457.204 Elementary Fluid Mechanics and Lab

Student Designed Test

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■ Description

Student designed tests are performed in addition to the elementary tests. Student can select one of five tests as given below. Each group should present proposal and final report of their own test at the end of the semester.

■ Lists

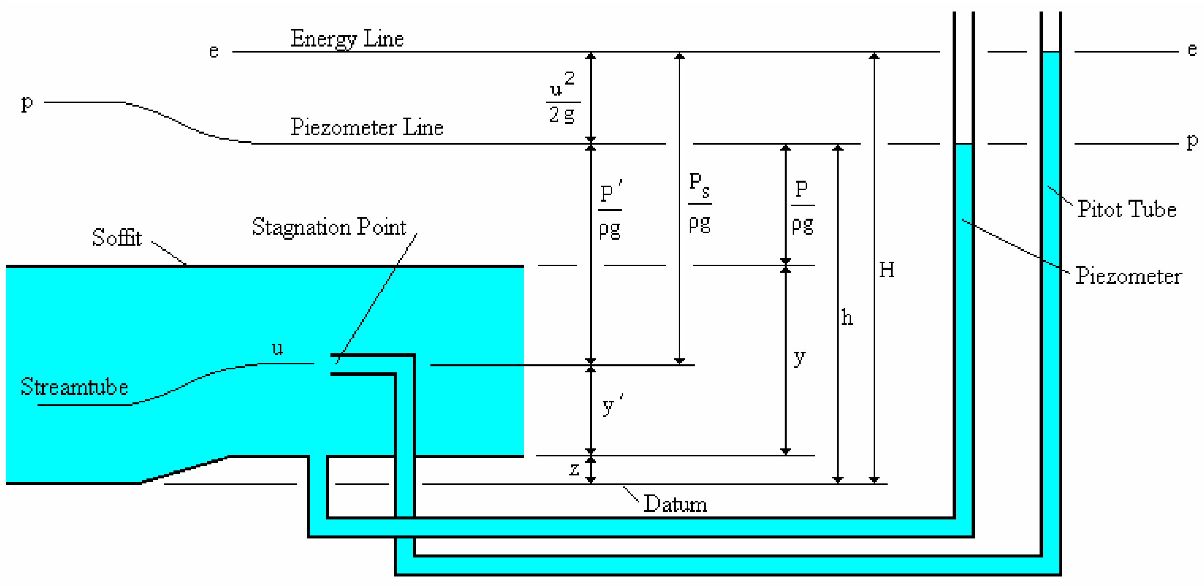
Student designed test #1. Application of the continuity equation with a closed conduit flow
Student designed test #2. Hydraulic jump phenomenon in open channel flow
Student designed test #3. Energy losses in pipe bends
Student designed test #4. Sediment transport in open channel
Student designed test #5. Flow and pollutant transport in confluent channel

ST 1: Application of the continuity equation with a closed conduit flow

1) Introduction

This test is to demonstrate how the conservation of mass and the continuity equation can be applied to the flow of an incompressible fluid through a closed conduit.

2) Test



- Measuring velocity profiles test

  Change the flow through the closed conduit and measuring the corresponding total head and piezometric head to determine the resulting fluid velocity at any point in the conduit.

- Application of the Continuity Equation

By using the Pitot tube to determine the change in velocity associated with a change in cross sectional area.

$$(\rho A_1 v_1) = (\rho A_2 v_2) = (\rho A_3 v_3)$$

3) Theory

- A physical system is defined as a particular collection of matter and is identified and viewed as being separated from everything external to the system by imagined or real closed boundary.

- A fluid object for analysis is a volume in space through whose boundary matter, mass, momentum, energy, and the like can flow.

- Conservation of mass

The mass of a closed system will remain constant over time.

