Environmental Performance Of Construction Materials – An Appraisal Of Sustainability Assessment Rating Systems

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Abstract— With the rising environmental problems there are huge concerns around our activities towards the environment. And one of the most important & common issues is affecting the environment during building construction phase. Starting from ground clearing, grading, excavation & reaching the use of non environmental finishing materials. These construction activities have impacts on the environment such as affecting the air quality, acoustics (noise), cultural & ecological resources, hazardous materials, human health & safety, land use, transportation and water quality.

The main aim of the research is to propose suitable strategies for the upgrade of our GREEN PYRAMID rating system for buildings by imbedding special grading points for construction phase and the use of environmentally friendly construction materials

This paper will first study an international worldwide known assessment rating system which the LEED rating system then compare it with the GREEN PYRAMID rating system. It will study the sustainable measures and weighting of the two systems generally and the measures and weighting related to construction materials specifically. Examples of LEED certified construction materials will be studied, their characteristics, manufacture, economic value to see whether they can be used in our Egyptian community or not. Furthermore, these sustainable construction materials could be implemented as points for reaching sustainability in the GREEN PYRAMID rating system. Finally a checklist will be produced as a proposal for the upgrade of the GREEN PYRAMID rating system concerning the category of materials & resources.

Keywords— About four key words or phrases in alphabetical order, separated by commas.

I. Introduction

TYPICAL activities during the construction phase of a project include ground clearing and removal of vegetative cover, grading, excavation, blasting, trenching, drilling, vehicular and pedestrian traffic, and project component construction and installation. The research will first study the impacts of those activities on the environment. Secondly it will follow a quantitative study which is studying and analyzing an international worldwide known assessment rating system which is the LEED rating system and comparing it with the GREEN PYRAMID rating system to insure the professional implementation of successful points leading to sustainability in construction phase and the use of sustainable construction materials.

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II. Environmental Impacts of Construction Materials During Construction Phase

According to the International Association For Impact Assessment (IAIA) [1] & the office of Indian energy and economic development-TEEIC (Tribal energy and environmental information clearing house) [2] the following environmental impacts are among some of the impacts which may result from construction activities.

A. Air Quality

Emissions generated during the construction phase include emissions from vehicles used to transfer construction materials; VOC emissions of construction materials; small amounts of carbon monoxide, nitrogen oxides, and particulates from blasting activities; and fugitive dust from many sources such as disturbing and moving soils (clearing, grading, excavating, trenching, backfilling, dumping, and truck and equipment traffic), mixing concrete, storage of unvegetated soil piles, and drilling and pile driving. Air quality impacts could also occur if cleared vegetation is burned.

B. Land Use

During construction, most land use impacts would be temporary, such as removal of livestock from grazing areas during periods of blasting or heavy equipment operations; curtailing hunting near work crews; or temporary effects to the character of a recreation area because of construction noise, preparing construction material on site or implementing it in the building, dust, and visual intrusions.

C. Hazardous Materials & Waste Management

Solid and industrial waste would be generated during construction activities. The solid wastes are expected to be nonhazardous and consist of mostly containers and packaging materials, miscellaneous wastes from equipment assembly and presence of construction crews (food wrappers and scraps), wastes from preparing construction materials on site or implementing it in the building. Industrial wastes would include minor amounts of paints, coatings, and spent

solvents. Most of these materials would likely be transported off-site for disposal. Other hazardous materials would include dielectric fluids in electrical equipment used in substations and pump and compressor stations; lubricants and coolants added to prime mover equipment in pump and compressor stations; and compressed gases (for welding), solvents and cleaning agents, and corrosion control paints and coatings used for pipelines. Impacts could result if hazardous wastes were not properly handled and were released to the environment.

D. Ecological Resources

Adverse impacts to ecological resources could occur from activities to integrate construction materials in site which are:

- Erosion and runoff
- Fugitive dust
- Noise
- Introduction and spread of invasive nonnative vegetation
- Modification, fragmentation, and reduction of habitat
- Mortality of biota
- Exposure to contaminants
- Interference with behavioral activities

E. Soils & Geologic Resources

Surface disturbance, heavy equipment traffic, and changes to surface runoff patterns can cause soil erosion. Impacts of soil erosion include soil nutrient loss and reduced water quality in nearby surface water bodies.

Sands, gravels, and quarry stone would be excavated for use; concrete for foundations and ancillary structures; for improving ground surface for lay-down areas and crane staging areas; and, as necessary, for backfill in pipeline trenches. Mining operations would disturb the ground surface, and runoff would erode fine-grained soils, increasing the sediment load farther down in streams and/or rivers.

