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FIELD EXPERIMENTATION ON WALL SURFACE TEMPERATURE WITH FABA BRICK IN HOT CONDITIONS

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Abstract. The processing of coal waste into building materials from *fly ash bottom ash* has been stipulated in Regulation number 22 of 2021 as Non-Hazardous material, with a note that the management requirements must still meet the standards and technical requirements set out and listed in the environmental document approval. Previous studiesstated that one of the physical characteristics of the use of this waste (*fly ash bottom ash*) can be in improving the quality of construction materials and environmental quality. The research questions of this study are: Does the facing east orientation quantitatively receiving more heat of the morning sun than other orientations? Does FABA brick walls affect the indoor thermal performance? The wall surface temperature measurement is carried out by the field experimentation with extreme climatic conditions, both sunny and rainy weather in 2021. The results of this study found that the surface temperature profile of the brick wall oriented to the east in sunny rainy/cold weather is cooler 2 % compared to the temperature on the western side. The wall surface temperature profile in the morning is 25% warmer than the ambient air temperature in sunny weather and 9% cooler in rainy weather. wall material with FABA brick proves that the orientation, location and character of the microclimate are significant to the thermal value.

Keywords : fly ash and bottom ash bricks, wall surface temperature, field research

1. INTRODUCTION

Coal waste material composed of *Fly Ash Bottom Ash* (FABA) is classified as hazardous waste, but after special handling, the Government finally made Regulation Number 22 of 2021 (Organization of Environmental Protection and Management), that *fly ash bottom ash* is now included in Non-Hazardous Waste [1]. As a study of Ageng et al [2], informed that the use *fly ash bottom ash* in several other countries with very supportive regulations, finally obtained a condition of achievement of using fly ash bottom ash up to 97%. It is said that the use of *Fly Ash* has been successfully used in the construction industry since more than 50 years but so far its application is still limited due to the lack of understanding about the characteristics of *Fly Ash* itself and the properties of concrete containing *Fly Ash*.

In its development, the by-product of coal combustion or the amount of *fly ash bottom ash* (FABA) is quite large. According to Antoni [3], the quality of *fly ash* depends on the source of power generation. For new ash sources, it is better than old or accumulated ash sources. Rapid utilization of this waste can be said to have a smaller environmental impact in ecosystem..

Products from the combustion of every one tonne of coal carried out by steam-electric power station produce around 15% - 17% *fly ash bottom ash*, as stated by the Ministry of Environment and Forestry of the Republic of Indonesia (KLHK). The physical character of *Fly Ash* is a fine powder with pozzolanic properties. This property is in the form of a material that has a low Calcium Oxide content, so it does not have a binding ability [4]. *Fly ash bottom ash* from a steam-electric power station activity is categorized as non-hazardous waste, but the management requirements must still meet the standards and technical requirements set out and

listed in the environmental document approval. As for *Bottom Ash* , it has a larger size than *Fly Ash*, which makes it easier for *Bottom Ash* to fall to the bottom of the furnace. Bottom Ash is shaped like river sand but with a coarser texture. On the basis of these characteristics, it is the background to study the position of replacing clay by this material in the manufacture of bricks [5].

Nurul et al., [6] took a closer look at the effect of using building materials made with *fly ash bottom ash* on their environmental effects. The characteristics of the chemical elements in *fly ash bottom ash* which are strongly bonded to cement (made into a concrete mixture), it turns out that it is difficult to wash or leached, especially when this material is used for outer walls and is exposed to the sun's heat, it is confirmed that it does not cause problems to the environment.

And the progress of utilizing *fly ash bottom ash* in the world of building construction, by Maja et al [7], it is said that the use *fly ash bottom ash* is very safe for construction materials and adhesives in building materials. According to Tiwai [8], Fly Ash is also suitable for use as a raw material in various industries because it is a material rich in oxides. And it was emphasized again by Norhaliza [9] [10], that fly ash bottom ash can not only be used as a main ingredient or mixed material in building construction, but can also be used in brick making, ceramics, road construction, concrete production and construction. other activities. Several alternative types of *fly ash bottom ash* have been developed by the Paiton steam-electric power station.

