457.204 Elementary Fluid Mechanics and Lab.
Elementary Test

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ET 2: Hydrostatic pressure

1. Objective

To determine the position of the centre of pressure of a plane surface immersed in water and to compare the experimental position with the theoretical results

2. Theory

※ Total immersion:

$$F = \rho g \bar{X} A$$

The sum of the moments of all these differential forces about any point must be equivalent to the moment about the same point of the resultant force F acting through its point of application. Taking moments about 'O':

$$M = \int X^2 \rho g dA$$

We know that; $\int X^2 dA$ is 2nd moment of area (I_{00}),

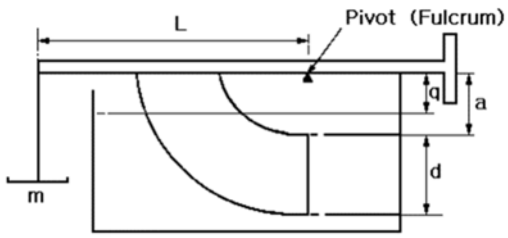
$$M = \rho g I_{00} = Fz$$

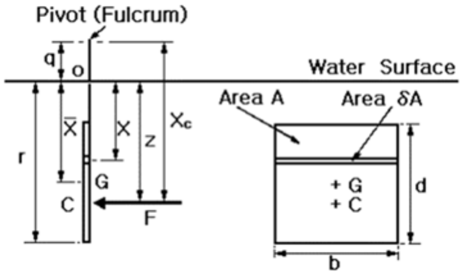
Therefore,

$$z = \frac{\rho g I_{00}}{\rho g A \bar{X}} = \frac{I_{00}}{A\bar{X}}$$

$z = \frac{I_{00}}{A\bar{X}}$ from parallel axis theorem $I_{00} = I_{gg} + A\bar{X}^2$

$$z = \frac{I_{gg} + A\bar{X}^2}{A\bar{X}} = \frac{I_{gg}}{A\bar{X}} + \bar{X}\ , \quad X_c = z + q$$





Since $I_{gg} = br^3/12$ and substituting $A = br$ and $\bar{X} = r/2$ in the equation for z, $z = 2/3r$.

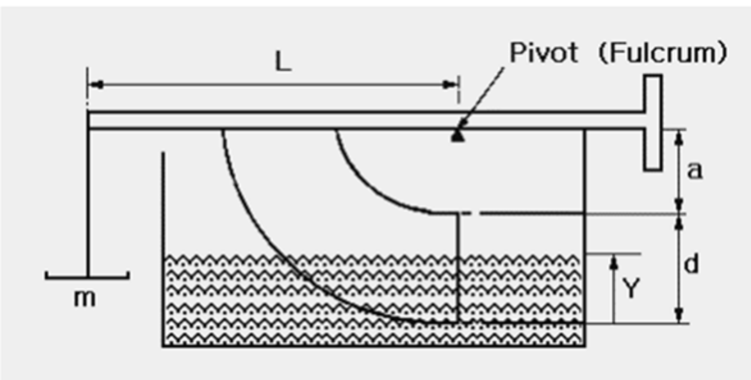
It can be clearly seen that the centre of pressure is always $2/3$ down the section of the plate that is submerged.

$$X_c = 2/3r + q$$

※ Partial immersion:

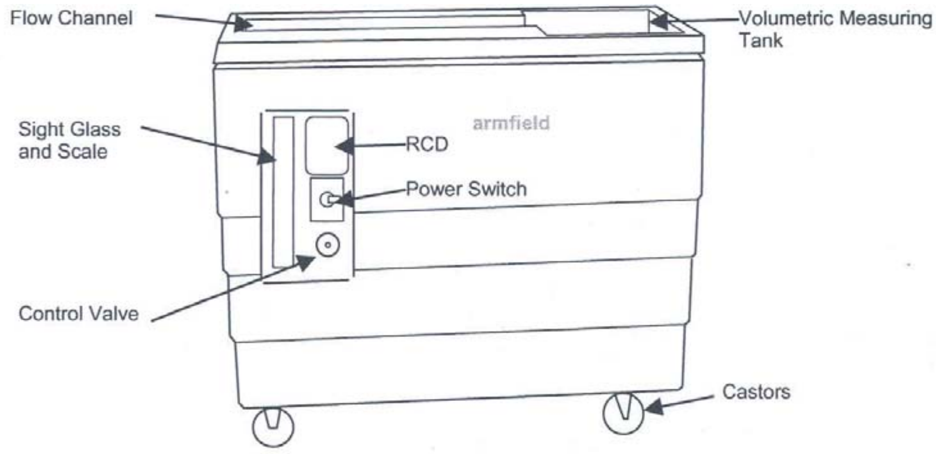
$$mgL = \frac{\rho g}{2} by^2 \left[(a+d) - \frac{y}{3} \right]$$

