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Structural Health Monitoring Using Recycled Steel Residues

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ABSTRACT

This project highlights the importance of real-time monitoring systems in civil engineering structures for ensuring safety and reliability. The addition of steel fibres to concrete can create a conductive network that lowers overall resistivity and enables resistivity measurements for monitoring systems. Through experimentation, the optimum percentage of steel fibre was determined and applied to cast M25-grade cubes. The fluctuation in the resistivity is measured by the buzzer system, and a warning system was added to provide alerts in case of potential failure. This technology has the potential to prevent accidents and save lives, making it a crucial area for ongoing research and development.

Keywords: Structural Health Monitoring, Resistivity measurement, Casting, Buzzer system.

I. INTRODUCTION

Structural Health Monitoring (SHM) is a vital process in the field of civil engineering that aims to detect deformation and damage within structures to prevent tragic failures that can lead to loss of lives and investments. While civil engineering infrastructures are designed for long service life, they are not maintenance-free. As the most expensive assets of any nation, suitable measures must be taken to avoid sudden collapses that can result from inherent drawbacks of materials like concrete, which is extensively used in civil engineering structures**.**

Concrete is the most commonly used material in civil engineering structures, but it is not immune to weakening and failure. Factors such as ageing of materials, aggressive environmental conditions, prolonged usage, overloading, and lack of maintenance can all contribute to the deterioration of concrete structures.The microstructure of concrete contains numerous cracks in the nano-scale, which join to form micro-cracks and eventually macro-cracks that can cause failure. Early detection of these damages through SHM and proper maintenance can greatly enhance the service life of concrete structures. In this article, we will delve deeper into the importance of SHM and its role in ensuring the safety and longevity of civil engineering structures.

II. SELECTION OF FILLER MATERIAL

The selection of filler material for resistivity measurement of concrete cubes depends on several factors, including the properties of the material, its cost, availability, and compatibility with the concrete matrix.

Steel fillers are commonly used for resistivity measurement of concrete cubes due to their relatively low cost, easy availability, and compatibility with the concrete matrix. Steel fillers are also durable and can withstand the harsh environmental conditions to which concrete structures are exposed. Additionally, steel fillers have good electrical conductivity, which is essential for resistivity measurement. While nanotubes and carbon fibres also have good electrical conductivity, they are generally more expensive than steel fillers and may not be as readily available. Moreover, their compatibility with the concrete matrix may be limited, and their incorporation into the concrete mix may require specialized techniques, which can add to the cost and complexity of the resistivity measurement process.

Utilizing steel waste as a filler material not only presents a sustainable solution but also offers an economically viable option. The incorporation of steel waste, which would otherwise end up in landfills, not only reduces the environmental impact but also contributes towards the conservation of natural resources. Moreover, utilizing steel waste as a filler material can result in a cost-effective solution that is capable of meeting the performance requirements of various industries,

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thereby providing an attractive alternative to traditional filler materials.

Overall, the selection of the filler material for resistivity measurement of concrete cubes should be based on a careful evaluation of the various factors involved, with consideration given to the specific requirements of the project and the available resources.

III. MIXING PROPORTION

The mixing proportion design for the ISSC is based onthe mixing proportion design method of conventional concrete.

Casting concrete of M25 grade involves a specific mix design that requires careful selection and proportioning of the ingredients to achieve the desired strength and durability. Here are the steps to cast concrete of M25 grade:

Materials: The materials required for M25 grade concrete are cement, sand, coarse aggregates,steel, and water.

Test carried for mix design;
Specific gravity of coarse aggregate
Obtained value = 2.69
Standard value = 2.5 – 3
Specific gravity of cement
Obtained value = 2.91
Standard value = 3.15
Specific gravity of fine aggregate
Obtained value = 2.66
Standard value =2.65 –2.67

Quality of materials required for 1 m3 of concrete:
Cement = 438 kg
Fine aggregate = 752kg
Coarse aggregate = 996 kg
Water = 197 L
steel (1 cube) = 0.53 Kg

Mixing: The materials are mixed thoroughly using a concrete mixer until a homogeneous mixture is obtained

IV. RESISTIVITY MEASUREMENT

Electrical resistivity is a measure of a material's ability to resist the flow of electric current. It is influenced by various factors such as temperature, pressure, and the presence of impurities.

In the context of structural health monitoring, changes in resistivity can provide information about the condition of the structure. For example, if a material undergoes deformation or damage, its resistivity can change due to changes in its physical properties such as shape, size, or composition. By monitoring changes in resistivity, it is possible to detect damage or deformation before it becomes a significant problem, enabling proactive maintenance and repair.

