

SUSTAINABLE MULTI HAZARDOUS RESILIENT COMMUNITY DEVELOPMENT – BIHAR

A Thesis

Submitted in partial fulfillment of the requirements for the award of
Master of Architecture degree in Sustainable Architecture

by

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**DEPARTMENT OF ARCHITECTURE
SCHOOL OF BUILDING AND ENVIRONMENT**

SATHYABAMA

**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)**

Accredited with Grade “A” by NAAC

JEPPIAAR NAGAR, RAJIV GANDHI SALAI, CHENNAI - 600 119

MAY 2021



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BONAFIDE CERTIFICATE

This is to certify that this Report is the bonafide work of **ARAVIND BALAJI MP (39890021)** who carried out the Thesis entitled “**SUSTAINABLE MULTI HAZARDOUS RESILIENT COMMUNITY DEVELOPMENT – BIHAR**” under our supervision from January 2021 to May 2021.

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I **ARAVIND BALAJI MP** hereby declare that the Thesis Report entitled “**SUSTAINABLE MULTI HAZARDOUS RESILIENT COMMUNITY DEVELOPMENT – BIHAR**” done by me under the guidance of **Ar. CATHERINE SELVARAJ** (Internal) and **Ar. P.S. GANESH, Principal Architect – GREENVIRON / Ar. BALAMURUGAN RAJKUMAR, Principal Architect -Proton Ateliers** (External) at Sathyabama Institute of Science and Technology is submitted in partial fulfillment of the requirements for the award of Master of Architecture degree in Sustainable Architecture.

DATE:

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I am pleased to acknowledge my sincere thanks to Board of Management of **SATHYABAMA** for their kind encouragement in doing this Thesis project and for completing it successfully. I am grateful to them.

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I would like to express my sincere and deep sense of gratitude to my Project Guide **Ar. Catherine Selvaraj** for **his** valuable guidance, suggestions and constant encouragement which paved way for the successful completion of my project work.

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ABSTRACT

Bihar is exposed to river bank erosion and flood because of various hydro meteorological and topographical characteristics of the basin in which it is situated. Kosi River changes its course over the period of time creates more problems in the livelihood.

These hazards create threat to local people who are living along the river resulting in losing of residential and agriculture lands. Locals are struggling to cope up with the changing climatic conditions. People are finding new solutions. The wave of adapting modern materials and techniques is deteriorating the traditional knowledge.

My Phase 1 Dissertation comprises of the study done on the overall socio-economic impact of the river bank erosion, flood on local populace and learning the vernacular techniques and to apply that knowledge to suggest possible design solutions.

My Phase 2 thesis comprises of sustainable community design that is both flood and earthquake resilient. I have done comparison study to find out that my form is stable enough to be an amphibious structure and have used simulations to prove my design is sustainable and have also solved ECBC, IGBC and GRIHA criteria to prove that my design is green rated community design.

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1. INTRODUCTION

Bihar is India's most food-prone state, with 76% of population in North Bihar living under the recurring threat of flood devastation. Bihar makes up 16.5% of India's flood affected area and 22.1% of India's flood affected population. About 73.06% of Bihar's geographical area, i.e., 68,800 square kilometres (26,600 sq. mi) out of 94,160 square kilometres (36,360 sq mi), is flood affected. On an annual basis, they destroy thousands of human lives apart from live-stock and assets worth millions. Bihar shares its northern border with the country, from which a slew of Himalayan rivers run down south. Rising water level in many of those wreaked havoc in 12 districts of North Bihar, as floodwater benched embankments, snapped roads, washed away small bridges and damaged standing paddy, maize, and jute crops.

Paura village of Bihar is exposed to river bank erosion and flood because of various hydro meteorological and topographical characteristics of the basin in which it is situated. Kosi River changes its course over the period of time which creates more problems in the livelihood.

These hazards create threat to local people who are living along the river resulting in losing of residential and agricultural land. Locals are struggling to cope up with the changing climatic conditions. People are finding new solutions in order to survive to extreme situations. The wave of adapting modern materials and techniques is deteriorating the traditional knowledge.

The research comprises of the study done on the overall socio-economic impact of the river bank erosion and flood on local populace. This thesis focuses on learning the vernacular techniques and to apply that knowledge to suggest possible solutions and will also explore flood resilient housing trying to answer the demand for new development which does not harm the environment and natural resources. The intent of this project is to design a community housing for displaced families of the flood prone areas in Paura, which would have the ability to survive natural disasters.

WHY BIHAR?

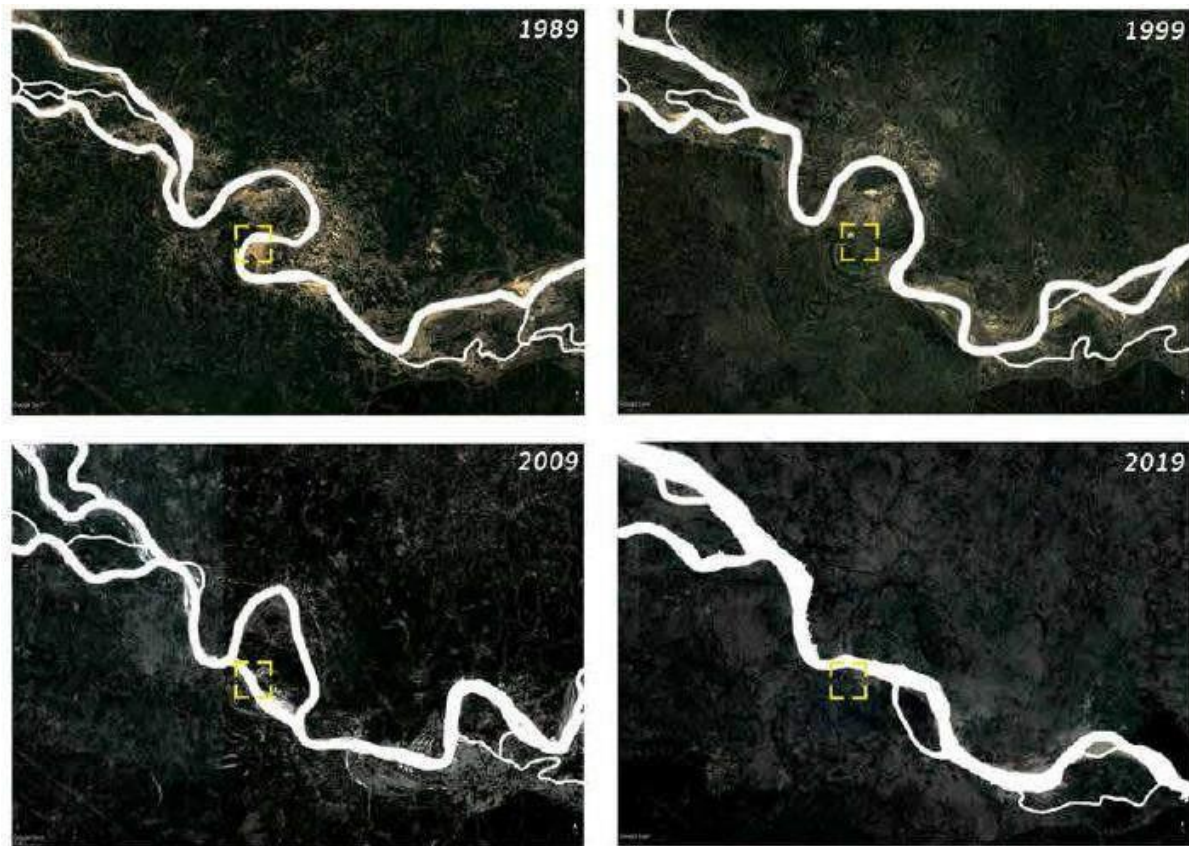
Bihar is India's most flood-prone state, with 76% population in the North Bihar living under the recurring threat of flood devastation. Bihar makes up 16.5% of India's flood affected area and 22.1% of India's flood affected population. About 73.06% of Bihar's geographical area, ie 68,800 square kilometers (26,600 sq mi) out of 94,160 square kilometers (36,360 sq mi), is flood affected. On an annual basis, they destroy thousands of human lives apart from livestock and assets worth millions. In total, they have claimed 9,500 lives since the government started publishing figures in 1979. Bihar shares its northern border with the country, from which a slew of Himalayan rivers run down south. Rising water level in many of those wreaked havoc in 12 districts of north Bihar as floodwater breached embankments, snapped roads, washed away small bridges and damaged standing paddy, maize and jute crops. As per 2011 Census, Bihar is the third most populous state of India with a population of 104,099,452. Of the total population of Bihar state, around 88.71 percent live in the villages of rural areas. In actual numbers, males and females were 48,073,850 and 44,267,586 respectively. Total population of rural areas of Bihar state was 92,341,4

WHY KOSI?

Kosi, with its seven tributaries known as Saptkosi, drains the eastern part of Nepal and parts of Tibet. Some of the headstreams emerge beyond the Nepalese border in Tibet. Approximately 50 kms north of Indo-Nepal border, the Kosi is joined by its seven tributaries and breaks southwards through the Shivalik Hills at the narrow Barahkshetra gorge. The river then flows on the plains of northern Bihar on its way to Ganga meandering through a course of approximately 700 kms. Originating from the glaciers of Tibet and Nepal, the river is exceptionally turbulent because of the steep gradient flow in Nepal. It has the history of changing its course every 50 to 100 years. The main cause of Kosi changing its course is exactly the steepness and the consequent heavy silt it carries

along with its swirling water. The river carries approximately 700 lakh tones of silt every year, which is almost five times the sediment load of any other river in Bihar

Kosi and its change of course



“Kosi has been changing its course whimsically. We have seen it change its course twice in the last ten years. The land that you are walking on was a deep flowing river a few years ago. All we see now is the bed of silt everywhere, where usually we used to find fertile soil” says Baldev Jadhav, Narahia village.

BIHAR



1st

India's most flood prone state



2nd

Poorest state of India



3rd

Most populated state of India



88.71 %

88.71% of Bihar's population
lives in rural areas



76 %

76% of Bihar's population are
flood affected



73.06 %

73.06% of Bihar's land is flood affected



9500

9500 dead until now. Bihar tops
the list of states in terms of
death of citizens due to floods.

POPULATION

The innocent are the ones who get affected the most by the occurring floods every year. And they lose almost everything and start their life afresh every year, which is really sad!

HOUSING

Since Kosi is too dynamic, the course gets changed almost every five years and because of this the houses gets damaged and people have to relocated and rebuild their houses every couple of years.

LAND

There is a change in course or in the time of flooding, the agricultural land gets affected a lot. The flood water takes 3-4months to dry up after flood in the fields. Because of this, farmers lose occupation.

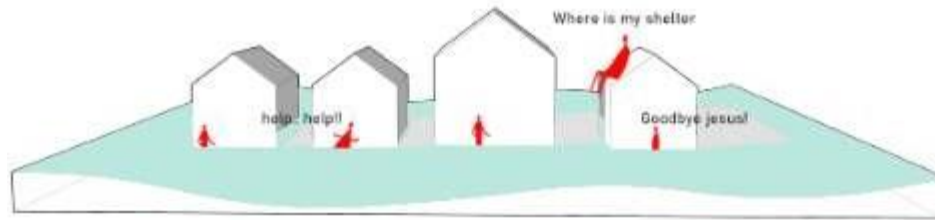
MIGRATION

Due to this Kosi flooding every year, the youth amongst the crowd are migrated away from hometown to neighboring states or countries, in search of employment because there is no permanent occupation

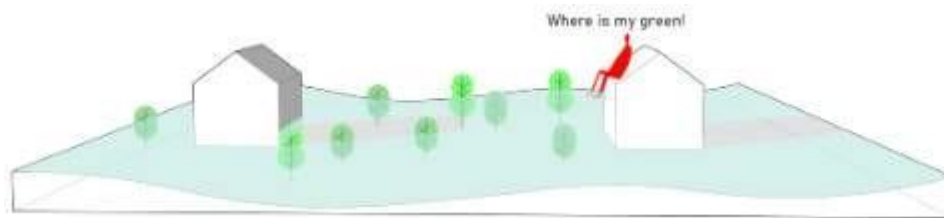
“Temperature rise is likely to make India’s summer monsoon much more unpredictable”

WHAT HAPPENED TO BIHAR?

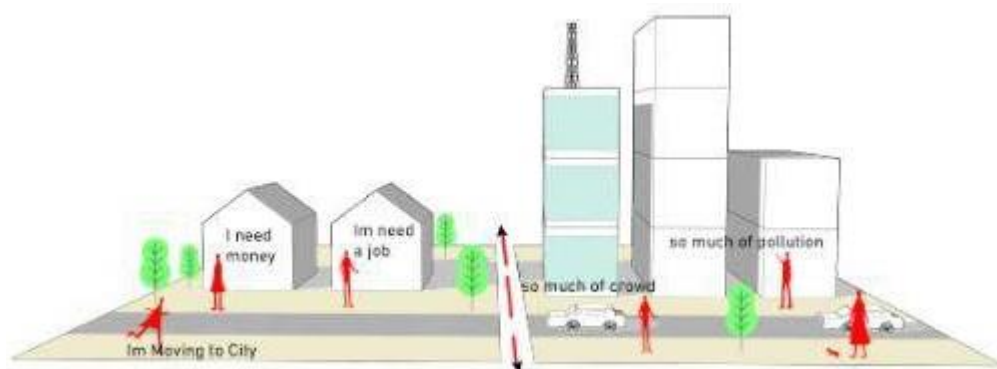
“Kosi has been changing its course whimsically. We have seen it change its course twice in the last ten years. The land that you are walking on was a deep flowing river a few years ago. All we can see now is the bed of silt everywhere, where usually we used to find fertile soil.” says Baldev Jadhav, Narahia village.



Since Kosi is too dynamic, the course gets changed almost every five years and because of this the houses gets damaged and people have to relocate and rebuild their houses every couple of years.



Once there is a change in course or in the time of flooding, the agricultural land gets affected a lot. The flood water takes 3-4 months to dry up after flood in the fields. Because of this, farmers lose occupation.



Due to this Kosi flooding every year, the youth amongst the crowd are migrated away from hometown to neighboring states or countries in search of employment because there is no permanent occupation.

WHAT PEOPLE NEED?

It is an urgent need that is to be looked upon, since Bihar is the state with lowest economy, the govt. doesn't consider planning much developments and also, Bihar's flood loss account to 30-40% of India's infrastructure damage due to disasters.

WHAT NEEDS TO BE DONE?

Housing

- 1: Economically weaker sections.
- 2: Low Income.
- 3: Middle Income

Public Space

- 1: Primary health Care
- 2: Space for cattle
- 3: Primary school
- 4: Basic Amenities



1.1. AIM

To study the aspect of flood resistant housing strategies for displaced families of in flood prone areas, which would have the ability to survive natural disasters.

1.2. OBJECTIVE

To understand the ways to increase resistance of the built form, specifically dwellings from flood

To understand the impact of the design changes in terms of changes in local lifestyle

To study the changes in housing typologies due to flood resistance

To understand various strategies employed by locals for increasing resistance to natural hazards

To increase the use of local materials and techniques to increase hazard resistance of the houses

1.3. SCOPE

To study is to identify different villages prone to flood and erosion

To study will focus on housing and resilient techniques used in vernacular house forms in Paura and nearby villages at the river banks of Kosi River.

To explore development of housing community by incorporating different modern materials

To suggest recommendation to the dwellings for ensuring self-sustainable and resilient housing

1.4. LIMITATIONS

The project will be restricted to Paura village or locality only.

The project will be focusing only on floods

The study and development will be restricted to addressing issues at micro level, the level at which it makes direct impact on the local populace

1.5. APPROACH AND METHODOLOGY

The collection of Secondary information will be done to understand flood situation in Paura and understanding different factors affecting built forms.

Study of typologies of vernacular housing in Bihar will be carried out and also to find the different strategies to withstand the flood. The findings will be incorporated in the final outcome which will be community housing for people. Initial stages include site studies and vernacular housing study of Paura area. The study will also focus on materials and details.

Further to explore different strategies by incorporating the new materials to withstand the flood and to come up with the design for a prototype of community housing for the disaster prone riverine area of Paura. To prepare appropriate housing solutions based on selected sites and specific conditions.

2. LITERATURE CASE STUDY - KOSI FLOOD REHABILITATION

RECONSTRUCTION OF MULTI-HAZARD RESISTANT HOUSES

LOCATION: PURAINI VILLAGE, BIRPUR, SUPAUL DISTRICT, BIHAR.

As a part of the ODR Collaborative, Hunnarshala helped the Bihar government formulate a policy that facilitated the reconstruction of 100,000 houses, while reaching the most vulnerable families in a cost effective manner in the wake of the Kosi floods. The government planned the rehabilitation package for each family based on a consultative process with Hunnarshala which integrated phased reconstruction with the Indira Awas Yojana.

For designing the program, Hunnarshala studied the traditional built forms and building techniques in the region and conducted design exercises with various focus groups to arrive at different design options for houses using varied combinations of brick and bamboo. Hunnarshala also introduced a number of technical innovations to make buildings cost effective and multi-hazard resistant. Some of the technical innovations that Hunnarshala was able to introduce during the program were:

- Introduction of Chemical treatment of Bamboo to increase longevity of the structure.
- Introduction of more robust Bamboo joining technique
- Development of details for incorporating Bamboo in foundation
- Introduction of Stub Foundation
- Development of Alternative Pile Foundation with the community
- Introduction of Rat-trap bond masonry
- Introduction of ECOSAN toilets

The local masons were trained in these techniques and employed by the Bihar Govt. to

oversee reconstruction. Hunnarshala demonstrated the technology as well as policy implementation for appropriate construction by building 42 houses in Orlaha village and 89 houses in Puraini village and trained more than 400 people for further implementing the program.

2.1. KOSI REGION

The Mithilanchal area of north Bihar is drained by river Kosi which during many centuries has carved out several courses for itself through deposition of silt in the plains. These river courses have been protected by earthen embankments due to which the intermediate space is utilized by the populations for agriculture as well as building their habitat. However, when the river overtops or breaches an embankment during flood season, the affected river course gets flooded suddenly and disastrous situation is created in the so called “protected area”. Such a situation developed on August 12, 2008 when the river breached its eastern embankment in its upper reach in Nepal and resumed an abandoned course after many decades. Five districts namely Araria, Madhepura, Saharsa, Supaul and Purnia were the worst affected by the flood waters causing loss of more than 2,00,000 homes and displacing more than a million people.

2.2. DURING FLOODS

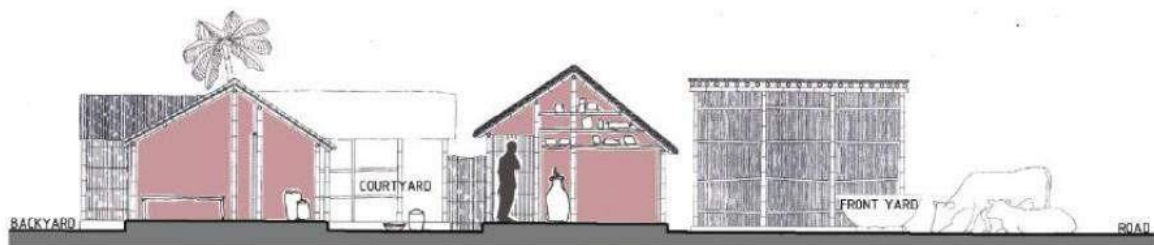
During floods, the water can rise up to 6-8 ft inside the house and can sometimes be present for up to a month as it slowly recedes. In parts of Madhubani, families have devised mitigation methods by stocking some dry food (sattu, chura etc.) on a loft that they can themselves climb into, in case of floods. These lofts are also made of bamboo. The bamboo is unaffected by the stagnant waters, but begins to decay when in contact with mud in the footings. Some families use tar or wrap the end of the bamboo with plastic to protect it from decaying.

2.3. GOVERNMENT’S ACTION

After tackling the immediate challenges of Kosi Disaster, the State Govt. had to deal with the problem of reconstruction and rehabilitation. The state govt. has pledged that Kosi region will improve with this reconstruction. To successfully complete it, the govt. has declared a policy, whose main objective was to provide such houses that which would be not only functionally useful to the residents but also safe in hazards like earthquake, wind storms and floods. These would be constructed with the help of locally available materials



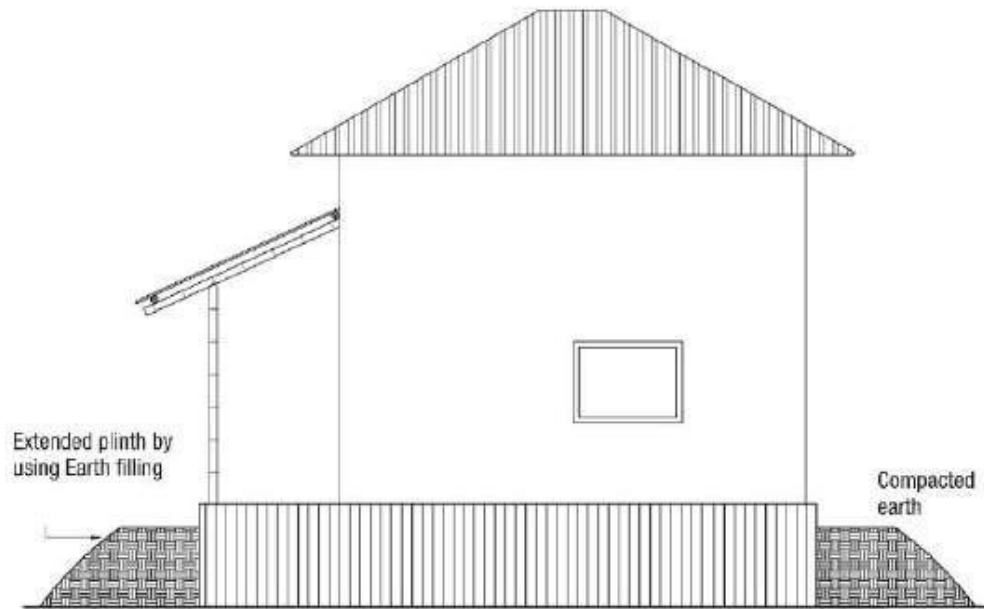
Plan



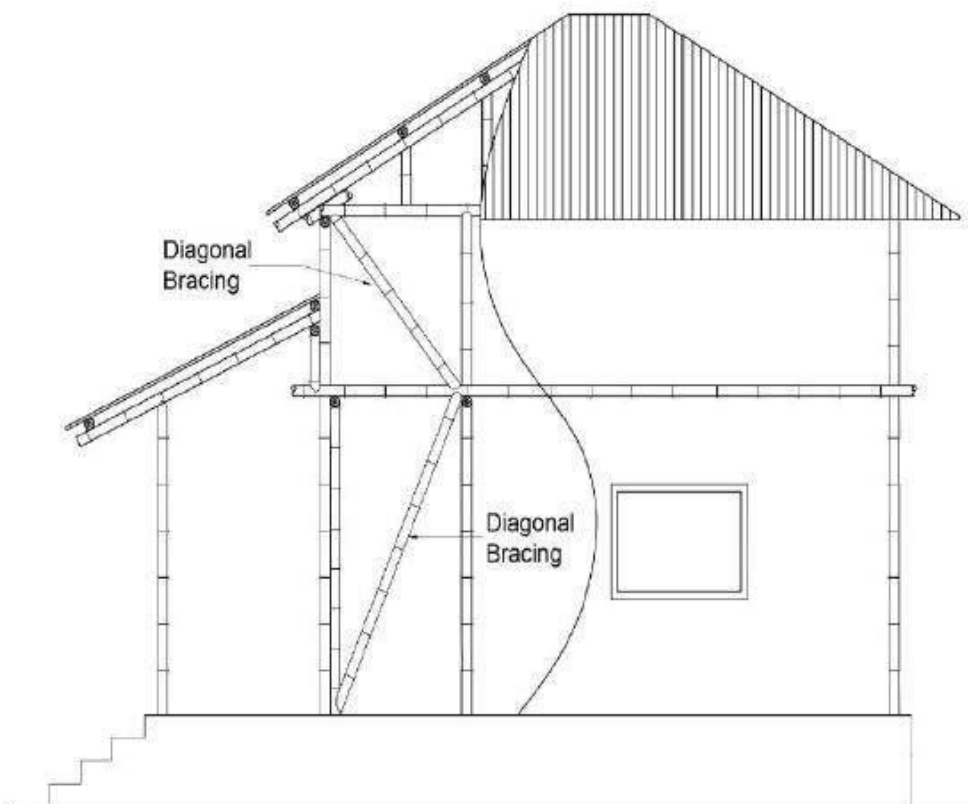
Section



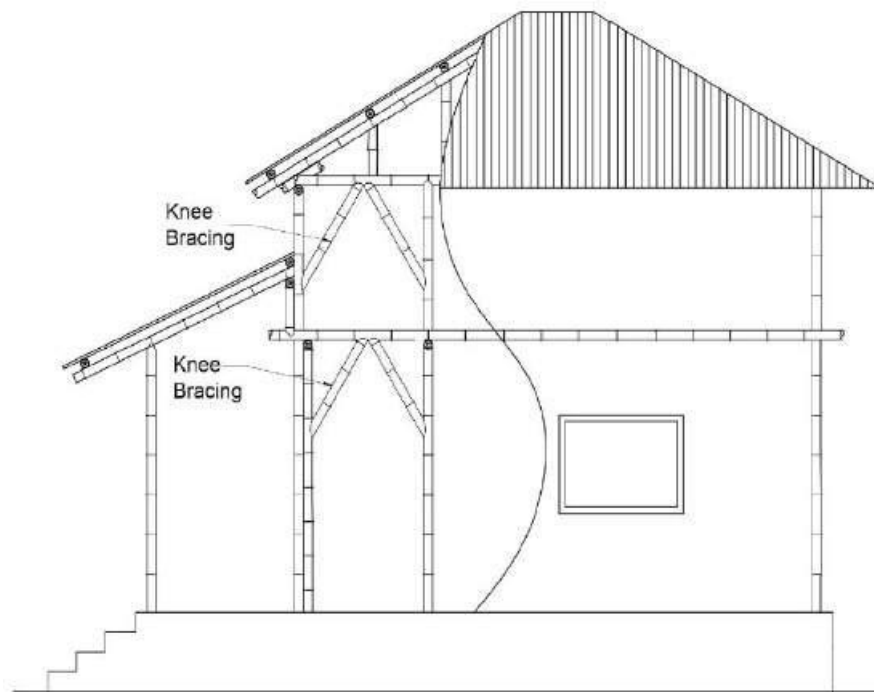
2.4. PROVISIONS FOR MULTI HAZARD SAFE CONSTRUCTION



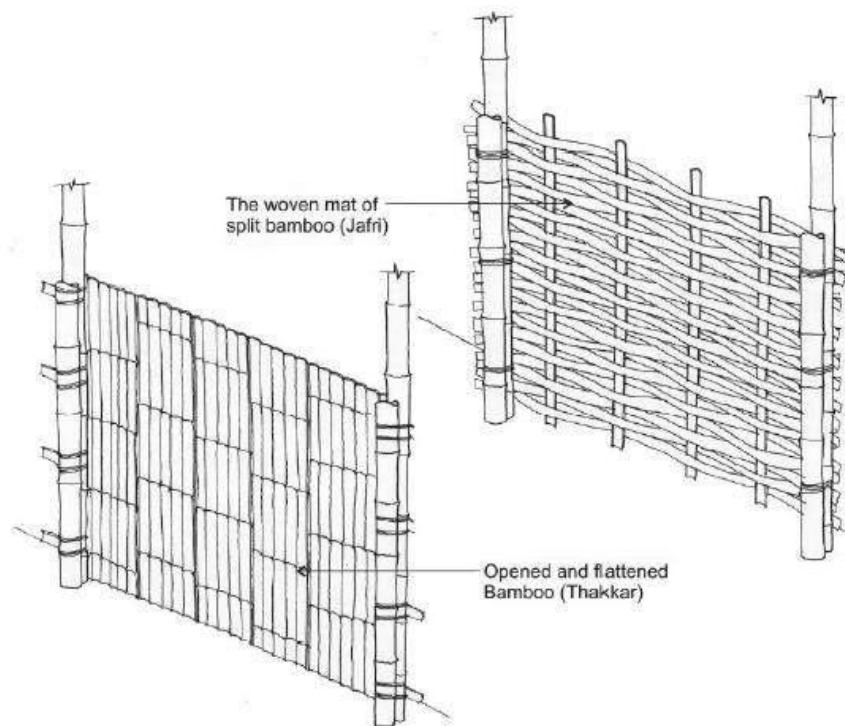
Raising and extending plinth by earth filling



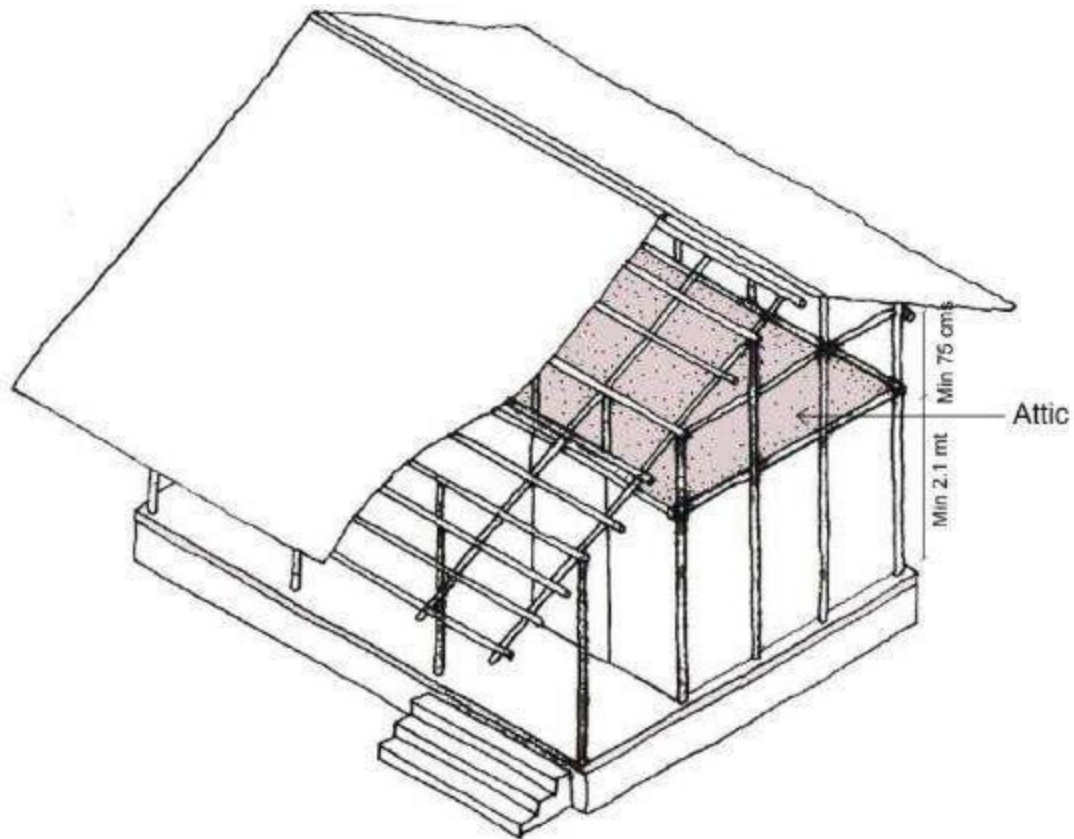
Diagonal bracing for Earthquake and Wind-resistance



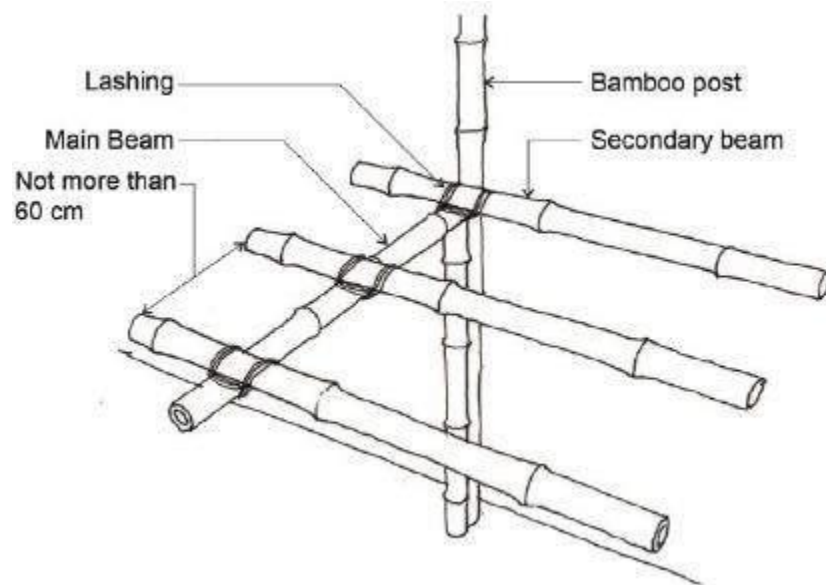
Use of Knee braces for Lateral load resistance



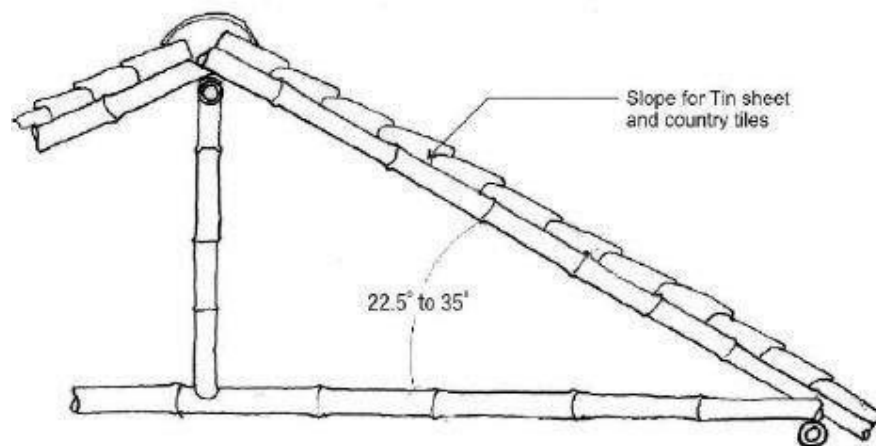
Bamboo Lattice different versions



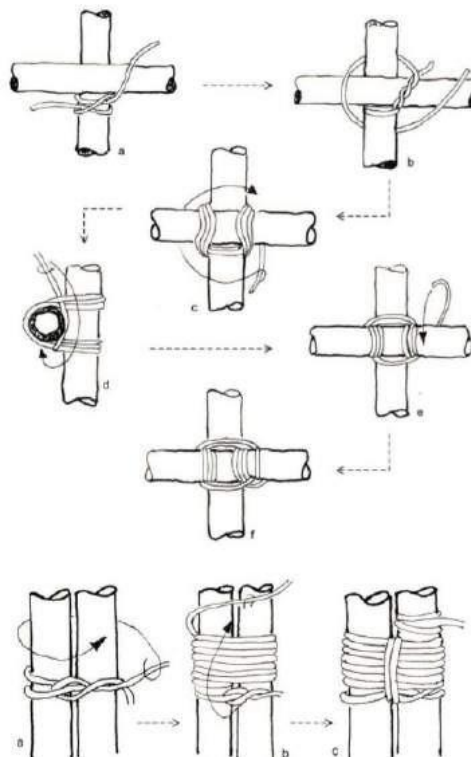
Attic floor in bamboo house



Attic beam joint detail



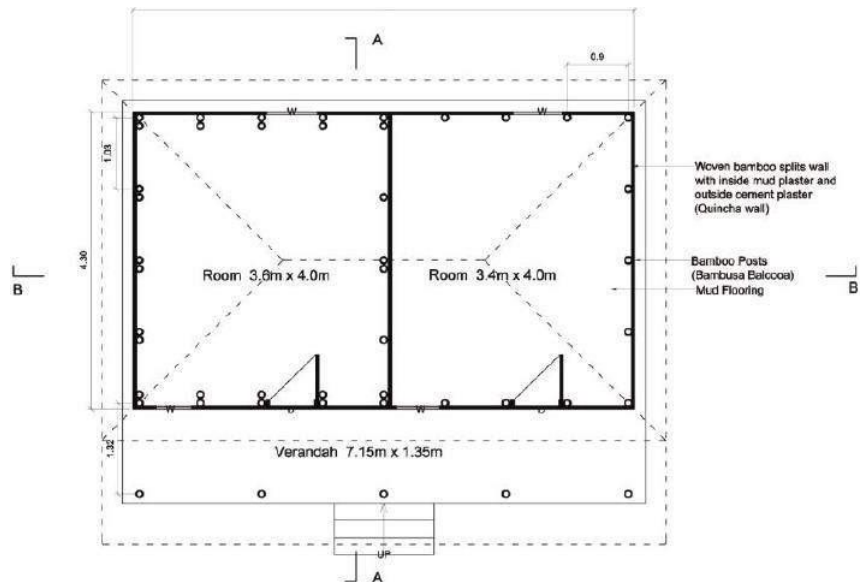
Roof slopes angle



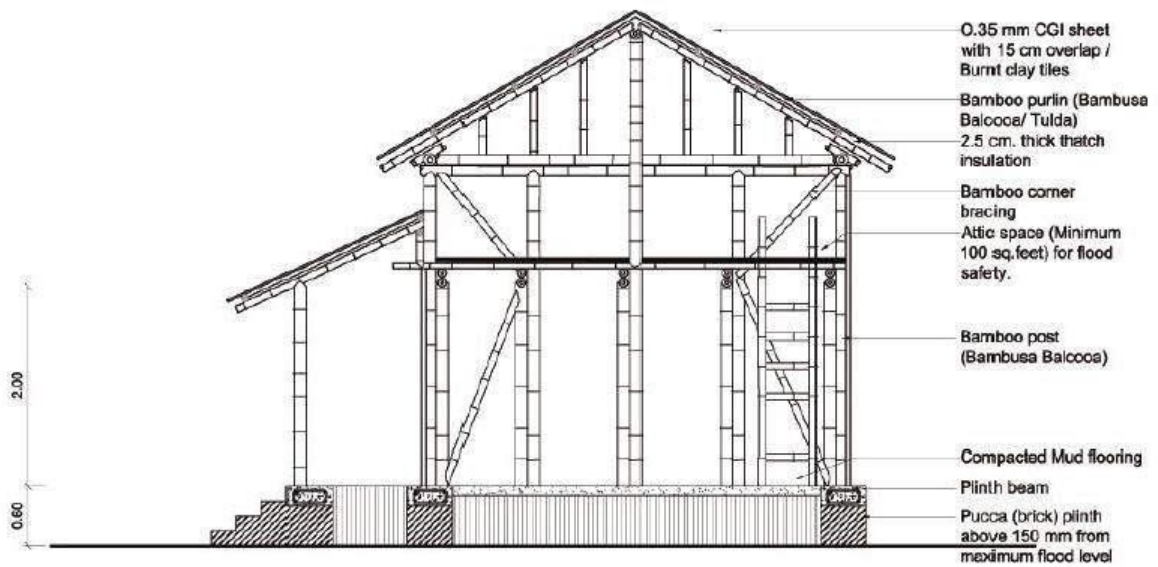
Bamboo joinery details

2.5. ALTERNATIVE 1 – BAMBOO TYPOLOGY

House with Bamboo walls and CGI Sheet Roof



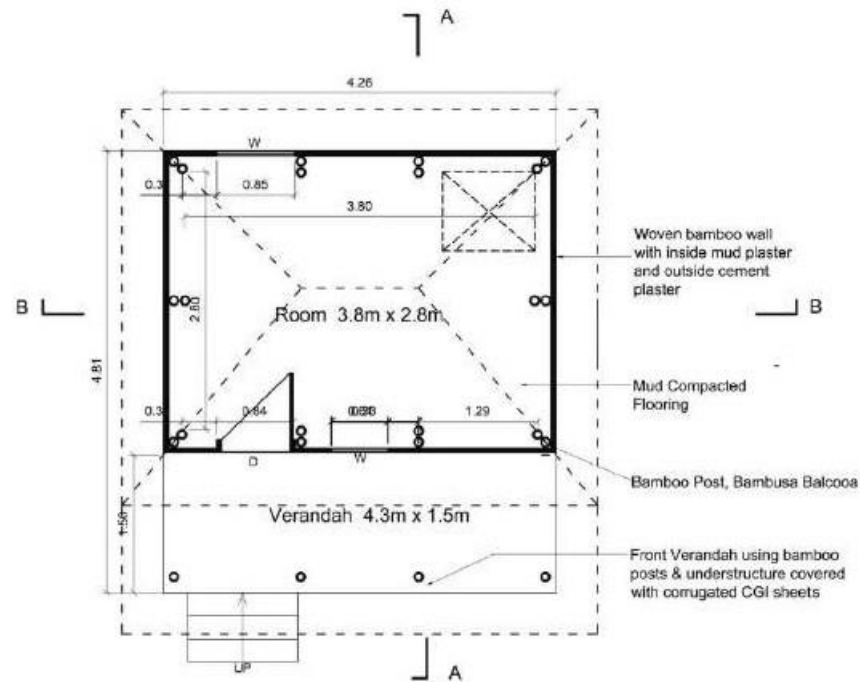
Plan



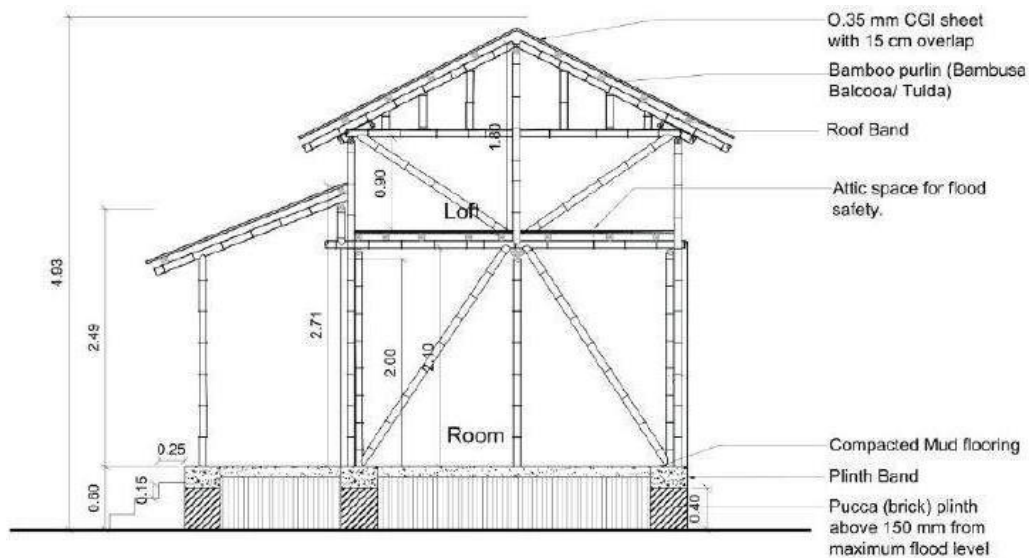
Section

2.6. ALTERNATIVE 2 – BAMBOO TYPOLOGY

House with Bamboo walls and CGI Sheet Roof



Plan



Section



It is noted that mud, grass, bamboo based construction make up more than 50 % of the houses in Bihar, with most of the houses in Mithilanchal under this category. Housing in North Bihar is determined largely by the socio-economic condition of the family. The rich people used to build courtyard houses using country burnt brick walls with a joist and plank roof using lime as bonding material. In the last decade, several sophisticated kiln baked bricks have replaced the country bricks, and the roof is now made with RCC. The Gangetic basin soils make good quality bricks and other pottery products including roofing tiles. The production of bricks largely caters to Government projects and the cost is high, approximately 2-3 times the national average. Sand and aggregate needed for RCC is not available in the region and often brought at high costs. Sand is brought from South Bihar or Gangajali from Nepal.

