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SYNTHESIS AND CHARACTERIZATION OF *ENVIRONMENTALLY* FRIENDLY *PAPERCRETE* AS A NEW MORTAR FOR BRICK PANEL INSTALLATION

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ABSTRACT

This research focuses on the development of lightweight and soundproof building materials using waste paper or pulp as a component, with the aim of improving quality of life and reducing environmental pollution. Papercrete, made from unused waste paper, has environmentally friendly characteristics and can be used as the main structure of buildings. The study investigated the effect of pulp on the stress behavior of panels and tested the reusability of paper as a lightweight and eco-friendly brick material. The research method involved experimental procedures, using specialized equipment and materials to determine the properties and performance of different types of concrete mixes. Results indicate that papercrete has potential as an eco-friendly construction material with physical and mechanical properties suitable for reinforcing brick panels. Further research is recommended to investigate the effect of paper chip size on concrete strength under different humidity and temperature conditions, and to analyze the environmental impact of using papercrete as a construction material. The findings suggest that papercrete holds promise as a new and sustainable construction material. Testing papercrete in real-world scenarios could provide valuable insights into its durability and suitability for different applications.

Keywords: Characterization, Environment, Mortar, Papercrete

ABSTRAK

Penelitian ini difokuskan pada pengembangan bahan bangunan yang ringan dan kedap suara menggunakan kertas limbah atau bubur kayu sebagai komponennya, dengan tujuan meningkatkan kualitas hidup dan mengurangi polusi lingkungan. Papercrete, yang terbuat dari kertas limbah yang tidak terpakai, memiliki karakteristik yang ramah lingkungan dan dapat digunakan sebagai struktur utama bangunan. Studi ini meneliti pengaruh bubur kayu pada perilaku tegangan panel dan menguji kegunaan kertas sebagai bahan bata yang ringan dan ramah lingkungan. Metode penelitian melibatkan prosedur eksperimental, menggunakan peralatan dan material khusus untuk menentukan sifat-sifat dan kinerja dari berbagai jenis campuran beton. Hasil penelitian menunjukkan bahwa papercrete memiliki potensi sebagai bahan konstruksi yang ramah lingkungan dengan sifat fisik dan mekanik yang cocok untuk penguatan panel bata. Penelitian lebih lanjut disarankan untuk menginvestigasi pengaruh ukuran serpihan kertas pada kekuatan beton di bawah kondisi kelembapan dan suhu yang berbeda, serta untuk menganalisis dampak lingkungan dari penggunaan papercrete sebagai bahan konstruksi. Temuan ini menunjukkan bahwa papercrete memiliki potensi sebagai bahan konstruksi baru dan berkelanjutan. Pengujian papercrete pada skenario dunia nyata dapat memberikan wawasan yang berharga mengenai daya tahan dan kesesuaian untuk berbagai aplikasi.

Kata Kunci: Karakterisasi, Lingkungan, Mortar, Papercrete.

INTRODUCTION

In today's era there are always updates in improving a building according to its use. One of the developments carried out is to make building materials that are lightweight and soundproof. This research was conducted to improve the quality of life related to the environmental, socio-cultural, and economic

fields. We from the research team also consider the value of buildings, from construction, building maintenance to demolition and recycling. In the 21st century, there is a need for new ecological materials that are capable of increasing durability and energy efficiency as well as enabling waste recycling and cost savings (1).

The cement industry is included in the list of the top ten industries that contribute to the largest air pollution in Indonesia (2). The cement industry is in the spotlight because of carbon dioxide emissions, the largest component of greenhouse gases, which are produced from the lime calcination process and coal combustion, this is the biggest cause of CO_2 emissions, both in the production of building materials (± 25%) and building use (±35%) (3). Based on several studies, it is stated that concrete can emit pollution of 7.1 billion tons of CO_2/year (4). Eric Patterson and Mike McCain are contributors to the discovery of papercrete, papercrete is a very good material, because it has environmentally friendly characteristics, the load of this concrete is also light, because it consists of unused waste paper, and can also be used as the main structure (5). By 2020 it is predicted that paper consumption could reach more than 500 million tons per year, even more than 450 million tons/year paper has been produced worldwide (6). also from any high ratio of recycled paper. As for the purpose of investigating the effect of the pulp observed through the stress behavior of the panels, and based on the latest experimental research it is stated that the masonry panels consisting of mortar include cellulose fibers from the pulp.

