HIGHWAY RESEARCH
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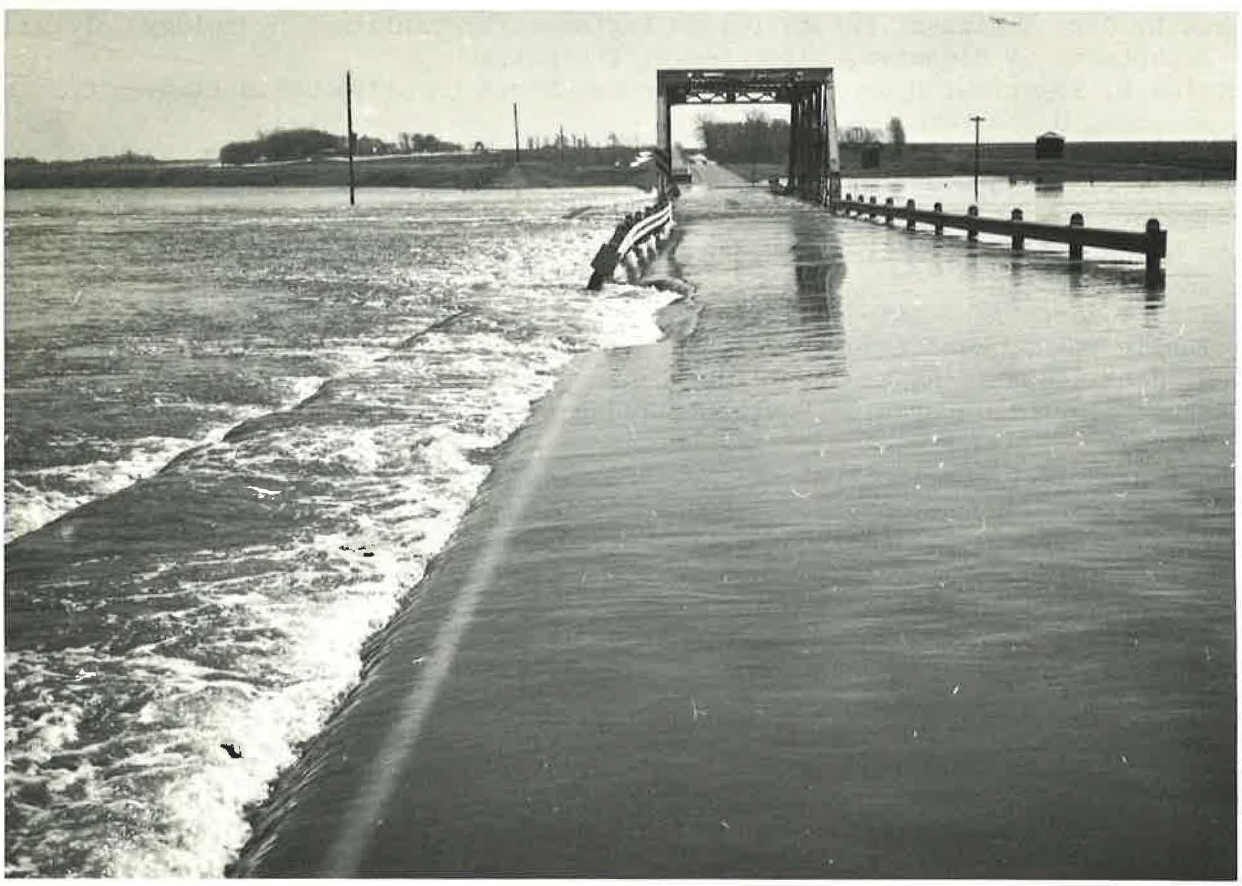
COMMITTEE ACTIVITY

Committee on Surface Drainage of Highways
Department of Design
Highway Research Board

Research Needs
Surface Drainage



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Research Problem Statement No. 1

I. Title:

Development of Energy Dissipators for Outlets of Culverts and Storm Drains.

II. The Problem Area:

There is an urgent need for development of criteria for the design and use of simple, practical, economical stilling devices for dissipating the energy of the flow from culverts and storm-drain outlets, up to 144-inch diameter or equivalent size. Damaging erosion of drainage channels often results from discharge of high velocity flow from the outlets of culverts and storm drains. Energy dissipators can be effective in reducing the velocity of flow from culverts to a degree that damage to the channel and channel bank will not undermine the culvert or endanger the highway embankment.

III. Objectives:

1. To develop criteria which will provide the designer with a method of selecting the type of energy dissipator most suited to the conditions.

