TERMINAL REPORT

2' x 2'x60' RECIRCULATING FLUME

by

D. B. Simons

Prepared for National Science Foundation
under Grant 4013 ($10,000)

Civil Engineering Research Section
Colorado State University
Fort Collins, Colorado

CER64DBS33

TERMINAL REPORT

2' x 2' x 60' RECIRCULATING FLUME

by

D. B. Simons

Prepared for National Science Foundation
under Grant 4013 ($10,000)

Civil Engineering Research Section
Colorado State University
Fort Collins, Colorado

CER64DBS33

Introduction

A description of an adjustable recirculating flume (designed primarily for the study of alluvial channels) is presented. Details of the flume and instrumentation are described. A list of research publications and theses with their respective authors is presented. In addition, a list of proposed research studies is included. Two copies each of published research reports and 1 copy each of the abstract from published theses are attached at the end of the report.

This report covers the period October 1959 to 1964 inclusive.

Design and Construction of Flume

A. R. Chamberlain, M. L. Albertson, W. L. Haushild, D. B. Simons and E. V. Richardson, were responsible for the design and construction of the flume. C. S. U. shop personnel constructed the flume. Construction commenced December 1958 and was completed October 1959.

Details of the flume (complete drawings are available and have been given to many universities) and pictures showing 2 views of the flume are given in the appendix.

The most important features of the flume are:

a) Precise control of the longitudinal slope of the flume (by a syncronized system of motorized jacks).

b) Clear Lucite walls the full length of flume (to allow observation and photography of bed forms and flow phenomena),

c) Stainless steel flume bottom (permanently corrosion resistant)

d) Fixed hopper at the head box end of flume(for the uniform addition of sediment to the upper end of the flume),

e) Movable hopper-spreader supported by the instrument carriage track (for uniform deposition of material throughout the length of the flume)

f) Recirculating return from the head box end of the pump to the tail box sump (for maintaining the sediment in continuous suspension while in transit from tailbox to head box).

Instrumentation

The flume is equipped with a manually operated instrument carriage supported by continuous and adjustable rails on top of the flume sidewalls.

Instruments that have been used with the carriage are as follows:

a) A Pitot-static tube and midget, inertialess velocity meters for measuring point velocities anywhere within the flume,

b) An electronic sounder (used in conjunction with a recorder) for mapping bed form profiles and recording their variation and movement with time,

c) Radio active tracer equipment for detecting the position of radio-active sediment particles (proposed),

d) Point probe for determining water surface elevations and bed form profiles,

e) Automatic water surface follower.

Other forms of instrumentation are the orifice in the return pipe for measuring discharge through the flume and an integrating sediment sampler at the tail box end of the flume used for measuring sediment discharge.

The flume proper was financed by N. S. F. Grant G-4013. The electro-mechanical syncronized jacking system, the instrument carriage and all other flume accessories were financed from Colorado State University funds.

The flume will be dismantled and reassembled in the new Hydraulics Laboratory at the foothills campus in the immediate future.

Research Papers and Theses

Research leading to the following publications has been performed

in the 2' x 2' x 60' flume.

1. M. S. Thesis - "The effect of fine dediment on the mechanics of flow in alluvial channels," by William L. Haushild.
2. M. S. Thesis - "Influence of temperature on sediment transport and roughness in alluvial channels," by Khalid S. Al-Shaikh Ali.
3. Ph.D. Dissertation - "A preliminary study of the effect of gradation of bed material on flow phenomena in alluvial channels," by Niwat Daranandana.
4. Geological Survey Water-Supply Paper 1498-G - "Some effects of fine sediment on flow phenomena," by D. B. Simons, E. V. Richardson, and W. L. Haushild.
5. Journal of the Waterways and Harbors Division Proceedings of the American Society of Civil Engineers - "Control structures for sand-bed channels," by F. C. Stepanich, D. B. Simons, and E. V. Richardson.
6. "Flow characteristics of low wier structures in alluvial channels," by J. D. Lawson and D. B. Simons.
7. "Flume studies of the transport of pebbles and cobbles on a sand bed," by R. K. Fahnestock and W. L. Haushild.
8. A large part of a 16mm sound movie 43 minutes long entitled "Flow in alluvial channels" was produced using this flume. The film has had wide acclaim in most parts of the world.