The coarse aggregate comes from Pakur district of Jharkhand. The quality of RCC is not good in the region. The shuttering is made from bamboo with a layer of mud to make it impervious. Most buildings in this category do not follow the earthquake safety requirements.

2.8. INFERENCE

They have used freshly cut bamboo which is a big mistake. They have used bamboo lattice and a cement based plaster. Generally they are a good pair, but since this is not working so well, they could have used another layer of wire mesh which could be tied to bamboo and would have acted as a reinforcement for the thick plaster. This is an alternative solution that I would be suggesting for my design.



3. CASE STUDY

3.1. BUILDING ELEVATED – COMMUNITY DRIVEN DISASTER-RESILIENT BAMBOO HOUSING ARCHITECTURE

Project name: Community driven disaster-resilient bamboo housing architecture

Firm: SEEDS (sustainable environment and ecological development society)

Completion year: 2018 gross built area: 23 Sq.m per house x 80 units

Project location: Golaghat, Assam, India

Partner: NEADS (north-east affected area development society)

SEEDS have built 80 [bamboo houses](#) as part of a community-driven flood response programme in Assam, [India](#). The non-profit organisation took up the housing reconstruction initiative in Assam after the devastating floods of 2017, working with local organisation NEADS (north-east affected area development society) to design and build the houses. the development was formulated with a vision to build resilient communities through participatory design, illustrating a model of contemporary vernacular architecture. (*SEEDS Builds Community-Driven, Disaster Resilient Bamboo Housing in India*, n.d.)

With its tropical-monsoon-rainforest-climate, the valley experiences heavy rainfall and gets flooded almost every year,' explains SEEDS.



In an area where the annual phenomenon of flooding and repeated loss due to that perpetuates poverty, environmentally sustainable solutions were discovered in the vernacular architectural typology of stilt houses built in bamboo. A 23-square-meter core house built atop stilts was designed following sphere humanitarian standards for disaster response within the given budget constraint, its' high stilts helping to cope with the annual flooding while its flexible joinery system allows the homeowners to shift the floor higher in case of over flooding – a unique feature that was adopted from the traditional practice of the region.



The layout of the house is simple and multipurpose, supporting the lifestyle of the local community. the stilts are high enough to allow day-to-day activities such as weaving, rearing livestock, and the storage of boats, used during floods or a play space for children, and a semi-open verandah is provided for social interaction, food preparation or basketry as done traditionally by the communities. (SEEDS Builds Community-Driven, Disaster Resilient Bamboo Housing in India, n.d.)

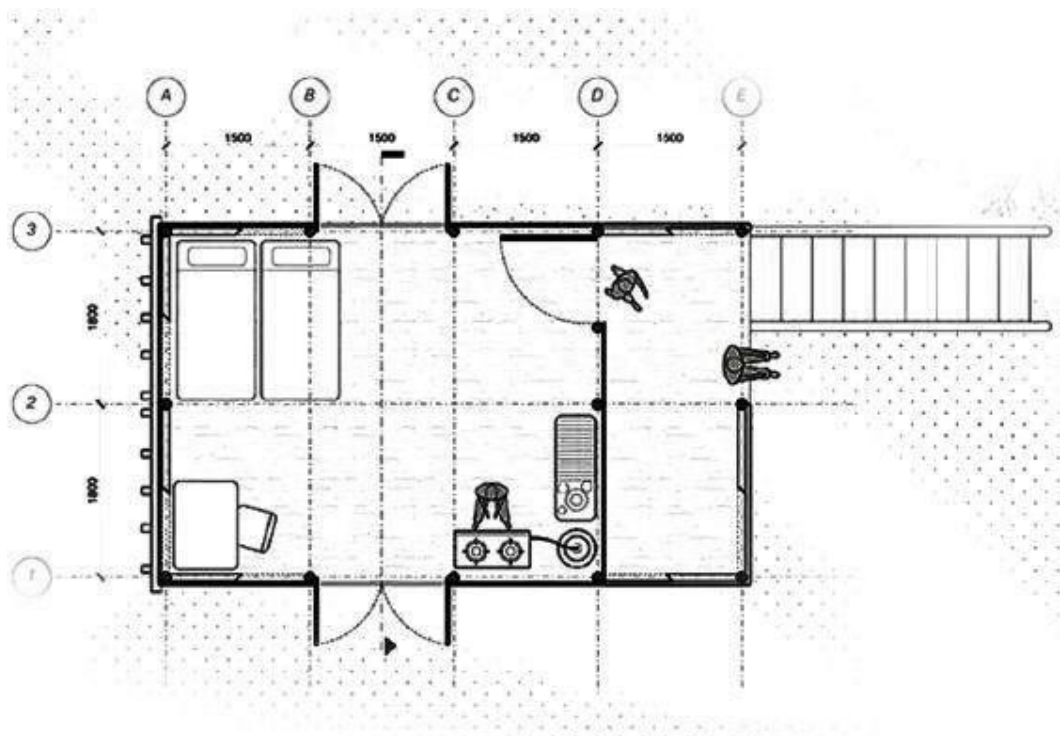
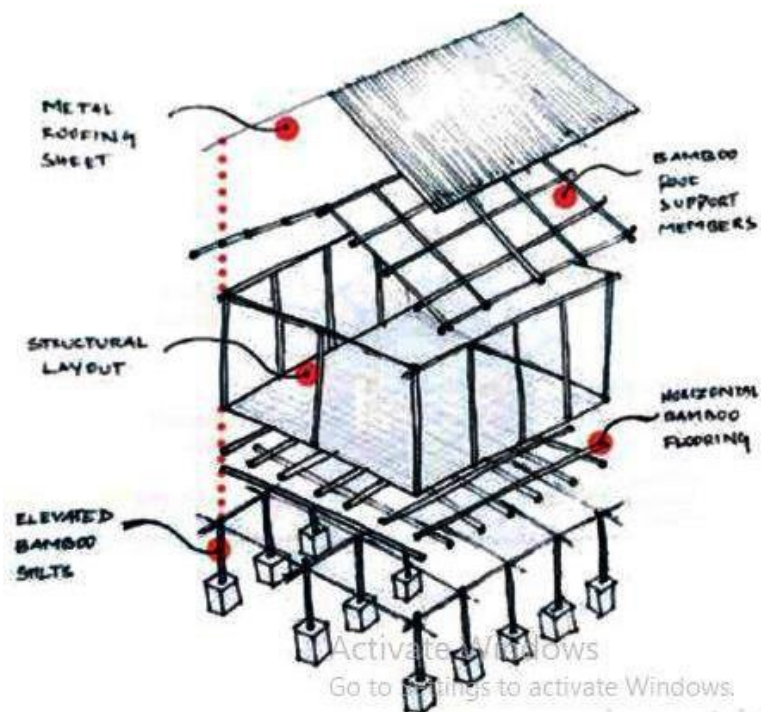
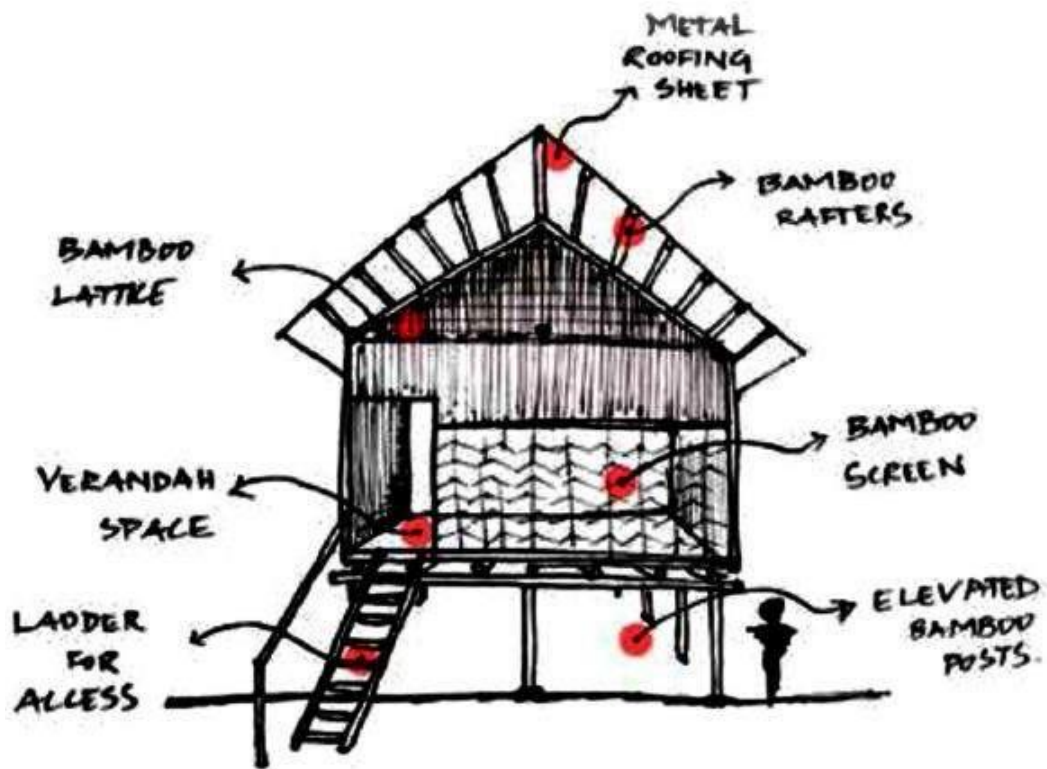


Figure 1: Building Elevated - Plan

(SEEDS Builds Community-Driven, Disaster Resilient Bamboo Housing in India, n.d.)



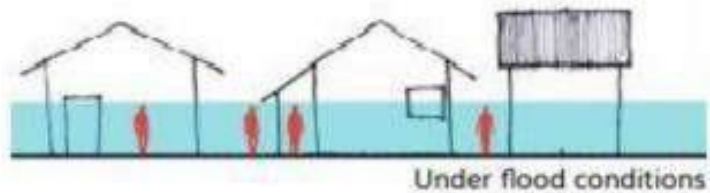
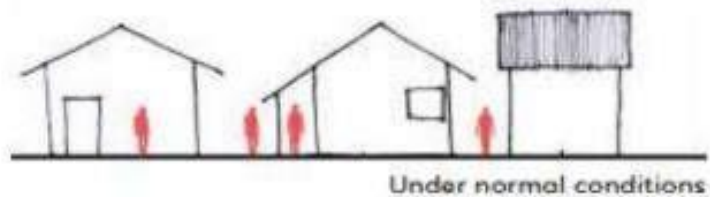
Activate Windows
Go to Settings to activate Windows.

RESULT

The community escaped 2018 floods and the houses aren't destroyed by floods. By the better analysis from the design team, the floor level was lifted according to it and the buildings flexible joinery system also allows the home owners to raise the floor even higher in case of over flooding.



Before



After



INFERENCE

- The material must be locally available and the construction technique should be simple to follow by the local people and to complete the project in short time.
- The Climatic condition is an important factor to be considered before designing. The design should be in such a way that it can sustain the climate in long run.
- Community participation is very crucial in the design for displaced people. The design should be discussed with people who will be accommodated in the dwellings, to identify their needs and usage.
- Vernacular architecture of the region can be adopted in the design to sustain the sense of peace.
- The design should be able to adapt to the future requirement and should be structurally robust, sufficiently sturdy and hard to withstand other climatic disasters.

3.2. AMPHIBIOUS HOUSE- BLOOMING BAMBOO HOUSE – PORTABLE STRUCTURE HOUSE

Project Details:

Architect – H&p Architects

Year of completion – 2016

Site Area – 680 Sq.m

Project cost – 2500 USD

Project duration – 185 days

Materials – Container

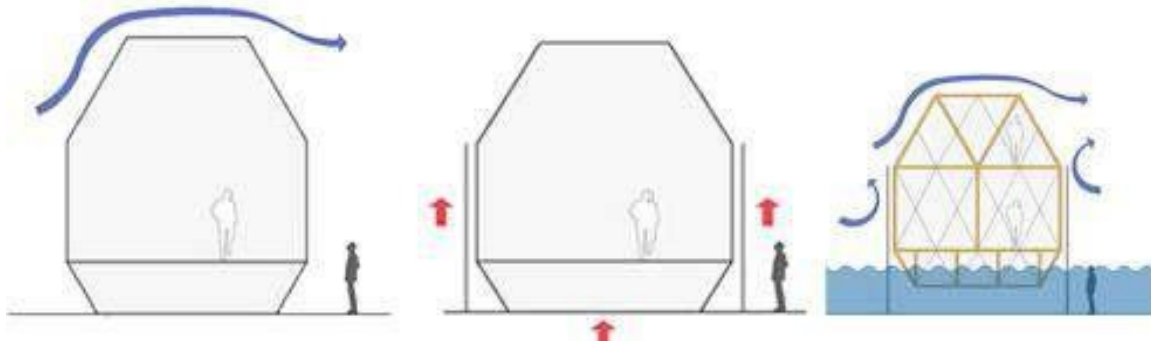
Type – Multi Functional



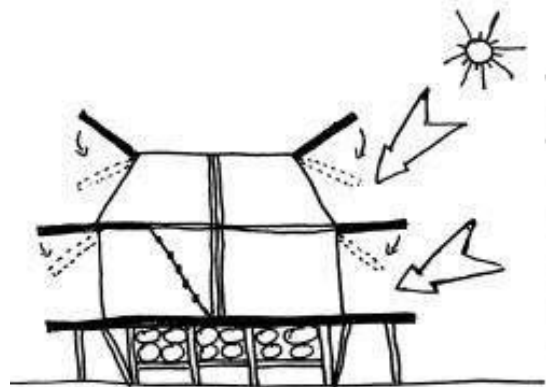
In Vietnam, the natural phenomena are severe and various: storm, flood, sweeping floods, landslides, drought, etc... The damage every year, which is considerable compared to the world scale, takes away about 500 persons. One solution to houses and homes for millions of these people is the goal of this BB (Blooming Bamboo) home. (*Blooming Bamboo Home by H&P Architects, n.d.*)

Each modular structure is 3.3m x 6.6m and is simply assembled with bolting, binding, hanging, placing... This pulled monolithic architecture is strong enough to suffer from phenomena like 1.5m-high flood. The space is multifunctional such as House, Educational, Medical and Community Centre and can be spreader if necessary. (*Blooming Bamboo Home by H&P Architects, n.d.*)

FORM DEVELOPMENT



The prototype unit is well illuminated with natural lighting. The openings are covered either openable shutters. The openings can be adjusted to control the light entering the unit. Diffused light enters the fully enclosed prototype unit through the gap in between two bamboos.



The prototype is well ventilated. The openable shutters allow for natural ventilation to take place. The shutters also support stack effect in the prototype unit. Openings are provided on all four sides so as to allow ventilation to take place on all faces of the unit. (*Blooming Bamboo Home* by H&P Architects, n.d.)

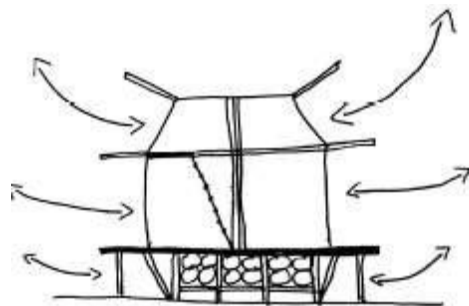




Figure 3: Examples of closed and open house
(Blooming Bamboo Home by H&P Architects, n.d.)



Figure 4: Amphibious House - Plan
(Blooming Bamboo Home by H&P Architects, n.d.)

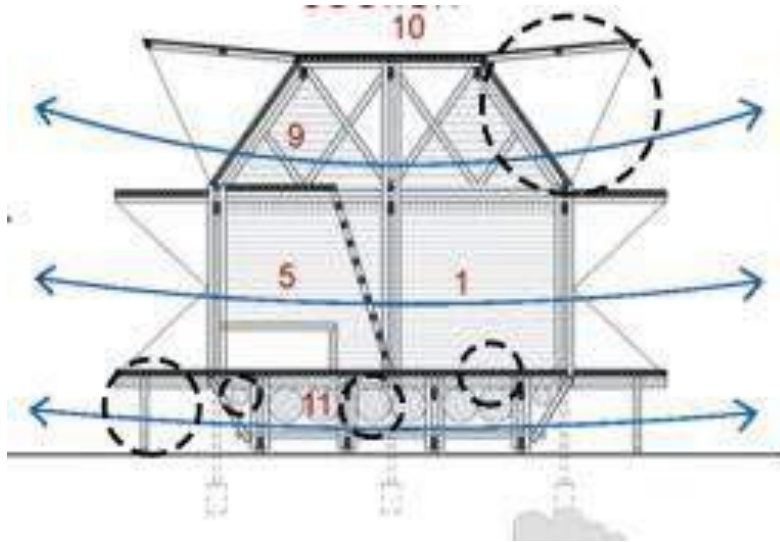
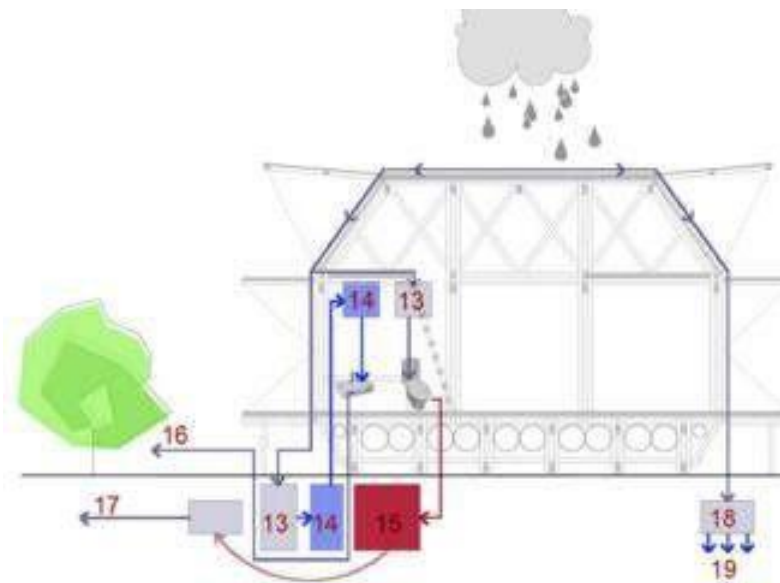


Figure 5: Amphibious House - Section
(Blooming Bamboo Home by H&P Architects, n.d.)

SERVICES



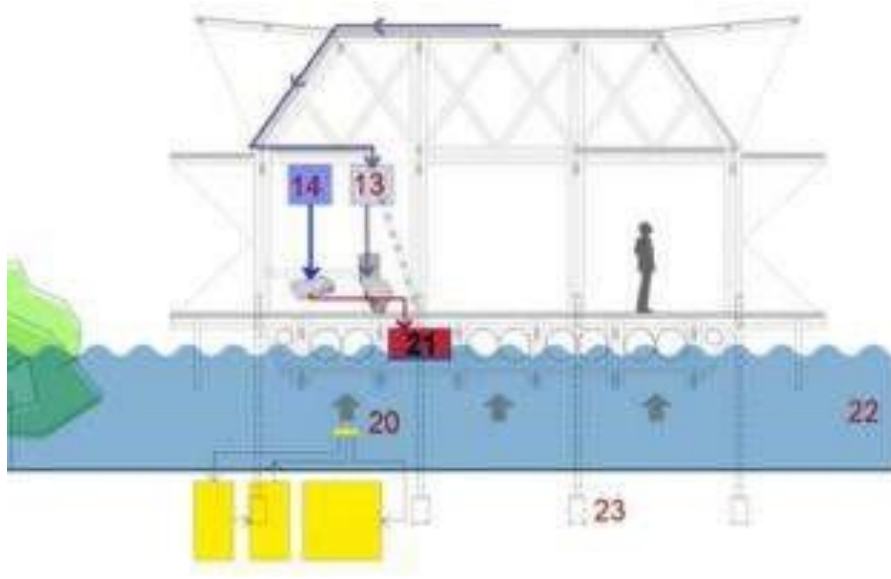


Figure 6: Amphibious House - Services

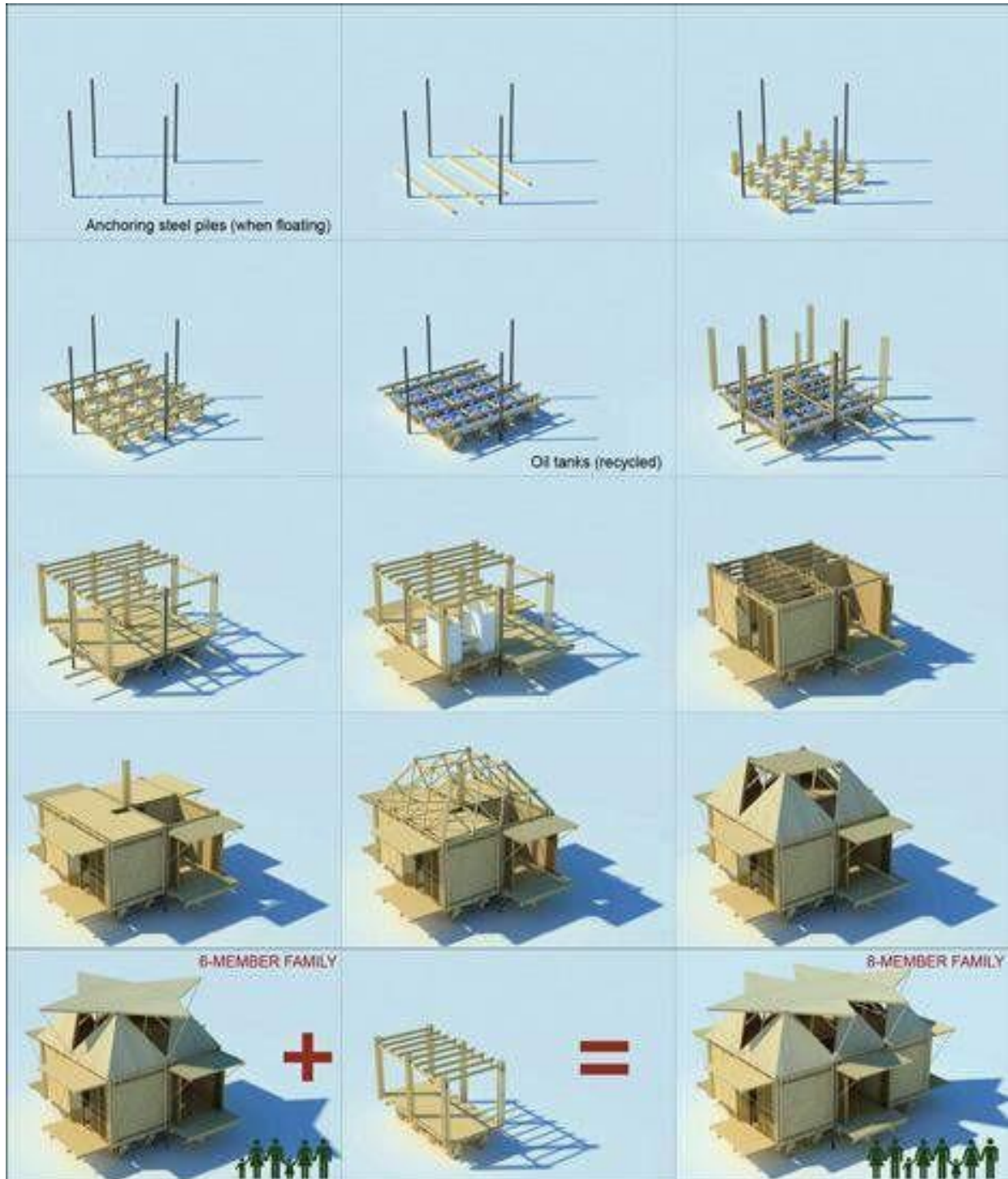
(Blooming Bamboo Home by H&P Architects, n.d.)

- | | |
|--|--|
| 1. Shared space | 15. Waste water tank |
| 2. Living room | 16. Water for gardening |
| 3. Worship | 17. Discharged to (after treated) |
| 4. Bedroom | 18. Filter tank for rain water |
| 5. Bathroom (with WC) | 19. Rain water cleaned and returned to the environment (underground reloading) |
| 6. Kitchen | 20. One-way valve (automatic closing when disassembled) |
| 7. Staircase to indoor terrace | 21. Waste water tank (for use during floods) |
| 8. Laundry + Drying | 22. Flood water |
| 9. Outdoor terrace | 23. Anchoring steel piles (when floating) |
| 10. Indoor terrace (sleeping + learning) | |
| 11. Top space for relax (also exit in emergencies) | |
| 12. Oil tanks (recycled) | |
| 13. Rain water tank | |
| 14. Clean water tank (filtered) | |

- The rain water is stored in separate unit below the module
- The water is filtered and then let into the clean water tank which is also placed below the module

- Three storage units are connected using one way valve which closes when disassembled.

SKELETON OF THE STRUCTURE





The module is raised 1.5m above the ground level to evade the initial flooding



20 L cans are used to fill the gaps and sides of the tank



The oil tanks are sealed completely and attached below the module



The upper part of the room has a opening which supports stack effect and can be closed during heavy winds



Bamboo is locally available building material



Ladder made of bamboo are used for vertical circulation to upper level of the module

3.3. FLOATING HOUSE - MAKOKO FLOATING SCHOOL

Project Type – School, Community Building

Architecture firm – NLE Architects Project

Location – Lagos, Nigeria, Africa

Project completion – 2013

Area of single unit – 220 Sq.m

NLE, the studio founded by Nigerian-born architect Kunlé Adeyemi, developed the Makoko Floating School as a prototype for building in African regions that have little or no permanent infrastructure, thanks to unpredictable water levels that cause regular flooding. Half-building, half-boat, the floating structure provides teaching facilities for the slum district of Makoko, a former fishing village in Lagos where over 100,000 people live in houses on stilts. (Frearson Amy, 2014)

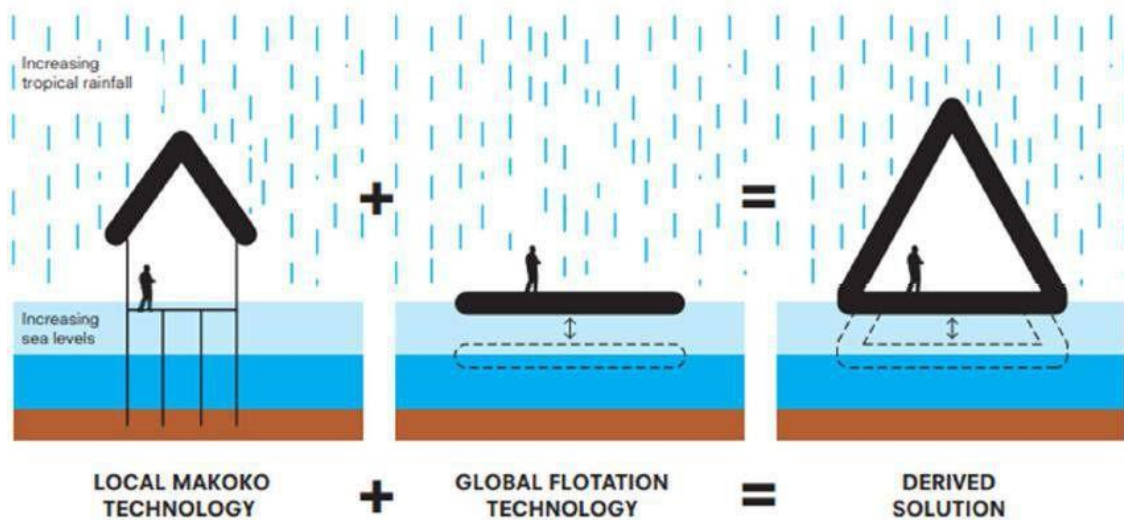


Figure 7: Makoko Floating School

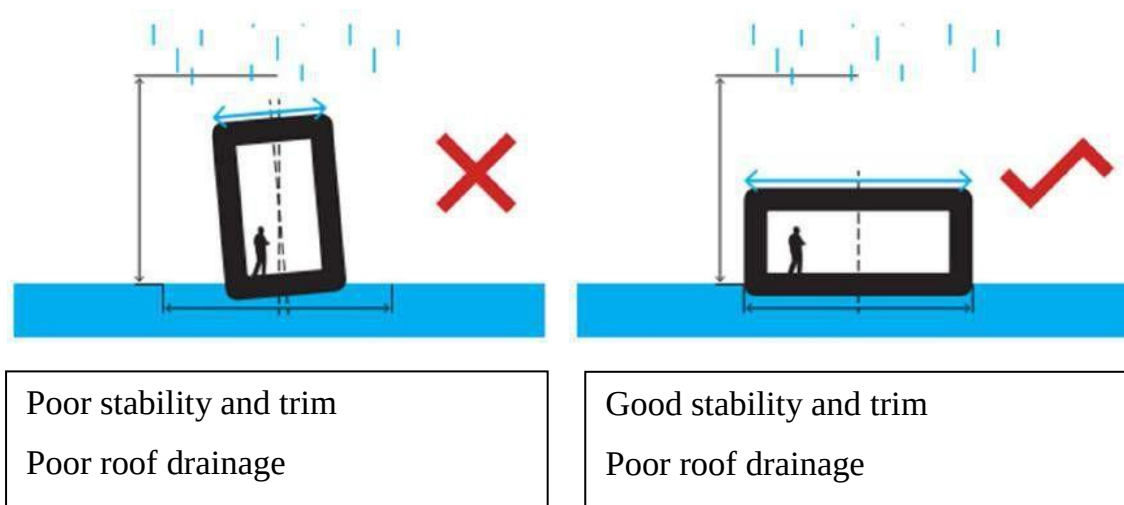
(Frearson Amy, 2014)

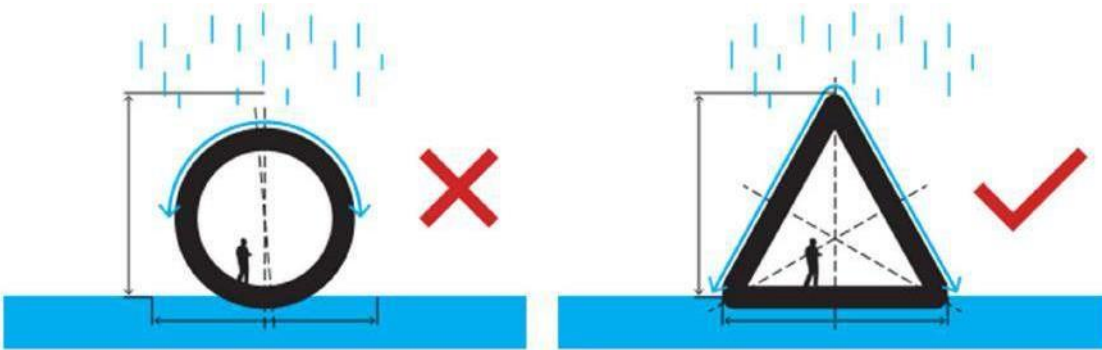
NLÉ developed a structure that can accommodate up to 100 adults, even in bad weather conditions. It is primarily used as a school, but can also function as an events space, a clinic or a market, depending on the needs of the community. (Frearson Amy, 2014)

STRUCTURAL CONCEPT



FLOATING CONCEPT





Poor stability and trim
Good roof drainage



Very Good stability and trim
Ideal roof drainage



SPATIAL ARRANGEMENT

It as triangular form in section constructed with parallel series of timber A-frames on a platform supported by emptied blue barrels. The 220m A-frame or pyramid building is 10 m high with 10m X10m base. It is an ideal shape for a floating object on water due to its relatively low center of gravity, which provides stability and balance even in heavy winds. It also has a total capacity to safely support a hundred adults, even in extreme weather conditions. (Frearson Amy, 2014)

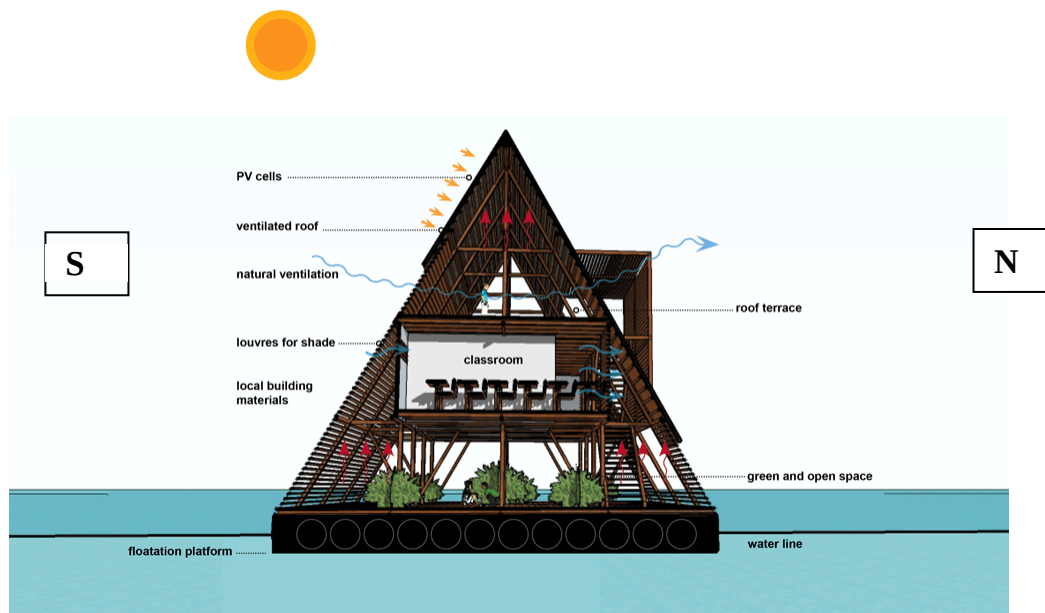
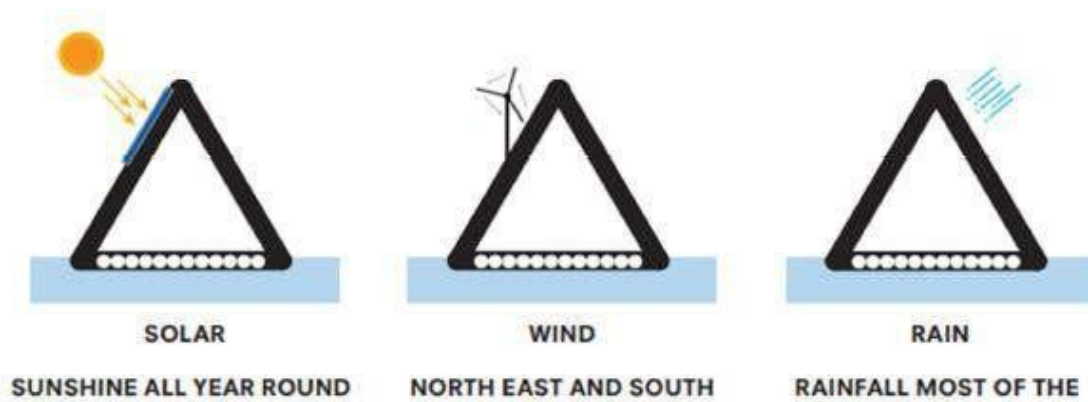


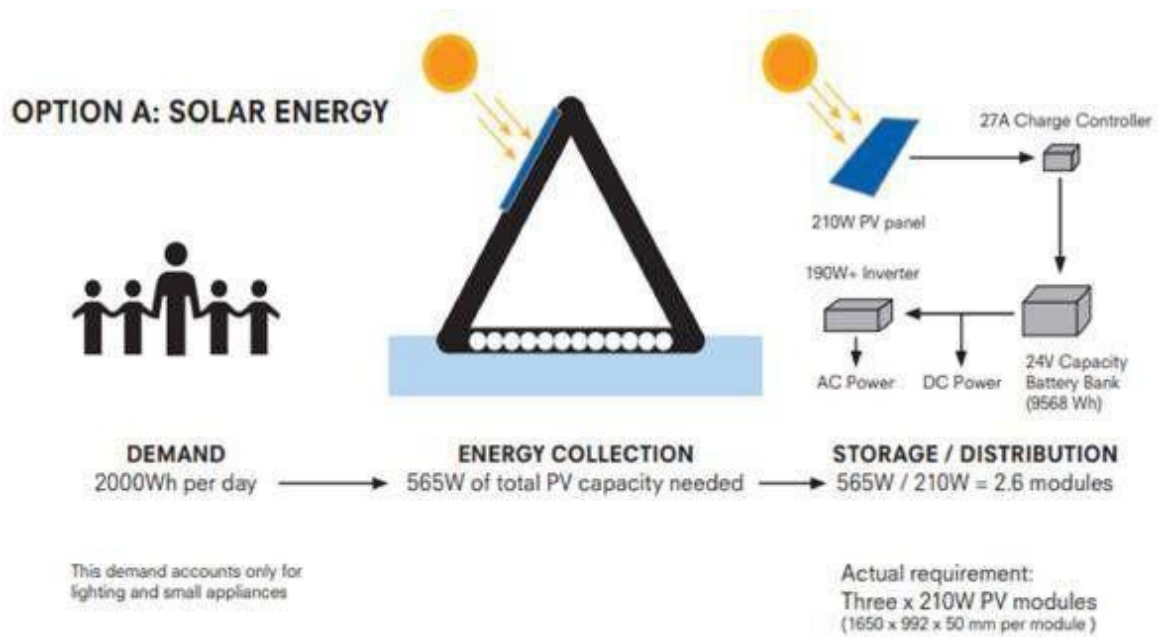
Figure 8: Detailed Cross Section

(Frearson Amy, 2014)