Listening to the notes from Fauzi et al [11] that *Fly Ash* in the construction industry is not a new technology but is a developing technology in improving construction quality and environmental quality. The addition *Fly Ash* to concrete provides economic, ecological and technical benefits. Concrete that has been mixed *with Fly Ash* which was tested in extreme cold weather has elasticity or resistance of 78 – 91 out of a scale of 100, because it has a relatively low dynamic elasticity so that it has better durability [12]. Meanwhile, bricks with a mixture of *fly ash bottom ash* have better water absorption of 0.3 - 6.1% compared to bricks without a mixture of *fly ash bottom ash* and have fire resistance of up to 30% [13].

From the previous studies [2, 3, 10, 15] and results of our previous preliminary study [14] showed that building materials with *fly ash bottom ash* have so far been categorized as environmentally friendly materials. As stated in the background that the status of fly ash bottom ash in particular and as a building material has been confirmed by Government regulations. In the application of building design with an approach to the concept of Green or Environmentally Friendly Building, it is stated that one of the parameters is the aspect of recycling waste materials and the thermal/temperature effect of using the material in order to create a comfortable and safe interior environment/ambience [16,17,18]. Thus, many studies related to concrete using waste materials have been carried out [19,20]. In the world of architecture/building design, as stated by Prianto in 2007, that tropical buildings that accommodate local materials/local wisdom are a form of concern for the realm of engineering in the issue of global warming [21]. So the question in the research that we will examine is "How far is the thermal character of the wall material in the form of fly ash bottom ash in the extreme conditions of the microclimate in the field directly? and how far is the difference in the orientation of the placement of the wall material to its thermal value?". And in this study, we have obtained brick material made from this coal waste, which has so far been developed by the Paiton steam-electric power station.

2. METHODS

This section explain the object of research, what tools are used for research and also the stages of the process of measuring the object of research.

2.1 Research Object

First, brick wall *material fly ash bottom ash* that has been processed/printed with certain dimensions (40x20x10cm) at the Java-Bali Steam Power Plant (steam-electric power station) Paiton, Probolinggo, East Java (see figure 1).brick units *fly ash bottom ash* are arranged into a wall with a size of 1.00m x 1.00m x 0.1m. Due to the implementation of this further research being constrained by the progress and in the era of the COVID-19 pandemic, the implementation was carried out in the area closest to the researcher on St. Akper, Bangkinang City District, Kampar Regency, Riau City (0°17'11.3" North Latitude 101°01 '44.0" East Longitude). Third, the object that has been formed into a block of brick wall is placed in an area/field that is free from obstructions, with the intention that the object can be exposed to sunlight from morning to evening optimally. (see figure 2).

