Insulated Metal Sheet Roofing

Raymundo V. Romero[1], Nelson V. Romero[2], Fe B. Romero[3]

*[1]*College of Engineering, Partido State University, Goa, Camarines Sur, Philippines, [2]College of Engineering, Partido State University, Goa, Camarines Sur Philippines, [3]College of Education, Partido State University, Goa, Camarines Sur, Philippines*

ARTICLE INFORMATION

Article History:
Received: December 22, 2016
Received in revised form: July 12, 2017
Accepted: August 2, 2017

Keywords:
Insulated metal roofing, mortars, corrugated galvanized iron, temperature, coconut fibers,

**Corresponding author: Raymundo V. Romero (munding25@yahoo.com.ph)*

ABSTRACT

Three models were used on study of insulating corrugated galvanized iron (GI) sheets using coconut fibers. Model 1 was with mortars and fibers. Model 2 was with mortars without fibers. Model 3 is the conventional model. Occurrence of physical defects was investigated for models 1 and 2 within the curing period. Internal temperatures were observed considering inside the bucket (IBT), carton box (ICBT), and wooden box (IWBT). Model 2 shows signs of more visible defects by which the mortar detached from the corrugated GI sheet. Compared with Model 3, the IBT, ICBT and IWBT are lower using Model 1 as top cover. Model 1 used to minimize the internal temperature of different kind and quality of boxes. Among the three containers, it is in the wooden box that the IBT, ICBT and IWBT are the lowest. The researchers recommended a similar study using model houses.

Introduction

Corrugated Galvanized Iron (GI) is popularly used in the Philippines as roofing material for reasons of being durable, light, corrugated and easy to transport (Warr, 2000). Its application started during the early years that continued until this modern era (Hall, 1988). However, its utilization is in need to be examined due to global warming that made concentrations of greenhouse gases to continue to warm (Sarofim et al., 2016) as it was predicted by scientists to endlessly rise for the coming years (Carter et al., 2007). Detriments of this phenomenon to the human beings could be heat stroke, dehydration and other variety of illnesses (Ping et al., 2011). This makes thermal comfort become a necessary aspect for living beings (Jivrajani, 2017).

Global warming also increased the strength of typhoons. The occurrence of extraordinary sea temperature has made to examine on a possible growth of tropical cyclones because of the changing climate (Ribera et al., 2008). The intensification in sea surface temperature brought by the increasing global temperature has already contributed to greater number of powerful typhoons in this current period (Emanuel, 2005). Stability of house roofing is needed

where in most cases, failures occurred on non-engineered buildings, which either took place in roof materials or the roof connections that are found to be defective (Ramli et al., 2014). Cao Duy et al.,(2007) recommended using of sandy bags in order to prevent roof damage. Lee and Rosowsky (2005) cited the three major parameters that influenced the uplift failure of the roof are the resistance, wind load, and dead load.

Roof insulation increases the durability and controls the climate system of a building (Knowles, 2003) and at the same time reduces and maintains the indoor temperature (Isma et al., 1997). It lowers the cooling load of the air conditioning system (Halwatura, 2013). Insulation is the foremost approach in saving energy in high climatic condition (D' Orazio et al., 2013) which is found effective in the deepest heating and cooling energy consumption (Finch et al., 2014) that at the same time made the roof structurally strong and prevented from cracks (Mozumder and Singh, 2012).

Previous studies had proven that coconut husks are effective as insulation material. When combined with bagasse in manufacturing of insulation board, the thermal conductivity is similar with conventional insulation materials such as cellulose fibers and mineral wool (Panyakaew & Fatios, 2011) but when combined with polypropylene exhibits thermal resistance value that is of vital importance since the innovated product provides a much cooler inside temperature showing slow rate of heat absorption and being more economical considering that recycled materials proves to be a promising item for consumption (Ganiron Jr., 2013). Coconut husks consisting mainly of pith and fibers are extremely high in lignin and phenolic content that are used as intrinsic in board production (Agham Rahul, 2012) but when these waste materials were added with polyurethane foam shows positive result as the thermal insulator of polyurethane foam decreases when the material was mixed with coconut husks (Agham Rahul, 2013).

The coconut choir when mixed with durian feel in manufacturing of particle board contributes towards a lower energy consumption of building wherein the hot pressing method was used for the preparation of the specimen with urea formaldehyde, phenol formaldehyde and isocyanate as the binding materials (Khedari et al., 2004). The coconut fiber significantly improved the strength mixed with the lightweight foam concrete which shows potential on producing composites for different purposes as well as the possibility of the invention of new products containing coconut fibers or the possibility of producing coconut fiber reinforced concrete to be used in main structural components like beams and columns (Othuman Maydin et al., 2015).

