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Pre-Feasibility Evaluation of the Eco-Cooler Model Made of Waste for Hot Humid Climates

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Abstrak

Berdasarkan hasil survei yang dilakukan Kementerian ESDM pada tahun 2018 terhadap bangunan komersial, peralatan pengguna energi terbesar dari setiap bangunan komersial adalah peralatan AC dengan rata-rata penggunaan energi di atas 62%. Oleh karena itu, upaya penghematan energi terkait pendinginan ruang akan memberikan dampak yang signifikan terhadap upaya penghematan energi di dunia. Salah satu caranya dengan menggunakan metode penangkap angin yakni Eco-Cooler. Di sisi lain, berdasarkan data Sistem Informasi Pengelolaan Sampah Nasional pada tahun 2021, timbulan sampah di Indonesia mencapai 30.881.803,15 ton per tahun. Sehingga penelitian ini bertujuan untuk mencari material eco-coooler yang paling ringan dan mampu bertahan terhadap cuaca menggunakan material komposit dari limbah. Penelitian ini menggunakan metode eksperimen dengan membuat prototype eco-cooler dengan menggunakan material olahan limbah seperti serbuk kayu, tongkol jagung,plastik dan pasir. Kemudian menggunakan 2 jenis ukuran yaitu diameter outlet (D_{1A}) sebesar 40 cm, dan diameter inlet (D_{2A}) sebesar 20 cm, sedangkan ukuran kedua adalah diameter outlet (D_{1B}) adalah 30 cm, dan diameter inlet (D_{2B}) adalah 15 cm. Setelah dicetak, eco-cooler ini kemudian ditimbang dan diamati selama sebulan untuk melihat ketahanannya terhadap cuaca dimana cuaca pada saat itu cukup fluktuatif. Parameter yang diuji pada penelitian ini adalah berat material dan kekuatan faktor cuaca pada iklim tropis lembab. Dari hasil penelitian ini didapatkan bahwa eco-cooler dengan material serbuk kayu memiliki berat paling ringan yakni 16 kg untuk diameter 40 cm dan 15 kg untuk diameter 30cm. Sementara itu, untuk material yang paling berat adalah pasir dengan berat 29 kg untuk diameter 40 cm dan 23 kg untuk diameter 30 cm. Dari segi ketahanan, serbuk kayu dan pasir yang paling bertahan terhadap cuaca. Sehingga dapat disimpulkan bahwa material eco-cooler yang paling ringan dan tahan cuaca untuk iklim panas lembab adalah eco-cooler dari material serbuk kayu.

Kata Kunci: Eco-cooler, limbah, iklim tropis lembab

Abstract

Based on the results of a survey conducted by the Ministry of Energy and Mineral Resources in 2018 on commercial buildings, the largest energy-using equipment of each commercial building is air conditioning equipment with an average energy use of over 62%. Therefore, energy-saving efforts related to space cooling will have a significant impact on energy-saving efforts in the world. One way is to use the wind catcher method, namely Eco-Cooler. On the other hand, based on data from the National Waste Management Information System in 2021, waste generation in Indonesia reached 30,881,803.15 tons per year. So this research aims to find the lightest eco-cooler material that can withstand the weather using composite materials from waste. This research uses an experimental method by making an eco-cooler prototype using processed waste materials such as wood powder, corn cobs, plastic, and sand. Then 2 types of sizes, namely the outlet diameter (D1A) of 40 cm, and the inlet diameter (D2A) of 20 cm, while the second size is the outlet diameter (D1B) is 30 cm, and the inlet diameter (D2B) is 15 cm. After molding, the eco-cooler was then weighed and observed for a month to see its resistance to weather where the weather at that time was quite fluctuating. The parameters tested in this study were material weight and weather strength in the humid tropical climate. From the results of this study, it is found that the eco-cooler with sawdust material has the lightest weight of 16 kg for a diameter of 40 cm and 15 kg for a diameter of 30 cm. Meanwhile, the heaviest material is sand with a weight of 29 kg for a diameter of 40 cm and 23 kg for a diameter of 30 cm. In terms of

durability, sawdust and sand are the most resistant to weather. Therefore, it can be concluded that the lightest and most weather-resistant eco-cooler material for hot humid climates is eco-cooler from wood powder material.

