Ministry of Higher Education and Scientific Research

Al-Mustaqbal University College

Chemical engineering and petroleum industries

(Fluid Flow Lab)

Experiment No. 4

Center of Pressure

Prepared by

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The aim of the experiment:

- Calculate the resultant pressure force of the liquid on a flat plate with **full** and **partial** immersion
- Determine the center of pressure .

Introduction:

The effects of pressures resulting from the weight of the static fluid must be taken into account when designing submersible structures such as dams, submarines and gates. The identification of stress concentration points and their distribution on geometric shapes is one of the important topics in engineering applications that can avoid the failure of dams and gates that are used for irrigation purposes and to raise the water level in order to get benefit from the potential water energy.

Apparatus:

- Quadrant.
- Balance arm.
- Weight hanger.
- Counterbalance.
- Horizontal indicator.
- Scale.
- Pivot.
- Water vessel.

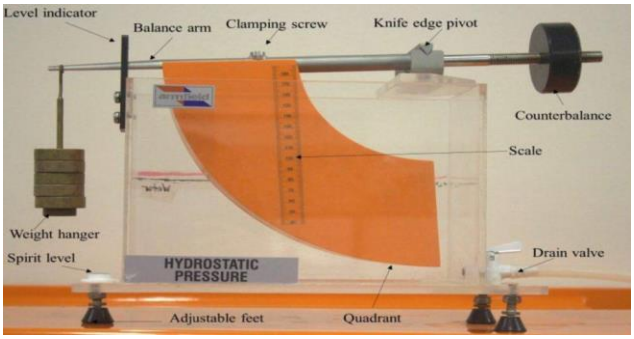

Fig.1: center of pressure instrument.

Procedures:

1. Make sure the device is in the horizontal position by balancing the amount of water in the device with loads equal to it.

2. Add a quantity of water and calculate the amount of weights and height fluid from the surface to the center of the body. This process is repeated and recorded readings

Theoretical Part:

- The liquid pressure force at any point on the upper and lower curved surfaces has no effect because the forces pass through the axis.
- The fluid pressure force (hydrostatic force) on the immersed vertical face is calculated from the following relation:

$$F_R = \rho\, g\, y_c\, A$$

Where:

F_R= resultant force of pressure.

ρ= density of water.

g= Gravitational acceleration.

Yc= the distance of the center of gravity of the surface affected to pressure from the free surface of the liquid.

A= area of the vertical surface.

We distinguish two cases of submersion of the plate:

A. Partially submerged:

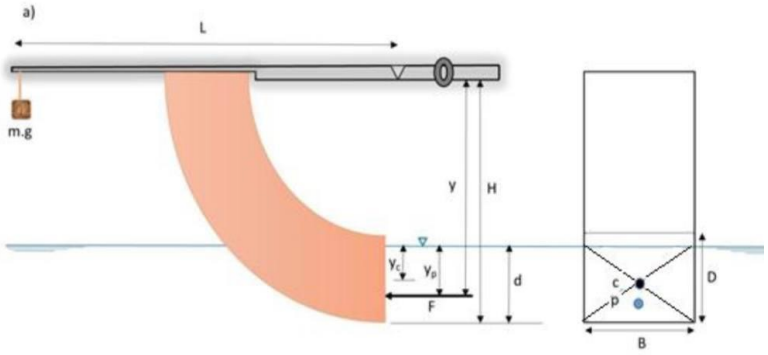

Fig.2: the case of partially submersion

The area A and Yc can be determined by using the following relations:

$$A = d \cdot B \qquad Yc = d/2$$

Thus, the resultant force can be calculated by the relation:

$$FR = \tfrac{1}{2} \rho g B d^2$$

B. Fully submerged:

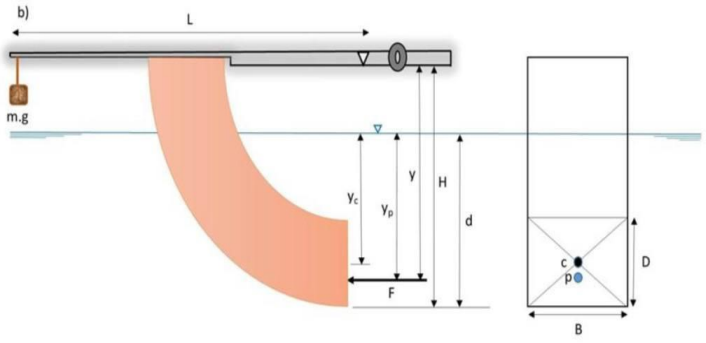

Fig.2: the case of fully submersion

The area A and Yc can be determined by using the following relations:

$$A = D \cdot B \qquad Yc = d - (D/2)$$

Thus, the resultant force can be calculated by the relation:

$$FR = \rho g B D (d - (D/2))$$

Where:

D =100 mm.

B = 75 mm.

Calculating the center of pressure:

The center of pressure is determined by calculating the distance from the free surface of the liquid **yp** and it is calculated from the beam balance equation, where the sum of the moments of the forces about the center of rotation is nil when the beam is in equilibrium.

$$\Sigma Mo = 0 \Rightarrow \quad M1 = M2$$

$$(m \cdot g).\ L = F_R \cdot y \Rightarrow \quad y = \frac{m.g.L}{FR}$$

Where:

M1: the moment produced by the weights.

M2: the moment produced by the force of pressure on the plate.

m: mass.

L: the length of the arm of weight.

F_R: force of pressure.

y: the arm of the force of pressure.

Thus, we can calculate $\mathbf{y_p}$ as follow:

$$\mathbf{y = y_p + (H - d)} \quad \Rightarrow \quad \mathbf{y_p = y - (H - d)}$$

Where:

L = 0.25 m.

H = 0.2 m.

Results and conclusions:

	Case of submersion	Mass (g)	d (m)	m.g.L (N.m)	F_R (N)	y (m)	y_p (m)
1	Partially	25	0.04				
2	Partially	50	0.06				
3	Partially	75	0.076				
4	Fully	175	0.116				
5	Fully	200	0.124				
6	Fully	225	0.132				

Discussion:

1. determine the values in the table above.

2. draw a curve to show the change of F_R with d.

3. draw a curve to show the change of y with d.