JMKSP (Jurnal Manajemen, Kepemimpinan, dan Supervisi Pendidikan)
Volume 9 (2) 2024, 855-868
E-ISSN 2614-8021, P-ISSN 2548-7094

Design Constant Head Permeability Meter Digital: A Project-Based Learning Media

Virma Septiani[1], Direstu Amalia[1], Viktor Suryan[1], Siti Salbiah Ristumanda[1], Suci Ryski Nur Afriyani[1]
[1]Politeknik Penerbangan Palembang, South Sumatra, Indonesia

Corresponding author e-mail: virmaseptiani@poltekbangplg.ac.id

Article History: Received on 2 May 2024, Revised on 21 May 2024, Published on 4 July 2024

Abstract: The permeability coefficient value is one of the most important parameters in soil mechanics. Quick, simple, and digital direct soil permeability tests in the field are needed to obtain data representing conditions. This research aims to create a portable soil permeability test tool based on microcontroller automation used as a project-based learning for Transportation Cadets peculiarly Palembang Aviation Polytechnic Cadets for new experiences of new learning circumstances. This research method based on the principle of permeability testing using the constant-head method by analyzing the requirements quantitatively. This principle uses water change level parameters, which are used to test the infiltration rate in sample soil. Furthermore, measurements of changes in water level are used by water leveling sensors and processed using Arduino Uno based on fuzzy logic with access to results via the web, tool design, and simulation using SIMULINK software. The results of designing a digital measuring instrument for permeability using the constant head method have been validated for its schematic circuit using SIMULINK and can work without error. In conclusion, a model based on Darcy's Law equation and constant head to find the permeability coefficient can be generated, which can then be a prototype of the tool. It concluded the design of constant head permeability meter digital is useful as project-based leaning media for the Palembang aviation polytechnic. Furthermore, the equipment design will be the first digital measuring tool for permeability coefficient using the constant head method. The design has advantage to measure the soil permeability coefficient at the airport in the fastest way.

Keywords: Constant Head, Design Permeability Test, Project-Based Learning, Soil Permeability Coefficient

A. Introduction

Information on soil permeability values is important for soil characteristics in order to determine the nature of the soil (Chen et al., 2019, 2020). There are several types of measuring equipment that can be used to determine permeability values, depending on the type of soil sample (Nazari et al., 2018). *A falling head permeameter* is a test tool that can be used to determine the value of the soil permeability coefficient (Zhang et al., 2020). The advantage of this tool is that testing can be carried out in the laboratory because the test material is a sample of a blood measurement (Lei et al., 2020). The disadvantage of this equipment is that the data collection process uses human power, so a supporting tool is needed, namely a data logger. Dara loggers are additional equipment that can process and store data digitally (Ilie et al., 2020). Digital data storage is very important in carrying out measurements because a measurement process that requires a long period and a large amount of data will lead to high measurement errors (Mishra et al., 2022).

Research Singh et al., 2021 used the support vector machine (SVM) technique to estimate soil permeability. Input variables include sand percentage (S), percentage of fly ash (Fa), Specific gravity (G), time (T), and head (H), while the permeability coefficient (k) is considered as the output. Meanwhile, Lei et al., 2020 used the *falling-head* and *rising-tail* method for permeability testing, which allows the inflow and outflow rates to be easily measured. The permeameter test using the centrifuge method is designed to speed up the flow of water and reduce the time required for testing. Then, Andres-Valeri et al., 2018 proposed a methodology based on saturated and unsaturated low constant high permeability tests to characterize in detail the infiltration performance of PC Materials during storm events and predict their infiltration behavior over time. Then, the results achieved were analyzed to describe the infiltration performance of the tested PC pavement (Andres-Valeri et al., 2018). From the research methods and results above, there still needs to be improved, namely tools that combine artificial intelligence mechanisms and systems. This is necessary to improve the weaknesses of the method above related to the accuracy of measuring instruments and storage data, which cannot be portable. Furthermore, the weakness of the accuracy of the water flow rate at the falling head is improved using a water leveling sensor (Onyema et al., 2022).

In various fields of study, including in aviation, laboratories, medical applications and industry, Arduino® boards, like the Arduino® Uno (ATmega328), have been widely adopted (Amalia et al., 2022). They offer a single-board microcontroller with programmable input/output peripherals, and they have been utilized in various monitoring applications due to their user-friendly operation, affordability, and moderate-to-high measurement accuracy (Zhu et al., 2022). The application of Arduino® in soil stiffness a low-cost, open-source Traditional lightweight deflectometer (LWD) onboard sensor signal interpretation system, utilizing Electro-Mechanical and Micro-Electro-Mechanical-System (MEMS) technology-based sensors in conjunction with an Arduino® Uno and ADS1262 Breakout Board (Nguyen et al., 2023). Moreover, in land management, soil moisture tensiometers usually equipped with mechanical manometers provide an easy and cost-effective monitoring of tension in unsaturated soils. Yet, periodic manual monitoring of many devices is a tedious task hindering the full exploitation of soil moisture tensiometers (Zhu et al., 2022).

