06. Solar Decathlon India.

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Teams representing RV College of Architecture at the Solar Dectahlon India (SDI) competition.

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Abstract :

Rapid urbanisation and globalisation has, today, put cities on an investigative as well as an empathetic trail of overcoming complex issues incorporating sustainable and resilient practices. Needless to say, the built environment plays a crucial role in the management of such urban complexities and transformations. Solar Decathlon, organized by The Indo-U.S. Science and Technology Forum (IUSSTF), the Alliance for an Energy Efficient Economy (AEEE), and The Indian Institute for Human Settlements (IIHS) is a challenge put forth to undergraduate and postgraduate students of India to explore net zero building concepts and propose design solutions incorporating energy efficient, affordable and resilient. The participants are encouraged to propose real time projects of the building sector with an overarching aim of combating climate change. This year-long challenge exposes the participant teams to self learning modules and mentorship programs to develop the necessary skills and tools to develop affordable and industry ready net zero solutions.

The report presented below entails the project works of three teams representing RV College of Architecture.

1. Team EnCircle:

Team EnCircle's project titled Aikyam provides insights into a net-zero energy community resilience shelter for PWD (Public Works Department.) Arunachal Pradesh. The project's intent is to enhance the microclimate of the site and provide shelter, aid, and comfort during disasters. Strategies such as using locally sourced, recycled, and rapidly renewable materials, along with life cycle assessments, showcase the project's dedication to sustainability.

2. Team Engriha:

Team Engriha highlights their project focusing on designing a net-zero construction worker housing colony. The team prioritises modularity, economic viability, structural stability, and reducing embodied carbon. The material selection process involves an in-depth analysis of various options, and they opt for innovative solutions like Ricron panels with corrugated jute cores.

3. Team Green Collars:

Team Green Collars Discuss their project, EKĀGRA, a net-zero-energy-water school in Nagaon. Their approach involves a holistic consideration of factors such as energy efficiency, water conservation, and circular economy principles.

Overall, each team addressed environmental issues, with a clear objective of achieving lower carbon footprints, and establishing a standard for sustainable practices in the building sector.

Keywords:

Sustainability, Net Zero, Carbon footprint, Materiality, innovation

Team EnCircle

Division : On Site Construction Workers Housing

Team EnCircle, as part of the Solar Decathlon (India), seized the opportunity to design a net-zero energy community resilience shelter for the PWD[1] Arunachal Pradesh in Itanagar. The team's mission was to enhance the microclimate of the space (using GRIHA[2] strategies) and providing shelter, aid, comfort, social resilience, water, and food resilience to people during disasters. The proposed project, Aikyam, is a G+2-story office building situated in the Civil Secretariat complex at Itanagar, with a site area of 3,640 sqm adjacent to NH415. This report delves into the comprehensive process followed by Team EnCircle in choosing the right materials, the initial choices, the reasons for rejection, and the final materials that were incorporated into the construction of the project to create a sustainable and environmentally friendly structure. The goal for the total embodied carbon emissions of the project to be achieved was at least 50% lesser than the base case (68% achieved).

Process of material selection for team encircle's Aikyam involved several key steps:

Identifying Contest Criteria and Material Criteria:

Team EnCircle began by analysing the ten contests in the Solar Decathlon competition. These contests likely covered various aspects of the building criteria and then defined essential material criteria, including U-value, earthquake resilience, environmental impact, sustainability, availability, moisture resistance, availability of skills, and cultural and aesthetic relevance.

[1]PWD: Public Works Department | District East Siang, Government of Arunachal Pradesh | India.

[2]GRIHA: Green Rating for Integrated Habitat Assessment. GRIHA is a rating tool that helps people assess the performance of their building against certain nationally acceptable benchmarks. It evaluates the environmental performance of a building holistically over its entire life cycle, thereby providing a definitive standard for what constitutes a 'green building'.

Understanding Materials with Low-Embodied Carbon:
Embodied carbon refers to all the greenhouse gas emissions generated throughout the materials' lifecycle from extraction to disposal , which includes , manufacturing, transportation, and disposal phases of a material. Reducing embodied carbon has emerged as a crucial objective in the battle against climate change since the building sector contributes significantly to global greenhouse gas emissions.

Design Strategies:
The team worked on the following predeterminants for material selection

1. **The use of locally sourced materials**: All materials apart from recycled steel, are available within a 300-kilometre radius. Recycled steel is bought from Jindal Steel and Power, Chhattisgarh, located 1850 km away from the site. Material suppliers are located within a 30 kilometre radius of the site, reducing the embodied carbon emissions due to reduction in transportation time.

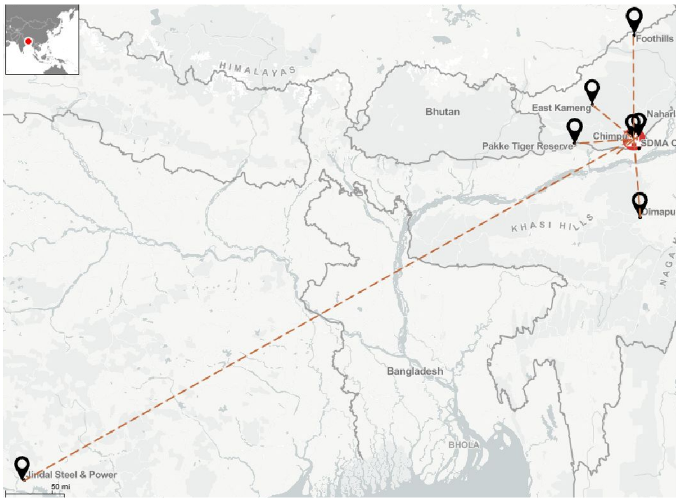


Fig. 1. Sourcing of materials (Source : Page 18, Team EnCircle design report)

2. **Recycled and Recyclable Materials**: Reduces the need for production procedures that are energy intensive and also helps in preventing trash from ending up in landfills.

3. **Rapidly Renewable and Natural Materials:** Since bamboo and wood are naturally replenishable materials, the embodied carbon footprint can be reduced by substituting these materials for more carbon-intensive ones.

4. **Fly Ash-Based Products:** Traditional cement produces a significant amount of carbon dioxide during production, which was reduced through the utilisation of fly ash-based products. Using earth blocks and fly ash-based building materials can result in usage of less water during the process of construction and also reducing water-related emissions.

5. **Minimising Cut and Fill:** To lower the emissions caused by soil extraction and transportation.

6. **Construction Waste Management:** To cut down on methane generation and emissions from decomposition.

7. **Afforestation and Social Forestry**

Exploring Material Options
Each material underwent rigorous assessment against the defined criteria. Factors like embodied carbon, seismic performance, thermal properties, environmental impact, and local availability were carefully considered. Prospective materials were also compared to conventional alternatives to determine their relative sustainability.

