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Study on Material Design, Performance, and Practical Application of Electrically Conductive Cement Compound

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Abstract. *Electrically conductive cementations composite has several advantageswhich include strain sensitivity and high conductivity (ECCC). The ECCC can also perform the role of a conductivity sensor in a safety system that monitors the health of a building. Understanding and predicting electrical resistivity as well as compressive stress are necessary when using ECCC (UCS). In this study, we developed ECCC using three conductivity fillers: waste steel slag (SS), graphite powder (GB), and near - field ground blast furnace slag (GGBS) (GGPS). By adjusting the concentrations of the three conductive fillers, cement, and curing age, we created 81 different mix ratio for the UCS test and 108 different concrete ratios for the conductivity test. Sandier soils are best for using ordinary Portland cement (OPC), which is frequently utilised for stabilising purposes. In a rotating kiln, unusual and local building materials like clay or other silicates are heated to high temperatures (>1500°C) to create Portland cement. Sandier soils are best for using ordinary Portland cement (OPC), which is frequently utilised for stabilising purposes. In a rotating kiln, unusual and local building materials like clay or other silicates are heated to high temperatures (>1500°C) to create Portland cement. Slag is a commercial waste product produced during the steelmaking process. At various phases of the steelmaking process, slag from both the electric arc furnace and the ladle furnace is produced in electric arc furnaces and refining ladle furnaces, respectively. A byproduct of blast furnaces used to manufacture iron, GGBS is a cementing ingredient mostly used in concrete. Between 1972 and 1976, the Battelle Memorial Institute in Geneva founded the Program in Science and Human Affairs to conduct research and address complex, interconnected concerns. DEMATEL is one of the decision-makers with a number of criteria. DEMATEL technique is frequently used to extract a difficult problem's complex structure. DEMATEL's goal is to scale from a complex system and the link between causal factors in order to describe the system's perceptible organisational structure. The cause and effect link between the criteria is evident while evaluating complexity. According to the results, ordinary Portland cement (OPC) has the highest ranking, while graphite powder (GP) has the lowest ranking. Resulting in ordinary Portland cement (OPC) ranked first, graphite powder (GP) has low rank.*

Keywords: *ECCC, DEMATEL, Electrically conductive cementations composite, ordinary Portland cement (OPC), graphite powder (GP).*

1. INTRODUCTION

In addition to having high conductivity and strain sensitivity, A catholic protection system can monitor the structural health using electrically conductive cementation composite (ECCC) as a conductive sensor. Prior to implementing ECCC, it is crucial to comprehend and forecast electrical resistivity and uniaxial compressive stress. In this study, we developed ECCC using three conductivity fillers: waste steel slag (SS), graphite powder (GB), and ground granulated blast furnace slag (GGBS) (GGPS). We made 81 different mix ratios for the UCS test and 108 different mix ratios for the resistivity test by varying the concentrations of the three conductive fillers, cement, and curing age. The findings demonstrate that, compared to other conductive fillers, GP significantly improves conductivity while having a higher detrimental impact on UCS. Sludge solids (GGPS and SS), on the other hand, increase conductivity while lowering UCS when their conversion ratio is greater than 20%. The UCS and conductivity of ECCC with SS are higher than those of GGBS. To further forecast UCS and resistance, we proposed a machine learning method based on random forests (RF). The Beetle Antenna Search (BAS) technique was used to modify the more complex RF model parameters. High predictive performance of this hybrid BAS-RF model is demonstrated by good correlation coefficients in the test sets (UCS and 0.98 for resistance). We assessed the effects of several conductive fillers on UCS and conductivity using the proposed BAS-RF model. The results of the laboratory experiments and those from the modelling show good agreement. This work pioneers the use of sewage sludge to create ECCC, opening the door for innovative construction. Due to their excellent qualities, cement mixes are a type of materials that are popular in the building and construction sector. including low cost, simplicity, longevity, and outstanding mechanical capabilities. Waste materials can be used to cement formulations to help mitigate environmental difficulties [3-5]. However, because these materials are semi-brittle, problems with fracture extension significantly reduce their mechanical performance [6–8]. Additionally recommended as a viable treatment is electrically conductive cement composite (ECCC) [9,10]. Because of its high conductivity, ECCC is an excellent monitoring sensor for determining internal electrical resistance and providing timely updates on changes to the structure [11–13]. Due of its high conductivity and lightweight characteristics, graphite powder (GP) has been added to ECCC to enhance its electrical performance [14]. However, the flat GB surface in the microstructure reduces the surface bonding resistance, which in turn reduces mechanical efficiency [16]. Determining how to blend mechanical and electrical properties is therefore vital. The metal wastage slag from the steelmaking process can be combined with granulated blast-furnace slag (GGBS) and steel slag (SS).

