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Research Article

A Case Study and Review of Nanotechnology and Nanomaterials in Green Architecture

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Abstract: Research methodology in this research is applied based on the objective and its objective is to obtain the consensus of experts familiar with the topic of study. This study seeks to deconstruct the conventional structures with green architecture topics such as the reduced power consumption and to make the application of technologies in achieving the objectives of green architecture computational and executive by entering the topic of Nanomaterials and its applied application in green architecture. In addition to the focus on the Nanomaterials in green architecture, this study has sought to indicate that what profound impacts the practical applications of technology in green architecture have on the macro economy of country and the economical status of family by doing some statistical calculations and tests. A summary of some of the Nanomaterials, which are used in green architecture, is presented after the theoretical principles. In this study, Pearson correlation coefficient has been used for testing the statistical hypotheses and the advance method of Partial Least Squares (PLS) has been used for evaluating the subsidiary hypotheses and finally, Friedman test for ranking the variables of subsidiary hypotheses. In this study, the regression method has been used for indicating the equation of energy (electricity) consumption and finally the suggestions have been proposed for power manufacturing and consumption planning at the macro level of country and also in the field of reducing the energy loss in the residential and industrial structures about the green architecture by using the Nanomaterials.

Keywords: Green architecture, future buildings, nanomaterials, nanotechnology

INTRODUCTION

Nanomaterials technology (Building materials) has a great potential for compliance with the environment (Soltani, 2007). Nanotechnology is now used in manufacturing the humans' daily consumption such as garment, cosmetics, tools, types of coatings and insulators, medicine and so on. Nanomaterials have been defined as the materials which at least one of its dimensions (length, width and thickness) is below 100 nm. A nanometer is 1000 of a μm or about 100000 times smaller than the thickness of a human hair. Physical and chemical properties of Nanomaterials (which existed in several shapes and forms such as particles, fibers, lumped, etc.) are fundamentally different with other types of microscopic materials. Fundamental changes are not only at the level of Nanoscale in terms of small size but in terms of new properties. Najafi (2002), the nanotechnology industry plays the fundamental role in the industries of building. In this regard, the major role is played by the insulators, different types of used tubes in the buildings, glass and concrete. Applying the Nano particles in the building industry in the main structures generally increases the mechanical properties and Carbon Nano Tubes (CNT) are the most important ones in this regard. In the building envelope and interior finishes, the application of building Nanocoatings is so important in interior and exterior facade of buildings is. Not only the Nanocoatings of building desorb the water and minimize the absorption of pollutants, but also make the façade resistant to UV radiation (Asadifard, 2004). Nanocoatings are used on the surfaces such as cement, brick, clay, typical stone, tile, marble, wood, ceramic, glass, steel and concrete. Nanomaterials are also used in the building materials as the reinforced concrete, self-cleaning and fire resistant glass which controls and save the energy consumption, in using nano colors which are resistant to the influence of bacteria in administrative, residential buildings, hospitals and so on. Thus it can easily be determined that we are facing with a new world of nanotechnology. Nanoscience experts believe that after producing the steam machinery, engines and development of IT, the Nanotechnology will create the new horizons for the human world. Nanotechnology is able to minify the materials, thus the new materials and technologies can be introduced to the world by rebuilding. For instance, the clay and ceramics can be changed into the dimensions of Nanoscale and mixed with nanopolymers as the powder; and the strong and resistant materials, which have never been provided, can be created in a neutral environment. In line with the application of sustainable concepts and development in the architecture, the topic "Green Architecture" is an

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effort to preserve the environment and create the human welfare. The building, which has the least inconsistency and conflict with its natural surrounding environment and with the region and the world in the wide consideration, is called the "Green Building" or "Sustainable Building". The purpose of designing these buildings is to reduce the harm on the environment, energy resources and nature and the laws, which have been mentioned below, dominate it:

- Reducing the consumption of non-renewable resources
- Developing the natural environment
- Eliminating or reducing the consumption of toxic or harmful materials to the nature in the building-construction industry

New techniques of houses and office buildings construction are the efforts to provide the quality, current economical savings in the field of construction and future use of it and the social and environmental interests and considerations (Gevorkian, 2010). Rational use of natural resources and appropriate management of building-construction have helped to conserve the limited natural resources and reduce the energy consumption (conservation of energy) and improve the environmental quality and sustainable design principles. The optimal quality is not provided unless the nature is taken into account and the use of long-life materials should also be considered. Achieving the high-quality standards, safety and welfare, which in fact provides the human health, is among the important objectives of sustainable architecture which can be achieved by the efficient management and utilizing the latest technologies. The building designing in green architecture should be in a way that:

