International Journal of Innovative Technology and Interdisciplinary Sciences
https://ijitis.org/index.php/IJITIS
ISSN: 2613-7305
Volume 6, Issue 3
DOI: doi.org/10.15157/IJITIS.2023.6.3.1206-1219
Received: 07.09.2023; Accepted:15.11.2023

Validation of the Hydrostatic Position of a Partially and Fully Submerged Vertical Curved Plane Surface Apparatus

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Abstract

Cultivating technological innovation and entrepreneurship development requires urgent attention in Africa, which is fertile ground for sustainable industrial hubs. The goal of this study is to validate locally made hydrostatic pressure equipment. To do this, specific goals need to be met, such as making hydrostatic position equipment from locally sourced materials, testing both ISO Standard and locally manufactured equipment, and comparing the locally manufactured equipment to an ISO Standard-certified one. Research and the Armfield hydrostatic position apparatus came up with the design method that was used in this project. Their work has been properly credited. The newly made equipment was used in the lab for tests, and the results were compared to those from ISO standard equipment based on what scholars thought. The Pearson product moment of correlation and t-test statistical methods were used to validate the newly fabricated apparatus. The new apparatus and the ISO Standard apparatus had a perfect fit of 1 for the correlation coefficient, and the t-test showed that there were no significant differences between the results from the two apparatuses when the same lab procedures were used. The newly fabricated hydrostatic pressure apparatus is much better than the ISO Standard one because it requires minimum operational and installation costs, no foreign exchange, little or no training costs, and locally sourced raw materials for fabrication. Sponsored creative innovation like this would sustain technological and entrepreneurial development and improve the nation's gross domestic product (GDP).

Keywords: Hydrostatic pressure; fabricated model validation; ISO standard apparatus; centre of pressure; creative innovations

INTRODUCTION

The advent of COVID-19 has posed so many problems in Africa's educational sector [1]. According to results in [2], there is a lack of functional laboratory apparatus in Africa's tertiary institutions, resulting in the graduation of half-baked graduates. Most tertiary institutions with little laboratory equipment currently have them in a dilapidated state. Institutions with laboratory equipment can't use them due to calibration issues, a lack of proper training on their use, and the unavailability of laboratory manuals. These challenges create a multitude of opportunities that make Africa's institutions fertile ground for creative innovations, technological advancements, and entrepreneurial developments. Hence, there is a need to fabricate and validate the hydrostatic position of a partially and fully submerged vertical curved plane surface apparatus.

Exploring these pockets of opportunities and proposing solutions to the challenges in Africa's tertiary institutions, this research seeks to validate the fabricated hydrostatic position of a partially and fully immersed vertical curved plan body apparatus with an imported ISO standard that would be used in her tertiary institutions to conduct laboratory practicals [2-4]. The objectives include fabricating an hydrostatic pressure apparatus using locally sourced materials, obtaining an imported hydrostatic pressure apparatus, carrying out laboratory experiments on the newly fabricated and imported apparatus, and validating the newly fabricated apparatus by comparing experimental results obtained from both apparatuses.

The fabrication was done using standard materials that meet ISO standards [5], [6], are reliable, and are sustainable [7-9]. Hydrostatic position apparatus operates based on Archimedes principles and Newton's law of motion [10-14].

Hydrostatic pressure apparatuses have global applications in science and engineering. It is applicable in simulations of a partially submerged cylinder subjected to current and waves [15], in experimental investigations on the failure modes of ring-stiffened cylinders under external hydrostatic pressure [16], in the determination of a ship's stability and hydrostatics [17], and [18], in the modeling of hydraulic structures, submarines, war boats, and other applications based on references [19-23]. Hydrostatic pressure is also applicable in vehicle steering dynamic calculation and simulation [24].

This research would help bridge the gaps identified in this work, which include inadequate laboratory equipment in tertiary institutions in developing countries, raise the morale of researchers to discover their creative ingenuity, and drive innovative technology and entrepreneurship development to the next level. The thoughts of the researchers here would equally provide hands-on experience to all undergraduate and postgraduate students in tertiary institutions. This would change the narrative stipulated earlier in this work to produce practical-oriented graduates instead of "half-baked graduates.

MATERIALS AND METHOD

The materials used in fabricating the apparatus include a Perspex water tank of 20 liters capacity, level adjustment support screws at the base, a quadrant of 75mm internal radius, 150mm outer radius, and 60mm width, a balance arm, a balance pan, a beam level indicator, an adjustable counter-balance with a distance of 285mm between the balance pan and knife edge, a set of standard weights, and a spirit level.

This apparatus was designed and fabricated with local material to enable students to determine the center of pressure of a totally or partially submerged curved plane surface [25-29]. It was fabricated and calibrated with standard precision to enable students to accurately determine the theoretical center of pressure and compare actual and theoretical hydrostatic thrust [30-33].

ISO standard-certified equipment is expected to produce accurate results that meet clauses 6 and 8 of the ISO 9001:2015 requirements. In view of this fact, validation of the locally fabricated apparatus is centered on experimental results obtained from the fabricated apparatus. Experiments were conducted on the newly fabricated hydrostatic position apparatus, and the results were compared with the results obtained from imported apparatus. The results obtained from the newly fabricated equipment and the ISO standard were validated using Pearson's product moment correlation coefficient.

In this research, laboratory experiments were conducted [34-41], using both apparatuses to determine the hydrostatic force and moment produced by the action of the curved plane surface partially and fully immersed in water [42-44]. The design of the center of pressure apparatus with demonstration was done based on the thoughts of [45]. The hydrostatic leveling of the fabricated equipment was factored according to [46].

Equipment Set-up and laboratory procedure

The equipment set up and laboratory procedures are based on the thought of [45].

Laboratory Procedure

The laboratory procedure is as follows:

1. Adjust the counterweight so that the beam is balanced horizontally with no water in the tank.
2. Add water up to the bottom edge of the quadrant.
3. Add weights to the pan and slowly add water to the tank until the beam is restored to a horizontal position. Record the weight, and measure H.
4. Measure and record H and r.
5. Calculate and tabulate the actual and theoretical values of the center of pressure yR, XCA, and XCT (the values are expected to be the same).
6. Calculate and compare the theoretical and actual depths of pressure (y_R and XCT). If the values are not reasonably close, check your measurement procedure.
7. Return to step 2 and repeat the measurements using at least three other water levels.

