DESIGN PROCEDURES AND CRITERIA FOR ROCK LINED CHUTE

Iowa Standard and Specification for Grade Stabilization Structure (410) should be followed to plan, design, and install rock lined chutes.

The following design procedures and criteria will supplement Standard 410 and be applicable to rock lined chutes shown on Iowa Standard Drawing No. 800. This material is adapted from material developed by the Natural Resources Conservation Service in Wisconsin.

The cross section of the complete chute shall be trapezoidal. Side slopes shall not be steeper than 2 horizontal to 1 vertical (2:1).

Rock Size

Rock size for chutes will be expressed on the D_{50} size (50 percent passing by weight). To provide an economical design, rock delivered from local quarries or field stone should be used. Therefore, a determination of the stone size likely to be used should be made prior to designing a rock chute.

Rock Lining Roughness

The roughness value of the rock lining varies according to the rock size. Manning's "n" values for the respective rock sizes are listed in Table 1. The "n" value is equal to 0.0395 $(D_{50})^{1/6}$; D_{50} in feet.

TABLE 1 - "n" Values for various rock sizes

Diameter (inches)	"n"
4	0.033
6	0.035
8	0.037
10	0.038
12	0.04

Rock Gradation

The rock gradation shall be:

% by Weight	Size (inches)*
100	$2 \times D_{50}$
50-80	$1.4 \times D_{50}$
25-50	D_{50}
10-30	$0.5 \times D_{50}$
0-5	$0.2 \times D_{50}$

* round to the nearest inch

Allowable Flow Velocity

The allowable velocity is affected by rock size, rock shape, and chute slope. The maximum velocities for various D_{50} sizes and shapes are:

Maximum Velocity (fps)	D_{50} Angular (inches)	D_{50} Rounded (inches)
10.8	12	
9.9	10	12
8.8	8	10
7.6	6	8
6.3	4	6

The allowable velocity will be the maximum velocity times a slope adjustment factor. The factors are listed in Table 2.

TABLE 2 - Slope Adjustment Factors for Allowable Velocity
(All rock sizes and shapes)

Horizontal to Vertical	Adjustment* ft/ft	Factor
3:1	0.333	0.80
4:1	0.25	0.85
5:1	0.20	0.89
6:1	0.167	0.91
7:1	0.143	0.92
8:1	0.25	0.93
9:1	0.111	0.94
10:1	0.10	0.95
12:1	0.083	0.96
16:1	0.063	0.97
>16:1	<.063	1.00

*Factor = Cos 0 - Sin 0
0 = angle of bed slope

Discharge (Q) and Velocity (V)

The discharges and velocities were determined by using the appropriate "n" value for each rock size, a selected cross-sectional area and chute slope. Uniform flow in the chute section was assumed.

The values in the following table can be interpolated for different chute slopes, flow depths, discharges, and velocities.

Chute Slope, %	10 (10:1)			12.5 (8:1)			16.7 (6:1)		
D_{50}, Inches *	4	6	8	6	8	10	6	8	10
Flow Depth (d_f), ft.	0.3	0.4	0.6	0.4	0.5	0.6	0.3	0.4	0.5
Peak Flow, c.f.s									
30	18	10		12			17	10	
35	21	11		14			20	12	
40	24	13		16	10		22	14	
45	27	15		18	11		25	15	10
50	30	16		20	12		29	17	12
55	33	18	10	22	13		32	19	13
60	36	20	11	25	15	10	35	21	14
70	41	23	13	30	18	12	41	25	17
80	47	27	15	34	21	14	47	28	20
90		31	18	38	23	16		32	22
100		35	20	43	26	18		35	25
120		42	24	51	32	22		42	30
140		48	29		38	26		49	36
160			33		43	30			41
180			38		48	34			46
200			42			38			51
Allowable Velocity	6.0	7.2	8.4	7.1	8.2	9.2	6.9	8.0	9.0