MATERIAL	AAC BLOCKS	GLASS		RAMMED EARTH	VINYL FLOORING	BAMBOO REINFORCED CONCRETE	SHEEP WOOL INSULATION
U-VALUE							
EARTHQUAKE RESILIENCE							
ENVIRONMENTAL IMPACT							
SUSTAINABILITY							
AVAILABILITY							
AFFORDABILITY							
MOISTURE RESISTANCE							
AVAILABILITY OF SKILLS							
CULTURAL AND AESTHETIC RELEVANCE							

Table showing the properties of the different materials considered. (Source : Page 17, Team Encircle design report)

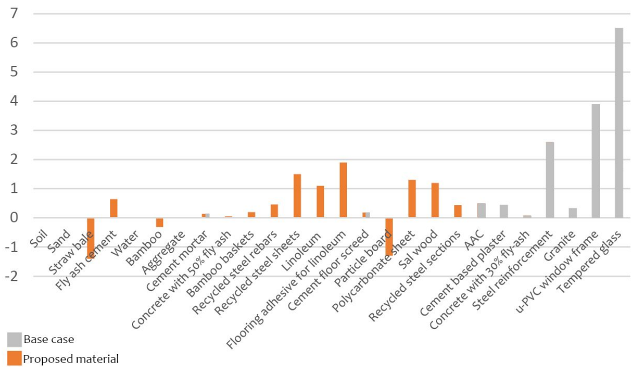


Fig. 2. Embodied Carbon values (Source : Page 17, Team Encircle design report)

Conducting Life Cycle Assessments

Life cycle assessments (LCAs) were conducted for shortlisted materials to analyse their environmental impact from cradle to grave. LCAs helped in quantifying the embodied carbon emissions and overall environmental footprint of each material, aiding in making informed decisions.

Prioritising Low-Embodied Carbon Materials

Reducing embodied carbon was a primary objective for Aikyam. Hence, materials with the lowest embodied carbon emissions were given precedence, provided they met other essential criteria.

Low-embodied carbon materials used by Team EnCircle

1. Walls Made of Earthen Blocks: Compressed earth blocks (CEBs), 600 x 200 x 155 mm, commonly referred to as earth blocks or compressed sand, are made by compressing a mixture of soil (55%), sand (22%), straw fibres (8%), water (3%), and cement (7%) with 30% fly ash. Sand and cement help in increasing the block's strength and make it more seismically resistant. Straw fibres serve

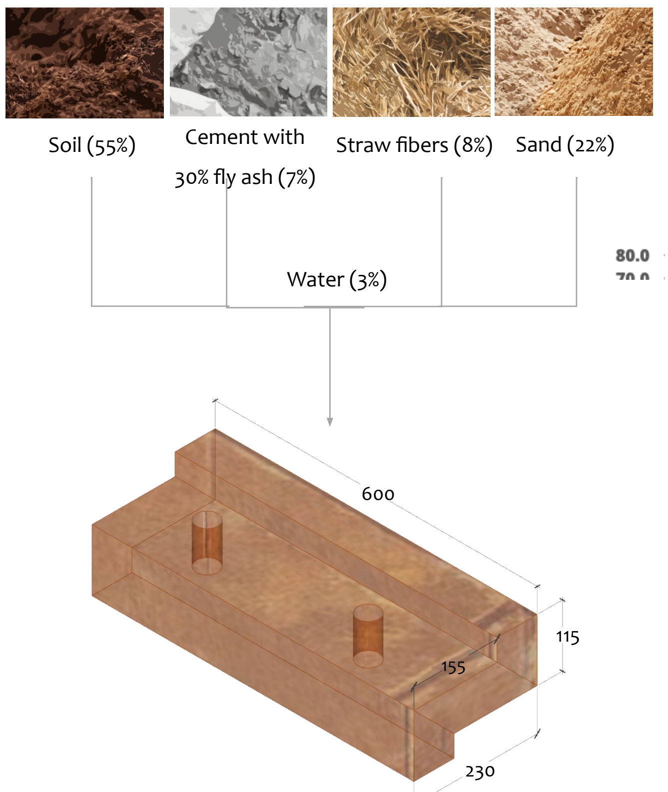


Fig.3. Compressed earth blocks (Source : Page 20, Team EnCircle design report)

as a binder to connect the various components together. All of these materials are readily available nearby, which reduces the transportation-related embodied carbon emissions. In order to hold the blocks together in the event of shear and lateral thrust, each block will include two 40 diameter voids for the insertion of bamboo. The bamboo can be fastened in place using 10mm aggregate and cement mortar. This method not only includes structural stability but also helps with sustainability and carbon sequestration.

2. Linoleum Sheets: It is an excellent alternative for flooring in locations that are susceptible to earthquakes due to its flexibility and endurance. It has low embodied carbon because it is made up of natural, renewable resources like linseed oil, wood flour, and jute, which are non-toxic and biodegradable. Additionally, it requires less maintenance, which means there is less need for harsh cleaning products or chemicals that could harm the environment.

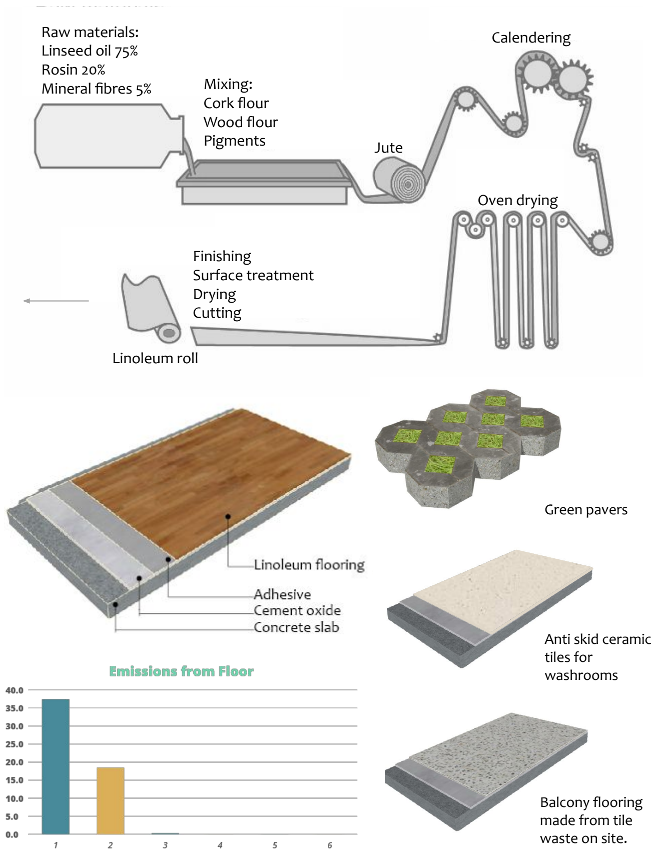


Fig.4. Linoleum flooring (Source : Page 18, Team EnCircle design report)

3. Fly Ash Concrete and Recycled Steel Columns and Beams: The World Steel Association published a report in 2018 stating that the average embodied carbon value of recycled steel is 0.46 kg CO2 eq per kg of steel, which is significantly lower than that of virgin steel because the recycling process uses significantly less energy and emits significantly lesser emissions than the production of virgin steel. A 2018 report by the World Business Council for Sustainable Development estimates that the embodied carbon value of concrete with 30% fly ash replacement is roughly 295 kg CO2 eq per cubic metre, while that with 50% fly ash replacement is estimated to be around 200 kg CO2 eq per cubic metre, which is half the value of conventional concrete, or 400 kg CO2 eq per cubic metre. Construction projects can maintain structural integrity while reducing their environmental impact by integrating these low embodied carbon materials.

