



AN INTEGRATED DESIGN APPROACH OF HIGH-PERFORMANCE GREEN BUILDINGS

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Abstract

The Large carbon footprint of conventional buildings coupled with their high energy consumption in recent years, there is a necessity for an emphasis on the design process of energy efficient high performance green buildings. However, there exists limited research on the integration of green technologies into a high performance green building with a special focus on energy, day lighting and green material. To solve this issue, an integrated design approach is presented from the perspective of making it practical and easier for architects and designers to design a high-performance green building. This paper introduces the benefit of application of Environmental Impact Assessment and the integration of various green technologies along with LEED rating system in the design process. Relevant case studies of various green buildings are exemplified and enumerated throughout the paper for the purpose of investigating the practicality of the approach. Lastly, the payback period for the initial cost premium for the construction of a high-performance green building is also given due consideration in the design process.

Keywords: High- Performance green buildings; Green technologies; Integrated design; Design process; Environmental impact assessment; LEED; Payback period.

1. INTRODUCTION

With the increasing influx of pollutants and greenhouse gases into the atmosphere and the ever increasing rate of aggrandizement of the IT sector and construction industry the energy requirements and pollution levels are rising steadily. There is a dire need for individuals at all levels to keep in mind sustainable development (i.e., meeting the demands of the current generation without compromising with the needs of the future generations).

In the construction field, we need building technologies that are not only highly effective in bringing down the carbon emissions but are also self-sufficient and enduring. Conventional building designs do not have a structured model that focuses on sustainability of the building. In order to go green these building designs have one or two designs alterations that cut long term costs for the client. But statistics show that these arbitrary ideas may do more harm than good to the buildings in the long run.

The solution to this is switching from regular buildings to High Performance Green Buildings. High Performance Green Buildings (HPGB) include design features that conserve water and energy; use space, materials and resources efficiently; minimize construction waste; and create healthy indoor environments. What is needed is an integrated design of a HPGB that makes it easier for the architects to come up with a green building model that takes into account all possible contingencies. An integrated design approach, in effect, looks at all possible alternatives to a design related issue and suggests the best alternative using design tools. Significant design tools for this purpose such as – Environment Impact Assessment, Day lighting analysis and innovative green technologies which contribute towards reduced costs and increased energy savings are discussed and evaluated.

A major drawback associated with HPGB is the initial investment and its slow rate of payback. However, by putting together the most efficient technologies along with smart planning, HPGBs can not only provide quicker payback but also cut down on operational and maintenance costs. Throughout the paper case studies have been presented to show the same and to encourage engineers to work on an integrated design that will exorcise this drawback and give the green building movement the momentum it needs.

2. INTEGRATED DESIGN APPROACH

The design approach for an integrated HPGB involves a close synchronization among designing, EIA, day lighting analysis as reflected by the IDeA flowchart below. It is a cyclic process involving testing and modifying. Figure 1 visually represents this Integrated Design Approach (IDeA) in a flow chart. All the tests are carried out with regard to the benchmarks set by LEED with a purpose of attaining a maximum rating. The design stage involves making a detailed 3D scaled model using software tools. The above step is done by the design team conventionally.

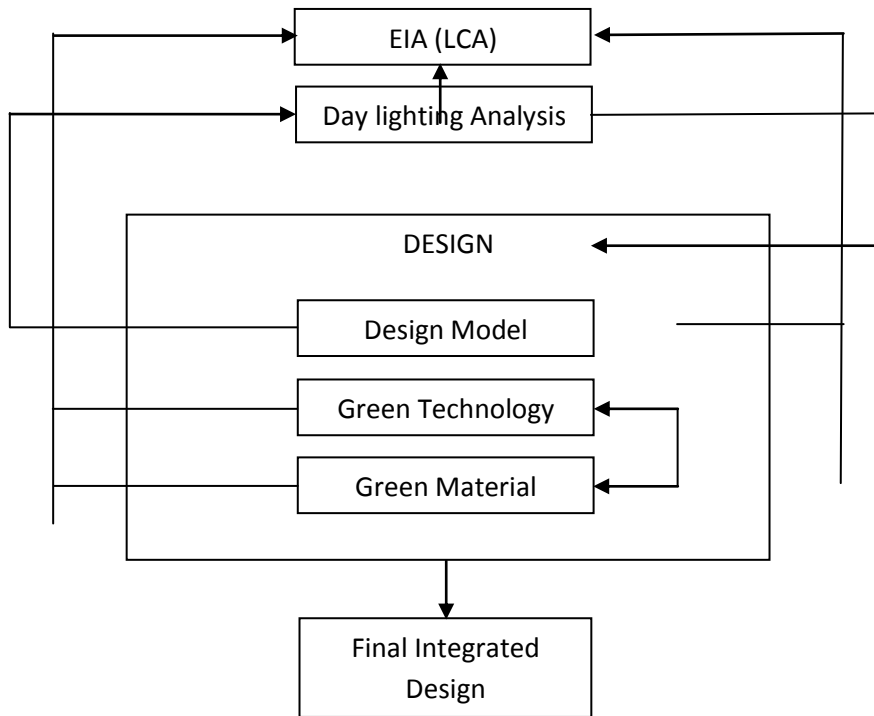


Fig: 1 Flowchart showing IDeA (Integrated Design Approach)

