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STATUS REPORT OF RESEARCH PROJECT
ON
THE EFFECT OF SPUR DIKES ON FLOOD FLOWS
THROUGH HIGHWAY BRIDGE ABUTMENTS

Prepared by
John B. Herbich,
R.P. Apmann, and S.M. Ali

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1. **Introduction**

The following report summarizes the studies performed during the period September 1959 to February 1960, at the Hydraulics Division of the Fritz Engineering Laboratory, Lehigh University, on the effect of spur dikes on flood flow through highway bridge abutments. The work is supported by the consulting engineering firm of Modjeski and Masters, Harrisburg, Pennsylvania.

The project is a continuance of the research work on spur dikes done at the Fritz Laboratory, initiated in February 1959. Results of that work are reported in two papers: THE EFFECT OF SPUR DIKES ON FLOOD FLOWS THROUGH HIGHWAY BRIDGE ABUTMENTS, by Robert J. Carle and James C. Kable, and THE DETERMINATION OF THE LENGTH OF SPUR DIKES FOR FLOOD FLOWS THROUGH HIGHWAY BRIDGE ABUTMENTS, by James C. Kable.

2. **Objectives**

The earlier work showed that spur dikes attached to bridge abutments placed at right angles to the flow, could be used to lessen scour of channel material about the abutments. Therefore, the stability and safety of the bridge would be increased in times of flood flow. The investigation was made using a single width of abutment opening.
Realizing that bridges are sometimes placed at a skew with the direction of flow, the present work is being done on abutments placed at an angle of 60° to the flow. Future research will be done with abutments placed at 75° to the flow direction. Tests will be made at three different openings between abutments, and four different discharges will be used.

After initially determining the effect of the abutment construction on the flow, spur dikes will be fitted to the abutments. The shape and length of the spur dike which is best for each abutment position will be the one which controls the flow pattern about the abutment best for the lowest cost of construction.

3. **Review of Literature**

Three papers on model studies of spur dikes were reviewed. In **HYDRAULIC MODEL STUDY OF SPUR DIKES FOR HIGHWAY BRIDGE OPENINGS**\(^{(3)}\), and **LABORATORY STUDY OF SPUR DIKES FOR HIGHWAY BRIDGE PROTECTION**\(^{(4)}\), Susumu Karaki of Colorado State University, presents a design curve for elliptically-shaped spur dikes fitted to round-ended abutments. The work was done on a movable bed model and the width and depth of scour were measured.
Erling Reinius of Chalmers Technical University, Göteborg, Sweden, reported an instance of a model study of a spur dike in his paper: MODEL STUDIES OF THE EROSION AT A BRIDGE SITE. No data are presented on the value of the spur dike.

4. Theoretical Analysis

Mathematical analysis of the problem of locating spur dikes is almost impossible, since the flow conditions are unlike potential flow cases. The use of flow nets would be time-consuming and the results would be questionable. An electrical model could be made, but to obtain reasonable results, the flow patterns would have to be determined from fixed bed model studies.

Although an exact analysis of the determination of size and shapes of spur dikes is not possible, certain physical principles may be applied to alter the flow patterns. After the proper installation of the spur dike, the flow pattern existing will be one in which eddies and separation are absent, and in which the velocity distribution is uniform across a section.

The most significant presentation of data is one in dimensionless form. A few of the variables influencing the flow pattern, and thus the shape and size of dikes, are:
a. Discharge, $Q$

b. Angle of Skew, $\theta$

c. Ratio, $\frac{\text{Breadth of Opening}}{\text{Breadth of Channel}} = \frac{L_1}{L}$

d. Froude Number, $V/\sqrt{gd}$

e. Various Shape Factors

5. Experimental Studies

The subject of the tests, run since September 1959, has been the determination of conditions of flow without spur dikes and the effect of the constriction caused by the embankment fill and the abutments on the flow.

The equipment used in the work is the same as described in Section 4 of Carle and Kable's report(1).

The bottom of the fixed bed tank was painted with new grid squares and a rail was placed on the side of the tank. Wheels were attached to the bridge. These changes facilitate the taking of readings.

