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OPTIMIZATION OF LIFE CYCLE ENERGY FOR A SCHOOL BUILDING USING BIM TOOLS

Mr. K. Sai Babu, M.Tech Scholar, Department of Civil Engineering, National Institute of Technology Warangal, Telangana, India.

Abstract:
The construction sector is consuming a lot of energy and natural resources, as well as having significant environmental effect. The building industry is responsible for an estimated 40% of global CO_2 emissions and 40% of natural resource consumption, however application of low embodied sustainable materials reduces the life cycle energy. Life cycle energy analysis (LCEA) of a school building in Kakinada is taken into this study. Energy used in all three stages construction, operational and demolition are considered. In this study, an attempt was made by the integration of BIM into sustainable designing of buildings to reduce life cycle energy and cost. The main objective of this research is to identify the available sustainable materials in Kakinada region, Andhra Pradesh (India). In this study three alternative building materials cement is AAC blocks, secondary glass, replaced with 20% fly ash are used. As a result, decrease in embodied energy was about 33.93% & corresponding carbon emissions decreased by 30.17%. A significant decrease in operational energy usage of around 11.92 %. The cost of total life cycle energy has there was an esimated cost saving of approximately 1.74 crores in terms of total life cycle energy.

Keywords Sustainable materials, Building information modelling (BIM), Embodied energy, Operational energy, Demolition energy, Total life cycle energy.

1.INTRODUCTION:

The construction sector is consuming a lot of energy and natural resources, as well as having significant environmental consequences. An estimated 40% of worldwide CO2 emissions and 40% of natural resource usage are attributed to the building sector. To enhance the energy efficiency of buildings, it is essential to employ innovative strategies such as green construction methods, the utilization of eco-friendly materials, and the integration of renewable energy systems.

In developing countries, construction and demolition waste generation is substantially higher. As a result, existing building construction methods and practices will result in increased natural resource use, such as building materials and energy usage, throughout the life cycle of a building. In sustainable development, locally available, energy-efficient, and durable building materials are utilized. It ensures that the building's occupants live in a safe and comfortable environment for the duration of its life span. Sustainability aims to minimize the environmental impact of buildings while optimizing the use of resources like water, power, and building materials.

The Life Cycle Assessment (LCA) is a useful technique for reducing building energy usage and greenhouse emissions. Towards the LCA, different methodologies can be implemented; in this study, two techniques have been implemented Over the lifespan, their energy consumption and carbon emissions are measured**.** The embedded energy, operational energy, and demolition energy of a building are all evaluated in a life-cycle energy assessment (LCEA).

BIM technology provides building owners and design teams with access to a range of interactive tools for making informed decisions in building design, resulting in improved energy efficiency at a cost-effective price. BIM can be used to run energy simulations using the data from these models since it has the capacity to store, update, and extract data that can be analyzed during the design phase to help decision-making. BIM can enable integrated model design and energy simulation evaluation throughout a building's life cycle.

The Life Cycle Sustainability Assessment (LCSA) is a comprehensive framework employed to evaluate the environmental, social, and economic consequences of products and activities. This method encompasses four primary stages: Life Cycle Inventory (LCI) analysis, Life Cycle Impact Assessment (LCIA), and the interpretation of objectives and scope. Both Life Cycle Costing (LCC) and Social Life

Cycle Assessment (S-LCA) can employ this four-phase LCA methodology. When this technique is used in the construction business, different social consequences can be analyzed, such as worker safety, good salary, and access to material resources.

Lifecycle assessment (LCA) is a methodical strategy used to evaluate the environmental impacts of a product or process across its entire life span. Its aim is to strike a balance between conserving natural resources, preventing pollution, enhancing the economic system, and sustaining a healthy ecosystem. LCA can be approached in a variety of ways; two approaches were utilized in this study: life cycle energy assessment (LCEA) and life cycle carbon emissions assessment (LCCO_2A). The inputs or processes that have the greatest impact on sustainability can be identified using integrated LCA approaches, and if these inputs can be enhanced, environmental sustainability can be reached more quickly.

