A Survey of Factors and Life Cycle Assessment in Selection of Green Construction Materials

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Abstract – During both the preliminary design phase, when broad, overarching decisions about the building's function and appearance are made, and the detailed construction plan level, material selection plays a crucial part in realizing the 'Green Buildings' goal (when materials present on the market are chosen). Architects and engineers responsible for making this option typically lack access to assessment tools aimed at assisting them in the selection of materials, despite the fact that this second factor is just as crucial to the actual fulfillment of 'greenness' standards. The environment is being harmed by human activities such as manufacturing, transportation, and mining. Saving the planet's natural resources has proven difficult for scientists and engineers since doing so means lowering society's performance, development pace, and standard of living. We have gone a long way in creating tools that might prevent more ecological damage and slow the depletion of vital resources. The notion of "green buildings" is based on the same idea. Increasing a building's energy efficiency utilizing green natural or renewable resources rather than non-renewable resources is a key component of green construction, according to this perspective. In this study, we discuss the criteria that should be used to pick green building materials.

Keywords – Materials Selection, Green Construction, Building Materials, Life-Cycle Assessment, Zero Energy Building

I. INTRODUCTION

The construction industry has a significant negative effect on the environment due to its use of 40% of the world's extracted natural resources, 70% of the power, and 12% of the world's drinkable water, as well as the generation of 45-66% of the garbage sent to landfills. In addition, it is projected to increase when the globe’s population increases from 6 billion in 2005 to approximately 9 billion by 2035. Reducing buildings' negative effects on the environment is of paramount importance here. Over the past few decades, much attention has been paid to decreasing the amount of energy needed during the building's operational phase (heating, ventilation, cooling, lighting, operating appliances, hot water, etc.) This has resulted in an increase in the dynamic buildings’ performance while in use.

The modern push toward the utilization of renewable energy sources has resulted in the rapid expansion of the Zero Energy Building (ZEB) concept [1], which requires that the annual balance of energy between the energy employed to operate the building as well as the energy realized from renewables, such as in "solar houses," be zero. The objective of the “Near-Zero” energy buildings was to usher in 2018, and the objective of newer buildings was to set in for 2020, as stated in the Directive of the European Parliament 2010/31/EU on buildings’ energy efficiency. At the same time, the environmental effect of building materials—during the construction phase—became an increasingly prominent topic of discussion (raw materials abstracted, process of manufacturing, and distribution to building sites). The factors established in the Life Cycle Assessment (LCA) technique (ISO 14040) allow for the quantification of such an effect, which may include energy demand, water depletion, contributions to greenhouse gas generation, etc.

Among these factors, the 'embodied energy' (EE) of construction materials has acquired special prominence due to its central role in mitigating the effect of structures while also being notoriously difficult to measure and transfer into public opinion. The term "embodied energy" often refers to the energy amount utilize in the abstraction, manufacturing, and transportation of materials; however, numerous Shi, Li, Guan, Sun, Guan, and Liu [2] argue that it ought to integrate the "recurrent" EE needed in the management and refurbishment of building components and materials, as well as the "demolition energy," required for the dismantling of buildings and the disposal of materials. If we exclude the various forms of ecological effects induced by construction materials, EE alone currently accounts for approximately 2% to 38 % of energy used throughout the 50-year lifespan of a typical structure and for 9-46% of the total energy spent in low energy consumption buildings. In fact, Brenner [3] argues that low-energy constructions outperform ZEBs throughout the course of their whole life cycle. This is because zero-energy buildings tend to utilize high materials that are energy-intensive (i.e., composed of high EE). To really adhere to a 'cradle to grave' attitude, it is necessary to consider not just the energy used during operation, but the energy employed during the entire life cycle. This requirement has recently been addressed by the concept of 'life cycle ZEB' or 'net-ZEBs.

Three billion tons of raw materials are used annually in cutting-edge building and construction operations, which is forty percent of the total global consumption. Around 40% of the world's materials, 30% of its energy, and 10%-40% of most nations' solid waste streams are used up by the construction and maintenance of structures. Sustainable construction practices help preserve finite, nonrenewable materials. The environmental problems caused by the mining, lumbering, logging, installation, processing, fabrication, recycling, reuse, and landfilling of construction industry source materials may be mitigated by the usage of green construction materials in building projects.

Large quantities of energy produced from fossil fuels and the relocation of megatons of earth during mining are required in the production of many of the materials used in construction. By comparison, polymers need 80-100 GJ/ton, steel and other metals require 30-50 GJ/ton, glass requires 20 GJ/ton, and cement/concrete products require 1.3-5 GJ/ton of energy input. However, the mining and processing of the raw materials required making one ton of cement results in the release of almost one ton of carbon dioxide and as much as six kilograms of nitrogen oxides. As a result, construction is a major cause of pollution and climate change across the world. Sustainable urban development necessitates construction practices that not only lessen their impact on the natural world, but also boost ecosystem health and save vital natural materials.