Measuring the fractional change in resistivity using the two-probe method can be useful for structural health monitoring (SHM) of concrete structures. The resistivity of concrete is influenced by factors such as temperature, moisture content, and cracking. By measuring the change in resistivity over time, it is possible to detect changes in the structural integrity of the concrete and identify potential problems before they become serious.

To measure the fractional change in resistivity using the two-probe method for SHM, can be followed by,

Install two probes on the surface of the concrete structure. Measure the resistivity of the concrete using the two-probe method and record the initial value.Monitor the resistivity of the concrete over time at regular intervals.

Analyse the fractional change in resistivity to identify changes in the structural integrity of the concrete. For example, an increase in resistivity could indicate the presence of cracks or other damage in the concrete.

Take appropriate action based on the results of the SHM analysis, such as repairing the damage or taking steps to prevent further deterioration.

V. CASTING AND CURING

Casting: The concrete is poured into the desired mould and compacted using a vibrator to remove any air voids.M25 concrete is a commonly used grade of concrete, which is used in a variety of construction projects. Steel is a strong and durable material that can be added to concrete to improve its strength, durability and mechanical parameters.During the mixing process, the steel is added to the concrete mixture in small amounts at a time. This ensures that the steel is evenly distributed throughout the mixture, and that there are no clumps or lumps. The mixture is then poured into a cube-shaped mould and left to set and harden for a predetermined period of time. A 15*15cmcube of M25 grade is casted.

Curing:Curing of concrete cubes is a process that involves keeping the concrete cubes moist and at a specific temperature for a certain period of time after they have been cast. The goal of curing is to

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ensure that the concrete develops its full strength and durability over time. The concrete cube is left in curing tank for at least 28 days to achieve maximum strength and durability. During the curing process, the concrete should be kept moist to prevent cracking.

VI. BUZZER SYSTEM

A buzzer system is an electronic device that produces a sound when activated.A typical buzzer system consists of a buzzer, a power source, and a control circuit. The buzzer is a small electromechanical component that produces a sound when an electrical current is passed through it. The power source can be a battery or an AC power supply, depending on the application. The control circuit controls the activation of the buzzer, which can be done manually or automatically.

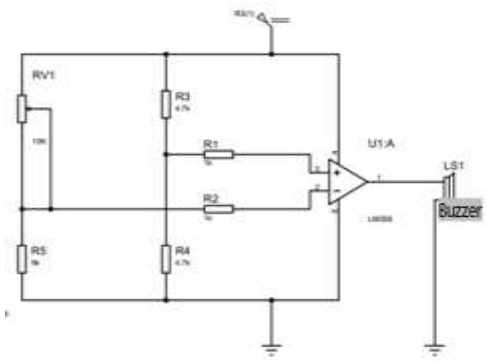

Fig 1. Block diagram of buzzer system

Main components:
1. 555 IC
2. LM 324
3. BC 107
4. Buzzer
5. Diode
6. Resistor
7. Capacitor

6.1.Detyails on 555 IC

The 555 IC consists of two comparators, a flip-flop, a discharge transistor, and a voltage divider. It can operate in three modes: monostable (one-shot), a stable (oscillator), and bistable (flip-flop). In monostable mode, the 555 IC acts as a timer that generates a single output pulse of a specific duration in response to a trigger signal. In a stable mode, the 555 IC acts as an oscillator that generates a continuous square wave output. In bistable mode, the 555 IC acts as a flip-flop that can be set and reset with external signals

6.2. Amplifier LM 324

The LM324 is a quad op-amp (operational amplifier) integrated circuit, which means it contains four individual op-amps in a single package.Each of the LM324's four op-amps has a differential input and a single-ended output, and they can be powered from a single supply voltage.The LM324 is commonly used in audio circuits, filters, voltage regulators, and other applications that require multiple op-amps. It is available in various package types, including DIP, SOIC, and SMD.

6.3.Bipolar junction transistor, BC 107

The BC107 is a type of bipolar junction transistor (BJT) that is commonly used in electronic circuits. It is a low-power NPN transistor with a maximum current rating of 200 mA and a maximum voltage rating of 45 V. The BC107 has a gain value (hfe) of typically 100 to 300, which makes it suitable for amplification and switching applications in low-power circuits. It is often used in audio pre-amplifiers, oscillators, and signal processing circuits.

