH	A-7	CLAY – organic
PT	NA	PEAT – muck
Rock	NA	NA

AASHTO Classification of Soil and Soil Aggregates

(With Suggested Subgroups)

General Classification	Granular Materials (35% or Less Passing No. 200)							Silt-Clay Materials (More than 35% Passing No. 200)			
Group Classification	A-1		A-3	A-2				A-4	A-5	A-6	A-7
	A-1-a	A-1-b		A-2-4	A-2-5	A-2-6	A-2-7				A-7-5 A-7-6
Sieve Analysis, Percent Passing											
No. 10	50 Max.										
No. 40	30 Max.	50 Max.	51 Min.								
No. 200	15 Max.	25 Max.	10 Max.	35 Max.	35 Max.	35 Max.	35 Max.	36 Min.	36 Min.	36 Min.	36 Min.
Characteristics of Fraction Passing No. 40:											
Liquid Limit				40 Max.	41 Min.	40 Max.	41 Min.	40 Max.	41 Min.	40 Max.	41 Min.
Plasticity Index	6 Max.		N.P.	10 Max.	10 Max.	11 Min.	11 Min.	10 Max.	10 Max.	11 Min.	11 Min.*
Usual Types of Significant Constituent Materials	Stone Fragments Gravel and Sand		Fine Sand	Silty and Clayey Gravel and Sand				Silty Soils		Clayey Soils	
General Rating as Subgrade	Excellent to Good							Fair to Poor			

Classification Procedure: Categorize test data proceeding from left to right on above chart to find the correct group by process of elimination. The first group from the left into which the test data will fit is the correct classification.

*A-7-5 subgroup plasticity Index is equal to or less than LL minus 30. of A-7-6 subgroup plasticity index > LL minus 30.

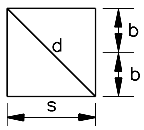
Group index is shown in parentheses after group symbol. Examples: A-1-3(3), A-4(5), A-6(12), A-7-5(17)

STANDARD SIEVE SIZES

US Customary		Metric
Sieve Designation	**Nominal Sieve Opening**	**Sieve Designation and Nominal Opening**
2	2 in	50 mm
1-1/2	1.5 in	37.5 mm
1-1/4	1.25 in	31.5 mm
1	1 in	25.0 mm
3/4	0.750 in	19.0 mm
5/8	0.625 in	16.0 mm
1/2	0.500 in	12.5 mm
3/8	0.375 in	9.5 mm
5/16	0.312 in	8.0 mm
1/4	0.250 in	6.3 mm
No. 4	0.187 in	4.75 mm
No. 5	0.157 in	4.00 mm
No. 6	0.132 in	3.35 mm
No. 8	0.0937 in	2.36 mm
No. 10	0.0787 in	2.00 mm
No. 12	0.0661 in	1.70 mm
No. 16	0.0469 in	1.18 mm
No. 20	0.0331 in	850 µm
No. 30	0.0234 in	600 µm
No. 40	0.0165 in	425 µm
No. 50	0.0117 in	300 µm
No. 60	0.0098 in	250 µm
No. 70	0.0083 in	212 µm
No. 80	0.0070 in	180 µm
No. 100	0.0059 in	150 µm
No. 140	0.0041 in	106 µm
No. 200	0.0029 in	75 µm
No. 270	0.0021 in	53 µm
No. 325	0.0017 in	45 µm
No. 400	0.0015 in	38 µm

PLANAR AREAS

Square



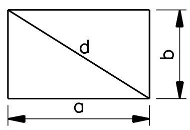
Diagonal = d = s $\sqrt{2}$

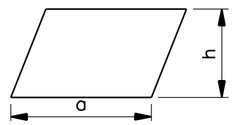
Area = $s^2 = 4b^2 = 0.5d^2$

Example: s = 6; b = 3; Area = $(6)^2$ = 36 Answer

d = 6 x 1.414 = 8.484 Answer

Rectangle and Parallelogram



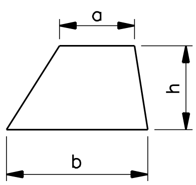


Area = ab or b $\sqrt{d^2 - b^2}$

Example. a = 6; b = 3.

Area = 3 x 6 = 18 Answer.

Trapezoid

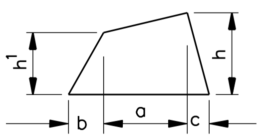


Area = $\frac{1}{2}h\left(a+b\right)$

Example: a = 2; b = 4; h = 3

Area = $\frac{1}{2}\times 3\left(2+4\right) = 9$ Answer

Trapezium

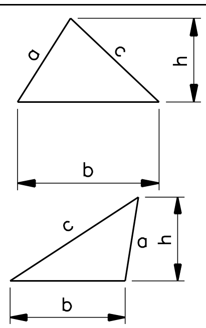


Area = $\frac{1}{2}\left[a\left(h+h^1\right)+bh^1+ch\right]$

Example: a = 4; b = 2; c = 2; h = 3; h^1 = 2.

Area = $\frac{1}{2}\left[4\left(3+2\right)+\left(2\times 2\right)+\left(2\times 3\right)\right] = 15$ Answer

Triangles



Both formulas apply to both figures.

Area = $\frac{1}{2}$ bh

Example: h = 3; b = 5

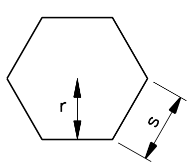
Area = $\frac{1}{2}\left(3\times 5\right) = 7\frac{1}{2}$ Answer

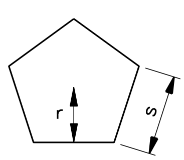
Area = $\sqrt{S\left(S-a\right)\left(S-b\right)\left(S-c\right)}$ where $S = \frac{a+b+c}{2}$

Example: a = 2; b = 3; c = 4

$S = \frac{2+3+4}{2}$ = 4.5; Area = $\sqrt{4.5\left(4.5-2\right)\left(4.5-3\right)\left(4.5-4\right)}$ = 2.9 Answer

Regular Polygons





Area:

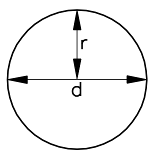
- 5 sides = $1.720477\ S^2 = 3.63271\ r^2$
- 6 sides = $2.598150\ S^2 = 3.46410\ r^2$
- 7 sides = $3.633875\ S^2 = 3.37101\ r^2$
- 8 sides = $4.828427\ S^2 = 3.31368\ r^2$
- 9 sides = $6.181875\ S^2 = 3.27573\ r^2$
- 10 sides = $7.694250\ S^2 = 3.24920\ r^2$
- 11 sides = $9.365675\ S^2 = 3.22993\ r^2$
- 12 sides = $11.196300\ S^2 = 3.21539\ r^2$

n = number of sides; r = short radius; S = length of side; R = long radius.

Area = $\frac{n}{4}S^2\cot\frac{180°}{n} = \frac{n}{2}R^2\sin\frac{360°}{n} = nr^2\tan\frac{180°}{n}$

PLANAR AREAS (continued)

Circle



$\pi = 3.1416$; A = area; d = diameter

p = circumference or periphery; r = radius

$p = \pi d = 3.1416d$ $\quad$ $p = 2\sqrt{\pi A} = 3.54\sqrt{A}$

$p = 2\pi r = 6.2832r$ $\quad$ $p = \frac{2A}{r} = \frac{4A}{d}$

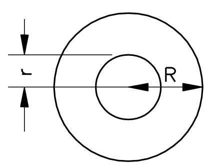
$d = \frac{p}{\pi} = \frac{p}{3.1416}$ $\quad$ $d = 2\sqrt{\frac{A}{\pi}} = 1.128\sqrt{A}$

$r = \frac{p}{2\pi} = \frac{p}{6.2832}$ $\quad$ $r = \sqrt{\frac{A}{\pi}} = 0.564\sqrt{A}$

$A = \frac{\pi d^2}{4} = 0.7854d^2$ $\quad$ $A = \frac{p^2}{4\pi} = \frac{p^2}{12.57}$

$A = \pi r^2 = 3.1416r^2$ $\quad$ $A = \frac{pr}{2} = \frac{pd}{4}$

Concentric Area



$\text{Area} = \pi(R^2 - r^2) = 3.1416(R^2 - r^2)$

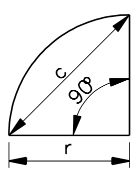
$\text{Area} = 0.7854(D^2 - d^2) = 0.7854(D - d)(D + d)$

Area = difference in areas between the inner and outer circles.

Example: R = 4; r = 2.

$\text{Area} = 3.1416(4^2 - 2^2) = 37.6992$ Answer

Quadrant

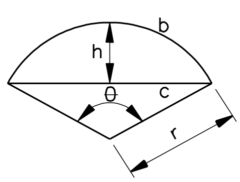


$\text{Area} = \frac{\pi r^2}{4} = 0.7854r^2 = 0.3927c^2$

Example. r = 3; c = chord.

$\text{Area} = 0.7851 \times 3^2 = 7.0686$ Answer

Segment



b = length of arc; θ = angle in degrees; c = chord = $\sqrt{4\left(2hr - h^2\right)}$

$\text{Area} = \frac{1}{2}\left[br - c(r-h)\right] = \pi r^2 \frac{\theta}{360} - \frac{c(r-h)}{2}\,p$

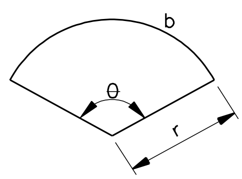
When θ is greater than 180° then $\frac{c}{2} \times$ difference between r and h is added to the fraction $\frac{\pi r^2 \theta}{360}$.

Example: r = 3; θ = 120°; h = 1.5

$\text{Area} = 3.1416 \times 3^2 \times \frac{120}{360} - \frac{5.196(3 - 1.5)}{2} = 5.5278$ Answer

PLANAR AREAS (continued)

Sector



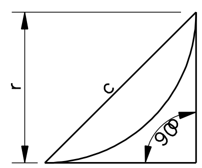
Area = $\frac{br}{2} = \pi r^2 \frac{\theta}{360°}$

θ = angle in degrees; b = length of arc

Example: r = 3; θ = 120°

Area = $3.1416 \times 3^2 \times \frac{120}{360} = 9.4248$ Answer

Spandrel

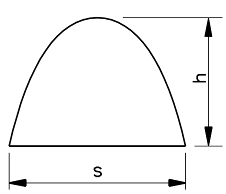


Area = $0.2146r^2 = 0.1073c^2$

Example: r = 3

Area = $0.2146 \times 3^2 = 1.9314$ Answer

Parabola



l = length of curved line = periphery – s

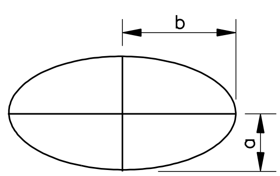
$$l = \frac{s^2}{8h}\left[\sqrt{c\,(1+c)} + 2.0326 \times \log\left(\sqrt{c} + \sqrt{1+c}\right)\right] \text{ where } c = \left(\frac{4h}{s}\right)^2$$

Area = $\frac{2}{3}sh$

Example: s = 3; h = 4

Area = $\frac{2}{3} \times 3 \times 4 = 8$ Answer

Ellipse



Area = $\pi ab = 3.1416ab$

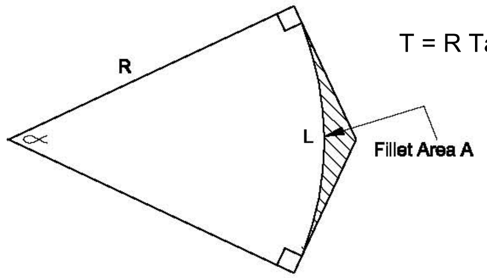
Circumference. = $2\pi\sqrt{\frac{a^2+b^2}{2}}$ (close approximation)

Example. a = 3; b = 4.

Area = $3.1416 \times 3 \times 4 = 37.6992$ Answer

Circumference = $2 \times 3.1416\sqrt{\frac{(3)^2+(4)^2}{2}} = 6.2832 \times 3.5355 = 22.21$ Answer

FILLET, APRON AND INTERSECTION APPROACH AREAS



$$T = R \text{ Tan } \frac{\alpha}{2}$$

ESTIMATING FILLETS & RETURN

Fillet Area

$$\text{Area A} = 2 \times \frac{1}{2} \times R \times R \text{ Tan } \frac{\alpha}{2} - \pi R^2 \frac{\alpha}{360°}$$

$$= R^2 \left[\text{Tan} \frac{\alpha}{2} - (0.008727 \times \alpha) \right]$$

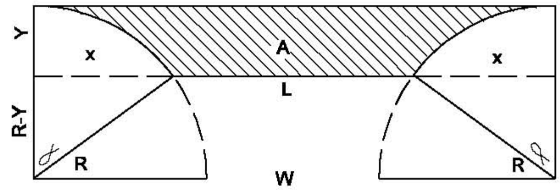
Area 90° Fillet = $0.2146 \times R^2$

Length of Return

$$L = 2 \pi R \times \frac{\alpha}{360°}$$

$$= 0.01745 \times R \times \alpha$$

Length of 90° Return = $1.5708 \times R$

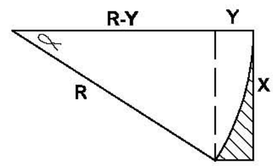


ESTIMATING AREA 90° APRON

$L = (2R + W) - 2X$ $\qquad$ $\text{Cos } \alpha = \frac{R - Y}{R}$

$X = \sqrt{2RY} - Y^2$ $\qquad$ A = Area

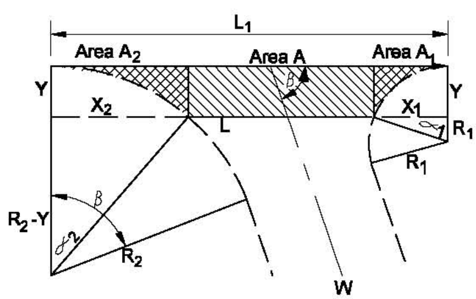
$A = (2R + W)Y + X(R-Y) - 0.01745 \; R^2\alpha$



A = Area

$$A = XY - \left[\pi R^2 \frac{\alpha}{360°} - \frac{1}{2} \times (R - Y) \right]$$

$$= XY + \frac{X(R-Y)}{2} - 0.08727 R^2 \alpha$$



ESTIMATING AREA APRON OTHER THAN 90°

$\text{Cos } \alpha_1 = \frac{R_1 - Y}{R_1}$ $\qquad$ $\text{Cos } \alpha_2 = \frac{R_2 - Y}{R_2}$

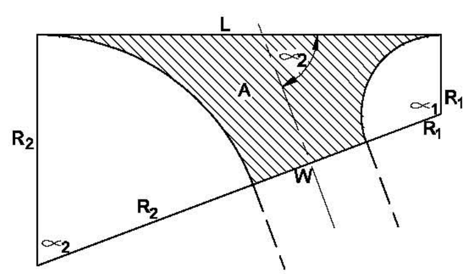
$X_1 = \sqrt{2R_1Y - Y^2}$ $\qquad$ $X_2 = \sqrt{2R_2Y - Y^2}$

$L_1 = (R_2 - R_1) \text{ Tan } \beta$ $\qquad$ $L = L_1 - (X_1 + X_2)$

$A = LY$

$$A_1 = X_1Y + \frac{X_1(R_1 - Y)}{2} - 0.008727 R_1^2 \alpha_1$$

$$A_2 = X_2Y + \frac{X_2(R_2 - Y)}{2} - 0.008727 R_2^2 \alpha_2$$



ESTIMATING AREA APPROACH OTHER THAN 90°

$\alpha_1 = 180° - \alpha_2$

$L = (R_2 - R_1) \text{ Tan } \alpha_2$

$$\text{Area A} = \frac{(R_1 + R_2)L}{2} - 0.008727(R_1^2 \alpha_1 + R_2^2 \alpha_2)$$

NOTES:

$\pi = 3.1416$ $\qquad$ $\frac{\pi}{180} = 0.01745$

$\frac{\pi}{2} = 1.5708$ $\qquad$ $\frac{\pi}{360} = 0.008727$

Horizontal Cylindrical Tank Volume

% Depth Filled	% Capacity	% Depth Filled	% of Capacity	% Depth Filled	% Capacity	% Depth Filled	% Capacity
1	0.20	26	20.73	51	51.27	76	81.50
2	0.50	27	21.86	52	52.54	77	82.60
3	0.90	28	23.00	53	53.81	78	83.68
4	1.34	29	24.07	54	55.08	79	84.74
5	1.87	30	25.31	55	56.34	80	85.77
6	2.45	31	26.48	56	57.60	81	86.77
7	3.07	32	27.66	57	58.86	82	87.76
8	3.74	33	28.84	58	60.11	83	88.73
9	4.45	34	30.03	59	61.36	84	89.68
10	5.20	35	31.19	60	62.61	85	90.60
11	5.98	36	32.44	61	63.86	86	91.50
12	6.80	37	33.66	62	65.10	87	92.36
13	7.64	38	34.90	63	66.34	88	93.20
14	8.50	39	36.14	64	67.56	89	94.02
15	9.40	40	37.39	65	68.81	90	94.80
16	10.32	41	38.64	66	69.97	91	95.55
17	11.27	42	39.89	67	71.16	92	96.26
18	12.24	43	41.14	68	72.34	93	96.93
19	13.23	44	42.40	69	73.52	94	97.55
20	14.23	45	43.66	70	74.69	95	98.13
21	15.26	46	44.92	71	75.93	96	98.66
22	16.32	47	46.19	72	77.00	97	99.10
23	17.40	48	47.45	73	78.14	98	99.50
24	18.50	49	48.73	74	79.27	99	99.80
25	19.61	50	50.00	75	80.39		

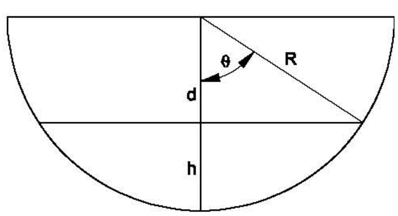
Use steps 2- 4 to compute less than half full tank volume. When more than half full, compute full capacity using step 1. Calculate unfilled volume portion using Steps 2-4, then deduct the unfilled portion volume from the total volume to determine filled volume. Piping, fittings and other interior tank volumes must be deducted from volumes computed using these methods.

