International Journal of Civil and Structural Engineering Research ISSN 2348-7607 (Online)
Vol. 8, Issue 1, pp: (40-46), Month: April 2020 - September 2020, Available at: www.researchpublish.com

UTILIZATION OF CALCINED PETROLEUM COKE AS PARTIAL REPLACEMENT TO CARBON FIBER AS ADMIXTURE TO THE ELECTRICAL CONDUCTIVITY OF CEMENT MORTAR

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Abstract: **The purpose of the research is to determine the influence of Calcined Petroleum Coke as a partial replacement to carbon fiber as an admixture to the electrical conductivity of cement mortar. Related studies were inspected beforehand by the researchers to have greater foresight with the study at hand. The physical and electrical properties of Calcined Petroleum Coke were determined through testing its resistivity and calculating its density, specific gravity and water absorption. The physical and mechanical properties of cement mortar with Calcined Petroleum Coke and carbon fiber were determined through flexural and compressive strength tests, with samples consisting of 0%, 25%, 50%, 75% and 100% of Calcined Petroleum Coke admixture content; The samples were tested consistently on the 7th, 14th, 21st, and 28th curing days. All of the aforementioned tests were applied with multiple trials. Through analyzing the results of the tests and existing data, the comparison between using carbon fiber and Calcined Petroleum Coke as partial admixture to the electrical conductivity of cement mortar was carefully taken into consideration. The findings of the study reveal that the use of Calcined Petroleum Coke as an admixture yielded greater mortar strength while 'helming' the resistive capabilities of the carbon fiber; in other words, the use of Calcined Petroleum Coke was found to be more cost-effective than its carbon fiber counterpart. From the data gathered, recommendations were given which will be beneficial to the construction industry and other related studies in the future.**

Keywords: **Cement Mortar, Calcined Petroleum Coke, Carbon Fiber, Conductivity, Resistivity.**

I. INTRODUCTION

The versatility and worldwide accessibility of concrete make it the world's first choice in various types of constructions and structures. Concrete is a composite material that has excellent strength properties and durability but is a poor electrical conductor. Although concrete has existed in various forms, it is still a material with possibilities for compelling innovations. Concrete that is excellent in both mechanical and electrical conductivity properties may have significant applications in various areas.

Over a number of years, numerous unsuccessful research efforts were made to develop this type of concrete. Motivated by this challenge, the Institute for Research in Construction (IRC) has succeeded in achieving this goal with electrically conductive concrete, a patented invention that offers future promise for the use in a variety of construction applications. [1]

Conductive concrete is synthesized to achieve stable and relatively high electrical conductivity by mixing a certain amount of electrically conductive material such as carbon fibers with the conventional concrete mix. [2] Different conductive components, mixing proportion, and preparation process determine the electrical property of the conductive concrete and also affect the convenience and cost control of the application. [3]

Calcined Petroleum Coke, as used in large electrical generating plants, is known for its electrical conducting properties that may contribute to the increase in the electrical conduction of conventional concrete if to be introduced as an admixture. [4]

One of the primary factors preventing greater applications of conductive concrete into civil infrastructures is its cost, although it is much cheaper than the existing ways of blocking out electromagnetic energy. [5]

Calcined Petroleum Coke, an electrically conductive material, can be utilized with carbon fiber as admixtures to produce an electrically conductive material such as cement mortar.

II. LITERATURE REVIEW

Coke is a porous solid carbonaceous material derived from the destructive distillation of low ash and low sulfur bituminous coal. Petroleum coke is a carbonization product of high-boiling hydrocarbon fractions obtained in petroleum processing. Calcined Petroleum Coke is a special petroleum coke that is made by placing high quality raw green petroleum coke into rotary kilns. [6]

Calcined Petroleum Coke has many industrial uses including the production of steel and aluminum. This carbonaceous solid derived from coal mining is of great help in producing electrically conductive concrete. [4]

Conductive concrete can be defined as a cementitious composite containing a certain amount of electronically conductive components [7]. One of the most practical applications of electrically conductive concrete is for the thawing of roads in countries that experience snowfalls. Conductive concrete can be widely used for radio interference shielding, electromagnetic defense, grounding, cathodic protection of reinforcing steel in concrete structures and protection of structures against static electricity and lightning. [3]

The conductivity is the first element of conductive concrete. The resistivity of the material is an index that reflects the concrete's conductive property. Therefore, truly and accurately obtaining the electrical resistivity data is of great importance to the research on the properties of conductive concrete, to the continuous perfection of the mixing proportion and process of conductive concrete and thus to the wider application of this new functional concrete material. [3]

Therefore, it is in this context that this study was conducted to reduce the cost of a conductive concrete without significantly affecting its conductivity by reducing the amount of carbon fiber reinforcement or in this case an admixture and partially replacing it with a much cheaper admixture in the form of Calcined Petroleum Coke.