Specification of components

The specification of the materials used for fabricating the apparatus is according to [47] and [48].

The apparatus is made up of four support columns of 8 mm in diameter (Φ =4 x 8 mm) galvanized steel rods with a height of 40 mm. It has a reservoir capacity of 400mm x 400mm x 150mm. The material used to fabricate the reservoir is transparent fiber glass. It has an inlet control valve of 2 x 1.0" gate valve and a quadrant with a dimension radius of 75mm internal radius, 150mm outer radius, 60mm width, and a face area of 100mm x 100mm. It has a minimum balance arm diameter of 40mm, a balance pan hook diameter of 10mm (= 10mm), a base of hook diameter of 40mm (Φ = 40mm), a beam level indicator area of 30 mm x 60mm, an adjustable counter-balance diameter of 75mm (Φ = 75mm), a distance between the balance pan and knife edge of 285mm, a set of standard weight masses of 5g, 10g, 20g, 50g, 100g, 500g, and 1000g, and a Spirit level of 20mm diameter (Φ= 20mm) as shown in Figures 1 and 2 below.

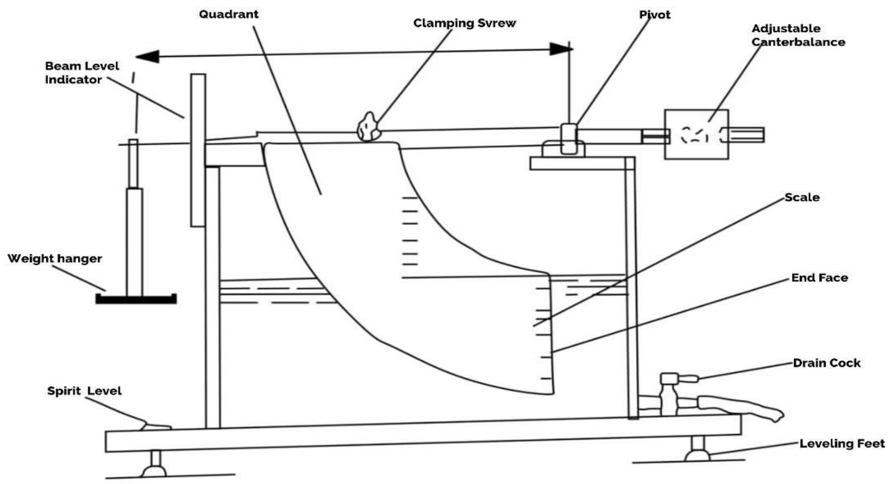

Figure 1. Detailed drawing of hydrostatic pressure apparatus [49]

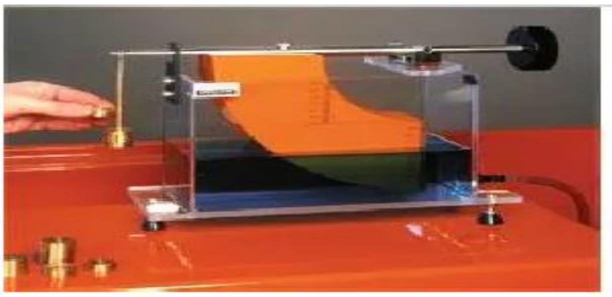

Figure 2. Partially submerged vertically curved pressure apparatus [36]

Isometric view of the hydrostatic position of a partially and totally immersed, curved plain body

Isometric views of the fabricated hydrostatic apparatus, the imported hydrostatic apparatus, and the fabricated hydrostatic apparatus are presented below in Figures 3-6, respectively.

