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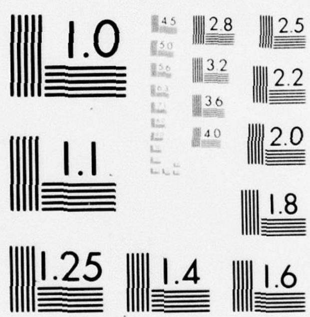

ENGINEERING AND SCIENTIFIC RESEARCH AT WES

Miscellaneous Paper O-73-6

May 1973

PROTECTION OF CONCRETE AGAINST CAVITATION DAMAGE, *by Leonard Pepper, Concrete Laboratory*

Cavitation has long been the bane of designers of hydraulic structures. Even the strongest concrete can be destroyed by cavitation, as can steel and other materials generally regarded as unusually strong, tough, and durable. The Arizona Spillway of Hoover Dam developed a hole 145 ft long by 30 ft wide to a depth of 24 ft due to cavitation removal of the concrete lining, and cavitation has also damaged concrete in Corps of Engineers dams.

Cavitation damage to concrete surfaces results from the formation of bubbles in flowing water in areas of low pressure which collapse with great impact force as they enter areas of high pressure. An example of the damage caused by this phenomenon is shown in fig. 1. Such cavitation erosion is the result of hydraulic heads greater than those which the structure was designed to withstand or, more frequently, unplanned irregularities in surfaces over which water flows at high velocity.

The Waterways Experiment Station in cooperation with other Federal agencies, notably the U. S. Naval Applied Science Laboratories, conducts a continuing program aimed at identifying materials of superior resistance to cavitation erosion that might be used to protect concrete, and the development of techniques for their use in both new construction and the repair of damaged existing structures. After it has been established by laboratory tests that a material has significantly greater resistance to cavitation erosion than does concrete, various adhesives, surface preparation procedures, and application techniques to produce optimum bond strength between the cavitation-resistant material and concrete are investigated.

Fig. 1. Example of cavitation damage on concrete surface

The materials and techniques that offer the greatest promise in the laboratory are field tested on 2- by 10-ft concrete slabs in the test conduit at Detroit Dam in Oregon. High-quality concrete exposed in the conduit, which is shown in fig. 2, is extensively eroded after 7 hr. Concrete coated with various epoxy formulations has withstood varying time intervals up to 200 hr in the conduit before showing signs of incipient failure.

Significant results of the field testing at Detroit Dam to date are:

a. Sheet neoprene, which is extremely resistant to cavitation erosion, presents bonding problems after about 5 hr in the conduit.

b. A test slab coated with liquid urethane withstood 64 hr of testing without any evidence of cavitation damage.

The urethane-coated slab is now being stored in water to determine the long-range effect of water absorption on the coating.

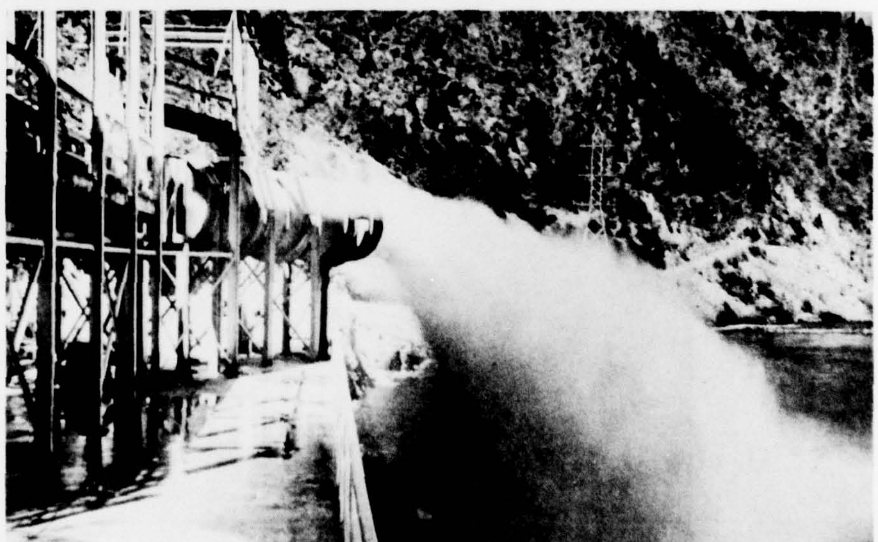

Fig. 2. General and closeup views of test conduit at Detroit Dam

RELATIONSHIP OF BENDS AND CHANNEL WIDTHS FOR PUSH TOWING, *by L. J. Shows, Hydraulics Laboratory*

The need for basic design information concerning the required channel width in bendways has been apparent since the canalization of streams and rivers for navigation was undertaken. Because of the ever-increasing amount and size of barge traffic, the many additional miles of improved channel now opened for barge traffic, and the great cost of maintaining navigable channels, the need for the design of channels of economical width in bendways has become increasingly more important. In an effort to improve current channel design procedures for use in the development of the Red River for navigation, an undistorted semifixed-bed hydraulic model reproducing a typical river bend was improvised in an existing model to a scale ratio of 1:80 at the Waterways Experiment Station. The channel configurations are typical of what can be expected in an alluvial stream in that the deep channel is on the outside of the bend and the bar on the inside. The maximum channel width used is 600 ft and extends through 90 degrees of curvature. The different radii are obtained by molding the pea rock banklines to the desired curvature. Channel widths required for a particular radius are determined by operating model towboats and successively reducing channel width available for navigation by changing the channel markers until limiting conditions are reached (fig. 1). The towboats and tows are similar to those used in the development of satisfactory navigation conditions in lock approaches and in critical reaches of navigable streams. The towboat's speed, rudder, and direction are remote controlled.

