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Energy performance analysis of integrating building envelopes with nanomaterials

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Abstract

The energy consumption in Egypt has increased sharply in the past few years, and ultra-energy efficient technologies are desperately needed for the national energy policy. This paper discusses and explores the possibilities offered by the use of nanomaterial technology which integrates with building envelope to improve the Energy efficiency and reduce energy consumption in buildings by the use of energy simulation software. The current study was aimed at testing the thermal performance of the Nano Thermal Model (NTM) and measuring heat-Transfer Rate, especially the quantity of Heat gain/loss through fabric, compared to conventional building envelope materials (baseline model) under typical Egypt-Aswan weather conditions. The results indicate the use of nanomaterials can improve the thermal performance of a building in hot dry climate like Egypt, that especially needed cooling loads during the summer months. It also shows that the nanomaterials integrated with the envelope of the future building will achieve the lowest scientifically and empirically recorded values of heat transition in the field of construction. This lowest rates of the fabric heat transfer through the envelope is up to 72% when comparing the performance of the wholly Nano Thermal Model to the traditional model improved.

Keywords: Energy consumption; Energy efficiency; Nanomaterials; Nano Thermal Model; Thermal performance

1. Introduction

The sector of architecture, engineering and construction may accept a wide range of Nanotechnology applications and the nanomaterials. There is an increasing rate of spending and financial support for developing the nanomaterial technology with the target of gaining short run profits for their great commercial value (Ge and Gao, 2008). Architectural Engineering and construction technology which are based on nanomaterials experience a lot of significant changes and constant developments that were the most important results of the chief technologies in the 21st century. Creating all the suitable conditions for achieving accuracy at the molecular and atomic level in materials engineering has led to production of materials of many unique qualities which in turn has provided new and promising solutions for many problems such as; reducing the rate of heat absorption in the outer envelope of the building, fire resistance, avoiding energy loss, resources conservation, reducing pollution, raising the internal environment efficiency, extending the life span of the building materials, lowering the costs of maintenance and processing, reducing and controlling the construction loads and

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increasing the tensile strength in the structural elements, etc. (Lalbakhsh and Shirazpour, 2011).

Therefore, the nanomaterials integrated with the envelope of the building are considered excellent economic alternatives which save a lot of money while raising the efficiency of the constructed environment and addressing the future environmental challenges (Lalbakhsh and Shirazpour, 2011). Nanomaterial technology will serve to provide much more internal and external architectural designs with human senses interaction due to the freedom given to the architects to develop the function and format to meet the various needs of users.

2. Background of nanomaterials

The term Nano is the literal derivative of the Greek word "Nanos" which means "dwarf" or a very small thing (Qian and Juan, 2004). Overall, the nanomaterials can be defined according to the scientific committee of the European Union as "Materials which have one or more external dimensions or an internal structure which can exhibit new properties compared to the same materials without the nanometric characteristics, or they are a sort of materials which are composed of separate functional parts and many of them have one or more dimensions with a measure of 100 nanometre or less".

3. An overview of energy performance analysis

3.1. Background of energy performance of the building envelope

Climate change and increasing energy costs have drawn large attention to energy performance and efficiency. In 2010, electricity consumption in residential (39.9%), industrial (32.7%), commercial (8.1%) and governmental (4.6%), buildings reached 58% of total electric energy demand in Egypt. Different studies have shown that the primary energy supply will not meet the demand starting from 2015; this gap is widening after 2020 (NREA, 2010). As a result, the demand for building envelope analysis, in which the physical separator of the building's interior and the exterior environment is evaluated, has increased. Rising energy costs, government regulations, new construction techniques and materials, and growing concerns about occupant health are further boosting this demand.

Minimising heat transfer through the building envelope is crucial for reducing the need for space heating and cooling. In cold climates, the building envelope can reduce the amount of energy required for heating; in hot climates, the building envelope can reduce the amount of energy required for cooling. A building envelope is the key factor that determines the quality and controls the indoor conditions irrespective of transient outdoor conditions (Sadineni et al., 2011). The inputs to Envelope-Related Energy Demand are areas of envelope elements (external walls, roofs and windows), U-values of envelope materials and site related parameters, concerning temperature and solar irradiation (Granadeiro et al., 2013).

The thermal energy performance of the building envelope and sustainability is significant to achieve optimal performance of buildings. Moreover, researches have shown that building envelopes contribute more than 50% of the embodied energy distribution in major building elements in residential buildings; it also contributes approximately 50–60% of the total heat gain in buildings (Mwasha et al., 2011).

3.2. The fabric heat transfer

Whenever there is a temperature difference between the conditioned indoor space of a building and outdoor ambient, heat is lost from buildings through the fabric of the building itself (roof, walls, floor, windows and doors) and through infiltration of cold air via any holes and gaps (Oxford, 2013). This is known as fabric heat gain or loss, depending upon whether heat transfer is to the building or from the building, respectively. The fabric heat transfer includes sensible heat transfer through all the structural elements of a building, but does not include radiation heat transfer through fenestration. Exact analysis of heat transfer through building structures is very complex, as it has to consider (Nptel, 2013):

1. Geometrically complex structure of the walls, roofs etc. consisting of a wide variety of materials with different thermo-physical properties.
2. Continuously varying outdoor conditions due to variation in solar radiation, outdoor temperature, wind velocity and direction etc.
3. Variable indoor conditions due to variations in indoor temperatures, load patterns etc.

For the fabric heat transfer calculations, the indoor conditions are generally assumed to be constant to simplify the analysis.

4. Model verification

4.1. Content and scope of the study

The research has done the empirical study – complementary of the analytical study at the level of design concepts and their contributions to the sustainable building assessment systems – relating to designing a thermal model to simulate the energy performance in the future architecture of a nano building constructed with nano materials which is illustrated in detail in the previous analytical study.

The empirical part aims at selecting the thermal performance for the nano model and indicating rates of saving energy consumption, rates of gained and lost energy, rates of internal thermal loads. This is done by comparing the nano model with the standard model and traditional building materials – to investigate the possibility of achieving