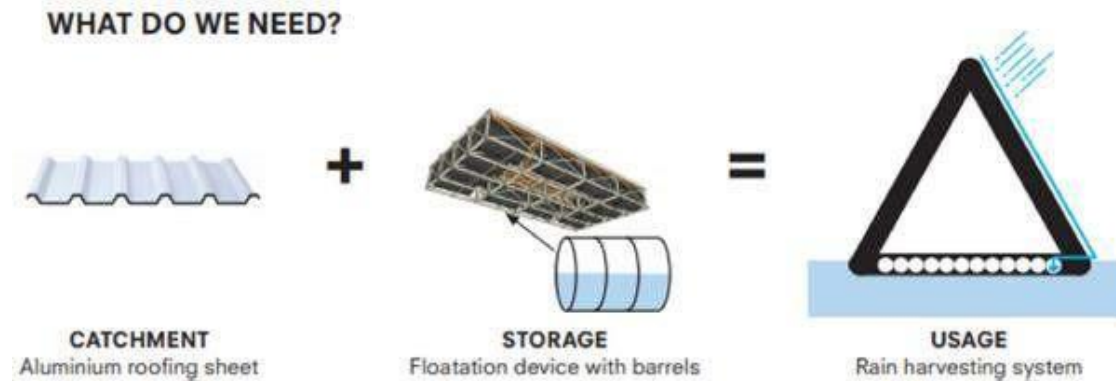
AVAILABLE RENEWABLE RESOURCES



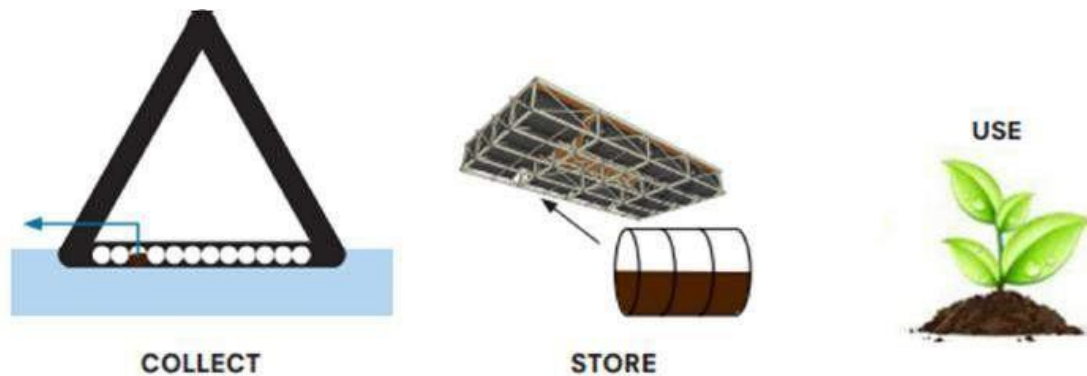
SOLAR ENERGY



RAIN WATER HARVESTING

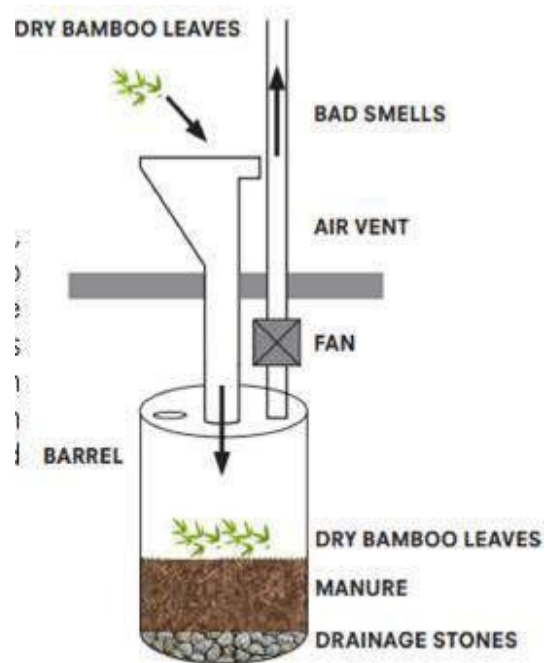


COMPOSE TOILETS IMPLEMENTATION

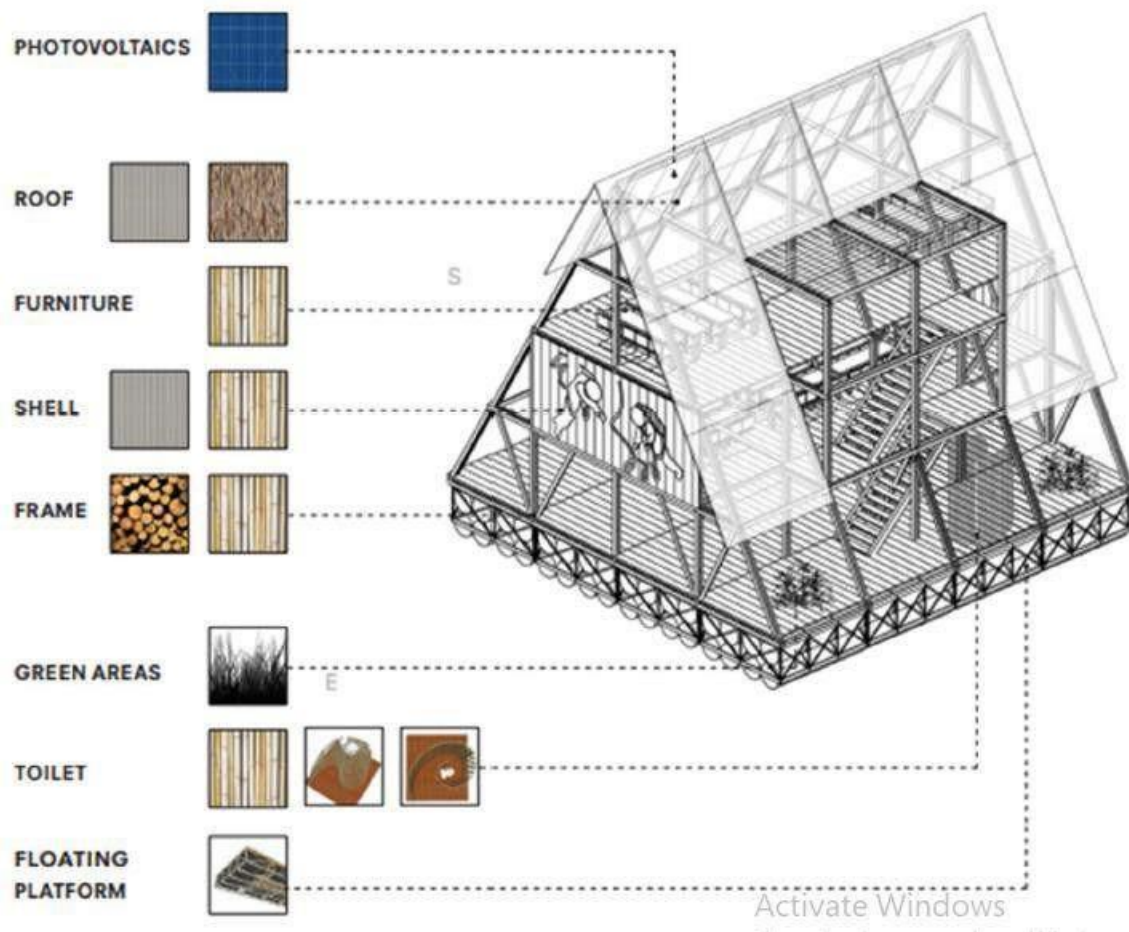


WORKING METHOD

In a compost bin, the waste from a toilet will, together with the supply of air, be broken down into compost. The heat generated by the decomposition will cause fluid to vaporize. This vapor is then evacuated through a ventilation pipe. The waste will be drastically reducing in volume and be emptied normally every second year. (Frearson Amy, 2014)



FLOATING BUILDING



STRUCTURE COLLAPSE

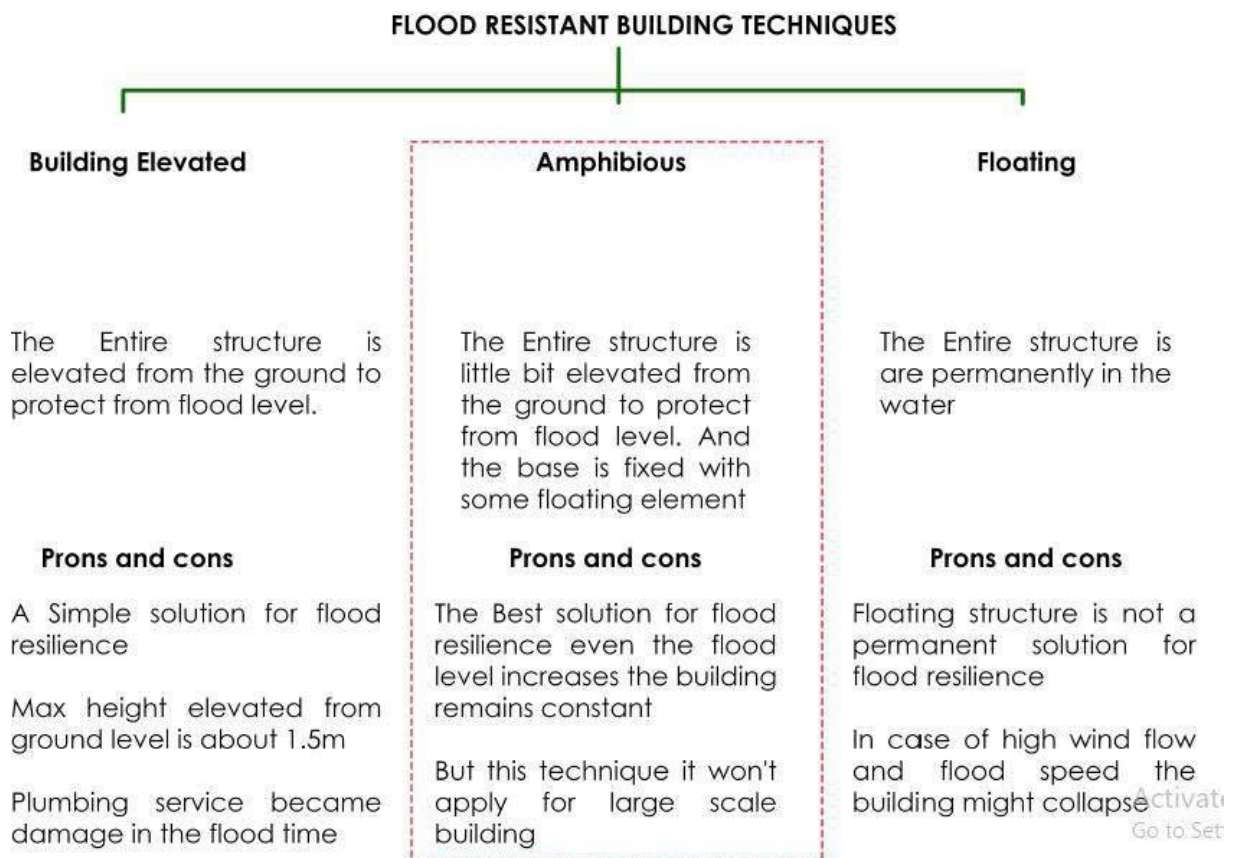
It had previously withstood weather conditions of greater severity in the past, than the conditions on the day of its collapse. A wind speed of only 27 knots (strong breeze) was recorded at the time of its collapse, whereas wind speed of 60 knots (violent winds) were recorded on numerous occasions in the period of its use between 2013 and 2016. Makoko Floating school structure collapsed due to deterioration resulting from lack of proper maintenance and collective management. (Frearson Amy, 2014)

3.4. COMPARITIVE ANALYSIS

Parameters	Elevated Housing	Amphibious housing	Floating House
Location	Assam	Vietnam	Africa
Locally available material	Bamboo and Metal sheet	Bamboo and Steel	Timber and Drum
Technology	Local technology	Non local technology	Non local technology
Cost	Cost effective	Cost effective	Cost effective
Construction time	62 days	185 days	294 days
Strength	Poor strength	Good strength	Good strength
Durability	Minimum 20 years	Minimum 20 years	Minimum 7 years
Maintenance	Once in a year	Once in a year	Once in a year

Service	Very poor	Good	Good
Weight	Reasonable weight	Reasonable weight	Reasonable weight
Achieved	Good performance 2017	Good performance 2018	Collapsed 2017

INFERENCE



4. SITE ANALYSIS

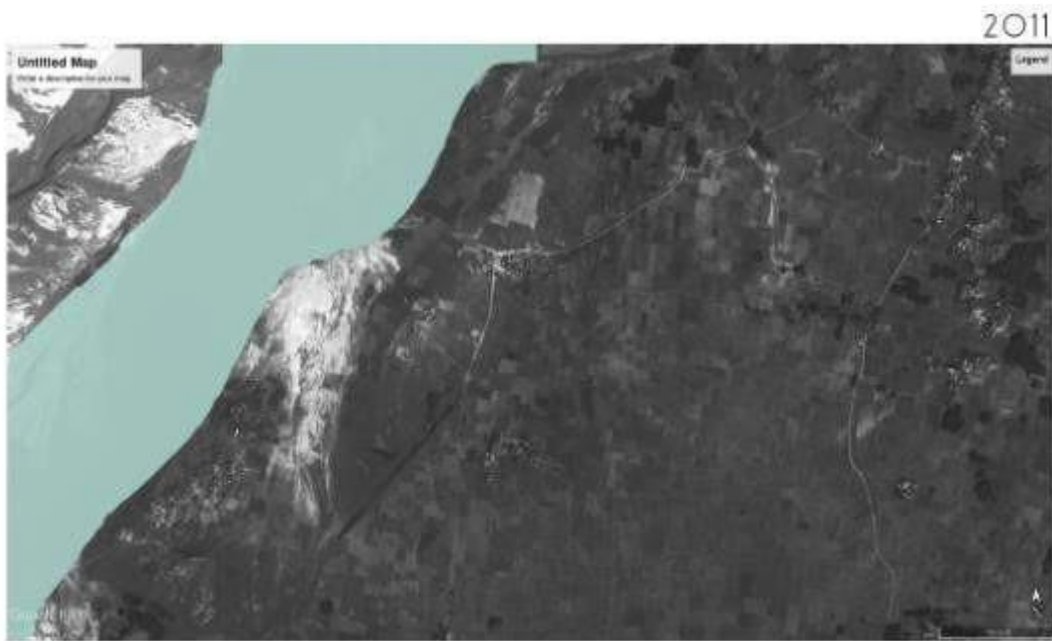
4.1. LOCATION

Bela is a large village located in Sitamarhi district of Bihar state, India. Bela village is located in Barachatti Block/ Tehsil. It is situated 7km away from sub-district headquarter Barachatti and 36km away from district headquarter Sitamarhi. As per 2009 status, Bibi Pesra is the gram panchayat of Bela village. The total geographical area of the village is 83 hectares.

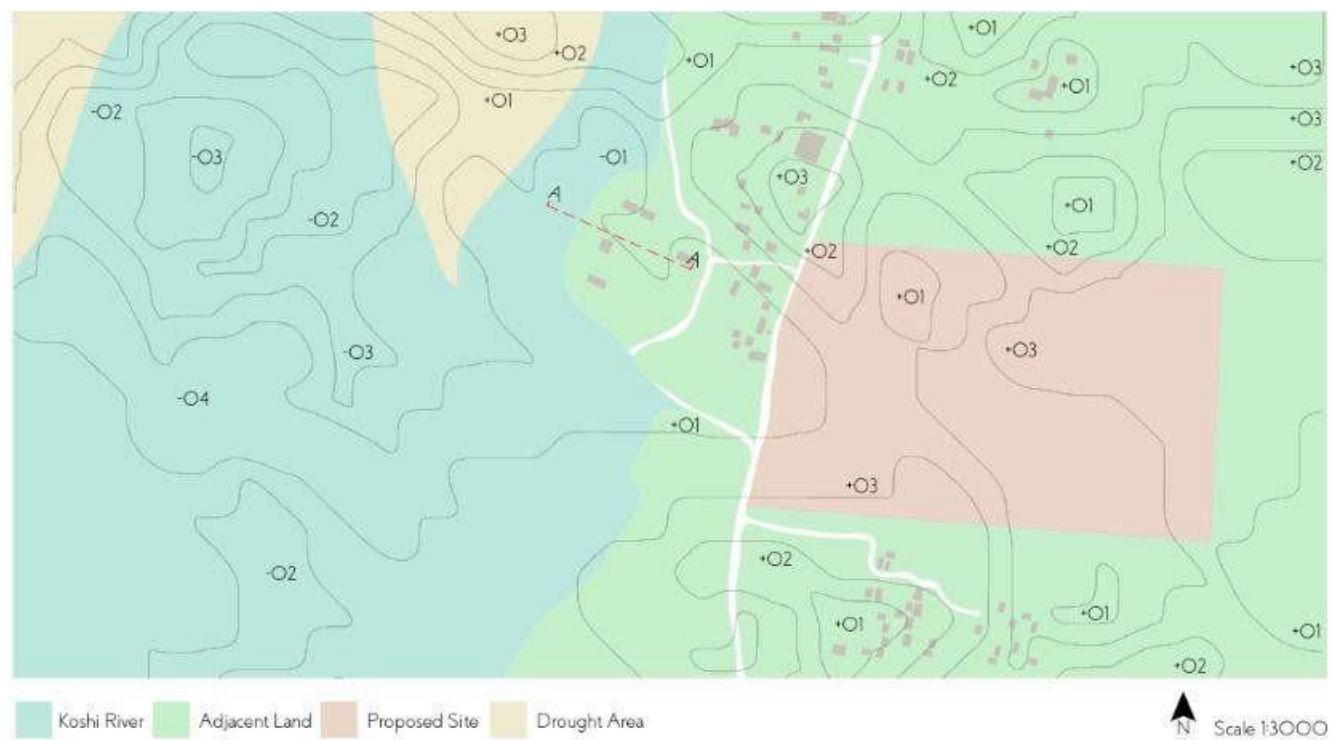
The village is affected by floods continuously for the past 10 years. Kosi has been changing its course whimsically in the last ten years. A minimum of at least 45 people dies because of floods and earthquakes in one year. Bela village in Sitamarhi district is most affected by disasters in Bihar district.

4.2. MORPHOLOGY OF THE SITE





4.3. PROPOSED SITE



4.4. SCHEMATIC SECTION



4.5. FLOOD MAP – 2010 TO 2019



As shown in the Flood Zone map, Sitamarhi district is the most affected by floods for the past 10 years. Comparing to the other districts of Bihar, Sitamarhi is the most affected district and so Site Selection is based on most affected prone zone.

4.6. EARTHQUAKE MAP – 2010-2019



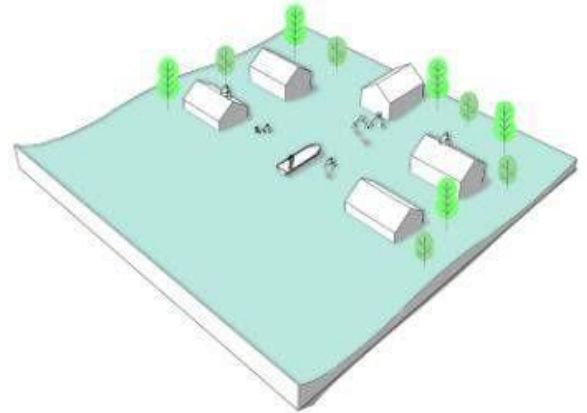
As shown in the Flood Zone map, Sitamarhi district is the most affected by earthquakes. Sitamarhi is situated in the northern part of Bihar. The district headquarter was shifted here after the town of Sitamarhi was devastated in one of the worst ever earthquakes in

January 1934. Average of 4-year once, this region is affected by the earthquake which creates more damage to livelihood

4.7. SITE ISSUES

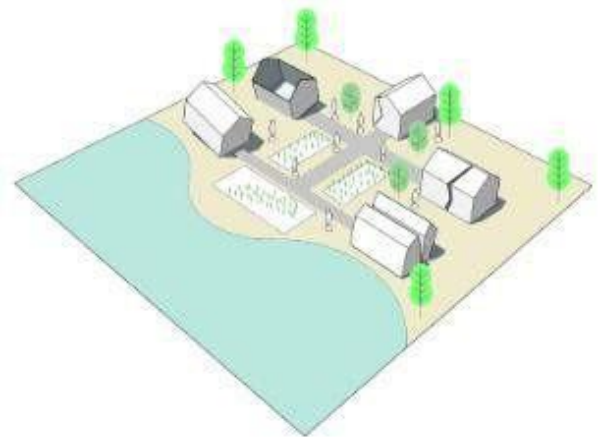
FLOOD

Originating from the glaciers of Tibet and Nepal, the river is exceptionally turbulent because of the steep gradient flow in Nepal. It has the history of changing its course every 50 to 100 years. Base Line Elevation of Water rises to 1.35m ht during flood and Radius of about 800m to 1km area is affected by flood.



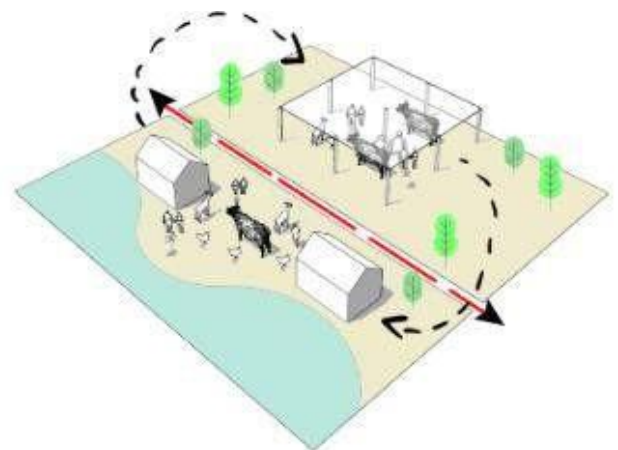
EARTHQUAKE

Average of 4 years once, this region is affected by earthquake which creates more damage to livelihood. The existing old house near river gets damaged and so the people rebuild structure every year after earthquake.



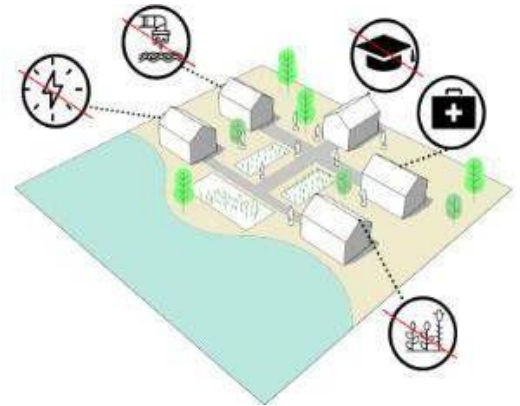
MIGRATION

Due to the melting glaciers at hot summer climate, there is a raise water level to great extent which causes flood. People migrate their livestock to temporary shed. People do not have affordability to take house for rent during flood times and so suffer the flood and some also lose their life



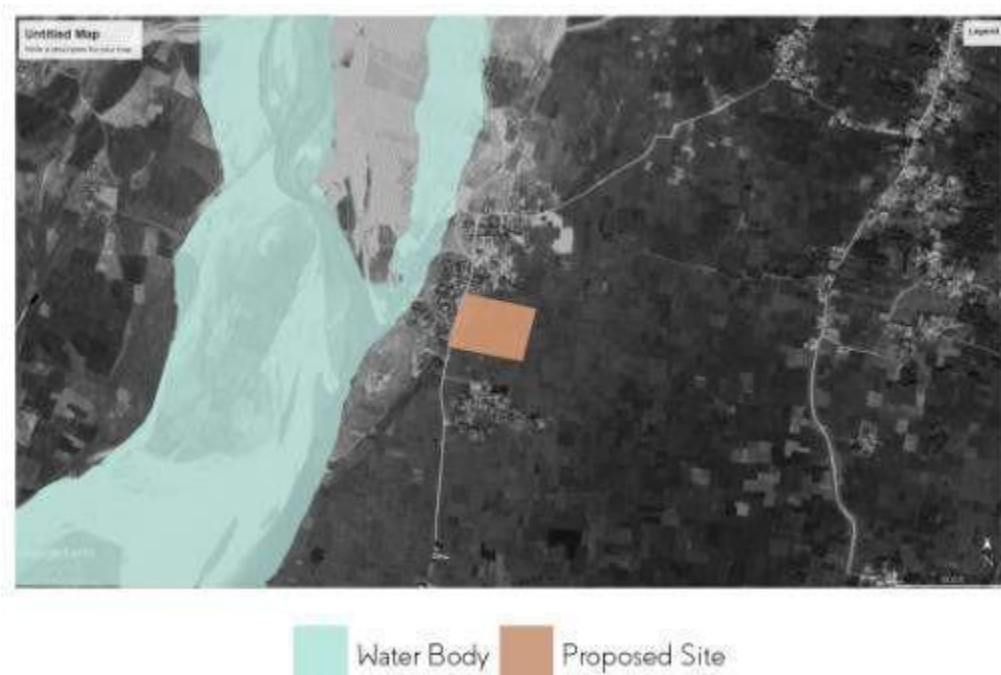
BASIC AMENITIES

People do not have even basic amenities. No electricity, no proper drainage system, no educational facilities, no first aid facilities, and also they lose their only occupation of agriculture and their crops during floods



4.8. STUDY OF EXISTING TYPOLOGY

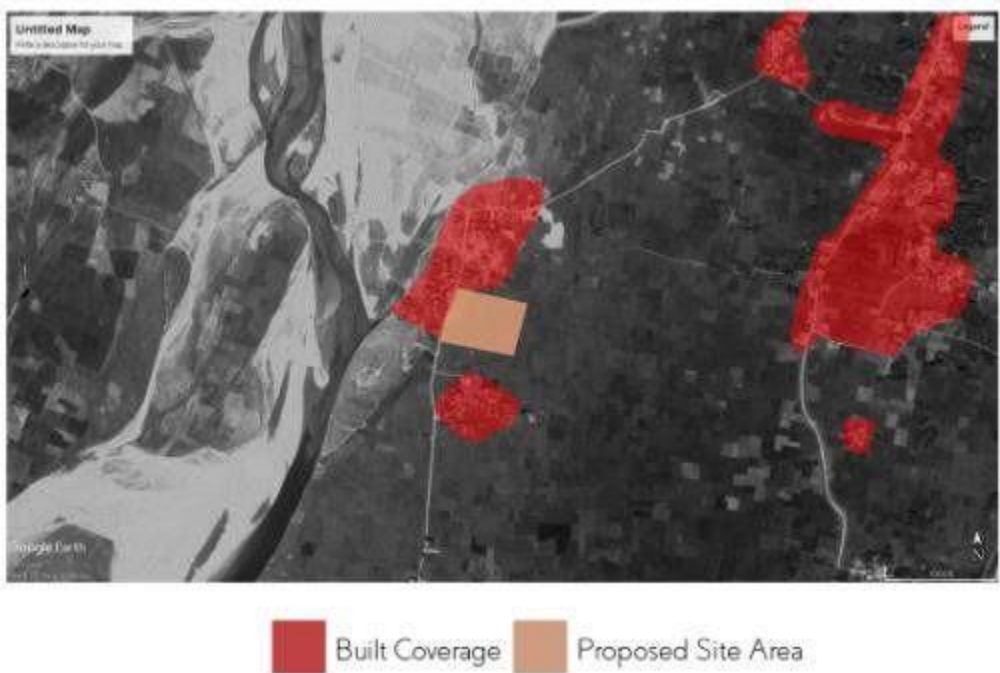
WATERBODY



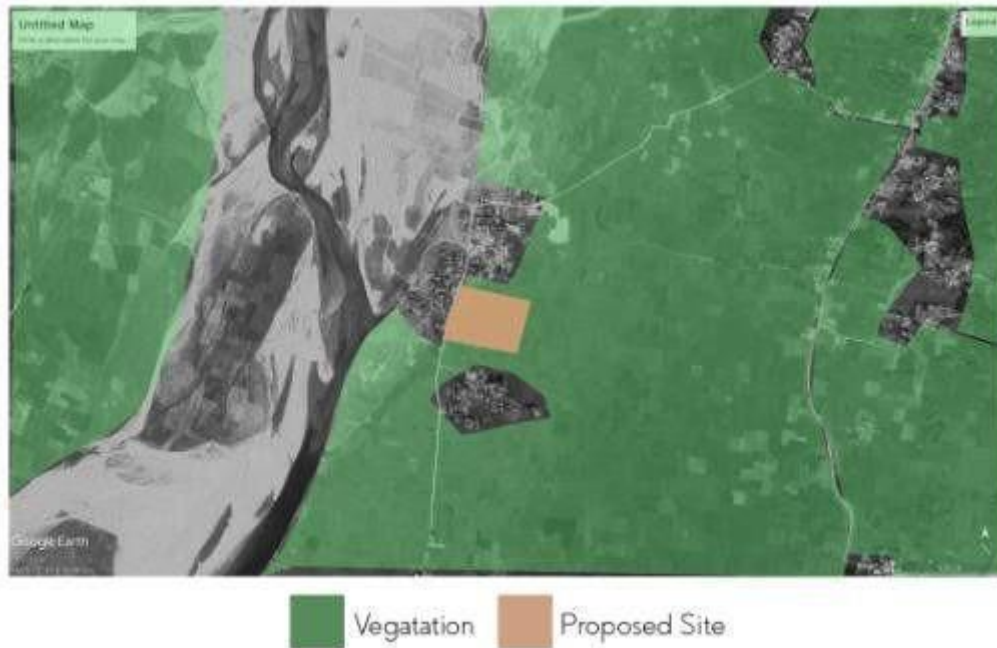
FLOOD AFFECTED AREA – 2018



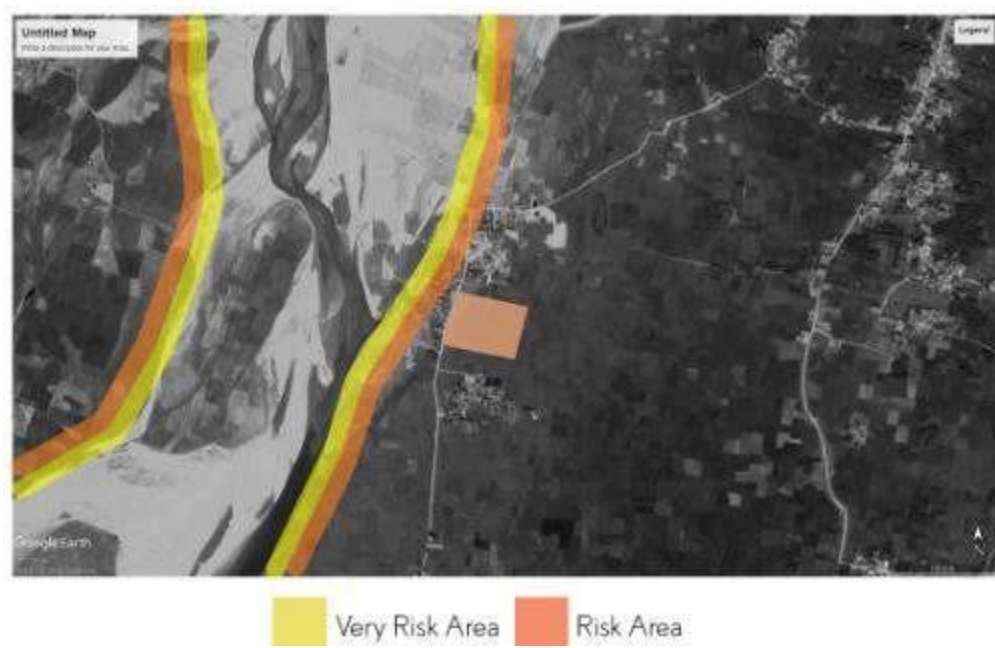
BUILT COVERAGE



VEGETATION



CRZ



RELIEF MAP



4.9. CLIMATIC DATA

Average temp – 26°C

Wind velocity – 6 m/s

Avg. Humidity - 62%

Wind direction:

Predominant wind direction – East

Southwest monsoon – East

Northeast monsoon – North & West

Soil type - clay soil, and loamy soil

Avg. rainfall - 1,027.6 mm

4.10. SWOT ANALYSIS

STRENGTH

Water scarcity is a strength to the site because of the high groundwater table near the river

No pollution around the surroundings and so the location restores peace.

Bamboo is widely planted in this area which is further used for their construction

The contour of the site is high from the river and so the site itself restricts some level of floodwater

WEAKNESS

Flood occurring every year is the major weakness

Earthquake occurring four to four year once is also a disadvantage to this region

People migrate during rainy seasons which brings changes in their life pattern

There are no basic amenities because of frequent flood and migration

Settlements are near the river which caused the death

Sometimes there might be diseases spreading because of the contamination of floodwater.

OPPORTUNITIES

Proper Sewage Treatment Plant can be achieved

Since the climate is Composite, i.e., too hot and too cold, thermal indoor & outdoor comfort to be achieved by using local materials.

THREAT

Flood & Earthquake are the major threat to this area

Spread of harmful diseases due to contamination of staggered flood water

The site is surrounded by Karuvelam tree, or Prosopis juliflora, which dry up the water bodies and result in the water-starved region

4.11. BIHAR BYE-LAWS

Minimum Setback for Residential Buildings

Avg. depth of plot (m)	Min. front set back (m)	Min. rear set back (m)	Min. side set back (m)	Min. side set back (m)
More than 45m	4.0	4.0	3.66	3.66

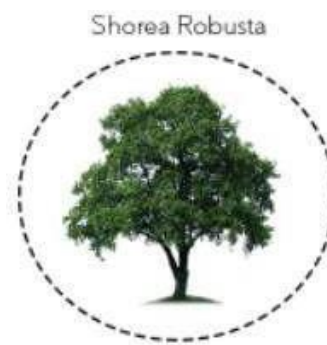
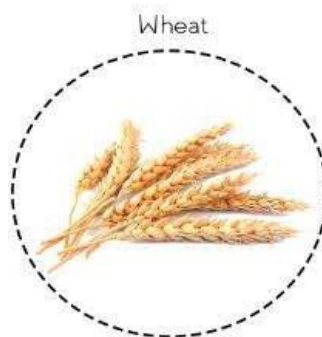
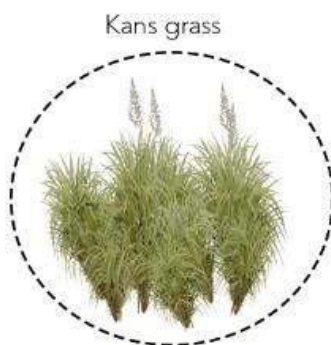
FAR for Residential Buildings

Road width (m)	FAR	Floors	Max. height (m)
4.8 (16')	1.8	G+2	10

Additional FAR up to 10% a max. of 0.25 shall be allowed for dwelling units means exclusively for EWS/LIG in a group housing Scheme

In case of rivers other than Ganges, no construction or re-construction of any building shall be allowed, within a strip of land of 50 m, or such distances as prescribed by the State govt., from the outer boundary of the riverfront of any river. As Bihar is located in seismic zone III.

4.12. NATIVE SPECIES



Bamboo



Paddy



4.13. NATIVE FISHES

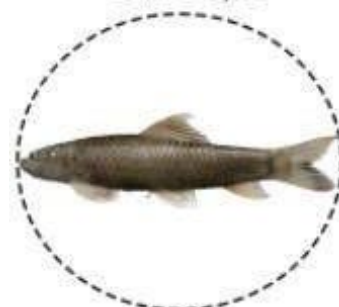
Golden Ruha



Labeo Boga



Garra Gotyala



Cirrhinus reba

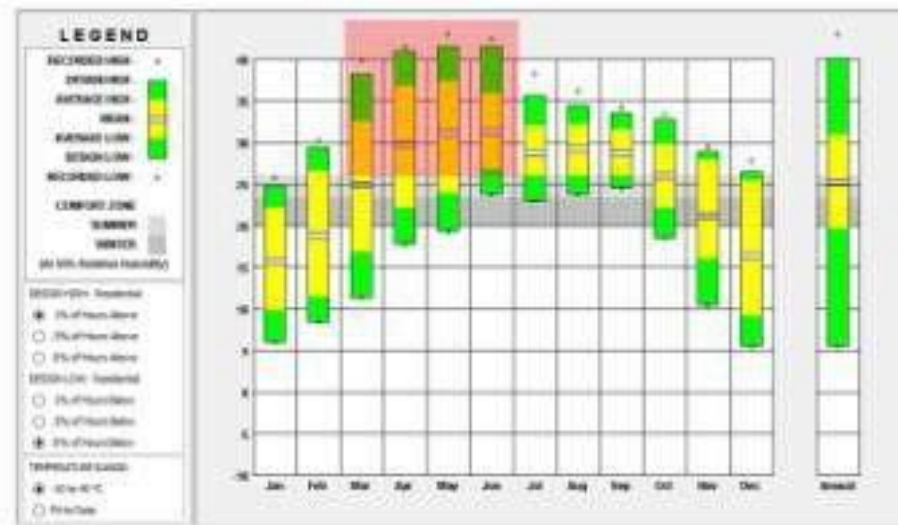


Labeo rohita



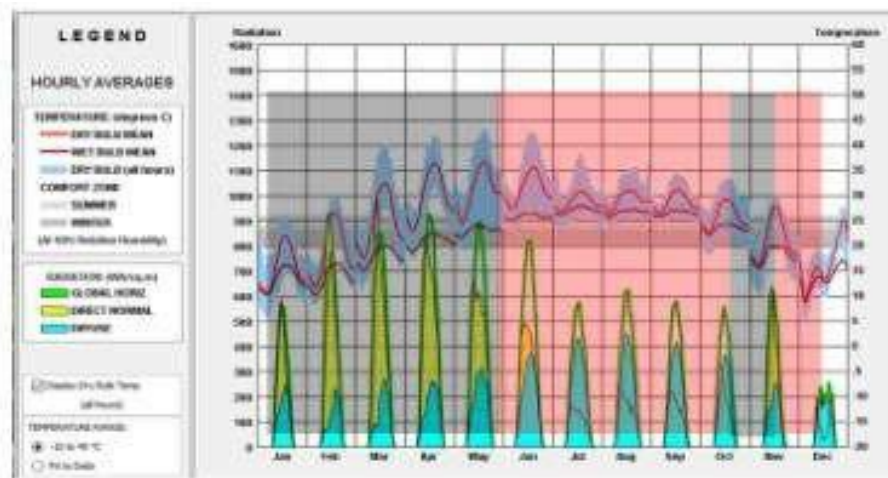
5. CLIMATE STUDY

5.1. TEMPERATURE RANGE



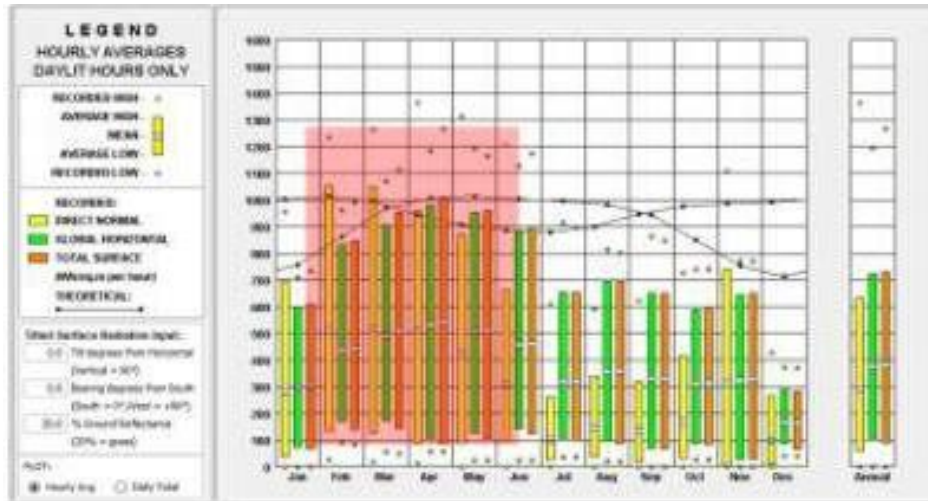
The temperature range is recorded to average high in March to June. The mean annual temperature is 26°C. the comfort zone lies between 23°C to 26°C in summer & 20°C to 23°C in winter.

5.2. MONTHLY DIURNAL RANGE



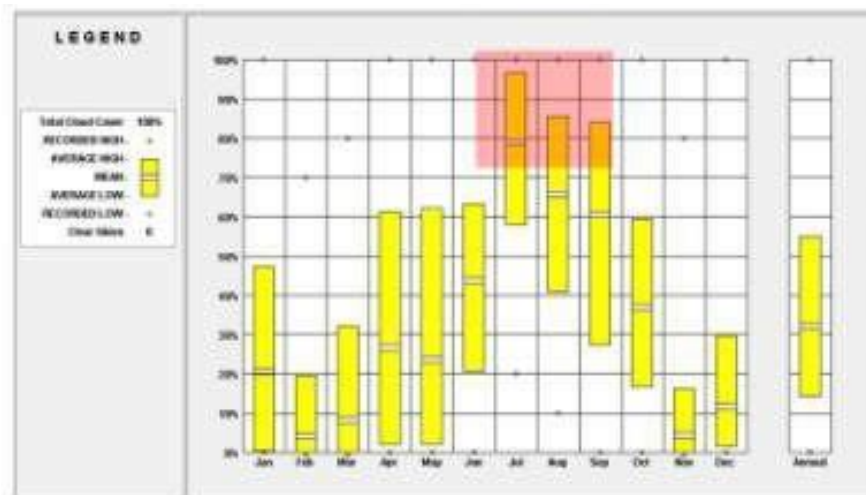
The diffused radiation is in the month of June to October & December due to the overcast sky condition. The direct normal radiation is high in the month of January to May & November

5.3. SOLAR RADIATION



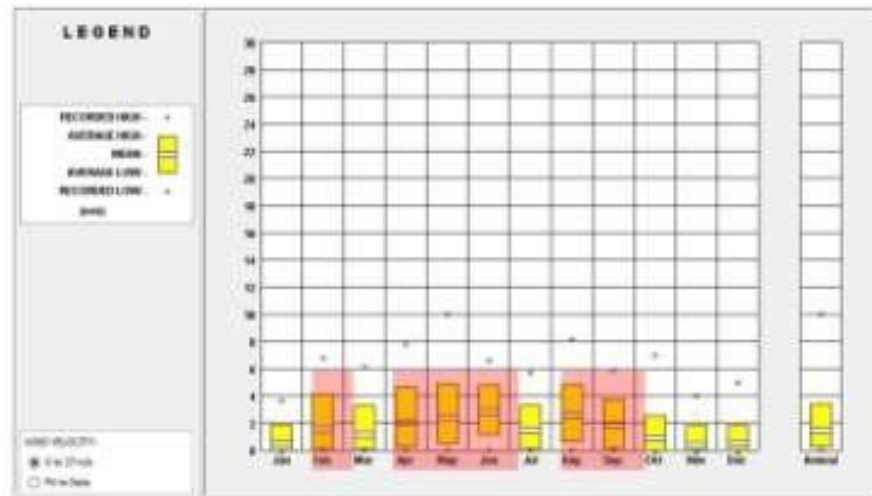
Direct Normal radiation on the walls are higher in Feb to Jun. Global horizontal radiation (all the light landing on horizontal surface) is generally higher and pv panels can be mounted on the roof top terrace.

5.4. SKY COVER



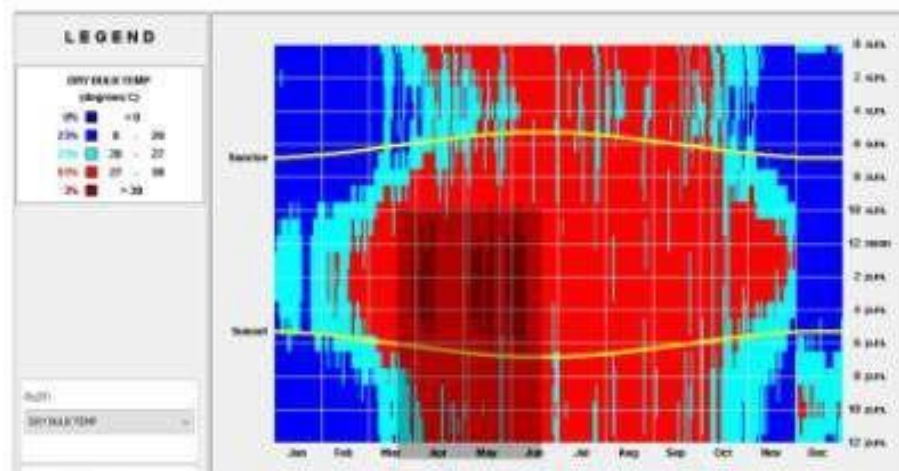
The sky cover range is high in the month of July to September. This overcast sky led to rainfall in these month Maximum sky cover is in month of July with 98%.