After this, scouting for feasible green technologies and materials and the integration of these into the building design is done. The next step involves analysing the materials employed, in the building design. This step, called Environmental Impact Assessment (EIA), is considered to be the most important since it governs the efficiency of the building in terms of energy requirements and thus the LEED rating. EIA involves a thorough assessment of the interaction between the various components of the new building and their compatibility with the building environment. Next, the approach focuses on day lighting analysis. It is done to analyse the thermal conditions of the building and the thermal comfort of the occupants (a major contributor to the indoor environment of the building). Various software are utilized to carry forth this analysis.

Based on the above assessments, changes may be suggested to the design (orientation, size of windows, HVAC requirements, artificial lighting etc.) or to the materials or the technologies used. These changes are then incorporated into the initial design model to achieve the final integrated design model.

3. ENVIRONMENTAL IMPACT ASSESSMENT

Environmental Impact Assessment is the assessment of all possible impacts, either positive or negative that a proposed project may have on the environment. The main purpose of integration of EIA in the design process is to provide information to decision makers and public about the environmental implications of the proposed project activity before decisions are made. Besides providing information, it also suggests measures for preventing or reducing those impacts. Overall EIA offers a systematic process of examination, analysis and assessment of planned activities with a view to ensuring environmentally sound and sustainable development.

EIA involves four basic steps, (a) identifying the impacts of the project and its design, (b) preparation of the EIA report, (c) review of alternative designs with less impact (d) implementing the changes in the design.

While the success of LEED has spurred environmental-conscious building practices and brought sustainability to the forefront of many owners, architects, and builders' minds, its ability to fundamentally improve the sustainability of built environments through reduced material consumption and emissions release throughout the entire life cycle has been questioned. Measuring total building resource consumption and emissions release through comprehensive life cycle assessment, Scheuer and Keoleian found that due to a lack of calibration across LEED points, the sustainability of LEED certified buildings was only loosely connected with total LEED point ratings [Scheuer 2002,1]. This limitation can be tackled using Life Cycle Assessment (LCA) which can be used as an effective tool in the design and selection of material.

LCA is the compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle. A number of environmental impact assessment (EIA) models or systems for buildings were developed. So far, some of the models, such as BREEAM [2], LEED [3] and GBC [4] are actually a type of subjective scoring system, which is made up of many items and corresponding scoring rules. Meanwhile, other assessment models, such as BEES [6], ATHENA [7], LCAid [8], Green Guide for

Housing Specification [8] and ECOPT-ECOPRO-ECOREAL [10] are objective evaluating models based on life cycle assessment (LCA). The scoring system has relatively wide coverage of environmental aspects, but the subjective nature of the scoring system sometimes makes it difficult for those models to provide in-depth results. Moreover, the coverage is not derived based on a systematic study of environmental impact related to the factors concerned [5]. LCA is a well-known analytical tool for assessing the environmental impacts of a product from a birth-to death perspective [11], i.e. from the acquisition of raw materials to the final disposal of products. Usually the LCA results are presented in the form of aggregation of environmental loads or impacts related to the functional unit, without considering their distribution in time and space [12]. Though some deficiencies still exist, the LCA-based methods, compared with the scoring methods, demonstrate an in-depth coverage of environmental impacts associated with design and building materials. LCA is divided into four steps: goal and scope definition, inventory analysis, impact analysis and interpretation. Here, the first three steps are highlighted. The environmental impacts of a building exist in all aspects during its life. The impact to be mainly focused is the manufacture and transportation of building materials, and the development and utilization of building sites.

Another benefit of LCA is that it can be used as an initial assessment tool in engineering materials for sustainability such as Engineered Cementitious Composites.

4. DAY LIGHT ANALYSIS

Day lighting analysis has emerged as a significant factor in sustainable design. Detailed day lighting analysis helps in a better understanding of the interaction of the building with its environment. It also helps design high performance envelopes to use daylight as the primary light source through façade design and glazing choices thus taking maximum advantage of solar radiation to minimize electricity demands for artificial lighting in high performance green buildings.