Keywords: eco-cooler, waste, hot humid climate

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Introduction

Climate change has had a very broad impact on human survival. An increase in the earth's temperature causes changes in the climate system which affect changes in nature and human life as well as the quality and quantity of water, forests, health, agricultural land, and marine coastal area ecosystems (UNG, 2020).

The increase of earth's temperature causes escalation of energy consumption to meet human thermal comfort. Based on data of energy consumption by type in 2019, expenditure of electrical energy ranks 3rd at 16% of the current total energy demand. Meanwhile, through the National Energy Policy (KEN) and the Paris Agreement, the government committed to reducing greenhouse gas (GHG) emissions through the use of new and renewable energy. There are five categories of GHG emission sources, namely: energy, industrial processes and product use, agriculture, forestry, other land use changes, and waste management. Currently, developed countries have begun to set targets for achieving net zero emissions by 2050 (Agency for the Assessment and Application of Technology, 2021).

In Indonesia, Hermanto (2005) said that around 60% of hotel electricity consumption in Jakarta was used to supply AC engine energy. Based on the results of the Benchmarking Specific Energy Consumption survey conducted on commercial buildings, the most significant energy user equipment from any commercial building was air conditioning equipment, with an average energy use above 62%, followed by lights and sockets, elevators and escalators, and other electricity equipments (Kementerian ESDM, 2018). Therefore, energy-saving efforts related to room cooling will have a significant impact on energy-saving efforts in the world such as wind catcher.

Another example of an application that can be used to catch wind is Eco-Cooler. Eco-Cooler is a device consisting of a used bottle cut into two parts and the bottle lid was stuffed into a piece of cardboard. The Eco-Cooler is then installed in the window in the direction of maximum airflow so that the wider end of the bottle faces towards outside. Air passes through the bottle and is compressed as it passes through the neck of the

bottle (see fig. 1). Compressed air while leaving the mouth of the bottle will expand quickly and provide air cold. In principle, the Eco-Cooler works based on the first law of thermodynamics formula (Pratiwi & Arifin, 2021).

