



## The Thermal Performance and Economic Impact of Using Marble Wastes for Hollow Concrete Block Production

Osama Ibrahim Ahmad Massoud<sup>1</sup>, Dina Mahmoud Sadek<sup>2</sup>,  
Mohammed Ibrahim Mohammed Abdel Hady<sup>3</sup>, Mahmoud Mohamed  
Abd Elrazike<sup>4</sup>, Khadiga Elsayed Ahmed Shakra<sup>5</sup>

- 1- Professor of Architecture Eng. Dept. faculty of Eng., Suez University, Cairo, Egypt.
- 2- Associate Professor, Building Materials Research and Quality Control Institute, Housing and Building National Research Center, Dokki, Giz, Cairo, Egypt
- 3- Lecturer, Civil and Architectural Constructions Dept. faculty of Industrial Education, Suez University, Cairo, Egypt.
- 4- Lecturer, Housing and Building National Research Center, Dokki, Giz, Cairo, Egypt.
- 5- Lecturer assistant Architectural Constructions Dept. faculty of Industrial Education, Beni Suef University, Cairo, Egypt.

### المخلص

في مصر، دراسة الإستفادة من مخلفات الرخام اصبح موضوع هام بسبب تراكم هذه النفايات وإلقائها في الأماكن القانونية والغير قانونية يؤثر سلبا على البيئة المحيطة من الناحية الصحية وعلاوة على ذلك، فإن تداخلها مع التربة يؤثر على الخصائص الهندسية للتربة. من ناحية اخرى، يمكن اعتبار هذه النفايات مفيدة من وجهة النظر الاقتصادية والبيئية من خلال إستخدامها لتقليل إستهلاك الموارد الطبيعية والتغلب على النقص المزمن في مواد البناء. معظم الدراسات والأبحاث السابقة كان الغرض منها الاستفادة من المخلفات في عناصر المبني مثل الخرسانة وبلاط الأرضية والطوب. وجد الكثير من هذه الأبحاث قامت بدراسة الخواص الميكانيكية والفيزيائية لصناعة الخرسانة والطوب. بينما وجد القليل من الأبحاث تدرس تأثير الأداء الحراري والإقتصادي عند إستخدام مخلفات الرخام في إنتاج الكتل الخرسانية المجوفة. الهدف من هذه الدراسة دراسة تأثير الإستبدال الجزئي للمواد التقليدية بمخلفات الرخام علي الأداء الحراري للكتل الخرسانية المجوفة ودراسة وتحليل الأداء الحراري للمبني. طريقة تدفق الحرارة كانت مستخدمة، لتحديد خواص الحرارة للبلوك الخرساني. لأربع خلطات بالمقارنة بالكتل الخرسانية التقليدية المصنوعة من المواد التقليدية مثل (الاسمنت والدولوميت والرمل). هذه الخلطات تحتوي علي (100% الركام الكبير للرخام) و (50% ركام صغير للرخام + 100% الركام الكبير للرخام) و (100% الركام الكبير للرخام + 30% بودرة رخام). بالإضافة إلي دراسة تأثير نسبة إستبدال مخلفات الرخام للكتل الخرسانية المجوفة علي استهلاك الطاقة للمباني. نتائج البرنامج التحليلي ركزت علي تقييم الأداء الحراري لمبني إسكان إجتماعي تم تطبيق أربعة أنواع من الكتل الخرسانية المجوفة باستخدام احجام مختلفة من مخلفات الرخام. نتائج التوصيلية الحرارية للكتل الخرسانية كانت 0.39 و 1.34 و 1.03 و 1.36 W/m.K علي التوالي.

### Abstract:

In Egypt, studies to utilize marble wastes are a special issue because a large amount of this waste has been throwing to the public places and in illegal places adversely affect the surrounding environment from healthy side and moreover, its intermixing with the soil affect the geometric properties of the soil. However, these wastes can be considered beneficial from the economic and environmental points of view through its using to decrease consumption of natural resources and obviation in chronic shortage of building materials. Mentioned several studies for some researchers have proposed reutilizing this

waste in building elements, such as concrete or paving block or bricks. It is possible to find a lot of researches in mechanical and physical properties for concrete, brick manufacture, while little effort has been made to the thermal performance and economic impact of using marble wastes for hollow concrete block production.

The aim of this study was to characterize and study Influence of marble waste as partial replacement conventional material on the hollow concrete blocks thermal performance in order to provide subsidies for a building's thermal performance analysis. The (Hot Box Meter Method) was adapted, to determine the concrete blocks thermal properties. For mixes were compared with the control hollow concrete blocks made with conventional materials (cement, dolomite and sand). These mixes incorporated (100% coarse marble aggregate CA), (50% fin marble aggregate FA+ 100% coarse marble aggregate CA) and (100% coarse marble aggregate CA + 30% marble powder MP). In addition to study effect of replacement percentage by marble waste of hollow concrete blocks on energy consumption for a buildings. The simulation results focused on the evaluating the thermal performance of building as an example of residential agglomerations, this model for house were constructed application four types by different sizes from marble waste in the manufacturing of hollow concrete blocks.

The results indicated that the concrete blocks overall thermal conductivity in the solid region was within the intervals of 0.93, 1.34, 1.03 and 1.36 W/m.K respectively.

**Keywords:** thermal performance, heat transfer; Energy consumption, thermal conductivity, cost, Simulation software.

## 1. Introduction

There is a high tenderly towards recycling of industrial waste specially the marble waste. Marble is one of the common natural building materials that are used in old ages because of its aesthetic properties and homogeneity. In recent years, the demand for the way of marble has increased due to the progress in construction industry, and the population increasing.

Shaq Al-Thoaban at South East Cairo, Egypt, is considered one of the largest marble manufacturing areas because it contains 500 large projects and about 300 workshops, which made Egypt, ranked the 4th in the marble world market and the 7th in the world in the production of stones, (Shaq Al-Thoaban) area produces around 800, 000 tons of wastes per year (Hamza et al., 2011).

The previous studies reported that the use of marble waste as replacement of the building elements (cement, sand and aggregate) could improve the phsico-mechanical properties of the elements.

Corinaldesi et al. (2010) and Rodrigues et al. (2015) stated that, the mechanical properties of concrete have enhanced where replaced by 10% of marble waste.

Ergun (2011) and Rana et al. (2015) stated that the use of 5% of marble powder and 10% marble slurry as replacement of cement increased the compressive strength of concrete. Aliabdo et al. (2014) reported that, the replacement of sand by 15% of marble powder is better for concrete strength than replacing cement.

Ahmed O. Mashaly et al. (2016) found that replacing of a cement substitute in cement and concrete production up to 40% with marble sludge. The results showed that using up to 20% of marble sludge, improved the physical and mechanical properties of concrete products.

While Gencel et al. (2012) found that, the usage of marble waste as alternative of the aggregate has a bad effect on the physical and mechanical properties of concrete paving blocks with an increase in marble content.

Dhanapandian et al. (2009); Bilgin et al. (2012) reported that, the incorporation of 50% of marble waste as replacement of raw clay material in manufacturing of clay bricks a good effect on the physical, chemical and mechanical strength of brick.

Also, Klrgez, M. S. (2007) and Hamza et al. (2011) found that marble waste improved the mechanical and physical properties of concrete and cement brick manufacture.

The building envelope is usually effect by the environmental conditions (solar radiation, temperature, relative humidity and wind speed), which effect the electrical energy consumption inside the building. The electrical energy consumption of air conditioning systems increases as the thermal conductivity of the opaque part increase. The out envelope of the building consists of opaque part (brick) and transparent (windows). The building envelope represents the main axis (major interface between indoors and outdoors) of all thermal control processes and isolates the internal environment from the external one. In addition affects the comfort sense for occupants and heating/cooling loads of internal in the building.

Simulation software (design builder) was used to calculate the electrical energy consumption for the case study that was a residential building for which 4 type of blocks were applied and the cost of each block was compared with the local cost.

The hollow concrete blocks is the most common building materials used, where its annual production reaches about 40 million m<sup>3</sup> there are two types of hollow concrete blocks, the first has one cavity and the other has two cavities Y.H. Ye, et al, (2005), Koski, J.A., (1992).

The literature survey showed that, the thermal resistance of the block increase as the number of cavities increase which contributes in improving the energy efficiency of the building while the mechanical properties at the same time S.O. Adepo et al, (2005). The hollow concrete blocks help to save energy and reduce the use of raw materials, which in turn reduces the environmental impact Navaratnarajah et al, (2014).

