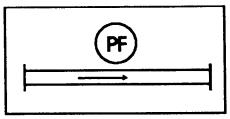
STD & SPEC 3.16




# PAVED FLUME

PF

## Definition

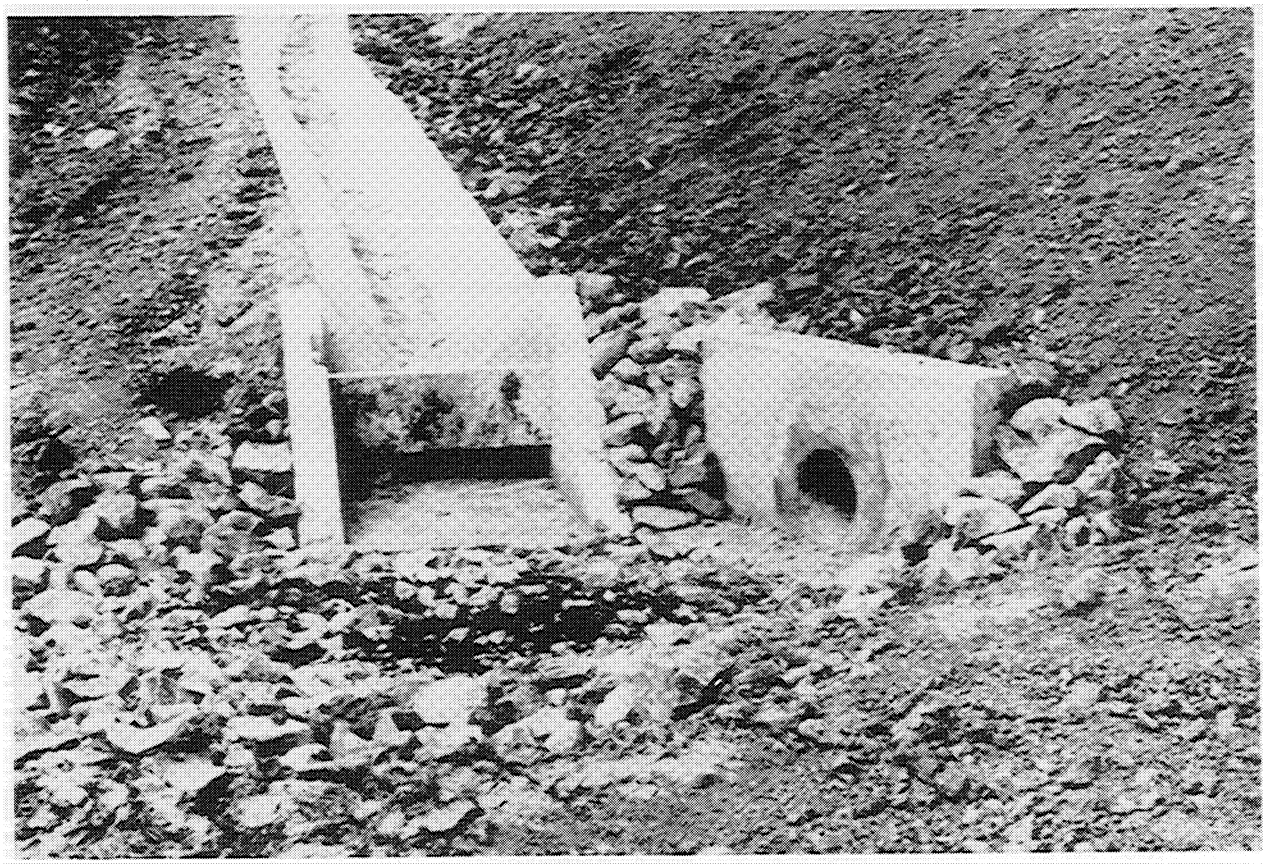
A permanent paved channel constructed on a slope.

## Purpose

To conduct stormwater runoff safely down the face of a slope without causing erosion problems on or below the slope.

## Conditions Where Practice Applies

Wherever concentrated stormwater runoff must be conveyed from the top to the bottom of cut or fill slopes on a permanent basis and a riprap-lined channel is not capable of conveying the runoff without erosion.