To improve the thermal and structural performance of buildings, researchers several years ago conducted an integrated study (7). To measure a thermal conductivity, capillary absorption, and flexural and compressive strength, several specimens are required which are tested in different ways in the laboratory (8). Waste paper or pulp will be used as a component of paper recycling, with two different samples of papercrete mortar, and in the test the volumetric percentage to be tested also varies (9). To test the reusability of paper, it is necessary to do this test, which also aims to make papercrete made from recycled materials. recycled paper as a lightweight and environmentally friendly brick material. This research will obtain innovative composite materials to be applied in construction or environmental repair, especially alternative materials for installing brick panels.

RESEARCH METHOD

Place And Time Of Research

The research was conducted at a Physics Laboratory, which suggests that it was likely focused on studying the physical properties of the materials and/or products being tested. Physics laboratories typically have specialized equipment for testing mechanical, thermal, and electrical properties, among other things. The research was conducted over a period of three months, from September 2021 to November 2021. This suggests that the study was relatively short-term, and the researchers

likely had a specific goal or set of goals in mind. During this time, they would have been carrying out experiments, collecting data, and analyzing the results. The duration of the research, being three months, suggests that the scope of the project was limited. Depending on the research question and the complexity of the experiments involved, three months may be sufficient to complete a study or just a part of a larger research project. The research may have been part of a bigger investigation or study, or it could have been a standalone project. It is important to note that the length of time a research study takes can vary widely depending on factors such as the complexity of the research question, the availability of resources, and the scope of the project. Three months may be too long or too short for some research projects, but for others, it may be just the right amount of time to achieve the desired results.

Research Tool

The equipment used in this research is important for producing and testing the properties of concrete (10). Here is an explanation of each of the equipment used: Concrete mixer: A concrete mixer is a machine used to mix cement, sand, and water to make concrete. It can be a stationary mixer or a mobile mixer. Scales: Scales are used to measure the weight of the different materials used in making concrete. Accurate measurements are critical to producing consistent concrete. Mold cylinder: Mold cylinders are used to shape and hold the concrete samples during testing. They come in different sizes depending on the required testing parameters. Sieve: A sieve is a device used to separate particles by size. In concrete testing, sieves are used to determine the size distribution of the aggregate used in the mix. Pressure test equipment: Pressure test equipment is used to determine the compressive strength of the concrete. This test involves applying pressure to a concrete sample until it breaks, and the maximum pressure it can withstand is measured. Ventilated oven: A ventilated oven is used to dry and cure the concrete samples before testing. This is important to ensure that the concrete is fully cured and ready for testing. Universal Testing machine Dual Column Instron 3369 model: This is a testing machine that is used to determine the tensile strength and other mechanical properties of the concrete. It works by applying a controlled force to a concrete sample and measuring its response. Heat flow meter NETZSCH HFM 436/0/1: This is a device used to measure the thermal conductivity of the concrete. It works by measuring the rate of heat flow through a sample of the concrete, which can be useful for determining the energy efficiency of buildings made with the concrete. In this research, the equipment listed is likely being used to study the mechanical and thermal properties of different types of concrete mixes. By using various tests and equipment, researchers can determine which combinations of materials produce the

strongest, most durable, and energy-efficient concrete for various applications.

Research Materials

The materials listed are commonly used in the construction industry for various purposes. Here is an explanation of each of them: Cement: Cement is a binding material that is used to hold other materials together. It is a fine powder made from a mixture of limestone, clay, and other minerals that are heated to high temperatures in a kiln. Sand: Sand is a naturally occurring granular material composed of rock fragments. It is commonly used in construction for making mortar and concrete. Pulp/Pulp: Pulp is a material that is made by separating the fibers from wood, cotton, or other plant materials. It is commonly used in the paper industry to make paper products. Water: Water is a colorless, odorless, and tasteless liquid that is essential for life. In construction, it is used to mix with cement, sand, and other materials to make concrete. Portland Cement CEM III/A 32.5 R LH: This is a type of cement that is commonly used in construction. It is made by grinding clinker, which is a combination of limestone and other materials, and adding a small amount of gypsum to the mix. Natural Aggregate: Natural aggregate is a material that is mined from the earth, such as sand, gravel, or crushed stone. It is commonly used in construction for making concrete and asphalt. In this research, these materials are likely being used to study the properties and performance of different types of concrete mixes. By manipulating the ratios and types of materials used, researchers can determine which combinations produce the strongest and most durable concrete for various applications.

