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Concrete Slump Quality and Volume Calculator using Raspberry PI - 5

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Abstract: *Testing of concrete quality is very important in all construction projects for its strength, durability, and safety. In all construction projects, the concrete slump test is used most commonly for measuring the workability and consistency of fresh concrete. This concrete slump test is done manually by an engineer or worker; it takes much time, and accuracy depends on the skill level of the engineer or worker. By doing this test manually, there is no proper accuracy or consistency. In this paper, we have proposed an automated Concrete Slump Quality & Volume Calculator, which is based on Raspberry Pi 5 along with another network of sensors. This machine will have a DHT-11 sensor through which various environmental factors are being monitored, i.e., temperature and humidity are some factors that are responsible for concrete behaviour. A rotation sensor is used for measuring the slump displacement. The pressure gauge is used for measuring the force on concrete. Further to that, wireless communication is done through the ESP-32 module, by which data can be accessed from anywhere by smartphone or computer. The reading of various sensors is collected and then it is sent to the Raspberry Pi for further processing. And by using an appropriate algorithm, the value of slump is calculated, and the estimated volume of concrete is also calculated by this system. The whole system is portable and cost cost-effective, and easy to use for quality concrete onsite checking. Our experimental work shows that the system developed by us will accurately check the quality of concrete slump with an error of ±5 as compared to manual methods of checking slump. By minimizing the role of humans, accuracy is increased, and results are obtained instantly as compared to manual methods. This system is better than traditional methods and helps to modernize the construction..*

Keywords: Raspberry Pi 5, DHT-11 Sensor, Pressure Gauge, Rotation Sensor, ESP-32 Module, Concrete Slump Measurement, Concrete Volume Calculation, Environmental Monitoring, Wireless Communication, Real Time Data Processing, Portable Construction Device, 3.7V 5000mAH Battery, Sensor-Based Concrete Testing

I. INTRODUCTION

Concrete is the most widely used construction material due to its strength, durability, and versatility. The quality of concrete should be proper as it is very much essential for our safety and the durability of structures. One of the most widely used tests to determine the consistency and workability of the fresh concrete is the slump test. In the traditional manual slump test, concrete is placed into a cone, and the amount it "slumps" or collapses when the cone is lifted is manually measured. The manual method of the slump test is effective but time-consuming and prone to human error.

Today's construction industry requires fast, accurate, and automated methods for quality control of different materials, which include concrete.

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In this paper, to overcome the above challenges, we have developed an automated Concrete Slump Quality and Volume Calculator, which is built using a Raspberry Pi 5 and a combination of sensors. The system is designed to be portable and low-cost to be used on any size of construction site. The building process of this automated system is not complicated and can be easily built with a few simple steps.

Automating the slump test process will help to reduce human error, save time, and provide more consistent results when measuring the quality of concrete. This is a big step towards modernizing quality control in the construction industry.

II. LITERATURE REVIEW

Concrete is the most commonly used construction material on our globe for every structure, such as buildings, bridges, roads, and many other structures. Quality of concrete should be ensured before and during the construction, as it is very important to get the best structural integrity and quality of concrete. Among all quality tests, the slump test is one of the most common methods used by engineers to determine the quality of fresh concrete. The slump test is manual, subjective, and prone to human error. We can see an increasing trend of research to modernize concrete testing through automated concrete testing, which includes the use of sensors and real-time monitoring.

2.1. Traditional Concrete Testing Methods

The quality of concrete is measured by human observation and manual measurement techniques, by conducting the concrete slump test manually, such as the Abrams cone slump test. The manual test does not require many types of equipment, except for the cone; it is simple, cheap, and depends much on the skill and judgment of the person conducting the test. The concrete may get uneven filling, inaccurate lifting of the cone, and inaccurate measurements will cause erroneous results. Besides that, quality concrete test rarely takes into account the environmental conditions such as temperature and humidity, which have a great effect on concrete strength, durability, longevity, and the early stage of fixing irregularity.

2.2. The Emergence of Smart Testing Systems

With the advancement of embedded systems and microcontrollers, researchers have started to propose automated and semi-automated methods for concrete testing. Early research on concrete testing has been mechanical by using an automated cone and lifting device to minimize human interaction with the system. These systems are available but very expensive and bulky, and not suitable for on-site operations where portability is important.

