Liquefaction alarm prototype using arduino uno microcontroller

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Abstract. This study aims to create an alarm tool that can detect disasters such as earthquakes and liquefaction in Palu City. It was laboratory research conducted in Sub department of Physics Education, Tadulako University. Research and experiments with modelling tools were conducted to simulate soil conditions during the earthquake and liquefaction. The research sample was focused on soil samples that have been affected by liquefaction disasters. The method used was the waterfall with the procedures of requirements analysis, system design, implementation, and testing of Arduino programs and software as ground movement monitoring. This study indicated that a liquefaction alarm prototype using a microcontroller component in the form of Arduino Uno, soil moisture sensor, and MPU6050 sensor could detect a natural liquefaction disaster was signed by a siren sound.

1. Introduction

Natural disasters are usually triggered by natural factors, non-natural factors, and human behavior. It may cause environmental damage and casualties [1]. Each country has different disaster vulnerability, including Indonesia. As located on three active plates and the equator, Indonesia has numerous active volcanoes and is highly prone to other natural disasters [2]. Only in a one-year period, thousands of disasters have occurred across Indonesia, including landslides, floods, earthquakes, tsunamis, and others. As of 2018, there have been 2,572 disasters that caused approximately 4,814 people lost their lives and were declared missing, 21,000 people were injured, and 300 houses were damaged [3].

Central Sulawesi is a province of Indonesia that has an active fault, called the Palu-Koro fault. On September 28, 2018, the Palu-Koro fault experienced a powerful movement, recorded on the seismographs of the earthquake measuring 7.4 on the Richter Scale [4]. In addition, the earthquake also triggered a tsunami as high as 2.2 meters that occurred in the coastal areas of Talise, Mamboro, and Donggala [4]. On the same day, there was a liquefaction disaster due to vibrations caused by an earthquake in several areas of Palu, namely Petobo, Balaroa, and Jonoge. It was the first time for the community around Palu to witness and experience such an event.

Liquefaction is an event that changes the structure and properties of the soil and the pressure in the soil due to movement, which causes the soil to be unable to control the strength and stiffness properties of the previous soil [5]. The 2011 Tohoku earthquake off the Pacific coast in Japan also caused liquefaction of large areas. In particular, severe liquefaction was reported in the northern part of the reclaimed land around Tokyo Bay [6]. Liquefaction has occurred in many locations as an impact of severe shaking. However, a local person in Central Sulawesi has not been familiar with the term liquefaction before the 2018 earthquake tragedy.
Based on the records within a century (1905–2005), there have been more than ten earthquakes with more than 4.5 SR in Palu City and its surroundings. Based on topographical, geological, and seismological conditions, the Palu City area can be damaged by earthquakes and secondary disasters (tsunami, liquefaction, and cliff landslides). On May 20, 1938, an earthquake with a magnitude of 7.6 on the Richter scale shook throughout the island of Sulawesi [7]. The liquefaction micro zonation mapping using the Ground Shear Strain (GSS) approach in Palu City and its surroundings shows that the potential liquefaction is in several villages: Baru, Besusu, Bayaoge, Nunu, Siranindi, Kamonji, Silae, Lare, Talise, and Kabonen [8].

Reviewing, studying, and analyzing all the supporting factors and the potential for such a large liquefaction disaster led to the importance of making an effort and action to prepare psychologically and physically. It is to reduce the risk and impact of the disaster, both before, during, and after the disaster occurs. However, liquefaction disasters due to earthquakes can come out of the blue, so it is necessary to have an early warning tool to inform the existence of liquefaction.

Research conducted by Ginting [9] produced an earthquake detector design tool equipped with an early warning alarm and automatic light control. It is one of the steps to accelerate evacuation in the event of an earthquake [9]. This tool was designed with a Hall Effect sensor A3144 as a vibration detector and a PIR sensor used to detect human body temperature.