The majority of energy is consumed during operation, with operational energy demand mostly controlled by climatic conditions, according to a recent study that found that embodied energy makes about 10% to 20% of the overall life cycle energy. Higher operating energy levels are required in extremely hot and cold areas to meet the needs of their heating and cooling systems.

According to other studies, the embedded energy for energy-efficient buildings can be as high as 40–60 percent of the overall life cycle energy, as shown in a study of a passive house where the operational energy was less than 40% of total energy usage.

Alternate Building Materials to Lower Embodied Energy and Embodied Carbon:

1.Replacement of cement with flash:

Cement being a high carbon content material results in increase of embodied energy use and carbon emissions. When such element is replaced in percentage of up to 20% to 25% there is a considerable reduction in the embodied energy and carbon emission. The reason it is not exceeded 25% is though the energy and carbon emission decrease the early strength of concrete decrease with increasing fly-ash content.

2.autoclave aerated blocks:

Autoclaved Aerated Concrete (AAC) blocks have become the favored choice of walling material for most real estate developers, primarily because of their cost-effectiveness and capacity to accelerate construction. In reality, however, because of the reduced weight of the material, carbon emissions from walls formed of AAC blocks would be significantly fewer than those from burnt clay brick walls.

3.secondary glass:

Secondary glass exhibits lower embodied energy and reduced embodied carbon when compared to primary glass.

2.METHODOLOGY:

2.1 Framework of Methodology:

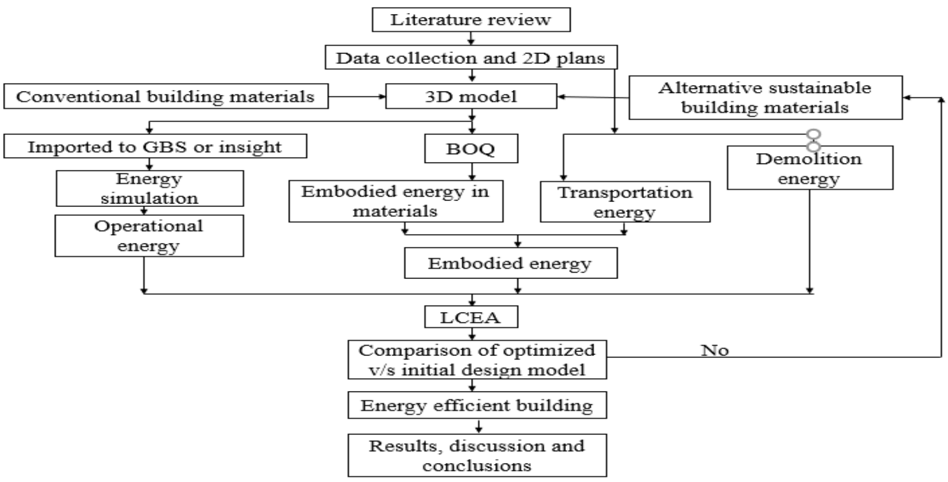

Figure 1 frame work of methodology

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The embedded energy, operational energy, and demolition energy of a building are all evaluated in a life-cycle energy assessment (LCEA).

Embodied energy (EE):

The energy needed for raw material extraction and processing, transport the finished product to the construction site, and build and maintain the structure is referred to as embodied energy. Embodied energy represents approximately10- 20% of a building's total energy use.

Operational energy (OE):

Operational energy accounts for 60–80 percent of total energy use. Comfort energy includes ventilation, heating, air conditioning (HVAC), lighting, hot water and maintenance.

Demolition energy (DE)

When a building's useful life is ended, it takes energy to dismantle it and transport the waste to a landfill. The aggregate of these three energies utilized over a building's lifetime is referred to as life cycle energy (LCE).

$$LCEA= EE+OE+DE$$

2.2 Information of Case Study:

A school building is taken into consideration from Kakinada, Andhra Pradesh and the buildings description is specified in table 1. The building's 3D Revit model is generated Through the assistance of available floor plans. The school building has 6 class rooms in each floor (Figure 2). The Structural plan of the building is also generated in estimating the reinforcement, concrete and the brickwork quantity etc., Regarding the structure and the quantities schedules are prepared from the Revit software and these quantities are used for calculating the Regarding the structure and the overall building, calculate the operational energy using Autodesk insights. And also calculate demolition energy of the school building.

