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Building Information Modeling (BIM) as Economical and Properties Assessment Tool for Building Units Alternatives Made with Lightweight Foamed Concrete

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Abstract

Lightweight foamed concrete brick is new construction materials. It gives a prospective solution to building construction industry, this research aims to study the cost, dead loads, environmental issues and energy consumption from using lightweight foam concrete bricks as construction materials by utilizing building information modeling technique. The results obtained from this modelling proved that the cost of brick work using lightweight foamed concrete units of grade A (2000 kg/m^3) and B (1800 kg/m^3) is higher by (19.4% and 11.9%) respectively than the activity cost using traditional fired clay bricks. For grade C (1600 kg/m3) that cost was very close to fired clay bricks (+2.9%). while the construction of brick work using light weight foamed concrete units of grade D (1400 kg/m3) and E (1200 kg/m3) was lower by (8% and 18.6%) than fired clay bricks. Besides that, the dead load generated by building units was decreased by (7.7-38.5%) for grade (B, C, D, E) than the load of fired clay bricks, while the load generated from used lightweight foam concrete bricks grade is very closed to fired clay bricks (+2.5%). There was a reduction in energy consumption by the rate of (4.1-62.2%) for heating and (9.8-73.4%) for cooling as wall sharing in energy consumption. Environmental analysis showed sustainable potential so that the production of lightweight foamed concrete units reduces **CO_2** emission by (46.5-67.9%) compared with the fired clay bricks. Finally; it can be concluded that building units produced in this research with LWFC, characterized with properties can efficiently compete the fired clay bricks.

Keywords: Lightweight Foam Concrete Brick; Building Information Modeling; Cost Analysis; Dead Load; CO2 Emission; Energy Analysis.

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1. Introduction

With the growth of construction, bricks become one of the most vital materials used for building in Iraq. Clay bricks are broadly used in many types of construction, especially for the wall elements of the building. However, the manufacturing process of clay bricks is not sustainable due to the producing a series of gas emission into the atmosphere such as carbon dioxide and other pollutants containing sulphur dioxide. At high concentrations, these volatile emissions can be a dangerous source of environmental pollutions, also the mining of raw clay for brick production are need high-energy [1,2]. Moreover, the clay bricks have many problems in controlling its quality during production processes. So, globally; different concrete building units introduced to construction industry in order to provide the requirements of sustainability and decrease the defects that burning clay brick has it. Concrete units are produced from dense aggregate (e.g. crushed limestone and sand) together with cement [1]. Currently, some types of concrete productions are being developed by entraining relatively large volume of air into the mortar by the use of foam agent as the materials for produce lightweight foam concrete [3]. The most significant features of foam concrete is low self-weight which ranges from (300-1800 Kg/m^3) [4]. Also the foam concrete as a product characterized by higher performance in thermal insulation due to the low thermal conductivity that can reach to 0.132 w/m.k [5]. So, the utilization of foamed concrete in production of building units may be contributed to reduce the energy consumption for heating and cooling, improved the indoor comfort in building and decrease the depletion of precious environmental resources as suggested by [6]. Moreover, the reduce of weight will help to increase productivity of labors due to easy to handling and this will decrease wear and tear on labors [7]. In addition of these features the manufacture of building units using foam concrete will consume a small fraction of energy compared to the production of clay bricks.

The most global concern now is the Environmental pollution and Global warming. The clay bricks making contributed directly or indirectly to generate a series of environmental, health problems, the phenomena of global warming and climate change. Therefor the foam concrete need to be investigated as a solution for manufacturing an alternative building units to reduce the environmental pollution, global warming and used efficiently and economically instead of clay bricks. In this paper, we study four topics about lightweight foam concrete bricks, the first subject is the cost of produce lightweight foam concrete bricks from local resources, second the dead load generated by using this units, third environmental issues and finally analysis energy consumption for heating and cooling loads. There are so many techniques to evaluate the construction processes and products in term of value engineering and performance assessment [8,9]. But nowadays, the technique called building information modelling (BIM) became the moderate one and the smarter tool for alternative assessment.