Using the "green building" method is the prudent option here. It's a method for making structures and infrastructure that consume fewer resources, have fewer negative effects on the environment, and provide better settings for people to live in. To be considered "green," a building must meet stringent environmental, economic, and engineering standards. These standards include, but are not limited to: low energy consumption, high indoor air quality, low resource consumption, low maintenance and replacement costs during the structure's lifetime, good occupant health and productivity, easy access to public transportation, and excellent environmental quality across air, water, land, and ecosystems.

In this article, we outline the considerations that should go into making material choices for environmentally friendly buildings. The article continues with the following structure: Section II presents a discussion of the principles of materials section. Section III discusses materials in general as well as green construction materials. Section IV focuses on the factors to consider in the selection of materials. Section V is about the life cycle assessment (LCA), with details such as a brief history of LCA, definition of LCA, and application of LCA, provided. Section VI is the last section of this article and provides concluding remarks to the paper.

II. MATERIAL SELECTION PRINCIPLES

Research

Manufacturer information such as Indoor Air Quality (IAQ), Material Safety Data Sheets (MSDS), source materials features, test data, recycled content data, product warranties, durability data, and ecological statements is gathered at this stage for evaluation. Further study on environmental concerns, government laws, building rules, construction industry papers, model green construction product specifications, and other sources of product data may be required at this stage. Through investigation, a comprehensive list of potential construction materials for a project may be compiled.

Evaluation

At this stage, we validate the technical details and fill in the blanks. Comparing construction materials of the same kind using environmental criteria makes evaluation and assessment straightforward. When comparing items with the same purpose, however, the assessment procedure becomes more involved. This might lead to a situation where processing both qualitative and quantitative data is required.

Selection

At this stage, an assessment matrix is used to assign weights to various environmental factors relevant to the project at hand. The product with the best environmental characteristics will be indicated by the highest overall score among those evaluated. The grading system's weighting of its many criteria may be adjusted to suit the needs of individual projects. The highest-rated materials are selected for their intended usage.

III. MATERIALS AND GREEN CONSTRUCTION MATERIALS

Definition of Materials

The word "materials" describes all of the physical things that are combined to form a building's interior and exterior. Most modern structures are made from a wide variety of materials, each of which has its own unique set of performance criteria and assembly complexities. A building's external wall assembly, for instance, would include weather-proofing, thermal insulation, mechanical rigidity for the enclosure system, and aesthetically pleasing interior and exterior finishes, among other functions. The building's inside and outside are linked by its many openings, such as windows, doorways, vents, and so on. There are several factors to consider when deciding the materials to use in a building's construction and design.

Definition of Green Building Materials

There is currently no clear-cut definition of "green construction materials," although they are often referred to as "environmentally friendly" or "environmentally responsible" materials. As a result of this ambiguity, several products have entered the market with a vague claim of "greenness" but no evidence to back up the claim. Asbestos, which was once added to many construction materials but has since been banned due to its carcinogenic effect, radon, which can be released from certain stones in a building and is linked to an increased risk of turpentine, and lung cancer, a solvent received by distilling the tree resin and also linked to an increased risk of cancer, are all examples of materials that are often mistakenly deemed "green" because of their "natural" status. Green building materials are those that (i) are safe for human health, meaning they do not lead to negative effects on the basis of indoor air quality, and (ii) are sustainable throughout their entire life cycle, wherein their sustainable development can be substantiated by the LCA approach, from cradle-to-grave point-of-view.

Both the interior climate (such as the presence of wetness in portions of the structure or on surfaces) and the indoor pollution (hazardous fibers dispersion, volatile organic substances, biological contaminant proliferation, and radon emissions) must be taken into account. One of the first problems that arise when trying to apply such a definition is the fact that there is no such thing as a "perfect green building material" that can be contrasted with "not-green" materials, since the production, transportation, installation, and disposal/recycling of materials typically mean a non-zero effect. Due to this, it is nearly impossible to compile a definitive list of eco-friendly materials; rather, in each design process, the most eco-friendly options should be selected from those currently available on the market, taking into account the most cutting-edge technologies and the desired level of performance. This places a heavy burden on those making design decisions and highlights the significance of materials choice.

Desired Features for Green Material

Materials for green construction are selected according to a variety of parameters. Materials that (i) are created from recycled and salvaged agro-industrial wastes, (ii) utilize less material without losing quality, (iii) are biodegradable, (iv) have minimal emissions of volatile organic compounds (VOC), and (v) don't contribute to ozone depletion are all examples. Products (vi) that are either naturally occurring or have had minimal processing; (vii) that are alternatives to natural wood but are not made of PVC; (viii) that help cut down on pesticide use and pollution; (ix) that help conserve energy and water; (x) that help lessen the negative effects of construction, demolition, renovation, or retrofitting on the environment.

IV. SELECTION OF MATERIALS

In building construction, material choice is crucial since it affects both the project's performance and the likelihood of success in meeting design objectives. The embodied energy of a construction, carbon dioxide emissions, energy used in the manufacturing process, environmental effect throughout the whole life cycle, energy needed to operate the structure, and any discomfort caused by poor air quality may all be mitigated by making smart material choices. For optimal results and choices, designers must take into account a number of elements while making material selections. Mechanical qualities, environmental performance, physicochemical parameters, and safety are only few of the factors that are taken into account. Nonetheless, the items' aesthetic qualities and esoteric significance may impact evaluations, sales, and material choices. More and more data suggests that decision making may be subpar when emotions are removed.