Full Tank Capacity

1) $$F = \frac{0.7854 \times D^2 \times L}{C}$$

Partial Tank Capacity

2) $$\cos\theta = \frac{d}{R} = \frac{R-h}{R}$$

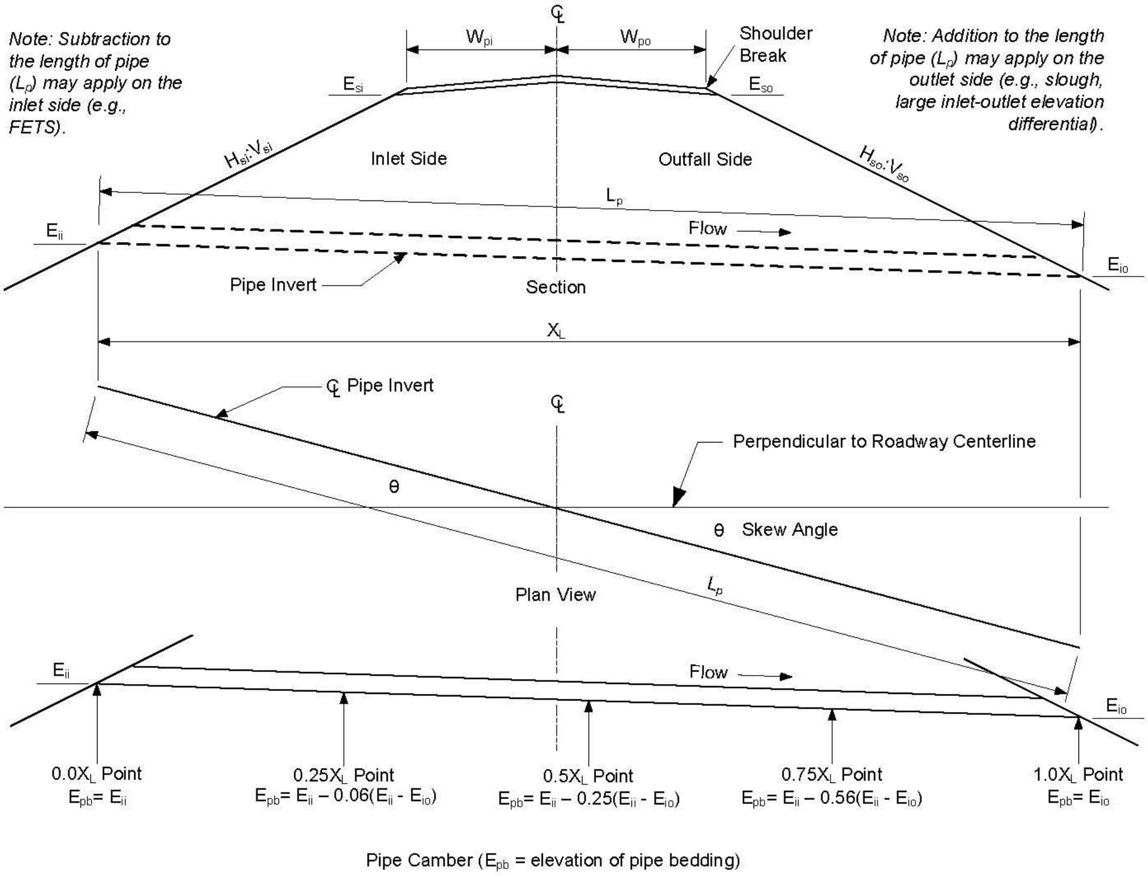


3) $$A = \pi R^2 \frac{\theta}{180} - R\sin\theta(R-h)$$

4) $$V = \frac{L\left[\pi R^2 \frac{\theta}{180} - R\sin\theta(R-h)\right]}{C}$$

F = full tank capacity, gal (L).
A = filled portion tank cross sectional area, in^2 (mm^2).
V = filled portion volume, gal (L).
L = interior tank length, (mm).
D = interior tank diameter, (mm).
R = interior tank radius, (mm).
h = liquid depth, in (mm).
d = R – h, (mm).
C = 231 in^3/gal (1,000,000 mm^3/L).

PIPE LENGTH AND CAMBER



Pipe Camber (E_{pb} = elevation of pipe bedding)

Note: Adjust the elevation of the pipe bedding to camber the pipe, unless otherwise specified on the Plans by the Geotechnical Section. Always build some drop from the inlet to the center of the pipe length, even if it is at the expense of decreasing the amount of camber. Do not camber irrigation pipes.

$$L_p = \sqrt{(E_{ii} - E_{io})^2 + \left[\frac{W_{pi} + \frac{H_{si}(E_{si} - E_{ii})}{V_{si}} + W_{po} + \frac{H_{so}(E_{so} - E_{io})}{V_{so}}}{\cos\theta}\right]^2}$$

$$S_p = \frac{L_p}{(E_{ii} - E_{io})}$$

Where:

- L_p = pipe length, ft (Round to next standardized pipe section length.)
- S_p = pipe slope, H:V
- W_{pi} = pavement width from centerline to shoulder break on inlet side, ft
- E_{si} = subgrade elevation on inlet side, ft
- E_{ii} = invert pipe elevation on inlet side, ft
- H_{si} = side slope horizontal component on inlet side, ft
- V_{si} = side slope vertical component on inlet side, ft (normally 1)
- W_{po} = pavement width from centerline to outfall side shoulder break, ft
- E_{so} = subgrade elevation, outfall side, ft
- E_{io} = pipe invert elevation, outfall side, ft
- H_{so} = side slope horizontal component, outfall side, ft
- V_{so} = side slope vertical component, outfall side, ft
- θ = skew angle (degrees) between pipe centerline and a line perpendicular to roadway centerline

Pavement Marking Material
Area and Continuous Linear Coverage for 4″ Width

Wet Material Thickness		Area Coverage			Continuous Linear Coverage Length per Line Width		
					4"	100 mm	100 mm
mil	mm	ft²/gal	m²/gal	m²/L	ft/gal	m/gal	m/L
Temporary Paint Striping							
9.0	0.229	178.25	16.57	4.39	534.75	165.68	43.91
10.0	0.254	160.42	14.90	3.94	481.25	149.03	39.37
11.0	0.279	145.84	13.56	3.59	437.52	135.56	35.92
Interim Paint Striping							
15.0	0.381	106.94	9.94	2.62	320.83	99.35	26.25
16.0	0.406	100.27	9.32	2.47	300.81	93.20	24.70
17.0	0.432	94.37	8.77	2.32	283.11	87.72	23.25
Epoxy							
18.0	0.457	89.13	8.28	2.19	267.39	82.85	21.95
19.0	0.483	84.44	7.85	2.08	253.32	78.49	20.80
20.0	0.508	80.21	7.45	1.97	240.63	74.52	19.69
21.0	0.533	76.39	7.10	1.88	229.17	71.00	18.82
22.0	0.559	72.92	6.78	1.80	218.76	67.78	17.96

Pavement Marking Material
Area and Continuous Linear Coverage for 6″ Width

Wet Material Thickness		Coverage Area			Continuous Linear Coverage Length per Line Width		
					6"	150 mm	150 mm
mil	mm	ft²/gal	m²/gal	m²/L	ft/gal	m/gal	m/L
Temporary Striping (Paint)							
9.0	0.229	178.25	16.57	4.39	356.50	110.47	29.27
10.0	0.254	160.42	14.90	3.94	320.83	99.35	26.25
11.0	0.279	145.84	13.56	3.59	291.68	90.40	23.96
Interim Striping (Paint)							
15.0	0.381	106.94	9.94	2.62	213.89	66.24	17.50
16.0	0.406	100.27	9.32	2.47	200.54	62.13	16.46
17.0	0.432	94.37	8.77	2.32	188.74	58.47	15.49
Epoxy							
18.0	0.457	89.13	8.28	2.19	178.26	55.20	14.63
19.0	0.483	84.44	7.85	2.08	168.88	52.33	13.87
20.0	0.508	80.21	7.45	1.97	160.42	49.68	13.12
21.0	0.533	76.39	7.10	1.88	152.78	47.33	12.54
22.0	0.559	72.92	6.78	1.80	145.84	45.20	11.98

Pavement Marking Material Coverage
Area and Continuous Linear Coverage for 8″ Width

Wet Material Thickness		Coverage Area			Continuous Coverage Length per Line Width		
					8"	200 mm	200 mm
mil	mm	ft²/gal	m²/gal	m²/L	ft/gal	m/gal	m/L
Temporary Paint Striping							
9.0	0.229	178.25	16.57	4.39	267.38	82.84	21.95
10.0	0.254	160.42	14.90	3.94	240.63	74.52	19.69
11.0	0.279	145.84	13.56	3.59	218.76	67.78	17.96
Interim Paint Striping							
15.0	0.381	106.94	9.94	2.62	160.42	49.68	13.12
16.0	0.406	100.27	9.32	2.47	150.41	46.60	12.35
17.0	0.432	94.37	8.77	2.32	141.56	43.86	11.62
Epoxy							
18.0	0.457	89.13	8.28	2.19	133.70	41.43	10.98
19.0	0.483	84.44	7.85	2.08	126.66	39.25	10.40
20.0	0.508	80.21	7.45	1.97	120.31	37.26	9.84
21.0	0.533	76.39	7.10	1.88	114.59	35.50	9.41
22.0	0.559	72.92	6.78	1.80	109.38	33.89	8.98

Montana Department of Transportation
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Helena, MT 59620-1001

PAINT & EPOXY APPLICATION CHART

METRIC & ENGLISH

4"/100mm STRIPE

100 mm =	0.100	m
1 mil =	0.0000254	m
1 liter =	0.001	m^3

METRIC

mils	m/L	m²/L	L/km
30	13.123	1.312	76.200
29	13.576	1.358	73.660
28	14.061	1.406	71.120
27	14.582	1.458	68.580
26	15.142	1.514	66.040
25	15.748	1.575	63.500
24	16.404	1.640	60.960
23	17.117	1.712	58.420
22	17.895	1.790	55.880
21	18.748	1.875	53.340
20	19.685	1.969	50.800
19	20.721	2.072	48.260
18	21.872	2.187	45.720
17	23.159	2.316	43.180
16	24.606	2.461	40.640
15	26.247	2.625	38.100
14	28.121	2.812	35.560
13	30.285	3.028	33.020
12	32.808	3.281	30.480
11	35.791	3.579	27.940
10	39.370	3.937	25.400
9	43.745	4.374	22.860
8	49.213	4.921	20.320
7	56.243	5.624	17.780
6	65.617	6.562	15.240
5	78.740	7.874	12.700
4	98.425	9.843	10.160
3	131.234	13.123	7.620
2	196.850	19.685	5.080
1	393.701	39.370	2.540

4” =	0.3333	ft
1mil =	0.0000833	ft
1 gal=	0.1336805	ft^3

ENGLISH

mils	ft/gal	ft²/gal	gal/mi
30	160.497	53.494	32.898
29	166.031	55.338	31.801
28	171.961	57.315	30.705
27	178.330	59.437	29.608
26	185.189	61.723	28.511
25	192.596	64.192	27.415
24	200.621	66.867	26.318
23	209.344	69.774	25.222
22	218.859	72.946	24.125
21	229.281	76.419	23.028
20	240.745	80.240	21.932
19	253.416	84.464	20.835
18	267.495	89.156	19.739
17	283.230	94.400	18.642
16	300.932	100.300	17.546
15	320.994	106.987	16.449
14	343.922	114.629	15.352
13	370.377	123.447	14.256
12	401.242	133.734	13.159
11	437.719	145.892	12.063
10	481.491	160.481	10.966
9	534.989	178.312	9.869
8	601.863	200.601	8.773
7	687.844	229.258	7.676
6	802.484	267.468	6.580
5	962.981	320.962	5.483
4	1203.726	401.202	4.386
3	1604.968	534.936	3.290
2	2407.453	802.404	2.193
1	4814.905	1604.808	1.097

CONVERSION EXAMPLES

100 mm =	0.100	m	4" =	0.3333	ft
1 mil =	0.0000254	m	1 mil =	0.0000833	ft
1 liter =	0.001	m^3	1 gal=	0.1336805	ft^3

METRIC

L/km

Find volume for 1 foot of 4 inch stripe:

$$v = l \cdot w \cdot h = 1m \cdot 100mm \cdot 15mil$$

$$v = (1m)(100mm)\left(\frac{1m}{1000mm}\right)(15mil)\left(\frac{0.0000254m}{1mil}\right)$$

$v = 0.000038m^3$ per meter of stripe

——

Find liters/kilometer for 15 mils thick stripe:

$$L/km = \left(\frac{0.0000381m^3}{m}\right)\left(\frac{1L}{0.001m^3}\right)\left(\frac{1000m}{1km}\right)$$

$$= 38.100L/km$$

ENGLISH

gal/mi

Find volume for 1 foot of 4 inch stripe:

$$v = l \cdot w \cdot h = 1ft \cdot 4in \cdot 15mil$$

$$v = (1ft)(4in)\left(\frac{1ft}{12in}\right)(15mil)\left(\frac{0.0000833ft}{1mil}\right)$$

$v = 0.000416458ft^3$ per foot of stripe

——

Find gallons/mile for 15 mils thick stripe:

$$\text{gal/mi} = \left(\frac{0.000416458\text{ft}^3}{\text{ft}}\right)\left(\frac{1\text{gal}}{0.1336805\text{ft}^3}\right)\left(\frac{5280\text{ft}}{1\text{mi}}\right)$$

$$= 16.449\text{gal/mil}$$

OTHER USEFUL CONVERSION FACTORS

LENGTH
miles → kilometers
mi×1.609=km

kilometers → miles
km÷1.609=mi

feet → meters
ft×0.3048=m

meters → feet
m÷0.3048=ft

AREA
square feet → square meters
$ft^2 \times 0.0929 = m^2$

square meters → square feet
$m^2 \div 0.0929 = ft^2$

VOLUME
gallons → liters
gal×3.78541=L

liters → gallons
L÷3.78541=gal

Material Weight Determination

Liquid and solid weight determination may be made using specific gravity to determine density. (See Appendix D for example calculations.)

Specific gravity is the ratio of material volume mass to an equal volume of water at the same temperature. The term "absolute specific gravity" refers to this value, but due to varying field parameters is rarely used in engineering work. See ASTM E12 and AASHTO M132 for an absolute specific gravity definition. Specific gravity requires material and water temperatures to be defined as used within the following equation:

Specific Gravity = (Material Density at Temp, T_m) / (Water Density at Reference Temp, T_{ref})

Liquid specific gravity is measured using a hydrometer, which is similar to instruments used to measure automobile antifreeze concentration. Specific gravity is used to determine material concentrations in water, because dissolved liquids and solids alter the specific gravity of water.

Engineering applications generally assume material and water temperatures are equal and at approximately room temperature. The following specific gravity definitions generally apply to engineering work:

- **Specific Gravity for Liquids and Solids**
  Material volume mass divided by the mass of an equal volume of water.

- **Apparent Specific Gravity (Solids)**
  Weight of a substance volume divided by the weight of an equal volume of reference substance**.**

- **Bulk Specific Gravity (Solids).**
  Material volume mass divided by a water volume mass equal to the material volume. Total volume includes solid matter volume, permeable voids and impermeable voids.

- **Bulk Specific Gravity (Saturated Surface Dry)**
  Bulk specific gravity is the weight of a given volume of aggregate, including permeable and impermeable aggregate voids, to the weight of an equal volume of water.

Material specific gravity may be used to determine material density, or weight (mass) per material volume.

Example: Calculate liquid and solid material weight using specific gravity

Material temperature is approximately 60.0°F (15.56°C) when specific gravity was obtained. Water is 62.3682 lb/ft^3 (0.999043 g/mL) at 60.0°F (15.56°C).

Material Specific Gravity = 1.7628
Water = 62.4 lbs/ft^3

Find: Weight (lbs) of 100 ft^3 of material.

$SG_m = D_m / D_w$
$D_m = SG_m \times D_w$
D_m = (1.7628) x (62.4 lbs/ft^3) = 110 lbs/ft^3 = (material density)
(100 ft^3) x (110 lbs/ft^3) = 11,000 lbs/100 ft^3 (material weight)

Reinforcing Bars

Reinforcing bar weight (mass) is determined using total bar length and weight (mass) per length. First determine length for each different bar size, then multiply total bar length by its weight per length to attain total weight (mass). Appendix D explains bar type identification and weight per unit length for ASTM A 615/A 615M bars.

Steel H Piles and Cross Sectional Structural Shapes

Size designations for structural steel members such as “W” beams and “H” piles are designated by nominal depth multiplied by weight per length. For example, a steel H pile, HP10 x 42 (HP250 x 62), has a 10” depth and weighs 42 lb/ft. To determine the weight for this steel member, multiply length by unit weight per length. Appendix D lists steel H pile technical data. For other structural shapes such as W beams, see ASTM A 6/A 6M.

Common Construction Material Properties

Material	Average Material Density		
	lb/ft³	lb/yd³	kg/m³
SOIL AND ROCK			
Granite, solid	148	3,996	2,371
Granite, crushed	98	2,646	1,570
Lime, hydrated	30	810	481
Limestone, solid	165	4,455	2,643
Limestone, aggregate, compacted, stabilized	140	3,780	2,243
Limestone, aggregate, crushed, loose, wet	110	2,970	1,762
Limestone, aggregate, crushed, loose, dry	95	2,565	1,522
Limestone, finely ground, loose, dry	100	2,700	1,602
Limestone, screenings, loose, dry	89	2,403	1,426
Limestone, dust, loose, dry	80	2,160	1,281
Pumice, ground	43	1,161	689
Pumice, stone	39	1,053	625
Quartz, solid	165	4,455	2,643
Quartz, sand	75	2,025	1,201
Rock, common, soft	105	2,835	1,682
Sand, common, loose, dry	100	2,700	1,602
Sand, common, loose, wet	120	3,240	1,922
Sand, common, consolidated, moist	115	3,105	1,842
Sand, common, loose, river	120	3,240	1,922
Sand, common, loose, moist	105	2,835	1,682
Sand, quartz, loose, dry	75	2,025	1,201
Soil (design)	120	3,240	1,922
Soil, common, loose, containing clay, moist	105	2,835	1,682
Soil, common, loose	77	2,106	1,249
Soil, common, mud, dry	110	2,970	1,762
Soil, common, mud, wet	120	3,240	1,922
Soil, clay, undisturbed, dry	110	2,970	1,762
Soil, clay, compacted, moist	130	3,510	2,082
Soil, sandy loam, loose, dry	90	2,430	1,442
Soil, loam, loose, dry	88	2,376	1,410
Soil, silty, loose, dry	75	2,025	1,201
Soil, peat, loose, dry	20	540	320
Soil, muck	40	1,080	641
Slag, solid	170	4,590	2,723
Slag, loose	110	2,970	1,762
Slag, crushed	74	1,998	1,185
Slate, solid	170	4,590	2,723
Slate, granulated	95	2,565	1,522
Slate, finely ground	85	2,295	1,362
Stone, crushed, loose	100	2,700	1,602
CONCRETE			
Portland Cement Concrete (design)	150	4,050	2,403
Scrap Concrete, loose	69	1,863	1,105
CEMENT AND MORTAR			
Bulk Cement	100	2,700	1,602
Mortar, hardened	100	2,700	1,602
Mortar, wet	150	4,050	2,403
Portland (sack)	94	2,538	1,506
Portland (barrel (bbl) = 4 sacks)	376	10,152	6,023
Portland (minimum truck-trailer shipment = 100 bbl)	37,600	1,015,200	602,294
Portland (minimum rail-car shipment = 173 bbl)	66,176	1,786,752	1,060,038
Portland (medium rail-car shipment = 231 bbl)	86,856	2,345,112	1,391,300
Portland (large rail-car shipment = 289 bbl)	108,664	2,933,928	1,740,630

Notes:

One (1) sack of Portland Cement = 94 lb = 42.6377 kg = 1 ft^3 = 0.037 yd^3 = 0.0283 m^3