1. The data required for calculation of the energy and carbon embodied within of building materials are taken from the ICE database (Carbon and Energy Inventory) by the University of Bath.
2. The material volumes and weights are collected from the Revit model with help of data sheets.

Table 1 Case study Building details

Building parameter	Specifications
Type of building	School building(G+1)
Gross build-up area	1002.728m^2
Height of each story	4m
Service life	50 years
Structure	Reinforced concrete structure (M_{20}, Fe415)
Walls	Brick masonry
Doors and windows	Timber, Ply wood, Glass
Finishes	Cement plastering, ceramic tiles, painting
Location	Kakinada (Andhra Pradesh)

2.2.1 Floor Plan:

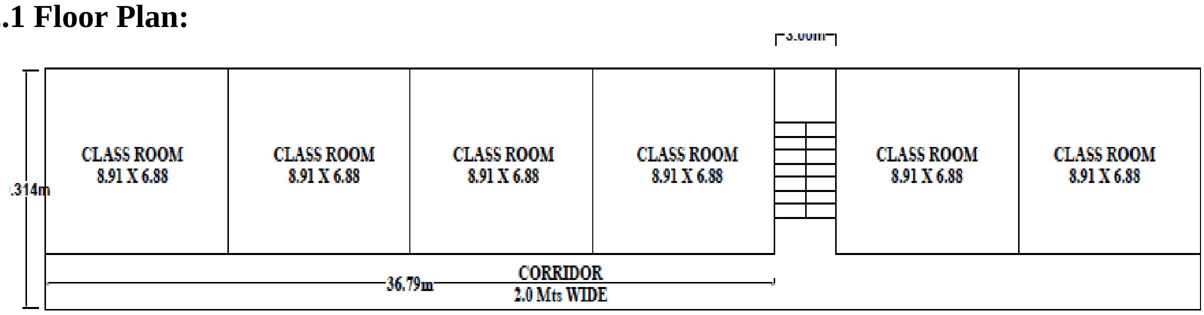

Figure 2 floor plan of the building

2.2.2 Revit 3D Model:

The school building's 3D model depicted in Figure 3 was generated using Revit software. Revit is a pivotal component of the Building Information Modeling (BIM) platform, facilitating the incorporation of multiple templates, such as architectural, structural, mechanical, electrical, and plumbing, within the same project file.

The school building floor plan was created in Revit Through the assistance of drawings collected and the whole structural plan of the G+1 school building was developed that has been covered with all the details of work like the foundation, columns, beam, stairs, floor tiles, ceiling, doors and windows., etc Through the assistance of drawings collected from the contractor.

The concrete used is of M20 grade, and the reinforcement steel is Fe415 grade. All external walls and the internal walls are 300mm thick. The slab has a thickness of 150mm, and the distance from one floor to another is measured at 4 meters.

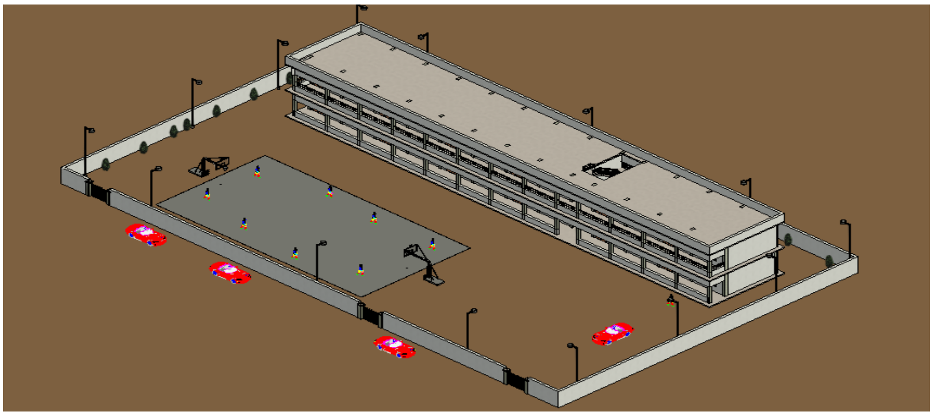

Figure 3- 3D model of school building

2.3 Study Assumptions:

The following assumptions were adopted during this study:

