Part 650 – Engineering Field Handbook

Chapter 16 – Soil Bioengineering for Streambank and Shoreline Protection

MO650.1600 Riprap Size for Channel Lining

A. The curves in Section MO650.1600.C give the stable riprap gradation for any specific design velocity from 2 to 20 feet per second (fps). The curves should be read to the nearest full inch for stones of three (3) inches or larger and to the nearest one-half (1/2) inch for stones under three (3) inches. (Times New Roman 11-point font, flush left)

B. Gradation limits should be set which would permit variation from the average sizes determined rom the curves. The gradation limits are as follows:

Curve	Percent Passing
d ₁₀₀	90 - 100
d ₇₅	60 - 80
d ₅₀	35 - 55
d ₂₅	10 - 30

B. Two design approaches may be followed.

- Only one gradation of riprap available: determine the d₅₀ size of the material. Determine safe design velocity from the riprap curves in MO650.1600.C. Design channel within this limit. (Times New Roman 11-point font, flush left, hanging indent)
- (2) Several gradations of riprap available: Several trials will be needed for different d_{50} sizes to determine the most economical design.

B. Riprap Size for Channel Lining Curves



MO210-650-H, 1st Ed., Apr 2021



MO650.1601 Manning's "n" for Riprap Lined Channels



MO210-650-H, 1st Ed., Apr 2021

MO650.1602 Riprap Lined Channel Design Tables

Riprap Lin	ed Channel
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Bottom	d ₅₀	= 2"	d ₅₀ = 3"		d ₅₀ = 4"		d ₅₀ = 5"		$d_{50} = 6''$	
Ft	V =	5.4	v = 0.1		v = 0./		v = 7.0		V = 0./	
	Q	D	Q	D	Q	D	Q	D	Q	D
	Grade = 2%									
2 3	29 32	1.23 1.14	59 63	1.75 1.65	100 104	2.27 2.14	198 203	3.09 2.93		
4 5	36 39	1.08 1.03	67 72	1.55 1.48	109 115	2.03 1.94				
6	43 51	1.00	78 89	1.44	122	1.87				
10 12	60 68	0.93	100 113	1.31	154 170	1.71	9			
Grade = 3%										
2	19 22	0.91	37	1.31	62 67	1.71	122	2.33	201	2.93
4 5	24 27	0.80	45 49	1.16	71 77	1.51	133 140	2.08		
6	30 27	0.75	53	1.07	83 07	1.40	151	1.94		
10 12	44 50	0.71 0.69	73 83	1.00 0.97	109 123	1.29	186 205	1.76		
I				Grade	= 4%				L	
2	14	0.74	27	1.07	45	1.39	88 93	1.91	142	2.40
4 5	19 21	0.66	34 38	0.95	54 58	1.23	98 106	1.70	158 166	2.17
6	24	0.61	42	0.88	64	1.15	113	1.58	175	2.00
8 10	29 35	0.59 0.58	50 59	0.85 0.83	76 88	1.11	130 145	1.51	196 221	1.91 1.85
12	40	0.57	68	0.81	98	1.04	162	1.40		

 d_{50} = Riprap size of which 50 percent by weight is smaller.

