Field Measurement of Bridge-Pier Scour

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AN ELECTRICAL apparatus, utilizing the difference in conductivity of water and a sand-water mixture, has been developed to record the scour depth at a point near a bridge pier or abutment. Routine operation of the instrument and collection of auxiliary data can be handled by an engineer or laboratory technician without special training. The initial field installation, which records data on a standard Esterline-Angus recorder, has been in operation on the Skunk River near Ames, Iowa, for more than a year. As pointed out in the companion paper, more measurements at simple sites such as the Skunk are needed in order to establish model-prototype conformity. The instrument can also be used at sites of complex geometry to accumulate design data.

● IN ORDER to make practical use of laboratory measurements, the research program on bridge-pier scour has been extended to include field measurements[1] with two primary objectives: to establish model-prototype relationships for certain idealized cases, and to study complex sites so that the reliability of the idealized systems as indicators of the general problem can be determined. To date, only the former of these two objectives has been attacked, but it is hoped that increased interest among bridge designers will stimulate the collection of more data for practical use. The development of equipment and techniques to facilitate and standardize efforts along this line has been a part of the research program, and the results of this development are considered an important part of the present report.

MEASURING INSTRUMENT REQUIREMENTS

Continuous measurements during the course of a flood are essential for determining the extent of scour at a pier because of the dependence of the scour upon the flood duration, and because the scour hole is partially refilled by deposition during the receding stage. Due to this latter fact, observations made after a flood has passed are usually misleading quantitatively, although their qualitative value may be important.

[1] The project described in this paper was conducted jointly by the Iowa Institute of Hydraulic Research and the Iowa State Highway Commission. Full financial support has been provided by the Iowa State Highway Commission.

Because the development of a suitable measuring device had to precede the field work, the factors which had to be considered will be reviewed. The first, scour depths to be measured, was known from the laboratory investigation to increase with both the pier size and the depth of flow. Since the field sites might range from small piers in small streams to piers several times as large in the deepest rivers, the instrument should be easily adaptable to a wide range of conditions with a reasonably constant relative accuracy. As already noted, a continuous record of scour throughout the period of high water is necessary, and the simultaneous recording of river stage would be highly desirable. Changes in sediment characteristics, the quality of the water, or atmospheric conditions should not cause ambiguous indications, and the operating power should not be obtained from power lines because these are most likely to fail during floods, when data are most urgently needed. Finally, the costs of installation and maintenance should be kept to a minimum so that units can be installed in many locations for the collection of design data.

OPERATING PRINCIPLE

In the laboratory, an instrument depending upon the difference between electrical conductivities of the stream and of the bed material was used, and this principle has been adapted to field conditions. A series of electrodes are placed on a vertical line in the pier

Figure 1. Skunk River site (very low water).

or on a support near the pier, extending downward to below the maximum expected scour depth. The number of electrodes required is dependent on the desired accuracy, which depends, of course, upon the spacing. Alternating current at any convenient power frequency is passed from each of these electrodes to a nearby common ground. The impedance to the flow of current through the bed is much greater than the impedance of the water, so that a continuous record of impedances at all measuring points will show a distinct difference at the bed level. Changes in the temperature or chemical content of the water will also change the values appreciably, but the difference remains as a reliable indicator.

The electrical impedance is measured by connecting a wire from each electrode to a terminal on a motor-driven selector switch. As the switch rotates, the electrodes are connected, in order, to a measuring circuit which records the electrical impedance on a strip chart driven by a clock motor. A continuous record against time is thereby obtained from which the bed level at any time can be ascertained by simply counting the number of electrodes showing high impedance. By adding an indication of the river stage to the same chart with the scour data, the desired relationship between water and scour depths can be obtained. Using a standard float, cord, and pulley attached to a precision rheostat, an indication of stage is provided for recording on the aforementioned scour depth chart. An extra terminal on the electrode switch is simply connected to the stage rheostat so that its resistance is recorded on every revolution of the switch. Still another pair of contacts on this switch are connected to a fixed resistor so that a standard is always available which can be compared with all other readings to indicate variations in overall sensitivity of the measuring circuit due to any cause whatsoever. This standard deflection on the chart also serves as an index for the location of the first electrode on the pier. Reliable power to operate the apparatus for

