



Comparative Analysis on Roof Covering Materials Sustainability as Constructed by Bamboo and Corrugated Galvanized Iron Sheet in Rural Areas Around Wolkite, Ethiopia

Hailu Abera^{1*}, Elmer C. Agon², Mamaru Dessalegn²

¹Department of Construction Technology and Management,
Wolkite University, Wolkite, 07, ETHIOPIA

²Department of Civil Engineering,
Jimma Institute of Technology, Jimma University, Jimma, 378, ETHIOPIA

*Corresponding Author

DOI: <https://doi.org/10.30880/ijscet.2022.13.03.014>

Received 2 March 2022; Accepted 13 March 2022; Available online 10 December 2022

Abstract: One of the most important components of any building is the roof, which protects the interior of the building from environmental influences. It is sustainable to switch roofing materials from expensive roofing materials to inexpensive and environmentally friendly materials. Today's roofing materials have negative effects on the environment due to the manufacturing process. Therefore, this research has mainly focused on the development of sustainable roofing materials through life cycle cost analysis. Approximately ten bamboo samples from homeowners in the Wolkite area and one Adama corrugated galvanized sheet were taken to analyze the life cycle costs. Data on the ecological and socio-economic aspects of the selected roofing materials were collected with the help of interviews and questionnaires. The cost of galvanized corrugated iron sheet of 1.8m² was \$38.19 while the cost of bamboo was \$3.91; the researchers concluded that treated bamboo roofs have lower life cycle costs per 1.8 square meters (approximately 89.76% less than corrugated galvanized iron), more environmentally friendly. And also using bamboo as roofing material, create a good job opportunity for the society by cultivating and preparing bamboo to the construction input.

Keywords: Building, sustainability, life cycle cost, roof, bamboo, corrugated galvanized iron sheet

1. Introduction

Roofing materials are one of the most important building materials. In addition to the main function of the roofing material, they expected safety, beauty of the building, light weight, durability; lower environmental impact, colorful and functional (Udagama and Kulatunga, 2014). Roofing plays an important role in the thermal envelope by protecting the building from extreme heat and cold. As a first line of defense, the roof is exposed to the most intense solar radiation of any other component of the building (Akbari and Levinson, 2008). There are many types of roofing

materials, such as galvanized corrugated sheets, fiber cement sheets, concrete tiles, burnt clay tiles, aluminum roofing sheets, asphalt shingles (Eygelaar, 1975). Instead of these well-known roofing materials, this research has mainly focused on the comparison between roofing materials made from bamboo and corrugated galvanized iron. Bamboo is one of the most useful natural resources in many parts of the world. It is a lignocellulose-containing biomass that is similar to the properties of wood, but has additional properties such as easy process ability, excellent strength, high elastic behavior, and abrasion resistance. For its various properties, it has been named the most important sustainable and environmentally friendly crop in the world (Singha and Borah, 2017).

Bamboo is a renewable, environmentally friendly and widely used substitute building material as wood resources are declining and deforestation of natural forests is restricted. Due to its rapid growth, adaptability to most climatic conditions and its properties, bamboo turns out to be a very suitable alternative (Raj and Agarwal, 2014). When we get to the study area (rural places around Wolkite) there is an overproduction of bamboo. Most of these materials were used to make home furnishings. Therefore, this research has focused on how the materials can be used as roofing, and methods on how to improve the durability of bamboo roofing material have been identified by discussing the idea with various stakeholders. The most common roofing material used in rural areas around Wolkite was galvanized corrugated iron, which is expensive. The material is not readily available, it is inaccessible to the poor and it is not environmentally friendly. It is susceptible to corrosion (requires additional protection against corrosion). It has a very low thermal resistance and poor acoustic properties (Evans, 2009). This was the main reason for this type of research and it is expected that a sustainable roofing material will be developed.