2. Building Information Modeling

Building Information Modeling (BIM) is a standout amongst the most significant progresses in the Architecture, Engineering and Construction (AEC) industries. The construction project simulates in a virtual environment by using BIM. With BIM technology an exact virtual model of a construction is digitally built, when finished, the computer-created model include accurate geometry and related information essential to support the building, manufacture and procurement activities required to understand the building [10] as shown in figure1. AEC industry sought long time to find the techniques to reduce the cost of project, increase the quality and productivity and decrease the project delivery time, BIM comes to achieve this aims due to their ability to utilize the computer to represent, generate and simulate the planning, design, construction and operation of a facility in n-dimensional (n-D) models [11].

BIM is digital representation for physical and practical characteristics of a facility it is working as shared knowledge resource for information about building forming a dependable basis for decisions through its lifecycle from beginning to destroyed [12]. The assessment of construction project can be measured statistically in qualitative and quantitative term [13]. In this research BIM will be the smart tool for main characteristics assessment of the new alternative.

3. Exprimental Work

3-1 Cost Analysis for Lightweight Foam Concrete Bricks (LWFC)

Material choice is often depend on cost, usually initial cost only. The marketing price of brick is governed by many factors, including production ways and appearance of the unit. Analysis the cost of various dry densities range 2000 kg/m^3 to 1200 kg/m^3, to produce 1 m3 from foam concrete brick will depend the ratio of materials used to produce it, LWFC bricks manufacture from Portland cement, local sand (Iraqi sand) and foam agent, to calculate the ratio of this materials in 1m^3 from LWFC will depend on the below design equation that developed by University of Dundee to calculate the mix ratio of foam concrete.

$$C+W+F=D \quad (1)$$

Where C = cement (PC content, kg/m3), W = water content, kg/m^3, F = fine aggregate (sand and/or RSA) content, kg/m^3, D = target plastic density, kg/m^3

The cost of 1ton of cement is 90000 IQD

The cost of 1 m^3 of sand is 28000 IQD

The ratio and total cost of materials used to manufacture LWFC bricks shown in Table 1. Now, we calculate the cost of product after added the cost of overhead. The overhead cost include the wages of labors, the wages of electric energy and water, Intesar and Faisel (2010) identify that the cost of overhead to produce LWFC bricks is 2667 IQD . By added this value to the cost of materials calculate in Table 1, we can obtain the final cost of LWFC bricks as shown in Table 2. After that, we calculate the cost of LWFC Brick size is 0.23 x 0.11 x 0.07 m before building, the brick size after building will be 0.24 x 0.12 x 0.08 m= 0.002304 m^3 when considered thickness of cement mortar 1cm.

Bricks casted in 1 m3 LWFC material = $\frac{1}{0.002304}$= **434** bricks

Cost of 1m^3 fired clay brick = 78663 IQD and when considered the 10% waste the final cost will be 78663+7866.3=86529.3 IQD. This value will be used to compare the results with LWFC bricks in constructed rise buildings. By utilize building information modeling (BIM) technique and used Revit software version

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2016 six rise building are modeling to evaluate the cost of construction rise buildings by using LWFC bricks and comparing with the cost of rise building constructed by using fired clay bricks.

These buildings have (636.22 $m^{2)}$ area, each building consist of four storeys and each storey include four flat, the specification, classification and properties of bricks used of these buildings show in Table 3 and 4. The modeling of rise buildings appearing in Figure 1. While Table 5 shows the cost of construction buildings by using LWFC bricks and compare results with building constructed by using fired clay bricks by depend on the value of cost finding in Table 2 and buildings modeling by using BIM technique and ability of Revit to create LWFC bricks in software and introduce all information need to build especially library for this construction units.