An earthquake alarm system based on the AVR Atmega 16 microcontroller using a piezoelectric sensor shows an active alarm if the sensor output voltage is 1 volt and the sensor is still sensitive to detect vibrations up to 200-centimeter distance for a load drop height of 30 cm. The system consists of automation capable of activating the Mp3 player, activating an alarm when vibration is detected. This alarm will continue to be active if there is still a vibration, and this alarm will be deactivated after the vibration is no longer detected for 5 minutes. The earthquake alarm test was carried out through a straightforward process by dropping a load of 100 grams, 200 grams, and 300 grams. The falling distance to the sensor and the falling height of the load were 10 cm, 20 cm, and 30 cm. The reference used to indicate the occurrence of earthquake vibrations is 2 MMI (Modified Mercalli Intensity), as stated in research conducted by Rahman and Yusfi [10].

There has been no alarm that functions as an early warning of an earthquake and liquefaction disaster, especially in Palu City. Accordingly, the researchers were interested in making a liquefaction alarm prototype to detect earthquakes and liquefaction based on the Arduino Uno microcontroller. The product of this study can be used as a prototype of an alarm that can detect the liquefaction phenomenon as part of a form of natural disaster mitigation.

2. Methods
This research was a laboratory experiment implemented to create and produce a liquefaction alarm based on an Arduino Uno microcontroller. The research was carried out at the Physics Laboratory of the Faculty of Education, Tadulako University, Palu, Central Sulawesi, in September 2020. The liquefaction alarm prototype testing was carried out in a transparent container with a size of 30 x 23.5 cm with a soil sample of 2 kg and a volume of 1.5 L of water, obtained a water content of 75% with a dry volume weight of 0.591 gr/cm$^3$ and the wet volume weight of 0.946 gr/cm$^3$. The sample used was a soil sample from an area affected by liquefaction: the Petobo area, Palu City. This study conducted testing of the tool's string and the system as a whole. The data were collected from the analysis of the results provided by the tool.

3. Results and Discussion
3.1 Testing Purpose
The tests were carried out to test the tool's performance. In addition, as a program in the form of a system application, it is necessary to test the relationship between hardware and software. It was expected that the test could detect whether the designed tools and applications worked as desired or not. Initial testing was done by testing the components separately and then continued by testing the whole system.
3.2 Tool's String Test Results

The design was based on the liquefaction alarm prototype using the Arduino Uno microcontroller using two types of sensors, namely the soil moisture sensor and the MPU6050 sensor with gyroscope and accelerometer. The results of the tests carried out are as follows:

3.2.1 Soil moisture sensor display

The soil moisture sensor tests detected soil moisture on waterless soil (dry soil) and wet soil until it melted. The test results are shown in Table 1 and Figure 1.

| No | Test Type    | Sample                  | Result                                                        |
|----|--------------|-------------------------|----------------------------------------------------------------|
| 1  | Waterless Soil | 2 kg of soil            | Generate sensor readings and display data on the application interface |
| 2  | Wet Soil     | 2 kg of soil + 1.5 L of water | Generate sensor readings and display data on the application interface |

Figure 1. The string of soil moisture sensor test results

3.2.2 The display of sensor mpu6050 with gyroscope and accelerometer

The MPU6050 sensor test was carried out to detect ground movement by placing the sensor on the test container and then giving it a vibration through a drill considered an earthquake vibration. The test results are shown in Table 2 and Figure 2.

| No  | Test Type    | Sample                  | Result                                                        |
|-----|--------------|-------------------------|----------------------------------------------------------------|
| 1.  | Waterless Soil | 2 kg of soil            | Generate ground motion values and display waves on the application interface |
| 2.  | Wet Soil     | 2 kg of soil + 1.5 L of water | Generate ground motion values and display waves on the application interface |

Figure 2. Test results of MPU6050 sensor's string

3.3 Overall System Test Results

System testing is executing a software system to determine whether the system matches the system specifications and runs as intended. This testing was intended to determine whether the software's...
functions, inputs, and outputs followed the required specifications [11]. This test was carried out by combining all sensor components along with the application software used.