- Minimizes the fossil fuel consumption and uses the alternative resources (Elvin, 2007)
- Minimizes the use of non-recyclable materials in a way that they can be used as the resources for creating the other structures after the end of useful life of building (Williams, 2008)
- The air conditioning and controlling the temperature of building and the interior decoration can be possible by using the environmental capabilities and the available local resources (sunshine, wind energy, energy of fluids such as water); (Droege, 2010)
- The buildings should be compatible with the surrounding natural environment and the natural materials of that environment should be used in building and beautifying the building such as the technique of green roofs (Kibert, 2008)

This study seeks to deconstruct the conventional structures with green architecture topics such as the reduced power consumption and to make the application of technologies in achieving the objectives of green architecture computational and executive by entering the topic of Nanomaterials and its applied application in green architecture. In addition to the focus on the Nanomaterials in green architecture, this study has sought to indicate that what profound impacts the practical applications of technology in green architecture have on the macro economy of country and the economical status of family by doing some statistical calculations and tests. A summary of some of the Nanomaterials, which are used in green architecture, is presented after the theoretical principles.

THEORETICAL FOUNDATIONS OF NANOSCALE MATERIALS

The organic architecture, which has been defined by Frank Lloyd Wright as the consistency of building structure based on locating on the nature, is discussed and evaluated now in terms of sustainable architecture and its new horizon, it Nanotechnology. Wright believed that the shape of architecture should be created from the heart of object nature and each object has a particular language for speech and expressing the feeling. For instance, he showed the proportions, layout and texture of brick house and the extent of horizon in a vast land. Baked brick is oriented from the nature and comes back to it again. Now imagine when the materials making the house are so small and cannot be seen by unaided eyes and then imagine that how the relationship between the shapes, human and the environment will be changed (O'Gorman, 2004).

Since the building can show different behavior in different time and places such as uncompromising, not flexible, or fluid and soft by using the nanotechnology achievements of an object, the theories of material understanding will be totally changed. In fact, the materials lose their own constant identity and the architecture will have no limited definition in the time and place not anymore. Behavior of structures and buildings is completely performance and field-oriented. They will be able be intelligently adapted to a variety of temperatures, air flow, energy consumption and the conditions of climate, geology and so on. All these circumstances are given to its structure and building by design planners as the raw data in order to become consistent with the environment while facing with the change of every factors affecting the human living conditions in line with achieving his comfort range (Bigdeli and Pishro, 2009).

In this section, a summary of applications of some of the nanomaterials used in the building-construction is presented and then the reason why the topic of statistical studies for the application of nanomaterials has been selected in this study will be investigated.

Nanocomposite materials: Nanocomposite materials with the basis of polymer (polymer matrix) are first presented during the 1970s and the technology of Sol-

Gel has been used in order to disperse the mineral Nanoparticles inside the polymer matrix (Hazem, 2010). Although, the conducted research in past two decades have been done for the commercial development of these materials by Toyota company in Japan in the late 1980s, but the field of nano-composite polymer is still in the beginning of its way. In these conditions, nano-alumina is the best nano-structure which promises a new horizon in the ceramic industry, because the application of these materials is a phenomenon which is in balance properly in the field of mechanical, electrical and thermal properties and is used in various fields.

High-Performance Concrete (HPC): High Performance Concrete (HPC) is one of the challenges which have been created in the field of building materials (Young, 2010). This type of resistant concrete is a kind of composite materials and among the complex and composed multi-fuzzy and composite materials. Properties, behavior and performance of concrete depend on the nanostructure of concrete and cement matrix material which creates the cohesion, bond and integration. Thus, the studies of concrete and cement paste at the Nanoscale are significantly important in order to develop new building materials and their use. The conventional method for developing the high performance concrete includes frequently various parameters such as the plan of combining the conventional concrete and reinforced concrete with different types of fiber. About the concrete and in addition to performance with better durability and mechanical properties, the Multifunctional High-Performance Concrete (MHPC) has additional properties in particular such as the electromagnetic feature and the ability to be used in nuclear structures (Radiation Protection) and its enhanced effectiveness in conserving the energy of buildings.