Current Studies Now Being Conducted

1. M.S. Thesis - "Longitudinal hydraulic sorting of bed material in alluvial channels," by Tariq Rafay.
2. M.S. Thesis "Statistical analysis of bed roughness patterns," by J. H. Algert.

Proposed Future Studies

1. A bed particle monitoring program using isolated radio active particles in the bed, mapped by a radiation scanning device connected to a recorder that continuously traverses up and down the flume.
2. Further development of the drag wire principle for measuring velocity, turbulence and lift and drag on individual particles of various sizes.
3. Investigation of the effect of suspended sediment on the universal constant Kappa (velocity distribution in the vertical).
4. Bed forms in alluvial channels and the forces and actions that generate, modify and eliminate them.
5. The mechanics of the development of armor and utilization of armoring in stable channel works.
6. The mechanics of sediment transport.
7. A study of the role of turbulence in open channel flow phenomena.

THESES ABSTRACTS

THE EFFECT OF FINE SEDIMENT ON THE MECHANICS OF FLOW IN ALLUVIAL CHANNELS

by

William L. Haushild

ABSTRACT

The apparent viscosity of water-bentonite complexes are nine to ten times greater than that of clear water when the bentonite concentration is 100,000 ppm, and the specific weight is about 7 percent greater than that of water.

The change in the sediment properties was approximated by analyses in the visual accumulation tube with various bentonite in water complexes. The standard deviation for the bed material (d = 0.54 mm) increased from 1.53 with clear water to 1.83 with 100,000 ppm of bentonite, the effective fall velocity decreased from 0.28 fps to 0.14 fps and the effective fall diameter decreased from 1.76×10^{-3} ft to 0.98×10^{-3} ft.

The forms of bed roughness, resistance to flow, and bed material transport for a water-bentonite complex flowing over a bed material in a flume study are the same as those occurring with clear water flowing over a finer bed material. The median size of the smaller bed material is closely approximated by the effective median fall diameter of the original sand in the water-bentonite complex.

INFLUENCE OF TEMPERATURE ON SEDIMENT TRANSPORT AND ROUGHNESS IN ALLUVIAL CHANNELS

by

Khalid S. Al-Shaikh Ali

ABSTRACT

Temperature variations affect the properties of the sedimentation fluid which, in turn, affect the fall velocities of sediment particles. Flume experiments indicate that variations in the fall velocities, caused by temperature variations, can produce relatively large changes in bed material transport and resistance to flow. The changes, which are not always in the same direction, are explained qualitatively on the basis that the "effective size" of the bed material, as characterized by its fall velocity, varies with temperature and that the relations between bed material transport and shear and flow resistance and shear vary with the "effective size".

A PRELIMINARY STUDY OF THE EFFECT OF GRADATION OF BED MATERIAL ON FLOW PHENOMENA IN ALLUVIAL CHANNELS

by

Niwat Daranandana

ABSTRACT

A preliminary study of the effect of gradation of bed material sand with respect to the bed form, regime of flow, sediment transport and resistance to flow was carried out in a 2-ft wide, 60-ft long flume at the Hydraulic Laboratory, Colorado State University. Two types of sand were employed; both had the same median fall diameter (0.33 mm) but differed considerably in gradation (σ = 1.27 and σ = 2.07). Depth and temperature were kept practically constant throughout the study. The two sands were investigated separately.

A functional relation between the dimensionless Chezy coefficient $\frac{C}{\sqrt{g}}$, total sediment concentration C_t, a measure of gradation σ, the ratio of sediment fall velocity to fluid velocity $\frac{w}{V}$, and energy slope S was developed with the aid of dimensional analysis.

The results of the study indicate significant differences in the behavior of the two sands. Bed material transport for the sand with the large measure of gradation σ was always larger than the transport rate for the more uniform sand when subjected to the same stream power or boundary shear. The range of resistance to flow caused by the form roughness was smaller for the graded sand than for the uniform bed material when the bed configuration was ripples, dunes, transition or antidunes. There was no significant difference in resistance to flow caused by the grain roughness of the two sands.

An accurate estimate of the total bed material discharge for a sand with a median fall diameter of 0.33 mm and a measure of gradation σ ranging from 1.27 to 2.07 can be obtained from the family of empirical

curves which were developed for a depth of flow of 0.5 ft and temperature of water sediment mixture of 20°C. For other conditions the curves can be used but results are less precise because of lack of data.

