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Towards maximizing the role of building materials to achive sustainability in the hardscape level as a gideline for biophilic design (special study of concrete and stone)

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Abstract:

Sustainability emerged as a result of the architectural trend changes witnessed by the natural environment, and the various development, that affected the various sectors in the current era is the most important of the built environment and the construction sector, where sustainable architecture that respects the environment, maintain the resources. Furthermore verify the needs of users based on a set of environmental principles and strategies that meet the eco-friendly building and for sustainable urban spaces to be friendly with the environment. The most important element must be reviewed by the design of these spaces is the choice of materials used so that they are materials to achieve sustainable environment.

So research aims to examine the role of materials and their applications at the urban hardscape level and stand on the most important points, and contemporary trends adversely affecting its processors and positively to their development.

Also discuss general environmental and human health impacts of materials and products industry, provide tools, techniques, ideologies, and resources for evaluating sourcing and specifying sustainable site materials and its energy which resulting from embodied, construction, maintenance, and recycling.

Keywords:

biophilic design sutainability ;building materials; concrete ;stone ;hardscabe materials ; life cycle of materials ; Giza zoo

Background

Many cities today are described as “concrete forests”, and their residents suffer from a distance from nature, so rates of depression, stress and anxiety rise amid the outbreak of a global pandemic of mental health disorders, which contributes to the high rates of disease and disability around the world (Haziran 2017). In order to get a natural environment for us to live, function, and learn, we should consider biophilic design for this matter. An environment without nature can badly impact health, efficiency, and well-being. Biophilic design is more than just adding a plant or two to the space!(Browning W, Ryan C, Clancy J (2014)). A positive effect can be generated by filtered sunlight, planting, green walls, water features, natural textures and materials, and views of nature. Biophilic design supports the use of natural building materials in the internal or external spaces to keep pace with nature, because of its positive impact on the environment and human. As biophilic design is compatible with sustainable design at this point,The research aims to achieve sustainability in urban contemporary reality in urban development in Egypt through the use of sustainable building materials environmentally ,friendly, non-polluting and is not involved in the production of pollutants .And also aims to reach the most important points affecting the surrounding environment and try to address them and to make it sustainable and how we can recycle it. Concrete and stone has been selected as a building materials to be studied in a more focused to explain types and characteristics and methods used in landscaping.

Nomenclature	
CIP	Cast-in-place
CKD	cement kiln dust
PCA	Portland Cement Association)
CBP	Concrete block paversStructure
BREEAM	BRE Environmental Assessment Method
LCA	Life Cycle Assessments

1. Definition of materials for sustainable sites:

Materials and products for sustainable sites are those that minimize resource use, have low ecological impacts, pose no or low human and environmental health risks, and assist with sustainable site strategies.

2. The life cycle of landscape building materials:

The typical life cycle of materials begins with extraction of raw materials from their sources and ends with the disposal of wastes which we can reuse it as inputs to extract the products. The ideal material life cycle would be a closed loop circular flow where waste from one process is feedstock for another, and waste released to the environment does not exist.

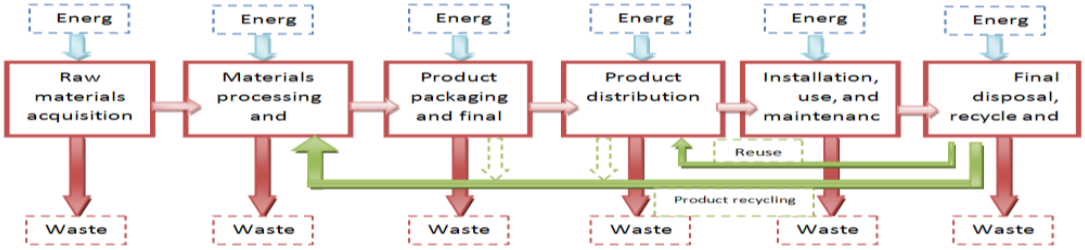

Figure 2.1: product life cycle stages along its vertical axis, illustrates the main elements of this process life cycle

Source: Calkins M., (2009), Materials for sustainable sites, A Complete Gide to the Evaluation, Selection , and Use of Sustainable Construction Materials, JhonWiely& Sons , New Jersy, USA, 1098765432