Trapezoidal Cross Section 2:1 Side Slopes

"D" = Depth flow in feet "Q" = Capacity in cfs "v" = Velocity in fps

Riprap Lined Channel

	d ₅₀ = 3"		d ₅₀ = 4"		d ₅₀	d ₅₀ = 5"		d ₅₀ = 6"		d ₅₀ = 7"	
Bottom Width	v =	6.1	$d_{50} = 4"$ $d_{50} = 5"$ $d_{50} = 6"$ $d_{50} =$ $v = 6.7$ $v = 7.8$ $v = 8.7$ $v = 9.$ Q D Q D Q D Q $Grade = 5\%$ 92 35 1.19 68 1.64 110 2.06 165 85 39 1.12 74 1.54 117 1.95 175 81 44 1.06 79 1.46 125 1.86 183 78 48 1.02 86 1.40 134 1.72 204 74 63 0.95 106 1.29 161 1.64 151 72 74 0.93 122 1.22 203 1.54 1.72 204 72 74 0.93 66 1.28 104 1.64 151 72 74 0.93 66 1.28 104 1.64 151 72 1.56 $1.$	9.5							
Ft	Q	D	Q	D	Q	D	Q	D	$\begin{array}{c c} d_{50} = \\ v = 9 \\ \hline 0 \\ \hline $	D	
				Grade	e = 5%						
2 3 4 5	22 24 27 31	0.92 0.85 0.81 0.78	35 39 44 48	1.19 1.12 1.06 1.02	68 74 79 86	1.64 1.54 1.46 1.40	110 117 125 134	2.06 1.95 1.86 1.78	165 175 183 193	2.49 2.37 2.25 2.17	
6 8 10 12	35 43 50 58	0.76 0.74 0.72 0.70	53 63 74 83	0.99 0.95 0.93 0.90	92 106 122 138	1.36 1.29 1.25 1.22	142 161 183 203	1.72 1.64 1.59 1.54	204	2.10	
				Grade	e = 6%						
2 3 4 5	18 20 24 27	0.81 0.75 0.72 0.69	29 33 37 41	1.06 0.99 0.93 0.90	55 61 66 73	1.45 1.36 1.28 1.24	89 98 104 113	1.82 1.72 1.64 1.57	135 147 151 161	2.21 2.09 1.98 1.92	
6 8 10 12	30 37 44 51	0.67 0.65 0.64 0.63	46 55 65 74	0.88 0.85 0.83 0.81	79 92 107 121	1.20 1.15 1.12 1.09	120 140 158 175	1.52 1.46 1.41 1.36	173 196 220	1.86 1.78 1.72	
				Grade	e = 7%						
2 3 4 5	15 18 21 24	0.73 0.68 0.65 0.63	25 28 32 36	0.95 0.89 0.85 0.82	47 52 58 64	1.31 1.22 1.16 1.12	76 84 90 98	1.65 1.56 1.48 1.42	114 121 130 140	2.00 1.89 1.79 1.74	
6 8 10 12	27 34 40 47	0.61 0.60 0.59 0.58	41 50 59 66	0.80 0.78 0.76 0.74	69 83 96 107	1.08 1.05 1.02 0.99	105 122 140 156	1.37 1.32 1.27 1.24	150 172 190 212	1.68 1.61 1.54 1.50	
d ₅₀ = Trapez 2:1 Si	Riprap coidal (de Slop	size of Cross Sec Des	which ction	50 perce	ent by	weight "D" = D "Q" = C "v" = V	is smal epth f apacity elocity	ller. low in f / in cfs / in fps	eet		

Riprap	Lined	Channe1

Pottor	d ₅₀	d ₅₀ = 4"		d ₅₀ = 5"		d ₅₀ = 6"		d ₅₀ = 7"		d ₅₀ = 8"	
Bottom Width	v =	6.7	v =	v = 7.8		v = 8.7		v = 9.5		v = 10.4	
Ft	Q	D	Q	D	Q	D	Q	D	Q	D	
					Grade	= 8%					
2 3 4 5	22 26 29 33	0.88 0.82 0.78 0.76	41 47 51 57	1.20 1.13 1.06 1.03	63 73 80 87	1.51 1.43 1.36 1.30	99 106 115 123	1.83 1.74 1.65 1.59			
6 8 10 12	37 46 53 61	0.74 0.72 0.70 0.68	63 75 88 99	1.00 0.97 0.94 0.92	94 110 127 142	1.26 1.21 1.17 1.14	133 155 172 193	1.54 1.48 1.42 1.37			
					Grade	= 10%					
2 3 4 5	18 21 24 28	0.76 0.71 0.69 0.67	33 38 42 48	1.04 0.98 0.93 0.90	53 59 65 72	1.31 1.23 1.17 1.13	77 85 93 102	1.57 1.50 1.42 1.37	114 121 131 141	1.90 1.79 1.71 1.65	
6 8 10 12	32 39 47 54	0.65 0.63 0.62 0.61	54 64 76 86	0.88 0.85 0.83 0.81	77 95 108 121	1.08 1.06 1.03 1.00	109 128 144 164	1.33 1.27 1.22 1.20	154 177 197 222	1.61 1.54 1.47 1.44	
					Grade	= 12%					
2 3 4 5	15 18 20 25	0.68 0.64 0.61 0.60	28 32 37 41	0.93 0.87 0.83 0.80	44 50 55 62	1.17 1.10 1.04 1.01	65 71 78 87	1.41 1.33 1.26 1.22	95 102 112 120	1.70 1.60 1.53 1.47	
6 8 10 12	28 35 42 48	0.58 0.57 0.56 0.55	46 56 67 77	0.78 0.76 0.74 0.73	68 82 96 108	0.98 0.95 0.93 0.91	95 113 128 146	1.18 1.15 1.11 1.08	132 152 172 195	1.43 1.37 1.32 1.29	
2 3 4 5 6 8 10 12 2 3 4 5 6 8 10 12	18 21 24 28 39 47 54 15 18 20 25 28 35 42 48 Bippap	0.76 0.71 0.69 0.67 0.65 0.63 0.62 0.61 0.61 0.61 0.60 0.58 0.57 0.56 0.55	33 38 42 48 54 64 76 86 28 32 37 41 46 56 67 77	1.04 0.98 0.93 0.90 0.88 0.85 0.83 0.81 0.93 0.87 0.83 0.87 0.83 0.80 0.78 0.76 0.74 0.73	Grade 53 59 65 72 77 95 108 121 Grade 44 50 55 62 68 82 96 108	= 10% 1.31 1.23 1.17 1.13 1.08 1.06 1.03 1.00 = 12% 1.17 1.10 1.04 1.01 0.98 0.95 0.93 0.91 weight 1	77 85 93 102 109 128 144 164 65 71 78 87 95 113 128 146	1.57 1.50 1.42 1.37 1.33 1.27 1.22 1.20 1.41 1.33 1.26 1.22 1.18 1.15 1.11 1.08	114 121 131 141 154 177 197 222 95 102 112 120 132 152 172 195	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	