Global warming is a worldwide problem that should not be neglected. If not given solution may result to sickness or even loss of lives. This study may provide solutions in economical way that could minimize utilization of cooling appliances like electric fans, air coolers and air conditioning units that are contributory to emission of gasses. Non utilization of these appliances saves energy and minimizes oil importation.

This study determined the effect of coconut fibers in the insulation of corrugated GI sheet metal roofing. Specifically, the following objectives were answered:

1. to describe the physical features of the insulated corrugated GI sheets;
2. to distinguish the defects that occurred during the curing period; and
3. to illustrate the internal temperatures as the insulated metal roofs were placed in different containers.

Framework of the Study.

The input-process-output concept guided this research. The input, which is the independent variable are the physical

features of the insulated metal roof models, the defects that occurred during the one month curing period, and the internal temperatures. The process, which is the intervening variables are the production, investigation, observation, testing and analysis of the insulated metal roof. The output which is the dependent variable is the data obtained from this endeavor.

Methods

The Three Models.

The corrugated GI sheets were insulated by pouring combined mixture of wet concrete and coconut fibers. Three sets of models were made. Model 1 is composed of corrugated GI metal roofing, which on one side was insulated by pouring a combination of cement mortars and of coconut fibers. The cement- sand ratio was 1:2. The size of the corrugated GI sheet was 23 cm x 46 cm. Before pouring the mortar, the coconut fibers were spread through the whole area of the GI sheet. Model 2 is composed of corrugated GI metal roofing insulated by pouring cement mortars on one side. The size of the GI sheet is similar to Model 1, which is 23 cm x 46 cm The insulation on this model has no coconut fibers. Model 3 is purely a corrugated GI sheet by which no insulation was added.

Instrument

The instrument used to gather the data are the following: weighing scale for measuring the weight of the constructed models, scaled thermometers to determine the temperature, while to measure the length of cracks during the curing period, a measuring tape was used.

Data Collection Procedure

On first part of the study, the data were collected through direct investigation by measuring the physical features like the weight, width, height and physical composition. The same procedure was done to collect the data on physical defects. The experimental design was applied using the control and experimental groups. Models 1 and 2 are the experimental groups where innovations were applied to insulate the metal roofing. Model 3 is the control group which represents the typical corrugated GI sheet with no insulation added. Each model was represented by three samples.

Measuring for internal temperature was done in three cases in order to determine the temperatures inside the bucket (IBT), carton box (ICBT) and wooden box (IWBT). The researchers made sure that the three tests became distinctive by considering that the materials, colors, shapes, sizes and thickness are different with one another. IBT was tested having materials of black plastic buckets with sizes of 18 cm in height, 0.30 cm thickness, with bottom closed at a diameter of 20 cm and with top open having a diameter of 25 cm. The volume of space occupied by this circular truncated cone shaped container is 7,186.39 cm^3. Scaled thermometers were put inside the buckets with one set covered with Model 1 and the other sets covered with Models 2 and 3. Observations were made by exposing them to direct sunlight. Every ten (10) minutes the IBT was read and recorded. Other data included in the observation was the outside temperature. A total of six (6) trials were done within one (1) hour duration of the activity.

The ICBT was tested using carton boxes with size of 38 cm in height, with closed bottom having a square area of 25 cm by 25 cm and with open top having a square area of 25 cm by 25 cm. The thickness of the box was 0.50 cm, with brown color. The volume is 23,750.00 cm^3. Thermometers were used by putting them inside the boxes covered with models 1, 2 and 3. Observations were made by exposing them to direct sunlight. In every after ten (10) minutes the ICBT was read and recorded. External temperature was also monitored. This process was done for one (1) hour covering a total of six (6) trials.

a b c

Figure. 1. The three models with a) Model 1, b) Model 2, and c) Model 3.

In order to collect the data for IWBT, wooden boxes with sizes of 14 cm in height, length of 38 cm and width of 36 cm were utilized. The thickness of the boxes was 1.20 cm with external color of brown and internal color of white. It has a space volume of 19,152.00 cm^3. Before covering with the three models, the thermometers were put inside. Observations were made by exposing them to direct sunlight. Every after ten (10) minutes the IWBT was read.. Other observed data was the outside temperature. This process was done for one (1) hour covering a total of six (6) trials.