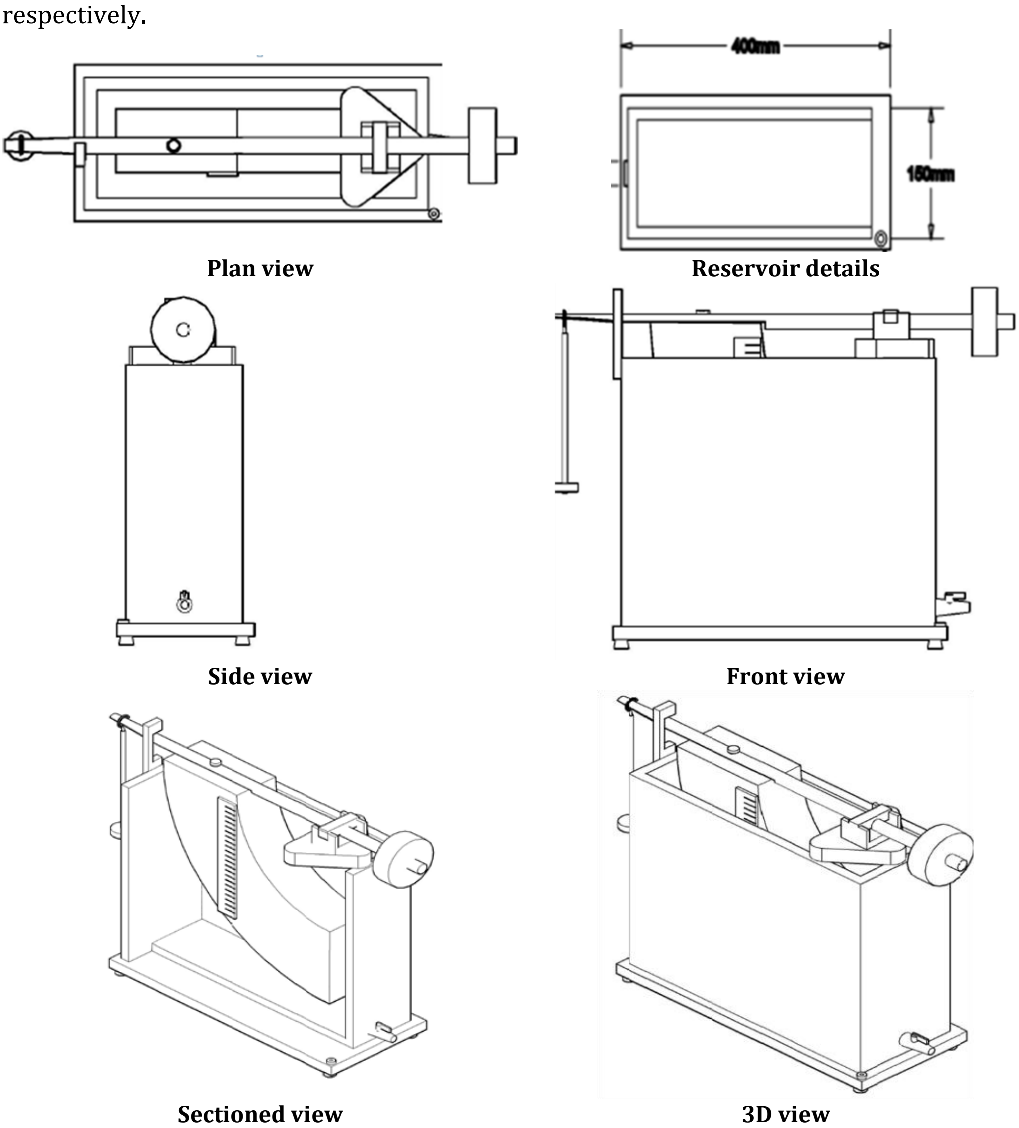

Figure 3. Isometric view of the fabricated hydrostatics apparatus.

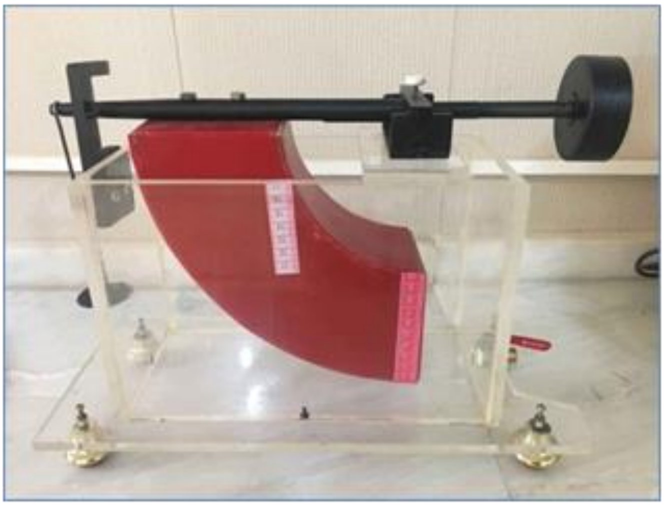

Figure 4. Fabricated hydrostatic position apparatus according to [45]

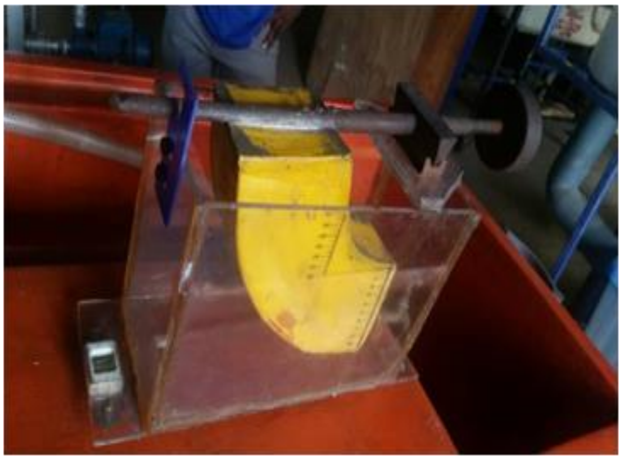

Figure 5. Fabricated hydrostatic position apparatus according to [45]

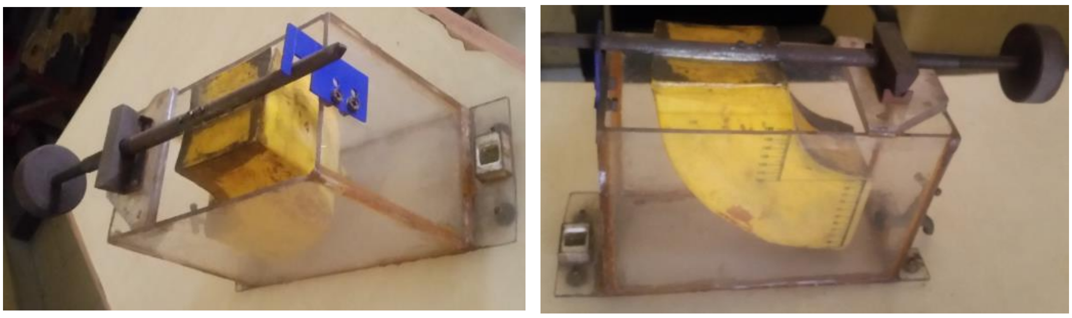

Figure 6. Different views of newly fabricated prototype in crude from

Methods

The method used in validating the fabricated hydrostatic apparatus is Pearson's product moment of correlation [2]. The results of the locally fabricated V-notch apparatus were compared with ISO-standard fabricated apparatus [3] and [45]. The experimental setup, laboratory procedures, analysis, and design were performed based on the thoughts of [49-

51], and [45]. The T-test statistical method was used to test the differences in results obtained from both apparatuses at 5% and 10% significant levels using the same laboratory procedure.

RESULTS AND DISCUSSION

In the views of [45], the formulae used for the hydrostatic pressure apparatus in the case of the partially submerged vertical plane and the experimental equations used for the fully submerged vertical plane are presented in Table 1 below.

Experiments were conducted on the newly fabricated and ISO standard imported hydrostatic position apparatus, respectively, and the results were computed and tabulated as shown in Table 2 based [45].

The tabulated results obtained from experiments conducted on the newly fabricated apparatus were compared and adequately validated with the ISO standard imported apparatus based on [45], [12], and [13], as shown in Table 3.

