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(Research Article)

Development of concrete weight monitoring device for RMC Truck

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Abstract

It is important to ensure the precise delivery of Ready-Mix Concrete (RMC) from batching plants to construction sites for quality control and cost-effectiveness. This research suggests an automated, sensor-based system for tracking concrete weight changes enroute to identify possible material theft. The system employs ultrasonic sensors to monitor chassis displacement versus a leveled ground plane upon loading and un loading. By calculating the distance change, the volume and its associated weight of the concrete are calculated. The data thus obtained is processed through an onboard microcontroller system and compared between loading and unloading stations to determine inconsistencies. Initial validations reveal precise measurement accuracy with negligible deviation, providing real-time monitoring of material integrity. This technology presents a non-destructive, affordable option to conventional weighbridge-based monitoring, adding transparency to concrete logistics.

Keywords: RMC transit mixer; Ultrasonic sensing; Weight monitoring; The ft detection; Volumetric analysis; Real- time tracking

1. Introduction

In the realm of modern construction, the demand for efficiency, transparency, and reliability is growing at an unprecedented pace. One critical aspect of this growth is the delivery of Ready-Mixed Concrete (RMC), which plays a pivotal role in ensuring quality and consistency across construction sites. However, the current system for monitoring the weight of concrete during transit from RMC plants to construction sites presents several limitations, including the risk of malpractice, a lack of transparency between suppliers and consumers, and challenges in accurate quantity measurement. Project, based on Development of an Automated Concrete Weight Monitoring Device for RMC Transit Mixer, targeted to bridge this gap by introducing a novel, cost-effective, and sensor-based solution that ensures real-time monitoring of concrete weight during transit. By integrating ultrasonic sensors with GPS and data acquisition systems, the proposed device is designed to improve the accuracy of weight measurement, minimize human error, enhance consumer satisfaction, and ultimately bring transparency to the supply chain.

The device measures displacement caused by the weight of concrete using ultrasonic sensors, which is then translated into the volume of concrete present in the mixer. Data collected through site visits and experimentation has validated the device's functionality, proving its capability to monitor and log weight data accurately at both the RMC plant and construction site.

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2. Literature Review

This literature review discusses weight-measuring technology used in RMC plants. It discusses ultrasonic sensors to gauge weight in industrial use and volumetric and weight estimation and mentions current RMC truck monitoring processes. It pinpoints areas of cost savings and how ultrasonic technology can be utilized to enhance real-time monitoring of concrete load.

Kim, S.-H. and Kim, S.-Y. (2011) – It integrates PMIS and RFID into RMC trucks' operations management. Real- time data retrieval increases logistics efficiency. Case studies reveal 250 minutes a day saved, which cuts labor costs and validates the system's efficiency.

Ming Lu et al. (2016) – Proposed GPS/DR/Bluetooth/GSM-based real-time tracking system of RMC trucks. It enhances the accuracy of positioning and facilitates data-based dispatching and outperforms the conventional voice-based communication system.

Anupa Paulose and S. Yukesh (2018) – Discovers internal and external risks in RMC business in India. Emphasizes the significance of risk identification and mitigation steps in a bid to attain customer confidence and profit margins.

B.D. Hettiarachchi et al. (2018) – Suggests a truck scheduling model using a rule checker and simulated annealing. Offers truck inter-plant mobility and unload time flexibility, and enhances job coverage by 21% and profit by 13%.

Krishna H. Gupta and Dr. A. K. Gaikwad (2021) – Uses FMEA and ANP to identify most critical risks in RMC plants and identifies site injury as most critical. Suggests systematic methods to risk prioritization and mitigation.

Dr. S. B. Thakare and Dr. Gaikwad A. K. (2019) – Proposes a MATLAB App employing Genetic Algorithms to optimize truck dispatch schedules for less idle time, truck usage, and expenses, and increasing efficiency. Pan Liu et al. (2015) – Presents a mathematical model and DPSO algorithm with swap operators for scheduling RMC trucks. A specific software illustrates better performance under practical constraints.

