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"Alternative Building Units Assessment Using Building Information Modelling"

A Thesis Submitted to Council of College of Engineering, University of Diyala in Partial Fulfillment of the Requirements for The Degree of Master of Science in Civil Engineering

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April, 2017 IRAQ Rajab, 1438

Certification

I certify that the dissertation entitled "**Alternative Building Units Assessment Using Building Information Modeling**" was prepared by **"Dunya Sabah Jarullah"** under my supervision at the University of Diyala as a Partial Fulfillment of the Requirements for the Degree of Master of Science in Civil Engineering.

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I certify that this thesis entitled **"Alternative Building Units Assessment Using Building Information Modelling**" presented by "**Dunya Sabah Jarullah"** has been corrected linguistically, therefore, it is suitable for debate by examining committee.

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We certify that we have read the thesis/ dissertation titled (**Alternative Building Units Assessment Using Building Information Modeling**) and we have examined the student (**Dunya Sabah Jarullah**) in its content and what is related with it, and in our opinion it is adequate as a thesis/ dissertation for the degree of Master of Science in Civil Engineering

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The thesis / dissertation was ratified at the Council of College of Engineering University of Diyala

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Dedication

To a strong and gentle soul
To whom taught me to trust in Allah
To whom made me believe in hard work and that so much could be done with little
To my mother
To whom work hard for earing an honest living for use
To whom supporting and encouraging me to believe in my self
To my father

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Dunya Sabah Jraullah

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ABSTRACT

Brick is one of the most used building materials in a variety of construction projects. Locally, these building units suffer from many defects; technical, production, specification, and environmental impact, besides the inefficient quality control on the properties of the produced building units that lead to negative effects on the overall construction processes. This research aims to produce sustainable and economic alternative bricks using lightweight foamed concrete (LWFC) made of local materials to substitute the traditional fired clay bricks. This LWFC is considered new construction material used in Iraqi construction sector, it can be produced from available local materials; Portland cement and fine sand.

Utilizing building information modelling (BIM) and considering the data of the experimental part of this study, Autodesk Revit software v.2016 was used to model and evaluate the new alternative building units. Six models for rise buildings were designed with Revit software to evaluate the lightweight foamed concrete bricks and compare them with fired clay bricks in terms of cost, materials, thermal and sound insulation, absorption and mechanical properties.

Detailed information and data were derived from intensive experimental studies and laboratory tests for the alternative brick units. Briefly; for the density of (1200 to 2000 kg/m^3) and brick size of (230*110*70 mm), the compressive strength was (4-45 MPa), water absorption (1-26%), thermal conductivity (0.1013-0.2538 w/k.m), shrinkage (0.011-0.056%), with no efflorescence and very little dimensions' tolerances.

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 when 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) compared to the load of fired clay bricks, while the

load generated from used lightweight foam concrete bricks grade (A) 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 reduced $\mathbf{CO_2}$ emission by (46.5-67.9%) compared to 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.

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LIST OF ABBREVIATIONS

ASTM- American Society for Testing Materials

BCA- British Cement Association

BIA- Brick Industries Association

BIM- Building Modeling Information

CO2 - Carbon Dioxide

HVAC- Heating, Ventilation, and Air Conditioning

IBC- Institute for BIM in Canada

LWC - Lightweight Concrete

LWFC, LFC, FC- Lightweight Foam Concrete

LWAC- Lightweight Aggregate Concrete

NRMCA- National Ready Mixed Concrete Association

OP- Ordinary Portland Cement

R- Thermal Resistance

SP- Super Plasticizer

U- Thermal Transmittance

CHAPTER ONE
INTRODUCTION

1.1 Background

As sustainability increasingly becomes a standard practice in the building industry, the demand for high-performance buildings also increases (Azhar et al, 2011). Goals related to sustainability are being set ever higher, demanding greater levels of resource efficiency and energy (Attia et al, 2012, Cemesova et al, 2015). With the demand for high-performance buildings and the resulting challenges posed to designers, builders and facility managers, the integration of building performance analysis into the design, construction, and operation and maintenance of buildings becomes crucial (Reeves et al, 2015). In order to achieve sustainable alternative bricks instead of traditional clay bricks can be utilizing Building Information Modeling (BIM) technique in decision making process due to ability to allow a project to be built virtually before being built physically. It creates and uses consistent, coordinated, computable information about a building project. This dependable digital information about a building can be used for production of high-quality construction documents, cost-estimating, performance predictions, construction planning, and energy analysis and eventually for managing and operating the facility (Metkari and Attar, 2013).

With the growth of construction industry**,** bricks become one of the most vital materials used in building in Iraq. Clay bricks are broadly used in many types of construction, especially in the wall elements of the building. However, the manufacturing process of clay bricks is not sustainable due to the production of 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 dangerous sources of environmental pollutions, also the mining of raw clay for brick production

requires high-energy (Lyons, 2010, Kadir and Mohajerani, 2011). Moreover, clay bricks have many problems in controlling their quality during production processes.