Table 1. The formulas used for the hydrostatic pressure computation for partially and fully submerged vertical planes [45]

Name	Unit	Symbol	Formula
Experimental equations used for the partially submerged vertical plane			
Hydrostatic thrust	N	F	F = ρ*g* Bd²/2
Experimental center of pressure	m	H	h'' = m*g*L/F
Theoretical center of pressure	m	h	h'' = H-d/3
Experimental equations used for the fully submerged vertical plane			
Hydrostatic thrust	N	F	$F = \rho g B D\left(d - \frac{D}{2}\right)$
Experimental center of pressure	m	h	$h'' = \frac{mL}{\rho B D\left(d - \frac{D}{2}\right)}$
Theoretical center of pressure	m	h	$h'' = \frac{\frac{D^2}{12} + \left(d - \frac{D}{2}\right)^2}{d - \frac{D}{2}} + H - d$

Table 2. Results of computation for partially and fully submerged vertical plane of newly fabricated and ISO standard hydrostatic apparatus [45]

Partially and fully submerged vertical plane of newly fabricated apparatus							
Mass (g)	**Depth (mm)**	**The measured moment (N.m)**	**The theoretical hydrostatic force (N)**	**Experimental center of pressure (m)**	**Theoretical center of pressure (m)**	**Experimental hydrostatic force (N)**	**The calculated moment (N.m)**
50	60	0.123	1.413	0.087	0.190	0.645	0.056
75	70	0.184	1.923	0.962	0.187	0.998	0.960
100	75	0.245	2.210	0.111	0.185	1.324	0.147

125	85	0.310	2.840	0.109	0.182	1.703	0.186
150	90	0.370	3.180	0.119	0.180	2.005	0.239
175	95	0.429	3.314	0.129	0.179	2.410	0.310
225	110	0.552	4.710	0.117	0.174	3.170	0.371
275	120	0.674	5.494	0.123	0.172	3.920	0.481
325	130	0.800	6.280	0.127	0.170	4.710	0.600
375	143	0.920	7.300	0.010	0.169	5.450	0.056
Partially and fully submerged vertical plane of ISO standard imported apparatus							
50	60	0.123	1.413	0.087	0.190	0.645	0.056
75	70	0.184	1.923	0.962	0.187	0.998	0.960
100	75	0.245	2.210	0.111	0.185	1.324	0.147
125	85	0.310	2.840	0.109	0.182	1.703	0.186
150	90	0.370	3.180	0.119	0.180	2.005	0.239
175	95	0.429	3.314	0.129	0.179	2.410	0.310
225	110	0.552	4.710	0.117	0.174	3.170	0.371
275	120	0.674	5.494	0.123	0.172	3.920	0.481
325	130	0.800	6.280	0.127	0.170	4.710	0.600
375	143	0.920	7.300	0.125	0.169	5.450	0.680

Table 3. Validation of Newly Fabricated Hydrostatic Position Apparatus with standardized [45]

Calculated moment (N.m) for standard apparatus based on Jasim, and Shamkhi (2020) invention (X)	Calculated moment (N.m) for newly fabricated apparatus (Y)	X^2	Y^2	XY
0.0560	0.0565	0.0031	0.0032	0.0032
0.9600	0.9605	0.9216	0.9226	0.9221
0.1470	0.1491	0.0216	0.0222	0.0219
0.1860	0.1890	0.0346	0.0357	0.0352
0.2390	0.2900	0.0571	0.0841	0.0693
0.3100	0.3110	0.0961	0.0967	0.0964
0.3710	0.3712	0.1376	0.1378	0.1377
0.4810	0.4815	0.2314	0.2318	0.2316
0.6000	0.6000	0.3600	0.3600	0.3600
0.6800	0.6805	0.4624	0.4631	0.4627
4.0300	**4.0893**	**2.3256**	**2.3572**	**2.3401**

$$\frac{\sum Xy}{\sqrt{\sum x^2 * \sum y^2}} = \frac{2.3401}{2.3572} = 0.998$$

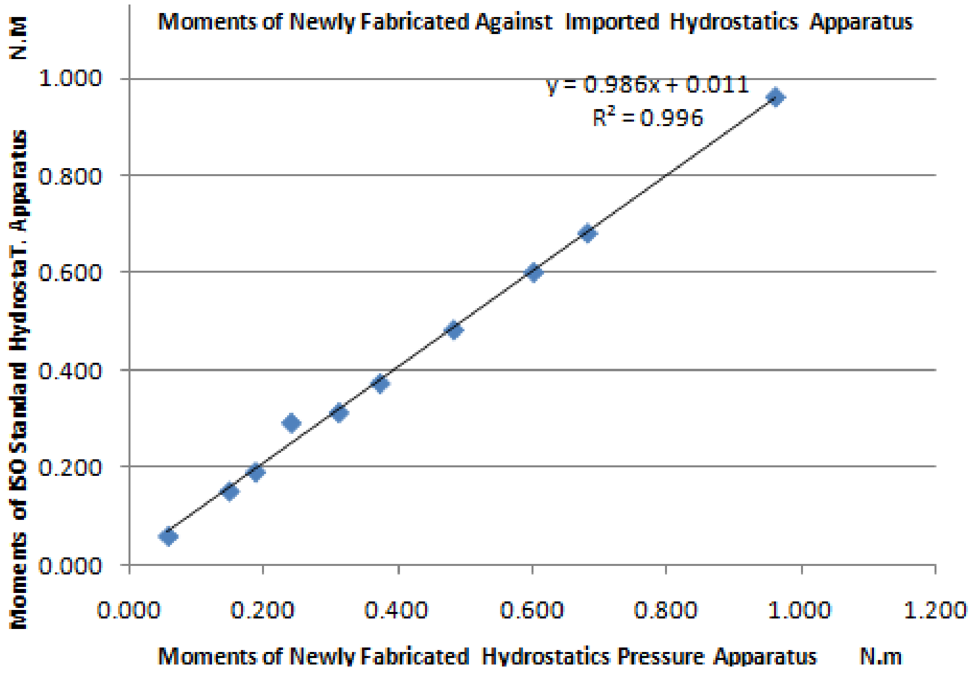

Figure 7. Graph of Newly Fabricated and Imported Hydrostatic Apparatus

T-test Statistic for new developed models

The T-test statistic for the results of the newly fabricated models against imported models is presented in Table 4 below.

