Towards advanced Building Technology Role through applying competitive building materials and systems

Dr. Sherif Mohamed Sabry Elattar
Associate Professor, Architecture Department,
Faculty of Engineering, Fayoum University
E-Mail: Sherifelattar67@hotmail.com

Abstract

Our communities demand from us today a new humanity and architecture. Arabian cities of the 21st century are seeking comfort and sophistication of economy and culture in a sustainable manner representing a great challenge.

In today's competitive business environment building technology systems became an absolute necessity, therefore building managers should pay enough attention to advantages and specifications concerning new building materials in order to maintain building investments and reduce its costs. That needs powerful building technology systems to achieve people requirements, and preserve their culture and personality in neighborhoods, towns, and cities.

Technology today offers a big variety of materials and finishing which differ and change without any scientific approach to evaluate its quality, or measure its impact over the presumed age of the building. This research paper attempts to formulate solutions to specific problems of habitation taking on special significance: thermal comfort, energy consumption, construction technology, urban form and regional development.

The research aims to reach an integrated environmental design benefiting from new building techniques and systems to afford more attractive homes and easier to lease making buildings more energy-efficient and less in maintenance and operating costs. Those balanced forms will be able to reflect the Arabian personality through its different spaces and vision elements and also will reduce the total costs with no negative impact on quality and efficiency. In addition, applying new materials in building technology systems will help self-erection systems to take place in a successive order.

1. Introduction

The building industry represents one of the largest, and most important, enterprises in world. For fast-growing economies in the world, there is a growing demand for practical, sustainable building designs that will provide a higher standard of living with minimal resource demand. Many of these problems are being met by innovations in building technology. These innovations, for example, apply recent advances in the fields of materials, manufacturing and thermo sciences to the construction of new buildings, to the retrofit or rehabilitation of existing buildings and to the efficient operation of buildings.

Since the large demand has been placed on building material industry especially in the last decade owing to the increasing population, which causes a chronic shortage of building materials the architects and civil engineers have been challenged to discover useful building and construction materials. The increase in the popularity of using environmental friendly, low cost and lightweight construction materials in building industry has brought about the need to investigate how this can be achieved by benefiting to the environment as well as maintaining the material requirements affirmed in the standards.

Therefore, it is logical to think that, in the immediate future, urban growth and its infrastructures will continue to produce maximum impact on the natural environment through the use of materials and the consumption of raw materials and energy. The number of construction works shall progressively increase however; these shall be undertaken by attempting to achieve the paradigm of sustainability, demanding an increasing durability of what is being built in order to minimize environmental impact.

2. Objectives and methodology

The specific objective of this paper is the development of a framework for selecting and evaluating sustainable building materials to assist both the designers and builders in the construction field. The paper offers to study the available literature and tools for determining the sustainability of construction materials for the purpose of identifying the most recent and important innovations in sustainable material technologies and identifying key areas for further research.

The paper outlines the problems of construction materials being used in architecture through a brief history of developments in building materials reaching the end of the 20th century and also of the construction materials of the future describing how new materials create the possibilities of a further development. The paper addresses certain issues pertaining to the energy, environment, alternative building technologies and sustainable building construction.

Energy consumption in manufacture and transportation of some common and alternative building materials and the implications on environment are presented.

3. Historical view

Engineering has been at man's service since the beginning of civilization evolution. Human activity in the field of construction engineering goes far back into the past, when man observing nature around him began to imitate and improve it in order to create safer and better living conditions. Moreover, relatively early he noticed that his engineering "works" apart from reliability, durability and functionality had to have elements of harmony and beauty. [1]

3.1 Ancient communities

First of all, ancient communities had at their disposal natural materials such as stone and timber. In the course of time, they learned how to use clay to form bricks, which were first dried only in the sun and then baked. In the main civilization centers (the Middle East, the Near East, and the Mediterranean region) the hot climate and inconsiderate economy led, in a short time, to the elimination of timber as a building material. Stone and brick — brittle materials — dominated architecture in the region of European civilization for several centuries: from stone pyramids in Egypt 3000 years B.C until the so-called First Industrial Revolution in England (the turn of the 18th and 19th centuries). They were suitable building materials for erecting walls and columns but at the same time, due to their low tensile bending strength, they caused a lot of problems in horizontal elements. Therefore a vaulted arch that was popular in ancient Rome, semicircular in its primary form, was the pattern that was to be employed for elements or structures of larger span. The arch in the course of time became lighter and less massive.

