Illustration by Jennis John Varghese | 8th sem

06. Educating Architecture Students about Green Buildings - A Case Study of Green Building Project in Undergraduate Courses.

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Abstract :
This article delves into the imperatives of addressing global warming through the design of a green buildings, reflecting a proactive response to the escalating environmental concern. Supported by compelling statistics, it underscores the potential catastrophic consequences if current trends persist. The article addresses the interconnected systems on Earth's surface and emphasizes humanity's impact on these systems, the learnings of which serve as an important educational tool for architects. The green building design, undertaken within the University Curriculum of eighth semester, employs case studies and site studies, with students employing the checklists of National green building codes such as GRIHA. The semester culminates with heightened student interest in comprehending green building concepts, design processes, and construction methods—forming an effective strategy to mitigate global warming effects.

Keywords:
Global warming, Green building design, Sustainability, Pedagogy, GRIHA.

Global warming is the result of an increase in the temperatures of the Earth's surface. This is not a new phenomenon but has been witnessed for billions of years. The reason for this being a subject of discussion is that the temperature has increased rapidly in the last few years. Specifically since 1760, the beginning of the Industrial Revolution, the burning of fossil fuels has increased. Other activities of mankind are causing a steady increase in the surface temperature of the Earth. The mean temperature on the surface of the Earth is about 14°C (highest temperature has reached 70.7°C (159°F), which was taken in the Lut Desert of Iran, and the lowest temperature recorded is -89.2°C (-129°F) on July 21st, 1983, at the Soviet Vostok Station on the Antarctic Plateau) (Lindsey R. 2009).
This temperature has gone up by about 1.1°C since the pre-industrial era, which is an unprecedented rise in comparison to the previous ten thousand years.

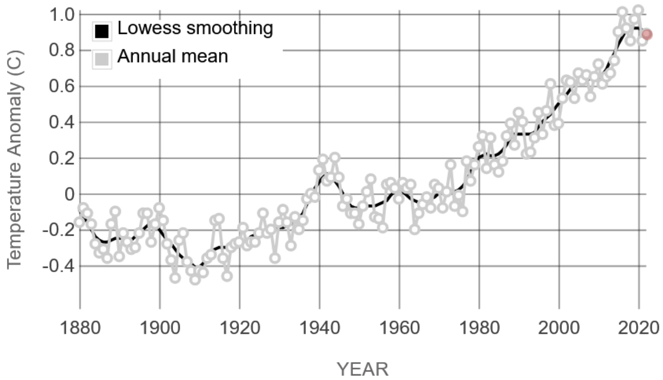


Fig.1 : Earth's global average surface temperature in 2020 statistically tied with 2016 as the hottest year on record, continuing a long-term warming trend due to human activities.
Source: https://climate.nasa.gov/vital-signs/global-temperature/

When radiation from the sun reaches Earth's surface, four things happen, one, part of the radiation is re-radiated back into space, two, part of it is absorbed in the upper atmosphere, three, part of it is absorbed by the Earth's surface (also called Insolation), and lastly, there is some outbound re-radiation from the Earth's surface into outer atmosphere. This outbound radiation (the long-wave IR waves), keeps the Earth's temperature in balance. However, with the increase in Greenhouse Gases (GHG), namely, carbon dioxide, methane, chlorofluorocarbons, nitrous oxide and water vapour, resulting from human activity, also known as anthropogenic activities, this outbound radiation and re-radiating have increasingly been trapped and absorbed back by the surface hence causing global warming.
Rapid industrialization is the major cause of this global warming, which in turn is causing climate change. Climate change is causing severe impacts on the weather, agriculture, livestock, rains, hurricanes, droughts, melting of the ice caps, and thus, human beings (Lindsey R., 2009). It is important to understand that there are two systems in play, one is the survival of the Earth's System and two, the survival of mankind as we know it.

Earth's System: The atmosphere is influenced by and linked to various features of Earth, like oceans, ice masses, land surfaces, and vegetation. Together, they make up an integrated Earth system, in which all components interact with one another in complex ways. Apart from these features, the atmosphere is impacted by solar radiation, volcanic activities, tectonic activities, Earth's orbital variations, human activities, and feedback of components on the Earth's system.(Heavens, N. G., Ward, D. S. & Natalie, M. M, 2013) Climate is constantly changing and the gradual change leads to an abrupt tipping point. The record shows that there have been abrupt changes in the climate system before, that indicate many ancient tipping points.

Mankind: Anthropogenic activities in the last few decades have been aggressive in exploiting natural resources and as a result causing irreparable damage to the Earth System. Consequent to these damages, the changes to the climate are rapid and detrimental. It is possible that the Earth System is rapidly changing to the tipping point. Comprehending the climate changes to slow the rapidity of changes, and to improve the quality of life is a priority. The Point of No Return (PNR) with a 2°C target in climate change, that reaches in 2035 according to present trends, can be pushed by about 07 years if negative emissions and, an increase in renewable energy share, strategies are adopted rigorously. (Aengenheyster, Matthias & Feng, Qingyi & Ploeg, Frederick & Dijkstra, Henk, 2018).

Educating the Architecture student:

95% of urban population growth is expected in the cities in emerging markets. 2.5 billion more people will join cities by 2050. 1.2 million Sq. Km. of new urban built-up area is expected to be added in the next three decades. Cities consume 2/3rd of global energy consumption and are responsible for 70% of GHG emissions. A 50% increase in urban water demand is expected by 2050. (United Nations, Department of Economic and Social Affairs, Population Division, 2019) 90% of waste is unmanaged in low-income countries, like ours, while construction consumes about 40% of natural resources. (Shitaw T, Girma Y E, Dessalegn E, 2022)
Thus, the contribution of architects in adopting sustainability practices could be enormous in mitigating global warming and climate change. Sustainability concepts must be taught & learnt in undergraduate schools of architecture so that they are a part of the professional services provided by every architect. Educating the architect is of paramount importance. Although the mitigation of global warming in the immediate future is difficult to achieve, environmentally friendly practices will pay dividends in the long run.
This article discusses the pedagogical approach adopted since 2018 in educating the higher semester students of the undergraduate architecture programme to equip them with the theoretical concepts and practical knowledge in understanding and designing green and sustainable buildings.
The topic 'Green Building concepts' is part of the syllabus of 'Materials and Methods of Building Construction (MMBC) VIII' subject in the Visvesvaraya Technological University (VTU) B. Arch curriculum from the year 2018. At RV College of Architecture, Bangalore, this topic is taught with gravity and rigor through a three-fold methodology of - Lectures, Case-Studies, and Design Project.

