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Reprocessing the Styropor as Thermal Insulation Materials: A Substitute for Concrete Block and Plywood Construction

Lelanie S. Cordero

Associate Professor 2, Chairman, Mechatronics, and Graphics Design Department, Cebu Technological University-Main Campus

Abstract -. This cross-sectional study investigated the innovative use of recycled Styropor as a thermal insulation material, a viable alternative to conventional building materials like concrete blocks and plywood. By addressing concerns regarding Styropor waste, the research intends to enhance energy efficiency and sustainable construction. Comparing the thermal insulation properties of Styropor to those of concrete blocks and plywood, the study investigates effective recycling methods and environmental benefits. Moreover, a laboratory investigation evaluates the thermal conductivity and compressive strength of alternative thermal insulation sheets. The feasibility of Styropor is evaluated based on structural factors, including load-bearing capacity, durability, and long-term stability. The results of this study shed light on the viability of recycled Styropor as a thermal insulation material in construction. The study found that the addition of graphene to three samples had a substantial effect on compressive strength and thermal conductivity. The researchers came to the conclusion that styropor+ graphene oxide could be a new material for shear wall insulation if the appropriate molding procedures, molder types, and ductility tolerance are observed. By reusing Styropor, the construction industry can reduce its environmental impact, conserve natural resources, and improve building energy efficiency. It is suggested that flimsy disintegrating materials provide strength; alternative decorative materials may be manufactured.

Keywords: *Recycling, Styrofoam, Thermal insulationmaterials*

Introduction

Concrete blocks were first used by grassroots communities thousands of years ago. Today, concrete blocks are still often used in the construction of big cities, commercial buildings, silos and walls, canals, and other non-load-bearing structures (Torkaman et al., 2014). These days, there are a plethora of creative applications for the use of concrete blocks in building construction. Thermal conductivity, compressive strength, weight, bulk density, ease of installation, pricing, and material savings are all common concerns among inventors. Reusing cans, bottles, and plastics helps keep the environment healthy. The thermal conductivity and weight of a block made with the typical soil: cement: sand ratio can be decreased by utilizing a fiber-based soil-cement block as an additive (Khedari et al., 2005). Ingenious forming building blocks were created by the 'Forest Products Research and Development Institute' using only soil, water, and lime as a binder together with a variety of Agri-forestry waste materials such as rice hulls, coconut coir dust, and wood ash.

Standley (2009) claims that if the blocks' compressive strength is between 197 and 386 pounds per square inch (psi), the partnerships are robust, durable, and equivalent to commercial solutions. Only at load-bearing nodes does the concrete or non-load-bearing wall make an appearance. Only skeletal frameworks are supported by it. One of the most ecologically and economically sustainable solutions to the alarming global trends of annual plastic disposal and natural resource depletion, according to Siddique & Khatib (2008), is to recycle plastic waste into concrete blocks. Recycled high-density polyethylene (HDPE) aggregate, fiber, and cementitious material performance in concrete (Abeysinghe et al., 2021).

Due to their low density, porosity, and water absorption, Rahman et al.'s (2012) recycled polymer materials utilized as aggregates in the concrete blocks investigated were classified as non-load-bearing lightweights. Al-Manaseer et al. (1997) found that plastic aggregates can be used as a 15% substitution equivalent of a stone aggregates additive in concrete. Because of their strength, durability, and resistance to moisture, they make for a great alternative to more conventional timber building materials (Song et al., 2010). Even though they aren't technically eco-unfriendly, they are the leading drivers of growing trash problems and environmental worries. Polystyrene and other polystyrene materials have become a particular focus of the government's efforts to educate the public about the environmental benefits of reducing, reusing, and recycling. Styrene was identified as a potential human carcinogen by the International Agency for Research on Cancer in 2002. In addition, styrene has been related to human leukemia and lymphoma, as stated by Elmore et al. (2015) in their study on carcinogens.

Materials made of translucent polycarbonate resin exhibit significant levels of impact resistance and flame retardancy; These characteristics allow them to be utilized as building materials in a variety of ways; they are safe to use and do not break as quickly as other timber building materials, except when polycarbonate solid sheets are used in place of plywood (Song et al., 2010).