4. Slabs, Including Waffle and One-Way Slabs: Compared to PVC (Polyvinyl Chloride) waffle pods, bamboo baskets often have a lower embodied carbon value. Bamboo is estimated to have an embodied carbon value of between 0.1 and 0.3 kilogrammes CO2 eq per kg of bamboo, compared to 1.5 to 2.5 kg CO2 eq per kg of PVC in waffle pods. Exposed bamboo basket pods not only reduce the carbon value but also add an additional touch of vernacularity and aesthetic when exposed . The carbon content and dead load of one-way slabs that alternate recycled steel reinforcement with bamboo reinforcement are significantly reduced.

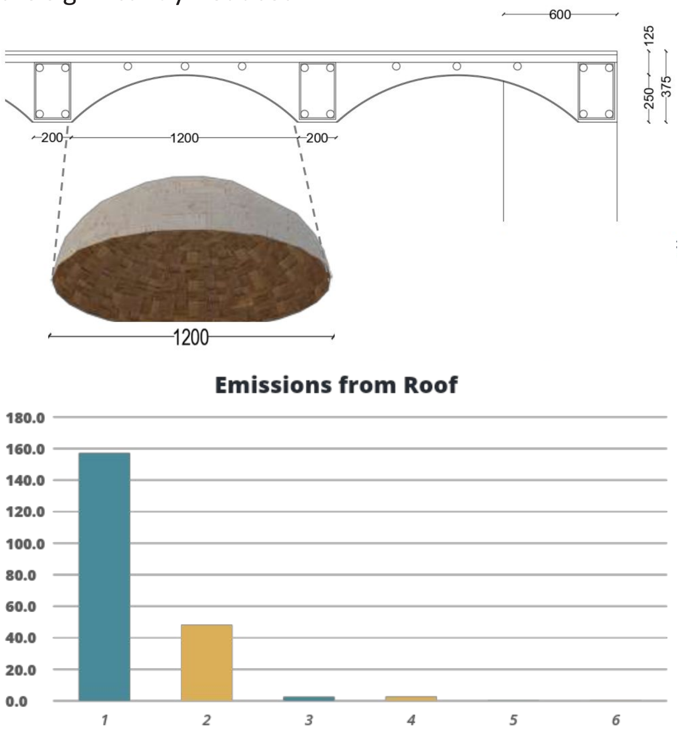


Fig.5. Structure - Waffle slab system (Source : Page 22, Team Encircle Design Report)

5. Fenestrations: Polycarbonate with Sal Wood Frames:
i. Sal wood: wood has a lower CO2 equivalent per kilogramme compared to other building materials, such as steel or aluminium, at 1.1 to 1.3 kg. As a result, the property will receive twice as many trees as were cut down.
ii. Particle board light shelves with reflective coating: Particle board has a lower embodied carbon value than solid wood, because it is typically made from smaller pieces of wood that would otherwise go to waste, it is created by compressing and bonding wood particles together with adhesives. This approach can use less energy and generate less waste compared to solid wood

iii. Polycarbonate: According to life cycle assessment research carried out by the University of Bath and the European Union, polycarbonate sheets have an embodied carbon value that ranges from 1.1 to 1.5 kg CO2 eq per kg of material.They can be used in earthquake prone areas due to their lightweight and flexible nature which allows them to absorb the seismic forces.

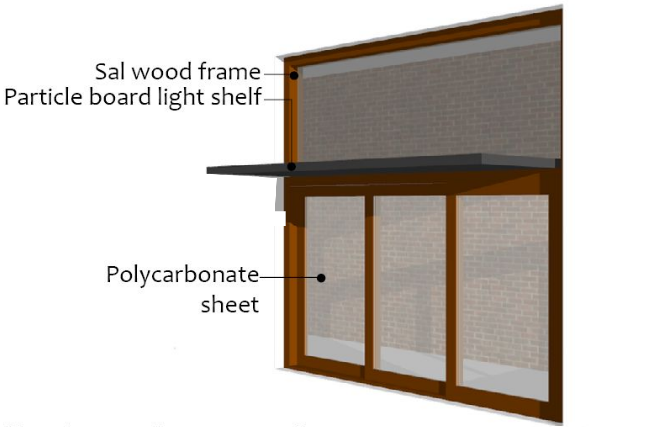


Fig.6. Fenestrations (Source : Page 19, Team EnCircle Design Report)

6. Fins: Wooden Frame with Bamboo Panel: Bamboo is a carbon-sequestering material, according to studies from the Delft University of Technology, with an embodied carbon value of -0.313 kg CO2 eq. Additionally it is conveniently located nearby, decreasing embodied carbon emissions from transportation. Bambusa Tulda,a fast-growing bamboo species that is known for its strength, durability, resistance to pests and diseases, sourced from Chimpu village . This sourcing method helps generate income for the locals through the sale of bamboo. Bamboo harvesting and trade are regulated by the local Forest Department.

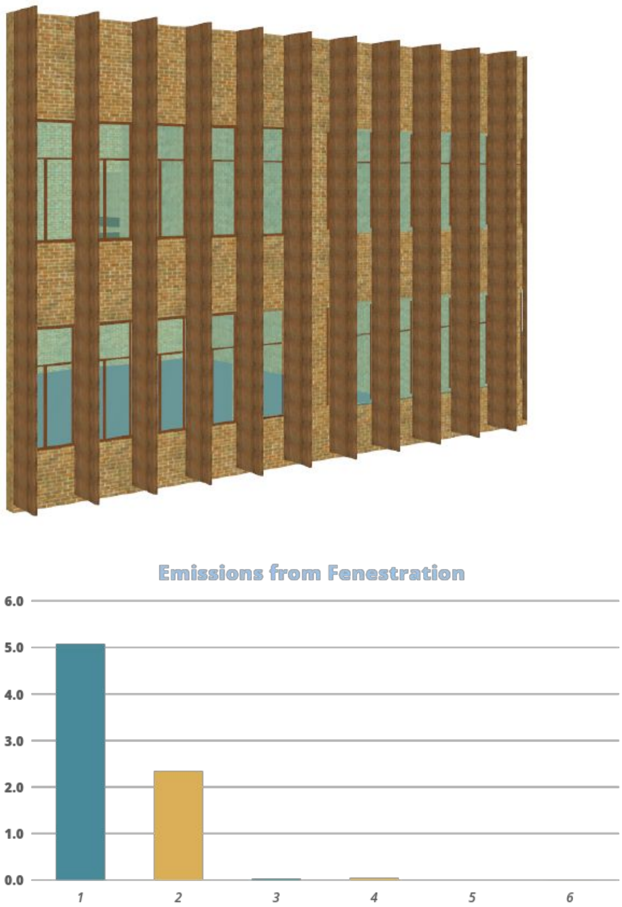


Fig.7. Bamboo fins (Source : Page 19, Team EnCircle design report)

7. Moss Concrete: By absorbing carbon dioxide during photosynthesis, moss minimises emissions from making cement. This cutting-edge application helps in creating a more aesthetically pleasing and environmentally friendly design.

8. Short pile foundation: Commitment to reducing embodied carbon emissions and enhancing seismic resilience, short piles not only offered a stable foundation but also minimised the use of virgin steel, leading to a lower environmental impact. By incorporating fly ash concrete, a byproduct of coal-fired power plants, the team reduced the need for traditional cement, which contributes significantly to carbon emissions during production.

