

Innovative Building Material for the House Construction for Solar Decathlon Middle East 2018 Competition

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Abstract. This experimental report describes the invention of a new type of block for the construction of a sustainable house for the Solar Decathlon Middle East 2018 Competition by the team SoLLite-Salalah from Dhofar University, Sultanate of Oman. The aim of the experiment was to create a material for exterior walls' construction that is environmentally friendly, light, easy to transport and assemble, resistant to heat transfer, and also with low manufacturing cost. The paper describes the project SoLLite-Salalah, the experiment itself and provides the results of the tests, which show that the sample block made by the team fulfils the requirements and can be used for the construction of the exterior walls of the house. This report also demonstrates that Solar Decathlon Competitions stimulate research and innovation and promote the idea of efficient housing by educating and training students.

1 Introduction

The term 'Efficient' has been always known, but only recently started being applied in building construction. 'Efficient', when applied to a building, means it benefits to the environmental, social and economic sustainability of the society [1]. Buildings are the biggest consumers of energy and materials. Therefore, the application of the term 'Efficient' in construction industry, which starts with the design of the building, makes the construction process sustainable [2, 3]. When applied during the design phase, the term 'Efficient' require selection of materials that are environmentally friendly (sustainable, green, and recyclable), optimally use the resources, produce minimum waste and do not harm people and the environment [4]. Currently, there are many efforts to boost sustainable construction and one of them is Solar Decathlon competition, which was organized by the U.S. Department of Energy [5]. Solar Decathlon is the biggest platform for research and innovations in sustainable housing, where the teams from different universities compete in designing, building and operating of a net-zero energy solar powered and efficient house [6]. The houses are elevated according to the ten contests, which are: 1) architecture, 2) engineering and construction, 3) energy management, 4) energy efficiency, 5) comfort conditions, 6) house functioning, 7) sustainable transportation, 8) sustainability, 9) communication and the last, but one of the most important 10) innovation. The competitions are beneficial for both the competitors and the public and promote sustainable housing, construction, reduction of energy and materials in

buildings [7-9]. The winning team is the one that designs and builds the most efficient house, thus the competing teams, aiming to win the competition, create and implement the best innovative ideas [10].

This experimental report discusses an innovative idea of the team SoLLite-Salalah from Dhofar University, Sultanate of Oman, which currently participates in Solar Decathlon Middle East 2018 (SDME 2018) competition. Aiming to reduce the energy consumption of the house by improving the envelope of the house, the team introduces a new type of a block for exterior walls construction, which is made of recycled materials.

2 Project description

SoLLite-Salalah project aims to design a model of a solar-powered house, that doesn't harm the environment, conserves natural resources, responses to the Middle East climate and culture, but flexible and adaptive to a different environment, it is light-weight and easy to transport, it is smart, but easy to assemble and operate, provides mobility if needed under stressed circumstances, i.e. – natural disasters shelter, refugees camps - and can also serve for tourists' housing during the Monsoon in Salalah, when population of the city drastically increases and the accommodations are scarce.

SoLLite team that competes with others twenty teams in SDME 2018 [11] consists of students and faculties of Dhofar University and partners from local industry in Salalah, Sultanate of Oman. The concept of the house – go beyond your own walls - suggests the

owner to be the designer of his own house and allows him to control the space and depending on family needs to change the layout, expand the house horizontally and vertically, form the pattern of facades' features. Two units attached to each other (considering the flexibility of the unit itself) make it suitable for function change (mini market, kids day care, café, etc.) Many units arranged together accompanied by communal facilities form a sustainable neighbourhood.

The flexibility is achieved by a grid based layout with squares 1.2x1.2 m and lithe interior and exterior walls (movable walls and sliding & folding partitions system) [12].

2.1 Defining and analysing the problem

As the aim of the team was to design and build an efficient house that is light-weighted, the problem was to find a material for exterior walls construction that is light, easy to transport and assemble and environmentally friendly also. The additional requirements to the material were – affordable cost, ability to be incorporated into the grid of the house and be resistant to heat transfer.

A good material for exterior walls (roof, floor) that do not transfer the heat from outside to the interior of the house can reduce significantly the cooling loads and, therefore the energy consumption [13-16].

3 Problem solving

The solution to the problem was found after a series of experiments in mixing recycled and natural materials for making a sample block to be further tested and case of its good performance to be used for construction of the exterior walls of the house.

3.1. Choosing the materials

In order to obtain an eco-friendly material each of the ingredients must be eco-friendly.

Table 1. Selected materials and their description.

Material	Description
Coal (Anthracite, dry)	Eco-friendly, fixed carbon 92-98%, Volatile Matter 2-8%, density 800–929 kg/m
Straw	Eco-friendly, lightweight, strong, durable, it takes dye well, can be woven into any shape, good thermal insulator
Paper and cardboards	Eco-friendly, lightweight, good thermal insulator
Clay	Eco-friendly, easy to control density and porosity, wear and corrosion resistant, high melting temperature, poor conductivity
Sawdust	Eco-friendly, light weight, good thermal insulator

The choice of the materials was based on study of the local market, availability of the materials, industrial companies (products and materials used for manufacturing and waste from manufacturing processes) as well as on properties of those materials. Materials that were selected for experimentation are - ground coal, straw, waste paper and paperboard, sawdust and clay, which when mixed with water, can be formed into bricks (see Figure 1). Table 1, which is given below, lists the materials and provides their description.



Figure 1. Materials selected for brick making.