A construction material is produced through multiple unit processes with inputs and outputs from nature and industry.[1]

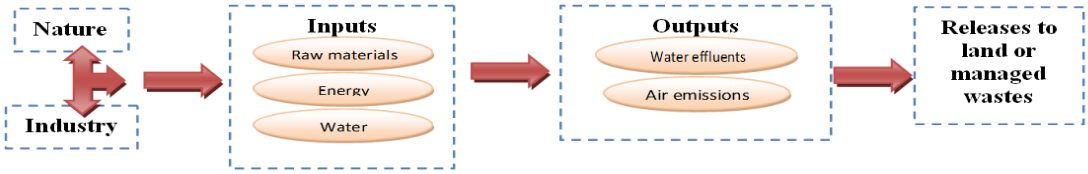

Figure 2.1: Inputs and waste outputs process

Source: by the author

3. Concrete:

Concrete is an essential material with a worldwide, it is the second most consumed substance on Earth after water . Concrete is made from coarse aggregates (gravel or crushed stone), fine aggregates (sand), water, cement and admixtures.

The Characteristics and Advantages of the concrete are summarized in Economical, Ambient temperature, hardened material, Ability to be cast, Energy efficiency, Excellent resistance to water, High temperature resistance, and Ability to consume waste.

3.1. Types of concrete pavement Divided intotwo types :

A. Cast in place concrete:

Cast-in-place (CIP) concrete is employed in pavements, walls, steps, and a wide range of site furnishings where strength, durability, and economy are factors.

CIP concrete pavement is a familiar element in the human-made landscape. Both strong and affordable, poured concrete is an excellent choice for large paved areas where the budget precludes the use of costlier unit pavers.

B. precast concrete:

Because of its durability, strength, and relative ease of forming, precast concrete is utilized in an enormous array of landscape applications. It may be the most widely adapted hardscape material currently available. Precast concrete has different types:

- Permeable precast paving
- Segmental precast retaining walls [2]

3.2. Concrete and the environment:

Concrete is produced from a mix of coarse and fine aggregates, cement—usually Portland—water, air, and often admixtures. Portland cement is the key ingredient in concrete, binding the aggregates together in a hard mass. However, it is also the ingredient in concrete that produces the greatest environmental burden.

3.2.1. Portland cement :

- The production of cement is an energy-intensive process using primarily fossil fuel sources. Cement composes about 10% of a typical concrete mix but accounts for 92% of its energy demand.

- Emissions from Portland cement manufacturing include carbon dioxide (C02), particulate matter, carbon monoxide (CO), sulfur oxides (SOx), nitrogen oxides (NOx), total hydrocarbons, and hydrogen chloride (HCI).

- The major waste material from cement manufacturing is cement kiln dust (CKD). An industry average of 38.6 kg of CKD is generated per metric ton of cement. In addition to about one ton of water is discharged in the production of one ton of cement.[3]

-

3.2.2. Coarse and fine aggregates

- Coarse and fine aggregates in concrete make up between 60% and 75% of the concrete volume. Aggregates are either mined or manufactured

- The primary impacts of aggregate extraction and processing are habitat alteration and fugitive dust Energy to produce coarse and fine aggregates from crushed rock is estimated by the (Portland Cement Association) PCA's Life Cycle Inventory to be 35,440 U/metric ton[4]

3.3. Enviromental impacts of concrete production:

- About 75% of U.S. concrete is produced at ready mix plants. Fugitive particulate matter, primarily consisting of cement and pozzolan dust with some aggregate dust, is the primary environmental and human health concern at ready mix plants

- Water consumption and pollution are often overlooked impacts of concrete and cement production. In addition to Energy use and emissions of ready mix concrete Vary widely by cement type and use of pozzolanic constituents such as fly ash, silica fume or slag.

- Transportation of materials throughout the life cycle of concrete varies. Where the concrete consisting of more than substance and all have different material properties affect the transportation method

- During mixing and placement, cement dust can have negative impacts on human health

- Concrete waste from construction and demolition is an environmental concern, but great strides have been made in the last decade to lessen the waste burden through reuse of concrete debris.