## Planning Considerations

Paved flumes are used routinely on highway cuts and fills to convey concentrated stormwater runoff from the top to the bottom of the slope without erosion. VDOT has developed standards and specifications for these structures which apply to all secondary and primary highway construction projects.

Fortunately, these structures have equal applicability to cut-and-fill slopes for construction projects other than highways. Therefore, for the sake of continuity and to prevent possible conflicts, the standards and specifications for paved flumes contained in this practice correspond to those of VDOT.

Consideration must be given to protecting structures against buoyancy failures. The potential for buoyancy failures due to hydrostatic uplift forces exists in channels constructed in periodically saturated areas (basically all channels will experience saturation of the subgrade by virtue of the function of the channel) and especially if a submerged outfall condition exists.

Paved flumes should be utilized and constructed carefully. Field experience has shown a significant amount of post-construction problems with these controls. If the base contains some unsuitable material or is too "soft," the flume will subject to undermining and fracturing. There are also many cases where the outlet velocities and flow rates of stormwater which travels in a paved flume are so great that erosion and flooding at the end of the structure are inevitable, no matter what type of treatment is installed at the outlet. In these cases, strong consideration should be given to a riprapped channel or to a system of inlets, manholes, and pipe to safely convey the stormwater to the receiving channel or drainage structure.

## Design Criteria

### VDOT Design

Paved flumes shall be designed and constructed in accordance with criteria established by VDOT for "Paved Flumes." Design criteria and construction specifications contained herein are extracted and summarized from the latest edition of the following VDOT publications:

Road and Bridge Specifications
Road and Bridge Standards
Drainage Manual

Users of this handbook should refer to the above publications for additional information or clarification, if needed.

Capacity

Paved flumes shall be capable of passing the peak flow expected from a 10-year frequency storm.

Cross-Sections

Plate 3.16-1 illustrates a typical trapezoidal cross-section of a VDOT "Standard Paved Flume (PG-4)." Where additional flow capacity is required, larger trapezoidal cross-sections may be designed. The following criteria apply to all trapezoidal flume designs:

1. The maximum slope of the structure shall be 1.5:1 (67%).

2. Curtain Walls shall be provided at the beginning and end of all paved flumes not abutted to another structure. The curtain wall shall be as wide as the flume channel, extend at least 18 inches into the soil below the channel, and have a thickness of 6 inches. Curtain walls shall be reinforced with #4 reinforcing steel bars placed on 6-inch centers.

3. Anchor Lugs shall be spaced at a maximum of 10 feet on center for the length of the flume. Where no curtain wall is required, an anchor lug shall be installed within 2 feet of the end of the flume. Anchor lugs are to be as wide as the bottom of the flume channel, extend at least 1 foot into the soil below the channel, and have a thickness of 6 inches. Anchor lugs shall be reinforced with #4 reinforcing steel bars placed on 4-inch centers.

4. The flume channel shall have at least a 4-inch thickness of class A-3 concrete with welded wire fabric (6 X 6 - W2.1 x W2.1) in the center for reinforcement.

5. Expansion Joints shall be provided approximately every 90 feet. Eighteen-inch dowels of #4 reinforcing steel placed on 5-inch centers shall be located at all required joints.

Outlet

Outlets of paved flumes should be protected from erosion. The use of an energy dissipator with OUTLET PROTECTION (Std. & Spec. 3.18) is recommended in order to temporarily reduce the existing velocity of the flow, thus preventing undermining of the structure and providing a stable transition zone between the flume and the receiving channel or drainage structure at the base of the slope. Plates 3.16-2 and 3.16-3 show a "Standard Energy Dissipator (EG-1)," which is designed for use in conjunction with the "Standard Paved Flume (PG-4)." OUTLET PROTECTION should still be utilized with the use of an "EG-1" structure to further dissipate flow energy and to provide a smooth transition into the receiving channel. Larger energy dissipator systems may be similarly designed for larger flume cross-sections.

## Construction Specifications

1. The subgrade shall be constructed to the required elevations. All soft sections and unsuitable material shall be removed and replaced with suitable material. The subgrade shall be thoroughly compacted and shaped to a smooth, uniform surface. The subgrade shall be moist at the time the concrete is poured.