6.4. Buzzer

A buzzer is an electronic device that produces a buzzing or beeping sound. It typically consists of an electromechanical or piezoelectric transducer that converts electrical energy into sound waves. When a current is applied to the buzzer, it causes the transducer to vibrate at a specific frequency, which produces an audible sound.

6.5. Diode

A diode is an electronic component that allows current to flow in only one direction. It is typically made of a semiconductor material and has two terminals called the anode and the cathode.When a voltage is applied across a diode in the forward direction (anode to cathode), the diode conducts current and has a very low resistance. However, when a voltage is applied in the reverse direction (cathode to anode), the diode does not conduct and has a very high resistance, effectively acting as an open circuit.

6.5. Resistor

A resistor is an electronic component that restricts the flow of electrical current in a circuit. It is typically made of a material with high resistance to the flow of electricity, such as carbon or metal film, and has two terminals that connect to the rest of the circuit.The resistance of a resistor is measured in ohms (Ω).Resistors are commonly used in electronic circuits for a variety of purposes, such as limiting current flow, dividing voltage, and controlling gain in amplifiers.

6.6. Capacitor

A capacitor is an electronic component that stores electrical charge and energy in an electric field. It is typically made of two conductive plates separated by a dielectric material, which can beair, ceramic, or plastic. The conductive plates are connected to the rest of the circuit via two terminals.Capacitance, measured in farads (F), is a measure of a capacitor's ability to store charge. The capacitance of a capacitor is determined by the size of the conductive plates, the distance between them, and the dielectric material used.Capacitors are commonly used in electronic circuits for a variety of purposes, such as filtering, timing, coupling, and power conditioning.

Fig. 1 Buzzer system.

VII. WORKING OF SHM

The addition of conductive materials, such as steel fibers, to the concrete mixture allows for the formation of a network of conductive pathways within the concrete material. These conductive pathways act as sensors, detecting changes in the electrical resistance of the concrete due to external loads.

When a load is applied to the concrete structure, it causes deformation, which alters the distance between the conductive pathways. As a result, the electrical resistance of the concrete changes, and this change in resistance can be measured by passing a small electrical current through the conductive pathways and measuring the resulting voltage drop.

The changes in the electrical resistance of the concrete can be correlated with the changes in the structural behaviour of the concrete structure, such as changes in strain or stress. By continuously monitoring these changes in resistance, the ISSC-based SHM system can detect any potential damage or degradation in the concrete structure and provide real-time alerts and warnings.

The conductive pathways formed by the addition of carbon fibers or carbon nanotubes to the concrete mixture can detect changes in the electrical resistance of the concrete due to external loads, allowing for the monitoring of changes in the structural behaviour of the concrete structure

VIII. STRENGTH ANALYSIS

The addition of steel fibers to the concrete mixture improves its strength and durability. Strength analysis was done, and there was an increase in compressive strength from 28 MPa (conventional concrete) to 30 MPa (steel fiber reinforced concrete).measurements can be useful for monitoring the internal damage and cracking of a material under compression load. When a material is compressed, its internal structure undergoes changes that can affect its electrical properties, including resistivity. By measuring changes in resistivity during compression, it may be possible to identify the occurrence of internal cracks.

IX. APPLICATION

Concrete filled with steel residuals have the Structural health monitoring character which can be used to detect early signs of damage in bridges and highways, allowing for timely repairs and maintenance to prevent accidents and ensure the longevity of the infrastructure. It can be used in buildings and structures to detect and monitor the condition of the concrete, allowing for early detection of any damage or degradation and preventing potential structural failures. Also it can be used in tunnels and underground structures to detect any damage or deterioration caused by water infiltration, chemical attacks, or other environmental factors. It can be used in industrial facilities to monitor the condition of concrete floors and walls, detecting any damage or wear and tear caused by heavy machinery or corrosive substances. This type of concrete has the potential to revolutionize the way we maintain and monitor our infrastructure, ensuring safety and longevity while reducing maintenance costs and downtime.

X. CONCLUSION

Structural Health Monitoring plays a crucial role in the field of civil engineering by detecting early signs of deformation and damage within structures. As concrete is the primary material used in civil engineering structures and can weaken over time due to various factors, such as ageing, environmental conditions, and lack of maintenance, SHM is essential in ensuring the safety and longevity of these structures. By detecting damages at an early stage, appropriate measures can be taken to prevent catastrophic failures that can result in loss of life and investments. Therefore, implementing SHM and ensuring proper maintenance of civil engineering structures is vital to protect these valuable assets and promote a safer and more sustainable future.

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