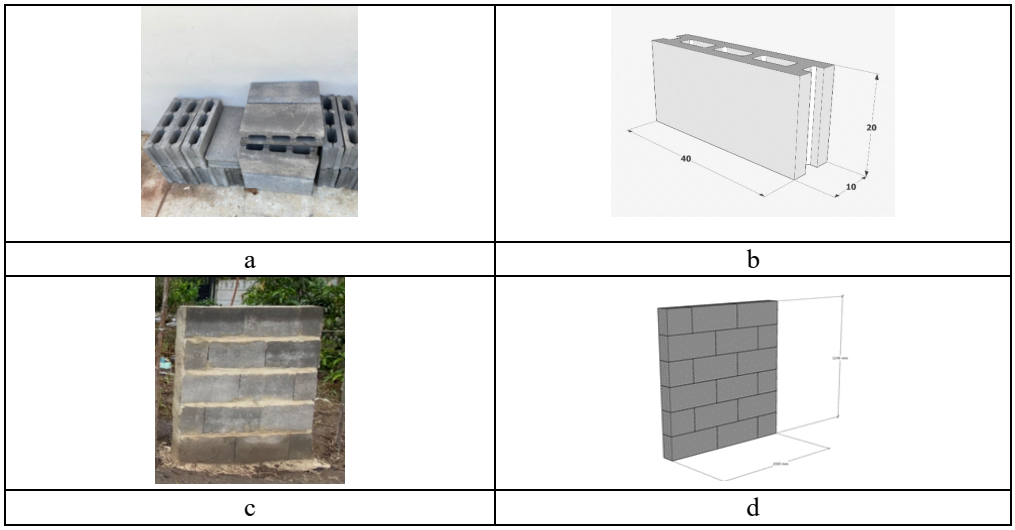
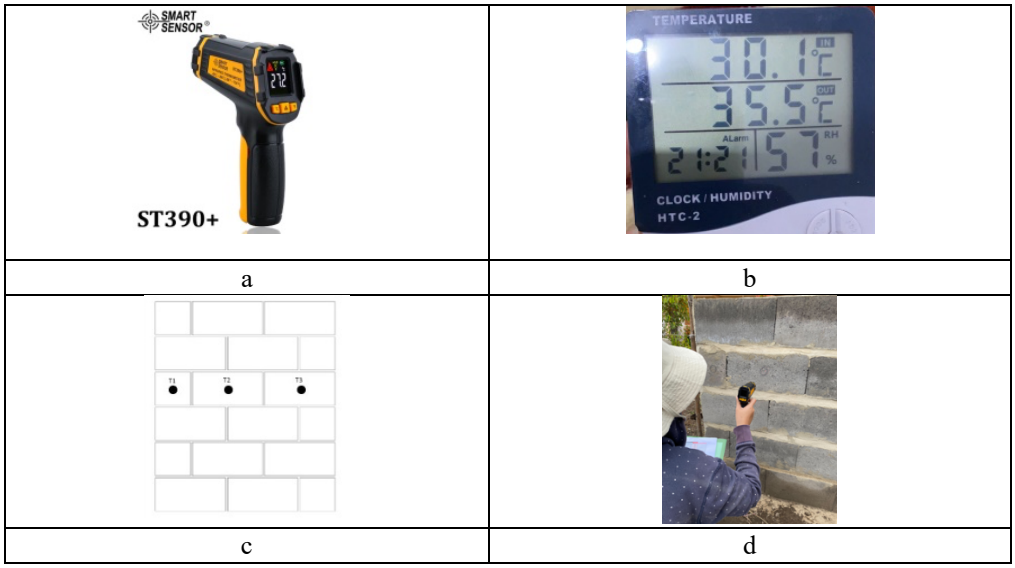


Figure 1. (a,b) Object and unit dimension sketches of *fly ash bottom ash* bricks and (c, d) Illustration of *fly ash bottom ash*

Figure 2. Visualization of objects facing east (b) Visualization of the object facing west (c) Situation of the research location in the city of Riau

2.2 Measurement Tools

There are two principal measuring instruments used in this observation, namely the Infrared Thermometer S7391 measuring instrument used to measure the wall surface temperature. And a digital thermometer is used to determine the air temperature and humidity of the environment around the test object.



a b

c d

Figure 3. (a, b) Measuring tools used and (c, d) Position of measuring points

2.3 Stages of Measurement

First, After the block units are arranged into a wall area measuring 1.00m x 1.00m, which is composed of 5 layers with 2.5 bricks for each layer, and their position is facing the exact East-West orientation (front side and back side of the wall), then a sample of 3 (three) measuring point positions is determined, both at the front of the wall and 3 measuring point positions at the back.

Second, at each measuring point, manual infrared shots were fired 3 times with a duration ranging from 10-15 seconds/shot and taken at 60 minute intervals from 06.00am to 18.00pm.

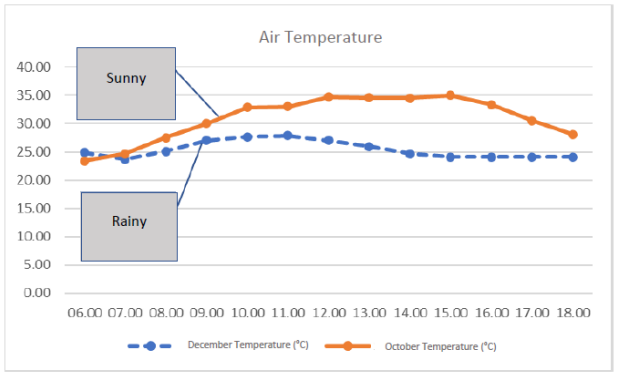
Third, three measurement data (wall surface temperature, ambient air temperature and humidity) were obtained in two extreme conditions (hot weather and rainy weather). Hot weather was presented on the measurement on October 13, 2021 and rainy weather was presented on December 13, 2021.