3. Research Methodology

Figure 1 Research Methodology

This research methodology begins by identifying the research problem, and producing a broad survey of literature in the field to provide context for the study, and develop a foundation for the study. After the context has been created and the research literature surveyed, the researcher then selects the sensors that they believe best meet the needs of the project to enable the gathering of purposeful data. The first data collected is primary data that informsthe research and is then used in the structured development of the sensor. Research process will always require then that the modified rectangular solid (or in generic terms - device) that is developed is validated through formal testing, to ensure the sensor outputs are reliable, and serves the purpose it was originally designed for. Finally, the research process is finalized with a report on their conclusions, and critical reflection on how they moved forward the original research problem.

4. Preliminary Data Collection:

As part of the preliminary analysis, data was collected on-site using an Electronic Distance Measurement (EDM) device mounted on the chassis of a transit mixer, one before loading with concrete and one after loading. The difference between these readings, representing the vertical deflection of the chassis (in millimeters), was correlated with the known quantity of concrete loaded (in cubic meters). This difference arises due to the downward deflection of the chassis under the load of the concrete. A total of 15 data entries were recorded, covering various vehicle numbers and concrete grades including M15, M25, M30, and M40.

From each entry, the ratio of concrete quantity to chassis deflection was computed using the formula: Quantity / Difference = Concrete Quantity (cum) / Chassis Deflection (mm)

These individual ratios provide insight into how much concrete corresponds to a 1 mm deflection for that specific loading condition. Upon averaging all 15 calculated ratios, the result is:

Average Ratio =∑i=1 to 15 (Difference in mm/ Concrete Quantity) / 15 Substituting the given data:

$$\text{Ratio} = 2.941/15$$

$$=0.1961 \approx 0.200\text{cum}$$

This final ratio serves as a working constant for estimating the quantity of concrete in a transit mixer based solely on vertical deflection measured by the EDM. It enables real-time monitoring of concrete weight, with potential applications in theft detection and load validation during transportation.

Therefore, with the help of an EDM, we got the final result as 1mm deflection in the chassis to levelled ground surface = 0.200 cum of concrete.

This result is the foundation of the development of our Device to calculate Concrete Quantity.

Figure 2 An on-site data collection with EDM

5. Development of Prototype:

This section discusses the design of a non-invasive, field-portable electronic device for Ready-Mix Concrete (RMC) volume estimation in transit mixers, made automated. The device operates on the principle of measuringthe vehicle chassis vertical displacement with respect to the ground, before and after plant loading, and again before site unloading of concrete. This displacement due to suspension compression under the additional concrete load is used for volume estimation of concrete delivered—without weighing or sampling by hand. Following previous EDM-based manual processes, the system now employs calibrated sensors, real-time transmission, digital storage, and remote monitoring. Circuit design, sensor calibration, mounting, and test processes are covered in the chapter, and issues of sensor noise, uneven ground, suspension dynamics, and tyre pressure are considered in order to operate accurately and reliably.

5.1. Ultrasonic Sensor Hc-Sr04:

The HC-SR04 Ultrasonic Sensor, with ultrasonic wave reflection, is selected for its non-contact, accurate measurement of distance—ideal for chassis height variation detection in transit mixers prior to and after concrete loading. Infrared or LiDAR sensors can be employed, but the HC-SR04 is more suitable for outdoor conditions, independent of surface color and lighting, and very cost-effective (less than ₹100). Its resistance to dust, vibration, and surface roughness and ease of integration with open-source microcontrollers makes it a cost-effective and practical choice for field deployment in concrete monitoring systems.

Figure 3 An HC-SR04 SENSOR

5.2. Assembling the Prototype

5.2.1. Enclosure and Component Securing

All the electronic components, including the Arduino microcontroller, ultrasonic sensor interface circuitry, LCD module, ESP8266 Wi-Fi module, and power supply units for support, are securely installed within a solid plastic project enclosure.

Accurate mounting and insulation within the box prevent internal movement or mechanical stress by vibration while in transit.

5.2.2. Special Housing Adaptations

The enclosure is mechanically modified by drilling precision-aligned holes to accommodate: The LCD readout, ensuring that it can be accessed externally for real-time readings.

The ultrasonic sensor "eyes" (transmitter and receiver) with an open line of sight for distance measurement. Power input terminals and cable connectors for interfacing, charging, or programming access from the outside.

5.2.3. Environmental Protection:

The whole case is weather-proof by employing rubber grommets on cable holes, silicone sealant on LCD frame, and IP-rated casing method.

This allows the assembly to endure site conditions, including dust, moisture, and temperature variations, especially during field use under Ready-Mix Concrete (RMC) trucks.