Possible geological hazards (earthquakes, landslides) can be activated by excavation and blasting for raw materials, increasing slopes during site grading and construction of access roads, altering natural drainage patterns, and toe-cutting bases of slopes. Altering drainage patterns accelerates erosion and creates slope instability.

F. Transportation

Materials transportation cause short-term increases in the use of local roadways. Heavy equipment would need to be continuously moved as construction progresses along the linear project. Overweight and oversized loads could cause temporary disruptions and could require some modifications to roads or bridges (such as fortifying bridges to accommodate the size or weight).

G. Water Resources

Water would be required for dust control, making concrete, and consumptive use by the construction crew. Depending on availability, it may be trucked in from off-site or obtained from local groundwater wells or nearby surface water bodies. Water quality can be affected by:

- Activities that cause soil erosion
- Weathering of newly exposed soils causing leaching and oxidation that can release chemicals into the water;
- Discharges of waste or sanitary water
- Herbicide applications
- Contaminant spills, especially oil.

Applying sand and gravel for road construction, layout areas, foundations, etc. can alter the drainage near where the material is used. Surface and groundwater flow systems could be affected by withdrawals made for water use, wastewater and stormwater discharges, and the diversion of surface water flow for access road construction or stormwater control systems. Excavation activities and the extraction of geological materials may affect surface and groundwater flow.

H. Acoustics (Noise)

Sources of noise during construction would primarily occur from equipment (bulldozers, chainsaws, pile drivers, and diesel engines) used for material installation. Other sources of noise include vehicular traffic and blasting.

III. Assessment Rating Systems and Construction Materials

As a result of the above impacts, various Assessment rating systems have emerged. The use of these rating systems became popular worldwide and even obligatory in some places to classify who barely fulfills the requirements of sustainability and who exceeds it. Examples of these rating systems are the LEED (American system), BREEAM (European system), CASBEE (Japanese system), Green Star (Australian system), Pearl (Arab system) and the GREEN PYRAMID (Egyptian system). All these rating systems consider the materials and resources used during construction of buildings, their impact on site and environment and they rate it according to a number of points. The GREEN PYRAMID rating system will be analyzed in comparison with the LEED rating system as it is the most commonly known rating system.

A. LEED- Green building rating system for new construction & major renovations

LEED stands for Leadership in Energy and Environmental Design which is a green building rating system originally developed in 1998 by the U.S. Green Building Council (USGBC) to provide a recognized standard for the construction industry to assess the environmental sustainability of building designs. (USGBC, 2002) [3]

Fig1.LEED Buildings rating system consists of 6 main prerequisites (USGBC, 2002)

A.1.Details of the category "Materials & Resources "

Prerequisite1 Storage & Collection of Recyclables
Credit 1 Building Reuse
Credit 2 Construction Waste Management
Credit 3 Resource Reuse
Credit 4 Recycled Content
Credit 5 Local/Regional Materials
Credit 6 Rapidly Renewable Materials
Credit 7 Certified Wood

B. GPRS – The Green Pyramid Rating System

The Green Pyramid Rating System is a national environmental rating system for buildings made by the Housing and Building National Research Center. It provides definitive criteria by which the environmental credentials of buildings can be evaluated, and the buildings themselves can be rated. Additionally, the System should assist building designers, constructors and developers to make reasoned choices based upon the environmental impact of their decisions. [4]

Fig2.Grren Pyramid rating system consists of 6 main prerequisites (EGBC, 2011)

B.1. Details of the category "Materials & Resources "
4.M.1 Presentation of a *Schedule of Principal Project Materials*
4.M.2 Elimination of exposure to hazardous and toxic materials
4.1 Regionally procured materials
4.2 Materials fabricated on site
4.3 Use of readily renewable materials
4.4 Use of salvaged materials
4.5 Use of recycled materials
4.6 Use of lightweight materials
4.7 Use of higher durability materials
4.8 Use of prefabricated elements

C. Materials & Resources category weighting in LEED & Green pyramid rating systems

TABLE I
A Comparison Between LEED & GPRS Category Weightings

LEED	Category %	GREEN PYRAMID	Category %
Sustainable sites	**20 %**	**Sustainable sites**	**15 %**
Water effeciency	**7 %**	**Water effeciency**	**30 %**
Energy & atmosphere	**25 %**	**Energy effeciency**	**25 %**
Materials & resources	**19 %**	**Materials & resources**	**10 %**
Indoor environmental	**22 %**	**Indoor environmental**	**10 %**
Innovation & design process	**7 %**	**Management**	**10 %**

It is observed from the comparison in TABLE I that the weight (percentage) of the category materials and resources in LEED rating system is nearly double the weight of this same category in GREEN PYRAMID which shows that there is a high concern on materials and resources in LEED more than GREEN PYRAMID. A result of this weighting was the appearance of many new construction materials which are LEED certified for their environmental quality. These materials will be analyzed to see whether they can be used in the Egyptian environment or not.

