DWE3314 Open Chanel (2,2,1,0)

Designation as a 'required' or 'elective' course:
This is a required course for the D.W.R Engineering Program.

Course Description:
Open channel flow and its classification. ,Properties of open channel flow, energy and momentum principales, critical flow with computation and applications, uniform flow with computation and applications, design of channel for uniform flow.

Textbook:
Open Channel Hydraulics Ven.Te Chow……………………………………………………………………

Prerequisites:
DWE 1202 Calculus-II
DWE 2305 Fluid mechanics

Course Topics:
1. Introduction
2. Types, state, and regims of flow
3. Kindes of open channel
4. Channel geometry
5. Velocity-distribution coefficients
6. Pressure distribution in a channel section
7. Effect of slope on pressure distribution
8. Energy, and specifuc energy in open channel
9. Critical flow
10. Uniform flow
11. Erodible and nonerodible channels
12. Best hydraulic section
13. Determination of section dimentions.

Program and Course Outcomes:

1. Ability to identify the types and rigims of flow in open channel.
1. Ability to identify the principals of momentum in open channel.
2. Ability to identify the energy and specific energy in open channel
3. Ability to analyze the problems of open channel flow and design open channel.
4. Ability to solve analysis and design problems related to bed material.

CHAPTER FIFTEEN

FLOW IN OPEN CHANNELS

CHAPTER ROAD MAP The flow of water in open channels can be observed in aqueducts, rivers, flumes, irrigation ditches, and other contexts. Although these contexts are quite different, a small set of concepts and a few equations generalize to most applications of open-channel flow. These ideas are introduced in this chapter.

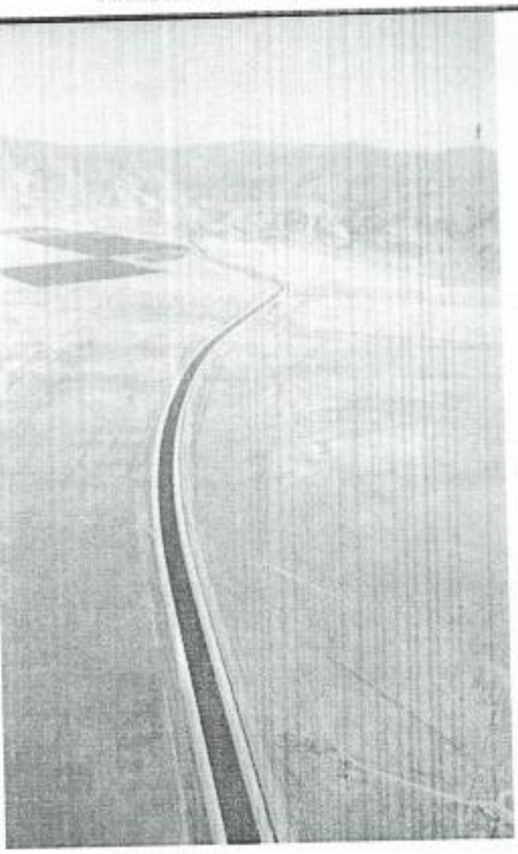


FIGURE 15.1
Aerial view of the California Aqueduct at the southwest end of the Tehachapi Mountains. (Macduff Everton/The Image Bank/Getty Images.)

LEARNING OUTCOMES

DESCRIBING FLOW (§15.1).

- Define an open channel.
- Define uniform flow and nonuniform flow.
- Define the Froude number.
- Calculate the hydraulic radius, and the Reynolds number.
- List the criteria for laminar and turbulent flow.

UNIFORM FLOW (§15.2, §15.3).

- Explain the physics of the energy equation and also explain the corresponding HGL and EGL.
- Calculate flow rate with the Darcy-Weisbach approach or the Manning equation.
- Define and explain the best hydraulic section.

NONUNIFORM FLOW (§15.4 to §15.7).

- Describe and compare rapidly varied flow and gradually varied flow.
- Describe critical depth, specific energy, supercritical flow, and subcritical flow.
- Describe a hydraulic jump and perform calculations.
- Describe the factors that are used to classify surface profiles that occur in gradually varied flow.

Open Channel Flow

A. Introduction

The beginning of any channel design or modification is to understand the hydraulics of the stream. The procedures for performing uniform flow calculations aid in the selection or evaluation of appropriate depths and grades for natural or man-made channels. Allowable velocities are provided, along with procedures for evaluating channel capacity using Manning's equation.

All the methods described herein will be based on the conservation of mass, momentum and energy (in the form of Bernoulli's theorem), and the Manning formula for frictional resistance. Steady uniform flow and steady non-uniform flow are the types of flow addressed in this section.