Table 3. Overall system testing

| No | Test Type       | Sample                  | Result                        |
|----|----------------|-------------------------|-------------------------------|
| 1. | Waterless Soil | 2 kg of soil            | Short beep sound with 1-sec interval | Displays waveform reading |
| 2. | Wet Soil       | 2 kg of soil + 1.5 L of water | Siren sound                   | Displays waveform reading |

Figure 3. Overall test results

The working principle of the liquefaction alarm prototype in this study is that the alarm will sound when the pore water pressure in the soil continues to increase, causing the soil from a solid-state to become more liquid due to earthquake vibrations. In this liquefaction alarm prototype design and manufacture, each component has been tested both separately and as a whole. It resulted in accordance to what has been programmed. After testing a series of tools on the liquefaction alarm prototype, it was found that the mpu6050 sensor with gyroscope and accelerometer and soil moisture sensor functioned properly, as shown in the test results in Table 1 and Table 2. It shows that each sensor can display sensor reading data on the interface application. While in the overall system test, which can be seen in Table 3, on soil testing without water content, the buzzer sound produced was in the form of a tone with short beeps with an interval of 1 second. This pattern of alarm sound indicates the area is experiencing an earthquake. Meanwhile, when the sample soil was added water, the sounds become siren pattern. It warns that the liquefaction had occurred.

The liquefaction alarm prototype took place in a transparent container measuring 30 x 23.5 cm with a composition of 2 kg of soil and 1.5 L of water. The mixing results found that the water content in the liquefaction prototype was 75%, the dry volume weight was 0.591 gr/cm³, and the wet volume weight was 0.946 gr/cm³. In this study, the high-water content in the prototype caused the low bearing capacity of the soil, which resulted in the low ability of the soil to withstand maximum pressure or load, which then caused liquefaction. It is relevant to the reference [12], which states that the bearing capacity of the soil is obtained from its shear strength. It can resist shear stress when the soil is loaded. The water content significantly affects the soil type; adding or reducing water content up to 20% can reduce the value of shear strength which is quite significant and will affect land stability. The soil samples used were from areas affected by liquefaction, namely the Petobo area, Palu City. The type of soil in the area is poorly graded sand containing little or no refined grains, commonly referred to as non-plastic (non-cohesive) soil [13]. Poorly graded soil types tend to be unstable and more susceptible to liquefaction than well-graded soil types [13].

This prototype liquefaction alarm used two types of sensors: the mpu6050 sensor with accelerometer and gyroscope to detect ground movement. By using the accelerometer sensor, a ground movement detector can detect the occurrence of shifts and ground movements so that losses can be minimized [14]. Then, the soil moisture sensor was used to measure the increase in humidity level due to pressure
on the soil pore water. Adding water with good conductor properties can result in a small resistance reading and vice versa. If the water content in the soil is reduced or low, it produces a considerable resistance value [15] so that it can be used to detect soil liquefaction due to vibration. This liquefaction alarm device has produced a tool to warn of natural disasters (earthquakes and small-scale liquefaction) and monitor earthquakes' movement.

In this prototype liquefaction alarm system, it is limited to several factors causing liquefaction. Therefore, there are still weaknesses. The amount of energy given to produce earthquakes has not become a fixed variable, the type of soil used has not been filtered in detail, the range of tools was still small, and the monitoring system could not be accessed online. Several factors limit this prototype liquefaction alarm because it requires further study and a longer time in the research process. The liquefaction alarm is also expected to be a medium for learning physics in classroom learning so as to complement the existing science instruments [16], energy conversion tools [17] and fluorine-doped tin oxide [18].

4. Conclusion
An alarm prototype using a microcontroller component in the form of Arduino Uno to detect earthquakes and liquefaction has been developed. Although it was still in a form of prototype, it can be used in the community as the early warnings for natural disasters and monitor the phenomenon of liquefaction. Researchers suggest that this tool is developed more digitally, like using electromagnetic waves, so that the intended reach is broader compared to this study. In addition, the use of frequency on the vibrator set is recommended to detect the amount of energy generated by the vibration. Also, researchers recommend using soil types with various samples of soil grains with different sizes and screening numbers and an online and android-based warning system so that all the public can know it.

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