As a good portion of the environmental impacts of concrete stem from the production of Portland cement, reducing the quantity used may be the most important step toward 'greener' concrete. Strategies for minimizing the environmental impacts of cement are twofold : reduce use of cement in a concrete mix, and substitute appropriate alternatives.[5]

3.4. Concrete and biophilic design

The impact of biophilic design on material selection can be grouped in a few ways - the use of naturally occurring materials; use of shapes and pattern inspired by nature; and avoiding the feel or sense of artificial material through for example - smell, sense of enclosure, sound and permanence.

Concrete comprises mostly of natural material: rocks and sand, which, using various finishing techniques can be part of the surface texture. Architectural precast is often referred to as Recon - and offers a cost effective, high quality alternative to stone. There are many recent examples of concrete structures, facades, and interiors inspired by natural rock and earth formations, including rammed concrete.

As well as revealing the natural aggregate on the surface of the concrete, concrete can be supplied in a range of colours through additional of pigments in the mix, often in earthy tones, the natural chaotic tonal pattern of the surface enhanced by the colour.

Concrete can also be cast against surfaces to create natural, appealing and durable textures such as timber boards, fossilised stone, or even plant forms. Fundamentally it can also be created in curves, and sinuous forms.[6]

Figure 4.1 Cement grille of eco-friendly city parking lot with green grass

Source:. https://www.alamy.com/cement-grille-of-eco-friendly-city-parking-lot-with-green-grass-geometric-decoration-city-streets-texture-background-concrete-road-pavement-texture-image384797584.html

4. Stone & stone aggregates:

Stone as a building materials include both natural and cut stone that can be used in many construction application. The major factors affecting the suitability and use of stone construction fall under two broad, but overlapping categories: physical and structural properties and aesthetic. The three factors of building stone that most influence is selection by design professionals for aesthetic reasons are pattern, texture, and color. The natural and

cut stone can be used in landscaping as a Wall stone, Flagging & steppers, Landscape boulders & slabs, and steps. [7]

4.1. Stone &Aggregates and the environment:

Natural stone as a natural product, it is inherently earth-friendly. Natural stone currently offers many attractive, environmentally friendly attributes, including an enduring life-cycle, durability, ease of care and maintenance, recyclability, and quarry and manufacturing best practices. The greatest environmental impacts from stone and aggregate materials occur during the materials acquisition phase.

4.2. Enviromental impacts of Stone &Aggregates production:

- Where the acquisitions is the greatest environmental impacts from stone and aggregate life cycle, while the processing stage can incur environmental and human health impacts and produce a large amounts of wastes. In addition to the impacts of the transportation which produce high polluting, fuel use costs, resource consumption, and emissions. Finally Construction and use stage have a potential environmental and human health impacts during these phases.

- Use of natural or recycled stone and aggregate structures, such as dry stack walls, gabion structures, gravel pavements, porous aggregate pavements, or gravel trench foundations, can minimize some of these impacts. They can be durable, reusable, permeable, and less resource- and energy-intensive alternatives to concrete, asphalt, and concrete block in appropriate applications.

- There are strategies to reduce the environmental impact of the stone and aggregates and it summarized in Useless Material, Design for Disassembly, and Source stone and Aggregate Materials Locally.[8]

4.3. Stone and biophilic design:

stone can be used to provide interest to existing natural views by incorporating them into outdoor walls, patios, seating areas, and landscaping.

5. Building materials assessment instrument:

(Building research Establishment Green guide to housing specification (United Kingdom)) has been selected as an assessment tool, where it is program with database that

demonstrates the impact of the construction materials used (in the landscapes and buildings all types) on the environment, in contrast to the rest of the programs that evaluate the construction materials used in buildings only

5.1. Environmental impact Assessment of landscape materials by Building research Establishment Green guide to housing specification (United Kingdom):

The Green Guide is part of BREEAM (BRE Environmental Assessment Method) an accredited environmental rating scheme for buildings. The Green Guide contains more than 1500 specifications used in various types of buildingThe environmental rankings are based on Life Cycle Assessments (LCA), using BRE's Environmental Profiles Methodology 2008.

