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Developing Sustainable Alternatives from Destroyed Buildings Waste for Reconstruction Projects

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Abstract

This paper examines the huge destruction that has taken place in some cities of Iraq due to the terrorist acts in recent years that led to the destruction of many buildings. It examines some of the factors that encourage the use of residues of these buildings in reconstruction processes, especially the sustainability factor, so that some residues of these buildings can be used as substitutes for natural building materials and find a difference in terms of energy consumption in the case of using natural building materials and again in the case of using the proposed alternatives. In this study, three alternatives were used: 10% recycled fine aggregates (RFA), 100% RFA, and crushed clay brick aggregate (CCBA) to produce recycled coarse aggregates. The results obtained through the use of building information modeling (BIM) technology were compared with the actual consumption of the building in the case of reconstruction using natural building materials. The simulation results were comparable to real data. They were analyzed in terms of the energy consumption life cycle and annual carbon emissions for each alternative. The best alternative was selected from the results obtained from BIM. The best alternative was found in the use of CCBA in the production of concrete roofs and floors. His final model is that the energy consumption was five times lower than the original unit, while the results of carbon emissions were equal as for the electricity consumption decreased from 23,500 kW/h to less than 23,000 kW/h.

Keywords: BIM; RFA; CCBA; Reconstruction; Destroyed Buildings in Iraq.

1. Introduction

Waste of destroyed buildings is one of the biggest problems going through some parts of Iraq. Which has a significant impact on the environment if it is buried in the landfill. The common causes of mass production of destroyed buildings are either natural or man-made disasters [1, 2]. It is very difficult to get rid of these large quantities of debris, and thus the process of managing the waste of destroyed buildings has become an unjustifiable social concern in modern and developed societies [3, 4]. The massive destruction that has taken place in some cities of Iraq recently due to terrorist acts weakens the country's economic ability to provide the necessary building materials for reconstruction. The most important factor will be the impact of these wastes on the environment in the future. Therefore, it is the right management to exploit these wastes and use them as substitutes for natural resources without affecting the proportion of the building's energy and electricity, so these proposed alternatives become environmentally friendly and sustainable.

BIM can be used to conduct energy analysis using natural materials or alternatives over the design phase [5]. This analysis can help find the percentage of the impact of using alternatives on the energy consumption of the building to choose the right alternative to achieve sustainable economic design [6-8]. In recent years, there has been a clear success using BIM in many projects to achieve sustainable design [9]. This will help improve the estimation of quantities,

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construction, construction cost and energy consumption of heating and cooling in the pre-construction phase [10]. There has been a great interest in design recently because it is possible to know the amount of energy consumption of the building throughout the life cycle of the building [11].

This study focuses on finding the difference in energy consumption in winter and summer in the case of the use of alternatives represented by the waste of destroyed buildings instead of natural materials in the process of construction using BIM technique, and to eliminate the concern and fears about the impact of using these alternatives in sustainable design. Thus, it was found that the use of some alternatives that are recycled aggregates (RA) or broken bricks instead of natural aggregates achieves sustainable construction because all alternatives have properties close to the properties of natural resources and thus can save natural resources from depletion.

The researchers found that bricks and concrete are among the most common waste from destroying buildings [12, 13]. There are some results that indicate the possibility of producing recycled concrete containing RCA or crushed bricks and used in the construction process where he explained that the presence of these materials within the concrete increases the compressive strength and therefore does not pose any risk in its use as a normal building material [14]. Letelier (2018) concluded that brick powder can be used in the concrete mix by 15% without a significant impact on concrete strength [15]. Marie (2017) found that through the use of RA and in different proportions can maintain the properties of mechanical and physical, concrete and thus can achieve sustainability using RA, but depends on the proportion of use within the concrete mix [16]. Mack (2018) found that the use of recycled concrete instead of the concrete produced from natural materials has a positive impact on the environment where it reduces the consumption of natural resources and also reduces the consumption of energy and fuel associated with the process of transporting building materials [17]. According to a study conducted by the Environmental Council of Concrete Organizations, a large amount of natural concrete can be saved up to 60% using RA as an alternative to NA [18].

2. Research Methodology

Figure 1 shows the steps of the research methodology. The research can be divided into the following parts.