3.2. Experimenting with the materials

The experiments were conducted in October, 2017 in the laboratories of the engineering workshop at Dhofar University by the students Marwa Salim Abdullah Barrami, Musallam Mohammed Musallam Jadad and Al Anood Al Mazini under the supervision of Laiqahmed Mombasawala, Engineering workshop supervisor and Marwan Bait Farhan, the coordinator of SoLLite-Salalah project.

The quantity of each ingredient, which was used for sample block making, is defined in Table 2.

Table 2. The quantity of materials used for brick making.

Material	Quantity (per block)
Coal (Anthracite)	135 grams
Straw	200 grams
Water	1.325 liters
Papers and cardboards	1.325 liters
Pottery clay	5912 gram
Sawdust	1000 grams

All the materials were brought to the lab, weighed the quantity of each ingredient (see Table 2), loaded into

an electric mixer and mixed well. Before mixing the clay, the coal, the straw, the paper and the card board were grinded (see Figure 1). The mixture was transferred to a mould made of solid concrete and with the dimensions of 150 mm x 150 mm x 150 mm as shown by Figure 2. The block was left to cast in the laboratory for one week, and then transferred outside to dry under the sun for three more days. When the surface was fully dry, the sample block was transferred back to the lab for testing. The weight of the mixture for one block before loading it into the mould was 1235 gr. When the process of casting was completed the weight of the block was measured and showed 1069 gr (see Figure 3).



Figure 2. The concrete mould for the block.



Figure 3. The measurement of the of the block before drying.

3.3 Testing the sample block

At the first the heat conductivity of the sample was tested. The test was executed via placing the sample on a hot plate, one side of which was heated directly and measuring the temperature at different distances from the heated surface. The top of the hot plate was heated up to 85 degrees Celsius and the temperature measurement was taken at various points at a distance of 2.5 cm (1 inch between each point from bottom to top of the block) after one hour of constant heat. The results of the heat conductivity test demonstrate that even though the plate was heated up to 85 degrees, there isn't a significant heat

transfer through the body of the brick. The results of the test are demonstrated by Table 3, which is given below.

Table 3. Temperature measurement after one hour.

Measuring Point from bottom to top	Surface temperature, degrees Celsius
0 cm	85.0 bottom
2.5 cm	36.3
5 cm	32
7.5 cm	31.5
10 cm	29.7
12.5 cm	27.4 top

The measurement of the temperature at the point 2.5 cm from the bottom shows 36.3 degrees (increase in temperature by 11.3 degrees). Here it is important to mention that the temperate in the lab before testing was set at 25 degrees Celsius and kept constant during the measurement period. The reading of the data that is given in Table 3 and the graph (see Figure 4) demonstrate that the temperature of the top surface of the block had increased by 1.4 degrees only.

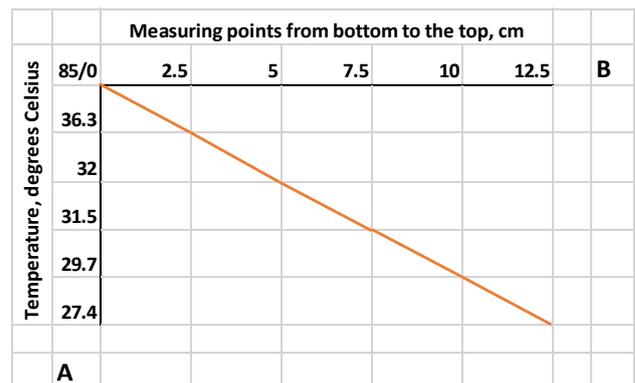


Figure 4. The graph demonstrating the increase of the temperature with the heat increase.

The second test, which was conducted, was the compression test that identifies the compressive strength of the sample block (see Figure 5).



Figure 5. Photographs showing the block at the beginning and at the end of compression test.



Figure 6. The Universal Testing Machine and the block the before compression.

The test was executed using the Universal Testing Machine as shown by Figure 6. During the test, unfortunately, the maximum strength of the block could not be reached, as it has compressed significantly, after which the testing was stopped. The block thickness has been decreased by 60% from its original size, and despite the deformation it did not break (see Figure 5).

The results of the compression test show that up to the level of 10,000 Newton force very less deformation was observed, compression force beyond that started deforming the block, particularly the height reduction and subsequently side bulging was observed as shown by the photographs (see Figures 6 & 7).



Figure 7. The brick deformation during the compression test.

The testing of the sample demonstrates that this type of block can be used for construction of the exterior (or interior) walls, where the load on the block does not exceed 10 KN.

4 Conclusions

This report, which describes how SoLLite-Salalah team that participates in Solar Decathlon Middle East 2018

competition through research and experiments tries to find the most efficient material for the house's walls construction, demonstrates that the experiment was successful as the aim of the team was achieved. The sample block, which was made by the team from recycled and natural materials, is environmentally friendly, light weighted and resistant to heat transfer. The results of the compression test show that the blocks can be used for the construction of the exterior/interior walls considering that the load on the block must not exceed 10 KN. This type of block can be safely used by the team for the exterior walls, as the main structure of the house is made of steel and the blocks, therefore, will not carry any structural loads except their own dead load weight. The blocks act as curtain walls that will be incorporated into a steel structure. Additional exterior finish is required to prevent moisture' absorption and interior finish for better aesthetical view.

The challenge that the team is still facing is the manufacturing of the blocks. After several meeting with construction materials manufactures was decided to manufacture the moulds outside the campus, but make the blocks at the engineering workshop of the university.

This paper also shows how Solar Decathlon competitions motivate the competing team composed of students, faculties and industrial partners for research and innovative ideas for efficient (sustainable) housing construction and reduction of energy consumption. Such competitions that are help all over the world educate students, promote the concept of sustainable living and contribute to the creation of a sustainable future community.

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