One (1) barrel of Portland Cement = 376 lbs = 170.5507 kg = 4 ft^3 = 0.1481 yd^3 = 0.1133 m^3

Common Construction Material Properties (continued)

Material	Average Material Density		
	lb/ft³	lb/yd³	kg/m³
WATER			
US Customary: 1 ft³ of water = 1,728 in³ = 0.037 yd³ = 7.48 gal = 62.34 lb 1 yd³ of water = 46,656 in³ = 27 ft³ = 202 gal = 1,6833.9 lb 1 gal of water = 231 in³ = 0.134 ft³ = 0.005 yd³ = 8.34 lb 1 lb of water = 27.7 in³ = 0.016 ft³ = 0.00059 yd³ = 0.12 gal			
US Customary to Metric: 1 ft³ of water = 28,300 cm³ = 0.0283 m³ = 28,300 mL = 28.3 L = 28.3 g = 0.0283 kg 1 yd³ of water = 764,600 cm³ = 0.7646 m³ = 764,600 mL = 764.6 L = 763,800 g = 763.8 kg 1 gal of water = 3,785 cm³ = 0.003785 m³ = 3,785 mL = 3,780 g = 3.78 kg 1 lb of water = 454 cm³ = 0.000454 m³ = 454 mL = 0.45 L			
Metric: 1 m³ of water = 1,000,000 cm³ = 1,000,000 mL = 1,000 L = 1,000,000 g = 1,000 kg 1 L of water = 1,000 cm³ = 0.001 m³ = 1,000 mL = 1,000 g = 1 kg 1 kg of water = 1,000 cm³ = 0.001 m³ = 1,000 mL = 1 L = 1,000 g			
Metric to US Customary: 1 m³ of water = 61,024 in³ = 35.32 ft³ = 1.308 yd³ = 264 gal = 2,203 lb 1 L of water = 61 in³ = 0.0353 ft³ = 0.0013 yd³ = 0.264 lb 1 kg of water = 61 in³ = 0.0353 ft³ = 0.0013 yd³ = 0.264 gal			
Notes: *Water @ 60°F = 62.3682 lb/ft³ = 8.3374 lb/gal = 7.481 gal/ft³ = 0.13368 ft³/gal* *Water @ 15.56°C = 0.999043 g/cm³ = 999.043 kg/m³ = 0.999043 g/mL = 0.999043 kg/L* *Water freezing point = 32°F = 0°C = 273°K* *Water boiling point (1 atmospheric pressure) = 212°F = 100°C = 373°K* *Approximate heat capacity superheated steam at atmospheric pressure = 0.47 BTU/lb•°F* *Total heat of saturated steam at atmospheric pressure = 1150.4 BTU* *Boiling point steam rising from water is at atmospheric pressure.*			
ASPHALT			
Shingles, loose	16	432	256
HMA Pavement, crushed	51	1,377	817
METAL			
Aluminum, solid	166	4,482	2,659
Aluminum, scrap, cubed	16	432	256
Aluminum, chipped	11	297	176
Brass, solid	524	14,148	8,394
Brass, cast	519	14,013	8,314
Brass, scrap	34	918	545
Bronze	552	14,904	8,842
Copper, cast	542	14,634	8,682
Copper, ore	135	3,645	2,162
Copper, scrap	41	1,107	657
Copper, fittings, loose	39	1,053	625
Copper, wire, whole	13	351	208
Copper, pipe, whole	8	216	128
Iron, wrought	480	12,960	7,689
Iron, cast, ductile	444	11,988	7,112
Iron, wrought	480	12,960	7,689
Iron, cast, chips or borings	165	4,455	2,643
Iron, ore	150	4,050	2,403
Lead, ore	735	19,845	11,774
Lead, commercial	710	19,170	11,373
Lead, scrap	59	1,593	945
Steel, solid (design)	490	13,230	7,849
Steel, trimmings	63	1,701	1,009
Steel, shavings	62	1,674	993
Zinc	437	11,799	7,000

Common Construction Material Properties (continued)

SPECIFIC GRAVITY OF COMMON AGGREGATES	
Dolomite	2.80 - 2.85
Granite	2.65 - 2.70
Granite Gneiss	2.70 - 2.85
Gravel (Quartz)	2.60 - 2.65
Greenstone	2.95 - 3.10
Limestone	2.70 - 2.79
Sand (Quartz)	2.60 - 2.65
Sandstone	2.55 - 2.65

Asphalt Materials Temperature-Volume Correction

Liquid asphalt volume changes with temperature. This change in unit volume per degree temperature is called the “Coefficient of Expansion,” a factor varying with material specific gravity. 60°F is standard temperature by which liquid asphalt volumes are determined. For liquid asphalt materials at temperatures other than 60°F, apply a correction factor to convert measured volume to an equivalent volume at 60°F.

See Appendix E page E-44 for a temperature volume correction factor table. Obtain asphalt material specific gravity before applying this factor. See the Asphalt Institute publication “Pocket Book of Useful Information,” for temperature and volume correction.

CHECKING SPREAD RATE FOR PLANT MIX SURFACING

Verify plant mix surfacing (PMS) placement rates to ensure specified quantities are applied. Asphalt truck delivery tickets can be used to check PMS placement rate. Refer to plan typical sections for PMS depth. Calculate the plan yield using the method below to calculate “target” rate:

1. Obtain the Rice specific gravity from the gyratory data entry form.
2. Multiply Rice specific gravity by 62.4 lbs/ft^3 water to calculate the weight of a cubic foot of PMS.
3. Multiply ft^3 PMS by the target density to get the ft^3 weight of PMS compacted to target density.
4. Multiply compacted ft^3 PMS by lift thickness to determine ft^2 weight compacted at target density.
5. Determine roadway section length.
6. Measure entire roadway paving width, and the width of new PMS (average top and bottom PMS widths to account for edge slopes).
7. Determine roadway section area by multiplying section length by placement width.
8. Multiply this area by the unit weight determined in step 4 above to attain target application rate.

Example:

PMS thickness is to be 0.35′ placed in two lifts. The first lift is 0.15’, the second 0.20’.

Rice specific gravity from gyratory data entry form: 2.440 x 62.4 = 152.26
152.26 x 0.945 (94.5% target density) = 143.9 lbs/ft^3.

143.9 x 0.20 (second lift thickness) = 28.78 lbs/ft^3 at 0.20’ thickness at target density.

Paving ending station 14+75 – beginning station 12+50 = 225 feet

225 ft length x ((11.2 bottom width + 8.8 top width) /2 to get average) = 2250 sq ft
2250 sq ft at 28.78 lbs/sq ft = 64755 lbs/2000 lbs = 32.38 tons

Based on delivery tickets, determine PMS total section weight:

34.25 tons placed over section
34.25 tons placed / 32.38 tons plan = 1.058 tons, or 5.8% tonnage overrun

Checking Tack Coat Spread Rate

Asphalt tack ensures bonding between adjacent PMS lifts. Use the two methods below to check liquid asphalt tack (emulsified asphalt) application rate using a temperature-volume correction table to verify tack application rate meets contract specifications.

Measure the road surface, check the distribution tank flow meter before and after application, and verify the distribution tank tack temperature. Then determine application rate based on the temperature-volume correction for emulsified asphalt.

Determine Area Covered — Measure the longitudinal length and treated roadway width. Use pavement markings, survey information, a tape measure or other means to obtain these distances. Calculate the roadway surface are to be treated.

Determine Quantity Used — Determine tack volume quantity used. Tack is typically diluted 50/50 with water for even distribution, so adjust tack quantity for dilution rate to determine actual tack applied. This quantity is calculated based on initial and final tack distributor flow meter readings. Take readings before and after tack application. The absolute value of the difference in these readings is the tack quantity sprayed over the surface.

Measure Temperature for Volume Correction — Measure the temperature of the tack in the distributor tank when it was sprayed on the roadway surface. This temperature is used with the temperature-volume correction table to obtain a multiplier used to adjust the used quantity volume.

Adjust Used Tack Volume — Prior to calculating tack rate, used tack volume must be adjusted for distribution tank temperature. Use the emulsified asphalt temperature-volume table to obtain the multiplier, and adjust the volume applied.

Determine Tack Rate — Tack rate (gal/yd^2) is based on adjusted tack volume used and treated area.

Example:
Tack Rate Calculation Without Residual Asphalt Content

Determine Area Covered:

Width of Coverage (W) = 12 ft
Length of Coverage (L) = 4,765 ft
Area of Coverage ($A_{Coverage}$) = L x W
= 12 x 4,765 = 57,180 ft^2 = 6,353.3 yd^2

Determine Used Quantity:

Beginning Flow Meter Reading (Q_B) = 123 gal
Ending Flow Meter Reading (Q_E) = 478 gal
Total Quantity Tack Used (Q_{Total}) = $Q_E - Q_B$ = 478 – 123 = 355 gal

Adjust Tack Volume Used:

Distributor Tank Temperature = 150°F
Temperature-Volume Multiplier = 0.97750 (from TV correction table)
Adjusted Tack Quantity (Q_{ADJ}) = $Q_{Total} \times M_{TV}$
= 355 x 0.97750 = 347.0 gal

Tack Rate = $Q_{ADJ} / A_{Coverage}$
= 347.0 / 6353.3 = 0.055 gal/yd²

Example:
Tack Rate Calculation With Residual Asphalt Content

Determine Area Covered:

Width of Coverage (W) = 10 ft
Length of Coverage (L) = 3,000 ft
Area of Coverage ($A_{Coverage}$) = L x W
= 10 x 3,000 = 30,000 ft² = 3,333.3 yd²

Determine Quantity Used:

Beginning Flow Meter Reading (Q_B) = 120 gal
Ending Flow Meter Reading (Q_E) = 500 gal
Total Quantity Tack Used (Q_{Total}) = $Q_E – Q_B$
= 500 – 120 = 380 gal

Adjust Volume of Tack Used:

Temperature of Tack in Distributor Tank = 122°F
Temperature-Volume Multiplier (M_{TV}) = 0.98450 (Temp/Vol correction table)
Adjusted Tack Quantity (Q_{ADJ}) = $Q_{Total} \times M_{TV}$
= 380 x 0.98450 = 374.1 gal

Determine Tack Rate:

= $Q_{ADJ} / A_{Coverage}$
= 374.1 / 3333.3 = 0.1122 gal/yd²

Determine Residual Tack Rate:

Percent Residual Asphalt (P_{RA}) = 0.58 (submitted by supplier as 58%)
Residual Tack Rate ($R_{Residual}$) = $R_{Tack} \times P_{RA}$
= 0.1122 x 0.58 = 0.065 gal/yd²

HMA Mixture Compaction Factors

Characteristic	Influence	Countermeasure
Aggregate		
Smooth Surfaced	Low interparticle friction	Use light rollers Lower mix temperature
Rough Surfaced	High interparticle friction	Use heavy rollers
Unsound	Breaks under steel wheel rollers	Use sound aggregate Use pneumatic rollers
Absorptive	Dries mix, difficult to compact	Increase mix asphalt binder
Asphalt Binder		
High Viscosity	Particle movement restricted	Use heavy rollers Increase temperature
Low Viscosity	Particles move easily during compaction	Use light rollers Decrease temperature
High Content	Unstable and plastic under roller	Decrease mix binder
Low Content	Reduced lubrication, difficult compaction	Increase mix binder
Mix Properties		
Excess Coarse Aggregate	Difficult compaction	Reduce coarse aggregate.
Excess Sand	Too workable, difficult compaction	Reduce mix sand Use light rollers
Too Much Filler	Stiffens mix, difficult compaction	Reduce mix filler Use heavy rollers
Too Little Filler	Low cohesion, may separate	Increase mix filler
Mix Temperature		
High Temperature	Mix lacks cohesion, difficult compaction.	Decrease mix temperature
Low Temperature	Mix too stiff, difficult compaction	Increase mix temperature
Course Thickness		
Thick Lifts	Holds heat – more time to compact.	Roll normally.
Thin Lifts	Loses heat – less time to compact.	Roll before mix cools. Increase mix temperature.
Weather Conditions		
Low Air Temperature	Cools mix rapidly.	Roll before mix cools.
Low Surface Temperature	Cools mix rapidly.	Increase mix temperature.
Windy Conditions	Cools mix – crusts surface.	Increase mix temperature.

HMA Construction Troubleshooting

Difficulty	Possible Causes	Possible Treatment
Mat Tears on Edges	• End plate not square • Cold material building up at end of feeder screws • Extensions installed incorrectly • Feeder gate closed too narrow	• Adjust • Remove material buildup • Check installation • Open gates
Screed Raises Each Time Machine Starts Forward	• Feeder screws, loaded too heavy • Sensor mounting • Feeder screws worn out • Idle time between loads • Temperature varying in mix	• Check feeder control paddles. • Refer to auto grade control information • Replace • Correct problems at plant or with trucks. Slow paver speed • Correct problem at plant
Feeder Screws Shadows	• Feeder screws loaded too heavy • Feeder screws high. • Feeder screws worn out. • Segregation in mix.	• Check feeder control paddles. • Lower feeder gates. Lower feeder screws. • Replace. • Correct problem at plant
Streak at Quarter Point (wide width)	• Screed needs adjustment. • Feeder gates closed down too far.	• Adjust torque arms. • Raise feeder gates
Bright Streak Down Center	• Too much lead crown • Feeder screws worn out • Feeder gates open too far	• Adjust torque arms. • Replace surfacing • Lower gates
Unable to Control Screed	• Cold screed • Mat thinner than largest aggregate • Screed pivot loose • Unstable mix	• Heat screed. • Increase mat thickness. • Tighten at torque tube and leveling arm connection. • Correct problem at plant
Inconsistent Mat Texture	• Varying mix temperature • Head of material fluctuating. • Sitting long periods between loads. • Vibratory running too slow. • Mat thinner than largest aggregate. • Extensions installed incorrectly. • Screed plate worn out. • Running hopper empty between loads. • Trucks holding brakes. • Feeder screws worn out. • Cold screed. • Material too cold. • Segregation in mix. • Pre-strike off not adjusted properly.	• Correct problem at plant or with trucks • Adjust feeder control paddles • Correct problem at plant or with trucks; Slow paving speed • Increase vibrating drive speed • Increase mat thickness • Check installation • Replace surfacing • Do not run feeders empty • Instruct drivers • Replace screws • Heat screed • Correct plant problem at plant • Correct problem at plant • Adjust pre-strike off.

HMA Construction Troubleshooting (continued)

Trouble	Possible Causes	Possible Treatment
Heat Checking; short transverse cracks during compaction	• Tender mixture • Uneven mat cooling during compaction	• Adjust paving speed • Adjust roller pattern; roll while mix > 240°F • Verify mix design stability and component materials
Screed Marks	• Trucks bumping finisher • Sitting long periods of time between loads • Pre-strike off not adjusted properly	• Instruct drivers • Correct problem at plant or with trucks; Slow paving speed. • Adjust pre-strike off
Ripples	• Head of material fluctuating • Feeder screws loaded too heavy • Auto grade control • Speed too fast • Screed plates worn • Roller unmaintained • Feeder screws worn out • Unstable mix • Excessive crown • Not enough lead crown. • Trucks holding brakes • Mix temperature varies • Pre-strike off adjusted improperly • Too much play in thickness control.	• Adjust feeder control • Check feeder control • Adjust sensitivity • Slow paver speed • Replace plates • Repair roller • Replace feeder screws • Check problem with plant • Adjust torque arms • Adjust torque arms • Instruct drivers • Correct at plant. • Adjust pre-strike off
Poor Surface Texture	• Material head fluctuating • Feeder screws over loaded • Extensions installed incorrectly • Trucks holding brakes • Cold material • Excessive mix moisture • Excessive speed • Varying mix temperature • Screed plates worn	• Adjust feeder paddles • Check feeder control paddles • Check installation • Instruct drivers • Correct problem at plant • Correct problem at plant • Cut paving speed • Correct problem at plant • Replace plates
Wavy Surface (Long)	• Running hopper empty between loads • Material head fluctuating • Feeders loaded too heavy • varying mix temperature • Overcorrecting thickness controls • Poor grade reference • Feeder screws worn • Feeder gates open too high • Mix segregation • Sitting long periods between loads	• Cut paving speed. Do not run feeders empty • Adjust feeder control paddles • Adjust feeder control paddles, lower feeder gates • Correct problem at plant • Instruct screed operator • Improve reference • Replace screws • Lower feeder gates • Correct problem at plant • Correct problem at plant or with trucks; Slow paving speed

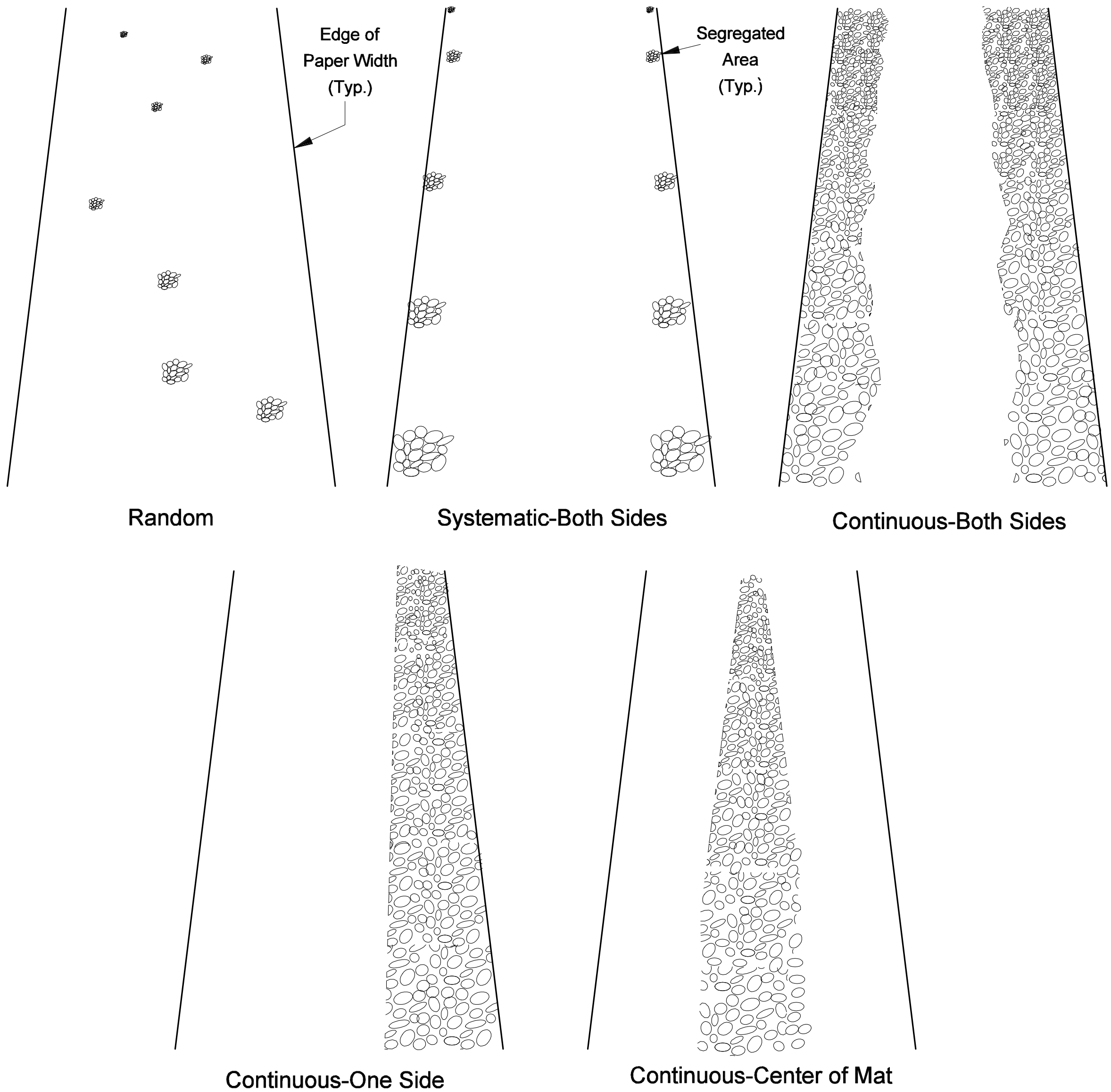
HMA Construction Troubleshooting (continued)