2. There are several complex types of energy dissipators suitable for the more costly applications such as for reclamation or flood control or the larger highway drainage structures. For most highway drainage systems, consisting of commercial culverts or storm drains, simpler more effective and economical devices are urgently needed.

3. Designs should be applicable to pipe or box culverts of all shapes operating over a wide range of discharge rates and relations of velocity head to depth of flow at the outlet.

IV. Urgency:

Drainage and erosion control costs average about 10% of the total cost of highway construction. Inadequate design data result in added maintenance or need for subsequent drainage and erosion control facility replacements and improvements. There is also recurring loss due to overdesigns where the design principles are not clearly established for erosion control structures. Erosion at culvert and storm-drain outlets is a perennial problem; better guidance and design will help to reduce construction and maintenance costs and advance good engineering practice.

Research Problem Statement No. 2

I. Title:

Flood-Frequency Predictions for Bridge and Culvert Design

II. Problem Area:

Highway drainage structures are designed for runoff events calculated to recur on the average of once in a certain number of years. As a basis for design, recurrence intervals of 10, 25 and 50 or more years are assigned depending upon the relative importance of the highway and the degree of risk that can be accepted. In order to determine the design capacity of a structure for a given recurrence interval, the engineer must either resort to a flood-frequency analysis or use ready-made flood-frequency curves from available sources.

Flood-Frequency analysis is a mathematical procedure for predicting the probability of future floods on the basis of past flood events. The procedure is predicated on records of stream flow which in most instances are too short to have included a maximum flood and which do not give a direct indication of the longer recurrence interval needed for design. The solution is obtained by statistical analysis of a series of the observed maximum floods. Mathematical functions are fitted through short term records that are plotted on probability paper and extended beyond the data. Such extrapolation for long recurrence intervals assumes that floods are really distributed according to a particular mathematical function.

A number of flood frequency techniques have gained wide use and acceptance. Examples are the Gumbel and log-Pearson Type III methods and their variations. The various techniques can give quite different design discharges. There is a need, then, to compare results and determine which technique, within regions of Hydrographic similarity, provides the most reliable and consistent means of predicting design discharges for highway bridges and culverts.

In the aggregate the states in cooperation with the U. S. Geological Survey have spent about $25 million accumulating flood information on about 2,000 small watersheds. A consodildated examination of these observations is warranted to delineate regions of homogeneous flood characteristics. Besides eliminating the artificiality of political boundaries, pooling of data would afford economy of scale in electronic computation. Resultant maps would show which portions of all states are best served by a particular flood-frequency technique.

III. Objectives:

1. To select for comparison those techniques commonly accepted by professional hydrologists and any new promising techniques.

2. To use the maximum number of gaged watersheds smaller than 100 square miles for a national comparison of analysis techniques.

3. To recommend the preferred technique region by region, giving consideration to watershed size, physiographic provinces, climatic differences and other factors controlling hydrologic homogencity.

4. To prepare regional maps of any statistical parameters needed to apply a preferred technique.

IV. Urgency:

Flood frequency predictions are basic elements in the design of highway drainage structures. The success or failure of a design is often dependent on the accuracy of such predictions. Engineers have frequently been misled into underdesign or applied factors of safety resulting in overdesign. The consequences have been expensive in either case. For the past 10 to 15 years the U. S. Geological Survey in cooperation with many state highway departments has collected runoff data from a large number of small rural watersheds. These data provide a real opportunity for a study and comparison of flood-frequency techniques. The results of such a study would reduce the risk element in the hydraulic design of bridges and culverts and lead to more uniform practice in the prediction of design discharges for such structures.

Research Problem Statement No. 3

I. Title:

Test and Evaluation of Expressway Drainage Design

II. Problem Area:

A number of expressway storm drainage systems in Chicago have been designed by the principles outlined in a paper by Tholin and Kiefer, Transactions, American Society of Civil Engineers, 1960. This is the most advanced method of design so far developed but it has been used very little, if at all, outside of the Chicago area. The validity of the method should be evaluated.

III. Objectives:

To measure the performance of the surface drainage system on selected portions of expressway in the Chicago area under actual storm conditions, measurements to include (a) continuous recording of rainfall over entire drainage area and (b) continuous recording of runoff on subunits of storm drain system for which rates of flow had been computed in the design process.

To compute runoff for the observed storms using equations from the design process.

To analyze computed vs. observed performance of subunits and of entire watershed.

To evaluate the validity of the design method.

To recommend improvements in the design method arising from analysis of performance.