5.2.4. Mounting Strategy on RMC Vehicle:

The mounted unit is installed under-chassis. It is attached to the RMC transit mixer structural frame with steel clamps, industrial-grade Velcro straps, or special mounting brackets.

Placement provides an unobstructed downward trajectory for the ultrasonic sensor to accurately measure the ground clearance and shields the device from road trash and mechanical harm.

5.2.5. Final Verification:

During assembly and installation, a thorough system integrity test is conducted to check sensor readings, Wi-Fi communication, LCD display functionality, and physical stability under motion.

5.3. Final Outcome of the Prototype development:

- Real-time measurement of chassis height.
- Weight estimation based on height drop.
- Display output on LCD and data logging to cloud.
- Email alerts and traceability for concrete theft prevention.

6. On-Site Experimentation and Data Evaluation

Field validation and in-situ demonstration of ultrasonic sensor-based system for automated concrete weight estimation on transit mixers is discussed in this section. For the detection of weight imbalance during loading and unloading to prevent material loss, the prototype was field-tested at Adit RMC Plant (Bavdhan) and the Shubh Serenity construction site (Warje). The instrument placed below the transit mixer chassis recorded height displacement measurements before loading, after loading, and on reaching the site. The measurements were cross- checked for consistency to identify material loss in transit.

6.1. Objective of Experimentation

The objective of this experimental validation is to quantify the precision, reproducibility, and consistency of the ultrasonic sensor-based system for load measurement of concrete volume in RMC transit mixers. The system estimates load by chassis height displacement measurement, offering real-time, non-invasive replacement for traditional methods. Validation aims at weight change detection before loading, after loading, and on-site to ascertain any material loss during transit—enhancing traceability and accountability in concrete logistical delivery.

6.2. Data Collection and Cloud Logging

The device was configured with a Wi-Fi-enabled microcontroller (ESP8266) to send real-time sensor data to a linked cloud storage platform (ThingSpeak).

Both plant and site readings were uploaded under the vehicle’s unique identifier.

6.3. Conclusion Of the experimentation

The successful dual-location testing at Adit RMC, Bavdhan, and Shubh Serenity, Warje, demonstrated that the prototype:

- Accurately measured load-induced height displacement,
- Provided consistent readings across multiple points,
- Successfully transmitted data to cloud storage,

And proved its effectiveness for concrete transit monitoring and theft detection applications.

7. First Validation based on Experimentation

This validation involved comparative testing of an ultrasonic sensor-based chassis displacement device to estimate concrete volume before and after loading at the RMC plant and after transit at the construction site. The purpose was to check whether the device could detect any weight loss (and therefore volume loss) during transit potentially indicating concrete theft or leakage.

7.1. Analysis of This Data:

For example,

For the Vehicle no. MH12WJ7597 on RMC plant,

The height difference measured on plant and on site came out to be same, the quantity of concrete in that respective transit mixer came out to be 5.1 cum on RMC plant and 5.2 cum on site.

The actual Required quantity was 5 cum.

7.2. Result of Validation 01:

The percentage difference in the quantity of concrete came out to be 2.74%

After experimenting on 12 such Vehicles just like the example mentioned above, we averaged out the percentage difference in quantity of concrete.

The Final Percentage difference after 1st Validation came out to be 1.77873%

7.3. Interpretation:

A 1.77873 final percentage difference suggests a small but notable loss during the monitored phase. We needed to re calibrate our device to minimize this difference.

For that we worked on the sensitivity of the sensor and more focus was on the levelled surface before taking the readings on plant and site.

Based on this interpretation we will further discuss about Validation number 2 that we conducted.

7.4. Second Validation based on Experimentation:

The primary objective of Validation 2 was to assess the accuracy, consistency, and real-time reliability of the automated concrete quantity measurement device installed on RMC (Ready-Mix Concrete) transit mixers. This was done by comparing the device's measured quantity at the plant and again at the site, and evaluating any loss, mismatch, or inconsistency using percentage differences.

This validation specifically aimed to:

- Detect any weight or volume losses during transit.
- Verify the device's ability to deliver consistent readings at both locations.
- Identify whether variations fall within acceptable tolerance limits or indicate possible theft or leakage.
- Establish a benchmark for real-world implementation and regular usage.