Materials and components are arranged on an elemental basis so that designers and specifiers can compare and select from comparable systems or materials as they compile their specification. The Landscaping element is covered in the assessment

This data is set out as an **A+** to **E** ranking system, where **A+** represents the best environmental performance / least environmental impact, and **E** the worst environmental performance / most environmental impact. BRE has provided a summary environmental rating - The Green Guide rating, which is a measure of overall environmental impacts covering the following issues: Climate change, Water extraction, Mineral resource extraction, Stratospheric ozone depletion, Human toxicity, Ecotoxicity to Freshwater, Nuclear waste (higher level), Ecotoxicity to land, Waste disposal, Fossil fuel depletion, Eutrophication , Photochemical ozone creation, and Acidification. [9]

5.1.1. Assessment of the concrete paving

From the assessment of the concrete paving types we can conclusion that the Concrete Block Pavers, CBP (60mm) over prepared recycled sub-base& the Concrete paving flags (60mm) laid over prepared recycled sub-base have a high rating(A+) than Concrete Block Pavers, CBP (60mm) over prepared sub-base&Concrete paving flags (60mm) laid over prepared sub-base with rating(A).

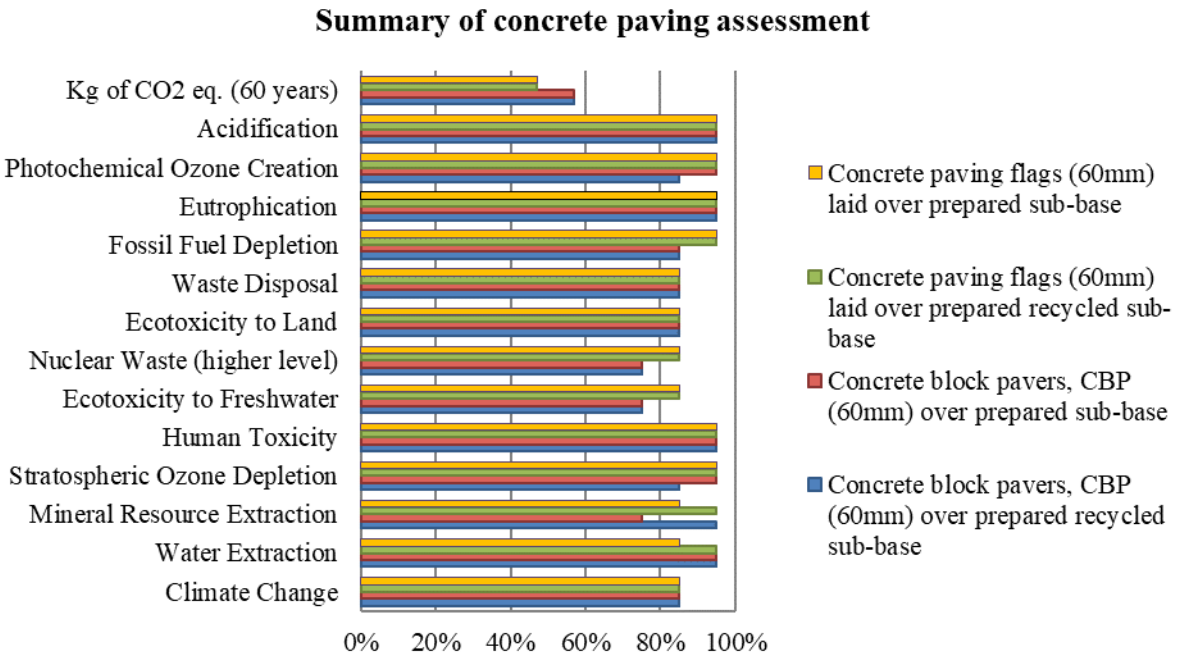

Figure 5.1 : shows a chart of an environmental assessment values of four types of concrete paving Using in landscape

Source: by the author 2016

5.1.2. Assessment of the stone gravel paving

From the assessment of the stone gravel paving types we can conclusion that Gravel over prepared recycled sub-base have a high rating(A+) than the Gravel over prepared sub-base(C) , which mean that the Gravel over prepared recycled sub-base have low environmental impacts in the landscape than the other type.