IV. LEED CERTIFIED CONSTRUCTION MATERIALS

The following case studies are examples of LEED certified construction materials which show the upgrade in material characteristics to be sustainable as a result of the high weighting of material & resources category in the LEED rating system. These examples will be studied to show the importance of the upgrade of construction materials.

A. EABASSOC Foamed Concrete

EABASSOC Foamed Concrete shown in Fig3. is a lightweight, free flowing material which is ideal for a wide range of Applications. It is made by adding special foam to a cement mortar slurry. This foam is made from EABASSOC Foaming Agent, a highly concentrated, highly efficient, low dosage liquid which is fed with water into a Foam Generator. [5]

A.1. Properties

- Does not settle
- No compaction or vibration needed
- Free flowing, spreads to fill all voids
- Non-hazardous
- Reliable quality control
- Highly cost effective
- Can be pumped

- Lightweight, reduces direct loading
- Excellent load spreading characteristics
- No maintenance required
- Excellent sound and thermal insulation
- Excellent resistance to freeze-thaw
- Does not impose lateral loads
- Low water absorption over time
- Excellent fire resistant property

Fig.3 Application of EABASSOC Foamed Concrete
Source: www.eabassoc.co.uk

Fig.4 EABASSOC Foamed Concrete after application
Source www.eabassoc.co.uk

A.2. Uses and Advantages

- Lightweight Blocks
- Void Filling
- Roofing Insulation
- Bridge Abutment
- Trench Reinstatement

It can be placed easily, by pumping if necessary and does not require compaction or leveling. It has excellent water and frost resistance and provides a high level of both sound and thermal insulation. The foamed concrete formed is very stable and lightweight, and will not sink into soft ground or impose undue loading on roofs and other structures. It is very versatile and since it has a huge range of dry densities and strengths, it can be tailored for optimum performance and minimum cost by choice of a suitable mix design.

B. FLORIM Tiles (FLOOR GRES)

LEED certification rewards the use of construction materials that have a significant percentage of pre-consumer recycled content (on average from 20% up). The Florim series with recycled content enable a building to earn up to two LEED credits in the "Materials & Resources" category. Florim tiles release substantially zero values of VOC (Volatile Organic Compounds), therefore do not emit any pollutants in theair.

Florim products therefore enable a building to earn one LEED credit in the "Environmental Quality" category. Light-coloured florim tiles have a Solar Reflectance Index much higher than 29 and for this reason they considerably reduce the heat island effect, enabling a building to earn one LEED credit in the "Sustainable Sites" category. Also All Florim ceramic tiles that contain a percentage of pre-consumer recycled material greater than 40% of their weight earn up to a maximum of 5 credits. [6]

Fig.5 Floor Gres Tiles.
Source: http://www.floorgres.it/en/leed.asp

B.1. Properties

- Low emission materials
- Heat island effect (High solar reflectance index)
- Innovation in design
- pre-consumer recycled content

C. BioBased Insulation

BioBased Insulation is working towards increasing the sustainability of spray foam insulation. One way is by replacing a portion of the petroleum content with bio-based content. The bio-based products contain 3-15% bio-content in the finished foam based on third-party testing. to make them more sustainable, alternative ingredients are used, such as using water as a blowing agent. There are open cell insulations, closed cell insulations and closed cell sealants.[7]

C.1. Properties

- Reduces energy consumption needed for climate control by reducing infiltration
- Minimizes sound transfer & Increases thermal resistance
- Reduce the risk of moisture accumulation within the building envelope
- Expands 100:1 filling voids, crevices and building cavities

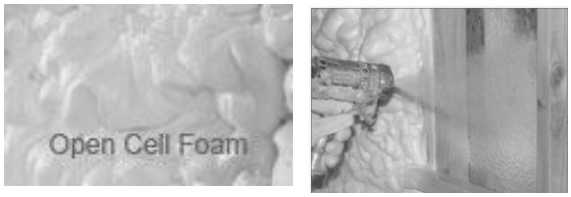

Fig.6 Bio Based spray Insulation
Source: Construction Specifications Institute (CSI)

D. Conclusion

It is concluded from analyzing the previous materials that all the materials are highly efficient material, with low emissions (low VOC), high recycled content or are manufactured regionally within a radius of 500 miles. The following differences were also concluded from the analysis of material certification(both LEED & GPRS).