- For this analysis, a 50-year lifespan for the school building was assumed.
- • When estimating demolition energy, the distance travelled to move building materials from one place to another and the impact of transportation modes were neglected.
- The type of "raw" materials used, whether they are sourced from recycled or natural sources, were not factored into the calculation of embodied energy during the construction of building materials.
- The embodied energy from repairs and maintenance over the span of a building's life was not taken into consideration.
- The potential effects on embodied energy of various construction methods and building products (such as changes in the efficiency of various manufacturing processes and the fuels used in the manufacture of the materials) were also neglected.
- This study's operational energy focus was restricted to buildings. Because of this, the potential impact at the urban scale (such as the transportation energy of building inhabitants and urban infrastructure) was not considered.
- Throughout the building's lifespan, the price of power per unit remains the same.

3.RESULTS AND DISCUSSIONS:

3.1 Embodied Energy:

Every structure consists of various processed elements, which each contributes to the overall embodied energy of the structure. Therefore, the selection of construction materials will have an effect on how much energy is used to construct a building.

The majority of calculations now used to describe embodied energy are derived from process energy analysis. 50 to 80 percent of overall energy requirements are typically accounted for by process energy needs. However, the calculation of embodied energy might differ by a factor of ten when different

calculating methodologies are used. Consequently, this leads to often better to accept information from a single source when comparing embodied energy as this provides consistency in method and base data.
In this study, embodied energy of materials is Determined for both traditional and sustainable materials.
The following formula was used to determine an individual building material's embodied energy:
EE material (MJ) = Embodied energy (MJ/kg) x Density (kg/m^3) x Quantity (m^3) ……eq 1
EC material (kg co_2) = Embodied carbon (kg co_2/kg) x Density (kg/m^3) x Quantity (m^3) ……eq2

Table 2 Embodied energy & embodied carbon for common building materials

Material	**Embodied energy coefficient (MJ/kg)**	**Embodied carbon coefficient (kg co_2/kg)**
Cement	5.5	0.93
Sand	0.081	0.0048
Gravel	0.083	0.0048
Steel	25	1.91
Bricks	3	0.23
Wood	10	0.71
Primary Glass	15	0.86
Ceramic tiles	12	0.74
Cement replaced with 20% fly ash	4.51	0.75
Autoclave aerated blocks	3.50	0.35
Secondary Glass	11.5	0.86

The overall embodied energy for a building would be equal to the totality of all building elements and transportation energy.

$$\text{EE total (MJ)} = \Sigma \text{ EE material} + \Sigma \text{ EE transportation}$$

Construction operations have a significant influence on the environment and air quality due to transportation. According to a recent study, transportation from manufacturers to the site accounted for 2% of total embodied carbon. It was also found that transportation contributes to 9% of the total embodied carbon and 10% of the total energy for a standard masonry residential unit. Material amounts, vehicle types and capabilities, and distances between suppliers and sites are all needed for the transportation energy evaluation.
The on-site data collected was employed to determine the energy consumption during the construction phase. The number of trips and fuel usage were recorded, and Google Maps was used to calculate distances from manufacturers or building supply retail locations to the site. Despite the fact that the return lengths were empty, they were included in the transportation energy calculation.

Energy in 1 L of diesel is equivalent to 0.038 GJ of energy.
Energy in 1 L of gas is equivalent to 0.0355 GJ of energy.

Table 3 Element wise mass of element, embodied energy and embodied carbons in case study of the building.

S.no	Element	Mass of element (kg)	Embodied energy (MJ)	Embodied carbon (kg co_2)
1	Footings	141784.5	139370.508	18609.68
2	Columns	136414.6	242379.6823	25919.98
3	Beams	142630.6	429890.6023	40174.17
4	Slabs	769770.1	819444.483	105670.52
5	Stair case	28377.5	45089.9295	5001.445

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6	Brick work	871124.8	2003648.304	171358.43
7	Doors	1900.7	19007	1349.497
8	Windows	4375.3	54632	3432.833
9	Plastering (1:6)	93360	68272.3	10813.328
10	Ceiling (1:4)	32086.4	32173.73	5203.386
11	Tiles	27630	331560	20446.2
	Total	2249454.5	4185468.539	407979.469

The embodied energy and embodied carbon coefficients for construction materials are extracted from the ICE (Inventory of Carbon and Energy) database. Using the provided equations in Table 2 (equation 1 and equation 2), the Embodied Energy and Embodied Carbon for each building material are calculated, allowing us to determine how much each building element contributes to embodied energy and carbon.