2. MATERIAL AND METHODS

Ordinary Portland cement (OPC): Sandalwood soils are a good fit for ordinary Portland cement (OPC), which is mostly used for stabilisation. In a rotating kiln, unusual and local building materials like clay or other silicates are heated to high temperatures (>1500°C) to create Portland cement. The clinker is mixed with gypsum (calcium sulphate) and cooled before being ground into a fine powder.

Graphite Powder (GP): Examples of products in this category include lubricants, paint, stove polish, "lead" pencils, electrodes, brake linings, batteries, powder metallurgy, fertilisers, glass manufacturing, conductive coatings, and foundry facing graphite. utilises ball bearings, brass instrument valves, open gear, railroad couplings, piano actions, air compressors, the food industry, machine shop labour, and so forth. Lubricating locks is a very common practise since it prevents liquid lubricant particles from becoming trapped. The problem is becoming worse.

Waste Steel Slag (SS): Slag is an industrial byproduct generated during the production of steel. Electric arc furnaces (EAFF) and refining ladle furnaces (LFF) both produce slag at various phases of the steelmaking process, referred to as ladle furnace slag (LFS) and electric arc furnace slag (EAFF), respectively. Slag can refer to garbage, an insult, or the byproduct of metal smelting or refining depending on where you are from. For the production of lightweight aggregate and cement, blast furnace slag is pelletized. In Portland cement concrete, foamed slag used as a lightweight aggregate. Granulated blast furnace slag is employed in the manufacture of cement, insulation, and construction materials.

Ground Granulated Blast-Furnace Slag (GGPS): As a by-product of blast furnaces used to produce steel and concrete, GGPS is a cementitious material. A precise ratio of iron ore, coke, and lime is fed into blast furnaces, which run at temperatures of about 1,500 °C. Granulated blast furnace slag is used to make cement as well as aggregate and insulation, and granulated slag sand is used to make blasting shot.

Method: The DEMATEL method is a specific problem, pin-up binding problems and contributing to finding solutions where a hierarchical system can work structural modeling techniques, the relationships between the components of the system for a reason dependent identity and context which may affect the fundamental idea of relationships. And due to the influence of the elements, the illustration makes more use of direction diagrams [15]. DEMATEL processes and analyzes and solves problems through a structured visualization method based on the basic principle. The approach to modeling this structure adopts the form of a directed graph, which is a causal effect to provide values of interrelated relationships and influence between factors. By analyzing the visual relationship of conditions between formal factors, all elements are divided provides researchers with structure between computer components Relationship and complexity can be found ways to solve computer problems [16]. The DEMATEL system manages integrated emergency management together. In the proposed method, there is no need to defuzzify the fuzzy numbers before applying the DEMATEL method. Therefore, this method can truly reflect the uncertainty of the estimate. Finally, we use DEMATEL, which is ours [17], to obtain the final results from twice different features in each combined BPA Laboratory for Results Testing and Evaluation (DEMATEL). A hierarchical model and a visual representation of the causal relationships between subsystems can be created using the DEMATEL approach, a potent technique for collaborative knowledge collection. However, smooth values are a good representation of the ambiguity of reality [18]. DEMATEL examines the interdependence between the size of stock investment ANP integrates factors and factors and their interdependencies. This section, firstly, establishes the network relationships through DEMATEL, and secondly, increases the weight relative to the ANP applications for each factor. Third, a systematic data collection procedure is presented [19]. The DEMATEL method efficiently calculates The effects between the criteria effectively divide the set of complex components into the sender organization and the recipient organization, modifying the correct technique for selecting the management gadget. Organizations need to make full use of limited resources in planning to implement optimal management systems [20]. DEMATEL procedures these biassed or impacted group barriers may have these emotional and causal group barriers as their root. As a result, there are obstacles to successfully implementing e-waste management; therefore, a causative or influential group should be given particular consideration. Decision-makers are therefore crucial. Identifying obstacles make sure the legal structure is solid enough to reduce the impact of influence-barriers. As a result, there is some consistency between the outcomes of the ISM and DEMATEL techniques. The creation of a framework for e-waste management the integrated ISM DEMATEL also revealed the structure of interconnections between these barriers [21]. DEMATEL studies are employed for a particular aim in that research.