Mass flow rate = 0

$$\frac{DM_{sys}}{Dt} = 0$$

4) Student designed test

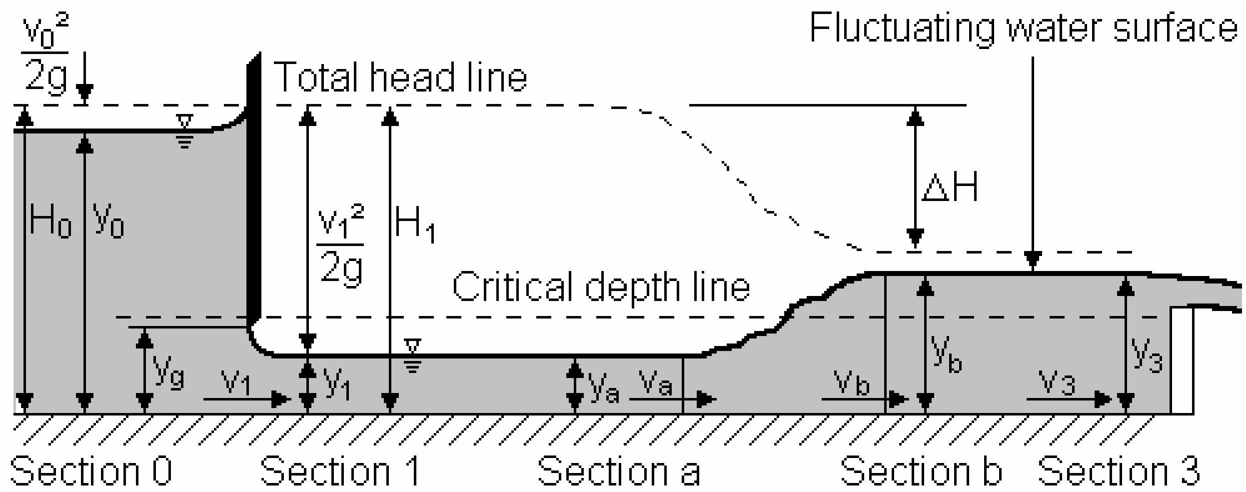
- Under steady flow conditions, the mass flow of water at all locations inside the conduit is constant despite changes in the cross sectional area.

ST 2: Hydraulic jump phenomenon in open channel flow

1) Introduction

This test is to investigate the characteristics of a standing wave (the hydraulic jump) produced when fast flow upstream changes to slow flow downstream with a consequent degradation of energy.

2) Test



- Using the adjustable sluice gate (undershot weir) upstream in combination with the overshot weir downstream to create standing waves in the working section.

- Measure y_a , y_b and observe the flow pattern.

3) Theory

- Froude number, $F_r = \frac{V}{\sqrt{gy}}$

- Specific energy = distance between channel bottom and energy line

- Students can decide if the flow is subcritical flow or supercritical flow through the Froude number and specific energy

- Hydraulic jump is a phenomenon which Supercritical flow changes to subcritical flow.

4) Student designed test

- Student can research about hydraulic jump occurring at streams.

  Ex) Application the hydraulic jump theorem to the field.

ST 3: Energy losses in pipe bends

1) Introduction

This test is to demonstrate the losses and characteristics associated with flow through bends, enlargements and fittings.

2) Test

- Calculate the head loss through hydraulic head difference in case of smooth pipe bends

- Calculate the head loss through hydraulic head difference in case of abrupt enlargement.

- Calculate the head loss by using the loss coefficient (K_L)

$$h_L = K_L \frac{(V_1 - V_2)^2}{2g_n}$$

- Discuss if the theoretical data is similar to the experimental data. If different, found out why.

3) Theory

- Bernoulli's theorem neglects the friction caused by viscous forces. But all real fluid has little friction to stress and therefore is considered viscous.

- Pipe flow, where pressure is driving force, actually generates not only wall friction but also loss for change of cross section or flow.

4) Student designed test

- Students can verify loss of hydraulic heads with the change of pipe cross section quantitatively in this test.