5.5. WIND VELOCITY



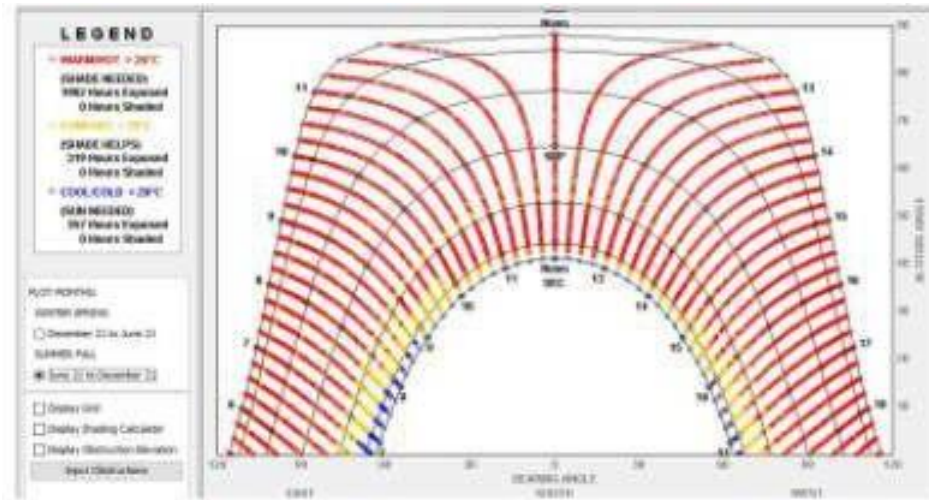
The wind velocity is high in the month of Feb, April to June, August & September. Average maximum is 5 m/s in the month of May and Average Minimum is 1.8 m/s in the month of November & December.

5.6. DRY BULB TEMPERATURE



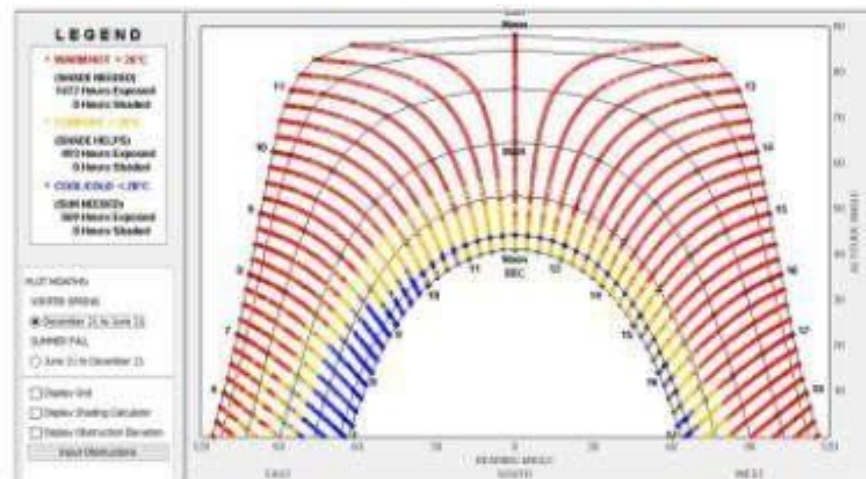
March to June are the hottest month with peak temperature higher than 38°C during the day time.

5.7. SUN SHADING – SUMMER FALL



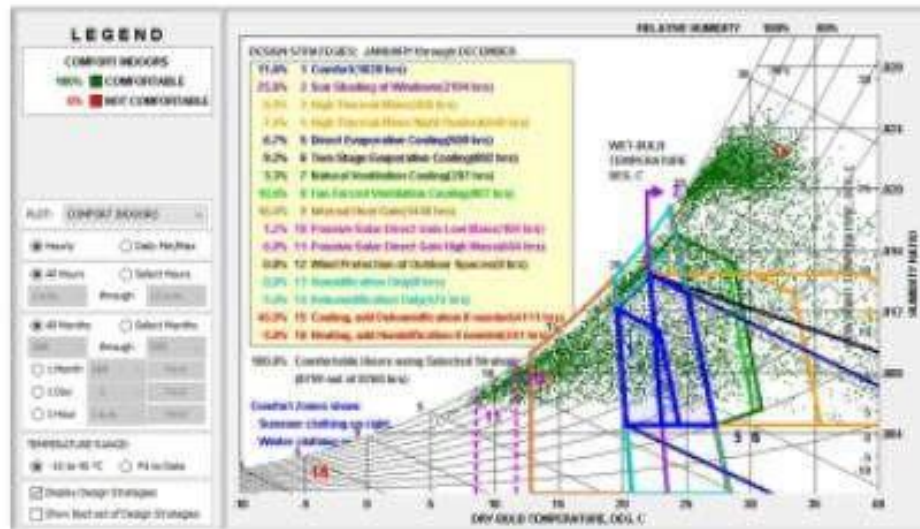
Shading device is needed for almost all the days of the year. From January to September, the site experiences very hot climate and so must proper shading devices is must.

5.8. SUN SHADING – WINTER SPRING



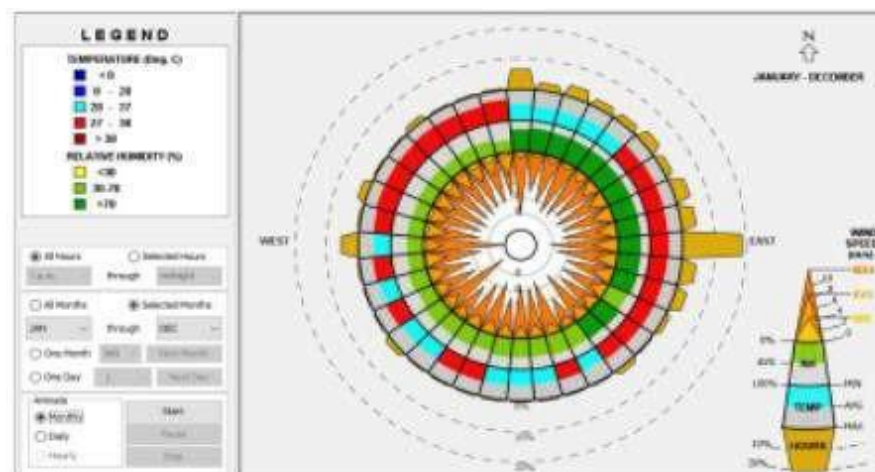
At winter spring, shading devise must be designed to lit in partial sunlight from September & October and full sunlight in the months of November & December.

5.9. PSYCHROMETRIC CHART



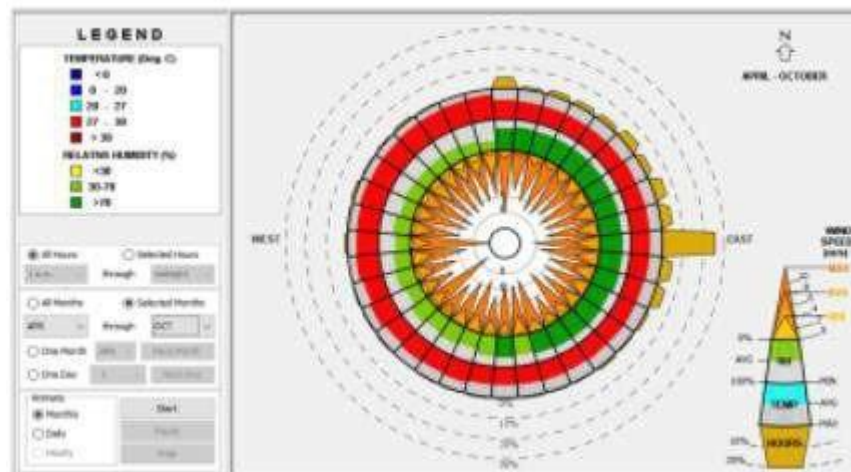
From the above psychometric chart, we could find the strategies to achieve 100% of comfortable hours for the Bihar region, which has only 11.6 % of natural comfort (1020 hours)

5.10. WIND WHEEL – JAN TO DEC



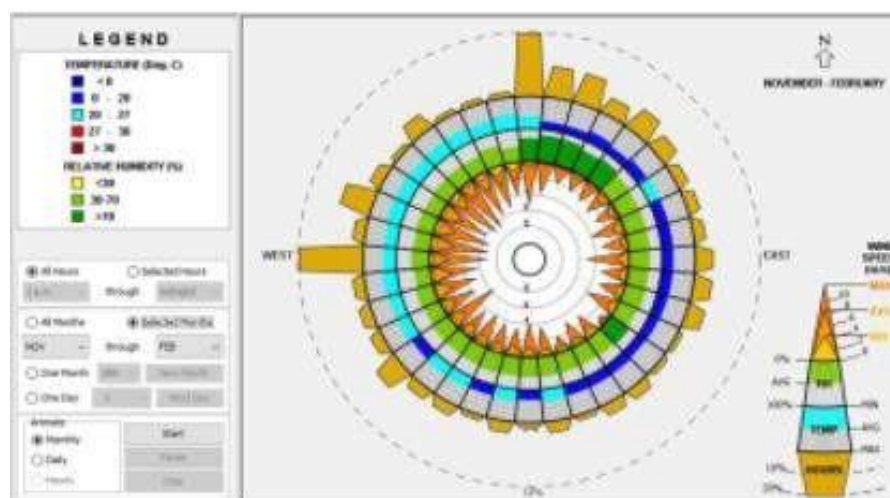
The predominant wind direction is from East. Maximum hours 19 % and average wind speed is 8 mph. The temperature ranges 27°C to 38°C. The relative humidity lies in between more than 70%

5.11. WIND WHEEL – APRIL TO OCT



The south-west monsoon winds retain in East direction for maximum hours of 25% and has maximum wind speed of 8mph. The temperature Range is 27°C to 38°C and relative humidity lies in between 30-70%.

5.12. WIND WHEEL – NOV TO FEB



The North-East monsoon winds brings gradual decrease in temperature from north & west, ranging from 20°C to 27°C and relative humidity is 30-70% with maximum hours of 10% & max wind speed is 8mph.

6. MAHONEY TABLE

Location: Sitamarhi, Latitude: 25.5941 N, Longitude:85.1376 E, Altitude: 53m

AIR TEMPERATURE

Air Temperature

	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec	high	AMT
Monthly mean max	22.1	26.2	32.5	37.6	37.7	35.7	32	31.8	31.1	30.1	27.7	23.8	37.7	30
Monthly mean min.	10.6	13.6	18.4	23.4	25.9	27.0	26.3	26.1	25.2	21.7	16.5	12.2	27.0	16.4
Monthly mean range	16.35	20	25	31	32	31	29	29	28	26	22	18	low	AMR

RELATIVE HUMIDITY

Relative Humidity

Step 2:

	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Monthly mean max	99.1	93.7	90.1	93.0	92.4	91.7	99	97.8	96.3	95.2	94.2	98.1
Monthly mean min	51.8	37.8	23.6	18.6	29.8	36.4	40	61.6	57	41	40.9	39.7
Average Relative Humidity	75.45	66	57	56	61	64	69	80	77	68	68	69
Humidity group	4	3	3	3	3	3	3	4	4	3	3	3

DIAGNOSIS

Diagnosis

Step 3:

	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Monthly mean max	22.1	26.2	32.5	37.6	37.7	35.7	32	31.8	31.1	30.1	27.7	23.8
Day comfort upper	27	29	29	29	29	29	29	27	27	29	29	29
Day comfort lower	22	23	23	23	23	23	23	22	22	23	23	23
Monthly mean min	10.6	13.6	18.4	23.4	25.9	27.0	26.3	26.1	25.2	21.7	16.5	12.2
Night Comfort upper	21	23	23	23	23	23	23	21	21	23	23	23
Night Comfort Lower	17	17	17	17	17	17	17	17	17	17	17	17
Thermal Stress Day	O	O	H	H	H	H	H	H	H	H	O	O
Thermal Stress Night	C	C	O	H	H	H	H	H	H	O	C	C

ANNUAL RAINFALL

Annual Rainfall

Step 4:

Rain Fall	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Average Rain fall (mm)	0	29	4.5	0	135	138	160	368	130	120	0	4

INDICATORS TABLE1

Indicators - Table 1

Step 5:

	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
	4	3	4	4	3	3	3	4	4	4	4	4
Humid : H1			YES	YES	YES	YES	YES	YES	YES			
H2	YES											
H3								YES				
Arid : A1		YES	YES	YES	YES	YES	YES			YES	YES	YES
A2												
A3												

INDICATORS TABLE 2

Step 6:

Indicators - Table 2

H1	H2	H3	A1	A2	A3
7	1	1	9		

H1 - 7

Spacing - Criteria 4 open space for **breeze penetration** . but protection from hot and cold wind
 Air Movement - Criteria 6 - Rooms single banked. permanent provision for air movement
 Opening - Criteria 11 - Minimun **openings 20 - 40%**

H2- 1

Air Movement - Criteria 8 - **No Air movement required**

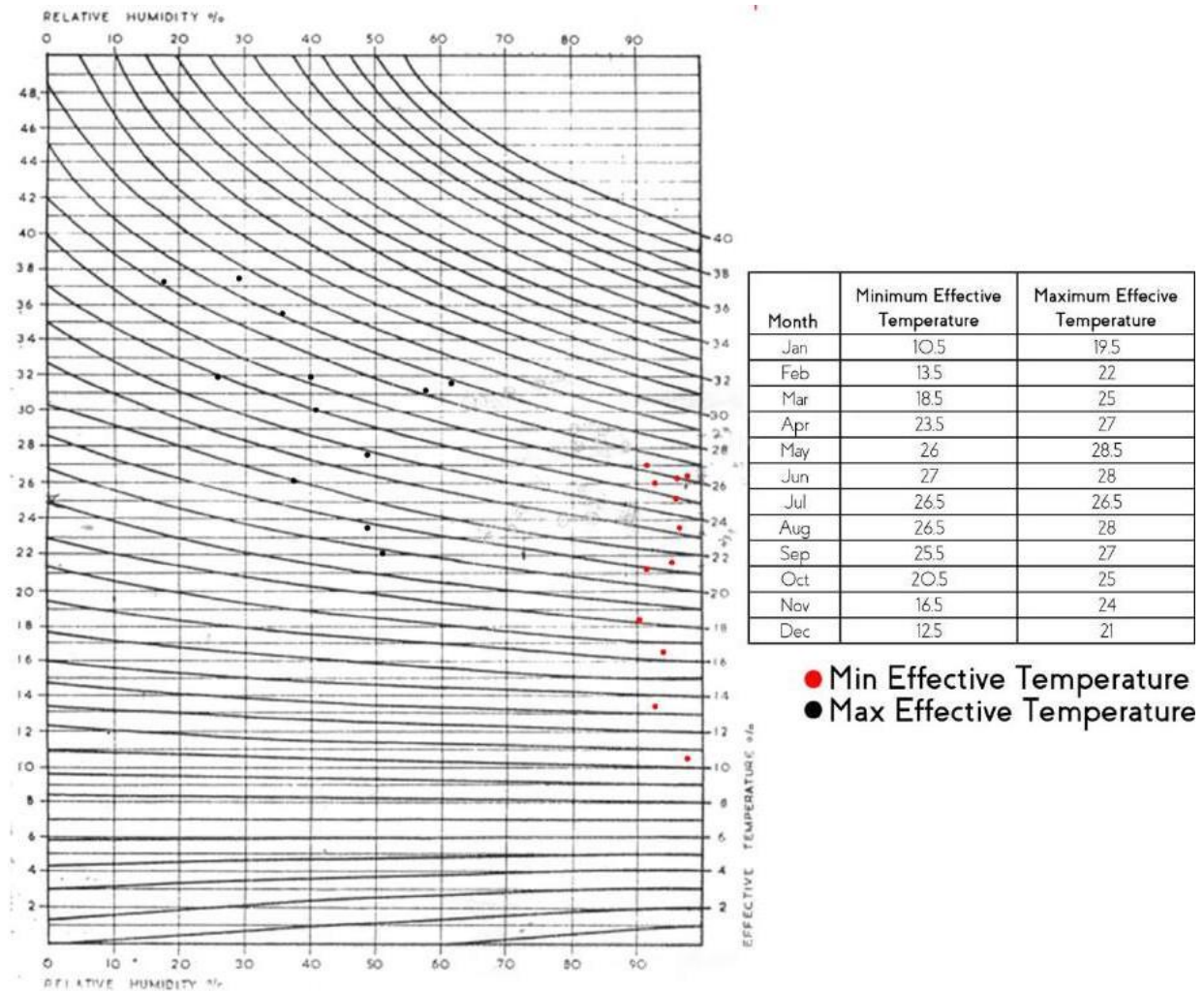
H3- 1

Opening - Criteria 11 - Minimun **openings 20 - 40%**

A1 - 9

Layout - Criteria 1- **Orientation toward north and south**
 Air Movement - Criteria 6 - Rooms single banked. permanent provision for air movement
 Walls - Criteria 13 - **Heavy external and internal wall**
 Roof - Criteria 15 - **Heavy roof. over 8hr time lag**

TO FIND EFFECTIVE TENPERATURE



Effective temperature is found by plotting minimum air temperature against maximum relative humidity and maximum air temperature against minimum relative humidity and projecting these points along the curved lines in the effective temperature graph

STEP 1:

To Calculated AMT Value

= (Highest mean daily max air temperature of the year + Lower mean daily min air temperature of the year) / 2

AMT Value = 30

STEP 2:

To find position of center comfort zone

$$T_{cc} = (AMT/4) + 17.2$$

$$T_{cc} = 24.7$$

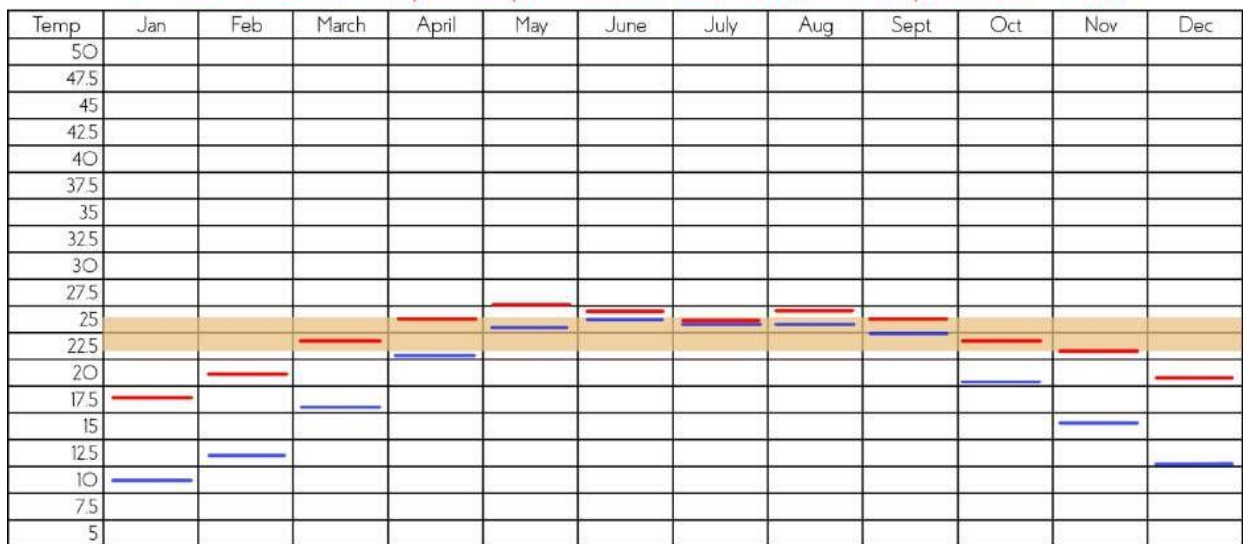
STEP3:

To calculate AMR value

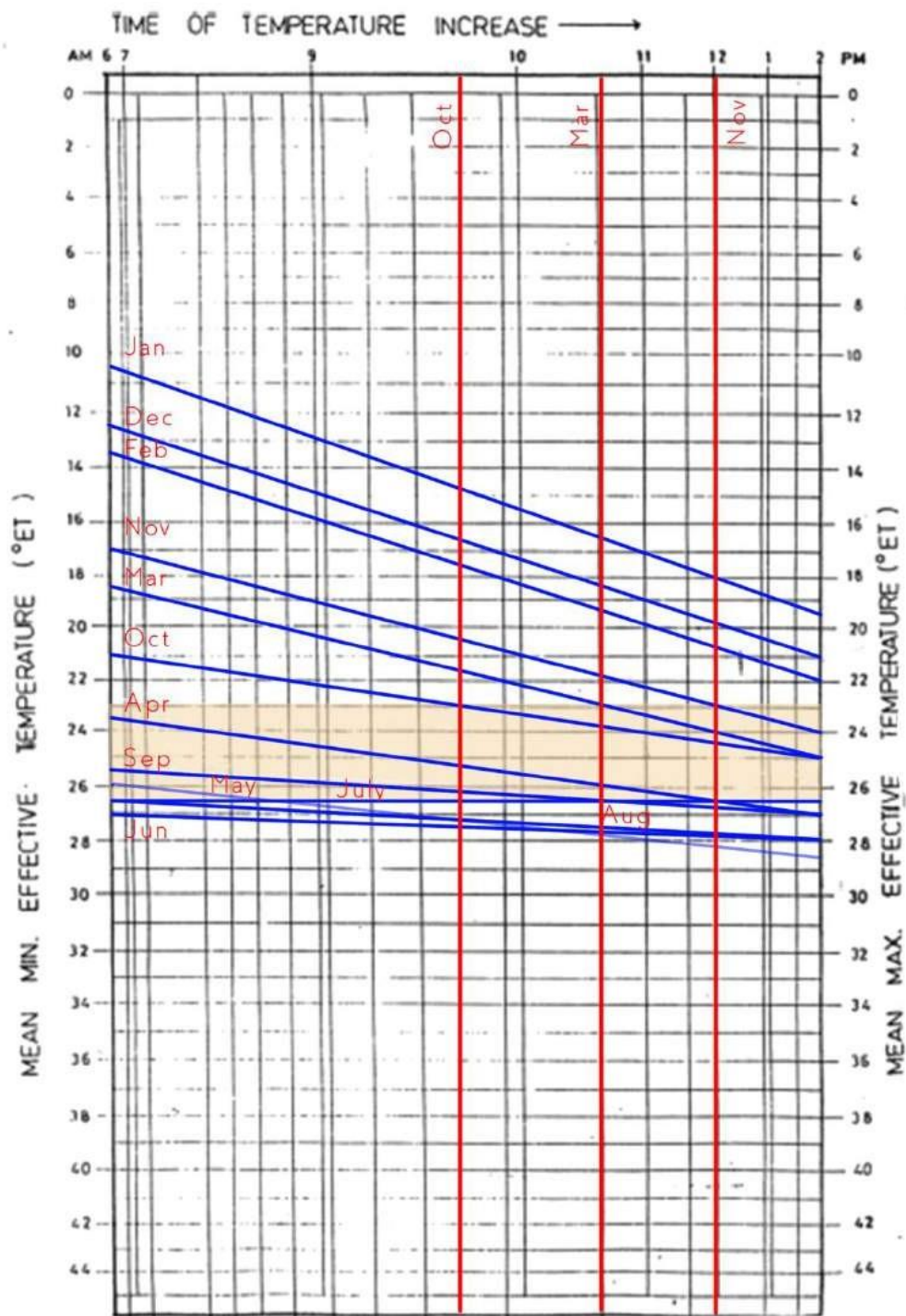
= Highest mean daily max air temperature of the year - Lower mean daily min air temperature of the year

$$AMR \text{ Value} = 16.4$$

Comfort Zone superimposed on Effective temperature chart



AMR Value : **16.4** Comfort Zone Range : **3.5** T_{cc} : **24.7**
 Comfort Range : $24.7 + 1.75 = \mathbf{26.45}$ and $24.7 - 1.75 = \mathbf{22.95}$



7. NICOLE TABLE

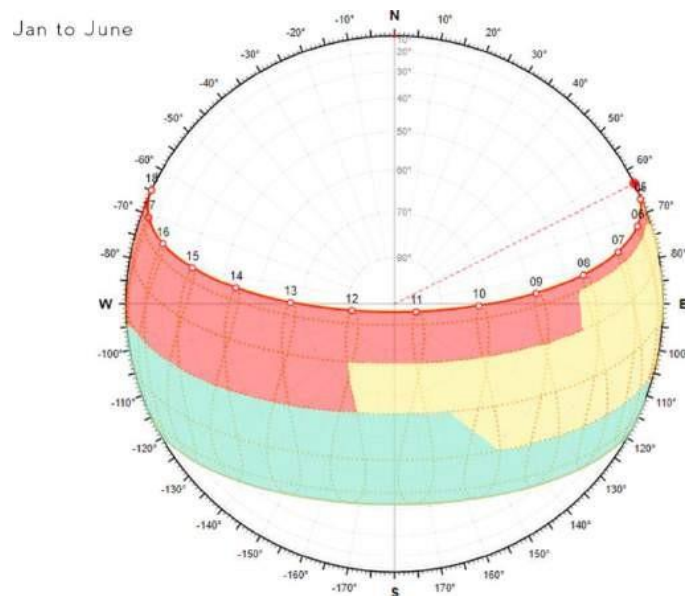
Months	Min.temp	Max.temp	Avg.temp	Netural	Lower Limit	Upper Limit
Jan	10.6	22.1	16.35	21.66	19.279	24.039
Feb	13.6	26.2	19.9	23.58	21.196	25.956
Mar	18.4	32.5	25.45	26.57	24.193	28.953
Apr	23.4	37.6	30.5	29.3	26.92	31.68
May	252.9	37.7	145.3	91.29	88.912	93.672
Jun	27	35.7	31.35	29.76	27.379	32.139
Jul	26.3	32	29.15	28.57	26.191	30.951
Aug	26.1	31.8	28.95	28.46	26.083	30.843
Sep	25.2	31.1	28.15	28.03	25.651	30.411
Oct	21.7	30.1	25.9	26.82	24.436	29.196
Nov	16.5	27.7	22.1	24.76	22.384	27.144
Dec	12.2	23.8	18	22.55	20.17	24.93

$$\text{Indoor Operative Temp. (}^{\circ}\text{C)} = 0.54 * \text{outdoor temp.} + 12.83$$

Where indoor operative temperature ($^{\circ}\text{C}$) is neutral temperature and outdoor temperature is the 30-day outdoor running means air temperature ($^{\circ}\text{C}$) The 90% acceptability range for the India specific adaptive models for naturally ventilated buildings is $\pm 2.38^{\circ}\text{C}$.

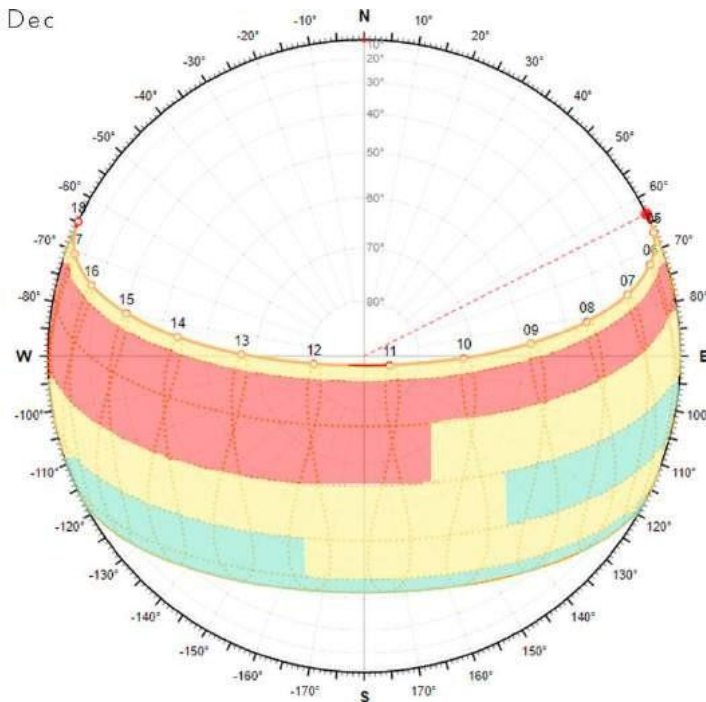
8. SUN CHART

JANUARY TO JUNE



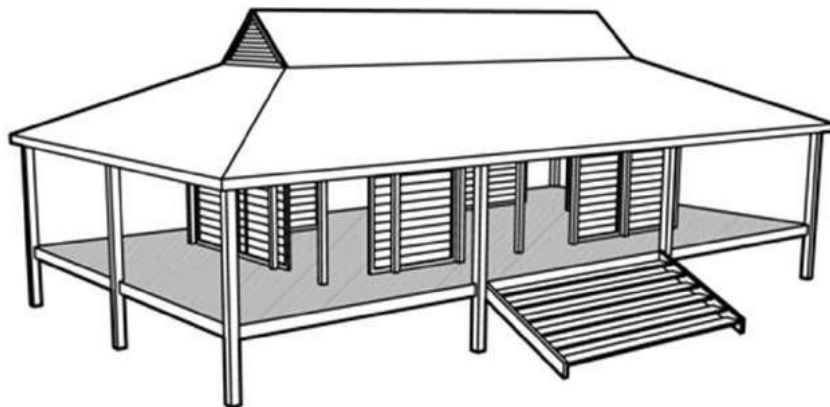
JULY TO DECEMBER

July to Dec



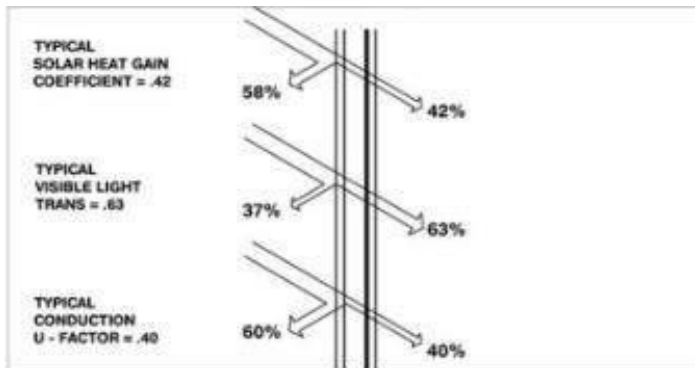
9. PASSIVE STRATEGIES

OPENABLE WALL



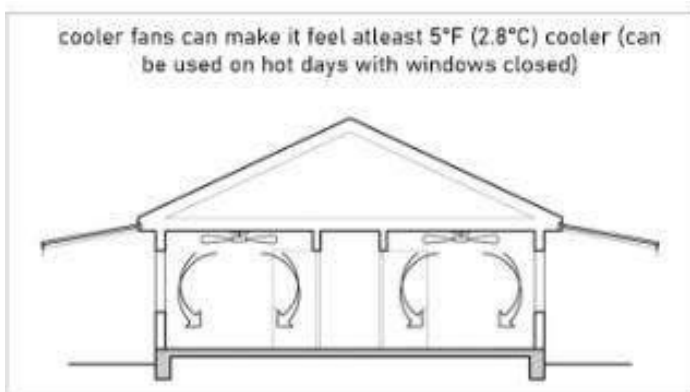
Traditional passive homes in hot humid climates used light weight construction with openable walls and shaded outdoor porches, raised above ground

DOUBLE PANEL LOW-E



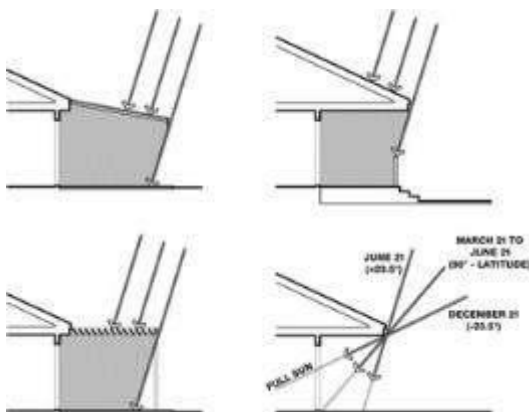
High performance glazing on all orientations should prove cost effective (Low-E, insulated frames) in hot clear summers or dark overcast winters

CEILING FAN



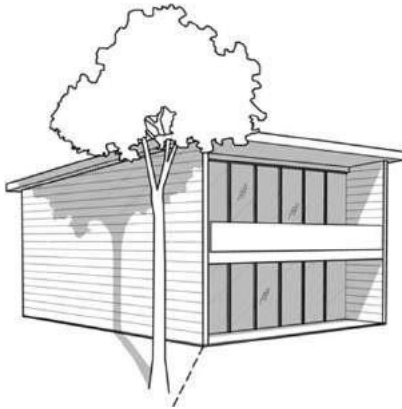
On hot days, ceiling fans or indoor air motion can make it seem cooler by 5-degree F (2.8°C) or more, thus less air conditioning is needed.

WINDOW OVERHANG



Window overhangs (designed for this latitude) or operable sunshades (awnings that extend in summer) can reduce or eliminate air conditioning

BUFFER SPACE



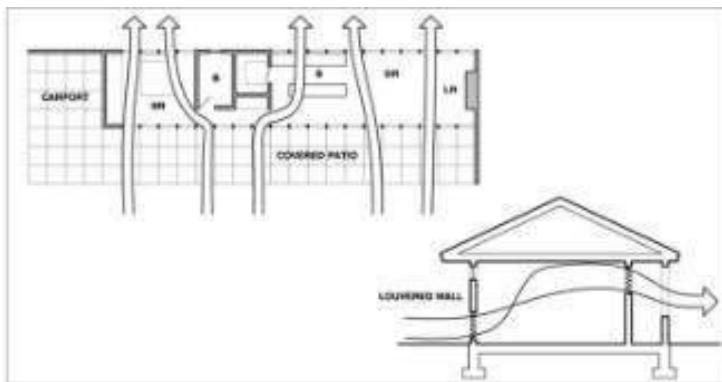
Minimize or eliminate west facing glazing to reduce summer and fall afternoon heat gain

VERTICAL FINS



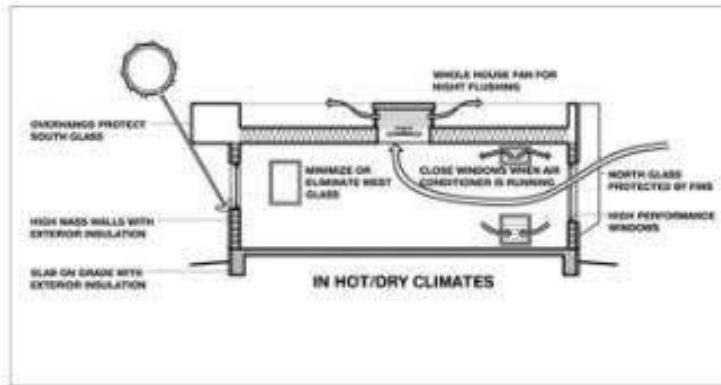
Orient most of the glass to the north, shaded by vertical fins, in very hot climates, because there are essentially no passive solar needs

OPEN PLAN



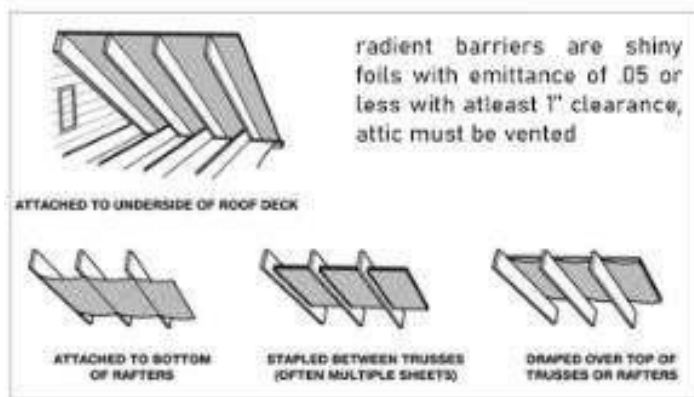
Use open plan interiors to promote natural cross ventilation, or use louvered doors, or instead use jump ducts if privacy is required

MINIMIZE OVERHEATING – Hot/Dry Climate



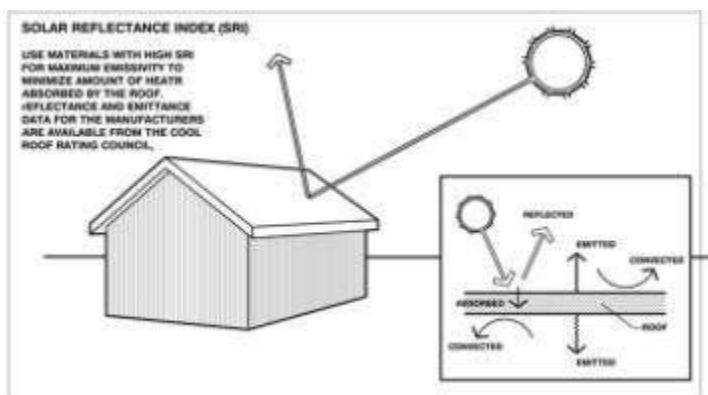
In this climate air conditioning will always be needed, but can be greatly reduced if building design minimizes overheating

RADIANT BARRIER



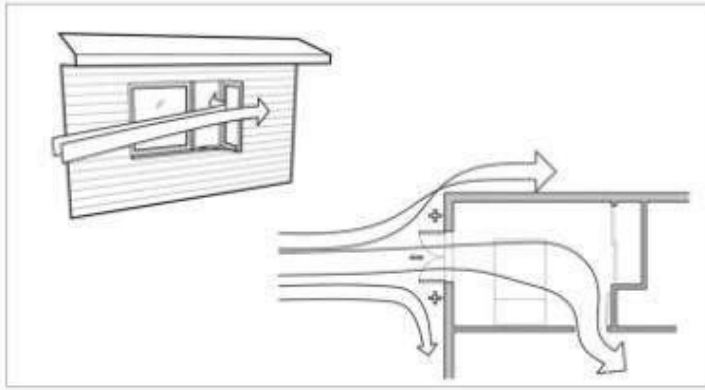
A radiant barrier (shiny foil) will help reduce radiated heat gain through the roof in hot climates

COOL ROOF



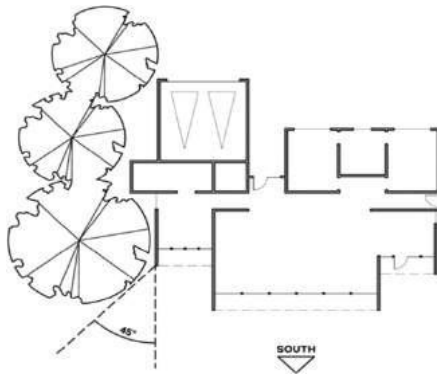
Use light colored building materials and cool roofs (with high emissivity) to minimize conducted heat gain

WINDOW ORIENTATION



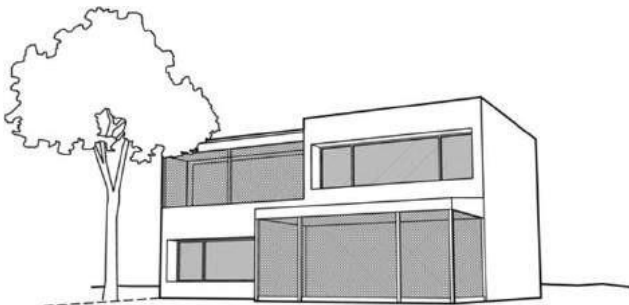
Good natural ventilation can reduce or eliminate air conditioning in warm weather, if windows are well shaded and oriented to prevailing breezes

LANDSCAPE MEASURES



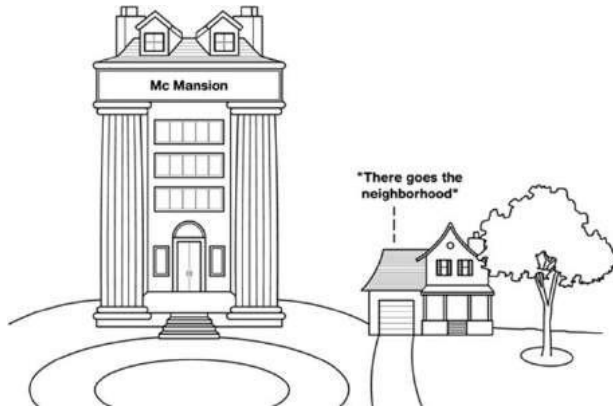
Use plant materials (bushes, trees, ivy-covered walls) especially on the west to minimize heat gain (if summer rains support native plant growth)

SCREENED PORCHES



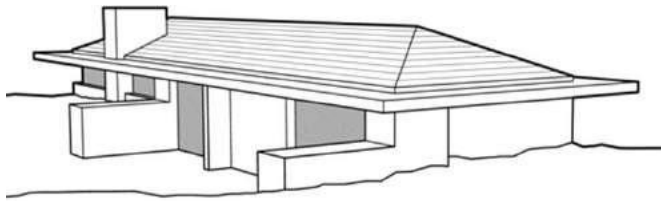
Screened porches and patios can provide passive comfort cooling by ventilation in warm weather and can prevent insect problems

SCALE OF BUILDING



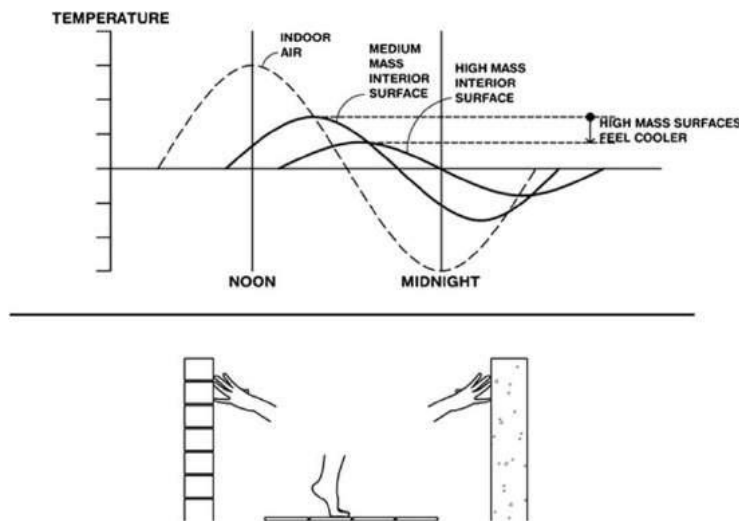
Keep the building small (right-sized) because excessive floor area wastes heating and cooling energy

EARTH SHELTERING



Earth sheltering, occupied basements, or earth tubes reduce heat loads in very hot dry climates because the earth stays near average annual temperature

HIGH MASS SURFACE



High mass interior surfaces (tile, slate, stone, brick or adobe) feel naturally cool on hot days and can reduce day-to-night temperature swings

10. AREA PROGRAM

10.1. AREA CALCULATION

Spaces	Types of Zone	Occupant Load	No.of occupant	Area Required(sq.m)	No.of units	Timing	Total Area(sq.m)
Economically weaker sections(1Rk)	Private Zone	12.5	240	50	60	24hrs	3000
Low Income Group(1BHK)	Private Zone	12.5	240	75	60	24hrs	4500
Middle Income Group(2BHK)	Private Zone	12.5	80	90	20	24hrs	1800
Primary Health care	Public Zone	10	50	500	1	8am to 9p.m	500
Live Stock Storage	Public Zone	30	13	400	1	8am to 9p.m	400
Primary School	Public Zone	4	38	150	1	9am to 5p.m	150
Multi Purpose Hall	Public Zone	14	71	100	1	9am to 5p.m	100
Basic Amenities	Public Zone	6	13	25	3	9am to 5p.m	75
Total Area							10525
Loading 30%							3158
Total Builtup area							13683

10.2. OCCUPANT CALCULATION

Occupant Calculation			
		Male 60%	Female 40%
Primary School (Student)	38	23	15
Teaching Staff	2	1	1
Non Teaching Staff	1	1	0
Primary Health Care	50	30	20
Vistors 15%	14	8	5
Total Occupant	104	62	42
Male 60% Ocuupant	62		
Female 40% Occupant	42		

To Achieve total built up area = total area + loading 30%

Occupant load is referring (clauses 4.3 and 4.4.2.1) NBC 2016 for residence, Educational and storage.