Fourth, after all the measurement results were tabulated, this data was then analyzed partially (each time period) and compared the two conditions so that it was obtained answer to this researcher's question.

3. RESULTS AND DISCUSSION

The scope of this research is limited to the microclimate of a location, because as we all know that this parameter has a very significant effect on the value of the results of field measurements (in-situ). Likewise with differences in location characters (object placement based on cardinal orientations) and the choice of measurement method that is carried out directly in the field, from various related studies so far it will be obtained the diversity and dynamics of the measurement results, so the choice of this method is very wide open for development. That's the method we chose to enrich our knowledge base in general and in particular related to material exploration from fly ash bottom ash in general or in particular to fly ash bottom ash bricks from the Paiton steam-electric power station production.

Hot weather conditions in the city of Riau in this case are represented by in-situ (field) measurements in October 2021, while cold/rainy weather conditions are represented by measurements in December 2021 this year. The pattern of this discussion is divided into two parts. The first part is related to the relationship between the microclimate profile of the city of Riau with the microclimate from around the location. And the second part is a specific discussion of the wall surface temperature profile of *fly ash bottom ash*.



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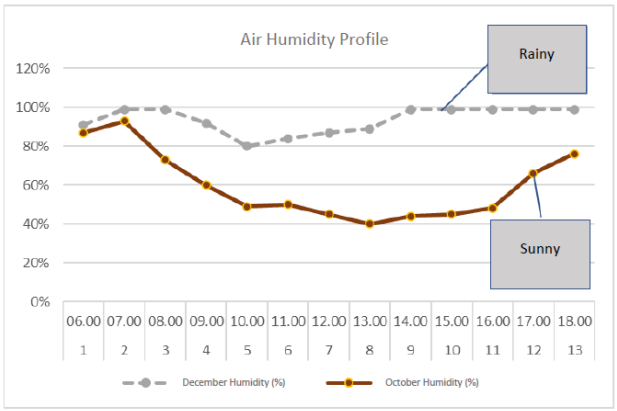


b

Figure 4. (a) Microclimate at the test site location in Riau city (b) Humidity profile

3.1 Measurements on sunny weather in October

1) Profile of air temperature and humidity in Riau city and microclimate of the measurement location.

The initial description related to the microclimate, we can convey first, that the difference in the average air temperature of Bangkinang District, Riau City according to Meteorological data (during October 2021, ranging from 23°C to 31°C [22], there are measurement data around the location there is no significant difference. The same thing happened to the profile of the data measuring the humidity of the air. The weather conditions in the measurements taken on October 13, we can assume the weather conditions are sunny or hot.

2) The wall surface temperature profile is between orientation to the east and West.

Based on the results of measurements of the surface temperature of the brick wall facing east, it has an average surface temperature of 40.2 °C, or a maximum temperature of around 47.6 °C which occurs at 10.00am and a minimum surface temperature of 20.2 °C. which happened at 06.00am. While the surface temperature profile of the brick wall facing west, has an average surface temperature of 37.6°C, or a maximum temperature condition of about 51.6°C which occurs at 15.00pm and a minimum surface temperature of 20.1°C which occurs at 06.00am (see figure 5). This graph also shows a condition of the average difference of the wall profiles in different directions, where there is a difference of 2.56°C or 2.8% cooler back wall/orientation to the west.

3) Wall surface temperature profile between morning session and afternoon session.

The graph in Figure 6 shows more detail regarding the temperature profile of the wall surface based on two different observation times, namely observations in the morning time range (06.00am-12.00pm) and afternoon time range (12.00pm-18.00pm). Where, both in the morning and during the day, the position of the wall surface temperature is above the average exterior air temperature / ambient air temperature.

a) Study of wall surface temperature in the morning against ambient air

The average temperature of the front wall surface in the morning has a difference of 25% (from 29.46°C to 39.49°C) hotter than the ambient air temperature . And the average back temperature is only 7% (from 29.46°C to 31.7°C). While the difference in temperature between the front and rear wall surfaces, has a difference of 25% hotter for the front.

b) Study of wall surface temperature during the day against ambient air temperature.