2. Statement of the Problem

Housing is a basic need for human being and is now becoming a burden for low- and medium-income group. Thus, we need cost effective housing and Bamboo is the best building material (Raj and Agarwal, 2014). From building components, recently roof covering materials take a higher cost especially in rural areas. Current roof covering construction methods and materials contribute to this outcome, because they met at a relatively high cost and a higher social impact. The continued growth in housing construction in rural areas around Wolkite loads and the pressure to do a research on roof covering materials to come up with new solutions. Moreover, currently building construction projects have higher negative environmental impacts while their quality is declining from time to time, this is because of its main component roof. Due to this fact the search for roof covering materials was a key and fundamental factor for the sustainable growth of the building networks in the future Ethiopia.

Generally, the development of the construction industry in Ethiopia is affected by numerous problems. Almost all housing projects in rural areas are completed ending with additional cost and a higher negative environmental impact. This is mainly due to the upper most part of the building, which is the roof cover. Therefore, this research warmed-up the idea of constructing bamboo roof coverings and addressed the benefits and negative impacts by investigating life cycle cost together with user benefits, environmental and social benefits.

3. Literature Review

The roof offers protection against extremes of weather including rain, sun and wind, and to provide shelter, clear and usable space beneath the canopy. Corrugated bamboo roofing sheets are produced from woven mats of bamboo that are soaked in adhesive resin and then pressed firmly together. The corrugations are formed by pressing the mats between two corrugated pressing plates. The sheets can be produced in a range of sizes to suit particular requirements and can easily be trimmed for special situations. Bamboos are the only raw material used for the sheets. The sheets are durable and stable and resistant to pest attack, severe weathering and fire. The main advantages of this roof covering are: Corrugated bamboo roofing sheets are an environmentally friendly and safe alternative to asbestos, zinc or corrugated iron roofing panels; The sheets are also quieter in the rain than corrugated roofing panels and the sheets are durable strong with excellent internal bond strengths and high resistance to weathering and biological agencies such as insect attack and have good appearance. Above all it must be strong enough to resist the considerable forces generated by wind and roof coverings. In this respect, bamboo is ideal as a roofing material- it is strong, resilient and light weighted (Sharma, et al., 2014).



Fig. 1 - Bamboo as a roof covering material (Henrikson and Greenberg, 2006)

4. Materials and Methods

4.1 Materials Used

The following listed materials were used in this research:

Table 1 - Materials used for bamboo and corrugated galvanized iron sheet roof covering construction

| | Types of roof covering | |
|-----------------------|---|--|
| | Corrugated galvanized iron sheet | Bamboo |
| Materials used | <ul style="list-style-type: none"> ✓ Corrugated galvanized iron sheet produced in Adama corrugated galvanized iron sheet factory ✓ Eucalyptus wooden Purlin ✓ Commonly adopted corrugated galvanized iron sheet nail | <ul style="list-style-type: none"> ✓ Locally available bamboo ✓ Eucalyptus wooden Purlin ✓ Commonly adopted corrugated galvanized iron sheet nail ✓ Potable or river water ✓ Boric acid |

4.2 Methodology

This study used both quantitative and qualitative techniques so that it will identify, acquire and examine the records in terms of the socioeconomic and environmental components along with carbon dioxide emission and thermal insulation for each roof protecting substances. The researchers gather 50 questionnaires out of the centered 60 and 20 interviews from the stakeholders and environmental safety authority residing round Wolkite. This questionnaires and interview allows in studying the socioeconomic and environmental components along with thermal insulation. The respondents decided on adopt no less than one conventional bamboo housing task as a client, neighborhood contractor or supervisor. Construction value of each roof protecting substances has been executed via way of means of constructing 1.8 square meters of bamboo and corrugated galvanized iron sheet roof covering. Hence, to reap the preferred objectives, the subsequent duties have been performed:

- I. The impact assessments outputs were interpreted by analyzing economic, environmental, and social aspects.
 - II. Life cycle cost analysis for each type of roof covering materials and the cost was estimated depending on the types of roofing materials.
 - III. Each roof covering alternatives were quantified based on the 1.8 square meter design of bamboo and corrugated galvanized iron sheet.
- **Bamboo roof covering construction steps:**
 - I. Harvesting: Preparing raw bamboo for the construction purpose.
 - II. Transporting: Taking the raw bamboo to the construction site.
 - III. Splitting the bamboo in to halves: Dividing the raw bamboo in to halves.
 - IV. Treating with chemical and traditional methods: Applying chemicals like boric acid after treating it with traditional methods like immersion in water.
 - V. Storing and drying: Putting the treated or untreated bamboo culm in a proper place.