For occupant load Male population may be assumed as two third and female population as one - third

Addition 15% for visitors

10.3. RESTROOM FIXTURE CALCULATION

Restroom Fixture Calculation	occupant	WC	Urinal	Wash Basin	Faucet	Health Faucet	Drinking Water
Student male	23	3	1	3	3	3	○
Student Female	15	3	○	3	3	3	○
Teaching Staff	3	○	○	○	○	○	○
Primary Health Care (Male)	3○	4	1	4	4	4	1
Primary Health Care(Female)	2○	3	1	3	3	3	○
Vistors 15%	14	2	1	2	2	2	○

For Restroom fixture calculation

Male 1 per 8 seat one water closet, Wash basin, faucet, Health Faucet, and 1 per 25 seat one urinal

Female 1 per 6 seat one water closet, Wash basin, faucet, Health Faucet, (NBC, 2016)

Rest Room Calculation						
Occupant	WC.Faucet.Health	Urinal	Washbasin	Area for WC. Faucet.Health Faucet	Area For Urinal and Wash basin	Total Area(sq.m)
Male 60%	7	2	7	2○	1○4	124
Female 40%	1	○	1	2	8	1○
Total area						134

For Restroom Area calculation

Male Toilet - 3 sq.m which include water closet, Faucet and Health Faucet and 12 sq.m for Urinal, Wash basin

Female toilet - 3 sq.m which include water closet, Faucet and Health Faucet and 9 sq.m for Wash basin

(NBC, 2016)

10.4. SITE AREA

Area	Area Sq.m	Percentage
Total Site Area	40468.6	100%
Total Built up Area	10525	26%
FSI (1.5)	10525	0.26
Height 4m	10525	26%
Plot Coverage 40%	10525	26%
Open Area	29441	73%
Total parking Area	503	1%
		100%

10.5. PARKING CALCULATION

Parking Calculation			
	No. of Vehicle	Types of Vehicle	Area of Parking
LIG+ MIG	320	Bicycle	432
Primary School	1	Two Wheeler	2
Primary Health Care	1	Two Wheeler	2
Boat Parking	23	Boat	67.2
Total Area			503

In Bela and thula village people mostly they used cattle for travel in some case they used bicycle and upper low class people they used two wheelers rarely. In case of flood every 6 house they have a boat for travel.

11. DATA COLLECTION

11.1. HOW TO ACHIEVE FLOOD RESISTANT STRUCTURE?

11.1.1. FLOATING HOUSE WITH STYROFORM PLATFORMS:

- Petroleum-based non-biodegradable foam. Such materials can have serious impacts upon human health, wildlife, and aquatic environment, and the economy



- Expanded Polystyrene (EPS) or Styrofoam is sensitive to sunlight in a process called photo degradation, or “breakdown by light.” Over months, continual exposure to sunlight affects the outer layer of the plastic, discoloring it and turning it into a powdery substance



- Animals that live on or near areas where Styrofoam is found in water sources or on the ground could be harmed if they consume the foam particles.
- Polystyrene is slow to degrade, and if disposed of improperly, the foam can leach chemicals into the environment harming water sources

11.1.2. FLOATING HOUSE WITH BAMBOO PLATFORMS:

- Bamboo is more susceptible to decay than timber in water, due to a lack of natural toxins.

- There are three causes of decay: beetle attack, termite attack and fungal attack(rot).

- Untreated bamboo can last 2–6 years internally, and less than a year if exposed to water.

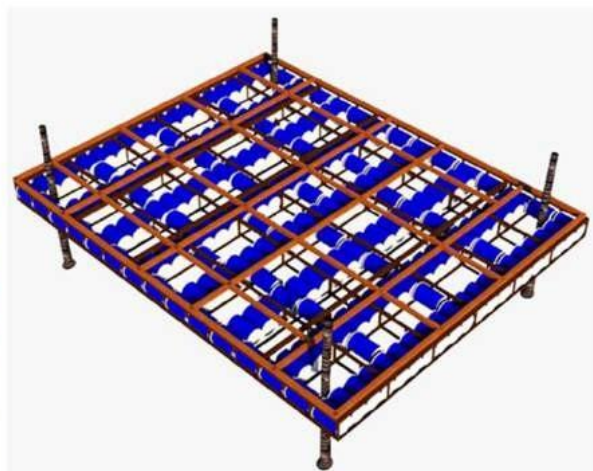


In order to protect bamboo from decay, two design principles are required:

- The bamboo must be kept dry throughout its life to protect it against rot (fungi)
- The bamboo must be treated to protect it against insects (namely beetles and termites)

11.1.3. FLOATING HOUSE WITH PLASTIC BARREL PLATFORM

- The footing of the floating house design is a structure that is under the house serving to withstand the total load of the building to float the house.
- This floating house material is plastic barrels that have a good buoyancy, lightweight and easy to obtain as it is commonly available around us
- A floating dock made primarily from plastic (which covers a host of durable, chemically-derived materials).
- It might not have the good looks of a wooden dock, but it's usually the most affordable option, and plastic can't rust or rot.
- Plastic barrels are convenient to buy and ship.



11.2. HOW TO ACHIEVE EARTHQUAKE RESISTANT STRUCTURE?

TECHNIQUES FOR EARTHQUAKE RESISTANCE HOUSE:

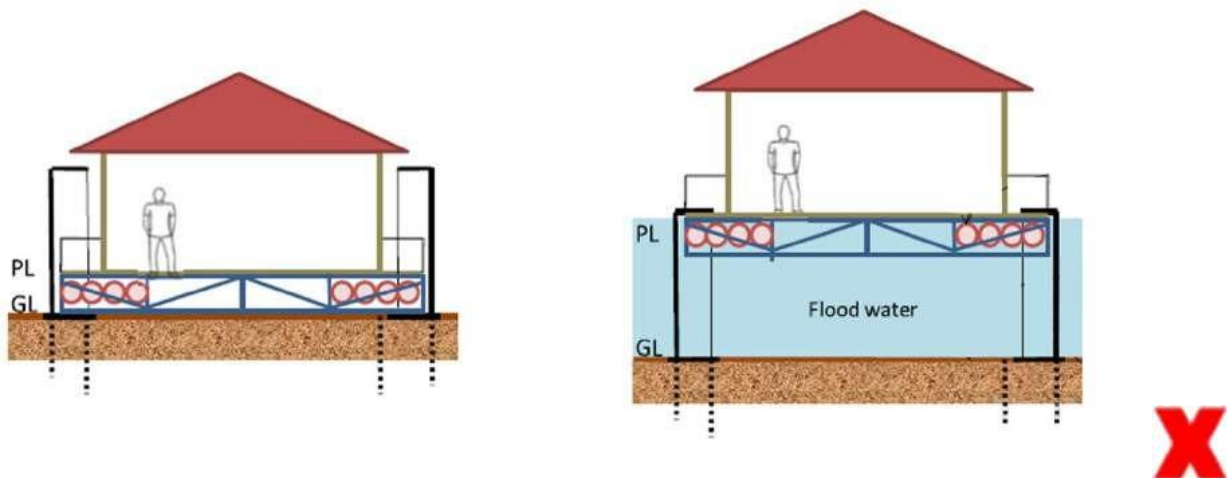
11.2.1. FLEXIBLE FOUNDATION

- The levitating or floating foundation separates the substructure of a building from its superstructure.
- One way of doing this is by floating a building above its foundation on lead-rubber bearings that comprise a solid lead core covered in alternating layers of rubber and steel.
- The bearings are attached to the building and its foundation with the help of steel plates.
- So, when an earthquake occurs, the floating foundation can move without moving the structure above it.
- Not a sustainable technique



11.2.2. INTEGRATED STRUCTURE USING BAMBOO

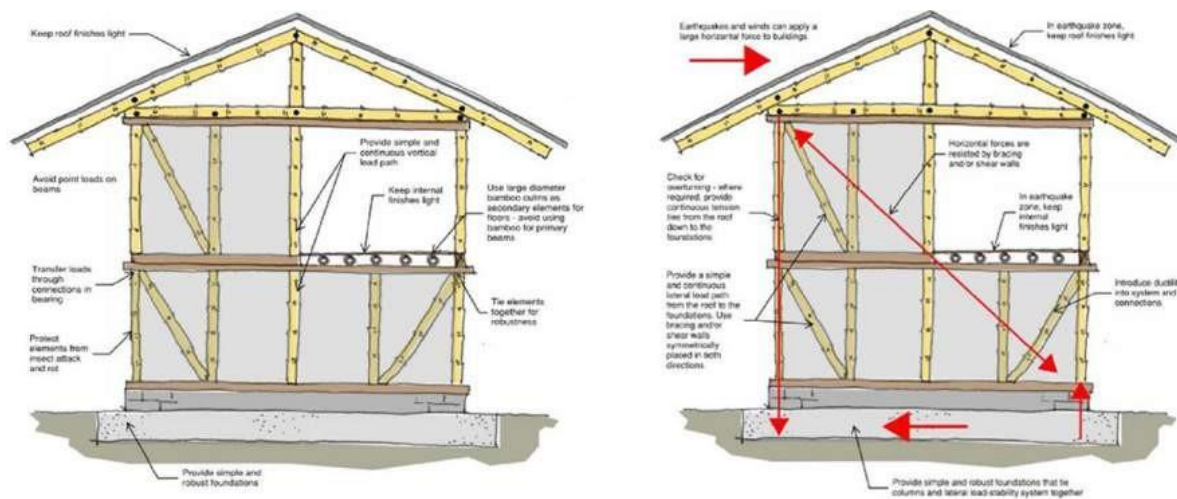
- Prefabricated and treated bamboo products are structurally sound and affordable substitute of timber. Their performance for seismic condition is notable.
- Stilted structure though suitable for flood-prone area are inapt for seismic or cyclonic zones and vice versa. Moreover, high height causes difficult access and fragmented neighborhoods. As a result, to address the multi-hazard issues, a house can neither be stilted nor be placed directly on ground.
- A radial solution bamboo house which is an integrated structure itself but has a base-isolation for seismic resilience as well as some scope to rise up during flood can be a feasible solution.
- As the house is not fixed on the ground but itself is an integrated structure, it's good in both seismic performance and flood proofing.



11.2.3. RECOMMENDATIONS WITH BAMBOO

- Historically traditional buildings made of bamboo have performed well in earthquakes for two key reasons:

- The lightweight nature of bamboo (high strength-to-weight ratio), which results in a light building overall.
 - Its ductility (essentially the capacity to absorb energy) in connections and joints, especially when nails are used.
- As with any structure, a bamboo house needs a structural system that is designed to withstand horizontal loads caused by earthquakes and wind. This can be provided by bracing or shear walls.

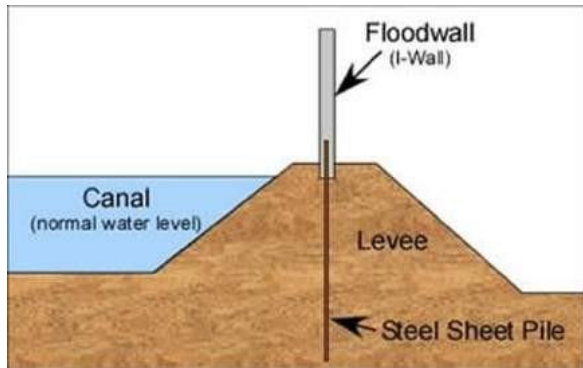


11.3. BEST FLOOD CONTROL METHOD?

11.3.1. FLOODWALLS & LEVEES

- Protects the area around the structure from inundation without significant changes to the structure
- Eliminates pressure from floodwaters that would cause structural damage to the home or other structures in the protected area

- In some cases, costs less than elevating or relocating the structure
- May fail or be overtopped by large floods or floods of long duration
- Requires considerable land (levees only)
- May be expensive depending on height, length, availability of materials, and other factors
- Requires periodic maintenance
- It is not a sustainable and easy way to reduce flood risk



11.3.2. FLOODWAYS

- The use of floodways in floodplains may be considered as an alternative to the construction of bridges.
- Maintain (wetland) functions of the floodplains
- Ensure controlled, well-directed areas of overflow: these can be wetlands or recharge areas
- Allow roads in floodplains to have lower embankments, thus saving costs
- Expensive

- Cannot be designed for a single community. Used only for large scale projects
- It is not a sustainable and easy way to reduce flood risk



11.3.3. VEGETATION

- Trees can provide an effective eco- friendly method of reducing the severity of flooding.
- Trees are Nature's helpers in the task of reducing geomorphological instability and slow down erosion phenomena, and this works for river basins too
- Most of the tree and shrub species that are typical of river banks and levees ("riparian vegetation") do absorb a lot of water (they are called hydrophilic species) and their roots strengthen the shores.
- They serve as a "filter" for floating objects (such as rocks, trees and debris), that are a major threat during floods because they crush on house and infrastructure
- maintaining a vegetation buffer of at least 20m along river banks is very effective in controlling floods.



11.4. HOW TO REDUCE INDOOR HEAT?

AN ANALYSIS OF INSULATION MATERIALS TO REDUCE INDOOR HEAT GAIN

11.4.1. RICE / WHEAT HUSK

MORPHOLOGICAL ANALYSIS - Good for insulation and acoustic properties

DENSITY & THERMAL PROPERTIES - Low thermal conductivity (resist heat flow and obtain heat slowly from their surroundings.)

MECHANICAL PROPERTIES - Low flexural (bending) strength

WATER ABSORPTION - Lowest water absorption after 24 hr of immersion



11.4.2. WOOD FIBERS

MORPHOLOGICAL ANALYSIS - Not good for insulation and acoustic properties

DENSITY & THERMAL PROPERTIES - High thermal conductivity (transfer heat and readily take up heat from their environment.)

MECHANICAL PROPERTIES - High flexural strength
(resist deformation under load)

WATER ABSORPTION - High water absorption after 24 hr of immersion



11.4.3. TEXTILE FIBERS

MORPHOLOGICAL ANALYSIS - Not good for insulation and acoustic properties

DENSITY & THERMAL PROPERTIES - High thermal conductivity (transfer heat and readily take up heat from their environment.)

MECHANICAL PROPERTIES - Moderate flexural strength

WATER ABSORPTION - High water absorption after 24 hr of immersion



Among the developed bio composites, rice husks showed better insulation property (0.08W/m.K) with a density of 378 kg/m³ and the lowest water absorption (40% after 24 hrs of immersion in water)

12. MATERIAL ANALYSIS

12.1. AN ANALYSIS OF MATERIALS FOR FOUNDATION

Material	Local Available	Durability	Weight	Cost	Workability	Maintance
Bamboo	✓	✓ More than 120 hr	✓ 300 – 400 kg/m ³	✓ Rs 70 per sq.ft	✓	✗
Timber	✓	✓ More than 120 hr	✓ 550 - 600 kg/m ³	✓ Rs 80 per sq.ft	✓	✗
Concrete	✓	✗ Less than 72 hr.	✗ 2100 - 2200 kg/m ³	✗ Rs 1300 per sq.ft	✓	✓
Steel	✗	✓ More than 90 hr	✗ 7000 - 7300 kg/m ³	✗ Rs 1500 per sq.ft	✗	✗

12.2. AN ANALYSIS OF MATERIALS FOR WALL

Material	Local Available	Durability	Weight	Cost	Workability	Maintenance
Bamboo	✓	✓ More than 120 hr	✓ 300 – 400 kg/m ³	✓ Rs 70 per sq.ft	✓	✗
Timber	✓	✓ More than 120 hr	✓ 550 – 600 kg/m ³	✓ Rs 80 per sq.ft	✓	✗
Brick	✓	✗ Less than 72 hr	✗ 1700 – 1800 kg/m ³	✗ Rs 1000 per sq.ft	✓	✓
Container	✗	✓ More than 90 hr	✗ 7000 – 7300 kg/m ³	✗ Rs 3000 per sq.ft	✗	✗

12.3. AN ANALYSIS OF MATERIALS FOR FLOOR

Material	Local Available	Durability	Weight	Cost	Workability	Maintenance
Bamboo	✓	✓ More than 120 hr	✗ 300 – 400 kg/m ³	✗ Rs 70 per sq.ft	✓	✗
Timber	✓	✓ More than 120 hr	✗ 550 – 600 kg/m ³	✗ Rs 80 per sq.ft	✓	✗
Mud	✓	✗ Less than 72 hr	✓ 100 – 120 kg/m ³	✓ Rs 10 per sq.ft	✓	✓
Brick	✓	✓ More than 90 hr	✗ 1700 – 1800 kg/m ³	✗ Rs 1000 per sq.ft	✓	✓

12.4. AN ANALYSIS OF MATERIALS FOR ROOF

Material	Local Available	Durability	Weight	Cost	Workability	Maintenance
Bamboo	✓	✓ More than 120 hr	✗ 300 – 400 kg/m ³	✗ Rs 70 per sq.ft	✓	✗
Timber	✓	✓ More than 120 hr	✗ 550 – 600 kg/m ³	✗ Rs 80 per sq.ft	✓	✗
Metal Sheet	✓	✗ Less than 72 hr	✗ 7800 – 8000 kg/m ³	✗ Rs 450 per sq.ft	✓	✓
Tatch	✓	✓ More than 90 hr	✓ 7000 – 7300 kg/m ³	✓ Rs 3000 per sq.ft	✓	✗

13. CONCEPT

3 PILLARS OF SUSTAINABILITY

Environmental - To reduce environmental impact in the community by achieving of GRIHA Affordable housing rating system

Social - The proposal will enhance the major social issues like Flood, Earthquake and basic needs

Economic - The proposal will be cost efficient by using locally available materials, technics and waste material

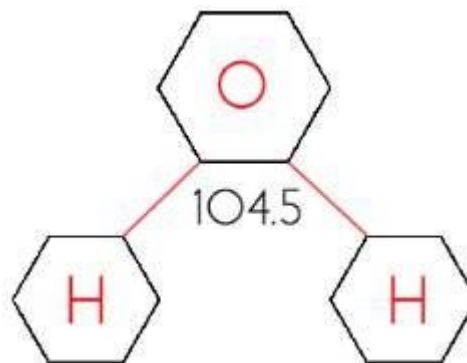
CONCEPT – H₂O

Why H₂O?

Water is the major issue and so the design concept is based on H₂O properties. A concept that relates both form and function of H₂O and also proving in the aspect of sustainable elements

FORM

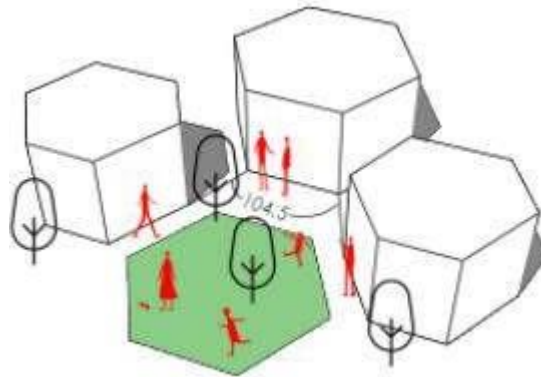
“85 % of natural elements are in hexagon” -john wins on



Both hydrogen and oxygen molecular are in hexagon so the proposal of the single unit is in the form of a hexagon.

The angle of H₂O is 104.5 degree so the arrangement of the cluster in the angle of 104.5 degree

FUNCTION



At the Site plan level, Oxygen is replaced as MIG, and Hydrogen is replaced as EWS and LIG

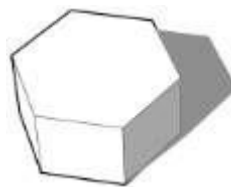
From H₂O bonding the cluster is evolved so it acts as social interaction with different economic people and green pocket is proposed in void space

The Form Selection is based on Most Structural Stability (Float and Earth Resistance)

Source: FEMA

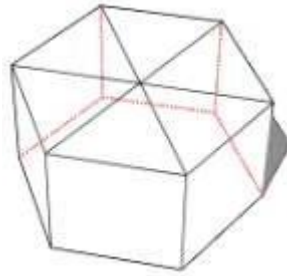
14. FORM

14.1. HEXAGON



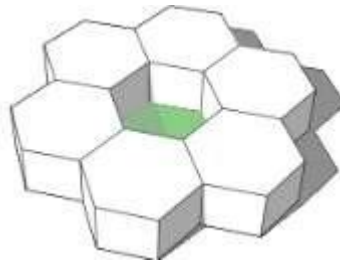
STRUCTURAL

Hexagon is mechanically stable with 6 sided strong base



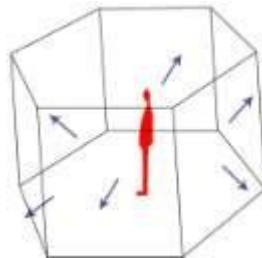
CLUSTER

Multiples of hexagon has minimized the perimeter area, (i.e) more filling with fewer edges



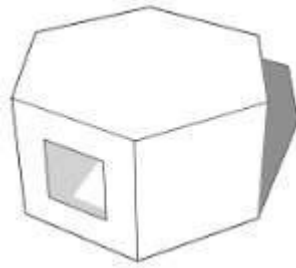
SURFACE AREA

It is most efficient geometric shape because it has a 120degree angle with more occupied space



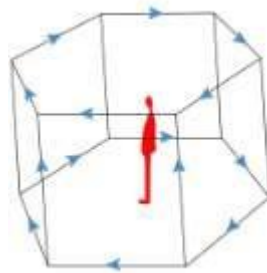
OPENING VOID

From ECBC code sidelight glazing factor is 0.1, (i.e) so the amount of light gain is less



MATERIAL USAGE

The entire load is distributed uniformly on all 18 sides so the material consumption is less. even if the form is made of lighter material

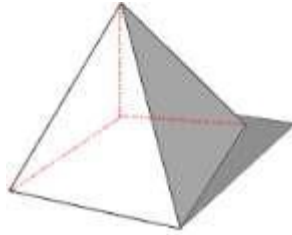


14.2. PYRAMID



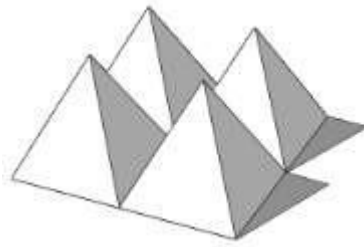
STRUCTURAL

The surface area of the base is comparatively large than the apex so the pyramid is naturally stable.



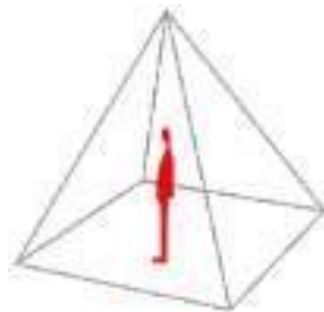
CLUSTER

Multiples of a triangle has maximum edges with more space in between the formation



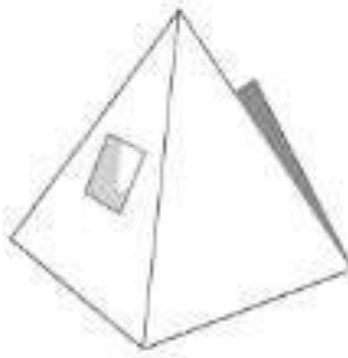
SURFACE AREA

The inner surface of the form is a 22.5-degree angle with less occupied space



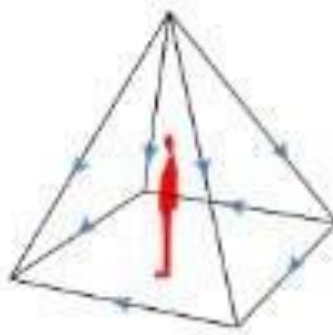
OPENING VOID

From ECBC code inclined top light value is 0.25 so the light gain inside the space is high

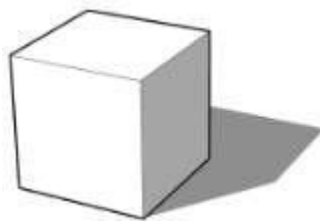


MATERIAL USAGE

The entire load is distributed uniformly on 8 sides of the structure so the material consumption is more

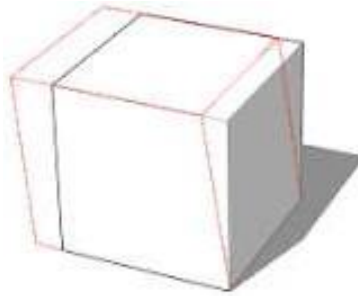


14.3. CUBE



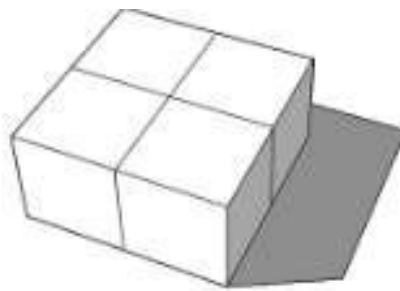
STRUCTURAL

It has 4 sides with equal length hence it has comparatively less stability.



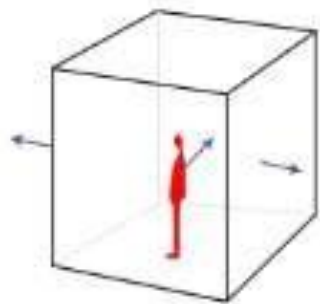
CLUSTER

Multiples of a cube has maximized the perimeter area compared to a hexagon



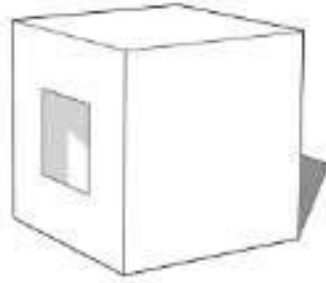
SURFACE AREA

It has a dihedral angle of 90 degrees with less occupied space compared to a hexagon



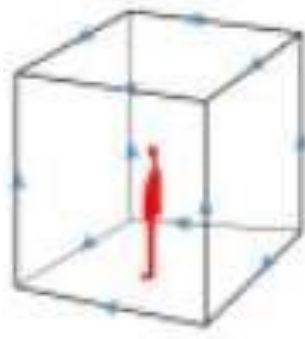
OPENING VOID

From ECBC code sidelight glazing factor is 0.1, (i.e) so the amount of light gain is less



MATERIAL USAGE

The entire load is distributed uniformly on all 12 sides of the structure so the material consumption is high compared to the hexagon

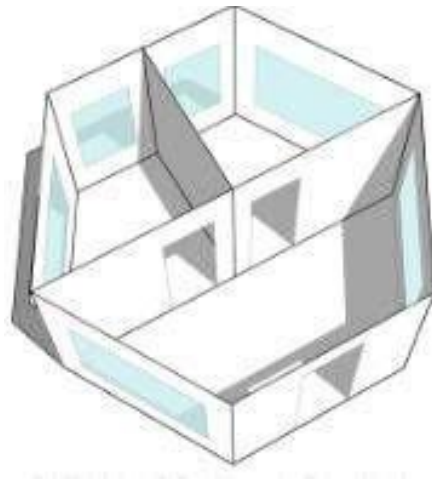


15. FORM – PASSIVE ARCHITECTURE

15.1. HEXAGON

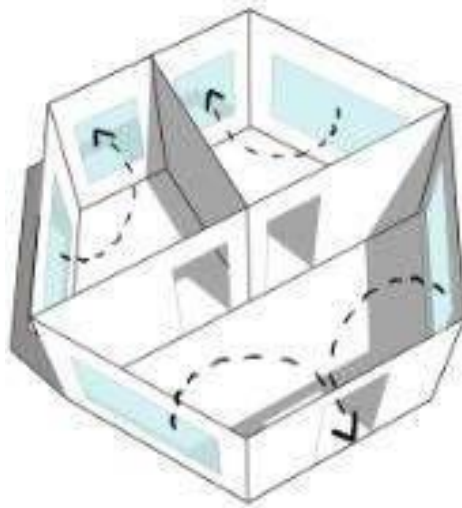
DAYLIGHT

As per GIRHA 90 % of Daylight should be achieved. since a hexagon has 6 sides it's easy to achieve this requirement



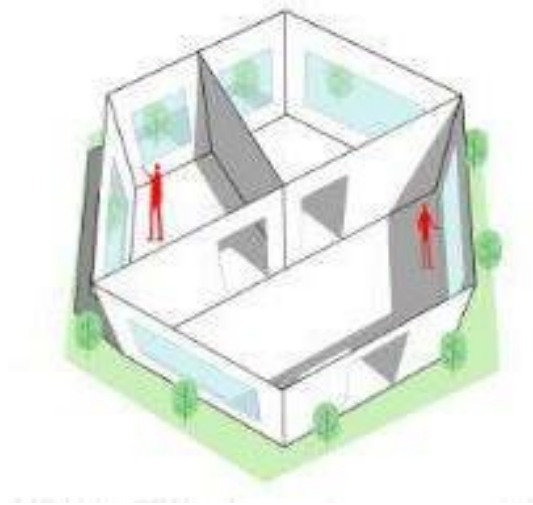
CROSS VENTILATION

As per GIRHA, 95% of cross ventilation should be achieved. since the hexagon has 6 sides it's easy to achieve this requirement.



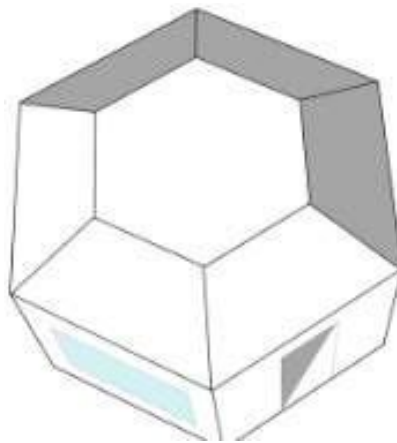
EXTERIOR CONNECTIVITY

As per GIRHA, 75% of exterior connectivity should be achieved since it has 6 sides it's easy to achieve this connectivity, from this human health and well-being is improved.



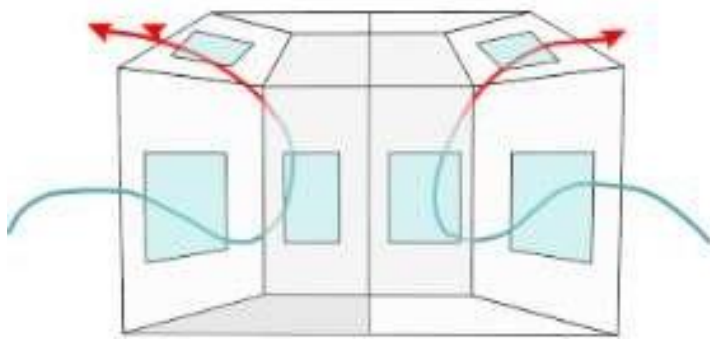
THERMAL CONDUCTION

As per GIRHA, a sloping roof can have 29% of SRI is enough to achieve because 1/4 part of the roof area is facing north, So thermal conductivity inside the building is less



STACK EFFECT

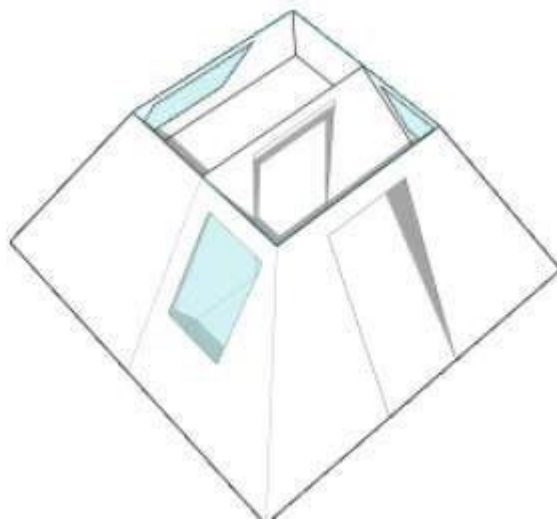
From this schematic section, every space has a vertical and inclined window on all sides, which helps to emit the hot air outside.



15.2. PYRAMID

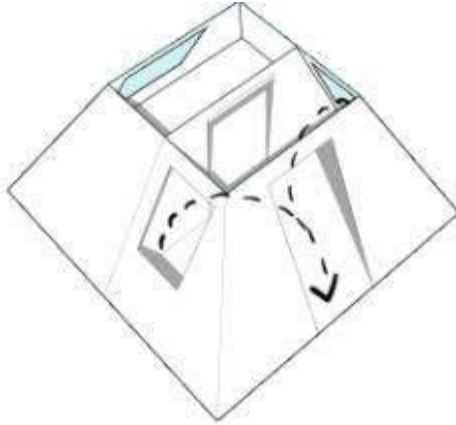
DAYLIGHT

The pyramid has only 4 sides and its difficult to achieve 90 percent of daylight



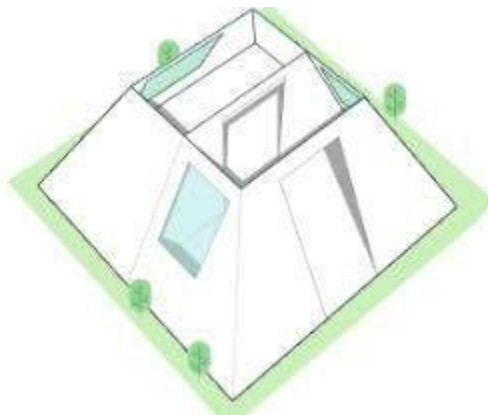
CROSS VENTILATION

The pyramid has only 4 sides and its difficult to achieve 95 percent of cross ventilation



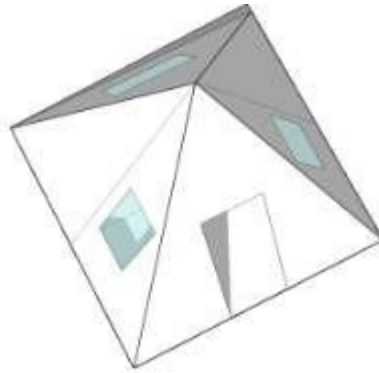
EXTERIOR CONNECTIVITY

The pyramid has only 4 sides and its difficult to achieve 95 percent of Exterior Connectivity.



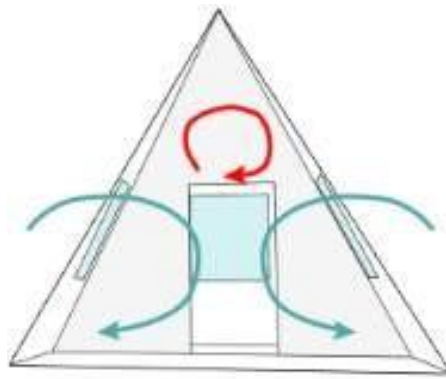
THERMAL CONDUCTION

The roof area of the pyramid has less thermal conductivity because 50% of the roof area is facing towards north



STACK EFFECT

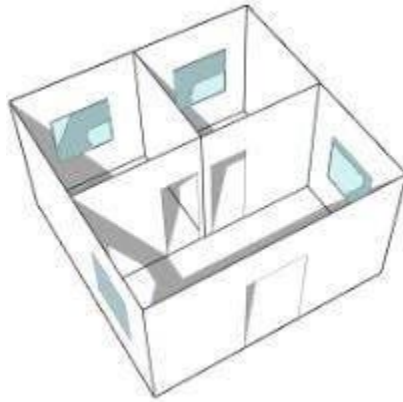
The pyramid has sharp edges at the top so it's difficult to achieve a stack effect in every space.



15.3. CUBE

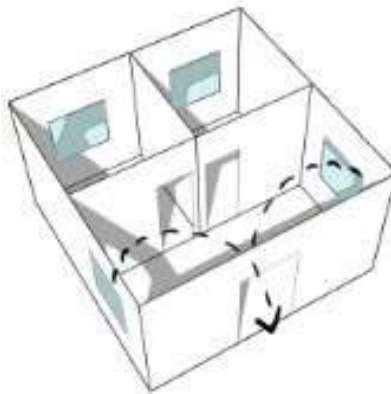
DAYLIGHT

The Cube has only 4 sides and its difficult to achieve 90 percent of daylight



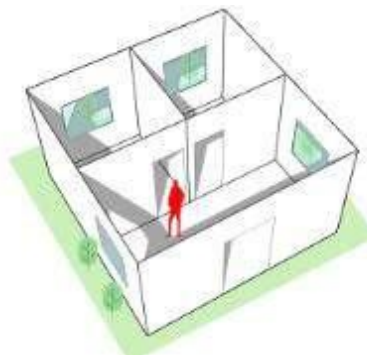
CROSS VENTILATION

The Cube has only 4 sides and its difficult to achieve 95 percent of cross ventilation



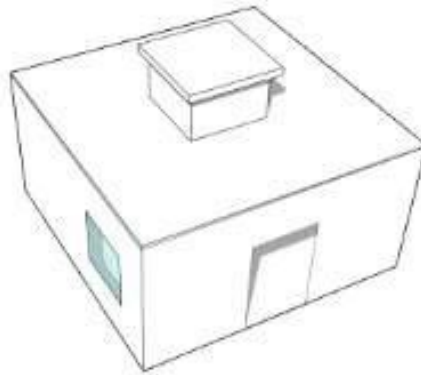
EXTERIOR CONNECTIVITY

The Cube has only 4 sides and its difficult to achieve 95 percent of Exterior Connectivity.



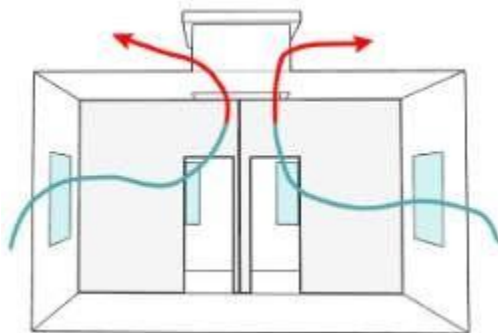
THERMAL CONDUCTION

The Cube has a flat roof, As per GIRHA flat roof need 78% of SRI, since 100% of the roof area is directly exposed towards the sun, thermal conductivity inside the building is high



STACK EFFECT

Stack effect ventilation can provide commonly but not in every space.



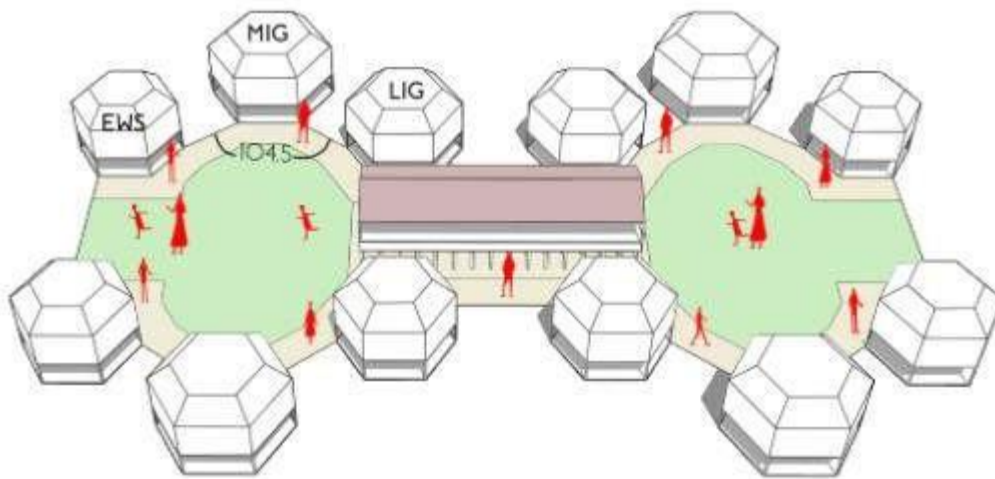
INFERENCE:

Overall comparison of all three forms as per FEMA standards, the hexagon is more efficient. At the same time from the concept design performance study, the hexagon is more efficient.

16. CLUSTER ARRANGEMENT

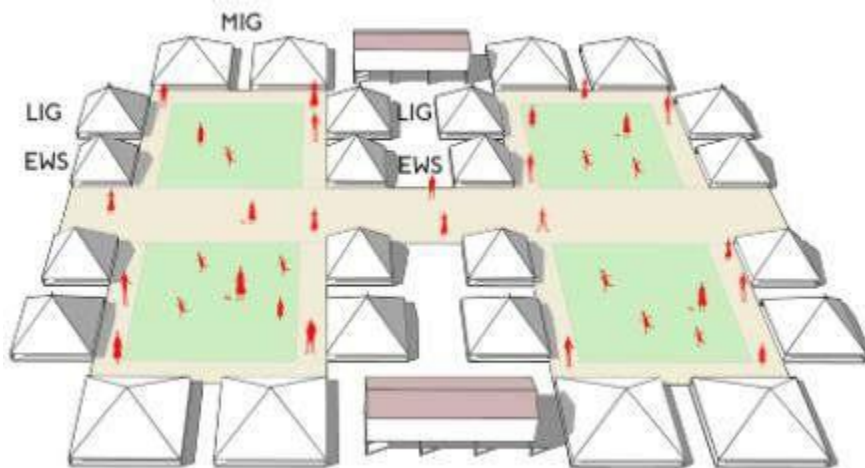
Hamlet structure will act as amphibious housing. The Structure withstands both flood and earthquake disasters.