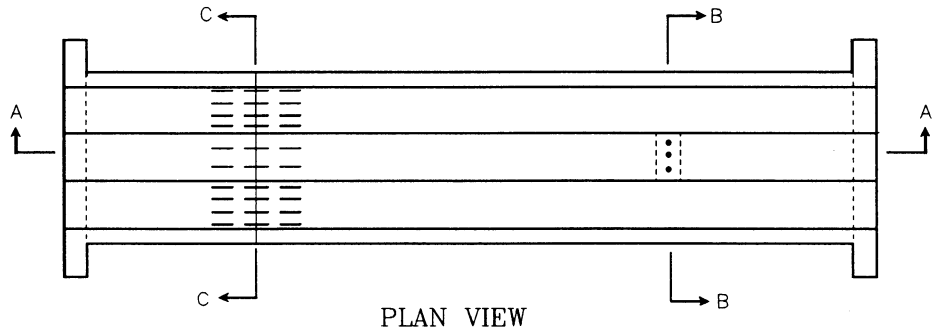
2. Anchor lugs and curtain walls shall be formed to be continuous with the channel lining.

3. Traverse joints for crack control should be provided at approximately 20-foot intervals and when more than 45 minutes elapses between consecutive concrete placements. All sections should be at least 6 feet long. Crack control joints may be formed by using a 1/8-inch thick removable template, by scoring or sawing to a depth of at least 3/4 inch or by an approved "leave-in" type insert.

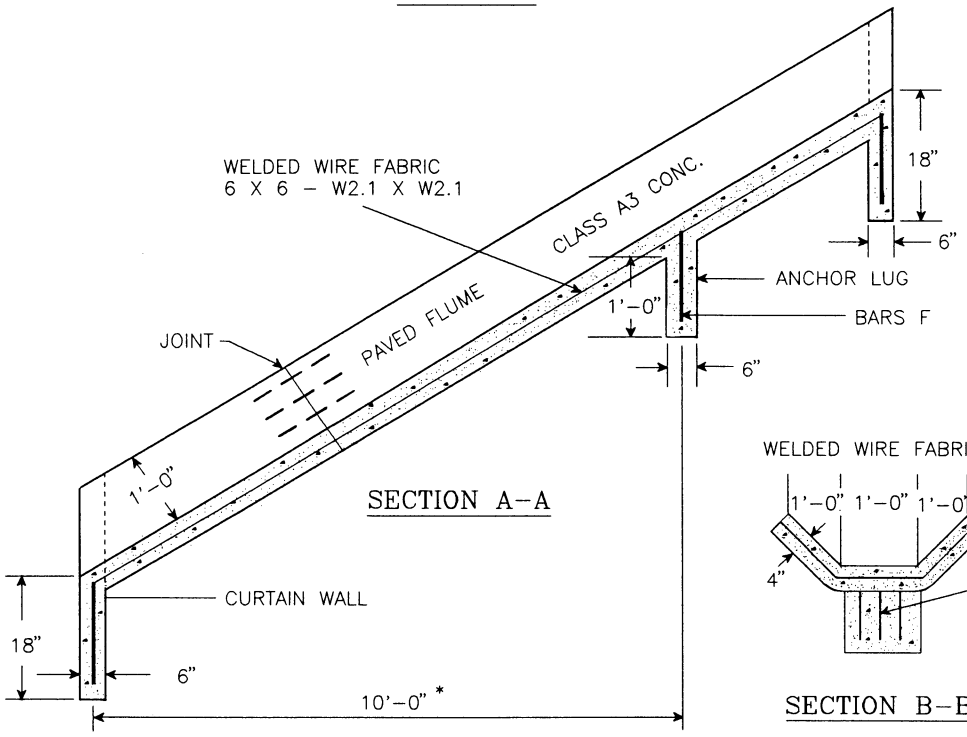
## Maintenance

Prior to permanent stabilization of the slope, the structure should be inspected after each rainfall. Damages to the slope, flume or outlet area must be repaired immediately. After the slope is stabilized, the structure should be inspected to ensure continued adequate functioning (see potential problems noted in Planning Considerations).

