Soil Strength using Ultrasonic Sensor

Project for Geotechnical Engineering Lab (CEC304) 2023

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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.

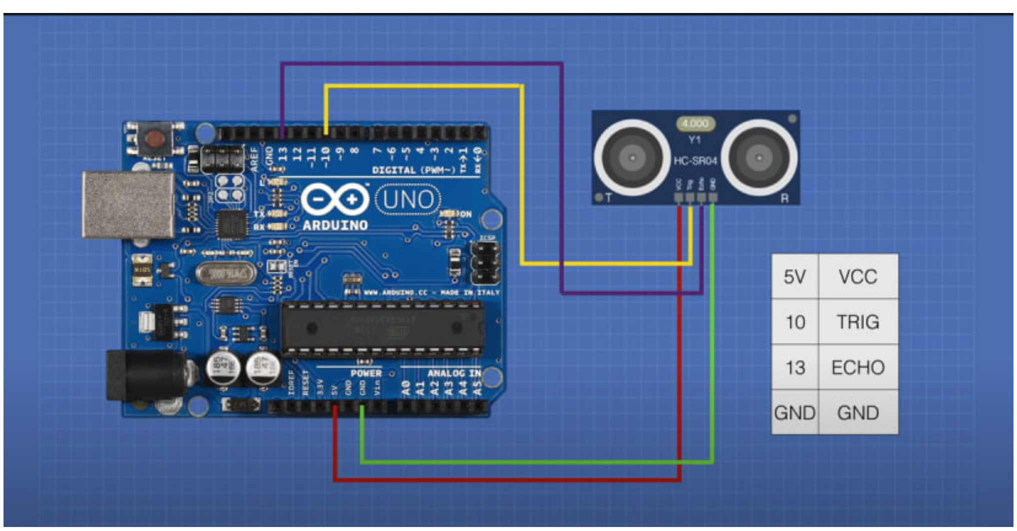
Relevance

- **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);
```

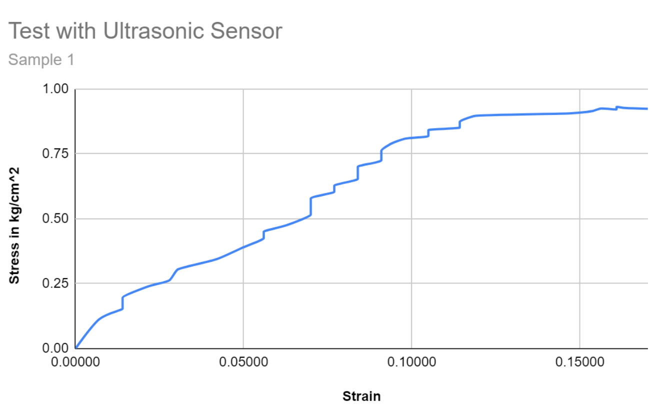
```
// Calculate the speed of sound based on temperature and humidity
  float soundSpeed = soundSpeedInAir + (0.606 * temperature) + (0.124
* humidity );

