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THE EMPLOYMENT OPTIMAL OF SUSTAINABLE MATERIALS AND LOCAL RESOURCES IN LIBYAN INTERIOR ARCHITECTURE

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الملخص : لطالما ألهمت العمارة المحلية التقليدية العمارة الحديثة من حيث الطراز والشكل المعماري والتصميم الداخلي بطريقة تلبي بها احتياجات شاغليها. ولقد أظهرت العمارة المحلية القديمة ايجاد الحلول والاجابات بشكل رائع ومحاولة تحقيق مبدأ الاستدامة، وفي الوقت الحاضر تحاول العمارة الحديثة والتصميم الداخلي إيجاد حلول للمشاكل الناتجة من الابتعاد عن الهوية والطراز المعماري لذلك يتم التركيز على المواد والموارد ومدى التأثير الناتج عنها من الناحية الصحية والاجتماعية والاقتصادية والبيئية على المدى الطويل من عمر المبنى. ويعالج البناء الأخضر نوعين من المشاكل المتعلقة بالمواد والموارد: إدارة النفايات وتأثيرات دورة الحياة. وتمت مناقشة هذه المسألة من قبل العديد من المهنيين والباحثين، ويبدو أن هذه المشكلة موجودة على الأرجح في البلدان غير النامية مقارنة بالدول النامية. والتي لم يتم فيها عدم أخذ اختيار المواد المناسبة بعين الاعتبار بشكل جيد. ولقد طور الباحثون عددًا من الافتراضات التي تساعد على حل مشكلات البحث ، والتي تشمل تطبيق المواد الخضراء والموارد في التصاميم الداخلية الليبية لتوفير بيئة صحية، لذلك تهدف الورقة إلى البحث عن إمكانيات اقتراح بعض المؤشرات باستخدام المواد والموارد المستدامة في الفراغات الداخلية. لهاذا يمر الجزء النظري بدراسة موجزة للتعريف بالمواد والموارد المستدامة في

ليبيا، واستخداماتها في جميع العناصر الداخلية وايضا التركيز على الرموز التقليدية للحفاظ على الهوية ليبية. وتحلل هذه الورقة استخدام المواد في منزل تقليدي بمدينة غدامس الليبية لتحديد الطريقة التي استجابت بها العمارة الداخلية التقليدية المحلية لمبدأ العمارة الخضراء.

Abstract:

Vernacular architecture has always inspired modern architecture not just in terms of forms and decoration but also the way it responds to people needs and local resources. In terms of sustainability, this architecture has shown great answers to the three bottom lines of sustainability. Nowadays, modern architecture and interior design is trying to find solutions to the problems resulted from modern far from identity constructions. Consideration for materials and resources focuses on the health and productivity consequences of material selections for building occupants, plus the long term social, economic, and environmental impacts of materials used in the design and construction of the building. Green building addresses two kinds of problems related to materials and resources: waste management and life-cycle impacts. This issue has been discussed by many professionals and researchers and it seems this problem is more likely existed in not developing countries comparing with developing countries.

The lack of selecting the right materials, have not been well taken into the consideration. Researchers have developed a number of assumptions that helps to resolve the research problems, which includes The application of the green material and resource in the Libya interior designs to provide a healthy environment to the interior spaces Therefore, the paper aims to search for the possibilities of proposing some indicators using sustainable

material and resource in the of internal Libya spaces. The theoretical part goes through a brief study to definition of sustainable material and resource in Libya, and its uses in all the elements of internal and emphasis about the traditional symbols to preserve the identity of Libya. The paper lately analyses the usage of the materials in a traditional house in Ghadames to define the way vernacular interior architecture responded to green terms.

Key words: Sustainable materials, Sustainable interior design, Libyan interior Architecture, Gahdames interior, vernacular interior.

1. Introduction

Materials are the easiest way for architects to begin incorporating sustainable design principles in buildings. Traditionally, price has been the foremost consideration compared with similar materials or materials designated for the same function.