VI. Fixing and constructing bamboo roof covering: Finally fix the bamboo roof covering.

4.2.1 Harvesting

The first step in constructing a house with bamboo roof covering, is harvesting the matured bamboo. Time and methods of harvesting are important factors to prolong the life of bamboo. From the questionnaires and interview gathered, the right bamboo harvested in the right time (3 to 5 years old) and season (during the dry season or winter), which would increase its life.

4.2.2 Transporting

Transporting takes a higher time if the material is far away from the construction site. A better solution to this is cultivating the bamboo near to the construction site. After harvesting the bamboo, the next step is taking the harvested bamboo to the construction site or to the treatment plant. This includes: -

- Cut the bamboo into pieces of the required length to make it easier for transportation
- Make bundles of the required pieces
- Tie them using rope or any other locally available tying material
- Take the harvested bamboo to the construction site
- Unload and store in appropriate place.

4.2.3 Splitting The Bamboo into Half's

Bamboo splits are produced after bringing the bamboo to the construction site by dividing the culm in to halves. They are produced by dividing the full thickness of the culm. The researchers used sharp splitting tools to avoid cracking and to make the work simple.



Fig. 2 - Splitting bamboo

4.2.4 Treating Bamboo by using Traditional and Chemical Methods

The durability of bamboo without any protective treatment is less than five years. Biological degradation can affect the usage, strength, utility and value of the bamboo. In order to improve the durability and performance, bamboo and bamboo products are treated with or without the use of chemicals. Treatment is absolutely necessary when bamboo is used as a structural member where safety is of major concern. Also, frequent replacement would be

time-consuming and involve costly labor. Increasing life by treatment is more economical in the long run (Bhawan and Marg, 2006).

In general, it has been found that untreated bamboo has an average life of 1-3 years where it is directly exposed to soil and atmosphere. When used under cover, the life expectancy of bamboo increases to 4-7 years but can be as high as 10-15 years in highly favorable circumstances (Paudel and Aye, 2014).

Traditional methods of treatment are cheap and can be done without the uses of special equipment. This includes storing bamboo in water/leaching, smoking and other traditional bamboo preservation methods. There were no need of treating the bamboo by smoke, because the peoples living in the study area use fire in their day to day life and that indirectly prolongs the life of bamboo roofing material.



Fig. 3 - Treating bamboo by immersing in water

Additionally, it is better to treat the bamboo chemically by using boric acid after one- two weeks getting out off from the water. Boric acid can be found naturally and which is used to control pests like insects and fungi (Cox, 2004).



a) Boric acid powder

b) Mixing boric acid with water

c) Applying boric acid

Fig. 4 - Treating bamboo with boric acid

4.2.5 Storing and Drying

Proper care was given when storing the bamboo before and after treatment. Once bamboo is ready for the construction: -

- Make the ground clean to store the culms.

- Suspend the bamboo about 10cm above the ground to avoid direct contact with the soil; by supporting it with stone or any other nutritious materials.
- Keep the bamboo in standing position for 2-3 weeks with the support of trees or any other supports.
- Provide good ventilation.
- Provide overhead shade to protect the culms from rain and other atmospheric moistures.



Fig. 5 - Storing raw and treated bamboo

4.2.6 Fixing and Constructing Bamboo Roof Covering

The construction process was done after treating the bamboo traditionally and chemically. The researchers, in collaboration with others in the shelter cluster, have identified the following main points to incorporate in bamboo roof covering construction: -.