Data Analysis Procedure.

Several statistical tools like the mean, and analysis of variance (ANOVA) were used in analyzing the data. Since there were three trials, averaging the data was done. The ANOVA was applied to determine the significant differences of temperatures inside the bucket, carton box, wooden box and the difference of external and internal temperatures among the three containers.

Results and Discussion

Given emphasis on this studies are the physical features of the three models, the defects that occurred during the curing period, and the comparative illustrations of the internal temperatures as the insulated metal roof models were placed on different containers. FONT STYLES ARE DIFFERENT

Physical Features

The following are the physical features of the models:

Model 1. The insulation is composed of coconut fibers and cement mortar. The bottom side has two metal corrugations while the top side was the insulation. The length is forty six centimeters (46 cm), the width is twenty three (23 cm), and the height is four centimeters (4 cm). The insulation is 66.64% sand, 0.04% coconut fibers, and 33.32% cement. The weight was two kilogram (2.0 kg) and is fire resistant.

Model 2. The insulation is composed concrete mortars with no coconut fibers. The bottom side has two metal corrugations while the top side was the insulator. The length is forty six centimeters (46 cm), the width is twenty three centimeters (23 cm), and the height is four centimeters (4 cm). The insulator is composed of 66.67% sand and 33.33% cement. The weight was 2.8 kg and is fire resistant.

Model 3. This model is purely the double corrugated GI metal roofing having no insulation. The length is forty six centimeters (46 cm), with width of twenty three centimeters (23 cm) and height of four centimeters (4.0 cm). The weight was 0.496 kg and is fire resistant.

Models 1, 2, and 3 were similar for both are containing the same material like

Table 1

The observed defects.

Weeks	Observed Defects Per Model Number		
	Model 1	Model 2	Model 3
First week	No visible defects	4 cracks were seen at total length of 33 cm	No insulation was poured so that it was excluded in the observation. This is the control group so that no innovation was made.
Second week	No visible defects	Additional of 2 cracks were seen at total length of 14 cm	
Third week	No visible defects	Additional of 4 cracks were observed at total length of 56 cm	
Fourth week	No visible defects	The insulation separated from the corrugated GI Sheet	

the corrugated GI sheet, length, and width and being fire resilient. The coconut fibers, although are fire hazard materials became fire resistant when covered with dried concrete. The weight and physical composition made the three models distinctive with each other. The weight of the insulated models increased but was found that Model 2 was the heaviest with composition of cement and sand. In most cases, outside forces is detrimental for the destruction of metal roofing but by increasing the weight, it made the metal roof more stable since the capacity to resist against strong wind was augmented. This was supported by Malone et al. (2013) who cited that heavier in weight outperforms the lightweight structure in many aspects.

Occurrence of Physical Defects

The observed physical defects which started right after the wet mortar was poured in the corrugated GI sheet models marked as 1, 2 and 3 were shown Table 1. The observation period covers four weeks.

No visible defect was observed in Model 1 in the whole observation. However, in Model 2 several imperfections occurred such as: four (4) cracks were seen at total length of thirty three centimeters (33 cm) within first week of observation; two (2) cracks appeared at total length of fourteen centimeters (14 cm) within the second week; within third week, an additional of four (4) cracks appeared with total length of fifty six centimeters (56 cm); and within fourth week, the insulator detached from the metal roofing material. This shows that Insulating metal roofing with cement mortar only is not feasible. It was supported by the evidence that during the early stage cracks becomes visible and that the binding between the insulation and the metal roof fails. Reinforcing the insulator with coconut fibers provides better result that no visible defect such as cracks was seen. Naturally, cracks occurred due to shrinkage and expansion of concrete caused by change in temperature (Negrutiu et al. 2016). In Model 1, crack on insulation was stopped due the coconut fibers that reinforced the insulator against expansion and contraction. The fiber reinforced models demonstrate largest reduction of the drying shrinkage (Choi, Park & Jung, 2011). Properties like breaking load and ductility improved with the addition of fibers so that the sharpness of the cracking pattern was reduced with the presence of coir fibers (Darsana et al., 2016).

Effects on Internal Temperature

The data obtained from the observation of IBT, ICBT and IWBT exhibits different trends using insulated and non-insulated

Table 2

Temperature inside the bucket (IBT).

