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NEW TECHNIQUES AND MATERIALS FOR CONSTRUCTING HYDRAULIC MODELS

by

Noel R. Oswalt, Glenn A. Pickering

Hydraulics Laboratory
U. S. Army Engineer Waterways Experiment Station
P. O. Box 631, Vicksburg, Miss. 39180

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20. ABSTRACT (*Continue on reverse side if necessary and identify by block number*)

Results of efforts to identify and evaluate new techniques and materials for constructing hydraulic models at the U. S. Army Engineer Waterways Experiment Station are reported. A literature search was made to determine types of materials available, and research personnel of other hydraulic laboratories were contacted by telephone and personal visits to obtain independent and additional evaluation.

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Preface

The In-House Laboratory Initiated Research (ILIR) reported herein was authorized by the Director of the U. S. Army Engineer Waterways Experiment Station (WES) in WESVB DA Form 2496, dated 6 September 1974.

During the course of the ILIR, conducted in the Hydraulics Laboratory at WES, numerous research personnel at other agency laboratories and universities were contacted by telephone or visited for their input into this general research effort.

This report was prepared by Messrs. N. R. Oswalt, Research Hydraulic Engineer, and G. A. Pickering, Chief of the Locks and Conduits Branch, under the general direction of Messrs. J. L. Grace, Jr., Chief of the Structures Division, and H. B. Simmons, Chief of the Hydraulics Laboratory. COL G. H. Hilt, CE, was Director of WES during the conduct of this study and the preparation and publication of this report. Mr. F. R. Brown was Technical Director.

Contents

Conversion Factors, U. S. Customary to Metric (SI) Units of Measurement

U. S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
inches	25.4	millimetres
feet	0.3048	metres
square feet	0.09290304	square metres
pounds (mass)	0.4535924	kilograms
pounds (mass) per cubic foot	16.01846	kilograms per cubic metre
Fahrenheit degrees	5/9	Celsius degrees or Kelvins*

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* To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use the following formula: C = (5/9)(F - 32). To obtain Kelvin (K) readings, use: K = (5/9)(F - 32) + 273.15.

NEW TECHNIQUES AND MATERIALS FOR CONSTRUCTING HYDRAULIC MODELS

Purpose

1. The purpose of this project was to identify and evaluate new techniques and materials for constructing certain types of hydraulic models at the U. S. Army Engineer Waterways Experiment Station (WES). Sponsored by the WES In-House Laboratory Initiated Research, the study is indicative of the ever-increasing demand to be innovative for the sake of time savings, costs, and improved modeling technology.

Background

2. Many of the present hydraulic models are constructed in permanent flumes which have existing water supply and drain lines. The availability of these facilities results in considerable savings of time and funds for model construction. In some cases, the scheduled testing program on certain models has been completed but the sponsoring agency wanted to retain the model for possible additional tests. This resulted in these facilities being unavailable for extended periods of time. The conventional methods and materials (cement paving to templates, Figure 1) used in the construction of hydraulic models result in a permanent-type model that cannot be easily removed and replaced later. Development of new techniques and materials for model construction could make it possible to dismantle the model when tests are thought to be complete and then reassemble the model at a later date if further testing is found necessary. In some cases, the new methods could also result in cost savings during the initial construction.

Scope

3. A literature search was made to determine the various types of

Figure 1. Cement paving to sheet-metal templates

material that could be used for model construction and the feasibility and availability of the various materials. Other hydraulic laboratories and universities were contacted about techniques and materials used in their model construction.

4. Individuals from five laboratories at WES were contacted during the initial literature search to obtain pertinent "first hand" information on materials, techniques, and known sources of innovative modeling. Many university hydraulic laboratory personnel were contacted by telephone and visits were made to some of these universities.

Literature survey

5. Basically, the literature search included personal contacts and review of current publications of new products magazines. This led to products developed in private industry for use in the oil, housing, shipping, transportation, and aerospace industries. Fortunately, Mr. W. L. Huff, project engineer in the Weapons Effects Laboratory at

WES, had recently written the major U. S. private industries concerning new products for use in his work. A review of the brochures from several of these companies concerning chemical and plastics research provided the properties and expectations of numerous products.

6. At least three major corporations agreed that rigid urethane foam is the best product developed recently for a multitude of uses.