Table 4. T-test for calculated moments obtained from the new and ISO standard apparatus.

S/NO	x	y	$d_1 = x_i - y_i$	$d_1 - \bar{d}$	$(d_1 - \bar{d})^2$
1	0.0560	0.0565	0.000500	-0.005430	0.000029
2	0.9600	0.9605	0.000500	-0.005430	0.000029
3	0.1470	0.1491	0.002100	-0.003830	0.000015
4	0.1860	0.1890	0.003000	-0.002930	0.000009
5	0.2390	0.2900	0.051000	0.045070	0.002031
6	0.3100	0.3110	0.001000	-0.004930	0.000024
7	0.3710	0.3712	0.000200	-0.005730	0.000033
8	0.4810	0.4815	0.000500	-0.005430	0.000029
9	0.6000	0.6000	0.000000	-0.005930	0.000035
10	0.6800	0.6805	0.000500	-0.005430	0.000029
$\sum x_1$	4.0300	4.0893	0.059300	0.000000	0.002265

The computation of the T-tabulation is summarized and presented in Table 5 below.

Table 5. Summary table of the T-tabulated

parameters	Statistical model	Results
Average difference	$\frac{\sum d_1}{n}$	0.0059
Variance	$d^2 = \frac{\sum(d_1 - d)^2}{N-1}$	0.0003
Standard deviation	$Sd^2 = \sqrt{\frac{\sum(d_1 - d)^2}{N-1}}$	0.0159
T-test	$t = \sqrt{\frac{d}{S_d / \sqrt{n}}}$	1.1821

Where
x = Calculated moment (N.m) for standard apparatus based on the [45] invention
y= Calculated moment (N.m) for newly fabricated apparatus

Hypothesis

$H_0: \mu_{1i} = \mu_{2i}$ (For all i), and that each pair of means are equal, any difference may have arisen by chance (or there is no significant difference in the in the results obtained from the two apparatuses)
$H_1: \mu_{1i} = \mu_{2i}$ (For all i), and there no significant difference in the two methods
$H_0; all\ di = 0$; There is significant difference in the results obtained from the two apparatuses (Newly fabricated and imported ISO standard apparatuses).
$H_1; all\ di \neq 0$; There is significant difference in the results obtained from the two apparatuses (Newly fabricated and imported ISO standard apparatuses).

Testing at 5% significant level

t_{cal}= 1.18 , $t_{0.975,}$ 9 = 2.26
In view of the fact that the computed t-value of 1.18 is lesser than the tabulated t-value of $t_{0.975,}$ 9 = 2.26, it is concluded that the results obtained from the two apparatuses showed no significant at 5% level. The null hypothesis (H_0) should be accepted while the alternate hypothesis (H_1) should be rejected.

Testing at 10% significant level

t_{cal}= 1.18/, $t_{0.975,}$ 9 = 1.83
Sequel to the fact that the computed t-value of 1.18 is lesser than the tabulated t-value of $t_{0.950,}$ 9 = 1.83, it is concluded that the differences in the result obtained from the two apparatuses is not significant at 10% level. The null hypothesis (H_0) should be accepted while the alternate hypothesis (H_1) should be rejected.

Table 2 shows the experimental results for the newly fabricated equipment and ISO-standard equipment invented by [45]. The experimental procedures for the experiment were performed as per ISO standards.

Table 3 shows the validation of newly fabricated hydrostatic position apparatus with standard imported apparatus invented by [45]. The calculated moment (N.m.) for newly fabricated apparatus and ISO standard apparatus based on the [45] invention represents X and Y, respectively. The validation was done using Pearson's product moment of correlation. The correlation coefficient obtained had a perfect fit of 1.

More so, Figure 7 and the result of Table 3 showed that the newly fabricated equipment gave the same result compared with the ISO standard apparatus based on [45], with great improvement, and it agrees with the thoughts of [52-55].

The newly fabricated equipment is much more effective and efficient in view of the fact that it is mobile, the material used for its construction can be locally sourced cheaply, low operational and installation costs are required, and it will definitely move entrepreneurship development to the next level when produced in mass quantity.

In view of the results in Tables 4 and 5, where the computed t-value of 1.18 is less than the tabulated t-value of $t_{0.975,}$ = 2.26, it is concluded that the differences in the results obtained from the two apparatuses are not significant at the 5% level. The null hypothesis (H0) should be accepted, while the alternate hypothesis (H1) should be rejected.

Conclusively, Tables 4 and 5 showed that the computed t-value of 1.18 is less than the tabulated t-value of 0.950, = 1.83. It is concluded that the differences in the results obtained from the two apparatuses are not significant at the 10% level. The null hypothesis (H0) should be accepted, while the alternate hypothesis (H1) should be rejected.

CONCLUSION AND FUTURE STUDY

The newly made equipment passed the quality assurance and control test according to clauses 8 and 9 of the ISO 9001:2015 standard. This is because the correlation coefficient between the newly made equipment and the ISO standard equipment was 1, and the t-test showed that the null hypothesis should be accepted at 5% and 10% significant levels. The newly fabricated apparatus has added advantages that make it much more effective and efficient compared with the imported one because it has a minimum operational and installation cost, is cheaper and available locally, and has easy mobility. The newly made hydrostatic position apparatus should be used in all colleges and universities. If it is mass-produced, it will help creative ideas and business growth reach a whole new level. It is recommended that the federal ministry of education and other relevant ministries sponsor and encourage the use of newly fabricated hydrostatic position apparatus like this, as it will help encourage creativity, innovation, entrepreneurship development, and improve the nation's GDP.

The newly fabricated apparatus should be digitized to increase accuracy in observing measurements. Accuracy in measurement is one limitation that could be encountered using this fabricated equipment. This limitation is mainly caused by human error due to parallax when taking measurements from the calibrated quadrant and weight balance. One of the major drivers of the thought presented in this research is technological and entrepreneurial development. Optimal production of the apparatus to maximize profit without compromising on the best standard is necessary. Game theory, Bayesian decision theory, and Markov Optimization tools could be useful in achieving the desired product optimization. More research should be done in the area of policy for adoption and use of the fabricated equipment. The federal ministries of developing countries around the world should sponsor bills that promote the use of fabricated hydrostatic pressure apparatus in tertiary institutions. This would help to encourage more production of this and other laboratory equipment, enhancing further production and driving creativity, technological innovation, and entrepreneurship development to a better position globally.