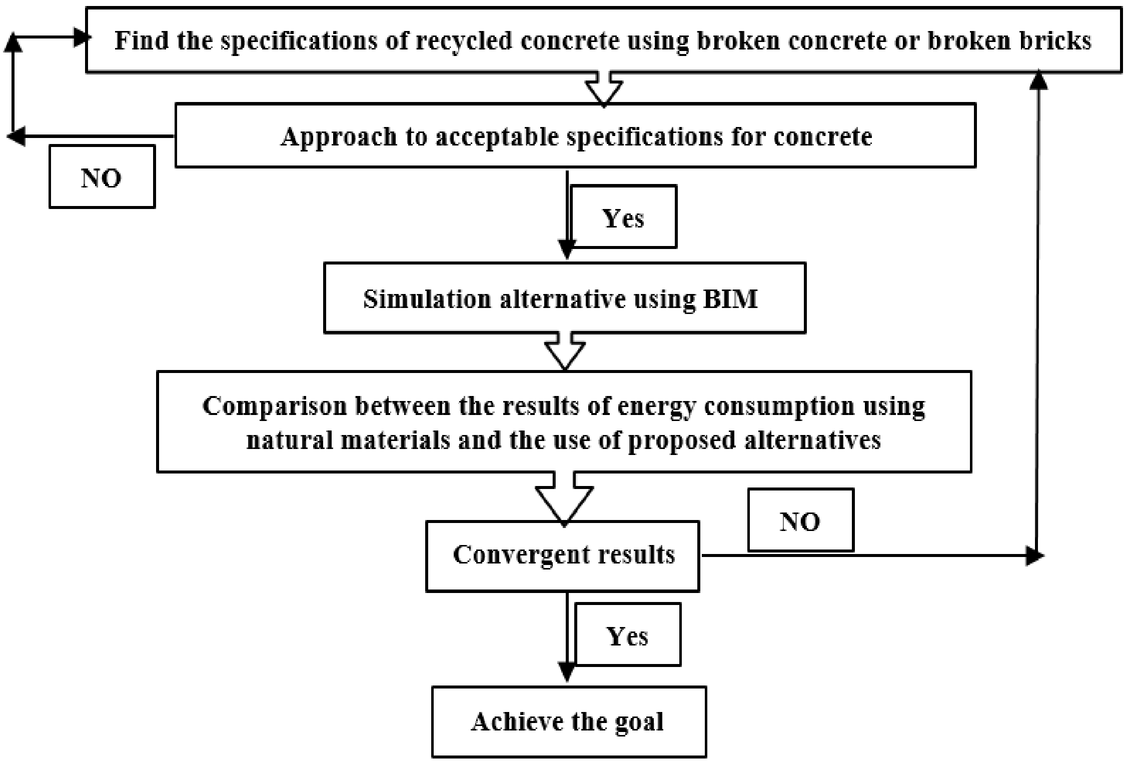


Figure 1. Research methodology

2.1. Selection of Alternatives

This represents the first part where it consists of some alternatives selected for the study based on the previous studies of their specifications. Three alternatives were selected: the first is recycled fine sand that product from crushed concrete, which is replaced by 10% of natural sand. The second alternative also represents recycled fine sand, but a 100% replacement of natural sand. The third alternative is the recycled coarse aggregate that product from the broken brick, which is replaced by natural aggregate as shown in (Table 1).

Table 1. Properties of recycled concrete

Alternatives	Replacement	Density (Kg/m^3)	Compressive Strength (Mpa)	Modulus of Elasticity (Mpa)	Thermal Conductivity (W/m.K)	Researcher
AL 1	10%RFA	2339.4	47.5	32392.5	2.06	[19]
AL 2	100%RFA	2216.2	27.1	24467.1	1.21	
AL 3	(1/2.2) C/RCA	1596	25	23500	0.77	[20]

2.2. Modeling a Case Study

This represents the second part where it involves modeling a destroyed multi-storey building with an area of 600 m^2, once using new building materials and again using alternatives, which include recycled sand and recycled gravel to produce concrete needed to rebuild the roofs of that building. Then space was determined to calculate the energy consumption in it as shown in (Figure 2).