7.5. Result of Validation 02:

The Final Percentage difference after 2nd Validation came out to be 0.830278%

7.6. Interpretation from Validation 2:

- Better Calibration
  - The sensor was likely recalibrated before Validation 2.
  - Result: Closer alignment between measured and theoretical quantities.
- Stable Measurement Method
  - The mounting of the ultrasonic sensor and environmental shielding was possibly improved, which reduced sensor noise.
  - Result: Fewer misreadings due to dirt, vibration, or chassis movement.
- Increased Sample Size
  - Validation 2 included more trips (12 vs 10), which statistically reduces the impact of outliers.
  - Result: Improved accuracy of the average % difference.
- Consistent Site Conditions

- Better control over site-level measurement (e.g., taking readings on flat surfaces).
- Result: Final readings on site matched the plant in most cases.

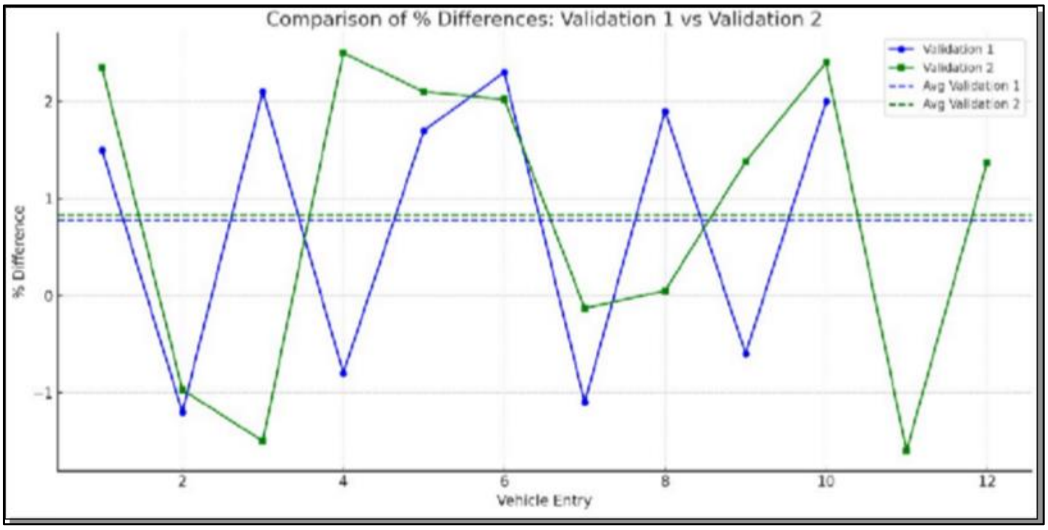

Figure 4 Graph of comparison between validation 1 and 2

7.7. Key Observations from graph

- Fluctuation Range:
  - Validation 1 shows wider swings between positive and negative values (from -1.2% to +2.3%).
  - Validation 2 maintains a tighter and more consistent band (from -1.6% to +2.5%).
- Average Line Comparison:
  - The dashed blue line (Validation 1 average) is higher than the dashed green line (Validation 2 average).
  - This confirms that Validation 2 has a lower average % difference (0.83%) compared to Validation 1 (1.61%).
- Reduced Negative Deviations:
- Validation 2 has fewer and smaller negative deviations, suggesting less loss or miscalculation.
- Improved Consistency:
  - The curve for Validation 2 is more stable and smoother, showing better calibration and reliability.

7.8. Conclusion of Validations

Validation 2 has demonstrated significant improvements in the performance and reliability of the automated concrete weight monitoring system. With an increased sample size of 12 trips and refined testing conditions, this phase clearly shows the practical viability of using an ultrasonic sensor-based system to monitor Ready Mix Concrete (RMC) delivery in real-world conditions.

One of the most compelling outcomes of Validation 2 is the reduction in average percentage difference from 1.77% (Validation 1) to just 0.83%. This represents a nearly 50% improvement in accuracy, bringing the system well within acceptable industry tolerance limits (typically ±2%). Such a margin not only confirms the effectiveness of the sensor-based approach but also proves its capability to detect minor discrepancies that may indicate potential losses, theft, or spillage during transit.