Amorphous nano-silica: In the concrete industry, silica is one of the most famous materials which play the important role in the cohesion and filling of High Performance Concrete (HPC) (Leydecker, 2008). Silica fume or micro silica is the conventional product which has a diameter about 0.1 to 1 mm and has silicon oxide about 90%. It can be stated that micro silica is a product which is used in upper range of nano-meter measurement scale and is applied in order to enhance the performance of cementitious materials composite. Product of nano silica composed of the particles, which have the lumped shape and can be dispersed as the dry powder particles or suspended in the solution liquid and its liquid is the most common type of Nano silica solution. This type of solution has been used in specific experiments on Self-Consolidating Concrete (SCC). Suspended Nano silica shows the multifunctional applications such as anti-wear, anti-slip, anti-fire and anti-reflection of surfaces.

Experiments have shown that the reaction of nano-silica materials (Colloidal Silica) with calcium hydroxide is much faster than micro-silica and the small amount of these materials have the same effect of Pozzolana of high amount of micro silica at the early ages.

Nanotubes: The fibers are usually used for reinforcing and improving the mechanical performance of concrete. Nowadays, the metal, glass, polypropylene, carbon and… fibers are applied in the concrete for reinforcement (Pongratz *et al*., 2009). However, any research has been published in the field of reinforced concrete by Carbon Nano tubes so far in order to use its results for reinforcement by Nanotubes. Carbon 60 (C 60) and new Nanotubes have the structure which makes them stronger and much lighter than the steel, so that they can bear bending and stretching without breaking, thus they will be replaced with the carbon fiber, which are used in composites, in the future. According to the research conducted at the Center for Concrete Research (Affiliated to ACI institute, Iranian branch), Nano tubes have the tensile strength higher than any other kinds of known concrete fiber; moreover, the Nano tubes show the specific significant thermal and electrical properties, so that their thermal conductivity is two times higher than Diamond and their electrical conductivity is approximately 1000 times higher than Copper. Nano tubes are a new class of products and they have created a new revolution in the field of advanced materials. A new generation of multifunctional Nanocomposites can be used as Carbon Nano tubes in the role of appropriate reinforcing fiber for those materials. Therefore, Carbon Nano tubes are among the key factors of achieving the above mentioned main goal and play the role as the multifunctional high performance building materials.

Steel nanowires: These Nano Structures promise the high performance in the electronic components due to the special properties (Jong and Hyun, 2007). Steel nanowires are among the most attractive Nanomaterials due to their unique properties which lead to their various applications. Nanowires can be used in the computers and other computing devices. We need the Nanoscale wires in order to achieve the complex electronic components at the nanoscale. Furthermore, the nanowires, themselves, can be as the bases of electronic components such as the memory. Organic, conductive, semi-conductive and silicon nanowires are the types of nanowires. The method of creating the nanowires is classified into the following techniques:

- Lithography including the Photolithography, E-Beam Lithography and Scanning probe lithography
- Electro-chemical precipitates in the cavities

Nanowires can be used in the medical applications (diagnosis, treatment), stem cells, electrical transmission, magnetic devices, chemical and biological sensors, biological markers and interconnects in nano-electronic and the research methodology is presented in the next section.

RESEARCH METHODOLOGY

Research methodology in this research is applied based on the objective and is descriptive and among Delphi survey based on the data collection; and its objective is to obtain the consensus of experts familiar with the topic nanotechnology.

Research method: This study first collected the research background and literature by preparing the plan of paper and then the data needed for the tests was collected from the reputable sources by designing the required tests of research. Required data in the manufacturing sector was prepared from reputable sources in line with new designing of parts in manufacturing Diesel generators from productive resources and its impact on reducing the cost of electricity manufacturing and increasing the production efficiency according to the principles of returns to the scale. In the distribution sector, data has been provided according to the principles of designing the nanowires and performance principles of these wires in reducing the current resistance and transfer rate. In the energy loss sector, the data has been prepared from the engineering reliable sources of residential and industrial structures and the principles of preventing from the loss of energy by using the nanomaterials and has been used in the statistical tests. The major performed duties and activities in this study include the determination of hypotheses, sources of data collection, determination of statistical tests and data analysis and each of them are investigated as follows.

Research hypotheses: Research Hypotheses are obtained from the main question. The main question of this research is that whether there is a significant correlation between the application of nanomaterials and reducing the energy consumption in terms of economics? Hence the energy consumption can be defined as the dependent variable and the applications of nanomaterials (in the sectors of manufacturing, distribution and energy loss) can be defined as the independent variables. It is noted that the reduction in the manufacturing sector refers to the reduced production costs and prorates total cost of manufactured electricity in a power distribution unit in the network. For assimilating the viewpoints in this study, the reduction of energy consumption is defined as the reduction of consumed energy cost (based on a currency) from now on. Thus the reduction of energy consumption is the main purpose of this research as one of the pillars of green architecture in both quantity and cost sectors of macro level of country.