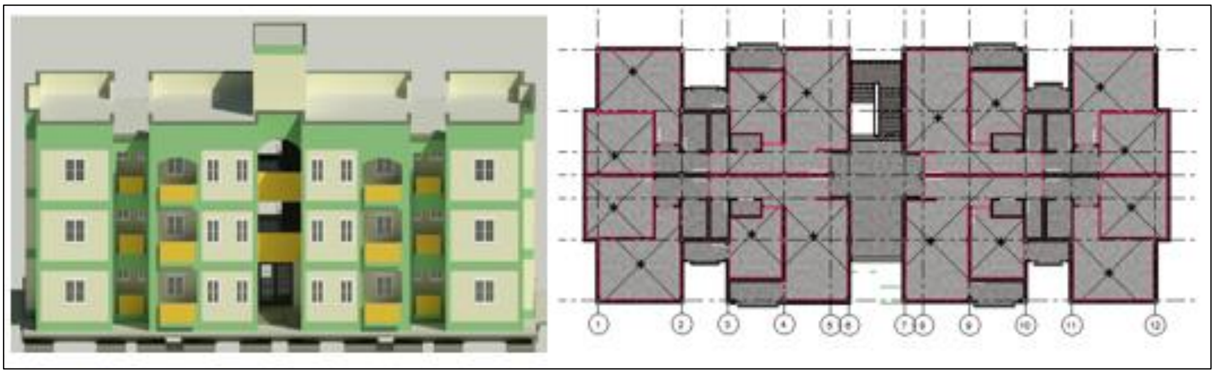


Figure 2. Modeling of destroyed building and identify spaces

3. Results and Discussions

The third part includes the results obtained from BIM models related to (NFA, NCA, RFA, and CCBA), finding the difference in the results and choosing the best alternative. The three-storey unit was modeled and analyzed using original building materials and analyzed using other alternatives. The apartment area is 600 m^2. Using the Revit environment, which provides the ability to analyze energy for all types of buildings, energy consumption is analyzed by heating and cooling loads. It was found that there was little difference in results between natural concrete and other types of recycled concrete. Where the highest energy consumption used for cooling and heating in the case of the use of alternative 1 and is equal to (202291 W- 113231 W) respectively, which represents a replacement rate of 10% of natural sand. While the energy consumption decreases as the percentage of replacement increases until it reaches 100% of the natural sand and the cooling load equal to (189810 W), and heating load equal to (108491 W) for alternative 2. While the energy consumption is less than normal in the case of the use of alternative 3 and is equal to (181402 W) for cooling load and (105326 W) for heating load, which represents the use of broken bricks instead of natural gravel as shown in (Figure 3). Thus, it was found that the higher the replacement ratio, the closer the results to the natural state and therefore those alternatives are environmentally friendly.

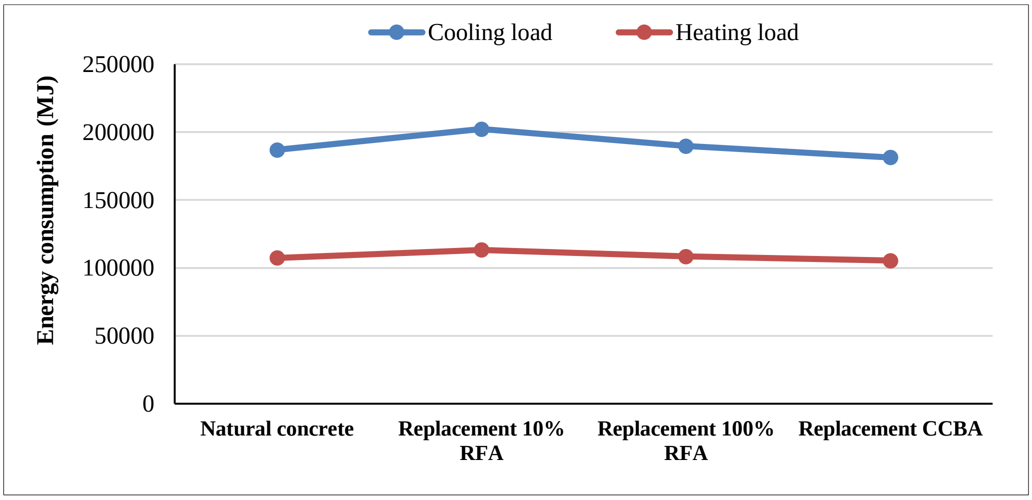
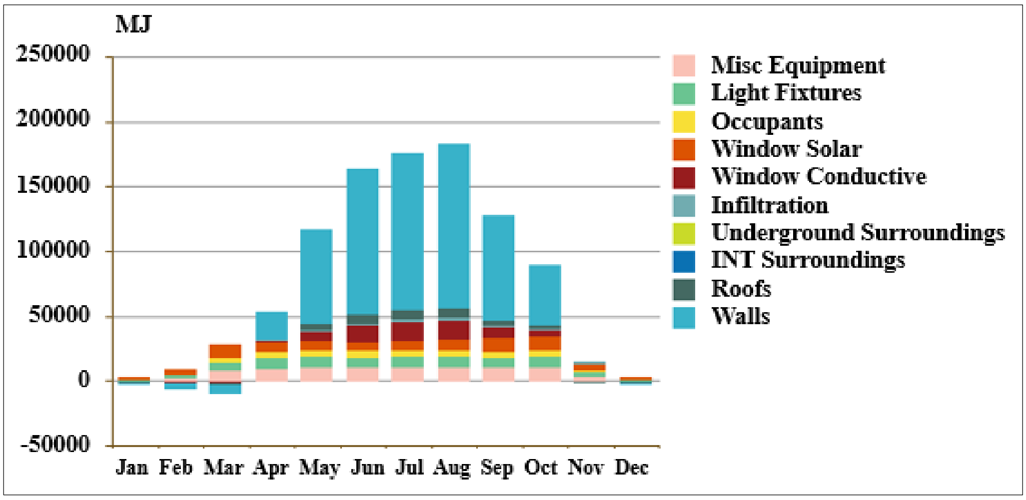
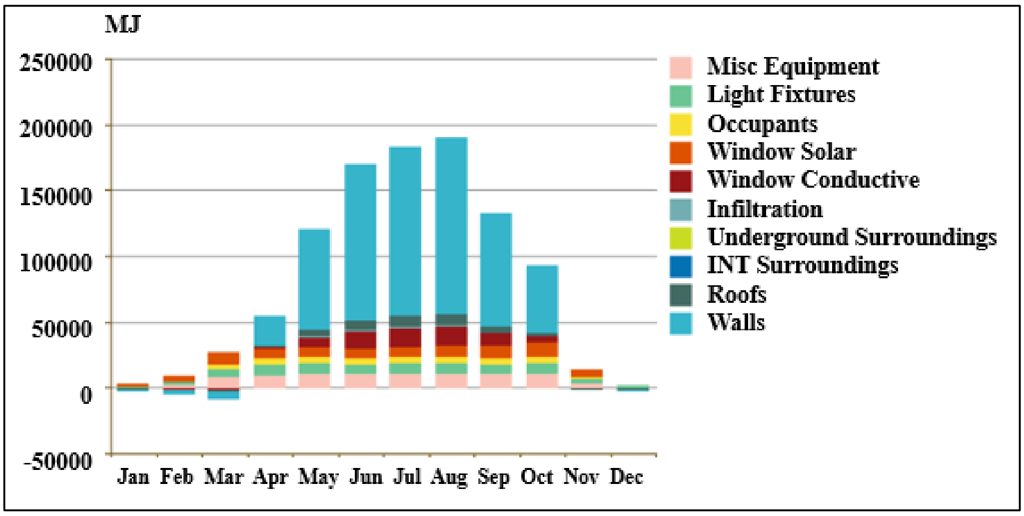