Trials	Time (m)	IBT (°C)		
		Model 3	Model 2	Model 1
1	10	38	36	36
2	20	40	36	36
3	30	39.5	36.5	36
4	40	39.5	38	38
5	50	39.5	38.5	38.5
6	60	39.5	39	39
Average		39.33	37.33	37.25

Note: 1. F= 5.65 > F critical = 3.89

2. Level of significance = 0.05.

roofing as cover of the different type of containers. The following are the result of the investigation:

Temperature inside the bucket (IBT). The mean external temperature during the activity was 46.5°C. The data was obtained from scaled thermometers placed inside the black plastic buckets covered with the different models. The IBT was taken from six trials for every ten minutes intervals. The recorded IBT data is presented in Table 2.

Model 1 as top cover of plastic buckets demonstrates less IBT. The temperature with Model 3 as top cover started the reading from 38 degrees Celsius and ended at 39.5 degrees Celsius, while with Model 2 the temperature increased from 36 to 39 degrees Celsius and in Model 1 it increased from 36 to 39 degrees Celsius. The average IBT using Model 1 as top cover was 37.25 while it was 37.33 and 39.33 degrees Celsius for Model 2 and 3 respectively. The analysis of variance (ANOVA) indicates that there is a significant difference on the recorded data.

Figure 2 shows the line graph representing the IBT. The temperature for Model 1 is denoted by a blue line with increasing trend but compared to other lines it is the lowest temperatures. The green line is denoted for Model 3 which shows to maintain the highest temperature compared to other two lines.

The result implies that the corrugated GI sheet metal having concrete and coconut fibers as insulator was able to delay the increase of internal temperature of a plastic bucket. The condition is the same for fibers that are glued externally on concrete slab surface which allow room temperatures to decrease down the comfort limit (Rodriguez et al. 2011).

Inside the carton box temperature (ICBT). The mean external temperature during this activity was 44°C. The data was taken from the carton boxes containing

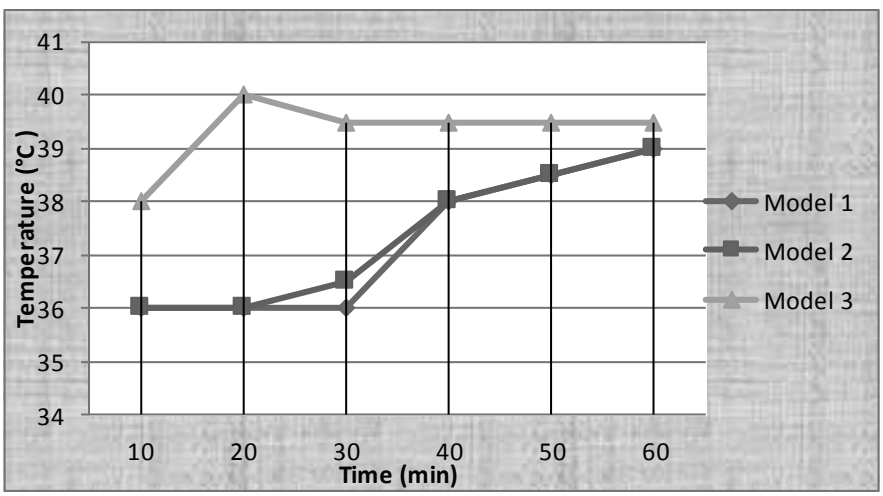

Figure 2. The temperature inside the bucket (IBT)

Table 3

Inside the carton box temperature (ICBT).

Trials	Time (m)	ICBT (°C)		
		Carton Box with Model 3	Carton Box with Model 2	Carton Box with Model 1
1	10	44	40	40
2	20	42	40	40
3	30	43.5	41	41
4	40	43.5	41	41
5	50	44	41.5	41
6	60	44	41.5	41
Average		43.5	40.83	40.67

Note: 1. F = 25.12 > F critical = 3.89.