Trouble	Possible Causes	Possible Treatment
Wavy Surface (Short)	• Auto grade control too sensitive • Material head fluctuating • Feeder screws loaded too heavy • Overcorrecting thickness control screws. • Mix segregation • Feeder screws worn • Poorly maintained rollers	• Adjust sensitivity. • Adjust feeder control paddles • Lower feeder gates • Instruct screed operator • Correct problem at plant • Replace feeder screws • Repair or replace roller
Rich or Fat Spots (Bleeding)	• Excessive mix moisture • Poor rolling operation • Pre-strike off improperly adjusted • Vibratory too fast • Eccentric weights incorrectly set	• Correct problem at plant • Instruct roller operator • Adjust pre-strike off • Cut vibrating drive speed • Correct weight, check timing
Poor Longitudinal Joint	• Not rolling joint soon enough • Overcorrecting thickness control • Feeder screws loaded too heavy • Too much or too little screed overlap • Poor raking	• Instruct roller operator • Instruct screed operator • Lower feeder gates • Correct steering • Instruct raker
Poor Compaction	• Vibratory running too slowly • Eccentric weight set incorrectly	• Increase vibrating drive speed • Reset, check timing
Tearing Full Width of Mat	• Excessive speed • Varying mix temperature • Screed plates worn • Cold screed • Mat thinner than largest aggregate • Material too cold • Excessive mix moisture • Pre-strike improperly adjusted • Vibratory running slowly	• Slow paving speed. • Correct problem with trucks or plant • Replace • Heat screed • Increase lift thickness • Correct problem at plant • Correct problem at plant • Correct adjustment • Increase vibrating drive speed.
Streak Down Center of Mat	• Not enough lead crown • Feeder gates closed too far • Feeder screws worn out	• Adjust torque arms • Raise feeder gates • Replace
Segregation in Mat	• Worn augers • Segregated mix in trucks • Running feeders out of mix between trucks.	• Replace screws • Load trucks in large batches and multiple batches at plant. • After truck pulls out, dump hopper and stop paver before mix falls below fender gates

HMA Segregation Troubleshooting (continued)

Trouble	Possible Causes	Possible Treatment
Systematic Spot Segregation on Both Sides of Mat	• Surge or Storage Silo	• Adjust timing on batcher gates or confirm batcher full indicator is working properly • Make sure batcher gates do not leak • Lessen material in silo to prevent cone formation • Make sure material drops vertically into batcher
	• Truck	• Load trucks in multiple drops (front, back, center)
	• Paver	• Prohibit emptying hopper between loads • Minimize dumping of hopper wings • Maintain constant gate opening between loads • Verify auger is not on with adequate mixture
Continuous Segregation Both Sides	• Surge or Storage Silo	• Make sure batcher gates open and close at the proper time or when batcher is full
	• Paver	• Make sure augers are not starved for mixture • Check for worn or improperly installed augers • Prohibit excessive raking of longitudinal joints on multiple lane paving
Continuous Segregation One Side	• Surge or Storage Silo	• Eliminate horizontal movement of materials placed in silo or batcher
	• Paver	• Check for worn or improperly adjusted gate on affected side • Check for worn or improperly installed auger on affected side • Prohibit excessive longitudinal joint raking
Continuous Segregation Center of Mat	• Paver	• Check for worn or improperly installed reverse augers.
Random Segregation	• Segregated Stockpile	• Use multiple stockpiles of single-sized aggregates • Construct stockpile in layers for multiple sized materials • Place material in stockpile rather than casting material
	• Cold Bins	• Do not load from segregated stockpile bottom or other segregated areas • Load into cold bin centers • Avoid forming cone in cold bins • Adjust loading operation to maintain constant aggregate level; do not empty bins • Check for occasional aggregate spillage between bins due to overloading; install bulkheads if necessary
	• Surge or Storage Silos	• Make sure batcher gates operate correctly • Make sure mixture level is always above cone on silo bottom
	• Truck Loading/Unloading	• Load all trucks in multiple drops (front, back, center) • Surge tail gate during unloading
	• Paver	• Maintain constant gate opening • Maintain constant auger speed and operation • Maintain uniform paving speed • Prohibit random dumping of wings • Prohibit improper raking

HMA Construction Troubleshooting (continued)



Reinforcing Bar Designation and Properties

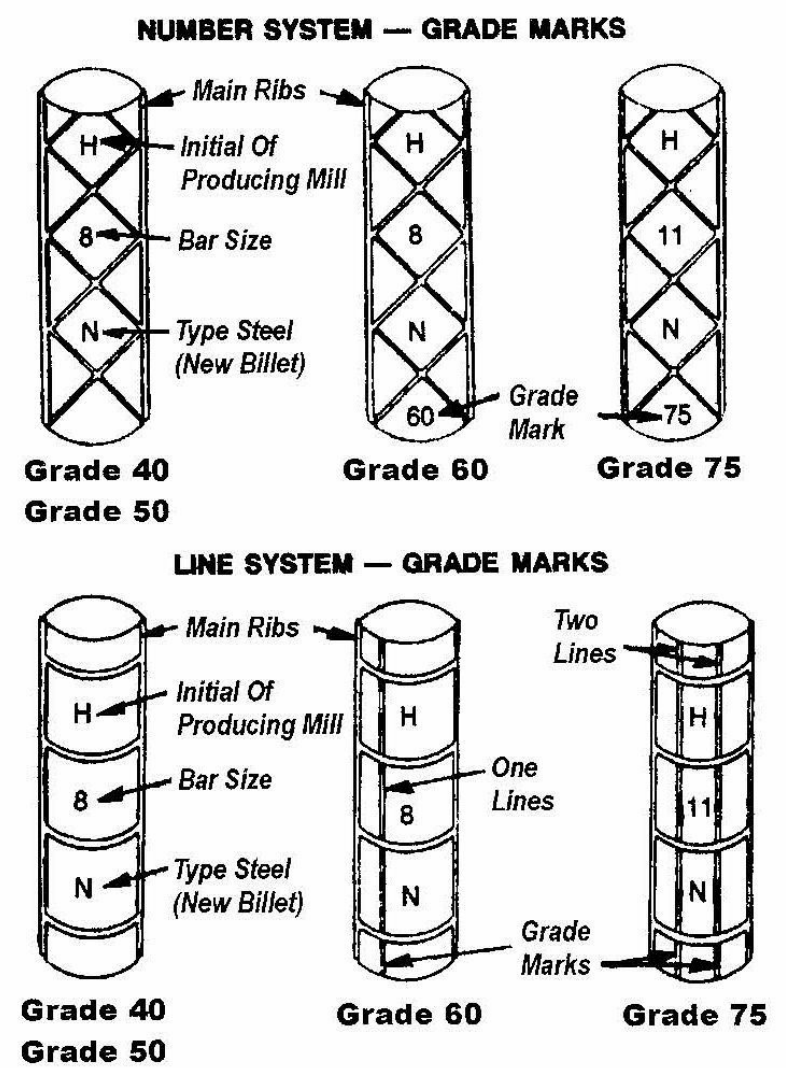
The ASTM specification for billet steel, rail steel, axle steel, and low alloy steel reinforcing bars (A 615M, A 616M, A 617M, and A706M respectively) requires bar identification marks denoting producer mill designation, bar size, steel type and minimum yield strength. Grade 60 (Grade 420) bars are marked in the following order:

1st mark– production mill (usually a letter).
2nd mark – bar size number (#3 through #18).
3rd mark– steel type:

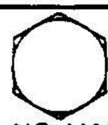
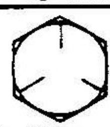
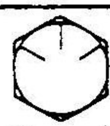
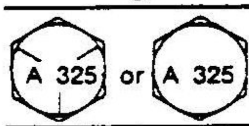
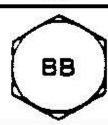
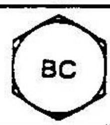
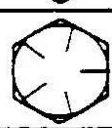
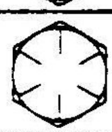
- S = billet meeting Supplemental Requirements for S1 of A 615M.
- N = new billet (A 615M).
- R = rail meeting ASTM A 617M, Grade 60 bend test requirement (A 616M) per ACI 318-83.
- I = rail (A 616M).
- A = axle (A 617M).
- W = low-alloy (A 706M).

4th mark– minimum yield strength:

Minimum yield designation is used for Grade 60 (Grade 420) bars only and can either be a single longitudinal line (grade line) or the number 60 grade mark. Grade lines are smaller and placed between two ribs on opposite sides of US made bars. A grade line must be continued at least 5 deformation spaces. A grade mark is the 4th mark on a bar. Grade 40 (Grade 300) and Grade 50 (Grade 350) bars are required to have only the first three identification marks without minimum yield designation. Bar identification may be oriented as illustrated or rotated 90 degrees. Grade mark numbers may be placed within separate consecutive deformation spaces, or placed on the side opposite bar marks. Grade 60 (Grade 420) indicates 60 ksi (400 MPa) minimum steel yield strength.

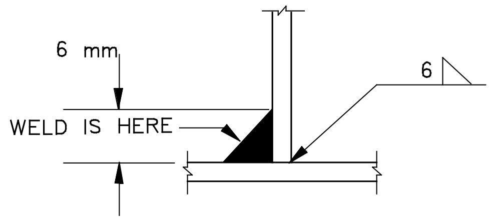


ASTM Grade Markings for High-Strength Bolts

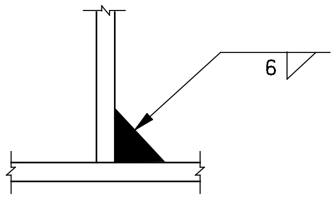
GRADE MARKING	SPECIFICATION	MATERIAL
 NO MARK	SAE-Grade 1	Low or Medium Carbon Steel
	ASTM-A 307	Low Carbon Steel
	SAE-Grade 2	Low or Medium Carbon Steel
	SAE-Grade 5 ASTM-A 449	Medium Carbon Steel, Quenched and Tempered
	SAE-Grade 5.2	Low Carbon Martensite Steel, Quenched and Tempered
	ASTM-A 325 Type 1 ASHTO-M 164	Medium Carbon Steel, Quenched and Tempered
	ASTM-A 325 Type 2 ASHTO-M 164	Low Carbon Martensite Steel, Quenched and Tempered
	ASTM-A 325 Type 3 ASHTO-M 164	Atmospheric Corrosion (Weathering) Steel, Quenched and Tempered
	ASTM-A354 Grade BB	Low Alloy Steel, Quenched and Tempered
	ASTM-A 354 Grade BC	Low Alloy Steel, Quenched and Tempered
	SAE-Grade 7	Medium Carbon Alloy Steel, Quenched and Tempered Roll Threaded After Heat Treatment
	SAE-Grade 8	Medium Carbon Alloy Steel, Quenched and Tempered
	ASTM-A-354 Grade BD	Alloy Steel, Quenched and Tempered
	ASTM-A 490 ASHTO-M 253	Alloy Steel, Quenched and Tempered

ASTM A 307 – low carbon steel externally and internally threaded standard fasteners
ASTM A 325 – high-strength steel bolts, nuts and washers for structural steel joints
ASTM A 449 – quenched and tempered steel bolts and studs
ASTM A 354 – quenched and tempered alloy steel bolts, studs and nuts
ASTM A 490 – quenched and tempered alloy steel bolts for structural steel joints
ASTM A 563, A194 – structural nuts
ASTM F 436 – structural washers

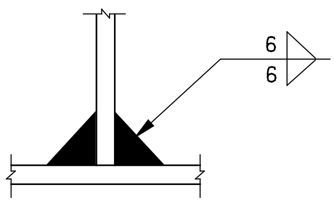
Welding Symbols



CALLED "OTHER SIDE"

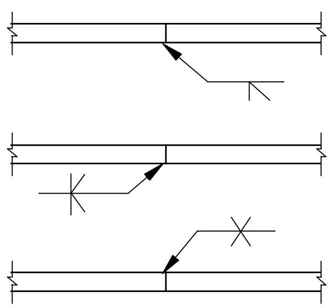


CALLED "THIS SIDE"

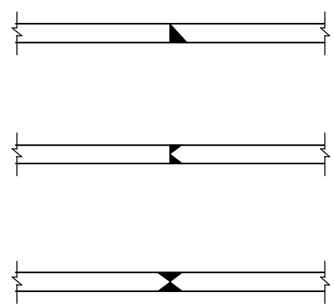


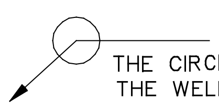
CALLED "BOTH SIDES"

THIS SYMBOL:

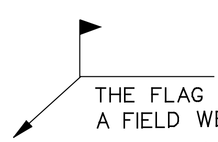


RESULTS IN THIS WELD:





THE CIRCLE MEANS THE WELD GOES COMPLETELY AROUND.

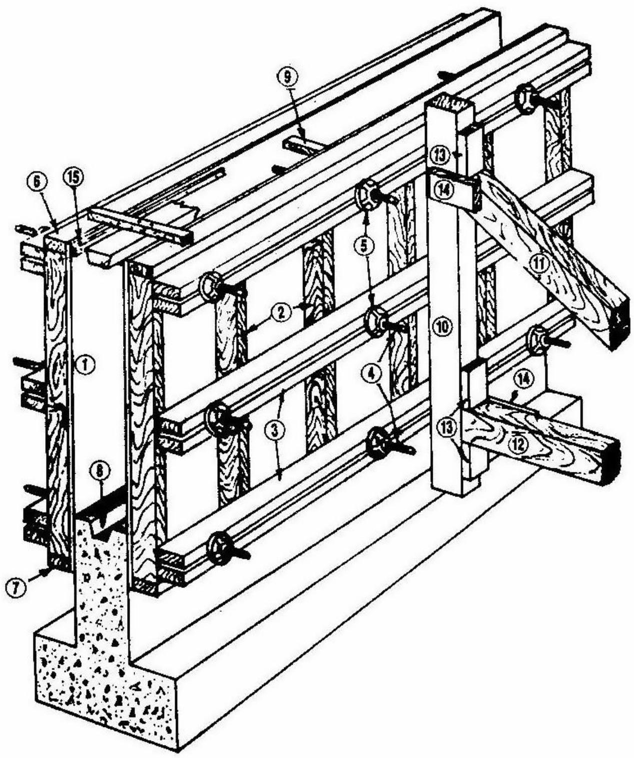


THE FLAG INDICATES A FIELD WELD. IT ALWAYS POINTS AWAY FROM THE WELD.

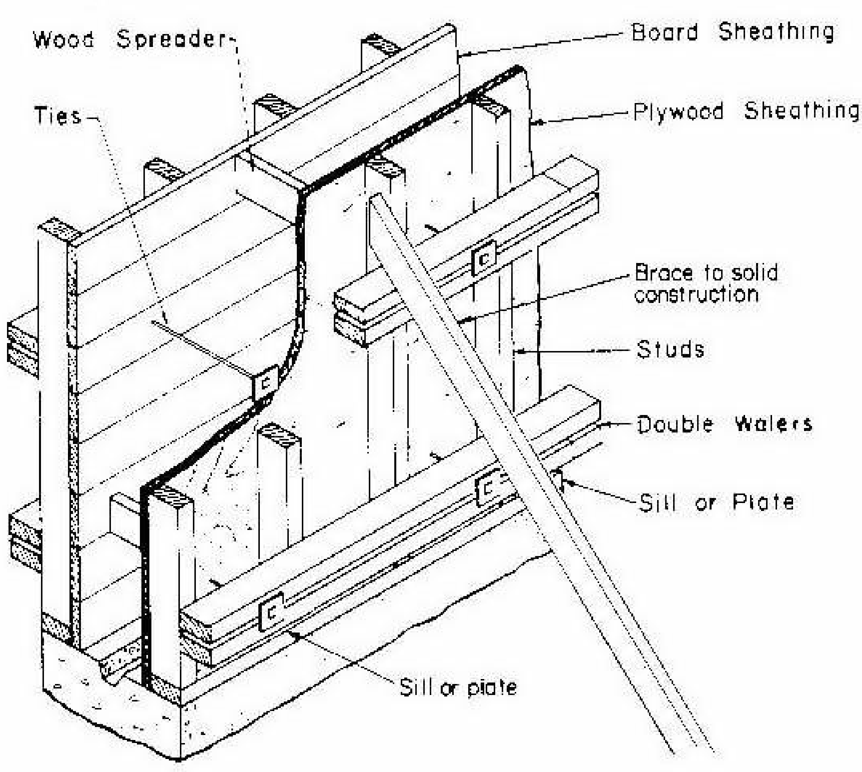
"THIS SIDE" AND "OTHER SIDE" WELDS ARE THE SAME SIZE UNLESS SPECIFIED OTHERWISE.

SYMBOLS APPLY BETWEEN ABRUPT CHANGES IN DIRECTION OF WELDING UNLESS GOVERNED BY THE "ALL-AROUND SYMBOL" OR OTHERWISE DIMENSIONED.