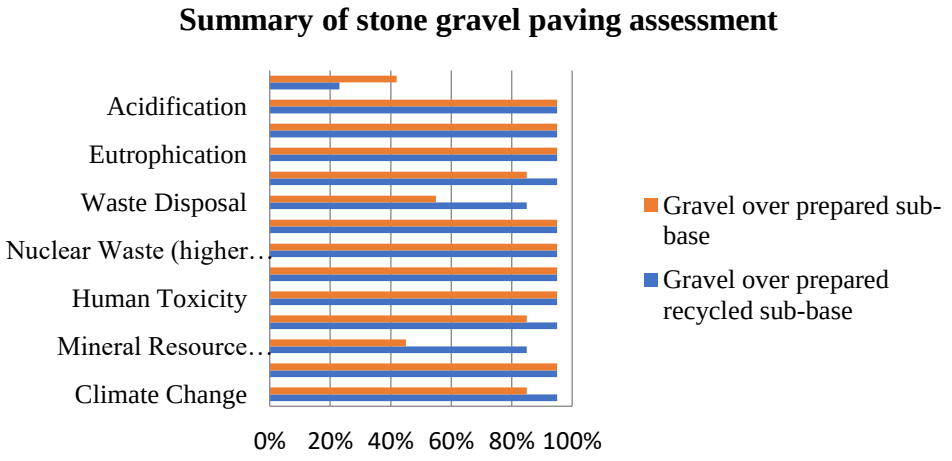

Figure 5.2 : shows a chart of an environmental assessment values of two types of gravel paving Using in landscape

Source: by the author

6. Analytical of local case studies (Giza zoo):

6.1. Architectural Description:

The Giza Zoo is considered one of the rare green spots in the heavily populated city of Cairo. The zoo, which is almost 80 acres in area, It is located across the River Nile adjacent to Cairo University.[10]

The zoo landscape consists of five hills. The most popular one is the Citadel Hill , where a stream flows through caves and ends in a waterfall that flows to a lake with two islands. These islands are connected by a suspension bridge (Figure 6.1) designed by Gustave Eiffel -- a French structural engineer who designed the Eiffel Tower in Paris and the armature for the Statue of Liberty. [11]

a

Figure 6.1 (a) :Gustave Eiffel suspension bridge

b

Figure 6.1 (b) :Hills and variety of vegetation in the zoo. Giza Zoo website photo.

Source: GEWAILY M., VISITOR EXPERIENCE IN ZOO DESIGN: DESIGN GUIDELINES FOR GIZA ZOO, MASTER OF LANDSCAPE ARCHITECTURE, B.S , Ain Shams University, Egypt, 2000

The original paths of the zoo were constructed of colored pebbles which were very carefully designed with different patterns all over the zoo.[12]

a

Figure 6.2 (a) : A bridge in the tea island**.**

b

Figure 6.2 (b) : Colored pebble patterns

Source: GEWAILY M., VISITOR EXPERIENCE IN ZOO DESIGN: DESIGN GUIDELINES FOR GIZA ZOO, MASTER OF LANDSCAPE ARCHITECTURE, B.S , Ain Shams University, Egypt, 2000

6.2. Using of concrete and stone in each of the elements of hard scape:

The zoo has a set of various elements of hard scape that appear throughout the park through a variety of building materials clearly, and are summarized in:

6.2.1. Paving:

The building materials used in the paving is:

A. Concrete*:*

Concrete block pavers come in a variety of shapes, sizes, and colors in some spaces in the zoo.But it destroyed and damaged as a result of the time factor and poor maintenance and use.

a  b  c 

Figure 6.3 (a,b,c): shows the application of the concrete as a colored concrete block paving in the path ways in different places in the zoo

Source: Field visit 2016

B. Gravel Stone and aggregates:

The main paths of the zoo were constructed of colored pebbles which were very carefully designed with different patterns all over the zoo. And the mixtures of light and dark colors are wonderful and the smooth shape and texture of the marble stone and colored pebbles add to their beauty. In addition to that Stone has considerable strength and is very durable and has long life low maintenance costs.

a  b 

Figure 6.4 (a,b) : shows the application of stone (specially colored pebbles) in a decorative paving in different shapes and Motifs

Source: Field visit 2016

c 

Figure 6.5 (c): shows the mix of using the colored pebbles and the marble in a beautiful motifs

Source: Field visit 2016

d 

Figure 6.6 (d): shows the using of pebbles as a steppers with a planted joints

Source: Field visit 2016

6.2.2. Steps:

The building materials used in the steps is:

A. Concrete*:*

Concrete is the most material used in the steps in the zoo

a

Figure 6.7 : shows the using of concrete in
a smooth shape in some places

Source: Field visit 2016

b

Figure 6.8 : shows the using of concrete in the steps of the sidewalk.

