THE DATABASE OF EGYPTIAN BUILDING ENVELOPES (DEBE): A DATABASE FOR BUILDING ENERGY SIMULATIONS

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ABSTRACT

This paper is a part of an ongoing research that aims to describe the influence of building constructions on energy consumption through a survey that is conducted in Cairo and its surrounding residential neighbourhoods. An inventory of the selected neighbourhoods envelope constructions and their characteristics is described in accordance with the new Egyptian energy standard for residential buildings. After thorough screening and classification, the constructions are digitalized and uploaded in an online open source database where constructions properties are listed, made available in .idf and .ddb formats (EnergyPlus and DesignBuilder respectively) and illustrated graphically. This Database of Egyptian Building Envelopes (DEBE) facilitates the input modelling of constructions and enables users to explore standard complying alternative constructions.

INTRODUCTION

Egypt is a country of a population of over 80 million (APMS, 2010), with only 43% of its land urbanized. The urbanization is concentrated in the Nile basin, resulting in the population density reaching 2141 per/square kilometer. Due to the increasing population growth and the shortage of more than 8 million residential units, Egypt's urbanization rate is expected to increase to cover 70% of its land (MHUUD, 2010).

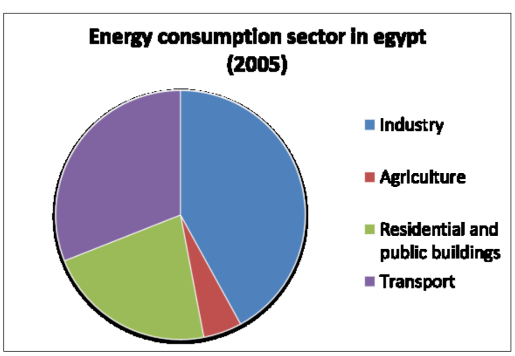


Figure 1, Energy consumption sectors in Egypt (Ministry of Electricity and Energy)

Besides the increase in urbanization, previous climate change studies that focused on Egypt confirm that there is an extrem impact of climate change on the built environment and comfort in Egypt (Broadous et al., 1986). In Egypt the extreme sensitivity to changes in temperature (Gleick, 1991) caused an increase in electricity consumption to put up with necessary cooling loads. This is evident in the fact that the number of air conditioners used in Egypt has risen from 700,000 in 2006 to 3 million in 2010 (MOEE, 2010). Air conditioners consume around 12 % of the maximum productive capacity of power stations. Resulting in a total consumption of 22% of Egypt's overall energy production in the building sector (see Fig. 1). These energy needs could be minimized by an intelligent choice of envelope materials.

With the advent of the new Energy Standard ECP 306-2005 in 2005, there is a strong need for a database to describe the physical and thermal properties of the most common building envelope constructions (floor, wall, roof and windows). Several research attempts quantified the building construction thermal and surface properties. However, these efforts are dispersed, hardly accessible and do not represent the existing construction techniques which should include insulation. Hence, there is an urgent need for an advanced database that compiles the full range of physical characteristics of building envelope components and facilitates whole-building energy simulation. Such a database would enable architects, engineers and modeller unfamiliar with advanced heat transfer analysis to develop simple and accurate descriptions of envelope systems in a form readable by most simulation programs , leading to a conscious choice of the envelope materials used.

In light of the afforementioned , this paper emphasises on the importance of the building envelope on the buildings energy consumption by documenting the process of the development of the Database of Egyptian Building Envelopes (DEBE). This is explained in the following sections:

- Literature Review
- Methodology

- Results analysis
- Discussion and conclusion

LITERATURE REVIEW

The main source of heat transfer between the building and the external environment is through the walls, roof and openings, which coincides with 50% of the energy loss in residential and commercial buildings (Kos´ny et al, 2006). Being aware of issue, various construction and envelope material databases have been created internationally. These databases provide accurate input data for energy simulation programs that in turn produce realistic and reliable results. Yet, these databases cannot be fully adapted elsewhere since construction materials and their thermal characteristics of buildings are contextual and related to the climate, people thermal sensation and country development, etc. In addition, the requirements of the coefficient of heat transmission (U-value) are quite different among various regions and countries (Suzette Michel, 2006). Hence, local effort to address that matter is crucial especially in a country with diverse construction methods and materials like Egypt.