A. Synthesis

Based on the researched articles, concrete is widely used in construction industries and it is also the most common material that can be easily improved. Based on past studies, there are various types of materials that can be added to concrete to increase its properties, one of them is carbon. Carbon materials (fiber or powder) can be used to increase concrete's mechanical and electrical properties. Concrete with carbon materials can be called Electrically Conductive Concrete.

Electrically conductive concrete can be produced with one problem, which is the cost. Carbon fiber's cost is usually expensive as an admixture to concrete even though it has several significance. One of its significance is for self-heating of pavements or concrete. [7] Even though carbon was introduced to concrete, several studies proved that it is environmentally friendly since it has no toxins that can affect the environment. [3] Also, it has no hazards to human beings. [8] Introducing another material that contains carbon that costs less is necessary for it to be publicly accepted and industries may invest in this study.

This study aims to provide another mechanically good and electrically conductive material that could be a replacement for carbon fibers at cheaper cost. Several studies similar to this can be useful sources to tackle that calcined petroleum coke is an alternative material to be used.

To accomplish this study, four-point probe was used to measure the resistivity of the specimen. Also, the unit weight, workability, compressive strength and flexural strength was measured according to the standard of ASTM C109 for compressive and ASTM C348-80 for flexural. Lastly, according to the research of D.D.L Chung, the water/cement ratio of 0.35 is the most effective compared to other water/cement ratios, which is why the water/cement ratio of 0.35 was used in this research. [9]

III. METHODOLOGY

The experimental method of research was used in the study of the conductive cement mortar mixture. The Calcined petroleum coke was added as a partial replacement for carbon fiber in mortar mixture. The data were gathered through testing and computations for the physical properties of Calcined Petroleum Coke, physical and mechanical properties of cement mortar with Calcined Petroleum Coke and carbon fiber, electrical resistivity of cement mortar with Calcined Petroleum Coke and carbon fiber, and the cost-effectiveness of the partial replacement of carbon fiber with Calcined Petroleum Coke as an admixture. The results were analyzed and reviewed to determine if the objectives are achieved.

The mixture was composed of materials such as sand, cement, water, carbon fiber, and calcined petroleum coke as a partial component. Type N cement mortar was used in this study. For every sample of mortar, there was an increase in percentage of calcined petroleum coke and a decrease in carbon fiber through the mixtures. All mixes used water-cement ratio of 0.35 and admixture-cement ratio of 0.5% by weight. Mixes only differ on the amount of calcined petroleum coke and carbon fiber in the admixture.

A. Project Construction Procedure

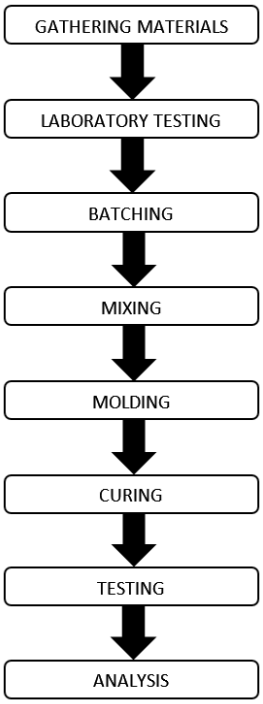

Fig. 1 Project Construction Procedure

The researchers gathered the materials such as cement, sand, water, carbon fiber and calcined petroleum coke. The short carbon fibers were pitch-based. Fibers of nominal length 5.0 mm were used. Coke passing through 2mm sieve were used in this study.

Calcined petroleum coke was tested to determine its specific gravity as well as its water absorption. The results were achieved through various noted computations.