CONCLUSION

Project Aikyam exemplifies the importance of low embodied carbon materials in creating a sustainable future for construction. Through a thoughtful and comprehensive selection process, the project prioritised materials that align with environmental responsibility, cultural relevance, and seismic resilience. Aikyam's harmonious blend of tradition and innovation serves as an inspiring example of how sustainable architecture can lead us towards a brighter, greener, and more resilient future for generations to come.

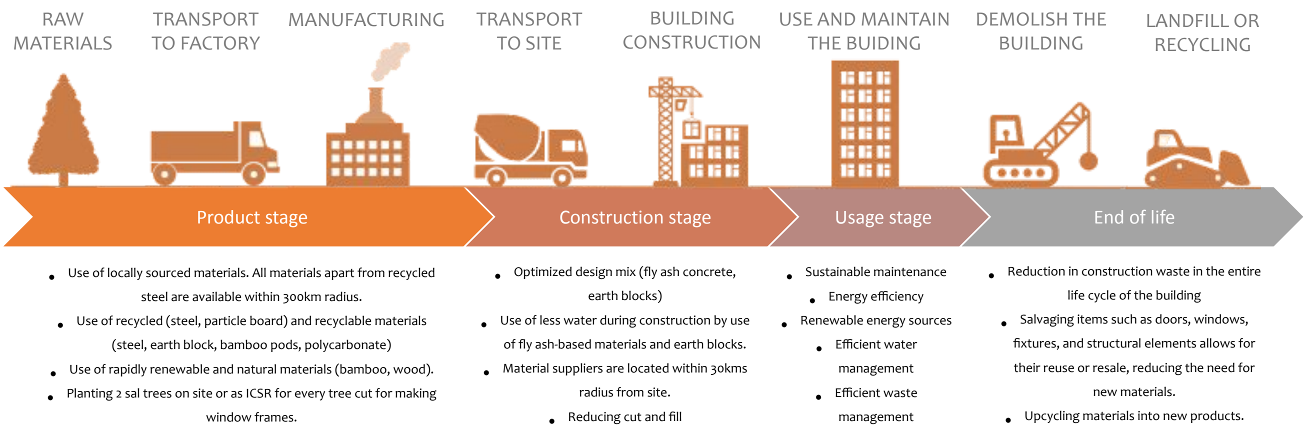


Fig.8. Cradle to grave: Embodied carbon reduction strategies (Source : Page 17, Team EnCircle design report)

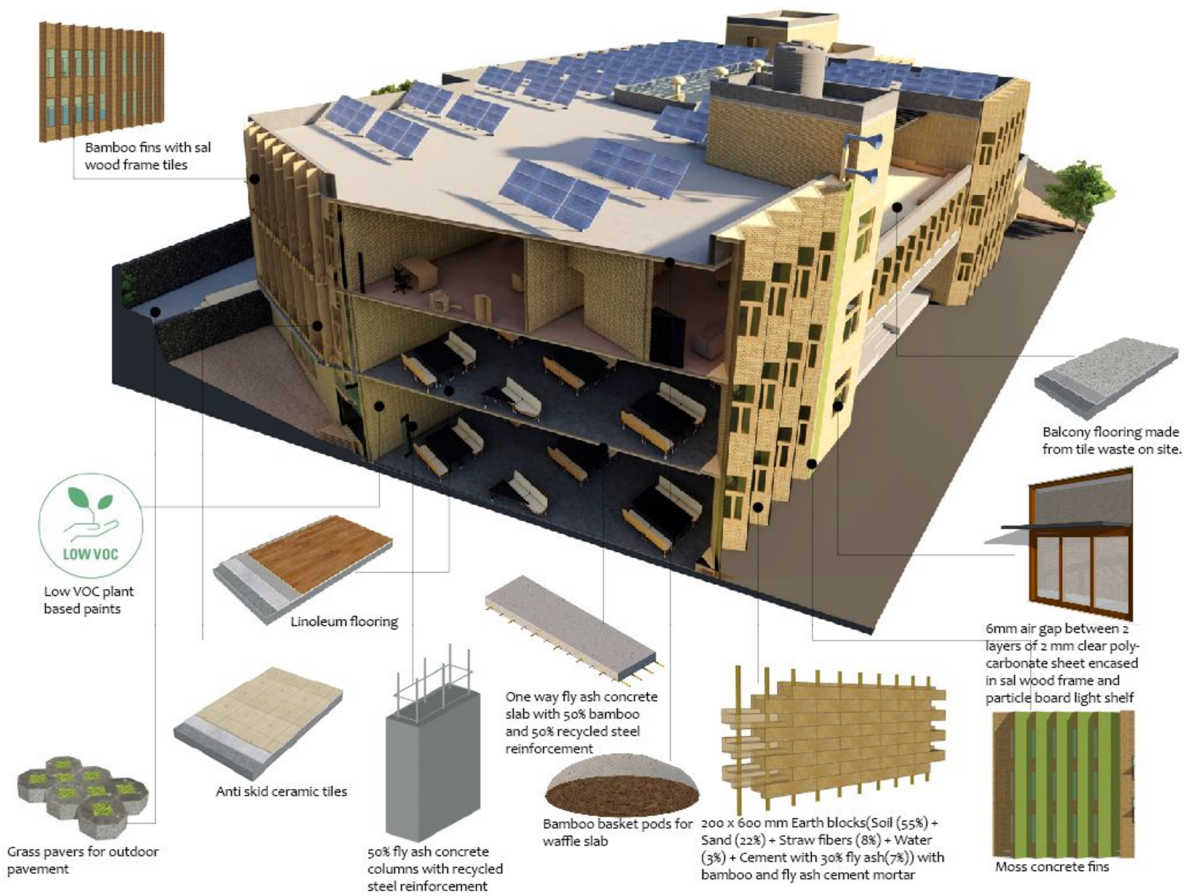


Fig.9. Materials : Embodied carbon reduction strategies (Source : Page 17, Team EnCircle Design Report)

Team EnGriha:

Division : On Site Construction Workers Housing

Introduction and Context :

EnGriha, embarked on a journey with the fundamental query: "Is it fair to assume that construction workers, as transient occupants, should be deprived of fundamental amenities and suitable living conditions?" EnGriha placed its primary focus on the development of a net-zero construction worker housing colony designed to cater to the unique requirements of this housing sector within India. Employing a data-driven methodology, they brought together students specialising in architecture and engineering to guarantee sustainability, comfort, and a high standard of living for the workers. The intervention site was in Vizag, under a project by KEC International, but the project works as an infill irrespective of the context making it a modular solution to urban housing problems.

Design and Optimization

The team had a clear set of major factors in mind that they aimed to achieve. Firstly, they prioritised modularity in their design, recognizing the need for easy relocation within a construction site for construction workers while minimising waste generation (less than 5%) at the current site.

Secondly, the team considered the economic aspect of the project. They acknowledged that construction worker housing represents a temporary and uncertain investment, which often discourages substantial investments in robust designs and long-term plans. Addressing this, they proposed a rental model, allowing excess housing units to be rented out for income generation, achieving an impressive return on investment of 62.19% per year. The modularity of the structure played a pivotal role in enabling this rentability.