In fact, Egypt is very rich in local building materials, which in turn produced different construction methods over time (see Fig2). Historically, this is clear in the materials used in residential architecture. The Pharaohs (5550 BC) used unbaked mud bricks reinforced with organic materials in constructing walls, domes and vaults. In 1867 AD, The Khedives used high thermal mass bearing stonewalls and concrete roofs. Nowadays, a reinforced concrete column and beam system is used for the structural Skelton along with backed bricks as walls and interior partitions. (See Fig. 2). Not forgetting to mention, the architecture of Hassan Fathy, who devoted his life to creating affordable housing for the poor through using local materials and utilizing ancient design concepts and construction methods such as vaults, arches and domes (Fathy, 1973).

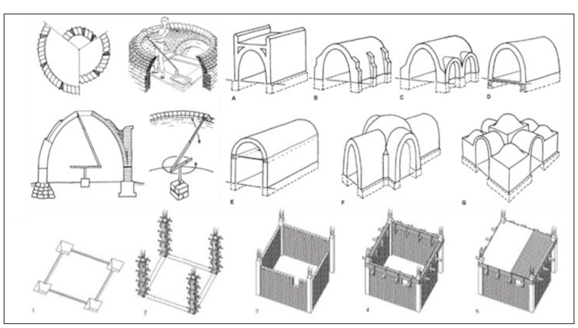


Figure 2, The evolution of residential buildigs in Egypt

Locally, several publications on Egyptian building envelope thermal performance have been published. This includes the work of Shebl in 2010, which provided useful specifications for the building envelope of buildings in the Toshky region in Egypt. In 2007, Attia studied the buildings envelope while investigating passive and active renovation strategies for an existing residential community in an attempt to evaluate the impact and potential of a low-energy retrofit. Further on in the same year, El Seragy, presented alternative ideas for the use of conical roof structures to enhance the environment within their enclosed or semi-enclosed space. One cannot totally overlook these efforts, yet they were applicable within a very specific region and did not aim to document, categorize or digitalize the present building envelope constructions in Egypt.

As for governmental efforts, in 1998 the Housing and Building Research Council (HBRC) published a guideline manual for the installation of thermal insulation. The manual included an inventory of most of the thermal characteristics of the building materials used in Egypt. It listed a variety of physical properties including density, thermal conductivity or specific heat capacity data available for Egyptian building materials. In addition, the manual lists a group of general guidelines that help one choose the appropriate insulation material to use and the means of calculating thermal transmittance of a few of them . However, this effort did not achieve a holistic description of a building's envelope components, as it did not extend to include thermal characteristics of floors, windows, doors or ground decks. Moreover, it discussed the topic from a building construction point of view rather than an energy conservation view.

Further, in 2005, the Housing and Building Research Council HBRC completed the development of a Residential Energy Efficiency Building Code (EEBC) for Egypt. The standard stated the maximum allowable U-values or minimum insulation R-values for the opaque elements of the building. It also specified the maximum allowable U-factor and Solar Heat Gain Coefficient (SHGC) for glazing as a function of the Window-to-Wall ratio. However, the U-values given for opaque constructions included only roofs and external walls, with no mention of the U-value of floors or ground decks, and only the thermal properties of a limited group of materials were available. Nevertheless, the development of the code is just the first of three important steps needed to launch a law enforced energy code. The three main steps, as mentioned by Joe Deringer, 2003, are: (1) Development, (2) Implementation and (3) Administration and Enforcement or voluntary compliance, with incentives. He argues further on in the same paper with reference to the means of implementation of the EEBC "implementation plan for the Egyptian codes should include appropriate successful activities that other countries have included in their implementation of energy efficiency commercial building codes. Such implementation activities typically include Develop all products as templates".

From the aforementioned, we deduce that none of the efforts in that field thought of creating an appropriate digitalized material database of building envelope components, which in turn hinders the use of advanced whole-building energy simulation tools.

METHODOLOGY

This paper is a part of an on-going research that aims to describe the influence of building constructions on energy consumption. The first phase includes the documentation of the thermal characteristics of the envelope materials of the residential buildings in the city of Cairo and the new residential neighbourhoods surrounding it. The second phase will include the commercial buildings in Cairo, and then extend to include the rest of the regions in Egypt. Explained in the following section is the methodology that is used to launch the database and that futuristically will be applied to the coming phases of the database.

