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EROSION CONTROL STRUCTURES

Erosion and excess runoff are products of many factors: soil type, plant cover, cropping practices, climatic zones, rainfall amounts and intensities, and degree and length of slope to name a few. Water erosion usually occurs as sheet erosion, which is the periodic removal of thin sheets of soil over an area, or as gully erosion that forms incised channels. The end product is sediment. It is in the construction stage that natural conditions such as topography, natural cover, soil conditions, and drainage patterns are being disrupted due to manipulations by man and machines. It should be the goal of each design and construction engineer to control these results within reasonable limits during the construction stage and finally to permanently stabilize the area for control of erosion and runoff upon completion of the job. There are a number of basic principles for controlling runoff and erosion that have proved sound over the years for other land uses and that can prove to be just as useful for highway construction. These include such things as proper attention to soil, foundation, and topography in site selection; minimum exposure of bare areas by control of clearing and grading operations; diversion of water away from critical areas; flattening slopes; reducing slope lengths; use of temporary cover; and control of equipment access and travel ways. A number of structural measures are discussed that may be used as either temporary or permanent installations. These include such things as grassed or paved waterways, buried pipe outlets, diversion terraces, benches, various types of grade control structures, retarding structures, chutes, inlets, and debris basins.

The techniques of controlling water erosion both during and after construction are generally well known and have been well proved for other land uses. These can include both temporary and permanent measures. The basic principles and some of the physical structures for erosion control that may be adapted to highway construction are presented here.

Erosion involves the movement of soil particles by water and wind. It is the result of many factors, the most important of which are soil type, plant cover, climatic zones, rainfall amounts and intensities, degree and length of slope, and conditions brought about by man's activities.

Water erosion of land surfaces is of two types, sheet erosion and gully erosion. Sheet erosion is the removal of thin sheets of soil over an area. Gully erosion is that that forms incised channels. These may vary in size from small rills that can easily be obliterated to those large enough to seriously affect project costs.

The end product of erosion is sediment. This can fill road ditches; cover road surfaces; pollute and fill rivers, streams, and lakes; increase costs due to damage to the construction site; and degrade the aesthetics of the area.

Projects are most vulnerable to these ravages of nature during the construction period. It is in this stage that rapid changes are being made in natural conditions, such as vegetative cover, topography, soils, infiltration, and drainage due to manipulation by man and his machines. It should be the goal of each design and construction engineer to control these changes within reasonable limits. This will involve protecting the area during the construction stage and permanently stabilizing the area to control erosion and runoff as the final step in completing the job. Needless to say, it must be recognized where problems will occur, and plans must be made in advance to overcome them. This may require a hard sell directed to those responsible for project planning, design, and construction. It must also be recognized that needed erosion control measures may significantly increase project costs.

There are a number of basic principles for controlling runoff and erosion that have been proved sound. Attention must be given to soil and foundation conditions in route selection, design, and construction. Soils with severe limitations for this particular use, if they cannot be bypassed, will require special attention. Local Soil Conservation Service (SCS) offices will usually have soil survey data and interpretations for use on most areas where new roads are being planned or old ones being reworked.

Erosion problems can be reduced by making the best use of topography. For example, erosion problems may be decreased by site location along the contour rather than up and down the slope.

Drainage patterns and conditions are important. Problems usually increase in about the same proportion as disruption in natural drainage patterns. Subsurface drainage problems should be anticipated inasmuch as they will influence slope stability, drainage needs, construction methods, and finally the success of stabilizing the area with vegetation.

Consideration needs to be given in the planning stage to the effect of the road on existing erosion control and water management systems and, conversely, the effects these systems will have on the road project. Most farmland will have some type of conservation system already installed. These may involve things such as terraces, waterways, drainage ditches, or irrigation pipelines and canals.

Other basic principles include clearing and grading to reduce areas and time of exposure, handling excess water generated by the operations, reducing degree and length of slopes, and control and routing of equipment.

TYPES OF STRUCTURES

There are a number of structural measures that may have a place either as temporary or as permanent installations. These include diversions, grassed or paved waterways, buried pipe outlets, bench terraces or berms, numerous types of grade control structures, chutes, inlets, retarding structures, debris basins, and others.

For some of these measures, where and how they may be used and location and design criteria will be discussed. For most of these the SCS has handbooks and standards that cover design criteria and procedures (1).

