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Preliminary Evaluation of Laboratory Grown Graphene as an Additive: Compressive Strength Analysis on Reinforced Mortar

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Abstract:
Graphene is structured in a hexagonal lattice of a one-atom-thick layer of carbon atoms which is assumed to be 200 times stronger than standard steel. It was proven that the inclusion of graphene in construction materials increases its strength indicating it suitable for resilience and maintenance. This presents that graphene can be a basis for a higher compressive strength of a material since the mechanical properties of graphene may contribute to the resistance of the material to any form of force. In this study, laboratory grown graphene was made from pencil lead was used as an additive to mortar cement. The procedure for the gathering of the data are the following: ASTM C109 and Blender Technique (Graphene Extraction). Based from the applied experimentation, the graphene had shown a significant effect within the mortar cement with the curing days of 3, 7, and 21 wherein compared to the controlled specimens, the values of compressive strength of the experimental specimens had doubled up. Thus, this concludes that a graphene-based mortar cement can be used as a sustainable construction material.

Keywords*:Graphene, Mortar Cement, Compressive Strength, Blender Technique.*

I. INTRODUCTION

In the construction industry, mortar is considered as one of the most used and feasible material when it comes to building infrastructures. Reference [1] defined mortar as a mixture of water to fine aggregate and binding material, which is used to hold building materials together. In addition, he described that the key elements of a high-quality mortar are as follow: strength, mobility, placeability, and water retention.

This research investigates the addition of the graphene, specifically the extracted graphene from the implemented method, to mortar. Reference [2] emphasized "graphene is the thinnest material known to mankind, but it is also incredibly strong - about 200 times stronger than steel". The chief scheme of this study is to recognize the influence of the extracted graphene, which is made through extracting the graphene from the graphite, into the compressive strength of the mortar cement. It attempts to fill the gap that many studies have only shown the framework of graphene. Thus, the research wants to determine the inclusion and effectiveness of the experimental graphene as a reinforcement material in terms of the compressive strength in mortar mixture.

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Moreover, this research intended to emphasize to a specific type of mortar namely the Type N mortar. A Type N mortar is described to suite for the general purposes wherein it is composed of 1:2 ratio of cement and sand accordingly. Consequently, this mortar will be subjected to such forces to test the maximum amount of stress that it can withstand, which is called as the compressive strength. For the scope of this study, it is done by focusing to innovate a new material into the nature of the mortar. On the other hand, this study is limited to properties such as the thermal, mechanical, water permeability, and tensile which are not covered by the study.

II.LITERATURE REVIEW

A.Graphite

Graphite is an allotrope of the chemical element, Carbon. It can be classified as both a metal and non-metal because of its capability to be flexible, but not elastic. It also has a high thermal and electrical conductivity. Thus, these characteristics of the graphite can offer a broad number of uses in metallurgy and manufacturing. Further, in the construction industry, graphite is deployed with different uses due to its structural strength at temperature, thermal shock resistance, high thermal conductivity, low thermal expansion, and good chemical resistance.

B.Graphene from Pencil Lead

Fundamentally, graphene is a single layer of graphite in which in a pencil lead, specifically its core, is composed of graphite which is composed of stack of atom-thick layers of carbon that are weakly bonded. Whereas natural graphite is a mineral that consists of graphitic carbon which is made up of the natural crystalline and usually used as an additive. In correspondence with graphene, graphite is composed of many layers of graphene, which is said to have unique properties that exceed those of graphite. The graphene extraction was done through the Blender Technique wherein the clay and wax mixture will be separated from the pencil lead and the small graphene flakes will start to levitate upon settling down for a while. To achieve the powdered form graphene, the suspended flakes were subjected under heat and this turns out as the wonder material – graphene.

C.Reinforced Mortar Strength

In the construction industry, mortars are commonly used as a binding force for many sectors. According to Reference [3], usually, mortar has a greater water to cement ratio than concrete which allows better workability and bonding properties. The reinforcement comes from its additive to overcome the microstructural level of hydration which determines the final properties of the cementitious matrix. Subsequently, compressive strength is subjected to vary under different circumstances. The kind of materials incorporated in the mortar and the components' proportion with one another can greatly affect the mortar's strength. The probability of failure of a material to resist compression may be due to the lapses within the testing procedure.