Lecture Method:

The studio faculty, which included an independent sustainability consultant Ar. Mini Shastry commenced the lecture sessions by introducing the definition of sustainability, its importance in architecture and the various terms and matrices used for measuring sustainability in the current Indian built environment practices. Green Rating for Integrated Habitat Assessment (GRIHA) methodology was introduced in these lectures.
The lectures by Ar. Minni covered topics related to Sustainable Site Planning, Construction Management, Energy Optimization, Occupant Comfort, Water Management, Solid Waste Management, Sustainable Building Materials, Life Cycle Costing (LCC), Socio-Economic Strategies, Performance Metering and Monitoring and Innovation. Thus, the basic concepts of proper site analysis, efficient construction planning, building massing, orientation and envelope optimization, Building Systems optimization, Indoor Air Quality and user well-being, water efficiencies, selection of building material based on carbon footprint and LCC etc. were dealt with in great detail. Mr. Harish Borah (expert in cost and carbon studies, was invited to deliver lectures on LCC and Life Cycle Assessment (LCA) etc.)

The Case Study:

Case studies of projects like TERI[1] Retreat, Gurgaon, and Govardhan ECO Village retreat Center, Galtare, Maharashtra, were discussed to enhance their comprehension.

The Design Project:

A Sustainable Design Project was introduced to the students along with the site and context. Students were then taken for a site visit where they were introduced to the site. The site was used for five consecutive years, and has helped to evolve a plethora of ideas for different design ideas from students.

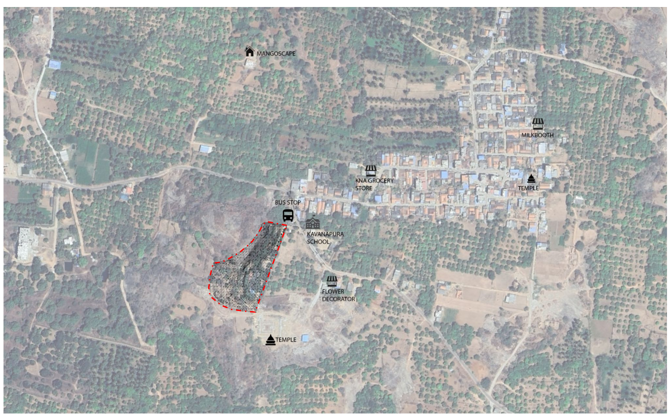


Fig 02. shows the location context and site surroundings.
Source: Page 6, student report 'Kshema'

[1]TERI : The Energy and Resources Institute

This site of about 11000 Sq.M. is located in the Ramanagara district of Karnataka, about 50 km away from Bengaluru, latitude of 12°38’33”N and a longitude 77°17’56”E with a moderate climate. The hilly terrain has a mango grove and is situated outside Kavanapura village.

After the site visit students presented their individual findings and observations.

Design of a green building is an onerous task, especially if concepts and applications are to be accomplished during one semester. Therefore, 5-6 students were teamed to take up the design project. The teams were then entrusted with the work of developing a “PROJECT BRIEF” with a built-up area ranging between 400 to 500 sq.m.

Students conceived projects like “Kalakriya”- an art centre (Fig, 02), “Kshema”- nature’s healing centre (Fig. 03), “Sattva”- an embodied way of living, etc.; all focused on sustainable building proposals. The brief was to include the purpose of the project on the site This encouraged them to explore materiality and the availability within about a 50km radius.

The teams submitted their programme proposals with occupancies, areas and themes, and obtained approval from the faculty. The next step was to analyse the site and the surroundings and devise passive strategies to reduce energy consumption. Case studies of climate analysis outputs were discussed and students were encouraged to apply the inferences in their projects.

The students used manual analysis methods like, psychrometric chart, Mahoney’s Table, and shading masks and also state-of-the-art tools and software like GeoSlope, ClimateStudio and Climate Consultant 6.0, etc. (Fig.3) to analyze the Slope, Wind (intensity and direction) patterns, monthly Air Temperature patterns, monthly Relative Humidity (RH) patterns, annual Rainfall analysis, and Solar Radiation analysis, etc. to identify the optimum passive strategies.

The green building studio attempts to innovate alternative solutions to step away from the mundane, energy-consuming building designs. Students explored various green building principles like orientation, siting, massing, solar radiation, etc. Design reviews were held regularly, and progress of work was monitored.

The final step was to validate their designs and strategies by applying metrics for calculating energy, water, waste, etc. consumptions in their projects. A template for the final project submission was provided. The final submission included a checklist that audits their design against the GRIHA[2] assessment method.

Most of the groups achieved a 3 to 4 star GRIHA rating for their project. The teams were able to achieve a 75% to 85% reduction in Water Performance Index (WPI) as compared to the GRIHA base-case. Teams validated a reduction of about 60%-80% in the Energy Performance Index (EPI) from the GRIHA base case. Out of this about 50% of reduction was demonstrated by optimising the building envelope and use of other passive strategies, thus providing the proof of concept for sustainability through proper selection of building materials

The semester culminated with an expert review by the faculty of all the proposals submitted by the teams and a final discussion on the outcomes of the studio.