Diversions

Diversions are designed, graded channels with a supporting ridge on the lower side, constructed across the slope. Their purpose is to intercept surface or subsurface water and to lead it to an outlet where it can be safely disposed of. These structures may be temporary or permanent and graded or level. Graded terraces move water in a planned direction at a nonerosive velocity; level terraces have closed ends and retain the runoff.

Diversions are useful above cut slopes, borrow areas, and gully heads. They can be constructed across cut slopes to reduce slope length into nonerosive segments and can be used to move runoff water away from critical construction sites. They may be built both on and off site.

Diversions should be located so that water will empty in established disposal areas, natural outlets, or prepared individual outlets. Individual outlets may be designed grassed or paved waterways, chutes, or buried pipe. Diversions should be designed to handle runoff from a 10-year frequency rain.

Berms

Berms are steps or benches in steep slopes. They are modifications of and serve about the same purpose as diversions. Properly located and designed, they reduce slope lengths and divide the volume of runoff water into workable slugs that are more easily handled. Capacity to carry the volume of water is obtained by grading the berm so that the outside edge is higher than the edge adjacent to the cut slope. Runoff water may be removed from the berm by use of paved waterways or buried pipe.

Waterways

Waterways serve as outlets for diversions, berms, or other structures. They may be natural or constructed, shaped to required dimensions, and vegetated or paved for disposal of runoff water. Usually they are constructed to one of three general cross sections: parabolic, trapezoidal, or V-shaped. Where they are to be vegetated, parabolic waterways are the most commonly used. This is the shape ordinarily found in nature.

Successful function of a waterway depends on protection from erosion. This can be done by designing for flow velocities that are nonerosive for the grass that will be used or by paving with concrete or rock. Waterways should be designed to carry runoff from a 10-year frequency rain, as a minimum.

Pipe Outlets

Pipe outlets also may be used to remove water from diversions and berms. If the retarding principle is used, which is to design to empty the structure in a 24- to 48-hour period, a small-diameter pipe may be used. The SCS uses a perforated vertical riser to get the water into the pipe. An orifice plate is designed for the bottom of the riser so that channel rather than pressure flow is maintained in the pipe. The advent of corrugated plastic pipe has made installation rather simple. Pipe outlets are designed to remove runoff volume from a 10-year, 24-hour storm, as a minimum. This may be removed in a 24- to 48-hour period depending on conditions.

Retarding Structures

Retarding structures consist of an earth embankment, a principal spillway, and an emergency spillway. They may be constructed on or off site. Their purpose is to store runoff temporarily, releasing it at a slow rate to protect the area below. They can reduce runoff peaks, permitting use of smaller culverts and bridges. When they are constructed on site and fill is used for the roadbed, they can eliminate bridges and may reduce costs. Because, in any one of the structures, there are numerous community benefits—flood prevention, grade control, and water for livestock, recreation, and irrigation—cooperation from local people and organizations such as soil and water conservation districts is very good. A number of state highway departments have memorandums of understanding with their conservation agencies that encourage this type of cooperation.

The principal spillway usually consists of a reinforced concrete riser and a horizontal pipe or monolithic concrete outlet through the earth fill. It is usually designed to empty the retarding storage area in 10 days or less. The emergency spillway, as a minimum, should handle the routed runoff from a 25-year frequency storm or from a storm with a frequency equal to the design life of the structure, whichever is greater.

The retarding storage should be able to contain the runoff expected to occur at a frequency consistent with the level of protection to be provided.

Grade Stabilization Structures

Grade stabilization structures stabilize grade or control head cutting in natural or artificial channels. They reduce channel grade and flow velocity and literally step runoff water down a slope at a controlled velocity. Grade stabilization structures may consist of earth embankments with pipe spillways or mechanical structures of concrete, masonry, steel, aluminum, or treated wood. Design depends on site conditions, but ordinarily these structures should handle runoff from a 25-year frequency storm.

Mechanical Structures

Mechanical structures retain, regulate, or control the flow of water. They have a place in grade stabilization and in retardation. Most structures are made up of four major parts: earth embankment, spillway inlet, spillway conduit, and spillway outlet. The three principal types of mechanical spillways are drop, drop inlet, and chute.

The embankment directs the flow of water through the spillway. The embankment for a drop spillway or chute generally extends from the spillway to high ground or to a vegetative spillway. In a detention pond, the embankment detains and impounds water as well as forces storm flow through the spillway.