## **2. The Research Methodology**

This study is consisting of five stages:

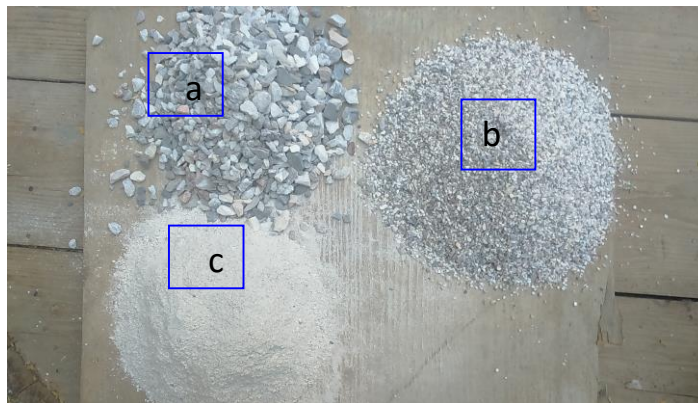
1. A Literature review has been conducted; the purpose of this review was to impact the properties of marble wastes on the properties of hollow concrete blocks, the bricks, properties of fresh and hardened concrete and other productions.
2. The experimental work of this study was carried out through four phase:
  - The first phase, sampling of marble wastes then transport of samples to the place of implementation of the test and production.
  - The second phase, the selection of the materials was carried out and the physical, mechanical and chemical characteristics of these materials were evaluated and production of concrete block mixtures with different contributions variables such the percentage of replacement rations of marble wastes
  - The third phase, Investigate of the properties of hollow concrete block units containing marble wastes and comparison with normal blocks such as the mechanical properties.
  - The fourth phase, Investigate of the properties of hollow concrete block units containing marble wastes and comparison with normal blocks such as the physical properties.

3. Typical residential building has been selected as case study for modeling of thermal condition and evaluation and testing of marble wastes as additive to concrete blocks mixtures for architectural conservation.
4. Using thermal simulation tools to optimize building performance for the evaluation of building thermal simulation tools based on specifications.

### 3. Experimental Procedure

#### 3.1 Materials

The study specimens used in this study were prepared from available local materials. The mixed materials were derived from the combination of numerous components are it crushed stone, Natural sand, ordinary Portland cement (OPC), water and marble waste as (coarse, fine, and marble powder) from Shaq Al-Thu`ban industrial group. The used ordinary Portland Cement (OPC) CEM I 42.5 N. produced by ASEC Minya cement company. Fine aggregates were used in this study it are natural siliceous sand. Rounded and clean fine aggregate with size 0.15 to 5 mm was used. The coarse aggregates used in this research were natural crushed stone aggregate passed from 14 mm sieve and retained on 4.75 mm sieve. Coarse marble passed from 14 mm sieve and retained on 4.75 mm sieve. Fine marble passed from 4.75 mm sieve. Marble powder is a solid waste material was used in study, which was obtained through the production process of marble can be used in this study as a filler material in cement while preparing hollow concrete block as shown in Figure (1). Its chemical analysis and physical properties is given in table (1). Water should be clean and free from harmful materials.



a- Coarse marble aggregate      b- Fine marble aggregate    c- Marble powder

**Fig (1): Small size by crusher to obtain coarse and fine marble aggregate**

#### 3.2 Methods (Blocks Manufacturing):

The experimental program includes studying the effect of recycling waste marble as replacement materials of aggregate and / or cement in hollow concrete blocks. A total of four concrete mixes were cement content of 200 kg/m<sup>3</sup> and sand to total aggregate ratio of 40% the control mix (mix<sup>1</sup>) included Portland cement and natural aggregates, while the other mixes of concrete blocks including different sizes of marble wastes (fine marble aggregate, coarse marble aggregate and marble powder) used as replacement of natural materials. Where (mix<sup>2</sup>) incorporated coarse marble wastes passing from 14 mm sieve replacing 100% of coarse aggregate. Tow mixes incorporated a combination of more than one type of marble waste in each mix; where (mix<sup>3</sup>) incorporated fine marble waste replacing 50% of sand and coarse marble waste replacing 100% of coarse aggregate, while (mix<sup>4</sup>) incorporated coarse marble waste replacing 100% of coarse aggregate and

marble powder replacing 30% of cement. Table (2) represents the proportions of mixes (by wt.) for mixes.


The mixes were mixed in a concrete mixer with a capacity of about 250 liters. In the first step of the mixing, coarse and fine aggregates were first mixed in the dry state until the mixture became homogenous. The second step consisted of adding all binding materials (cement, and marble powder) were added to the dry mixture and mixing was continued until the mixture became homogenous. Finally, mixing water was added to the rotating mixer and mixing was continued to assure complete homogeneity. Then hollow concrete blocks of 39× 20× 20cm molds were pressed using a hydraulic press. Figures (2) show the production process of hollow concrete blocks and the casting process. The curing process was done by sprinkling water for 28 days.

**Table (1): Chemical analysis and physical properties of marble powder**

Compound	Oxides Contents (%)
Silicon Oxide SiO <sub>2</sub>	2.34
Aluminum Oxide Al <sub>2</sub> O <sub>3</sub>	0.32
Ferric Oxide Fe <sub>2</sub> O <sub>3</sub>	0.23
Calcium Oxide CaO	55.5
Magnesium Oxide MgO	1.07
Sodium Oxide Na <sub>2</sub> O	0.12
Potassium Oxide K <sub>2</sub> O	0.05
TiO <sub>2</sub>	0.05
P <sub>2</sub> O <sub>5</sub>	0.03
SO <sub>3</sub>	0.29
Loss on Ignition (L.O.I)	40.10
TOTAL	99.90

According to ASTM C114-15

**Table (2): Represents the proportions of mixes (by wt.) for mixes.**

Mix 	Ingredients						
	Cement	Natural aggregate		Water	Waste marble		
		Sand	Dolomite		Fine FA	Coarse CA	Powder MP
Mix 1	200	813	1219	88	—	—	—
Mix 2	200	813	—	84.00	—	1219	—
Mix 3	200	414	—	83.50	414	1219	—
Mix 4	140	813	—	84.20	—	1219	60



**Fig (2) show the production process of hollow concrete blocks**

#### **4. Testing of hollow concrete blocks**

Hollow concrete blocks were tested for the determination of compressive strength, and thermal conductivity.

##### **4.1 Compressive strength**

Compressive strength test was carried out according to The Egyptian Standard Specifications (ESS) 1292-1 and 1292-2 and ASTM C140 [16-18]. Five hollow concrete blocks were tested in compression at 7, 28, 56 and 180 days. Finger (3) shows compressive test.

The compressive strength “ $f_c$ ” was calculated using the formula:

$$f_c = \frac{P_c}{A} \quad (1)$$

$P_c$  maximum compressive load (N),

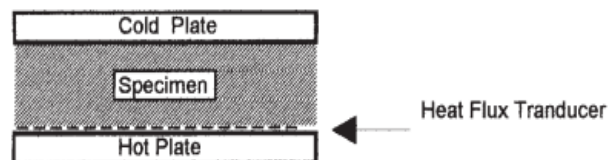
$A$  is the cross-section area of the specimen (mm<sup>2</sup>).



**Fig (3): Compressive strength test**

##### **4.2 Thermal conductivity**

Thermal conductivity (K) is the property of a material's ability to conduct heat. Heat transfer by conduction involves transfer of energy within a material without any motion of the material as a whole. The calculation is derived from amount of the heat flow per square area absorbed by sample after switching instrument's plate's temperature set points from one after reaching thermal equilibrium condition to another until reaching new thermal equilibrium condition. Accurate experimental corrections for heat absorbed by the heat flow meters and for edge heat losses are applied to get the best accuracy.



**Fig (4): schematic outline of the structure of the test equipment for the method [source: ASTM C518– 02e1].**

Requires testing of two identical samples typically 30 ×30 ×5 cm, were cast for the determination of thermal conductivity at test ages of 28 days. To verify the suitability and the accuracy of the equipment used for measuring the thermal conductivity based on the hot wire method, Figure (4) shown a schematic outline of the structure of the test



equipment for method. Flat-parallel sample is sandwiched between two isothermal plates. Each plate has a temperature sensor and a heat flow meter transducer converting the heat flow into electric voltage. This test can be described as follows; the sample is placed between two plates, the first one is a flat electrical heating plate and the other one is flat electrical cooling plate. Figure (5) shows the details of thermal conductivity apparatus used in this study. All the information about the sample is recorded and the test started. It may be 6 to 8 hours till the condition of steady state reach. Through this time the software store the temperature of the hot plate and the cooled plate and the heat flux through the samples. Finally the thermal conductivity was calculated using the following Equation;

$$K = \frac{Q.L}{A. \Delta T} \quad (2)$$

Where

“Q” is the heat load on the sample [W].