The project-based learning effort is based on studies by some teacher educators who have attempted to ensure that teachers can advance practices in ambitious directions, so that all cadets, particularly those who were previously underserved by schools, can experience opportunities for rich learning (Almulla, 2020). Moreover the learning process with this system will undoubtedly be applied to cadets within the Ministry of Transportation, especially the Airport Engineering Technology Study Program (Suryan et al., 2023). The learning outcomes of this course are airport soil mechanics and the operation and maintenance of the airport engineering Facilities courses. In airport soil mechanics, cadets must be able to practice and classify soil types based on their permeability coefficient. Furthermore, the operation and maintenance of the airport engineering facilities course requires all cadets to know some regulations and how to inspect airport facilities, especially those related to the soil around the airport. Based on the requirements, a project-based learning media is urgently required as a data logger using a water leveling sensor was carried out to measure the soil permeability coefficient digitally. Therefore, a practical, portable, and efficient measuring instrument is needed to measure the soil permeability coefficient with greater accuracy. The use of this tool is to motivate cadets to conduct experiments when they work on assignments. With a project-based learning approach using tools, cadets can practice simultaneously with the trial and error method, so learning outcomes can be achieved more effectively if not using tools (Suryan et al., 2023).

B. Methods

Soil permeability is the ability of the soil to allow water to flow through the soil. Soil has solid particles with interconnected cavities that allow water to pass through these cavities (Lei et al., 2020). By applying hydraulic pressure to a fully saturated soil sample, the permeability level of the sample can be determined, and the rate of water flow through the sample can be measured. The value of the soil permeability coefficient is expressed in the form of speed. The method for measuring the level of soil permeability depends on the characteristics of the sample (Head & Epps, 2011).

In soil mechanics, the study of water flow through soil is important to study. This is necessary so that problems such as underground seepage occurring under various hydraulic conditions can be predicted, problems involving water pumping for underground construction can be investigated, and stability analyses of earth dams and earth retaining structures subjected to seepage forces can be carried out (Santos et al., 2020). In controlling the rate of water seepage in the soil, there is a main physical parameter called hydraulic conductivity, known as the permeability coefficient (k) (López-Acosta et al., 2019). In international units (SI), the coefficient is expressed in cm/s. Factors that influence the soil permeability coefficient are fluid viscosity, pore size distribution, grain size distribution, pore number, mineral particle roughness, and degree of soil saturation (Liu & Jeng, 2019). Soil permeability coefficients based on soil types can be seen in Table 1 (Das & Sobhan, 2014).

Table 1. Permeability coefficient based on soil type

Type of Soil	K (cm/s)
clean gravel	100-1,0
coarse sand	1,0-0,01
fine sand	0,01-0,001
silty sand	0,001-0,00001
clay	<0,000001

(Zhang et al., 2020)

The concept of fluid flow flowing through soil cavities is the idea of a French scientist, namely H. Darcy (1986), known as (Darcy's Law). Darcy found that the flow rate remains proportional to the hydraulic head under laminar flow (Gao et al., 2020). This was discovered when Darcy tested water flow through layers of sand with various thicknesses and pressures. Darcy also discovered that Darcy's law does not apply to turbulent flows at high speeds. Based on his findings, Darcy's Law plays an important role in the analysis and design of various practical problems in geotechnical engineering as long as the flow through the soil remains laminar (Mir, 2021). The simple equation for the speed of water discharge through saturated soil is expressed in Darcy's Law 1 (Das & Sobhan, 2014; Head & Epps, 2011; Mir, 2021; Zhang et al., 2020).

$$v = ki \quad (1)$$

information:

v = water discharge speed (cm^3/s)

k = permeability coefficient (cm/s)

i = hydraulic gradient

Based on Equation 1, v is the speed of water discharge based on the gross cross-sectional area of the soil. However, the actual speed of water (seepage velocity) through space is greater than v. Figure 1. Shows the relationship between discharge velocity, which shows soil with length L with gross cross-sectional area A. If the amount of water flowing through the soil in unit time is q, then q can be expressed in Equation 2 (Das & Sobhan, 2014; Head & Epps, 2011; Mir, 2021; Zhang et al., 2020).