This manner, in turn, led to the thought process of exploring the idea of producing a shear wall consisting of utilized styropor and graphene oxide form into a sheet as a substitute for polycarbonate and plywood or chb wall for non-load bearing applications. Therefore, the researcher came to the conclusion that reusing used polystyrene as an alternative thermal insulating material would be a good idea. This would be a new material innovation in green technology that would help solve the problem of environmental trash.

Methods and Materials

The study used experimental methods of two variables in employing experiments conducted to formulate an alternative material using used styropor and graphene oxide. A laboratory simulation was steered in order to know the parameters that assess the efficiency of the alternative thermal insulating material especially the compressive strength. Exfoliating technique of the graphite was used in this method in producing the graphene oxide, where the chemical structure forms a two-dimensional hexagonal honeycomb lattice pattern. The study was tested at the Mechatronics laboratory, regarding the thermal conductivity and the compressive strength test result was done at the Mega testing center Inc. laboratory. The materials used in the design of the alternative thermal insulating sheets are Used Styropor, Graphine Oxide, laboratory apparatus, and mixing hand tools. The mixed design of alternative thermal insulating sheets is cast in an innovative design molder. The three (3) pair sample was cured and tested in the laboratory, and it was observed in the age of curing time, the samples are tested on the 7th day, 15th day, and 30th day after curing.

Moreover, the study was conducted at Industrial Automation Laboratory Building, Cebu Technological University, R. Palma St. Cebu City, Philippines. Instrument likewise, the study utilized laboratory results to measure the efficiency of the Alternative Thermal Insulating Sheet in terms of Thermal Conductivity and Compressive Strength. The gathered result was tabulated, analyze, and treated using statistical treatment.

Results and Discussion

This chapter provides an analysis as well as an interpretation of the data that was collected. The researcher provided answers to particular issues that arose throughout the course of the study, as well as presented and talked about those issues. Within the scope of the study, it was discussed the make-up of an alternative type of thermal insulating material, the components used in the manufacturing process, the outward look of the product, and the effectiveness of thermal insulating materials in terms of their heat conductivity and compressive strength.

Components in the production of the substitute thermal insulating materials.

In this section, the various building blocks that go into the formation of alternate thermal insulating materials are presented.

Steps a. dissolving styropor in acetone and b. preparing graphene oxide

Measuring apparatus like Digital scale, Beaker and graduated cylinder, glass stirrer and 24 volts power supply, alligator clip, colored wire, aluminum stick were used in dissolving graphite

COMPONENTS	Function
Acetone	A chemical to dissolve the acetone
Hydrogen Peroxide	Used as an oxidizer
Graphite	comprise of a lacked layer of graphene.
Digital scale	Measuring the weights in digital
Beaker	Aide in pouring the solution
Graduated cylinder	to measure the volume of a liquid
Glass stirrer	to mix the solution
24 volts power supply,	to dissolve graphite and aluminum strip in a mixture
Alligator clip	Used to hold the graphite and aluminum strip

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Colored wire	Connecting wire, the alligator to the power supply
Aluminum strip/sheet	As an ion agent in the chemical exfoliation of graphite in a solution
Graphene Oxide	Compound of carbon, obtained by treating graphite with strong oxidizers and acids
Thin Sheet	Used as a molder of the materials

Actions in merging the components to make graphene oxide:

Formulation of Graphite and Hydrogen Peroxide

Supplies	Amount
Graphite	100 grams
Hydrogen Peroxide	500 grams
Distilled Water	5 Liter
Electrical power supply	24 volts dc

MIXING GUIDE OF Graphene Oxide innovate by (ROBERT MURRAY) enthused by Tour's Method

If there is smoke present during the mixing of the two substances, wait a few minutes until the fumes have completely dissipated before adding the 100 grams of graphite intercalated with the 500 grams of hydrogen peroxide to the 1000 grams beaker. The following step is to transfer it to a larger jar, add 1 liter of distilled water, stir it, and then let it for 1 day. Then, stir it again and add more distilled water. You repeat this five times. The next step is to dry the graphene in an oven or outside until there is no longer any water in the graduated cylinder or beaker. The outcome is a two-dimensional powder of graphene oxide.