Figure 3. Results of analysis energy consumption by heating and cooling loads for residential buildings

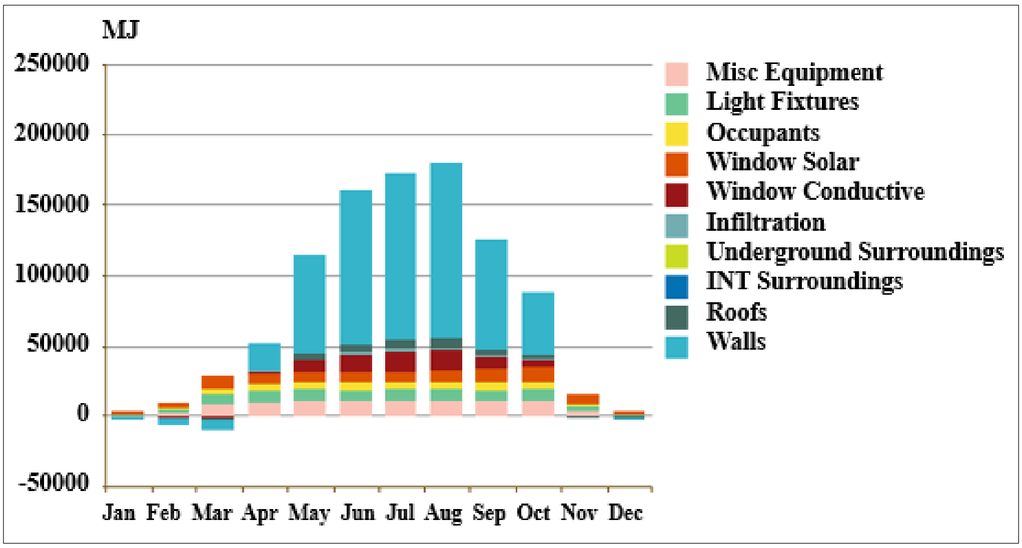
The results of the monthly energy consumption analysis used for cooling were found to be equal (185000, 190000, 165000, 16000) MJ during August and resulting from the use of (NC, 10% RFA, 100% RFA, CCBA) respectively, the monthly energy consumption analysis used for cooling was found to be equal (185000, 190000, 165000, 16000) MJ as shown in (Figure 4). Thus, there was no significant difference in the results of energy consumption in the case of the use of RA or crushed bricks, which in turn plays an important role in the conservation of natural resources on the one hand and the preservation of land that can be used as a landfill in the case of non-use resounding.



