Taylor Able, Lou Baker
EM324 Fluid Mechanics
Section 2468
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Lab 0: Fluid Hydrostatics

Objectives

The objective of this lab was to compare theoretical predictions of hydrostatic pressure as a function of depth with experimental observations.

Background

As depth increases, the hydrostatic pressure experienced by an object also increases. The theoretical relationship between depth, h, and hydrostatic pressure, p_1 is given by Equation 1,

$$p_1 = \gamma h + p_2 \tag{1}$$

where γ is the specific weight of water and p_2 is some reference pressure, typically the pressure at the free surface (atmospheric pressure) [1]. When the analysis is conducted on a gage basis, p_2 goes to zero and Equation 1 reduces to Equation 2.

$$p = \gamma h \tag{2}$$

The model described by Equation 2 indicates that the relationship between the depth and the hydrostatic pressure is linear with γ, the slope of the line, being constant.

Procedures

This experiment was conducted in the LeJeune Hall diving well. Pressure measurements were taken using a hydrostatic pressure transducer at depths from 0 to 15 ft at 1 ft. increments, where 0 ft is at the free surface, as shown in Figure 1. A total of 16 measurements were recorded for analysis.

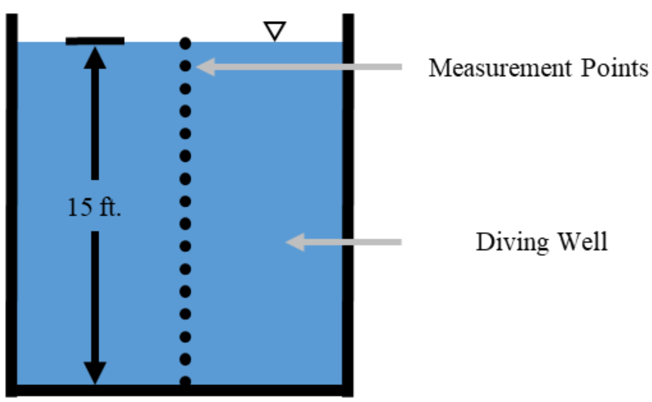

Figure 1: Schematic of the LeJeune Hall diving well. The black dots indicate measurement points from the free surface to the bottom of the tank.

Results

The experimental data is provided in Appendix A. Theoretical pressures were calculated using Equation 2 over a depth range of 0 to 15 ft, with the specific weight of water as $\gamma = 62.4$ lbf/ft^3 [2]. The code used for this analysis is included in Appendix B. Figure 2 shows a plot of pressure as a function of depth for both the experimental data and theoretical results.

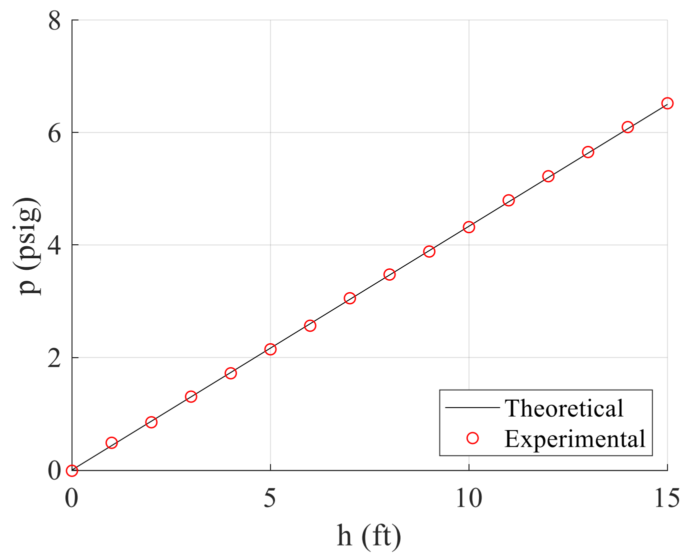

Figure 2: Theoretical (black line) and experimental (red circle) hydrostatic pressure as a function of depth (i.e. distance from the free surface, 0 at the surface and increasing downward).

As show in Figure 2, as the depth increases from the free surface down to 15 ft, the experimental hydrostatic pressure increases linearly from 0 at the surface to a maximum of 6.5 psig.

The percent difference for specific weight and for pressure was calculated using Equation 3,

$$y_{\%diff} = \frac{|y_e - y_t|}{\frac{y_e + y_t}{2}} * 100\% \tag{3}$$

where the subscript e indicates the experimental value and the subscript t indicates the theoretical value. The slope of the experimental line (i.e. the specific weight) was constant with a value of 62.7 lbf/ft^3, 0.4% different from the theoretical value of 62.4 lbf/ft^3. The percent difference values for each observation were calculated and are included in Table 1. The maximum percent difference for the pressure at a given depth was 10.9%, with the vast majority of difference values being on the order of 2% or less.

Table 1: Comparison of theoretical predictions to experimental results.

Depth (ft.)	Theoretical Pressure (psig)	Experimental Pressure (psig)	Percent Difference (%)
1.0	0.43	0.48	10.85
2.0	0.87	0.85	2.19
3.0	1.30	1.30	0.29
4.0	1.73	1.72	0.83
5.0	2.17	2.14	1.02
6.0	2.60	2.56	1.37
7.0	3.03	3.05	0.64
8.0	3.47	3.47	0.23
9.0	3.90	3.88	0.42
10.0	4.33	4.32	0.37
11.0	4.77	4.79	0.57
12.0	5.20	5.22	0.43
13.0	5.63	5.65	0.34
14.0	6.07	6.10	0.48
15.0	6.50	6.52	0.30

Discussion

The model presented in Equation 2 assumes that 1) the fluid is static (i.e. shear forces are negligible) and that 2) the specific weight is constant with depth. The water in the pool was observed to be largely still, thus the first assumption was deemed appropriate. The slope of the experimental data was shown to be constant, thus the validity of the second assumption was confirmed. Therefore, the most likely difference between the experimental observations and the theoretical predictions was likely a result of measurement uncertainty with the pressure transducer having a stated uncertainty of +/- 0.01 psi. Additionally, the theoretical specific weight value used in the model was for water at 60°F [1]. The water in the pool was actually 82°F. However, given the comparatively small variation of the specific weight of water with temperature over such a small temperature difference, it is unlikely that this contributed significantly to the difference between the measured and calculated values.