Emotions serve a variety of purposes throughout the decision-making process and are crucial to solving every significant challenge we confront. Affect, or how one feels in response to a stimuli, facilitates comparisons between seemingly unlike occurrences and intricate concepts. Zhen, Xie, Dong, and Chen [4] claim that emotions serve as information that guides decisions, a spotlight that illuminates novel information for further processing, a motivator that shapes one's tendencies toward action or aversion, and a medium of exchange for their respective experiences (just as money does for goods). Hence, designers want data on sensorial and apparent values, which are influenced by a wide range of factors including but not limited to culture, cognition, and emotion. Unfortunately, there is a lack of exposure to data on how values are really viewed. The influence of materials on emotions is not always measurable, making it much more challenging to offer information on these values.

Many researches on sustainable material qualities have been conducted, revealing the incorporation of both objective and subjective metrics into discussions on what constitutes a sustainable material. Sustainable materials have a high percentage of recycled content, produce few harmful byproducts, decompose quickly, may be recycled and reused several times, and are devoid of harmful byproducts. Sustainable materials are ones that are simple to create with, safe to use, provide high levels of satisfaction to the user, meet a public need, do more with less resources, are socially and artistically rewarding, and break trends. While there are more and more resources available to learn about sustainable materials, academics have yet to settle on a clear classification, which sometimes leads to ambiguous definition and use of the word. The term's multifaceted nature makes it difficult for construction professionals to agree on a single definition, which in turn makes it more challenging to choose the appropriate building materials. Designers require access to data on all the aspects and their relationships in order to pick materials thoroughly. There are a lot of ways to approach the materials selection issue. A multi-attribute decision framework matrix was created by Kim, Hong, and Song [5] to take into account all the factors that might have an impact on a final choice.

Lee, Jiang, Lee, Huang, and Cheng [6] proposed a Grey Relational Analysis (GRA)-based multi-objective optimization model to take into account several criteria and needs at once. Dittrich, Katzenbeisser, and Reisinger [7] used a ranking system to assign relative importance to qualities and order materials in terms of how well they meet a number of criteria. In order to quantitatively rank its preferences, Kumar, Ramesha, Jagadha, Gururaj, Kumar, and Chaitanya [8] devised a simplified version of a fuzzy logic technique that takes into account the decision-maker's experience and judgment and translates it to fuzzy descriptions. Ni, Zhao, Xu, and Wang [9] designed a model for multi attribute decision making that takes into account the weights given to each element and the connections between them. To choose sustainable materials, Mohamed, Mohamed, Abo-bakr, and Eltaher [10] created a multi-objective optimization model that takes into account things like price, mechanical qualities, process performance, and environmental effect over the product's whole life cycle. Yet, research into the ways in which sustainable design elements may affect consumer opinion and final choice of construction materials is lacking.

Factors Considered in Materials Selection

Natural, renewable, or plentiful

Do the items use quickly renewable resources like cork or bamboo? Renewable resources include both wood and wood products. It takes far less timber to produce engineered wood items since many of them are crafted from rapidly reproducing species like aspen. When most people hear the word "renewable," they picture alternative energy sources. They are correct in their observation that the phrase "renewable material" refers to any resource that does not deplete with time and may be produced quickly. So, the phrase does not only relate to energy sources, but also other elements that may be reused and naturally replaced in construction.

Several different sustainable construction technologies and materials go into making up a natural structure. Durability and the application of minimally-manufactured, renewable, or abundant materials are crucial in natural construction, as are resources that, even when salvaged or recycled, provide healthy living conditions and preserve the indoor air quality. Natural construction often makes more use of human labor compared to how it does to technological advancement. Zhou [11] note that "local ecology, geology, and climate; on the character of the specific construction site; and on the demands and personalities of the builders and users" all have a role.

The driving force behind natural construction is the desire to minimize the negative impacts of structures on the ecosystem without compromising on human health and convenience. Sustainable construction practices like natural building prioritize the use of locally sourced, renewable, reclaimed, and repurposed resources. More and more attention is being paid to the usage of quickly renewable materials. In addition to using eco-friendly materials, designers put extra thought into the structure's aesthetics. A building's orientation, use of local climate and environmental condition, and a focus on natural ventilation via design may significantly save operating costs and have a good effect on the environment. Constructing on a smaller footprint, using renewable energy sources, recycling gray water, and reusing rainwater are all popular practices.