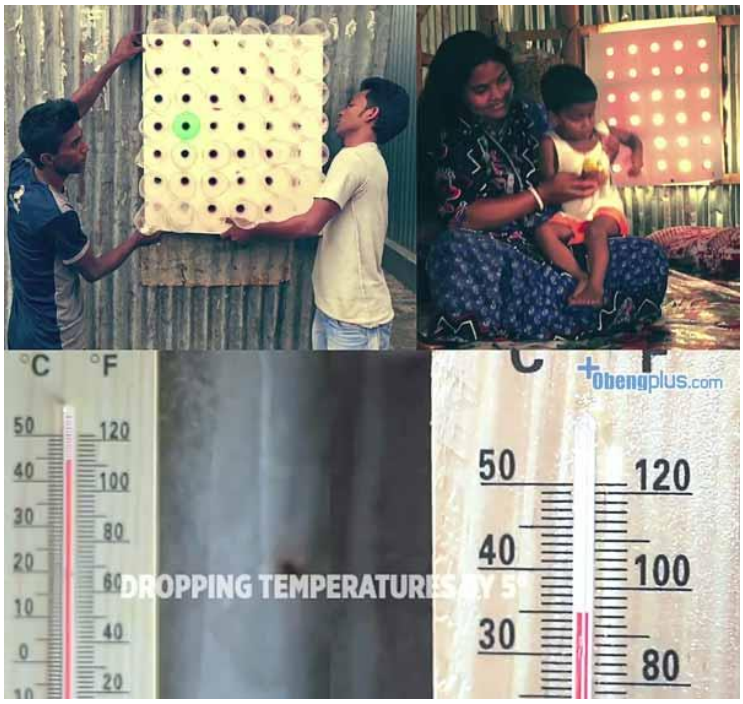

Figure 1. Eco-cooler from bottle
Source: http://obengplus.com/articles/11379/1

There were several studies related to Eco-Cooler, the results of which were as follows, Eco-Cooler was able to reduce temperatures to 5°C (Naveenkumar et al., 2018). From the numerical simulation results, the results obtained are temperatures ranging from 0.34°C which can be felt by human skin with an outlet airflow velocity of about 13 m/s (Khan et al., 2019). Of the three specimens, 4-inch inlet and 1-inch outlet diameter bottles were better than the other 2 bottles. In other words, an inlet that is larger than an outlet has a better ability (Bhanuprakash et al., 2018).

In previous studies, research has been carried out regarding the design of the Eco-Cooler model that can be applied to residential homes, and from several models that have been simulated using the Ansys application, type C has the advantage of several samples that have been tested. The simulation model C resembles a glass with an inlet (D1) of 20 cm and an outlet (D2) of 10 cm (see fig. 2). This sample has a better wind range than all models with a wind range of around 2.77 meters and a maximum minimum wind speed of around 0.499 m/s (Pratiwi & Arifin, 2021). Therefore, this model used for this research.

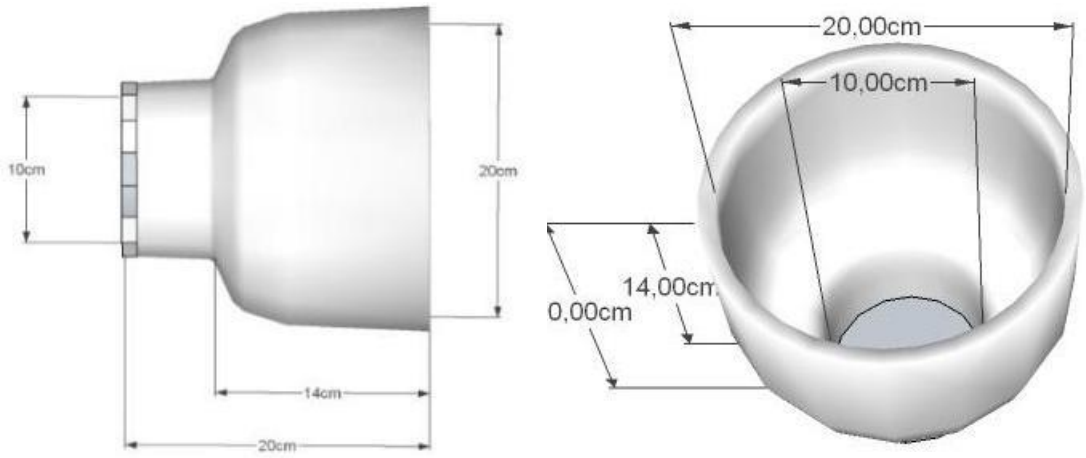

Figure *2*. Model of Eco-cooler type C

Meanwhile, based on data from the National Waste Management Information System (SIPS) in 2021, waste generation in Indonesia reached 30,881,803.15 tons/year with the composition of food waste being ranked 1st, plastic waste being ranked 2nd and wood/twig/leaf waste ranked 3rd (Sistem Informasi Pengelolaan Sampah Nasional, 2021) (fig. 3).

Food waste is food that it was not eaten. The causes are many and occur in the process of production, processing, distribution, presentation, and consumption. Waste occurs in every link from production to consumption (Dr. Sugiarto Mulyadi, 2019).