16.1. HEXAGON - HAMLET



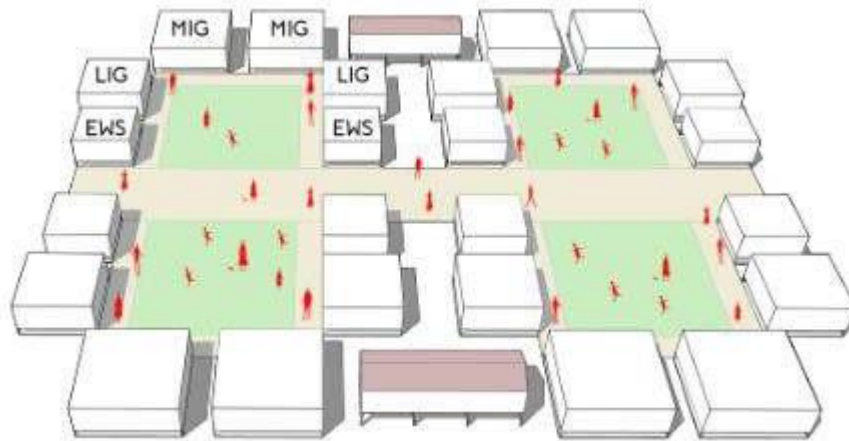
From the Concept, the cluster is evolved

16.2. PYRAMID – HAMLET



The Cluster is evolved according to the functionality of spaces

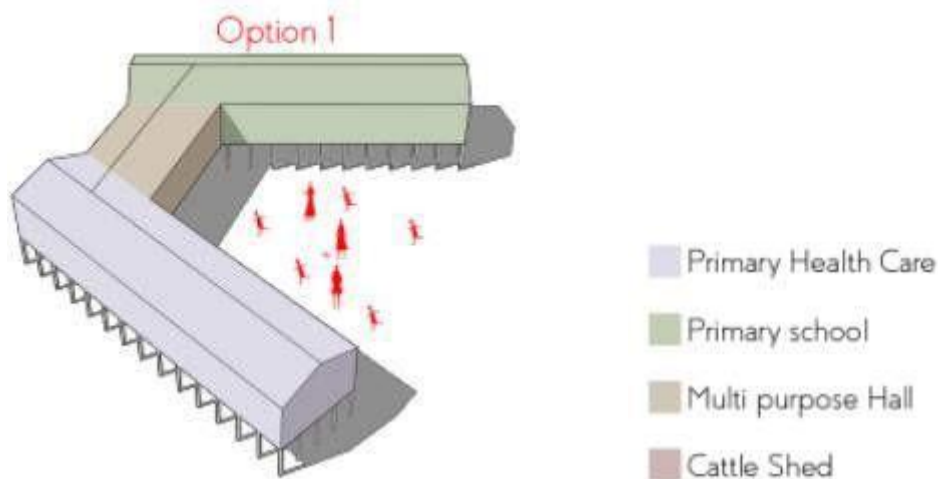
16.3. CUBE – HAMLET

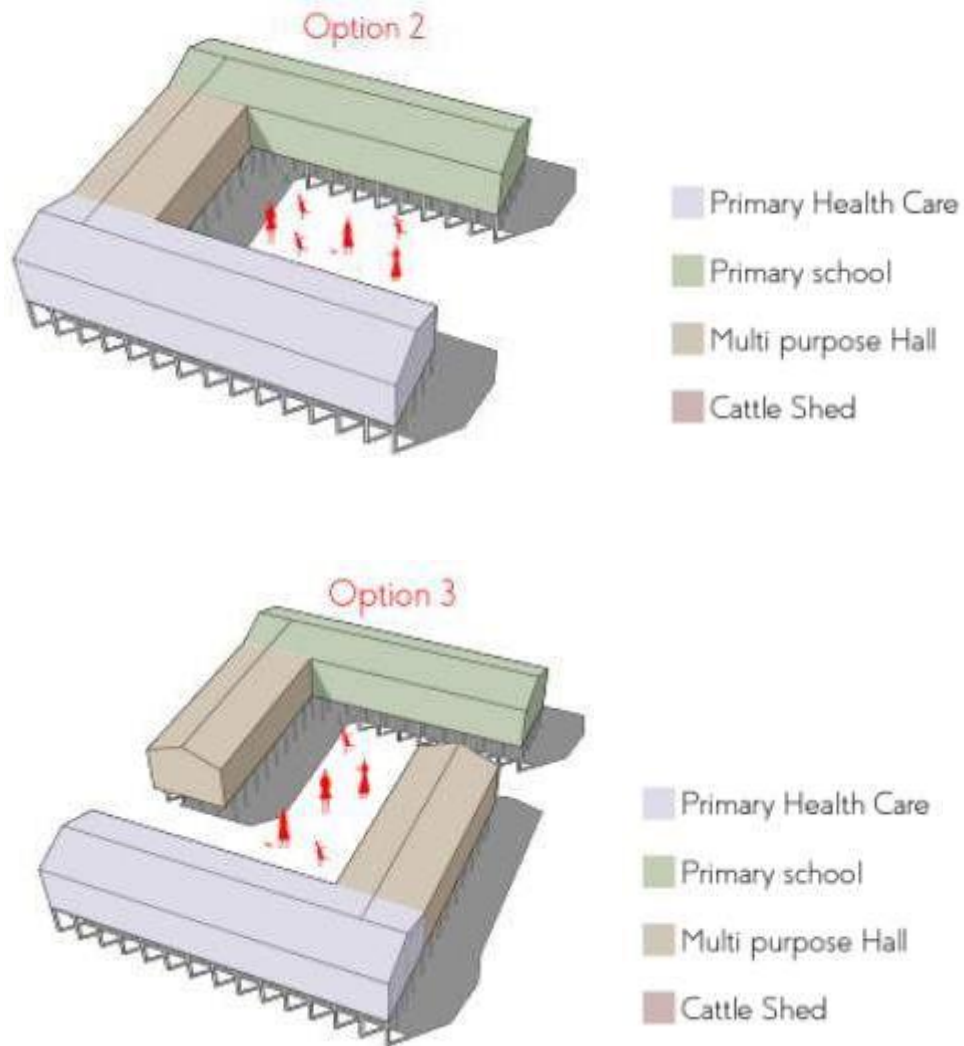


The Cluster is evolved according to the functionality of spaces

17. PUBLIC AREA ARRANGEMENT

The public area structure is just elevated above 2m from ground level. The structure withstands both flood and earthquake disasters.

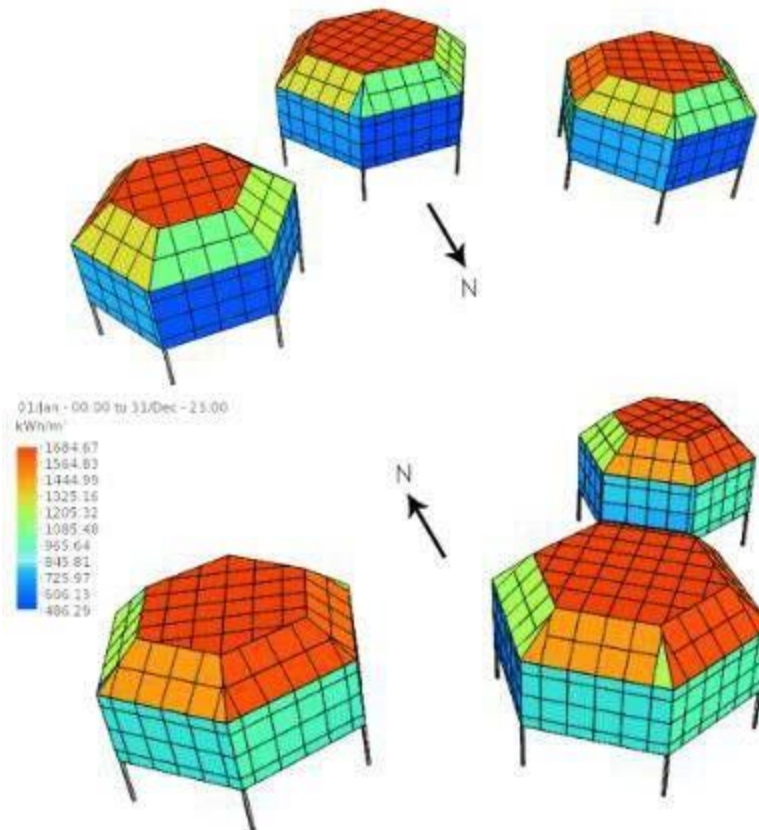




18. FORM ITERATION

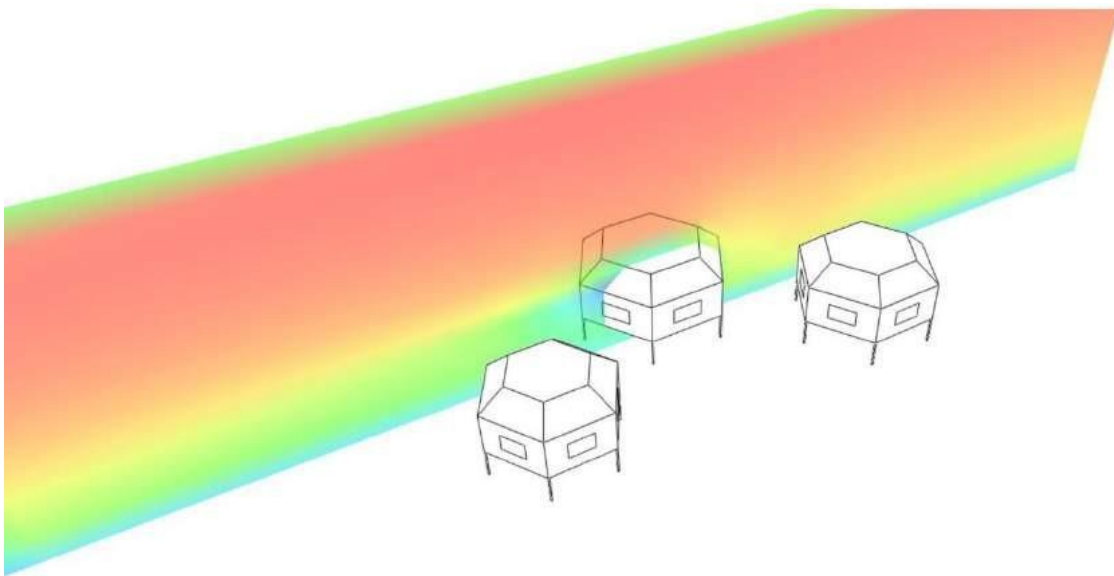
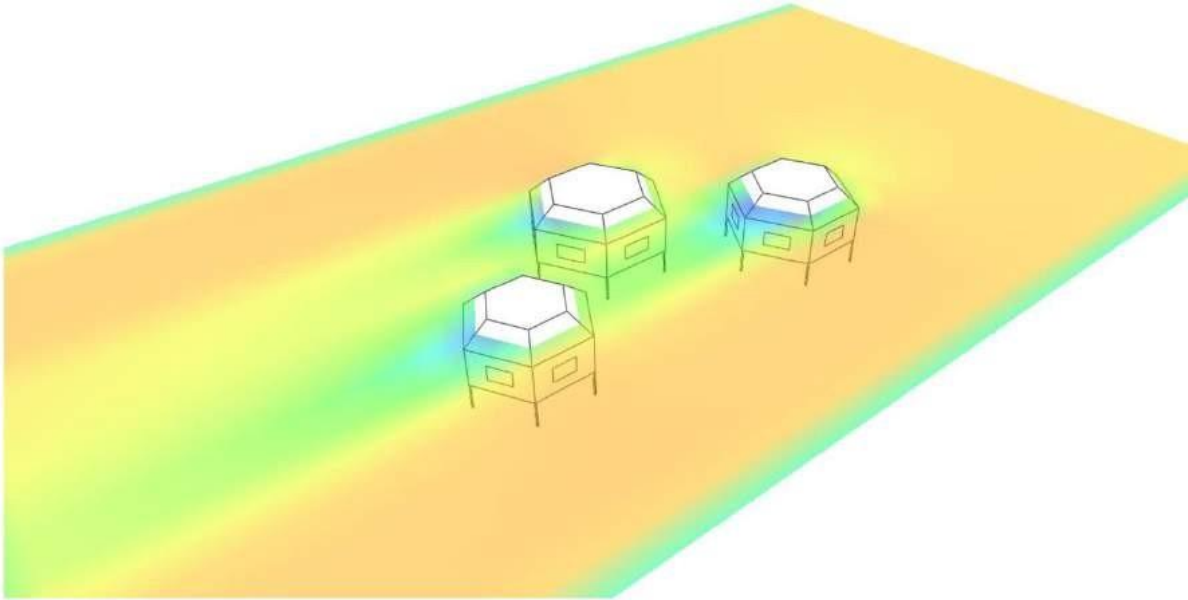
18.1. HEXAGON – HAMLET

SOLAR RADIATION



From this figure, annually 2090hrs of radiation with 965kW/hr falls on the south and west part of the cluster and 3762hrs of radiation with 1564kW/hr falls on the roof area which is nearly half the portion.

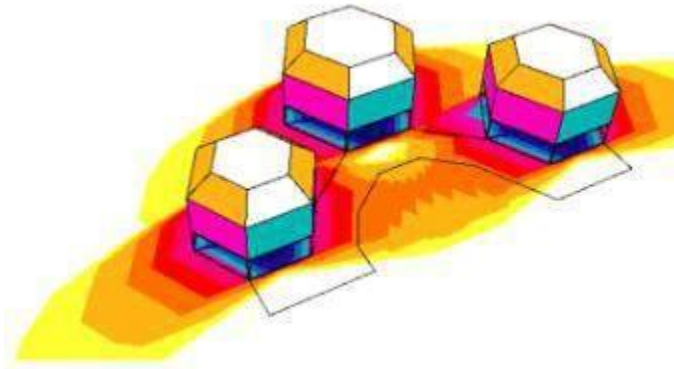
WIND ANALYSIS



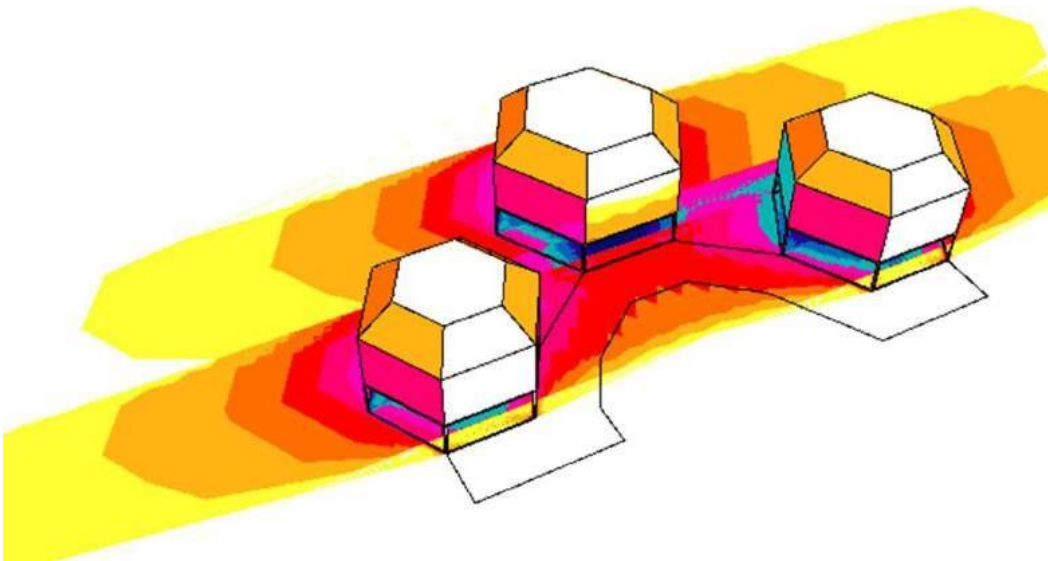
The average wind speed at the site is 9m/s, the hexagonal cluster has an inclined roof so the airflow changes up to 1.9m/s while it passes through the form.

SHADOW ANALYSIS

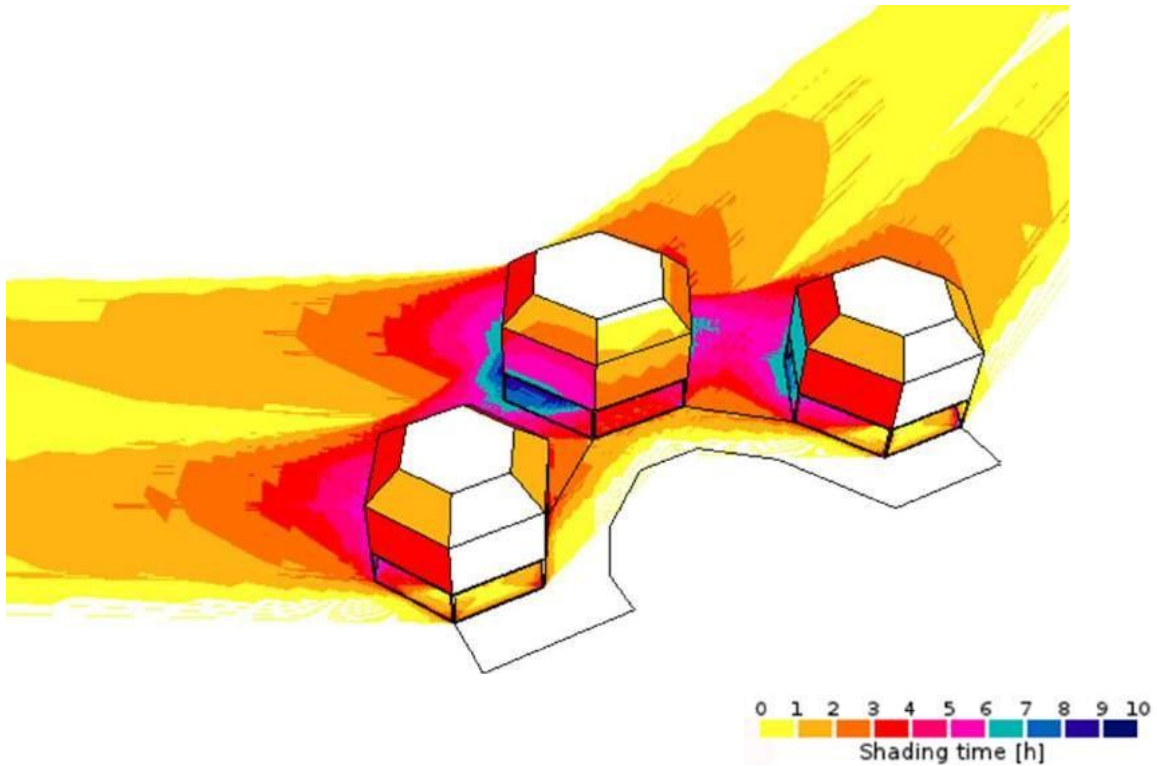
June 21



September 21



December 21

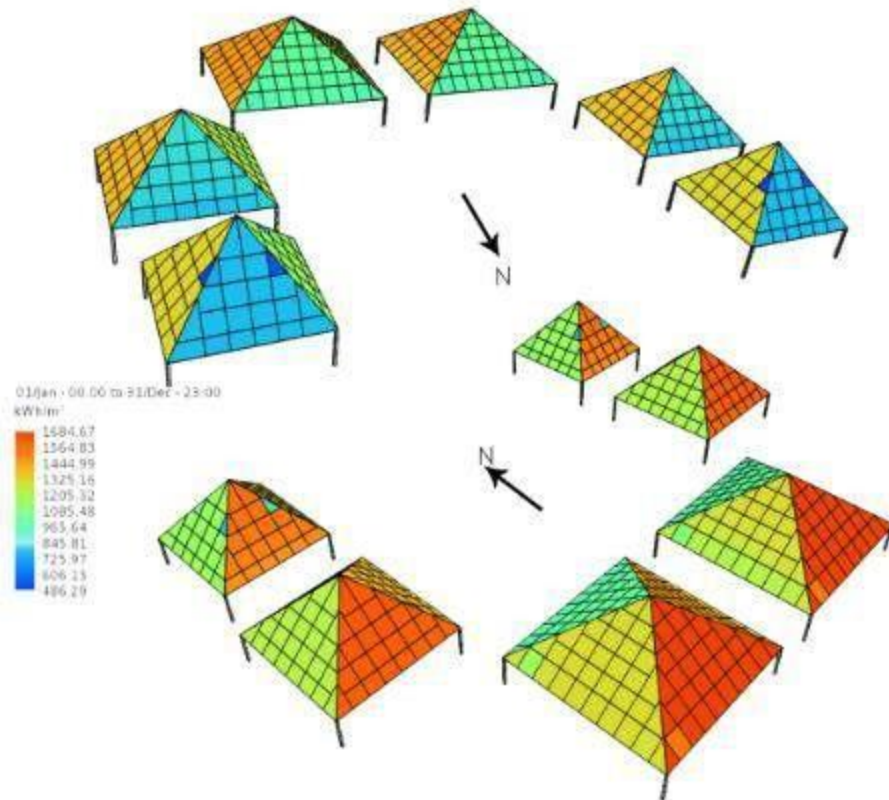


As per Griha an angle of obstruction is less than 70 degree to achieve day light

From hexagon hamlet there is no shadow obstruction on adjacent building
So that daylight can easily achieve in both summer and winter solstice.

18.2. PYRAMID – HAMLET

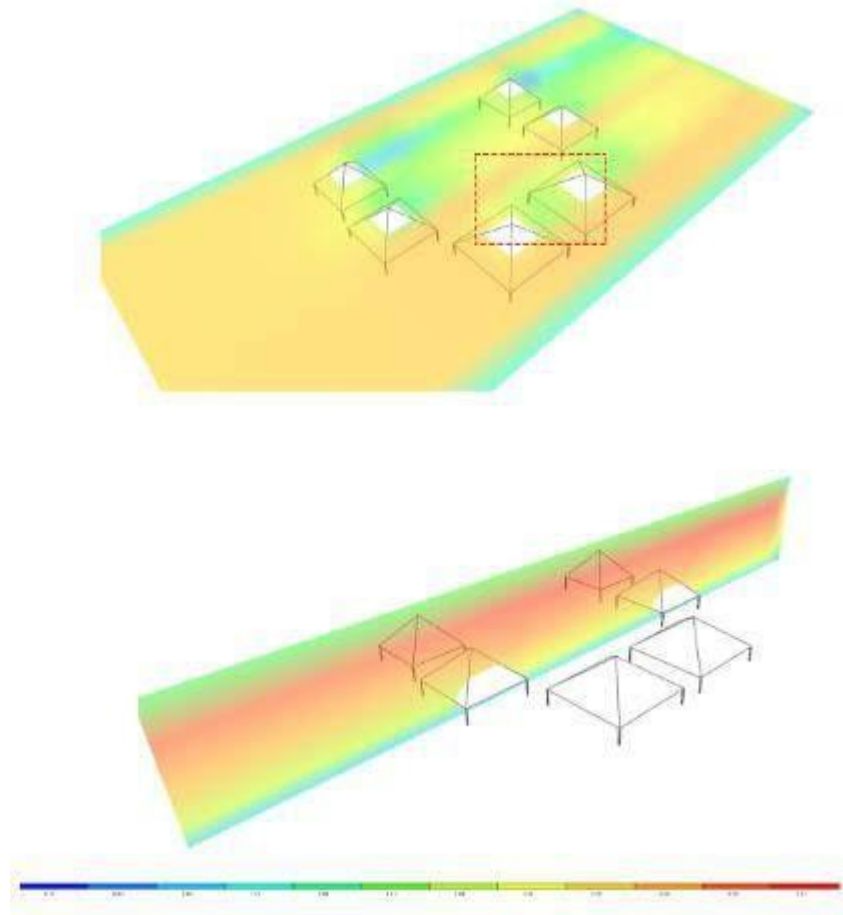
SOLAR RADIATION



From this figure, annually 3344hrs of radiation with 1444kW/hr falls on the south and west part of the cluster, and 2090 hrs of radiation with 1085 kW/hr falls on the north.

WIND ANALYSIS

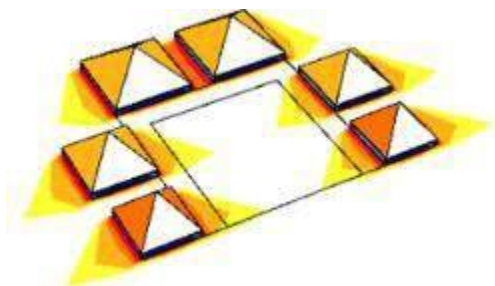
The annual wind direction is from the east and the average wind speed is 9m/s



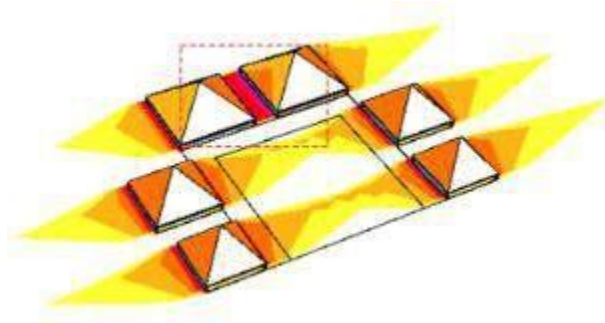
The pyramid cluster form has an inclined roof so the airflow changes up to 1.9m/s while it passes through the form.

SHADOW ANALYSIS

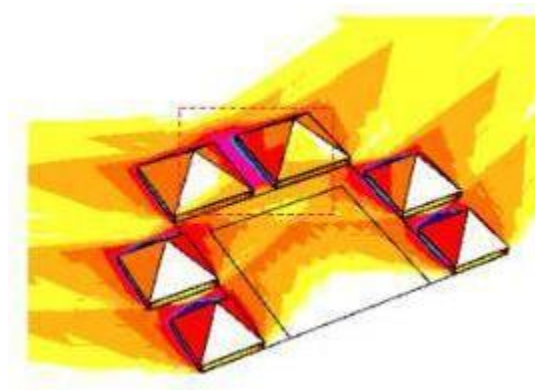
June 21



September 21



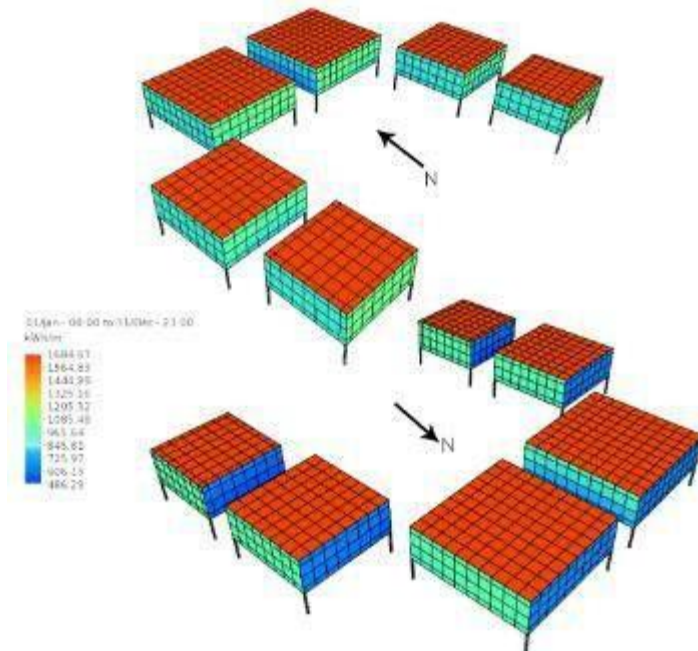
December 21



For the Pyramid hamlet, the angle of obstruction is more than 70 degree so there is a mutual shading on the adjacent building till dec to feb it is extremely cold so the shadow obstruction will cut down the direct heat and light inside the building in winter solstice

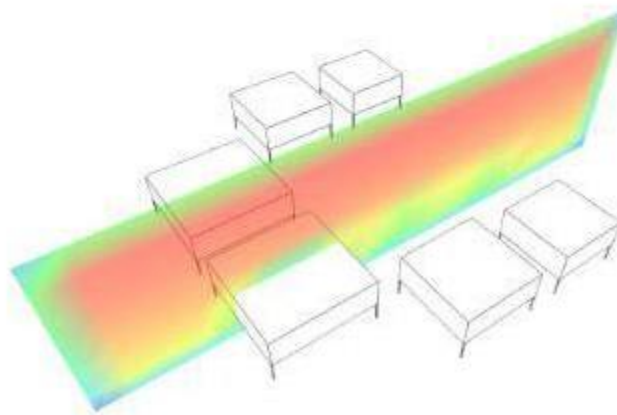
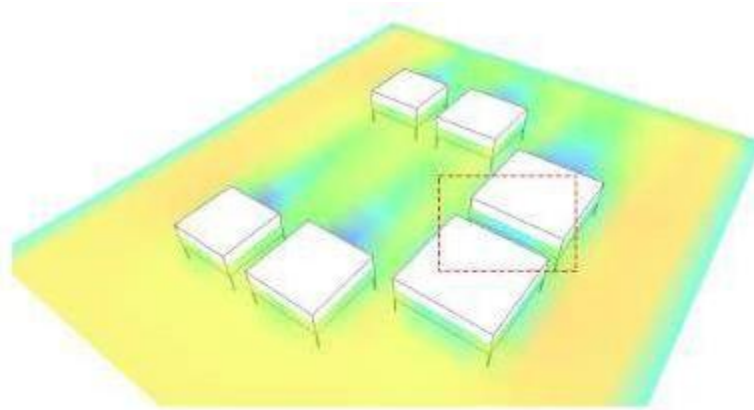
18.3. CUBE – HAMLET

SOLAR RADIATION



From this figure, Annually 2090 hrs of radiation with 1325 kW/hr falls on the south and west part of the cluster, and 4189 hrs of radiation with 1684 kW/hr falls on the roof

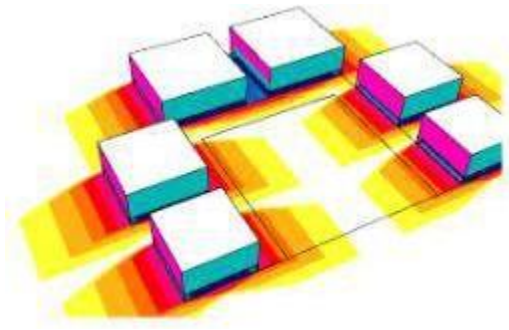
WIND ANALYSIS



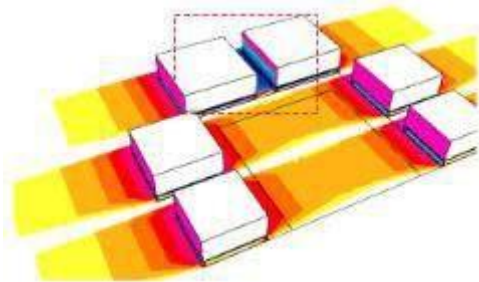
The cube cluster form has an inclined roof so the airflow changes up to 0.6m/s while it passes through the form.

SHADOW ANALYSIS

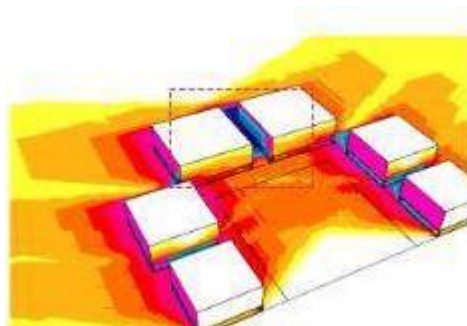
June 21



September 21



December 21

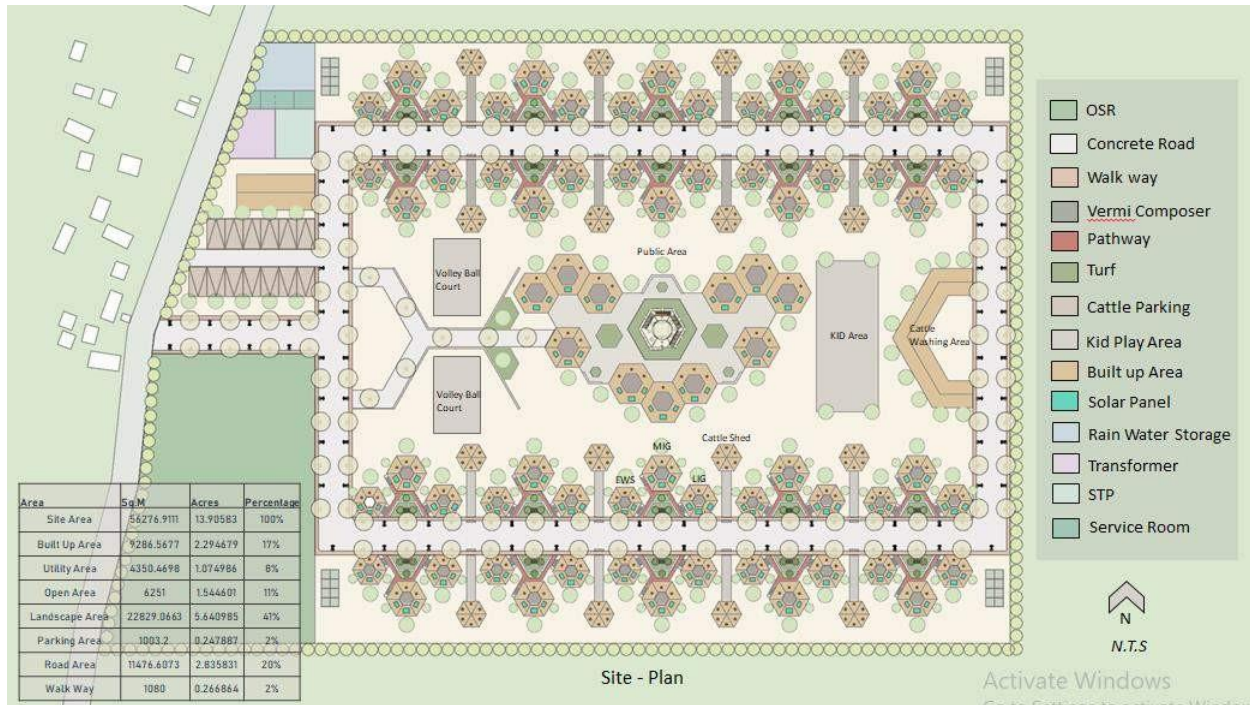


For the Cube hamlet, the angle of obstruction is more than 70 degree so there is a more mutual shading on the adjacent building till dec to feb it is extremely cold so the shadow obstruction will cut down the direct heat and light inside the building in winter solstice

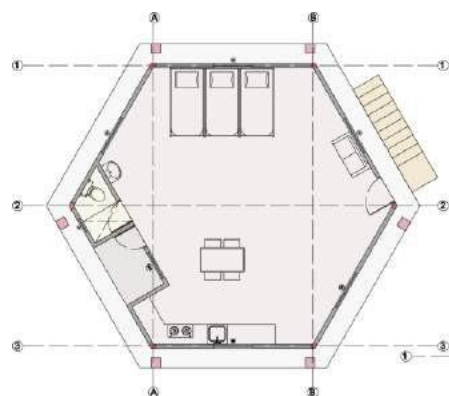
INFERENCE:

Overall hexagon hamlet is performed better comparing other two forms at the same time concept of function is also proved

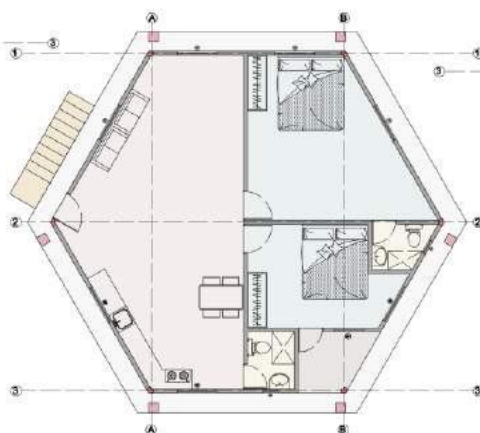
19. SITE PLAN



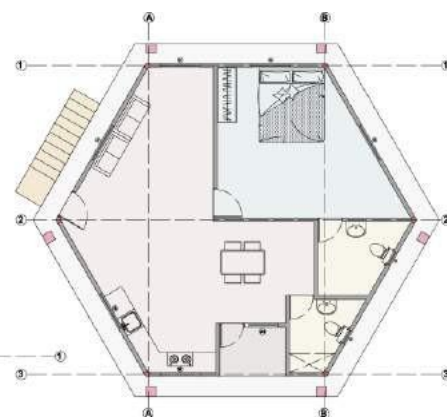
20. FLOOR PLAN & SECTION



EWS – 65 sq.m



MIG – 85 sq.m



LIG – 75 sq.m



N.T.S

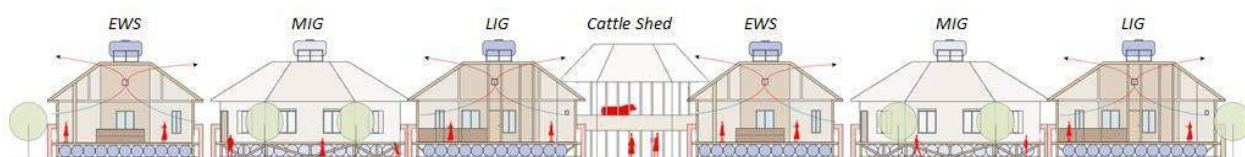
- Living and Kitchen
- Bedroom
- Restroom
- Balcony

Typology (EWS)	Area (sq.m)
Living Dining and kitchen	56.2119
Toilet	2.0786

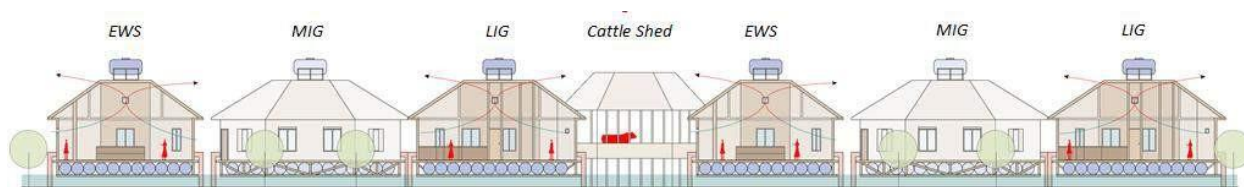
Typology (LIG)	Area (Sq.m)
Living	15.5113
Kitchen and dining	24.3271
Bedroom Area	21.1094
Toilet Area	3.8754

Typology (MIG)	Area (Sq.m)
Living	21.706
Kitchen and dining	21.814
Bedroom Area	13.0381
Master Bedroom Area	22.0725
Toilet Area	4.9502

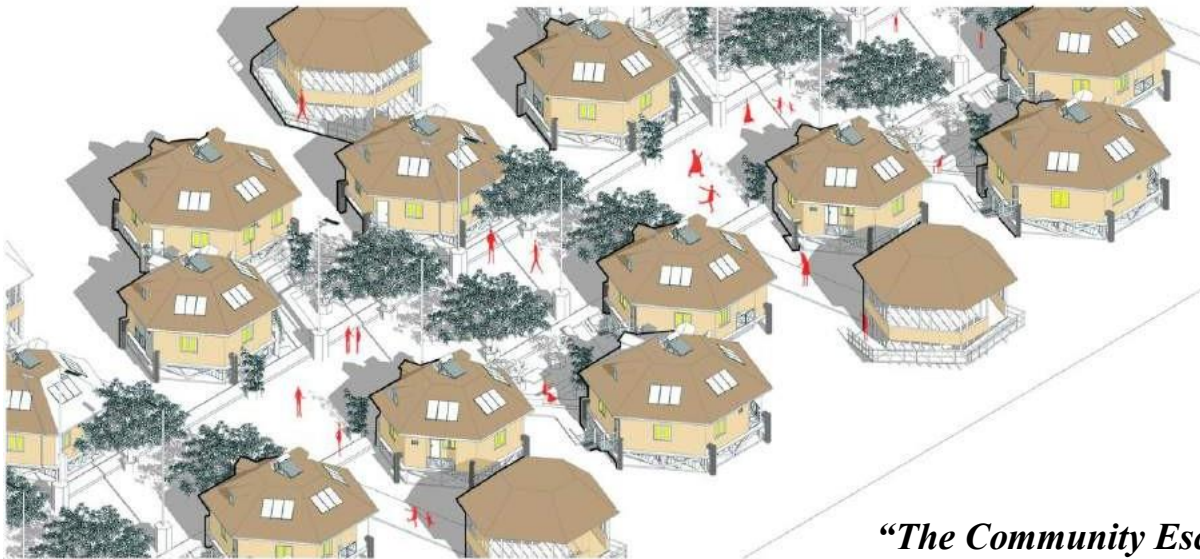
BEFORE FLOOD



DURING FLOOD

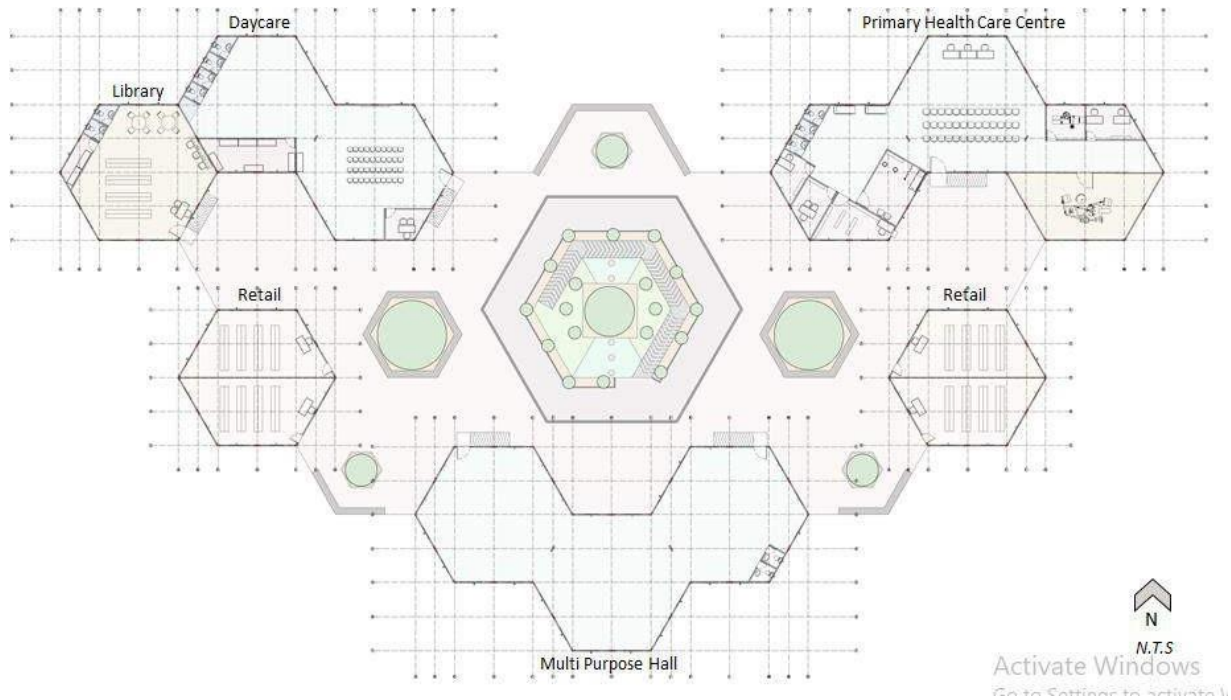


Section – NTS



“The Community Escaped “

PUBLIC AREA



Public Area	Area (Sq.m)
Library	110.5083
Day Care	211.1699
Kioks	246.278
Multi Purpose hall	365.98
Primary Health Care	276.9582
Toilet	31.3553
Total Area	3190.0897

