CIV ENG Y1 FLUID MECH SUMMARY

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1 FUNDAMENTALS

Definitions

Fluid: A substance that deforms continuously under an applied shear stress.
Density, ρ: The mass m per unit volume V of substance, where $\rho = \frac{m}{V}$.
Specific weight, γ: The weight per unit volume of substance, where $\gamma = \rho g$.
Specific gravity, S: The ratio of a substance's density ρ to the density of water ρ_{water}, where $S = \frac{\rho}{\rho_{\text{water}}}$.
Compressibility: The ease of changing a fluid's density.

Continuum hypothesis

- Only the collective reaction of all molecules in a given volume to applied forces are considered.
- Assumptions:
  - A large number of molecules in a given volume.
  - The physical scale of the object of interest in the fluid is large enough.

Stresses in fluids

- Stresses can be normal or tangential to the surface of a fluid.
  - Normal stresses create forces that compress/expand fluid elements without altering shape.
  - Shear stresses create forces that deform their shape without altering volume.
- Fluid motion can cause stresses in the fluid, vice versa.
  - Stationary fluids only experience normal pressure stresses.
  - Moving fluids experience both normal and shear stresses.

2 FLUID STATICS

Definitions

Absolute pressure: The pressure with respect to a vacuum, where $p_{\text{vacuum}} = 0$.

Gauge pressure: The pressure with respect to local atmospheric pressure, where $p_{\text{atm}} = 0$.

Manometer: Usually a liquid-filled U-tube that measures pressure differences between 2 locations.

Centre of pressure: The point where the overall pressure force can be taken to act from.

Pressure

- Pressure p acts normally to any surface in contact with the fluid, where $p = \frac{F}{A}$.
- The speed of pressure transmission through a fluid depends on the speed of sound in the fluid and the shape of the vessel.

Hydrostatic pressure

- In a static fluid, $\sum F_x = \sum F_y = \sum F_z = 0$ for any fluid element. Thus:
  - Pressure is constant in the horizontal x-y planes.
  - In the z^*-axis, pressure p changes according to the hydrostatic equation:

$$\frac{dp}{dz^*} = \rho g \Leftrightarrow p = \int \rho g \; dz^*$$

- The general approach to solving hydrostatic pressure questions is to equate the pressures of two points at the same depth and manipulate accordingly.

Forces on containers

Flat bottoms

For a container of base area A, the force F_{bottom} exerted by a fluid filled to height h on its bottom:

$$F_{\text{bottom}} = pA = \rho g V = W_{\text{fluid}}, \text{ where } V = Ah \text{ is the volume of fluid.}$$

Vertical sidewalls

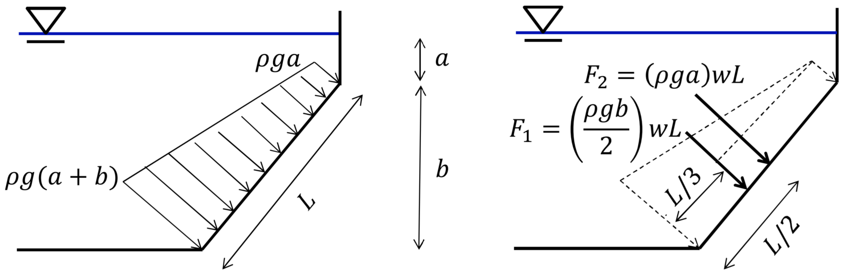
For a container of width b, the force F_{side} exerted by a fluid on its sidewall when filled to height h is:

$$F_{\text{side}} = \int_0^h p \; dA = \rho g b \int_0^h z^* \; dz^* = \frac{1}{2}\rho g b h^2 = \left(\rho g \frac{h}{2}\right) bh$$

- F_{side} can also be interpreted as the pressure at half-depth $\frac{h}{2}$ times the surface area of the sidewall.
- The centre of pressure is $\frac{h}{3}$ units from the base of the triangle.

Straight surfaces at an angle

For a plate of length L and width w, the overall pressure force can be split into 2 forces, due to a constant load F_2 and a linearly-distributed load F_1:



Complex geometries

- Split the overall pressure force into its vertical and horizontal components:
  - The vertical component F_v is the total weight of the fluid above up to the free surface (even if there is a partially submerged structure above).
  - The horizontal component F_h is the pressure force on a vertical wall of the same height.
- This method of projection does not tell you where the centre of pressure is.

Partially submerged structures

- For an object in a fluid, the buoyant force F_b is equal to the weight of the fluid displaced:

$$F_b = \rho g V_{\text{object}}$$

- Structures jutting below the fluid experience an upward force equal to the weight of fluid displaced by that segment up to where the free surface should be.

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3 TURBULENCE

Definitions

Ideal fluid: A fluid that only experiences normal stresses (and thus, zero viscosity).

No-slip condition: The velocities of the fluid and a solid surface are identical at the interface.

Boundary layer: A region where flow velocity changes greatly.

Dynamic viscosity, μ: A fluid's resistance to losing momentum to shear forces.

Kinematic viscosity, ν: Like dynamic viscosity, but when density variations are negligible, where $\nu = \frac{\mu}{\rho}$.

Laminar: A flow that is organised and layered with minimal friction.

Turbulent: A flow that is disorganised and random with significant friction.