Recycled content

In addition to lessening the load on landfills, the use of recycled content cuts down on the demand for raw materials. Common recyclables include paper, cardboard, plastic, steel, and aluminum. Cellulose insulation and paper worktops are two common uses for recycled paper. Carpet is made with plastic. Recycled metals may be resmelted and used again. Hundreds of businesses have tried to get an ecological advantage in the marketplace by emphasizing the recycled materials in their wares. The Federal Trade Commission (FTC) has authority over such representations, and in 1992 it released the first edition of its Green Guides, which provide definitions for a variety of environmental words. The ISO 14021 standards of recycled content are used to award points in the LEED Rating System. Such definitions may still leave a lot of room for interpretation, and manufacturers will naturally lean toward reading them in their advantage. Verification of recycled content claims by independent certification is helpful. The term "recycled content" describes the percentage of a product's raw materials that have been reused or recycled. Pre-consumer recycled content refers to materials that are recycled before they reach the customer (sometimes known as post-industrial). They are considered post-consumer if they are redirected after being used by consumers.

Reusability and recyclability

Once their useful life is through, many things, such as metals, may be recycled. Some things can be thrown away, while others can be used again. The European Waste Framework Directive (2008/98/EC), under Article 3, defines reuse as "any activity through which items or components that are not garbage is employed again for the same purpose as for which they were intended". It is important to comprehend the various reusability classes, since each class is obliged to vary in degrees of environmental consequences, spanning from very tiny to very big items. One of them is remanufacturing, which may be defined as the industrial recycling of materials. It is important to remember that bringing an EOL product back to life via remanufacturing uses energy. Scientists in [12] conducted a thorough investigation showing that remanufacturing may result in considerable cost savings when contracted to traditional processing (i.e., the establishment of novel products using raw materials). They discovered that the potential energy savings from remanufacturing vary widely across different products.

Agyei Boakye et al. [13] conducted a first LCA assessment to assess the usefulness of recycling PET bottles. The authors found that reusing a single conventional 500 ml water bottle instead of producing a new bottle from scratch would result in a savings of approximately 33g of CO_2/bottle, and 1 MJ in terms of processing energy. Moreover, they showed that reusing a PET bottle only once resulted in around 182% less CO_2 output and 74% energy savings than the recycling EOL option.

The Kjaer Weiss cosmetics company out of Denmark is another fascinating case study. Kirsten Kjaer, the company's founder, saw a way to set her beauty line apart from the competition by designing its containers to be refilled (making them reusable) while maintaining its high luxury reputation. Kjaer Weis demonstrates how simple it is for a customer to refill a reusable compact on their own by removing the used cosmetic cartridge and replacing it with a refill tray. This method is 30% cheaper than buying a new compact. Refillable versions of its most popular products—mascara, lip gloss, and eyeliner—account for around 25% of yearly sales [14].

Reusing materials from products that have reached the end of their useful life rather than sending them to landfills is the essence of recycling. This has several advantages, including a slower pace of natural resource harvesting thanks to the utilization of recycled materials, less trash transported to landfills, and less energy use. Nevertheless, restricted economies-of-scale and the chances of EOL contamination of product imply that recycling is not the most preferred EOL choice throughout the globe. The Plastics Industry Association created a global recycling class model known as Resin Identification Code (RIC) to categorize different plastics on the market since not all plastics are recycled in the same way. Commonly recycled plastics include PET, HDPE, and PVC, but PP, LDPE, and PS are not because they tend to be trapped in recycling machinery.

Others are thinking of utilizing natural polymers that can be recycled. Although there are still some obstacles to be overcome (such as high production costs), biodegradable plastic packaging alternatives have been studied by Salini, Resmi, and Antony [15] and are expected to become widely used in the next years. Recyclable polymer composites for food packaging were the subject of investigation by Hejna [16]. The study concluded that biodegradable polymers may be utilized for food packaging if the safety of such packaging could be guaranteed. Further study and innovation are needed in this field. Unfortunately, no relevant research from the cosmetics business was located.

Durability

Choose materials that would not break easily and would not need to be replaced often. This will prevent the need for unnecessary future maintenance. The designer's prior knowledge and the data obtained via iterative design iteration are the usual starting points for material selection. The information gleaned from one application of a system may be put to use in another. The effectiveness of this method is heavily reliant on the designer's team's familiarity with the chosen building system. The designer will not have optimized the design for cost or usage of materials because of a lack of familiarity with the specific building technology. The long-term performance of the building's materials and systems should be linked to the potential environmental and operational stresses they will face. Nowadays, there is a special challenge in the field of durability. The technical definition of this common phrase is "the duration of service life of a specific material or system under specified parameters of outdoor and interior environment and structure of the assembly," but the popular meaning is "the capacity for extended time performance."

There are no "not durable" materials per such; rather, materials will have varying degrees of longevity depending on environmental factors and how they interact with one another. As we are essentially discussing Risk Management, we will have to analyze a number of potential outcomes for the design process. The cost-benefit analysis for each of these possibilities should include in both monetary and intangible gains. The monetary impact of a failure has to be included in with the costs of building, operation, and maintenance. Any aspects of sustainability that can't be measured monetarily must be accounted for on the non-economic side. The rate of damage is proportional to the environment's harshness; hence the harshness of the environment used to generate the damage function should be taken into account. To rephrase, we can pinpoint the exact moment of failure in the controlled laboratory setting, but we need to make an educated guess as to when it will occur in the real world (i.e. What might the service life be in the real world?).