- Steep slope (minimum 30 degrees) is better because it allows proper flow of the rain water.
- Limit the projection of the roof on all sides to minimum 12 inches.
- Fix the roof cover firmly to the purlin.



Fig. 6 - Fixing and constructing bamboo roof covering

5. Result and Discussions

5.1 Economic Perspective of Using Bamboo and Corrugated Galvanized Iron (CGI) Sheet

A. Economic Benefits of Using Bamboo

Compared to CGI sheet, bamboo material is not expensive to harvest and construct. Also it is available, accessible and risk-free roofing material in rural areas. If the roof cover is constructed with bamboo, more economic activities will be created in the region, particularly in the marketing and selling of the material. Opportunities for export should also be explored to earn foreign exchange.

B. Economic Benefits of Using CGI Sheet

The establishment of CGI sheet production factory will have a foreign exchange saving effect to the country by minimizing material imports.

C. Economic Impacts of Using Bamboo

The construction of roof covering material by using bamboo has not any negative impact on the societies or as well as on the government economy.

D. Economic Impacts of Using CGI Sheet

As the researchers tried to calculate the initial construction cost, this roofing material needs a higher initial construction cost. Compared to bamboo roof covering material CGI sheet is expensive to produce and transport. The economic criteria, number of respondents and their weight of answer regarding to bamboo roof covering material is shown in the table below and it is discussed at the end of tables.

Table 2 - A response on the economic perspectives of bamboo roof covering material

| Criteria | No of Respondents | | | | Weight |
|-------------------------|-------------------|----------|------------|---------|--------|
| | Very High (4) | High (3) | Medium (2) | Low (1) | |
| Durability | 10 | 19 | 30 | 11 | 168 |
| Availability | 36 | 22 | 8 | 4 | 230 |
| Construction simplicity | 13 | 18 | 23 | 16 | 168 |
| Wight of the material | 22 | 17 | 21 | 10 | 191 |
| Strength | 11 | 23 | 25 | 11 | 174 |
| Required maintenance | 15 | 23 | 21 | 11 | 179 |

The economic criteria, number of respondents and their weight of answer regarding to corrugated galvanized iron sheet roof covering material is shown in the table below.

Table 3 - A response on the economic perspectives of CGI sheet roof covering material

| Criteria | No of Respondents | | | | Weight |
|-------------------------|-------------------|----------|------------|---------|--------|
| | Very High (4) | High (3) | Medium (2) | Low (1) | |
| Durability | 15 | 23 | 21 | 11 | 182 |
| Availability | 2 | 6 | 25 | 37 | 113 |
| Wight of the material | 20 | 19 | 18 | 13 | 186 |
| Strength | 22 | 21 | 17 | 10 | 195 |
| Construction simplicity | 25 | 20 | 10 | 15 | 195 |
| Required maintenance | 17 | 19 | 18 | 16 | 177 |