Two of the hundred projects that came out of this

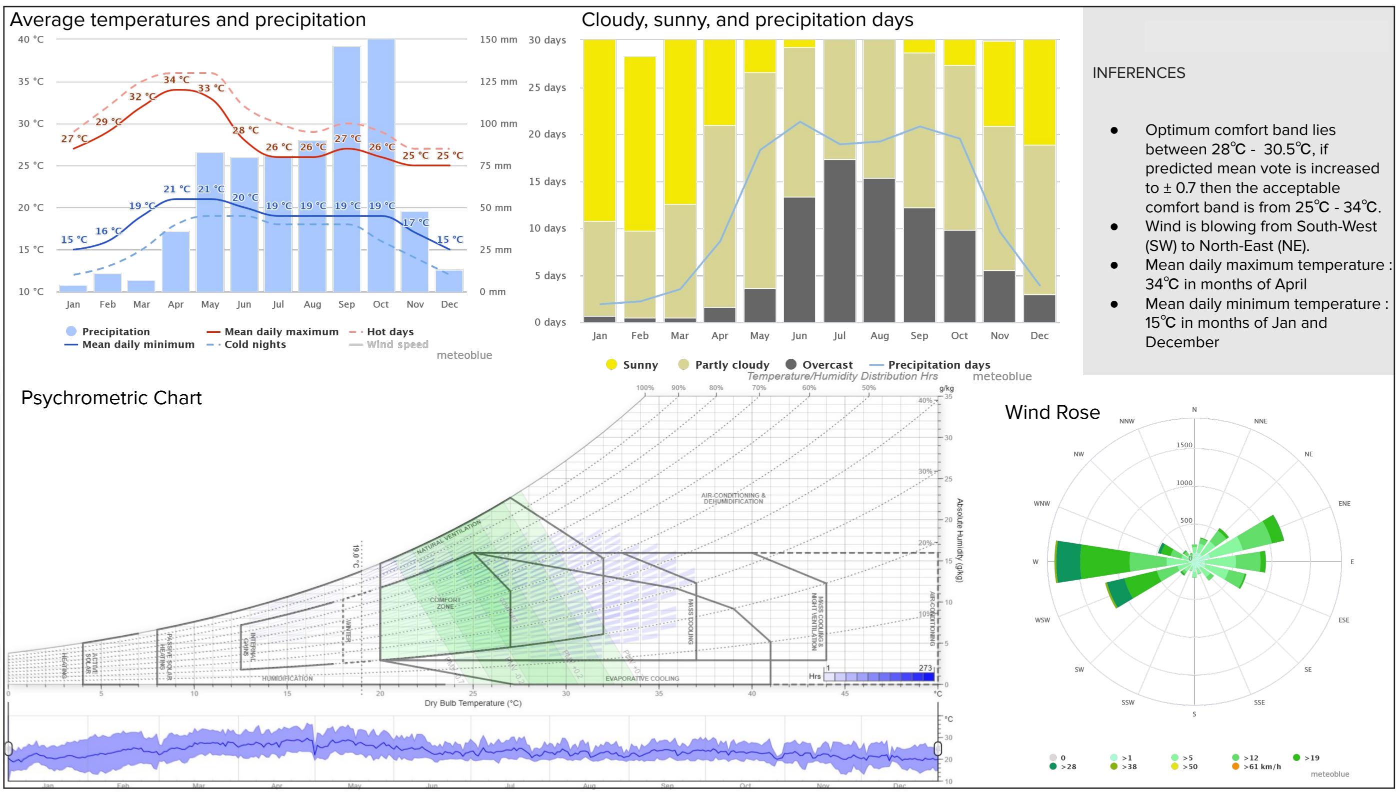


Fig 03. : shows some inferences achieved on climate, wind and temperature
Source: Page 4, student report ‘Kalakriya’

[2]GRIHA : The Energy and Resources Institute

pedagogical approach are described below to elaborate on the innovative strategies that the student groups were able to achieve through their projects.

The project "Kalakriya", designed by one of the teams in the Academic Year(AY) 2021, focused on a low environmental impact design by retaining the natural characteristics of the site as much as possible.

The project aimed to envision a thriving and diverse community that would sustain on a net positive (or zero) systems of water, financial, societal and ecological balance. The objectives were to use minimal natural resources, to promote the three R's - Reduce, Reuse and Recycle, to encourage efficient construction practices, energy and water efficiency.

The concept revolved around the idea of a courtyard structure. This would provide an open plan with maximum natural lighting, ventilation and interaction between two or more spaces as elaborated in (Fig. 04)

Students optimized the envelope by optimizing the U-value of the materials, proper use of shading devices for openings and ensuring daylight utilisation within the built structure (Fig. 05). They calculated the overheated periods and experimented with shading mask solutions for different heated orientations. Thus decided on the Vertical Shading Angles (VSA) and Horizontal Shading Angles (HSA) required for designing horizontal and vertical shading devices respectively. (Fig. 06)