This process is primarily undertaken to identify materials with higher energy values compared to others and to explore alternative materials that can help reduce energy and carbon footprints.

The amount of embodied energy and embodied carbon for the educational building, studied on an element-by-element basis, is 4,185,468.539 MJ and 407,979.469 kgCO2, respectively.

Table 4 outlines the materials used in each building element and their respective contributions to the building's embodied energy and carbon.

Table 4 Quantity of materials used, embodied energy and embodied carbons in case study of the building.

S.no	Material	Mass (kg)	Embodied energy (MJ)	Embodied carbon (kg co_2)
1	Cement	187185.6	1029521	174082.6
2	Sand	595707.2	48252.28	2956.8
3	Gravel	802246.5	66586.46	3850.78
4	Steel	33849.2	846230	64651.97
5	Bricks	596560	1789680	137208.8
6	Wood	4100.2	41002	2911.142
7	Glass	2175.8	32637	1871.188
8	Ceramic tiles	27630	331560	20446.2
	Total	2249454.5	4185468.74	407979.48

The educational building's analyzed materials have a combined embodied energy of 4,185,468.539 MJ and an embodied carbon of 407,979.469 kgCO2.

Table 5 Transportation energy in case study of the building

S.No	VEHICLE	MATERIAL	QUANTITY (m^3)	QUANTITY (t)	CAPACITY(t)	ROUND TRIP	DISTANCE(km)	fuel consumption(L/km)	fuel(L)	ENERGY(MJ/L)	ENERGY(MJ/L)
1	truck	Gravel	281.49	802.25	8	202	42	0.15	1272.6	38	48358.8
2	truck	sand	350	616	8	154	64	0.15	1478.4	38	56179.2
3	truck	cement	129.99	187.58	8	48	145	0.15	1044	38	39672
4	truck	steel	33.85(t)	33.85	8	10	145	0.15	217.5	38	8265
5	truck	red bricks	372.85	596.56	8	150	15	0.15	337.5	38	12825
6	truck	tiles	12.28	27.63	8	8	400	0.15	480	38	18240
7	truck	wood	4.94	4.067	8	2	20	0.15	6	38	228
8	truck	glass	0.86	2.175	4	2	30	0.3	18	38	684
	TOTAL ENERGY CONSUMPTION OF TRANSPORTING CONSTRUCTION MATERIALS										184452

The number of trips and fuel consumption were noted, and Google Maps was used to determine the distances from manufacturers or retail sites for building supplies to the site. Using the formula that 1 L of diesel oil energy is equal to 38 MJ of energy, the total energy used to transport construction materials is estimated.

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The toal energy consumption of transporting construction materials are 184452 MJ. In this research, transportation energy accounts for 4.2% of the complete embodied energy of the materials.
Total embodied energy ;

$$EE\ total\ (MJ) = \Sigma\ EE\ material + \Sigma\ EE\ transportation$$

Total embodied energy= 4185468.74+184452

=4369920.7MJ

The total amount of"embodied energy and embodied carbon"for the educational building for the materials taken into study are 4369920.7MJ, 407979.469 $kgCO_2$ Respectively.

Table6 Element wise mass of element, embodied energy and embodied carbons in case study of the building after changing materials.