Meanwhile, during the day, the average front wall surface temperature has a difference of 20% (from 32.97°C to 41.43°C) hotter than the air temperature. environment. And the average temperature of the back reaches 26% (from 32.97°C to 44.33°C). While the difference in temperature between the surface of the wall, has a difference of 7% hotter for the back.

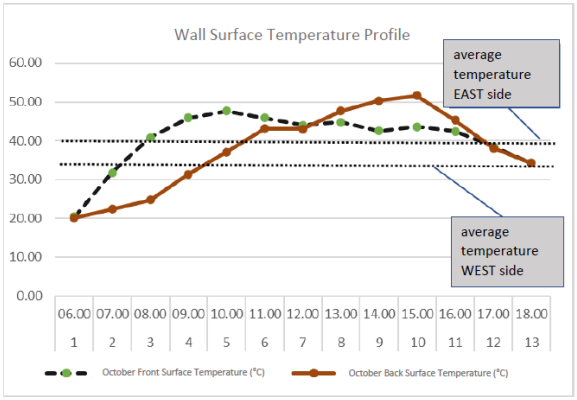
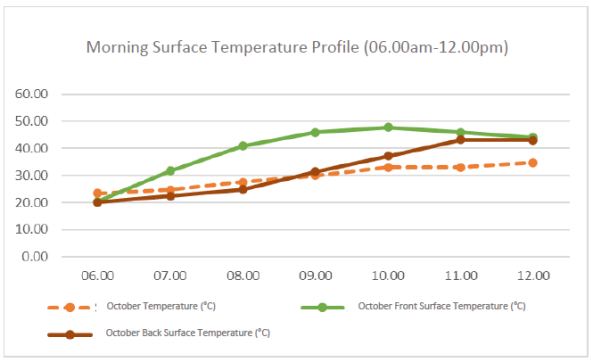


Figure 5. Surface temperature profile of *fly ash bottom ash* in a sunny atmosphere (October 2021)



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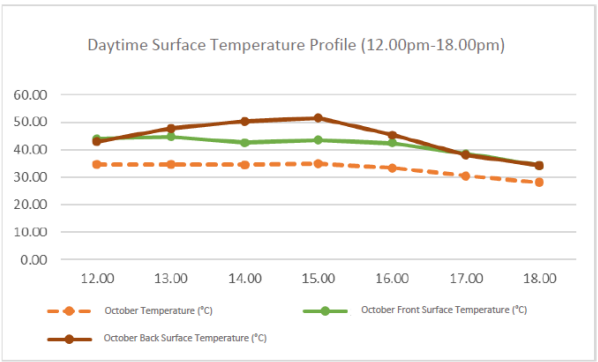

b

Figure 6. Surface temperature profile of fly ash bottom ash in sunny conditions (a) measurements in the morning (06.00am-12.00pm), (b) measurements during the day (12.00pm-18.00pm)

3.2 Measurements on rainy weather in December

1) Profiles of air temperature and humidity in the city of Riau and the microclimate of the measurement location.

From the Meteorological data on the weatherspark page, it was noted that in December, the air temperature ranged from 23°C to 30°C which was not much different from the data in December [21].

2) Wall surface temperature profile between orientation to East and West.

Brick wall fly ash bottom ash in rainy/wet conditions, the results of measuring the surface temperature of the bricks facing east/forward were still measured, where the average surface temperature was 23.7°C, and conditions the maximum temperature reached 27.7°C which occurred at 10.00am, and the minimum average surface temperature of 20.1°C which occurred at 06.00am. While the surface temperature profile of the brick wall facing west, has an average surface temperature of 24.2°C, or a maximum temperature condition of about 28.7 °C which occurs at 10.00am and a minimum surface temperature of 20.7 °C which occurs at 06.00am (see figure 7). This graph also shows the condition of the average difference of the wall profiles in different directions, where there is a difference of 0.49°C or 2% colder the wall on the front/east direction. This is inversely proportional to the same conditions in the October measurement.

3) Wall surface temperature profile between morning session and afternoon session.