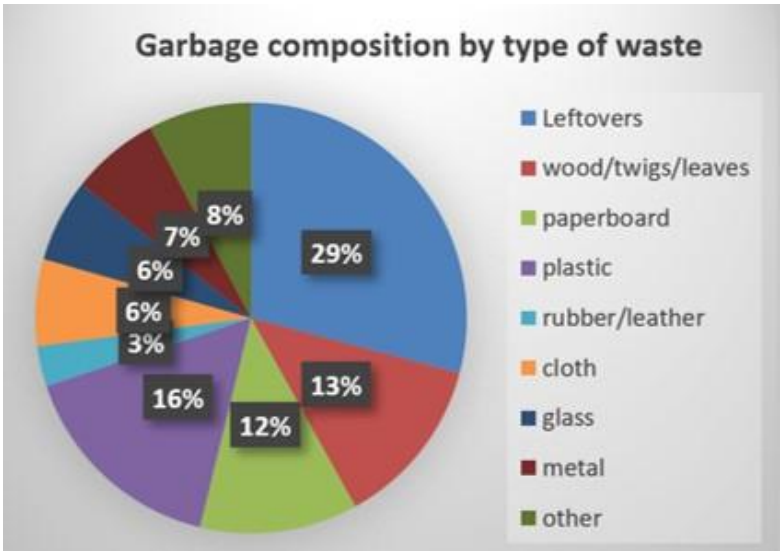

Figure 3. Garbage composition by type of waste
Source: National Waste Management Information System (SIPS) (2021)

One of the food waste is corn cobs. Corn is the leading commodity of Gorontalo Province. In recent years, the demand for corn has increased. With the increasing demand for corn, corn has an impact on the high corncob waste produced. Of course, this will cause problems for the environment. One of the sectors that have not been utilized optimally in Gorontalo is the utilization of corn cob waste which is only disposed of and burned (Siradjuddin Haluti, 2014).

Therefore, corncob waste is one of the materials that can be used, one of which is as a construction material. As for one of the studies that have been carried out related to the use of waste as a construction material, namely, in research on the use of corncob waste ash as an added material with variations in combustion temperature on the compressive strength of concrete, where the results show that this cob ash has a positive effect on increasing the value of the compressive strength of concrete (Hardiputranto et al., 2021).

The second rank is plastic waste. According to Lambert & Halliwell (2004) in (Sofiana, 2010), plastics are classified into 2 types, namely: thermoplastic and thermosetting (temperature regulator). These three types have different structures and characteristics. Thermoplastic is a type of plastic that is generally used for packaging raw materials with the types LDPE, PP, and ACETATE. The characteristics of thermoplastics can be reshaped easily and processed into other forms, which are light, energy efficient, and inexpensive. Meanwhile, the type of thermosetting, The most commonly used plastics in everyday life, are in the form of thermoplastics.

Recycled plastic has several advantages, including: (1) it has strength because this plastic can only be completely decomposed within 80 to 300 years, so its strength is not in doubt; (2) plastics are also water repellent, as they are designed to protect the product inside from air and water; (3) they have attractive designs and colors. Plastic packaging is designed to attract consumers' attention with attractive colors; (4) cheap, mostly plastic packaging is used as a wrapper or single-use packaging, so it will be thrown away when it is not used anymore. This plastic packaging waste can be obtained free of charge if you have a strategy for collecting it; (5) pliable and flexible.

Waste of wood is the remains or parts of the wood that are considered uneconomical in a certain process, time, and place but may still be used in the process, place, and different times (Widharmana, 1973). In Indonesia, three types of wood industries predominantly consume wood in relatively large quantities, namely sawing, veneer/plywood, and pulp/paper. The cause of the problem is the actual sawmill waste. In the field, there are still some that are piled up, and some are thrown into the river

(water pollution) or burned directly (contributing to increase carbon emissions in the atmosphere).

Indonesia's total sawn timber production reaches 2.6 million m3 per year (Forestry Statistics of Indonesia 1997/1998). Assuming that the amount of waste that formed 54.24 percent of the total production, sawing waste is generated as much as 1.4 million m3 per year; this number is quite large because it reaches about half of sawn timber production (I Wayan, 2016).

