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HYDRAULICS

NON - UNIFORM FLOW IN OPEN CHANNEL

TOPIC 3.4

by

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NON -UNIFORM FLOW IN OPEN CHANNEL

3.4
- Rapid Varied Flow

3.4 : RAPID VARIED FLOW (RVF)

- ❖ Developed mainly at hydraulic structures and most of the related problems can be solved by using the continuity equations and energy principles provided that the energy losses are known.
- ❖ However, if losses are unknown, the momentum principle must be used;
  Net force= rate of change of momentum
- ❖ For RVF, the momentum equation will be introduced in the context of the HYDRAULIC JUMP (an important phenomenon in open channel flow and an example of RVF – stationary surge wave)

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3.4.1: Hydraulic Jump: Types and Uses

- ❖ Hydraulic jump analysis is the most common application of the momentum equation in open channel flow.
- ❖ The hydraulic jump, an abrupt change in depth from supercritical to subcritical flow, always is accompanied by a significant energy loss.
- ❖ A hydraulic jump primarily serves as an energy dissipater to dissipate the excess energy of flowing water downstream of hydraulic structures such as spillway and sluice gate.

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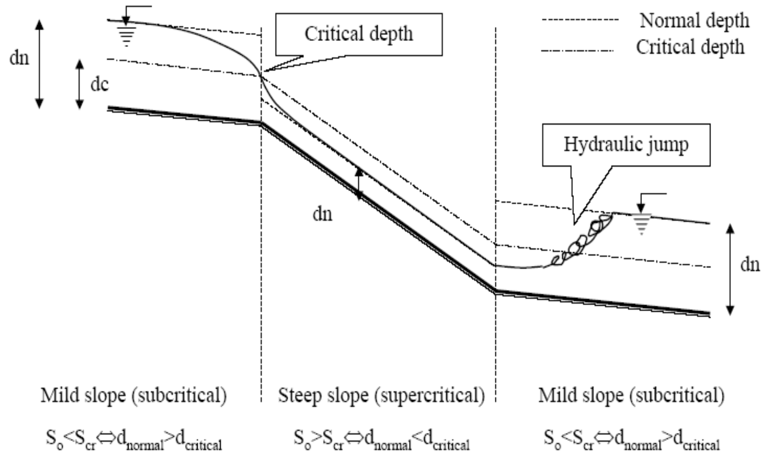
Transition from subcritical to supercritical and vice-versa



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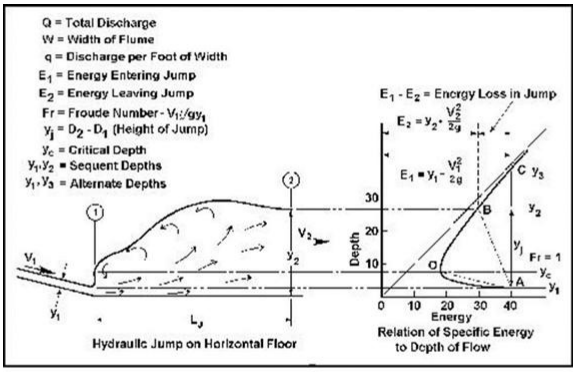

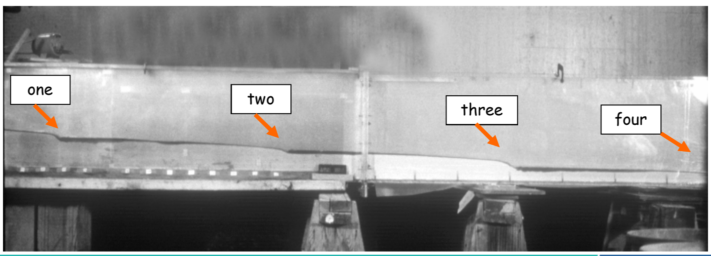

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3.4.1 (a)Types of Jump

- Hydraulic jumps on horizontal floor are of several distinct types. These types can be conveniently classified according to the Froude number, Fr.

❖ For **Fr = 1**, ; the flow is critical, and hence **no jump** can form.

❖ For **Fr = 1 to 1.7**, ; the water surface shoes undulations, and the jump is called **undular jump**.