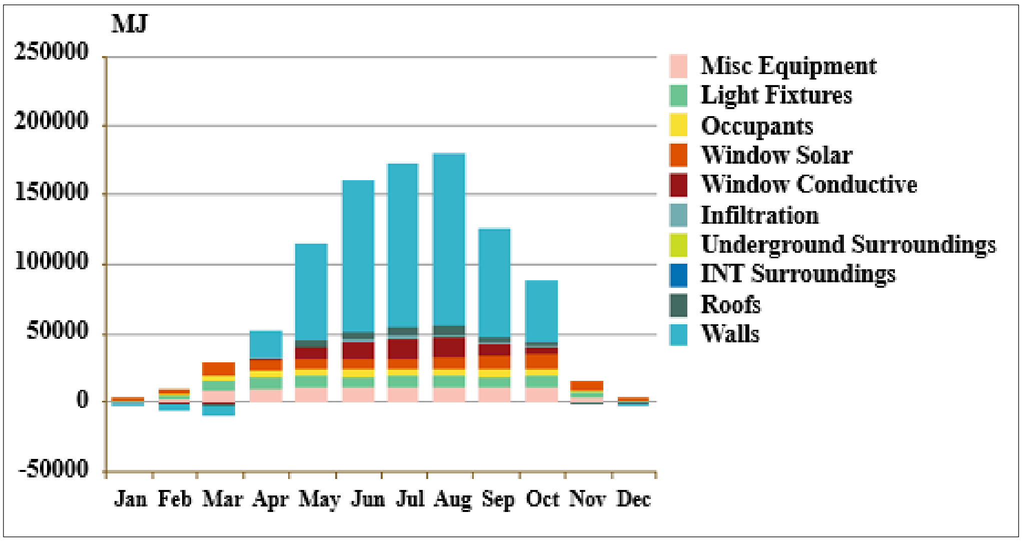
(a) Natural concrete



(b) Replacement 10% RFA



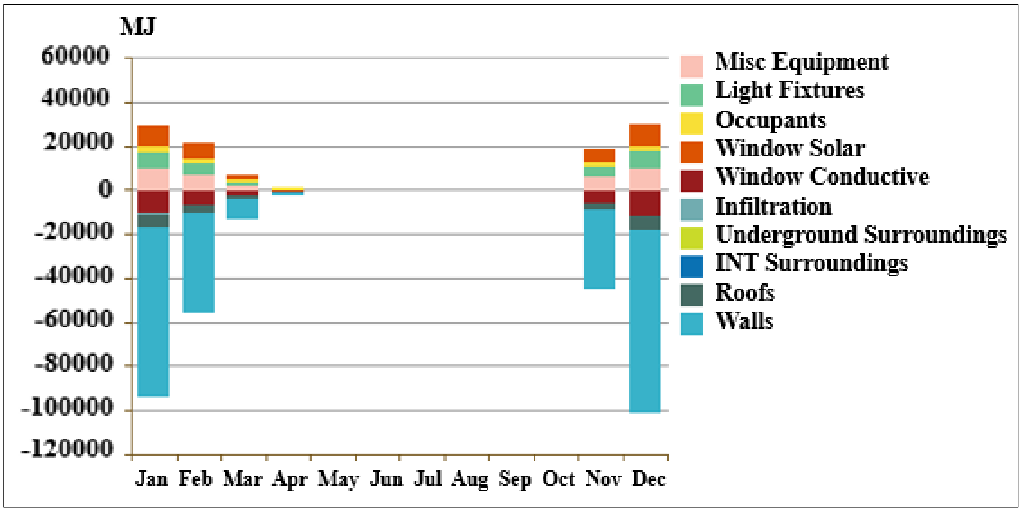
(c) Replacement 100% RFA



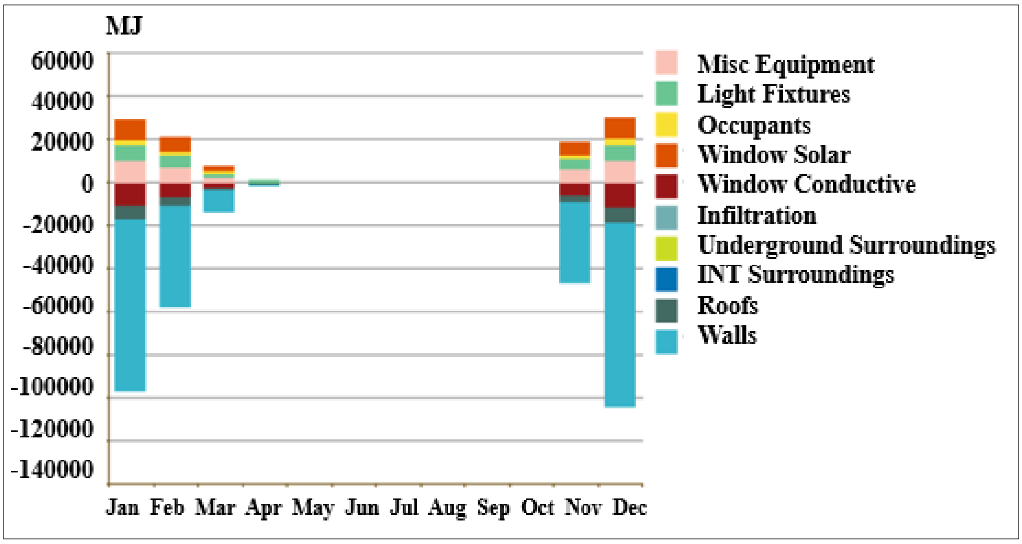
(d) Replacement CCBA

Figure 4. Comparison of monthly cooling load between natural and recycled concrete of residential buildings

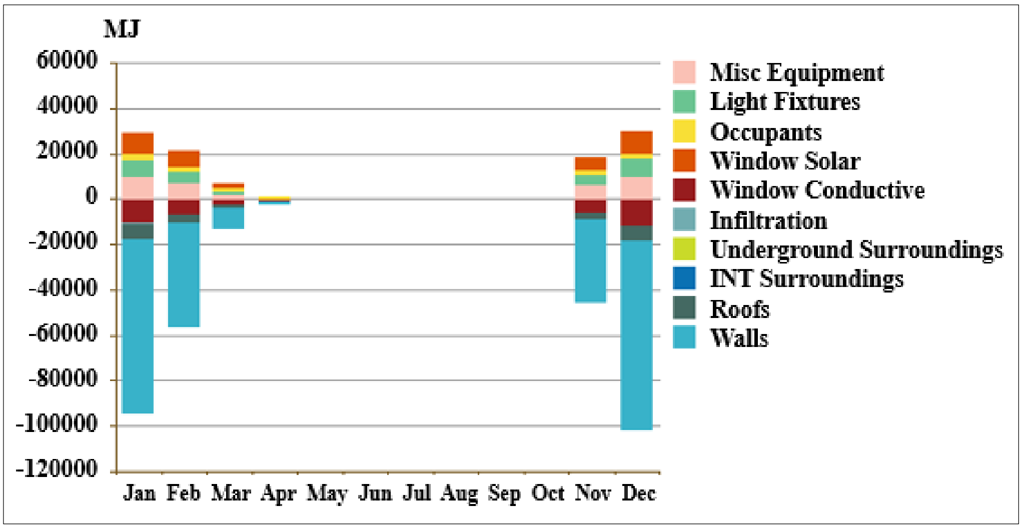
The results showed the highest consumption of energy used for heating in December and January. The results of the monthly