Fig.2 : Render of the overall cluster with the panel installed (Source : Page 12, Team EnGriha design report)

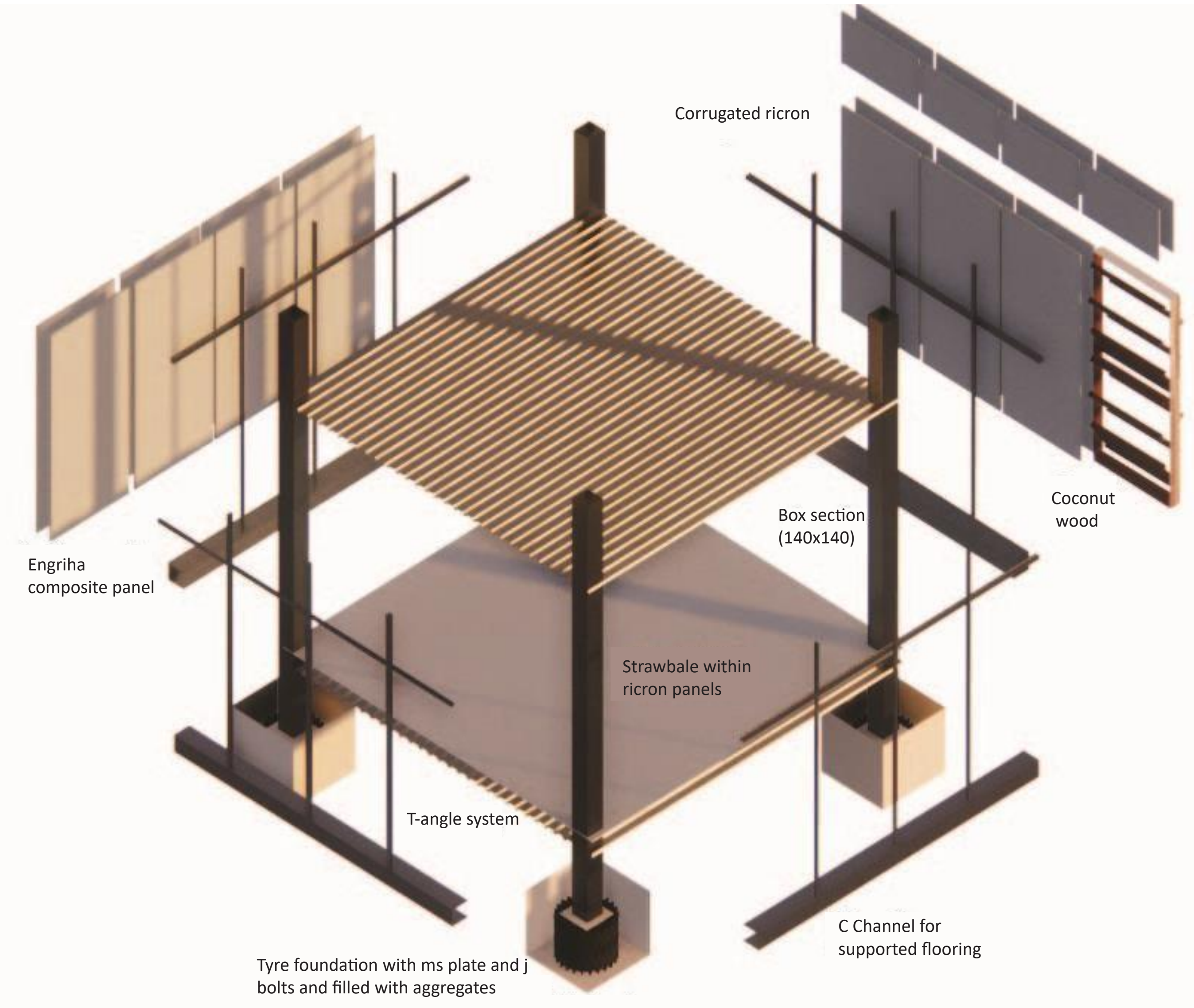


Fig.1 : Exploded view of one unit showing the location of the panel (Source : Page 11, Team EnGriha design report)

The third crucial factor was to ensure structural stability. To meet this requirement, the team adopted a panel and structure system, consisting of primary and secondary members constructed using steel, while the walls were composed of a composite panel.

Lastly, the team placed great emphasis on addressing Embodied Carbon. Given their choice to use steel for structural components due to its ease of construction, strength, and stability, they innovated by incorporating natural and recycled materials to balance the high embodied carbon associated with steel. This forward-thinking approach aimed to minimise the environmental impact of the construction worker housing colony

With the structure and foundation firmly established, the team turned its attention to the crucial aspect of panel selection. A wide array of market-available panelling materials presented themselves as potential options, including familiar choices such as tin corrugated sheets, Polyurethane Foam panels, Aluminium Composite Panels panels, cement boards, and even treated bamboo panels. The team then embarked on the process of narrowing down these choices, considering various factors. Their first and foremost consideration was to reduce Embodied Carbon, which quickly narrowed the options down for panelling materials. They were astonished by the significant carbon emissions associated with the production of these widely used panels. Next, they scrutinised the options based on cost, leading them to focus on three remaining choices: cement boards, Vaspar Concepts, the company (corrugated plastic panels), and bamboo panels. In addition to these market-available options, the team also contemplated the possibility of developing a custom solution which is currently not available in the market. This comprehensive evaluation ensured that the final panel selection would align with their project's environmental goals and budgetary constraints.

Corrugation density can be changed based on the U value required Corrugated Jute Ricron Panel Grasshopper code Prototyping.

Initially, the team explored the possibility of using Vaspar Concepts' panels due to their recycled and lightweight nature. However, upon closer examination, it became evident that these panels would significantly strain the project's budget. To put it into perspective, using these panels for the walls alone would have consumed nearly 50% of the budget.

While bamboo was considered a viable option, it didn't quite offer the structural resilience needed for continuous assembly and disassembly. Consequently, bamboo was reserved for the use in common areas, leaving the team with no viable choice for the living units themselves. At this juncture, the team discovered Ricron, a panel material crafted from recycled MLP (Multilayer Plastic).