Several studies have used wood waste, including in Banjar Sala, Abuan Village, Susut Subdistrict, and Bangli Regency which made wood waste into acoustic bricks with a composition of 30% cement, 50% sand, and 20% sawdust so that 20% savings can be achieved with a size of 36-40 cm a thickness of 8-10 cm and a height of about 18-20 cm (Tika et al., 2017).

Another research is in the Kendal area, to be exact, UD. Dadi Mulyo, Central Java. The process of making bricks goes through 3 stages, namely the process of mixing materials, the printing process, then the drying process. The drying process of bricks takes 3-5 days depending on the conditions of sunlight (Irwan, Sukendar; Afida, 2016).

This study uses a type of composite material. Composites have been widely used in industries such as shipping and transportation for more than 50 years. However, there are several industries, composite materials have just developed into the main material chosen. The use of composite materials in the building industry is growing rapidly.

Composites are combinations of engineered materials that produce a finishing material with better overall properties than the initial constituents. Some examples of simple composites are wood. Wood is a natural composite of cellulose fibers in a lignin matrix. Engineered wood is wood fibers, strands, or veneers bonded using adhesives. Concrete is a combination of aggregates, cement, additives, and water (Moffit, 2013).

Sustainable construction includes construction methods that contribute to creativity, protect the natural environment and offer users or builders, adequate and restore it (Mohanad I. Altuma & Redvan Ghasemlounia, 2021). It is expected to become a sustainable construction material and be able to reduce the negative impact of waste which is increasing every year with a mixture of materials from waste management.

Weather factors and their changes, such as high temperatures, rainfall intensity, wind differences, and increased radiation, can affect the durability of building materials that enclose buildings. Based on this, we need materials that can adapt and have little risk of damage to these climate change factors (Phillipson et al., 2016).

Referring to these two things, namely efforts to utilize wind by using eco-coolers and efforts to utilize waste that can be applied to buildings later, the purpose of this study is to find the lightest and most weather-resistant material for eco-coolers using composite materials from waste.

Methodology

This research uses an experimental method by making a prototype eco-cooler using processed waste materials such as sawdust, corn cobs, plastic, and sand. Then use 2 types of sizes, namely the outlet diameter (D1A) of 40 cm, and the inlet diameter (D2A) of 20 cm, while the second size is the outlet diameter (D1B) which is 30 cm, and the inlet diameter (D2B) is 15 cm as shown in table 1 and figure 4.