Source: Field visit 2016

B. Stone:

Stone are used (especially marble)clearly in stairs of the entrances of the zoo because of its sustainability characteristics and it used in the stairs of a bridge in the middle of the zoo.

a

Figure 6.9 (a) : shows the using of the natural stone has been extracted from the Fossilized Forest

Source: Field visit 2016

b

Figure 6.10 (b) : shows the using of the white marble in the entrance stairs

Source: Field visit 2016

6.2.3. Walls:

Stone are used in the walls in the zoo in a variety shapes and types, and that because of its beautiful shape and durability. And it used as regular and irregular shapes to boundary the places of animals and lakes. In addition to that the stone are used for cladding some walls in some places in the zoo.

a

Figure 6.11 (a) : shows the using of the painted limestone Rocks to build a boundary wall for the animals area

Source: Field visit 2016

b

Figure 6.12 (b) : shows the using of limestone in the cladding of the wall

Source: Field visit 2016

c

Figure 6.13 (c) : shows the using of the pharaonic stone in the cladding of the wall

Source: Field visit 2016

6.2.4. Seating:

The building materials used in the Seating is:

- ***Concrete:***

Concrete used also in the seating because of their characteristics (flexibility and ease of configuration) and help get the shape you want.

a

b

Figure 6.14 (a,b):The figures show the different application of concrete for making a seating in different shapes

Source: Field visit 2016

6.3. Construction materials used:

The zoo contains many of the building materials used in hard scape, and when the work of the field study was the discovery that the asphalt is more of the materials used in floors, followed by the stone, which was used in many of the hard scape elements, followed by concrete, and brick in addition to the use of some other materials such as wood and iron.

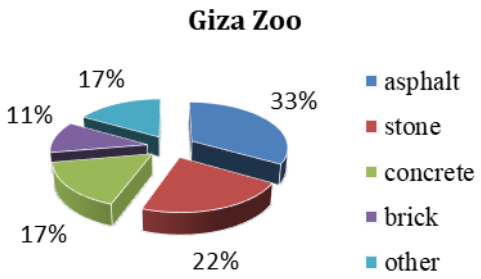

Figure 6.15 : shows the pie chart of the materials uses in the Giza zoo

Source: by the author 2016

6.3.1. The effect of the construction materials used on the environment:

Good choice for building materials used in the zoo led to reduce the environmental impact in general, that most of the construction materials used have a slight impact on the environment. Where it is in accordance with the Building research Establishment Green guide to housing specification program that was used to determine the impact of construction materials in the landscape of the environment, the construction materials used in the zoo has got a rating (A) which mean that the material have low environmental impact, Except for the asphalt has got rating (B).

After comparing the two materials in terms of achieving sustainability in the hard scape, we find that the stone to achieve sustainability of the highest rates in most of the elements. See figure (6.16).