21. VIEWS







22. SHADING DEVICE CALCULATION

HORIZONTAL SHADING ANGLE (HSA)

HSA = Azimuth angle - window orientation

VERTICAL SHADING ANGLE (VSA)

$VSA = \tan^{-1} [\tan (\text{Altitude}) / \cos (\text{HSA})]$

SUNSHADE DESIGN FOR BUILDING AT SITAMARHI, BIHAR

STEP 1 – DETERMINE THE PERIOD OF YEAR WHEN SHADING IS REQUIRED

1st April to 31st August

In this period, Longest sun path is on 21st June and shortest sun path is on 1st April

STEP 2 – DETERMINE THE TIME DURATION WHEN SHADING IS REQUIRED
AT DIFFERENT FACADES

Southern and Western facades have to be shaded

Southern facade– 11 am to 5 pm (1st April – shortest sun path)

Western façade – 12 pm to 5 pm (21st June – Longest sun path)

STEP 3 – FIND AZIMUTH AND ALTITUDE ANGLES FOR THESE DATES EVERY
HOUR AND FIND HSA AND VSA

HSA for designing Vertical shading device – *Western façade (21st June)*

WEST	12:00 PM	1:00 PM	2:00 PM	3:00 PM	4:00 PM	5:00 PM
Azimuth	128.56	-101.27	-90.33	-84.70	-79.94	-75.91
Altitude	85.95	79.21	65.80	52.34	38.99	25.84
HSA	-141.44	-371.27	-360.33	-354.7	-349.94	-345.91

VSA for designing Horizontal shading device – *Southern façade - 1st April*

SOUTH	11:00 AM	12:00 PM	1:00 PM	2:00 PM	3:00 PM	4:00 PM	5:00 PM
Azimuth	136.47	169.13	-152.10	-126.42	-111.63	-101.88	-94.35
Altitude	61.84	68.18	66.10	57.16	45.34	32.44	19.12
HSA	-43.53	-10.87	-332.1	-306.42	-291.63	-281.88	-274.35
VSA	68.78	68.53	68.62	69.05	69.99	72.10	77.76

STEP 4 – DETERMINE THE TIME DURATION WHEN SHADING IS REQUIRED AT DIFFERENT FACADES

Design the depth of the shading based on the **Lowest Possible HSA** (Vertical shading device) and **Lowest Possible VSA** (Horizontal shading device) for a window of height 1500mm

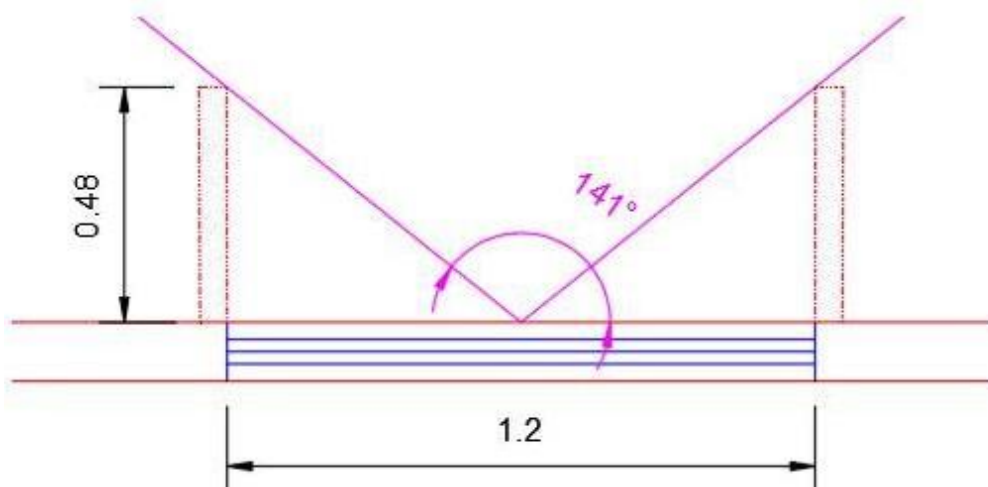
*Shading device is designed for **HSA of -141.44** (Lowest is considered)*

*Shading device is designed for **VSA of 68.53** (Lowest is considered)*

EAST & WEST FAÇADE SHADING

Width of window – 1200 mm

With HSA -141.44° and **depth of sunshade 480mm**, window is fully shaded during summer solstice



SOUTH FAÇADE SHADING

Depth = width / tan (VSA)

$$= 1200 / \tan (68.53) = 1200 / 2.542$$

Depth of vertical sunshade= 590mm

23. STRUCTURAL LOAD AND COST CALCULATION

23.1. EWS – LOAD AND COST CALCULATION

EWS - Structural Load and cost Calculation										
Base Structure										
Material	Area (Sq.m)	Area (Sq.ft)	Height(m)	No of units	Total Quality(cu.m)	Total Quality (cu.ft)	Total Quantity Cu.m(kg/m3)	Total Weight(kg)	Rate / sq.ft	Total Amount
Column(Bamboo)	3.6	38.7504	5	6	21.6	762.79752	650	14040	60	2325.024
Top and Bottom wall frame(Bamboo)	52.6637	566.8720668	0.12	2	12.439288	444.3526639	650	8215.5372	60	34012.324
Base Truss(Bamboo)	0.888	9.558432	7.4	6	5.328	188.1547216	650	3463.2	60	573.50592
Stair Case(Bamboo)	2.43	26.15452	1.05	1	2.5515	90.10545705	650	1658.475	60	1569.3912
Shear Wall(Concrete)	0.09	0.96876	2	6	1.08	38.139876	2400	2592	1000	40953.8636
							Total Weight	29969.212	Total Rate	₹ 80,434.11
Super Structure										
Mud Flooring	60	645.84	0.025	1	1.5	52.97205	750	1125	30	19375.2
Exterior Wall(Bamboo)	49.89	537.01594	3	1	5.9848	211.422046	650	3891.42	60	32220.9576
Interior Wall (Bamboo)	10.2	109.7928	3	1	1.02	36.020994	650	663	60	6587.568
Insulation(Rice Husk)	37.5	403.65	3	1	0.9375	33.10753125	378	354.375	45	18164.25
							Total Weight	6033.795	Total Rate	₹ 76,347.98
Roof Structure										
Thatch	74	796.536	0.025	1	1.85	65.332195	500	925	95	75670.92
Roof Slab(Bamboo)	74	796.536	0.12	1	8.88	313.594536	650	5772	60	47792.16
Roof Truss(Bamboo)	37.4	402.5736	0.12	1	4.488	158.4923736	650	2917.2	60	34154.416
Insulation(Rice Husk)	58	624.312	0.025	1	1.45	51.206315	378	548.1	45	28094.06
							Total Weight	10162.3	Total Rate	₹ 175,711.54
Sub Structure										
Product	Length(m)	Depth(m)	Width(m)	No of units	Total Area(Sq.m)	Total area (sq.ft)	Total Quantity sq.m(kg/m)	Total Weight(kg)	Rate / sq.ft	Total Amount
Window (W)	0.9	0.05	1.2	1	1.08	11.62512	2.1	2.268	320	3720.0384
Window (W)	1.2	0.05	1.5	5	9	317.8323	2.1	18.9	320	107706.336
Door (D)	0.9	0.05	2.1	1	1.89	66.746783	650	61.425	60	4006.68698
Door (D)	0.75	0.05	2.1	1	1.575	55.6206525	650	51.1875	60	3337.23915
Sun Shade	0.72	0.05	0.1	6	0.432	15.2559504	650	280.8	60	915.357024
Ventilation	0.45	0.05	0.45	4	0.81	28.604907	2.1	1.701	290	6007.03047
							Total Weight	416.2815	Total Rate	₹ 119,690.69

Other Load	Kg
Live Load (3 Head)	210
Applicance	60
Utensile	400
Good Storage(One Month)	250
Solar Panel (1.2kw)	67.5
Solar Water Heater(100LPD)	47
Total	1034.5

Total Weight of Structure	46581.589
Total Weight Mounted on Ground	4250.475
Total Weight Unmounted on Ground	42331.114
Other Load	1034.5
Total Weight	47616.089
Misellaneous 5%	2380.8044
Over all Weight	49996.893

Plastic Barrel Details		
Weight of single Plastic Barrel	8.6	KG
Diametre of plastic barrel	0.7	Metre
Height of Plastic Barrel	0.93	Metre
Total Weight of Barrel In Newton	86	Newton
<i>Safety Factor = 1.5(Code Book 2009)</i>		

<i>Calculate Buoyancy of Fully Submerged Plastic barrel</i>	
Buoyancy (Fa) of Plastic Barrel	$\pi.d^2/4.p.g.L$ (d =inner diameter) ρ is 1000 g is 10
	3580.5
So the total buoyancy of 1 plastic barrel is (Fa - G) = 2458.12 - 86	
	3494.5
Total Load / One plastic Barrel x 1.5(Safety Factor)	
Total Plastic Barrel Needed	20
Area required for plastic barrel (sq.m)	43.61258893
Total Floating force for 20 Plastic Barrel	69890

Summary		
Total Weight of Floating Structure	45746.42	Newton (Downward Direction)
Safety Factor	1.5	
Upward Buoyancy (Fa)	69890	Newton (Upward Direction)
Stablity Control (Fa/G>1.5	66395.5/45031.85	
	1.5	
From the calculations, it is evident that the structure can float up during flood		

Summary	
Total Structure Cost	₹ 452,184.31
Labour Cost (Rs 350 sq/ft)	₹ 22,400.00
Recycled Plastic Barrel (Rs 380 per piece)	₹ 7,461.86
Total Amout	₹ 474,584.31

23.2. LIG– LOAD AND COST CALCULATION

LIG – Structural Load and cost Calculation										
Base Structure										
Material	Area (Sq.m)	Area (Sq.ft)	Height(m)	No of units	Total Quality(cu.m)	Total Quality (cu.ft)	Total Quantity Cu.m(kg/m3)	Total Weight(kg)	Rate / sq.ft	Total Amount
Column(Bamboo)	3.6	38.7504	5	6	21.6	742.79752	650	14040	60	2325.024
Top and Bottom wall frame(Bamboo)	67.2036	723.3795504	0.12	2	16.128864	569.5859935	650	10483.8	60	43402.773
Base Truss(Bamboo)	1.08	11.62512	9	6	6.48	228.839256	650	4212	60	697.5072
Stair Case(Bamboo)	2.43	26.15652	1.05	1	2.5515	90.10545705	650	1658.48	60	1569.3912
Shear Wall(Concrete)	0.09	0.96876	2	6	1.08	38.139876	2400	2592	1100	41953.8636
							Total Weight	32984.2	Total Rate	₹ 89,948.56
Super Structure										
Mud Flooring	70	753.48	0.025	1	1.75	61.800725	750	1312.5	30	22604.4
Exterior Wall(Bamboo)	58.89	633.89196	3	1	7.0448	249.561922	650	4593.42	60	38033.5176
Interior Wall (Bamboo)	54	581.256	3	1	5.4	190.69938	650	3510	60	34875.36
Insulation(Rice Husk)	75	807.3	3	1	1.875	66.2150425	378	708.75	45	36328.5
							Total Weight	1024.7	Total Rate	₹ 131,841.78
Roof Structure										
Thatch	88	947.232	0.025	1	2.2	77.69236	500	1100	95	89987.64
Roof Slab(Bamboo)	88	947.232	0.12	1	10.56	372.923232	650	6864	60	56833.92
Roof Truss(Bamboo)	48	516.672	0.12	1	5.76	203.412672	650	3744	60	31000.32
Insulation(Rice Husk)	70	753.48	0.025	1	1.75	61.800725	378	6615	45	33906.6
							Total Weight	12349.5	Total Rate	₹ 211,727.88
Sub Structure										
Product	Length(m)	Depth(m)	Width(m)	No of units	Total Area(Sq.m)	Total area (sq.ft)	Total Quantity sq.m(kg/m)	Total Weight(kg)	Rate / sq.ft	Total Amount
Window (W1)	0.9	0.05	1.2	1	1.08	11.62512	2.1	2.248	320	3720.0384
Window (W)	1.2	0.05	1.5	4	10.8	381.39876	2.1	22.48	320	122047.603
Door (D1)	0.9	0.05	2.1	4	7.56	266.979132	650	245.7	60	16018.7479
Door (D)	0.75	0.05	2.1	1	1.575	55.6204525	650	51.8975	60	3337.23195
Sun Shade	0.72	0.05	0.1	6	0.432	15.2559504	650	280.8	40	915.357024
Ventilation	0.45	0.05	0.45	5	1.0125	35.75613375	2.1	2.12425	210	7508.78809
							Total Weight	604.762	Total Rate	₹ 153,547.77

<i>Other Load</i>	<i>Kg</i>
Live Load (4 Head)	280
Appliance	65
Utensile	400
Good Storage(One Month)	250
Solar Panel (1.5kw)	90
Solar Water Heater(100LPD)	47
Total	1132

<i>Total Weight of Structure</i>	<i>56085.17</i>
Total Weight Mounted on Ground	4250.475
Total Weight Unmounted on Ground	51834.693
Other Load	1132
Total Weight	57217.168
Misellaneous 5%	2860.8584
Over all Weight	60078.027

Plastic Barrel Details		
<i>Plastic Barrel Details</i>		
Weight of single Plastic Barrel	8.6	KG
Diametre of plastic barrel	0.7	Metre
Height of Plastic Barrel	0.93	Metre
Total Weight of Barrel In Newton	86	Newton
<i>Safety Factor = 1.5(Code Book 2009)</i>		

<i>Calculate Buoyancy of Fully Submerged Plastic barrel</i>	
Buoyancy (Fa) of Plastic Barrel	$\pi.d^2/4.p.g.L$ (d =inner diameter) ρ is 1000 g is 10
	3580.5
So the total buoyancy of 1 plastic barrel is (Fa - G) = 2458.12 - 86	
	3494.5
Total Load / One plastic Barrel x 1.5(Safety Factor)	
Total Plastic Barrel Needed	24
Area required for plastic barrel (sq.m)	53.22349083
Total Floating force for 24 Plastic Barrel	83868

Summary		
Total Weight of Floating Structure	55827.55	Newton (Downward Direction)
Safety Factor	1.5	
Upward Buoyancy (Fa)	83868	Newton (Upward Direction)
Stablity Control (Fa/G>1.5	83868/55050.8	
	1.5	
From the calculations, it is evident that the structure can float up during flood		

Summary	
Total Structure Cost	₹ 587,065.99
Labour Cost (Rs 350sq/ft)	₹ 22,400.00
Recycled Plastic Barrel (Rs 380 per piece)	₹ 9,106.23
Total Amout	₹ 609,465.99

23.3. MIG– LOAD AND COST CALCULATION

MIG - Structural Load and cost Calculation										
Base Structure										
Material	Area (Sq.m)	Area (Sq.ft)	Height(m)	No of units	Total Quantity(cu.m)	Total Quantity (cu.ft)	Total Quantity Cu.m(kg/m3)	Total Weight(kg)	Rate / sq.ft	Total Amount
Column(Bamboo)	3.6	38.7504	5	6	21.6	762.79952	650	14040	60	2325.024
Top and Bottom wall frame(Bamboo)	83.0425	893.86947	0.12	2	19.9302	703.8290339	650	12954.6	60	53632.1682
Base Truss(Bamboo)	1.464	15.758496	12.2	6	8.784	310.2043248	650	5709.6	60	945.50976
Stair Case(Bamboo)	2.43	26.15652	1.05	1	2.5515	90.10545705	650	1658.48	60	1569.3912
Shear Wall(Concrete)	0.09	0.96876	2	6	1.08	38.139876	2400	2592	1100	47953.8636
							Total Weight	36954.7	Total Rate	₹ 100,425.96
Super Structure										
Mud Flooring	80	861.12	0.025	1	2	70.6294	750	1500	30	25833.6
Exterior Wall(Bamboo)	76.89	827.64396	3	1	9.2268	325.84676	650	5997.42	60	49658.6376
Interior Wall (Bamboo)	84	904.176	3	1	8.4	296.64348	650	5660	60	54250.56
Insulation(Rice Husk)	90	968.76	3	1	2.25	79.458075	378	850.5	45	43594.2
							Total Weight	13807.9	Total Rate	₹ 173,337.00
Roof Structure										
Thatch	104	1119.456	0.025	1	2.6	91.81822	500	1300	95	106348.32
Roof Slab(Bamboo)	104	1119.456	0.12	1	12.48	440.727456	650	892	60	47647.36
Roof Truss(Bamboo)	58	624.312	0.12	1	6.96	245.790312	650	4524	60	37458.72
Insulation(Rice Husk)	80	861.12	0.025	1	2	70.6294	378	756	45	38750.4
							Total Weight	16492	Total Rate	₹ 249,724.80
Sub Structure										
Product	Length(m)	Depth(m)	Width(m)	No of units	Total Area(Sq.m)	Total area (sq.ft)	Total Quantity sq.m(kg/m)	Total Weight(kg)	Rate / sq.ft	Total Amount
Window (Wt)	0.9	0.05	1.2	1	1.08	11.62512	2.1	2.268	320	3720.0384
Window (Wt)	1.2	0.05	1.5	6	10.8	381.39876	2.1	22.68	320	122047.463
Door (Dt)	0.9	0.05	2.1	5	9.45	333.723195	650	307.125	60	20023.4349
Door (Dt)	0.75	0.05	2.1	1	1.575	55.6204525	650	51.875	60	3337.23195
Sun Shade	0.72	0.05	8.1	4	6.432	15.2559504	650	280.8	60	915.357024
Ventilation	0.45	0.05	0.45	5	1.025	35.75613275	2.1	2.12425	210	7508.78809
							Total Weight	666.187	Total Rate	₹ 157,582.46

Other Load	Kg
Live Load (4 Head)	280
Applicance	75
Utensile	400
Good Storage(One Month)	250
Solar Panel (1.5kw)	90
Solar Water Heater(100LPD)	47
Total	1142

Total Weight of Structure	66120.812
Total Weight Mounted on Ground	4250.475
Total Weight Unmounted on Ground	61870.337
Other Load	1142
Total Weight	67262.812
Misellaneous 5%	3363.1406
Over all Weight	70625.952

Plastic Barrel Details		
Weight of single Plastic Barrel	8.6	KG
Diametre of plastic barrel	0.7	Metre
Height of Plastic Barrel	0.93	Metre
Total Weight of Barrel In Newton	86	Newton
<i>Safety Factor = 1.5(Code Book 2009)</i>		

<i>Calculate Buoyancy of Fully Submerged Plastic barrel</i>	
Buoyancy (Fa) of Plastic Barrel	$\pi.d^2/4.p.g.L$ (d =inner diameter) ρ is 1000 g is 10
	3580.5
So the total buoyancy of 1 plastic barrel is (Fa - G) = 2458.12 - 86	
	3494.5
Total Load / One plastic Barrel x 1.5(Safety Factor)	
Total Plastic Barrel Needed	28
Area required for plastic barrel (sq.m)	63.27941129
Total Floating force for 28 Plastic Barrel	97846

Summary		
Total Weight of Floating Structure	66375.48	Newton (Downward Direction)
Safety Factor	1.5	
Upward Buoyancy (Fa)	97846	Newton (Upward Direction)
Stablity Control (Fa/G>1.5)	101340.5/66797.96	
	1.5	
From the calculations, it is evident that the structure can float up during flood		

Summary	
Total Structure Cost	₹ 681,040.22
Labour Cost (Rs 350 sq/ft)	₹ 22,400.00
Recycled Plastic Barrel (Rs 380 per piece)	₹ 10,826.73
Total Amout	₹ 703,440.22

24. ECBC - ECO-NIWAS SAMHITA 2018 CALCULATION

24.1. ECBC CALCULATION FOR EWS

CALCULATION 1:

OPENABLE WINDOW-TO-FLOOR AREA RATIO

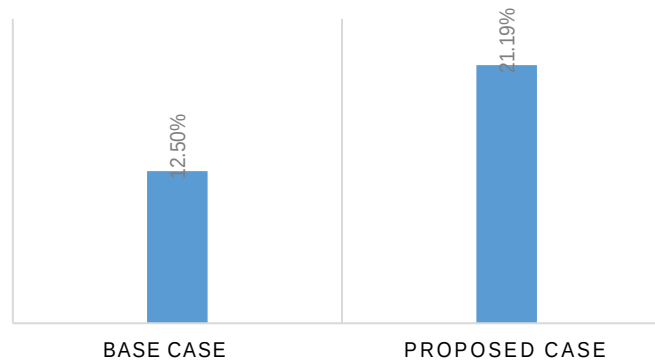
Intent: Operable window-to-floor area ratio (WFR_{op}) indicates the potential of using external air for ventilation. Ensuring minimum WFR_{op} helps in ventilation, improvement in thermal comfort, and reduction in cooling energy.

WINDOW FLOOR RATIO							
<i>Details of exposed door, windows and ventilators</i>							
<i>Opening (Window/door/ Ventilator) Name</i>	<i>Opening Width (m)</i>	<i>Opening Height(m)</i>	<i>Opening area (sq.m)</i>	<i>Width of Glass in Opening (m)</i>	<i>Height of Glass in Opening (m)</i>	<i>Glass Area in opening (m²)</i>	<i>Opaque area (m²)</i>
W	1.2	1.5	1.8	1.13	1.43	1.6159	0.2
W1	0.9	1.2	1.1	0.83	1.13	0.9379	0.1421
D	0.9	2.1	1.9	0	0	0	1.89
D1	0.75	2.1	1.6	0	0	0	1.575
V	0.45	0.45	0.2	0	0	0	0.2025

<i>Calculation of total openable window - floor area ratio (WFR_{op})</i>					
<i>Opening (Window/door/Ventilator) Name</i>	<i>Opening area (sq.m)</i>	<i>Openable area for each floor (Sq.m)</i>	<i>Remarks</i>	<i>Nos</i>	<i>Total Openable area (Sq.m)</i>
W	1.8	1.62	90% openable	5	8.1
W1	1.1	0.972	90% openable	1	0.97
D	1.9	1.701	90% openable	1	1.70
D1	1.6	1.4175	90% openable	1	1.42
V	0.2	0.18225	90% openable	1	0.18
Total Openable area (A _{openable})					12.37

<i>Calculate the window openable area to floor area ratio (WFR_{op})</i>			
<i>A (openable)</i>	<i>A (carpet area)</i>	<i>WFR(op) = A (openable)/A (carpet area)</i>	<i>WFR(op) in %</i>
12.37	58.4	0.211862158	21.19
<i>Bihar is in composite climate. As per ECBC standards , the minimum WFR(op) for this climate is 12.50%. Ths, this project complies with the ECBC requirements.</i>			

WINDOW FLOOR RATIO



CALCULATION 2:

WINDOW WALL RATIO – VISIBLE LIGHT TRANSMITTANCE

Intent: Visible light transmittance (VLT) of non-opaque building envelope components (transparent/translucent panels in windows, doors, ventilators, etc.), indicates the potential of using daylight. Ensuring minimum VLT helps in improving daylighting, thereby reducing the energy required for artificial lighting

WINDOW WALL RATIO & VISUAL LIGHT TRANSMITTANCE					
<i>No.of openings</i>					
<i>Orientation</i>	<i>W</i>	<i>WI</i>	<i>D</i>	<i>DI</i>	<i>V</i>
North	1	0	0	0	0
North East	1	0	0	0	0
North West	1	0	0	0	0
South	1	0	0	0	0
South East	1	0	1	0	0
South West	0	1	0	1	1
Total	5	1	1	1	1

Total Wall Length	
<i>Orientation</i>	<i>Wall length (m)</i>
North	5
North East	5
North West	5
South	5
South East	5
South West	5
Total	30

Calculation of window-to-wall ratio (WWR)						
<i>Orientation</i>	<i>Opening Name</i>	<i>Opening Area (Sq.m)</i>	<i>Non-opaque (glass) area in the opening</i>	<i>No. of opening</i>	<i>Total opening in Sq.m</i>	<i>Total non-opaque (glass) area in Sq.m</i>
North	W	1.8	1.6	1	1.8	1.6
North East	W	1.8	1.6	1	1.8	1.6
North West	W	1.8	1.6	1	1.8	1.6
South	W	1.8	1.6159	1	1.8	1.6
South East	W	1.8	1.6	1	1.8	1.6
	D	1.89	0.0	1	1.9	0.0
South West	W1	1.08	0.94	1	1.1	0.9
	D1	1.58	0	1	1.6	0.0
	V	0.2025	0	1	0.2	0.0
Total					13.7	9.0

Envelope area of the building			
<i>Orientation</i>	<i>Total Wall length (m)</i>	<i>Total Wall height (m)</i>	<i>Envelope area (Sq.m)</i>
North	5	3	15
North East	5	3	15
North West	5	3	15
South	5	3	15
South East	5	3	15
South West	5	3	15
Total			90

Calculation of VLT (Visible Light Transmittance)		
A (non-opaque)	A (envelope)	WWR = A (non-opaque) / A (envelope)
9.0	90	0.100193333
<i>As per ECBC, for WWR of 0.03 (range 0–0.30), the minimum required VLT is 0.27 (27%). The glass used in this project has a VLT of 0.54(54%) (as per certified specification for the product). Thus, this project complies with this requirement. Also, it complies with the recommended value.</i>		

Proposed Glass Details

Product Name: AIS Ecosense Enhance – Nimbus Thickness : **6mm** VLT – **0.54%**

Internal Reflection – **21%**

External Reflection – **14%** SHGC value : **0.68%** U – Value – **5.4 w/m²k**

CALCULATION 3:

THERMAL TRANSMITTANCE OF ROOF

Intent: Thermal transmittance (Uroof) characterizes the thermal performance of the roof of a building. Limiting the Uroof helps in reducing heat gains or losses from the roof, thereby improving the thermal comfort and reducing the energy required for cooling or heating

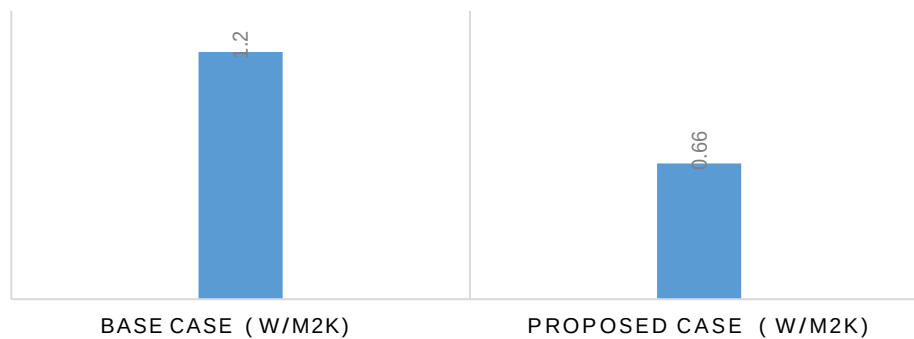
Thermal transmittance of roof shall comply with the maximum Uroof value of 1.2 W/m².K.

THERMAL TRANSMITTANCE OF ROOF			
Roof construction details			
<i>Material layer</i>	<i>Thickness, t (m)</i>	<i>Thermal conductivity, k(W/m.K)</i>	<i>Thermal resistance of material, R=t/k (m².K/W)</i>
Thatch	0.025	0.07	0.36
Bamboo	0.12	0.189	0.63
Rice Husk Insulation	0.025	0.08	0.31
Sum of all material thermal resistance			1.30

Total thermal resistance			
	Roof		
R _{si} (m ² .K/W)	0.17	Standard from ECBC	
R _{se} (m ² .K/W)	0.04		
R _f = R _{si} +R _{se} +R ₁ +R ₂ +R ₃ +... = 0.17+0.04+1.30 =1.51m ² .K/W			

Thermal transmittance of roof
$U_{roof} = 1/R_f = 0.66 \text{ w/m}^2.K$
<i>This is less than the maximum U_{roof} value of $1.2 \text{ w/m}^2.K$. Hence it complies with this requirement.</i>

THERMAL TRANSMIT TANCE OF ROOF



CALCULATION 4:

CALCULATION OF EQUIVALENT SHG

SHGC Equivalent is the SHGC for a non-opaque component with a permanent external shading projection (overhang and side fins). It is calculated by multiplying the External Shading Factor (ESF) with the SHGC of unshaded non-opaque component. ESF values are defined based on the projection factor (PF)

SOALR HEAT GAIN COEFFICIENT										
Calculation of equivalent SHGC of non-opaque openings, for each orientation										
Orientation	Opening name	Width of Glass in Opening (m)	Height of Glass in Opening (m)	No. of openings	Glass Area in opening (m ²)	H overhang (m)	V overhang (m)	PF overhang (m)	ESF overhang	SHGC equivalent
North	W	1.13	1.43	1	1.6159	0.6	2.4	0.25	0.922	0.63
North East	W	1.13	1.43	1	1.6159	0.6	2.4	0.25	0.876	0.60
North West	W	1.13	1.43	1	1.6159	0.48	1.2	0.40	0.802	0.55
South	W	1.13	1.43	1	1.6159	0.6	1.5	0.40	0.665	0.45
South East	W	1.13	1.43	1	1.6159	0.48	1.2	0.40	0.697	0.47
South West	W1	0.83	1.13	1	0.9379	0.48	1.2	0.40	0.695	0.47

Low-solar-gain Low E Double glazing	U-Value : 5.4 w/sq.m
	SHGC - 0.68. 68% of solar heat transmitted
	VT- 0.54 54% of VLT

The glass chosen has SHGC value of 0.68. All windows in this project has SHGC value lesser than the given SHGC value and so performs better

CALCULATION 4:

RESIDENTIAL ENVELOPE TRANSMITTANCE VALUE

Intent: Residential envelope heat transmittance (RETV) is the net heat gain rate (over the cooling period) through the building envelope (excluding roof) of the dwelling units divided by the area of the building envelope (excluding roof) of the dwelling units. Its unit is W/m²

Calculation of 3 terms of RETV formula**Calculation of Term-I**

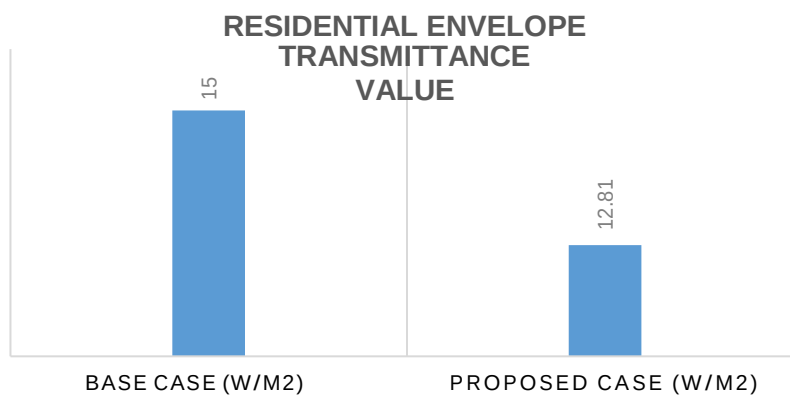
<i>Orientation</i>	<i>Component</i>	<i>(a) Area (m²)</i>	<i>(b) U value (W/m².K)</i>	<i>(c) Orientation factor</i>	<i>(a) X (b) X (c)</i>
North	Opaque area 1 (bamboo wall)	13.2	1.61	0.55	11.69
	Opaque area 2 (timber window frame)	0.1841	2.17	0.55	0.22
North East	Opaque area 1 (bamboo wall)	13.2	1.61	0.829	17.62
	Opaque area 2 (timber window frame)	0.1841	2.17	0.829	0.33
North West	Opaque area 1 (bamboo wall)	13.2	1.61	0.821	17.45
	Opaque area 2 (timber window frame)	0.1841	2.17	0.821	0.33
South	Opaque area 1 (bamboo wall)	13.2	1.61	1.089	23.14
	Opaque area 2 (timber window frame)	0.1841	2.17	1.089	0.44
South East	Opaque area 1 (bamboo wall)	11.31	1.61	1.211	22.05
	Opaque area 2 (timber window frame)	2.0741	2.17	1.211	5.45
South West	Opaque area 1 (bamboo wall)	12.1425	1.61	1.202	23.50
	Opaque area 2 (timber window frame)	1.9196	2.17	1.202	5.01
Term-I total					127.22

Calculation of Term-II

<i>Orientation</i>	<i>Component</i>	<i>(a) Area (m²)</i>	<i>(b) U value (W/m².K)</i>	<i>(c) Orientation factor</i>	<i>(a) X (b) X (c)</i>
North	Non-Opaque (glass) area	1.6159	5.4	0.55	4.80
North East	Non-Opaque (glass) area	1.6159	5.4	0.829	7.23
North West	Non-Opaque (glass) area	1.6159	5.4	0.821	7.16
South	Non-Opaque (glass) area	1.6159	5.4	1.089	9.50
South East	Non-Opaque (glass) area	1.6159	5.4	1.211	10.57
South West	Non-Opaque (glass) area	0.9379	5.4	1.202	6.09
Term-II total					45.35

Calculation of Term-III					
<i>Orientation</i>	<i>Component</i>	<i>(a) Glass Area (m²)</i>	<i>(b) Equivalent SHGC</i>	<i>(c) Orientation factor</i>	<i>(a) X (b) X (c)</i>
North	W	1.6159	0.63	0.55	0.56
North East	W	1.6159	0.60	0.829	0.80
North West	W	1.6159	0.55	0.821	0.72
South	W	1.6159	0.45	1.089	0.80
South East	W	1.6159	0.47	1.211	0.93
South West	W1	0.9379	0.47	1.202	0.53
Term-III total					4.33

RET_V Calculation
RET _V = 1/envelope area * ((a coefficient* Term-I total)+(b coefficient*Term-II total)+(c coefficient*Term-III total))
RET _V = 1/90*((6.06*127.20)+(1.85*45.35)+(68.99*4.33))
RET _V = 12.81 W/m ²
<i>This is less than the maximum RET_V of 15 W/m². Hence it complies with this requirement.</i>



24.2. ECBC CALCULATION FOR LIG

CALCULATION 1:

OPENABLE WINDOW-TO-FLOOR AREA RATIO

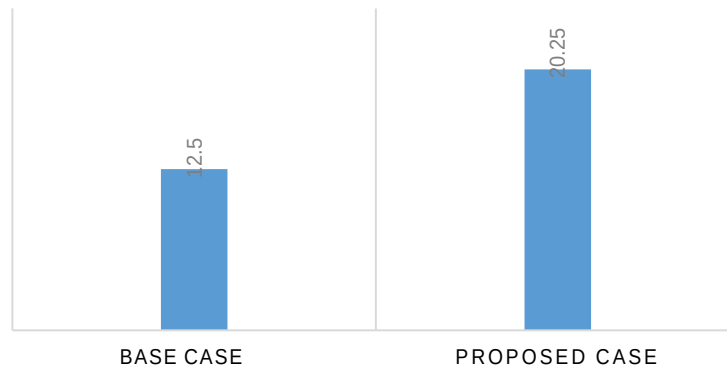
Intent: Openable window-to-floor area ratio (WFR_{op}) indicates the potential of using external air for ventilation. Ensuring minimum WFR_{op} helps in ventilation, improvement in thermal comfort, and reduction in cooling energy.

WINDOW FLOOR RATIO							
<i>Details of exposed door, windows and ventilators</i>							
<i>Opening (Window/door/ Ventilator) Name</i>	<i>Opening Width (m)</i>	<i>Opening Height(m)</i>	<i>Opening area (sq.m)</i>	<i>Width of Glass in Opening (m)</i>	<i>Height of Glass in Opening (m)</i>	<i>Glass Area in opening (m2)</i>	<i>Opaque area (m2)</i>
W	1.2	1.5	1.8	1.13	1.43	1.6159	0.2
W1	0.9	1.2	1.1	0.83	1.13	0.9379	0.1421
D	0.9	2.1	1.9	0	0	0	1.89
D1	0.75	2.1	1.6	0	0	0	1.575
V	0.45	0.4	0.2	0	0	0	0.18

<i>Calculation of total openable window - floor area ratio (WFR_{op})</i>					
<i>Opening (Window/door/Ventilator) Name</i>	<i>Opening area (sq.m)</i>	<i>Openable area for each floor (Sq.m)</i>	<i>Remarks</i>	<i>Nos</i>	<i>Total Openable area (Sq.m)</i>
W	1.8	1.62	90% openable	6	9.72
W1	1.1	0.972	90% openable	1	0.97
D	1.9	1.701	90% openable	1	1.70
D1	1.6	1.4175	90% openable	1	1.42
V	0.2	0.162	90% openable	2	0.32
Total Openable area (A _{openable})					14.13

<i>Calculate the window operable area to floor area ratio (WFR_{op})</i>			
<i>A (openable)</i>	<i>A (carpet area)</i>	<i>WFR(op) = A (openable)/A (carpet area)</i>	<i>WFR(op) in %</i>
14.13	69.8	0.2025	20.25
<i>Bihar is in composite climate. As per ECBC standards , the minimum WFR(op) for this climate is 12.50%. Ths, this project complies with the ECBC requirements.</i>			

WINDOW FLOOR RATIO



CALCULATION 2:

WINDOW WALL RATIO – VISIBLE LIGHT TRANSMITTANCE

Intent: Visible light transmittance (VLT) of non-opaque building envelope components (transparent/translucent panels in windows, doors, ventilators, etc.), indicates the potential of using daylight. Ensuring minimum VLT helps in improving daylighting, thereby reducing the energy required for artificial lighting

WINDOW WALL RATIO & VISUAL LIGHT TRANSMITTANCE				
<i>No.of openings</i>				
<i>Orientation</i>	<i>W</i>	<i>WI</i>	<i>D</i>	<i>D1</i>
North	2	0	0	0
North East	1	0	0	0
North West	1	0	0	0
South	1	1	0	1
South East	0	0	0	0
South West	1	0	1	0
Total	6	1	1	1

Total Wall Length	
<i>Orientation</i>	<i>Wall length (m)</i>
North	5.5
North East	5.5
North West	5.5
South	5.5
South East	5.5
South West	5.5
Total	33

Calculation of window-to-wall ratio (WWR)						
<i>Orientation</i>	<i>Opening Name</i>	<i>Opening Area (Sq.m)</i>	<i>Non-opaque (glass) area in the opening</i>	<i>No. of opening</i>	<i>Total opening in Sq.m</i>	<i>Total non-opaque (glass) area in Sq.m</i>
North	W	1.8	1.6	2.0	3.6	3.2
North East	W	1.8	1.6	1.0	1.8	1.6
North West	W	1.8	1.6	1.0	1.8	1.6
South	W	1.8	1.6	1.0	1.8	1.6
	W1	1.1	0.9	1.0	1.1	0.9
	D1	1.6	0.0	1.0	1.6	0.0
South East	V	0.2	0.0	2.0	0.4	0.0
South West	W	1.8	1.6	1.0	1.8	1.6
	D	1.9	0.0	1.0	1.9	0.0
Total					15.7	10.6

Envelope area of the building			
<i>Orientation</i>	<i>Total Wall length (m)</i>	<i>Total Wall height (m)</i>	<i>Envelope area (Sq.m)</i>
North	5.5	3	16.5
North East	5.5	3	16.5
North West	5.5	3	16.5
South	5.5	3	16.5
South East	5.5	3	16.5
South West	5.5	3	16.5
Total			99

Calculation of VLT (Visible Light Transmittance)		
A (non-opaque)	A (envelope)	WWR = A (non-opaque) / A (envelope)
10.6	99	0.107407071
<i>As per ECBC, for WWR of 0.03 (range 0–0.30), the minimum required VLT is 0.27 (27%). The glass used in this project has a VLT of 0.54 (54%) (as per certified specification for the product). Thus, this project complies with this requirement. Also, it complies with the recommended value.</i>		

Proposed Glass Details

Product Name: AIS Ecosense Enhance – Nimbus

Thickness: **6mm** VLT – **0.54%** Internal Reflection – **21%**

External Reflection – **14%** SHGC value : **0.68%** U – Value – **5.4 w/m²k**

CALCULATION 3:

THERMAL TRANSMITTANCE OF ROOF

Intent: Thermal transmittance (Uroof) characterizes the thermal performance of the roof of a building. Limiting the Uroof helps in reducing heat gains or losses from the roof, thereby improving the thermal comfort and reducing the energy required for cooling or heating

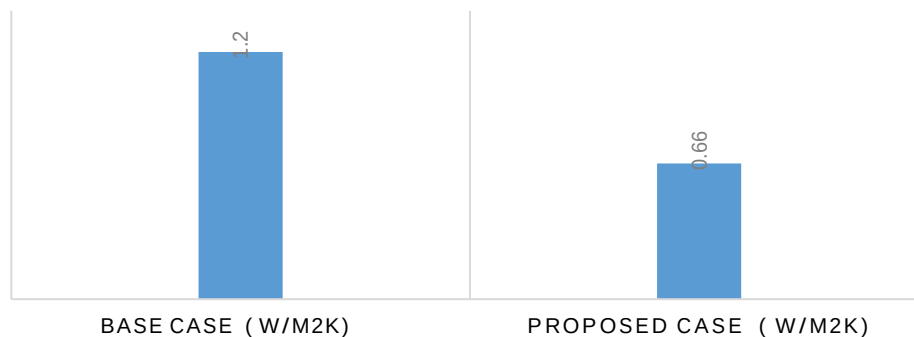
Thermal transmittance of roof shall comply with the maximum Uroof value of 1.2 W/m².K.