In addition the analysis of building products, from the raw materials collection to their final disposal, provides a better understanding of the long-term costs of materials. These costs are not only paid by the client, but also by the owner, the occupants, the society, and the environment. The principles of Life Cycle Design provide important guidelines for the selection of building materials. Each step of the manufacturing process, from gathering raw materials, manufacturing, distribution, and installation, to ultimate reuse or disposal, is examined for its environmental impact. A material's life cycle can be organized into three phases: Pre-Building; Building; and Post-Building. These stages parallel the life cycle phases of the building itself.

In order to achieve sustainability in Libyan interior design, designers should go back to role models in traditional design. An analytical look to the elements use in residential units in old

Ghadames explores the beauty of interior design that answers sustainable terms preserves local identity. The optimal employment of sustainable materials and local resources in Ghadames interior architecture shows the creativity of such traditional designs and the great ability to respond to local climate and environment.

1.1.Research problem.

The problem is more likely existed in non-developing countries compared with developing countries. The lack of selecting the right materials, have not been well taken into the consideration. This includes the application of the green material and resources in the Libyan interior architecture to provide a healthy environment to the interior spaces and also emphasis about the traditional symbols to preserve the identity of Libya architecture. On the other hand, a lot of answers are found in vernacular architecture that needs exploring and refining.

1.2.Methodology

To size the suitable materials in Libyan interior design, the research survey the classification of these materials. All requirements and criteria is acknowledged in order for these materials to reach sustainable design checklists. A systematic literature review takes place in the research by gathering information from different resources including assessment systems, previous studies and case studies. In addition the review search the criteria required for any project and the materials related to it by analyzing the old Libyan house as an example of sustainable material usage in the elements of Libyan interior architecture. The Libyan case study selected is the old Ghadames house and all interior elements are analyzed considering materials and resources focusing on the health and productivity

consequences of material selections for building occupants, plus the long term social, economic, and environmental. The materials and elements are evaluated in terms of sustainable design criteria and identity determination.

2. Classification and Criteria Required for Any Project of Materials used in Interior Architecture

2.1 Collection and Storage of Recyclable Materials

This is meant of how to promote waste reduction and cutback resulted from building occupation and which is get rid of by transporting it to landfills.

Requirement: Design a place functioned to collect and storage the waste materials and separate them in order to recycle them. For example, consider a recycling center space with distinct places for at least metals, plastics, glass, paper, and cardboards. These recycling points should be taken in consideration by not only the designers but also the owners and the managers. Terms to be examined:

- The way these recyclables are kept and delivered by building occupants from different departments and stories. In other words, the system and place of collecting waste materials for recycling; either by using individual bins at each desk for example or by assigning a midpoint area such as lounges, cafeterias, or pantries.
- The period of time these recyclable are collected from each point. (department or story)
- The place all these recyclable waste is delivered to for final assembly.
- The frequency of collecting the waste by recycling management programs.

The average individual production of waste is 1.82 kg per day. As a prerequisite, LEED certified buildings have to reduce waste hauled in landfills; by recycling metal, glass, paper, plastic, and cardboard [1].

Using Materials with Recycled Content: Materials with a recycled content are materials used in a product with portion that have been diverted from the solid waste flow. These products can be concrete, steel and furniture for example. There are two kinds of materials concerning their recycled content:

1. Pre - Consumer Recycled Content
2. Post - Consumer Recycled Content

Pre-consumer recycled content is the waste material output or product that has been diverted from the waste flow of some industries to other industries or landfilled. It is the waste during the industry operation, and does not reach the consumer. Slag, fly ash, shavings, sawdust, crusher dust, walnut shells, and others are considered a post-industrial, pre- consumer recyclable materials.

Post-consumer recycled content is the waste product or material brought from the consumer. It is usually created from residential, industrial, or institutional locations. This waste product will not be used for its original purpose [1]. Newspapers, glass, construction and demolition waste, plastic bottles, cans and steel are all post-consumer recyclables created by consumers after a product has reached the end of its use.