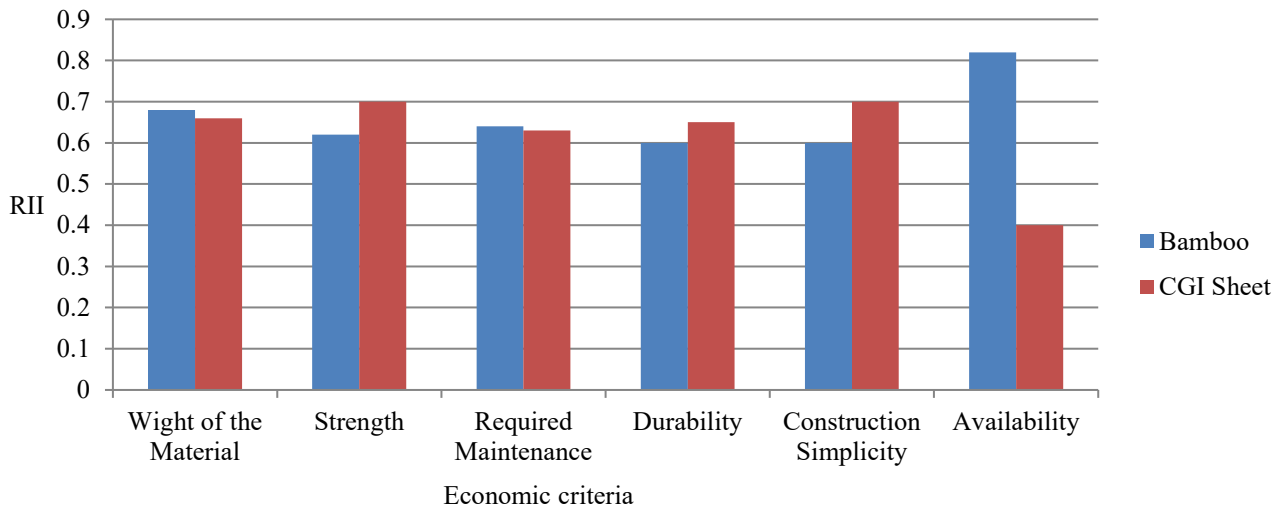


Fig. 7 - RII of each economic criteria for bamboo and CGI sheet roof covering materials

- **Weight of the material:** All materials and components have a different weight. Weight is either good, bad, or indifferent to the performance of the roof covering. Generally, CGI sheets are lighter and are easier to lift, transport and install and therefore make the installation easier and which indirectly minimizes the construction cost than heavy products like bamboo.
- **Strength:** Based on the questionnaires and interviews CGI sheet is stronger than bamboo roofing sheet. Its strength makes the material to resist higher external loads, leading to a minimum repairing and maintenance cost.
- **Required maintenance:** It is known that all roofs require some level of maintenance during their lifetime. If the material needs a rapid maintenance, the cost of that material becomes higher. Based on the results of this research bamboo roof covering have a higher maintenance cost than CGI sheet.
- **Durability:** Mostly the cost of new roofing material directly correlates to how long our new roof will last. Also, keep in mind that the weather conditions in the region make an impact on the life of the roof, as does the building construction and design, the frequency of maintenance, and of course the quality of the roofing material. The longest-lasting roofing materials are normally the most durable and more economical at the long run. As the researchers tried to gather data, corrugated galvanized iron sheet have a substantial lifespan than bamboo roofing material.
- **Construction simplicity:** CGI roofing sheets are mostly used roof covering materials and offer maximum design freedom. Due to this fact CGI roofing systems are easy to construct compared to bamboo roof covering, this will minimize the construction cost.
- **Availability:** Those types of roofing materials like bamboo which, are naturally available obtained abundantly than CGI sheeting. Here in the study area bamboo roofing material is more available than CGI sheet. This reduces the transportation cost highly.

5.1.1 Construction Cost of Bamboo and Corrugated Galvanized Iron Sheet

As construction material is the dominant work item in calculating the cost of a roof, it is reasonable to compare the roof types classified according to construction materials. This means that construction costs of different roof covering materials can vary in an extremely large interval, considering the chosen construction materials and methods. Toward this aim, construction costs of bamboo and CGI in residential houses around Wolkite were compared with each other.

Table 4 - Cost comparison of constructing 1.8 square meters of bamboo and CGI sheet

| No. | Description | Unit | Quantity | Unit price (USD) | Total price (USD) |
|--------------------------|--|----------------|----------|------------------|-------------------|
| 1. | Roofing work | | | | |
| 1.1 | Raw bamboo mat, price includes boric acid treatment, purlin and nail cost | m | 8.5 | 0.46 | 3.91 |
| Total carried to summary | | | | | 3.91 |
| 1.2 | Corrugated galvanized iron sheet, price includes purlin and nail cost | m ² | 1.8 | 13.14 | 23.65 |
| 1.3 | 8mm thick chip wood ceiling under the 1.8m ² corrugated galvanized iron sheet roof covering, price includes purlin, corner list and nail cost | m ² | 1.56 | 9.32 | 14.54 |
| Total carried to summary | | | | | 38.19 |

From this cost comparison, it can be seen that, bamboo roofing system is economical than corrugated galvanized iron sheet roofing system. Bamboo roofing system minimizes around 89.76% of corrugated galvanized iron sheet roofing cost.