Table 1. Type of Eco-Cooler

No.	Type	Dimension (cm)			
		a	b	c	d
1.	D_A	40	20	14	20
2.	D_B	30	15	14	20

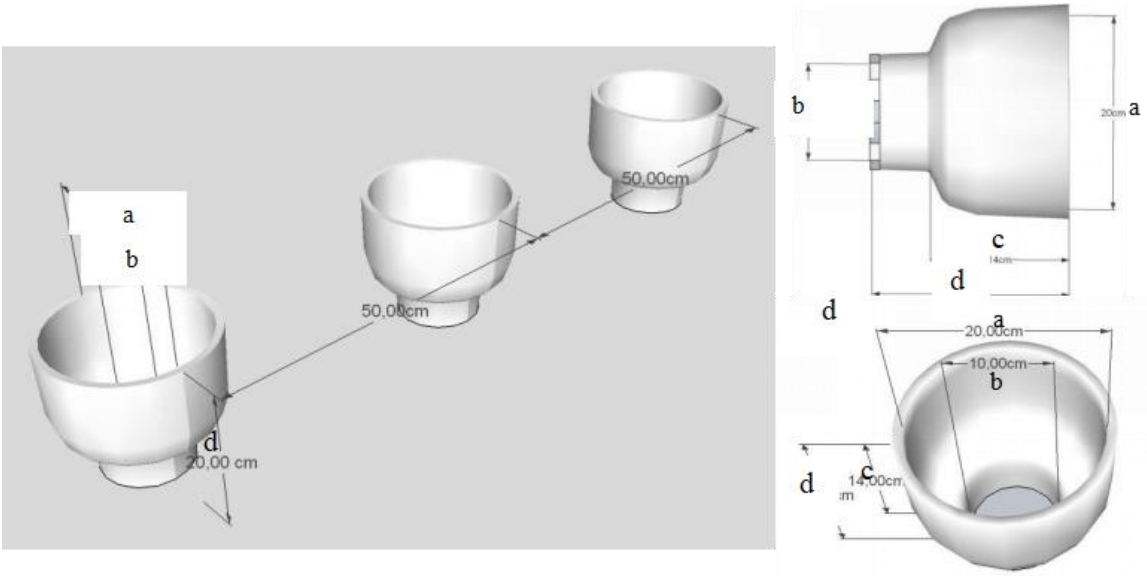

Figure 4. Dimension of Eco-Cooler

Each material namely sawdust, corn cobs and plastic were finished using lightweight concrete. Then, the three materials are juxtaposed with the material that is generally used in making vents (roster), namely sand. The sizes and materials used can be seen in Table 2 and Figure 5, then measured using a scale, as shown in Figure 6. The parameters to be tested are the weight of the material and the strength of the weather factor in a humid tropical climate.

Table 2. Size and type of materials

No	Material	Material Size			
		D_{1A}	D_{2A}	D_{1B}	D_{2B}
1	Sawdust	40	20	30	15
2	Corncobs	40	20	30	15
3	Plastics	40	20	30	15
4	Sand	40	20	30	15

Material Preparation

1. To get an overview and general knowledge, the steps taken are to collect as much information about sawdust, plastic waste, and corncob waste as possible.

2. Data collection:

a. Searching for information about sawdust from furniture, plastic waste, and corn cob waste.

b. Determining the amount of material to be used

c. Collecting data related to Gorontalo weather data for a month during the measurement process

3. Manufacture of Eco-Cooler type C molds with 2 sizes.

The previously used waste materials were chopped or mashed first and then mixed with the white cement material.

4. Data processing and analysis.

Testing the Eco-Cooler models based on the weight of the material compared to the four selected materials, as shown in table 2. Then, the results of the prototype were observed for 4 weeks to see the resistance of each material to weather factors in a humid tropical climate. In observing changes in the physical material, it is juxtaposed with weather data obtained from the BMKG 2022 data specifically for the Gorontalo City.

There are 2 variable in making eco-cooler molds, namely dependent variable and independent variable. The dependent variable is the amount of material used, where it needs 2 buckets for each outlet diameter of 40 cm, while for a diameter of 30 cm is only a bucket. Then the independent variable is the weight material. The composition of used materials can be see in table 3.

Table 3. Composition of used material

No	Size of Molds	Quantity (bucket)			Mixed Materials
		Plastic	Sawdust	Corncobs	
1	Diameter (40 cm)	2	2	2	White cement, A plus and used materials
2	Diameter (30 cm)	1	1	1	White cement, A plus and used materials

Figure 5. Used Materials (1) Sawdust, (2) Plastics, (3) Corncobs, (4) Sand

Figure 6. Measure tool

Data collection techniques and data analysis

Data were collected by (1) measuring the weight of the eco-cooler prototypes based on the material, and (2) observing the physical changes of the material for a month to see the weather resistance for each eco-cooler of the selected material. Meanwhile to observe changes in the physical material, it is compared with weather data obtained from the BMKG 2022 data specifically for the Gorontalo City location.

Results and Discussion

Results

Weather data is taken from BMKG Gorontalo, Djalaluddin Gorontalo airport station, with a range of 16 September 2022 - 16 October 2022 (BMKG Gorontalo, n.d.). This data was taken to determine the weather conditions of Gorontalo for a month during the measurement process and associated with the results of observations of the printed material.From the results of the weather data, it was found that in a month during the measurement process, Gorontalo's weather was quite volatile, with an average minimum temperature of 23.6°C, an average maximum temperature of 33.1°C and an average temperature of 27.3°C. °C, the average humidity reaches 84.9%, with 6.8 mm of rainfall, 5.7 hours of irradiation, and an average wind speed of 1.6 m/s.

