Manufacturing of Soil Coefficient Permeability Meter with Data Acquisition System Based on Internet of Things (IoT)

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Abstract: Soil permeability coefficient and measuring instrument using a data acquisition system based on Internet of Things (IoT) has been successfully made. The measuring equipment uses the falling head permeameter concept. MPX10GP sensor is used to measure water level. The measurement range is 6-40 cm water level, to obtain + 36 permeability coefficient value of each 1 cm. The data from the subsequent measurement systems is transmitted into the internet network so that it can be accessed by smartphone. Based on the measurement results of three samples, the slopes of Mount Ngantang have a soil permeability coefficient value of 0.0016 cm/s, the Institut Teknologi Sepuluh Nopember (ITS) pond embankment is 0.0005 cm/s, and the Bengawan Solo River embankment is 0.0002 cm/s. These results match with the reference and the difference value is only 2.7%. By using this research method, it is expected to draw up a map of the area that is prone to landslides quickly and accurately.

Keywords: Internet of Things (IoT), soil permeability coefficient, hydrostatic pressure.

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I. INTRODUCTION

One of the parameters that can be used to determine the soil characteristics of an area is soil permeability. Several things that affect soil permeability are the ratio of voids, distribution between pores, and degree of saturation [1]. Soil permeability describes the ability of the soil to pass through water [2]. Soil that has a high permeability value can increase the rate of infiltration thereby reducing the rate of water runoff in open pipes [3]. The quantity determined as a measure of soil permeability is the coefficient of permeability (k). The parameter k describes the hydraulic permeability of the soil, namely the ability of water filtration through the subsoil layer. The value of k in mineral soils will vary in the range of $10^{-10} - 10^{-2}$ m/s [4].

Measurement of soil permeability is important for various things, such as agriculture [5], urban planning [6], dam construction [7]. The importance of measuring soil permeability in dam construction is closely related to erosion [7] or what is common in Indonesia is the bursting of dam embankments during heavy rains [8]. When the permeability of the soil is too high, all soil pores will be covered and there will be a decrease in strength in the soil so that if it is under pressure there will be potential for erosion [9]. By knowing the value of soil permeability, it is hoped that this accident can be avoided. Research on measuring soil permeability is still quite a bit. Because the instruments circulating in the market are conventional and less sophisticated [10]. One of the conventional soil permeability measurements is the pumping test [11]. Measurement in this way takes a long time and requires user monitoring during the measurement process [12]. In this era of society 5.0, all human activities are increasingly facilitated by sophisticated technology [13]. Moreover, Internet of Things (IoT) technology is currently being intensively developed so that humans can carry out their activities effectively and efficiently [14]. By taking advantage of these opportunities, this research is carried out on the development of IoT-based soil permeability measuring instruments with the aim of providing convenience equipment for soil permeability measurement so that accurate real-time measurement data is obtained and can more save the time than conventional measurement methods.

II. METHOD

Samples of the measurement are clay and not clay. The main method in this research are,

A. Falling Head Method

Measurement of the soil permeability coefficient has been done in the Instrumentation Laboratory, Department of Physics, Institut Teknologi Sepuluh Nopember by using the

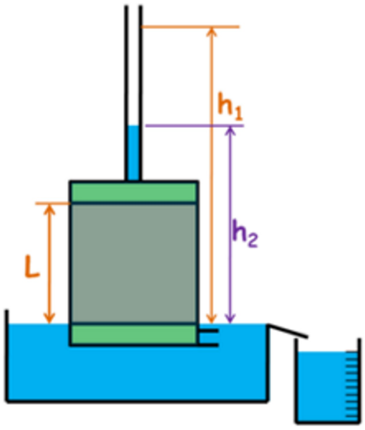

FIG. 1: Falling head method scheme. [15]

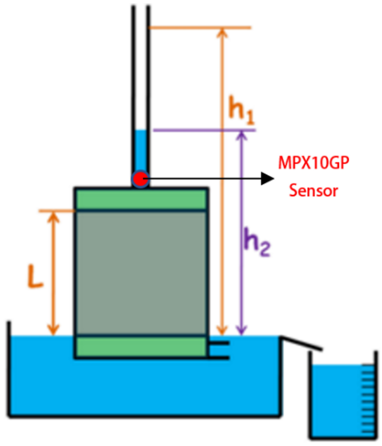

FIG. 2: Falling head method with the sensor improvement.

falling head method. Filling the casing with water and allowing it to seep into the ground is how the test is carried out. At certain intervals following the start of the test, the water depth inside the casing is measured. These measurements are carried out until the rate of decline is very modest or until the permeability can be accurately determined based on an adequate number of readings. The measurement scheme is illustrated in Fig. 1. Then, digital measurement scheme is implemented by installing an MPX10GP sensor for the measurement of the water height changing. Arduino is used for height and time measurements so that it can be done at the same time. The details are shown in Fig. 2.