ACKNOWLEDGMENT

The authors want to express their gratitude to all of their companions, colleagues, and the management and faculty of the Federal University of Technology, Ikot Abasi, Kenule Beeson Saro-Wiwa Polytechnic, Bori, Chukwu Emeka Odumegu Ojukwu University, Uli, as well as the Centre for Occupational Health, Safety, and Environment (COHSE) for their financial, academic, and moral support.

Funding

This research does not receive fund from any agency.

Data Availability Statement

All relevant data used for this research are included in the paper.

CONFLICT OF INTEREST

The work presented in this publication has not been influenced by any apparent conflicts of interest between the authors and their respective institutions.

REFERENCES

[1] Willies D, (2023). The Impact of COVID-19 Pandemic on the Education System in Developing Countries. *Journal of Education and Practice*. 9(1):15-26 DOI: 10.47604/ajep.1882, https://www.researchgate.net/publication/369581290_The_Impact_of_COVID-19_Pandemic_on_the_Education_System_in_Developing_Countries.

[2] Akpan P.P., Uneke L.A. and Sunday L.U. Efficiency of Locally Fabricated Venturi Meter Marched with ISO Standard, *International Journal of Emerging Technology and Advanced Engineering*, 2015; 5(11):232-241. http://www.ijetae.com/files/Volume5Issue11/IJETAE_1115_41.pdf.

[3] Akpan P.P., Uneke L.A. and Sunday L.U. Fabrication of an Orifice Meter Using Local Materials: Means of Enhancing Technological Innovations and Entrepreneurship. *International Journal of Emerging Technology and Advanced Engineering*, 2015; 5(11): 221-231. http://www.ijetae.com/files/Volume5Issue11/IJETAE_1115_40.pdf. https://www.ijera.com/pages/v11no9.html#.

[4] Kim J-H, Kim J-H, Lee S-H, Park J, Lee S-K. Hydrostatic Forces on Submerged Plane Surfaces, 2019; 14(8): e0220639. https://doi.org/10.1371/journal.pone.0220639.

[5] Pramono, A., Sulaiman, F., Alfirano, Alhamidi, A. A., & Milandia, A. Fabrication of the Ti/SiC Based Composites by Self-Propagating High Temperature Synthesis. *International Journal of Innovative Technology and Interdisciplinary Sciences*, 2023; 3(4), 513–520. https://doi.org/10.15157/IJITIS.2020.3.4.513-520, https://www.ijitis.org/index.php/ijitis/article/view/58.

[6] Simoes D., Furtado A., PereiraJ., & Martins R.F. (2020). Enhancing the handling of standard substitution weights on a hydrostatic weighing apparatus, *ACTA IMEKO*. 9 (5), 27, doi:10.21014/acta_imeko.v9i5.933,https://www.researchgate.net/publication/34 8195267_Enhancing_the_handling_of_standard_substitution_weights_on_a_hydrostaticweighing_apparatus.

[7] Muhammed, L., Iyenagbe, U., & Wali, M. (2023). Design modification and performance evaluation of mini-hydrostatic pressure apparatus for inclined plane circular surface. *Engineering Solid Mechanics*. 11(2),191-204. doi:10.5267/j.esm.2022.12.002/ http://m.growingscience.com/beta/esm/5898-design-modification-and-performance-evaluation-of-mini-hydrostatic-pressure- apparatus-for-inclined-plane-circular-surface.html.

[8] Zhang Y., Zhang H., Wang K., Li Y., Mo Y., & Wen L. (2022). Design, fabrication, and characterization of a hydrostatic electroactive soft actuator for bio-inspired robots. doi:10.1016/j.birob.2022.100077,https://www.researchgate.net/publication/ 364441393_Design_fabrication_and_characterization_of_a_hydrostatic_electroactive_soft_actuator_for_bio-inspired_robots/citations/.

[9] Wu X. (2018). Design, fabrication and experiment of dataset acquisition apparatus for dual imaging plane. *Journal of Physics Conference Series. 2*519(1):012018, doi: 10.1088/1742-6596/2519/1/012018.

[10] Tomoko M. Tatsuki Y., Teruaki T., & Shimizu Y.A. (2006). A new hydrostatic pressure apparatus for studies of marine zooplankton. (Accessed 5 July, 2023).

[11] Falconer J. Hydrostatic Force on a Submerged Gate, *YouTube· LearnChemE*, 2018; https://www.youtube.com/watch?v=IC4lqBFueJ4 (Accessed 5 July, 2023).

[12] Pienika, R., Cataldo, J., & Ramos, H. M. (2022). CFD Analysis of a Hydrostatic Pressure Machine with an Open Source Solver. *Fluids*, 8(1), 9. https://doi.org/10.3390/fluids8010009, https://www.mdpi.com/2311-5521/8/1/9.

[13] Longo, S., Tanda, M.G.,& Chiapponi, L. (2021). Hydrostatic Forces on Submerged Curved Surfaces. In: Problems in Hydraulics and Fluid Mechanics. Springer Tracts in Civil Engineering . *Springer, Cham.* https://doi.org/10.1007/978-3-030-51387-0_2 https://link.springer.com/chapter/10.1007/978-3-030-51387-0_2.

[14] Scicluna, D., Muscat-Fenech C.D., Sant, T., Vernengo, G., & Tezdogan, T. (2017). Preliminary Analysis on the Hydrostatic Stability of a Self- Aligning Floating Offshore Wind Turbine. *Journal of Marine Science and Engineering*. 10(12). https://doi.org/10.3390/jmse10122017, https://www.mdpi.com/2077-1312/10/12/2017.

[15] Aniszewski, W., Ageorges, V., Perret, G., & Moureau, V. (2022). Simulations of a Partially Submerged Cylinder Subjected to Current and Waves. arXiv preprint arXiv:2208.14793, https://arxiv.org/abs/2208.14793.