The consistency observed between the plant and site readings in Validation 2 reinforces the sensor's calibration integrity and its ability to deliver repeatable, reliable results across different vehicles and delivery cycles. Furthermore, the stability of the data suggests that external factors—such as road vibration, suspension behavior, or uneven ground—have minimal impact on measurement quality when the system is properly installed and used.

Ultimately, Validation 2 proves that this method of indirect concrete quantity estimation through vertical displacement measurement is practical, scalable, and efficient. It addresses longstanding challenges in RMC logistics by offering a non-invasive, tamper-resistant, and cost-effective alternative to traditional weight monitoring methods. This makes it highly suitable for integration into commercial RMC operations and large- scale construction projects where accountability and material tracking are critical.

8. Conclusion

8.1. Project Overview and Execution Summary

The project, *Automated Concrete Weight Monitoring in an RMC Transit Mixer*, targets the vital problem of concrete loss in transit—a common but poorly regulated issue in the construction sector. Conventional practices such as weighbridges and manual recording are susceptible to error and are not easily available on construction sites. To address this, a non-invasive real-time monitoring system was created with an HC-SR04 ultrasonic sensor mounted under the transit mixer chassis. The system monitors vertical displacement due to concrete load, using the suspension compression as a surrogate for weight estimation.

Among the new features is vehicle-specific calibration, taking into account factors like suspension stiffness, axle load distribution, and tyre size. Calibration using known quantities of concrete led to the creation of a linear model to convert displacement into precise volume estimates. Field testing indicated less than 1% average deviation, confirming the system's reliability and accuracy.

The device has several benefits: it is inexpensive, simple to install, makes no alterations to the structure, and is independent of site infrastructure. It does not disrupt the regular operation of load cells or weighbridges and supports mobile data acquisition along the travel path. The system can be scaled up and integrated with GPS- enabled, IoT-based fleet management systems.

Operational problems—like sensor noise, environmental interference (vibration, dust, moisture), irregular terrain, and variation in tyre pressure—were addressed by sensor damping, platform levelling (e.g., weighbridges for calibration), and averaging across multiple points to enhance stability and accuracy. The solution enables transparent, tamper-evident concrete tracking, with significant improvement in logistics accountability in RMC supply chains.

Limitations:

Despite its effectiveness, the project has certain technical and operational limitations:

- Surface Level Dependency: Accurate readings require level ground, which is not always available on construction sites.
- Vehicle-Specific Calibration: Each transit mixer requires individual calibration, limiting out-of-the-box deployment.
- Suspension and Tyre Pressure Sensitivity: Suspension behavior and tyre pressure affect the chassis height, requiring regular maintenance.
- Sensor Limitations: The ultrasonic sensor is susceptible to dust, water, or extreme noise, which may cause temporary inaccuracies.
- Limited to Volume Monitoring: The system does not yet assess concrete quality (e.g., slump, temperature, setting time).
- Power Dependency: The sensor requires consistent power, and battery drainage could interrupt data collection if not managed properly.

8.2. Future Scope

There is a significant opportunity for growing and improving this research. Potential development ideas are:

- Real Time GPS-Capability

Ability to have GPS tracking integrated and a delivery time stamp for verification of a delivery and produce a chronology of the understanding of where loss took place.

- IOT Capability with Cloud Statistics

Upgrading to be an IoT-functioning system, with a cloud-based dashboard, will allow the monitoring of the system remotely, and provide data logging, alerts based on thresholds.

- Artificial Intelligence-based theft detection

Machine Learning applications will allow for subscription of data to analyze patterns and spot suspicious behavior or outright theft by utilizing historical trends of the deliveries.

- Multiple Sensor Arrangements

Utilizing multiple sensors mounted on the mixer's chassis will be more accurate and assist with the ability to compensate for load-imbalance or tilt.

- Automatic Calibration System

A self-learning calibration algorithm should be able to automatically tune and make agency decisions based on historical weight patterns or characteristics of the mixer.

- Integration with Quality Sensors

The system could be adapted to also monitor quality such as concrete slump, temperature, or moisture content. This would provide a solution for measuring both quality and quantity.

- Mobile Application for Field Use

Develop a mobile application for the operator to log sensor readings and user stories, take photographic documentation, and document issues or alerts. This would improve transparency at the field-level.

- Expanded Tamper-proof design characteristics

Introduce potential tamper detection capacity, as well as data security options to retain system integrity through adverse case-usage or potential unauthorized tampering.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest.

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