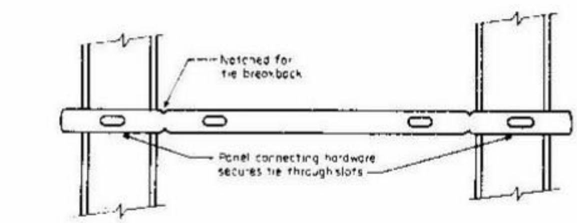
Formwork Nomenclature



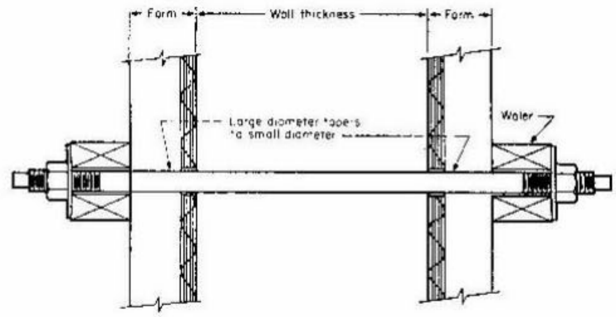
1. SHEATHING
2. STUDS
3. WALES
4. FORM BOLTS
5. NUT WASHER
6. TOP PLATE
7. BOTTOM PLATE
8. KEY-WAY
9. SPREADER
10. STRONGBACK
11. BRACE
12. STRUT
13. CLEATS
14. SCAB
15. POUR STRIP



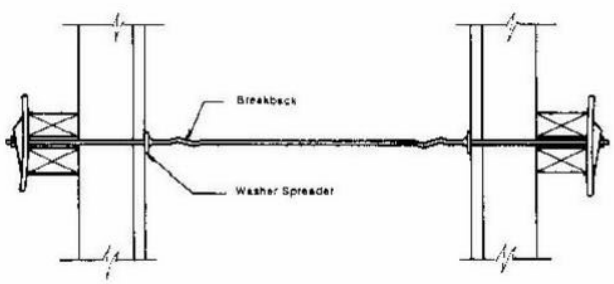
Formwork Ties



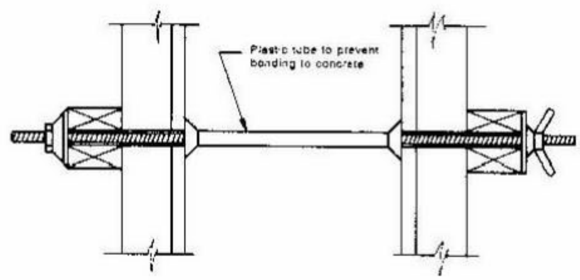
Flat tie.



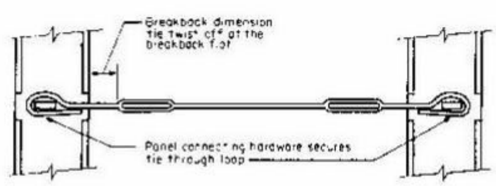
Taper tie.



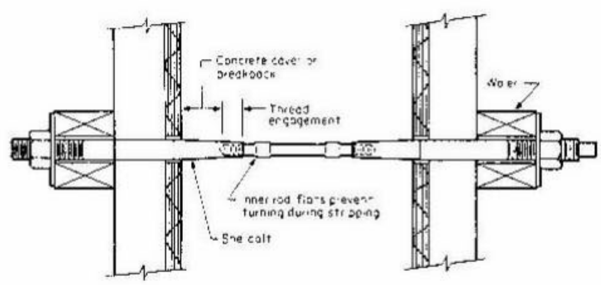
Snap tie.



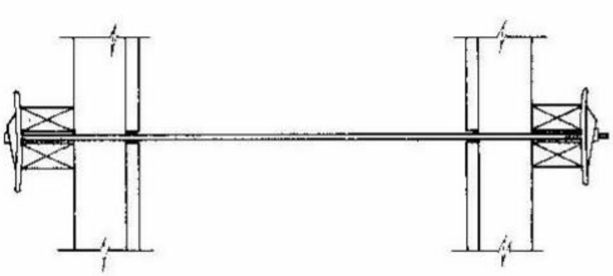
Threaded bar tie.



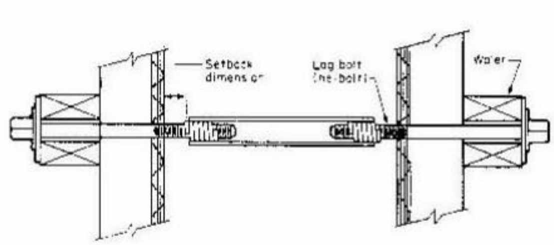
Wire panel tie.



She-bolt.

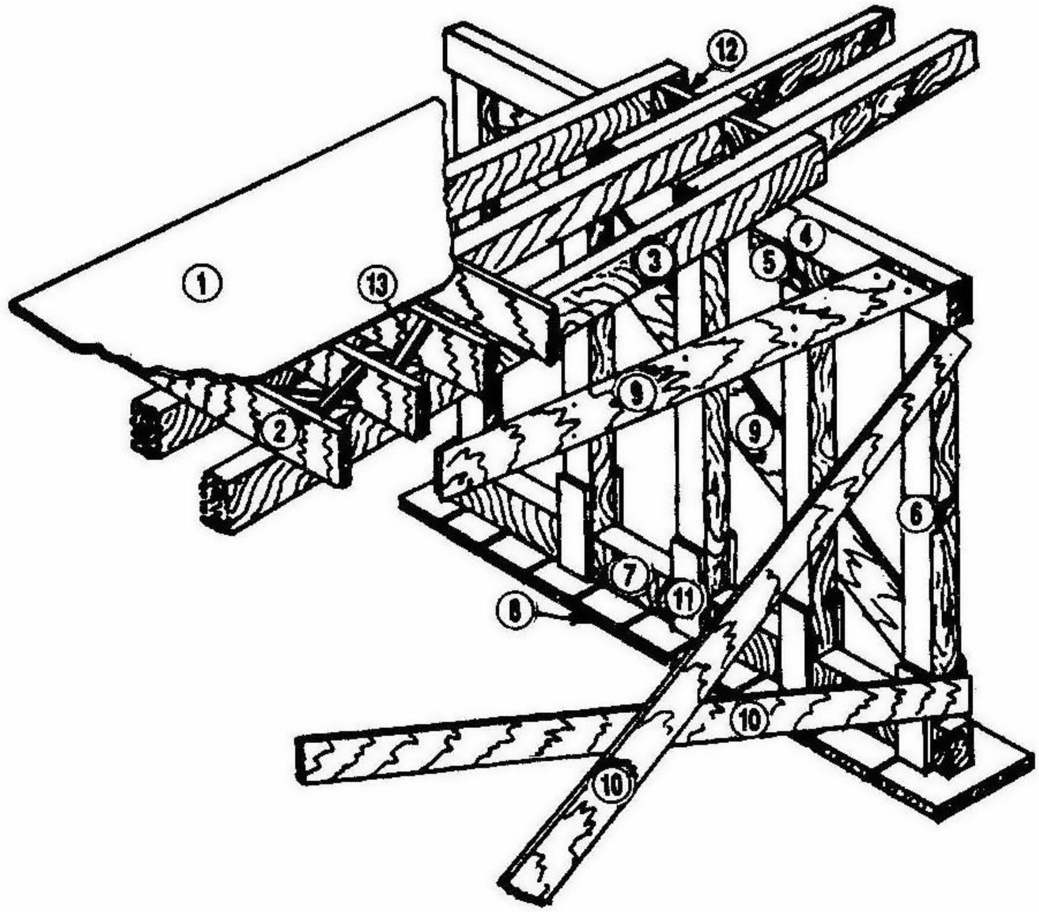


Pull-out tie.



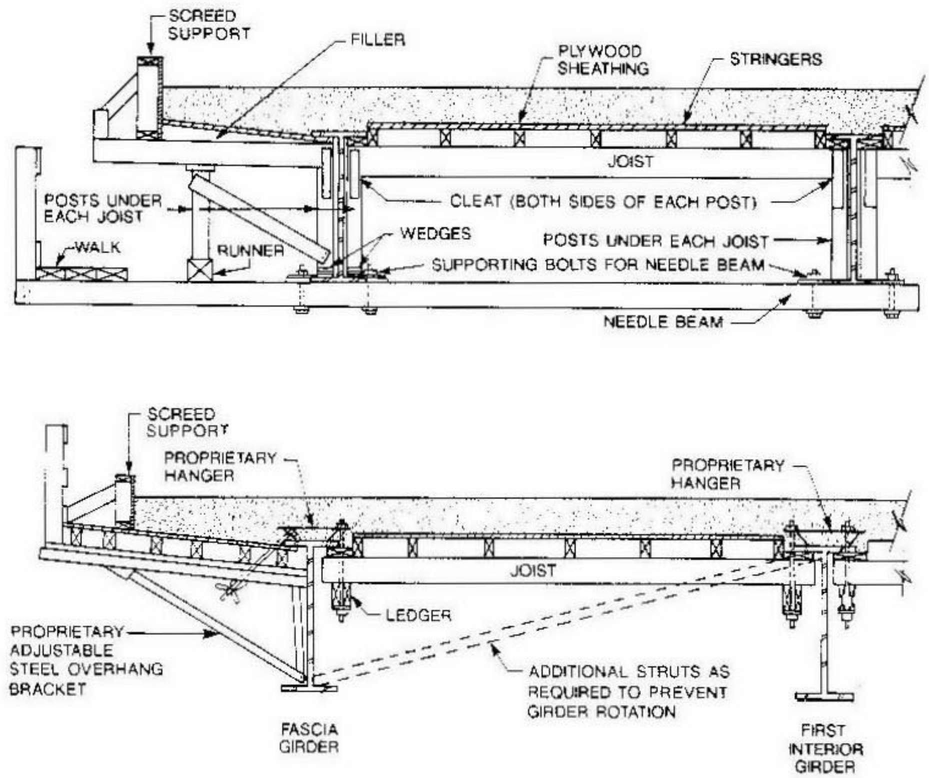
Coil tie.

Falsework Nomenclature

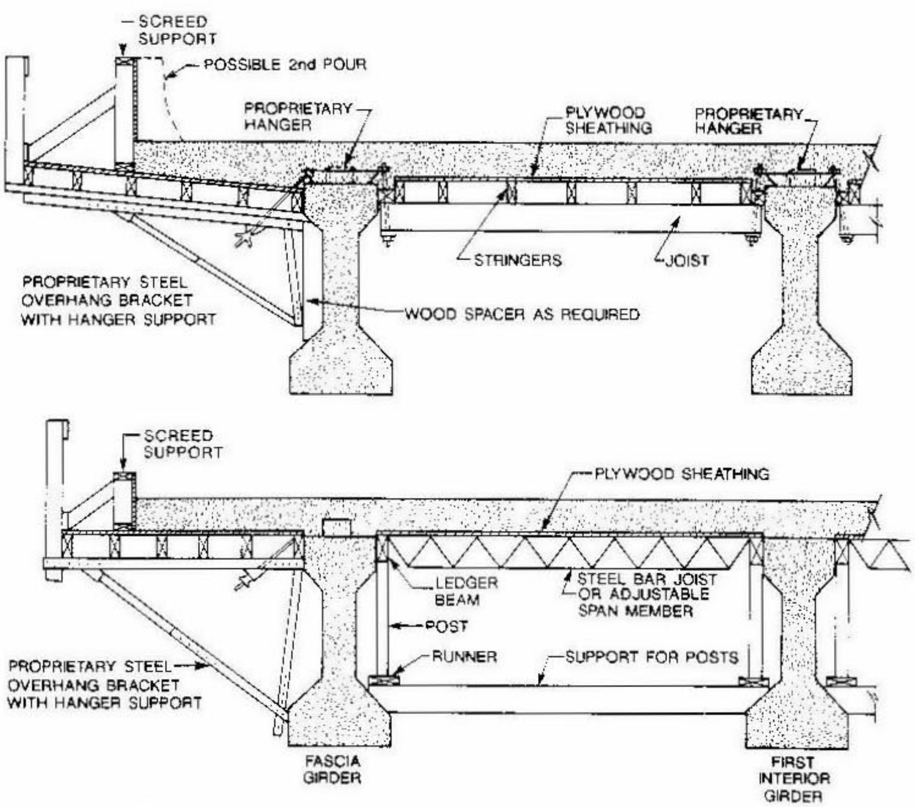


1. SHEATHING
2. JOIST
3. STRINGER
4. CAP
5. CORBEL
6. POST
7. SILL
8. FOOTING
9. SWAY BRACE
10. LONGITUDINAL BRACE
11. SCAB
12. BLOCKING
13. BRIDGING

Falsework Nomenclature (continued)



Bridge deck forming methods with steel stringers.

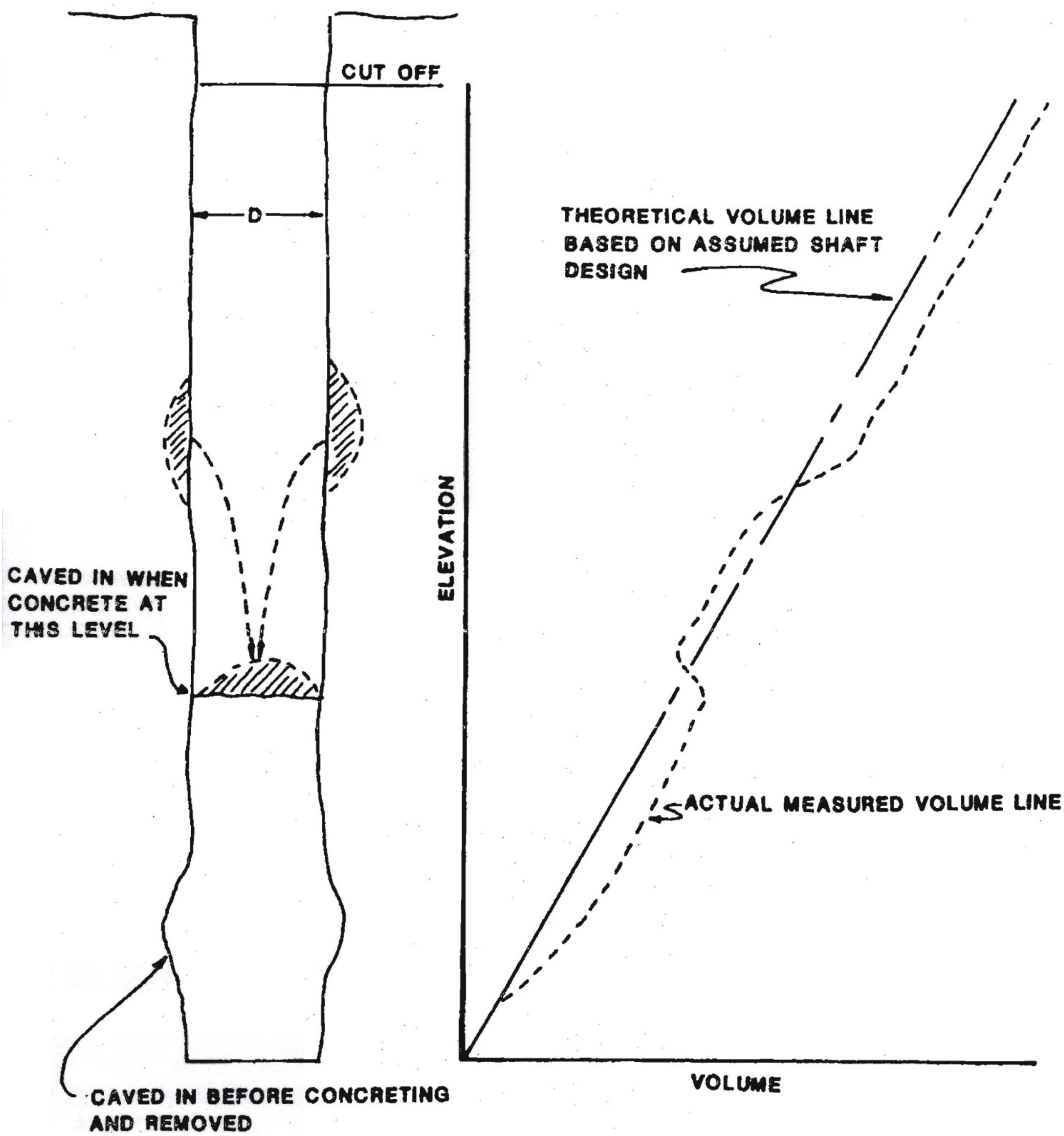


Bridge deck forming methods with precast AASHTO girders.

Drilled Shaft Diameter and Volume

Base Diameter		Volume per Foot Height	Volume per Meter Height	Base Diameter		Volume per Foot Height	Volume per Meter Height
(in)	(mm)	(yd^3)	(m^3)	(in)	(mm)	(yd^3)	(m^3)
12	300	0.029	0.071	122	3,050	3.007	7.306
14	350	0.040	0.096	124	3,100	3.106	7.548
16	400	0.052	0.126	126	3,150	3.207	7.793
18	450	0.065	0.159	128	3,200	3.310	8.042
20	500	0.081	0.196	130	3,250	3.414	8.296
22	550	0.098	0.238	132	3,300	3.520	8.553
24	600	0.116	0.283	134	3,350	3.627	8.814
26	650	0.137	0.332	136	3,400	3.736	9.079
28	700	0.158	0.385	138	3,450	3.847	9.348
30	750	0.182	0.442	140	3,500	3.959	9.621
32	800	0.207	0.503	142	3,550	4.073	9.898
34	850	0.234	0.567	144	3,600	4.189	10.179
36	900	0.262	0.636	146	3,650	4.306	10.463
38	950	0.292	0.709	148	3,700	4.425	10.752
40	1,000	0.323	0.785	150	3,750	4.545	11.045
42	1,050	0.356	0.866	152	3,800	4.667	11.341
44	1,100	0.391	0.950	154	3,850	4.791	11.642
46	1,150	0.427	1.039	156	3,900	4.916	11.946
48	1,200	0.465	1.131	158	3,950	5.043	12.254
50	1,250	0.505	1.227	160	4,000	5.171	12.566
52	1,300	0.546	1.327	162	4,050	5.301	12.882
54	1,350	0.589	1.431	164	4,100	5.433	13.203
56	1,400	0.633	1.539	166	4,150	5.566	13.527
58	1,450	0.680	1.651	168	4,200	5.701	13.854
60	1,500	0.727	1.767	170	4,250	5.838	14.186
62	1,550	0.777	1.887	172	4,300	5.976	14.522
64	1,600	0.827	2.011	174	4,350	6.116	14.862
66	1,650	0.880	2.138	176	4,400	6.257	15.205
68	1,700	0.934	2.270	178	4,450	6.400	15.553
70	1,750	0.990	2.405	180	4,500	6.545	15.904
72	1,800	1.047	2.545	182	4,550	6.691	16.260
74	1,850	1.106	2.688	184	4,600	6.839	16.619
76	1,900	1.167	2.835	186	4,650	6.989	16.982
78	1,950	1.229	2.986	188	4,700	7.140	17.349
80	2,000	1.293	3.142	190	4,750	7.292	17.721
82	2,050	1.358	3.301	192	4,800	7.447	18.096
84	2,100	1.425	3.464	194	4,850	7.603	18.475
86	2,150	1.494	3.631	196	4,900	7.760	18.857
88	2,200	1.564	3.801	198	4,950	7.919	19.244
90	2,250	1.636	3.976	200	5,000	8.080	19.635
92	2,300	1.710	4.155	202	5,050	8.243	20.030
94	2,350	1.785	4.337	204	5,100	8.407	20.428
96	2,400	1.862	4.524	206	5,150	8.572	20.831
98	2,450	1.940	4.714	208	5,200	8.740	21.237
100	2,500	2.020	4.909	210	5,250	8.908	21.648
102	2,550	2.102	5.107	212	5,300	9.079	22.062
104	2,600	2.185	5.309	214	5,350	9.251	22.480
106	2,650	2.270	5.515	216	5,400	9.425	22.902
108	2,700	2.356	5.726	218	5,450	9.600	23.328
110	2,750	2.444	5.940	220	5,500	9.777	23.758
112	2,800	2.534	6.158	222	5,550	9.956	24.192
114	2,850	2.625	6.379	224	5,600	10.136	24.630
116	2,900	2.718	6.605	226	5,650	10.318	25.072
118	2,950	2.813	6.835	228	5,700	10.501	25.518
120	3,000	2.909	7.069	230	5,750	10.686	25.967

Theoretical Versus Actual Drilled Shaft Concrete Volume



Contract Final Process

- Acronyms

  CAS, Contract Administration Section
  CASB, Construction Administration Services Bureau
  CASS, Contract Administration Section Supervisor
  CC, Certificate of Completion
  CRB, Civil Rights Bureau
  DCE, District Construction Engineer
  DEES, District Environmental Engineering Specialist
  DEO, District Engineering Officer
  FHWA, Federal Highway Administration

- Process

1. The 90% Complete Memo is submitted.
   a. The EPM emails the 90% Complete Memo to the DEO.
   b. The DEO adds their costs, saves the file to the SiteManager_Contracts share drive, and enters the key date.
2. The EPM suspends time assessment when the work is complete (just have punch list items and need to do a final inspection) and enters the Time Assessment Suspension key date.
3. Project inspections (walk-through) are completed.
   a. The contract is inspected by the EPM, DCE and contractor.
   b. The General Storm Water Permit close-out checklist is completed by the EPM and the DEES.
      - The Maintenance Superintendent, Environmental Engineering Specialist, District Biologist, Agronomist, and county or city personnel, if applicable, are invited to the inspection.
   c. The contract is re-inspected, if needed, to ensure all punch list items are complete.
   d. The EPM enters the Final Inspections key date.
4. The EPM enters the General Storm Water Permit Turnover event when the permit is transferred to Maintenance or the local government. The DEES is contacted to get this information, if needed.
5. The EPM completes the Seal Coat Inspection and enters the key date.
6. The Contractor's Substantial Work Complete form (CSB105_15_2) is completed.
   a. The contractor submits the completed form to the EPM.
   b. The EPM signs the form and enters the Substantial Work Complete Date event. Contract time is formally discontinued.
   c. The EPM sends the form to the DEO, who obtains the DCE signature.
   d. The DEO scans the form and saves it on the SiteManager_Contracts share drive as a backup.
   e. The DEO sends the original form to the CASB.