Main hypothesis: There is a significant correlation between the barriers of Nanomaterials and the reduced energy consumption.

Subsidiary hypotheses:

- There is a significant correlation between the application of nanomaterials in the manufacturing sector and the reduced cost of energy (consumed electricity).
- There is a significant correlation between the application of nanomaterials in the distribution sector and the reduced energy consumption.
- There is a significant correlation between the application of nanomaterials in the control of energy loss and the reduced energy consumption.

Data analysis methods: First, Pearson correlation coefficient test is used in order to examine and determine the existence or lack of significant correlation of research variables in the main hypothesis and sub-hypotheses. Structural equation method of PLS has been used in order to determine the correlation of subsidiary hypotheses (Application of nanomaterials in the sectors of manufacturing, distribution, energy loss) as the independent variables with the energy consumption as the dependent variable. Finally, Friedman test is used in this study for ranking the applications of Nanomaterials.

RESULTS

First, the conceptual model of research and the correlation of main and subsidiary hypotheses of research are shown in Fig. 1 schematically and then the related economic and statistical tests are presented as follows:

Results of Pearson correlation coefficient: Results of Pearson correlation coefficient (Table 1) indicate that all variables have a significant direct correlation with the reduced energy consumption and this is correlation is confirmed at the significant level 99%:

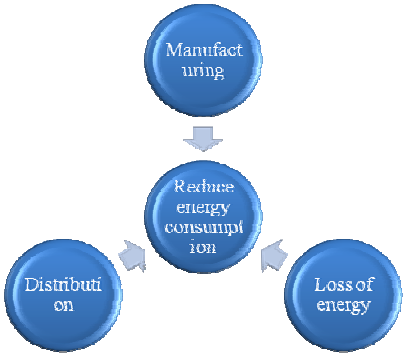

Fig. 1: Correlation of main and subsidiary hypotheses of research

Table 1: Pearson correlation coefficients of independent and dependent hypotheses

	Correlation coefficient	Sig.	Test result
Application of nanomaterials in manufacturing sector	0.084488	0.001	A significant direct correlation
Application of nanomaterials in distribution sector	0.088511	0.000	A significant direct correlation
Application of nanomaterials in control of energy loss	0.158695	0.000	A significant direct correlation

Table 2: Effectiveness coefficients of independent variables on dependent variable

	Estimated model coefficients	Student's t	Result
Manufacturing sector→ total cost of energy	-0.045	2.746	Significant direct correlation
Distribution sector→ energy consumption	-0.268	1.656	Significant direct correlation
Energy consumption→ reduced energy loss	-0.366	2.375	Significant direct correlation

Table 3: Comparison and ranking

	Average ranking	Rank
Manufacturing sector	4.93	2
Distribution sector	3.28	3
Reduced energy loss	5.23	1

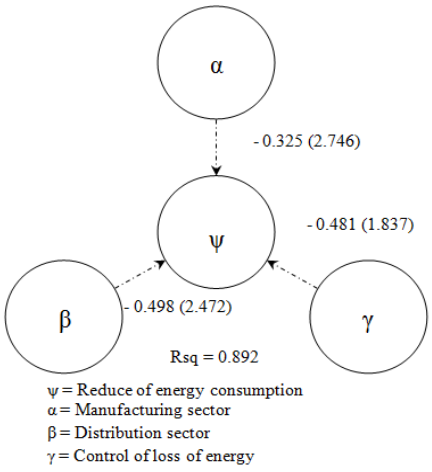

Fig. 2: The graph of correlation between the application of nonmaterial's and reduced energy consumption in green architecture (software VPLS output)

- The correlation coefficient of application of nanomaterials in the manufacturing sector is equal to 0.084488 and the statistics Sig. is equal to 0.001.
- The correlation coefficient of application of nanomaterials in the distribution sector is equal to 0.088511 and the statistics Sig. is equal to 0.000.
- The correlation coefficient of application of nanomaterials in control of energy loss is equal to 0.158695 and the statistics Sig. is equal to 0.000.

Factor analysis for main variables and factors: In this section, the factor analysis method based on new and advanced structural equation method of VPLS (Visual Partial Least Square) is used in order to analyze and investigate the main factors and coefficients, estimate the coefficients of independent variables and determine the effectiveness of each of the independent variables on each other. The graph, which shows the output of software VPLS and contains the coefficients of variables and their significant level (Statistics t), is presented in Fig. 2.