Embodied Energy

The total amount of energy that is not renewable or primary energy that is released into the atmosphere as a result of the extraction, production, construction, maintenance, and disposal of a building material is referred to as the embodied energy of that material. This refers to an energy amount needed to process, transport, and set up a product or material to the location where it will be consumed. Choose local goods wherever you can, as well as those that don't take a significant lot of energy to create. Embodied energy is a metric that is examined in order to analyze the life cycle of buildings. It is directly connected to the built ecosystem's sustainability and plays an important role in the evaluation process. Recurrent embodied energy, operational energy, and initial embodied energy are the three categories under which embodied energy and carbon emissions are investigated and assessed in connection to buildings.

Initial Embodied Energy

This refers to the nonrenewable energy that is used up throughout the stages of raw material acquisition, processing, production, transportation, and building. For instance, the extraction of the ore, production, shipping, manufacture, and delivery to the construction site all contribute to the original embodied energy that a steel window holds. The origin, category, and nature of the construction material all have an impact on the initial amount of energy that is embodied in the material.

Recurring Embodied Energy

It refers to the amount of energy that is not renewable that is used up over the lifetime of a building for activities such as maintenance, repair, restoration, refurbishing, or replacement of materials, elements, or systems. It is affected by the longevity of the structure itself, as well as the materials, systems, and elements that are put inside it, as well as their respective levels of durability and ease of maintenance.

Operating Energy

It refers to the energy that is continuously used in buildings for functions such as heating, cooling, ventilation, and lighting. This energy may be obtained by either passive or active energy systems. The original amount of energy that was embodied in the building decreases in significance as time passes, but the operational energy continues to rise along with the age of the structure. The building industry places a significant emphasis on initial embodied energy as a primary consideration. For example, concrete is the most prevalent man-made substance in the world. Cement manufacturing accounts for about 8% of the globe's overall CO_2 emissions and is the leading source of embodied carbon in the physical environment. Concrete is also the most common material used in construction.

It is anticipated that embodied carbon will account for close to 50% of the total carbon footprint of new buildings between now and the year 2050. It is the key factor responsible for environmental problems such as the depletion of natural resources, the generation of greenhouse gases, and the deterioration of the ecosystem. The initial embodied energy is represented in Giga Joules (GJ) units or Mega Joules (MJ) units per unit of weight or area. The measurement of embodied energy is a complicated procedure that is affected by the geographical area of the manufacturing technology as well as the production technique. This is because embodied energy is a measure of the energy that is used during production.

The most important thing for civil engineering and architectural professionals to focus on is cutting down on the amount of carbon dioxide that buildings release into the atmosphere. To develop environmentally responsible projects, it is necessary to investigate and quantify the amount of embodied energy or carbon included in the building materials. The Life Cycle Assessment (LCA) is a helpful method that is used to identify the issues throughout the building's life cycle that have the largest influence on the surrounding environment. It's possible that the evaluation may need you to compare several materials that provide the same purpose; for instance, you could compare a frame structure made of steel, wood, or concrete. Instead of making judgments based on fashion or profits, sustainable choices may be made by first gaining an understanding of the EE of materials utilized in design and construction.

Air Quality

Source control was identified as the most cost-effective and effective approach to "eliminate individual sources of pollutants or reduce their emission" by the United States EPA (Environmental Protection Agency) that ranked an indoor air pollution as among the top 5 ecological threats to the health of the public. Cost, beauty, and functionality are the primary factors that guide the design of Egyptian homes. Consequently, tracking the built ecosystem with the objective of enhancing indoor ecological quality, particularly IAQ, is essential for generating meaningful criteria that might aid in the decision making process. Health problems brought on by haphazard material choices may be mitigated by the establishment of criteria and the implementation of standards.

Although previous research in Egypt measured exposure after people had left the building, more work has to be done to track indoor air quality (IAQ) in unoccupied spaces in order to separate the impact of design and materials from that of occupants' activities. Based on a meta-analysis of recent research conducted in countries with comparable characteristics, it has been shown that construction-related indoor pollutants are at their highest during the first six months following completion. According to prior research, decomposition agents may be able to reduce some volatile organic compounds (VOCs).

Pollutants within buildings come from a wide range of different sources. Indoor air pollution is caused by both exogenous (from outside) and endogenous (from inside, such as construction materials, furniture, and human activities) factors. Coatings and flooring materials release a variety of volatile organic compounds. Formaldehyde, a known carcinogen, is often found in homes. Ammonia, radon gas, and particles are among other pollutants linked to material use. Although previous research has focused on monitoring only one or two of these characteristics, a more thorough approach to assessing exposure to numerous pollutants is needed.

The European Collaborative Union (ECU) and the World Health Organization (WHO) are only two of the many international groups that have created guidelines for indoor air quality. Allowable exposure limits are also specified by other standards by the Environmental Protection Agency and the American Society of Heating, Refrigeration, and Airconditioning Engineers (ASHRAE), Health Canada in Canada, and organizations in China, and the Finnish Society of Indoor Air Quality and Climate (FiSIAQ) in Finland. Most of the detailed requirements, however, are not consistent with one another. Indoor air quality (IAQ) assessment is a component of green construction grading framework such as Leadership in Energy and Environmental Design (LEED), which awards points for following best practices throughout the design, construction, and post-occupancy phases of a building's life cycle.