Table 1 Cost Analysis of Materials Used in Production of LWFC Brick

Class	A	B	C	D	E
Amount of cement (Kg/m3)	869.565	782.609	695.65	608.69	521.74
Amount of sand (Kg/ m3)	869.57	782.609	695.65	608.69	521.74
Amount of foam (litter)	0.745	1.17	1.6	2.02	2.45
Cost of cement (IQD)	78261	70435	62609	54782	46957
Cost of Sand (IQD)	24348	21913	19478	17043	14609
Cost of foam (IQD)	1863	2925	4000	5050	6125
Total cost (IQD)	104472	95273	86087	76875	67691

Table 2 Total Cost of Manufacture and Production $1m^3$ from LWFC Bricks

Class	A	B	C	D	E
Cost of materials (IQD)	104472	95273	86087	76875	67691
Wage of labor and manufacturing expense	2667	2667	2667	2667	2667
Total cost of $1m^3$ (IQD)	107139	97940	88754	79542	70358

Table 3 Specification of Rise Building Elements

Structural element	Dimensions (mm)
Isolated rectangular foundation	1000*1000*450
Column	300*300
Beam	300*500
Slab	180
External walls	250*2500
Internal walls	125*2500
Floor thickness	160

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Doors	1000*2000
Windows	1500*1200
Height of storey	3000

Table 4 Type of rise buildings and specification of bricks used in constructed.

Type of rise buildings	Type of bricks used	Density of bricks (kg/m^3)	Thermal conductivity (w/k.m)
Class A	Lightweight foam concrete bricks grade A	2000	0.25375
Class B	Lightweight foam concrete bricks grade B	1800	0.17136
Class C	Lightweight foam concrete bricks grade C	1600	0.14398
Class D	Lightweight foam concrete bricks grade D	1400	0.13546
Class E	Lightweight foam concrete bricks grade D	1200	0.10130
Class F	Fred clay bricks	1950	0.27

Table 5 Cost of Constructed Walls by Using LWFC Brick and Fired Clay Bricks

Class	No. of bricks	Total Cost (IQD)
A	212733	52544911
B	212733	48077530
C	212733	43610149
D	212733	38930035
E	212733	34462654
Fired clay bricks	212733	42333754

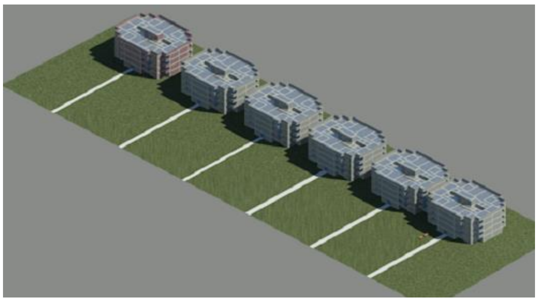

Figure 1: Rendering Site for Six Rise Buildings

3-2 Dead Load Generated from Using Lightweight Foam Concrete Bricks

Dead load is most important issues, the design of dimensions and amount of reinforcement for structural elements such as slab, beam and foundation depend on loads applied on the structural elements, reduce weight of construction elements such as walls will contributed to reduce dead load, LWFC bricks characterized by lower weight reach to below 1200 kg/m^3, in this paper will analysis the dead load generated from using LWFC bricks as construction materials and also compare the results with fired clay bricks. By using Revit and for the rise buildings, we can analysis the dead load generated for each storey as shown in Table 6 and Figure 2.

Table 6 Dead Load by Rise Buildings

Class of buildings	Load (KN/M)				
	Story 1	Story 2	Story 3	Story 4	Roof
A	781.25	829.25	829.25	829.25	112.5
B	703.13	746.33	746.33	746.33	101.25
C	625	663.4	663.4	663.4	90
D	546.88	580.48	580.48	580.48	78.75
E	468.75	497.55	497.55	497.55	67.5
Fired clay bricks	761.72	808.52	808.52	808.52	109.69