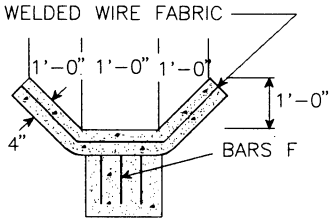
# PAVED FLUME




PLAN VIEW




SECTION A–A

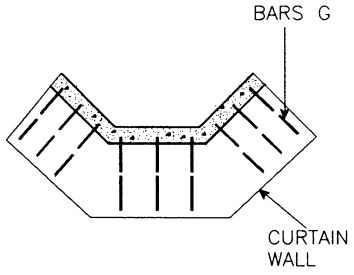



SECTION B–B

* 10'–0" C–C MAXIMUM TYPICAL SPACING BETWEEN ANCHOR LUGS. WHERE CURTAIN WALL IS NOT REQUIRED ANCHOR LUG IS TO BE A MAXIMUM OF 2' FROM END OF CHANNEL.

SCHEDULE OF REINFORCING STEEL

| MARK | NO. | LENGTH | | SIZE | SPACING C–C | SHAPE |
|---|---|---|---|---|---|---|
| | | 2:1 | 1 1/2:1 | | | |
| F | 3 | 1'–2" | 1'–2" | 4 | 4" | STRAIGHT |
| G | 9 | 1'–5" | 1'–5" | 4 | 6" | STRAIGHT |
| DOWELS | 10 | 1'–6" | 1'–6" | 4 | 5" | STRAIGHT |

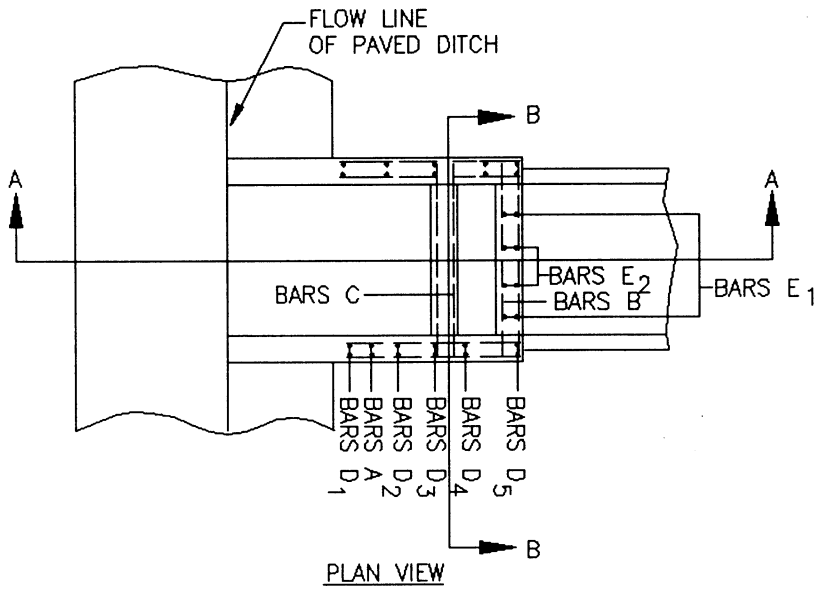



SECTION C–C

NO. SHOWN ARE FOR ONE ANCHOR LUG, CURTAIN WALL AND JOINT

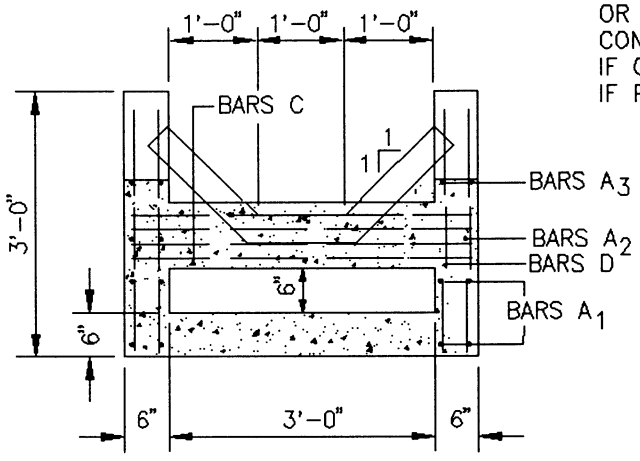
Source: VDOT Road and Bridge Specifications Plate 3.16-1