Conclusions

The objective of this lab was to compare the theoretical values for hydrostatic pressure, predicted as a function of depth, to experimentally observed values. Pressure values were taken over a range of depths from 0 to 15 ft in the LeJeune Hall diving well. Experimental data showed that hydrostatic pressure increased linearly with depth, as predicted by the theoretical model, and that the specific weight was a constant value, evaluated to be 62.7 lbf/ft^3, 0.4% different from the theoretical value of 62.4 lbf/ft^3. The experimental results for hydrostatic pressure agreed with the model predictions to within 11% for all observations, and to within 2% for the vast majority of depths.

References

[1] Munson, Bruce, Young, Donald, Okiishi Theodore, and Wade Huebsch. *Fundamentals of Fluid Mechanics 9th Edition*. New Jersey: John Wiley & Sons, Inc., 2006.

Appendix A: Experimental Data

Depth (ft)	**Pressure** (psig)
0.0	-0.01
1.0	0.48
2.0	0.85
3.0	1.30
4.0	1.72
5.0	2.14
6.0	2.56
7.0	3.05
8.0	3.47
9.0	3.88
10.0	4.32
11.0	4.79
12.0	5.22
13.0	5.65
14.0	6.10
15.0	6.52

Appendix B: MATLAB Code

```
%% LB0 - Hydrostatics (Example Lab)
clear
close all
clc

% Define parameters
gamma_theoretical = 62.4; % specific weight of fresh water, lbf/ft^3 (Table
1.5)

% Create a vector of 1000 theoretical depths from 0 to 15 ft.
h_theoretical = linspace(0,15,1000);

% Create a vector of theoretical hydrostatic pressures, in lbf/ft^2
p_theoretical = gamma_theoretical * h_theoretical;
% Note: gamma is in lbf/ft^2 so the resulting pressure is in lbf/ft^2

% Create a plot of theoretical values
figure % Always start a new figure with the statement "figure"
hold on
plot(h_theoretical, p_theoretical/144,'k-') % Convert from base units at
plotting time
xlabel('h (ft)')
ylabel('p (psig)')
grid

% Load experimental data
data = xlsread('EM324 Example Lab Data LB0.xlsx');

% Parse data
h_experimental = data(:,1); % depth, in ft
p_experimental = data(:,2)*144; % hydrostatic pressure, in lbf/ft^2 (gage)
% Note: MATLAB does not keep track of units.  I strongly recommend you
% convert all data into base units (e.g. cm or mm to m, in. to ft., and psi
% to lbf/ft^2 to preclude hours of soul-crushing de-bugging.)

% Plot data on the same set of axes (note: "hold on" already on)
plot(h_experimental, p_experimental/144,'ro'); % Plot experimental data as
discrete points
% Include a legend
legend('Theoretical','Experimental','Location','SouthEast')
% After trying to insert this figure into the report, it's clear that the
% font is too small.  Increasing the font size programatically is a snap
% Name the current axes
ax = gca; % gca means "get current axes" which is the axes default name.
% Assign them the name "ax" instead.
% Use object property assignment to change the value
ax.FontSize = 16; % "ax" is the object, "FontSize" is the property, and 16
% is the thing that I want to make ax.FontSize
% Let's just fix the font style while we're at it.
ax.FontName = 'Times New Roman';

% The relationship between the pressure and depth appears to be linear,
% also suggested by the model.  Use a linear fit to calculate gamma (i.e.
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% the slope of the line)
fitParameters = polyfit(h_experimental,p_experimental,1);
% This is a polynomial fit, order 1 (i.e. a linear fit)
gamma_experimental = fitParameters(1);
% In the form y = mx + b, fitParameters(1) is m and fitParameters(2) is b.

% Print the result
fprintf('The experimental value of the specific weight of pool water is %g
lbf/ft^3. \n',gamma_experimental)

% Create a vector of theoretical values equal in size to the vector of
% experimental values
p_theoretical_compare = gamma_theoretical * h_experimental;
% Calculate the percent difference between the theoretical predictions and
% the experimental observations for gamma
pd_gamma = abs(gamma_experimental - gamma_theoretical)./...
    ((gamma_experimental + gamma_theoretical)/2)*100;
% Print the results
disp('The percent difference between theoretical and experimental values
for')
fprintf('specific weight was %g%%. \n',pd_gamma)

% Calculate the percent difference between the theoretical predictions and
% the experimental observations for pressure
pd_p = abs(p_experimental - p_theoretical_compare)./...
    ((p_experimental + p_theoretical_compare)/2)*100;
% Note: we can't do this directly with p_theoretical because it is a 1x1000
% vector.  We can't compare that directly to p_experimental, which is a
% 1x16 vector.  Thus we need to calculate a theoretical vector that is 1x16
% so that we can compare the hydrostatic pressure at each of the 16 depth
% values.

% Calculate the maximum difference between the theoretical predictions and
% the experimental observations
pd_max = max(pd_p);

% Print the result
disp('The maximum percent difference between theoretical predictions')
fprintf('and experimental values is %3.1f%%. \n',pd_max)
```