In past years of work with embedded computing, microcontrollers like Arduino and single board computers like Raspberry Pi have given us the ability to perform cheap, small, smart computing that can be performed on the go for concrete testing. These have enough power to collect data from a sensor, process it, and send it somewhere else in real time, which should yield more consistent results as compared to doing it manually.

2.3. What Role Does Raspberry Pi Play in Construction?

The Raspberry Pi 5 is not like many other single-board computers in that it is capable of processing data, it is small enough to be portable, and it has great I/O support, so we can take in data from other sensors like an ESP-32.

The OS we run on Pi 5 is based on Linux gives us the raw speed on the kernel level, which is needed for speed. The Raspberry Pi has been used for things like structural health monitoring, environmental monitoring, and autonomous drone control. In the realm of concrete testing, we feel that the Raspberry Pi would be a good fit in terms of cost, flexibility, and processing power.

2.4. Why Should We Monitor the Environment with a DHT-11 Sensor?

The properties of concrete are greatly affected by temperature and humidity in the environment. The higher the temperature, the faster the reaction of the hydration, but if the temperature is too high, the final strength may be low. The same goes for high humidity.

The DHT-11 is an inexpensive digital temperature and humidity sensor that provides decent probabilistic accuracy. The DHT-11 is used in agriculture, industrial monitoring, and in the smart home has shown that it is a very useful tool.

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When measuring concrete slump and volume, we will also measure the environmental variables, which will increase the accuracy and consistency of our final assessment of concrete quality.

2.5. Why Should We Use a Pressure Gauge?

A pressure gauge is a mechanical device that converts the pressure of a measured fluid or gas system into a signal, usually a linear signal that can be used to measure the pressure exerted by fresh concrete, which gives us an idea of the density of the concrete. Using this technology to measure the workability of concrete and not just rely on slump measurements, but also gather more mechanical data from the pressure gauge.

Multiple studies have shown that characterizing fluid properties and measuring the force can provide a better characterization of the semi-fluid material. We will be using a pressure gauge in this device to produce a more direct, quantifiable metric that will be an improvement over just measuring slump displacement visually, and we will have a better assessment.

2.6. Slump Measurement: Measurement of vertical displacement of concrete after removal of the Cone.

Traditional Slump Measurement: Using a ruler to measure the vertical displacement.

Our Automated Device: Using rotation sensors to detect movement angle and displacement.

Rotation sensors are used in robotics, aerospace, and automotive applications for tilt and rotation. With a rotation sensor in our device, we get accurate movement and automate the measurement process. This reduces the subject error and gives repeatable slump measurement.

2.7. Wireless Communication: ESP-32 Modules.

Communication to send data wirelessly to data receivers, which can be anything we have today, like a mobile, computer, or in the cloud, is very important in monitoring devices. It is now becoming essential to collect data from various sensors in one place and be monitored remotely, anywhere, without a lot of people in one location.

We shall be making use of ESP-32 in this device to send data to the receivers. The data receivers can be anything, like a mobile, a computer, or the cloud. Wireless communication helps to increase data transparency, decrease response time, and make better decisions. Remote monitoring also helps to reduce congestion on site, and one supervisor can monitor several tests.

2.8. Literature Review Highlights and Research Gaps.

1. Literature Review Highlights.

- Manual slump testing is still performed to this day, but it is subject to human error.
- Automation reduces human error. Research has shown that automated systems with the help of sensors and controllers reduce human error and increase the repeatability of tests.
- Use of Raspberry Pi and Microcontroller. Several studies have shown that with the help of Raspberry Pi, data can be collected, processed in real-time, and transmitted wirelessly to construction monitoring.
- Effect of Environment on Concrete Behavior. Slump tests are affected by temperature and humidity. By making use of the sensor DHT-11, we are able to have a more accurate slump test by considering other environmental factors.
- Pressure and Displacement. By making use of pressure gauges and rotation sensors, we are able to understand more about concrete workability apart from just the visual inspection.
- Wireless Monitoring and Data Sharing. Wireless communication helps to monitor in real-time and share data with others. This is becoming increasingly important in large construction projects.
- Portable and Cost Effective. Existing automated systems tend to be large and expensive and are not readily portable.