IV. Discussion:

This study is deliberately limited to evaluation of drainage design on expressways by the "Chicago" method. All of the major expressways constructed since 1948 have been designed by this method. Evaluation of the method by investigation of the performance of systems so designed would open the way to wider use of the method. The engineer working with urban drainage problems is in urgent need of a more reliable means of designing storm sewers.

Research Problem Statement No. 4

I. Title:

Test and Evaluation of Inverted Siphons for Sanitary, Combined and/or Storm Sewers.

II. Problem Area:

The construction of expressways and subways in urban areas usually necessitates numerous adjustments in existing sanitary, combined and/or storm sewers. While this can sometimes be accomplished by rerouting, occasionally the only alternative is to siphon the sewer beneath the expressway (or subway). Certain empirical rules for the design of such structures have evolved from analysis and experience but no thorough evaluation of the performance of inverted siphons has been made. There is a distinct need for good information on design procedures and design details which have proved to be successful.

III. Objectives:

To make a state-of-the-art study and define the nature and extent of the problem.

To select one or more existing installations for intensive observation.

To analyze performance of such installation(s) according to best theory available, including comparison of design capacity with actual performance under carefully recorded conditions.

To develop a design manual on inverted siphons for sanitary, combined, and/or storm sewers specifically related to the types of problems covered by the study.

IV. Discussion:

This study could range from a compilation of design details of a single installation and evaluation of its performance to a comprehensive investigation of many installations. The extent to which good records are available on performance of existing installations will determine the amount of effort required. The short range objective is to provide information for use by designers confronted with the problems of getting a sewer line past a new expressway or subway which cuts through its path. The intent is to direct the effort at the situation where an existing line must be disturbed rather than the one where a new sewer line is being designed. In the latter case the head losses inevitably involved with the siphon can be taken into account, whereas for the existing line such losses were not contemplated and therefore their effect on the overall capacity of the line must be calculated.

Research Problem Statement No. 5

I. Title:

Scour Around Bridge Piers and Abutments

II. Problem Area:

The determination of depths of scour around bridge piers and abutments during floods and from tidal currents has long been a matter of concern to bridge engineers. Failure of some structures in recent years by undermining from excessive scour has emphasized the need for better ways to predict scour. The development of an ultrasonic scour meter under the sponsorship of the Bureau of Public Roads provides a means of mapping the scour hole at both the nose and the downstream end of a bridge pier during a flood. Although model studies of scour at piers date back to 1894, field measurements are needed to correlate laboratory studies. In addition to obtaining field data on scour in bed types represented by model studies, data should be collected on other types of bed material and on clear streams and sediment laden streams, including those subject to ice and drift.

III. Objectives:

To develop methods for estimating maximum scour depths for bridge design and as a basis for designing scour protection.

IV. Urgency:

Most failures of bridges which have occurred have been due to undermining of foundations by scour. Since this usually results in loss of the entire structure, or in large unnecessary costs to prevent failure, the problem requires urgent attention.

Research Problem Statement No. 6

I. Title:

Evaluation of Need for and Methods of Erosion Control in Drainage Channels.

II. Problem Area:

Development of criteria for selection of erosion protective measures.

III. Objectives:

Procedures have been established for design of stable channels using vegetative cover, protective surfacings, flexible linings, pavements, riprap and other treatments. Guidance is needed on field and laboratory methods for evaluating need and effectiveness under varying local conditions. Criteria must be developed for selection under specified conditions including channel velocities, soil types, geomorphology, and operational and maintenance requirements. Designs should be compatible with principles of highway safety and environmental pollution control.

IV. Urgency:

With a wide range of possible methods and materials, many of which are new, designers need guidance to obtain the most economical concepts for specific operational requirements. Improved techniques will lead to major savings in construction and maintenance of drainage facilities and adjacent roadways and shoulders and lessen adverse effects of erosion, including sedimentation of watercourses.

Research Problem Statement No. 7

I. Title:

Scour Control in Bridge Pier Construction

II. Problem Area:

Scour has sometimes damaged cofferdams or otherwise adversely affected temporary installations needed to accomplish beidge pier construction at underwater locations. A number of methods have been used to counteract the forces of scour. For example, the method using willow mats to protect pier footings from scour, as used before 1893 on the Memphis, Tennessee bridge crossing the Mississippi River, is still in use today even to the dimensions of the mats. Sometimes piers have been constructed by building up an island and sinking a caisson through it. Other techniques have also been employed.