“L” is the length of the sample that the heat flow travels through [m].

“A” is the cross sectional area that the heat is applied to [m<sup>2</sup>].

And “ΔT” is the temperature different across the sample top and bottom surface [°C]



**Fig (5): measurement of sample testing, system configurations and applications heat Flow.**

## 5. Thermal Simulation

The desire for search of safe and structural materials keeping in view the economy and energy of whole structure. Therefore the recycling of wastes from other industries will increase the eco efficiency of hollow concrete blocks.

Experimental studies on thermal performance of building walls representing the different types of existing systems to compare their thermal performance.

This study describes potential for using thermal simulation tools to optimize building performance. After (reviewing current trends) in thermal simulation, it outlines major criteria for the evaluation of building thermal simulation tools based on specifications.

### 5.1 Thermal modeling tool

There are several computer tools for building thermal modeling with several simulation methods. The evaluation of the thermal performance of the hollow concrete blocks with low emissivity treatment on the surface of the cavities was carried out using the Design Builder Software [19] is a complete building design and environmental analysis tool that include the variety large of simulation and analysis functions. It resembles a style and technique 3D modeling interface with extensive solar, thermal, acoustic, lighting and cost analysis function. Figure (8) shown in steps of the thermal simulation model.

Measurement of thermal conductivity of building blocks which are composite in as the nature. Test building for comparison of different types of building walls was conceptualized. Since the nature of the construction, location and the external conditions are similar in nature for the different types of walls; their thermal performance. To simulate the heat exchange inside the cavities, a simplified and standardized method using equivalent conductivity was used.

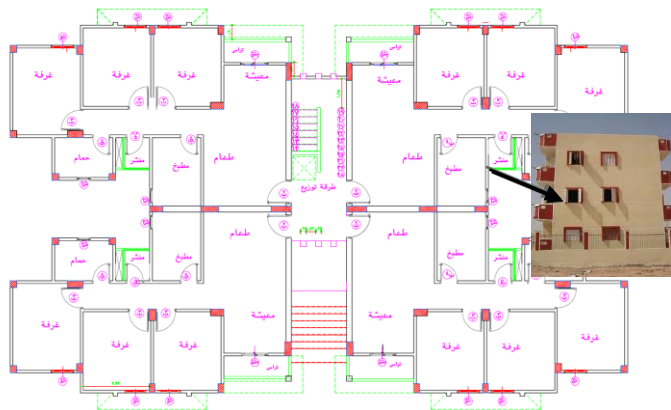
#### The main assumptions considered for the simulation process are:

- Two dimensional model;
- Steady state condition;
- Equivalent conductivity (radiative and convective part);
- All thermo physical properties kept constant;
- Emissivity values of the emitting and receiving surfaces are equal ( $\epsilon_1 = \epsilon_2$ );
- Thermal resistance of the voids calculated according to B.3 of EN ISO 6946:1996 [20].
- Thermal resistance of the holes with non-rectangular shape is assumed equal to a rectangular hole with the same area and the same dimensional ratio ( $d/b$ ) [20].

### 5.2 Modeling

This study investigates simulation analysis which aims at improving the thermal performance of buildings through variations of external walls in Egypt. The finding of this paper presents preliminary thermal analysis done for an air conditioned standard building. The study focused on the thermal performance assessment of the building's local construction wall materials and the analysis has been carried out using dynamic thermal simulations using the hourly weather data of Cairo and setting climatic and treatments for the future extension zone buildings of New Capital Cairo.

The simulations in this study was carried out in two consecutive stages, the first stage addressed the air temperature and energy usage on a year round to define the peak day and the worst orientation among the main four orientations and results focused on the peak day occupancy time and the worst orientation performance of the building. The second stage investigates the effects of using marble wastes in industry of hollow concrete blocks and potential thermal impacts of internal courtyard. Results were analyzed and compared in the four stages when using marble wastes.



**Fig (6): Case study residential building plan**

A typical residential buildings space was selected for assessment as in figure (6) to (7), wall construction materials were selected according to survey done for façade materials of residential buildings.

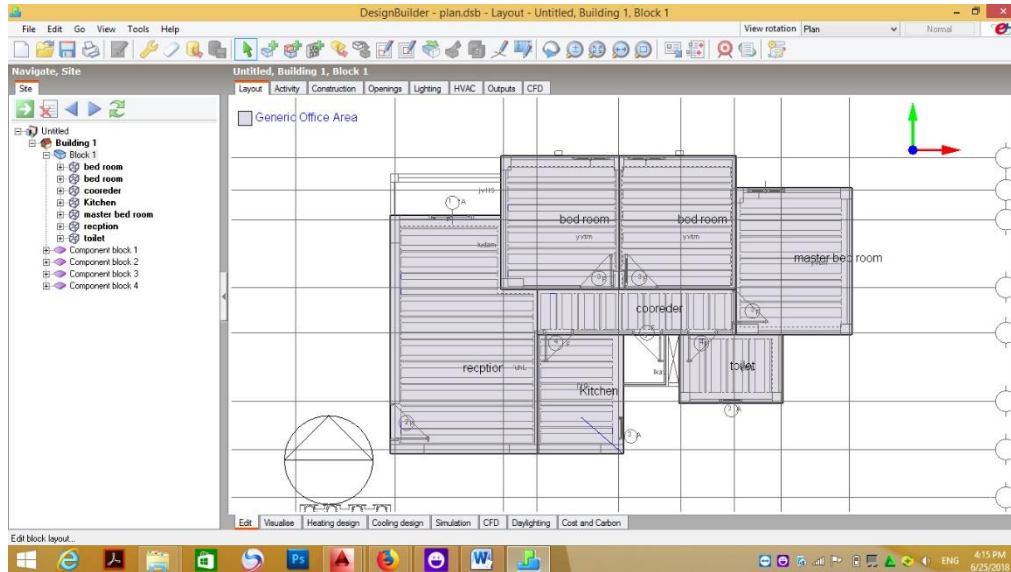
### 5.3 Envelop properties

A case study house has been selected for modeling and evaluation of thermal condition in fig (7). The house consists of;



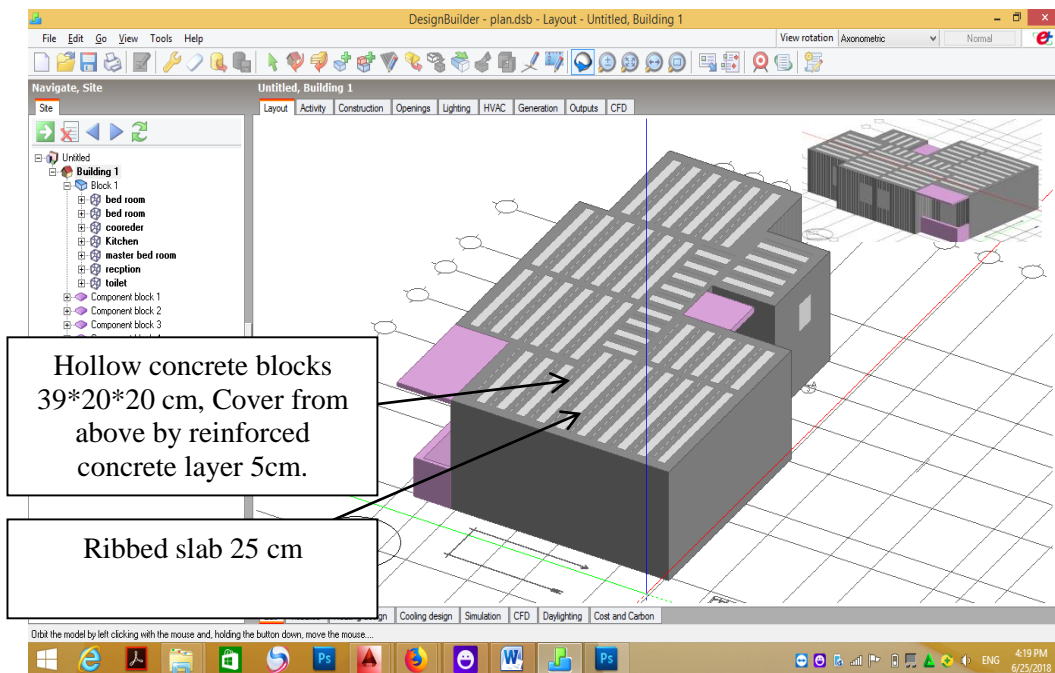
**House:** This house is for bedrooms, the kitchen, bathroom and reception.