$$q = vA = A_v v_s \quad (2)$$

Information:

q = amount of water flowing through the soil

A = cross-sectional area of the soil sample

v_s = seepage speed

A_v = cross-sectional cavity area of the soil sample

It can be seen in Equation 3 (Das & Sobhan, 2014).

$$A = A_v + A_s \quad (3)$$

Information:

A_s = area of soil solids in the cross-section of the soil sample

Equation 3 can be substituted into Equation 2 so that its form can be seen in Equation 4 (Das & Sobhan, 2014; Mir, 2021).

$$v_s = \frac{v(A_v+A_s)}{A_v} = \frac{v(A_v+A_s)L}{A_vL} = \frac{v(V_v+V_s)}{V_v} \quad (4)$$

Information:

V_v = volume of voids in the soil sample

V_s = volume of soil solids in the soil sample

The form of Equation 4 can also be written in another form, which can be seen in Equation 5 (Das & Sobhan, 2014; Mir, 2021).

$$v_s = v\frac{1+\left(\frac{V_v}{V_s}\right)}{\frac{V_v}{V_s}} = v\left(\frac{1+e}{e}\right) = \frac{v}{n} \quad (5)$$

Information:

e = void ratio

n = porosity

The derivation of equation (1) (Das & Sobhan, 2014).

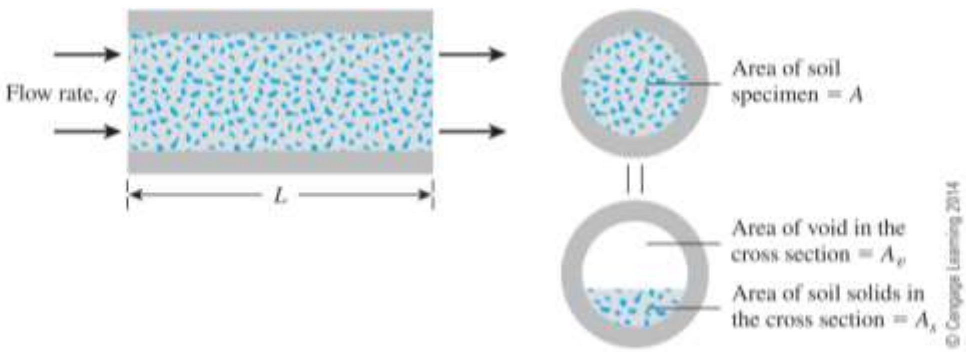


Figure 1. Soil cavity measurement mechanism

The soil permeability coefficient also has a relationship with the properties of the fluid flowing through it in the form of an equation, which can be seen in Equation 6 (Das & Sobhan, 2014).

$$k = \frac{\gamma_w}{\eta}\overline{K} \quad (6)$$

Information:

γ_w = unit weight of water

η = water viscosity

$\bar{K}$ = absolute permeability

Based on Equation 6, the soil permeability coefficient is a function of unit weight and water viscosity, which in turn is a function of temperature during testing. Therefore, Equation 7 is obtained (Das & Sobhan, 2014).

$$\frac{k_{T_1}}{k_{T_2}} = \left(\frac{\eta_{T_2}}{\eta_{T_1}}\right)\left[\frac{\gamma_{w(T_1)}}{\gamma_{w(T_2)}}\right] \quad (7)$$

Information:

k_{T_1}, k_{T_2} = permeability coefficient at temperatures T_1 dan T_2respectively

η_{T_1} = viscosity of water at temperatures T_1 dan T_2 respectively

$\gamma_{w(T_1)}, \gamma_{w(T_2)}$ = unit weight of water at temperatures T_1 dan T_2 respectively

In determining the k value, a temperature of 20°C is the standard used. Within the test temperature range, it can be assumed that the value $\gamma_{w(T_1)} \cong \gamma_{w(T_2)}$. Therefore, Equation 8 (Das & Sobhan, 2014; Head & Epps, 2011; Mir, 2021; Zhang et al., 2020).

$$k_{20°C} = \left(\frac{\eta_{T°C}}{\eta_{20°C}}\right) k_{T°C} \quad (8)$$

The Constant-head method is one of the standard methods for testing soil permeability carried out in the laboratory. The Constant-head method is used to test the permeability coefficient with coarse-grained soil samples. In the Constant-Head method, the water flow supply at the inlet is adjusted so that the height difference between the inlet and outlet remains constant during the test. The amount of water that passes through the sample in a known time is measured (Das & Sobhan, 2014; Head & Epps, 2011; Mir, 2021; Zhang et al., 2020). The constant-head method testing tool with general settings can be seen in Figure 2 (Head & Epps, 2011).

