Environmental Impacts of Building Materials for Minarets of Historical Mosques

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ABSTRACT
This paper focuses on building materials which contribute to environmental impacts as a result of energy consumption and depletion of natural resources. The topic of sustainability assessment rapidly gains importance. Consequently, there is need to assess building materials according to their environmental impacts. Minarets are the subject samples which are significant formal elements in mosque. The research objective is to assess environmentally the minarets’ materials of historical mosques in Mosul. The research conduct a survey to building materials used in all parts of the Minarets. In order to evaluate the sustainability of the major materials of the Minarets, the comparison is conducted for the environmental impact of Life Cycle Inventory LCI for clay brick and limestone by the aid of GaBi 6.0 Education software. The results of the survey shows that 70% of constructed Minarets in old Mosul city were used clay brick other than limestone which was represent 30%. Clay brick contributes higher environmental impact than limestone due to manufacture process which consumes more energy for firing and drying. The research recommended to use local materials to reduce transport effects and reuse building materials in order to reduce the environmental impacts resulted from manufacture process.

INTRODUCTION

Building materials are affecting on ecological environmental in terms of energy consumption, depletion of natural resources and emissions [1]. Environmental impacts are generated from mining, manufacturing, construction, use and demolition at the end use processes [2-3]. Attention are being required to minimize environmental impacts of buildings by different parties in various ways including: enhancing construction techniques, developing more effective methodologies and techniques for evaluating environmental impacts of building materials, and choosing environmental–friendly materials. As a way to evaluate the environmental impacts of buildings materials effectively, the life cycle approach can be applied [4]. The concept of environment in Islamic perception means more than a simple enumeration of its components of the ecological system; it transcends this to establish a link between these components and human. Thus, built environment in Islamic World was a reflection of Muslims view of the environment as a living entity [5]. The architecture of Mosul was an example of the architecture of Islamic cities. As well as the mosque is a representative building for Islamic architecture [6].

The reasons for choosing minarets as a subject to investigating the environmental impact of building materials can be attributed to; Firstly, its being a simple formal component-based type. Secondly, minarets “seem unrelated to its function of the adhan (calling the faithful to prayer)” [6]. Finally, the functional and behavioural attributes of minaret can be neutralised, therefore the minaret can be studied apart from the mosque’s other components. The minaret is an expression basically based on the Arabic word indicating "sign" or "marker". It is the principal vertical feature of most mosques which “provides a local landmark as well as allowing the voice of the muezzin (the man appointed to call for prayer) to carry over a considerable distance when calling for prayer” [7]. In Mesopotamia, minarets initially emerged in the twelfth century and the cylindrical shaft was distinguished in early forms [8].

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Methodology:
Quantitative data collected for 10 Minarets about the building materials for each Minaret referring to construction date, structural and finishing materials and the dimensions and quantities of the materials. The research, conducts a field survey to document this data which, enhanced by historical resources. According to the ISO 14044 standard details the selection of system boundary of the study will be cradle to grave [9]. By the aid of GaBi 6.0 Education software the task is to build (plan-model) for each material which represent the system with its boundaries. A plan-model is the manner the system becoming investigated is described in the software. According to the survey two plan-models must be built; the first for clay brick and the second for limestone. The plan-model made up of processes representing the actual processes taking place. Each process consists of input and output flows which represent all the material and energy flows passing between the processes and to end from the system. Although GaBi 6.0 Educational data sets can be implemented, still need for more data collected from technical reports.

The methodology is presented within four basic steps; goal and scope definition, inventory analysis, impact assessment and interpretation. In order to define the goal and scope of the project and then conduct an inventory analysis, data documentation form had been proposed with two main parts. The first part of the data documentation form is concerned of organization and documentation the goal and scope of the proposed project. While the second part of the form is concerned for life cycle inventory. All inputs and outputs for each process are quantified and classified then relating to unit process and functional unit in proposed table. The third step is performing impact assessment by applying GaBi Educational. The main task at this stage is to design the plan-model of the material within the system boundary proposed earlier.

All quantitative and qualitative data collected and documented in the data documentation form are converted into GaBi Education software. To get the results of impact assessments, GaBi has options to classify and characterize the environmental impact by selecting an impact assessment method. Moreover, depending on the goal and scope of the project the impact categories can be selected. Five impact categories were assessed; Global Warming Potential GWP, Acidification Potential AP, Ozone Depletion Potential ODP, Eutrophication Potential EP, and Human Toxicity Potential HTP. The analysing step performed by GaBi balance application based on plan of the project. After getting the environmental impact results of the product, the fourth step of the framework is ready to perform which it is an interpretation of the results.