**Material:** for Design Builder Software model materials for the building are either chosen from Design Builder Software library or created from user library table (3). Construction materials were chosen based on the façade and roof materials, materials were concrete hollow blocks with utilization replacement percentage by marble wastes.



Drawing one apartment from building wherein attaching walls for neighboring to making of adiabatic even not to be influenced on calorie load in apartment interior

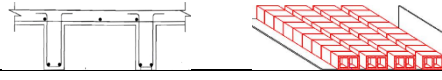
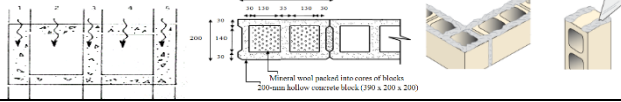
**Fig (7A): Case study apartment plan**

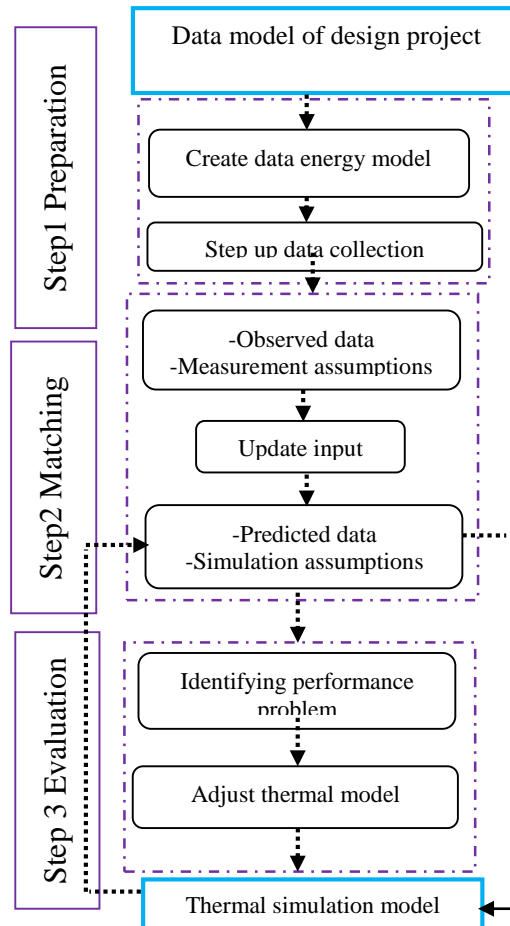


**Fig (7B): Perspective shot for case study**

**Fig (7): Perspective for case study**

**Table (3): Material properties for the case study building.**

Material description		U-Value (w/m <sup>2</sup> k)	R-value (w/m <sup>2</sup> k)
Roof <sub>1</sub>	100mm thick suspended concrete floor	5.29	0.181
Roof <sub>2</sub>	200mm hollow block slabs 	2.100	0.476
Wall <sub>1</sub>	200*125*60 mm Brick concrete solid	2.597	0.385
Wall <sub>2</sub>	390*200*200 mm hollow concrete block 	2.200	0.455
Door	40mm thick hollow core plywood door	2.98	0.65- 40
Window	single glazed 6mm with oriel	6.121	0.810



**Fig (8): Work flow to produce and steps of the thermal simulation model**

## 6. Results and discussion

### 6.1 Compressive strength

The compressive strength of hollow concrete blocks is of crucial importance for design and safety assessment purposes. Table (4) shows the effect of marble waste size (coarse

marble, fine marble and marble powder) on the 7, 28, 56 and 180 days compressive strength of hollow concrete blocks. It can be observed that in general, the compressive strength values for hollow concrete blocks containing coarse marble aggregate are higher than those for blocks containing fine marble as recycled aggregate, regardless of replacement percentage of conventional aggregates (sand or dolomite). On the other hand, in case of using marble powder as a replacement of cement, the compressive strength values for hollow concrete blocks containing marble powder were found to be lower than those of blocks containing the coarse or fine marble aggregate, regardless of replacement percentage of conventional materials. Hence, from the technical point of view, it is perfected to be marble waste as coarse aggregate than being used as fine aggregate and marble powder of cement.

Compared with control block, the addition of coarse marble at 100% resulted in a concrete strength decrease of 3.22% at 28 day, while using of marble waste at (50% fine marble FA + 100% coarse marble CA) reduced the block strength by 16.1%, while the decrease by using (100% CA + 30% marble powder MP ) was 21.3% in the same ages. These results indicate that a higher percentage of replacement resulted in a lower compressive strength.

**Table (4) shows Comparing between the effects of the different sizes of marble waste**

The increasing of Portland cement replacement with marble sludge addition lead to decreasing in compressive strength resulting in potential reduction in the cementing materials causing a dilution of C2S and C3S which are the main constituents and strength providers of cement Bonavetti et al., (2000); Güneysi et al., (2009); Ergun, (2011) due

Mix	Compressive strength			
	7 days	28 days	56 days	180 days
0%	110	155	170	195
100% CA	106	150	159	192
50%FA+ 100%CA	98	130	154	164
100% CA + 30%MP	91	122	149	157

to the higher water demands of concrete mixtures containing higher marble content as a result of their higher specific surface area more than cement.

On the other hand, the pore-filling effect of fine marble powder with providing the suitable nucleus for hydration means increasing in compressive strength. This marble sludge is could be assumed as ultrafine aggregates filling concrete voids Bonavetti et al., (2000); Ergun, (2011) that enhance the properties of the transition zone surrounding aggregate Aliabdo et al., (2014).

Also, the reason of improving compressive strength of concretes by the addition of fines marble are accelerating the hydration of clinker minerals, especially C3S and carboaluminates are formed and they act as nucleation sites for CH and CeSeH reaction products at early ages, resulting in an improvement in early strength Heikal et al., (2000); Ergun, (2011); Meddah et al., (2014).

Using different types of cement Gencel et al. (2012) investigated the feasibility and effects of using waste marble as aggregate replacement on physical and mechanical properties of concrete paving blocks. They reported that there are indirect relation between marble content and mechanical strength while freeze-thaw durability and abrasive wear resistance increase. Rana et al. (2015) have shown that to achieving the

best performance of concrete properties occur by replacing up to 10% of cement with marble slurry.

## 6.2 Thermal conductivity

The apparent thermal conductivity of is related to density. Tests of the same density at varying containing material were conducted in accordance with ASTM C 518 steady state thermal transmission properties by means of the (Heat Flow Meter) to determine if a the materials content effect' was present. Table (5) exhibits this consistency of measured conductivity in several samples of at varying material content. For the range of density typically used as hollow concrete blocks there is little or no containing material effect results of measurements at test containing material of 1 to 4" are representative of the material in use.

**Table (5) Exhibits this consistency of measured conductivity in several samples of at varying containing material**

Mix	Samples	Thicknesses (cm)	Density	Thermal conductivity (W/m.K)
Mix 1	control	5	2189	0.93
Mix 2	100% CA (hollow)	5	2187	1.34
Mix 3	50%FA+ 100%CA (hollow)	5	1970	1.03
Mix 4	100% CA + 30%P (hollow)	5	1950	1.36

### ▪ Effect of using different sizes of marble waste

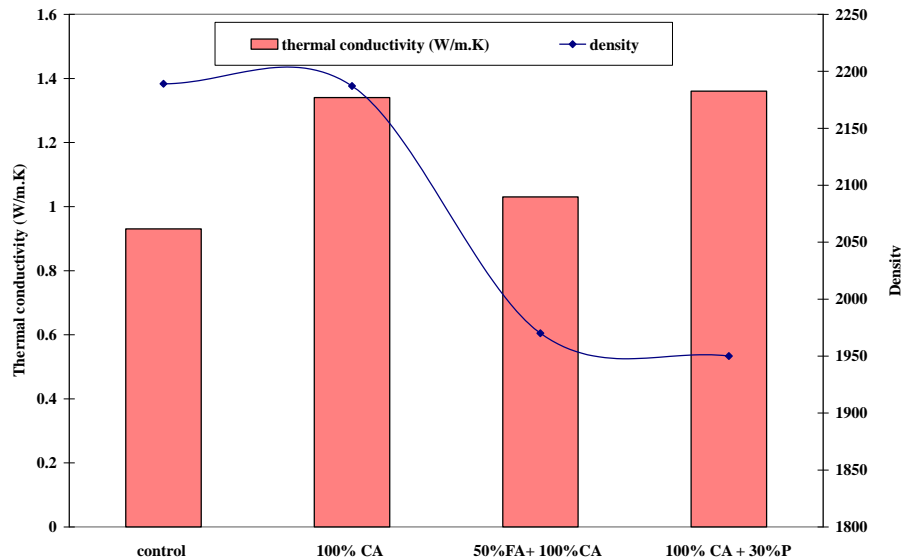
Table (5) and Figure (9) shows comparing between the effects of the different sizes of marble waste on density and thermal conductivity for choose samples. For mixes were compared with the control hollow concrete blocks made with conventional materials (cement, dolomite and sand). These mixes incorporated (100% coarse marble aggregate CA), (50% fin marble aggregate FA+ 100% coarse marble aggregate CA) and (100% coarse marble aggregate CA + 30% marble powder MP).