Contacts with universities

7. Telephone calls to leading U. S. universities with hydraulic laboratories* were made to determine if there were known new model materials or techniques other than those currently in use at WES. Unfortunately, the basic model-building materials were the traditional wood, grout, sheet metal, and plastics with only minor deviations in construction techniques.

Visits to hydraulic laboratories

8. Contacts with Messrs. Dale Harris of Iowa University, George Hecker of Alden Research Lab, Svien Vigander of the Tennessee Valley Authority (TVA), and Tom Rhone of the United States Bureau of Reclamation (USBR) led to a visit to TVA and USBR laboratories for observations and discussion of some new materials and techniques. Considerable information and insight of related problems were obtained during these visits plus optimism for using certain 8- to 12-pcf** density urethane foams in construction of models of hydraulic structures.

9. USBR laboratory. Messrs. Tom Rhone and Eugene Ziegler of USBR conducted a tour of the entire laboratory and shops area during which the following observations were made:

a. Both low- and high-density urethane foams have good possibilities on certain types of models described below; however, the preshaped material cost is high and purchasing delays are common.

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* University of Iowa, Massachusetts Institute of Technology, University of California, University of Illinois, California Institute of Technology, Texas A&M University, and Colorado State University.

** A table of factors for converting U. S. customary units of measurement to metric (SI) units is presented on page 4.

b. USBR has been pleased with their 8- to 12-pcf foam for modeling hydraulic structures at 1:80 and 1:100 scales because of its workability (easily shaped and modified). The problems of laminating both vertically and horizontally were explained, indicating a better glue could be used to prevent hardening and separation at the joints.

c. The 8- to 12-pcf density urethane foam has good possibilities at WES on hydraulic model structures that usually require extensive shaping, cutting, and forming. The 1975 cost is $4.50/lb, or approximately $40 per cubic foot; however, the ease of shaping greatly reduces the labor cost, according to USBR. A supply should be kept at WES, if feasible, to prevent purchasing delays.

d. A 2- to 3-pcf urethane foam used for model topography on 1:80- and 1:100-scale models at USBR was not very impressive because of time-consuming cutting and uplift problems which required unsightly anchors throughout the model. The present WES sand and grout would be preferred until better glues and cutting techniques are perfected.

e. Mr. George Hecker and Alden Research Lab have used the technique of forming, cutting, and placing 2- to 3-pcf density foam to reproduce topography in hydraulic models concerning thermal discharges.

10. Certain disadvantages of using new high-density foams with epoxy were discovered. A hydraulic model at USBR coated with an epoxy was not satisfactory from the standpoint of safety or performance. Two workmen had become ill from the toxic vapors although protective masks had been worn during application. Also, the sand beneath the epoxy had slumped, causing the epoxy to pull away from the model walls.

11. TVA laboratory. TVA uses an epoxy casting method for their small-scale (1:100) structures, using vacuum tanks to mold and exhaust fans to remove vapors. This method is extremely slow and can be hazardous to craftsmen if the epoxy is improperly handled during the casting operation and is there fore not recommended for model construction. Most urethanes and plastics are best obtained in standard molded forms.

Experimental Model

12. Samples of five urethane foams (4, 5, 8, 10, and 12 pcf) and various glues were studied at WES after the visit to the USBR

laboratory. Samples of each material were laminated and submerged for 10 days to determine the glue's adhesive ability and the urethane's durability in water.

13. The most favorable materials, 6-pcf urethane foam and fiberglass resin glue, were used in a functional demonstration model at WES. The 6-pcf urethane in 4- by 8-ft sheets of 1- to 4-in. thickness was selected for the following reasons: light weight, waterproofness, workability, and availability.

14. Photo 1, taken during construction, shows the laminations of urethane foam after being glued and shaped but before application of the outer coating of automotive paint primer used to seal the lamination joints. USBR personnel had stated that their epoxy glue hardened and separated at the joints. The fiberglass resin at WES has held satisfactorily at all joints with uniform urethane thicknesses. However, slight separations occurred at joints where the urethane sheets were cut thinner than 1 in. Such cuts tended to cause the material to warp and stress the glue. A maximum expansion of 1/16 in. in a 6-ft depth of 6-pcf urethane did occur during construction with a near-constant temperature (10°F differential) and a varying humidity (20 to 100%). The model is presently operative and in excellent condition in a temperature controlled flume. Although the 6-pcf urethane foam with the fiberglass resin and the automotive primer was satisfactory for this specific model, the search for improved glues and sealers will continue.