The graph in Figure 08 shows the wall surface temperature profile based on two different observation times, namely observations in the morning time range (06.00am-12.00pm) and afternoon time range (12.00pm-18.00pm) as was done in the data study in October. However, the graph also shows the opposite condition compared to the general conditions in the measurements in October, that both in the morning and afternoon conditions, the position of the wall surface temperature is below the average exterior air temperature / ambient air temperature.

a) Study of wall surface temperature in the morning against ambient air

The average front/eastern wall surface temperature is 9% different (from 26.19°C to 23.93°C) cooler than the ambient air temperature. And the average temperature of the back is only 6% (from 26.19 °C to 24.73 °C). While the difference in temperature between the surface of the wall between the front and back, has a difference of 3% hotter for the front.

b) Study of wall surface temperature during the day against ambient air

Meanwhile, the average front wall surface temperature has a difference of 5% (from 24.87°C to 23.72°C) which is cooler than the ambient air temperature. And the average temperature of the back is only 4% (from 24.87°C to 23.98°C). Meanwhile, the difference in temperature between the front and rear wall surfaces, has a difference of 1% hotter for the back.

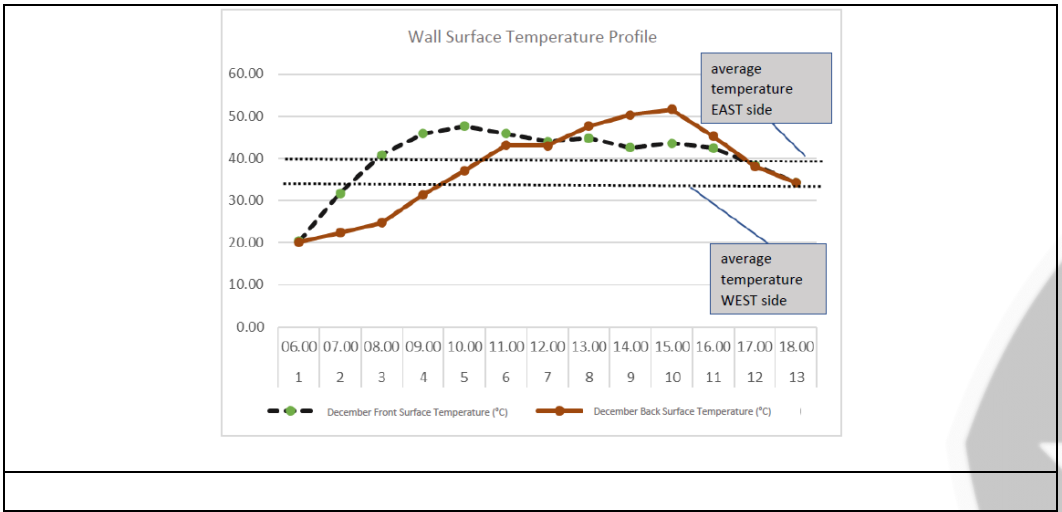

Figure 7. Surface temperature profile of *fly ash bottom ash* in rainy conditions (December 2021)