2.2 Waste management reduction (redirect & reuse waste)

It refers to constriction of the waste and toxins that are transported to main landfills or discarded to be burned. This waste is produced in the daily course of building operation such as tiles, bricks, asphalt, wood, and rubber. The amount of waste disposed to

landfills could be controlled by recycling, reusing, and reduction programs. This waste can be classified in two groups.

2.2.1Construction demolition waste

This group has any waste derived from construction, renovation and demolition areas. Reusing the building or parts of it can expand the life cycle of these materials. It also help in sustaining resources, preserving cultural wealth, decreasing waste and environmental impacts of new structures as they relate to materials production and transport.

Requirement: Control at least 75% of the present structure and shell of the building (structural frame and building without window assemblies and non-structural roofing material).

2.2.2 Solid waste recycling

Recycling is the accumulation of recyclable waste materials to convert them to new usable items. This recyclable material could be collected either individually from the whole debris in specialized containers and hauling trucks or be classified straight form the general disordered debris flow.

2.3 Green material

Green materials can be recycled content materials, regional and local materials, rapidly renewable materials, certified wood materials, or nontoxic materials.

2.3.1 Recycled content

Products used in building should be reduced, recycled, and reused rather than using products from raw materials. This method will help in reserving natural resources, decreases energy consumption, and lessen carbon dioxide emissions.

The product should have a high percentage of materials diverted from the waste flow of some industries (pre-consumer recyclables) or brought from the consumer (post-consumer recyclables). This total material amount, volume, or weight percentage is called the recycled content for a product. Examples of main building materials which can be recycled are paper, plastics, glass, metal, concrete, wood, and brick.

- **Reduction**

This is called 'Dematerialization' strategy. The strategy works by "take less and give more" concept, which means achieve high performance and lessen material consumption. A cut in the amount or volume of the resources is essential to reduce the whole material usage. Moreover, this cut will reduce the waste formation within each individual system or group of industrial product Products with such characteristics have reused, recycled, or junk materials [2].

- **Reusing**

Reusing materials decreases raw materials extraction from natural, reduces the amount of waste disposed to landfills, and increases economic savings. Analyzing the hierarchy of waste management and life cycle assessment, it is obvious that reusing and recycling is a priority taking in consideration the 'zero waste – reincarnation' concept [3]. After the building life come to an end by ending its service, its life span could be expanded by reusing and recycling its structural components and materials. Many of the sustainable interior designs use salvaged, refabricated, and reused materials such as wood, glass, doors, windows, and bricks. The reusing concept takes in account other sustainable development factors; economic, social, and environmental.

Reusing recovered, salvaged, and refurbished materials mixed with new materials could be used to construct the structural component and materials of a new building rather than be disposed to landfills. In addition, this would minimize the energy spent in transportation to disposal points [3]. Table no. 1 shows the maximum distances needed for some reclaimed materials. If the distance needed to divert the material from the building site is bigger than the one on the table, then buying a new material is a more sustainable than choice in this case taking in consideration the carbon fingerprint of the whole action.

Table 1. Maximum Transportation Distances for Reclaimed Materials [3].

Material	Distance (KM)
Reclaimed tile	161
Reclaimed bricks	402
Reclaimed slate	483
Reclaimed timber	1609
Reclaimed steel	4023

- **Recycling**

To recycle a product or a material is to remanufacture it after been already used to get a new usable product. Waste materials that are recyclable are collected from construction sites or waste landfills. Recycled waste materials can be a source of building materials.

Material recycling has major benefits on environment, and economy. Reprocessing a waste product to get a different product can lead to energy savings, cleaner air, less waste, and more Green House Gases reduction. Table no 2 shows the environmental effects of several building materials. To mention, Aluminum recycling can give us the most energy savings in the list; 95%.

Going down the list comes second plastic with 70% and paper with 40%. After glass and cardboard come with 5-30% [4].

Table 2. Environmental Effects of Recycling Building Materials [4], p.133).