15. A second model, Dickey-Lincoln School Lake, is being constructed with the 6-pcf urethane foam at a 1:200 scale. This functional water-quality model will be used to determine the withdrawal characteristics of the Dickey Lake outlet works and will provide an excellent opportunity to train other craftsmen and develop additional construction techniques.

Commonly Used Model Construction Materials

16. The most common model construction materials are: bricks, concrete blocks, sand, gravels, various soils, cement grout, wood

(standard plywood, plastic-coated plywood), metals (plate, sheet metal), transparent and opaque plastics, and fiberglass. All these materials are most frequently obtained as stock (standard) shapes and sizes for reasons of normal use and economics. Photos 2-8 show hydraulic models constructed of the commonly used materials. The use of Styrofoam for architectural, topographic, display models is common.

Discussion of Results

17. The selection of 6-pcf urethane for the two models mentioned does not mean it is best for all models. The 8-, 10-, and 12-pcf urethanes (more costly) would have worked as well. The 12-pcf material is easily carved, sawed, milled, and otherwise shaped, which would be excellent for making certain hydraulic structures such as spillway crests and other smooth overflow weirs. In brief, the project engineer or model builder must consider the desired usage and performance of his model in selecting the best construction techniques and materials. Basic factors of physical model size, location, duration, and function must first be considered before selecting the most available, economical, and functional material to accomplish the task.

Conclusions

18. Insight gained through this study has led to the following conclusions:

a. At present, the additional cost required to permit all models to be removed, stored, and reinstalled later would exceed the occasional need to remove and replace a specific model. The model layout and pertinent structures should be kept whenever possible to assist if reconstruction becomes necessary.

b. If it is known that a model study will be operated intermittently, a special flume should be constructed to avoid occupying an on-line flume used for the normal rapidly changing projects.

c. Due to the availability and low relative cost of sand and grout, physical models of considerable size

(1000 sq ft and up) should continue to be built with these materials. The cost of the finished model including materials and labor is presently about $2.50 per sq ft.

_d_. Model material selection is important and should be based on the desired results, physical dimensions, time parameters, and other considerations pertinent to the specific model. Special emphasis should be placed on developing new skills and techniques in using the various model construction materials.

_e_. Table models or other small models less than 200 sq ft are easily constructed and should be fabricated of plastic, urethane foam, and other lightweight materials which permit optimum modification, renovation, or reinstallation.

_f_. Certain critical sections of larger models requiring frequent change should be constructed of either wood, sheet metal, plastic, or urethane foam for easy modifications.

_g_. An ongoing effort is established at WES to continue developing new model construction techniques with existing materials and those being discovered.

