Experimental Investigation on Graphite-Modified Self-Sensing Smart Concrete with Embedded SHM Sensors

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Abstract— Smart concrete provides an effective solution for continuous structural health monitoring by integrating sensing capability within the material itself. This study presents a graphite-modified self-sensing concrete combined with embedded environmental sensors to achieve a dual monitoring system. Graphite powder is incorporated as a conductive additive to enable piezoresistive behavior, where variations in stress, strain, and crack development result in measurable changes in electrical resistance. In addition, FC28 moisture sensors and DHT11 temperature-humidity sensors interfaced with an Arduino platform are embedded within the concrete specimens to monitor curing and environmental conditions in real time. Concrete mixes containing 0%, 5%, and 10% graphite by weight of cement are investigated. The results indicate that graphite-modified concrete exhibits comparable compressive strength to conventional concrete while providing reliable self-sensing capability, demonstrating its suitability for smart infrastructure applications.

Index Terms—Smart concrete, self-sensing, graphite powder, piezoresistivity, structural health monitoring.

I. INTRODUCTION

Concrete is the most widely used construction material in civil infrastructure due to its strength, durability, and economic advantages. However, conventional concrete is a passive material that cannot detect internal damage such as micro-cracking, excessive strain, or deterioration caused by environmental exposure. As a result, structural failures are often identified only after visible damage occurs. Structural health monitoring (SHM) systems have been developed to address this limitation, but traditional approaches rely on external sensors and periodic inspections, which are often costly and limited in sensing coverage. Smart concrete incorporating conductive materials offers an alternative approach by enabling the material itself to act as a sensor.

II. MATERIALS AND MIX PROPORTIONS

Ordinary Portland Cement (OPC) 53 grade, manufactured sand, and crushed granite coarse aggregate of 20 mm maximum size were used in this study. Graphite powder was added as a conductive filler to impart electrical conductivity to the concrete. Three concrete mixes were prepared: SC0 (0% graphite), SC5 (5% graphite), and SC10 (10% graphite) by weight of cement. The selected graphite content range is consistent with values reported in the literature for achieving effective self-sensing behavior without significantly compromising mechanical strength.

III. EXPERIMENTAL PROGRAM

Concrete cube specimens were cast with uniform dispersion of graphite powder achieved through dry mixing with cement prior to adding aggregates and water. During casting, FC28 moisture sensors and DHT11 temperature-humidity sensors were embedded at predetermined locations within the specimens and connected to an Arduino microcontroller for data acquisition. Standard curing procedures were followed. Compressive strength tests were conducted using a compression testing machine, while electrical resistance measurements were recorded under incremental loading to evaluate piezoresistive behavior.

IV. RESULTS AND DISCUSSION

The compressive strength results indicate that graphite-modified concrete exhibits strength values comparable to those of conventional concrete, particularly at lower graphite contents. Electrical resistance measurements show a clear reduction in resistivity with increasing graphite content due to the formation of conductive pathways. Under applied loading, systematic variations in resistance were observed, confirming the self-sensing capability of the material. Sensor data revealed that moisture content decreases with curing time, while temperature and humidity variations influence electrical response, highlighting the importance of integrated sensor monitoring for accurate interpretation of self-sensing data.

V. CONCLUSION

The study demonstrates that graphite powder can effectively transform conventional concrete into a self-sensing smart material without significantly affecting mechanical performance. The integration of embedded FC28 and DHT11 sensors provides additional insight into curing and environmental conditions, enhancing the reliability of structural health monitoring. The proposed graphite-modified smart concrete system offers a cost-effective and scalable solution for intelligent civil infrastructure.

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