5.2 Social Perspective of Using Bamboo and Corrugated Galvanized Iron (CGI) Sheet

A. Social Benefits of Using Bamboo

CGI roofing sheet is more common in the urban areas and some rural areas. Therefore, the researchers found that bamboo roofing sheets are a good replacement as roof covering material in rural areas. According to research center for forest ecology and environment, bamboo provides employment to a range of people and there will be extra employment generation in its forward and backward linkages, such as cultivation and harvesting of bamboos, primary processing and marketing. A unit producing half a million square meters of bamboo roofing sheet per year will create employment for many peoples.

B. Social Benefits of Using CGI Sheet

The production company will create forward linkage with the construction sector and also generates income for the government.

C. Social Impacts of Using Bamboo

The negative aspect is the transport of the bamboo material if it is far away from the construction site. That is why plantation of suitable bamboo for construction has to increase in closer to the construction site. It can contribute to less traffic, more local material and increase the utility for bamboo.

D. Social Impacts of Using CGI Sheet

CGI sheet was produced in the factory, which doesn't create as much employment opportunity as bamboo roof covering material to the people.

The indexes were then ranked and calculated for each of the criteria in each group which gives the relative importance index (RII) of the groups as shown in the figure below.

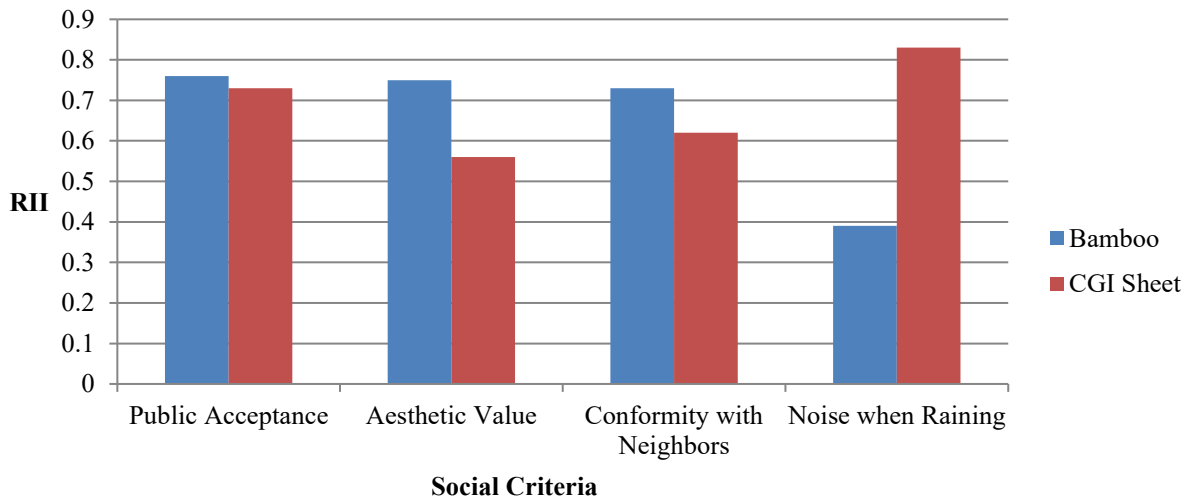


Fig. 8 - RII of each social criteria for bamboo and CGI sheet roof covering materials

- **Public acceptance:** Public acceptance is crucial for the large-scale demonstration and application of roof covering materials. Hence, bamboo roof covering material is more accepted by the public than CGI sheet.
- **Aesthetic value:** Roof covering adds beauty to our house and can provide a better value when the roof is attractive and enhance the overall appearance of our home. Bamboo roofing systems are newly developed traditional roofing systems, but in doing so, provide an even more aesthetically pleasing finish than CGI sheet. It is a beautiful asset that will add value to any home.
- **Conformity with neighbors:** In rural places around Wolkite the peoples mainly use grass as a roof covering material. So, bamboo compared to CGI sheet have highly confirmed with the neighbor.
- **Noise when raining:** In most cases roof is the least important path of noise admission. However, in locations subjected to high snow fall, the roof becomes an important element to consider. Hence, bamboo roofs offer better performance than CGI sheet due to their density and thickness and are particularly effective in blocking out sounds of low to medium frequency.