The top-down approach demonstrates that graphene creation in electrochemical exfoliation involves both chemicals and energy. The electric current from the electrodes drives ions from the solution into the structure of the graphite. When ions from the solution are driven between the graphene sheets in the graphite, they react in the solution to form gas bubbles, which split the graphite layer by layer, causing the graphite to exfoliate. In general, graphite can disintegrate before fully exfoliating into graphene. When graphite is withdrawn from the electrode, the ions are no longer pushed between the sheets of graphene by electricity, and the consequence is tiny bits of graphite rather than functional graphene.

Groundwork in dissolving styropor in acetone

The steps for dissolving styropor and acetone in a pail without a graphene oxide sample are detailed below. After dissolving and mixing the melted styropor, transfer it into a molder. Another sample combines this method with graphene oxide (the researcher wishes to conceal the method) and waits for the materials to cure.

Physical Characteristics Of The Product

By combining the necessary components and deforming the materials, the physiognomy of thermal insulating materials can be created. The images below depict various samples of non-graphene oxide after curing in the sun.

Non-Graphene Oxide

Physical Appearance of the non-graphene oxide

The first week after demolding, the materials are the same size as the molder. Then, after a month, the materials begin to diminish slightly. In addition, within a year, the materials begin to fracture and become brittle, the flattened shape becomes curved, and the ductility is poor. When materials come into contact with a flame, they instantaneously catch fire.

With 100 grams of Graphene Oxide

Graphics below are styrophene (with 100 grams of graphene oxide in a dissolved styropor)

Letter A

1. Mold in a molder without minding any form.
2. Plasticity is clear
3. Visible crack at the middle
4. When the materials are near to the flame it melts like water to look at but when it touches you can feelthe hardness of the materials.
5. Bulk of air is present inside the materials

Letter B

1. Mold with 16 inches by 16 inches by 6-millimeter width, pressed by another sheet above the molder.
2. air is not present in the materials
3. Similar to acrylic when it touches
4. Color is faded not the same as the letter A too much blacken
5. Hair line of cracks is noticeable in the upper portion.

The Efficiency of Alternative Thermal Insulating Materials As To:

This section of the study discusses the effectiveness of thermal conductivity and compressive strength, where the results of laboratory tests are presented in the table below.

Thermal Conductivity

ASTM D635: Rate of Burning and/or Amount and Time of Burning of Plastics in a Horizontal Position, "This way of testing was made for polymeric materials that are used to make parts for devices and appliances. The results are meant to be a first sign of how acceptable they are in terms of their ability to catch fire for a certain use...This standard is used to measure and explain how things behave...to heat and flame under controlled conditions, but it doesn't include all the factors needed to figure out how dangerous a material, object, or assembly is when it's in a real fire., **Test Procedure:** One end of the test piece is held horizontally, and the other end is put in a gas flame for 30 seconds. After the flame is taken away, the test sample is watched to see how long and how much it burned. A material's average burning rate is given if it burns to the 100 mm mark from the end that was lit. **End Result:** The test gives a measure of how flammable the material is. Materials can be categorized if it makes sense and is in line with the standard's appendix (i.e. HB, CC1, or CC2).

From the actual testing of a 2”x2” uncompressed Styrophene,

Graphics A, after the testing guide of ASTM D635, in which the specimen is placed on a flat surface and allowed to stand, tests of both thermal temperature and butane torch are collectively carried out. Looking at the other side of the specimen is a butane torch measuring 100mm distance from the nozzle to the specimen, and on the opposite side of the specimen is a thermal thermometer that displays the temperature. The specimen generates 34.9 degrees Celsius in 35 seconds of actual testing time.

Graphics B, Actual contact with the opposite side of the specimen to determine whether or not the heat released is bearable by hand. Since we can observe that neither the outward appearance of the specimen nor its chemical composition has changed, this indicates that the flame on the other side is not having any effect on the other side.

Graphics C, When the flame of the torch is not present at the specimen, the chemical reaction of combustion emits heat and light (flame). However, when the flame of the torch is not available at the specimen, the fire immediately goes out. This can happen because graphene oxide has retardation characteristics.

Graphics D, When the specimen is hit with flame, the surrounding area gets floppy. Through these testing procedures, these materials can be classed as appropriate and in line with the standard that is based on ASTM D635. Chemical change is typically irreversible, although new materials are typically generated.