It can be found for the figure that mixes containing control showed the lowest thermal conductivity followed by mix containing (50% FA+ 100% CA), the mix containing (100%CA) and finally mix containing (100% CA + 30% MP) showed the highest thermal conductivity. While density found for the figure that mixes containing control was the highest density followed by mix containing (100% CA), the mix containing (50% FA+ 100% CA), and finally mix containing (100% CA + 30% MP) showed the lowest density. Marble powder incorporation had a positive effect on density, shrinkage and plasticity during all stages of the production process, anticipating some modifications in the industrial production line [9].

Panels were tested with three different sizes of marble waste and also different ratios. Control sample were similar in overall thermal performance. The sample 100% CA had a 44% high thermal conductivity than the control sample, while sample 50%FA+ 100% CA had a 10.75% high thermal conductivity than the control sample, while sample 100% CA + 30%MP had a 46.24% high thermal conductivity than the control sample. Therefore, uses the marble wastes to make hollow concrete blocks will influence on the thermal conductivity negative. The lower resistance and conductivity values are justified

by the presence of aggregate with a lower density and lower thermal conductivity than the natural aggregate.

This is an expected outcome due to the high specific gravity of waste marble dust and also filler effect of marble dust because it has finer particles than fine sand aggregate. The porosity of the concrete decreased and ultrasonic pulse velocity increased with increasing percentage of marble dust additions.



**Fig (9): Effect and comparing between the effects of the different sizes of marble waste on density and thermal conductivity.**

Table (6) and Figure (10) to Figure (14) shows comparing between the effects of the different sizes of marble waste on thermal conductivity, energy consumption, price and compressive strength for choose samples.

Figure (10) shows the effecting using different sizes of marble waste on the thermal conductivity and energy consumption of hollow concrete blocks using in building. For mixes were compared with the control hollow concrete blocks made with conventional materials (cement, dolomite and sand). These mixes incorporated (100% coarse marble aggregate CA), (50% fin marble aggregate FA+ 100% coarse marble aggregate CA) and (100% coarse marble aggregate CA + 30% marble powder MP).

It can be found for the figure that mixes containing control showed the lowest thermal conductivity followed by mix containing (50% FA+ 100% CA), solid cement brick, the mix containing (100%CA) and finally mix containing (100% CA + 30% MP) showed the highest thermal conductivity. While energy consumption found for the figure that mixes containing solid cement brick was the highest energy consumption followed by mix containing (100% CA), the mix containing (100% CA + 30% MP), the mix containing (50% FA+ 100% CA) and finally mix containing control showed the lowest energy consumption.

Hollow concrete blocks for mixes were compared with the control hollow concrete blocks, with (100%CA), (50%FA+ 100%CA) and (100% CA + 30%MP) had 44.09%, 10.75% and 46.24% to the thermal conductivity respectively, while the energy consumption was 2.13%, 0.58% and 0.83% respectively.

Figure (11) shows the effecting using different sizes of marble waste on the thermal conductivity and price of hollow concrete blocks using in building. For mixes were cost



and compared with the control hollow concrete blocks made with conventional materials (cement, dolomite and sand).

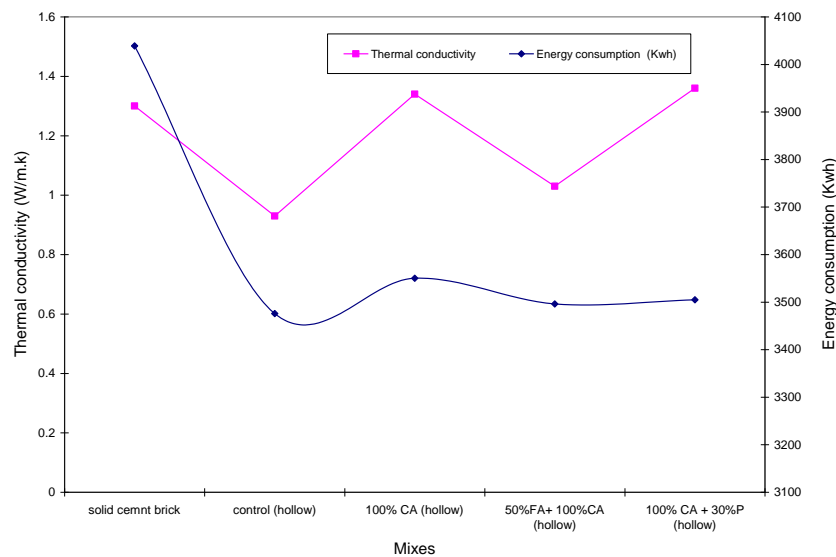
It can be found for the figure that mixes containing control showed the lowest thermal conductivity followed by mix containing (50% FA+ 100% CA), solid cement brick, the mix containing (100%CA) and finally mix containing (100% CA + 30% MP) showed the highest thermal conductivity. While the cost found for the figure that mixes containing solid cement brick was the lowest cost followed by mix containing (100% CA + 30% MP), the mix containing (50% FA+ 100% CA), the mix containing (100% CA) and finally mix containing control showed the highest cost.

The mixes were compared with the control hollow concrete blocks, with (100%CA), (50%FA+ 100%CA) and (100% CA + 30%MP) had 44.09%, 10.75% and 46.24% to the thermal conductivity respectively, while the decrease of price was 19.37%, 22.39% and 27.54% respectively.

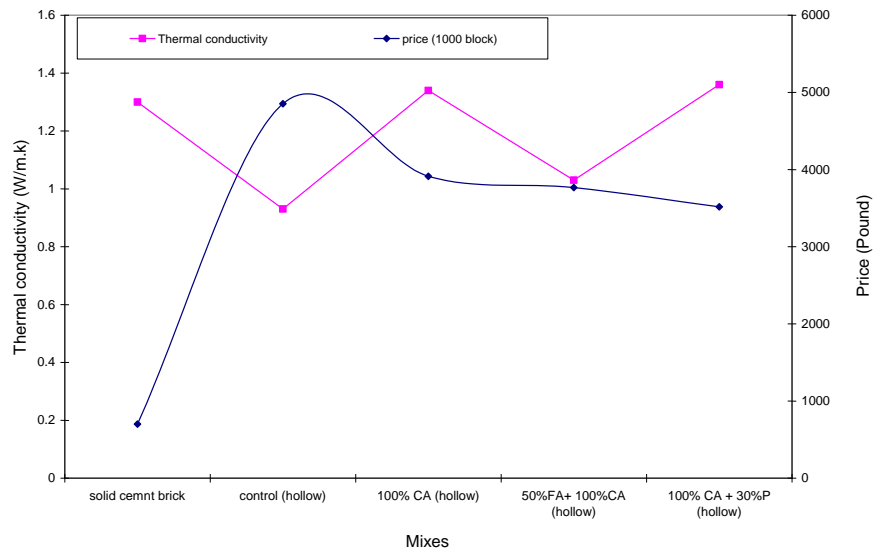
Figure (12) shows the effecting using different sizes of marble waste on the energy consumption and price of hollow concrete blocks using in building. For mixes were cost and compared with the control hollow concrete blocks made with conventional materials (cement, dolomite and sand).

It can be found for the figure that mixes containing solid cement brick showed the highest energy consumption followed by mix containing (100% CA), the mix containing (100% CA + 30% MP), the mix containing (50% FA+ 100% CA) and finally mix containing control showed the lowest energy consumption. While the cost found for the figure that mixes containing solid cement brick was the lowest cost followed by mix containing (100% CA + 30% MP), the mix containing (50% FA+ 100% CA), the mix containing (100% CA) and finally mix containing control showed the highest cost.