1 Classification of open channels:

may be classified as ..

A artificial → open canal

natural → open channel as river

B Prismatic channel having a cross-section constant.

non - Prismatic channel .

C Rigid boundary channel sides as concret channel.

mobile - boundary channel sedimentary

2 Classification of flow :

The common classification is based on rate of change of free surface depth.

A Laminar and Turbulent flow

الجريان الطباقي والاضطرابي والمحدد هنا هو حساب رقم رينولدز كالاتي :

$$R_e = \frac{V R_h \rho}{\mu}$$

حيث ان :

V = mean Velocity of flow.

R_h = hydraulic radius as A/P.

ρ = mass density of water.

μ = Viscosity of liquid.

if.. $R_e \leq 500 \rightarrow$ Laminar flow.

$R_e \geq 2000 \rightarrow$ turbulent flow.

between these two limits the flow is "transition".

B Sub critical and super critical flow ..

• المحدد هنا هو حساب رقم فرود Froude number كالاتي:

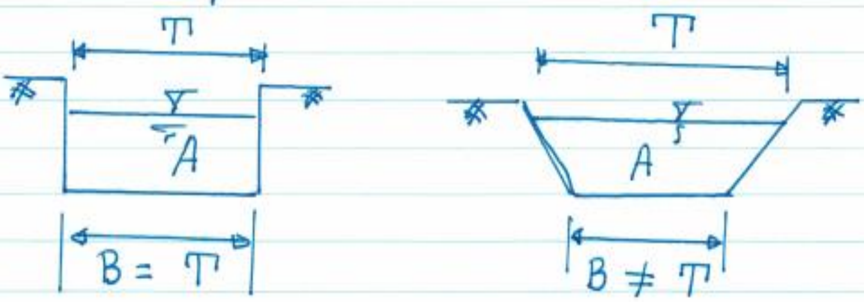
$$F_r = \frac{V}{\sqrt{g\, y_d}}$$

حيث ان :

V = mean Velocity

$$y_d = \text{hydraulic depth} = \frac{\text{Area}}{\text{width of water surface}}$$

$$y_d = \frac{A}{T}$$



If.. $F_r < 1$ sub critical flow.

$F_r > 1$ super critical flow.

$F_r = 1$ Critical flow.

C steady and un steady flow ..

قياس تغير الاعماق او السرع نسبة الى الزمن وكالاتي:

if..

$$\frac{\Delta h}{\Delta t} = 0 \rightarrow \text{steady flow.}$$

$$\frac{\Delta V}{\Delta t} = 0 \rightarrow \text{steady flow}$$

$$\frac{\Delta h}{\Delta t} \neq 0 \rightarrow \text{un steady flow}$$

$$\frac{\Delta V}{\Delta t} \neq 0 \rightarrow \text{un steady flow.}$$

D uniform and non uniform flow ..

when the depth and velocity remain constant along the length of flow it is called uniform flow.

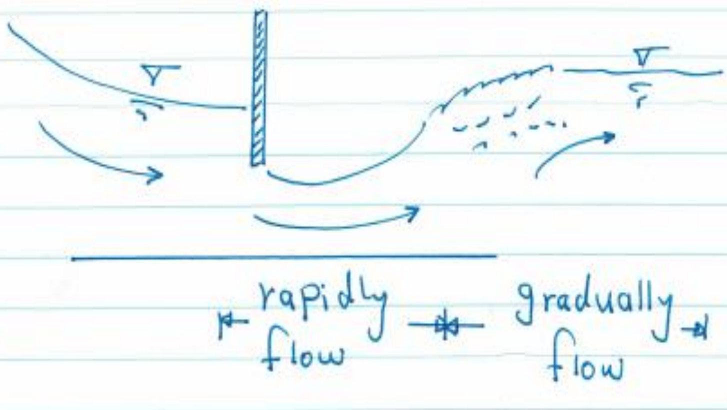
if.. $\frac{\Delta h}{\Delta x} = 0$ and $\frac{\Delta V}{\Delta x} = 0 \rightarrow$ uniform flow.

$\frac{\Delta h}{\Delta x} \neq 0$ and $\frac{\Delta V}{\Delta x} \neq 0 \rightarrow$ non uniform flow.

e gradually and rapidly varying flow:

- gradually varying flow is non uniform flow when the depth change gradually due to area or slope changes.

- rapidly varying flow is non uniform flow if the slope change rapidly or suddenly.



3 uniform flow (Flow at normal depth):

This is the simplest and common type of flow and occure when conditions are steady and slope is not steep.

Normal depth: For a given channel geometry, slope, and roughness, and a specified value of discharge Q, a unique value of depth occurs in a steady uniform flow. It is called the normal depth. The normal depth is used to design artificial channels in a steady, uniform flow and is computed from Manning's equation.