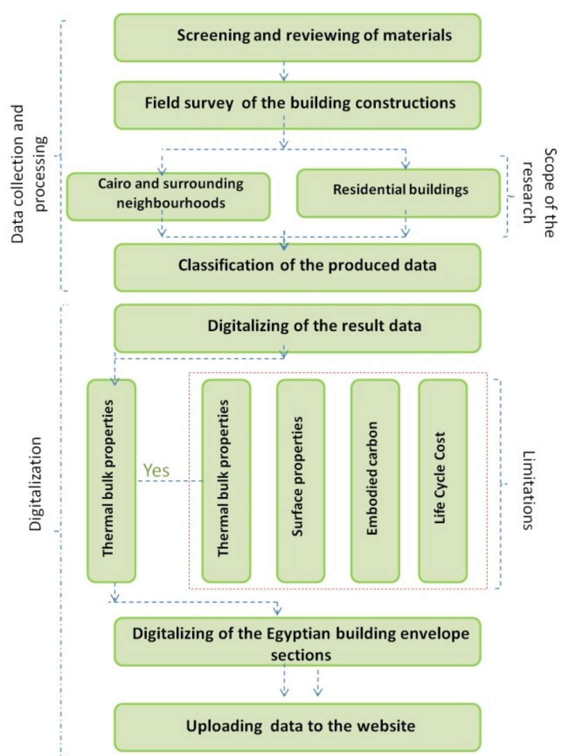


Figure 3, The steps followed to create the datbase

The methodology to develop the database is the following four main steps (see Fig. 3):

- Screening and reviewing the construction materials in the Egyptian standards.
- Conducting a field survey of the existing building constructions.
- Classification of the gathered materials and building constructions.
- Digitalizing the data in different simulation programs formats.

Screening and reviewing the construction materials in the Egyptian standards

In order to create envelope component sections that are representative of the region, a detailed digital inventory of the building materials must be created that is in accord with the thermal and surface properties of the materials in the Egyptian thermal insulation specification manual. The manual consists of a theoretical literal inventory of thermal properties of the most common building materials used in construction (see Table 1). The properties listed in the manual are explicit to the materials density, thermal conductance and specific heat capacity with frequent absence of one or more of these properties of some materials.

Table 1Egyptian building materials thermal properties

Number	*Material*	*Density (kg/m^3)*	*Thermal conductance (watt/m.C)*	*Specific heat (J/kg.C)*
	Bricks:			
1	*Hollow Foam*	*530*	*0.2*	*-*
2	*Solid Foam*	*800*	*0.25*	*-*
3	*Hollow Gypsum*	*750*	*0.41*	*-*
4	*Solid Gypsum*	*950*	*0.39*	*-*
5	*Hollow Leka*	*1200*	*0.39*	*1000*
6	*Hollow Red Brick*	*1790*	*0.6*	*840*
7	*Solid Red Brick*	*1950*	*1.00*	*829*
8	*Solid Cement Brick*	*1800*	*1.25*	*880*
9	*Hollow Cement Brick*	*1140*	*1.6*	*880*
10	*Solid Cement Brick*	*2000*	*1.4*	*840*
11	*Lime stone*	*985*	*0.33*	*850*
12	*Sand Brick*	*1800*	*1.59*	*835*
13	*Hollow Sand Brick*	*1500*	*1.39*	*811*

The numbers above are only guidelines and a representation of the Egyptian market and are in anyway binding.

Conducting a field survey of the existing building constructions:

The second stage is listing the existing envelope construction sections. In order to do this, first the types of construction section used in the region had to be identified, and documented. This is achieved through a field construction and as built survey.

The scope of the first phase of the research is directed to the metropolitan of Cairo, which includes the governorates of Giza, Helwan and Sixth of October. This region is one of the most congested regions in Egypt where its core is urbanely decaying due to overpopulation and pollution and so the construction of new developing residential compounds on the outskirts of Cairo is currently in great acceleration. Hence, the research should be suitably beneficial for the region.

Figure 4, Al Rehab City masterplan,Cairo. Egypt.