3.2 Middle Ages

The ratio of span-to-width of piers carrying vertical and horizontal loads became increasingly greater. During the early Middle Ages no improvements were implemented. In the Baroque, Rococo and Neo-classicism the basic construction forms were not changed and only various ornaments and adornments were added. It was a complete change in the way of the perception of the world that has its roots in the Renaissance and then the Enlightenment that made architecture free from the enchanted circle of vertical pier and arch or double-curved roof.

Wood has always been one of the basic building materials. However, considering its limited life (15–25 years) and lack of moisture resistance and fire resistance, wooden buildings have always been only temporary.

3.3 The 19th and 20th centuries

Steel and cement are two relatively new building materials that were introduced at the turn of the 18th and 19th centuries. First cast iron then puddle and cast steel and finally refined and high strength steel proved to be very good construction materials. They are so-called ductile materials that have high tensile and compressive strength. This strength enables the construction of steel bent elements with spans that some years ago were beyond consideration. The subsequent improvements of the production technology made it possible to obtain steel with increasingly better properties.

The other "invention" of the First Industrial Revolution that caused progress in architecture was cement. So-called "portland cement" that was patented in 1824 by J. Aspdin proved to be an excellent hydraulic binder that was used for the production of a new material — concrete. This material is relatively cheap and easy to produce. Based on aggregates and water present in nature and using the cement mentioned above, it was possible to "cast" various shapes of elements and structures. Soon concrete became the most popular building material of the 20th century.

In the 20th century, despite such competitive materials as steel and concrete, wood retained its significant role in building in many developed countries. It was possible due to the progress in woodworking and processing technology in the last 40 years which resulted in the durability of modern wooden structures.

4. Innovative Building Technologies and Practices

Innovative Building Technologies and Practices save Energy and Money. Investing in energy-efficient technologies and practices allows building owners, developers, and operators to realize cost savings in homes and buildings that are more comfortable, productive and marketable. These technologies and the whole building approach will produce buildings that use less energy and can be more cost-effective.

Some of the guiding principles in developing the sustainable alternative building technologies can be: Energy conservation; Minimize the use of high energy materials; Concern for environment, environment-friendly technologies; Minimize transportation and maximize the use of local materials and resources; Decentralized production and maximum use of local skills; Utilization of industrial and mine wastes for the production of building materials; Recycling of building wastes, and Use of renewable energy sources.

Building technologies manufactured by meeting these principles could become sustainable and facilitate sharing the resources especially energy resources more efficiently, causing minimum damage to the environment. [2]

4.1 Carbon fiber reinforced polymer

This material was first applied in the strengthening of the Ibach Bridge near Lucerne in Switzerland in 1991. Today this technique of the strengthening of building structures is increasingly more often used. [3]

In 1996 in Winterthur, Switzerland, the Storchenbrücke, a cable-stayed single pylon bridge of 124 m length, was built with one pair of CFRP cables and 11 pairs of steel cables for support. Here the CFRP stay cables were applied experimentally for the first time. [4]