With a known tow size and maximum drift angle (the angle between the tow and a tangent to the curve at the bow of the tow) assumed by the tow in navigating a particular bend, the required channel width for one-way and two-way traffic can be easily computed. However, studies indicate that the drift angle is dependent on many factors. Some of the more critical are: (a) radius of curvature, (b) degrees of curvature traveled by tow, (c) tow draft, width, and length, (d) speed of tow in relation to currents, (e) direction and velocities of currents, (f) direction of travel of tow (upstream or downstream), (g) tow flanking or driving around the bend, and (h) alignment and position of tow entering bend. Under certain conditions the drift angle could be less than the maximum, particularly in bends with short radii or with tows equipped with high-powered towboats. Tests are being conducted using tows of various lengths and widths that could be using the waterway and maintaining constant as many of the variables as practical, including clearance between bankline and tow and between tows in the case of two-way traffic.

In general, the results of the model study to date have indicated that for a particular radius of curvature the maximum drift angle for the same length of tow is about the same regardless of the tow width when traveling through 90 degrees of curvature for the following conditions:

a. Driving in slack water or upstream against 4-mph currents.

b. Flanking downstream with the currents.

This would mean that the channel width would have to be increased by the amount of increase in the width of

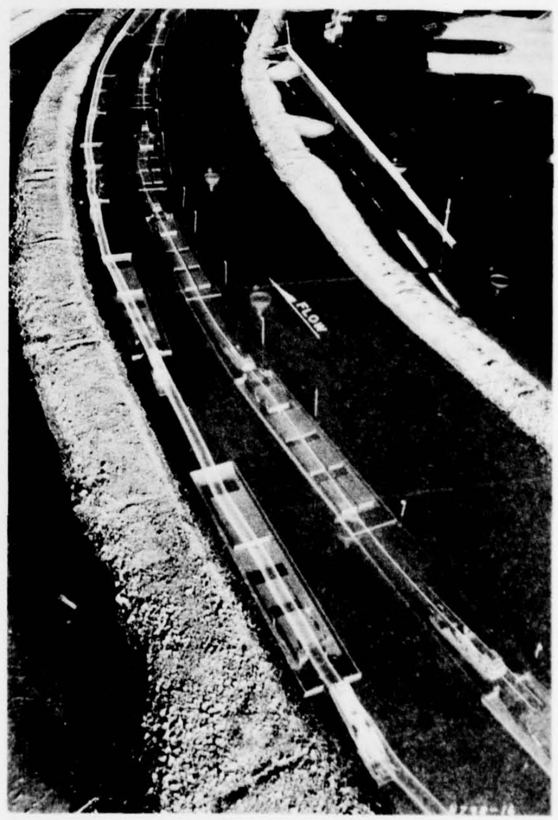

Fig. 1. Time-exposure photo of upbound and downbound tow

the tow or tows. However, it was determined that when tows are driving downstream with 4-mph currents (the speed of the tow in relation to the currents being just enough to maintain steerage), the drift angle would be increased to at least twice the drift angle required for the conditions stated above. The drift angle for the wider tow would be greater than for a narrower tow. Because of this condition, the actual channel width for a wider tow would have to be considerably greater than the amount of increase in tow width.

The above are some of the factors affecting the design of channel widths for navigation in bends and should be considered in the development and improvement of inland waterways.

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Hydraulics Laboratory:

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C-5A Aircraft Live Flight Support Test Operations, Harper Lake, California, by R. W. Grau, Miscellaneous Paper S-73-6, Feb 1973.

Test Fills for Rock-Fill Dams, by D. P. Hammer and V. H. Torrey III, Miscellaneous Paper S-73-7, Mar 1973.

Automatic Data Processing Center:

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Explosive Excavation Research Laboratory:

Demolition of Ft. Meade Dam, Sturgis, South Dakota, June 1972, by B. B. Redpath, Miscellaneous Paper E-73-1, Jan 1973.

Thermal and Reactor Analysis of Nuclear Rocket Transients, by R. R. Mills, Jr., Miscellaneous Paper E-73-2, Mar 1973.

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Aquatic Plant Control Program; Report 1, Controlled-Release Herbicides, by E. O. Gangstad, R. H. Scott, Jr., and R. G. Cason, Sep 1972.

Aquatic Plant Control Program; Report 2, Response of Aquatic Weeds to Laser Radiation, by R. W. Couch, Dec 1972.

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