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Smart and Healthy within the 2-degree Limit

The 5 Degrees of Forced Climate Refugees
Negative carbon and positive energy eco-cycle housing solutions

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ABSTRACT: Severe climate and weather events together with political conflicts linked to climate change are the most pressing driving forces for critical numbers of people to leave their homes seeking safe haven. Climate refugees are becoming the next captious challenge we will face. Temporary refugee settlements prove to have high environmental burdens given the short lifespan of the industrial materials produced with high embodied carbon that they are built with. Despite this finding, alternative natural-based low impact materials with a carbon neutral production and construction process do exist. This paper presents the outcomes of a one-year project in designing and constructing a negative carbon and positive energy eco-cycle home. The idea is to achieve a self-sufficient and low impact temporary shelter design with the lowest carbon emissions during construction and after demolition. The design complies with premium passive house standards and was constructed in an experimental urban living lab for proof of concept. The house is now under monitoring to evaluate its performance. The project was carried out in Sweden, but the methodology could be applied in other climatic contexts.

KEYWORDS: Climate refugees, Eco-cycle design, Negative carbon, Positive energy, Urban living labs

1. INTRODUCTION

The world has recently witnessed a surge of disasters associated with climate change. There is an acute need for sustainable, quick, and economic housing that can provide temporary shelter for climate refugees (Fornalé and Doebbler, 2017). Emergency shelters seldom touch upon passive means in achieving indoor thermal comfort and energy efficiency (Borge-Diez et.al, 2013). The main focus is on time and cost efficiency while energy efficiency and impact on the environment often remains a secondary goal (Dabaieh and Borham, 2015). Temporary shelters are mainly constructed using industrial material with high embodied energy and carbon in the construction process, ignoring the potential of using natural materials with minimal carbon footprint. The latter are also cost and time efficient solutions and suitable for acute and temporary building purposes (Dabaieh, 2017a&b).

This paper discusses a proof of concept for an eco-cycle refugee shelter. This shelter is designed to be energy self-sufficient, depending mainly on passive means for cooling, heating, daylight and natural ventilation, and it is equipped with necessary everyday features (Dabaieh and Alwall, 2018). Passive systems like Trombe windows, green walls, an Earth Air Heat Exchanger (EAHE), green roofs and a cool roof were used (Dabaieh, 2017a) in addition to passive strategies like orientation, shading, thermal zoning, high thermal mass and reducing thermal bridges. The building's main skeleton is made from straw, reeds, and clay and uses wooden frame bearing walls. This experimental house applies building performance simulation, material lab testing, and urban living lab test cells for proof of concept as a three-phase methodology. The experimental refugee house was built in 11 working days using the help of 7 refugees who were trained onsite. The house is now under monitoring for one year as part of a post occupancy evaluation in Lund, Sweden in order to assess the performance, verify the feasibility and design efficiency of the passive systems, and calculate its actual energy consumption and production. The house after construction is shown in fig. (1).

2. METHODOLOGY

This research project applies an experimental urban living lab for proof of concept. The project followed three main phases explained below:

- Architectural design and building simulation:

The house prototype was designed applying premium passive house standards for the Swedish climate. The design target was to reach a negative carbon and positive energy performance by using natural materials as the main building skeleton and passive means for heating, cooling, daylighting and natural ventilation. Four building performance simulation programs; DesignBuilder, DIVA for Rhino, TRNSYS and ANSYS were used to assess the building performance. The design was rectified and adjusted after several simulation runs to achieve the targeted performance levels.

- Lab testing, LCA, LCC and energy calculations:

Several material lab tests were conducted to test the performance of the suggested building materials, which are mainly straw, reeds and clay. Tension, compression, water resistance and fire proofing together with other thermophysical measurements for thermal conductivity, diffusivity and heat capacity were tested. The results informed the design and the simulation was re-made to comply with final expected building performance levels. In this phase a detailed life cycle analyses (LCA) and life cost analysis (LCC) were conducted to measure the total impact of the building and the payback time. The estimated energy consumption and energy production were also calculated in this phase.

- Living lab test cells and proof of concept:

To test the performance of the three main passive solutions, Trombe windows, green walls and the EAHE, test cells were needed for a preliminary assessment. Together with the eco-cycle system for black and grey water treatment, organic waste for biogas production and testing the zero-energy earth fridge and the dry cloth and dish washing pedal machines, the test cells were incorporated in the building's main skeleton during the construction process.

3. RESULTS & DISCUSSION

The outcome of the simulation showed 40 % less energy would be consumed per year for heating and cooling demands than the amount set by the Passive House Standards. That is due to using the three passive systems; EAHE, Trombe windows and the green wall. TRNSYS simulation results are shown in fig (2). The ANSYS simulation also showed the effective performance of the green wall and the open cycle EAHE for natural ventilation complying with Passive House Standards. The energy calculations showed an annual surplus of 200 kWh/m2 which could be sold to provide a source of income for refugees. The LCA calculations showed a negative carbon output of - 1.2 KgCO2/kg due to using natural fibres (straw, reeds and wood). In addition to the low-tech approach in the main building construction, the raw material was sourced from nearby the project site. The main building components are recyclable or can be easily returned to nature as compost. The payback time was calculated as 10 years, which might not be cost efficient unless it is granted a temporary building permit in Sweden, specifying that it is to be demolished after 15 years.

Fig. (1) The refugee house after construction.

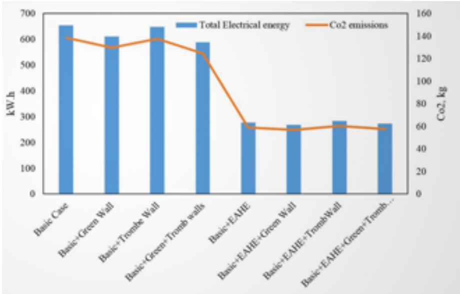

Fig. (2) The TRNSYS *simulation for heating and cooling using the three passive systems and the equivalent carbon emissions for electricity consumption.*

4. CONCLUSION

This study shows how refugee housing can be quick, affordable, and designed and constructed using eco-cycle means with minimal impact on the environment. Refugee housing can help prevent the mounting increase of climate change effects and reduce the impacts of associated humanitarian crises. Architects, among other professionals, must find innovative solutions for applying appropriate low-impact, affordable technology to improve the lives of affected populations.

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