III.METHODOLOGY

The provided flow of procedures stated must be followed to successfully meet the purpose of the research and to obtain the set of parameters. The materials are considered as the key elements in performing an experiment. For the preparation of the materials and test specimens, it is ought to be constrained. After the collection of the raw materials, it is employed to the precise experimental treatment to produce a more effective outcome. Moreover, the materials used for this experiment are the following: Graphene, Pencil Leads (Graphite), Portland Cement Type I, Fine Aggregates, and Mixing Water. The collection of graphene was conducted through shear exfoliation. After the extraction of the graphene powder, it was transferred to a mold and was cured. In this experiment, 2 procedures are done which includes the following: ASTM C 109/ C 109 M and Shear Exfoliation in Liquids (Graphene Extraction). The test specimens that are used are carefully examined under different controlled conditions. Moreover, the inevitable occurrence of threats during

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the execution of the experiment can be carried out. Thus, the established experimental treatment seeks to perform a good quality procedure that could overcome all the possible threats.

IV.RESULTS

In this part, the results carried out from the experiment done in this study are presented and discussed which has an aim to determine the influence of the extracted graphene into the compressive strength of the mortar cement. Also, it aims to compare the compressive strength of the experimental and controlled variable. Moreover, some of these aspects were already elaborated from the previous chapters introduced in this study.

The compressive strength analysis of the reinforced mortar is put to test under the Universal Testing Machine (UTM) in accordance with the American Society for Testing and Materials (ASTM) International by implementing the 3, 7, and 21 curing days with 3 mortar test specimens for each curing age. For the data, Specimen Unit A depicts as the experimental data whereas Specimen Unit B represents the controlled or standard data. Furthermore, the statistical treatment applied in this study is a one-tailed t-test for the difference in means with a 95% and 90% confidence interval.

Based from the overall results gathered by the researchers from the applied experimentation, it had proven that the inclusion of the extracted graphene into the mortar cement had signified a remarkable effect. From the 3 curing ages deployed, the values of the compressive strength of the experimental specimens had clearly shown an increase in values as per each curing age had took place. The experimental specimens had manifested a more exceptional results compared to the results of the controlled specimens. Thus, the results are an indication that the extracted graphene can be used as an additive material within the construction materials.

To precisely analyze the results, a statistical treatment is employed wherein a one-tailed t-test for difference in population means with equal variances within the data samples are assumed. In this study, the given confidence interval for 3 and 7 days is 95%. On the other hand, for 21 days the confidence interval is 90% since based from the results of the experimental specimens under this curing age, the values somehow did not double up as compare to the curing ages of 3 and 7 days.

As seen in Table 4, this had signified that all of the means of the experimental specimens are greater than the means of the controlled specimens which rejects the given null hypothesis, (H0): $\mu 1 \leq \mu 2$, and satisfies the alternative hypothesis, (Ha): $\mu 1 > \mu 2$. Hence, this presumes that from the addition of the extracted graphene, the experimental specimens have shown relevant results. To further assess these results, the test statistical values are then considered to whether tell if it will correlate with the results of the hypothesis testing as well to provide a more accurate result.

In each curing age of 3, 7, and 21 days the computed test statistics are approximately (~) 5.93, 6.07, and 1.89 respectively. The computed test statistic from the results must be greater than the one-tail critical t-value of 2.132, for the level of significance of 0.05, and 1.533, for the level of significance of 0.10, which had depended on the degrees of the freedom (df) = 4 that is given from this data. By looking at the values, it is evidently seen that the test statistics for 3 and 7 days had successfully exceeded the critical t-value of 2.132 as well as the test statistic for 21 days in which it had surpassed the critical t-value of 1.533. This exhibits that all the values did fall at the rejected region which unveils that the alternative hypothesis is accepted where it concludes that the Specimen Unit A is greater than the Specimen Unit B. had manifested that the null hypothesis, (H0): $\mu 1 \leq \mu 2$, is certainly rejected whereas the alternative hypothesis, (Ha): $\mu 1 > \mu 2$, is the one accepted. To summarize, it had suggested that the experimentation implemented in this study, which is the extraction of graphene, can significantly affect the mortar.