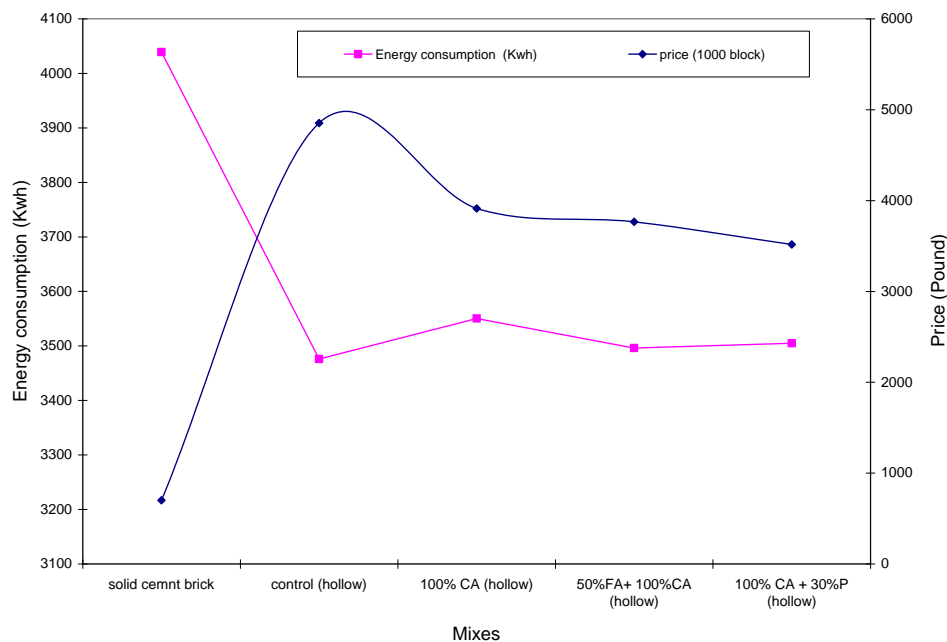
The mixes were compared with the control hollow concrete blocks, with (100%CA), (50%FA+ 100%CA) and (100% CA + 30%MP) had 2.13%, 0.58% and 0.83% to the energy consumption respectively, while the decrease of price was 19.37%, 22.39% and 27.54% respectively.



**Fig (10): Effect and comparing between the effects of the different sizes of marble waste on Thermal conductivity and Energy consumption.**



**Fig (11): Effect and comparing between the effects of the different sizes of marble waste on Thermal conductivity and price.**



**Fig. (12): Effect and comparing between the effects of the different sizes of marble waste on Energy consumption and price.**

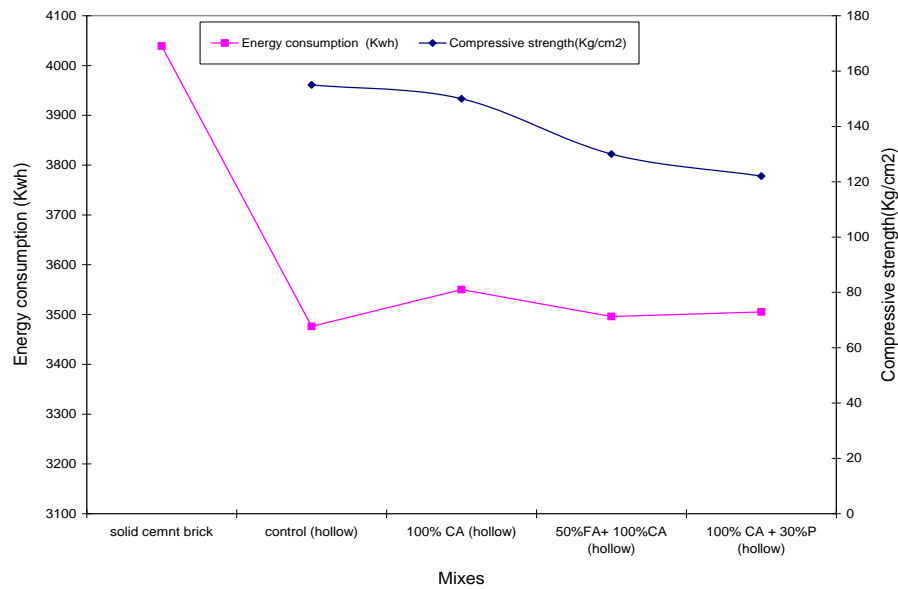
Table (6) shows comparing between the effects of the different sizes of marble waste on Thermal conductivity, Energy consumption, Price and Compressive strength for choose samples.

Figure (13) shows the effecting using different sizes of marble waste on the energy consumption and compressive strength of hollow concrete blocks using in building. For mixes were compared with the control hollow concrete blocks made with conventional materials (cement, dolomite and sand).

It can be found for the figure that mixes containing solid cement brick showed the highest energy consumption followed by mix containing (100% CA), the mix containing (100% CA + 30% MP), the mix containing (50% FA+ 100% CA) and finally mix containing control showed the lowest energy consumption. While the compressive strength found

for the figure that mixes containing control was the highest of compressive strength followed by mix containing (100% CA), the mix containing (50%FA+ 100%CA) and finally mix containing control showed the lowest compressive strength (100% CA + 30%MP).

The mixes were compared with the control hollow concrete blocks, with (100%CA), (50%FA+ 100%CA) and (100% CA + 30%MP) had 2.13%, 0.58% and 0.83% to the energy consumption respectively, while the decrease of compressive strength was 3.23%, 16.13% and 21.29% respectively.

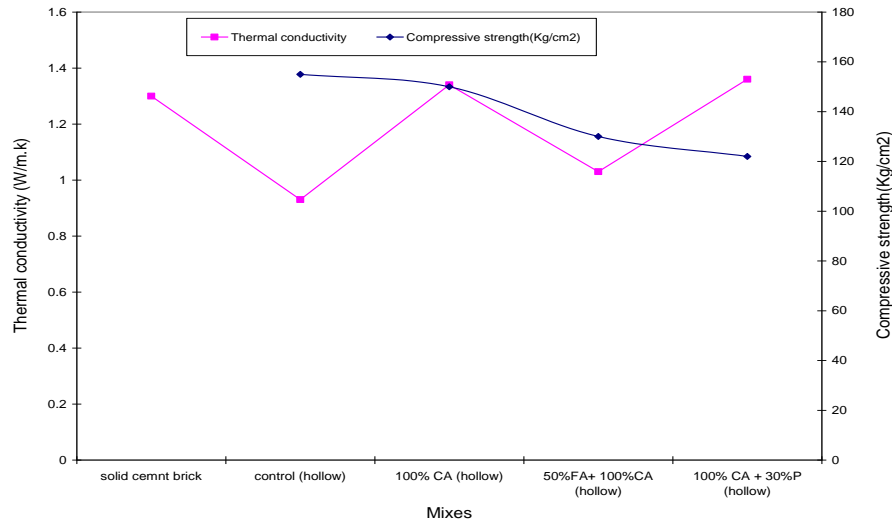


**Fig. (13): Effect and comparing between the effects of the different sizes of marble waste on Energy consumption and Compressive strength.**

Figure (14) shows the effecting using different sizes of marble waste on the thermal conductivity and compressive strength of hollow concrete blocks using in building. For mixes were compared with the control hollow concrete blocks made with conventional materials (cement, dolomite and sand).

It can be found for the figure that mixes containing control showed the lowest thermal conductivity followed by mix containing (50% FA+ 100% CA), solid cement brick, the mix containing (100% CA) and finally mix containing (100% CA + 30% MP) showed the highest thermal conductivity. While the compressive strength found for the figure that mixes containing control was the highest of compressive strength followed by mix containing (100% CA), the mix containing (50%FA+ 100%CA) and finally mix containing control showed the lowest compressive strength (100% CA + 30%MP).

The mixes were compared with the control hollow concrete blocks, with (100%CA), (50%FA+ 100%CA) and (100% CA + 30%MP) had 44.09%, 10.75% and 46.24% to the thermal conductivity respectively, while the decrease of compressive strength was 3.23%, 16.13% and 21.29% respectively.



**Fig. (14): Effect and comparing between the effects of the different sizes of marble waste on Thermal conductivity and Compressive strength.**

Table (6) shows comparing between the effects of the different sizes of marble waste on Thermal conductivity, Energy consumption, Price and Compressive strength for choose samples

System	Mixes	Thermal conductivity W/m.K	Energy consumption Kwh	Price 1000 block L.E	Compressive strength Kg/cm <sup>2</sup>
Using solid cement bricks in walls with roof from reinforced concrete	solid brick	1.3	4039	700	106
Using hollow concrete blocks in walls and roof	control (hollow)	0.93	3476	3813.95	155
Using hollow concrete blocks in walls and roof	100% CA	1.34	3550	3075.23	150
Using hollow concrete blocks in walls and roof	50%FA+ 100%CA	1.03	3496	2960.18	130
Using hollow concrete blocks in walls and roof	100% CA + 30%P	1.36	3505	2763.69	122

### 6.3 Total energy savings

It is important to understand that not all building systems will necessarily achieve simultaneously what may be perceived to be desirable goals. The designer must balance the potentially conflicting goals of:

- Minimizing energy use, including heating and cooling energy as well as the energy used to produce the building materials
- Minimizing cost, including heating and cooling cost as well as the cost associated with particular building-construction practices

Figure (15) to Figure (19) shows comparing between the effects of the different sizes of marble waste on energy consumption for choose samples.