The field survey was conducted on “Al Rehab city” one of Cairo’s newly constructed residential cities

Figure 5, The different residential typologies in Al Rehab City.

located on the Cairo Suez road .It is set on an area of 10 million m^2 in New Cairo and accommodates 200,000 inhabitants (See Fig.4). The city was divided into ten phases each built on an area of 240 feddans. The city encloses two main residential typologies, the villas which have 31 different designs with varied internal space areas that range from 174 m^2 to 660 m^2, and the residential buildings which have 50 different models with various apartment sizes that range from 58 m2 to 306 m^2. (See Fig.5)

Al Rehab is the first city built by the private sector in Egypt and is considered one of the most successful residential cities prototypes, due to this success the same private investor is now applying the Rehab experience on a bigger scale in a new city named ‘’Madinaty’’ , which is being built on 8 thousand feddans and designed to accommodate 600,000 inhabitants in 120,000 housing units. So , The choice of Al Rehab city was based on it being a rolemodel of success for relaestate investors and it being duplicated as a model in many of the furure urban agglomerations . (See Fig.6)

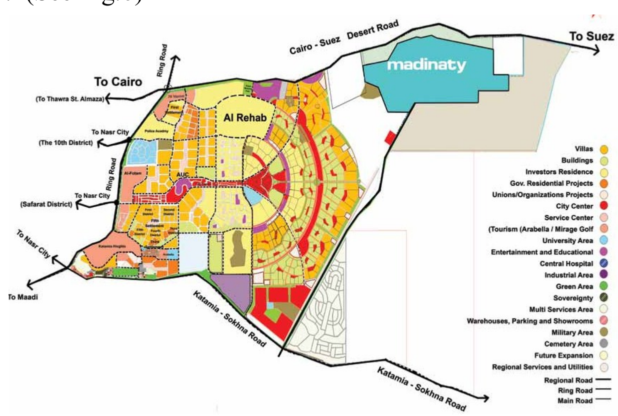


Figure 6, New Cairo City map

Digitalizing the Egyptian building materials and the envelope construction sections:

This step comprises the preparation of the data to be uploaded on the website by putting it in the proper digital format, which would allow its input on energy simulation software. First is the digitalizing of the building material where building material properties include:

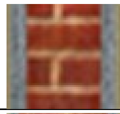
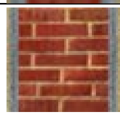
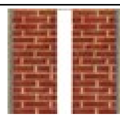
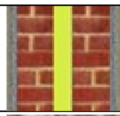
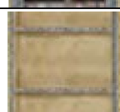
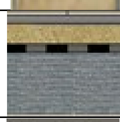
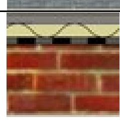
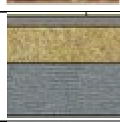
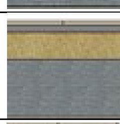
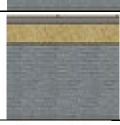
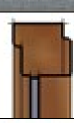
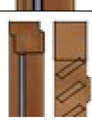
a) Thermal physical properties: This includes the material’s thermal conductivity, specific heat capacity and density.

b) Surface properties: which include Emissivity, solar absorptance, visible absorptance, roughness, colour and texture.

c) Embodied carbon: this includes data on embodied carbon contained in the material.

d) Life cycle cost.

Table 2 Egyptian building materials thermal properties

	Graphical illustration	*Material description*
Exterior walls		Single Red Brick Wall 125mm
		Double Red Brick Wall 250mm
		Double Red Brick Wall 360mm
		Double Red Brick Wall with air gap 360mm
		Cement Brick Wall (Solid) 200mm
		Limestone Wall 500mm
Roof		Typical Roof without Insulation 250mm
		Dome Brick Roof 300mm
Ground		Ground Slab Floor 200 mm
Floor		Flat Slab Floor 120mm
		Flat Slab Floor 250mm
Windows		Wooden Window Frame: Single Glazing 3mm
		Wooden Window Double Framed

The total aim of the research is to cover all four sets of properties, but we focus in this paper on the bulk thermal properties, where the other sets will be covered after receiving the user's feedback and receiving funding to do the required empirical tests needed to acquire the rest of the properties mentioned. So, the data available was compiled digitally using DesignBuilder (DB) and EnergyPlus (EP). The reason for selecting DB and EP was that:

a) They passed the BESTEST for accuracy.

b) DesignBuilder's input is easy and visual (Attia, 2007)

c) EP is an open source software that allows researchers and individuals to run simulations even with other Graphical User Interfaces (GUI) such as OpenStudio.

The thermal characteristics of the materials were used to fill the DesignBuilder's material data template and then exported in .ddb so they could be used to create the construction sections.

