



Soil Strength using Ultrasonic Sensor

Project for Geotechnical Engineering Lab (CEC304) 2023

Group 1

Objective

To measure soil compaction and moisture content indirectly using an ultrasonic distance sensor by calibrating the readings with the results from Unconfined Compression Test.

Overview

The project aims to assess soil compaction and moisture content indirectly by employing an ultrasonic distance sensor, calibrated against results from the Unconfined Compression Test. This innovative approach combines modern sensor technology with established geotechnical testing to provide efficient and non-invasive soil quality assessments.

Unconfined Compression Test

The Unconfined Compression Test is designed to evaluate the cohesive strength of soil. In this test, a cylindrical soil specimen, typically undisturbed, is subjected to axial loading in an unconstrained manner. Unlike other compression tests, the unconfined compression test doesn't employ lateral confinement, allowing the soil to deform freely. This test provides insights into the undrained shear strength and stress-strain characteristics of the soil under quasi-static loading conditions. It is particularly valuable for cohesive soils such as clays, where the undrained behavior is a critical consideration in geotechnical engineering analyses. The results obtained from the Unconfined Compression Test are essential for understanding soil stability, foundation design, and predicting the behavior of soil under various loading conditions.

Using Arduino with Ultrasonic Distance Module

The Arduino serves as the central processing unit, interfacing with the Ultrasonic Distance Module to measure the distance between the sensor and the soil surface. This distance reading can be correlated with soil compaction, providing real-time, non-invasive insights into soil conditions. The Ultrasonic Distance Module emits ultrasonic waves and measures the time taken for the waves to return after bouncing off the soil surface, enabling precise distance calculations. Through calibration against results from traditional tests such as the Unconfined Compression Test, this integrated system offers a practical and efficient method for indirect soil quality assessments. The Arduino-Ultrasonic setup is not only cost-effective but also portable, allowing for on-site measurements and contributing to the advancement of geotechnical engineering practices.

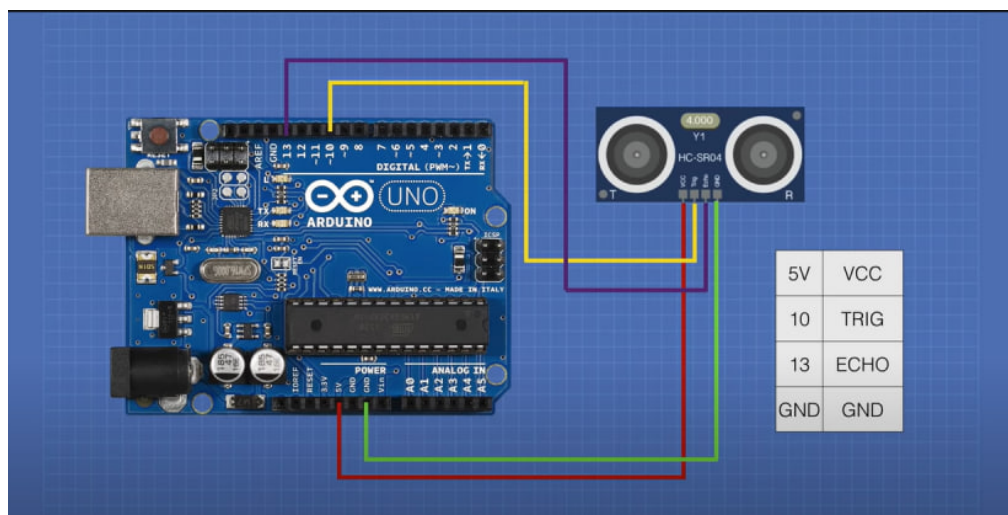
Relevance

- **Efficiency and Non-Invasiveness:** Traditional methods of soil compaction and moisture content measurement involve time-consuming and invasive techniques. This project leverages the efficiency of an ultrasonic distance sensor, allowing for quicker and non-invasive field assessments.
- **Real-time Monitoring:** The integration of ultrasonic sensors with modern data loggers and microcontrollers enables real-time monitoring of soil conditions. This capability is crucial for dynamic fields like agriculture, construction, and environmental monitoring.
- **Environmental Monitoring:** Geotechnical engineers can apply this method to monitor the impact of land use changes on soil quality. The non-invasive nature of the ultrasonic sensor makes it suitable for long-term environmental studies.