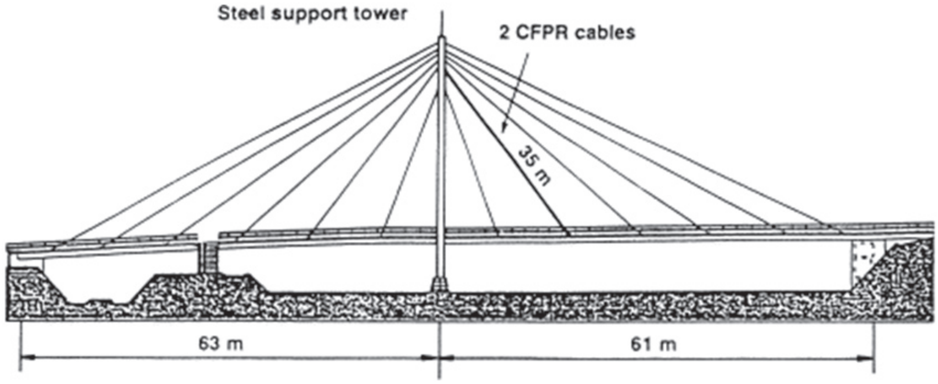

Figure (1) - Cable-stayed bridge in Winterthur, Switzerland

From the above it follows that with very high resistance to axial tension exceeding even twice that of high tensile strength steel, the elastic modulus of CFRP stay cables is not much lower than that of the steel cables, whereas the mass density is about five times lower. Therefore CFRP is the material of the future especially as it is durable, fatigue resistant, and non-corrosive. [5]

4.2 High-performance concrete

The transition from high strength plain concrete (class up to C50) to HSC and HPC was possible due to some additives such as silica fume and super plasticizers' to plain concrete. Further, the additionally formed calcium silicate hydrates in the matrix cause the mortar to be more compact and stronger. As a result, the concrete structure becomes very homogenous. [6]

HSC and HPC have the following characteristic features: (i) high compression strength; (ii) greater brittleness (and lower tensile strength in relation to compression strength); (iii) very low porosity and absorbability (about 3% by weight); (iv) high durability and freeze resistance due to high tightness; (v) adhesion to the reinforcement increased by 40%; (vi) shrinkage and creep reduced by 50%; being completed to 70% as soon as the 7th day of curing; (vii) increased heat of cement hydration and (viii) reduced fire resistance because of high tightness, which makes it impossible for the water contained in the hardened concrete to get out and causes its transformation into high-pressure steam during a fire. [7]

From the above specification it is seen clearly that towards the end of the 20th century there appeared a new generation of high quality concrete which will gradually replace plain concrete in architecture practice. The new type of concrete has already made it possible to build such structures as the Kuala Lumpur City Centre in Malaysia (1996, height 452 m), one of the highest buildings in the world at present.

4.3 Glass (GF), carbon (CF) and aramid (AF) fibres

The introduction of glass (GF), carbon (CF) and aramid (AF) fibres as tendons to prestressed structures are usually used as either wires or wire strands with about 60–65% epoxy resin matrix fibres, modified appropriately. Their main advantage is lightness (density about five times lower than that of steel), and similar strength, lower modulus of elasticity and lower failure elongation than those of steel. Materials such as glass or plastic must not be neglected in this account. So far both have been used to produce finishing details of buildings.

Many of these types of glass have high mechanical strength, three to six times greater than that of plain glass, high thermal resistance and resistance to temperature changes (up to 150 K) and do not cause injury when broken. They can carry heavy loads in building facades, glazed roofs and skylights, screens and windows in sports objects, hospitals and schools, and noise shields in streets and highways.

4.4 Fibre concrete

The common use of fibre concrete most often reinforced with steel fibres for shotcretes used in tunnel shell, repair and reconstruction work of bridges or cooling towers, wear resistant heavy loaded floors of storehouses. The main advantage of concrete reinforced with steel fibres is not only two times higher than its tensile strength, but also several times higher its ductility.

4.5 The renaissance of wood

In modern structures wood is used in the form of: (i) traditional solutions (ii) solutions based on the technology of laminated timber, which makes it possible to produce large size structural elements or whole spans. In both cases progress has been made due to: (i) new industrial technologies of production, preservation and chemical modification of wooden structures; (ii) the application of high strength timber and (iii) new construction solutions adapted to modern technologies. In the 21st century this material, easily available in nature, workable and light in weight, will undoubtedly serve as a supplement for concrete and steel structures.