Water enters the spillway through the inlet, which may be in the form of a box, a weir in a wall, or a culvert. The box may be straight, flared, or curved. The culvert entrance may be round, square, or rectangular, with a square edge, hood, or flared entrance.

Vertical walls extending into the soil foundation under the inlet are known as cutoff walls. Their main purpose is to prevent water seepage under the structure. Similar walls extending laterally from the inlet to prevent seepage and erosion around the ends of the structure are called headwall extensions.

The conduit receives water from the inlet and conducts it through the structure. The conduit may be closed in the form of a box or pipe or open as in a rectangular channel. Cutoff walls or antiseep collars are usually constructed as a part of the conduit to prevent seepage along its length.

Water leaves the structure through the outlet, which discharges water into the channel below at a safe velocity. The outlet may be a cantilever (propped) type, a plain apron outlet, or an apron with any type of energy dissipator to minimize the erosive effect of the discharge. Vertical walls known as toe walls extend below the front of the apron to prevent undercutting. Wing walls are vertical walls extending from the outlet into the channel banks to protect against the swirling effect of the water as it leaves the structure. Types of spillways are given below.

Straight Drop Spillway

The straight drop spillway is a weir structure in which flow passes through the weir opening, drops to a level apron or stilling basin, and then passes into the downstream channel. It may be constructed of reinforced concrete, rock masonry, sheet steel piling, timber, or prefabricated metal.

Box Inlet Drop Spillway

A box inlet drop spillway is a rectangular box open at the top and downstream end. Runoff directed to the box and headwalls enters over the upstream end and the two sides. The flow drops to an apron and leaves through the open downstream end. An outlet structure is attached to the downstream end of the box.

Drop Box Culvert

The drop box culvert is a rectangular box inlet drop spillway placed at the upstream end of a culvert. It may be built as an integral part of a new culvert, or it can be fastened by dowel bars to the upstream headwall of an existing culvert. This is an excellent device for reducing channel grade.

Concrete Chute Spillway

The concrete chute spillway is an open channel with a steep slope in which flow is carried at supercritical velocity. It usually consists of an inlet, a vertical curve section, a steep-sloped channel, and an outlet. Most of the drop in water surface takes place in a channel. Flow passes through the inlet and down the paved channel to the floor of the outlet.

Formless Concrete Chute

The formless concrete chute is a spillway constructed of concrete without special forming. The earth subgrade is excavated to the dimensions and contour of the structure. Concrete is placed against the subgrade to the depth required and troweled into shape.

Sod Chute Spillway

The sod chute spillway is a steep, sodded section of a water course constructed to conduct the design flow at a safe velocity. It is adapted to small drainage areas and sites where good, dense sod can be developed and maintained. When the channel below the chute is narrow or conditions at the lower end are not favorable for establishment of vegetation, a toe wall drop spillway should be used. The toe wall raises the end of the sod chute above the unfavorable conditions, such as poor soil or wet or rocky conditions, and permits maintenance of a good sod.

Drop Inlet Spillway

A drop inlet spillway is a closed conduit generally designed to carry water under pressure from above an embankment to a lower elevation. It may be constructed of monolithic concrete or of pipe. Metal pipe drop inlet spillways and sod chutes are ordinarily designed to handle runoff from a 10-year frequency storm. Those of concrete are ordinarily designed to handle flow from a 25-year frequency storm. More complex or expensive structures may be designed to handle a 50- to 100-year frequency flow.

Debris Basins

The debris basin is a structure that temporarily detains runoff water carrying heavy loads of silt, sand, or gravel. It usually consists of an earth embankment and a perforated pipe principal spillway. Runoff water slows upon entering the impoundment. A large part of the debris settles out, and the water is automatically drawn out through the principal spillway. The structure should be designed to store the expected debris yield for the life of the structure, or provisions should be made for periodic cleanout. Debris basins may be permanent or temporary. Those to trap debris generated by construction are usually temporary and are removed once the job is completed and the area stabilized.

CONCLUSIONS

Erosion and sediment production both during and after construction can be controlled. Control must be planned in advance. Some of the structures discussed may be used either as a part of the main water disposal system or to stabilize side drainage entering the road system. A number of state and local highway departments are finding some of these principles and measures useful, especially on secondary and rural road systems.

REFERENCE

1. Engineering Field Manual for Conservation Practices. Soil Conservation Service, Washington, D. C.