Material	Energy savings, [%]	Air pollution savings, [%]
Aluminum	95	95
Cardboard	24	-
Glass	5-30	20
Paper	40	73
Plastics	70	-
Steel	60	-

Every year, factories around the world produce twenty five billion tons of concrete which means that we consume concrete in building more than any other material. Since concrete is a durable material, it does not get wore by time rather than the building or the concrete structure becomes undesirable and there is need to structural changes [3]. For such concrete remains or shred can be recycled to other building products such as concrete tiles, mosaics, or gravel stones.

Some materials are made of many components. They are less recyclable as these components need to be divided from the whole structure in order to get recycled. It is favored to do such proceedings in terms of environmental impact. Rather these materials could be directly reused or repurposed. Glass waste is gathered from building sites and used to manufacture glass floor tiles and mosaic ceramic. Usually steel is one of the most recyclable material because it can be easily removed from the unwanted structure or debris. Materials that cannot be reused as they are, should be divided into recyclable components. For

instance, it is usually difficult to remove rubber from construction debris. At this point, such materials are not recyclable unless there is a way to easy detach them from the mixed waste.

2.3.2 Regional and locally sourced materials

The idea of selecting regional materials as a sustainable choice is its ability to encourage local economy and decrease the whole energy consumed and therefore lessen the greenhouse gas emissions in favour of addressing global warming and environmental pollution.

The travelling distance of a product or a material from extracting or manufacturing site to the building site is a measure to how this material is sustainable. LEED (USGBC rating system) encourage this distance to be less than 800 km, as the shorter the distance, the less energy are consumed and less GHG emissions. [5]. The usage of regionally and locally produced materials has a further aim which is boosting the local economy, and lessen the effects from the transportation. The main cause of global warming is the greenhouse gases emitted in the atmosphere and some of them are from transporting. In addition material transportation is a main element in energy consumption mostly from heavy materials like concrete, steel, and masonry. The lowest in energy consumption from means of transportation is the marine ships. Second in place comes trains and then trucks. Airplanes are the biggest consumer of energy between all [6].

Table 3. Energy Consumption in Transportation of Materials [6].

Transport mode	MJ/t/km	Co2 k/km
By air	33…36	-
By road (diesel)	0.8…2.2	0.069
By rail (diesel)	0.6…0.9	0.060
By rail (electric)	0.2…0.4	0.065
By sea	0.3…0.9	0.115

Local materials could reduce costs and carbon economy in case there are available with suitable amount. Any materials that are existed so far from the project should be replaced with more sustainable material [7].

2.3.3 Rapidly renewable materials

Using rapidly renewable materials main aim is to support a building material that came from agricultural products and take less than ten years to regrow and get harvested. Examples of rapidly renewable materials are bamboo flooring, wool carpeting, linoleum flooring, cork flooring, sunflower seed board panels, wheat board cabinetry, and cotton insulation [3].

2.4 .Classification of Materials used in Interior Architecture

Materials used in interior architecture can be classified according to where they are used in the interior space. It is useful to acknowledge what is used where so the designer's decision regarding material choices would be easier. They are classified as following:

2.4.1 Floor Materials

- Wood: it should be certified by organizations that it came from responsibly managed forests; which is such as the Forest Stewardship Council (FSC)
- Rapidly renewable flooring materials: for example; bamboo, cork and rubber. These materials are characterized of short harvesting periods (less than ten years), strength, and moisture resistance.
- Natural Stone

2.4.2 Wall Materials

- Paint: paint products with low violate organic components VOCs, non-toxic components that might emit toxic gas as

ammonia, or formaldehyde. Sustainable paint will contribute in better indoor air quality IAQ [3].

- Plaster: Using a natural clay plaster rather than artificial one favor a good moisture absorption and release.
- Wall tiles: tiles which have a waste diverted components for example recycled porcelain, ceramics, and glass tiles.
- Wallpapers: they should made from rapidly renewable materials such as cork, or plant fibers.

2.4.3 Ceiling Materials

- Gypsum and foam could be used according to Global Resource Limitations criteria.
- Cork, bamboo, and rubber could be used according to rapidly renewable materials criteria.