S.no	Element	Mass of element (kg)	Embodied energy (MJ)	Embodied carbon ($kgCO_2$)
1	Footings	141784.5	123546.348	15732.5646
2	Columns	136414.6	227667.4903	23245.039
3	Beams	142630.6	415320.97	37525.1548
4	Slabs	769770.1	733851.459	90108.1554
5	Stair case	28377.5	41996.3775	4438.9812
6	Brick work	257324.56	702323.3226	73804.622
7	Doors	1900.7	19007	1349.497
8	Windows	4010.1	43364.7	3173.541
9	Plastering (1:6)	93360	57181.1328	10813.328
10	Ceiling (1:4)	32086.4	26770.7088	4221.018
11	Tiles	27630	331560	20446.2
	Total	1635289.06	2722589.509	284858.101

After replacing the top three materials with the most significant influence on embodied energy and carbon, the quantities, embodied energy, and embodied carbon of these materials are outlined in Table 4 and 5. Following these material substitutions, the collective embodied energy and embodied carbon for the educational building, assessed on a per-element basis, amount to 2,722,589.509 MJ and 284,858.101 kgCO2, respectively.

Table7 Quantity of materials used, embodied energy and embodied carbons in case study of the building after changing materials.

S.no	Material	Mass (kg)	Embodied energy (MJ)	Embodied carbon (kg co_2)
1	cement	164433.6	741595.5	125341.8
2	sand	418257	33878.81	2007.633
3	gravel	802246.5	66586.46	3850.783
4	steel	33849.2	846230	64651.97
5	bricks	182962	640367	64036.7
6	wood	3735	37350	2651.85
7	glass	2175.8	25021.7	1871.188
8	ceramic tiles	27630	331560	20446.2
	Total	1635289.1	2722589.47	284858.124

Following the material replacements, the levels of embodied energy and embodied carbon have been altered for the educational building for the materials taken into study are 2722589.47MJ, 284858.124 $kgCO_2$ Respectively.

Table 8 Transportation energy in case study of the building after changing the materials.

S.No	VEHICLE	MATERIAL	QUANTITY (m^3)	QUANTITY (t)	CAPACITY(t)	ROUND TRIP	DISTANCE(km)	fuel consumption(L/km)	fuel(L)	ENERGY(MJ/L)	ENERGY(MJ)
1	truck	gravel	281.49	802.25	8	202	42	0.15	1272.6	38	48358.8
2	truck	sand	237.646	418.26	8	105	64	0.15	1008	38	38304
3	truck	cement	114.19	164.44	8	42	145	0.15	913.5	38	34713
4	truck	steel	33.85(t)	33.85	8	10	145	0.15	217.5	38	8265
5	truck	AAC blocks	295.1	182.962	4	92	15	0.3	414	38	15732
6	truck	tiles	12.28	27.63	8	8	400	0.15	480	38	18240
7	truck	wood	4.94	4.067	8	2	20	0.15	6	38	228
8	truck	glass	0.86	2.175	4	2	30	0.3	18	38	684
	ENERGY CONSUMPTION OF TRANSPORTING CONSTRUCTION MATERIALS										164524.8

The overall energy used for transporting construction materials amounts to 164,524.8 MJ. In this research, transportation energy accounts for 5.69% of the total embodied energy of the materials.Total embodied energy after changing the materials;

EE total (MJ) = Σ EE material + Σ EE transportation

Total embodied energy= 2722589.47MJ +164524.8MJ

=2887114.27MJ

The combined sum of embodied energy and embodied carbon for the educational building for the materials after changing the materials are taken into study are 2887114.27MJ, 284858.124 kgCO_2 Respectively.

Table 9 Embodied energy& Embodied carbon comparison

	Embodied energy (MJ)	Embodied carbon (kgCO_2)
Case study building	4369920.7	407979.469
After changing materials	2887114.27	284858.124
% Reduction	33.93%	30.17%

The total amount of embodied energy and embodied carbon for the educational building for the materials taken into study are 4369920.7 MJ, 407979.469 kgCO_2. And after changing the materials the total amount of embodied energy and embodied carbon for the are 2887114.27MJ, 284858.124 kgCO_2 Respectively.

After changing the materials, it has been reduced to 33.93%of the total embodied energy and 30.17% of the total embodied carbon.

3.2 operational energy:

The operational energy of a building is influenced by how its occupants act and plan their time, as well as by the level of comfort people require and the weather.

Operational energy typically refers to the energy needed for factors like "heating, lighting, window to wall ratios, ventilation, and air conditioning (HVAC), building orientation, demotic hot water (DHW) systems, and general appliances used in kitchens, bathrooms, living rooms, laundries", and among other things. Over the course of the buildings' lives, it accumulates energy.

