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Field Evaluation of Tentative Design Procedure for Riprap-Lined Channels

An NCHRP staff digest of the essential findings from the final report on the field evaluation phase of NCHRP Project 15-2, "Design to Control Erosion in Roadside Drainage Channels," by A. G. Anderson, Professor of Civil Engineering, St. Anthony Falls Hydraulic Laboratory, University of Minnesota.

THE PROBLEM AND ITS SOLUTION

The objective of NCHRP Project 15-2 has been to develop criteria and design procedures for the use of aggregate or riprap linings for drainage channels suitable for conditions intermediate between those for which turf cover performs satisfactorily and those for which paved channels or pipe flumes are more economical. The tentative design procedures, developed from analysis of previous research on sediment transport and verified by limited experimental testing in the hydraulics laboratory, were published in *NCHRP Report 108*, "Tentative Design Procedures for Riprap-Lined Channels." During the field evaluation phase of the study, riprap linings for five channels were designed in accordance with the procedures described in *Report 108*. Four of the channels have been constructed and are performing satisfactorily. Two have been subjected to discharges approaching the design discharges without signs of erosion.

The results of the project are particularly noteworthy from an implementation standpoint in that (1) practical design procedures have been prepared in easy-to-use table and chart form and published in *NCHRP Report 108*, (2) channels built in accordance with the design procedures have successfully undergone laboratory and considerable field evaluation, and (3) the design procedures are already being incorporated into manuals and publications on erosion control by highway agencies. Loan copies of the agency report on the field evaluation phase of the study are available from the Program Director, NCHRP, Transportation Research Board, 2101 Constitution Avenue, N.W., Washington, DC 20418.

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FINDINGS

The drainage channels designed and constructed in accordance with the procedures described in *Report 108* and subjected to field evaluation are listed in Table 1. Data used in the design of the riprap lining for each channel, and photographs of performance, are included in the field evaluation report, which has been distribute to all state highway agencies.

The Hop Brook site in Manchester, Conn., is a stream relocation with a design discharge much greater than that initially intended to be included within the scope of the project. The study procedures were extrapolated to determine the desired riprap size and the cost estimate for the 4,400-ft-long relocation compared with the cost of a paved lining. The riprap lining was constructed at an estimated saving of $94,000. The only evidence of stress after several years of use has been localized at the side inlets where excess energy from the inlet flow was not appropriately dissipated. This situation was easily corrected during maintenance operations.

The channel at Moose Lake, Minn., was also a stream relocation between a railroad embankment and a highway. During the first year after construction the channel was subjected to a flow near the design discharge as a result of unusually heavy rainstorms in the area. Inspection indicated that the channel effectively withstood the attack of the flood flow.

The field evaluation sections in Wisconsin and Montana were typical roadway channels with relatively small design discharges. The roadside ditch along a two-lane highway in a sandy soil area of Chippewa County, Wis., was unstable and in need of some type of erosion control. A locally available gravel was selected as the riprap lining in accordance with the Project 15-2 design procedures and placed as the ditch lining. Inspection after four years of service indicated that vegetation has been established in the channel and it is in good condition.

The Montana site is the median ditch of a divided Interstate highway near Billings. Because of the non-critical nature of the site and the concern that the design procedure may be unnecessarily conservative, the median size of the riprap actually used was 4 in., even though the design procedure indicated that a median size of more than 7 in. would be desirable. The channel has successfully withstood one hydrologic event approximating the design discharge. This same event caused failure of the blanket-type lining of a nearby channel. The blanket lining has since been replaced by riprap.

Inspection of the study drainage channels indicated that special care should be taken with regard to culverts and other transition structures leading into riprap-lined drainage channels. Such structures cause localized increases in velocity and scouring forces that are not accounted for in the design procedures. These increased scouring forces must be counteracted by the placement of appropriately larger sizes of riprap based on a study of culvert hydraulics or local experience.

APPLICATIONS

Based on the previous laboratory studies and the observations made during the field evaluation phase, the design procedures contained in *NCHRP Report 108* are unquestionably useful for the design of riprap-lined channels. The channels

Table 1. DRAINAGE CHANNELS DESIGNED ACCORDING TO PROPOSED TENTATIVE DESIGN PROCEDURES

Location	Present State	Design Q (cfs)	Design Slope	Riprap d_{50} (ft) Design	Riprap d_{50} (ft) Used	Bottom Width (ft)	Side Slopes	Design Depth (ft)	Max. Q to date (cfs)[a]	Present Condition
Manchester, Conn.	Const. 1969	3900	0.007	1.06	1.5	20	2:1	9.15	1500	Very good, vegetation on sides and top. Mean size of riprap appears to vary somewhat along channel.
Moose Lake, Minn.	Const. 1971	275	0.003	0.21	0.25	12	3:1	4.0	250	Channel very good. All riprap in place. Erosion at outlet of culvert at upstream end.
Klamath Falls, Ore.	Design	1100	0.0054	0.43		15	2.5:1	5.3	-	Chandler Wayside Park
Chippewa County, Wis.	Const. 1969	6	0.017	0.08	0.08	10	4:1	0.5	-	Roadside drainage. Good condition. Some damage from truck wheels.
Montana I-90-8(66)	Const. 1971	18	0.05	0.6	0.33	0	6:1	-	-	Median strip. Appears to be in good condition. Riprap gravel uniformly graded 2-in. minimum to 8-in. maximum.

[a] Approximate

for which they have been used were effective in transporting surface runoff without erosion. In all cases in which the riprap lining was in place a year or more, vegetation has grown through the interstices of the rock. In some cases the rock is no longer visible and the channel appearance is greatly improved.

In the development of the design procedures, conservative values of constants were chosen. Additional factors of safety are introduced by (1) the selection of riprap gradations equal to or larger than the design size and (2) the eventual establishment of vegetation in the lining. Performance of the median ditch at the Montana site indicates that the design procedure may be unduly conservative, particularly in non-critical situations. Continued observations should be made by user agencies to further evaluate the conservative nature of the procecures.

Implementation of the research product- riprap design procedures- is already in progress. The Kansas Highway Department has used the procedure to prepare specifications for a series of predesigned channels all having side slopes of 4:1 and varying bottom widths to accomodate a range of discharges and longitudinal slopes. The Minnesota Highway Department has combined the riprap lining with topsoil to support the growth of grass. As the vegetation develops, the root structure penetrating the riprap provides a significant increase in resistance to erosion.

The FHWA is using *NCHRP Report 108* as the source document for the section on riprap linings in a new publication on stable channel designs and is also including the procedure in the curriculum of FHWA-sponsored workshops for hydraulic engineers.