3. RESULT AND DISCUSSIONS

TABLE 1 Electrically conductive cementations composite

Alternative
ordinary Portland cement (OPC)
graphite powder (GP)
waste steel slag (SS)
ground granulated blast-furnace slag (GGBS)

Table 1 lists several alternatives for electrically conductive cements, including ground granulated blast-furnace slag, discarded steel slag, graphite powder, and ordinary Portland cement (OPC) (GGBS). Evaluation Preference: Ground granulated blast-furnace slag, scrap steel slag, graphite powder, and ordinary Portland cement (OPC) (GGBS).

TABLE 2. Electrically conductive cementations composite

	OPC	GP	SS	GGBS	Sum
OPC	0	8	7	9	24
GP	2	0	8	4	14
SS	9	2	0	6	17
GGBS	8	1	5	0	14

Table 2 demonstrates that DEMATEL's decision-making process and assessment laboratory used the following materials for Alternative: regular Portland cement (OPC), graphite powder (GP), waste steel slag (SS), and pulverised granulated blast-furnace slag (GGBS). Evaluation Preference: Ground granulated blast-furnace slag, scrap steel slag, graphite powder, and ordinary Portland cement (OPC) (GGBS).

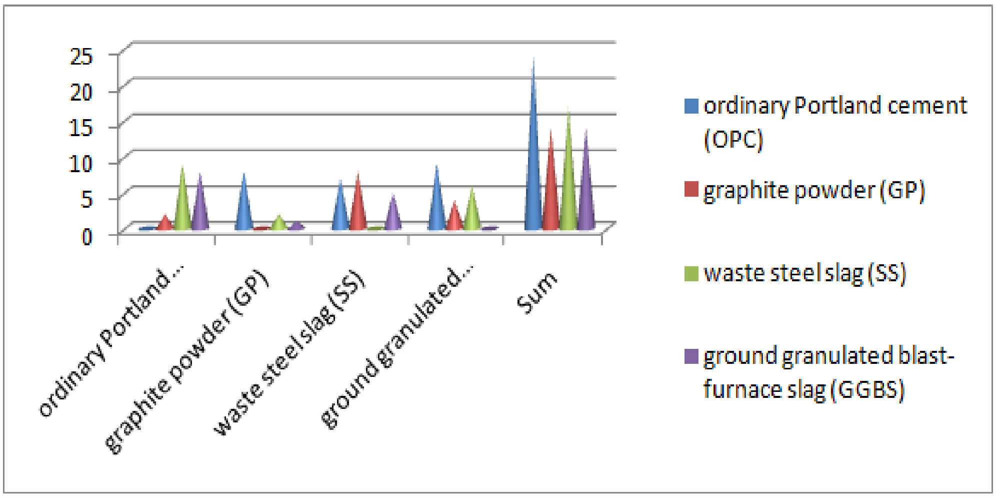

FIGURE 1. Electrically conductive cementations composite

Figure 1 illustrates the DEMATEL Decision Making Trail and Evaluation Laboratory in Alternative: regular Portland cement (OPC), graphite powder (GP), waste steel slag (SS), and pulverised granulated blast-furnace slag (GGBS). Ground granulated blast-furnace slag; waste steel slag, graphite powder, and regular Portland cement (OPC) are preferred in the evaluation process (GGBS).