Materials and Equipment

1. Ultrasonic Distance Sensor
2. Arduino Microcontroller
3. Unconfined Compression Test apparatus
4. Soil samples

Circuit Diagram



Code

```
#define trigPin 10
#define echoPin 13

#define soundSpeedInAir 331.5 // m/s at 0 degrees Celsius and 0%
humidity

float duration, distance;

float temperature = 25.7; // Temperature in degrees Celsius
float humidity = 59.0;    // Relative humidity in percentage

void setup() {
    Serial.begin(9600);
    pinMode(trigPin, OUTPUT);
    pinMode(echoPin, INPUT);
}

void loop() {
    // Write a pulse to the HC-SR04 Trigger Pin
    digitalWrite(trigPin, LOW);
    delayMicroseconds(2);
    digitalWrite(trigPin, HIGH);
    delayMicroseconds(10);
    digitalWrite(trigPin, LOW);

    // Measure the response from the HC-SR04 Echo Pin
    duration = pulseIn(echoPin, HIGH);
```

```
// Calculate the speed of sound based on temperature and humidity
float soundSpeed = soundSpeedInAir + (0.606 * temperature) + (0.124
* humidity );

// Calculate the adjusted distance measurement
distance = (duration / 2) * (soundSpeed / 10000); // Convert to cm
and four decimal places

// Send results to Serial Monitor
Serial.print("Distance = ");
if (distance >= 400 || distance <= 2) {
    Serial.println("Out of range");
} else {
    Serial.print(distance, 5); // Display with four decimal places
    Serial.println(" cm");
}

delay(12000);
}
```

Procedure

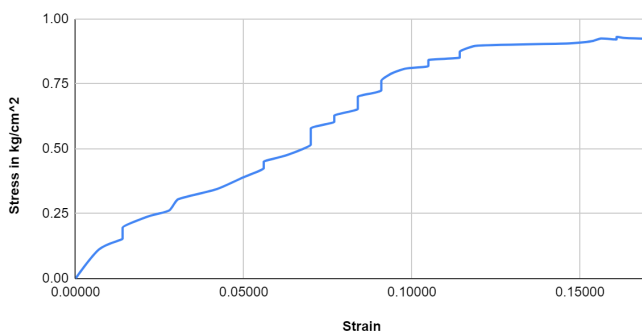
1. Connect the ultrasonic distance sensor to the Arduino microcontroller as shown in the circuit above and ensure it's programmed to read distance data.
2. Place the ultrasonic sensor at a known height on the bottom plate of the UCS apparatus such that the ultrasonic sensor measures the initial height of the upper plate. This height is taken as the reference height.
3. Begin by taking measurements with the ultrasonic sensor and simultaneously, take readings using the Unconfined Compression Test.
4. Analyze and plot the data of both to compare them
5. Repeat for more soil samples and take the average of the observations.

