Batter Chute Design

Presented by:

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Experience

- P.E. – NH, MA, ME
- CPESC - 2011
- Solid waste designer for 20+ years
- Industrial facility drainage and landfill cell and closure construction projects
What is a Batter Chute?

A batter chute or “drainage chute” is a steep drainage channel that passes down the face of a slope.
Natural Condition

In nature, water finds the path of least resistance.
Engineered

Engineered batter chutes are typically more uniform and range from concrete-lined dam spillways...
Engineered

... to riprap-lined channels.
The Power of Water

Oroville, California dam spillway failure – March 2017
Landfill Final Cover System

- Steep slopes (3H:1V)
- Tall slopes (> 100 feet)
- Limited area
- Perimeter roads
- Detention basins
- Highly regulated
Landfill Cap System
Gabion-Lined Downchute

TYPICAL GABION DOWNCOMER DETAIL

NOT TO SCALE
Landfill Cap System

DROP INLET STRUCTURE FES-1N CONNECTION DETAIL

NOT TO SCALE
Landfill Cap System
Anatomy of a Batter Chute

INLET(S)

CHANNEL

1

X

OUTLET
Anatomy of a Batter Chute

SUBCRITICAL FLOW

SUPERCritical FLOW

SUBCRITICAL FLOW

1

X
The **Froude Number** is “the inertia force on an element of fluid to the weight of the fluid element”

\[ Fr = \frac{v}{(g \, h_m)^{1/2}} \]

- \( v \) = velocity
- \( g \) = acceleration of gravity
- \( h_m \) = hydraulic mean depth

\[ h_m = \frac{A}{T} \]

- \( T \) = width of channel open surface
- \( A \) = cross-sectional area

The diagram illustrates the relationship between \( y \) and \( E \) with subcritical, critical, and supercritical flow regimes.
Inlet Erosion Protection

SUBCRITICAL FLOW

TRANSITION ZONE IS POTENTIAL AREA FOR EROSION

X

1

y₁

y₂

SUPERCRITICAL FLOW
**Example Design**

Adapted from ME DEP (2003)

### Design Criteria

<table>
<thead>
<tr>
<th>Design Parameter</th>
<th>Criteria</th>
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<tbody>
<tr>
<td>Slopes Requiring Terracing/Benching</td>
<td>Any 2:1 slope with vertical height ≥ 20 feet</td>
</tr>
<tr>
<td></td>
<td>Any 3:1 slope with vertical height ≥ 30 feet</td>
</tr>
<tr>
<td></td>
<td>Any 4:1 slope with vertical height ≥ 40 feet</td>
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<tr>
<td>Minimum Bench Width</td>
<td>≥ 6 feet</td>
</tr>
<tr>
<td>Bench Reverse Slope</td>
<td>6:1 or flatter (reverse slope from top of lower slope to toe of upper slope) and minimum 1’ in depth</td>
</tr>
<tr>
<td>Bench Gradient to Outlet</td>
<td>2% to 3%</td>
</tr>
<tr>
<td>Maximum Flow Length Along Bench</td>
<td>≤ 800 feet</td>
</tr>
<tr>
<td>Bench Gradient to Outlet</td>
<td>2% to 3%</td>
</tr>
<tr>
<td>Maximum Flow Length Along Bench</td>
<td>≤ 800 feet</td>
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</tbody>
</table>
Channel Erosion Protection

SUPERCritical FLOW

1
X

y_2
Manning's Equation

\[ Q = VA = \left( \frac{1.49}{n} \right) AR^{2/3} S^{1/2} \]

\[ V = \left( \frac{1.49}{n} \right) R^{2/3} S^{1/2} \]
Channel Geometry

TRAPEZOIDAL

TRIANGULAR

RECTANGULAR

PARABOLIC
Channel Erosion Protection

- Rock needs to be large and angular to stay on slope
- Rock can be secured (gabion or grouted in place)
- Alternative armoring system can be used
Rock-Filled Gabion Baskets
Corrugated HDPE-Lined Swale

MEGA-DITCH BATTER CHUTE, SOUTHBRIDGE, MA
Corrugated HDPE-Lined Swale
Corrugated HDPE-Lined Swale
Geomembrane-Lined Swale
Centralized Sediment Mgmt.
Geoweb/Geocell
Geoweb/Geocell
Articulated Concrete Block

ARMORFLEX BY CONTECH
Grout-Filled Geotextiles
Outlet Erosion Protection

SUPERCritical FLOW  SUBCRITICAL FLOW

1
X
Stable Outlet Options

- DROP-INLET
- HEADWALL
- ENERGY DISSIPATER
- PLUNGE POOL
Outlet Erosion Protection