Research Stages

The experimental research procedure consists of several stages. Firstly, a small part is obtained to make it easier to form into paper pulp, and then it is cut into small pieces. Next, it is soaked for 24 hours and then dried in a ventilated oven at a temperature of 500 degrees Celsius. Once it is dried, it is blended again to obtain the desired size, and then it is homogenized and dried overnight in a ventilated oven at a temperature of 50±5° to extract excess water, followed by room temperature. The next stage involves the separation process of the paper-making process, where the aggregate is weighed after 24 hours to determine the mass variation. Portland component CEM III/A 32.5 R LH and natural aggregate in the range of 0 to 4 mm are added to the papercrete specimen to improve its quality and mechanical strength while reducing porosity. Tap water is added to the total water/cement ratio at a 1:2 ratio to enable more precise mixing. The waste paper and pulp are prepared in different volumetric ratios. Lastly, the pulp is dried at ambient temperature 20±2°C and left for 28 days under controlled conditions. It should be noted that the temperature of the fabricated mortar can affect the technical properties of the old mortar. This comprehensive experimental

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procedure allows for the characterization and improvement of the quality and mechanical strength of the papercrete specimen.

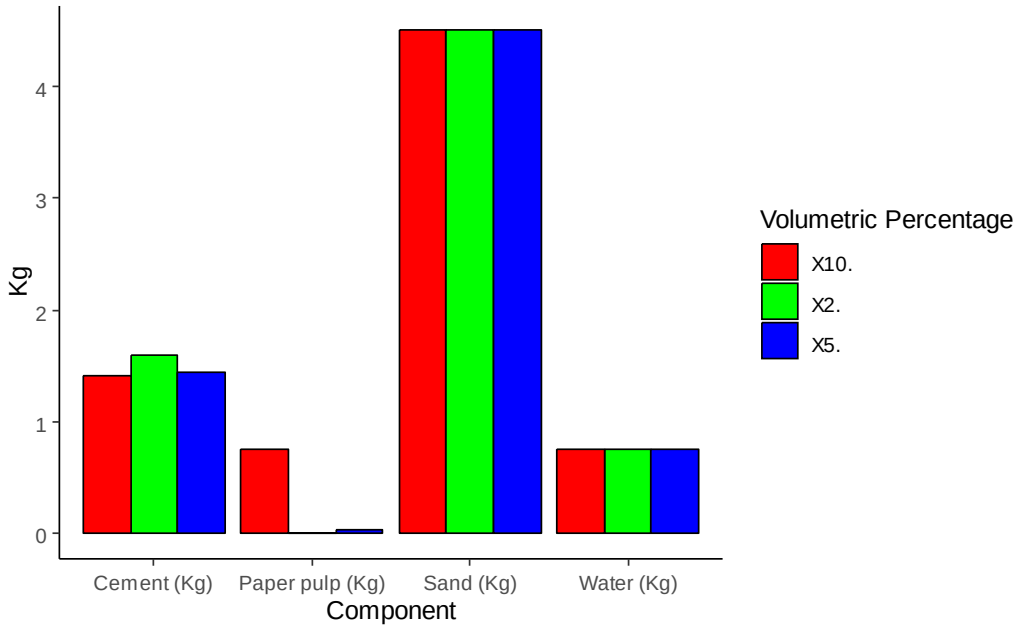

Figure 1: Proportion of components to be tested in plot

The plot visualizes the volumetric percentages of different components (Cement, Sand, Paper Pulp, and Water) in a mixture. The mixture contains different percentages of cement (2%, 5%, and 10%) and a fixed amount of sand (4.5 Kg) and water (0.75 Kg). The bar chart shows the weight (in Kg) of each component for each volumetric percentage. The bars are color-coded to represent different volumetric percentages. The plot enables us to compare the weight of each component at different volumetric percentages and identify any trends or patterns.

Table 1: Proportion of components to be tested

	Specimens			
	Reference	Volumetric Percentage		
Component		*2%*	*5%*	*10%*
Cement (Kg)	1.6	1.45	1.420	1.30
Sand (Kg)	4.5	4.5	4.5	4.5
Paper pulp (Kg)	-	0.03	0.75	0.15
Water (Kg)	0.75	0.75	0.75	0.75

Mechanical strength test

Results of the experimental experiments to measure the mechanical strength we did by testing the tensile strength and compressive strength. Instron 3369 dual column universal testing machine is one of the model testing machines for testing mortar specimens. With the results obtained, we will perform an analysis of the mechanical strength test by comparing the ratio of volumetric, pulp to classical concrete, and compressive strength to volumetric ratio which we will display in graphical form.