TABLE 3. Normalization of direct relation matrix

Normaliion of direct relation matrix				
	OPC	**GP**	**SS**	**GGBS**
OPC	0	0.333333333	0.291666667	0.375
GP	0.08333333	0	0.333333333	0.166666667
SS	0.375	0.083333333	0	0.25
GGBS	0.333333333	0.041666667	0.208333333	0

Table 3 displays the normalizing of direct relation matrices for ground granulated blast-furnace slag, waste steel slag, graphite powder, and ordinary Portland cement (OPC) (GGBS). The entire data set's diagonal value is zero.

TABLE 4. Calculate the total relation matrix

Calculate the total relation matrix				
	OPC	**GP**	**SS**	**GGBS**
OPC	0	0.333333333	0.291666667	0.375
GP	0.083333333	0	0.333333333	0.166666667
SS	0.375	0.083333333	0	0.25
GGBS	0.333333333	0.041666667	0.208333333	0

Table 4 displays the calculated total relation matrix for ground granulated blast-furnace slag, waste steel slag, graphite powder, and ordinary Portland cement (OPC) (GGBS).

TABLE 5. T= Y (I-Y)-1, I= Identity matrix

I			
1	0	0	0
0	1	0	0
0	0	1	0
0	0	0	1

Table 5 Ordinary Portland cement (OPC), graphite powder (GP), waste steel slag (SS), and ground granulated blast-furnace slag (GGBS) are the common Values in Table 5's T= Y (I-Y)-1, I= Identity matrix.

TABLE 6. Y Value

Y			
0	0.333333	0.291667	0.375
0.083333	0	0.333333	0.166667
0.375	0.083333	0	0.25
0.333333	0.041667	0.208333	0

Table 6 illustrates the relationship between the Y Value and the total relation matrix value for ordinary Portland cement (OPC), graphite powder (GP), waste steel slag (SS), and ground granulated blast-furnace slag (GGBS).

TABLE 7. I-Y Value

I-Y			
1	-0.33333	-0.29167	-0.375
-0.08333	1	-0.33333	-0.16667
-0.375	-0.08333	1	-0.25
-0.33333	-0.04167	-0.20833	1

Table 7 displays the I-Y values for ground granulated blast-furnace slag, scrap steel slag, graphite powder, and ordinary Portland cement (OPC) (GGBS) Table 4 T= Y(I-Y)-1, Table 5 Y Value Subtraction Value, and Table I = Identity Matrix

TABLE 8. (I-Y)-1 Value

(I-Y)-1			
1.758985992	0.70887	0.961437	1.018124
0.582586937	1.280092	0.724305	0.612895
0.90811721	0.469353	1.59145	0.816632
0.799794205	0.387409	0.68221	1.535044

Table 8 Ordinary Portland Cement (OPC), Graphite Powder (GP), Waste Steel Slag (SS), and Ground Granulated Blast-Furnace Slag (GGBS) are shown in Table 8 as the (I-Y)-1Value, whereas Table 6 displays the Minverse Value.

TABLE 9. Relationship total matrix (T)

					Ri
OPC	0.758985992	0.70887	0.961437	1.018124	**3.447417**
GP	0.582586937	0.280092	0.724305	0.612895	**2.199878**
SS	0.90811721	0.469353	0.59145	0.816632	**2.785552**
GGBS	0.799794205	0.387409	0.68221	0.535044	**2.404457**
Ci	**3.049484343**	**1.845724**	**2.959402**	**2.982695**	

Table 9 demonstrates how the direct relation matrix is multiplied by the inverse of the amount that it is deducted from the identity matrix to get the total relation matrix.

TABLE 10. Ri & Ci

Ri	Ci
3.447417	3.049484
2.199878	1.845724
2.785552	2.959402
2.404457	2.982695

Table 10 displays the Ri, Ci Value for ground granulated blast-furnace slag, waste steel slag, graphite powder, and ordinary Portland cement (OPC) (GGBS).

TABLE 11. Rank, Identity, Ri+Ci, and Ri-Ci

	Ri+Ci	Ri-Ci	Rank	Identity
OPC	6.496901	0.397933	1	effect
GP	4.045602	0.354154	4	cause
SS	5.744955	-0.17385	2	effect
GGBS	5.387152	-0.57824	3	cause

Table 11 Ordinary Portland cement (OPC) is in the first rank effect, graphite powder (GP) is in the fourth rank cause, waste steel slag (SS) is in the second rank effect, and ground granulated blast-furnace slag (GGBS) is in the third rank cause, according to Table 11. The DEMATEL method is used to produce the end product.