The results of the construction section site survey is grouped according to the position of the section in the building envelope: wall, roof, floor, ground and window. An architecture friendly graphical section of each building envelope component is created to illustrate -to the more visually oriented users- the exact layers used in each. Then, the digitalizing of the envelope sections began. The literal data acquired from

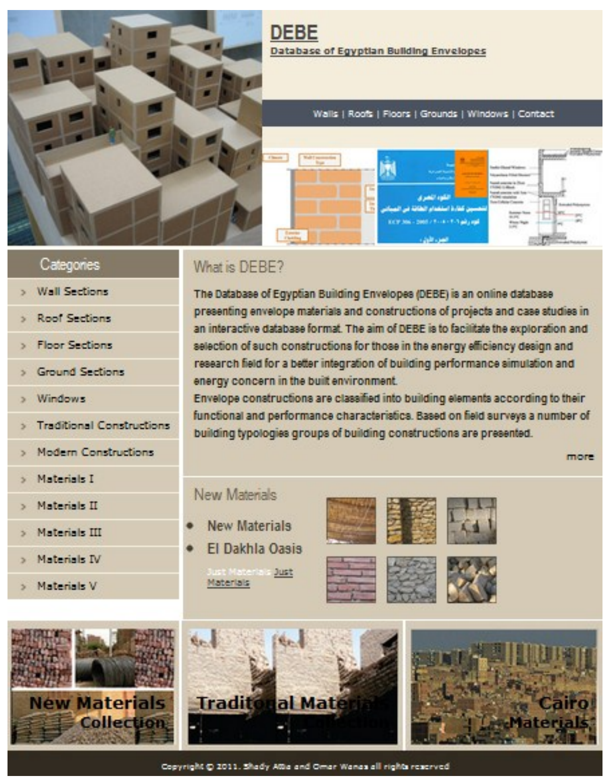


Figure 7, The website's homepage

the survey is entered in DesignBuilder software template titled construction (exterior wall, roof, floor and ground) and Fenestrations. Each section is formed from the Egyptian building materials digitalised previously. A material is assigned to each layer in the section until the building section successfully matches the physical section.

The various building envelope sections produced in DesignBuilder are then exported and saved in .ddb and .idf (DesignBuilder and EnergyPlus respectively).

RESULTS AND ANALYSIS

In order for this data to be easily and freely accessible, the material digital inventory and the digital building envelope sections (Table 2) were all uploaded onto an open source website. The uploading process and sections of the website are explored in this section. (See Fig. 7.)

First, the material digital inventory is classified into:

- Traditional materials.
- Cairo materials.
- New materials.

The materials produced by this research are uploaded in the Cairo materials section with both .ddb and .idf extensions. (See Fig. 8.)

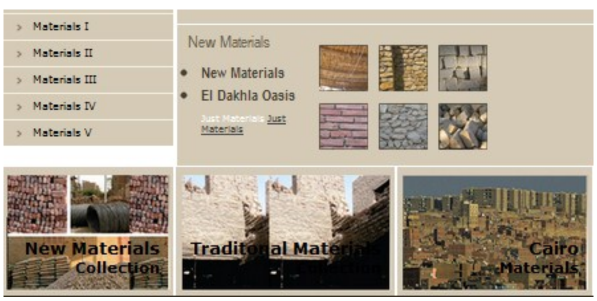


Figure 8, the website's Material Section

Second, the building envelope sections are uploaded each in a tab according to its location in the building: wall, roof, floor, ground and windows. Each one of these tabs encloses two sections a residential use tab and a commercial one as it is our future intention to perform the same research procedure and methodology to expand the database so that it includes commercial buildings as well as residential. (See Fig. 9.)

On opening the residential tab in any construction section one finds a list of the available building envelope sections with a graphical thumbnail of each section adjacent to it. (See Fig. 10.)

When the user chooses the required construction section, he is directed to the construction's thermal properties window .This window is divided into three main segments:

a) First segment to the left contains the graphical presentation and the quality level tab, the user's rating tab and the download counter of the building construction section.

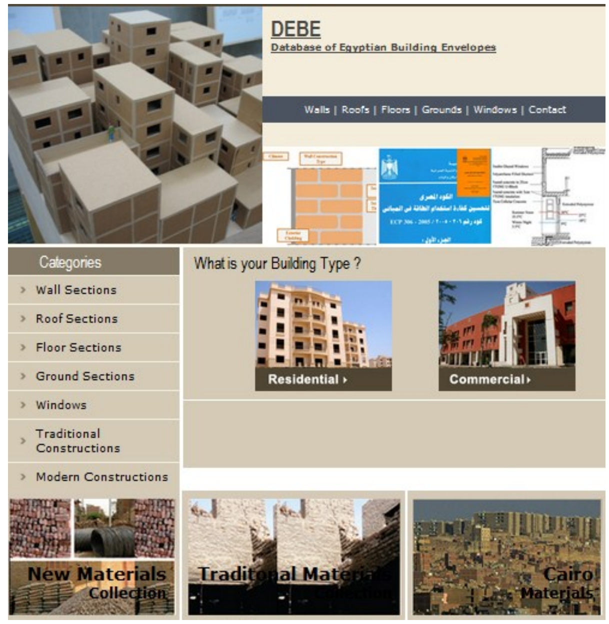


Figure 9, The website's Residential -commercial window.

