



Smart Monitoring Of Water Absorption In Roads Using Sensor Technology

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Abstract: This research paper presents a Smart Monitoring System for Water Absorption in Roads utilizing advanced sensor technologies. The system enables real-time detection and analysis of moisture levels within permeable pavements using embedded Internet of Things (IoT)-based sensors. Designed with wireless communication and cloud integration, the solution offers a cost-effective and scalable alternative to traditional manual inspection. Data collected from capacitive and resistive sensors are transmitted to a central dashboard where administrators can assess pavement health, identify potential failures, and schedule maintenance proactively. This paper highlights the system's architecture, data collection methods, and potential applications in smart urban infrastructure.

I. INTRODUCTION

Urbanization and climate change have intensified challenges related to road infrastructure, particularly regarding water drainage and absorption. Traditional pavements are vulnerable to water stagnation, leading to surface deterioration, potholes, and accidents. Monitoring water infiltration manually is labor-intensive and inefficient. This study introduces an IoT-enabled water absorption monitoring system that uses embedded sensors to track moisture content in permeable pavements in real-time. The system enhances infrastructure resilience by enabling timely intervention before significant damage occurs.

Literature Survey

1. IoT-Based Pavement Monitoring System Author: J. Sharma et al. Year: 2022 Summary: This paper proposed the integration of moisture and temperature sensors in roads to improve real-time monitoring and traffic safety. IoT-Enabled Pavement Monitoring: Used piezoresistive sensors and microcontrollers to assess structural integrity under variable loads.
2. Smart Roads: Integrating Embedded Sensors for Pavement Health Author: K. Ramesh, M. Gupta Year: 2021 Summary: Researchers developed an automated system using humidity and strain sensors, allowing municipalities to respond swiftly to structural weaknesses.
3. Wireless Sensing for Stormwater Management in Pavements Author: L. Nguyen Year: 2020 Summary: This study focuses on leveraging wireless soil moisture sensors to optimize drainage designs in porous asphalt and concrete roads.
4. Permeable Pavement Condition Monitoring Author: A. Dey and B. Kale Year: 2019 Summary: Researchers embedded pressure and moisture sensors in porous pavements and demonstrated how sensor data helped predict failure patterns.

II. METHODOLOGY

3.1 SYSTEM ARCHITECTURE

KEY COMPONENTS INCLUDE:

- CAPACITIVE MOISTURE SENSORS: INSTALLED BENEATH ROAD SURFACES TO MEASURE WATER CONTENT.
- MICROCONTROLLER (ARDUINO/ESP32): COLLECTS SENSOR READINGS AND PROCESSES THEM.
- WIRELESS TRANSMITTER (WI-FI/LORA): SENDS DATA TO THE CENTRAL DASHBOARD.
- CLOUD DASHBOARD (THINGS BOARD/NODE-RED): VISUALIZES REAL-TIME SENSOR DATA
- POWER SUPPLY (Solar/Battery): Supports continuous outdoor operation.

3.2 Sensor Deployment

Sensors are embedded at multiple depths within the road to capture layered data. Calibration ensures accurate readings across

Different soil and aggregate types

3.3 Data Flow and Communication

1. Sensor detects water level/moisture change.
2. Microcontroller records and timestamps data.
3. Data is transmitted wirelessly to a local gateway.
4. Cloud dashboard logs and displays data with alerts.
5. Authorities are notified of unusual absorption patterns or saturation risks.
6. Power is supplied through rechargeable batteries or solar modules.
7. Data is relayed to cloud storage for continuous monitoring and future analysis

III. SYSTEM WORKFLOW

1. INITIALIZATION: DEVICES BOOT UP AND PERFORM SENSOR CALIBRATION
2. SENSING & DATA ACQUISITION: MOISTURE LEVELS ARE SAMPLED PERIODICALLY.
3. TRANSMISSION: READINGS ARE PACKAGED WITH TIMESTAMP AND SENSOR ID, THEN TRANSMITTED TO THE CLOUD.
4. ANALYSIS: REAL-TIME GRAPHS AND ALERTS ARE DISPLAYED ON THE MONITORING INTERFACE.
5. STORAGE: DATA IS ARCHIVED IN CLOUD DATABASES FOR TREND ANALYSIS AND PREDICTIVE MODELING.

IV. ALGORITHM & PROTOCOLS

- Moisture Detection Logic:
- Convert analog signal from sensor to digital value.
- Compare against pre-defined thresholds.
- Trigger alert if moisture exceeds acceptable levels.
- MQTT or HTTP API used for sending data from edge devices to the cloud.
- Data packets include sensor ID, timestamp, and water level.

ADVANTAGES

- Provides timely detection of water accumulation.
- Reduces the risk of road collapse due to hidden moisture damage.
- Enables predictive maintenance, lowering long-term repair costs.
- Scalable to highways, city roads, and industrial sites.
- Environmentally sustainable with low energy consumption.

LIMITATIONS

- Sensor accuracy can be affected by soil composition.
- Wireless communication may be interrupted in remote areas.
- Battery-powered nodes require periodic recharging.
- Sensor lifespan is limited by environmental exposure.
- Installation disrupts existing roadways unless planned during construction.

V. CONCLUSION & FUTURE SCOPE

This smart monitoring system introduces an effective way to manage road health by continuously tracking water infiltration levels. The use of embedded sensors and realtime cloud reporting supports data-driven infrastructure maintenance. The approach significantly enhances the lifespan of roads and improves safety for users.

Future Enhancements:

- Integration with machine learning models for predictive insights.
- Mobile application for real-time on-site alerts.
- Use of renewable energy to power remote sensor nodes.
- Expansion to monitor other parameters like temperature and pressure.
- Blockchain integration for secure, tamper-proof data management.

Future Scope

1. **Advanced Sensors:** Development of more durable, accurate, and multi-functional sensors.
2. **IoT and Cloud Integration:** Real-time monitoring, data analysis, and decisionmaking using IoT and cloud platforms.
3. **AI and Machine Learning:** Predictive maintenance and optimization of road design using AI algorithms.
4. **Sustainability:** Enhancing green infrastructure and adapting to climate change with smart monitoring.
5. **Smart Cities:** Integration into urban planning for flood control, stormwater management, and resilience.
6. **Global Deployment:** Expanding adoption worldwide and creating data standards for global use.
7. **Cost-Effective Solutions:** Developing affordable sensors for use in developing countries.

VI. REFERENCES

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