Figure 2 about the calculations of structural equation method show that the coefficient of determination is equal to R = 0.892 and this indicates that the changes of dependent variable (reduced energy consumption) with the dimensions of subsidiary hypotheses (Application of nanomaterials in the sectors of manufacturing, distribution and energy loss) are defined and described in this study with estimation 89%. For significant evaluation of variables, the effectiveness coefficients of each of the independent variables on the dependent variable and the statistic t have been also inserted in Table 2.

The value of estimated Student's t for each of the coefficients of model is higher than the significant level 95% (1.96), thus it can be concluded that the research hypotheses are confirmed as follows:

- With one unit increase in the application of nanomaterials in the manufacturing sector, the cost of energy generation is reduced equal to 0.045.
- With one unit increase in the application of nanomaterials in the distribution sector, the energy consumption is reduced equal to 0.268.
- With one unit increase in the application of nanomaterials in reduced energy loss, the energy consumption is reduced equal to 0.466.

Prioritizing the barriers of sustainable development by using Friedman test: Non-parametric Friedman ANOVA test is used in order to evaluate the way of ranking each of the factors of reducing the energy consumption. Table 3 compares and ranks the factors of reduced energy consumption.

In Table 3, the order of prioritizing the factors of reduced energy consumption from the rank 1 to 3 is as reduced energy loss, manufacturing and distribution sectors, respectively.

CONCLUSION

This study sought to study and investigate the application of nanomaterials in reduced energy consumption, which is one of the objectives of green architecture, economically and practically by introducing the nanomaterials and their application in the green architecture. An overview of results obtained from the statistical tests is presented as follows:

- The results of Pearson Correlation Coefficient indicate that all variables have a significant direct correlation with the reduced energy consumption and this correlation is confirmed with significant level 99%. Thus, the main and secondary hypotheses are confirmed. Correlation coefficient of application of nanomaterials in the manufacturing sector is equal to 0.084488 and the statistics Sig. equal to 0.001 and in the distribution sector is equal to 0.088511 and the statistics Sig. equal to 0.000 and also the correlation coefficient of application of nanomaterials in control of energy loss is equal 0.158695 and the statistics Sig. equal to 0.000.
- Structural equation method shows that the amount of coefficient of determination is equal to 0.892 which shows that changes of dependent variable (reduced energy consumption) with the dimensions of subsidiary hypotheses (Application of nanomaterials in the sectors of manufacturing, distribution and energy loss) are defined and described in this study with estimation 89%. The value of estimated Student's t for each of the coefficients of model is higher than the significant level 95% (1.96), thus it can be concluded that the research hypotheses are confirmed as follows:
  - With one unit increase in the application of nanomaterials in the manufacturing sector, the cost of energy manufacturing is reduced equal to 0.045.
  - With one unit increase in the application of nanomaterials in the distribution sector, the energy consumption is reduced equal to 0.268.
  - With one unit increase in the application of nanomaterials in reduced energy loss, the energy consumption is reduced equal to 0.466.
- Non-parametric Friedman ANOVA test is used in order to evaluate the way of ranking each of the factors of reducing the energy consumption. Based on the rating from one to three, the priority of reduced energy consumption factors includes the reduced energy loss, manufacturing and distribution sectors, respectively.

RECOMMENDATIONS

- For providing an equation for energy consumption (electricity) in the green architecture studies, the regression equation for time and place domain of this research will be as follows by using Pearson correlation coefficient test:

$$Y = a + 0.084488\ x1 + 0.088511\ x2 + 0.158695\ x3$$

In which:

  - a represents the constant value in regression equation
  - Variables x in the model represents the application of nanomaterials in the sectors of manufacturing, distribution and reduced energy loss
  - Parameters of model represent the coefficient of effect of independent variables in the model

This structural equation can be used in strategic planning and annual budgeting in the Department of Energy. It is suggested that the relevant ministry should repeat the research and obtain the country results for future planning according to the limited spatial domain of this study.

- By using the nanotechnology in the manufacturing sector, the nonrenewable fuels can be saved for the electricity manufacturing. Therefore, it is recommended to use the nanomaterials in designing the power manufacturing centers.
- By using the nanowires in the sectors of transmission and distribution of electric power, the electricity loss in the in network and manufactured electricity needed to supply the power of network can be reduced. Finally, the reduction of manufactured electricity will lead to the reduced consumption of fossil and nonrenewable fuels and this is among the objectives of Green architecture.
- The final suggestion of this, which is directly associated with the architecture, offers that the nanomaterials can be utilized in designing the houses and architecture of houses and industrial sites in order to reduce the thermal and cooling energy loss which is as the result of the electricity consumption and direct consumption of nonrenewable energies. Everything, which is done in this section by the designers, will be used directly in the development of green architecture concepts.

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