Preparing for implementation:
(i) Survey of building materials of the minarets:

<table>
<thead>
<tr>
<th>Mosque</th>
<th>Minaret Name</th>
<th>Minaret Cons. Date</th>
<th>Building Materials Survey for the Minarets</th>
<th>Structural Material</th>
<th>Finishing Material</th>
<th>Structural Material</th>
<th>Finishing Material</th>
<th>Structural Material</th>
<th>Finishing Material</th>
<th>Structural Material</th>
<th>Finishing Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ansari</td>
<td>1772</td>
<td>Brick</td>
<td>Brick</td>
<td>Brick</td>
<td>Steel</td>
<td>Brick</td>
<td>Steel</td>
<td>Brick</td>
<td>Plaster</td>
<td>Brick</td>
<td>Plaster</td>
</tr>
<tr>
<td>Askar</td>
<td>1672</td>
<td>Stone</td>
<td>Brick</td>
<td>Brick</td>
<td>Steel</td>
<td>Brick</td>
<td>Steel</td>
<td>Brick</td>
<td>Plaster</td>
<td>Brick</td>
<td>Plaster</td>
</tr>
<tr>
<td>Omer</td>
<td>1682</td>
<td>Stone</td>
<td>Brick</td>
<td>Brick</td>
<td>Steel</td>
<td>Brick</td>
<td>Steel</td>
<td>Brick</td>
<td>Plaster</td>
<td>Brick</td>
<td>Plaster</td>
</tr>
<tr>
<td>Alakawl</td>
<td>1703</td>
<td>Stone</td>
<td>Brick</td>
<td>Brick</td>
<td>Steel</td>
<td>Brick</td>
<td>Steel</td>
<td>Brick</td>
<td>Plaster</td>
<td>Brick</td>
<td>Plaster</td>
</tr>
<tr>
<td>Alomer</td>
<td>1720</td>
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<td>Brick</td>
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<td>Plaster</td>
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<tr>
<td>Alask a</td>
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<td>Stone</td>
<td>Brick</td>
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<td>Steel</td>
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<td>Brick</td>
<td>Plaster</td>
<td>Brick</td>
<td>Plaster</td>
</tr>
<tr>
<td>Azywa</td>
<td>1779</td>
<td>Stone</td>
<td>Brick</td>
<td>Brick</td>
<td>Steel</td>
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<td>Steel</td>
<td>Brick</td>
<td>Plaster</td>
<td>Brick</td>
<td>Plaster</td>
</tr>
<tr>
<td>Khzai</td>
<td>1796</td>
<td>Stone</td>
<td>Brick</td>
<td>Brick</td>
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<td>Brick</td>
<td>Steel</td>
<td>Brick</td>
<td>Plaster</td>
<td>Brick</td>
<td>Plaster</td>
</tr>
</tbody>
</table>

Table 1 show the data survey for building materials of each part of the 10 minarets. The table consist of construction date of the minaret and the name of the mosque. The survey shows that the common building materials 70% is clay brick and 30% is limestone distributed to each part of the minaret as structural materials or finishing materials. The data listed in the table are the raw data to conduct first and second step of the Life Cycle Assessment LCA methodology.

(ii) Design the plan-model of LCA for stone and clay brick:
Within plan-model, processes are connected with flows to design two projects; one for stone and the other for brick. Every process will have an input, an output, or both. In order to make sure it is using the correct amounts of material for each process, the processes need to be connected and a functional unit had to be set. The system boundary for both projects is cradle to grave. This step represents an inventory analysis according to
International Organization for Standardization ISO 14040 standard. Before running the balance of each project the scaling factor need to be changed according to the amount of the materials used in the sample.

RESULTS AND DISCUSSIONS

From the results shown in Figures 1 and 2, the five impact category for Minarets used clay brick are much higher than for those used limestone. This expected because of the high quantities of electricity and natural gas required by processes involved in manufacturing and extraction stages of clay brick. Within the clay brick group shown in Figure 1, the highest impacts for all categories are by Alhadbaa Minaret in Annori mosque due to the height and huge base of Alhadbaa Minaret.

Fig. 1: Results of environmental impact of Minarets used clay brick.

If each stage of the life cycle is examined in more detail, the contribution to environmental impact was from mining the clay which is essentially due to the consumption of fuel needed to operate the earth moving machinery. Meanwhile, manufacturing stage consume large amounts of diesel and electricity. Moreover, this stage requires high level of water consumption in the melting process. The stage in which clay brick is actually produced is the one that generates the greatest impact for all impact categories. This is basically due to the consumption of fuel needed in the drying and firing processes besides the emissions of CO, NOx and SOx that come mainly from these processes. Finally, results show that limestone is slightly significant in the environmental impact due to no need for firing in manufacturing stage. The most effective flows are the emissions to air which caused increase in ozone depletion potential.

Fig. 2: Results of environmental impact of Minarets used limestone.
Summary:

The results of this study show that clay brick was essential material used in construction of historical minarets as structural and finishing material. The environmental impacts of using clay brick are much higher than for minarets which constructed with limestone. Although clay brick was not popular in other historical building in Mosul but it used widely for three reasons; Firstly, the light weight of clay brick make it possible to used it in higher parts of historical buildings so it was used in minarets, arches, and domes. Secondly, the ability of moulding in exact form and size. Thirdly, the ability to carving made clay brick perfect finishing material for inscriptions and calligraphy which were popular in historical buildings in Mosul.

REFERENCES