ST 4: Sediment transport in open channels

1) Introduction

This test is to understand sediment transport by using a demonstration with changeable slope and sand on the channel bed. Then we can observe local scour around a model pier.

2) Test

- Sediment transport test.

  We can observe a section of one side at the moment to start sediment transport in a demonstration with changing flow rate and slope conditions.

- Pier scour test

  We can measure depths of local scour around a model pier with changing flow rate and slope conditions.

3) Theory

- Condition of sediment transport

  • When shear stress caused by growing flow rate or slope of channel is higher than critical shear stress, sand on the bed starts to move.

- Bridge scour = General scour + Constriction scour + Local scour

4) Student designed test

- Students can find the flow rate and slope conditions to begin sediment transport.

- After setting up a model pier, students can measure depths of scour around a model pier with changing slope condition.

ST 5: Flow and pollutant transport in the confluent channel

1) Introduction

This test is to carry out qualitative analysis of flows in meandering channels. We can survey the velocity profile and pollutant mixing in three dimensions.

2) Test

- Measure the velocity profile (secondary flow) with Micro-ADV
  - After analyzing qualitatively, we can understand the difference between meandering channel and straight channel.
  - Measurement primary flow and secondary flow in meandering channel, we can understand the velocity profile in three dimensions.

- Observe pollutant advection and diffusion with salt water.
  - After understanding the velocity profile in meandering channel, we can observe pollutant advection and diffusion qualitatively.

3) Theory

- Reason of meandering
  - Uneven quality of bed: Erosion is greater on the outside of the bend where the soil is

not protected by deposits of sand and rocks.

• Obstacles in river: Flow conflicts obstacles that exist on one side of the channel and changes the direction to the other side of the channel. In that time meandering of the channel occurs.

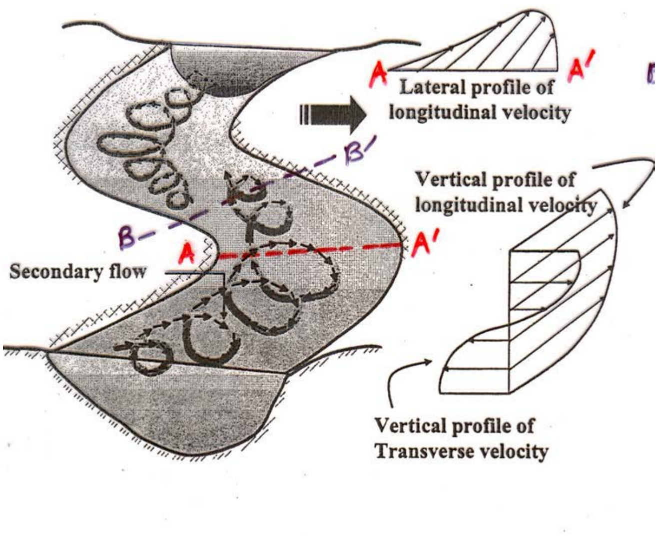
- Mechanism of meandering

• When producing meandering characteristic of natural streams, the values of maximum velocity and depths are concentrated in apex.

• With the flow velocity growing and depth falls in apex, the secondary motion assist in scouring the outer side.

- Secondary flow

A secondary flow is a relatively minor flow superimposed transversely on the primary flow.



Meandering and secondary flow in open channel (Seo et al, 2005)

- Advection

Movement of substance by mean velocity of flow.

- Diffusion
  - Molecular diffusion: Caused by random movement of molecules (Brown motion).
  - Turbulent diffusion: Phenomenon occurs due to turbulent eddy.

4) Student designed test

- Make the scenario about the flow of meandering channel and mechanism of pollutant and discuss the results of scenario compared to experiments. (Possible to use RAMS modeling)

- The flow velocity is compared to the data of RAM2 by measuring u(x), v(x) at the measurement point of meandering channel.

- After making concentration of pollutant vertically constant, spread pollutant and compare the results of tests to the results of RAM4 modeling.