The validity and flexibility of current sediment transport equations when applied to the uniform and graded bed material sands were tested. The modified Einstein's procedure appears best if the stream discharge and the suspended load concentration can be predetermined. Einstein's method is best when the computation is based on one representative size range, the bed material is well graded ($\sigma = 2.07$) and upper regime conditions prevail. Bishop's procedure gives good results for the low and intermediate values of σ.

CONTROL STRUCTURES IN ALLUVIAL CHANNELS

by

Frederick C. Stepanich

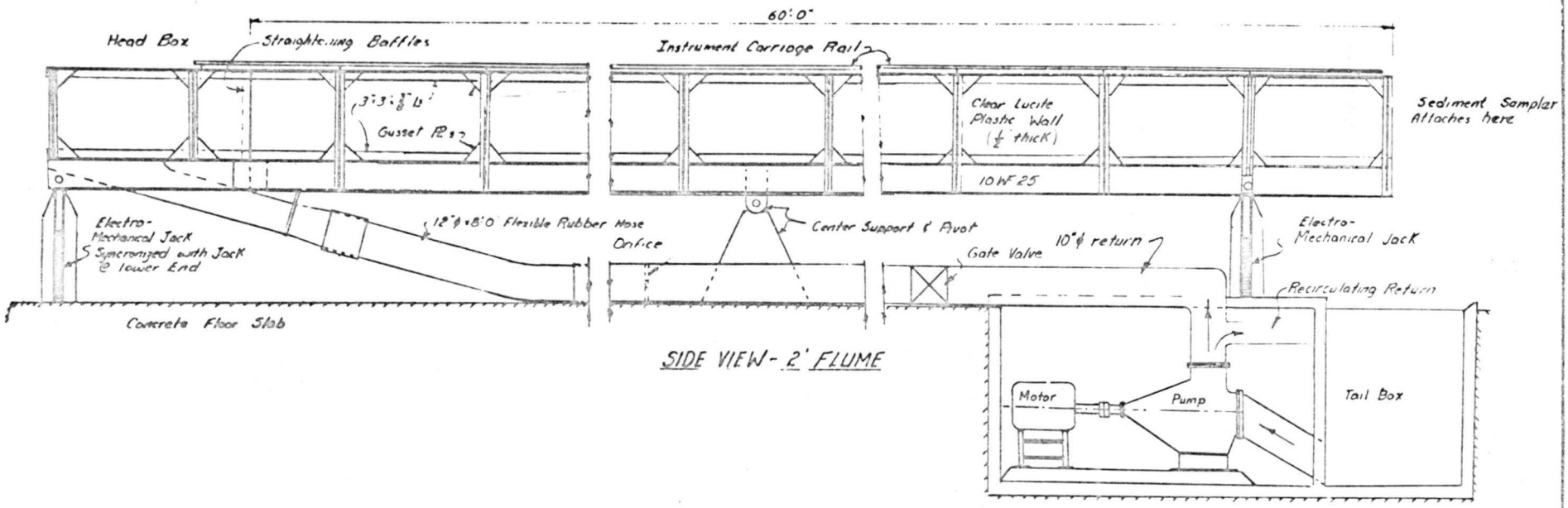
ABSTRACT

The reliability of a control structure as a stage-measurement device was investigated by use of a 2-foot wide, 60-foot long recirculating flume. Such a measuring device should be independent of upstream and downstream bed form and flow conditions.

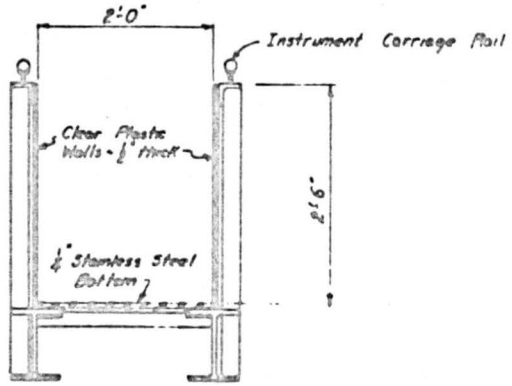
Twenty-three structures were studied which involved the following five structure roughnesses: sand grains, 1/2 inch, 1 inch, 2 inch and 4 inch rock. A uniform sand 0.33 mm in diameter was used as the flume bed material over which flow was adjusted to generate the upstream bed forms of ripples, dunes, ripples superimposed on dunes and a transition region of washed out dunes. Stage measurements for constant discharges were taken upstream, downstream and along the structure at 15 positions. In all runs 4350 items of data were collected.