[16] Cho S., Muttaqie T., Do Q.T., Kim S., Kim S. M., & Han D., (2018) Experimental investigations on the failure modes of ring-stiffened cylinders under external hydrostatic pressure,*International Journal of Naval Architecture and Ocean Engineering*. 10(6)711-729, https://doi.org/10.1016/j.ijnaoe.2017.12.002, https://www.sciencedirect.com/science/article/pii/S2092678217302844.

[17] Magalona R. .Ship Hydrostatics and Stability, (n.d.). https://www.academia.edu/25769401/ Ship_ Hydrostatics_and_Stability (Accessed 5 July, 2023).

[18] Biran A., & López-Pulido R. (2014). Hydrostatic Curves , *Ship Hydrostatics and Stability* (Second Edition) , Chapter 4 - Hydrostatic Curves, 97-116, https://www.sciencedirect.com/ science/article/abs/pii/B9780080982878000049.

[19] Rajaji, V., Dutta, U., Sreeparvathy, P. C., Sarma, S. C., Sorb, Y. A., Joseph, B., ... & Narayana, C. (2018). Structural, vibrational, and electrical properties of 1 T– TiT e 2 under hydrostatic pressure: Experiments and theory. *Physical review B*. 97(8), 085107. https://journals.aps.org/prb/abstract/10.1103/PhysRevB.97.085107.

[20] Yan, H., Yang, F., Pan, D., Lin, Y., Hohman, J. N., Solis-Ibarra, D., ... & Melosh, N. A. (2018). Sterically controlled mechanochemistry under hydrostatic pressure. *Nature*. 554(7693), 505-510., https://journals.sagepub.com/doi/full/10.1177/1687814018768142.

[21] Khakimzyanov, G., & Dutykh, D. (2019). Long wave interaction with a partially immersed body. *Part I: Mathematical models*. arXiv preprint arXiv:1903.07617. , 27, (2,): 321-378, https://doi.org/10.48550/arXiv.1903.07617, https://arxiv.org/abs/1903.07617.

[22] Yao W., Li X., Xia K.,& Hokka M., (2021).Dynamic flexural failure of rocks under hydrostatic pressure: Laboratory test and theoretical modeling, *International Journal of Impact Engineering*, 156, https://doi.org/10.1016/j.ijimpeng.2021.103946. https://www.sciencedirect.com/science/article/pii/S0734743X21001330.

[23] Santillán G, K. Y., Dahmann, C., & Fischer-Friedrich, E. (2022). Hydrostatic pressure and lateral actomyos in tension control stretch and tension of the basement membrane in epithelia, *bioRxiv*. doi: https://doi.org/10.1101/2022.09.02.506324 https://www.biorxiv.org/content/10.1101/2022.09.02.506324v2.abstract.

[24] Muhamad W. (2019). Vehicle Steering Dynamic Calculation and Simulation. International Journal of Innovative Technology and Interdisciplinary Sciences, 2 (1), 87–97. https://doi.org/10.15157/IJITIS.2019.2.1.87-97 https://www.ijitis.org/index.php/ijitis/article/view/20.

[25] Chan B. J. Hydrostatic Force On A Submerged Surface, Scribd, (n.d.). https://www.scribd.com/doc/281369072/Hydrostatic-Force-on-a-Submerged-Surface (Accessed 5 July, 2023).

[26] Haque M.S. Lab 3: Measurement of Hydrostatic force. *YouTube.* (2020). https://www.youtube.com › watch (Accessed 5 July, 2023).

[27] Ahmari H. P.E. (2018.). Lab 1 Hydrostatic Pressure, *Applied Fluid Mechanics Lab* https://youtu.be/LfqadPBKim8 (Accessed 5 July, 2023).

[28] Yadav D. Hydrostatic Force, (2022) (Accessed 5 July, 2023).

[29] Vilaplana, R., Gallego-Parra, S., da Silva, E. L., Martínez-García, D., Delaizir, G., Muñoz, A., ... & Manjón, F. J. (2023). Experimental and theoretical study of β-As 2 Te 3 under hydrostatic pressure. *Journal of Materials Chemistry C*. 11(3), 1037-1055. https://pubs.rsc.org/en/content/articlelanding/2023/tc/d2tc03357g/unauth.

[30] Bodkhe, N., Kanekar, S. L., & Tushar, G. B. (2015). Design, Analysis & Fabrication of Pneumatic Material Handling System. *International Journal of Mechanical Engineering and Technology*(IJMET). 6(8).12-23.

[31] Wilfred, C. C., Nwigbo, S. C., Nwankwo, T. A., & Chukwunonso, O. U. (2021). Design and Fabrication of a Classical Fibre Glass Laboratory Venturimeter Apparatus. *International Journal of Innovative Science and Research Technology,* June. 6, (6):557-567, https://ijisrt.com/assets/upload/files/IJISRT21JUN270.pdf.

[32] Yadav A., Chauhan P., Kumar R., Chohan J. S., & Kumar R. (2021). Design and Analysis of Hybrid Fused Filament Fabrication Apparatus for Fabrication of Composites. doi:10.2174/2666145414666210412150641,https://www.researchgate.net/publication/350839749_Design_and_Analysis_of_Hybrid_Fused_Filament_Fabrication_Apparatus_for_Fabrication_of_Composites.

[33] Bacosa C. A. (2023). Design and Fabrication of Cohesiometer Apparatus For Soil Stability and Landslide Analysis, *Seybold Report,* March, 18(3),130-142, doi: 10.17605/OSF.IO/BW92X, https://www.researchgate.net/publication/369252974_Design_and_Fabrication_of_Cohesiometer_Apparatus_For_Soil_Stability_And_Landslide_Analysis.

[34] Dizon M.D. (n.d.). Hydrostatic Thrust, SCRIBD, https://www.scribd.com/document/354940601/Hydrostatic-Thrust (Accessed 5 July, 2023)

[35] "Applied Fluid Mechanics Lab Manual", EXPERIMENT #1: HYDROSTATIC PRESSURE, *SCRIBD,* (n.d.). https://uta.pressbooks.pub/ appliedfluidmechanics/chapter/experiment-1/. (Accessed 5 July, 2023).