V. CONCLUSIONS & RECOMMENDATIONS

It is concluded from the following comparison (TABLE II) that both rating system have nearly similar requirements under the "Material & Resources" category, but with some differences, for example the LEED rating system in the regional material requirement is more concerned about the distance upon which the material is considered regional (which is 500 miles) as USA is a large country while in GPRS, the rating system just stated that the material to be considered regional must be from Egypt. Thus dividing Egypt by regions should be recommended to specify the regional materials as each region in Egypt has its own properties.

Also concerning the renewable material requirement LEED stated that to gain a point the material should be from a *rapidly* renewable source (maximum of 10 years), while GPRS only stated "a renewable source". That is why it is recommended in GPRS that a time line should be specified for a material to proof that it is rapidly renewable.

LEED required the building to maintain 75-100% of existing walls, floors & roofing if present in addition to the use of reused materials, while GPRS only requires the use of reused materials. Thus maintaining the existing structure of a building if present should be a prerequisite in GPRS.

In case of the use of recycled materials the requirement of the LEED was Recycled content 10% (*post consumer + ½ post industrial) while the GPRS recycled content was 10% (30% post consumer + 80 % post Industrial content +50% agricultural waste by products*). Thus increasing the dependence on agricultural waste materials is recommended as Egypt has a high percentage of agricultural lands which produce high amount of agricultural wastes which is mostly dumped in rivers and seas thus by using these wastes, water pollution is prevented. Also increasing the dependence on post consumer construction wastes is recommended to decrease pollution produced from the great percentage of construction and building waste in Egypt.

TABLE II
Comparison Between LEED & GPRS Regarding Materials & Resources Category

Points of comparison	LEED - Material Certification	GPRS- Material Certification
Regional materials	20-50% of materials extracted and manufactured within *500 miles of site*	25-75% of materials extracted and manufactured in *Egypt*
On site materials	Not mentioned	-Materials fabricated on site
Renewable materials	Use *rapidly renewable* building materials and products (made from plants that are typically harvested within a ten-year cycle or shorter) for 5% of the total value of all building materials and products used in the project.	5-20% of materials from *renewable* materials(earth materials, natural stone, palm tree products, bamboo, wool, cotton for insulation, agrifiber, linoleum and products made from crop fibres, such as rice and barley straw.)
Reused materials	5-10% salvaged, refurbished or reused materials, *Maintain 75-100% of existing walls, floors & roof*	25-75% reused building material
Recycled materials	Recycled content 10% (***post consumer + ½ post industrial)***	Recycled content 10% (***30% post consumer + 80 % post Industrial content +50% agricultural waste by products)*** Recycling content in steel, concrete, aggregates
Light weight materials	Not mentioned	25% of Total materials are light weight
Durability	Not mentioned	25% of Total materials with higher durability
Prefabricated materials	Not mentioned	Use of prefabricated elements
Life cost cycle	Not mentioned	Life cost cycle analysis of materials in project
Building Reuse	Recycle and/or salvage at least 50-75% of construction,demolition & land clearing waste	Not mentioned
Certified Wood	Use a minimum of 50% of wood-based materials &products, certified with the Forest Stewardship Council	Not mentioned

As a result of the comparison between the two rating systems and the analysis of the LEED certified construction materials it is recommended to increase the weight of "Materials & Resources" category in the GREEN PYRAMID rating system

in order to increase the concern on the use of materials during construction in addition to the following checklist (Table III) which contains several points of concern under the category

TABLE III
Checklist For The Upgrade Of The Green Pyramid Rating System

CATEGORY	POINT TO BE UPGRADED
REGIONAL MATERIALS	SPECIFY A MAXIMUM DISTANCE FOR THE MATERIAL TO BE REGIONAL
RENEWABLE MATERIALS	SPECIFY THAT THE MATERIAL SHOULD BE FROM A SOURCE WHICH IS RAPIDLY RENEWABLE (SPECIFY A TIME)
REUSED MATERIALS	IF THERE ARE PARTS OF AN EXISTING BUILDING THE SYSTEM SHOULD SPECIFY THE REUSING OF EXISTING WALLS, FLOORS OR ROOF MATERIALS
RECYCLED MATERIALS	INCREASE THE DEPENDENCE ON POST CONSUMER AND AGRICULTURAL WASTE MATERIALS
CONSTRUCTION WASTE MATERIALS	SPECIFY THE RECYCLING OR REUSE OF MATERIALS PRODUCED FROM CONSTRUCTION WASTE OR LAND CLEARING WASTE (EX. EXCAVATION OR GROUND REMOVAL)

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