Thermal conductivity test

To determine the thermal conductivity, a thermal test was conducted on a sample of three test objects, each with a dimension of 300 mm × 300 mm × 20 mm. The NETZSCH HFM 436/0/1 heat flow parameter was used for single samples in multiple configurations. The samples were placed in a laboratory with a temperature of 23 ± 2°C and a relative humidity of 50 ± 5%.

Water absorption test

The absorption test was tested by performing a correlation analysis in response to the slope of the line connecting the measurement of representative points and representing the absorbent capacity of the material. The water absorption coefficient C, expressed in [kg/(m^2 x $min^{0,5}$)].

The sample will then be dried at a temperature of 600 degrees Celsius, this is equal to 200 degrees Celsius at a depth of 6 mm, which is immersed for about 6mm. by considering more linear regression points that represent the capacity of the absorbent material, it is necessary to evaluate the coefficient of C more efficiently. by calculating the weight, size at the time of the initial immersion; 10, 20, 45, 90, and 120 minutes, which is as water absorption by capillary absorption. The equation for modeling water absorption due to a capillary action is as follows:

$$A = (s\ t^{0,5} + a_0) \quad [1]$$

The physical unit for water absorbed by the unit area due to water immersion is as A [mg / mm^2], and for the adsorption capacity of the material is S [mg / (mm^2 x $min^{0,5}$)], while for t [minute] is the elapsed time in the amount of time for absorption of the pores of the specimen. With a result obtained from the absorption by the combined specimen of unit area and root of time squared, we can show a measurable relationship. we will display graphical and numerical results, one of which is linear regression, which we get from the results of experiments on the test machine. The test results that we report are also in the form of correlation coefficient R^2, absorption capillarity coefficient S, and percentage of absorption variation

RESULT

Mechanical Test

The experimental results that we have obtained are in the form of experimental research, with the output of statistical data analysis. The probabilistic method is also a method for determining the results of the

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concrete strength test, and is displayed in modern data results

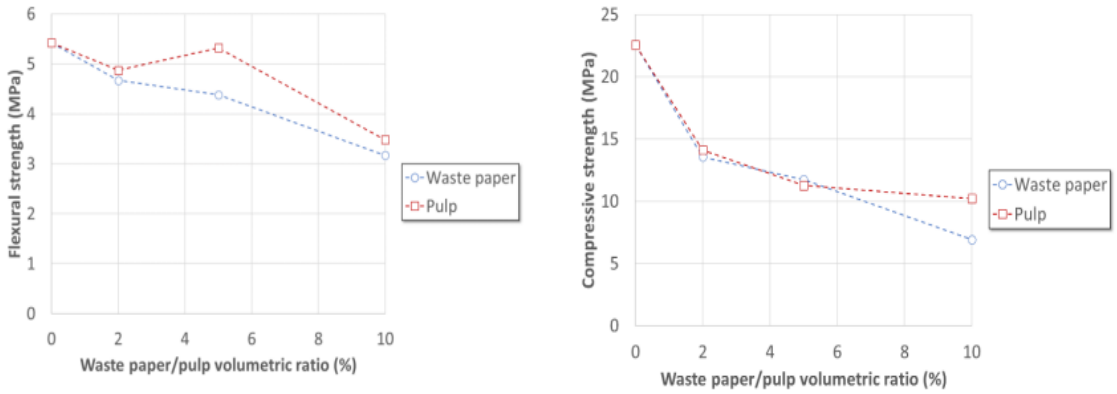

Figure 2: Comparison graph of pulp volumetric, compressive strength test results on concrete, and flexural strength test on papercrete material

As for the results we get in the graph, the flexural strength in the volumetric ratio is the same, while for the papercrete specimen it gives a higher compressive strength than the used paper sample. Based on the results of the above graph analysis, it is narratively depicted that, for the flexural strength of concrete, the compressive strength of concrete will increase with increasing volumetric ratio, but this is an exception for the PULP 5 sample.

Thermal Test

According to the analysis, the waste paper sample always has a higher volume than the pulp sample, and the area of the pores and gaps between the particles prevents the passage of heat, resulting in an inverse correlation with the thermal conductivity of the porous media. The results also indicate that an increase in the amount of recycled paper is inversely proportional to bulk density, which leads to a decrease in thermal conductivity. The analysis suggests that waste paper is more insulated than pulp at the same volumetric percentage. The thermal conductivity of a porous medium is inversely proportional to the area of the pores and gaps between the particles, which restricts the passage of heat through the medium.