Compressive Strength

The ASTM D695 Standard Test Methods for Compressive Properties of Rigid Plastics cover the measurement of the mechanical properties of unreinforced and reinforced rigid plastics, including high-modulus composites when filled in compression at relatively low uniform rates of straining or loading. This test method covers the determination of the mechanical properties of unreinforced and reinforced rigid plastics, including high-modulus composites. The specimens used in the tests are all of a uniform shape. This approach can be used for composite moduli ranging from 41,370 MPa (6,000,000 psi) up to and including the maximum value. (astm international, the United States)

Tests can be conducted in line with Test Method [40] D3410/D3410M or D6641/D6641M to determine the compressive characteristics of resin-matrix composites strengthened with oriented continuous, discontinuous, or cross-ply reinforcements. This test procedure introduces the compressive load into the specimen through shear at wedge grip interfaces. Tests can also be conducted in accordance with Test Method [40] D6641/D6641M.

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Or you might use Test Method D695, which involves applying a compressive load to the specimen through end loading.

Reinforced Plastics, Including High-Strength Composites and Highly Orthotropic Laminates— ASTM D695, Section 6.7 Reinforced Plastics In order to properly test reinforced materials, the following specimens are required. The standard test specimen for strength measurements must take the form of a right cylinder or prism, with its length being twice its major width or diameter, with the exception of the circumstances described in sections 6.3 through 6.8. It is recommended that specimens have dimensions of 12.7 millimeters in diameter and 25.4 millimeters in length (prism) or 12.7 millimeters in diameter and 25.4 millimeters (cylinder). The standard test specimen that is going to be used for modulus or offset yield measurements needs to have dimensions in such a way that the slenderness ratio falls anywhere between 11 and 16:1. In this particular scenario, the optimal specimen dimensions are a prism measuring 12.7 millimeters in diameter and 50.8 millimeters in height, or a cylinder measuring 12.7 millimeters in diameter and 50.8 millimeters in height. 6.7.2 A compressed test specimen for materials thicker than 3.2 millimeters (0.125 inches) must be utilized for testing elastic modulus on materials thinner than 3.2 millimeters (0.125 inches) or for testing elastic modulus on materials where the slenderness ratio does not provide for enough length for connection of a compress meter or another device of a similar kind.

NOTE 4: If the failure for the specimens used in 6.7.1 is caused by delamination rather than by the intended shear plane fracture, the material may be tested in line with 6.7.2.

Testing Result of Styrophene

The results of the tests performed on the four samples are shown in table no. 2, and it can be inferred from these results that the addition of even a negligible quantity of graphene oxide can impact the materials' overall strength.

Laboratory Test Result of Styrophene

Particular	MaximumLoad (kN)	Kg conversion
Sample 1. Without graphene oxide in 7^{th,} 15th & 30th day of curing	2.0	203.94 kg
Sample 2. With 100 grams graphene oxide in 7th day of curing	4.0	407.89 kg
Sample 3. With 100 grams graphene oxide in 15th day of curing	10.0	1019.72 kg
Sample 4. With 100 grams graphene oxide in 30th day of curing	15.0	1529.57 kg

Relying on the STM D695 is ISO 604 equivalent (determination of compressive strength properties), a test technique used for evaluating the compressive characteristics of un-reinforced and reinforced plastics, the laboratory testing of alternative thermal insulating sheet (styrophene) specimen of 2"x2" uncompressed molded materials revealed that the admixture contained one kilogram of used styropor dissolved in acetone..

Sample 1: 7TH 15 TH, & 30TH DAY OF CURING OF 2” X 2” STYROPHENE without graphene oxide curing, the results presented only 2 Kn of maximum load allowable this means

203.94 kg equivalent load this implied that the new materials is less strength compare to acrylic that specify in Lehigh Valley Plastics Physical Properties of acrylic typical .236" thickness (exact measurement of acrylic does not specify) on astm d695 with maximum strength of 18,000 psi. Sample 2: 7TH DAY OF CURING OF 2" X 2" STYROPHENE with the 100 grams of graphene oxide weighted 4KN of maximum load this means 0.58016 psi or 407.89 kg. Sample 3: 15 TH DAY OF CURING OF 2" X 2" STYROPHENE with the 100 grams of graphene oxide weighted 10KN of maximum load this means 1.4504 psi or 1019.72 kg. Sample 4: 30TH DAY OF CURING OF 2" X 2" STYROPHENE with the 100 grams of graphene oxideweighted 15 KN of maximum load this means 2.1756 psi or 1529.57 kg.