$$\therefore \frac{m}{y^2} = \frac{\rho b}{2L}[a+d] - \frac{\rho b}{2L}\left(\frac{y}{3}\right)$$

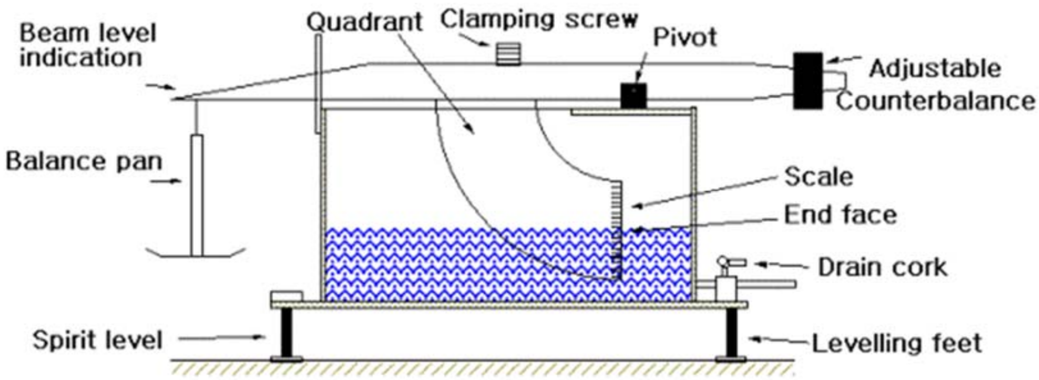


3. Equipment Set-up

1) Hydraulics Bench



2) Hydrostatic Pressure Apparatus



4. Procedure

① Place the quadrant on the two dowel pins and using the clamping screw, fasten to the balance arm.

② Measure a, L, depth d and width b, of the quadrant end face.

③ With the Perspex tank on the bench, position the balance arm on the knife edges (pivot).

④ Hang the balance pan from the end of the balance arm.

⑤ Connect a hose from the drain cock to the sump and another from the bench feed to the triangular aperture on the top of the Perspex tank.

⑥ Level the tank using the adjustable feet and spirit level.

⑦ Move the counter balance weight until the balance arm is horizontal.

⑧ Close the drain cock and admit water until the level reaches the bottom edge of the quadrant.

⑨ Place a weight on the balance pan, slowly adding water into the tank until the balance arm is horizontal.

⑩ Record the water level on the quadrant and the weight on the balance pan.

⑪ Repeat the above for each increment of weight until the water surface level reaches the top of the quadrant end face. Then remove each increment of weight noting weights and water levels until the weights have been removed.

5. Results and Calculations

※ Total immersion:

Mass m (g)	r (mm)	X_{cA} (mm)	X_{cT} (mm)	M (N.m)	F (N)

$mgL = FX_{cA}$

• Plot X_{cA} actual against X_{cT} theoretical for the partial and fully submerged cases. Explain the reasons for any discrepancies between the actual and theoretical results.

• Explain why the centre of pressure is always below the centroid.

※ Partial immersion:

Mass m (g)	Height of water y (mm)	X_{cA} (mm)	X_{cT} (mm)	M (N.m)	F (N)

• Plot $\frac{1}{y^2}$ against y

• Give reasons for the discrepancies, if any, between the measured and predicted values of the above expressions for the graph parameters.