2. Level of significance = 0.05.

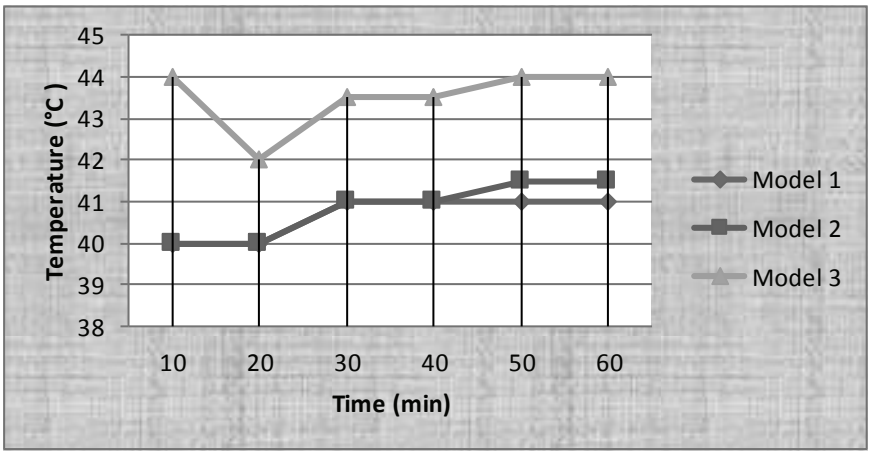

Figure 3. Inside the cartoon box temperature (ICBT)

scaled thermometer covered with the three types of models 1. The recorded ICBT data is presented in Table 3.

It reveals that using Model 3 as cover, the ICBT is at 44 degrees Celsius during the initial reading which slightly decreased to 42 degrees Celsius after 20 minutes and slightly increased to 44 degrees Celsius after 60 minutes. The average temperature is 43.5 degrees Celsius which appeared to be the highest ICBT if compared using the other two models as cover. With Model 1, it exhibits a ranging record from 40 degrees Celsius up to 41 degrees Celsius with an average ICBT of 40.67 degrees Celsius. The ANOVA computation had demonstrated a significant difference on the presented data.

Reflected on Figure 3 are the ICBT of the three models. The green line which is representing Model 3 is showing to be the highest temperature line while Model 1 (blue line) demonstrated the lowest. The result implies that the corrugated GI sheet metal roofing insulated with coconut fiber reinforced concrete is very effective in controlling the internal temperature of a carton box. The result was supported by Manohar et al. (2006) who found that coconut fiber when mixed with sugarcane fiber have acceptable values for use as building thermal insulation.

Inside the wooden box temperature (IWBT). The mean external temperature during the data gathering was 46°C. The data were taken from the wooden boxes

Table 4

Inside the wooden box temperature (IWBT).

Trials	Time (m)	IWBT (°C)		
		Model 3	Model 2	Model 1
1	10	39	32	32
2	20	40	34	34
3	30	41	36	36
4	40	41	37	37
5	50	41	37.5	37
6	60	43	38	38
Average		40.83	35.75	35.67

Note: 1. F = 18.81 > F critical = 3.89

2. Level of significance = 0.05.

containing scaled thermometer shielded with the different models. The recorded data for IWBT are presented in Table 4.

When the wooden boxes were enclosed with Model 3, the IWBT appeared to be the highest if compared to other models. The IWBT increased from thirty nine (39) degrees Celsius to forty three (43) degrees Celsius having an average IWBT of 40.83 degrees Celsius. Using Model 1 as cover, the temperature increased from thirty two (32) to thirty eight (38) degrees Celsius with an average IWBT of 35.67 degrees Celsius. The ANOVA result shows that there is significant difference on the presented data.

Shown in Figure 4 is the IWBT of the different models. Although there is a slight increase for the IWBT of Model 1 (blue line) the temperature appeared to be in the lowest position showing that it is the lowest temperature. The IWBT for Model 3 (green line) was located on the top most portion of the graph demonstrating that it is the highest temperature. The result implies that insulating the corrugated GI sheet metal with mixture of concrete and coconut fibers is effective in reducing and delaying the increase of temperature inside the wooden box. The result was strengthened by Peñamora et al. (2002) who studied on corrugated roofing boards using coconut fibers and found that the coir roof board had new low thermal conductivity. It specifies good insulation properties that can be used in a house even without a ceiling.

Difference between internal and external temperature. The difference of the internal temperature from the external temperature on each container was computed for every conducted trial. Table 5 shows that from the start of observation, IWBT has a temperature difference of 12.17 °C or 26.17% difference, which decreased to 6.80 °C or 14.62%, ICBT has a temperature difference of 2.67 °C or 6.07% which