# *ENERGY DISSIPATOR*

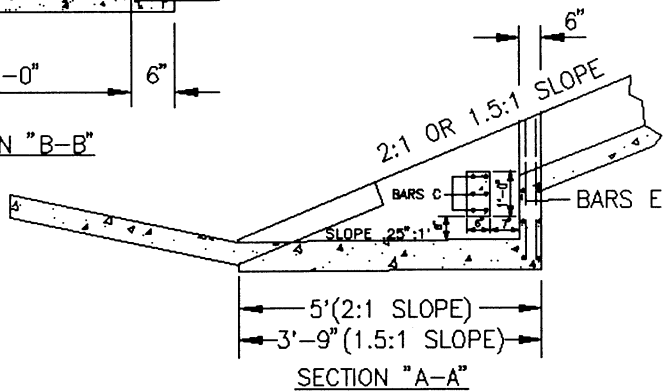



PLAN VIEW

THIS ITEM MAY BE PRECAST OR CAST IN PLACE. CONCRETE TO BE CLASS A3 IF CAST IN PLACE, CLASS A4 IF PRECAST.




SECTION "B-B"



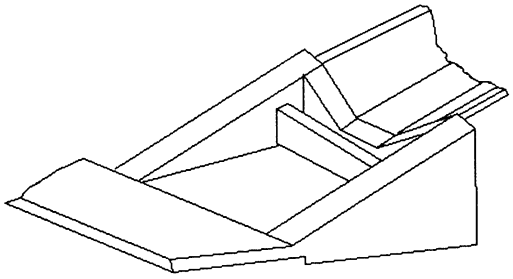

SECTION "A-A"

Source: VDOT Road and Bridge Specifications

Plate 3.16-2

# *ENERGY DISSIPATOR*

## *(CONTINUED)*



ISOMETRIC

SCHEDULE OF REINFORCING STEEL

| MARK | NO. | LENGTH | | SIZE | SPACING C–C | SHAPE |
|---|---|---|---|---|---|---|
| | | 2:1 | 1.5:1 | | | |
| $A_1$ | 8 | 2'–10" | 2'–10" | 3 | 8" | STRAIGHT |
| $A_2$ | 4 | 2'–6 1/4" | 1'–10" | 3 | 8" | STRAIGHT |
| $A_3$ | 4 | 1'–0 3/4" | 0'–10" | 3 | 8" | STRAIGHT |
| B | 6 | 3'–9" | 3'–9" | 3 | 8" | STRAIGHT |
| C | 8 | 3'–8" | 3'–8" | 3 | 2 1/2" | STRAIGHT |
| $D_1$ | 4 | 1'–2 1/2" | 0'–8" | 3 | 8" | STRAIGHT |
| $D_2$ | 4 | 1'–6 1/2" | 1'–1 1/2" | 3 | 8" | STRAIGHT |
| $D_3$ | 4 | 1'–10 1/2" | 1'–7" | 3 | 8" | STRAIGHT |
| $D_4$ | 4 | 2'–2 1/2" | 2'–0 1/2" | 3 | 8" | STRAIGHT |
| $D_5$ | 4 | 2'–6 1/2" | 2'–6" | 3 | 8" | STRAIGHT |
| $E_1$ | 4 | 1'–11 1/2" | 1'–11 1/2" | 3 | 8" | STRAIGHT |
| $E_2$ | 4 | 1'–5 1/2" | 1'–5 1/2" | 3 | 8" | STRAIGHT |

| APPROXIMATE QUANTITIES | | | |
|---|---|---|---|
| | | CONCRETE | REINFORCING STEEL |
| | | CU. YDS. | LBS. |
| ENERGY DISSIPATOR | 2:1 | 0.7479 | 61.20 |
| | 1.5:1 | 0.5921 | 57.63 |

Source: VDOT Road and Bridge Standards

Plate 3.16-3