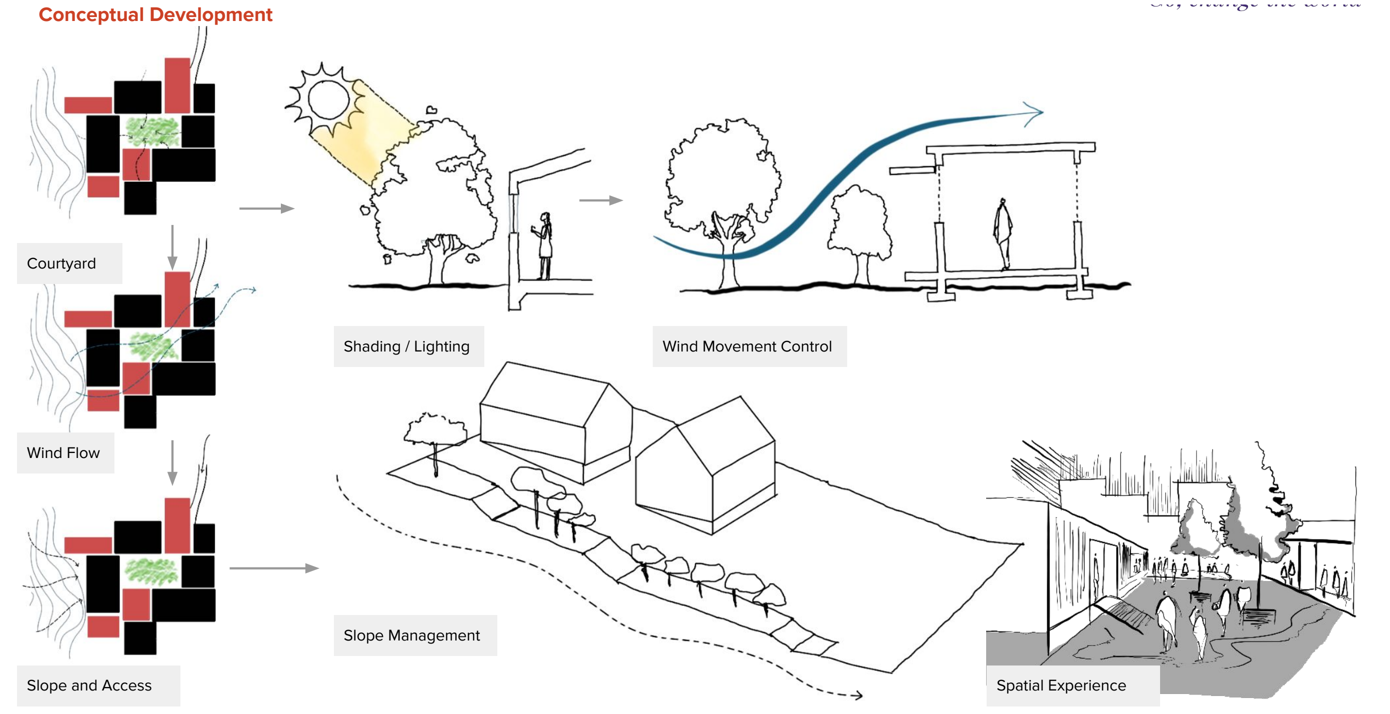
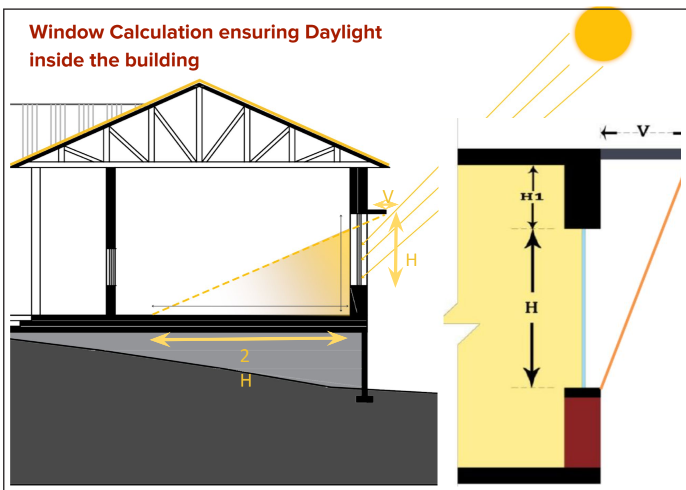


Figure 04: Shows the building footprint consideration and courtyard concept; Source: Page 08, student report 'Kalakriya'

Window Calculation ensuring Daylight inside the building

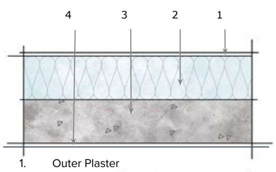


Daylight Alternative 1 - GRIHA	
The WWR and SRR to not exceed 60% and 5% respectively &; All the fenestrations meet the SHGC requirement of ECBC-2007/Weighted Façade average SHGC meets SHGC requirements of ECBC-2007 OR Any combination of the above strategies on 100% of the fenestrations	0
Minimum of 25% of the living area should meet adequate level of daylight (daylight factors) as prescribed in SP 41	0
Adequate daylight factors are achieved in more than 50% of total living area	2
Adequate daylight factors are achieved in more than 75% of total living area	4

Envelope Optimisation

Building massing and orientation, as well as insulated walls, control heat gain. The building's windows face south and north to improve daylighting and solar control. Several simulations and analyses were done to get the final proposed design.

Façade Direction	WWR
North	40%
South	25%
East	10%
West	4.5%



1. Outer Plaster
2. XPS
3. AAC
4. Inner Plaster

Roof details

	ROOF	WINDOW
STANDARD DESIGN	Cement plaster 0.01m +XPS 0.00m+ RCC slab 0.15m + inner cement 0.01m **U VALUE - 0.33**	6mm (solar control glass) - 12mm air gap - 6mm clear glass **U VALUE - 3**
PROPOSED DESIGN	Outer cement plaster 0.01m +XPS 0.015m+ RCC slab 0.15m + inner cement 0.012m **U VALUE - 0.21**	Vertical sealed double glazed window - 20mm air gap - ordinary glass of medium coloured having SHGC 0.18 **U VALUE - 1.95**

Figure 05: Envelope Optimization ; Source: Page 15, student report 'Kalakriya'