The materials were divided into its respective samples such as mixture with 0%, 25%, 50%, 75% and 100% of partial replacements. Researchers used 0.35 water/cement ratio for each type of sample. A total of 120 samples were produced throughout the study.

Materials such as cement, calcined petroleum coke, carbon fiber, sand and water were mixed together into its specific mix proportion. After mixing, the materials flow table test was performed.

The mixture of cement mortar was placed in a mold with grease having a dimension of 2 x 2 x 2 in and 4 x 4 x 16 cm. After 24 hours, the researchers removed the mortar cement in the molds and proceeded to curing.

The curing period before the specimens undergo to mechanical test were 7, 14, 21 and 28 days.

The researchers tested the compressive (ASTM C109) and flexural strength (ASTM C348-80) of the cement mortar.

The results from the testing were analyzed to determine whether it passes the standards for compressive and flexural strength and the resistivity of cement mortar.

The cement mortars having calcined petroleum coke as a partial replacement to carbon fiber was then compared to the cost-effectiveness of the cement mortar having a full carbon fiber as an admixture.

IV. RESULTS AND DISCUSSION

Presented are the results of tests that were conducted at Technological University of the Philippines and Cavite Testing Center Corp. For physical, mechanical and electrical properties of conductive concrete that will determine its effectiveness.

TABLE I: PHYSICAL PROPERTIES OF THE MATERIALS

Material	Test	Result
Cement	Specific Gravity	3.15
Cement	Density	3.15
Sand	Specific Gravity	2.747
Sand	Absorption, %	2.39
Calcined Petroleum Coke	Specific Gravity	2.23
Calcined Petroleum Coke	Absorption, %	1.82
Calcined Petroleum Coke	Electrical Resistivity, μΩ-m	485.7

A standard specific gravity test is used in the concrete. The values presented that the cement is Type 1 cement, also known as general-purpose Portland cement.

The computed specific gravity and absorption of aggregates show that the fine aggregates will give an optimum contribution to the compressive strength of the concrete.

The addition of Calcined Petroleum Coke powder has been feasible. The result of the resistivity test implies that an electrically conductive is achievable without compromising the mechanical properties of conventional concrete.

TABLE II: PHYSICAL PROPERTIES OF CEMENT MORTAR

Sample Mark	Average Unit Weight (kg/m3)	Average Diameter of the Mortar Paste (cm)
A (10%)	2057.533	18.03
B (25%)	2096.928	17.55
C (50%)	2055.894	17.87
D (75%)	2146.774	18.40
E (100%)	2145.597	19.12

The table shows the different results of the unit weight of the samples having 28 days of curing time. Sample D provides the highest unit weight among them all having an average result of 2146.774 kg/m3 and Sample C having the lowest with an average result of 2055.944 kg/m3. Sample A has an average result of 2057.533 kg/m3, Sample B has an average result of 2096.928 kg/m3 and Sample E has an average result of 2145.597 kg/m3.

The table also shows the result from the table flow test of cement mortar having 3 trials per sample. Sample E provides the highest result having an average result of 19.12 cm and Sample B provides the lowest result having an average result of 17.77 cm. Sample A has an average result of 18.03 cm, Sample C has an average result of 17.87 cm and Sample D has an average result of 18.40 cm.

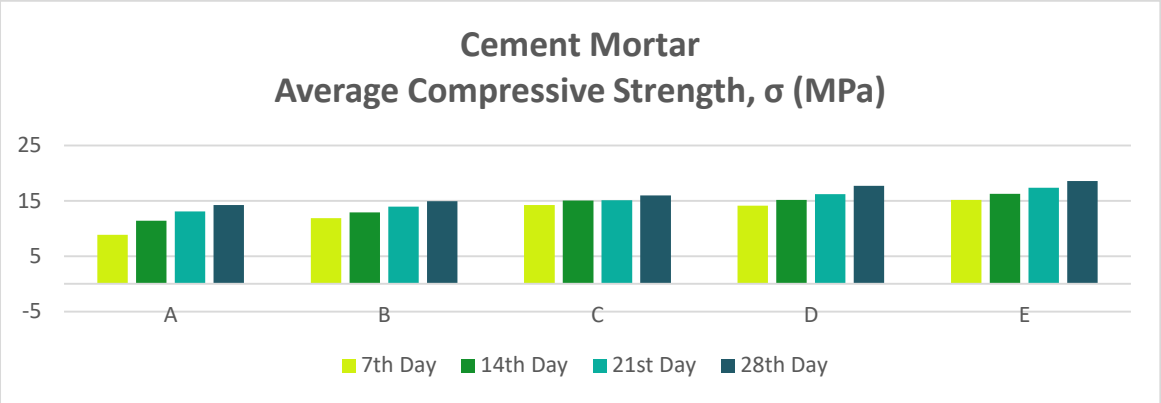

Fig. 2 Graphical representation of Compressive strength per block.