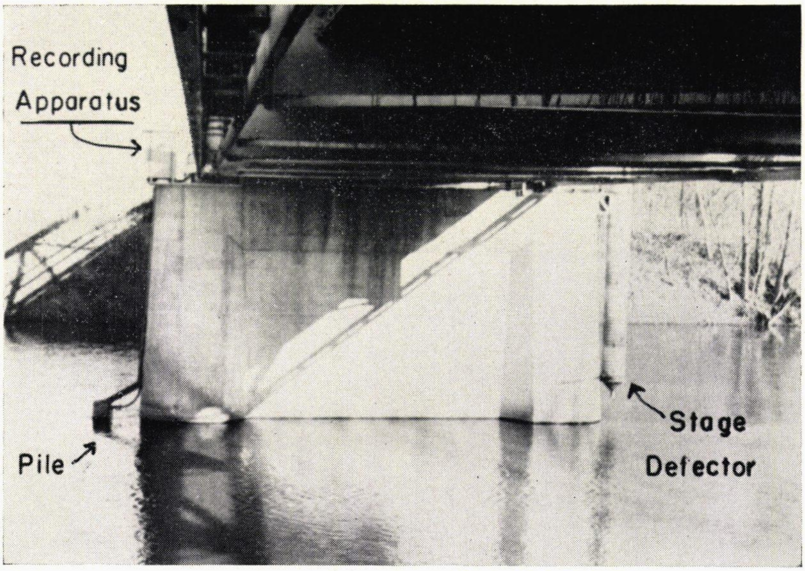

Figure 2. Measuring apparatus at the field site.

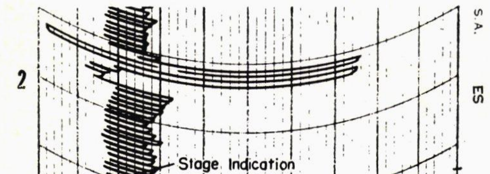

Figure 3. Typical section of a record chart.

two weeks is furnished by regular automobile storage batteries which drive the switch motor and an inverter to supply alternating current.

INSTALLATION AT A FIELD SITE

With a measuring device available, the next problems were the selection of a field site simple enough to be modeled reliably in the laboratory for comparison, and the installation of the necessary apparatus. This phase of the project was handled primarily by the Iowa State Highway Commission, with which the field project was jointly conducted. The characteristics used as a guide in selecting a site were: A single pier located in the center of a river and aligned with the direction of flow; a bed of sand without gravel or clay and extending downward at least as far below the surface as any possible scour; a straight, uniform approach channel free of shore projections and having steep sides; a pier arrangement which produces local scour rather than overall degradation because of excessive contraction; an established recording gage near the site. After an extensive survey, a site meeting all the specifications was selected on the Skunk River near Ames, Iowa, fortunately near the headquarters of the Highway Commission for ready servicing. At a section which had been artificially straightened about 40 years earlier, the bed consisted of sand free of cementing materials, and a county highway crossed the stream on a bridge with a single pier in the center (see Fig. 1). At this point, the width of the stream is approximately

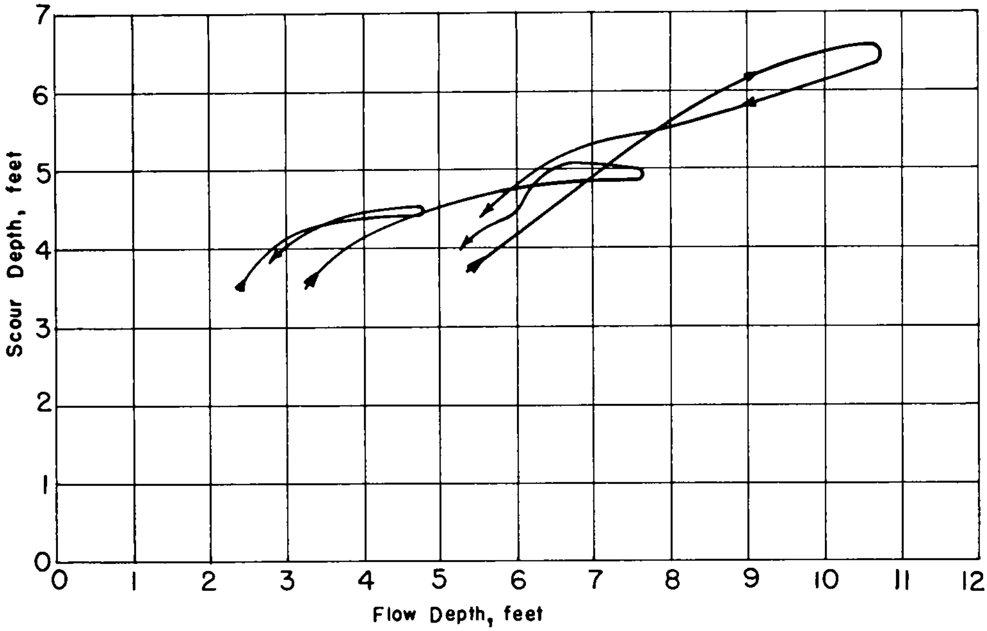

Figure 4. Summary of data collected at the Skunk River site.