Tools for day lighting analysis such as Ecotect, Google Sketch up, Green building studio, Revit, eQuest, Rhino have been found to help analyse and generate detailed reports that predict what the amount of daylight and heat at every part of the building and help make design changes for the heat and daylight available to the building. This has been found to be true in the case of San Francisco Public Utilities Commission Project where the designers were aiming for a LEED platinum rating, used Google Sketch up and Ecotect for daylight modelling and then brought those results into Revit [13]. With this the team was able to establish maximum lease depth of 60 feet to maximize day lighting and exterior views. Light shelves were also strategically placed to help minimize solar heat gain and maximize daylight penetration. One another case where day lighting analysis benefitted the design team was in Grange Insurance Audubon Centre in Columbus where, the results from day lighting analysis using these tools helped in changing the orientation of the building in the design to maximize sun exposure [13].

5. PAYBACK

Case Study-Detailed Analysis of the Construction, Operating, Maintenance, and Rehabilitation Costs of Green Toronto Schools [20]

According to the case study it was shown that operating or maintenance cost savings alone could never outweigh the average initial cost premium of the three green schools, estimated at \$1.3 million. Also these green schools would need approximately 25 years of savings in rehabilitation costs, and 13 years of savings in operating, maintenance and rehabilitation costs combined to recover the extra initial cost premium. The results prove that green schools can indeed save money in the long term despite their high initial capital cost. Assuming a conservative 50-year building lifespan, green buildings would at the very least save three times their extra capital cost premium over their lifespan. This considerable yet conservative amount makes the green buildings in the study more cost-effective in the long term than comparable conventional ones.

However with the advancements in construction technologies and the emergence of newer green materials and technologies, it is safe to assume that the design approach presented in this paper will be able to better address the shortcomings of payback period by comprehensive analyses and testing modules.

6. GREEN TECHNOLOGIES

The term "technology" refers to the application of knowledge for practical purposes. Any material which is employed into construction with the purpose of lowering energy consumption, operating and maintenance costs by a fair margin in comparison to conventional technology is called Green Technology material. The following materials listed below are major contributors in energy savings for high performance green buildings.

6.1 Double Skin Facades

Harrison and Boake, (2003) in the Tectonics of the Environmental Skin, described the Double Skin Facade system as "essentially a pair of glass "skins" separated by an air corridor. The main layer of glass is usually insulating. The air space between the layers of glass acts as insulation against temperature extremes, winds, and

sound. Sun-shading devices are often located between the two skins. All elements can be arranged differently into numbers of permutations and combinations of both solid and diaphanous membranes”.

Major Advantages of double skin facade are as follows [14]:

1. Lower construction cost compared to solutions that can be provided by the use of electro chromic, thermo chromic or photochromic panes.
2. Acoustic insulation.
3. Thermal Insulation. During the winter: the external additional skin provides improved insulation by increasing the external heat transfer resistance. During the summer: the warm air inside the cavity can be extracted when it is ventilated (naturally or mechanically).
4. Energy savings and reduced environmental impacts.
5. Reduction of the wind pressure effects.
6. Transparency – Architectural design.
7. Low U-Value and g-value low thermal transmission (U-Value) and the low solar heat gain coefficient (g value).

6.2 Chilled Beams

A chilled beam is a type of convection HVAC system designed to heat or cool large buildings [15]. There are two types of Chilled Beams: Passive and Active. Common to each, is a cooling coil which provides radiant cooling via circulated cool water. Chilled beams can be either recessed in the ceiling or exposed below the ceiling. Passive Chilled Beams consist of a cooling coil in an enclosure. Active Chilled Beams provide ventilation air to a space in addition to cooling. Multi-Service Chilled Beams can be either Active or Passive. They can integrate a wide variety of other building services such as lighting, speaker systems, IT systems, Sprinkler heads, photocells, etc. There are many advantages of Chilled Beams. Less Supply of Air is needed. Consequently smaller duct work and smaller air handling units are required. Almost no maintenance required as the system consists of no moving parts and no filters to maintain.

	Fan Coil Unit	Active Chilled Beam
Filter Changes:		
Frequency	Twice Yearly	N/A
Cost per Change:	\$30	
Cost over Lifetime (20 years)	\$1,200	\$0
Clean Coil and Condensate System:		
Frequency	Twice Yearly	Every 4 years
Cost per Change:	\$30	\$30
Cost over Lifetime (20 years)	\$1,200	\$150
Fan Motor Replacement:		
Frequency	Once during life	N/A
Cost per Change:	\$400	
Cost over Lifetime (20 years)	\$400	\$0
Life Cycle (20 years) maintenance cost:	\$2,800	\$150

Table.1 Maintenance Costs comparison of Fan coil unit and Active Chilled Beam [21]

Less building floor area is required. Mechanical room size and mechanical shaft size is reduced. Ceiling space is reduced. Compared to large VAV systems 50,000 CFM and greater, a chilled beam system can reduce ceiling space by as much as 18 inches [16]. Compared to small VAV systems 20,000 CFM and less, a chilled beam system can reduce ceiling space by as much as 12 inches [16].