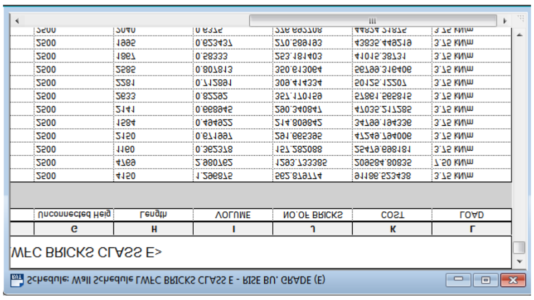

Figure 2 Properties, Cost and Load for Rise Building

3-3 Emission of Carbon Dioxide (CO_2) from Bricks Industry

The main environmental challenges for our society is threat of climate change. Carbon dioxide (CO_2) emission from many industries is considered one of the major greenhouse gases. Brick is one of the most important construction materials, it is essentially used for the construction of exterior and interior walls in buildings. Bricks manufacture industry needs huge inputs of resources and leads to numerous adverse environmental effects. The bricks industry has a large effect relating to energy use and carbon emissions, therefor now, the process of manufacture bricks are focused on improved to satisfy economic and quality request. The production of lightweight foam concrete bricks came to reduce the CO_2 emission from production fired clay bricks. The affects of foam concrete production on the environmental is similar to production of normal concrete but foam concrete doesn't use coarse aggregate in production so can

conserved on the natural resource. The quantities of CO_2 materialized in concrete are mainly a function of the cement content in the mix designs in order to calculate the Amount of CO_2 emission from foam concrete production the NRMCA (2012) determine that the amount of CO_2 produce from cubic meter of concrete is 5% to 13% of the weight of concrete produced and the percentage 13% of weight (equation below) depend to calculate the amount of CO_2 emission from LWFC.

CO_2 emission = 13% W

Where W is weight of lightweight foam concrete bricks.

The amount of CO_2 emission for LWFC bricks will compare with CO_2 emission from fired clay bricks, which found by Venta 1998, the results shown in Table 7.

Table 7 Carbon Dioxide (CO_2) Emission from Production 1m^3 of LWFC Bricks

Type of bricks	CO_2 emission Kg/m^3
LWFC grad A	260
LWFC grad B	234
LWFC grad C	208
LWFC grad D	182
LWFC grad E	156
Fired clay bricks (natural gas -fired kiln)	333.516
Fired clay bricks (light oil –fired Kiln)	485.640

3-4 Analysis Energy Consumption

Energy efficiency is an important issue for high quality buildings. Energy not only meet to high percentage of the operating cost of buildings but it also has a major influence on the thermal comfort of the occupants. Increasing energy costs and awareness on the effects of global warming lead to increase the demand for energy efficient design and construction. The close association between energy consumption in buildings and environmental destruction arises due to consume a lot of energy solutions try to construct a building and responding its requirements for heating, cooling, ventilation and lighting cause intense exhaustion of precious environmental resources, so to reduce energy and achieve height thermal comfort in buildings can been provide by selection materials with low thermal conductivity. Necessities for energy efficiency in a building envelope surrounding the heated and cooled parts of the building has been appointed built on resistance or contribution to heat transfer coefficient through a unit of the construction, respectively R-value or U-value. By using BIM technique and same rise buildings, we can

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finding the value of R and U which are considered the main factor in calculating heating and cooling loads as shown in Figure 3 and 4. After compute U and R, we can analysis the heating and cooling loads by identify many parameters used in the design process, the first step to analysis is identify the space and zone used in design in our case we identify 64 space and four zone for each building, then identify the type of building, the rise buildings modeling in this paper are multi- family buildings and modeling in Baghdad, Iraq location that means the design process will depend on the weather of Baghdad and set on their temperature in each month, after that will identify the building service such as van single duct. Know we should introduce the value of U which finding in Figure 4. Also select the ground level of building in our case, we depend level one, then introduce the information about each space and zone such as people, temperature, the area for each person and other factors. The results of heating and cooling loads show in Figure 5.

