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Hydraulic Model Experiment Involving Tidal Motion

Part I. Experimental Facilities
Part II. Similitude
Part III. Experimental Result and Theoretical Consideration
and
Part IV. Tidal Mixing

By

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Synopsis

The importance of the hydraulic model experiment for hydraulic phenomena in the sea is now being recognized in the world. Among these phenomena, tha tidal motion and the long-period oscillations of the sea level are treated in this paper.

In Part I, we describe in some detail the experimental facilities used. In Part II, we discuss the dynamical similitude, which is the most important in the model experiments. In Part III, we describe the results of two kinds of experiments: the bay model and the inlet model. Moreover, the theoretical consideration on these obtained results is made, and we propose a method to decide the scale of the model in such an experiment as involving the tidal current. Lastly, in Part IV, we take up the problem of the tidal mixing and show the availability of the hydraulic model experiment on tidal mixing of the same scale as the tidal excursion.

Hydraulic Model Experiment Involving Tidal Motion

Part I. Experimental Facilities

1. Introduction

With the growth of economy and the advance of civil engineering, coastal constructions of large scale are projected these years in Japan and other countries. This means altering nature more or less, so that it is easily presumed that various natural phenomena in the vicinity will be influenced by these constructions. In order to design and execute the projects rationally, it is necessary to understand all about the phenomena which will probably be influenced by them. Regarding the hydraulic phenomena, it must be understood how the tidal motions, and accompanying oscillations, tsunamis, storm surges and so on which are the oscillations of long period, and wind wave, swell and so on which are the oscillations of short period, are influenced in these regions. It is very difficult to treat these problems theoretically and we must approach the problems along other lines. One way to approach them is to study on a mathematical model by a digital computer. Although this method is convenient, because the effects of the boundary conditions and various constants in the equations are easily examined, we can compute only roughly because of the limited capacity of computers now existing.

The other way is the hydraulic model experiment. This is also a kind of analog computer, but this way has its special features. For example, complicated hydraulic phenomena are all visible in the model and there is a possibility of Lagrangean view. These are, among others, great conveniences of this method.

It is supposed that even if the other method is developped in the future, the hydraulic model experiment will be used more and more because of these conveniences. On this point of view, a study on the hydralic model experiment of the tide and tidal current, which are developped very little so far, has been made.

2. Facilities for the experiment

The hydraulic model experiments are carried out by using the experimental facilities designed for an estuary model experiment at the Hydraulic Laboratory of Disaster Prevention Research Institute, Kyoto University. The equipment consists of a pneumatic tide generator, a water basin, a river flow feeder, two automatic control systems, and a measuring system.

1. Tide generator

As these phenomena are caused by comparatively long period oscillations such as the tidal oscillation or its accompanying oscillation, it is necessary to provide the oscillations of water level as one of the boundary conditions. For this purpose, there are several methods, for example, by drawing and pouring the water alternatively by the pump, by operating up and down a half submerged plunger, and by applying pressure changes over the water surface. The last one, that is the pneumatic tide generator, is used in this experiment because it is easy to provide the uniform oscillation over a wide breadth of the basin and to control the water level. As shown in Fig. 1, it is composed of an air chamber, a roots blower, and a control valve. Our air chamber, which is made of reinforced concrete, is 20 m in breadth, 2 m in height, and the water communicates through the gap beneath the front wall. The roots blower of 7.5 HP and the control valve are shown in the center and on the right hand side of Photo. 1 respectively.

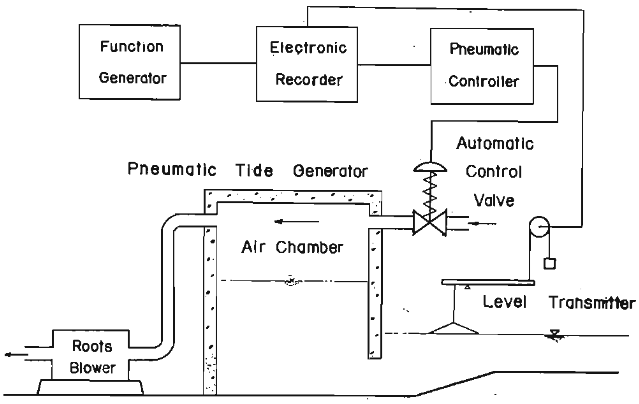

Fig. 1. Schematic diagram of the pneumatic tide generator and the automatic control system.