Contract Final Process

f. The CAS scans the form and saves it on the HQ SiteManager_Contracts share drive.

7. The CASB processes liquidated damages, if applicable.
   a. If the liquidated damages are not disputed, they are submitted to the Transportation Commission.
   b. If the liquidated damages are disputed, the CASB performs a final review, and submits a recommendation to the Transportation Commission.
8. The CRB generates the Final Labor Certificate and enters the Final Labor Certification key date, if applicable.
9. The Materials Bureau generates the Final Materials Certificate.
   a. Materials obtains all of the required signatures on the certificate and sends it to CAS.
   b. CAS enters the Final Materials Certification key date when it is received.
10. The project final is completed.
    a. The EPM checks the project quantities and assembles all documents external to SiteManager. They complete the surfacing history report, mileage comparison memo, and enter any plan comments (good or bad) and quantity changes not covered by a change order in the plan discrepancies window.
       - The EPM generates a progress estimate. The estimate is approved and paid if it is greater than $500.
       - The EPM enters the Final Due to District checklist event.
    b. The DEO checks the project final.
       - If corrections are required, the DEO works with the EPM to resolve them. When complete, the DEO notifies the EPM.
       - The EPM generates a progress estimate. The estimate is approved and paid if it is greater than $500.
       - The DEO enters the Final Due to Helena checklist event.
    c. The CAS checks the project final.
       - If corrections are required, the CAS works with the EPM to resolve them.
       - The CAS enters the Final Checked by CAS checklist event.
       - When everything is complete, including the final certifications, CAS notifies the EPM.
       - The EPM generates the final estimate. It is not approved at this point.
11. The Contractor's Request for Certification and Acceptance form (CSB105_15_3) is completed.
    a. The CAS sends the draft final estimate and form CSB105_15_3 to the contractor. The CAS enters the Final Due to Contract checklist event. The EPM receives an email that this information has been sent to the contractor.
    b. The contractor submits the completed form to the EPM.
    c. If there are no issues, the EPM approves the form and enters the Contractor's Final Estimate Review checklist event.
    d. The EPM scans the form and saves it on the SiteManager_Contracts share drive as a backup.

Contract Final Process

11. The CC is generated.
    a. The EPM initiates the CC and enters the Issuance of CC checklist event. The EPM scans the form and saves it on the SiteManager_Contracts share drive as a backup.
    b. The EPM sends the CC and the original form CSB105_15_3 to the DEO.
    c. The DEO collects the District signatures on the CC.
    d. The DEO sends the CC and the original form CSB105_15_3 to the CASB.
    e. The CAS collects the headquarters signatures on the CC and enters the Contractor Final Release critical date.
    f. The CAS scans the CC and form CSB105_15_3 and saves them on the HQ SiteManager_Contracts share drive.
12. The CAS sends the final estimate to Accounting and the contractor is paid.
13. The CASB submits completed CCs to the Transportation Commission. They give final acceptance at their next meeting. When accepted, the CASS enters the Accepted Date critical date.
14. If the contract is full-oversight, FHWA issues a federal concurrence. CAS enters the Federal Concurrence key dates.
15. The contract is closed to Accounting. CAS enters the Close to Accounting checklist event.
16. The CASS enters the Physical Work Complete Date critical date when everything is complete.
17. CAS zips the Helena and district SiteManager_Contracts share drives and loads them onto DMS. Any videos are deleted before the drives are zipped.

Contract Final Process

- Events and Key Dates in flowchart

Time Assessment Suspension – EPM
Site work is completed and time is suspended until the final inspection is scheduled.

Final Inspections – EPM
Final inspections are complete for site work and General Storm Water Permit transfer.

General Storm Water Permit Turnover – EPM
General Storm Water Permit is transferred to Maintenance or county.

Surfacing History Report – EPM
Surfacing history report is submitted to the Materials Bureau.

Mileage Comparison – EPM
Mileage comparison is submitted to the Materials Bureau.

Final Due to District – EPM
Contract final is submitted to the district.

Final Due to Helena – DEO
Contract final is submitted to Helena.

Final Checked by CAS – CAS
Contract final is checked in Helena.

Seal & Cover Inspection – EPM
Seal coat is inspected upon the warranty expiration.

Substantial Work Complete Date – EPM
Contract specific warranties are complete and the contractor has submitted form CSB105_15_2.

Final Labor Certification – CRB
Final labor certificate is complete.

Final Materials Certification – CAS
Final materials certificate is complete and received by CAS.

Final Due to Contractor – CAS
Final estimate (unprocessed) is sent to the contractor with a blank form CSB105_15_3.

Contract Final Process

Contractor's Final Estimate Review – EPM

Contractor has returned a completed form CSB105_15_3.

Issuance of CC – EPM

Certificate of Completion is generated and sent to the district.

Contractor Final Release Date – CAS

All signatures have been obtained on the Certificate of Completion.

Final Estimate Released – CAS

Final estimate is sent to Accounting and the contractor is paid.

Accepted Date – CASS

Certificate of Completion is accepted by the Commission at the next available meeting.

Close to Accounting – CAS

Closing request has been sent to Accounting.

Federal Concurrence Requested – CAS

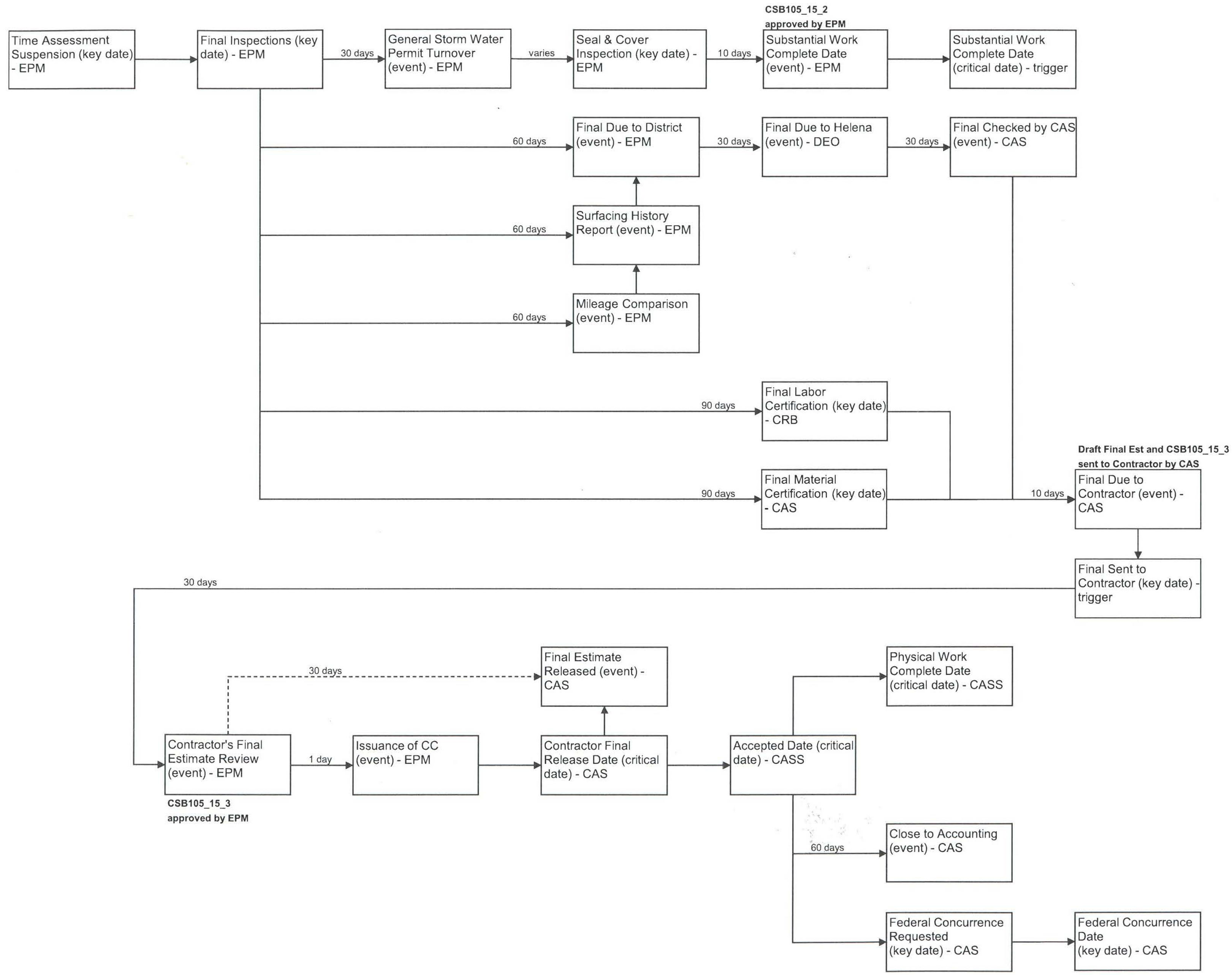
Final information is sent to FHWA for concurrence (only on full oversight contracts).

Federal Concurrence Date – CAS

Final concurrent is received from FHWA (only on full oversight contracts).

Physical Work Complete Date – CASS

Everything is complete and the contract is locked down.



Rev: September 2011

Mass Diagrams

Unclassified excavation grading shown using a mass diagram to illustrate earthwork quantity distribution and movement throughout the project. Mass diagrams represent net cumulative negative or positive excavation volumes along project stationing.

Designers develop mass diagrams after preliminary alignment and grades are established, and apply approximate shrink/swell factors to earthwork volumes. Shrink and swell factors are determined using soil type characteristics, foundation consolidation observations, volume changes during grading and haul, and past construction data. Special borrow is typically not included in mass diagrams.

Mass Diagram Terminology

Horizontal Axis
The horizontal axis is stationing distance along centerline.

Vertical Axis
The vertical axis is cumulative earthwork volume at any given point along project length.

Unadjusted Volume
The unadjusted volume is the excavation and/or embankment volume prior to shrink or swell factor application. Volumes are calculated between two cross sections by measuring cut and/or fill at each cross section (the area between the existing ground surface and the proposed subgrade), and multiplying the area(s) by the distance between the two sections and dividing by two. This calculation method is known as the average end area calculation.

Shrink/Swell Factor
Most in place undisturbed soils are below or above optimum moisture and not at optimum density. Excavating the material, hauling to a final location, depositing at a new location, and compacting at optimum moisture to optimum density all cause final compacted material volumes to differ from original unit volumes. The ratio of this volume difference is the shrink or swell factor.

Most soils shrink since they are below optimum density in their undisturbed state. Rock tends to swell. Shrink and swell factors are estimated for a project based on known soils information and information from nearby construction projects. Since these factors are not highly accurate until project completion, average shrink or swell factors are selected for new projects based upon soils information and past experience.

Adjusted Volume
The adjusted volume is the unadjusted volume of excavation and/or embankment between cross sections multiplied by the shrink or swell factor.
The mass diagram is constructed using adjusted volumes.

Mass Ordinate
The mass ordinate is cumulative excavation and embankment volume at a given station. At each cross section, excavation and embankment volumes are added or subtracted to the previous mass ordinate volume to generate the volume quantity at that station. This point is plotted using the horizontal and vertical axes. Projects always start with a mass ordinate of zero.

Mass Line
The mass line created by connecting points representing excavation volumes along the mass ordinate.

Positive Mass
Mass lines sloping upward represent increasing excavation volumes along stationing. If the last mass ordinate for the project is a positive volume, more excavation than necessary is available to construct embankment.

Negative Mass
If mass diagram lines slope downward, less excavation is available along stationing than is needed for project embankment. If the last mass ordinate is a negative volume, the project has more new embankment than excavation, and shortfalls must be accounted for by “borrowing” fill from outside project limits.

Balance Line
The horizontal axis is also known as the balance line and represents cumulative mass volumes of zero.

Balance Point and Intermediate Project Balance
Project balances occur when excavation equals embankment. Balance points occur where the mass line crosses the balance line. This means excavation volume equals embankment volume between two adjacent balance point locations.

Balanced Project
Balanced projects have a zero excavation balance at project completion, although a mass ordinate of exactly zero is unlikely. Balancing projects as closely as possible is desirable. Even a rough balance indicates the project can be constructed almost entirely within the project limits with limited excess excavation or borrow. The last mass ordinate point indicates project waste or borrow.

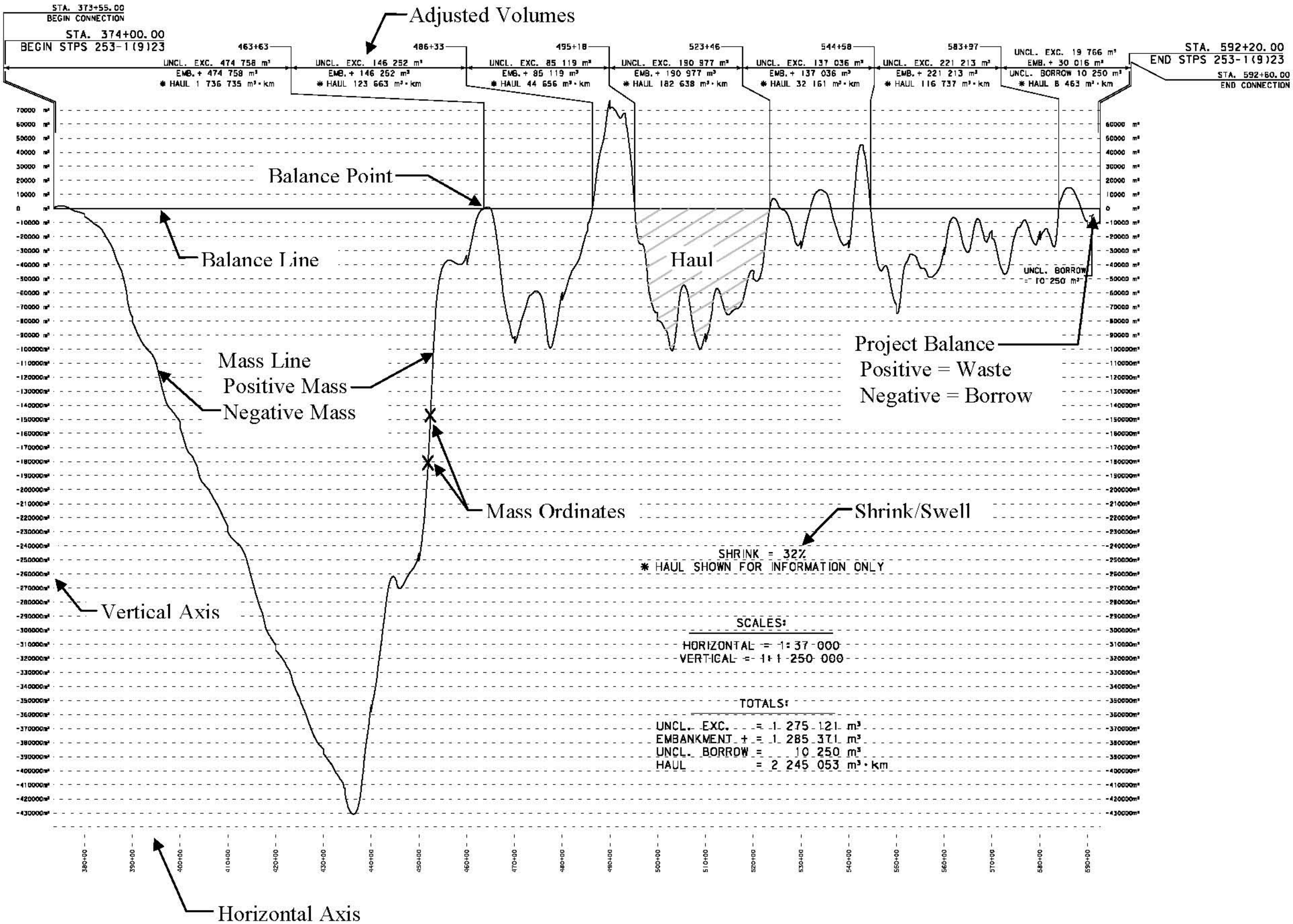
Haul

"Haul" is the material volume multiplied by the distance it must moved. It is calculated for each intermediate project balance by measuring the area on the mass diagram between the mass line and the horizontal axis. The unit of measure for haul is yd^3 • mile.

Mass diagrams are used to assess:

- Grading operation sequence and limits.
- Net borrow and waste earthwork volumes.
- Haul direction and distance. A mass line above the balance line represents a haul direction ahead on stationing. A mass line below the balance line represents a haul direction back on stationing. Economical haul distances are typically those less than a mile, or two miles between balance points.

Contractors use mass diagrams to estimate earthwork item bid prices, locate waste and borrow areas, evaluate traffic control, and schedule grading operations. Contractors do not have to base construction upon Departmental mass diagrams. Often, the assumption the first mass ordinate is zero does not apply. If contractors choose to borrow or waste material at project beginning, cumulative volumes along stationing do not match diagrams in which the first mass balance point is zero.