4.6 Plastics

As far as plastics are concerned it has to be said that progress in the field of chemistry of plastics goes forward much quicker than in the domain of other construction materials. Therefore it should be assumed that in the coming years new construction materials based on high-molecular weight polymers will compete successfully with traditional materials. [8]

Plastics are very suitable for use in building structures, especially because of their lightness (mass density ρ=1000–1400 kg/m^3), high chemical resistance, high light transmittance, ease of forming. The most important disadvantages of plastics are: low coefficient of elasticity, high rheological deformability, low thermal resistance and ageing caused by UV radiation. The tensile strength of plastics without reinforcement is 10–80 MPa, but an efficient reinforcement with glass fibres enables an increase of this value to 130–600 MPa (in the direction parallel to the fibres).[9] The modulus of elasticity of plastics is relatively low (2 GPa), but plastics reinforced with glass fibres can achieve values comparable with that for steel (55 GPa). [10]

Modern chemistry tries to neutralize the disadvantages of plastics by adding compounds that are able to absorb UV energy and re-emit it as waves of greater length, which have no destructive influence. The flammability of plastics is being limited by the application of additives, which stop fire after the removal of a flame. The introduction of the reinforcement causes not only significant increase of the tensile strength and the modulus of elasticity, but also considerably prevents plastics from creeping. The previous limitations have resulted in plastics being applicable only as secondary construction materials in architecture: (i) in laminar elements (“sandwich” type); (ii) in translucent elements and structures such as skylights, roofs and walls and (iii) in 3D structures. [11]

Amongst the 3D structures in which plastics are used are: folded plate structures, membrane structures made of reinforced resins, rigid cellular plastics, film and fabric, spherical domes and pneumatic structures. In the most cases the above-mentioned structures act together with steel tendons. From the foregoing it is clear that the area of applications of plastics in architecture is very wide. It serves not only as a complement, but often is responsible for the proper work of the traditional construction materials: steel, concrete, ceramics and wood. [12]

4.7 Smart materials

Smart materials are materials that have one or more properties that can be significantly altered in a controlled fashion by external stimuli, such as stress, temperature, moisture, pH, electric or magnetic fields. There are a number of types of smart material, some of which are already common.[13] Among the various existing smart materials there are piezoelectric ceramics, electroactive polymers, and shape memory alloys and carbon nanotubes (CNTs) which exhibit extraordinary mechanical properties. Those materials differ in the structural and electrical characteristics making them promising for developing unique and revolutionary smart composite materials. [14]

5. Need for sustainable and durable building technology alternatives

The world population is expected to increase by almost 2 thousand million people between the years 2000 and 2030, and almost all these inhabitants shall live in African, Asian and Latin American cities. The number of inhabitants presently living in large urban areas already reaches the figure of 3000 million; between 2000 and 2015 this figure shall be increased by 972 million; every 5 years the urban population in Africa, Latin America and Asia doubles in number. However, it is estimated that more than 60% of this population shall live under indescribable living conditions. An increase in population is coupled to a raise in atmospheric emissions and these adversely affect the durability of building materials. [15]

Although the expression “sustainable construction” is being used more and more, it is necessary to distinguish between the sustainability of the construction activity and the sustainability of works constructed. [16]

The concept of sustainability has an economical interpretation. Sustainability applied to construction, can be interpreted in different ways.[17] The concept “sustainable construction” has been used to characterize *construction that includes environmental criteria in the project concept*, *in the way of building*, *maintaining and*, *when the time comes*, *of demolishing the works*. [18] , [19] Sustainable construction may allow the construction industry to become a sustainable development. [20]

Extensive use of energy-intensive materials (Steel, cement, glass, aluminum, plastics, bricks, etc.) can drain the energy resources and adversely affect the environment. On the other hand, it is difficult to meet the ever-growing demand for buildings by adopting only energy efficient traditional materials (like mud, thatch, timber, etc.) and construction methods. Hence, there is a need for optimum utilization of available energy resources and raw materials to produce simple, energy efficient, environment friendly and sustainable building alternatives and techniques to satisfy the increasing demand for buildings. [21]

6. Suggested framework for sustainable building materials

The goal of Building Technology was always to produce buildings that are more energy efficient, comfortable, and affordable. The emphasis is to develop simple generic solutions that are appropriate to the local area, are very cost effective, and will be accepted by the local people. Therefore the suggested methodology aims to design and construct buildings that are energy efficient, as well as attractive, as they should establish a level of energy efficiency, while keeping upgrade costs within reason. In order to reach this goal, teams consisting of architects, engineers, builders, equipment manufacturers, material suppliers, community planners, mortgage lenders, and contractor trades all work together to produce buildings that incorporate energy- and material saving strategies from design through construction.