Capillary Water Absorption Tests

The water absorption test conducted by the analyst revealed that an increase in recycled paper content leads to a significant rise in water absorption due to the lower density of papercrete, which permits greater water penetration into the specimen matrix, thereby creating spaces in the sample. The results showed that water absorption is inversely proportional to the density of the fiber cement. Therefore, additional layers should be added to the paper mixture to control water absorption, as concluded from the analysis results.

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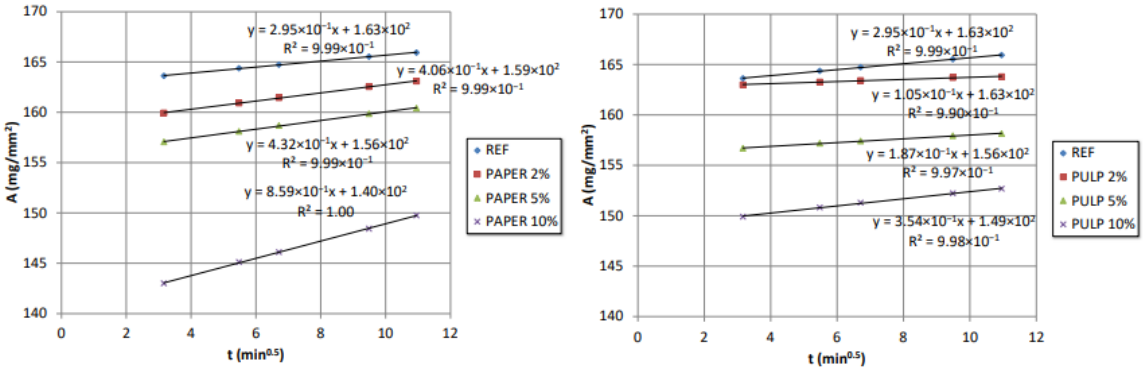

Figure 3: Capillary absorption vs. time square root

DISCUSSION

The mechanical test results of the experimental research were analyzed using statistical data analysis and probabilistic methods. The comparison graph in Figure 2 shows the volumetric ratio of pulp, compressive strength test results on concrete, and flexural strength test on papercrete material. The graph shows that the flexural strength in the volumetric ratio is consistent, but the papercrete specimen has a higher compressive strength than the used paper sample. Based on the graph analysis, it is narratively depicted that, for the flexural strength of concrete, the compressive strength of concrete will increase with increasing volumetric ratio, except for the PULP 5 sample. In the thermal test, the waste paper sample has a higher volume than the pulp sample, and the pores and gaps between the particles prevent the passage of heat, resulting in an inverse correlation with the thermal conductivity of the porous media. An increase in the amount of recycled paper is inversely proportional to bulk density, leading to a decrease in thermal conductivity. The analysis suggests that waste paper is more insulated than pulp at the same volumetric percentage. The capillary water absorption tests showed that an increase in recycled paper content leads to a significant rise in water absorption due to the lower density of papercrete, allowing greater water penetration into the specimen matrix, creating spaces in the sample. The water absorption is inversely proportional to the density of the fiber cement. Therefore, additional layers should be added to the paper mixture to control water absorption, as concluded from the analysis results shown in Figure 3.

The mechanical test results showed that papercrete has potential as an eco-friendly construction material with suitable physical and mechanical properties. The thermal and capillary water absorption tests provided insights into the insulation and water absorption properties of papercrete, which can be improved through adjustments in the mixture composition. These findings suggest that papercrete can be a sustainable construction material for reducing environmental pollution and improving the quality of life. Further research is recommended to investigate the effect of

paper chip size and humidity and temperature conditions on concrete strength and environmental impact analysis of papercrete.

CONCLUSION

In conclusion, the research findings indicate that papercrete has the potential to be a sustainable and eco-friendly construction material. The mechanical test results show that papercrete has physical and mechanical properties suitable for reinforcing brick panels, while the thermal test results demonstrate that waste paper is more insulated than pulp at the same volumetric percentage, leading to a decrease in thermal conductivity. However, the capillary water absorption test results indicate that an increase in recycled paper content leads to a significant rise in water absorption, and therefore additional layers should be added to the paper mixture to control water absorption. Based on these findings, further research is recommended to investigate the effect of paper chip size on concrete strength under different humidity and temperature conditions, and to analyze the environmental impact of using papercrete as a construction material. Additionally, testing papercrete in real-world scenarios could provide valuable insights into its durability and suitability for different applications. This research provides a promising foundation for the development of lightweight and soundproof building materials using waste paper or pulp as a component.

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