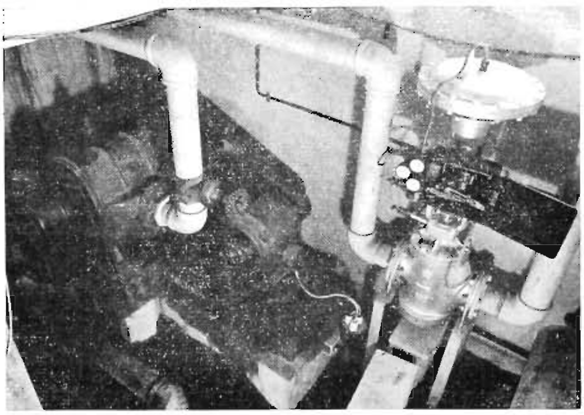

Photo. 1. Details of the pneumatic tide generator, roots blower and control valve.

The method of providing the tide is as follows : when the pressure in the air chambe is decreased by sucking the air with the blower in the control room, the water level in the chamber rises, while, when the air flows into the chamber, the level falls and the water in the chamber flows out into the basin. By controlling the volume of the air flowing into the chamber by a control valve, the tidal range can be varied adequately. The amplitude and the period of the oscillation of water level which can be generated are from 0.1 to 4.0 cm and from 1 to 60 minutes respectively.

In the early experiments, the control valve is controlled by hand, but in the later experiments it is done by an automatic control system.

2, Automatic control system

The advantage of the experiment exists in the ability of repeating it as often as required under the same conditions, which requires the use of the automatic control system for the generation of tide.

As shown in Fig. 1, this system is composed of a function generator, an electronic recorder, a pneumatic controller, and a level transmitter. The detail of these meters is described in the annual report of Disaster Prevention Research Institute (Mem. Issue, 5th Anniv. 1956), therefore, the principle of this system is briefly explained here. First, an order is issued from the function generator, which holds the chart of required tide, in the form of the voltage corresponding to the required water level. Then the pneumatic controller converts it into the air pressure which acts on the control valve. By the action of the control valve, the pressure in the air chamber, and therefore, the water level in the basin are controlled. At that time, the response from the level transmitter is carried through the feed-back circuit to the recorder to record it. And the difference between the order and the response is issued again as a new order to the pneumatic controller.

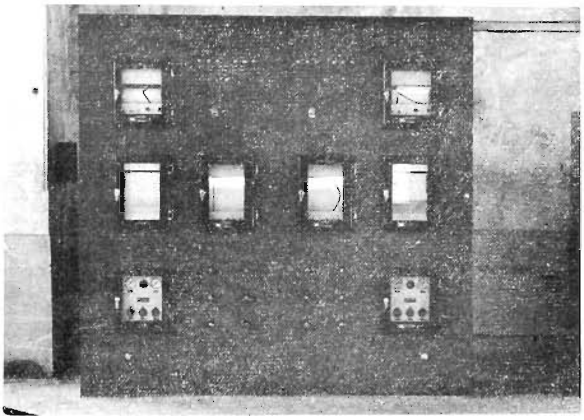

Photo. 2. Automatic control system.

In Photo. 2, two sets of these meters are seen symmetrically. A trial level transmitter is made for our experiments and it consists of the potentiometer acting in proportion to the displacement of the float on the water surface in a tank connected with the basin through a siphon tube (Photo 3).

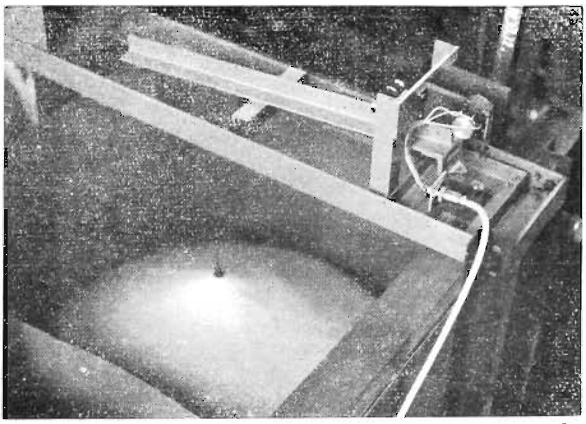

Photo. 3. Water level transmitter for automatic control.

In this way any

optional wave, even other than tidal wave, can be obtained by simply putting the chart on the function generator.

3. Model basin

In the hydraulic model experiment, it is necessary to construct special models in each case, so that there is actually a concrete base with few side walls. On this base, the model is constructed with concrete blocks, and mortar in case of need. Dimensions of our basin in 20~25 m in breadth, and 35 m in length.