The Leupold, Volpel midget current meter was found to have insufficient range for the high velocities encountered in the 60° skew case. A new meter was ordered and will be placed in service in late February 1960. Several of the higher discharge tests could not be run because the velocities were too high for the old meter.
For the series of tests at 60° skew, three abutment openings have been selected. They are: 23-1/2 in., 41-1/2 in., and 50-1/2 in. For each opening, four discharges should have been run: 1 cfs, 2 cfs, 3 cfs, and 4 cfs. In tests where the 3 cfs and 4 cfs runs were omitted, the data will be taken when the new meter is available;

6. Experimental Observations

With the corners of the abutments lettered as in the accompanying figure, it was noted that for the worst conditions, that is, test 3d (59-1/2 in. opening with 4 cfs flow) and test 2b (23-1/2 in. opening with 2 cfs flow), separation and turbulence along edge FG of the downstream abutment was pronounced. An abrupt hydraulic jump was formed between points F and G (Fig. 2). Separation also occurred at points A and B, and although milder there, it seemed sufficient to cause scour in a prototype (Fig. 3).
At smaller discharges similar conditions prevailed, although on a less pronounced scale. At points A and B, the separation was noticeably less, and this section acted as a transition for the flow.

Based on the model tests, the following tentative conclusions may be made:

a. Conditions in the skewed bridge case are much more severe than in the right angle approach case. The skewed bridge will scour at comparatively low discharges.

b. Very little construction of dikes need be made near section AB of the upstream abutment. A dike is necessary at section EF of the downstream abutment and stub dikes should be installed below both abutments; this is particularly necessary below point G in the downstream abutment, since supercritical flow exists there.

Contours of depth and velocity field are attached for all experimental work to date to show the drawdown at corners and the high velocities and gradients encountered.
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   Chalmers University of Technology
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   November 1956
APPENDIX

Figures 2-15         9-20
FIG. 2 - HYDRAULIC JUMP FORMED ALONG LEFT ABUTMENT AT Q = 4 cfs; ABUTMENT OPENING = 59-1/2 in.

FIG. 3 - SEPARATION ALONG RIGHT ABUTMENT AT Q = 4 cfs; ABUTMENT OPENING = 59-1/2 in.
FIG. 4 - GENERAL VIEW LOOKING UPSTREAM
Q = 2 cfs; ABUTMENT OPENING = 23-1/2 in.

FIG. 5 - GENERAL VIEW LOOKING UPSTREAM
Q = 2 cfs; ABUTMENT OPENING = 41-1/2 in.
FIG. 6 - FLOW PATTERN THROUGH ABUTMENTS

\[ Q = 2 \text{ cfs}; \]

ABUTMENT OPENING = 23-1/2 in.
Fig. 7 - VELOCITY DISTRIBUTION

Flow 1 cfs
Abutments at 60°
Opening Between Abutments 41-1/2 in.
Fig. 8 - VELOCITY DISTRIBUTION

Flow 2 cfs
Abutments at 60°
Opening Between Abutments 41-1/2 in.
Fig. 9 - VELOCITY DISTRIBUTION

Flow 3 cfs

Abutments at 60°

Opening Between Abutments 41-1/4 in.
Fig. 10 - VELOCITY DISTRIBUTION

Flow 1 cfs
Abutments at 60°
Opening Between Abutments 23-1/2 in.
Fig. 11 - VELOCITY DISTRIBUTION

Flow 2 cfs

Abutments at 60°

Openings Between Abutments 23-1/2 in.
Fig. 12 - VELOCITY DISTRIBUTION

Flow 1 cfs

Abutments at 60°

Openings Between Abutments 59-1/2 in.
Fig. 13 - VELOCITY DISTRIBUTION

Flow 2 cfs

Abutments at 60°

Openings Between Abutments 59-1/2 in.
Fig. 14 - VELOCITY DISTRIBUTION

Flow 3 cfs

Abutments at 60°

Openings Between Abutments 59-1/2 in.
Fig. 15 - VELOCITY DISTRIBUTION

Flow 4 cfs

Abutments at 60°

Openings Between Abutments 59-1/2 in.