5.3 Environmental Perspective of Using Bamboo and Corrugated Galvanized Iron Sheet

A. Environmental Benefits of Using Bamboo

Bamboo provides considerable environmental benefits. Promoting sustainable development should not be done by encouraging the importation of building material. It is better to increase the use of local natural material and development of eco-construction techniques. If bamboo becomes a roofing material in housing construction it can benefit the environment by reducing carbon dioxide concentrations. Therefore, it is an alternative roofing material. The cultivation of bamboo is also beneficial for soil conservation or erosion prevention and afforestation activities.

B. Environmental Benefits of Using CGI Sheet

As the researchers tried to gather information from different stakeholders by using questionnaires and interviews, producing or using CGI sheet has not any environmental benefit.

C. Environmental Impacts of Using Bamboo

Environmental impacts of roof covering materials ranges from different phases of a building life cycle: in the production of materials and products, in the construction of the roofing material itself, up to the final demolition. Here bamboo roof covering material doesn't need any further production in the factory or industry. So this roof covering material has no impact on the environment.

D. Environmental Impacts of Using CGI Sheet

The use of locally available roofing materials like bamboo doesn't need any processing. On the other hand, production of CGI sheet emits a higher amount of carbon dioxide to the atmosphere, which pollutes the environment and affects human health as well.

The analysis of environmental aspects for the criteria, number of respondents and their relative importance index of answer is shown in the table below.

Table 5 - Percentage of response and ranks of each criterion for bamboo roof covering material

| Criteria | Percentage of respondents | | | | R.I. I |
|--|---------------------------|----------|------------|---------|--------|
| | V. High (4) | High (3) | Medium (2) | Low (1) | |
| Thermal insulation | 41.43 | 37.14 | 12.86 | 8.57 | 0.78 |
| CO ₂ emission during production | 4.28 | 12.86 | 28.57 | 54.29 | 0.42 |

Table 6 - Percentage of response and ranks of each criterion for CGI sheet roof covering material

| Criteria | Percentage of respondents | | | | R.I. I |
|--|---------------------------|----------|------------|---------|--------|
| | V. High (4) | High (3) | Medium (2) | Low (1) | |
| CO ₂ emission during production | 57.14 | 34.29 | 5.71 | 2.86 | 0.86 |
| Thermal insulation | 14.29 | 24.29 | 25.71 | 35.71 | 0.54 |

- Carbon dioxide emission during bamboo and corrugated galvanized iron sheet production: According to Tapan et al. 2013 as energy intensive industry, the iron and steel industry has the potential of being one of the highest carbon emitter sectors. In addition, as the researchers tried to gather information from environmental protection authority, a great quantity of carbon dioxide is emitted to the atmosphere through the different phases of a building life cycle.

Nowadays several efforts are used in reducing carbon dioxide emissions in the construction of different building components and materials. Therefore, studies on local alternative roofing materials are important. The results obtained demonstrate that production of corrugated galvanized iron sheet emits a larger amount of carbon dioxide than bamboo roofing material.

- Thermal insulation: Most of Ethiopian cities have a climate which requires the roof to limit heat gain. As the researchers tried to gather information on both roof covering materials, bamboo roof covering offers an excellent performance in limiting solar radiation heat than corrugated galvanized iron sheet.

6. Conclusions

This paper highlights and summarizes bamboo roofing system in comparison with corrugated galvanized iron sheet. In the study area, corrugated galvanized iron sheet is high in cost and short in supply. In the present scenario, it is best to use natural roofing materials. The best of which is bamboo, that is simple as well as economical and affordable for low income group people to satisfy their basic need. Bamboo has greater advantage in that it does not pollute an environment.