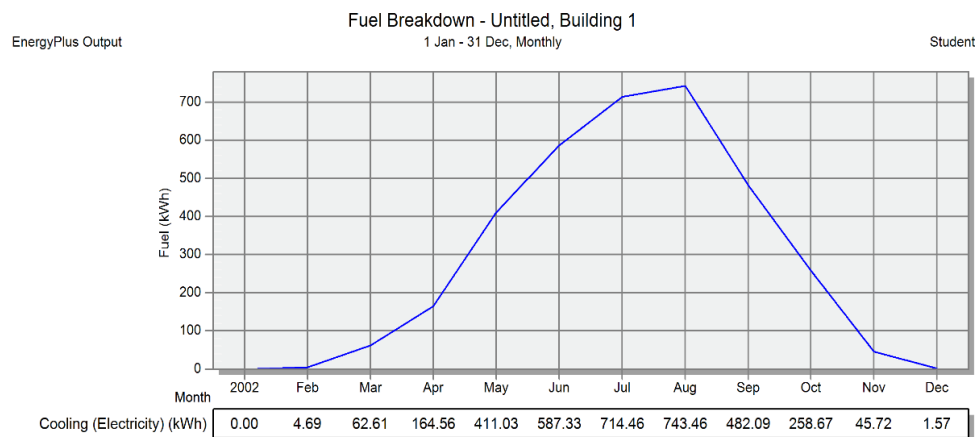
Figure (15) and (16) shows the effecting using different sizes of marble waste on the energy consumption of control hollow concrete blocks using in building. For mixes were compared with the control solid concrete bricks made with conventional materials (cement, dolomite and sand).

It can be found for the figure that the percentage of saving in electricity equal 14% when using hollow concrete blocks in walls instead of solid concrete brick in wall and in [hollow concrete blocks roofs] instead of [roof reinforced concrete].

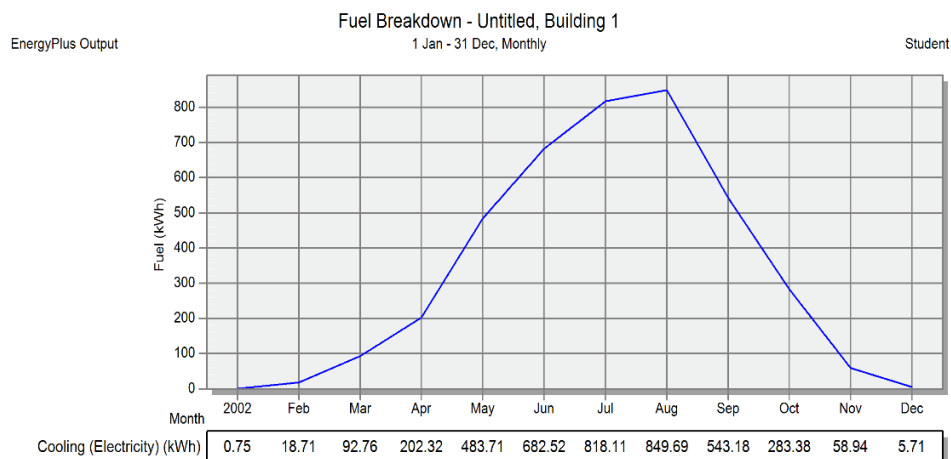
Figure (17) shows the effecting using different sizes of marble waste (100% CA) on the energy consumption of hollow concrete blocks using in building when using blocks in walls and roof. It can be found for the figure that the percentage of saving in electricity equal 3550 Kwh

Figure (18) shows the effecting using different sizes of marble waste (50% FA+ 100% CA) on the energy consumption of hollow concrete blocks using in building. It can be found for the figure that the percentage of saving in electricity equal 3496 Kwh.

Figure (19) shows the effecting using different sizes of marble waste (100% CA + 30%MP) on the energy consumption of hollow concrete blocks using in building. It can be found for the figure that the percentage of saving in electricity equal 3505 Kwh.

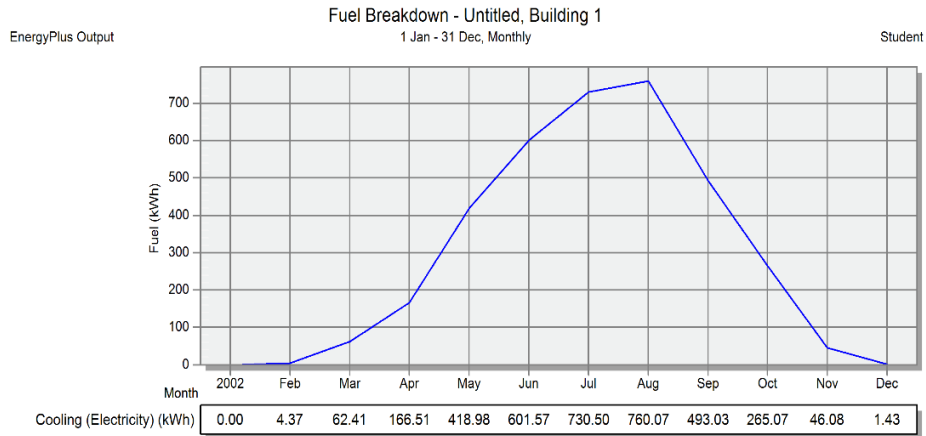


**Fig. (15): Monthly consumption of electricity for building under study by using hollow concrete blocks in walls and roof**

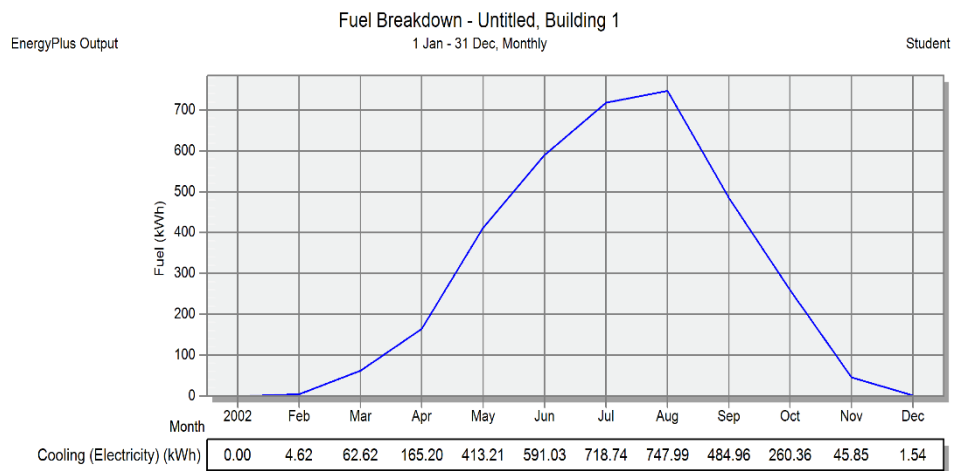


**Fig. (16): Monthly consumption of electricity for building under study by using solid concrete brick in wall and of roof reinforced concrete**

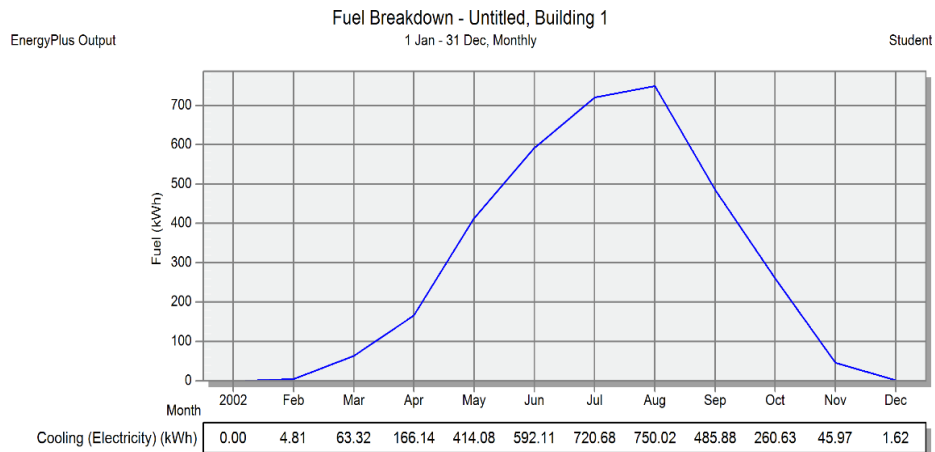




**Fig. (17): Monthly consumption of electricity for building under study by using hollow concrete blocks in walls and roof  $K= 1.34$  ,  $p= 2187$  by mix containing (100% CA).**