**Example Designs**

**Apron**

**Plan View**

Note: For use as conduit outlet protection where there is no well-defined channel immediately downstream.

\[ W = 3D_0 + 0.4L_a \]
\[ W = 3D_0 + 1L_a \]

Source: CT DEP (2002)

**Preformed Scour Hole**

**Plan View**

\[ \frac{1}{3} \]

Source: ASCE (1992)
Basin Inlet

Example Design

Plan View

Profile

Adapted from MassHighway (2004)
Location of the Hydraulic Jump

CASE A

VELOCITY HIGH AND DEPTH LOW = JUMP AWAY FROM TOE

CASE B

VELOCITY AND DEPTH MATCHES = JUMP CLOSE TO TOE (OPTIMAL)

CASE C

VELOCITY HIGH AND DEPTH HIGH = JUMP OCCURS OVER SLOPE (POTENTIAL FOR PROBLEMS)
Hydraulic Above the Channel

ACTS LIKE A HYDROFOIL (AIRPLANE WING)
Case C – Resulting in Damage
Consider Below-Grade Flow
Size Recess Based on Flow

Size a recess to ensure that jump occurs close to the toe of slope.
Sizing Guidance

Rock Sizing for Batter Chute Outlets
STORMWATER MANAGEMENT PRACTICES

Photo 1 – Rock-lined drainage chute
Photo 2 – Rock-lined drainage chute used in the stabilization of a gully

1. Terminology
In the stormwater industry, a ‘chute is a steep drainage channel, typically of uniform cross-section, that passing down the face of a slope. The channel gradient is usually steeper than 10%. Common terminology also includes ‘batter chutes’ and ‘drainage chutes’.

The term ‘outlet structures’ refers to a wide range of outlet control devices constructed at the base of chutes to control soil erosion adjacent to the outlet and to dissipate the flow energy. These outlet structures typically consist of rock pads, rock mattresses, aprons, or various types of concrete energy dissipators.

2. Design of rock pad outlet structures for batter chutes
The following design procedure is not appropriate for the design of energy dissipators at the base of dams or basin spillways:

The critical design parameters are the mean rock size (dmean) and length of rock protection (L).

The recommended rock sizing design chart/tables are based on the acceptance of some degree of rock movement (rearrangement) following the first heavy storm event.

Recommended mean (dmean) rock sizes and length (L) of rock protection for minor chutes are presented in Tables 1 and 2. These rock sizes are based on information presented within ASCE (1982) rounded up to the nearest 100 mm increment, with a minimum rock size set at 100 mm.

Table 1 – Mean rock size, dmean (mm) for batter chute outlet protection

<table>
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<tr>
<th>Depth of approach flow (mm)</th>
<th>Flow velocity at base of Chute (m/s)</th>
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<tbody>
<tr>
<td>50</td>
<td>100 100 100 200 200 200 300</td>
</tr>
<tr>
<td>100</td>
<td>100 200 200 200 200 300 300 300 400</td>
</tr>
<tr>
<td>200</td>
<td>200 300 300 300 400 400 400 400 400</td>
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Table 2 – Recommended length, L (m) of rock pad for batter chute outlet protection

<table>
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<th>Depth of approach flow (mm)</th>
<th>Flow velocity at base of Chute (m/s)</th>
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<td>60</td>
<td>1.0 1.5 2.1 2.7 3.4 4.3 5.8 6.8 7.9</td>
</tr>
<tr>
<td>100</td>
<td>1.3 2.0 2.7 3.4 4.1 5.8 6.8 7.9</td>
</tr>
<tr>
<td>200</td>
<td>2.1 2.7 3.4 4.3 5.2 6.1 6.8 7.0</td>
</tr>
<tr>
<td>300</td>
<td>2.3 2.7 3.4 4.3 5.2 6.1 6.8 7.0</td>
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3. Reference

This fact sheet is prepared for educational purposes as part of a series developed and published by Catchments & Crepas Pty Ltd. (www.catchmentsandcrepas.com.au)
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Additional Design Information

Catchments & Creeks

Fact Sheets: Rock Sizing

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Additional Design Information


- Older document
- >700 pages
Additional Design Information

Figure 9.21 — Proportions of the USBR basin II (Chow, 1959).

Figure 9.22 — Proportions of the USBR basin IV (Chow, 1959).
Questions?

Thank You!