2.4.4 Insulation Materials

- Sustainable materials with an effective energy performance for example Cotton Batt and Rockwool would be used as insulators efficiency [3].

2.4.5 Windows Materials

Windows selection is an essential part of the sustainable design as they should control most of the heat gain and loss of a space. Pinpoints in windows assemblies are:

- Low- E coating boosting the level of insulation.
- Double glass with inert gases like Argon and Crypton.
- Certified wood from FSC certified forests.

2.4.6 Furniture and Fabrics Materials

- Reused building elements like doors and windows can be reused to make furniture such as tables.
- Wood products should be from responsibly managed forests.

- Adhesives, waxes, stains, polishes, varnishes, and paint used in the furniture should be clear of any toxic components.
- Fabrics and carpets that are made from natural materials such as cotton, bamboo, hemp, or wool. In addition, Sisal, Coir, Jute, and Sea grass could be used to make natural fibers.

3. The Analysis of Sustainable Material Usage in the Elements of Libyan interior architecture.

Vernacular architecture has always offered unique sustainable solutions through its urban context, architectural forms, to interior space arranging and materials. In order to acknowledge the use of sustainable materials in Libyan interior architecture, a study to the most prominent example is presented. The study id for the old house of Ghadames city.

3.1 Ghadames Background

Ghadames is a city southwest of the capital Tripoli by 700 km in the middle of the desert. Its urban and architectural context is a very suitable respond to the Saharan climate in a sustainable method. Old Ghadames used to have 7000 inhabitants living in 1600 residential units. In 1982, the residents moved to the new neighborhood offered by the government which were designed in a modern way. The modern city didn't offer the thermal comfort of the old city nor reach the social core of the Ghadames people. The city has a desert climate. Most of the seasons are dry and hot with temperature reaching 48ºC [8].

3.2 The Idea of Design

The design of the traditional building in Libya and especially in Ghadames as many vernacular architecture responses to the local

climate using natural resources. This is found in the three main levels of design; the first level is the construction materials. The second level concerns about the building forms, heights in the city level, and the systems implied in the buildings and streets.

These systems including how these forms and city veins are ventilated and lighted. It is how the streets and squares are designed to fulfill the thermal and social comfort in this hot oasis. The design of the city context and the building goes to the third level to show an unique interior organization of the unit spaces. Figure (1) shows a typical residential unit plan in Gadames.

Fig1 an illustrative example of a typical housing unit in Gadames ,Source: ar.libyanembassy.de

This paper focuses on the first level which is the construction materials and interior elements that shows a high respond to the environmental, social, and economic conditions [9].

3.3 Materials and Building Method

The city urban design is a compact method where building units are attached to each other for climatically and socially benefits. This compact relatively dense city texture form a shield from the desert heat and cold weather through the building units. It also prevent hot sunrays from reaching the living spaces; rooms inside the units and squares in the outside. The main building materials

are local produced materials such as mud, clay, limestone, gypsum, and palm tree wood. These materials are locally collected on a cheap way and are characterized by their great isolation, durability and strength. Here the sustainable design is reached by using natural, local, rapid renewable, and energy efficient materials. The materials used are collected locally from the surrounding environment. Building materials in Ghadames are mainly:

- Stones: are used to construct walls especially the lower parts (up to 1.5 meters high).
- Mud bricks: are used to build the upper walls, stairs, and basement walls by mixing it with hay.
- Gypsum: is used in domes, floors, and walls.
- Lime: is used in painting walls with white.
- Palm trunks: are used as ceiling panels and in wall cabinets and doors
- Palm leaves: are used in floors, and doors and also are used to prevent leakage of gypsum to the basement.
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Fig2 General view of molding Mud brick, Source: [10]

Fig3 Using palm trunks in ceiling, Source: [10].

3.4. The Interior Decorative Elements

3.4.1 Al-Kowat

They are small dugs in the walls for putting daily stuff and tools. They have a square and semi-circular shape with a frame of gypsum surrounding them for decoration [11].