Case Study–Viterbo University, La Crosse, WI

The following costs were analysed in the case study and conclusions were drawn [17]. Construction Costs, HVAC, Electrical, General Construction, Operating Costs, Maintenance Costs HVAC Cost Increase. Chilled beam terminal unit costs are higher as more units are generally required

Chilled water piping costs are higher to distribute chilled water to the beams

- Insulation costs may be higher to insulate the piping (Depends on dew point requirements) HVAC Cost Decrease
- Smaller central air handling unit sizing (About 65% less than an “All Air” system)
- Using 100% outdoor air to the chilled beams reduces the supply and return air ductwork sizing required
- For the same level of control, chilled beam controls are less expensive (Only simple zone valves required)

- Lower balancing costs (less and easier adjustments to make) Electrical Cost Increase
- Connected Higher GPM = Higher pump motor horsepower Electrical Cost Decrease
- Reduced Electrical Infrastructure: Lower kW/ton required by chiller to produce warmer average chilled water supply temperatures. Although connected pump motor horsepower is typically higher, this is more than offset by the connected fan motor horsepower. Above changes should result in reduced electrical infrastructure costs, operating Costs. Although total pump energy is generally somewhat higher, this is more than offset by the reduction in fan energy. A one inch diameter water pipe can transport the same cooling energy as an 18 inch square air duct.

6.3 Paints:

Paints may have major negative impact on the indoor air quality of a building, if they contain chemicals called Volatile Organic Compounds (VOCs) and other toxic components that evaporate into the air and harm the health of the occupants. Latex, water based paints have significantly lower environmental impacts than oil or solvent-based paints since they don't use petroleum carriers or have nearly as many smog-forming emissions. According to the US Environmental Protection Agency (USEPA), 9% of the airborne pollutants creating ground level ozone come from the VOCs in paint. Low and zero VOC paints have little or no smog-forming emissions.

6.4 Water Efficiency:

Reducing water consumption and protecting water quality are key objectives in sustainable building. Buildings consume 20 percent of the world's available water, a resource that becomes scarcer each year, according to the United Nations Environmental Program [18]. The protection and conservation of water throughout the life of a building may be accomplished by designing for water efficient fixtures like low dual-flush toilets, sensor based urinals and other low flow fixtures which reduce portable water consumption by over 49.7%. The Wisconsin State Agriculture Building office, Madison, Wisconsin installed water fixture flush valve diaphragms and aerators and discontinued use of their irrigation system resulting in a 54% reduction in water use and an annual savings of 757,724 gallons (more than an Olympic Sized swimming pool) [19]. Some of the other steps that can be used to reduce wastage are: Rain water harvesting through tanks and recharge pits throughout the site, sewage treatment plant to treat 100% of onsite waste water for reuse, use of non-processed waste water treated on-site for landscaping thereby minimizing the use of portable water.

6.4 Other technologies:

- Green roof
- LED based low energy lighting systems
- Green power : Studying and using the renewable energy potential including solar, wind, geothermal, biomass, hydro, and bio-gas strategies
- CO2 and airflow monitor

7. FUTURE SCOPE OF THE STUDY

The way ahead will surely have to do with more detailed analyses of the inner workings of these various assessment tools and how each of the systems can work in perfect harmony with each other. Also the concept of precedence and conflict resolution need to be expounded.

8. CONCLUSION

This article was an attempt to make a qualitative assessment of a novel design approach. Initially a review of some of the common green technologies used in a high Performance green building had been done. It was found from relevant case studies that these technologies have contributed to reduction of costs in the long run along with reduced energy consumption and better human comfort. From this a conclusion was drawn that these technologies hold a significant position in the functioning of a green building to achieve high performance and greater sustainability. Further examples of case studies show that the inclusion of assessment tools such as Life cycle assessment or Day lighting analysis in the design process will result in a more efficient high performance green building design. However, there is room for improvement in the fundamental design process involved in high performance building design that is currently being followed. The current system of design often only takes into account the LEED rating system or other similar systems, but these systems lack comprehensive assessment tools that evaluate the direct impact that a material's life cycle has on the environment. But the integration of these two assessments together with the conventional design approach could overcome this shortcoming. This type of integrated approach is rarely followed and could be a potential model of designing a high performance building which helps the designers take well informed decisions and improve the sustainability of the project. Although further research and testing is required to conclude this to be true, these types of buildings are just emerging and may very well be the norm in the future. It is safe to assume that the design approach discussed in this paper shows the characteristics of adaptability to cater to the dynamic design needs of buildings in the future.

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