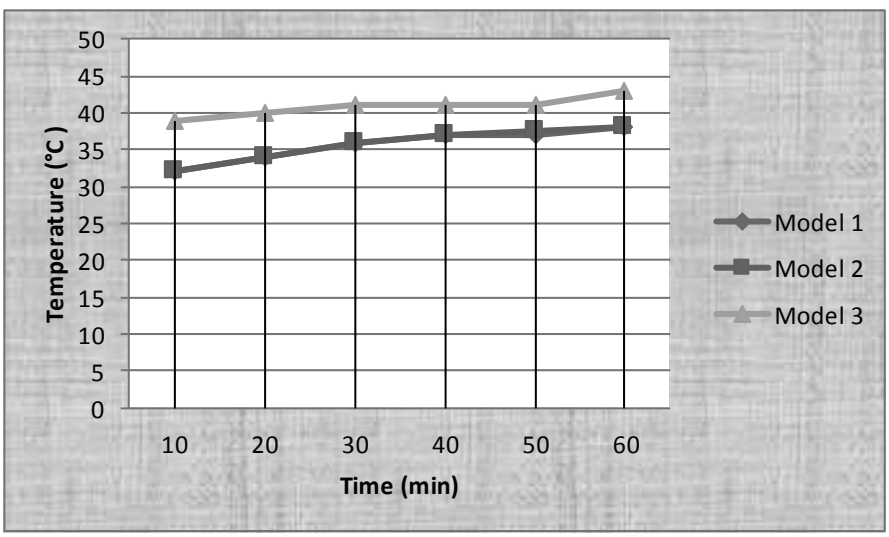

Figure 4. Inside the wooden box temperature

Table 5

Difference between external and internal temperatures

Trials	Time (m)	Difference from External Temperature (°C)					
		IWBT	%	ICBT	%	IBT	%
1	10	12.17	26.17	2.67	6.07	9.8	21.08
2	20	10.50	22.58	3.90	8.86	9.17	19.72
3	30	8.80	18.92	2.17	4.93	9.17	19.72
4	40	8.20	17.63	2.17	4.93	8.00	17.20
5	50	8.00	17.20	1.83	4.16	7.67	16.49
6	60	6.80	14.62	1.83	4.16	7.34	15.78
Mean		9.08	19.52	2.43	5.52	8.52	18.33

Note: 1. F = 54.17 > F critical = 3.89

2. Level of Significance = 0.05

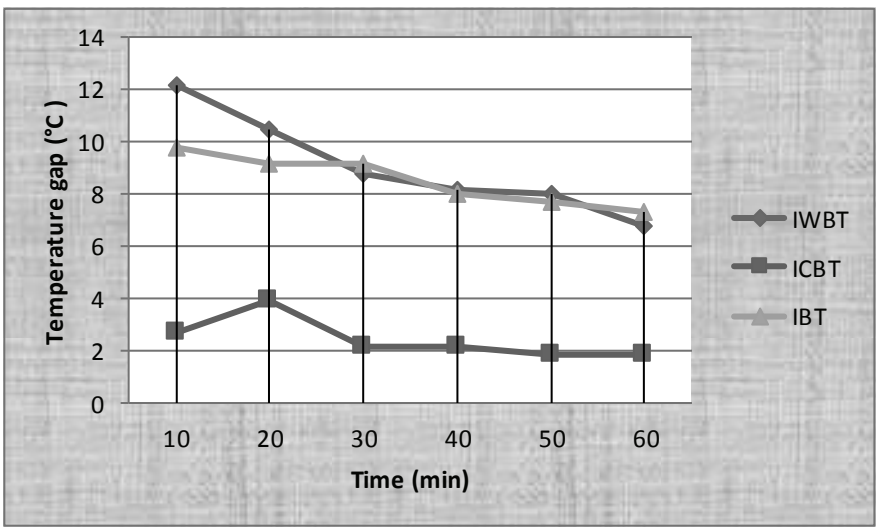

Figure 5. Comparison of the containers' temperature

decreased to 1.83 °C or 4.16%, and IBT has a temperature difference of 9.8 °C or 21.08% which decreased to 7.34 °C or 15.78% in one hour of observation. The mean difference from the external temperature was 9.08 °C or 19.52%, 2.43 °C or 5.52%, and 8.52 °C or 18.33% for IWBT, ICBT and IBT respectively. The ANOVA result shows that there is a significant difference on the data presented on the table.

In Figure 5, the blue line which is representing the temperature for the wooden box (IWBT) has the largest difference between external and internal temperatures recorded for every ten minutes of measurement. Hence, the internal temperatures that took place on this container was the lowest compared to other two containers. Aside from the kind of the material that the wooden box was made, other factor that contributes to attain low internal temperature data is the thickness since the thickness of the wooden box was the largest compared to other two containers. The smallest difference between the external and internal temperature appeared in carton box (ICBT). It is on this container that the hottest temperature took place during the series of measurement. Aside from the kind of material, other factor could be attributed to the space volume of the box since it is the largest among the three containers.