From the results of compressive strength testing of the samples for 7th, 14th, 21st and 28th day conducted by the researchers show that Sample E provides the highest strength among them all having an average strength of 18.5611 MPa having a 28 days of curing. The highest individual strength of the sample is 19.2130 MPa for the whole trial. On the other hand, Sample A provides the lowest compressive strength having an average strength of 14.24 MPa for the 28th day of the samples. The compressive strength of the samples is increasing from its 7th, 14th, 21st and 28th days of curing. As for the figure shown, the compressive strength of the cement mortars in samples B, C, D and E passed the standard of ASTM C109 for they are stronger than the sample A.

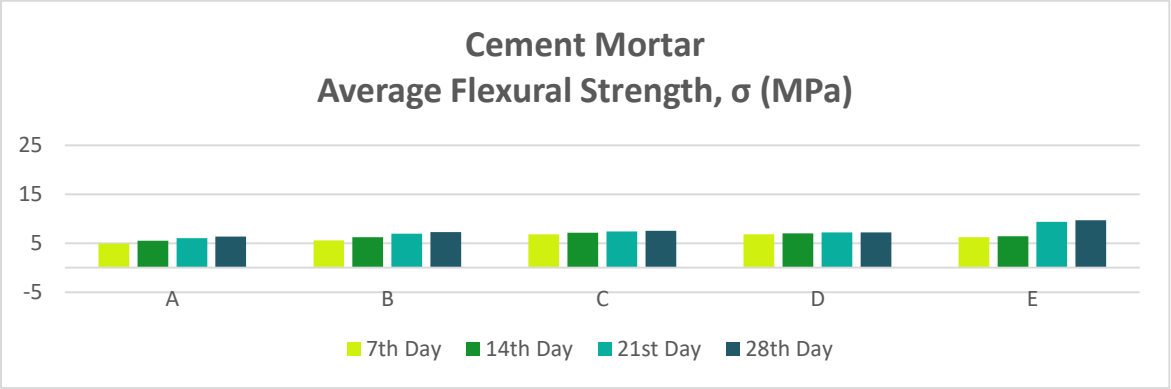

Fig. 3 Graphical representation of Flexural strength per block.

From the result of flexural strength testing conducted by the researchers on the 7th, 14th, 21st and 28th day of the samples shows that Sample E provides the highest average flexural strength of 9.6744 MPa with a curing time of 28 days. Sample E has the highest individual strength of 9.8540 MPa from the whole trial conducted. On the other hand Sample, A got the lowest average flexural strength of 6.3900 MPa for its 28th day. The flexural strength of the samples is increasing from its 14th, 21st and 28th days of curing. . As for the figure shown, the flexural strength of the cement mortars in samples B, C, D and E passed the standard of ASTM C348-80 for they are stronger than the sample A.