So, globally; different concrete building units are introduced to the construction industry in order to provide the requirements of sustainability and to decrease the defects in burned clay brick. Concrete units are produced from dense aggregate (e.g. crushed limestone and sand) together with cement (Lyons, 2010).

Currently, some types of concrete production are being developed by entraining relatively large volume of air into the mortar by the use of foam agent as materials for producing lightweight foam concrete (Kearsley and Wainright, 2001). The most significant feature of foam concrete is low self-weight which ranges from 300 to 1800 Kg/m^3 (Mazhar and Alex, 2007). Also the foam concrete as a product is characterized by higher performance in thermal insulation due to the low thermal conductivity that can reach to 0.132 w/m.k (Krishna, 2012).

So, the utilization of foamed concrete in the production of building units may contribute in reducing the energy consumption for heating and cooling, improve indoor comfort in buildings and decrease the depletion of precious environmental resources as suggested by Othuman (2011). Moreover, the reduction of weight will help in increasing the productivity of laborers due to the easiness in handling and this will decrease wear and tear of laborers (Lochonic, 2003). In addition to 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 making of clay bricks contributes directly or indirectly to generate a series of environmental, health problems, the phenomena of global warming and climate change. Therefore, the foam concrete need to be investigated as a solution for manufacturing alternative building units to

reduce the environmental pollution, global warming and to be used efficiently and economically instead of clay bricks

1.2 Problem Statement

Brick is the most important material used in construction of masonry based buildings in Iraq and it is considered a key material to build a durable construction. But this industry suffers from many problems which can be summarized as follows:

1. The raw material (clay) used in producing clay bricks mines out the agricultural fields and this will negatively impact the Agriculture wealth.
2. The process of manufacturing of clay bricks includes many stages; every stage requires intensive labor force, equipment, and high energy consumption during the production process.
3. Integration of construction management with sustainability concept through the development of environment friendly construction units.
4. Higher carbon dioxide (CO2) emission resulting from the production process which is of direct effect on increasing the global warming and climate change.
5. Most of the locally produced bricks have many defects such as; low compressive strength, higher water absorption, greater tolerances in dimension, efflorescence and other defects.
6. Most of the nowadays available alternatives are of high costs compared to clay bricks and thus it is hard for them to compete with this product.

For the above mentioned facts, the research problem can be formulated as follows:

"Is it possible to produce alternative building units from local resources by simple method and economical production process with less negative impact on the environment throughout utilizing foamed concrete?".

1.3 Research Objectives

This research aims at achieving the following objectives:

1. Producing new building units via delineating local materials, and investigating the characteristics and properties of these units.
2. Using the Building Information Modeling (BIM) technique to assessment the new building units from the economical, geometrical design, the environmental impacts of these units, to find the energy embodied in these units, and the effect on the HVAC of the building and comparing with fire clay bricks.

1.4 Research Justifications

1. Developing the construction industry by providing new alternatives to traditional building systems
2. Building units represent a high cost rate in most construction projects.
3. The building units affect other construction activities as finishing or the geometrical design of the structural system when used in masonry wall elements.
4. Sustainable construction requires improved building units with positive efficiency on the environmental requirements of the construction.
5. This work is designed to be applicable and effective in the construction industry.

1.5 Scope Of The Research

This research focuses on producing building units using foam concrete of specific density range (1200 - 2000 Kg/m^3) from local materials (ordinary Portland cement type 1 , local Iraq sand , foam agent type ARCEL SP20 and super plasticizer type GLENIUM). The resulting units will assessed by four criteria, the first criteria is quality (engineering performance) which include: compressive strength, water absorption, dry shrinkage, thermal conductivity and acoustic insulation in addition to the efflorescence and dimension of resulting units, the second criteria is economics and geometrical design of brick units, the third criteria is energy consumption by using resulting units

and last criteria is impact resulting units on environmental. The second and third criteria will adopted building information modeling technique by visualization six virtual rise buildings to assessment the effect of resulting units on building. The assessment and comparing process will done with solid fire clay brick.

1.6 Methodology Used

To achieve the goal of this study; a research methodology was approved considering the verity area of work that should be performed to get the results. This methodology comprises of the following:

1. A comprehensive literature review to identify the level of present situation and knowledge related to clay bricks manufacturing process and properties, lightweight foam concrete will be used as the main material, and building information modeling (BIM) to provide a background for this technique and its importance for the research and construction industry.
2. Production of lightweight foamed concrete and investigation of the main properties and possible improvements, detailed laboratory testing of the lightweight foam concrete samples that are to be used in the improvement of the sustainable lightweight foam concrete building units.
3. Add new families represent LWFC bricks to Revit environmental of non-existing by defining their physical and thermal properties.
4. Utilizing 3D of building information modeling technique to visualization six virtual rise buildings.
5. Calculate the cost estimation and geometrical design by utilizing 5D of BIM technique.
6. Analysis energy consumption from using LWFC bricks as construction building units in the virtual rise buildings by utilizing 6D of BIM.

7. Building up the environment profile of the lightweight foam concrete bricks so as to get reference of the carbon dioxide (CO2) emission from the product manufacturing process.
8. Analysis results and assessment the LWFC bricks by four criteria quality, economics and geometrical design, energy consumption and environmental impact also compare this results with solid fire clay bricks as shown in figure 1.1.