Based on Fig. 1, the equation used to determine the soil permeability coefficient is shown as follows

$$-\ln \frac{h_2}{h_1} = \frac{kA}{aL}(t_2 - t_1) \tag{1}$$

$$k = \frac{aL}{A(t_2 - t_1)} \ln \frac{h_2}{h_1} = \frac{2.303aL}{A(t_2 - t_1)} \log \frac{h_2}{h_1}. \tag{2}$$

The changing parameters in Eq. (2) are h and t. h_1 is the initial measurement water height, h_2 is the next measurement water height, k is soil permeability coefficient, t_1 is initial time, t_2 is the time after measurement, A is area of the sample, L is sample height, and a is tube area.

In Fig. 2, the sensor is located below the surface of the water to minimize disruption to the system that is measured. The parameters obtained from the height of the hydrostatic fluid equation are shown in Eq. (3)

$$P = \rho g h, \tag{3}$$

where P is pressure (Pa), ρ is density (kg/m^3), g is the gravitational acceleration (m/s), and h is the height (m). Based on that equation, the height is proportional to the fluid pressure value.

B. Sensor Calibration

Sensor calibration is done with the aim to get high accuracy of the sensor. Level calibration is done by preparing a calibrator, which is a ruler with a length of 100 cm. Furthermore, the tube is filled with water slowly so that the water level increases. The data is taken for sensor calibration when the level is increased. Furthermore, the volume of water in the tube is released slowly resulting in a decrease in fluid volume which results in a shortening of the sensor measuring distance to the level. This data is stored as calibration data during decreasing levels. The water level drops due to a decrease in volume. The sensor provides its reading value. After the sensor gets the analog measurement data, Arduino converts it into a digital value by using the Analog to Digital Converter (ADC) feature. The result obtained is a comparison of the ADC value with the actual distance which is then carried out by a mathematical operation so that the ADC value that is read is the true value.

C. Acquisition System

The data logger system is also implemented for the improvement of this permeability measurement tool. Then, design of the measurement system is done by creating a data acquisition system consisting of a display, storage memory, where the integrated system is usually called a data logger. So that, this method is called Internet of Things (IoT). The IoT system topology used is shown in Fig. 3.

Based on Fig. 3, unidirectional communication occurs, namely between the sensor to the Arduino, and the Arduino to the cloud to be further accessed by mobile phones that operate with the Android system. Wi-Fi module ESP8266 is used for data communication between Arduino and cloud because this module is cheap and easy for operation.

III. RESULTS AND DISCUSSION

A. Characteristics of Measuring Instruments

The process of characterizing the measuring instrument is carried out through data collection of changes in water level.

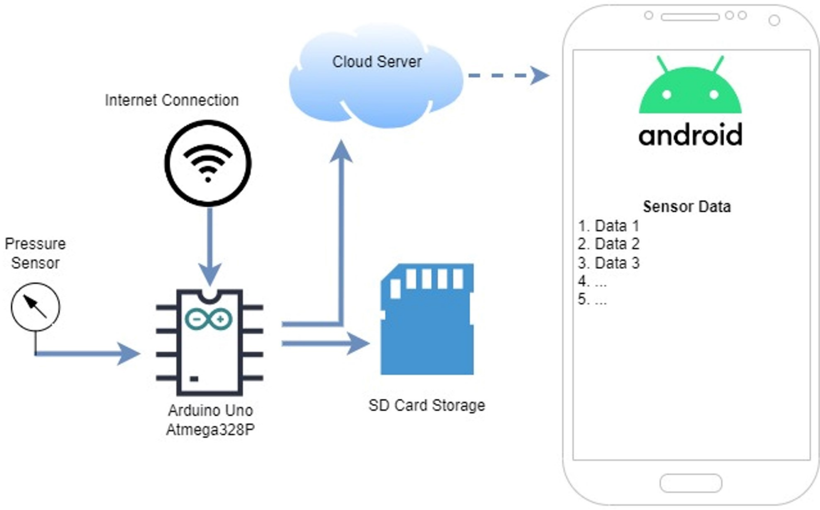

FIG. 3: IoT connection system

The measurement range tested for the above data is at the level of 6 cm to 49 cm. The analog voltage output data from the sensor is amplified using a differential amplifier with a gain of 100 times. Then, the data is used to determine the value of the soil permeability coefficient using Eq. (2). The sensor calibration data as mentioned in methodology is shown in Fig. 4. In Fig. 4, the red line shows the measurement of increasing the water level, while the blue line shows the decrease in the water level. The data increases or decreases approaching a linear line. This shows that the accuracy of the pressure sensor used for measuring the water level is relatively good.