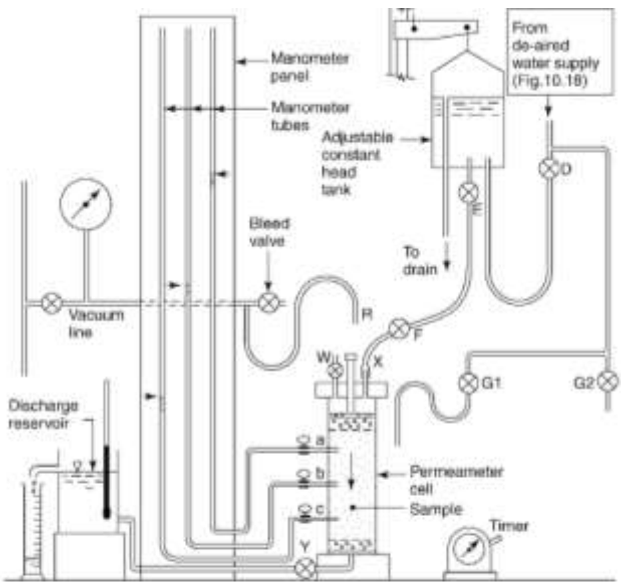


Figure 2. Constant-Head Method Permeability Test

Design and simulation of permeability measurements using the constant head method digitally using MATLAB software. Meanwhile, the software uses Equation 12 to get the soil the soil permeability coefficient value. Permeability test results data consisting of sensor and stopwatch readings as well as calculation results of soil permeability coefficient values, then a program to carry out permeability testing by taking the necessary data digitally. Collected seepage water column data, seepage water temperature, and water height on the manometer are obtained from sensor readings. Meanwhile, the stopwatch to obtain time data will use the existing time system on the laptop.

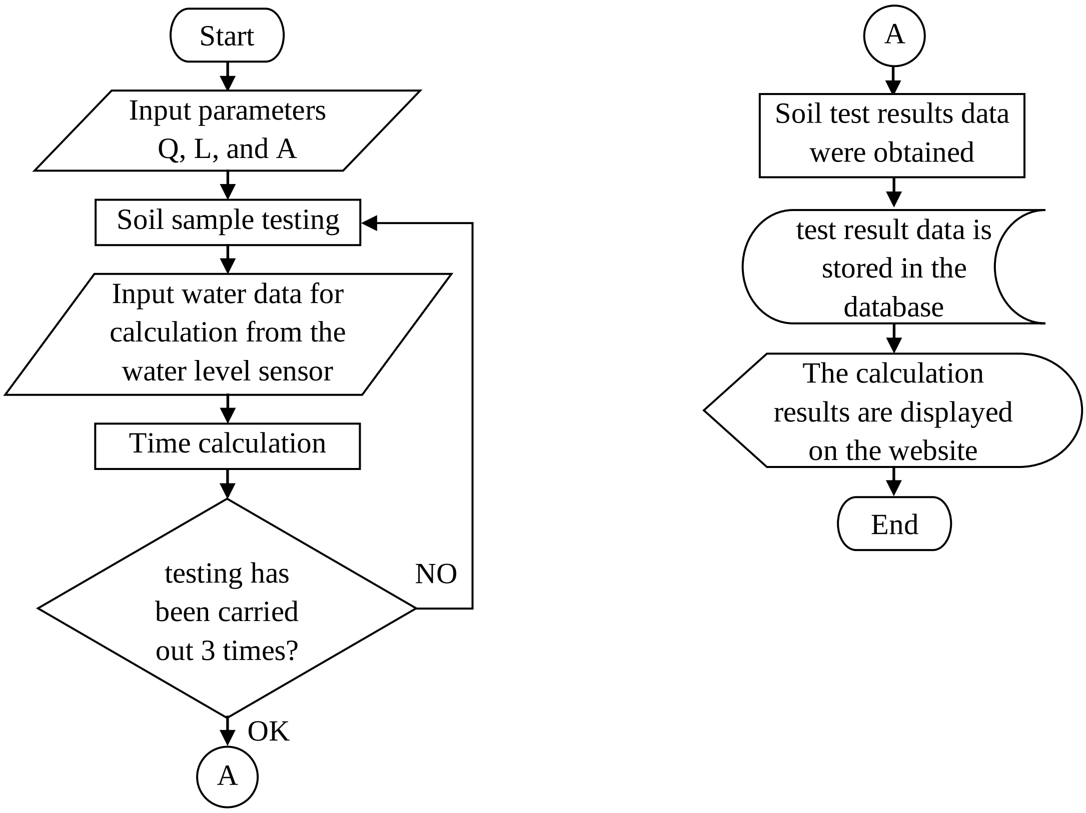


Figure 3. Software Flowchart Next, the simulation to test the performance of the tool design was used by Simulink in MATLAB.