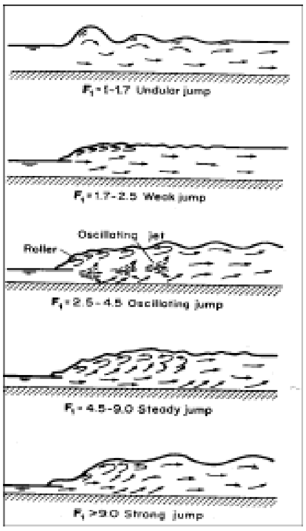
❖ For **Fr = 1.7 to 2.5**, ; a series of small rollers develop on the surface of the jump, but the downstream water surface remains smooth. The velocity throughout is fairly uniform, and the energy lost is low. This jump may be called **weak jump**.

❖ For **Fr = 2.5 to 4.5**, ; there is an oscillating jet entering the jump bottom to surface and back again with no periodicity. Each oscillation produces a large wave of irregular period which, very commonly in canals. This jump may called an **oscillating jump**.

- For **Fr = 4.5 to 9.0**, ; the downstream extremity of the surface roller and the point at which the high velocity jet tends to leave the flow occur at practically the same vertical section. The action and position of this jump are least sensitive to variation in tailwater depth. The jump is well-balanced and the performance is at its best. The energy dissipation ranges from 45 to 70%. This jump may be called a **steady jump.**

- For **Fr = 9.0 and larger**, ; the high-velocity jets grabs intermittent slugs of water rolling down the front face of the jump, generating waves downstream, and a rough surface can prevail. The jump action is rough but effective since the energy dissipation may reach 85%. This jump may be called a **strong jump**.

Types of Hydraulic Jump – Variation of Energy Dissipation



Water surface only slightly disturbed, since incoming flow is nearly critical.Note that at F_1=1.7, $y_2 \approx 2y_1$
Dissipation < 5%

Pre-jump stage, little active turbulence.
Dissipation 5-15%

Waves generated in jump (not fully formed) are carried downstream. This is undesirable.
Dissipation 15-45%

True hydraulic jump forms. This is a more **steady standing wave**, hence more predictable and desired in design.
Dissipation 45-70%

Rough, and somewhat intermittent jump.
Dissipation 70-85%

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3.4.1 (b) The use

1. To dissipate energy in water flowing over dams, weirs, and other hydraulic structures and thus prevent scouring downstream from the structures
2. To recover head or raise the water level on the downstream side of a measuring flume and thus maintain high water level in the channel for irrigation or other water-irrigation or other water-distribution purposes
3. To increase weight on an apron and thus reduce uplift pressure under a masonry structure by raising the water depth on the apron
4. To increase the discharge of a sluice by holding back tailwater, since the effective head will be reduced if the tailwater is allowed to drown the jump
5. To indicate special flow conditions, such as the existence of supercritical flow or the presence of a control section so that a gauging station may be located
6. To mix chemicals used for water purification
7. To aerate water for city water supplies
8. To remove air pockets from water supply lines and thus prevent air locking.

3.4.2: Momentum Principles, Conjugate depth, Dissipated energy, Power

- Relationship between hydraulic jump equation and momentum equation.
- There are several assumptions;
  - Flat channel bed
  - Uniform channel cross section
  - Uniform velocity and water depth
  - Ignore the stress at channel surface
  - Frictionless
- Hydraulic jump occurs at short distance
  - Momentum for water flows in the channel section per unit time (N)
  - From Newton Second Law, the changing of momentum per time equal to combination of external forces
    - $\sum F = wQ(v2 - v1)/g$
    - M1 = M2

Hydraulic Jump Height/Depth

(the different of height before & after hydraulic jump) ,

$y_j = y_2 - y_1$ (m)

Conjugate Depth

(determine the depth before & after hydraulic jump)

$y_1/y_2 = ½ [(\sqrt{1 + 8 Fr_2^2}) - 1]$ (m)

$y_2/y_1 = ½ [(\sqrt{1 + 8 Fr_1^2}) - 1]$ (m)

Energy Loss from jump (into heat),

$\Delta E = E_1 - E_2$ (m)

$\Delta E = (y_2 - y_1)^3/4y_1y_2$ (m)

Power dissipated or obtained from jump,

$P = \rho g Q \Delta E$ (W)

EXAMPLE 3.9

At the bottom of spillway, a rectangular channel with 30 m width, the velocity of flow, 28.2 m/s and depth before jump is 0.96 m. The hydraulic jump is immediately (abruptly) occurred. Calculate the height of hydraulic jump and the power dissipated.

EXAMPLE 3.10

In a rectangular channel with 0.6 m width, hydraulic jump occurs when Froude Number is 3. Normal depth before jump is 0.6 m. Determine the energy loss and power dissipated in this situation.

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