b) The middle segment consists of the construction and thermal description of the building construction section.

c) Finally the third section contains the download icon where the user can choose whether to download it in energy plus format or DesignBuilder format. (See Fig. 11.)

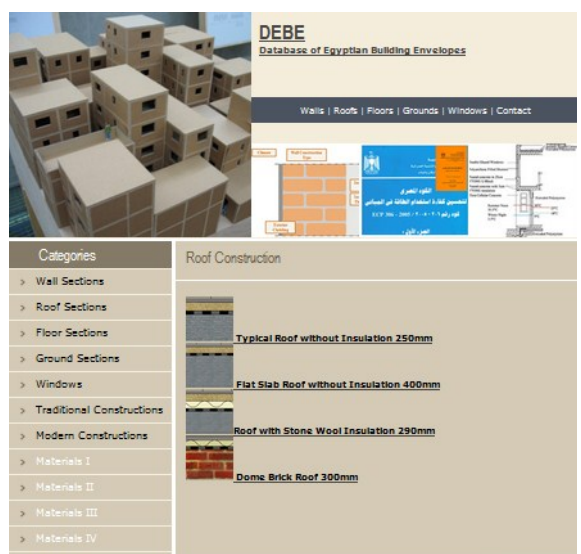


Figure 10,The website's roof construction window

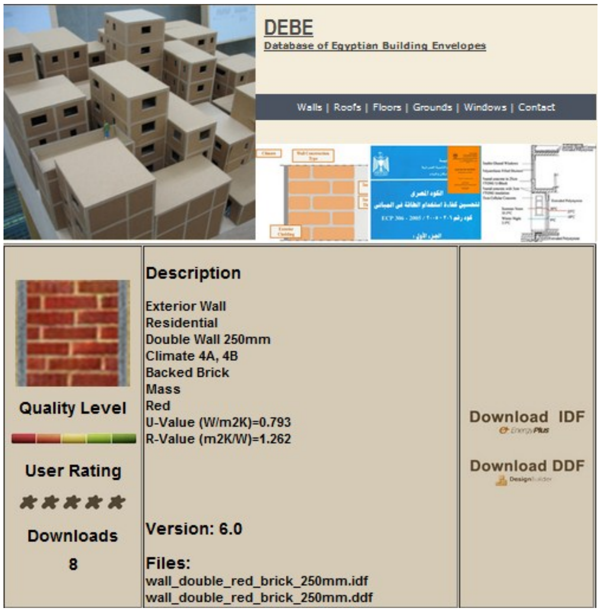


Figure 11, The website's construction thermal properties window

CONCLUSION AND DISCUSSION

Energy simulations are a primary method of optimizing buildings' energy performance and so the presence of a local digitalized construction and material database minimizes the potential for inaccuracies and makes the input of constructions in energy simulation programmes as simple as selecting the specific material configuration and setting dimensions and orientation (DOE). Due to the previous effort , the website of " The Database of Egyptian Building Envelopes" has been launched, making the data of the Egyptian building envelopes and materials available worldwide for students , Architects, construction practitioners and energy simulation experts that are working on building projects in Egypt. This will help the emergence of a new generation of energy efficient residential units that will put Egypt back on the road to sustainable architecture. Users will have the suitable input files for whole building energy simulations and will be able to create a series of parametric analysis leading them to the optimum choice for his project. The website can be accessed by all users at the following address: http://www.shadyattia.net/research/DEBE/index.html.

A short tutorial of how to use the website is also available at :

http://www.youtube.com/watch?v=JwlvwNDWk-E

- This research is mainly based on theoretical data due to the lack of instruments and funding to perform empirical validations, and so "A Quality Level Indicator" icon on each construction section's properties on the online database, indicating its degree of credibility and validity was added.

- The database is a crucial needed step in the field of energy simulation and architecture design. It is a virtual documentation of the available data on this topic and even though there might be few information gaps due to the lack of research in the field, yet it is an attempt to promote our research and provide reliable and consistent data.

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