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Optimization of the electrical conductivity and mix design of graphene and recycled carbon fiber reinforced self-sensing concrete through the piezoresistive effect

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ABSTRACT

Advances in technology are leading to the automation of structural health monitoring. Current attempts to attach sensors or detectors onto concrete structures for monitoring damages are problematic due to high cost, low durability, and limited sensing capabilities among other issues. Self-sensing concrete addresses these issues by acting as both the sensor and the structure by adding conductive fillers such as graphene or carbon fiber, but one of the barriers that prevent it from widespread market use is the need for optimal mix designs that maximize functionality while minimizing cost. This study investigates the optimal graphene content as conductive powder, recycled carbon fiber content as conductive fiber, W/C ratio, and superplasticizer content to maximize the workability, compressive strength, and electrical conductivity while minimizing the cost. A Response Surface Methodology (RSM) with a Central Composite Design (CCD) was employed through the use of the statistical analysis software Design-Expert to determine the optimal amount of variables. A total of 25 experimental runs were used with different levels being studied for each factor. Graphene was studied at levels ranging from 0.06% to 0.14%, while recycled carbon fiber was studied at levels ranging from 0.6% to 1.4%. The W/C ratio was studied at levels ranging from 0.4 to 0.6, and the superplasticizer was studied at levels ranging from 0.6% to 1.4%. The results of the RSM yielded an optimum mix design of 0.10% graphene content, 0.6% recycled carbon fiber content, 0.4 W/C, and 1.4% superplasticizer content. The combined effects of these variables showed a predicted slump of 129.37 mm, a compressive strength of 26.6 MPa, FCR of 114.43%, and cost of 3.67 Php/kg or ~8500 Php/m^3.

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