Conclusion and Recommendations

The physical features of the corrugated GI sheets changed when insulated with coconut fiber specifically that the weight and the width of the materials were amplified. Model 2 was found to be defective specifically that cracks appeared on insulator and at the end it detached from the corrugated GI sheet metal within the curing period. The three boxes which embraced different features appeared that using Model 1 as top cover the internal temperature is lower compared to the internal temperature utilizing Model 3.

This research activity was successful to show that insulating the corrugated GI sheet with coconut fibers and concrete mortar is effective to cut and delay the increase of the internal temperature on three different kinds of containers. It was also demonstrated that the internal temperature on the wooden box is the lowest compared to the other containers. In order to obtain a more realistic result, a continuous approach shall be conducted by applying not on box models anymore but on buildings and houses for the success of this study can promote a new technique of reducing building temperature in economical and cleanest way. It is economical on the sense that using coconut fiber to reduce temperature will not use electrical energy and it is clean for it is not producing chemicals like carbon dioxide that are damaging the ozone layer of the earth.

Acknowledgement

The researchers would like to express gratitude to Professor A. P. Malinis of Bicol University, Professor H.A. Mabesa of Central Bicol State University of Agriculture and Engr. S. B. Barandon of Camarines Sur Polytechnic College. They are the panelists who provided constructive remarks on this research output during the 2015-in-house review held at Partido State University. The researchers would like also to thank Professors L. Lanciso and P. Candelaria, the research director and the vice president for research and extension of Partido State University respectively, for spearheading that event. Specially, the researchers would like to express gratitude to Dr. R. Bradecina, the President of Partido State University, for the encouragement and support.

■ ■ ■

References

Agham Rahul D. (2012). State of the art insulation materials: a review. *International Journal of Engineering and Innovative Technology*, 2(6), 97-102.

Agham Rahul D. (2013) Performance of coconut husk mixed polyurethane foam as an alternative insulating material, *International Journal of Engineering and Innovative Technology*, 2(9), 100-104.

Cao Duy, T., Nguyen Xuan, C., Nguyen Dai, M., Nguyen Huu, H., & Bui Tat C. (2007). Typhoons and technical solutions recommended for existing and new houses in the cyclonic regions in Vietnam. *Electronic Journal for Structural Engineering*, 8-18. Retrieved from http://www.ejse.org/Archives/Fulltext/2008/Special2/VET200802.pdf

Carter, T. R., Jones, R. N., Lu, X., Bhadwal, S., Conde, C., Mearns, L. O., O'Neill, B. C., Rounsevell, M. D. A., & Zurek, M. B. (2007). New assessment methods and the characterization of future conditions. In Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., & Hanson, C. E. (Eds.), *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (pp. 133-171). Cambridge: Cambridge University Press.

Choi, S. Y., Park, J. S., & Jung, W.T. (2011). A study on the shrinkage control of fiber reinforced concrete pavement, Procedia Engineering, 14(2011), 2815-2822. Retrieved from https://doi.org/10.1016/j.proeng.2011.07.354

Darsana P., Abraham R. Joseph, A., Jasheela A., Binuraj, P.R., & Sarma, J., (2016) Development of coir-fibre cement composite roofing tiles, *Procedia Technology*, 24(2016), 169-178. doi: 10.1016/j.protcy.2016.05.024

D'Orazio, M., Di Giuseppe, E., DI Perna, C., & Morodo M. (2012). Thermal performance of an insulated roof with reflective insulation: Field tests under hot climatic conditions. *Journal of Building Physics*, *36*(3), 229-246. doi: 10.1177/1744259112448181

Emanuel K. (2005). Increasing destructiveness of tropical cyclones over the past 30 years. *International Weekly Journal of Science*, doi:10.1038/nature03906

Finch, G., Dell, M., Hanam, B., & Ricketts, L. (2014). Conventional roofing assemblies: measuring the thermal benefits of light to dark roof membranes and alternate insulation strategies. *Proceedings of the 28th RCI International Convention and Trade Show*. Retrieved from http://rdh.com/wp-content/uploads/2014/04/Conventional-Roofing-Assemblies.pdf

Ganiron Jr., T. U. (2013). Investigation on the use of coco coir polypropylene as thermal insulator, *International Journal of Advanced Science and Technology,* 59(2013), 13-26. Retrieved from http://dx.doi.org/10.14257/ijast.2013.59.02

Hall, A. B. (1988). *American galvanized iron roofing and cladding from the 1870's to 1920's* (Masters' Thesis, University of Pennsylvania, Philadelphia, PA). Retrieved from http://repository.upenn.edu/hp_theses/301