STA. 373+55.00
BEGIN CONNECTION
STA. 374+00.00
BEGIN STPS 253-1(9)23
Adjusted Volumes
463+63
UNCL. EXC. 474 758 m³
EMB.+ 474 758 m³
* HAUL 1 736 735 m³·km
486+33
UNCL. EXC. 146 252 m³
EMB.+ 146 252 m³
* HAUL 123 663 m³·km
495+18
UNCL. EXC. 85 119 m³
EMB.+ 85 119 m³
* HAUL 44 656 m³·km
523+46
UNCL. EXC. 190 977 m³
EMB.+ 190 977 m³
* HAUL 182 638 m³·km
544+58
UNCL. EXC. 137 036 m³
EMB.+ 137 036 m³
* HAUL 32 161 m³·km
583+97
UNCL. EXC. 221 213 m³
EMB.+ 221 213 m³
* HAUL 116 737 m³·km
UNCL. EXC. 19 766 m³
EMB.+ 30 016 m³
UNCL. BORROW 10 250 m³
* HAUL 8 463 m³·km
STA. 592+20.00
END STPS 253-1(9)23
STA. 592+60.00
END CONNECTION
Balance Point
Balance Line
Haul
UNCL. BORROW
= 10 250 m³
Mass Line
Positive Mass
Negative Mass
Project Balance
Positive = Waste
Negative = Borrow
Mass Ordinates
Shrink/Swell
SHRINK = 32%
* HAUL SHOWN FOR INFORMATION ONLY
Vertical Axis
SCALES:
HORIZONTAL = 1:37 000
VERTICAL = 1:1 250 000
TOTALS:
UNCL. EXC. = 1 275 121 m³
EMBANKMENT + = 1 285 371 m³
UNCL. BORROW = 10 250 m³
HAUL = 2 245 053 m³·km
Horizontal Axis

Steel Girder Structure Grading

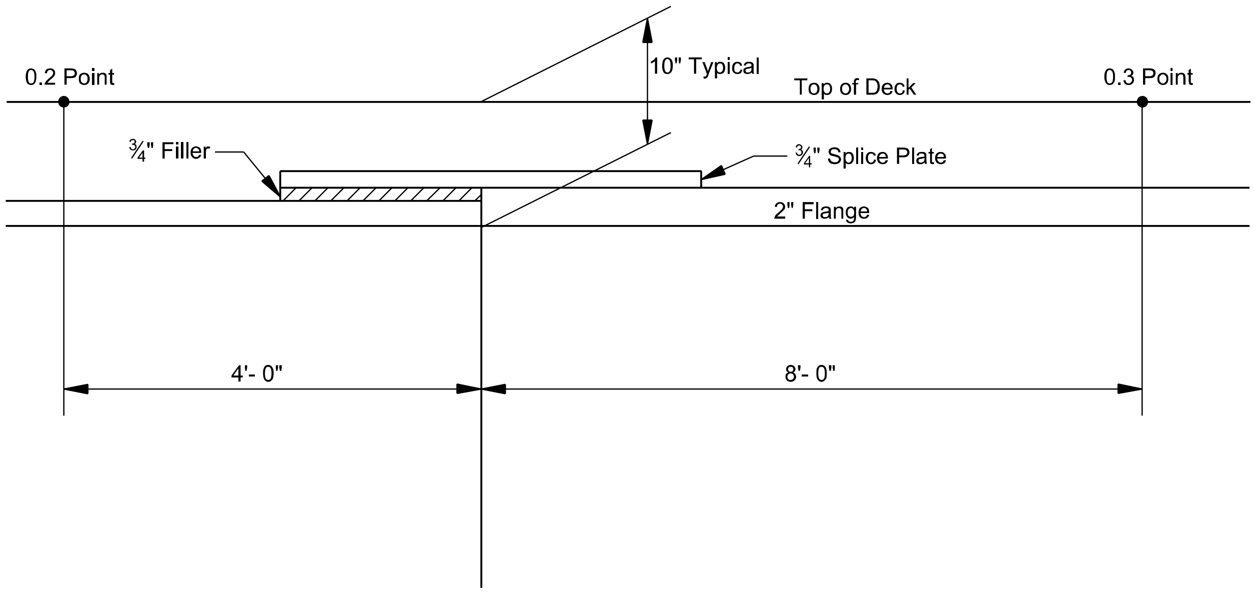
Most steel girder bridges are designed with welded plate girders instead of rolled beams. Typical practice is to cut the web plate along a curve conforming to the dead load (D.L.) deflection and any vertical curve offset. This eliminates the unsightly appearance of a sag in the bottom flange. Cutting the web plate affects deck form grades. If girders are fabricated perfectly and the substructure is built exactly to plan grade, the haunch will vary only if slab thickness changes. This means the slab top should be a constant distance from the top flange bottom. However, tolerances allowed in fabrication and construction almost eliminate the chance of in-place girders at exact plan elevation. Deck forms must account for deviations from plan grade, or slab thickness will vary. Thin decks reduce reinforcing steel cover, whereas thick decks add dead load. For these reasons, the actual elevation of in-place girders must be determined.

The actual elevations of in-place girders are controlled by elevation at bent or pier elevations, and field splice elevations. Grading field splices is therefore the first step in establishing deck form grades.

Grading Field Splices

Contract documents include a “Steel Erection Plan” special provision, requiring Contractors to submit an erection plan, which must include handling field splices during assembly.

The first step is field splice grade calculation. To do this, know the planned top of deck or top of web elevation, total dead load deflection, vertical curve offset, and dead load deflection due to girder weight alone. Calculate deck top elevation in the usual manner or interpolate from tenth-point elevations given by contract documents. Deadload deflections are given for tenth points. For other points on simple spans, estimate deflection by using the deflection at the 0.5 tenth point and the square of the distance from splice to bearing, divided by span length squared. Plans sometimes list deadload deflection due to girder weight alone, and list corresponding girder and deadload weight. Girder deflection alone is proportional to positional deadload weights. The following figure illustrates a typical field splice grade calculation for which the girder web is cut at a cambered location.



Given in Plans:

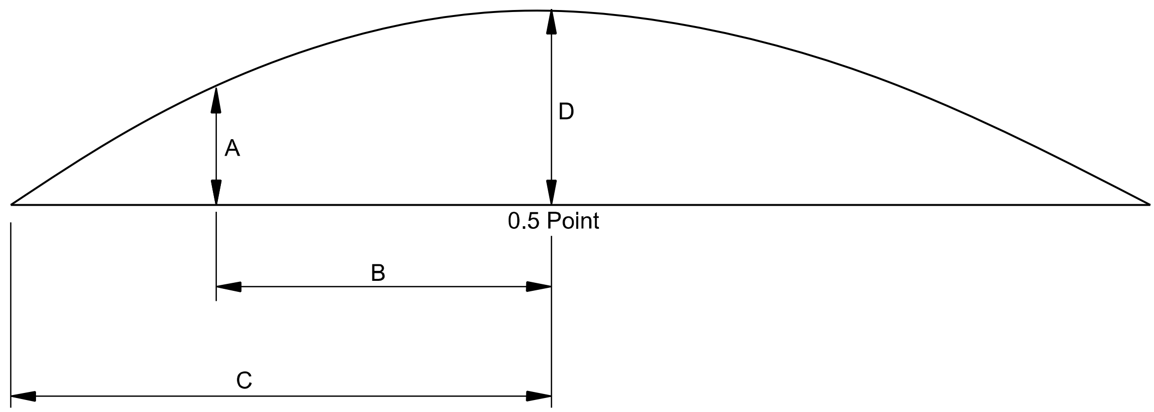
Finished grade at 0.2 Point = 5212.10

Finished grade at 0.3 Point = 5212.13

By Interpolation

Finished grade at splice $5212.10 + 0.03 \times \left(\frac{4}{12}\right) = 5212.11$

Typical Field Splice Grade Calculation



$$A = D - D\frac{B^2}{C^2}$$

where: A = deflection at splice

B = distance from splice to midspan

C = ½ span length

From Plans: B = 32′

C = 60′

D (girder alone) = 1″ = 0.0833′

D (total) = 3″ = 0.2500′

$$A \text{ (girder alone)} = 0.0833 - 0.0833 \times \frac{32^2}{60^2} = 0.0596'$$

$$A \text{ (total deflection)} = 0.2500 - 0.2500 \times \frac{32^2}{60^2} = 0.1789'$$

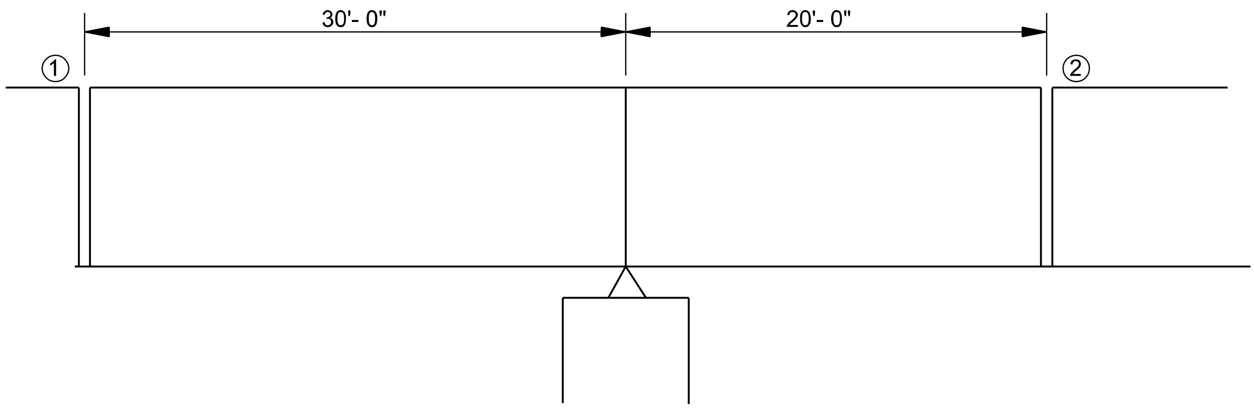
Field Splice Grade Calculation (continued)

Deadload deflection for continuous span splices are estimated by interpolating using adjacent tenth points.

		top splice grade calculation
finished grade at top deck	=	5212.11
– 10″		– 0.8333
finished grade at web top	=	5211.2767
+ total deadload deflection		0.1789
		5211.4556
– deflection girder alone		– 0.0596
plan elevation top web of erected girder	=	5211.3960
+ flange plate (2″)	=	+ 0.1667
+ splice plate (¾″)	=	+ 0.0625
plan top splice grade	=	+5211.6252

Typical Field Splice Grade Calculation (continued)

Intermediate supports must also be considered when adjusting field splice grade. When one girder end is raised, the other drops, so it may not be possible to adjust splices at each end to plan grade. If grade at one end is above or below plan when the opposite end is correct elevation, the section will need balancing. An example follows:



plan grade @ ① = 5126.12

plan grade @ ② = 5126.30

difference = 0.18′

① set @ plan elevation 5126.12

elevation from shot at ② 5126.36

plan elevation @② <u>5126.30</u>

② is 0.06 high

raising ① will lower ②.

calculate amount of raise = $0.06 \times \left(\frac{30}{50}\right) = 0.036$

② will lower $0.06 \times \left(\frac{20}{50}\right) = 0.024$

new grade @① = 5126.12 + 0.036 = 5126.156 difference = 0.18′

new grade @② = 5126.36 – 0.024 = 5126.336

The girder section is now balanced with each end 0.036′ above plan grade. The correction to this girder is larger than those typically found in the field.

Splice Adjustment for Continuous Girders, Deck Forms and Deck Top Grades

Each girder profile must be determined after splices are graded and tightened. Shoot each tenth point elevation to the nearest 0.01 ft, as done for prestressed beams. Inspectors typically calculate absolute slab form bottom elevations, and check these elevations during installation. Contractors typically profile beams and perform cut and fill calculations.

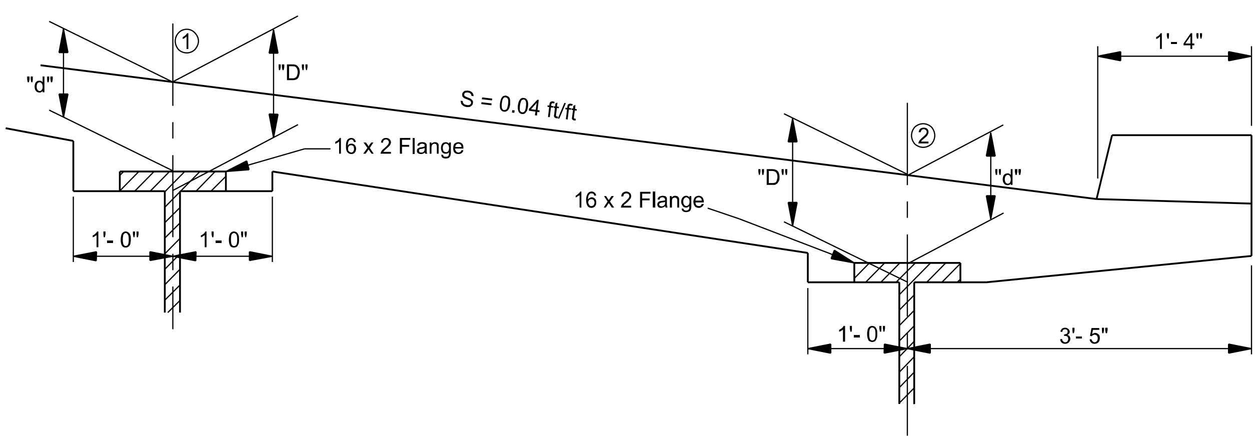
Observe safety regulations. If possible, record elevations on a cloudy afternoon or other time when girder temperature is uniform. Large temperature differences between top and bottom flanges when girder bottom is shaded may cause upward girder deflection or a deck sag.

Girder load conditions must be known when tenth-point elevations are shot to estimate girder deflection. Shoot elevations before form placement, as deflection due to the girder alone is given on the plans. Alternatively, estimate deflection by multiplying deadload by the proportion of form weight to concrete weight. Ideally, collect tenth point elevations before slab form construction.

“D” Depth Method

Although several methods are available to compute grade, the “D” Depth Method is best for steel girder bridge deck form and screed grade computation.

Example:



total D.L. deflection = 1-7/8″

D.L. deflection of steel = <u>3/8″</u>

D.L. deflection of concrete = 1 -1/2″

plan grade @ ① = 3944.16

plan grade @ ② = 3942.80

(10″ – 2″) concrete D.L.
↓ ↓
plan top girder as erected @ ① = 3944.16 – 0.6667 + 0.1250 = 3943.6183

(10″ – 2″) Conc. D.L.
↓ ↓
plan top girder as erected @ ② = 3942.80 – 0.6667 + 0.1250 = 3942.2583

shot @ ① = 43.64

shot @ ② = 42.22

Computing Deck Form and Screed Grades Via "D" Depth Method:

43.64 – 43.6183 = 0.0217 (girder @ ① is high)

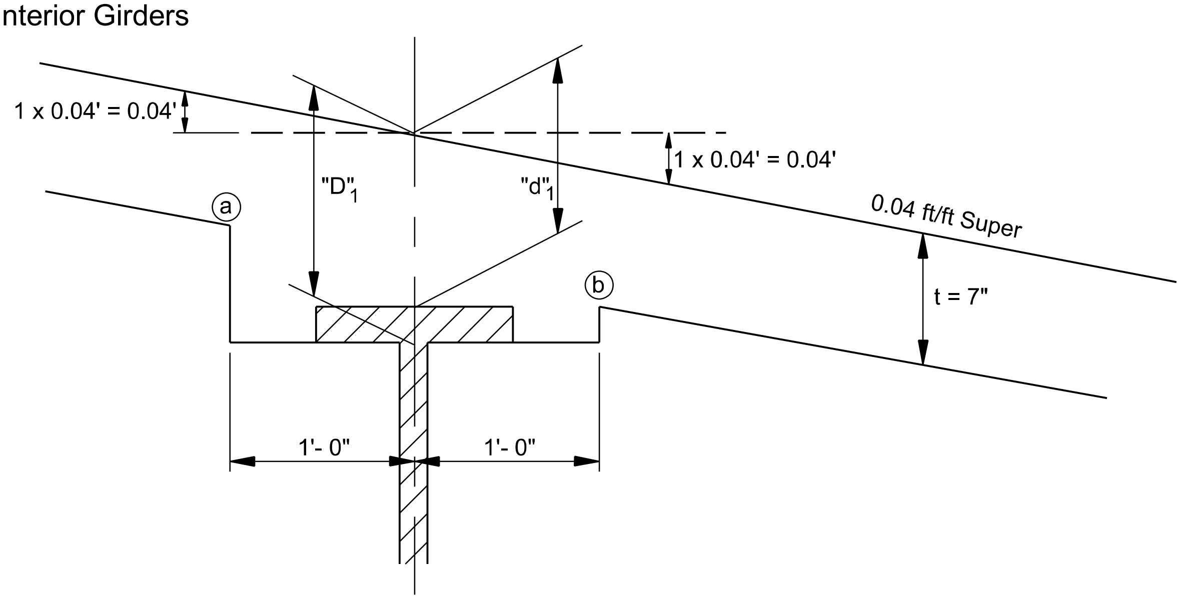
so new "D_1" = 0.8333 – 0.0217 = 0.8183′

42.2583 – 42.22 = 0.0383 (girder at ② is low)

so new "D_2" = 0.8333 + 0.0383 = 0.8716′

Deck Form Grades

Interior Girders



"d_1" = D_1 – 0.1667 = 0.8183 – 0.1667 = 0.6516

○

top deck @ a = 0.6516 + 1.00 × 0.04 = 0.6916

less t = 7″ = – 0.5833

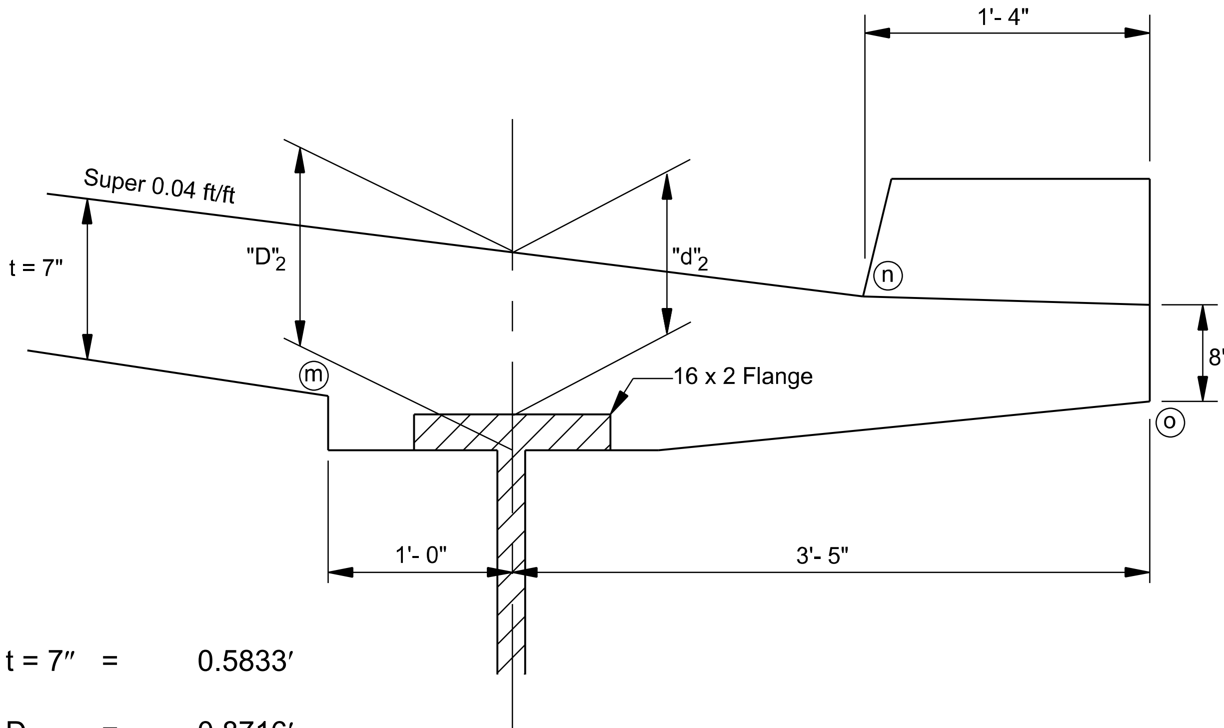
Fill to (a) = 0.1083 = 1-5/16″

top deck @ (b) = 0.6516 – 1.00 × 0.04 = 0.6116

less t = 7″ = – 0.5833

Fill to (b) = 0.0283 = 5/16″

Cut and fill depth is calculated relative to girder top.



t = 7″ = 0.5833′

D_2 = 0.8716′

d_2 = 0.8716 – 0.1667 = 0.7049′

(m) = 0.7049 + 1.00 × 0.04 – 0.5833 = 0.1616′ or fill 1-15/16″

(n) = 0.7049 – 0.04 × 2.0833 = 0.6216′ or fill 7-7/16″

(o) = (n) – 8″ = 0.6216 – 0.6667 = -0.0451 or cut 9/16″

Deck Form and Screed Grade Computation Using the "D" Depth Method (Continued)

Special Situations
Check absolute form elevation after forms and reinforcing bars have been placed, and necessary form adjustments have been made.