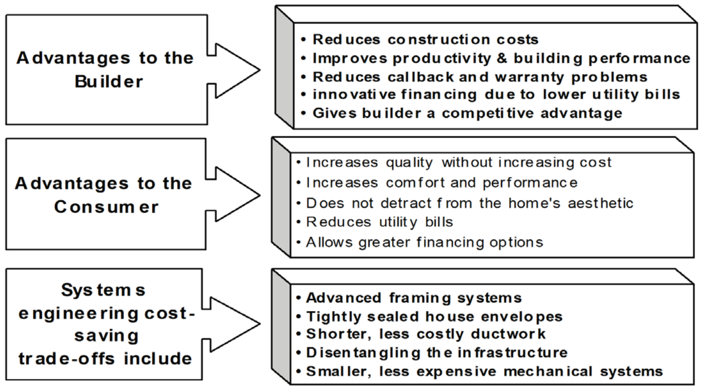

Figure (2) - Suggested framework objectives

The framework represents a new way of doing business that will result in improved building quality, performance, asset value, affordability, and energy efficiency. The framework is an analytical, presentational and management tool which involves problem analysis, stakeholder analysis, developing a hierarchy of objectives and selecting a preferred implementation strategy. It begins with Executive Forums in which construction industry leaders develop a vision of their industry. Participants represent all phases of the building process and may include manufacturers, developers, contractors, owners, architects, engineers, financial backers, utilities, and researchers. The final products of the Executive Forums include:

- A draft vision statement that articulates where the industry area sees itself in 20 years

• A set of performance targets for the technology area

These documents will be available for review and become the basis for the next phase, Setting Work team formation & assignments.

Once the vision is complete, a larger group of industry stakeholders gathers for a second series of workshops. In these workshops, participants develop short, mid, and long-term strategies for achieving the goals established in the vision.

This approach ensures the most strategic allocation of public and private-sector resources for technology development and accelerates the RD&D process.

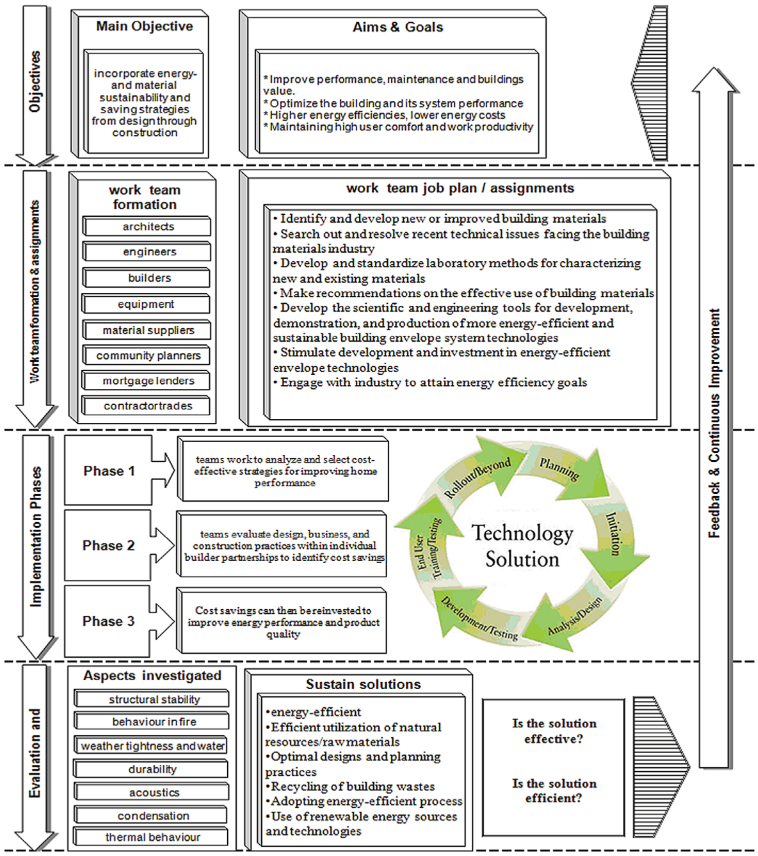

Figure (3) - The suggested framework for strategic partnerships creation helping to accelerate the adoption of new sustainable technologies

7. Results

• Various technology programs are concerned with the use of modern and innovative materials, besides developing reliable and rugged, low cost, with preparing for future technologies. New innovative technologies were launched in the few past decades aiming to create cost effective and at the same time high-performance construction materials.