The following formula was used to determine the average annual energy use (OE annual)

OE annual (kWh/year) = Total energy use (kWh/m^2 /year) x Area(m^2)

Total operational energy for life span of 50 years = OE annual (kWh/year) x 50

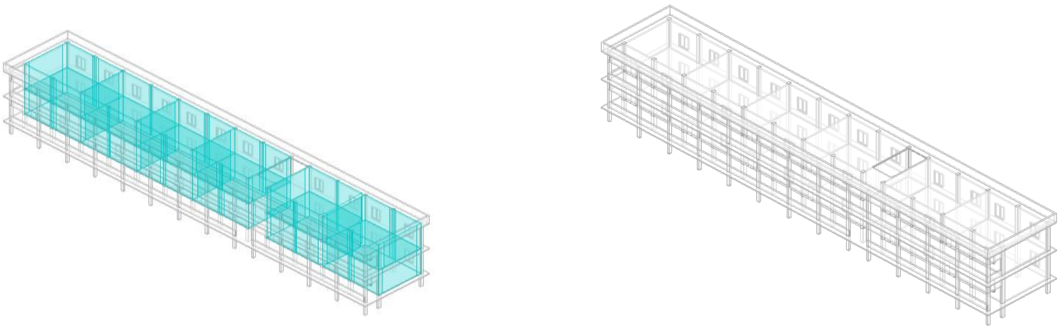

Figure 4: analytical spaces and system spaces

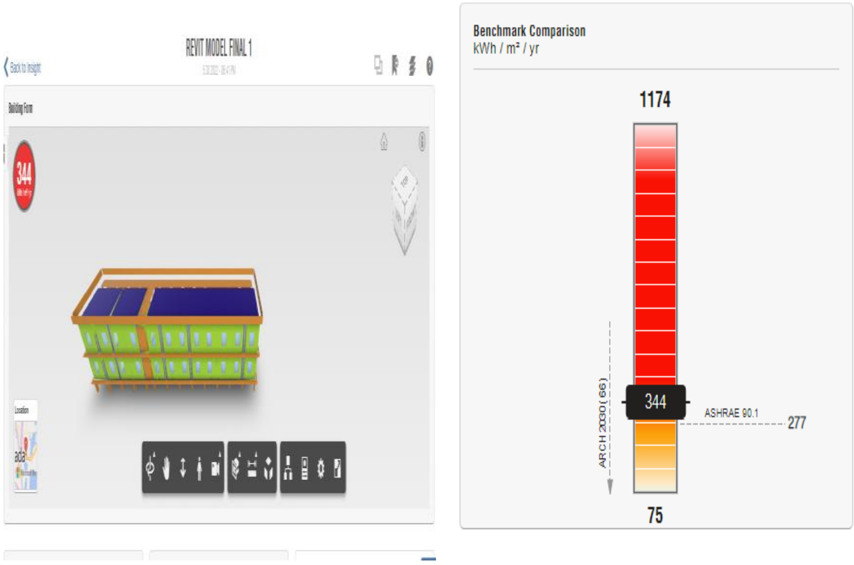

Figure 5 simulated operational energy usage in the case study

As per simulation results, the case study's annual operational energy consumption is 344 kwh/m^2/year, and the building's operation schedule is 12/6. (i.e, 12 hours per day for 6 days a week).

Annual OE (kWh/year) = Total energy use (kWh/m^2 /year) x Area(m^2)

Annual OE (kWh/year) = 344 (kWh/m^2 /year) x758(m^2)

=260752 (kWh /year)

Total operational energy for life span of 50 years= 260752 x50

=13037600 kWh

Figure 6: Simulated operational energy usage for after material change and best orientation.

As per simulation results it was found annual operational energy for after material change and best orientation is 303 kwh/m^2/year and the operating schedule of the structure is 12/6 (i.e, 12 hours per day for 6 days a week).