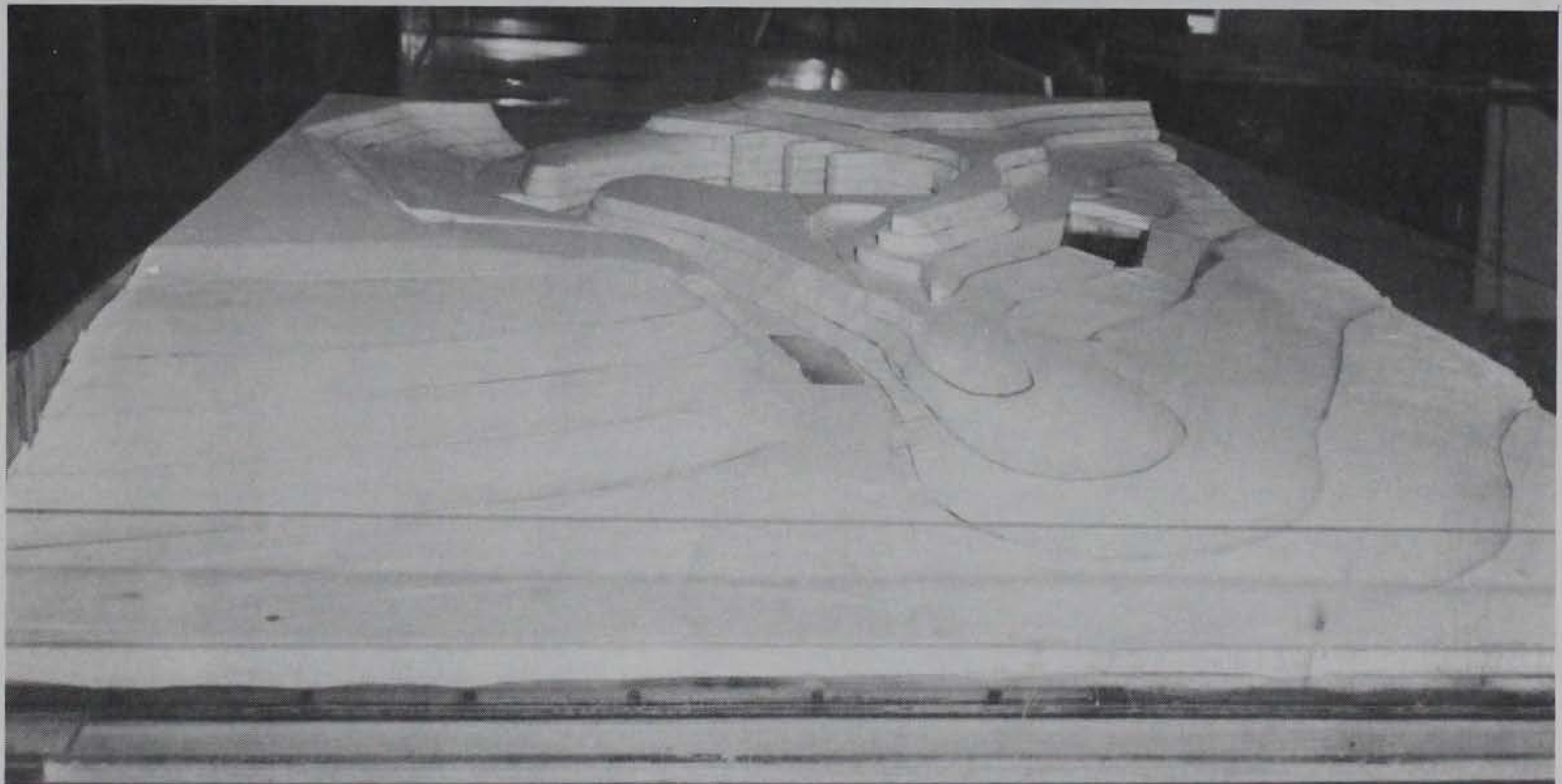

Photo 1. WES demonstration model of 6-pcf urethane foam and fiberglass resin