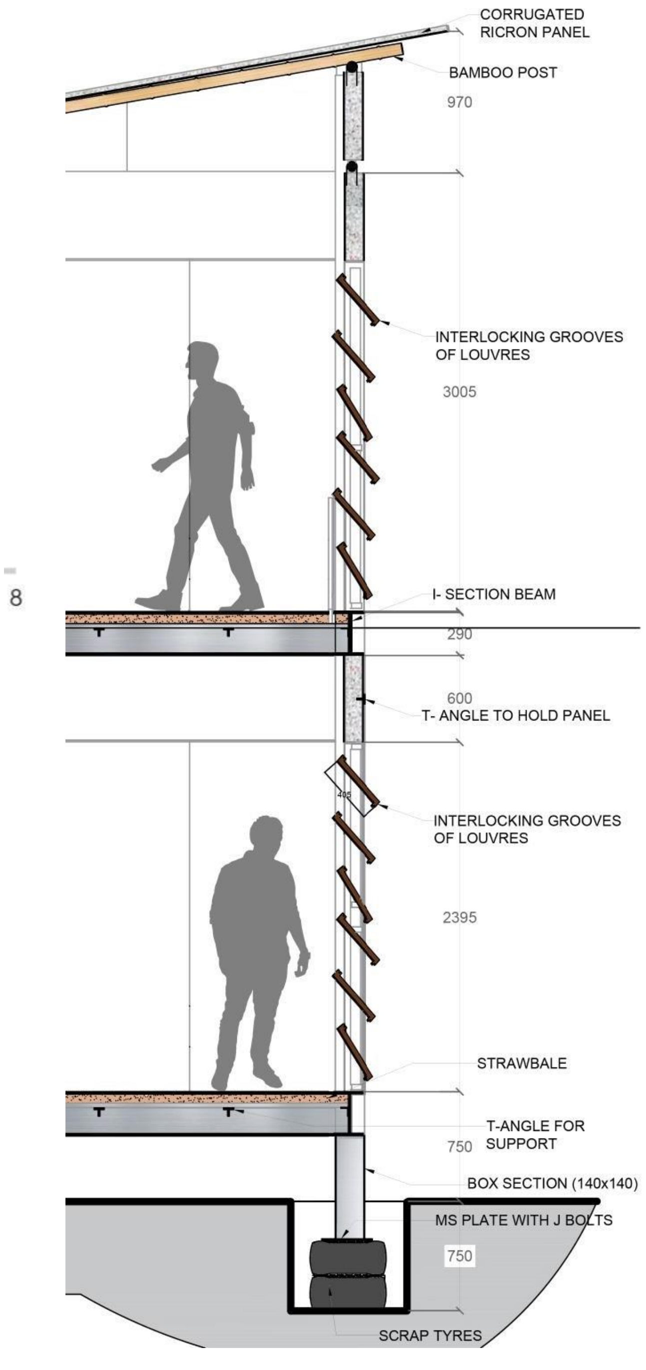


Fig.3 : Section through louvred panel (Source : Page 12, Team EnGriha design report)

Fig.4 : View of a unit with the panel installed (Source : Page 36, Team EnGriha design report)

Ricron was not only cost-effective, but it also addressed environmental concerns by repurposing MLP waste. Encouraged by discussions with their industry partner, RICRON India Pvt. Ltd., examination of Central Institute of Plastics Engineering And Technology (CIPET) test results, and conducting their own series of tests, the team went ahead in selecting RICRON as their exterior cladding material. However, the challenge still remained with the core material. Given the advantages of corrugation and the alternating layers of air and insulation seen in the Vaspar Concepts panel, the team decided to utilise corrugated jute as the core material. This innovative approach aimed to strike a balance between structural integrity, environmental sustainability, and cost-effectiveness in the panel design.

Testing

To validate the simulated U-value obtained through Grasshopper, the team conducted physical testing on the constructed panel. This testing took place over a 6-hour period, starting from 11 am to 5 pm. To facilitate the testing process, they built a plywood chamber to enclose one side of the EnGriha panel. During the testing, the panel was positioned so that one side remained shaded within the chamber, while the other side was exposed to direct sunlight. To monitor the panel's performance, thermometers were affixed to both the inner and outer surfaces of the panel. Hourly readings were diligently recorded throughout the 6-hour testing period. Upon completing the testing and collecting the necessary data, the team calculated the composite U-value for each panel, which was determined to be 0.253 W/m² K. Remarkably, this experimental value closely aligned with the previously simulated U-value obtained through Grasshopper, which had been calculated to be 0.258 W/m² K. This congruence between the simulated and experimental results affirmed the accuracy and reliability of their simulation methodology

Thermal comfort comparison of the unit

In order to analyse the impact of corrugation value, density, volume, and the resulting U-value of jute, the team created a Grasshopper code. This code enabled them to determine the equivalent volume of jute when it was in corrugated form and calculate the final U-value of the panel. Initially, they conducted simulations to assess the panel's performance, focusing on obtaining the composite U-value. Key parameters such as the thickness of the Ricron panel, the equivalent thickness of the corrugated jute, and air were used as input variables. These parameters were input into the Grasshopper simulation, which was then executed to calculate the composite U-value. The outcome of this simulation revealed a composite U-value of 0.258.

Results

TIME OF DAY	INSIDE (K)	OUTSIDE (K)	DIFFERENCE IN TEMPERATURE (ΔT)
11:00 AM	306.65	306.85	0.2
12:00 AM	311.18	311.21	0.03
1:00 PM	311.75	312.04	0.29
2:00 PM	310.15	310.35	0.2
3:00 PM	309.15	310.35	1.2
4:00 PM	308.15	308.32	0.17
5:00 PM	307.25	307.45	0.2

(Source : Page 35, Team EnGriha design report)

Reading

Q VALUE		K VALUE	R VALUE	U VALUE
Q1	0.105269507	0.035528458	3.949770826	0.253179246
Q2	0.015790426	0.035528458	3.949770826	0.253179246
Q3	0.152640785	0.035528458	3.949770826	0.253179246
Q4	0.105269507	0.035528458	3.949770826	0.253179246
Q5	0.63161704	0.035528458	3.949770826	0.253179246
Q6	0.089479081	0.035528458	3.949770826	0.253179246
Q7	0.105269507	0.035528458	3.949770826	0.253179246

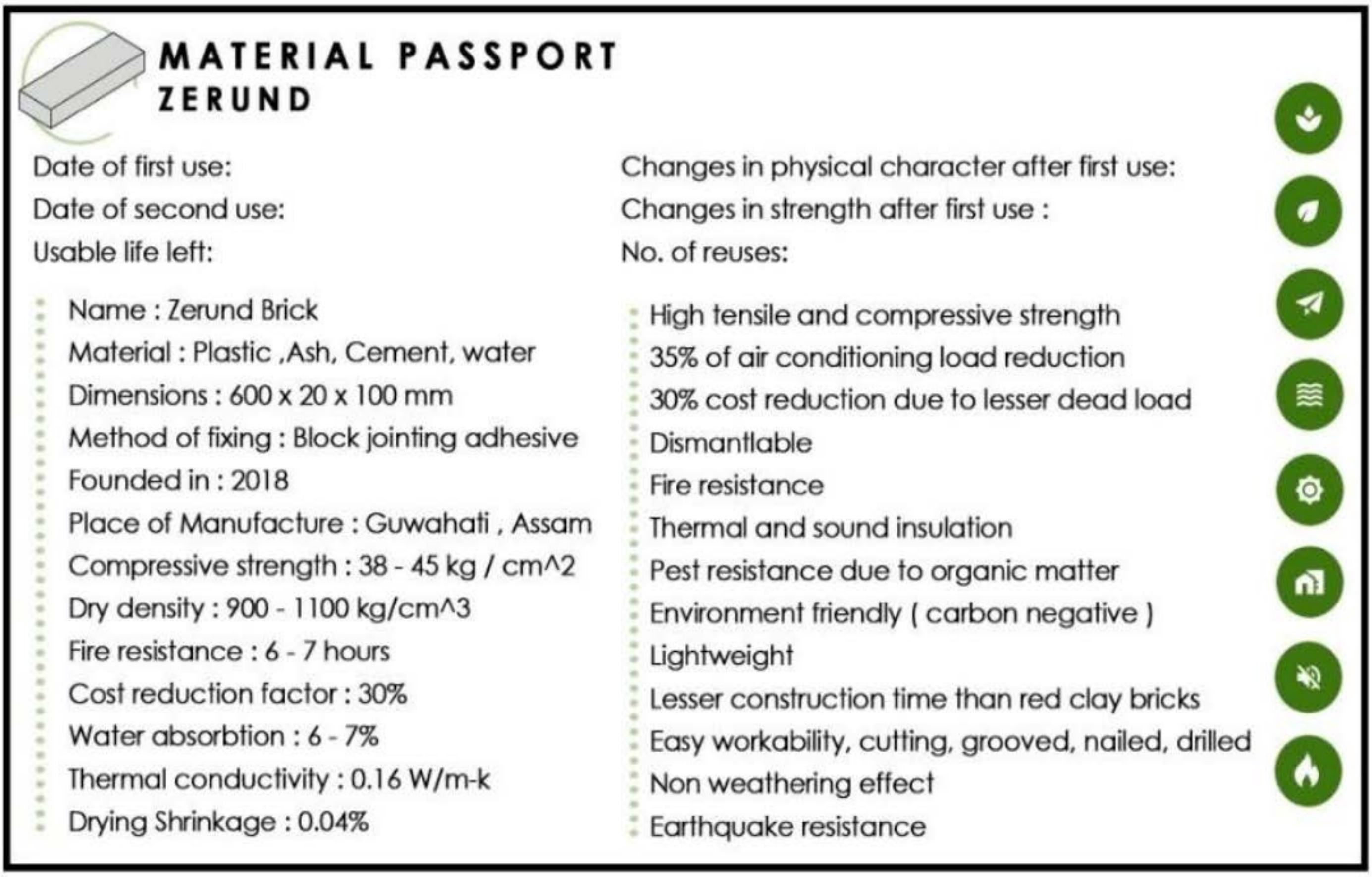
(Source : Page 35, Team EnGriha design report)