energy consumption analysis used for heating were found to be equal (100000, 102000, 101000, 99000) MJ during December and in January it equal to (95000, 98000, 97000, 90000) MJ as shown in (Figure 5). So the lowest alternative is the CCBA.



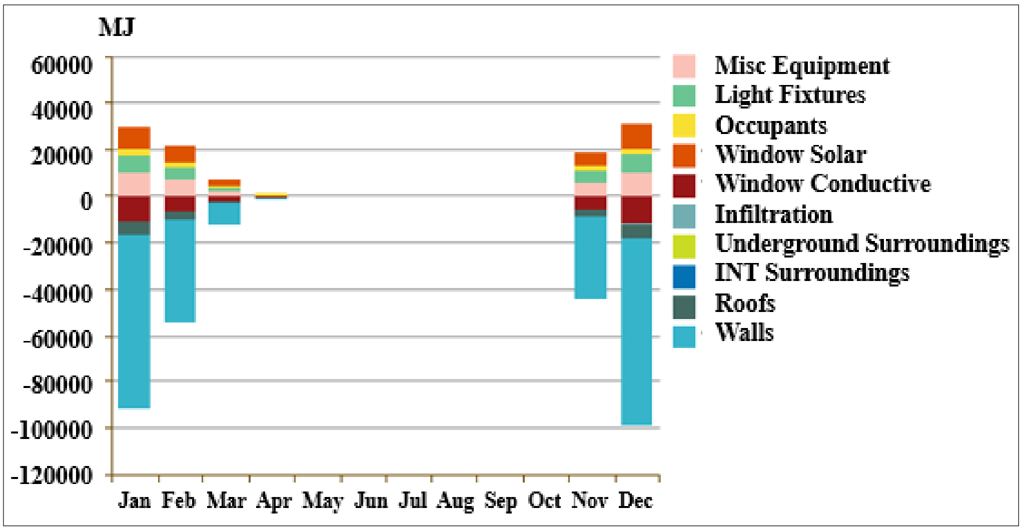
(a) Natural concrete



(b) Replacement 10% RFA



(c) Replacement 100% RFA



(d) Replacement CCBA

Figure 5. Comparison of monthly heating load between natural and recycled concrete of residential buildings