Chute Slope, %	20 (5:1)			25 (4:1)			33 (3:1)		
D_{50}, Inches *	8	10	12	8	10	12	8	10	12
Flow Depth (d_f), ft.	0.3	0.4	0.5	0.2	0.3	0.4	0.2	0.2	0.3
Peak Runoff, c.f.s.									
30	13			17	12		25	18	13
35	15	10		20	14	10	31	21	16
40	17	12		23	16	11	37	24	18
45	20	13		26	18	13	42	27	20
50	22	15	10	29	20	14	47	30	22
55	24	17	11	32	22	16		33	25
60	27	18	12	35	24	18		36	27
70	31	21	15	41	28	21		42	31
80	35	24	17	46	32	24		48	35
90	40	27	20	52	38	27			41
100	44	30	22		43	30			47
120	53	38	27		51	37			
140		44	32			44			
160		50	37			50			
180			41						
200			46						
Allowable Velocity	7.8	8.8	9.6	7.5	8.4	9.2	7.0	7.9	8.6

* D_{50} sizes are for angular rock. For rounded rock increase D_{50} by 2 inches.

Design

Design of rock lined chutes can also be completed by using Ohio Engineering Programs-Hydraulic Formulas for trapezoidal sections. The depth and bottom width can be varied until a design with velocities less than or equal to the allowable velocity is determined.

The practical limit for design width with the depths and slopes in these charts should be about 30 feet. In no case shall the bottom width exceed 50 feet.

Rock Chute (Slope) Section

The flow in the chute is considered to be uniform. All chute flows listed in the table are supercritical which causes a hydraulic jump in the outlet section. The total rock lined section must be straight (no curves in centerline).

The maximum chute slope will be 3 horizontal to 1 vertical (3:1). the allowable velocity shall be the maximum velocity times the factors shown in Table 2 for slopes deeper than 10 percent.

The minimum depth of the chute will be the flow depth (d_f) plus 0.5 foot freeboard.

Inlet Section

This section must provide a suitable transition from the upstream end of the inlet to the upstream end of the chute. For this reason the bottom width at the upstream end of the inlet shall be within 100 to 150 percent of the chute bottom width. The length of the inlet shall be the larger of 10 feet or 1.5 times the design velocity.

The minimum depth for the inlet section (d_i) shall be 2 times the chute flow depth (d_f) plus 0.5 foot.

The slope of the inlet section may be a continuation of the upstream waterway slope but shall not exceed four percent (4%).

Upstream Waterway

The maximum waterway slope upstream from the rock chute shall be 4 percent or less for a minimum distance of 100 feet. The design velocity of this waterway must be less than the maximum permissible velocity shown in Exhibit 7-3, page 7-19, Chapter 7 in the Engineering Field Handbook. The waterway may be used for a transition section to change the bottom width and/or side slopes to those that match the chute inlet dimensions.

Outlet Section

The outlet section shall be flat (0% grade). This will cause a hydraulic jump to occur on the rock-lined section.

The depth of the outlet section shall be 2 times the chute flow depth (d_f) plus 0.7 foot. The length of the outlet section shall be 15 feet when flow continues downstream in a channel. The length may be reduced to 10 feet when the chute flow outlets into a flowing stream which has a minimum flow depth of 2 times the chute flow depth (d_f).

Special design will be required when the chute flow outlets onto large, flat stream channels that flow intermittently. Energy dissipating basins or large rock "splash pads" might be considered. Design for these situations will need to be site specific.

The width at the downstream end of the outlet section shall be no less than 50 percent nor greater than 150 percent of the chute bottom width.

Downstream Waterway

The bottom width and side slopes of the downstream waterway shall be the same as the bottom width and side slopes at the downstream end of the outlet section. A transition section in the waterway at least 50 feet long must be provided for other waterway dimensions or configurations.

The slope of the waterway shall be 2 percent or less for a minimum distance of 100 feet. A slope that provides a minimum design depth of 2 times the chute flow depth (d_f) is most desirable and suggested.

Rock Lining Thickness

The minimum thickness will be 2 times the D_{50} rock size which is the same as the maximum rock size.

The larger rock must be uniformly distributed throughout the rock mass and firmly in contact with each other. Smaller rock and spalls shall fill the voids between larger rock.

Bedding

Where the rock lined chute is placed on easily eroded soils (EFH Exhibit 7-3,page 7-19), a suitable bedding or filter fabric must be placed beneath the rock. If a sand-gravel bedding is used, the bedding thickness shall be a minimum of one-third the rock thickness. Filter fabric shall be Class I non-woven geotextile, unless site specific design is done according to recommendations in Design Note No. 24.