Workplaces often adhere to additional regulations outlined by agencies like OSHA and NIOSH. Many IEQ elements and acceptable thermal comfort limitations have been addressed in Egypt's house design and planning construction rules, however there is little data accessible in the form of IEQ standards or recommendations. The goal of this research is to enhance existing principles by providing an IAQ index that may be used to set realistic expectations and facilitate sound decision-making.

Waste Reduction

Selecting materials that can be utilized effectively without producing excessive waste is crucial. The building industry is both a major contributor to landfills and a voracious user of materials. In addition to using up 40% of the world's raw materials, previous research has revealed that the construction industry uses up about 40% of globe's energy, adds about 5% to 15% to the GDP, and accounts for about 5% to 10% of all jobs. It has been estimated that 40% of Canada's, 35% of Brazil's, and 65% of Hong Kong's solid waste comes from the building industry. There may be a sector- and material-specific variation in the volume of trash produced by building sites. For instance, Juveria, Rajeev, Jegatheesan, and Sanjayan [17] reports that across the board, the average percentage of wasted materials is 21% for sand, 19% for PVC water pipes, 20% for aggregate, 19% for timber for formworks, 17% for steel reinforcement, 8% for cement, 16% for concrete, 14% for facing stones, and 15% for ceramic tiles. Bricks account for 6.82% of all construction waste, followed by tiles at 6.68% and mortar from plaster at 6.63%. This is in contrast to the range of 2% to 12% for wood and 1% to 10% for plain cement concrete.

There is mounting evidence that using a variety of waste reduction strategies improves both environmentally friendly building practices and productivity. The project's waste management system serves to lessen the amount of waste produced during construction. Key measures for addressing the issue include off-site building, waste-effective tendering, legislative action and tax standards, waste categorizing and reuse, recycling, waste forecast instrument, a site waste management plan (SWMP), a design for deconstruction and adaptability, and waste-conscious deconstruction. Significant reductions in the amount of waste sent to landfills can be achieved through the implementation of effective site management practices such as material logistic administration, waste exclusion, reuse optimality, and contractual provision.

Table 1. Material Factors That Influence Resource Efficiency

Recycled Content	Products whose recycled content may be easily identified, preferably containing postconsumer material but also incorporating post-industrial content.
Natural, plentiful or renewable	Materials gathered from responsibly managed sources, ideally those with third-party certification (such as certified timber).
Resource efficient manufacturing process	Products packaged in ways that minimize their environmental impact by using recycled materials or other means of lessening their impact on landfills or the environment.
Locally available	Materials, elements, and systems for construction that may be sourced locally or regionally, reduce the need to transport these goods long distances.
Salvaged, refurbished, or remanufactured	Products and materials that were not thrown out, but rather rehabilitated, mended, or restored such that they now have better aesthetics, functionality, quality, or worth.
Reusable or recyclable	Ease of disassembly and recycling or reuse at their useful life's end is key considerations in the selection of these materials.
Recycled or recyclable product packaging	Packaged products manufactured from or including recycled materials.
Durable	Long-lasting or comparably long-lasting materials to more traditional products

Tam, Shen, Fung, and Wang [18] ranked the most effective methods for controlling construction waste as follows: retooling and training of superintendents of the strategies of materials waste reduction; application of modular design model; application of incentives for motivation of labor to reduce materials waste on site; buy raw materials in large quantities but enough for the task; and retraining and education of individual for transportation, handling and storage. To further reduce construction waste on-site, it is crucial to educate and inform workers about waste management, to standardize designs and materials, to establish waste management techniques for particular materials, and to ensure that construction materials are handled correctly.

Sayyed, Almurayshid, Almasoud, Alyahyawi, Yasmin, and Elsafi [19] argues that the most effective ways to reduce material waste are to ensure that sufficient quantities are supplied, to store those materials properly, to ensure that their specifications are accurate, to encourage a shift in mindset among workers with regard to the handling of materials, and to designate a waste management officer. Specific approaches for each of the building materials might minimize the overall amount of waste. The aggregate should be kept in separate bunkers and open stockpiles, while blocks should be "stacked on pallets or flat grounds and stored in a container or a covered facility". Nevertheless, employing ready mixtures of concrete, moving using cranes and pulleys, effectively storing materials, enhancing site amenities, assigning competent workers, using suitable formwork, and procuring material from certified sources all help to cut down on waste throughout the concrete-making process. Reducing reinforcement waste and enhancing formwork performance may be accomplished via the use of competent cutters and the careful storage of steel reinforcement to prevent corrosion. The largest amount of concrete debris is reduced as a result of construction.