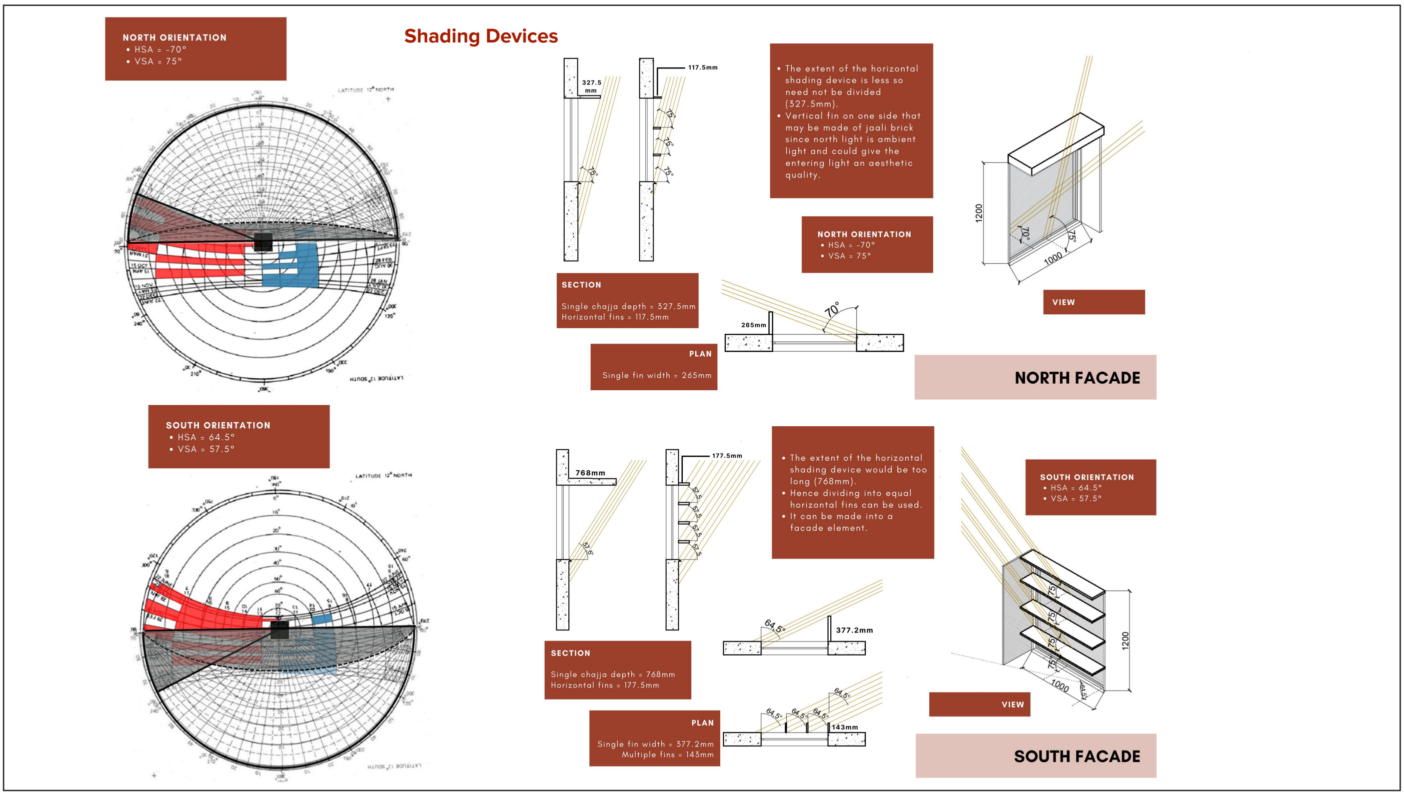


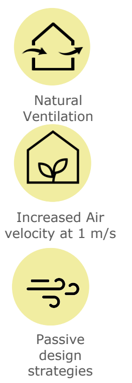
Figure 06: overheated periods, shading mask, Vertical Shading Angles (VSA) and Horizontal Shading Angles (HSA)
Source: Page 14, student report 'Kalakriya'

Energy Performance

Target Energy Performance Index

GRIHA benchmark for EPI = **75** kWh/sqm per year
Achieved EPI = **13** kWh/ sqm per year

Operating hours	Daytime occupancy		24-hours occupancy					
	5 days a week		7 days a week					
Climate zone	Institutional	Office	Health-care Facility	Hospitality	Office	Residential	Retail	Transit Terminal
Composite	90	90	250	275	225	70	225	300
Hot and dry	90	90	250	275	225	70	225	300
Warm and humid	90	90	275	275	225	70	225	300
Moderate	75	75	250	250	210	50	210	300
Cold	90	120	275	300	275	100	225	275



Building massing and orientation, as well as insulated walls, control heat gain. The building's windows face south and north to improve daylighting and solar control.

Our goal to achieve net-zero energy building is done by using several passive design strategies, efficient lighting fixtures and equipment and an optimized HVAC system

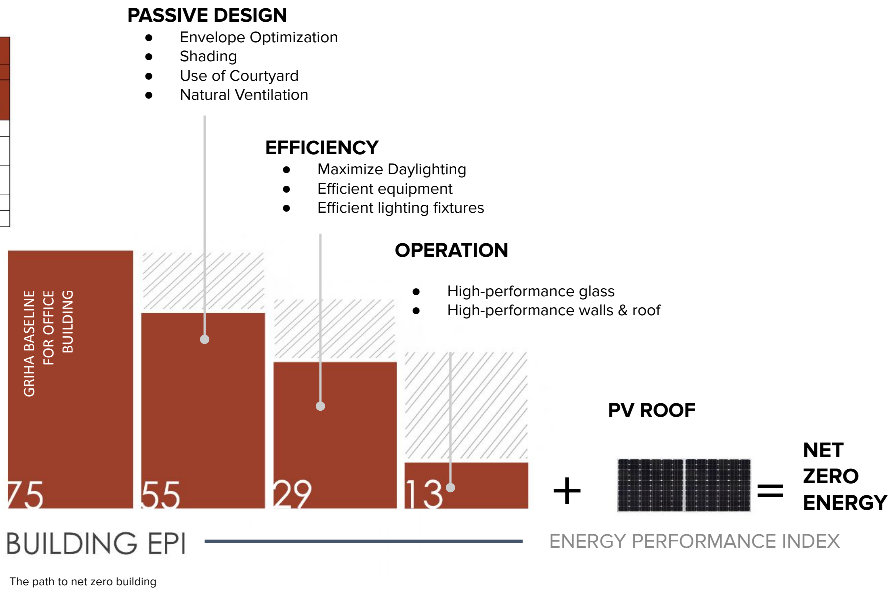


Fig 07: elaborates on the required criteria to achieve net zero energy building and the practical calculation to achieve an EPI that is less than a benchmark as given by GRIHA ; Source: Page 12, student report 'Kalakriya'

Students optimized the envelope by optimizing the U-value of the materials, proper use of shading devices for openings and ensuring daylight utilisation within the built structure (Fig. 05). They calculated the overheated periods and experimented with shading mask solutions for different heated orientations. Thus decided on the Vertical Shading Angles (VSA) and Horizontal Shading Angles (HSA) required for designing horizontal and vertical shading devices respectively. (Fig. 06)

The annual water consumption was calculated to be 175475 litre as against GRIHA's base case of 522315 litre annual consumption. This demonstrates the reduction of water usage by 66.40%. This was achieved by using efficient plumbing fixtures reducing the per day consumption. Freshwater requirement was reduced by using recycled water from STP[3] for non-domestic usage and filtered rainwater for domestic usage. (Fig 08)

[3]STP – Sewage Treatment Plant

Water Performance Index (WPI)

WPI benchmark as per various building typologies

WPI benchmark as per various building typologies (liter/person/day)				
Typology	Base case	25%	50%	75%
Healthcare Facility	572	429	286	143
Hospitality	320	240	160	80
Institutional	80	60	40	20
Offices	52	39	26	13
Residential	120	90	60	30
Retail	48	36	24	12
Banquet/Wedding Hall	80	60	40	20
Multiplex	24	18	12	6
Transit and Terminal Station	60	45	30	15

$$\text{WPI (liter/person/day)} = \frac{\left(\text{Domestic water} + \text{Flushing water} + \text{Irrigation water} + \text{Cooling tower water}\right) - \left(\text{Stored rainwater} + \text{Treated wastewater}\right)}{\text{Occupancy}}$$