The amount of water collected in a container can be expressed in the form of Equation 9 (Das & Sobhan, 2014).

$$Q = Avt = A(ki)t \quad (9)$$

Information:

Q = amount of water collected

t = length of time for water to collect

The form of the equation to find the permeability coefficient value can be obtained by looking at Equation 10 (Das & Sobhan, 2014).

$$i = \frac{h}{L} \tag{10}$$

Information:

h = total height of water

L = height of the soil sample in the tube based on Equations 9 and 10, Equations 11 and 12 are obtained (Das & Sobhan, 2014; Head & Epps, 2011; Mir, 2021; Rizaman et al., 2021; Zhang et al., 2020).

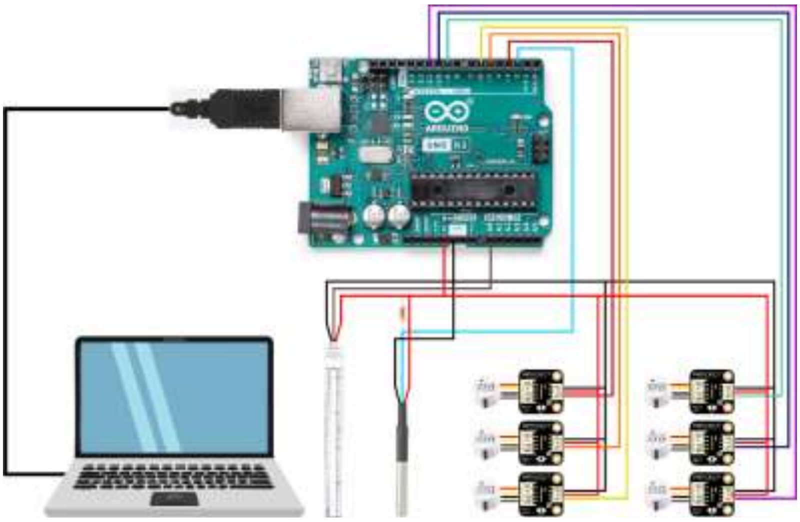
$$Q = A\left(k\frac{h}{L}\right)t \tag{11}$$

$$k = \frac{QL}{Aht} \tag{12}$$

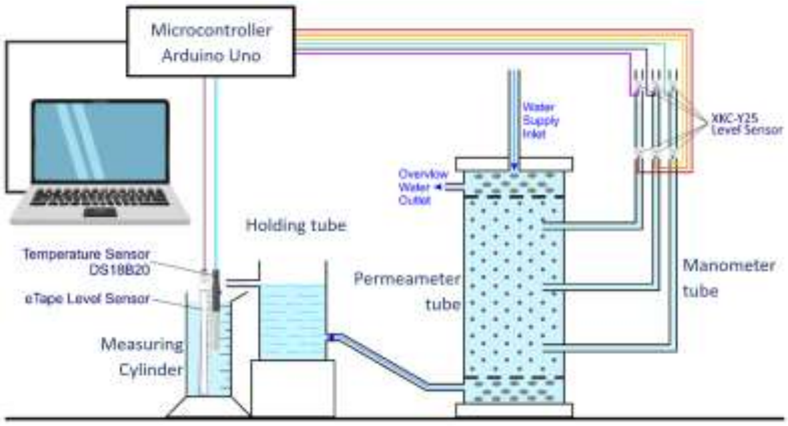
This research begins with observations and interviews with Sultan Mahmud Badarudin II airport practitioners as sources in the industrial world and literature studies. Furthermore, the research also interviewed cadets as end users in this learning. Based on the observations, interviews and literature studies, design constant head permeability meter digital.

C. Results and Discussion

Results of the schematic design of the tool circuit and design of the digital constant-head permeameter tool are shown in Figure 4. There are seven level sensors used in this research. One level sensor function to read the water level in the measuring cup, which will be a parameter for calculating the volume of water in the measuring cup shown in Figure 4 (Cloete et al., 2016). There are seven level sensors used in this research. One level sensor function to read the water level in the measuring cup, which will be a parameter for calculating the volume of water in the measuring cup (Edaris & Abdul-Rahman, 2016), and the other six levels in the manometer pipe so that the hydraulic gradient value can be known. Then, there is a temperature sensor used in this research, which functions to determine the temperature of seepage water that has passed through the soil sample. The output of the four-level sensors used is connected to the analog pin of the microcontroller. In contrast, the temperature sensor used is connected to the digital pin of the microcontroller. The results of the sensor readings will be sent to the program on the laptop via microcontroller (Sandra et al., 2017).