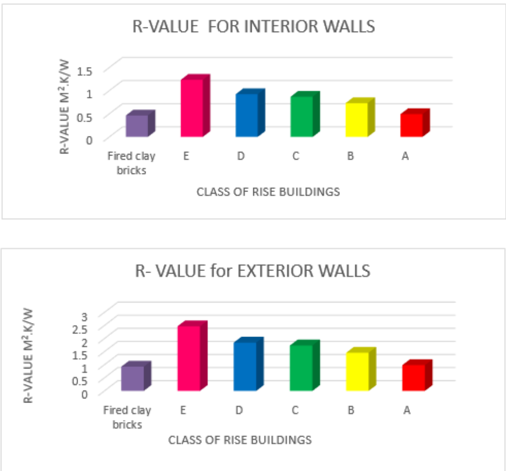
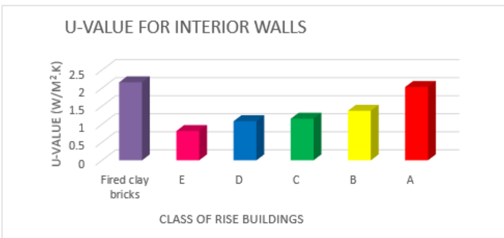
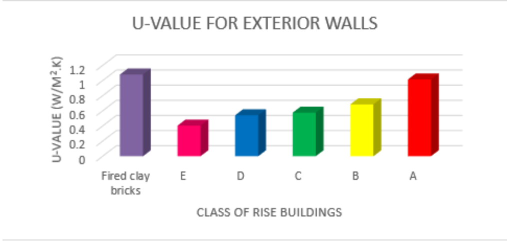


Figure 3: R-value for exterior and interior walls for rise buildings



(a)



(b)

Figure 4: U-value for exterior and interior walls for rise buildings

Figure 5: Heating and cooling load for rise buildings

4. Result and Discussion

4-1 Cost Analysis

From Table 3 shows that the cost of materials used to produce LWFC bricks grade (D) and (E) is lower than the cost of manufacture LWFC bricks grade (A), (B) and (C) due to the grade (E) and (D) have less percent of materials return to their lower density. Also we can note from Table 4 that the cost of materials used to made LWFC bricks represent big part from the total cost, therefor Table 5 appear that the cost of construction rise building with LWFC bricks grade (A) and (B) is higher than constructed the same rise building with fired clay bricks while when used LWFC bricks grade (C) is much closed to cost of constructed by using fired clay bricks, but when used LWFC bricks grade (D) and (E) is lower than rise building constructed by using fired clay bricks.

4-2 Dead Load

The results in Table 6 shows that dead load generated from using LWFC bricks as construction buildings units is lower than using fired clay bricks except LWFC bricks grade generated dead load closed to the load generated from fired clay bricks due to LWFC bricks have density lower than fired clay bricks and this return to introduce foam agent to mortar that made pores in the concrete which leads to reduce the weight of bricks.

4-3 CO2 Emission

From Table 7, we can conclude that foam concrete production release small quantities of CO2 when compare to fired clay bricks with natural gas fired kiln and light oil fired kiln. This return that the production of LWFC bricks are not pass in fired stage that responsible on the most CO2 emission in brick production.

4-4 Analysis Energy

The results of heating and cooling depended on the value of thermal transmittance (U-value), while the value of U inversely proportional with thermal resistance (R-value), so the value of U increase with decrease R-value, while the value of R depend on thermal conductivity of bricks and the thickness of walls and when the thickness of walls is constant for external and internal walls, thermal conductivity will play significant role in R-value and U-value. Figure 3 and 4 for U-value and R-value showed that the rise building class (E) height R-value for exterior and interior walls and low U- value due to it is has low thermal conductivity reach to (0.1013 w/m.k), this value decreasing gradually until has small value for walls of rise buildings class (A), which has height thermal conductivity reach to (0.25375 w/m.k). Figure 5 shows that rise building constructed with using LWFC bricks have lower heating and cooling load than rise building constructed by using fired clay bricks due to LWFC bricks have lower U-value and height R-value comparing with fired clay bricks.

5. Conclusion

According to the application on the cases studied in this research, it was found that building information modelling technique (BIM) can be used as smart tool for many purposes in construction processes, some of these benefits are:

1. Smart visualization of building to investigate the structural elements and orientation of whole building relative to the sun bath, wind and suitability for land geometry.