Halwatura, R. U. (2013) Effect of turf roof slabs on indoor thermal performance in tropical climates: A life cycle cost approach. *Journal of Construction Engineering*, doi: 10.1155/2013/845158

Isml, K. A. R., & Castro, J. N. C. (1997). PCM thermal insulation in buildings. *International Journal of Energy Research*, *21*(14), 1281-1296. doi:10.1002/(SICI)1099-114X(199711)21

Jivrajani, C. (2017) A review on the usage of agro based material for developing thermal Insulation, International Journal of Advance Engineering and Research Development, 4(2), 345-358

Khedari, J., Nankongnab, N., Hirunlabh, J., & Teekasap, S. (2004) "New low-cost insulation particleboards from mixture of durian peel and coconut coir," Build. Environ., 39(1), 59–65.

Knowles, M. (2003). Sustainability characeristics of SPF roofing and insulation system. *Modern Materials, 1*(1), 16-21.

Lee, K. H., & Rosowsky, D. V. (2005). Fragility assessment for roof sheathing failure in high wind regions. *Engineering Structures*, 27, 857-86. doi:10.1016/j.engstruct.2004.12.017

L. J. Peñamora, R.N. Palomar, and N.J. Melencion (2002) Corrugated roofing boards from coconut fiber: Applications and initial results. *PCARRD R&D Highlights 2002, Los Ba*ños, Laguna: PCARRD,

Malone, B. P., Miller, M. H., & Gupta, R. (2013). Gravity and wind load path analysis of a light-frame and a traditional timber frame building. *Journal of Architectural Engineering*, 20(4), doi:10.1061/(ASCE)AE.1943-5568.0000136,B4013001.

Manohar, K., Eramlakhan, D., Kocchar, G., & Haldar, S. (2006). Biodegradable fibrous thermal insulation. J. Braz. Soc. Mech. Sci. & Eng. [online]. 28(1), 45-47. ISSN 1678-5878. http://dx.doi.org/10.1590/S1678-58782006000100005.

Mozumder, A., & Kumar Singh, A. (2012). Solar heat flux reduction through roof using porous insulation layer. *Energy Procedia*, 30, 446 – 45. doi: 10.1016/j.egypro.2012.11.053

Negrutiu, C., Sosa, L. P., Constantinescu, H., & Heghes, B. (2016). Crack analysis of reinforced high strength elements in simulated aggressive environments. *Procedia Technolgy, 22*, 4-12. doi: 10.1016/j.protcy.2016.01.002

Othuman Maydin, M.A., Rozlan, N.A., & Ganesan, S. (2015) Experimental study on the mechanical properties of coconut fibre reinforced lightweight foamed concrete, Journal of Material and Environmental Science, 6(2), 407-411.

Panyakaew, S. & Fotios, S. (2011). New thermal insulation boards made from coconut husk and bagasse, *Energy and Buildings,* 43(7), 1732-1739. doi: Retrieved from https://doi.org/10.1016/j.enbuild.2011.03.015

Ping, B., William, S., Loughnan M., Lloyd, G., Hansen, A., Kiellstrom, T, Dear, K., & Saniotis, A. (2011). The effects of extreme heat on human mortality and morbidity in australia: implications for public health. *Asia-Pacific Journal of Public Health*, 23, 27S-36. doi: 10.1177/1010539510391644

Ribera, P., Garcia-Herrera, & R., Gimeno, L. (2008). Historical deadly typhoons in the Philippines. *Weather, 63*(7), 194-199

Ramli, N. I., Majid, T. A., Wan Chik, F. A., Muhammad, M. K. A., & Che Deraman, S. A. (2014). Assessment of pull-through failure of nail connection for rural roofing system under wind load in Malaysia. *Journal of Civil Engineering Research*, *4*(3A), 135-137

Sarofim, M. C., Saha, S., Hawkins, M. D., Mills, D. M., Hess, J., Horton, R., Kinney, P., Schwartz, J., & St. Julian, A. (2016). Temperature-related death and illness. *The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment*, 43-68. Retrieved from http//dx.doi.orgll0.7930/JOMG7MDX

Warr, A. (2000). *Roofing corrugated iron-options for repairs*. Paper presented at Material Evidence, Conserving Historic Building Fabric Seminar, New South Wales Heritage Office. Retrieved from http://www.environment.nsw.gov.au/resources/heritagebranch/heritage/warra.pdf