The result suggests that the styrophene produced belongs to materials with a reduced modulus or tests with a compressive test failure (nominal), where: NOTE 6: The compression tool may not be required for testing of materials with a lower modulus (for example, 700 Mpa to 3500 Mpa (100,000 psi to 500,000 psi)) if the loading surfaces are kept smooth, level, and parallel to the extent that buckling does not occur. (ASTM D695), but the significance of this testing is that we now know the maximal load strength if we used styrophene, even though testing according to the rules is not required.

Laboratory result using t-test formula

Days	non-graphene oxide	with 100 grams graphene oxide	p-value
7	203.94	407.89	0.073468465
15	203.94	1019.72	
30	203.94	1529.57	

Using the t-test formula, it was determined that the p-value of the compressive strength in 3 samples of 7-day intervals in a series of tests was 0.073468465, which is greater than the significance level of 0.05. This indicates that the hypothesis-driven experiment accepts the hypothesis that there is a significant difference between the two samples.

Laboratory results using Chi-square formula

observed (o)	summation						
					(o-e)^2/e		
Days	non-graphene oxide	with 100 grams graphene oxide		(subtract value-expected value)^2			
7	203.94	407.89	611.83	expected value			
15	203.94	1019.72	1,223.66				
30	203.94	1529.57	1,733.51				
	611.82	2957.18	3,569.00	days	non-GO	with 100 GO	
				7	93.55	19.36	
				15	0.16	0.03	
expected (e)	= (row total x column total)			30	29.25	6.05	
	Over all total						
				x^2	148.40		
Days	non-graphene oxide	with 100 grams graphene oxide		df	1		
7	104.88	506.95		**p-value**	**3.8731E-34**		
15	209.77	1,013.89					
30	297.17	1,436.34		df = (number of rows-1) x (number of columns -1)			

Using the chi-square formula, it is evident that the skewedness of the p-value of 3.8731 is positive, indicating that the null hypothesis is not acceptable and that there is still a significant difference between the two groups.

Summary

The major goal of this study was to address the environmental debris problem of styropor by using it as an aggregate in alternative thermal insulating sheets, which would lead to new material innovation in green technology. The research attempted to establish the efficiency of heat conductivity and compressive strength to replace typical CHB or plywood as wall insulation.

The compressive strength result was based on a Mega Testing Center, Incorporated laboratory test, while the thermal conductivity test was performed at the Mechatronics Laboratory. The product was tested for one month (7th, 15th, and 30th days were used as sampling design). The study employs a time-series experimental design. It resulted in sample 1 without graphene oxide measuring 2KN=.29008 psi maximum load on the 7th, 15th, and 30th days, and sample 2 measuring 4KN=0.58016 psi on the 7th day, sample 3 measuring 10KN=1.4505 psi on the 15th day, and sample 4 measuring 15KN = 2.1756 psi on the 30th day.

Discussion

Based on alternative thermal insulating sheets designed (graphene+used styropor+ acetone), "styrophene." The results of the four samples showed that one sample without graphene oxide has less strength than the three specimens with 100 grams of graphene oxide admixture; this indicates that adding graphene oxide to the sheet can increase the strength of materials cured for different amounts of time. These findings are consistent with those of Dikin et al. (2007), who concluded that this material outperforms many others in terms of rigidity and strength. Its combination of macroscopic flexibility and rigidity results from the unique interlocking of nanoscale graphene oxide tiles.

Conclusion

Based on the results, the specimen made of the three samples with graphene admixture clearly affects compressive strength compared to non-graphene oxide sample 1, and the thermal conductivity is appropriate and follows the standard's base on astm d635 (extent time of burning plastics). Thus, with the right molding method, molder, and frame, styropor+ graphene oxide might become a new shear wall insulation material. These methods also convinced one that burning the waste styropor is not the solution.

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