• Modern-day construction poses demands on engineers and architects which can lead to the future deterioration of built structures. This can compromise the cultural, scientific and technological image of a generation.

• Not all building automation applications are promising. For some applications, there are already results forming real-world implementations and/or simulations studies. For other applications, the investigation still has to be done to identify the most promising applications and determine their potential.

• It is difficult to sustain the building activity in the long-term to meet the future demand for buildings by using the currently available energy-intensive materials and building techniques/technologies. Therefore alternative building technologies developed are energy efficient making it so important to switch over to the use of energy efficient building materials and technologies and devise methods and mechanisms for the sustainable construction practices.

• The development of construction engineering in the course of centuries meant a constant struggle with available materials, spans, or height, active loads and the forces of nature — water, fire, wind and earthquakes. Some of those elements have primary and the other secondary significance. Amongst those mentioned first, an essential role has always been attributed to the influence of the material on construction development.

• Durability of the materials, directly derived from natural materials like soil, thatch/leaves, timber, etc. is questionable.

• Quest for durable building materials is an ongoing phenomenon ever since man started construction activity. In the coming years new construction materials will compete successfully with traditional materials.

• Need for building materials will grow at an alarming rate in future, in order to meet the demand for new buildings.

• Both the materials and technologies used since ancient times have allowed many past works to have lasted thousands of years. Some were made out of permanent materials such as stone while others were made out of more ephemeral materials such as adobe bricks or cob walls. The overall durability of built structures depends on the durability of their materials.

• Sustainable construction can refer either to the building process or, alternatively, to the built-object. In fact, construction involves the consumption of raw materials and energy and the use of land upon which the structure is established.

8. Recommendations

• New, innovative approaches must be followed in the area of material development in order to create customary components and technologies for the future.

• Errors from past urban development and the needs of developing communities should be kept in mind for developing new building technologies in developing countries. Such technologies should rely on: a) traditional materials, better exploited to minimize hazard with respect to natural disasters; b) new, advanced materials, when available at affordable prices; and c) local resources and natural remediation systems readily available on site.

• Issues related to energy expenditure, recycling, biodegradable, environmental and sustainability with respect to future demand need to be addressed during the manufacture and use of any new building material.

• Regarding the use of modern building materials the following points require attention: Energy consumed in the manufacturing processes – energy intensity; Problems of long distance transportation; Natural resources and raw materials consumed; Recycling and safe disposal; Impact on environment, and Long-term sustainability.

References

1 - Flaga, K., Advances in materials applied in civil engineering, **Journal of Materials Processing Technology**, Volume 106, Issues 1-3, October 2000, Pages 173-183

2 - Reddy, B. V. Venkatarama, Sustainable building technologies, current science, vol. 87, no. 7, October 2004

3 - Hellenic National Statistical Service. Statistical index—census of buildings' inventory. Athens, 2001.

4 - N. Papamanolis, The main construction characteristics of contemporary urban residential building in Greece, Building and Environment **40** (2004), pp. 391–398.

5 - Flaga, K., Advances in materials applied in civil engineering, **Journal of Materials Processing Technology**, Volume 106, Issues 1-3, October 2000, Pages 173-183

6 - A.M. Papadopoulos, Energy cost and its impact on regulating the buildings' energy behaviour, Advances in Building Energy Research **1** (2007), pp. 105–121.

7 - Flaga, K., Advances in materials applied in civil engineering, **Journal of Materials Processing Technology**, Volume 106, Issues 1-3, October 2000, Pages 173-183

8 - Flaga, K., Advances in materials applied in civil engineering, **Journal of Materials Processing Technology**, Volume 106, Issues 1-3, October 2000, Pages 173-183

9 - M.R.C. Doughty, G.P. Geoffrey and P. Hammond, Sustainability and the built environment at and beyond the city scale, Building and Environment **39** (2004) (10), pp. 1223–1233.