(a)



(b)

Figure 4. (a) Schematic of tool circuit(b) Tool design

Schematic testing of tools includes testing the series of tools created, including function verification, sensor, and microcontroller communication. The schematic testing uses MATLAB simulation. The components used to design this tool are the level eTape, sensor DS18B20, sensor level XCK-Y25, resistor 4,7 KΩ microcontroller Arduino Uno.

The eTape level sensor produces an analog output namely voltage with a range of 0 Volts to 5 Volts (Vcc) (Parikesit et al., 2019). In the Arduino IDE software serial monitor, eTape level sensor reading output is shown in the form of Analog to Digital Converter (ADC) values with a resolution of 10 bits so that the ADC value range namely 0 to 1023 (Shrenika et al., 2017). Level sensor XKC-Y25-T12V and DS18B20 temperature sensor produce output digital, namely 1 (HIGH) or 0 (LOW). On serial Arduino IDE software monitor, reading output XKC-Y25-T12V sensor is shown in the form of values 1 and 0 (Kaczmarek et al., 2020), while for the temperature sensor reading output DS18B20 is shown in the form of an existing value converted by the program to temperature degrees Celsius (Hariono et al., 2021). Results Readings from each sensor are displayed in serial monitor so the application can receive the results sensor reading using serial communication method to then carry out data processing so that soil permeability test can be carried out.

The SIMULINK MATLAB model is validated for the circuit that has been created and can work without any errors. In this case, SIMULINK is very helpful in validating the circuit and working of the tool being designed.

The use of media in the learning process aims to be able to take place appropriately and efficiently to increase student interest and attention (Sugiyanto et al., 2020). Based on this tool provide beneficial practical experiences in designing, building, and testing electronic or mechanical devices, while also teaching basic concepts in soil permeability coefficient (Gomez-del Rio & Rodriguez, 2022). The project-based learning contributes in-depth and practical experiences in understanding and implementing, while also improving various skills such as problem-solving, design, and programming. In addition, this project provides a basic knowledge for further research in engineering and science (Pan et al., 2021). The focus of problem-based learning lies in knowledge application while project-based learning, which is based on the learning science of active construction, emphasizes knowledge construction. This process of creating new knowledge allows cadets to test and achieve their ideas in the way they want, which promotes their innovation competence. Thus, it is necessary to encourage teachers in higher education to adopt project-based learning(Guo et al., 2020). Moreover, the ability of cadets to prepare lecture presentation material for class meetings with a project-based learning approach varies, some of which do not even reflect the ideal PjBL. There are still some gaps between their theoretical thinking and the reality on the ground to realize effective project-based learning (Danim, 2023).

D. Conclusions

The SIMULINK model for measuring permeability using the constant head method has been created. The model is based on Darcy's Law Equation and Constant head to find the permeability coefficient. This equipment design will be the first digital measuring tool for permeability coefficient using the constant head method. The design has advantage to measure the soil permeability coefficient at the airport in the fastest way. Furthermore, these results can be used as project-based leaning media for the Palembang aviation polytechnic. Moreover, Cadets gain learning in the process of conducting interviews, design and literature studies which can be seen from the results and their understanding of the material that has been given.

E. Acknowledgement

Thank you to the Politeknik Penerbangan Palembang for research funding.

References

Almulla, M. A. (2020). The effectiveness of the project-based learning (PBL) approach as a way to engage students in learning. *Sage Open*, *10*(3), 2158244020938702. https://doi.org/doi.org/10.1177/2158244020938702

Amalia, D., Hadiansyah, R., & Septiani, V. (2022). Smart parking IoT based: design and prototype. *JMKSP (Jurnal Manajemen, Kepemimpinan, Dan Supervisi Pendidikan)*, *7*(1), 67–81. https://doi.org/https://doi.org/10.31851/jmksp.v7i1.6677

Andres-Valeri, V. C., Juli-Gandara, L., Jato-Espino, D., & Rodriguez-Hernandez, J. (2018). Characterization of the infiltration capacity of porous concrete pavements with low constant head permeability tests. *Water*, *10*(4), 480. https://doi.org/doi.org/10.3390/w10040480