Figure 6 illustrates the results of a carbon emission analysis based on the isolation rate of alternatives, where the result of this alternative is equal to (30, 32, 31, 30) metric ton/ yr for using (NC, 10% RFA, 100% RFA, CCBA) respectively. The results showed the highest annual carbon emissions appeared in the case of 10% RFA replacement while the annual carbon emissions were lower and closer to the normal state of concrete in the case of 100% RFA replacement and the use of CCBA. This means that the use of concrete containing recycled bricks can keep carbon emissions within normal limits, when used with concrete containing RFA, the carbon emissions are slightly more natural. The lowest alternative is the CCBA.

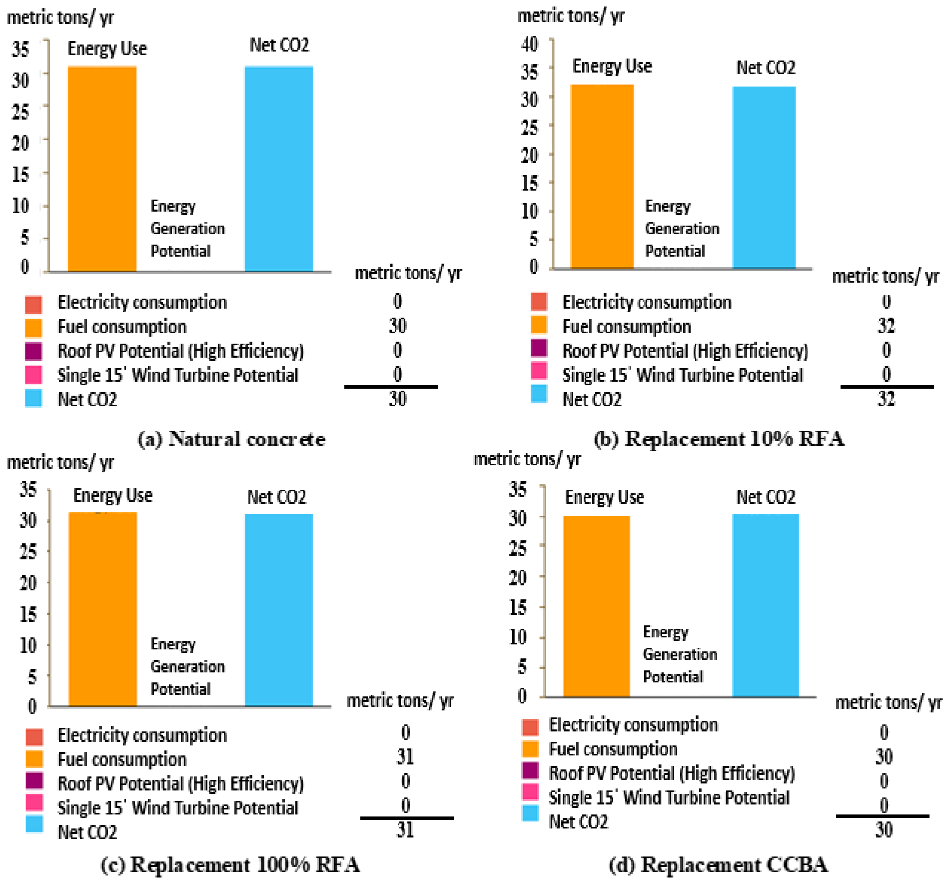
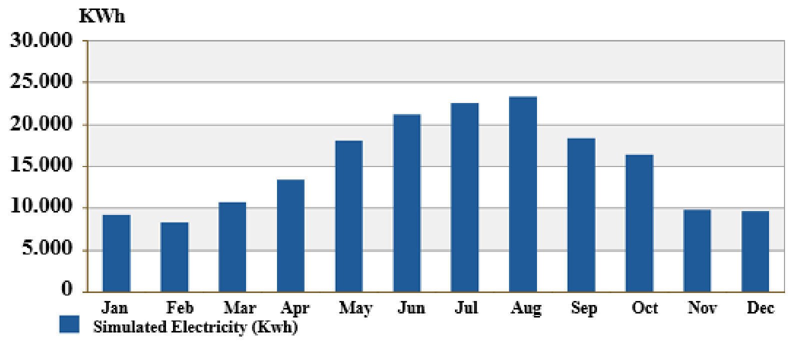
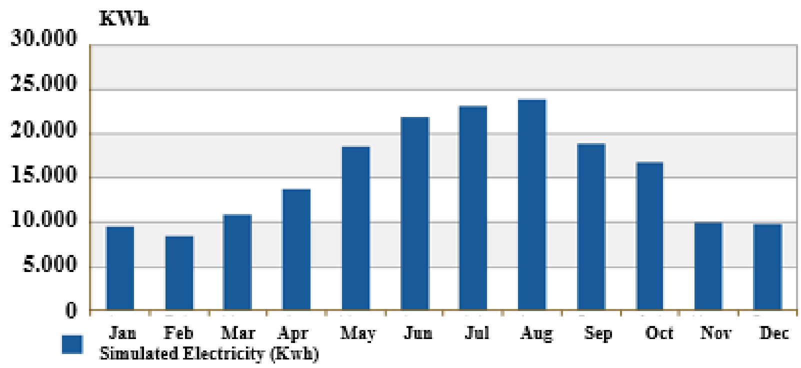