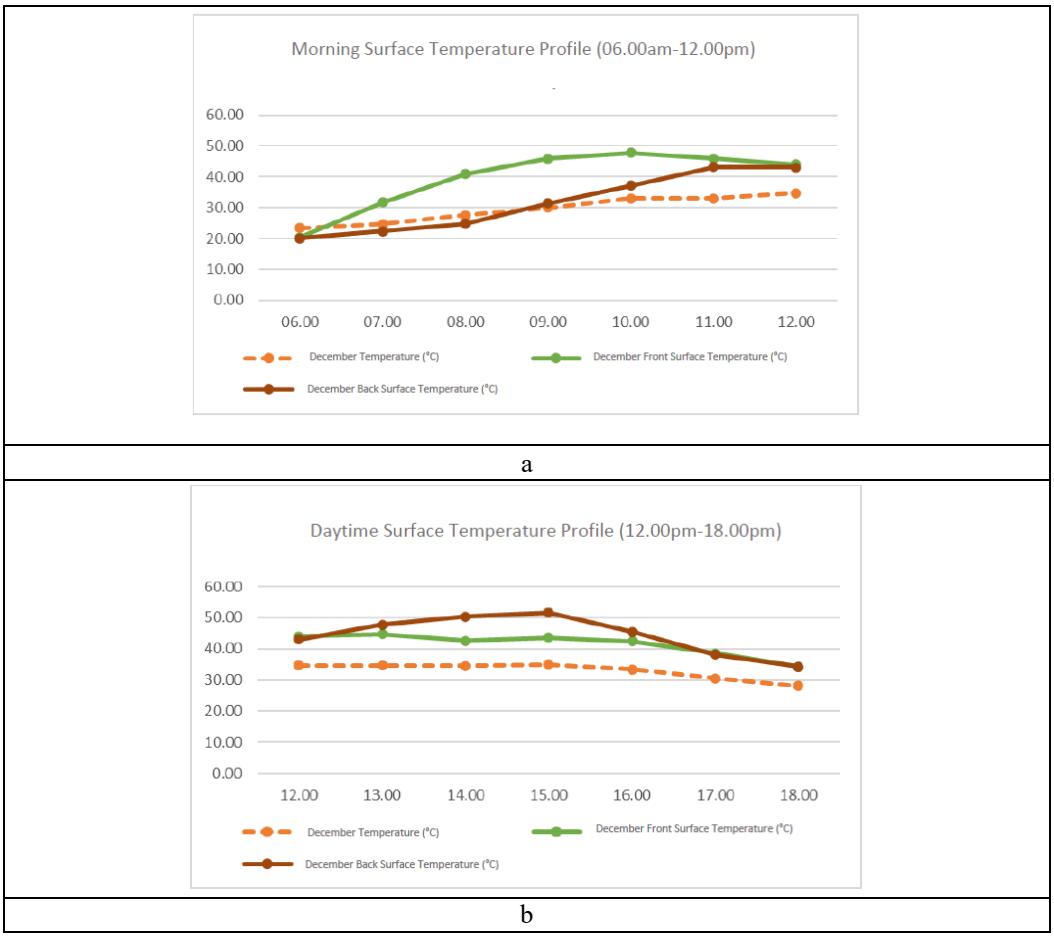

Figure 8. Surface temperature profile of *fly ash bottom ash* in rainy conditions (a) measurement in the morning (06.00am-12.00pm), (b) measurements during the day (12.00pm-18.00pm)

3.3 Characteristics of Comparison of Profiles of Average Surface Temperature of ash bottom ash between Two Different Weathers.

In this section, we will compare the two surface temperature profiles of *fly ash bottom ash* between observations of hot/sunny conditions and cold/rainy conditions. We can see this in Figure 9 below.

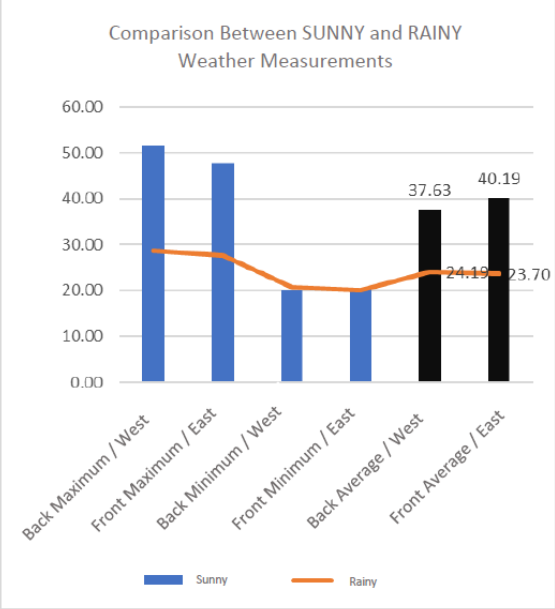

Figure 9. Comparison of measurements between sunny and rainy conditions

First, the maximum temperature comparison profile of the *fly ash bottom ash* brick wall on the Back / West in sunny atmosphere is much higher / hot than in rainy atmosphere, which has a difference of 79.5% hotter. Second, the comparison profile for the front wall, although it only has a difference of 72.1%. But the minimum temperature comparison profile of this brick wall on the Back / West and front / East in the SUNNY atmosphere is slightly lower than in the RAINY atmosphere, that is. It has a difference of 3.3% and 1%. And Third, Comparison of average surface temperatures, the graph shows that the value of the surface temperature of the wall in SUNNY weather has a higher position / heat than rainy weather by 55.6% for the West and 69.6% for the East.