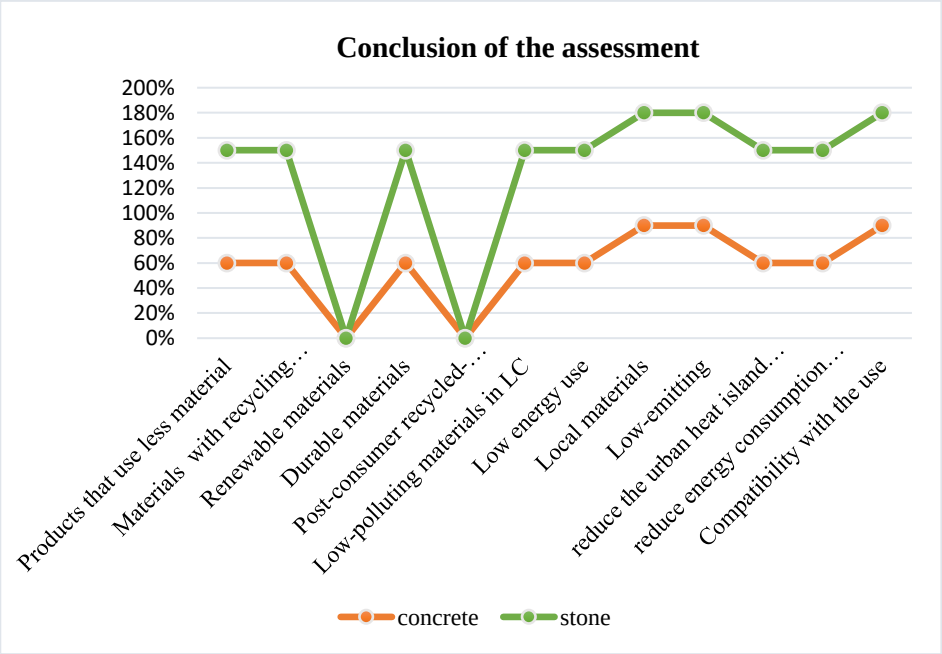

Figure 6.16: shows the conclusion of the assessment of the four materials in terms of the elements of sustainability

Source: by the author 2016

7. The results that have been reached through the analytical study :

- That most of the materials used in the zoo are local materials, safe for the environment and human, can be recycled except the asphalt.
- Re-use of building materials on some of the construction waste that is used on the site is limited .As The proportion of materials lacking of the recycled materials and Post-consumer recycled-content materials, and that the lack of industries that are working on the production of building materials recycled or recycled content.
- Also eliminates the use of renewable materials, as most of the materials used are manufactured products, with the exception of the stone, which is not considered a renewable material where it needs to be millions of years in order consists again.
- Most of the materials used are compatible with use dramatically and also help reduce the urban heat island effect on with the exception of asphalt, which has an effect on it.

The zoo has adopted a set of strategies that achieve sustainable building materials, including: methods of rationalization in use

and the use of local materials and safe materials that can be reused again

8. The strategies used to achieve sustainable building materials:

Through field visit, the conclusion that the zoo has used some strategies to achieve sustainable materials by:

- Using materials that minimize resource use, where that most of the materials used are durable materials and can be reused again or recycling such as stone
- In addition to, the materials are used have low environmental impact, as most of the materials used are durable materials, and are Low-polluting materials in LC.
- Also the used materials are posing no or low human and environmental health risks, cause they are Low-emitting materials and products.
- Finally, the Materials used assist with sustainable site design strategies, as reduce the urban heat island effect, and reduce energy consumption of site operation, like the stone and concrete in paving.
- While lacking the strategies that employ clean energy from natural sources like the sun and wind to achieve energy efficiency, and due to technical and economic factors due to the newness of these applications in the Egyptian construction market.
- In addition to no use of high permeability materials in paving to reduce storm-water runoff and allow rain water to run into the ground to replenish groundwater instead of surface waters of neighbors.

9. Recommendations:

- The need for standards and strategies to achieve sustainability in the landscape in the form of an integrated system puts controls requirements ,that must be met in a sustainable sites that attempt to reach what is better and more sustainable in the future mode.

- In addition, standards must be set for building materials that are used in the landscape in order to achieve sustainable landscape mode and biophilic design strategies.

- The need to encourage the use of local building materials, recycled materials with recycled content, in order to conserve resources and raw materials, and environmental quality

- Must study the nature and properties of building materials to determine the suitability of materials for use in the methods of the landscape application.

- the need to recognize the effect of these substances on the environment, in addition to study different impacts on the environment during the life cycle of every building material from the acquisition of raw materials to the construction and use

- The need to avoid the negative effects of building materials the some of the strategies to has been trend to reduce and to minimize these interactions , and these strategies are different for each material:

A. Concrete:

- Reduce use of cement in a concrete mix,
- and substitute appropriate alternatives
- Substituting recycled materials for virgin aggregates in concrete

B. stone:

- Useless Material,
- Design for Disassembly,
- And Source stone and Aggregate Materials Locally.

- We recommend architects trend towards the use of environmentally friendly building materials, which realized the principles of sustainability in the official and private project

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