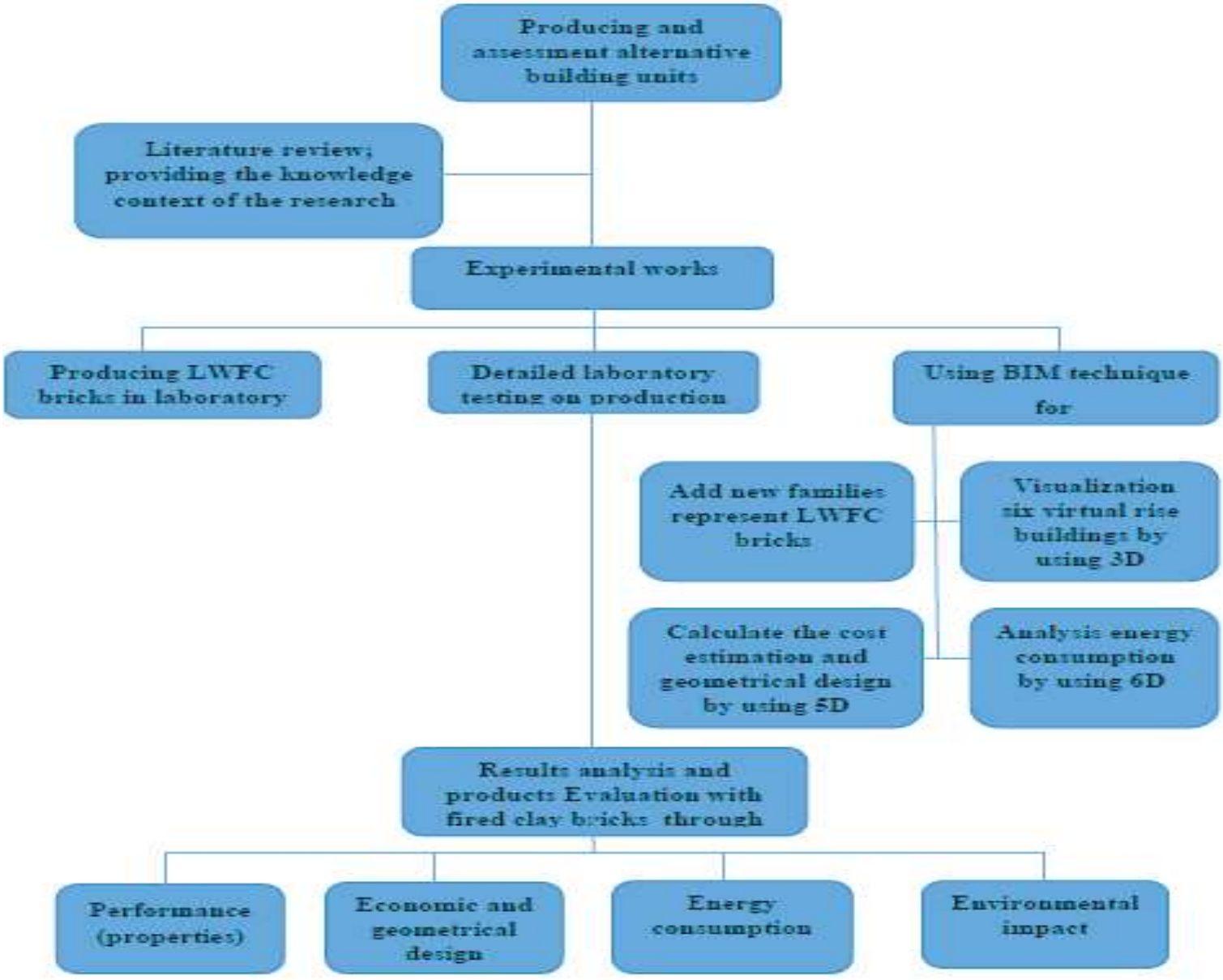

Figure 1.1 Research Methodology (Researcher).

1.7 Research Layouts

The structure of this research includes five chapters in the following arrangement:

Chapter 1: Provides an introduction to the whole research and discusses the background of the study. It explains the present problem in the brick industry, also summarizes the major goals and objectives of the research, research justification, scope of the research, methodology used and the research layout.

Chapter 2: Provides the literature review on the various subjects that are associated with the research context. It reviews the types of bricks, clay bricks, foam concrete and building information modeling areas.

Chapter 3: Describes the experimental works used in this research. The preparation of materials, the mixing procedures and approaches used in testing the samples. In addition, it describes the use of Revit as an application software to BIM technique in studying the general effects of the new alternative on the construction system.

Chapter 4: Presents and discusses the results generated from laboratory tests, Revit software and environmental study. These results of the alternative building units were compared to the traditional clay bricks properties.

Chapter 5: Illustrates the research conclusions and results which are categorized into sections relative to the investigated area. Recommendations for future work are also presented for further research areas which are out of the scope of the current study.