Observations and Graphs

Proving ring constant	0.275 kg	Strain rate	1.25	mm/min		Reference Value	6.52078	cm		
Least count of dial gauge	0.01 mm	Sample No.	2							
Dial Gauge Reading	Axial Strain $\epsilon = \frac{\Delta L}{L}$	Corrected $A_c = A_o (1 - \epsilon)$	Proving Ring Reading	Axial Compressive Stress P/A_c	Ultrasonic Reading	Compression	Delta L	Axial Strain		
Axial Deformation (ΔL)	strain		Load P							
Division	mm	cm ²	Div.	Kg	Kg/cm ²	cm	cm	cm		
0	0	0	11.34	0	0.0000	6.52078	0.10632	0	0.00000	
25	0.25	0.0033	11.3774	0.8	1	6.46762	0	0.05316	0.00699	
50	0.5	0.0066	11.4151	1.4	1.75	6.41446	0.05316	0.10632	0.01399	
75	0.75	0.0099	11.453	1.6	2	6.41446	0.10632	0.10632	0.01399	
100	1	0.0132	11.4912	2.2	2.75	6.3613	0.21264	0.15948	0.02098	
125	1.25	0.0164	11.5296	2.6	3.25	6.30814	0.23035	0.21264	0.02798	
150	1.5	0.0197	11.5683	3.2	4	6.29043	0.15948	0.23035	0.03031	
175	1.75	0.023	11.6073	3.6	4.5	6.20183	0.6379	0.31895	0.04197	
200	2	0.0263	11.6465	4.2	5.25	6.14867	0.31895	0.37211	0.04896	
225	2.25	0.0296	11.686	4.8	6	6.09551	0.79738	0.42527	0.05596	
250	2.5	0.0329	11.7257	5.4	6.75	6.09551	0.70878	0.42527	0.05596	
275	2.75	0.0362	11.7657	6	7.5	6.04235	0.69106	0.47843	0.06295	
300	3	0.0395	11.806	6.4	8	5.98919	0.74422	0.53159	0.06995	
325	3.25	0.0428	11.8466	6.8	8.5	5.98919	0.86826	0.53159	0.06995	
350	3.5	0.0461	11.8874	7.4	9.25	5.98919	0.42527	0.53159	0.06995	
375	3.75	0.0493	11.9286	7.6	9.5	5.93604	0.79738	0.58474	0.07694	
400	4	0.0526	11.97	8	10	5.93604	0.37211	0.58474	0.07694	
425	4.25	0.0559	12.0117	8.4	10.5	5.88288	0.42527	0.6379	0.08393	
450	4.5	0.0592	12.0537	8.6	10.75	5.88288	0.53159	0.6379	0.08393	
475	4.75	0.0625	12.096	9	11.25	5.88288	0.58474	0.6379	0.08393	
500	5	0.0658	12.1386	9.2	11.5	5.82972	0.47843	0.69106	0.09093	
525	5.25	0.0691	12.1815	9.6	12	5.82972	0.53159	0.69106	0.09093	
550	5.5	0.0724	12.2247	9.8	12.25	5.812	0.53159	0.70878	0.09326	
575	5.75	0.0757	12.2682	10.2	12.75	5.77656	0.69106	0.74422	0.09792	
600	6	0.0789	12.312	10.4	13	5.7234	0.58474	0.79738	0.10492	
625	6.25	0.0822	12.3561	10.8	13.5	5.7234	0.6379	0.79738	0.10492	
650	6.5	0.0855	12.4006	11	13.75	5.65252	0.6379	0.86826	0.11424	
675	6.75	0.0888	12.4453	11.2	14	5.65252	1.11633	0.86826	0.11424	
700	7	0.0921	12.4904	11.4	14.25	5.61708	1.22265	0.9037	0.11891	
725	7.25	0.0954	12.5359	11.6	14.5	5.40445	1.29352	1.11633	0.14689	
750	7.5	0.0987	12.5816	11.8	14.75	5.35129	1.18721	1.16949	0.15388	
775	7.75	0.102	12.6277	12	15	5.33357	1.16949	1.18721	0.15621	
800	8	0.1053	12.6741	12	15	5.29813	1.22265	1.22265	0.16088	
825	8.25	0.1086	12.7209	12	15	5.29813	1.24037	1.22265	0.16088	
850	8.5	0.1118	12.768	12.2	15.25	5.28041	0.9037	1.24037	0.16321	
875	8.75	0.1151	12.8155	12.2	15.25	5.22726	0.86826	1.29352	0.17020	

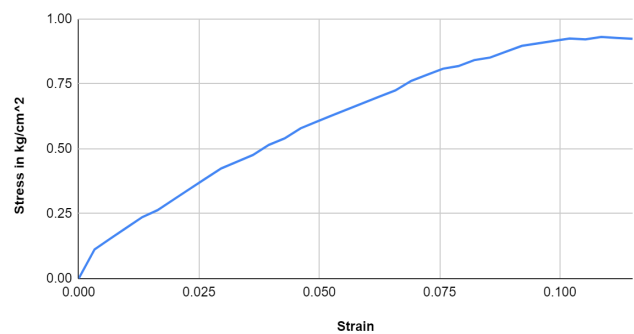
Test with Ultrasonic Sensor

Sample 1



UCS Test

Sample 1



Result

Unconfined Compressive Strength = 1.194 kg/cm²

UCS Test

Corresponding Strain of Sample 1 = 0.1116

Test with Ultrasonic Sensor

Corresponding Strain of Sample 1 = 0.16321

$$\text{Error} = \frac{0.16321 - 0.1116}{0.1116} * 100\% = 46.24\%$$

Conclusion

In summary, the Arduino-Ultrasonic setup offers a cost-effective and portable solution for real-time soil quality assessments. The observed 46% error may stem from factors like soil composition variations, sensor calibration, or environmental influences. Refinement of calibration processes and consideration of external factors are crucial for improving accuracy in future applications.

Precautions

1. When samples are pushed from the drive sampling tube the ejecting device the principal concern should be to keep the degree of disturbance negligible.
2. The specimen shall be handled carefully to prevent disturbance, change in cross section, or loss of water.
3. The specimen shall be of uniform circular cross-section with ends perpendicular to the axis of the specimen
4. Circuit connections should be made properly with appropriate voltage inputs.
5. The microcontroller and sensors should be handled carefully.

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