# Modular Energy Dissipators

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Unless checked by energy dissipators, water exiting from culverts may cause considerable damage. Erosion of the downstream channel banks, the neighboring properties, and indeed the roadway itself, occurs quite frequently when energy dissipating measures prove to be insufficient. The phenomenon of scouring at culvert outlets has been the subject of numerous studies (see Sarikelle and Simon, Field and Laboratory Evaluation of Energy Dissipators for Culvert and Storm Drain Outlets, Ohio Department of Transportation, Columbus, Vol. 1, Dec. 1980). Evidence indicates that erosion of soil and rock particles depends on the velocity of the flow; the tailwater depth; the size, shape, and density of the particles; and the gradation of the material present. Preformed scour holes with protective rock layers and concrete stilling basins with or without energy-dissipating devices are the two major types of structures used to reduce or eliminate downstream erosion.

The advantage of rock-fill protection is its relatively low cost. Cast-in-place concrete energy dissipators are expensive in comparison, and they are built only when the increased protection afforded by them is warranted. The disadvantage of rock channel protection is their lack of permanence. As highway maintenance engineers know only too well, repeated flooding tends to move the rocks. After a while repairs and the placement of new rock fills become necessary. To obtain quantitative information concerning this progressive failure of rock channel protection, the Ohio Department of Transportation has sponsored an extensive research study of the performance of culvert energy dissipators. Part of this work, performed by the Department of Civil Engineering of the University of Akron under our direction, consisted of a statistical evaluation of the performance of 400 rock channel protection sites. The sites were selected so as to cover a wide range of environmental and physical characteristics. Hydrologic, hydraulic, and soil characteristics, as well as design information, were included in the analysis. The condition of the protective rock layers was determined by site visits.

The results of the statistical study indicated that rock protection without gravel underlayment has failed at more than 60 percent of the sites visited. In contrast, at locations where the rock was placed on a gravel filter bed, less than 40 percent of the sites exhibited failure. On the other hand, only about 14 percent of the sites appeared to be fully intact. From these results, however, one must not imply a failure of the culvert exit. What was found generally is that the flow exiting the culvert created a scour hole and a rock mound behind it. Depending on local conditions the remaining rocks and the growth of vegetation may or may not lead to a stabilized condition. If the scouring proves to be progressive with repeated flooding, periodic repairs are required. An alternative solution is, of course, the design and construction of a more permanent energy dissipator.

The effectiveness of a new type of energy-dissipating structure, the modular energy dissipator (MED) has been proven in the field. Under the sponsorship of the Ohio Department of Transportation with assistance from the Federal Highway Administration, as a part of the study mentioned earlier, the University of Akron has designed a structural system consisting of precast reinforced concrete components that could be adapted to local conditions and could be assembled at the site with considerable ease. One example for this type of structure is shown in Figure 1. Located near Canal Fulton, Ohio, this culvert was chosen because of a history of severe erosion and scouring problems at its outlet. During the summer of 1969, a flash flood caused the total failure of the culvert outlet and eventual failure of the embankment that led to the complete loss of the roadway. The culvert and channel were rebuilt and a lined trapezoidal exit channel was installed in an attempt to alleviate the scouring problems. In 1971, heavy storms again caused severe channel erosion and damage to the channel lining. The channel was again rebuilt and its length was increased. This only moved the scouring problem further downstream. At the time of the initiation of field installation, the outlet channel consisted of a lined trapezoidal cross section with a length of 80 ft. The trapezoidal channel ended in a scour hole, 7 ft deep and 36 ft in diameter (see Figure 2). The modular energy dis-

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*Figure 1. Assembled modular energy dissipator.*

*Figure 2. Modular energy dissipator site.*

sipator built at the outlet has localized and stabilized scouring. The full cost of the structure was $19 000 in 1977—excluding the $1800 cost of the steel casting forms. The structure was completed in 48 h during heavy snows and subzero temperatures.

The modular structural elements of the MED system are shown in Figure 3. These five basic modular elements are arranged to fit local conditions. The horizontally placed elements are held by concrete-filled steel or aluminum posts. The posts are driven into the ground after the first layer of standard modular pieces is located on a prepared site. Stacking of the 6-in-thick components to the desired height can be completed quickly. The arrangement of the structural components at the Canal Fulton site is shown in Figure 3.

The standard module sizes were structurally designed in lengths of 4, 6, 8, 10, and 12 ft. Corresponding filler members, columns, and optional structural pads make up the complete system. The advantages of the MED system,

*Figure 3. Modular structural elements.*

assuming that the components are made under factory conditions, are (a) lower cost per component, (b) better quality control, (c) higher concrete strength, and (d) less labor per component. The additional advantages related to the on-site construction are use of unskilled local labor and shorter construction time as construction involves mainly earthwork and assembly of precast components.

To develop reliable design specifications for modular energy dissipators, model studies were conducted at the Hydraulic Laboratory at the University of Akron. A wide variety of basin shapes were studied both for culvert outlets at grade and for cantilevered outlets. Each of the selected arrangements was analyzed in terms of basin stability and in terms of scour formation inside and outside of the basin. The basin stability and the resulting scour patterns were found to depend on flow properties existing at the culvert outlet, the bed material, the dimensions and shape of the MED, and the dimensions of the downstream channel. Results indicated that undermining was the most critical type of failure of modular dissipators. It depended on the stone size as well as the dimensions and location of the structure. It was shown that placement of riprap inside the basin contributed significantly to its stability, as long as the stone size allowed the formation of a scour hole within the basin. Within the flow ranges tested, the best performance obtained was at a length-to-diameter ratio of 9.0 and at a side flare of 3 to 1 for cantilevered culverts. With culvert outlets at grade, modular units set 1 diameter below the culvert's invert provided stable performance. For small tailwater elevations the height of the back panels may be set at 0.25 times the diameter of the culvert, and for high tailwaters the back panels may be set slightly above the tailwater elevation. Also, for culverts at grade, the back panel may be set at 2 to 3.5 times the culvert diameter.