2. Research Gaps.

- Lightweight and portable. Most of the existing automated slump testers are made for laboratory work and not for construction work.
- Use of environmental factors correction. Very few studies have been made to combine the data from the sensor (temperature and humidity) and use it to correct the slump and volume calculation in real-time.
- Integration of the communication system. Many of the previous works have only focused on one aspect (just automation), and do not come with a package (sensors, processor, and communication protocols).
- Cost and complexity. Previous solutions, where image processing and mechanical automation tend to be expensive, require experts to set them up and are too complex for the field workers.
- Lack of real-time feedback. Many systems still require post-processing, and construction teams need immediate feedback to make decisions faster.
- Scalability and adaptability: Very few works have been done on how these can be easily scaled or adapted for different concrete mixes, environments, and construction projects.

2.9. Limitations and Challenges.

1. One of the major challenges is the integration of multiple sensors and sub-devices, which are DHT-11 for environmental monitoring, the pressure gauge for force measurement, and the rotation sensor for slump displacement. Each sensor has its own data communication protocol and voltage requirements. Ensuring that all sensors could reliably send data to the Raspberry Pi without interference or power issues requires careful design and testing of connections.

2. Connections were also a challenge, as the ESP-32 modules were also connected to the Raspberry Pi. Although these modules provide good wireless communication, robust wireless connectivity to the devices cannot be guaranteed in construction sites, as Wi-Fi would always be interrupted by other factors and multiple pieces of construction equipment that are also transmitting data. A data communication protocol backup must always be included in case the main data communication protocol is not able to communicate.

3. Limitation on Variability of Environment: The major limitation of this system is the variability of the environment around the concrete mixer. The accuracy of the DHT-11 sensor for measuring temperature and humidity is ± 2°C and ±5% of relative humidity only. This may not be accurate for very precise concrete behavior prediction in very critical projects, but it is still sufficient for projects that are not very critical. Sensitive environmental sensors can be added in the future to improve the performance of the system, at the expense of money and management.

Moreover, the concrete behaviors are not only affected by temperature and humidity, but also by wind speed, solar radiation, and ambient pressure, which are parameters measured by other sensors not included in our project. This device is an improvement over traditional methods, but it doesn't cover the effects of all environmental factors on concrete behaviors.

4. Sensor accuracy and calibration: It is challenging to maintain the accuracy of all the sensors, especially in a construction environment where the equipment is rugged, dusty, and subject to rough handling. Errors in alignment of the rotation sensor and errors in the readings of the pressure gauge lead to inaccurate results on slump or volume. For instance, the assessment is always erroneous when there is a deviation in the accuracy of the readings of the sensors.

The data refresh rate of the DHT11 sensor is slow, which may affect the rate at which the environment data is updated in real time, which may affect the measurements if the temperature and humidity fluctuate greatly during testing.

5. Although the device is designed to be portable and powered by a 3.7V 5000 mAh battery, after a while, the battery would drain faster when all the sensors and data communication are active, especially when tested on site. With the design, the device could sustain itself for hours, but may not sustain the whole day's work on larger construction sites without a secondary power source or battery.

The design can be extended to add features like **recharging of the battery** and a **secondary power source**.

Raspberry Pi 5, despite its power, has some limitations for real-time processing when compared to full industrial computers. If there are many sensor inputs that are highly periodic and need to manage a real-time wireless transmission as well, it is reasonable to expect some delays in data (even though they are not significant, but still

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expected). It is not a critical issue if we are talking about small batches or concrete production, but in the case of large batches and fast production, it can be a limitation.

6. Usability and training.

Even though the device is easy to use, some basic technical knowledge is needed to operate the device. Especially, it is needed to connect the sensors, to use the software, and to set up the wireless network. For workers who have never worked with sensor-based devices, minimal training is enough to handle the device, which leads to minimal effect on the deployment time.

III. RESULTS AND DISCUSSION.

Different concrete mixes were used in different trials, and environmental conditions were varied to test the system's accuracy. The measurement of slump was compared to conventional slump measurement, and it was found that the error in the measurement was ±5%. It has been shown that the automated device used in our research can be used to repeat conventional testing or even better than that.

The DHT-11 sensor has been used for environmental information, and the system has been designed to be aware of the environmental conditions because they can affect concrete behavior, but they are not considered in manual tests. The information about temperature and humidity has been added to the calculation process, and the result has become more reliable and consistent if the conditions were varied weather-wise.