Water-surface profiles, stage-discharge curves, total head-discharge curves and coefficient of discharge-discharge curves resulted from the analysis of the data. It was found that certain combinations of structure slope, roughness and approach length provide the means for establishing a reliable stage-discharge curve. The usefulness of the prototype structure are limited to an intermediate range of flows. Small flow measurements are limited because of the effect of structure roughness and large flow measurements are limited because of the effect of submergence. Consideration was given to possibilities of taking sediment samples on the structure.

APPENDIX



SIDE VIEW - 2' FLUME



SEC. THRU FLUME

2'-2'-60' RECIRCULATING ADJUSTABLE FLUME

Colorado State University Hydraulics Laboratory - Ft. Collins, Colorado

FIGURE 1

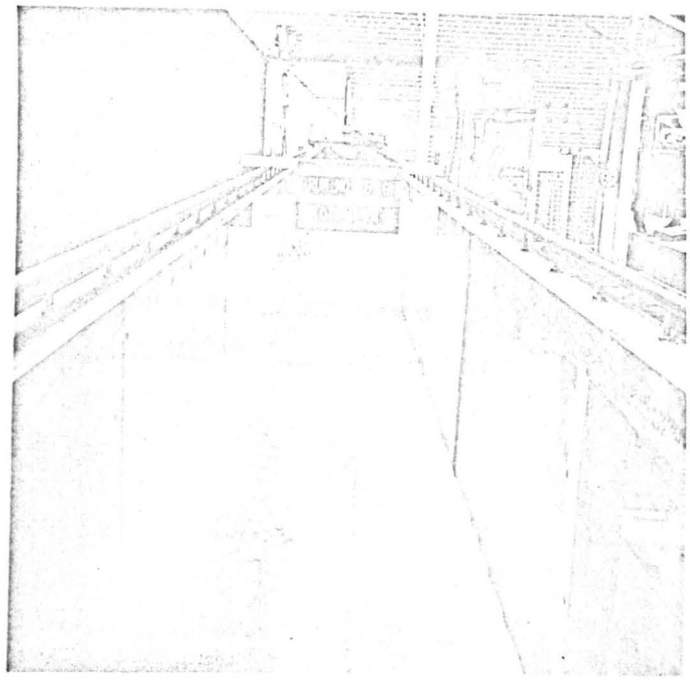


Fig. 2. Longitudinal view of the flume looking upstream.

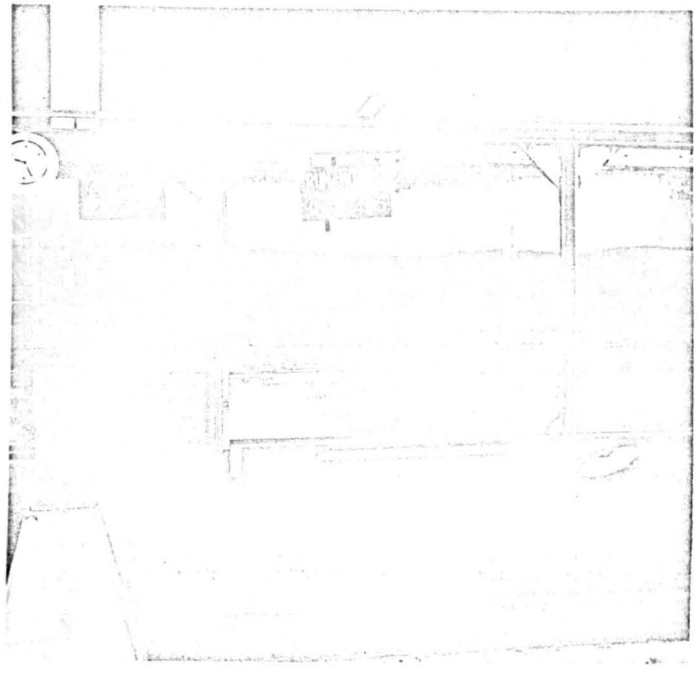


Fig. 3. Side view of the pivot point, flume and return pipe (note the dunes for the run in progress)