Domestic water	191.25L
Flushing water	289.5L
Irrigation water	26.19L
Treated waste-water+ Stored rainwater	142.5L
Occupancy	30

WPI (Liter/person/day) = (191.25+289.5+26.19)- (142.5)/30

= (506.94)- (142.5)/30

= 364.44/30

= **12.148 Litre/ person/ day**

Water Quality & Self Sufficency (WPI)- GRIHA points		
Ensure that the project meets water quality norms for drinking/domestic use as per BIS 10 500 : 2012 and treated water for irrigation and discharge should be as per the CPCB	0	0
Ensure that the project demonstrates reduction from GRIHA benchmark WPI		
Percentage reduction from GRIHA benchmark - < 75%	5	5
Criterion total	5	5

WPI Reduction $= \frac{\text{(Base case WPI as per GRIHA benchmark} - \text{Design case WPI) x 100}}{\text{Base case WPI as per GRIHA benchmark}}$

= (80-12.148)X100/ 80

= **84.815%**

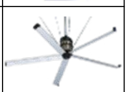
Fig 08: showcases the Water Performance Index(WPI) reduction calculation ; Source: Page 29, student report 'Kalakriya'

Low-wattage and high-luminescence lighting fixtures were chosen and lighting loads were calculated. An EPI[4] of 7.61 kWh/sqm/year was achieved which was much less than the GRIHA benchmark case of 13 kWh/Sq. m/ year. This was achieved by using fewer electrical lighting equipment by proposing solar-operated lighting devices and utilizing maximum solar energy during day and night. (Fig. 09, 09a) "Kshema", designed by one of the teams in AY 2023, experimented with more naturally available sustainable materials. During this AY[5], green building approach was narrowed down and a comprehensive GRIHA checklist format was provided to the batch for a better presentation of analysis and design at the end.

To reduce vehicular movement on site and reduce the carbon footprint produced by fuelled transportation, provision for electric vehicle shuttle services, bike paths was made.

Water conservation during construction was proposed using gunny bags for watering and compacting rammed earth walls. This method ensures that water is used efficiently by minimizing losses through evaporation and the amount of water used can be carefully measured and monitored. Furthermore, stormwater and treated wastewater are proposed to be utilized for purposes like cleaning, flushing and irrigation for water efficiency during operation.

Equipment Load Calculation

Appliances	Cost in rupees	Power	
Farberware Classic FMO07ABTWHA Microwave oven	15,299	700	
Godrej 190 L 5 Star Inverter Direct-Cool Single Door Refrigerator	16,990	285	
High Volume low Speed (HVLS) Fan HF-12 B5	20,000.00	750	

Appliances	Cost in rupees	Power	
Dell Latitude series laptop	59,828	137	
Havells Exhaust fan (Ventil air) @200mm	1290	32	
HP SMART TANK 750 WI FI DUPLEXER PRINTER	23,020	0.1 watts (off); 1.10 watts (sleep)	

Rate of equipments used

Appliances	Nos.	Wattage	No. of hours per day	No. of days	Energy consumed annually (kwh)
Printer (commercial)- Standby	1	30	0.5	240	3600
Printer (commercial)	1	400	1	240	96000
Microwave	1	700	0.5	240	84000
Refrigerator	1	285	24	240	1641600
Water purifier	1	25	0.5	240	3000
Projector	1	300	1	240	72000
Pump	1	60	8	240	115200
Fan	22	750	7	240	1260000
Laptops	7	50	7	240	84000
16A power socket	2	1000	1	240	240000
6A power socket	25	100	2	240	48000
CCTV	2	20	24	365	175200
Electric Stove	1	1500	0.5	240	180000
Exhaust Unit	3	60	1	240	14400
Generators	1	800	1	240	192000

Total (Wh)	**4209000.00**
Total (kWh)	**4209.00**
Built up area	**553.30**
EPI	**7.61**

Fig 09: lighting load calculation ; Source: Page 18, student report 'Kalakriya'

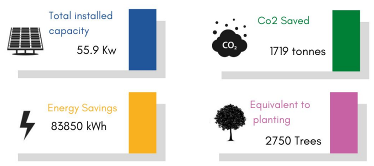
[4]EPI - Environmental Performance Index
[5]AY - Annual Year

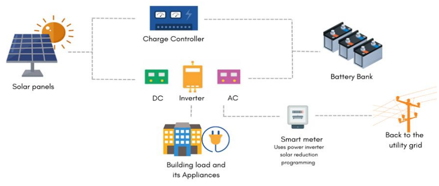
Solar Potential

The site receives an average solar irradiance of 1266.52 W/sqm.1 kWp solar rooftop plant will generate an average over the year 5.0 kWh of electricity per day(considering 5.5 sunshine hours) Total roof area of the project is 699 sqm and the rooftop available for the solar panels after eliminating the joineries and connection is 80%. Hence total electricity generation from solar plant annually is 83850 kWh.

MODULE SPECIFICATIONS
Loom Solar Panel - Shark 440
Size : 6.9 ft * 3.4 ft
Monocrystalline solar panel
Series : (12*6)*2 of 144 cells

1. Size of Power Plant	
Feasible Plant size as per your Roof Top Area :	55.9kW
2. Cost of the Plant :	
MNRE current Benchmark Cost (without GST) :	Rs. 38236 Rs. / kW
View Benchmark Cost List	
Without subsidy (Based on current MNRE benchmark without GST) :	Rs. 2137392
With subsidy 0 (Based on current MNRE benchmark without GST) :	Rs. 2137392
3. Total Electricity Generation from Solar Plant :	
Annual :	83850kWh
Life-Time (25 years):	2096250kWh
4) Financial Savings :	
a) Tariff @ Rs.8/ kWh (for top slab of traffic) - No increase assumed over 25 years :	
Monthly :	Rs. 55900
Annually :	Rs. 670800
Life-Time (25 years) :	Rs. 16770000