[36] Wedage U. (n.d.). The Centre of Pressure On A Partially Submerged Plane Surface Original Title:Experiment to Determine the Centre of Pressure on a Partially Submerged Plane Surface, *SCRIBD.*

[37] Al-Shataif D. (n.d). Hydrostatic Pressure - Fluid-Mechanics-Lab-Manual, 15-23, *SCRIBD*, https://www.scribd.com/document/ 499642872/Hydrostatic-Pressure-Fluid-Mechanics-Lab-Manual-15-23 (Accessed 5 July, 2023).

[38] Hines J. (2010). Fluids Lab - Experiment 3 - Center of Pressure On A Submerged Plane Surface, *SCRIBD,* https://www.scribd.com/doc/66292621/Fluids-Lab-Experiment-3-Center-of-Pressure-on-a-Submerged-Plane-Surface. (Accessed 5 July, 2023).

[39] Shabrina S. (2017). G2 - Hydrostatic Pressure & Forces, Department of Civil Engineering Kulliyyah of Engineering, *International Islamic University Malaysia*, Fluid Mechanics Lab Manual, CIVE 2116 – Civil engineering Lab I, Hydrostatic Pressure & Forces , SRIBD, https://www.scribd.com/document/500763070/G2-Hydrostatic-Pressure-Forces (Accessed 5 July, 2023).

[40] "PSEd" Hydrostatic Force on a Submerged Surface Center of Pressure Formula, (2022). https://www.apsed.in/post/hydrostatic-force-on-a-submerged-surface-center-of-pressure-formula (Accessed 5 July, 2023).

[41] Mirdo S. (n.d.).Center of Pressure On A Submerged Plane Surface, *SCRIBD.* https://www.scribd.com/doc/48248012/Center-of-Pressure-on-a-Submerged-Plane-Surface. (Accessed 5 July, 2023).

[42] Sandro L.,. Tanda M. G., and Chiapponi L. (2021). Hydrostatic Forces on Submerged Curved Surfaces, *Problems in Hydraulics and Fluid Mechanics Book.* DOI: 10.1007/978-3-030-51387-0_2.

[43] Marcel E. (n.d.). Introduction to Engineering Fluid Mechanics . *Oxford university press* https://global.oup.com/academic/ product/introduction-to-engineering-fluid-mechanics-9780198719885?cc=us&lang=en& .

[44] Weenink, R. P. and Wingelaar,T. T. (2021). Hydrostatic Pressure Due to Immersion Submersion, Sec. *Environmental, Aviation and Space Physiology*. Volume II https://www.scribd.com/doc/127720820/Experiment-to-Determine-the-Centre-of-Pressure-on-a-Partially-Submerged-Plane-Surface#.

[45] Jasim N., & Shamkhi M. S. (2020). The design of the center of pressure apparatus with demonstration, *Cogent Engineering*, *Taylor & Francis*. 7(1),1-21, doi:10.1080/23311916.2020.1843225.https://www.researchgate.net/publication/3453125

68_The_design_of_the_center_of_pressure_apparatus_with_demonstration_The_design_of_the_center_of_pressure_apparatus_with_demonstration.

[46] PospíšilJiří J. and Rostislav D. P. (2018). Basic Principles of Hydrostatic Levelling, 2018; DOI: 10.2478/gse-2018-0008

[47] F9092 – Fluid Properties & Hydrostatics Bench , *Armfield Limited*, England, n.d.; https://armfield.co.uk/product/f9092-fluid-properties-hydrostatics-bench/(Accessed 5 June, 2023).

[48] "Applied Fluid Mechanics Lab Manual" Armfield Book, 2019; https://www.researchgate.net/publication/335273723_Applied_Fluid_Mechanics_Lab_Manual/figures?lo=1 (Accessed 5 June, 2023).

[49] Newboyz J. (2020). Hydrostatic Force and Centre of Pressure on a Submerged Surface, *The University of the South Pacific School of Engineering and Physics*, MM222 – Fluid Mechanics, Lab 1: Hydrostatic Force and Centre of Pressure on a Submerged Surface. https://www.academia.edu/43983017/Hydrostatic_Force_and_Centre_of_Pressure_on_a_Submerged_Surface.

[50] Djama M. Tutorial 3 Hydrostatic force on submerged bodies, n.d.; https://www.academia.edu/23199888/Tutorial_3_Hydrostatic_force_on_submerged_bodies. (Accessed 5 July, 2023).

[51] Papaevangelou G., Psilovikos A. R.., Ioannidis D. Statistical analysis and simulation of a hydrostatic force experimental device*. Proceedings of the 2006 IASME/WSEAS Int. Conf. on Water Resources*, Hydraulics & Hydrology, Chalkida, Greece, May 2006; 11-13, 2006 (81-85), https://www.academia.edu/4050494/Statistical_analysis_and_simulation_of_a_hydrostatic_force_experimental_device.

[52] Anyata B.U., Akpan P.P. and Uneke L.U. (2015). Cultivating Technological Innovation in the Mind, American Journal of Engineering Research, 4 (11): 103-108. http://www.ajer.org/papers / v4(11)/M041101030108.pdf.

[53] Akpan P. P. , Augustine L. B., Petaba L. D., Uyoh F. U. and Nwikina B. B. (2021).Validation of Simulated Hydraulic Jump Models, *International Journal of Engineering Research and Application*. 11 (9), 07-14, doi. 10.9790/9622-1109030714.

[54] Biswaranjan M. and Kim S. (2022). Experimental Validation *of a* Hydrostatic Transmission, doi:10. 3390/en15010376 Energies, https://www.mdpi.com/journal/energies.

[55] Ahmed M., Hewavitharana L., Macry C. & Ahmed K. (2022). Design and Construction of a Low-Cost 'Hydrostatic Force on a Submerged Surface' Experiment Setup Paper presented at 2006 GSW, unknown. 10.18260/1-2-620-38982. https://peer.asee.org/design-and-construction-of-a-low-cost-hydrostatic-force-on-a-submerged-surface-experiment-setup.