Few of the methods used to combat scour at bridge construction sites have been described in engineering literature. This is because the methods were born more as ideas of innovation and invention than scientific investigation. Many good methods have either been handed down by experience or died with their originators. What is needed is a concentrated effort to document the techniques that have been used and make them universally available to construction engineers.

III. Objectives:

To examine from published references the nature of scour as related to bridge pier construction.

To compile, through literature search, construction records and interviews with experienced bridge construction engineers, case histories illustrative of various methods of scour control.

To document and evaluate the relative effectiveness of techniques employed.

To develop guidelines for systematic recording of experience with scour on bridge construction projects.

IV. Urgency:

Compilation and dissemination of scour problems encountered during construction and their solutions would provide a basis for improving construction procedures and would lead to lower construction costs by reducing the contingency allowance for unanticipated foundation construction difficulties.

Research Problem Statement No. 8

I. Title:

Effectiveness of Scour Prevention Measures at Bridge Piers and Abutments.

II. Problem Area:

Scour around bridge piers and abutments has frequently undermined foundations and caused structural damage or failure. To combat scour, engineers have tried a variety of protective measures, some designed and constructed as part of the original structure and others installed after high water and serious scour experience. Of the latter, the scour protection may have been formally designed and constructed or the remedial measures may have been applied by maintenance forces as part of a flood emergency. In most cases there has been no documentation of the effectiveness of scour prevention measures.

It is proposed that studies and field surveys be undertaken to evaluate the efficacy of measures to prevent or control scour. Both effective and ineffective treatments need to be reported and compared. It is anticipated that such documentation would prove invaluable in determining the need for scour protection and would define the types of treatment to be applied for safeguarding future structures.

III. Objectives:

To search, document, and classify methods of scour protection from the standpoint of both preconceived treatments constructed as part of the original structure and post-construction treatments installed after scour has occurred.

To make field surveys of structures that typify various protective treatments and determine relative effectiveness for a range of exposure conditions. To critically analyze and evaluate the various types of protection and develop recommendations for practices judged most effective in controlling scour at bridge piers and abutments.

IV. Urgency:

Either the lack of scour protection or failure of poorly-conceived protection can cause the loss of a bridge, possibly human life. Ill-conceived, ineffective scour protection is expensive and wasteful. Highway engineers can ill-afford to waste money and materials on ineffectual methods. A review of methods should result in more prudent design and identify areas of research which would further improve scour control practices.

Research Problem Statement No. 9

I. Title:

Spur Dikes at Bridge Abutments

II. Problem Area:

Many highway crossings of major streams have long approach fills on the flood plain to reduce structure costs. These fills block the passage of overbank flow and divert flood plain flow to a bridge opening. Eddies, formed when lateral flow from the flood plain mixes with main channel flow, cause scour at bridge abutments and at adjacent piers and reduce the effectiveness of part of the bridge opening. Spur dikes, projecting upstream from bridge abutments, have been effective in preventing serious problems at these locations, but research data are needed to develop criteria for the design of the spur dikes.

Although existing research data and field observations of existing dikes have been very helpful in the design of spur dikes, additional research information is needed to improve designs and to give engineers more confidence in their performance. Needed research on these structures consists of two parts which can be programmed concurrently. Part 1 includes extensive laboratory testing of various types and shapes of dikes in both fixed and movable bed models. Part 2 consists of field observations and measurements of flood conditions at existing dikes.

III. Objectives:

To expand present data so that adequate criteria can be developed for the design of spur dikes taking into account various types, shapes and orientation.

To analyze and evaluate performance of prototype installations in the field during and following flood flow.

IV. Urgency:

Good design criteria and additional field observations of existing dikes will encourage a wider and better use of these structures. It is estimated that the use of spur dikes in conjunction with new bridge construction and remedial work on existing bridges could approach savings of $3 million annually.

Research Problem Statement No. 10

I. Title:

River Training Works as Related to Highways

II. Problem:

The highway engineer is often confronted with the problem of stabilizing channels at highway stream crossings. The task may involve training works associated with either a channel relocation or control of channel shifting and bank erosion. Most river training installations are expensive and many have failed to accomplish desired results. A need exists for information on this subject compiled for ready use by highway engineers. Case histories, design methods and details, costs and materials relating to control of river meanders and undesirable channel shifting should be studied and presented in a form useful to the highway designer.

III. Objective:

To prepare a state-of-the-art report on river training works with specific application to the highway river crossing problem.

IV. Urgency:

Failure to recognize the need for training works at highway river crossings can result in costly structural failures, some often occurring during or shortly after completion of construction. Guidelines are needed for design and for implementing the hydraulic aspects of the national bridge inspection program.

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