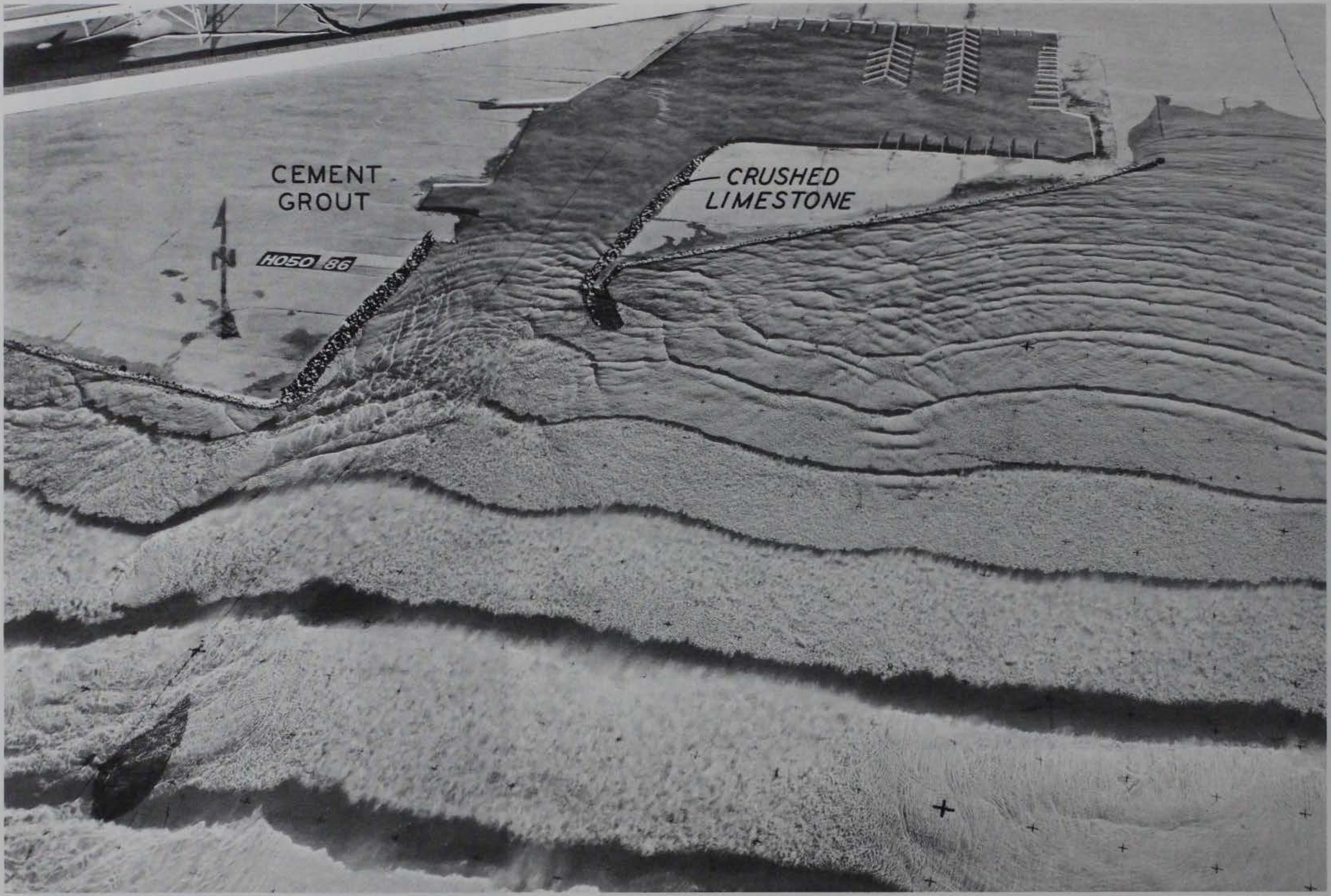

Photo 2. Cement grout paved to sheet-metal templates on wave dynamics model

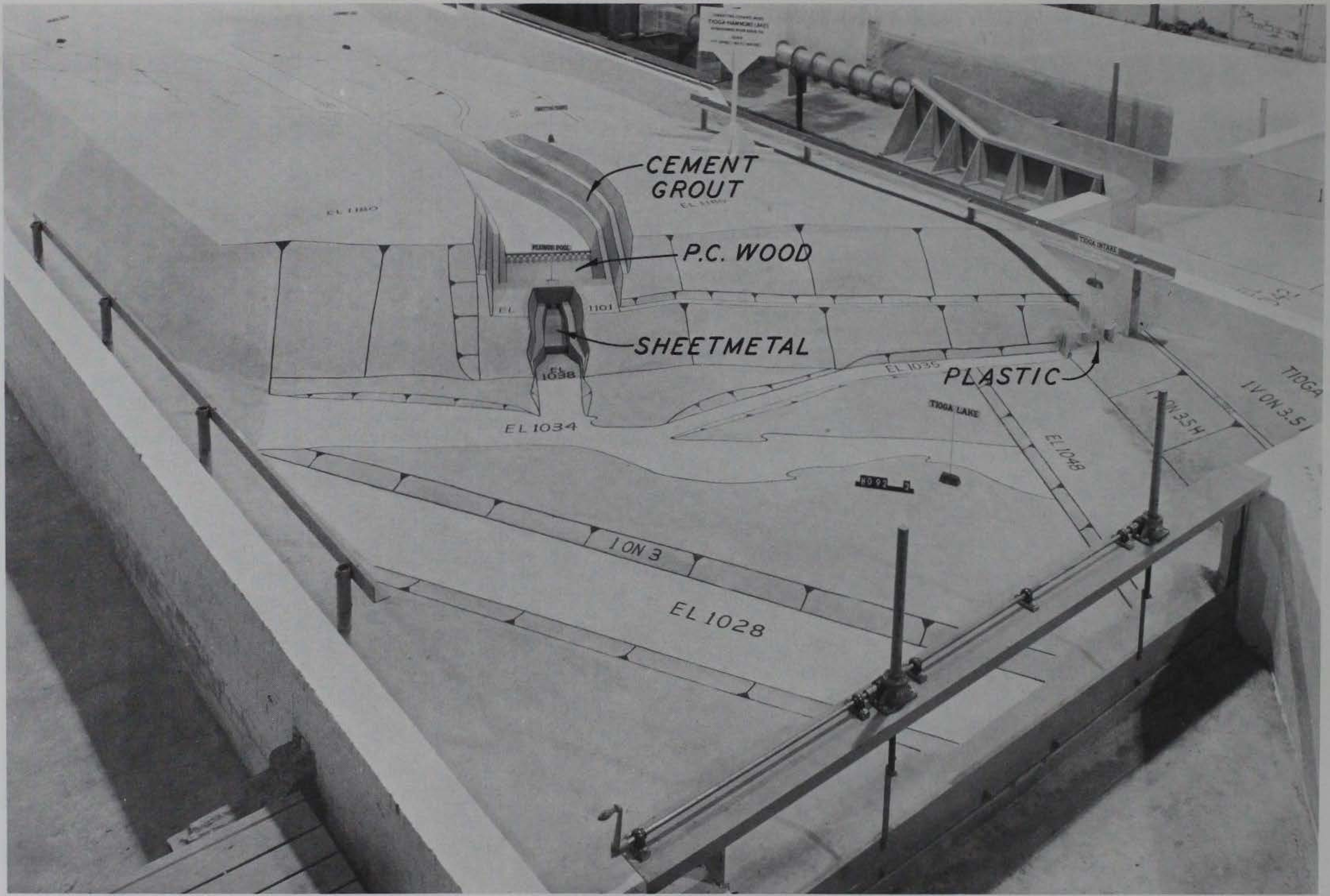

Photo 3. Cement grout, wood, sheet metal, and transparent plastic on hydraulic structures and channel model

