SESSION ON

TRANSPORTATION OF SILT AND DETRITUS

Presiding:

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HYDRAULIC MODELS—GEOMETRICAL OR DISTORTED

by

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A decade has passed since the return of this writer from a year of study in the hydraulic laboratories of Germany. At that time, although the move had been made to inaugurate practical experimental hydraulics on a large scale in the United States, considerable skepticism was still evident in many parts as to the general reliability of models. The effect was to put the proponents on their mettle and incite them to produce adequate and immediate proof as to the accuracy of their results. Their greatest initial problem, in this same connection, was to convince the Missourians that distortion could be carried beyond limits which had been rigidly and arbitrarily established by the older, European school of thought. Although laboratories had been long since established in the technical universities of England, France, Italy, Switzerland, and Germany, it was only in the last-named country that experiments had been conducted on a relatively broad and practical basis. And even in Germany there had been demonstrated a definite fear of distortion and its possible effects. The attitude was generally taken that a moderate exaggeration of vertical dimensions over the horizontal was to be condoned, but that the factor four or five represented a maximum limit. This made it possible to build models of the Elbe. Rhine, or any other European River with reasonable economy, but precluded experiments relating to our great American Rivers. It soon became evident that if river laboratories were to play an important role in the United States it would be necessary to apply distortions in excess of those approved by the Europeans. Fortunately, the results obtained were sufficient to convince even the most doubtful of the skeptics; but, as such things go, there ensued a swing in the opposite direction, and with the passing of years there has been shown an increasing tendency to distort river and harbor models beyond logical limits. The height of optimism was reached recently when the model of a great river system was built in the hydraulic laboratory of an important technical university with an exaggeration of 210 applied to the vertical scale.

In the last few years, models have become so fashionable that. in many cases, engineers have attempted to substitute testing for thinking. Now experimentation, especially as related to hydraulics. is a fine thing, but it should never be considered as more than an aid to the processes of thought. The model study should be regarded as a guide and indicator, not an integrator for all the odds and ends of data which can be poured into it. Models cost money to build, and more to operate. They serve a valuable purpose not limited in scope, but are not cure-alls for every problem, nor should they be built on any kind of pretext. Quite recently there arose a problem for which a model study was desired. The project being hardly large enough to merit the name, it was decided that a very small sum should be stipulated for the cost of the experiment. In fact the sum was so small that it would have been better not to have undertaken the test at all. Failure to obtain results, in such a case, reflects unjustly on all other model tests.

In recent years we have seen model studies conducted in every branch of science and engineering. There have been models of rivers and harbors, airplanes, ships, earth structures, frame structures, buildings, locomotives, machines of every kind, molecules, atoms, and electrons, until we have been led to believe that a well built model will provide the answer to any perplexing question.

In the field of hydraulics, models have been classified according to their beds, as fixed and movable; and according to their dimensions, as distorted and undistorted. There is yet another classification—that as to purpose—which may be given as follows:

- a. Illustrative models. These are of little scientific value, yet are used in every science for instructional purposes. They serve to acquaint the layman with engineering problems and their solutions, and are found abundantly in museums and college laboratories, and at expositions. Since they are designed and built for appearance rather than for test we may drop them from further consideration.
- b. Specific models. These are the kind that are built and tested to produce the answer to a particular problem, such as the de-

sign of a spillway, the location of contraction works in a river, or of jetties at a harbor entrance. They are extremely valuable and pay big dividends in dollars and cents. The only trouble is that the data obtained from them are not as a rule sufficiently correlated with other similar data. Because they always represent a specific project and thus pay for themselves, they are frequently discarded and destroyed when they have served their immediate purpose. In the case of spillways, so many models have been built that, were all the facts and data to be brought together, principles of design might be evolved which would have a general application. In this way the cost of future tests might be greatly reduced.

c. General models. These are the rarest of all models because they are not self-supporting; yet, paradoxically, they often yield the most valuable results. Their principal limitation lies in the fact that they are so often built and operated on insufficient funds that it becomes frequently necessary to stop short of attaining data adequate to establish or sustain a principle. In many cases the inaccuracies resulting from faulty equipment are so great as to invalidate the results. The experiments of Gilbert, Kramer, et al, relative to determination of bed-load movements are among the most valuable that have been conducted, but so many efforts have been wasted by university students in conducting desultory tests of broad-crested weirs, whereby from one set of observations they have attempted to establish general laws, that tests of this nature have fallen into disrepute.