Based on these data, it can be concluded that the weather during the month during the measurement process it fluctuated that it has a large risk impact that can damage building materials. This can be seen from the high rainfall and high humidity. And even so, the air temperature remains high until it reaches an average maximum temperature of 33.1°C as shown in table 4.

Table 4. Weather parameters

No	Indicator	Average Value
1	Temperature minimum (°C)	23.6
2	Temperature maximum (°C)	33.1
3	Average of temperature (°C)	27.3
4	Average of humidity (%)	84.9
5	Rainfall (mm)	6.8
6	Duration of sunshine (hours)	5.7
7	Average wind speed (m/s)	1.6

From these results, it was found that of all materials used for both types of sizes was found that sawdust material has the lightest weight compared to other materials, meanwhile sand is the heaviest material (see table 5).


Figure 7. The weight measurement process

Table 5. Eco cooler's weight based on type of material used

No	Size of molds	Materials			
		Plastic	Sawdust	Corncobs	Sand
1	Diameter (40 cm)	26 kg	16 kg	27 kg	29 kg
2	Diameter (30 cm)	17 kg	15 kg	21 kg	23 kg

Meanwhile, based on the results of observations made for a month on the eco-cooler prototype for the four materials, it was found that the materials whose sturdy and strong to use were sawdust and sand, as shown in Table 6.

Discussion

From the result of this study, it was found that the eco-cooler with sawdust material had the lightest weight of 16 kg for a diameter of 40 cm and 15 kg for a diameter of 30 cm. Meanwhile, the heaviest material is sand with a weight of 29 kg for a diameter of 40 cm and 23 kg for a diameter of 30 cm. Therefore, in terms of the building structure, an eco-cooler with sawdust material is the least burdening on building construction structures, and sand materials are the most burdensome for building construction

structures. This is to research that has been done previously that lighter materials make the dimensions of beams, columns, and foundations smaller than the general material (Vigiantiningsih, n.d.).

Table 6. Observation result for a month

No.	Eco-Cooler's Model	Materials	Conditon after a month
1	D30M1	Corncobs	Smudges appear on the surface
2	D30M2	Plastic	Slightly cracked
3	D30M3	Sawdust	Solid and strong
4	D30M3	Sand	Solid and strong
5	D40M1	Plastic	Slightly cracked
6	D40M2	Sand	Solid and strong
7	D40M3	Sawdust	Smudges appear on the surface
8	D40M4	Sawdust	Solid and strong

Then from the results of observations made for a month, it was found that the eco-cooler with sawdust material is a material that is still sturdy and strong even though it faces the quite fluctuating weather in Gorontalo. Then, in this case, the sawdust material supports research that states to overcome the risks due to climate or weather, a material that can adapt and has a small risk of damage to these climate change factors is needed (Phillipson et al., 2016).

Figure 8. The results of Eco-cooler type D40 for a month

Figure 9. The results of Eco-cooler type D30 for a month

Conclusion

Based on results, the data of the weight measurement and observations made for a month, the material from sawdust has the lightest weight of 16 kg for diameter of 40 cm and 15 kg for a diameter of 30 cm. Meanwhile, the heaviest material is sand with a weight of 29 kg in diameter 40 cm, and 23 kg with a diameter of 30 cm. So, in terms of the building structure, the material is the least burdensome sawdust building construction structures, than materials sand weighs the most on the structure building construction. Meanwhile for durability aspect, from the results of the observations for a month, sawdust material and sand are the most resistant to factor weather.

Therefore, it can be concluded that the most lightweight and weather-resistant eco-cooler material for a humid tropical climate is an eco-cooler with sawdust material. So that in the future, this eco-cooler with sawdust material can be carried out for further testing.

Acknowledgment

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