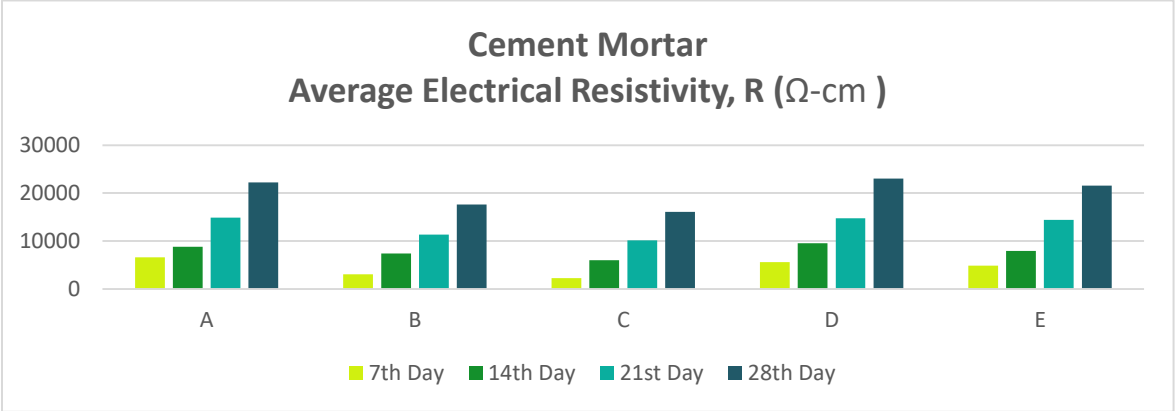

Fig. 4 Graphical representation of electrical resistivity per block.

The electrical resistivity testing shows that Sample D got the highest resistance for its 28th day having an average result of 23000.99 ohms. It has the highest individual resistance of 23345.00 ohms. Samples A and E has almost the same resistance with 22194.02 ohms and 21574.24 ohms respectively. Sample C got the lowest resistivity for the 28th batch having an average of 16112.64 ohms. The resistivity for each time of curing is increasing as to the result from the four-point probe testing and Sample C is the best mortar to be used since it has the lowest resistance among all of them.

V. CONCLUSION

Considering the findings extracted from the test results of the samples of study, the following conclusions were developed to satisfy each of the objectives of the study at hand:

Firstly, the researchers successfully determined the physical and electrical properties of Calcined Petroleum Coke; the substance does not degrade the mechanical properties of the cement mortar whilst also being able to increase the resistivity of the stated mortar.

Secondly, the compressive and flexural strengths of mixtures 'B' to 'E' are stronger than mixture 'A'; the use of Calcined Petroleum Coke with carbon fiber yielded sufficient strength to be considered as viable admixtures.

Thirdly, though mixtures with combined Calcined Petroleum Coke and carbon fiber were determined to create lesser mortar resistivity compared to pure mixtures 'A' and 'E', all mixtures achieved sufficient resistivity to be considered effective.

Lastly, quantitatively considering the costs and qualitatively considering the work required to create the cement mortar samples, the researchers have substantiated that the use of Calcined Petroleum Coke as an admixture yielded greater mortar strength while helming the resistive capabilities of the carbon fiber; the use of Calcined Petroleum Coke was found to be more cost-effective than its carbon fiber counterpart.

VI. RECOMMENDATION

If such cement mortar tests samples are to be created again, the mixtures should be combined with accurate amounts of necessary substances and proper mixing procedures in order to create desirably consistent compositions for the samples; a highly essential rule of thumb for achieving precise test results.

It is recommended, if not imperative, to seek guidance and/or assistance from trained machine testing operators for the samples to achieve more satisfying results, in terms of data accuracy.

Taking the positive aspects of the Calcined Petroleum Coke as an admixture into consideration, both quantitatively and qualitatively - it is logically reasonable to accept the findings of the study as a reliable source of information for the future proponents that will create any related research.

The researchers of the study encourage the future proponents who are interested with related topics to further study the other positive applications of conductive concrete such as thunderstorm protection, the manipulation of concrete temperature and radio interference shielding. The researchers also encourage the future proponents to test the applications on more critical structural components such as concrete.

ACKNOWLEDGMENT

Primly, the researchers are entirely grateful and would like to radiate their boundless appreciation and gratitude to their research adviser, Engr. Mark G. Costelo for his persistent support, tireless guidance and most importantly, his knowledge which helped the researchers yield rewarding results in their study. Also, the researchers would like to thank the panelists, Engr. Drexler B. Sibal, Engr. Carmelo O. Zapanta Jr., Engr. Siva Das P. Abaya and Engr. Arnel M. Avelino for providing the research with abundant amounts of critique and insight.

The researchers would also like to give thanks to Technological University of the Philippines and Cavite Testing Center Corporation for their generous amount of guidance and assistance in morphing the completion of the research from just a possibility into a reality.

The researchers would also like to give thanks to their family, friends and circles for being part of their endeavors, supporting them for good and comforting them from ill-fated times.

Above all, the researchers give their unmatched and incalculable thanks to their Divine Architect for providing them with more than enough will and skill to reach the frontier of their research, rewarding them with fruitful lessons - not just in their academe but also beyond.

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