ويعرف الجريان المنتظم من خلال ثلاثه معادلات اساسيه:

1 continuity Equation معادله الاستمراريه

2 Energy flow Equation معادله الطاقه

3 momentume equation معادله الزخم

وهي مشتقه من قانون نيوتن الثاني للحركه.

B. Definitions

Critical flow: The variation of specific energy with depth at a constant discharge shows a minimum in the specific energy at a depth called critical depth at which the Froude number has a value of one. Critical depth is also the depth of maximum discharge, when the specific energy is held constant.

Froude number: The Froude number is an important dimensionless parameter in open-channel flow. It represents the ratio of inertia forces to gravity forces. This expression for Froude number applies to any single-section channel of nonrectangular shape.

Hydraulic jump: Hydraulic jumps occur at abrupt transitions from supercritical to subcritical flow in the flow direction. There are significant changes in the depth and velocity in the jump, and energy is dissipated. For this reason, the hydraulic jump is often employed to dissipate energy and control erosion at stormwater management structures.

Kinetic energy coefficient: As the velocity distribution in a river varies from a maximum at the design

Continuity equation. The continuity equation is the statement of conservation of mass in fluid mechanics. For the special case of steady flow of an incompressible fluid, it assumes the simple form:

$$Q = A_1V_1 = A_2V_2 \qquad \textbf{Equation 3}$$

where Q = discharge (cfs)
A = flow cross-sectional area (ft^2)
V = mean cross-sectional velocity (ft/s) (which is perpendicular to the cross section)

The subscripts 1 and 2 refer to successive cross sections along the flow path. The continuity equation can be used with Manning's equation to obtain steady uniform flow velocity as:

$$V = Q/A = [(1.49/n)R^{2/3}S^{1/2}] \qquad \textbf{Equation 4}$$

Energy flow

Flowing water contains energy in two forms, potential and kinetic. The potential energy at a particular point is represented by the depth of the water plus the elevation of the channel bottom above a convenient datum plane. The kinetic energy, in feet, is represented by the velocity head:

$$\text{Kinetic energy} = \frac{V^2}{2g} \qquad \textbf{Equation 5}$$

In channel flow problems it is often desirable to consider the energy content with the channel bottom. This is called the specific energy or specific head and is equal to the depth of water plus the velocity head:

$$\text{Specific energy} = d + \frac{V^2}{2g} \qquad \textbf{Equation 6}$$

At other times it is desirable to use the total energy content (total head), which is the specific head plus the elevation of the channel bottom above a selected datum. For example, total head may be used in applying the energy equation, which states that the total head (energy) at one point in a channel carrying a flow of water is equal to the total head (energy) at any point downstream plus the energy (head) losses occurring between the two points. The energy (Bernoulli) equation is usually written:

$$d_1 + \frac{V_1^2}{2g} + Z_1 = d_2 + \frac{V_2^2}{2g} + Z_2 + h_{loss} \qquad \textbf{Equation 7}$$

In this equation, cross-section 2 (subscript 2) is downstream from cross-section 1 (subscript 1), Z is the elevation of channel bottom, and h_{loss} represents loss of head between cross-sections 1 and 2. A convenient way of showing specific head is to plot the water surface and the specific head lines above a profile of the channel bottom (See Figure 1).

Note in Figure 1 that the line obtained by plotting velocity head above the water surface is the same line as that obtained by plotting specific head above the channel bottom. This line represents the total energy, potential and kinetic, of the flow in the channel, and is called the "total head line" or "total energy line."

The slope (gradient) of the energy line is a measure of the friction slope or rate of energy head loss due to friction. Under uniform flow, the energy line is parallel to the water surface and to the streambed. For flow to occur in a channel, the total head or energy line must slope negatively (downward) in the direction of flow.

Figure 1: Channel Flow Terms

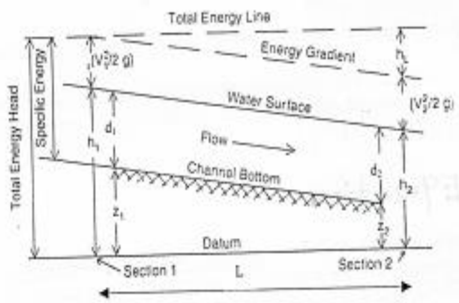
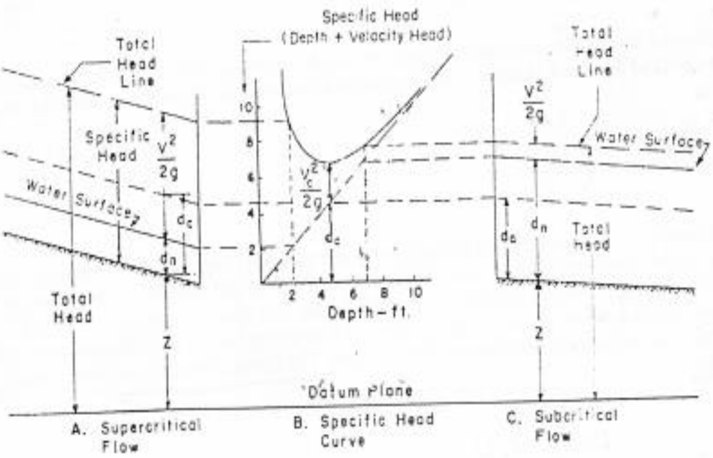