 d_{50} = Riprap size of which 50 percent by weight is smaller.

Trapezoidal Cross Section 2:1 Side Slopes "D" = Depth flow in feet "Q" = Capacity in cfs "v" = Velocity in fps

Riprap	Lined	Channe1	

Detter	d ₅₀ = 4"		d ₅₀ = 5"		d ₅₀ = 6"		d ₅₀ = 7"		d ₅₀ = 8"	
Width	v =	6.7	v = 7.8		v = 8.7		v = 9.5		v = 10.4	
FL	Q	D	Q	D	Q	D	Q	D	Q	D
Grade = 14%										
2 3 4 5	13 16 18 22	0.62 0.58 0.56 0.55	24 28 32 36	0.84 0.79 0.75 0.73	38 43 49 55	1.07 1.00 0.95 0.92	56 62 69 77	1.28 1.21 1.15 1.12	81 89 97 106	1.54 1.45 1.38 1.34
6 8 10 12	26 31 37 44	0.54 0.52 0.51 0.50	42 51 61 70	0.72 0.70 0.68 0.67	61 74 87 98	0.90 0.87 0.85 0.83	85 101 116 131	1.08 1.05 1.02 0.99	117 136 157 176	1.30 1.25 1.21 1.18
				Grade	= 16%					
2 3 4 5			22 26 29 34	0.78 0.73 0.70 0.68	34 39 44 50	0.98 0.92 0.88 0.86	49 56 63 70	1.18 1.12 1.07 1.03	72 79 88 97	1.42 1.34 1.28 1.24
6 8 10 12			38 47 56 65	0.67 0.65 0.64 0.63	56 68 80 91	0.84 0.81 0.79 0.78	76 92 106 121	1.00 0.97 0.94 0.92	105 124 143 162	1.20 1.16 1.12 1.10
				Grade	= 20%					
2 3 4 5			18 21 25 29	0.68 0.64 0.62 0.60	28 33 38 43	0.86 0.81 0.78 0.76	40 46 53 59	1.04 0.98 0.94 0.91	58 65 73 81	1.24 1.17 1.12 1.08
6 8 10 12			33 41 50 57	0.59 0.58 0.57 0.56	48 59 71 80	0.74 0.72 0.71 0.69	66 80 93 106	0.89 0.86 0.84 0.82	90 107 124 143	1.06 1.02 0.99 0.98
d ₅₀ =	Riprap	size of	which	50 perce	ent by	weight	is smal	ler.		

Trapezoidal Cross Section 2:1 Side Slopes "D" = Depth flow in feet "Q" = Capacity in cfs "v" = Velocity in fps