The criteria or elements stated above that should be taken into account when choosing the materials to be used in sustainable building may be categorized according to the ways in which the material or product can enhance the following characteristics of the built environment: resource efficiency, energy efficiency, water management, indoor air quality, and cost. Resource efficiency may be achieved by using materials that fulfill one or more of the above factors in **Table 1.**

Materials, components, and systems that aid in decreasing building and facility energy use are essential to achieving maximum energy efficiency. Reduced water usage in buildings and landscaping, as well as increased water recycling and reuse, are two key components of water conservation. Materials that fulfill one or more of the following requirements may improve IAQ (**Table 2**):

Table 2: Materials Requirements to Improve IAQ

Low or non-toxic	Materials that have been shown via testing to have little or no carcinogenic, teratogenic, or irritating emissions.
Minimal chemical emissions	Products that give out a negligible amount of VOCs. Items that do all that while also minimizing their impact on the environment by way of chemical emissions.
Low-VOC assembly	Materials and techniques of installation that produce no or very few volatile organic compounds (VOCs) via mechanical attachment are preferred.
Moisture resistant	Products and methods that prevent the development of biological pollutants in structures, especially those that are exposed to moisture.
Healthy environment maintained	Materials, systems, and components that can be cleaned with little effort and no or low volume of volatile organic compounds.

When the total cost of ownership (TCO) of a construction product is less than or on par with that of "traditional" goods, or falls within a certain cost threshold, the product may be termed affordable.

V. LIFE CYCLE ASSESSMENT

A brief history of LCA

Energy efficiency, raw material use, and waste management were early areas of attention for the LCA technique, which has its roots in the 1960s and 1970s. In 1969, for instance, the Coca-Cola Corporation underwrote research contrasting the environmental impacts and resource demands of various beverage container types. In the meanwhile, the "Ecobalance," a system somewhat similar to the American inventory, was being created in Europe. In 1972, British researcher Ian Boustead determined how much power was required to manufacture glass, plastics, steel, and aluminum drinking containers. The Handbook of Industrial Energy Analysis was written by Boustead and released in 1979. While curiosity about LCA remained high, intellectual progress was slower than expected. The actual interest in LCA spread across a far larger variety of sectors, design organizations, and merchants in the mid-1980s and early 1990s. In the early 1990s, LCA was put to external use in fields like marketing.

The Society of Environmental Toxicology and Chemistry (SETAC) became involved at this time in an effort to standardize the overall structure, methodology, and nomenclature of life cycle assessment (LCA) by bringing together the LCA professionals. ISO became engaged in 1994, taking up the work that SETAC had begun, and the first publication in the ISO 14040 standard series occurred in 1997. Hence, a common methodological groundwork was established via standardization, facilitating the comparison of various LCAs. The construction industry has been employing LCA since 1990, and interest in LCA has skyrocketed since the turn of the century. Thus, it is a crucial instrument for assessing structures. In addition, LCA's widespread use may be attributed to the method's qualitative integration of crucial areas including framework, effect assessment, and data quality [20].

Definition of LCA

"Compiling and evaluating the inputs, outputs, and possible environmental consequences of a product system throughout its life cycle," as well-defined by ISO 14040, is what LCA is all about. LCA considers each phase of the product's existence, from sourcing raw materials to generating electricity to assembling finished goods and disposing of them after usage. There are four stages outlined in ISO 14040: 1) the specification of the aim and scope, where the goal specifies the product to be examined, the functional unit, the system boundaries, impact categories, and handling of uncertainty, and the scope specifies the audience, the purpose of the study, and whether or not the findings are made public. The second step, identified as LCI (life-cycle inventory) analysis, entails accumulating and measuring outputs and inputs for products in the entire life cycle, as well as collecting data required to achieve the established study's objectives. Assessment of the importance of possible environmental consequences across a product system's life cycle impact assessment (LCIA); fourth, there is interpretation, which is the process of drawing conclusions and making suggestions based on the inventory analysis results, the impact evaluation, or both. **Fig. 1** depicts the interplay between these four stages.

The focus and application of an LCA determine its scale. Both the narrowness and the generality of an LCA might vary significantly depending on its goals. Environmental performance is an area where there is very little debate over which elements of performance should be definitively evaluated, despite the fact that there are many diverse methods to the comprehensive assessment of building materials. The whole life cycle must be included in all material performance evaluations (Life Cycle Assessment, LCA). Among the many things an LCA takes into account are: Everything from (1) obtaining and transporting raw materials to (2) making and distributing finished goods to (3) using and maintaining those goods to (4) recycling and disposing of them in the end. LCA is a method to consider according to the European branch of the Society of Environmental Toxicology and Chemistry (SETAC).