The horizontal scale of the model is always 1/500, which is decided by the area of prototype and the dimensions of the basin. The vertical scale is not kept constant.

4. River flow feeder

In order to handle the problem in the estuary, it is necessary to provide the river flow. For this purpose, a river flow feeder is attached to this facilities. The optional river flow is also provided by the automatic control system.

The water is circulated so as not to change the total volume of the water in the basin. The water is sucked from the basin by a pump of 7.5 HP and fed to the rim of the model. The maximum discharge is 20 l/sec.

5. Measuring system

The electric measuring system and optical measuring system are used in this experiment.

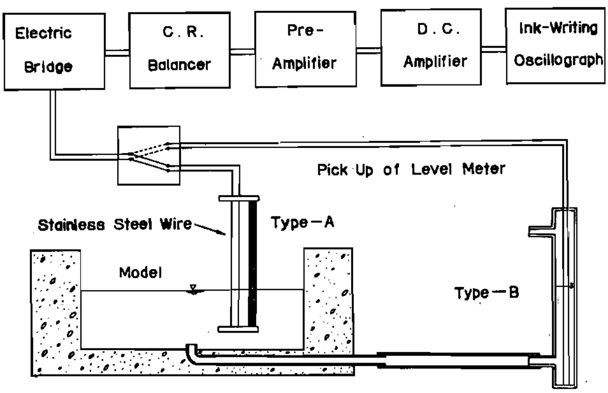

Fig. 2. Water level meter.

The measurements of the water levels and a part of velocities of flow are done by electrical method.

The water level meter of an electric resistance type used are shown in Fig. 2. The pick up of type-A or type-B is used in each experiment. The principle of this level meter is as follows: the change of the electric resistance corresponding to the water level causes the change of voltage. This change of voltage is carried on the carrier of 1.5 KC to the electric bridge, then it is amplified through the pre-amplifier and D.C. amplifier, and recorded in the ink-writing oscillograph as the change of water level. The pick up of type-A and type-B are shown in Photo. 4 and 5 respectively, and the other part in Photo. 6. The detail of this meter is also described in the annual report above mentioned. The current velocities are mainly measured by tracing the floats, and the moment type current meter as shown in Photo. 7, is constructed and used in the later ex-

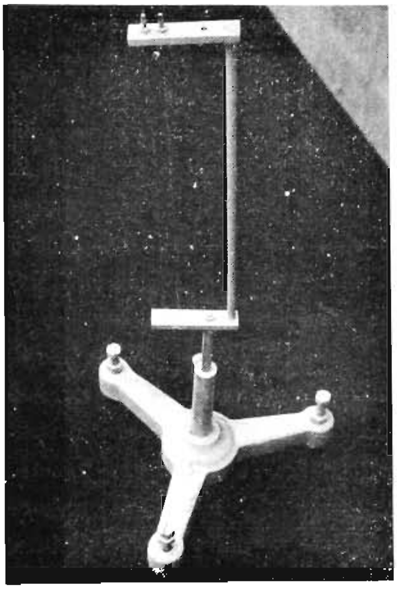

Photo. 4. Pick up type A of the water level meter used in the bay model.

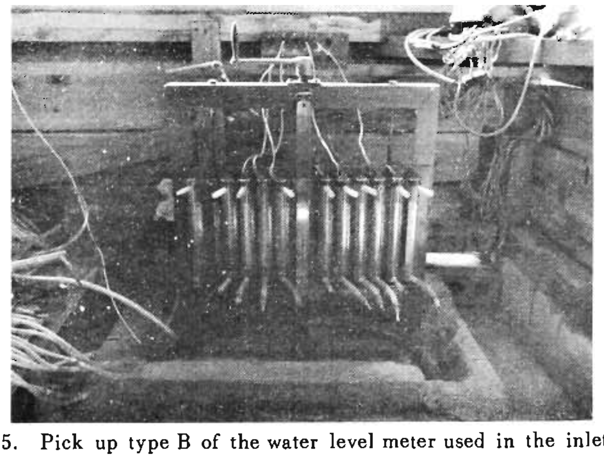

Photo. 5. Pick up type B of the water level meter used in the inlet model.