Figure 2: Definition Sketch of Specific Head



3 Momentum Equation :

وهي مشتقه من قانون نيوتن الثاني للحركة

ان تطبيق معادله الزخم يكون واضحاً عندما يكون هناك خسائر
في الجريان لا يمكن تخمينها من خلال معادله الطاقه واوضح
تطبيق لها في جريان القنوات المفتوحه يكون عند تغير
الجريان من جريان سريع (Super critical flow) الى
جريان بطيء (Subcritical flow) وهذا التغير يطلق عليه
هيدروليكيا مصطلح (القفزه الهايدروليكيه).

2

Hydraulic jump

1. **General.** The hydraulic jump consists of an abrupt rise of the water surface in the region of impact between rapid and tranquil flows. Flow depths before (supercritical depth, d_1) and after (subcritical depth, d_2) the jump are less than and greater than critical depth, respectively. The depth d_1 is calculated based on the hydraulics of the channel. The depth d_2 is calculated as shown in part 2. The zone of impact of the jump is accompanied by large-scale turbulence, surface waves, and energy dissipation. The hydraulic jump in a channel may occur at locations such as:

   a. The vicinity of a break in grade where the channel slope decreases from steep to mild.

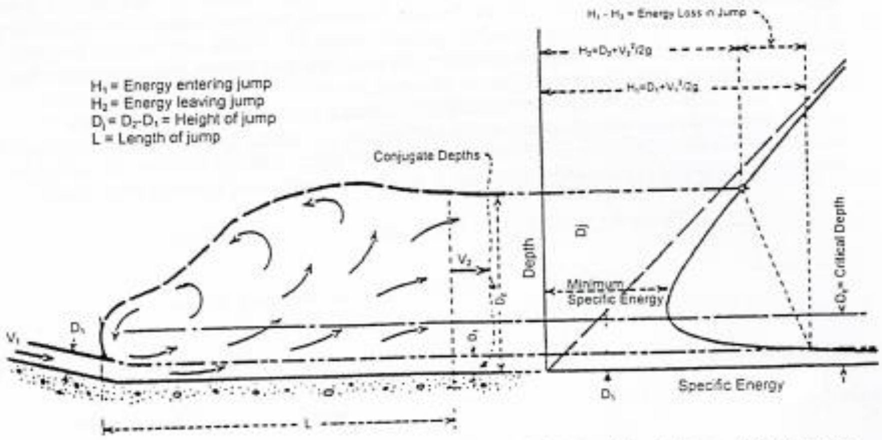
   b. A short distance upstream from channel constrictions such as those caused by bridge piers.

   c. A relatively abrupt converging transition.

   d. A channel junction where rapid flow occurs in a tributary channel and tranquil flow in the main channel.

   e. Long channels where high velocities can no longer be sustained on a mild slope.

Hydraulic Jump and Depth of Flow



(A) Hydraulic Jump - On Horizontal Floor

(B) Relation of Specific Energy to Depth of Flow

2. **Hydraulic jump computations for depth of flow (d_2).** The formula for the hydraulic jump is obtained by equating the unbalanced forces acting to retard the mass of flow to the rate of change of the momentum of flow. When the slope is small ($\cos\theta \approx 1$, $\sin\theta \approx 0$) the general formula for this relationship is given as:

$$V_1^2 = g\left(\frac{a_2\bar{y}_2 - a_1\bar{y}_1}{a_1\left(1-{}^{a_1}\!/_{a_2}\right)}\right) \qquad \text{Equation 9}$$

where V_1 = the velocity before the jump
a_1 and a_2 = the areas before and after the jump, respectively
$\bar{y}_1$ and $\bar{y}_2$ = the corresponding depths from water surface to the center of gravity of the cross-section

Since the terms $\bar{y}_1$ and $\bar{y}_2$ refer to the center of gravity of the cross section, solving for the depth, d_2, after the jump depends on the geometry of the channel.