Team Green Collars
DPS EKAGRA – You Run the School
Solar Decathlon India: Winners – Educational Division

Solar Decathlon India's challenge to combat Climate Change defined the main aim of the team Green Collars to design a net-zero-energy-water building while partnering with leaders in real estate development enabling the team to explore innovative and affordable market-ready solutions. The team worked on innovative and regional solutions in order to design an educational building and addressed unique building problems faced in India.
With the global GHG (Green House Gas) emissions raising the global temperature and making climate change a real threat, the future of life, as we know it, on our planet earth stands questionable. The AEC (Architecture, Engineering, and Construction) sector is responsible for 30% of total global final energy consumption (Source: International Energy Agency). One of the few ways we can attempt to ensure a safe and satisfactory future for the generations to come is by curating current systems to align with sustainable practices while establishing the importance of the same among the youth.
The school, EKĀGRA, DPS (Delhi Public School) in Nagaon aimed to accomplish this goal. The total site area is 77,054 sqm of which phase 1 of the project was proposed with a site area of 43,820 sqm. Located in the warm and humid suburbs of Nagaon, Assam, the school with an area of 8,072 sqm hosts 1,800 students and 200 teachers and staff, with the possibility of future expansion. The campus, owned by GYANDEEP FOUNDATIONS works on a Build-Own-Operate (BOO) model and targets to serve students in Nagaon and its neighbouring villages.

Design:

While designing the school, the team focused on two primary aspects - one, to design a facility that enhances the sharing of knowledge while ensuring productive learning in schools, and two, making the building a net zero energy, water, and carbon built environment.
In order to achieve this, the team began their material exploration alongside the design process, team members who were in-charge of materials and innovation proposed multiple combinations to the rest of the team, after which the team decided on the most optimal solution based on various aspects of sustainability. For instance, the energy division preferred materials with low thermal transmittance values; the water division wanted materials with appropriate run-off coefficients which also reduce water consumption while construction; choosing materials with low carbon emissions was the first priority for the embodied carbon division, while the engineering and resilience team favoured strong and earthquake resistant materials. The health and well-being division focused on low VOC (Volatile organic compounds) materials while the costing division demanded materials within the budget.
The team focused on the concept of circular economy which ensured that the materials are kept in circulation for as long as possible through reuse, remanufacturing and recycling at the same time making products as durable as possible. The team also developed material passports (Fig 1) for every material used in the building construction hence making it vastly easier at the end of the building's life to recover the value, preventing these


MATERIAL PASSPORT
ZERUND

Date of first use:
Date of second use:
Usable life left:

Changes in physical character after first use:
Changes in strength after first use :
No. of reuses:

- Name : Zerund Brick
- Material : Plastic ,Ash, Cement, water
- Dimensions : 600 x 20 x 100 mm
- Method of fixing : Block jointing adhesive
- Founded in : 2018
- Place of Manufacture : Guwahati , Assam
- Compressive strength : 38 - 45 kg / cm^2
- Dry density : 900 - 1100 kg/cm^3
- Fire resistance : 6 - 7 hours
- Cost reduction factor : 30%
- Water absorbtion : 6 - 7%
- Thermal conductivity : 0.16 W/m-k
- Drying Shrinkage : 0.04%

- High tensile and compressive strength
- 35% of air conditioning load reduction
- 30% cost reduction due to lesser dead load
- Dismantlable
- Fire resistance
- Thermal and sound insulation
- Pest resistance due to organic matter
- Environment friendly (carbon negative)
- Lightweight
- Lesser construction time than red clay bricks
- Easy workability, cutting, grooved, nailed, drilled
- Non weathering effect
- Earthquake resistance

Fig.1 : Zerund brick material passport (Source : Page 23, Team EKAGRA design report)

materials from being dumped or incinerated during demolition or renovation.
Based on the above mentioned criteria, the team chose the best option for different building elements, such as :

Walls:
Agrocrete blocks were considered initially for their low embodied carbon and the availability of agricultural raw materials on site. However, because of the distance of the manufacturing unit from the site, the transportation costs and emissions were high, due to which it was eliminated. Finally, for the external walls, Zerund bricks with circular voids for bamboo poles were used, while bamboo mat boards and reclaimed mosaic enhanced the interior and south façade respectively. Lime plaster was applied externally, and labour ensured smooth implementation. The building prioritised sustainability with moulds over kilns to reduce its carbon footprint. Block jointing adhesive replaced cement mortar, which further helped in cutting down the emissions. The walls are easily dismantlable, promoting reusability and waste reduction. The construction resulted in a carbon-negative walling system (Fig 3) with embodied emissions of -17.3 kg-CO2 e per unit.