Then, sensor accuracy can be known by calculating %FSO. So, %FSO is described as sensor accuracy, and it is calculated using the following equation.

$$Err\ (mV) = \text{Actual value} - \text{Sensor output value} \quad (4)$$

$$\%FSO = \frac{Err(V)}{\text{Full scale }(4.6V)} \times 100\% \quad (5)$$

Based on calculations, the highest %FSO value is at the level of 10.5 cm, which is 0.02%. That is, the tolerance of the data given by the sensor is (0.02% x measurement range) = (0.02% x 43 cm) = 0.0086 cm = 8.6 mm. So that each reading of a scale of one cm, the $\pm$ is 8.6 mm. For example, at a distance reading of 10 cm on the sensor, the actual data is 9.14 to 10.86 cm. This information can be used as a reference that the measuring instrument that has been made with the MPX10GP sensor has a good reading value.

B. Data Transmission Data Using Internet of Things (IoT)

In this data transmission system, TCP/IP communication is used, namely communication where the microcontroller is set to a certain IP which then the IP address can be accessed into the internet network. To check that there is no data changing during the transmission process, here is the test data from the microcontroller which is then accessed by the network.

TABLE I: Value of data send and data receive on TCP/IP communication

Sender Digital Data (Decimal)	Receiver Digital Data (Decimal)
1023	1023
900	900
800	800
700	700
600	600
500	500
400	400
300	300
200	200

From Table I, the data sent by the microcontroller was successfully received by the receiving device. This proves that this communication will maintain the data properly so that the data displayed by other devices can receive the actual data.

C. Soil Permeability Coefficient Measurement Data

The test samples in this study were the slopes of Mount Ngantang, the embankment of the Institut Teknologi Sepuluh Nopember (ITS) pond, and the embankment of the Bengawan Solo River. The average value of the measurement results is presented in Table II.

Soil permeability coefficient measurement values are compared with references in a book [16], so the samples chosen to

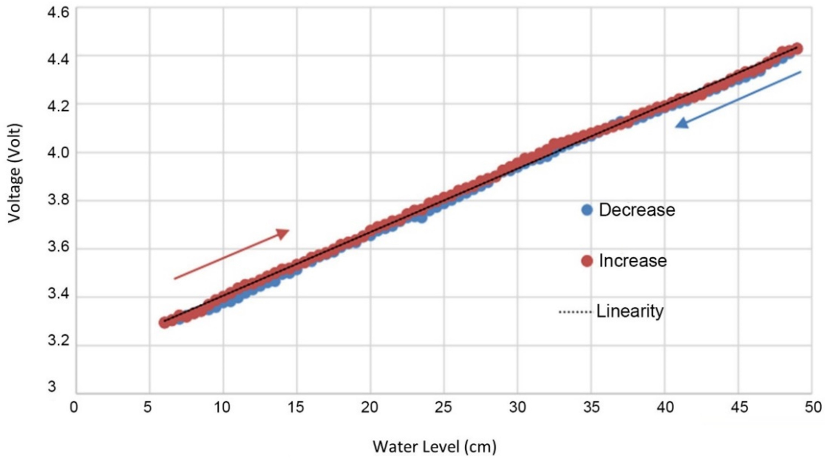

FIG. 4: Graph of sensor output voltage with water level

TABLE II: Soil Permeability Coefficient Measurement

Soil Permeability Coefficient (cm/s)		
Mount Ngantang	**ITS Pond**	**Bengawan Solo River**
0.0016	0.0005	0.0002

have the same characteristics with the reference. From the literature study that has been carried out, there is a match between the values of the measurement tools that have been made and the reference with the difference around 2.7%. The theory is used to explain the range of soil permeability coefficient values based on the composition of the material.

Based on Table II, the largest permeability coefficient value is owned by a sample of the slopes of Mount Ngantang which is prone to landslides. The smallest soil permeability coefficient value is owned by the Bengawan Solo River embankment, and the pond embankment has a permeability coefficient value between the two samples. Areas that have a high coefficient of soil permeability have a high potential for landslides. Thus, this research can be used to map areas prone to landslides.

IV. CONCLUSION

Based on the research that has been done, the soil permeability measuring instrument made has a relative measurement deviation of $\pm$ 8.6 mm. Based on the measurement results of three samples, the slopes of Mount Ngantang have a k value of 0.0016 cm/s, the ITS pond embankment is 0.0005 cm/s, and the Bengawan Solo River embankment is 0.0002 cm/s. These results match with the reference and the difference value is only 2.7%. So that, it can be concluded that this IoT technology for soil permeability coefficient measurement is success and can also be applied to this research without any disturbance in the data transmission process so that data can be monitored in real-time by the receiving device.

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