The most forward step recently undertaken in this country has been by the United States Waterways Experiment Station at Vicksburg, Mississippi, in establishing within its own organization the "Hydraulics Research Center," designed to correlate, evaluate, and disseminate experimental data from many sources, both foreign and domestic. Our technical colleges can aid greatly in this work by assigning thesis subjects of limited scope, the results of which will dovetail with the results of other experiments. An effort must be made continually to keep the student from feeling that it is incumbent upon him to make some "startling new discovery" in the field of science. He should be impressed with the fact that he is but a small brick in the edifice of scientific achievement; that perfection is necessary on his part if he is to remain part of a perfect structure; but that no one unit is irreplaceable when we have

such foundations and corner stones as Newton, Bernoulli, Chezy, Francis, Gaillard, et al, to build upon.

In no field of scientific or engineering endeavor does the theoretical touch so closely upon the practical as in the realm of hydraulics. In spite of this, so little is understood of the properties and propensities of water that it is all but impossible to state any explicit law controlling its action. We know its unit weight, of course, and also that pressure is distributed equally in all directions. We know, too, that its rate of flow is affected by resistance encountered in the channel or conduit which carries it, so we assign a value to "n" of the equation which will give us the desired answer. Since "n" in a river includes the effects of roughness. snags, bends, overbank growth, etc., it is readily seen to be little more than an approximation of the truth. Yet, strangely enough. experience has been so great that computations can be made with reasonable sureness, especially if an opportunity exists to check them by the performance of a model. Once a model has been built and operated to reproduce conditions obtaining in the natural river. it is a relatively simple matter to determine the effects of proposed changes in its depth or alignment. Just so, it is also easy to catalogue the type and degree of applied roughness necessary to simulate natural conditions. By keeping records over a considerable period and by tying all results together it should be possible eventually to arrive at index figures representative of all types of resistance found in natural flowing streams and rivers.

Another fertile field for research is in the determination of forces at work in the cross section of a river. Because spiral flow has been identified in pipes and in narrow, deep channels it has been assumed that the same phenomenon occurs in wide, relatively shallow rivers, and that it is this which makes the bed material move over to and deposit upon the convex banks of bends. The results of many tests will be required to determine the full truth or fallacy of this contention, and many more will be needed before the effects of all existing forces can be evaluated and catalogued. What, for instance, causes bed materials to move across stream in the direction of decreasing velocities when helicoidal flow is definitely absent, and what factors determine the percentage of bed material and suspended load that will be carried into the two arms of a branching channel? Numerous data have been accumulated in answer to the

second part of this query, but only a few of the great many possible cases have been tested.

As now can be seen, this paper is, in effect, a plea for closer cooperation on the part of instructors of experimental hydraulics, embodying the expressed wish that they coordinate their assignments to a common end. Students should be taught (in the humble opinion of this writer) not to make revolutionary discoveries, but to think, to evaluate, and to contribute each his part to the comprehensive plan of science. Too many are emerging from our present-day schools with grandiose conceptions of directing and organizing, but with little or no idea of how to approach a job methodically in the capacity of a subordinate. It is rare indeed that we find a newly graduated engineer who can write intelligently and draw neatly. Even more seldom do we find one who can plot his data with accuracy and letter with perfection.

All this may seem a far cry from hydraulic research, but research of any kind is the same in its requirements, which include: neatness, orderliness, impartiality, careful planning, a cold-blooded analysis of data, and a thorough knowledge and appreciation of the work of others who have preceded. When enough students have been so trained and have become sufficiently interested to probe for commonplace data there will be revealed an answer to the question first propounded and oft discussed: "What are the ultimate limits of distortion in hydraulic models?" Following this, an answer will be obtained to the question: "Can greater distortion be applied to models of small scale than to those of large?" Then being on the road to knowing what our models are all about we should be able to evaluate the roughness factor, improve our open-channel formulas, and learn something about the many complex and conflicting forces of flowing water.