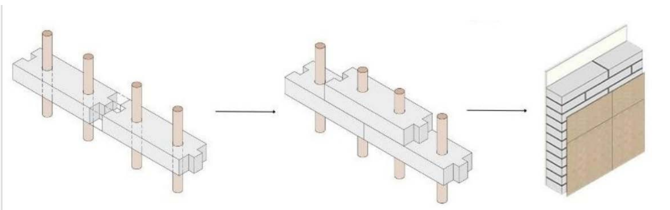


Fig.2 :Walling system : Zerund bricks (Source : Page 24, Team EKAGRA design report)

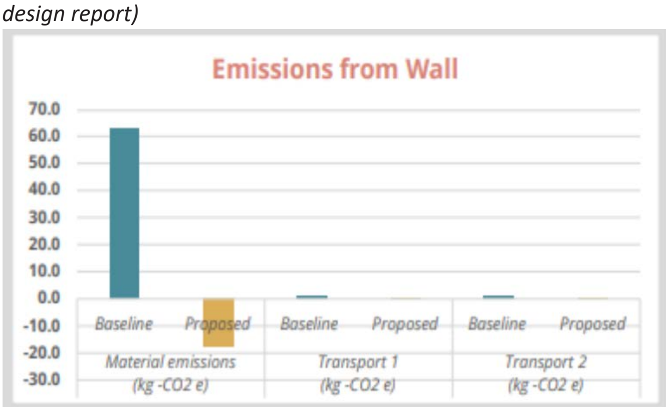


Fig.3 :Emission from wall (Source : Page 24, Team EKAGRA design report)

Floor slabs:
At first, clay tiles embedded with rice husk were considered to incorporate locally available materials. Due to insufficient data regarding their embodied carbon values and load bearing capacities, it was not carried forward.
The final design featured sustainable construction elements, such as filler slabs using local terracotta pots, ACC Ecomaxx[3] concrete, and steel reinforcement. This reduced usage of concrete in slab by 30% while supporting the local industry and enhancing aesthetics.

The flooring consisted of 40mm IPS(Indian Patent stone) flooring mixed with 10mm red oxide, skillfully coloured with natural oxide pigments. It is durable, cost-efficient, and easy to maintain, with embodied carbon emissions of 35.4kg - CO2 e per functional unit.

Fig.4 :Flooring composition (Source : Page 24, Team EKAGRA design report)

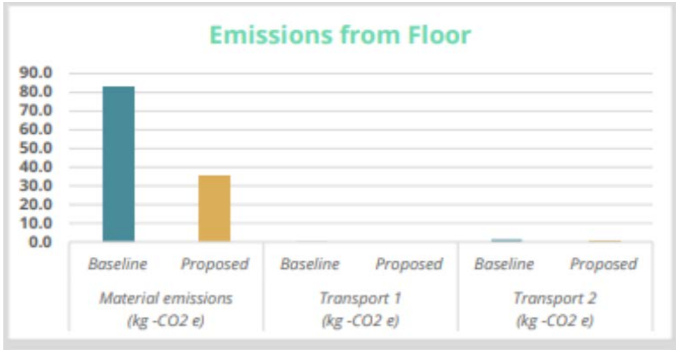


Fig.5 :Reduction of Ec from base case (Source : Page 24, Team EKAGRA design report)

Roofs:
A bamboo truss system was the basis of the roof design from the start. However, as the design progressed, the system was layered with other materials to achieve the final result.
The building's North Light truss system was made from carbon-sequestering bamboo. Onsite bamboo treatment reduced transport related emissions, while fish mouth joints eliminated the need for gusset plates. Bamboo corrugated sheets with glass wool insulation were used for sheeting. Manual labour for truss fabrication increased energy efficiency, resulting in an embodied carbon of 13.8 kg - CO2 e per unit.

Fenestrations:
Bamboo Wood was one of the materials that was considered for fenestrations, however, this was replaced with Bamboo ply based on the advice of the team's industry partner, owing to the higher embodied carbon value and cost of Bamboo Wood.
Louvres made of beaten bamboo, chajjas[4] constructed with stabilised clay, rice husk, bamboo fibres, and lime and skilfully crafted bamboo ply doors were used throughout the building. These components act as carbon sequestering elements, resulting in remarkable embodied carbon emissions of -1.1 kg CO2e per functional unit. The extensive use of locally available bamboo led to incorporating a bamboo plantation as part of the design.

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[3]ACC Ecomaxx: ACC(Autoclaved cellular concrete) ECOMaxX is a green concrete block with minimum 30% reduction in embodied carbon designed to meet sustainable construction needs.
[4]Chajjas: A chajja is an overhanging eave of roof covering found in Indian architecture. It is characterised with large support brackets with different artistic designs. It is used to protect fenestrations from the harsh weather conditions

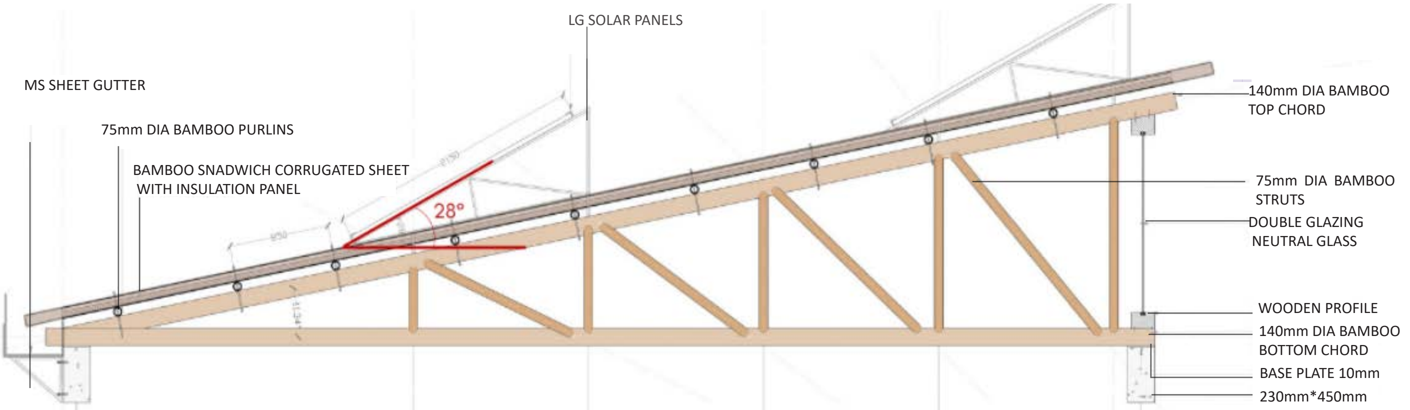

Fig.6 :Section showing northlight roof (Source : Page 33, Team EKAGRA design report)

Structural system:

Bamboocrete was an initial consideration due to the extensive availability of bamboo in Assam, but this was quickly disregarded since various studies showed that for a building of this scale, in earthquake Zone V, bamboo crete would not be suitable.

Finally, the main structure of the building, including columns, beams and foundation, was made using RCC. To reduce carbon emissions, ACC Ecomaxx green concrete was chosen, which has 45% lower embodied carbon than ready-mix concrete. It incorporates fly ash, recycled concrete aggregates, and aluminium can fibres, along with steel reinforcement. Despite higher transport emissions, ACC Ecomaxx concrete was preferred because of its eco-friendliness.

Due to the site being in earthquake zone V, the structure is built without compromising on strength. The embodied carbon per functional unit of the building is 39.8 kg-CO2e.

Conclusion:

EKĀGRA, the net zero school designed by Team Green Collars, sets a remarkable precedent for sustainable architecture in educational institutions. The innovative approaches, smart material choices, and carbon-reducing strategies have not only created an environmentally friendly campus but also offered an inspiring model for future projects. With EKĀGRA, Team Green Collars has proven that combining sustainability with creativity and determination can lead to a brighter, greener future for all.

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