Chen, L.-M., Chen, J.-W., Chen, T.-H., Lecher, T., & Davidson, P. C. (2019). Measurement of permeability and comparison of pavements. *Water*, *11*(3), 444. https://doi.org/doi.org/10.3390/w11030444

Chen, L.-M., Chen, J.-W., Lecher, T., Chen, T.-H., & Davidson, P. (2020). Assessment of clogging of permeable pavements by measuring change in permeability. *Science of the Total Environment*, *749*, 141352. https://doi.org/doi.org/10.1016/j.scitotenv.2020.141352

Cloete, N. A., Malekian, R., & Nair, L. (2016). Design of smart sensors for real-time water quality monitoring. *IEEE Access*, *4*, 3975–3990. https://doi.org/doi.10.1109/ACCESS.2016.2592958

Danim, S. (2023). The Capability of Students to Collect Materials for Course Presentations Based on Project Learning. *JMKSP (Jurnal Manajemen, Kepemimpinan, Dan Supervisi Pendidikan)*, *8*(1), 61–66. https://doi.org/https://doi.org/10.31851/jmksp.v8i1.10338

Das, B. M., & Sobhan, K. (2014). Principles of Geotechnical Engineering, Eighth edi. *United State of America*.

Edaris, Z. L., & Abdul-Rahman, S. (2016). Performance comparison of PID tuning by using ziegler-nichols and particle swarm optimization approaches in a water control system. *Journal of Information and Communication Technology*, *15*(1), 203–224. https://doi.org/doi.10.32890/JICT2016.15.1.10

Gao, Y., Lin, Q., Bijeljic, B., & Blunt, M. J. (2020). Pore-scale dynamics and the multiphase Darcy law. *Physical Review Fluids*, *5*(1), 13801. https://doi.org/doi.org/10.1103/PhysRevFluids.5.013801

Gomez-del Rio, T., & Rodr\'\iguez, J. (2022). Design and assessment of a project-based learning in a laboratory for integrating knowledge and improving engineering design skills. *Education for Chemical Engineers*, *40*, 17–28. https://doi.org/doi.org/10.1016/j.ece.2022.04.002

Guo, P., Saab, N., Post, L. S., & Admiraal, W. (2020). A review of project-based learning in higher education: Student outcomes and measures. *International Journal of Educational Research*, *102*, 101586. https://doi.org/https://doi.org/10.1016/j.ijer.2020.101586

Hariono, T., Mahdalena, A., & Ashoumi, H. (2021). Automatic Water Temperature Control System In Hydroponic Plants With Peltier Tec1 12706 And Temperature Sensors DS18B20. *Multidiscipline International Conference*, *1*(1), 438–445. https://doi.org/doi.org/10.30630/joiv.6.1.865

Head, K. H., & Epps, R. J. (2011). Manual of Soil Laboratory Testing, Volume 2: Permeability, Shear Strength, and Compressibility Tests (Vol. 2). *Dunbeath, UK: Whittles Publishing*.

Ilie, A. M. C., Goebel, C., & Illangasekare, T. (2020). *Performance assessment of soil moisture sensors under controlled conditions in laboratory setting and recommendations for field deployment*.

Kaczmarek, W., Panasiuk, J., Borys, S., Pobudkowska, A., & Majsterek, M. (2020). Analysis of the kinetics of swimming pool water reaction in analytical device reproducing its circulation on a small scale. *Sensors*, *20*(17), 4820. https://doi.org/doi:10.3390/s20174820

Lei, G. H., Liu, F. X., & Xia, S. W. (2020). A note on falling-head and rising-tail permeability tests on saturated soils in centrifuge. *Canadian Geotechnical Journal*, *57*(8), 1232–1238. https://doi.org/doi.org/10.1139/cgj-2019-0222

Liu, Y. F., & Jeng, D. S. (2019). Pore scale study of the influence of particle geometry on soil permeability. *Advances in Water Resources*, *129*, 232–249. https://doi.org/doi.org/10.1016/j.advwatres.2019.05.024

López-Acosta, N. P., Espinosa-Santiago, A. L., & Barba-Galdámez, D. F. (2019). Characterization of soil permeability in the former Lake Texcoco, Mexico. *Open Geosciences*, *11*(1), 113–124. https://doi.org/doi:10.1515/geo-2019-0010

Mir, B. A. (2021). *Manual of geotechnical laboratory soil testing*. CRC Press. https://doi.org/doi.org/10.1201/9781003200260

Mishra, M., Lourenço, P. B., & Ramana, G. V. (2022). Structural health monitoring of civil engineering structures by using the internet of things: A review. *Journal of Building Engineering*, *48*, 103954. https://doi.org/doi.org/10.1016/j/jobe.2021.103954