10 - Flaga, K., Advances in materials applied in civil engineering, **Journal of Materials Processing Technology**, Volume 106, Issues 1-3, October 2000, Pages 173-183

11 - Uren S, Brown A, Gooch F. Sustainable construction in practice. In: Proceedings of International Conference on sustainable building, 2000.

12 - Flaga, K., Advances in materials applied in civil engineering, **Journal of Materials Processing Technology**, Volume 106, Issues 1-3, October 2000, Pages 173-183

13 - Wikipedia, the free encyclopedia, http://en.Wikipedia.org/wiki/smart_materials

14 - Inpil Kanga, and others, Introduction to carbon nanotube and nanofiber smart materials, **Composites Part B: Engineering** , Volume 37, Issue 6, 2006, Pages 382-394 JCOM 731 " Nanoengineered composites and Ceramic Laminates" Special Issue.

15 - World Watch Institute, World Summit Policy Briefs, August 2002.

16 - Mora, Eduardo Peris, Life cycle, sustainability and the transcendent quality of building materials, **Building and Environment** , Volume 42, Issue 3, March 2007, Pages 1329-1334

17 - M.R.C. Doughty, G.P. Geoffrey and P. Hammond, Sustainability and the built environment at and beyond the city scale, Building and Environment **39** (2004) (10), pp. 1223–1233.

18 - Hendriks Ch F. Durable and sustainable construction materials. AENEAS. Nl, 2000.

19 - Uren S, Brown A, Gooch F. Sustainable construction in practice. In: Proceedings of International Conference on sustainable building, 2000.

20 - Mora, Eduardo Peris, Life cycle, sustainability and the transcendent quality of building materials, **Building and Environment** , Volume 42, Issue 3, March 2007, Pages 1329-1334

21 - Reddy, B. V. Venkatarama, Sustainable building technologies, current science, vol. 87, no. 7, October 2004

نحو تقنية بناء متقدمة من خلال
مواد بناء وأنظمة ملائمة

د. شريف محمد صبري العطار
قسم العمارة، كلية الهندسة،
جامعة الفيوم.
sherifelattar67@hotmail.com

الملخص:

تتطلب منا مجتمعاتنا حالياً عمارة جديدة لحياة جديدة. فالمدن العربية في القرن الواحد والعشرين تبحث عن الحق في الاقتصاد والحضارة بصورة مستدامة مما يشكل تحد كبير. وفي عالم الاقتصاد المتسم حالياً بالمنافسة الحادة أصبحت نظم تقنيات البناء ضرورة ملحة وبالتالي يجب أن يولي المتحكمين في البناء الاهتمام لمواصفات وفوائد مواد البناء من أجل رفع كفاءة الاستثمار في البناء وترشيد تكلفته. يتطلب هذا أرفع مستوى لأنظمة لتقنيات البناء لتحقيق متطلبات المستخدمين والحفاظ على تقاليدهم وهويتهم في الأحياء والمدن.

تتيح التقنية حالياً بدائل عديدة لمواد البناء والتشطيبات والتي تتغير وتتطور من دون أن نوظف منهجية علمية لتقييم نوعيتها أو قياس تأثيرها على العمر الافتراضي للمبنى.

ويسعى هذا البحث لتطوير حلول لمسائل محددة ذات أهمية خاصة المأوى من: الراحة الحرارية، استهلاك الطاقة، تقنيات البناء، التشكيل العمراني، والتنمية الإقليمية.

ويهدف البحث للوصول لتصميم بيئي متكامل بالاستفادة من نظم وتقنيات البناء الحديثة للحصول على مساكن أكثر جاذبية يسهل تأجيرها، وعالية الكفاءة في استخدام الطاقة ومنخفضة تكاليف التشغيل والصيانة وتلك الأنماط المتوازنة ستعكس الهوية العربية من خلال فراغاتها المختلفة وعناصرها البصرية وستخفض التكلفة الكلية من دون تأثيرات سلبية على النوعية والكفاءة. بالإضافة لذلك فاستخدام مواد البناء الحديثة في نظم تقنيات البناء سيمكن من تحقيق نظم التدعيم الذاتي (self-erection systems) بشكل ناجح.