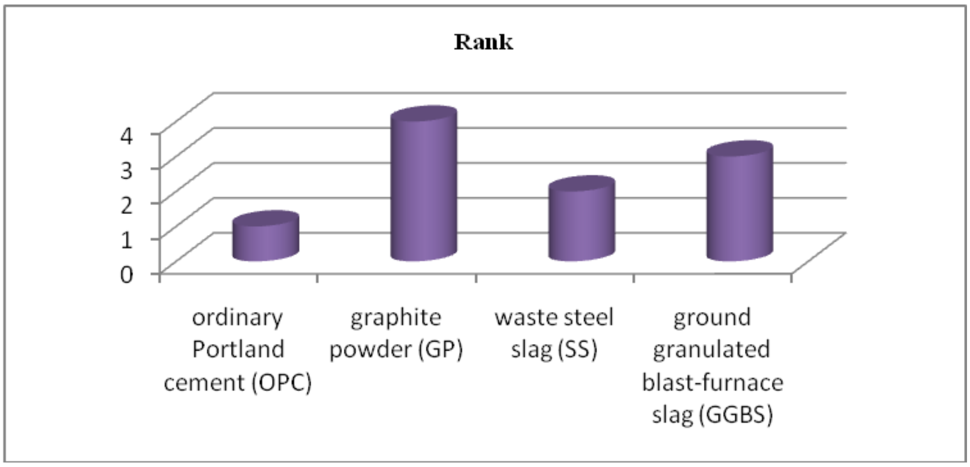

FIGURE 2. Rank

Figure 2 Ordinary Portland cement (OPC) is in the first rank effect, graphite powder (GP) is in the fourth rank cause, waste steel slag (SS) is in the second rank effect, and ground granulated blast-furnace slag (GGBS) is in the third rank cause, as shown in Figure 2's calculation of Ri+Ci and Ri-Ci to get the cause and effect. The DEMATEL method is used to produce the end product.

4. CONCLUSION

Electrically conductive cementation composite (ECCC) can be utilised as conductivity sensors in a cathodic protective device for the measurement of structural performance in addition to having high thermal conductivity and strain sensitivity. Prior to implementing ECCC, it is crucial to comprehend and forecast electrochemical properties and uniaxial compressive stress (UCS). In this research, we developed ECCC using three conductivity fillers: waste steel slag (SS), graphite powder (GB), and ground granulated blast furnace slag (GGBS). By varying the three conductive fillers' concentrations, cement, and curing age, we created 81 different mix ratios for the UCS test and 108 different mix ratios for the resistivity test. The results show that GP has a greater negative effect on UCS while improving conductivity substantially more than other conductive fillers. On the other hand, sludge solids (GGPS and SS) increase conductivity while decreasing UCS when their conversion ratio is higher than 20%.ECCC with SS has a greater UCS and conductivity than GGBS. Additionally, we suggested a machine learning technique based on random forests (RF) to predict UCS and resistance. The Beetle Antenna Search (BAS) algorithm tailored the more complex RF model parameters. The DEMATEL method aids in identifying solutions that can be used to solve a particular issue, back-up binding issues, hierarchical system structure modelling methodologies, a causal identity, and the connections between system parts that affect the fundamental idea of context relationships. Additionally, illustration uses more direction diagrams as a result of the effect of the elements [15]. Through a systematic visualisation method based on the fundamental idea, DEMATEL examines, analyses, and resolves issues. The method for modelling this structure uses a directed graph to show the values of associated relationships and the interaction between various components. All elements are separated into a causative group and an effect group by examining the visual relationship of circumstances between systematic factors. It offers researchers a framework between system elements, relationships, and complexity to help them discover solutions to systemic issues [16]. Integrated emergency management is coordinated through the DEMATEL system. The proposed approach does not require removing fuzzy numbers before using the DEMATEL approach. As a result, this approach can accurately reflect the estimate's level of uncertainty. In order to collect the final results from various aspects twice in each Integrated BPA Results Testing and Evaluation Laboratory, we then employ DEMATEL, which is ours [17] (DEMATEL).

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