Compared to corrugated galvanized iron sheet, bamboo roof covering has higher aesthetic value, lesser durability, highly available, less carbon dioxide emission during production which is good for the environment. This roofing material has a higher weight with a higher public acceptance. It also helps to reduce the intrusion of noises due to rain, has high levels of thermal insulation and offers more conformity with neighbors than CGI sheet.

Bamboo roof covering is an alternative low-cost roofing material which was mainly produced naturally. This roofing material has a lower lifecycle cost compared to corrugated galvanized iron sheet. From this paper, it is concluded that bamboo roofing system minimizes 89.76% cost of corrugated galvanized iron sheet roofing.

Compared to corrugated galvanized iron sheet, the life of bamboo after harvesting is not long because of the sun and the dry environment. Therefore, bamboo needs treatment by using traditional methods like immersing in water, smoking or by using chemicals like boric acid to last for many years.

Acknowledgments

The authors would like to thank Wolkite University for their support in applying a test in their building workshop, Wolkite environmental protection authority and other stakeholders for providing information and data during this research preparation.

References

- Ar. Dhenesh Raj and Ar. Bindu Agarwal (2014). Bamboo as a Building Material. *Journal of Civil Engineering and Environmental Technology*, 56-61 .
- Arghya Das and Saikat Sarkar (2018). Importance of Bamboo in Building Construction. *International Research Journal of Engineering and Technology*, 389.
- Bebija L. Singha and R.K. Borah (2017). Traditional Methods of Post Harvest Bamboo Treatment for Durability Enhancement. *International Journal of Scientific & Engineering Research*, 518-522.
- Cox, C. (2004). Boric Acid and Borates. *Journal of Pesticide Reform*, 10-15.
- Evans, D. (2009). A Guide for Village Carpenters on How to Build a Safer Shelter. Myanmar: Un-Habitat.
- Eygelaaar, J. (1975). Roof Structures for Low-Cost Housing Cost Comparison for Various Roofing Materials. Nairobi: Housing Research and Development Unit.
- Hashem Akbari and Ronnen Levinson (2008). Evolution of Cool-Roof Standards in the US. *earthscan journal*, 1-32.
- Irina Romanova and Nataliya Skanavi (2017). The selecting of roofing material for pitched roofs by the analytic hierarchy process. Moscow: Theoretical Foundation of Civil Engineering .
- Kigomo, B. N. (2007). Guidelines for Growing Bamboo. Nairobi: Kenya Forestry Research Institute.
- MNE (2011). Drawing of roof plan and details. Ankara: Ministry of National Education.
- P. Sharma, K. Dhanwantri and S. Mehta (2014). Bamboo as a Building Material. *International Journal of Civil Engineering Research*, 249-254.
- Research Centre for Forest Ecology and Environment, V. (2001). Corrugated bamboo roofing sheets. Beijing, China: A Repository of Agricultural Research Outputs.
- Robert Henrikson and David Greenberg (2006). Visionary Bamboo Designs for Ecological Living. Vietnam.
- Serdar Ulubeylia, Aynur Kazazb, Bayram Erb, M. Talat Birgonulc (2014). Comparison of Different Roof Types in Housing Projects in Turkey: Cost Analysis. Elsevier, 20-29.
- Shyam K Paudel and Solomon Ayeh (2014). Bamboo School Building . Ghana: International Network for Bamboo and Rattan.
- Tapan Sarker, Roberto Corradetti and Muslima Zahan (2013). Energy Sources and Carbon Emissions in the Iron and Steel Industry Sector in South Asia. *International Journal of Energy Economics and Policy* , 30-42.
- U.D.G.U.C Udagama and A. K. Kulatunga (2014). Development of Sustainable Roofing material from Waste. Research Gate (pp. 1-6). Sri Lanka: Asela Kulatunga .
- Vishwakarma Bhawan and Shaheed Jeet Singh Marg (2006). Preservation of Bamboo. New Delhi: National Mission on Bamboo Applications, Government of India.