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TABLE I: COMPRESSIVE STRENGTH OF SPECIMEN UNIT A AND SPECIMEN UNIT B – 3 DAYS

Type N	Specimen Unit A - Experimental			Specimen Unit B - Controlled		
Curing Age	Max. Force kN	Max. Stress kN/mm^2	Max. Stress MPa	Max. Force kN	Max. Stress kN/mm^2	Max. Stress MPa
M3 - 1.1	32.9625	0.01319	13.19	12.8562	0.00514	5.14
M3 - 1.2	37.2500	0.01490	14.90	18.2813	0.00731	7.31
M3 - 1.3	43.8250	0.01753	17.53	18.2750	0.00731	7.31

TABLE II: COMPRESSIVE STRENGTH OF SPECIMEN UNIT A AND SPECIMEN UNIT B – 7 DAYS

Type N	Specimen Unit A - Experimental			Specimen Unit B - Controlled		
Curing Age	Max. Force kN	Max. Stress kN/mm^2	Max. Stress MPa	Max. Force kN	Max. Stress kN/mm^2	Max. Stress MPa
M7 - 1.1	63.7375	0.02550	25.50	27.9000	0.01116	11.16
M7 - 1.2	58.8250	0.02353	23.53	21.7750	0.00871	8.71
M7 - 1.3	47.1625	0.01886	18.86	24.8250	0.00993	9.93

TABLE III: COMPRESSIVE STRENGTH OF SPECIMEN UNIT A AND SPECIMEN UNIT B – 21 DAYS

Type N	Specimen Unit A - Experimental			Specimen Unit B - Controlled		
Curing Age	Max. Force kN	Max. Stress kN/mm^2	Max. Stress MPa	Max. Force kN	Max. Stress kN/mm^2	Max. Stress MPa
M21 - 1.1	55.5875	0.02224	22.24	53.3875	0.02135	21.35
M21 - 1.2	70.1438	0.02806	28.06	49.7938	0.01992	19.92
M21 - 1.3	95.0500	0.03802	38.02	51.9313	0.02077	20.77

TABLE I: COMPUTED MEAN FROM ONE-TAILED T-TEST

3 Days	Experimental	Controlled
Mean	15.2067	6.5867
7 Days	Experimental	Controlled
Mean	22.63	9.9333

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21 Days	Experimental	Controlled
Mean	29.44	20.68

Findings and Conclusion

For this study, the compressive strength of reinforced mortar incorporated with laboratory grown graphene was examined through experimental testing. The addition of the extracted graphene had made the mortar into a reinforced mortar owing to the fact that Graphene-Info (2019) stated, that the molecular structure of graphene is made up of "angstrom layer of carbon atoms arranged in a hexagonal lattice" which makes it a strong material. It was observed that the extracted graphene gave a notable rise on the compressive strength of the Type N mortar test specimens, which were cured for 3, 7, and 21 days. With the use of one-tailed t-test for the difference in means with a 95% and 90% confidence interval, a comparative study between the experimental variables and controlled variables are done. The results revealed that at comparatively low inclusions of approximately less than 0.05% by mass of the cement, the extracted graphene has improved the compressive strength of the cured experimental mortar and increased it by at most 50% during the curing ages of 3 and 7 days. The amount of graphene flakes to be added must be controlled in a way that will not affect the workability of the mortar. Unlike with other nanomaterials, the researchers' method of production of the graphene additive, is non-hazardous. Thus, indicating the potentials of the graphene reinforced mortar for a more environment-friendly construction industry seeing that the materials employed are only graphite pencil leads and a highly foaming mixture. The knowledge and information gained in this study will not only impart a better comprehension on the effects of the extracted graphene on mortar, but also to provide beneficial concepts and ideas for future related studies.

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