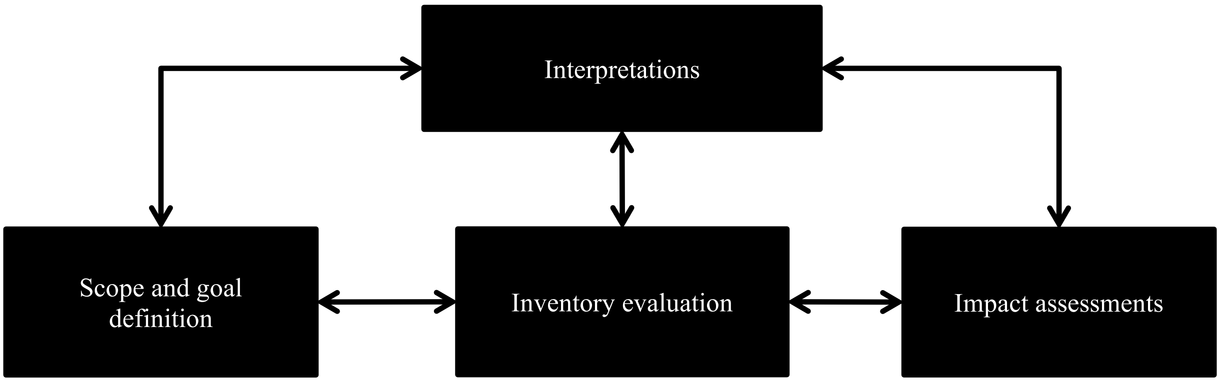

Fig 1. Relationship between LCA phases per ISO 14040

This may be done by doing the following: (i) identifying and quantifying the usage of energy, materials, and waste released into the environment connected with a product, process, or activity; (ii) determining the effect of these resources and waste and their ecological discharges; and (iii) evaluating and putting into practice possibilities for improvement.

Application of LCA

LCA in ecolabelling

Labels for environmental friendliness come in three distinct varieties: category labels (ISO 14024), environmental product declarations (EPDs) (ISO 14025), and self-declared environmental statements (ISO 14021). As defined in ISO 14025, type III ecological declarations wherein EPD is an example, are designed primarily for employment in B2B (business-to-business) communications; however, they may also be used in B2C (business-to-consumer) communications under particular circumstances. The EPD's goal is to help consumers make informed purchasing decisions by providing quantitative environmental information about a product's life cycle. Product category rules (PCR) govern the administration of EPD programmes across the globe, outlining the specific guidelines and requirements for the creation of the LCA study. However, anyone can claim the title of "programming language operator," so PCRs can vary greatly from one another. In a perfect world, EPDs would allow for unbiased comparisons of similar products that adhere to the same PCRs and would summarize LCA results that have been independently verified.

Green Building Assessment and Certification Schemes and EPDs Functionality

The environmental and energy effects of buildings may be evaluated using any number of software packages available today. In 1990, the United Kingdom established the first mechanism for certifying environmental friendliness; it was called the Building Research Environmental Assessment Method (BREEAM). A system similar to BREEAM was launched in 1998 under the green construction rating model, known as Leadership in Energy and Environmental Design (LEED®). The LEED® rating model was established by the Green Building Council of the U.S. to help with these issues. The LEED® rating model is a consensus-centric, voluntary instrument, which acts as a guidance and assessment approach, with the goal of improving the quality of interior environments for building occupants while reducing negative effects of human health and the environment.

To get their LEED certification, the project team must earn points in many areas, one of which is "Materials and Resources." One such credit is "Building Product Disclosure and Optimization—Environmental Product Declarations," which specifies the need for EPDs for a certain percentage of the materials used in a building. This rebate is meant to encourage consumers to choose items and materials with positive life-cycle benefits on the environment, economy, and society for which data is readily accessible. The German Sustainable Building Council (GSBC) in Germany and the Green Building Initiative (GBI) in the U.S. are only two examples of initiatives that utilize the LCA approach to assess the sustainability of a building's design, building, operations, and maintenance.

VI. CONCLUSION

Material selection has been defined as a multifaceted process that is affected by a wide range of interconnected elements. As a result, knowing how to efficiently and reliably analyze the trade-offs between technical, ecological, economic, and performance concerns is essential when faced with the difficulties of choosing acceptable materialchoices from a variety of possibilities. We may draw the conclusion that many different materials can be used in eco-friendly building, but we must choose the one that best meets as many of the criteria as possible. The selected materials should improve the building's energy efficiency. Making this complicated subject more accessible to the general public, a code for the selection criteria for the green material is being established. This is a win-win for the environment, the economy, and the conservation of scarce resources. It is necessary to establish a system that works as a single repository for data pertaining to every aspect of local and recycled construction materials and as an exchange of knowledge for most construction professionals, given the current trend toward more integrated methods to choosing building materials. As such, this paper is a part of a larger effort to enhance the design-decision making process, with the goals of (1) providing novel insights into other factors or variables indispensable to the dependable material selection process and (2) challenging researchers and practitioners to prioritize products that are made locally or employ recycled materials. The suggested system's capability of comparing local and reused building material possibilities using several parameters against user-specified weightage would allow decision-makers to clearly examine the consequences of their previously-implicit activities on the outcomes of the project performances, and thus make material selections which result in more improved project design and execution. The contribution of combining diverse data sets for assessing the use of local and recycled construction products and materials will increase the desire for usage in a larger mainstream environment and give a benchmark against which future green innovations may be evaluated.

Data Availability

No data was used to support this study.

Conflicts of Interests

The author(s) declare(s) that they have no conflicts of interest.

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Ethics Approval and Consent to Participate

The research has consent for Ethical Approval and Consent to participate.

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