  // 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);
}
```

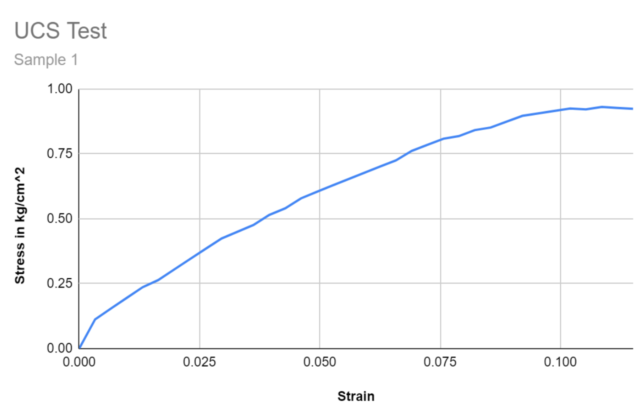
Procedure

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 Strai e = fIL L	Corrected / Ac = Ao l-e	Proving Ring Reading		Axial Compressive Stress P/Ac		Ultrasonic Reading	Compression	Delta L	Axial Strain
Axial Deformation (ΔL)		strain									
				Load P							
Division	mm		cm²	Div.	Kg	Kg/cm²		cm	cm	cm	
0	0	0	11.34	0	0	0.0000		6.52078	0.10632	0	0.00000
25	0.25	0.0033	11.3774	0.8	1	0.0879		6.46762	0	0.05316	0.00699
50	0.5	0.0066	11.4151	1.4	1.75	0.1533		6.41446	0.05316	0.10632	0.01399
75	0.75	0.0099	11.453	1.6	2	0.1746		6.41446	0.10632	0.10632	0.01399
100	1	0.0132	11.4912	2.2	2.75	0.2393		6.3613	0.21264	0.15948	0.02098
125	1.25	0.0164	11.5296	2.6	3.25	0.2819		6.30814	0.23035	0.21264	0.02798
150	1.5	0.0197	11.5683	3.2	4	0.3458		6.29043	0.15948	0.23035	0.03031
175	1.75	0.023	11.6073	3.6	4.5	0.3877		6.20183	0.6379	0.31895	0.04197
200	2	0.0263	11.6465	4.2	5.25	0.4508		6.14867	0.31895	0.37211	0.04896
225	2.25	0.0296	11.686	4.8	6	0.5134		6.09551	0.79738	0.42527	0.05596
250	2.5	0.0329	11.7257	5.4	6.75	0.5757		6.09551	0.70878	0.42527	0.05596
275	2.75	0.0362	11.7657	6	7.5	0.6374		6.04235	0.69106	0.47843	0.06295
300	3	0.0395	11.806	6.4	8	0.6776		5.98919	0.74422	0.53159	0.06995
325	3.25	0.0428	11.8466	6.8	8.5	0.7175		5.98919	0.86826	0.53159	0.06995
350	3.5	0.0461	11.8874	7.4	9.25	0.7781		5.98919	0.42527	0.53159	0.06995
375	3.75	0.0493	11.9286	7.6	9.5	0.7964		5.93604	0.79738	0.58474	0.07694
400	4	0.0526	11.97	8	10	0.8354		5.93604	0.37211	0.58474	0.07694
425	4.25	0.0559	12.0117	8.4	10.5	0.8741		5.88288	0.42527	0.6379	0.08393
450	4.5	0.0592	12.0537	8.6	10.75	0.8918		5.88288	0.53159	0.6379	0.08393
475	4.75	0.0625	12.096	9	11.25	0.9301		5.88288	0.58474	0.6379	0.08393
500	5	0.0658	12.1386	9.2	11.5	0.9474		5.82972	0.47843	0.69106	0.09093
525	5.25	0.0691	12.1815	9.6	12	0.9851		5.82972	0.53159	0.69106	0.09093
550	5.5	0.0724	12.2247	9.8	12.25	1.0021		5.812	0.53159	0.70878	0.09326
575	5.75	0.0757	12.2682	10.2	12.75	1.0393		5.77656	0.69106	0.74422	0.09792
600	6	0.0789	12.312	10.4	13	1.0559		5.7234	0.58474	0.79738	0.10492
625	6.25	0.0822	12.3561	10.8	13.5	1.0926		5.7234	0.6379	0.79738	0.10492
650	6.5	0.0855	12.4006	11	13.75	1.1088		5.65252	0.6379	0.86826	0.11424
675	6.75	0.0888	12.4453	11.2	14	1.1249		5.65252	1.11633	0.86826	0.11424
700	7	0.0921	12.4904	11.4	14.25	1.1409		5.61708	1.22265	0.9037	0.11891
725	7.25	0.0954	12.5359	11.6	14.5	1.1567		5.40445	1.29352	1.11633	0.14689
750	7.5	0.0987	12.5816	11.8	14.75	1.1723		5.35129	1.18721	1.16949	0.15388
775	7.75	0.102	12.6277	12	15	1.1879		5.33357	1.16949	1.18721	0.15621
800	8	0.1053	12.6741	12	15	1.1835		5.29813	1.22265	1.22265	0.16088
825	8.25	0.1086	12.7209	12	15	1.1792		5.29813	1.24037	1.22265	0.16088
850	8.5	0.1118	12.768	12.2	15.25	1.1944		5.28041	0.9037	1.24037	0.16321
875	8.75	0.1151	12.8155	12.2	15.25	1.1900		5.22726	0.86826	1.29352	0.17020





Result

Unconfined Compressive Strength = 1.194 kg/cm^2

UCS Test

Corresponding Strain of Sample 1 = 0.1116

Test with Ultrasonic Sensor

Corresponding Strain of Sample 1 = 0.16321

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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