Photo 4. Cement grout with crushed coal, movable-bed navigation model

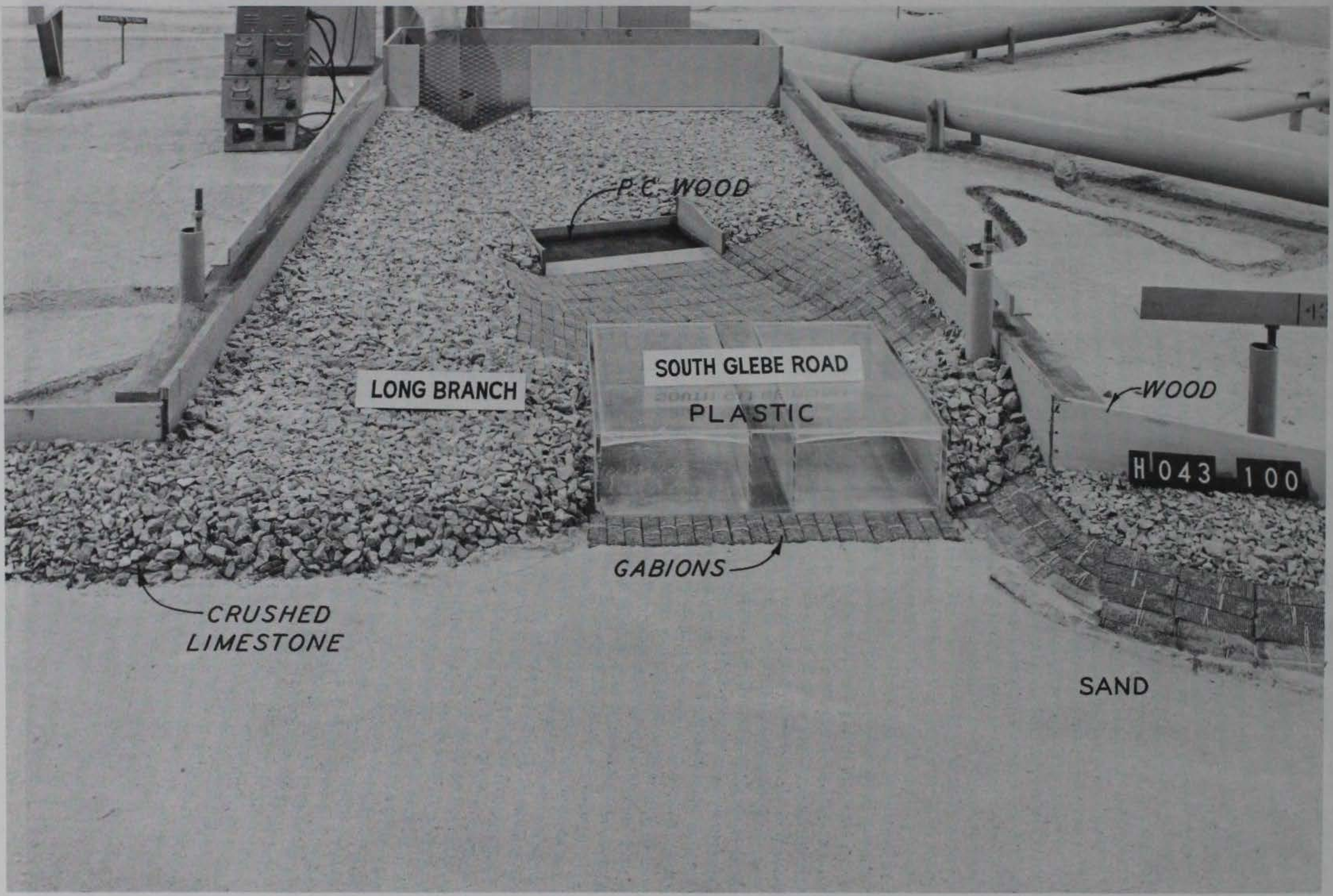

Photo 5. Open-channel movable-bed model of materials indicated