135 feet and overbank flow does not occur until a stage of approximately 12 feet is reached.

A 12-inch square concrete pile into which the measuring electrodes had been cast was sunk, by jetting, directly in front of the pier and secured firmly. The electrodes, 29 in number, were made of stainless steel, were 1 inch in diameter, and were spaced 6 inches on centers. Wires from these electrodes were brought up through a central pipe to the top of the pile, and through rigid conduit from that point to the top of the pier. They were thus protected from ice or other debris in the water and from vandals. At the downstream end of the pier, the stage float and rheostat were mounted in a steel culvert fastened to the pier, and connecting wires were run through pipe to the measuring apparatus (see Fig. 2).

PERFORMANCE

A typical section of the recorder chart for this installation is reproduced in Fig. 3, and it can be seen that time, river stage, scour depth, and sensitivity factor are all represented. When the apparatus is serviced biweekly, the stage, scour depth, and general bed level between pier and abutment are all checked by a weighted line and the data are entered at the end of the used chart. This independent check on the performance is sufficient for detecting any possible malfunction of the apparatus or change in the general level of the river bed. In addition to making these measurements, the routine servicing consists of replacing the storage batteries with freshly charged ones, winding the clock motor on the recorder, and replacing the record chart.

Since the apparatus was installed in the spring of 1953, one major flood and two minor ones have occurred on the stream, and Fig. 4 is a summary of the data collected by the instrument. In this figure, the direction in which the stage is changing is indicated by arrows, and the curves show a definite relationship between scour depth and water depth as predicted on the basis of earlier laboratory investigations. At the maximum scour condition indicated by these curves, the pilings supporting the pier were exposed on the upstream side, although probably not enough to endanger the structure. However, this should point up the need for a careful consideration of this potential source of danger.

SUMMARY

The instrument developed for measuring scour depth in the field has been used for a period of over a year with only routine servicing. The data obtained have provided the necessary and sufficient prototype information for comparison with a model study as described in the following paper in these Proceedings. The servicing procedure established includes routine maintenance of the recording portion of the instrument and check measurements of the water surface elevation and the stream bed elevation between the piers and in the scour hole. Personnel of the Iowa State Highway Commission laboratories—without special training—have capably handled the field operation. Probably any engineer and most engineering aides would be equally competent.

Now that a tried instrument is available, the field measurement program should be expanded. The measurement of scour at sites of simple geometry should eventually serve to establish the needed model-prototype relationship. The measurement of scour at sites of more complex geometry, both typical and extreme, should provide the factual data to guide the designer in his estimate.

Model-Prototype Comparison of Bridge-Pier Scour

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QUALITATIVELY, the patterns of scour around bridge piers and abutments obtained in the laboratory have also been observed in the field. Moreover, certain apparent anomalies of field scour have been rationalized on the basis of the concept of scour formulated during the laboratory study. The first quantitative comparison of scour in model and prototype has been the laboratory study of a 1:12 model of the Skunk River pier described in the companion paper. Although the results of this study indicate that as a first approximation the depths of scour in model and prototype might be related simply by the geometric ratio, the single site investigated does not supply sufficient evidence for a general conclusion. Field measurement of scour at other sites of simple geometry is therefore needed.

● BECAUSE the purpose of the laboratory investigation of scour around bridge piers and abutments, being conducted by the Iowa Institute[1], is to find a means whereby scour in the field can be predicted, the establishment of the model-prototype relationship has always been considered a part of the general program. The measurement of scour in the field described in the preceding paper in these Proceedings made possible a study of model-prototype conformity. This study, plus qualitative model-prototype comparisons plus certain conclusions drawn from the laboratory investigation, is very encouraging in that the model-prototype relationship indicated is simple. However, other aspects of the laboratory investigations and the fact that only one quantitative model-prototype conformity study has been made suggest that caution should be exercised in drawing any general conclusions at this time. More field measurements at sites of simple geometry are needed. Simple sites are desirable because of the ease of modeling and of interpreting the results. The Skunk River bridge is a good example of a desirable site. There should be other sites scattered throughout the country where the needed field data can be obtained.

[1] A project sponsored jointly by the Iowa State Highway Commission and the Bureau of Public Roads.