The force applied by the concrete on the pressure gauge has been measured, and it is the information about workability and density of the mix can be obtained from this sensor. The rotation sensor has been used to measure the displacement of the slump in a rotational manner without any manual intervention. The data is sent wirelessly by the ESP-32 module, and it is received by the mobile and computer in real-time.

The device is portable and easy to use for on-site applications. The device can be used to make the slump test easier and less dependent on skilled labour, and it will reduce human error as well. The real-time data collection and the wireless accessibility have been an advantage for the device to be used in large projects that require constant quality control on the site.

The results of the system have shown that the device can make the concrete quality testing more modern, faster, and reliable.

IV. CONCLUSION

Concrete Slump Quality and Volume Calculator with Raspberry Pi 5 has shown how we can use modern technology to enhance traditional construction works. This project has shown that it is possible to use a portable, low-cost, and easy-to-use device to automate the measurement of concrete slump and volume, which are important indicators of concrete quality.

The device uses different sensors to collect information from the environment and the device, such as DHT-11 for temperature and humidity, a pressure gauge for the force applied, and a rotation sensor for the slump displacement, and it has been used to collect real-time data and process it in a consistent manner. The use of ESP-32 modules to send data wirelessly to the remote device has added more advantages to the device and made it more flexible to be used on the busy construction site.

The system is less dependent on skilled labour and can avoid many of the common human errors associated with manual testing methods. Tests have shown that the device can maintain an accurate measurement of slump within ±5%. Taking environmental conditions into account when measuring will result in more consistent and accurate evaluations of the concrete properties.

In conclusion, this project has demonstrated a significant step forward in advancing quality control methods in the construction industry. Quality control using this system addresses many of the issues associated with traditional methods through the provision of speed, accuracy, transparency of data, and portability. In future work, it would be interesting to extend the analysis of the concrete quality through the application of intelligent analysis techniques based on AI. Another interesting extension of this work would be to connect the system to the cloud to allow for larger groups

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of users. Overall, this system has the potential to make construction processes faster, safer, and more technologically advanced.

REFERENCES

1. Raspberry Pi 5 Documentation. (https://www.raspberrypi.com)

According to the official documentation of the Raspberry Pi 5, we were able to guide the configuration of the board, the operation of the GPIO, as well as the use of wireless capabilities, which was fundamental to the development of this project in terms of real-time data acquisition and processing.

2. Texas Instruments - Pressure Sensors Overview. (https://www.ti.com/sensors/pressure-sensors/overview.html)

In this resource, we have been able to get information about the type of pressure sensors to use as well as how they work. In addition, it explains how the environment can affect the readings of a pressure sensor. In this project, we used the information provided by Texas Instruments to configure the operation of the pressure gauge that allows us to measure the force exerted by the concrete and thus have a more accurate evaluation of the slump and workability of the concrete.

3. ESP32 Technical Reference Manual – Espressif (https://www.espressif.com/en/products/socs/esp32)

With this technical manual, we were able to configure the operation of the wireless using the module ESP-32. In this manual, we can find information about how to configure the Wi-Fi module, Bluetooth operation, as well as the energy-saving modes of data transmission

4. DHT-11 Temperature and Humidity Sensor - Adafruit Industries - (https://learn.adafruit.com/dht)

In this guide published by Adafruit Industries, we were able to configure the operation of connecting, programming, and calibrating the DHT-11 sensor. With this sensor, we can know the temperature and humidity of the environment, which is a parameter that affects the behaviors of fresh concrete.

5. Neville, A. M. (2011) - Properties of Concrete (5th ed)

Due to the high level of respect accorded to this textbook, the author provided the basics of a concrete material, e.g., what is the purpose of carrying out a slump test, and how temperature and humidity can affect concrete setting and hardening. This knowledge was useful in comprehending why accurate measurements are important when characterizing concrete material.

6. Concrete: Microstructure, Properties, and Materials (4th ed.). Mehta, P. K., & Monteiro, P. J. M. (2014). McGraw-Hill-Education.

The author of this book teaches more about concrete material science and modern testing techniques. It helped us understand the behaviors of concrete in different field conditions and justify the inclusion of environmental information and force measurement on the device.