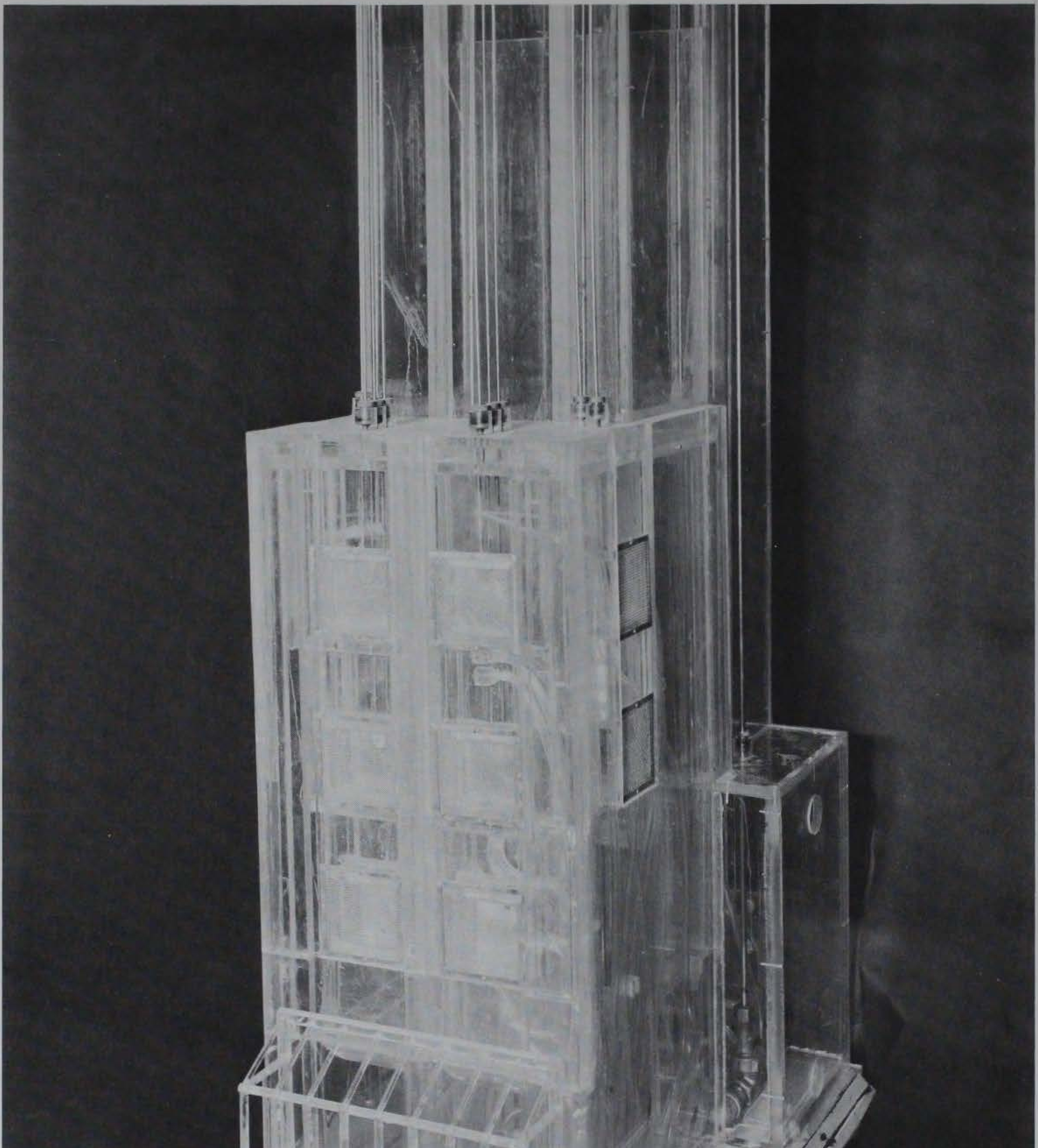

Photo 6. Water-quality intake tower constructed of plastic and metal

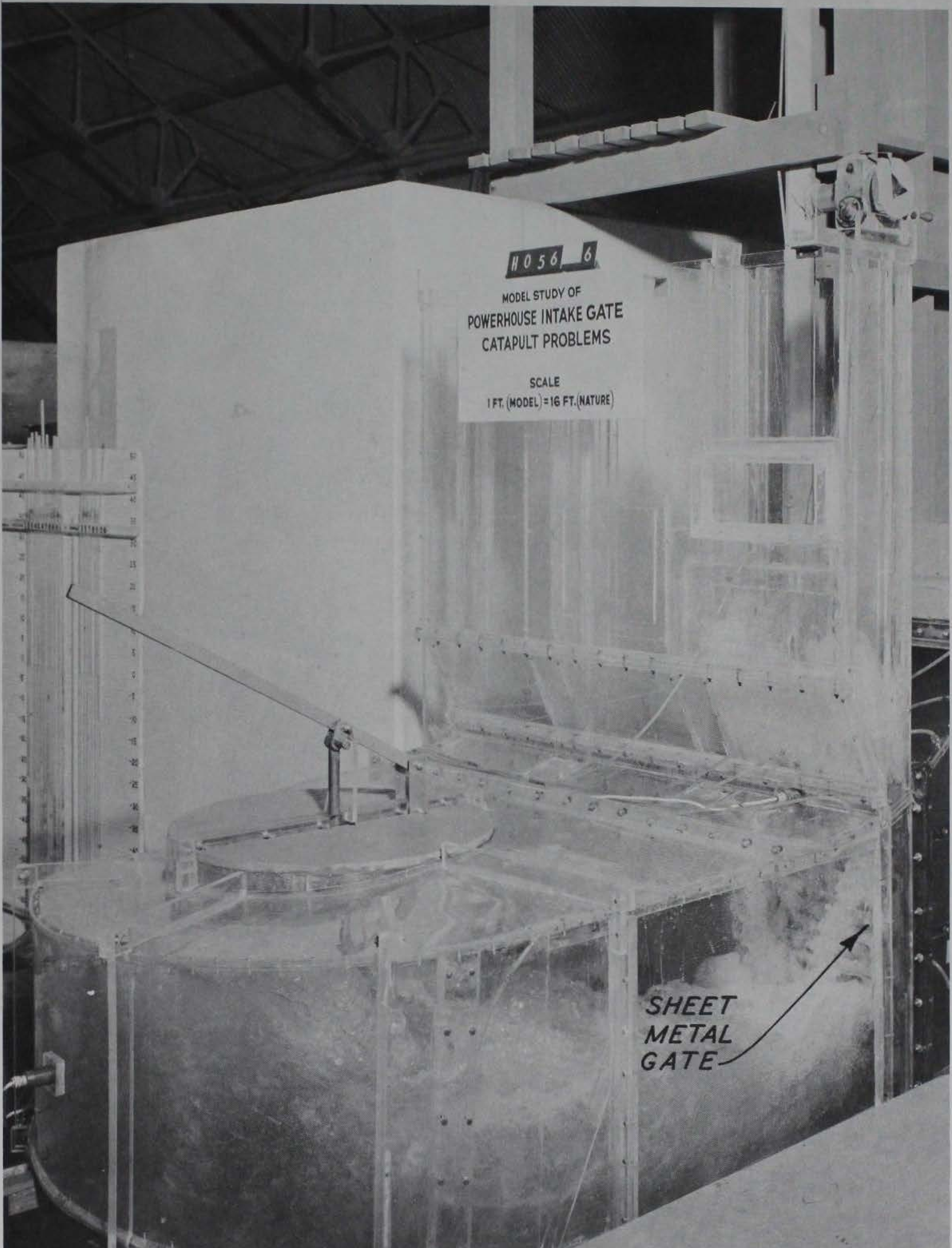

Photo 7. Hydraulic structures model of plastic and various metals