Schematic working diagram of PV Panels

Renewable energy utilization		
Would you select Alternative 1 or Alternative 2?	Alternative 1	
Alternative 1: On-site/Off-site renewable energy system installation to offset a part of the annual energy consumption of internal artificial lighting and HVAC systems (Mandatory requirements must be met through On-site renewable energy system)	7	7
Alternative 2: Off-site renewable energy system to offset 100% building energy demand	0	
Criterion Total	7	7
Low ODP materials		
All the insulation used in building should be CFCs and HCFCs free	1	
All the refrigerant in the HVAC and refrigeration equipment should be CFCs free		
The fire suppression systems and fire extinguishers installed in the building are free of halon		
Criterion Total	0	

Fig 09a: equipment load calculations ; Source: Page 20, student report 'Kalakriya'

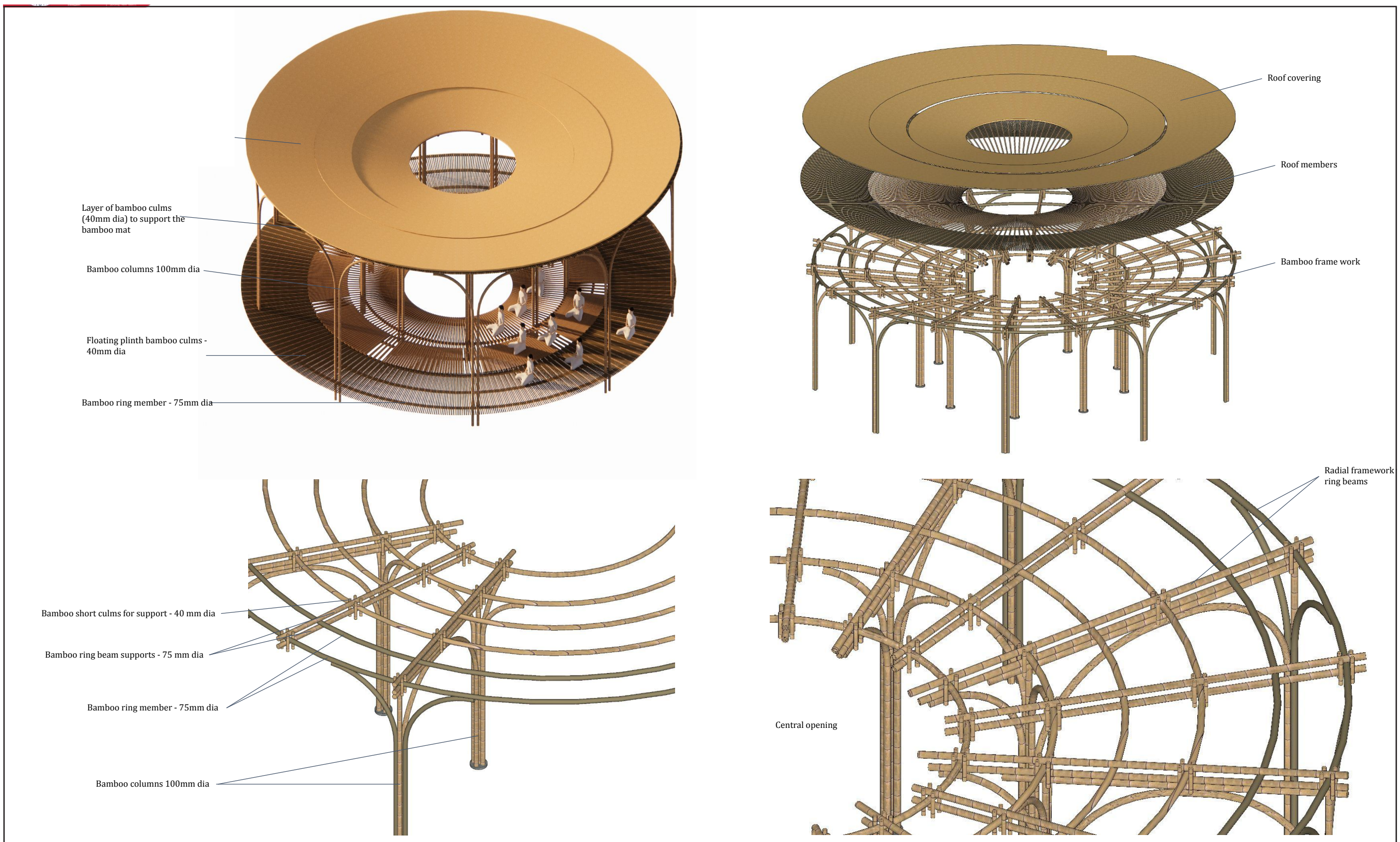


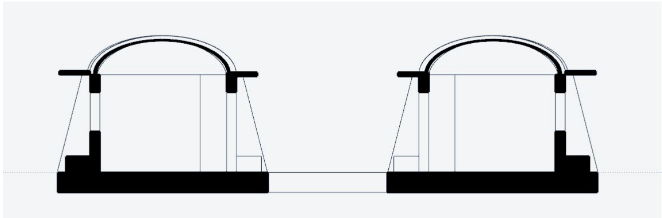
Fig 10: Elaborating on use of bamboo in the design. ; Source: Page 12, student report 'Kshema'

Hybrid recycling techniques were proposed, which combine both on-site and off-site recycling methods. This involves segregating waste directly at the source, such as having designated containers for wood, earth, and non-recyclables like plastics. This includes multi-colored waste bins for e-waste, biomedical waste, organic waste, plastics, paper, and other non-organic solid waste. Additionally, it lessens the workload for waste handlers, leading to cost savings.

To further minimize waste, excavated earth from the site was repurposed as a building material in the form of rammed earth walls and mud bricks for vault construction.