Deflection along a continuous span is influenced by load position and magnitude anywhere on the girder. Continuous girder deflections are usually computed for selected load conditions. Load deflections over a partially formed deck are not useful. Girder deflection must be known to set form grades. Therefore, if continuous girder tenth-points are shot with forms or forms and rebar in place, they must be totally in place over continuous spans, meaning forms cannot be adjusted to grade during installation. Forms should be adjusted to grade after initially installed and tenth-point elevations are established.

Dead load deflection due to forms, rebar etc. are proportional to total plan deadload deflection:

Example:

total deadload deflection	=	2-9/16″
structural steel deadload deflection	=	– 3/8″
concrete and rebar deadload deflection	=	2-3/16″
total deadload (plans)	=	1994 lb/ft of girder
structural steel deadload	=	– 351 lb/ft of girder
concrete and rebar deadload	=	1643 lb/ft of girder

forms and rebar in place

form weight (calculate from form system member)	=	75 lb/ft of girder
rebar weight (from erection plan)	=	+ 150 lb/ft of girder
		225 lb/ft

concrete and rebar deadload deflection = 2-3/16

– form and rebar deadload deflection $\left(\frac{225}{1643}\right) \times 2-3/16$ = – 5/16

deadload deflection to be used in 10th point calculation = 1-7/8

Establishing tenth-point elevations along continuous spans before deck forming operations is a simple and quick method for engineer and contractor. Other methods may warrant a meeting to evaluate expected grade and form complications.

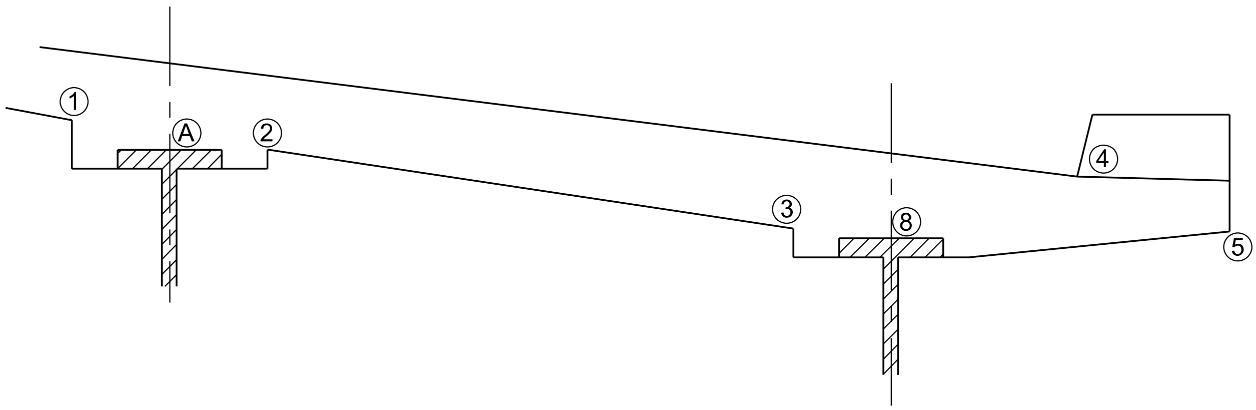
Contract documents show typical distances from web top to deck top. The depth from girder top to deck top, deadload deflection or camber diagrams can provide deck slab elevations.

Form Grade Point Elevation Method

Cut or fill from tenth-points to forms is calculated using deck grade elevations rather than "d" depths.

Calculation time can be saved by using the ADP Bridge Elevation Program to compute grade. This program cannot be used on curved girder bridges, or if non-standard superelevation transitions and run-offs are used.

After form cut and fill distances have been calculated, include them in a sketch and share this information with the contractor for deck forming, and retain a copy for inspection usage (page D-63).



total deflection = 2½″

structural steel deflection = – ½″

concrete deadload deflection = 2″

Calc. Finish Gr. Elev.	+ Conc. D.L. Defl.	Form Gr.
① 2241.6650	0.1667	2241.8317
② 2241.6250	0.1667	2241.7917
③ 2241.3950	0.1667	2241.5617
④ 2242.0842	0.1667	2241.2509
⑤ 2241.3342	0.1667	2242.5009

shot @ Ⓐ Elev: 2241.66

shot @ Ⓑ Elev: 2241.43

from girder Ⓐ:

Fill: 0.1717′ or 2-1/16″ to ①

0.1317′ or 1-9/16″ to ②

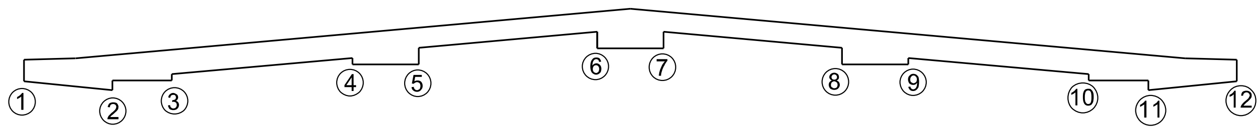
from girder Ⓑ:

fill: 0.1317′ or 1-9/16″ to ③

fill: 0. 8209′ or 9-7/8″ to ④

fill: 0.0709′ or 7/8″ to ⑤

Form Grade Point Elevation Method



AHEAD-ON-LINE

Beam Tenth Point	Deck Form Points											
	①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩	⑪	⑫
0 1 Brg. Br. 1	F 3/4	C 1/2	F 1-1/4	F 7/8	F 1-1/8	F 1-3/8	F 1-1/4	F 1	F 1-1/8	C 3/4	C 3/8	F 5/8
0.1	F 1/2	C 3/8	F 1-1/8	F 3/4	F 1	F 1-1/8	F 1-1/8	F 1	F 3/4	F 1	C 1/2	F 1/2
0.2												
0.3												

Continue for remaining tenth points

Deck Form Grades
Span 1, E.B.

Prestressed Girder Span Grades

Form and rail grade calculation along prestressed girder spans are very similar to those discussed in previous steel span subsections. Prestressed girder structures may be designed as simple spans, meaning loads along other spans don't influence the simple span. Tenth-point elevations can simply be shot and computed for individual spans. Without splices, grade calculation is unnecessary.

Finishing Machine Rail Grades

Longitudinal rails guiding the finishing machine are supported by the overhang or even exterior girders, and therefore subject to deadload vertical deflection. Allowance for this deflection must be made to set rail grades.

Finishing machine rail grades must correspond to previously established girder tenth-point elevations. How this is done is up to the contractor. Inspectors then check absolute form elevations after installation. The preferred method uses girder tenth points as benchmarks to establish rail grades, which should not be set from bridge benchmarks unless girder tenth points are checked to ensure tenth point and rail elevations are correctly related.

The "tenth-point offset method" to set finishing machine rail grades is preferred. The main advantage is that offset established for known loading and deflection conditions will not change under other loading conditions, so deadload deflection due to concrete and finishing machine does not need to be estimated. Finish machine rail offsets are calculated in a manner similar to that used for form grades using the "D" depth (preferable) or grade point elevation method.

CONCRETE MIX VERIFICATION/WATER

REFERENCE: SUBSECTION 551.B.7 of this *MANUAL*

WATER/CEMENT (W/C) VERIFICATION PROCESS for CONCRETE with CEMENT ONLY (i.e., NO FLYASH or SILICA FUME):

1. Obtain a copy of the Contractor's "Concrete Mix Design Certificate" (see next sheet).
2. Locate the "Actual Water/Cementitious Ratio" on the Certificate.
3. Compare batch ticket with the Certificate. (see second sheet following this one).

WATER/CEMENTITIOUS (W/C) RATIO DATA FROM BATCH TICKET:

1. Determine actual amount of water batched (based on example batch ticket data):

Actual Water Batched:	154.0 gallons
Free Moisture in ¾" Cr.:	12.0 gallons
Free Moisture in 3/8" M/R:	11.04 gallons
Free Moisture in Sand:	45.06 gallons
Actual Water:	222.10 gallons (Use 222.1)

2. CALCULATIONS:

Design Water:	225.0 gallons
Actual Water:	222.1 gallons
Water Allowed to be Added:	2.9 gallons***** (see TO ADD quantity on batch ticket)

*****Quantity of water that can be added manually @ point of delivery. If added manually, a slash should be made through the quantity and initialed by the Inspector.

Therefore, 225.0 gallons x 8.345 lb./gal. (unit wt. of water) = **1,877.63** lb.

Quantity of cement batched: **5,500** lb.

WATER/CEMENT RATIO: **1,877.63/5,500.00** = **.341** (indicated on the WATER/CEMENT portion of batch ticket).

NOTE: Many times, the batch ticket DESIGN W/C number is lower than the approved mix design number. In this example, the actual w/c ratio was below the approved mix design w/c ratio of .3443, thus, making the mix acceptable. The Inspector needs to compare their calculated w/c ratio to the approved mix design, as there may be some leeway before the Contractor exceeds their approved w/c limit.

Helena Sand & Gravel
Concrete Mix Design Certificate

Client:	Cretex West Precast Plant		Date:	3/3/11	
Project:	MDT Precast Bridge Beams		Design Slump:	8½"	
Mix Design Number:	333331		Air Content:	1.6%	
Mix Description:			Actual Water/Cementitious Ratio:	0.3443	S.G.
Design Strength:	7000	PSI	Cement / Type:	I & II	3.15
Cementitious Content:	7.85	Sack	% Class "C"Fly Ash:	0%	2.75
Maximum Water/Cement			Silica Fume	0%	2.15
			Unit Weight	152.1	P.C.F.

		Aggregate Type & Size			Bulk Specific Gravity	Percent By Volume	
Gravel	55.00%	# 57	1 1/2" To 3/4"		2.700	0.0%	
		# 67	3/4" To #4		2.690	55.00%	
		# 8	3/8" To #8		2.660	0.00%	F.M.
Sand	45.00%	ASTM Concrete Sand (Coarse)		100.00%	2.633	45.00%	3.1
		ASTM Concrete Sand (Fine)		0.00%	2.614	0.00%	3.2
					Sum:	100%	

	Material	Description			Volume		SSD Weights	
	Water:	30.5	Gallons		4.07	CF	254	Lbs
	Cement:	7.85	Sack		3.75	CF	738	Lbs
	Fly Ash:	0.00	Sack		0.00	CF	0	Lbs
	Silica Fume	0.00	Sack		0.00	CF	0	Lbs
	Air Content:	2%			0.43	CF		
	Gravel:	# 57	1 1/2" To 3/4"		0.00	CF	0	Lbs
		# 67	3/4" To #4		10.31	CF	1730	Lbs
		# 8	3/8" To #8	Sand Total	0.00	CF	0	Lbs
	Sand:	ASTM Concrete Sand (Coarse)		8.43	8.43	CF	1386	Lbs
		ASTM Concrete Sand (Fine)			0.00	CF	0	Lbs
Admixtures:	Micro Air:	0.00	Oz./ 100 Wgt				0.0	Oz / CY
	Delvo:	0.0	Oz./ 100 Wgt				0.0	Oz / CY
	Poly 1025:	8.0	Oz./ 100 Wgt				59.0	Oz / CY
	Glenium 3030:	14.0	Oz./ 100 Wgt				103.3	Oz / CY
	VMA 362	0.0	Oz./ 100 Wgt				0.0	Oz / CY
	NC 534	0.0	Oz./ 100 Wgt				0.0	Oz / CY
			TOTAL:		27.0		4108.0	Lbs / CY

Remarks:

2 C COPY

HELENA
SAND & GRAVEL
PO Box 5960
Helena, Montana 59604
Office: (406) 442-1185
Fax: (406) 442-1105
Dispatch: (406) 227-8585

#1

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CONSTRUCTION & READY MIX
759 Highway 93 North
Hamilton, Montana 59840
Office: (406) 961-4719
Fax: (406) 961-4857
Dispatch: (406) 363-7230

C069677

READY-MIX CONCRETE ■ ASPHALT PAVING ■ SAND & GRAVEL ■ CRUSHED ROCK

LIMITED WARRANTY
The only liability of **SELLER** for product defect is the return of the purchase price. In no event shall **SELLER** be liable for any direct, indirect, incidental or consequential damages resulting from the use of the products or arising out of breach of any warranty. All claims for damages or shortages must be made within 24 hours of delivery. We do not assume responsibility for any damage beyond the curb line.

Warning: Injuries to eyes. Causes skin irritation. Contains Portland Cement.
Read the following warning before using:
Contact with wet unhardened concrete, mortar, cement or cement mixtures can cause skin irritation, severe chemical burns or serious eye damage. Avoid contact with eyes and skin. Wear waterproof gloves, a fully-buttoned, long-sleeve shirt, full-length trousers and tight fitting eye protection when working with these materials. If you have to stand in wet concrete, use waterproof boots that are tight at the top and high enough to keep concrete from flowing into them. If finishing concrete, wear knee pads to protect knees. After contact with any of these materials, wash off immediately with fresh, clean water. Indirect contact through clothing is as dangerous so promptly rinse these materials from clothing. Seek immediate medical attention if you have persistent or severe discomfort. In case of eye contact, flush with plenty of water for at least 15 minutes. Consult physician immediately. **KEEP OUT OF REACH OF CHILDREN! USER AGREES TO CONVEY THIS WARNING TO ALL PERSONS WHO MAY USE OR COME INTO CONTACT WITH WET (UNHARDENED) CONCRETE, MORTAR, CEMENT OR CEMENT MIXTURES.**

Warning: Hot Asphalt emits nuisance fumes. Avoid breathing fumes. Also, Asphalt may cause severe burns. Wear Protective safety gear (long sleeves, pants and gloves). If burned, cool with water and see a physician.

Warning: Prolonged inhalations of **dust** from this gravel product may be hazardous to your health. Measures to control fugitive dust should be taken when handling this product.

WATER ADDED AT CUSTOMER'S OWN RISK

ADDITIONAL WATER ADDED TO THIS CONCRETE WILL REDUCE ITS STRENGTH
Buyer's agent agrees to accept responsibility for reduced strength due to water added above design.

Arrived at job with ____________ inch slump.
Added ________ gal water at customer request.
Other additions ____________________
☐ Test cylinders taken

RECEIVED BY X ____________________
Buyer's Agent receipt of concrete and approval of any added items.

LEAVE PLANT	ARRIVE JOB SITE	START DISCHARGE	FINISH DISCHARGE	LEAVE JOB SITE	ARRIVE PLANT
1:19	:	:	:	:	:

DRIVER'S COMMENTS

Order No.	Cust. No.	Seller or Customer Job #	Customer PO/Phase Code	TICKET NO.	Driver	Project No.
8010	10530	NEWSHOP		0182673	27117	NEWSHOP

Customer: Cretex Concrete Products West In
Delivery Address:
Date: 11/11/11
Delivery Instructions: NEW SHOP BY CITY COUNTY SANITATIRESET DRUM COUNTERS
Map / Zone
13:31

Load Qty	Delivered Qty	Order Qty	Product Code	UOM	Product Description	Unit Price	Amount
7.50	49.50	49.50	333331		Cretex 7000 PSI	0.00	0.00
1.00	49.50	1.00	491442		DELVO (RETARDER)	0.00	0.00
7.50			467756		ENERGY CHG CON	0.00	0.00

SLUMP TEST ____ TEMP 65° PLANT 81

TRUCK	USER LOGIN	DISP TICKET NUM	TICKET NUM	TICKET ID	TIME	DATE
0735	BRYAN	0182673	75017	81056	13:03	11/11/2011

LOAD SIZE / MIX CODE / SEQ / LOAD ID

Load Size | Mix No. | Mix Description | Slump | Type | CC | Use | Truck | Plant | Sales Tax
TOTAL DUE

MATERIAL	DESIGN QTY	REQUIRED	BATCHED	VAR	% VAR	MOISTURE	ACTUAL WAT
3/4CR	1030 lb	7825 lb	7800	-25	-.32%	1.30 M	12.00 gl
3/8W/R	610 lb	4728 lb	4700	-28	-.59%	2.00 M	11.04 gl
CSAND	1400 LB	10878 LB	10820	-58	-.53%	3.60 M	45.06 gl
AGI-II	730 lb	5535 lb	5500	-35	-.63%		
MRWR	11 /C	609 oz	606	-3	-.49%		
DELVO	5.00 /C	0276.75 oz	275.00	-1.75	-.63%		
WATER	30.0 gl	154.4 gl	154.0	-0.4	-.26%		154.00 gl

NON-SIMULATED NUM BATCHES: 1
LOAD TOTAL: 30163 lb DESIGN W/C: 0.339 WATER/CEMENT: 0.341T DESIGN WATER: 225.0 gl ACTUAL WATER: 222.1 gl TO ADD: ~~2.9 gl~~ 0
SLUMP: 4.00 " WATER IN TRUCK: 0.0 gl ADJUST WATER: 0.0 gl /load TRIM WATER: 0.0 gl /yd