**Fig. (18): Monthly consumption of electricity for building under study by using hollow concrete blocks in walls and roof  $K= 1.03$  ,  $p= 1970$  by mix containing (50%FA+ 100%CA).**



**Fig. (19): Monthly consumption of electricity for building under study by using hollow concrete blocks in walls and roof  $K= 1.36$  ,  $p= 1950$  by mix containing (100% CA + 30%MP).**

## 7. Economic study

The results in this study showed that the marble wastes mixtures can be used to produce hollow load bearing concrete blocks, while (50%FA+ 100%CA) and (100% CA + 30%MP) marble wastes mixtures can be used to produce hollow non-load bearing concrete blocks at 28 days. Economically, According to table(6), (7) the cost estimate materials and marble waste ratios could reduce between 22.33% and 27.54% per 1000,block for hollow non-load bearing concrete block production for mixtures (50%FA+ 100% CA) and (100% CA + 30%MP), respectively. For the hollow load bearing concrete block production, mixture (100% CA) can reduce the cost at 19.36% per 1000, block.

**Table (7) Prices average for materials is used in study**

Materials and commodities	Unity	average price (pounds)
Price of cement	Ton	900
Price of sand	cubic meter	80
Price of coarse aggregates	cubic meter	160
Price of marble fragments	Ton	zero
Price of marble powder	Ton	zero
Price of fine marble waste	Ton	45
Price of coarse marble waste	Ton	90
Price of water	cubic meter	3
Electricity (pounds /block)	Hour	60

## 8. Conclusions

- The physical and mechanical properties of cement composites were affected by using marble sludge: water absorption and apparent porosity increased with increasing marble content, while the density and compressive strength decreased.
- The compressive strength of hollow concrete block is decreased with addition of waste marble powder up to 30% replace by weight of cement.
- 25% and 50% of fine marble waste ratio in mixture to make a hollow non-load bearing concrete block.
- The generality test results revealed that the coarse aggregate of the recycled waste materials (marble wastes) can be utilized in hollow concrete blocks mixture as reasonable substitute of natural dolomite.
- Using the environmental pollutants in serving the environment to maintain the general health of the citizen and improve economics of the industry, have put forth a simple step to minimize the costs for construction with usage of marble wastes which is freely or cheaply available.
- Production of various mixed ratio of hollow concrete blocks from marble waste used as a fine aggregate and coarse aggregate and powder, could be a profitable disposal alternative in the future and will be of the highest value possible for the foreseeable future.
- The addition of marble wastes has negligible effect on the mechanical properties during the entire process, anticipating no costly modifications in the industrial production line.
- Implementing sustainability in the element of waste management consider sustainable waste management sequence to lessen waste generation

- Economic and social environment and applying all sustainable architecture strategies.
- Thermal insulation property of hollow concrete block is suitable due to presence of air in hollow concrete units.
- Uses the marble wastes to make hollow concrete blocks will influence on the thermal conductivity negative.

## 9. References

1. Hamza, R. A., El-Haggar, and Khedr ,S.(2011) Marble and Granite Waste: Characterization and Utilization in Concrete Bricks. International Journal of Bioscience, Biochemistry and Bioinformatics:Vol. 1(4)
2. Corinaldesi, V., Moriconi, G., & Naik, T. (2010). Characterization of Marble Powder for its Use in Mortar Concrete. Construction and Building Materials, 24, 113-117. [Online]. ScienceDirect.
3. Rodrigues, R., de Brito, J., Sardinha, M., 2015. Mechanical properties of structural concrete containing veryfine aggregates from marble cutting sludge. Constr. Build. Mater. 77, 349e356.
4. Ergun, A., 2011. Effects of the usage of diatomite and waste marble powder as partial replacement of cement on the mechanical properties of concrete. Constr. Build. Mater. 25, 806e812.ESS. No. 1109, 2002.
5. Rana, A., Kalla, P., Csetenyi, L.J., 2015. Sustainable use of marble slurry in concrete. J. Clean. Prod. 94, 304e311.
6. Aliabdo, A.A., Abd Elmoaty, M.A., Auda, E.M., 2014. Re-use of waste marble dust in the production of cement and concrete. Constr. Build. Mater. 50,28e41.
7. Ahmed O. Mashaly, Baher A. El-Kaliouby, Basel N. Shalaby, Amr M. El eGohary, Mohammed A. Rashwan, 2016 Effects of marble sludge incorporation on the properties of cement composites and concrete paving blocks, Journal of Cleaner Production 112 (2016) 731e741
8. Gencil, O., Ozel, C., Koksall, F., Erdogmus, E., Martínez-Barrera, G., Brostow, W., 2012. Properties of concrete paving blocks made with waste marble. J. Clean. Prod. 21, 62e70.
9. Dhanapandian, S. and Gnanavel, B. 2009. Studies on granite and marble sawing powder wastes in industrial brick formulations. Asian Journal of Applied Sciences. 2 (4) : 331-40.
10. N. Bilgin, H.A. Yeprem, S. Arslan, A. Bilgin, E. Günay, M. Mars\_oglu " Use of waste marble powder in brick industry" Construction and Building Materials· 29 (2012) 449–457.
11. Klrglz, M. S. (2007). The usage of the wastes of marble and brick industries in cement manufacturing as mineralogical additive, PhD Thesis, Ankara: Gazi University Graduate School of Natural and Applied Sciences. (<https://tez.yok.gov.tr/UlusalTezMerkezi/>)(for reading abstract of thesis, please write full name of author known Mehmet Serkan KIRGIZ to search engine above webpage then click "Bul"button).
12. Y.H. Ye, W.M. Sun, et al, Experimental Study on hollow block masonry walls filled with foaming concrete, 10th Canadian Masonry Symposium, Banff, Alberta, June 8 – 12, 2005
13. Koski, J.A., 1992. How Concrete Block are Made. Masonry Construction, pp: 374-377.

14. S. O. Adepo , K. A. Imoukhuede, S. S. James, Experimental analysis of heat conduction through hollow building blocks, *International Journal of Engineering Technologies and Management Research*, 5(5), 179-183. DOI: 10.5281/zenodo.1296942.
15. Navaratnarajah, Sathiparan & K. N. Anusari, M & N. Samindika, N. (2014). Effect of Void Area on Hollow Cement Masonry Mechanical Performance. *Arabian Journal for Science and Engineering*. 39. 7569-7576.
16. Egyptian Standard Specifications. Load bearing concrete masonry units, 2005. Rep. No. 1292-1.
17. Egyptian Standard Specifications. No-load bearing concrete masonry units, 2005. Rep. No. 1292-2.
18. Standard Test Methods for Sampling and Testing Concrete Masonry Units and Related Units, Copyright ASTM International Provided by IHS under license with ASTM C140 – 11a, Current edition approved Aug. 1, 2011. Published September 2011. Originally approved in 1938. Last previous edition approved in 2011 as C140 – 11. DOI: 10.1520/C0140-11A.
19. Design Builder. Available online: <http://www.designbuilder.co.uk> (accessed on 10 January 2013).
20. EN ISO 6946:1996 Building Components and Building Elements-Thermal Resistance and Thermal Transmittance - Calculation Method; European Committee for Standardization: Brussels, Belgium, 1996.
21. Bonavetti, V., Donza, H., Rahhal, V., Irassar, E., 2000. Influence of initial curing on the properties of concrete containing limestone blended cement. *Cem. Concr. Res.*30, 703e708.
22. Güneyisi, E., Gesoglu, M., Ozbay, E., 2009. Effects of marble powder and slag on the properties of self-compacting mortars. *Mater. Struct.* 42, 813e826
23. Heikal, M., El-Didamony, H., Morsy, M.S., 2000. Limestonefilled pozzolanic cement. *Cem. Concr. Res.* 30, 1827e1834.
24. Meddah, M.S., Lmbachiya, M.C., Dhir, R.K., 2014. Potential use of binary and composite limestone cements in concrete production. *Constr. Build. Mater.* 58,193e205.
25. Rana, A., Kalla, P., Csetenyi, L.J., 2015. Sustainable use of marble slurry in concrete. *J. Clean. Prod.* 94, 304e311.