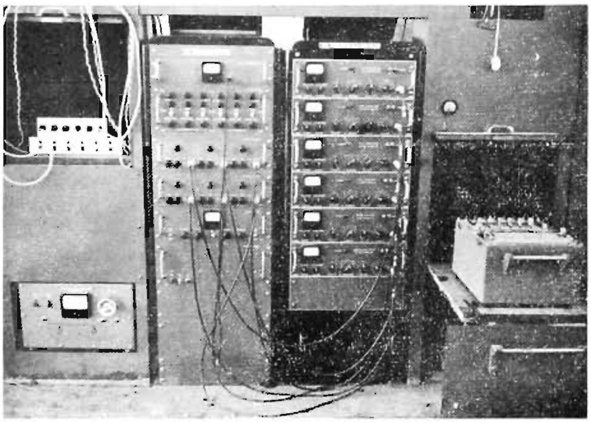

Photo. 6. Water level meter.

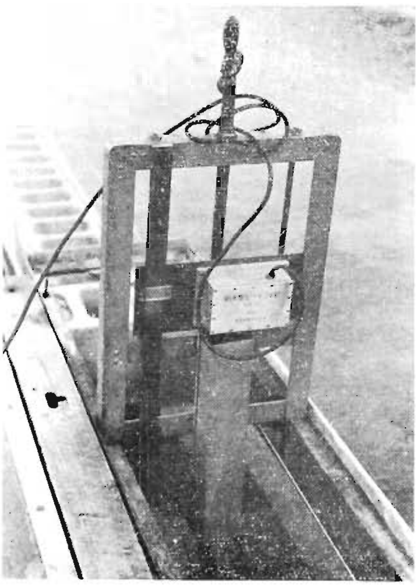

Photo. 7. Pick up of the moment type current meter.

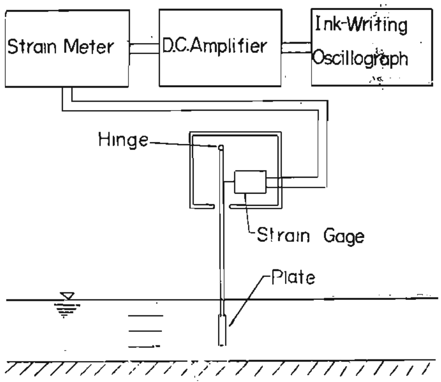

Fig. 3. Moment type current meter.

periment. As shown in Fig. 3, this current meter measures the moment caused by the drag force on the submerged plate. Through the same procedure as the water level meter, it is recorded by the oscillograph. Although this type of current meter is not so accurate by itself, it can measure rather a small velocity of flow by the use of calibration curve.

The patterns of the tidal current in wide regions are measured by an optical method. That is, many floats are scattered on the water surface and they are photographed intermittently at constant intervals. To protect them from the direct effect of the wind, these floats are made to suspend just

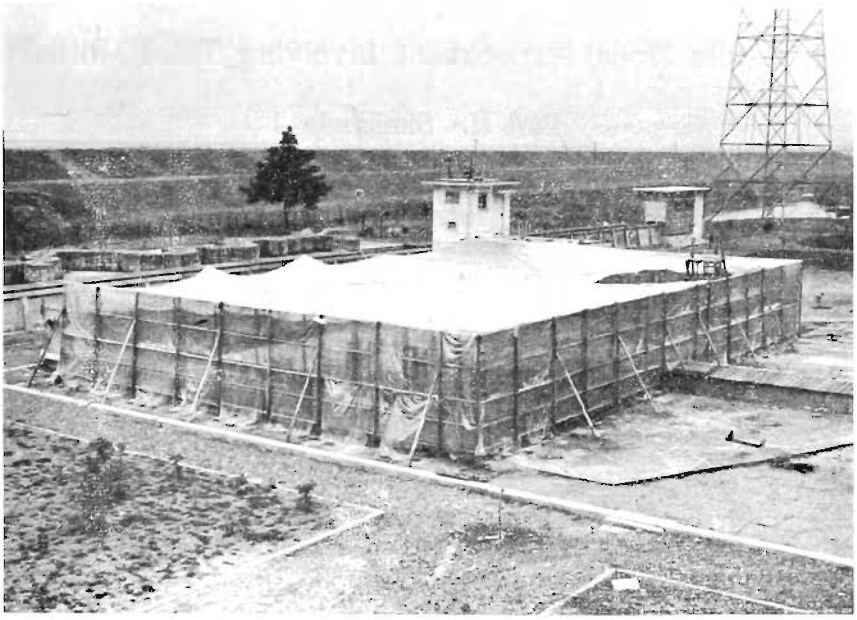

Photo. 8. Wind protection cover of the bay model.

beneath the water surface by adjusting their weight, and the wind protection cover is used in some experiments as shown in Photo 8.