Bamboo has been one of the major construction materials proposed in this project. Bamboo is known for its low carbon emission in addition to its vast availability, its flexible feature and for its biodegradable nature. (Fig. 10)

The material composition of the various building components was used to reduce their Thermal Transmittance(U – Value). For wall construction, the use of 2 lines of bamboo with mud plaster gave a U-value of



Dorms section

Dorms view

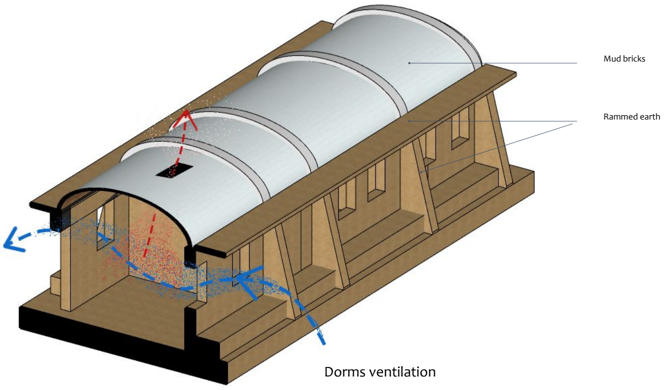


Fig 11: Elaborating on use of materials ;
Source: Page 10, student report 'Kshema'

1.4W/m² and for a wall constructed with rammed earth, the U -value achieved was 1.9W/m² which is lesser than that of a standard brick masonry wall (2.0 W/m²).
For roofing, earth vaults with bamboo reinforcement were used giving a U-value of 0.31 as compared to a concrete 6" thick roof slab with a thermal transmittance range of 1.67 - 0.83 (Fig 11)
A Double Glazed Unit (DGU) with an air gap of 6mm of U -value - 3.6W/m² was used for the windows, this value is lesser than that of single glazed window of a U value - 5W/m² Window Wall Ratio (WWR) of 25% was designed to increase daylight and natural ventilation.
As a result of reduction in energy consumption, an Energy Performance Index (EPI) of 29.642Wh/m²/annum was achieved which is 57.65% less as compared to GRIHA base case of 70Wh/m²/annum.

Parameter	Data
Site Area (m2)	11000
Total Built up Area (m2)	400
Occupancy	40
Occupancy Schedule Weekdays// Weekends Usage Hours per day	7 days a week 24 hr/day
Number of days building used (Annually)	360
Annual Electricity Consumption in Lighting (kWh)	1917.12
Annual Electricity Consumption in Ventilation (kWh)	1050
Total Annual Electricity Consumption (kWh)	12424.5
Energy Performance Index (EPI) (kWh/m2/annum)	29.642
GRIHA EPI and Percentage Reduction	57.65
EPI Considering only lighting and ventilation	7.4175
Percentage reduction from GRIHA	89.23

Fig 12(a): EPI reduction calculation ;
Source: Page 19, student report 'Kshema'

The project proposed use of water efficient plumbing fixtures, reduction of fixtures by designing common wet areas, and shorter distance to STP to reduce material cost. Use of filtered rain water collected through catchment areas and sewage treated water that would not compromise on the hygiene of the user. was used for landscape, planting native shrubs and trees. In addition, a drip irrigation system was used to reduce use of water intensity. All these adaptations resulted in reducing the water consumption by 77%.

Lighting load =	1917.12	EPI =	Total energy consumed
Power demand =	9939.68		Total built area
	11856.8		Lighting Load + Electrical Load
			Total Built Area
	29.642		
			6121.5+12484.6
			400
			11856.8
			400
			29.642
		GRIHA Base Case EPI = 70 (Residential)	

Fig 12(b): EPI reduction calculation ;
Source: Page 19, student report 'Kshema'

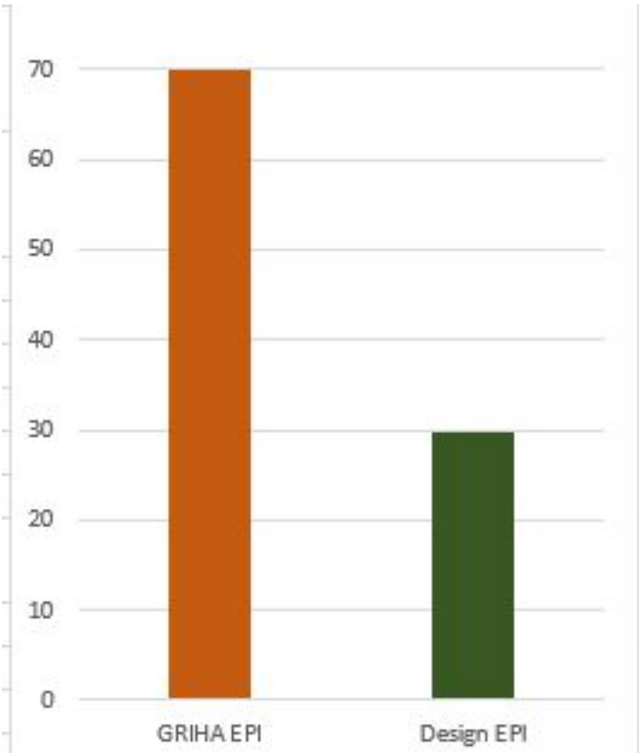


Fig 12(c): EPI reduction calculation ;
Source: Page 19, student report 'Kshema'

Conclusion:

The students have evinced interest in the project from the outset as the idea of design audit based on the GRIHA checklist fascinated them. It was in-turn fascinating to witness the teams to be innovative and resolve the given predicament.

The following points may be deduced from the feedback from the students:

1. Most of the students felt that they were introduced to the concept of green buildings well and they could retain the principles involved. (Weighted average of 7.6 was achieved on a 10-point scale)

2. Most of the students felt that they could relate to the latest construction trends. (Weighted average of 7.6 was achieved on a 10-point scale)

3. There was a mixed response about the Green Building lecture material's utilization thus indicating a scope for improvement. Although a lot of students understood and could use the information well, a small section of the students felt it could have been elaborated better. (Weighted average of 6.8 was achieved on 10-point scale)

4. There was a mixed response about the Project Checklist/ Self-Assessment tool's utilization indicating a scope for improvement. Although a lot of students could use it well, a small section of the students felt some difficulty in using the same. (Weighted average of 6.8 was achieved on a 10-point scale)

5. There was a mixed response about the insights about the Greenabout Green Building Project Design process indicating a scope for improvement. Although a lot of students felt that they were useful, a small section of the students felt some difficulty in relating to the same. (Weighted average of 7.3 was achieved on a 10-point scale)

6. Some students indicated that they needed more practical exposure with case studies, to understand the entire design and assessment process.

This pedagogical process experiment stands as a good example of cross-sectional integration of design and construction towards a greener and more sustainable architectural profession. Going forward, more relevant case studies may be introduced to reinforce the connection between concept and reality.

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