3.4.2 Gypsum Works

They are for decoration. They are usually square frames and might be a narrow cut opening. They are not produced direct on the wall, they are produced individually and then get attached to the wall [11].

3.4.3 Arch Decoration

Arches are framed on the sand by drawing the motifs on the sand then the bumps appeared on the arch. The motifs are geometrical shapes, calligraphy, and pieces of glass [11].

3.4.4 Wall Drawings

For drawings in the wall they used powder dyes. The colors are brought from the northern coastal cities and mixed by a sticking

material. The sticking material are manufactured from Arabic gum and egg yolk. This mixture is called (Zind Jafoor). The colours are mainly red, yellow and green. To paint the drawings, naturally made brushes are used either from chicken feathers, horse's hair, and camel hair. The drawings are geometric shapes, mainly intersecting inclined lines. The decorations are for interior walls only. Women are the one who make the decorations while men build the house. They place the drawings around "Kowat", gypsum work, and cupboards. Some relate these drawings to pagan and Byzantine art. The ring of Solomon is found in some decorations. They use colours that convert their desert life and environment, shown in Figure below [11].

Fig 4 House Decorations Source[12].

3.4.5 Doors

The material used for the door are "San'norr wood" or other local wood from other trees like olive trees. The interior doors such as for storages and cupboards are made from olive tree wood. They have iron hinges. Outside doors are decorated by bright colour plant motifs, shown in Figure 5[11].


Fig5 Doors Source: [12].

3.5 DECORATED TOOLS AND CARPETS

3.5.1 Mirrors

Mirrors are used in small dark places. They reflect the light to increase the light intensity in these places. They also gives wideness sense to these places. They are placed either directly to the wall or hanging from them [11].

3.5.2 Brass Plates

There are different types and usually reflect the luxury and financial status by their quality and quantity. They varies in dimensions and weight. A 20 cm depth ones might weight one kilogram. A smaller one with 12 cm depth has a weight of 250 grams. They are only for decoration [11].

3.5.3 Copper Plates

Like the brass plates, they vary in size and weight [11].

3.5.4 Plates

Wooden plates made from palm tree thorns. They are usually large. They are decorated with coloured shells and other materials, shown in Figure 6. This method is not known any place in Libya

except in Ghadames and so called Ghadames plates.

3.5.5 Furnishing

Ghadames did not have good quality mats so they brought carpets from near cities. Local carpets are usually rough and made in "Bani Wazweet". People prefer imported carpeted from "Kayrawan" or Iran. Pillows are made from imported cloth as well. There are also round leather plants with colourful plant drawings. In addition, there are long pillows decorated with square and octagonal shapes which are brought from Sudan.

Fans are decorated with bright coloured wool. The house has several stoneware used for holding water and fluids or for holding fire or oil lamps. Moreover, tools and utilises are put in the "Al-Tma'nht room" in the front of the house to show to the visitors the hidden beauty of the house [11].

Fig6 Plates on the Wall Source: [12].

4. Conclusion

Through the research discussion of the application of sustainability in interior design materials and the analysis of traditional Libyan house in Ghadames, the paper found a set of indicators, which

includes the application of the ideal usage of sustainable material and resource in the Libya interior designs to provide a healthy environment in the interior spaces. This is represented by building materials that are locally produced and are collected in a cheap way such as mud, clay, limestone, gypsum, and palm tree wood. These materials are characterized by their great isolation, durability, and strength. Here the sustainable design is reached by using natural, local, rapid renewable, clean, and energy-efficient materials.

Ghadames, which was and still is a historical witness of Libyan heritage is the best example in terms of the optimal utilization of sustainable local materials and resources in Libyan interior architecture. Due to the use of decorating tools and carpets and moreover the interior decorative elements such as al-kowat, gypsum works, arch decoration, wall drawings, and doors. All of them are produce by local, natural, and sustainable materials, which gave them an architectural identity and style in interior design in Libyan architecture.

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