2. Very efficient tool in quantities take off and cost estimation, it was used effectively to compare alternative cost and find the best alternative in term of cost and material.

3. This technique was used efficiently in calculating the heating and cooling load for building constructed with different type of material and comparing them clearly.

4. BIM technique provided the researcher with exact load generated on the structural members to compare the effect of different alternative on the overall behavior of each structural element and to find the best alternative of building unit.

5-1 Analysis Cost

1. The cost of producing 1.0 m^3 of LWFC bricks are decrease with decrease the density of bricks due to the minimal amount of materials used in production. The saving in cost for one cubic meter of LWFC bricks is 8.69%, 17.2%, 25.8% and 34.3% when change the LWFC bricks from grade A to grade B, C, D and E.

2. The cost of produce one cubic meter of fired clay bricks is lower by 19.2%, %, 11.7%, 2.5% than the cost of produce LWFC bricks for density 2000, 1800 and 1600 kg/m^3, but is higher by 8.1% and 18.7 than LWFC bricks have density 1400 and 1200 kg/m^3.

3. The cost of constructed rise buildings from LWFC bricks are decreased with decreased the density of bricks, the save in cost is 5,774,833 IQD, 11,154,966 IQD, 17,575,579 IQD and 23,350,412 IQD when change the type of LWFC bricks from A to B, C, D and E.

5-2 Dead Load

The loads generated from walls of rise buildings constructed by using LWFC bricks are decrease when the weight of bricks decrease. The loads of walls constructed by using LWFC bricks grade E is lower by 40%, 33.3%, 25% and 14.3% than using LWFC bricks grade A, B, C and D respectively. While when comparing the loads generated from walls of rise buildings constructed by using fired clay bricks is higher by 7.7%, 17.9%, 28.2% and 38.5% than the using LWFC bricks grade B, C, D and E respectively. Except the use of grade (A), it will be lower by 2.5%.

5-3 Analysis of Heating and Cooling Load

1. The R-value (thermal resistance) for external and internal walls of rise buildings constructed by LWFC bricks was high and increased with decrease the density of bricks due to decrease thermal conductivity when the thickness of walls keeps constant. The R-value of walls constructed with LWFC bricks grade A, B, C, D and E were higher by 6%, 36.5%, 46.7%, 49.8% and 62.5% respectively than the walls used fired clay bricks.

2. The U-value for external and internal walls of rise buildings constructed by used LWFC bricks is low and decrease with increase the R-value. The U-value of walls constructed by used LWFC bricks is lower than using fired clay bricks.

3. The cost of heating load decreases with decreasing U-value of walls by 33.2%, 44.1%, 47.3% and 60.6% when change the constructed walls from grade A to B. C, D and E respectively. The heating load for rise building is higher when constructed with fired clay bricks by 4%, 35.9%, 46.3%, 49.4% and 62.2% than using LWFC bricks grade A, B, C, D and E.

4. The cooling load also decreases with decreasing U-value of walls by 43%, 57.7%, 58.4% and 70.8% when change the constructed walls from grade A to B. C, D and E respectively. The cooling load for rise building is higher when constructed with fired clay bricks by 9.7%, 48.5%, 61.8%, 62.4% and 73.3% than using LWFC bricks grade A, B,C,D and E.

5-4 Analysis the CO2 Emission

The CO2 emission from production of LWFC bricks decreases with decreasing density due to reduce the amount of materials that mainly responsible for CO2 emission. The CO2 decrease by 10%, 20%, 30.8% and 40% for LWFC bricks grade A, B, C, D and E respectively. while the CO2 emission from fired clay bricks produce by using Natural gas -fired kiln will higher by 22%, 29.8%, 37.6%, 45.4% and 53.2% than LWFC bricks of grade A, B, C, D and E respectively. Also the fired clay bricks produce by using oil -fired kiln will be higher by 46.5%, 51.8%, 57.2%, 62.5% and 67.9% than LWFC bricks grade for LWFC bricks grade A, B, C, D and E sequentially.

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