Annual OE (kWh/year) = Total energy use (kWh/m^2 /year) x Area(m^2)

Annual OE (kWh/year) = 303 (kWh/m^2 /year) x758(m^2)

=229674 (kWh /year)

Total operational energy for a 50-yearS lifespan = 260752 x50

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=11483700 kWh

Table10: operational energy comparison

	Operational energy(kwh)	Operational energy (MJ)
Case study building	13037600	46935360
After changing materials	11483700	41341320
% Reduction	11.92%	11.92%

3.3 Demolition Energy:

The energy necessary to "dispose, store, and transport these items from the building site to the disposal sites and/or final treatment plants"is considered during the demolition process. This includes the energy used by machines to destroy the current building. When juxtaposed with the manufacturing and operational stages, this period is typically relatively small. Typically, this represents 1-4 percent of a building's life cycle energy consumption.

Table11 Demolition energy content of building materials

Construction Type	Demolition Energy (MJ/m^2)
Light (e.g. wood frame)	35
Medium (e.g. steel frame)	106
Heavy (e.g. masonry, concrete)	176

The demolition energy for modest structures (e.g., 465-1395 m2) is listed in Table4.6 based on Matt's suggestion that "the greenest building is the one previously built." It is predicted that as building size increases, The energy needed for the dismantling process per unit area will decrease.

The demolition energy of the school building = 176(MJ/m^2) x 1002.728m^2

=176480.13 MJ

3.4 Life Cycle Energy Assessment:

According to the ISO 14040 standard, life cycle assessment is a method for analyzing a building's environmental impact from its concept through its construction, usage, and end-of-life phases.

The embedded energy, operational energy, and demolition energy of a building are all evaluated in a life-cycle energy assessment (LCEA).

$$LCEA= EE+OE+DE$$

For case study of the building:

Total life cycle energy = 51297308.669 MJ

We know that , 1MJ = 0.28 kwh

Total life cycle energy = 51297308.669 x0.28 kwh

=14363246.42 Units (assume cost of 1 unit electricity as 9 RS)

=14363246.42 x 9

=129269218 Rs

So , the case study building has total life cycle energy cost component of 12.93 crores

After changing the materials :

Total life cycle energy =44404914.4 MJ

Total life cycle energy = 44404914.4 x0.28 kwh

=12433376.032 Units

=12433376.032 x 9

=111900385 Rs

So , the after changing the materials building has the comprehensive energy throughout the lifecycle cost component of 11.19 crores.

So, there was an esimated cost saving of approximately 1.74 crores in terms of comprehensive energy throughout the lifecycle.

Table12 comparison of total life cycle energy and cost

	Total life cycle energy(MJ)	**cost**
Case study building	51297308.669	129269218
After changing materials	44404914.4	111900385
% Reduction	13.43%	

The life cycle energy assessment for these structures, whether before or after optimization, is displayed in the table. It's evident that there has been a decrease of around 13.5% in the overall energy consumption. Operational energy is the most significant component among all energy types, both before and after the optimization.

4.CONCLUSIONS:

- Opting for alternative sustainable construction materials with a lower embodied impact led to a reduction in embodied energy by approximately 33.93%, and the associated carbon emissions decreased by 30.17%. Implementing appropriate energy optimization measures in the school building resulted in a noteworthy reduction in operational energy consumption of approximately 11.92%.
- The comprehensive life cycle energy for the school building in the case study initially amounted to 51,297,308.669 MJ, with an embodied carbon of 407,979.469 KgCO2. After implementing sustainable material changes to enhance the building's sustainability, The comprehensive energy throughout the lifecycle reduced to 44,404,914.4 MJ, and the embodied carbon decreased to 284,858.124 $KgCO_2$.
- The comprehensive reduction Regarding the energy throughout the lifecycle, accounting for the change in materials, amounts to approximately 6,892,394.269 MJ/m^2 (equivalent to 13.43% reduction). Correspondingly, embodied carbon emissions have also diminished by 123,121.345 $KgCO2/m^2$ (a reduction of 30.17%). This eco-friendly approach aids in curbing greenhouse gas emissions. Therefore, the recommendation for sustainable construction in buildings involves opting for low-carbon concrete mixes, incorporating recycled materials, and choosing locally available materials. These practices help minimize transportation requirements, subsequently Diminishing energy usage and carbon emissions.
- The overall expense associated with the energy throughout the lifecycle indicates an estimated cost reduction of approximately 1.74 crores, affirming that the implemented practices are financially efficient.

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