Nazari, S., Hassanlourad, M., Chavoshi, E., & Mirzaii, A. (2018). Experimental investigation of unsaturated silt-sand soil permeability. *Advances in Civil Engineering*, *2018*, 1–12. https://doi.org/doi:10.1155/2018/4946956

Nguyen, H.-T., Lee, Y., Ahn, J., Han, T. H., & Park, J. K. (2023). A low-cost lightweight deflectometer with an Arduino-based signal interpretation kit to evaluate soil modulus. *Sensors*, *23*(24), 9710. https://doi.org/https://doi.org/10.3390/s23249710

Onyema, C., Pallam, S. W., & Abioye, A. (2022). The Design and Construction of a Water Fountain with Water Level Monitoring and Automatic Sprinkler System with Ground Moisture Sensor and Real-Time Clock. *Iconic Research and Engineering Journals*, *5*(7), 272–292.

Pan, G., Seow, P.-S., Shankararaman, V., & Koh, K. (2021). An exploration into key roles in making project-based learning happen: Insights from a case study of a university. *Journal of International Education in Business*, *14*(1), 109–129. https://doi.org/doi.org/10.1108/JIEB-02-2020-0018

Parikesit, E., Kusbandono, W., & Sambada, F. A. R. (2019). Microcontroller Based Simple Water Flow Rate Control System to Increase the Efficiency of Solar Energy Water Distillation. *International Journal of Applied Sciences and Smart Technologies*, *1*(2), 129–146. https://doi.org/doi: 10.24071/ijasst.v1i2.1923

Rizaman, A. R., Selamat, H., & Khamis, N. (2021). Digitaization of Analogue Meter Reading Using Convolution Neural Network. *MEKATRONIKA*, *3*(1), 28–34. https://doi.org/doi:10.15282/mektrinuka.v3i1.7149

Sandra, R., Simbar, V., & Syahrin, A. (2017). Temperature Monitoring System Prototype Using Arduino Uno R3 with Wireless Communication. *Jurnal Teknologi Elektro*, *8*(1), 80–86.

Santos, J., Pires, T., Gouveia, B. P., Castro, A. P. G., & Fernandes, P. R. (2020). On the permeability of TPMS scaffolds. *Journal of the Mechanical Behavior of Biomedical Materials*, *110*, 103932. https://doi.org/doi.org/10.1016/j.jmbbm.2020.103932

Shrenika, R. M., Chikmath, S. S., Kumar, A. V. R., Divyashree, Y. V, & Swamy, R. K. (2017). Non-contact water level monitoring system implemented using LabVIEW and Arduino. *2017 International Conference on Recent Advances in Electronics and Communication Technology (ICRAECT)*, 306–309. https://doi.org/doi:10.1109/ICRAECT.2017.51

Singh, B., Sihag, P., Pandhiani, S. M., Debnath, S., & Gautam, S. (2021). Estimation of permeability of soil using easy measured soil parameters: assessing the artificial intelligence-based models. *ISH Journal of Hydraulic Engineering*, *27*(sup1), 38–48. https://doi.org/doi: 10.1080/09715010.2019.1574615

Sugiyanto, S., Setiawan, A., Hamidah, I., & Ana, A. (2020). Integration of mobile learning and project-based learning in improving vocational school competence. *Journal of Technical Education and Training*, *12*(2), 55–68. https://doi.org/doi:10.30880/jtet.2020.12.02.006

Suryan, V., Amalia, D., Septiani, V., Sukahir, S., Nurfitri, M. A., & Chandra, P. W. A. (2023). Airport Runway Defect Detection Device: A Project-Based Learning

Media. *JMKSP (Jurnal Manajemen, Kepemimpinan, Dan Supervisi Pendidikan)*, *8*(1), 642–650. https://doi.org/doi: 10.31851/jmksp.v8i1.13185

Zhang, Y., Li, H., Abdelhady, A., & Yang, J. (2020). Comparative laboratory measurement of pervious concrete permeability using constant-head and falling-head permeameter methods. *Construction and Building Materials*, *263*, 120614. https://doi.org/doi:10.1016/j.conbuildmat.2020.120614

Zhu, H.-H., Huang, Y.-X., Huang, H., Garg, A., Mei, G.-X., & Song, H.-H. (2022). Development and evaluation of arduino-based automatic irrigation system for regulation of soil moisture. *International Journal of Geosynthetics and Ground Engineering*, *8*(1), 13. https://doi.org/https://doi.org/10.3390/s23249710