Diagramanicly the value of the amount of surface temperature of the brick wall *fly ash bottom ash* in two different weather conditions can be seen in the following table. Where in his understanding that the positive value (+) in table 01 reads a condition of the situation becomes colder and vice versa for the value (-).

Table 1. Nilai Presentase Perbedaan Selisih dari Kondisi Pengukuran Pada Cuaca Cerah ke Cuaca Hujan

	Temperature (°C)	Humidity (%)	Front Facade Temperature(°C)	Back Facade Temperature(°C)
Maximum Difference	20.3%	-6.5%	41.9%	44.3%
Minimun Difference	-1.3%	-100.0%	1.0%	-3.4%
Average Difference	17.9%	-56.7%	41.0%	35,7%

4. CONCLUSION

4.1 Conclusion

Based on the results of research and data analysis that has been implemented, it can be concluded some points as follows:

A) Some notes from measurements in sunny air (lots of sunlight)

The average surface temperature profile of east-oriented walls is 2.8% warmer than west-oriented walls. The average surface temperature profile in the morning session for the front/east is 25% warmer than the ambient air temperature. And for the wall on the back is only 7%. While the difference between the surface temperature of the front and rear walls is a difference of 25% hotter for the front. The average surface temperature profile during the daytime session for the front/east is 20% hotter than the ambient air temperature. And for the wall on the back it reaches 26%. While the difference between the surface temperature of the front and rear walls is 7% hotter for the back.

B) The following is a note from measurements on rainy air (lots of rainfall)

The average profile of the surface temperature of the east-oriented walls is 2% cooler than the west-oriented walls. The average surface temperature profile in the morning session for the front/east is 9% cooler than the ambient air temperature. And for the wall on the back is only 6%. While the difference between the surface temperature of the front and rear walls is a difference of 3% hotter for the front. The average surface temperature profile during the daytime session for the front/east is 5% cooler than the ambient air temperature. And for the wall on the back reaches 4%. While the difference between the surface temperature of the front and rear walls is 1% hotter for the back.

The characteristics of the wall surface temperature comparison between measurements in sunny conditions have a higher/hot position than measurements in rainy weather, namely there is a difference of 55.6% for the West and 69.6% for the East. From the study above, in response to the results of Nurul's study [3], that the character of this fly ash bottom ash will reduce its environmental impact when it is optimally positioned in the sun, and from our measurement results, where the object is measured at different weather conditions (rainy days and hot days) and different orientations (orientation to the east and west), finally we can recommend that the use of dominating fly ash bottom ash (eg for the main faade of buildings) should be positioned towards the EAST for a hot area location (eg. for buildings in coastal cities). And vice versa, positioned towards the WEST for cold areas (eg buildings in mountainous areas).

4.2 Suggestion

Based on the conclusion,the suggestion or recommendation from this research is as follows:

1. First, a direct measurement result in the field so that it can represent the humid tropics, with the case in Riau City, it should be equipped with a measurement time that represents summer conditions (range from June to August, generally has an average air temperature range between 24°C to 34°C) and rainy season conditions (range from December to February, generally have an average air temperature range between 23°C). C to 31°C).
2. Second, optimization of the value of measuring the surface temperature of the fly ash bottom ash brick wall, and also measured on the diversity of wall orientation according to the direction of the wind. When in this case, it is carried out on the orianation facing East and West, with the result that the hottest value is obtained in the orientation to the East, both in the hot musin (October measurement) and the rainy season (December measurement), what about the direction of orientation of other buildings? For this reason, one of the research object facilities in the form of a model house developed in the Technic Faculty Building Technology laboratory of Diponegoro University, the building is placed on a rotary rail.
3. Third, for the closer benefit of the needs of the broad community reel (not just academic study / theoretical development), then it would be nice for the measurement results to be compared also with the position of the object covered by the roof, even if possible an object with a scale of 1: 1.

5. ACKNOWLEDGEMENT

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