Figure 6. Comparison of annual carbon emission between natural and recycled concrete of residential buildings

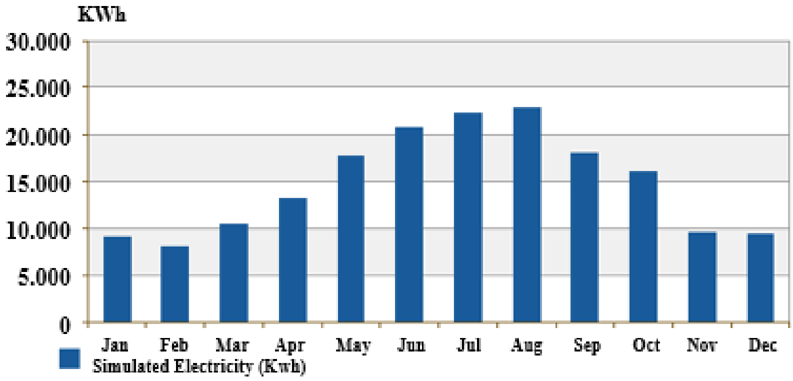
As shown in (Figure 7), comparing the results with the original simulation, alternatives to simulating electricity were variable, because simulated household electricity was (23,500 kW/h), while concrete contained 10% RFA, 100% RFA and CCBA are equal to (24,000- 23,000- 23,000) kW/h, respectively. The results showed the highest annual electricity use appeared in the case of 10% RFA replacement while the electricity use was lower and closer to the normal state of concrete in the case of 100% RFA replacement and the use of CCBA.



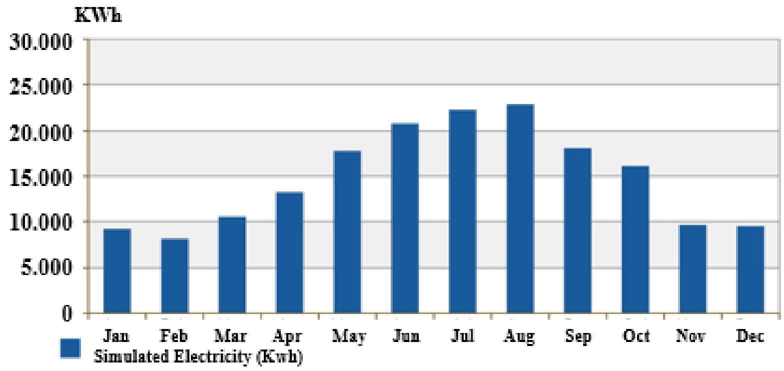
(a) Natural concrete



(b) Replacement 10% RFA



(c) Replacement 100% RFA



(d) Replacement CCBA

Figure 7. Comparison of monthly electricity consumption between natural and recycled concrete of residential buildings

4. Conclusion

The authors tried to show the importance of using the waste of destroyed buildings in the reconstruction again and its environmental benefits, as well as achieving the sustainability criterion for buildings in terms of energy consumption and thus reduce higher electricity bills and stir energy consumption by proposing alternatives that can be extracted from the waste of destroyed buildings and used again on Reconstruction of destroyed cities in Iraq. BIM technology was used to simulate a destroyed residential building and use its waste in its reconstruction again and find the difference in the results of energy analysis in the case of reconstruction using natural building materials and again in the case of using the proposed alternatives.

The results showed an excellent ability of BIM technique to choose the best alternative to building materials through the results obtained and compared with natural simulation. Crushed bricks are recommended for the production of recycled coarse aggregates and for the production of concrete for surfaces. In addition, it is essential that the Iraqi government seeks to raise awareness of the direction of sustainable recycling in the reconstruction of Iraq's devastated cities.

5. Conflicts of Interest

The authors declare no conflict of interest.

6. References

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