THERMAL TRANSMITTANCE OF ROOF			
Roof construction details			
<i>Material layer</i>	<i>Thickness, t (m)</i>	<i>Thermal conductivity, k(W/m.K)</i>	<i>Thermal resistance of material, R=t/k (m².K/W)</i>
Thatch	0.025	0.07	0.36
Bamboo	0.12	0.189	0.63
Rice Husk Insulation	0.025	0.08	0.31
Sum of all material thermal resistance			1.30

Total thermal resistance			
	Roof		
R _{si} (m ² .K/W)	0.17	Standard from ECBC	
R _{se} (m ² .K/W)	0.04		
R _f = R _{si} +R _{se} +R ₁ +R ₂ +R ₃ +... = 0.17+0.04+1.30 =1.51m ² .K/W			

Thermal transmittance of roof
$U_{roof} = 1/R_f = 0.66 \text{ w/m}^2.K$
<i>This is less than the maximum U_{roof} value of $1.2 \text{ w/m}^2.K$. Hence it complies with this requirement.</i>

THERMAL TRANSMIT TANCE OF ROOF



CALCULATION 4:

CALCULATION OF EQUIVALENT SHG

SHGC Equivalent is the SHGC for a non-opaque component with a permanent external shading projection (overhangs and side fins). It is calculated by multiplying the External Shading Factor (ESF) with the SHGC of unshaded non-opaque component. ESF values are defined based on the projection factor (PF)

SOALR HEAT GAIN COEFFICIENT										
<i>Calculation of equivalent SHGC of non-opaque openings, for each orientation</i>										
<i>Orientation</i>	<i>Opening name</i>	<i>Width of Glass in Opening (m)</i>	<i>Height of Glass in Opening (m)</i>	<i>No. of openings</i>	<i>Glass Area in opening (m2)</i>	<i>H overhang (m)</i>	<i>V overhang (m)</i>	<i>PF overhang (m)</i>	<i>ESF overhang</i>	<i>SHGC equivalent</i>
North	W	1.13	1.43	2	3.2318	0.6	2.4	0.25	0.922	0.63
North East	W	1.13	1.43	1	1.6159	0.6	2.4	0.25	0.876	0.60
North West	W	1.13	1.43	1	1.6159	0.48	1.5	0.32	0.834	0.57
South	W	1.13	1.43	1	1.6159	0.6	1.5	0.40	0.665	0.45
	WI	0.83	1.13	1	0.9379	0.6	1.2	0.50	0.778	0.53
South West	W	1.13	1.43	1	1.6159	0.61	1.5	0.41	0.695	0.47

Low-solar-gain Low E Double glazing	U-Value : 5.4 w/sq.m
	SHGC - 0.68. 68% of solar heat transmitted
	VT- 0.54 54% of VLT

The glass chosen has SHGC value of 0.68. All windows in this project has SHGC value lesser than the given SHGC value and so performs better

CALCULATION 4:

RESIDENTIAL ENVELOPE TRANSMITTANCE VALUE

Intent: Residential envelope heat transmittance (RETV) is the net heat gain rate (over the cooling period) through the building envelope (excluding roof) of the dwelling units divided by the area of the building envelope (excluding roof) of the dwelling units. Its unit is W/m²

Calculation of 3 terms of RETV formula**Calculation of Term-I**

<i>Orientation</i>	<i>Component</i>	<i>(a) Area (m²)</i>	<i>(b) U value (W/m².K)</i>	<i>(c) Orientation factor</i>	<i>(a) X (b) X (c)</i>
North	Opaque area 1 (bamboo wall)	12.9	1.61	0.55	11.42
	Opaque area 2 (timber window frame)	0.3682	2.17	0.55	0.44
North East	Opaque area 1 (bamboo wall)	14.7	1.61	0.829	19.62
	Opaque area 2 (timber window frame)	0.1841	2.17	0.829	0.33
North West	Opaque area 1 (bamboo wall)	14.7	1.61	0.821	19.43
	Opaque area 2 (timber window frame)	0.1841	2.17	0.821	0.33
South	Opaque area 1 (bamboo wall)	12.045	1.61	1.089	21.12
	Opaque area 2 (timber window frame)	1.9012	2.17	1.089	4.49
South East	Opaque area 1 (bamboo wall)	16.14	1.61	1.211	31.47
	Opaque area 2 (timber window frame)	0.36	2.17	1.211	0.95
South West	Opaque area 1 (bamboo wall)	12.81	1.61	1.202	24.79
	Opaque area 2 (timber window frame)	2.0741	2.17	1.202	5.41
Term-I total					139.80

Calculation of Term-II

<i>Orientation</i>	<i>Component</i>	<i>(a) Area (m²)</i>	<i>(b) U value (W/m².K)</i>	<i>(c) Orientation factor</i>	<i>(a) X (b) X (c)</i>
North	Non-Opaque (glass) area	3.2318	5.4	0.55	9.60
North East	Non-Opaque (glass) area	1.6159	5.4	0.829	7.23
North West	Non-Opaque (glass) area	1.6159	5.4	0.821	7.16
South	Non-Opaque (glass) area	2.5538	5.4	1.089	15.02
South East	Non-Opaque (glass) area	0	5.4	1.211	0.00
South West	Non-Opaque (glass) area	1.6159	5.4	1.202	10.49
Term-II total					49.50

Calculation of Term-III

Orientation	Component	(a) Glass Area (m ²)	(b) Equivalent SHGC	(c) Orientation factor	(a) X (b) X (c)
North	W	3.2318	0.63	0.55	1.11
North East	W	1.6159	0.60	0.829	0.80
North West	W	1.6159	0.57	0.821	0.75
South	W	1.6159	0.45	1.089	0.80
	W1	0.9379	0.53	1.089	0.54
South West	W	1.6159	0.47	1.202	0.92
Term-III total					4.92

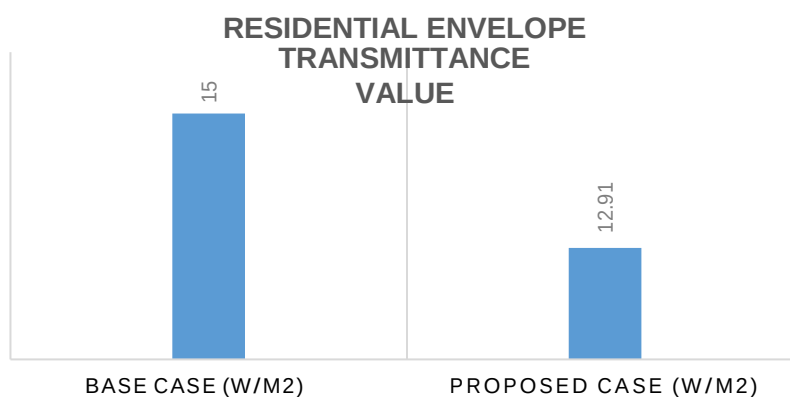
RETV Calculation

RETV = 1/envelope area * ((a coefficient* Term-I total)+(b coefficient*Term-II total)+(c coefficient*Term-III total))

RETV = 1/99*((6.06*139.80)+(1.85*49.50)+(68.99*4.92))

RETV = 12.91 W/m²

This is less than the maximum RETV of 15 W/m². Hence it complies with this requirement.



24.3. ECBC CALCULATION FOR MIG

CALCULATION 1:

OPENABLE WINDOW-TO-FLOOR AREA RATIO

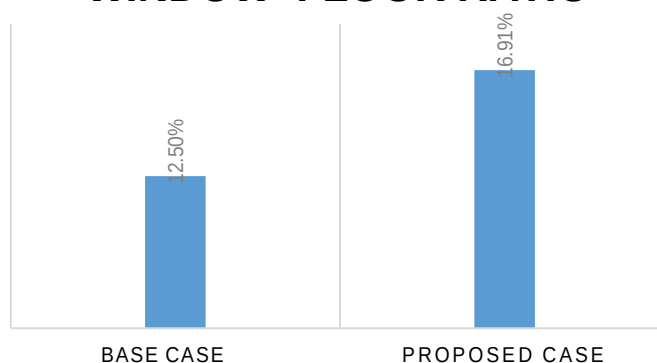
Intent: Openable window-to-floor area ratio (WFRop) indicates the potential of using external air for ventilation. Ensuring minimum WFRop helps in ventilation, improvement in thermal comfort, and reduction in cooling energy.

WINDOW FLOOR RATIO							
<i>Details of exposed door, windows and ventilators</i>							
<i>Opening (Window/door/ Ventilator) Name</i>	<i>Opening Width (m)</i>	<i>Opening Height(m)</i>	<i>Opening area (sq.m)</i>	<i>Width of Glass in Opening (m)</i>	<i>Height of Glass in Opening (m)</i>	<i>Glass Area in opening (m2)</i>	<i>Opaque area (m2)</i>
W	1.2	1.5	1.8	1.13	1.43	1.6159	0.2
W1	0.9	1.2	1.1	0.83	1.13	0.9379	0.1421
D	0.9	2.1	1.9	0	0	0	1.89
D1	0.75	2.1	1.6	0	0	0	1.575
V	0.45	0.4	0.2	0	0	0	0.18

<i>Calculation of total openable window - floor area ratio (WFR_{op})</i>					
<i>Opening (Window/door/Ventilator) Name</i>	<i>Opening area (sq.m)</i>	<i>Openable area for each floor (Sq.m)</i>	<i>Remarks</i>	<i>Nos</i>	<i>Total Openable area (Sq.m)</i>
W	1.8	1.62	90% openable	6	9.72
W1	1.1	0.972	90% openable	1	0.97
D	1.9	1.701	90% openable	1	1.70
D1	1.6	1.4175	90% openable	1	1.42
V	0.2	0.162	90% openable	2	0.32
Total Openable area (A _{openable})					14.13

<i>Calculate the window operable area to floor area ratio (WFR_{op})</i>			
<i>A (openable)</i>	<i>A (carpet area)</i>	<i>WFR(op) = A (openable)/A (carpet area)</i>	<i>WFR(op) in %</i>
14.13	83.6	0.169072967	16.91
<i>Bihar is in composite climate. As per ECBC standards , the minimum WFR(op) for this climate is 12.50%. Ths, this project complies with the ECBC requirements.</i>			

WINDOW FLOOR RATIO



CALCULATION 2:

WINDOW WALL RATIO – VISIBLE LIGHT TRANSMITTANCE

Intent: Visible light transmittance (VLT) of non-opaque building envelope components (transparent/translucent panels in windows, doors, ventilators, etc.), indicates the potential of using daylight. Ensuring minimum VLT helps in improving daylighting, thereby reducing the energy required for artificial lighting

WINDOW WALL RATIO & VISUAL LIGHT TRANSMITTANCE					
<i>No.of openings</i>					
<i>Orientation</i>	<i>W</i>	<i>WI</i>	<i>D</i>	<i>DI</i>	<i>V</i>
North	2	0	0	0	0
North East	1	0	0	0	0
North West	1	0	0	0	0
South	1	1	0	0	1
South East	1	0	0	0	1
South West	0	0	1	0	0
Total	6	1	1	0	2

Total Wall Length	
<i>Orientation</i>	<i>Wall length (m)</i>
North	6
North East	6
North West	6
South	6
South East	6
South West	6
Total	36

Calculation of window-to-wall ratio (WWR)						
<i>Orientation</i>	<i>Opening Name</i>	<i>Opening Area (Sq.m)</i>	<i>Non-opaque (glass) area in the opening</i>	<i>No. of opening</i>	<i>Total opening in Sq.m</i>	<i>Total non-opaque (glass) area in Sq.m</i>
North	W	1.8	1.6	2.0	3.6	3.2
North East	W	1.8	1.6	1.0	1.8	1.6
North West	W	1.8	1.6	1.0	1.8	1.6
South	W	1.8	1.6	1.0	1.8	1.6
South East	W1	1.1	0.9	1.0	1.1	0.9
	V	0.2	0.0	1.0	0.2	0.0
South West	W	1.8	1.6	1.0	1.8	1.6
	V	0.2	0.0	1.0	0.2	0.0
	W	1.8	1.6	1.0	1.9	0.0
Total					15.9	12.2

Envelope area of the building			
<i>Orientation</i>	<i>Total Wall length (m)</i>	<i>Total Wall height (m)</i>	<i>Envelope area (Sq.m)</i>
North	6	3	18
North East	6	3	18
North West	6	3	18
South	6	3	18
South East	6	3	18
South West	6	3	18
Total			108

Calculation of VLT (Visible Light Transmittance)		
A (non-opaque)	A (envelope)	WWR = A (non-opaque) / A (envelope)
12.2	108	0.113418519
<i>As per ECBC, for WWR of 0.03 (range 0–0.30), the minimum required VLT is 0.27 (27%). The glass used in this project has a VLT of 0.54(54%) (as per certified specification for the product). Thus, this project complies with this requirement. Also, it complies with the recommended value.</i>		

Proposed Glass Details

Product Name :AIS Ecosense Enhance – Nimbus Thickness : **6mm** VLT – **0.54%**

Internal Reflection – **21%**

External Reflection – **14%** SHGC value : **0.68%** U – Value – **5.4 w/m²k**

CALCULATION 3:

THERMAL TRANSMITTANCE OF ROOF

Intent: Thermal transmittance (Uroof) characterizes the thermal performance of the roof of a building. Limiting the Uroof helps in reducing heat gains or losses from the roof, thereby improving the thermal comfort and reducing the energy required for cooling or heating

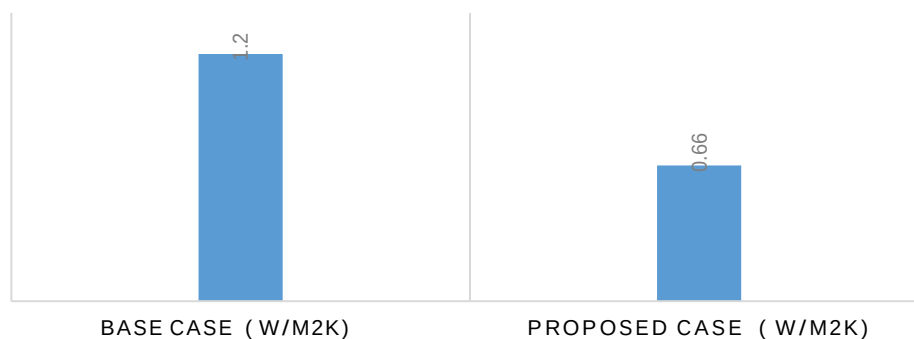
Thermal transmittance of roof shall comply with the maximum Uroof value of 1.2 W/m².K.

THERMAL TRANSMITTANCE OF ROOF			
Roof construction details			
<i>Material layer</i>	<i>Thickness, t (m)</i>	<i>Thermal conductivity, k(W/m.K)</i>	<i>Thermal resistance of material, R=t/k (m².K/W)</i>
Thatch	0.025	0.07	0.36
Bamboo	0.12	0.189	0.63
Rice Husk Insulation	0.025	0.08	0.31
Sum of all material thermal resistance			1.30

Total thermal resistance			
	Roof		
R _{si} (m ² .K/W)	0.17	Standard from ECBC	
R _{se} (m ² .K/W)	0.04		
R _f = R _{si} +R _{se} +R ₁ +R ₂ +R ₃ +... = 0.17+0.04+1.30 =1.51m ² .K/W			

Thermal transmittance of roof
$U_{roof} = 1/R_f = 0.66 \text{ w/m}^2.K$
<i>This is less than the maximum U_{roof} value of $1.2 \text{ w/m}^2.K$. Hence it complies with this requirement.</i>

THERMAL TRANSMIT TANCE OF ROOF



CALCULATION 4:

CALCULATION OF EQUIVALENT SHG

SHGC Equivalent is the SHGC for a non-opaque component with a permanent external shading projection (overhang and side fins). It is calculated by multiplying the External Shading Factor (ESF) with the SHGC of unshaded non-opaque component. ESF values are defined based on the projection factor (PF)

SOALR HEAT GAIN COEFFICIENT										
Calculation of equivalent SHGC of non-opaque openings, for each orientation										
Orientation	Opening name	Width of Glass in Opening (m)	Height of Glass in Opening (m)	No. of openings	Glass Area in opening (m ²)	H overhang (m)	V overhang (m)	PF overhang (m)	ESF overhang	SHGC equivalent
North	W	1.13	1.43	2	3.2318	0.6	2.4	0.25	0.922	0.63
North East	W	1.13	1.43	1	1.6159	0.6	2.4	0.25	0.876	0.60
North West	W	1.13	1.43	1	1.6159	0.48	1.5	0.32	0.834	0.57
South	W	1.13	1.43	1	1.6159	0.6	1.5	0.40	0.665	0.45
South East	W	0.83	1.13	1	0.9379	0.6	1.2	0.50	0.626	0.43
South West	W1	0	0	1	0	0.48	1.5	0.32	0.755	0.51

Low-solar-gain Low E Double glazing	U-Value : 5.4 w/sq.m
	SHGC - 0.68. 68% of solar heat transmitted
	VT- 0.54 54% of VLT

The glass chosen has SHGC value of 0.68. All windows in this project has SHGC value lesser than the given SHGC value and so performs better

CALCULATION 4:

RESIDENTIAL ENVELOPE TRANSMITTANCE VALUE

Intent: Residential envelope heat transmittance (RETV) is the net heat gain rate (over the cooling period) through the building envelope (excluding roof) of the dwelling units divided by the area of the building envelope (excluding roof) of the dwelling units. Its unit is W/m²

Calculation of 3 terms of RETV formula**Calculation of Term-I**

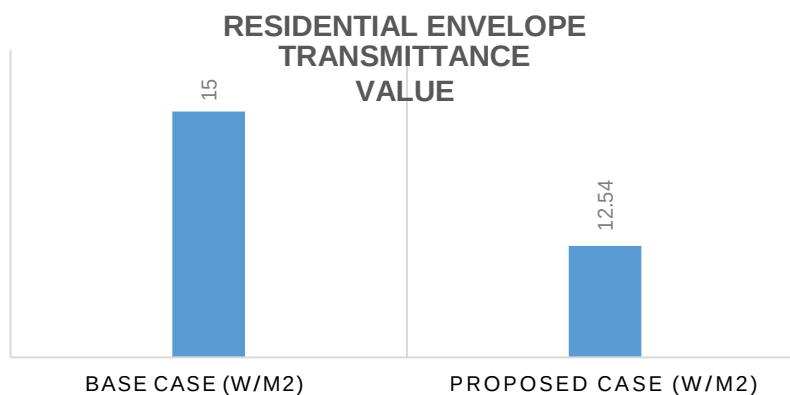
<i>Orientation</i>	<i>Component</i>	<i>(a) Area (m²)</i>	<i>(b) U value (W/m².K)</i>	<i>(c) Orientation factor</i>	<i>(a) X (b) X (c)</i>
North	Opaque area 1 (bamboo wall)	14.4	1.61	0.55	12.75
	Opaque area 2 (timber window frame)	0.3682	2.17	0.55	0.44
North East	Opaque area 1 (bamboo wall)	16.2	1.61	0.829	21.62
	Opaque area 2 (timber window frame)	0.1841	2.17	0.829	0.33
North West	Opaque area 1 (bamboo wall)	16.2	1.61	0.821	21.41
	Opaque area 2 (timber window frame)	0.1841	2.17	0.821	0.33
South	Opaque area 1 (bamboo wall)	14.94	1.61	1.089	26.19
	Opaque area 2 (timber window frame)	0.5062	2.17	1.089	1.20
South East	Opaque area 1 (bamboo wall)	16.02	1.61	1.211	31.23
	Opaque area 2 (timber window frame)	0.3641	2.17	1.211	0.96
South West	Opaque area 1 (bamboo wall)	14.31	1.61	1.202	27.69
	Opaque area 2 (timber window frame)	2.0741	2.17	1.202	5.41
Term-I total					149.57

Calculation of Term-II

<i>Orientation</i>	<i>Component</i>	<i>(a) Area (m²)</i>	<i>(b) U value (W/m².K)</i>	<i>(c) Orientation factor</i>	<i>(a) X (b) X (c)</i>
North	Non-Opaque (glass) area	3.2318	5.4	0.55	9.60
North East	Non-Opaque (glass) area	1.6159	5.4	0.829	7.23
North West	Non-Opaque (glass) area	1.6159	5.4	0.821	7.16
South	Non-Opaque (glass) area	2.5538	5.4	1.089	15.02
South East	Non-Opaque (glass) area	1.6159	5.4	1.211	10.57
South West	Non-Opaque (glass) area	1.6159	5.4	1.202	10.49
Term-II total					60.07

Calculation of Term-III					
<i>Orientation</i>	<i>Component</i>	<i>(a) Glass Area (m²)</i>	<i>(b) Equivalent SHGC</i>	<i>(c) Orientation factor</i>	<i>(a) X (b) X (c)</i>
North	W	3.2318	0.63	0.55	1.11
North East	W	1.6159	0.60	0.829	0.80
North West	W	1.6159	0.57	0.821	0.75
South	W	1.6159	0.45	1.089	0.80
South East	W	0.9379	0.43	1.089	0.43
South West	W1	1.6159	0.51	1.202	0.99
Term-III total					4.89

RET_V Calculation
RET _V = 1/envelope area * ((a coefficient* Term-I total)+(b coefficient*Term-II total)+(c coefficient*Term-III total))
RET _V = 1/108*((6.06*149.57)+(1.85*60.07)+(68.99*4.89))
RET _V = 12.54 W/m ²
<i>This is less than the maximum RET_V of 15 W/m². Hence it complies with this requirement.</i>



25. IGBC RATING SYSTEM FOR GREEN AFFORDABLE HOUSING

25.1. CREDITS

25.1.1. CREDIT 1 PROXIMITY TO PUBLIC TRANSPORT - POINT 1

Intent: Encourage use of public transport, so as to reduce negative impacts caused from automobile use

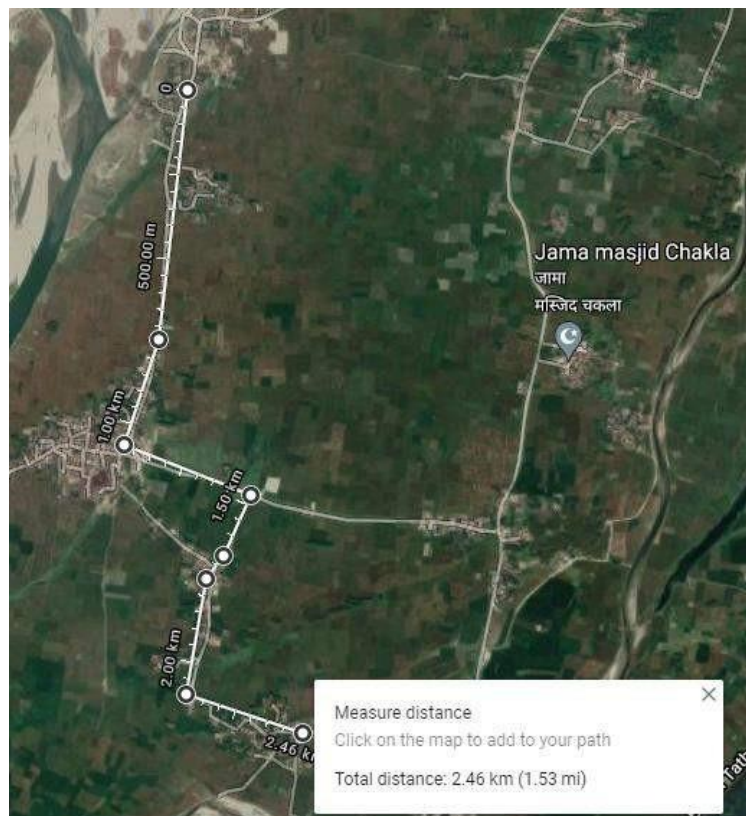
Requirements:

Option1: Public Transport Locate the building within 1 km walking distance from an intra-city railway station (or) a bus-stop (or) other modes of public transport

Option2: Shuttle Service The project can operate or have a contract in place for shuttle services (from / to the nearest intra-city railway station or bus-stop), for at least 25% of the building occupants.

Benefits Anticipated:

1. Saving on fuel in commuting
2. Less dependence on vehicular usage



Distance from the bus stop (ghuran town) to site is about **2.46m**

Possible Point IGBC: 1points

Achieved Point: 0points

25.1.2. CREDIT 2 TOP SOIL PRESERVATION – POINT 2

Intent: Preserve excavated top soil and reuse later for landscaping applications thereby, reducing negative impacts to the site and surroundings

Requirements: Preserve top 150 - 200 mm soil from excavation & reuse the soil for landscaping purposes within the same site and plant vegetation to prevent soil erosion

- Adopt the following measures:
- *Stockpile the fertile topsoil prior to construction and reuse the same during landscaping.*
- *Cover stockpiled topsoil with tarpaulin so as to reduce its exposure to air borne dust from construction activities.*
- *Stockpiled soil can be reused later on-site or sold / donated for off-site use.*

Benefits Anticipated:

1. Preserves the fertile top soil

Declaration: “All the above measures will be followed during construction and an separate guideline and awareness session will be conducted for the general contractor”

Possible Point IGBC: 2points

Achieved Point: 2points

25.1.3. CREDIT 3 ACCESS TO SOCIAL INFRASTRUCTURE – POINT 2

Intent: provide access to basic amenities, so as to reduce negative impacts caused from automobile use

Requirements: Provide access to at least six basic amenities within a walking distance of 1 km from the site entrance

- *Crèche / School / Anganwadi, provisional store, clinic, pharmacy, primary health center / dispensary, ATM, entertainment zones, milk booth, saloon, parks, restaurant – Point 1*
- *Additionally, provide the following within the campus:*
- *Seating facility and toilets in the common area for service staff & visitors
Minimum one toilet for every 200 dwelling units ○ Tot-lot for children – Point 1*

Note: The project shall mandatorily have Creche or School as one of the basic amenities.

Benefits Anticipated:

1. Savings on fuel in commuting
2. Less dependence on vehicular
3. usage Encourages people to walk or cycle, thereby improving health

Case 1: There are no amenities around 1 km. so the proposal, deals with basic amenities like

- Anganwadi
- Provisional Store
- Clinic

- Pharmacy
- Primary health care center
- Saloon
- Parks

Case 2: Seating Facility and common toilet are proposed

Possible Point IGBC: 2points

Achieved Point: 2points

25.1.4. CREDIT 4 GREEN COVER ON-SITE - POINT 2

Intent: Minimize disturbances or restore the site so as to reduce long-term negative environmental impacts, thereby promoting habitat and biodiversity

Requirements: Provide vegetation / landscaping for atleast 15% of total site area

- *Select plants, shrubs and trees which are local or adaptive species to the region*
- *Design buildings with minimal footprint*
- *Consider retaining the natural topography on the site or sites that have fully grown trees, avoid felling of trees or consider transplanting of trees which may obstruct the construction activities $\frac{3}{4}$ For every tree uprooted, plant atleast 5-7 saplings While designing the landscape, restrict the grass area $\frac{3}{4}$ Grass requires about 6-10 liters of water for every 1 sq.m.*

15% - Point 1

20% - Point 2

Benefits Anticipated:

1. Increased green cover
2. Restoring native and adaptive plants will require less maintenance, irrigation and fewer application of chemical fertilizers
3. Attracts birds and other habitat

Spaces	Area Sq.m	Percentage
Total Landscape Area	22829.0663	100%
Case 1:		
Turf Area	1200	5%
Case 2:		
Plant Area (Native Species)	5945	26%
Tree Area (Native Species)	15684.0663	69%
Summary		
Total Site Area	56276.9111	100%
Total Landscape Area	22829.0663	41%

Possible Point IGBC: 2points (for 20% landscape)

Achieved Point: 2points (41% of landscape area provide)

TREE TYPOLOGY

Species name(Tree)	Photo	Nativity	Water Requirement	Drought Tolerant	Spread(Feet)	Height (Ft)	Fruit Bearing	Flower bearing	Maintenance
Azadirachta indica		Indian subcontinent	Dry to medium	Yes	50.00 to 75.00	50.00 to 75.00	NO	Yes	Medium
Bambusa Polymorpha		Indian subcontinent	Dry to medium	Yes	20.00 to 40.00	30.00 to 60.00	NO	No	Low
Barringtonia racemosa		Indian subcontinent	Dry to medium	Yes	50.00 to 75.00	50.00 to 75.00	Yes	No	Low
Ficus religiosa		Indian subcontinent	Dry to medium	Yes	60.00 to 100.00	60.00 to 100.00	NO	No	Low
Callistemon citrinus		Indian subcontinent	Dry to medium	Yes	2.00 to 3.00	3.00 to 5.00	Yes	Yes	Low

PLANT TYPOLOGY

Species name(Plants)	Photo	Nativity	Water Requirement	Drought Tolerant	Spread(Feet)	Height (Ft)	Fruit Bearing	Flower bearing	Maintenance
Lagerstroemia speciosa		China	Medium	Yes	6.00 to 20.00	6.00 to 25.00	Yes	Yes	Medium
Tabebuia spectabilis		Colombia	Medium	Yes	30.00 to 50.00	60.00 to 90.00	Yes	Yes	Low
Bauhinia purpurea		China	Medium	Yes	20.00 to 25.00	12.00 to 20.00	Yes	Yes	Medium
Plumeria alba		Caribbean	Dry to medium	Yes	15.00 to 25.00	15.00 to 25.00	Yes	Yes	Medium

25.1.5. CREDIT 5 HEAT ISLAND EFFECT: NON ROOF- POINT 2

Intent: Minimize heat island effect so as to reduce negative impacts on micro-climate, human and bio-diversity

Requirements: Provide one or combination of the following, for atleast 25% of exposed non-roof impervious/ hardscape areas within the project site

- *Shade the footpaths, pathways, roads, uncovered surface parking and other impervious/ hardscaped areas with tree cover*
- *Install open grid pavers (or) grass pavers (or) light colored materials with solar reflective index (SRI) between 29-64*

25% - Point 1

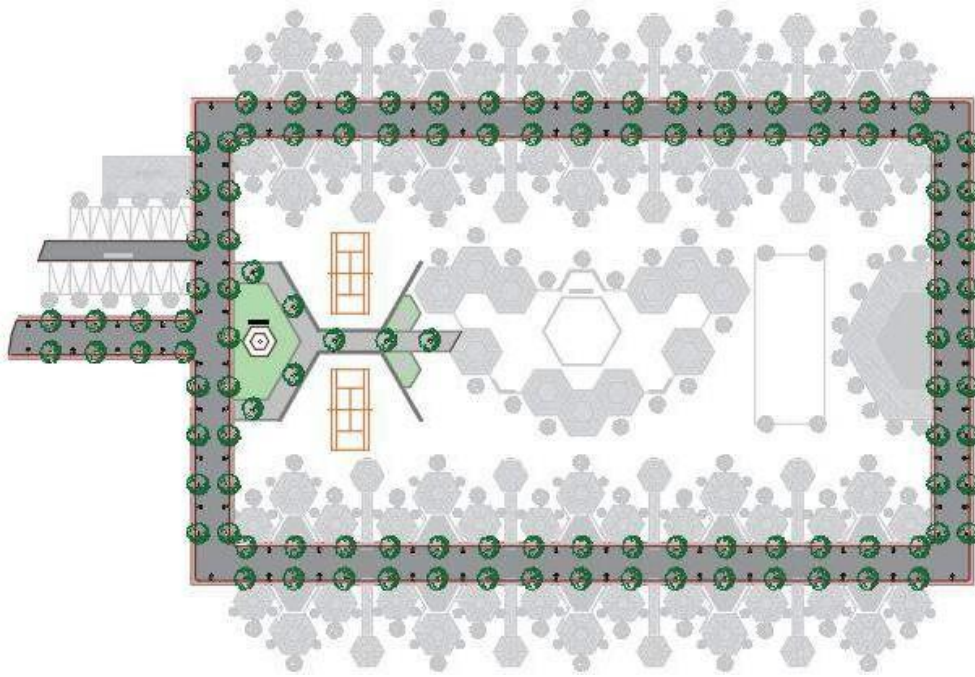
50% - Point 2

Benefits Anticipated:

1. Reduction in local temperatures
2. Better ambience

Non Roof Area Plan

Driveway – Light grey Concrete road SRI – 41%



Walk way paver block

SRI – 38%

Rate – Rs 30 per sq.ft



25.1.6. CREDIT 6 HEAT ISLAND EFFECT: ROOF- POINT 2

Intent: Minimize heat island effect so as to reduce negative impact on micro-climate, human and bio-diversity

Requirements: Cover atleast 50% of the exposed roof areas with reflective materials to reduce heat islands

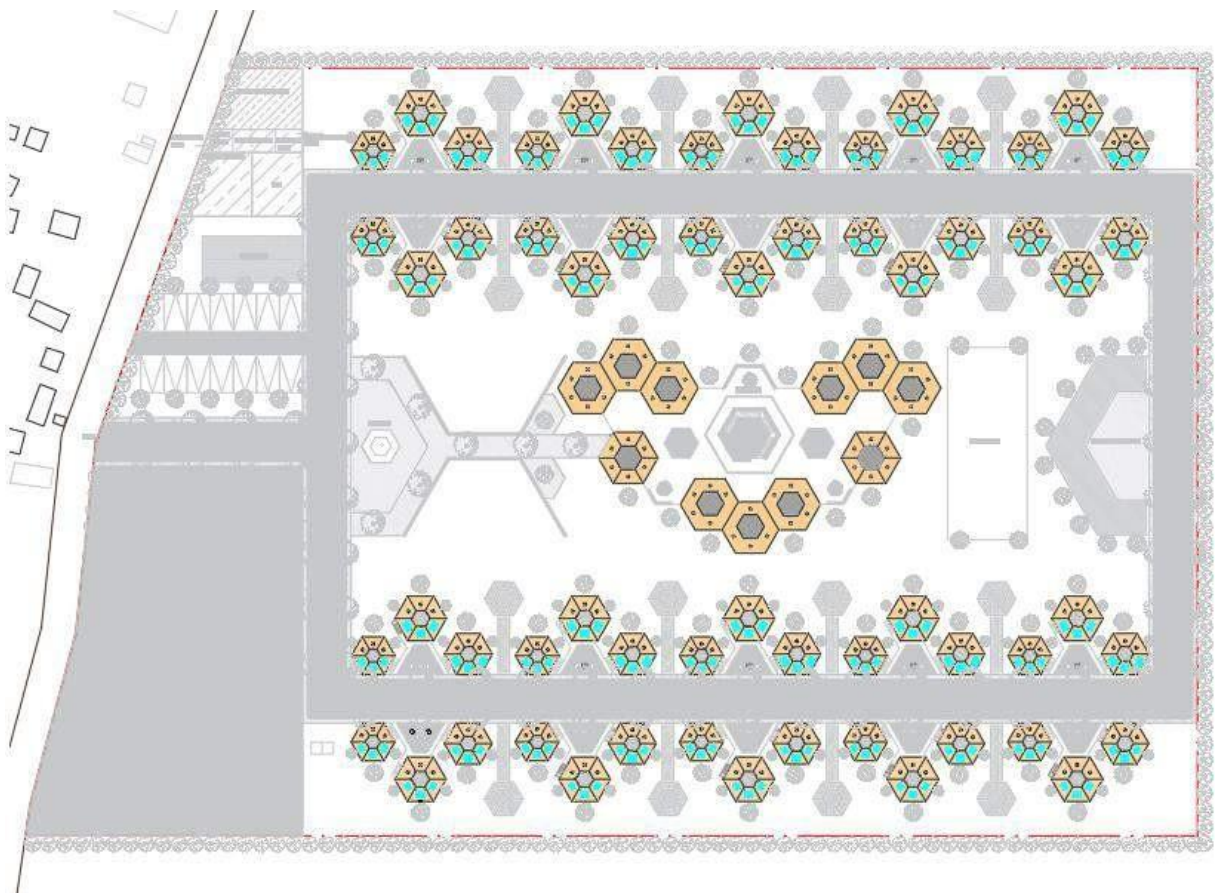
- *White surface applications (or) Light coloured china mosaic tiles/ white tiles with high solar reflective index SRI.*

75% - Point 1

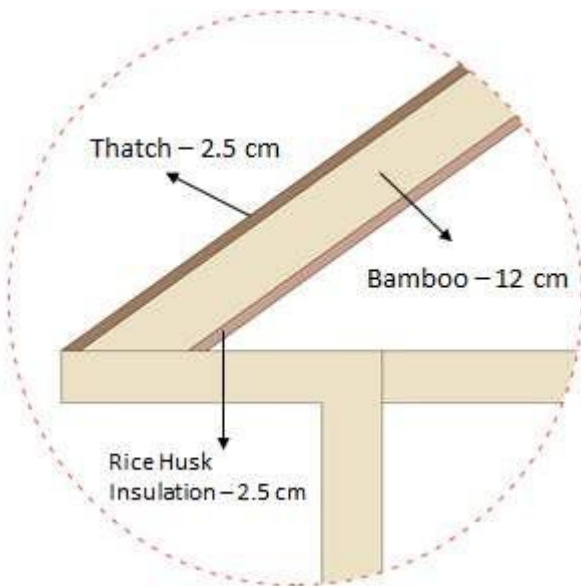
95% - Point 2

Benefits Anticipated:

1. Reduction in local temperatures
2. Better ambience



Roof Detail - A



Thatch –

U Value 2.8 w/m²K

Bamboo –

U Value 1.6 w/m²K

Rice Husk Insulation

U Value 3.2w/m²K***Possible Point IGBC: 2points******Achieved Point: 2points*****25.1.7. CREDIT 7 PARKING FACILITIES FOR TENEMENTS - POINT 1**

Intent: Provide adequate parking within the site to minimise disturbance caused due to parking on public roads, thereby, enhancing the quality of civic life

Requirements: Provide one or combination of the following, for atleast 25% of exposed non-roof impervious/ hardscape areas within the project site

- *Provide parking on-site to cater two wheeler parking facility to each tenement*
- *Equivalent car parking spaces / Follow the local bye-law parking regulations which ever is stringent*

Benefits Anticipated:

1. Avoid parking on roads
2. Reduced traffic snarls

Declaration: “Tenet mostly use bicycle and cattle for traveling so the proposal address only bicycle and cattle parking “

Possible Point IGBC: 1points

Achieved Point: 0points

25.1.8. CREDIT 8 DESIGN FOR DIFFERENTLY ABLED - POINT 2

Intent: Ensure that the building design caters to differently abled and senior citizens for their wellbeing

Requirements:

Non-slippery ramps with hand rails on atleast one side for easy access till main entrance and special parking provision for differently abled near lifts/ main entrance

- *Case 1: Projects with lift facility – provide uniform flooring levels/ ramps with hand rail till lift facility*
- *Case 2: Projects without lifts – project shall provide a declaration mentioning that preferred allotments of housing are provided for differently abled in ground floor and ramps shall be provided till ground floor*

Benefits Anticipated:

1. Comfortable living conditions for the differently abled and senior citizens

Declaration: “There is no preferred allotment for differently abled “

Possible Point IGBC: 2points

Achieved Point: 2points

**25.1.9. CREDIT 9 BASIC FACILITIES FOR CONSTRUCTION
WORKFORCE - POINT 2**

Intent: Provide facilities for wellbeing and hygiene of the construction workforce to enhance the quality of life and promote safe and healthy work conditions

Requirements: Provide the following on-site basic facilities for construction workforce

- *Adequate drinking water facilities to workforce*
- *Safety and personal protective equipment*

- *Sanitary measures to meet or exceed local / labour bye-law requirement (OR)
Provide atleast one toilet seat/ urinal for every 50 workers (separate for men and women)*
- *Adequate illumination levels in construction work areas*
- *First-aid and emergency facilities*

Benefits Anticipated:

1. Better work environment leading to better productivity
2. Health and wellbeing

Declaration: “All the above measures will be followed during construction and an separate guideline and awareness session will be conducted for the general contractor”

Possible Point IGBC: 2points

Achieved Point: 2points

25.2. WATER CONSERVATION

25.2.1. CREDIT 1 AVAILABILITY OF POTABLE WATER - POINT 1

Intent: Ensure that households are provided with piped water supply to meet water requirements, so as to ensure that the community is habitable

Requirements:

Provide piped fresh water supply and storage system, considering per capita consumption of 90 liters fresh water per person per day

Benefits Anticipated:

1. Community will be encouraged to reside
2. Availability of potable water
3. Improved hygiene and quality of life

Total Occupant: 220 head

Per head Requirement: 90 liters

Total Water Requirement: 19.8 KLD

Proposed Size of Under Ground Sump: 29.7KLD

Declaration: There is a proper pipeline facility and RO Drinking water facility in each dwelling units as well as in public area

Possible Point IGBC: 1points

Achieved Point: 1points

25.2.2. CREDIT 2 RAINWATER HARVESTING - POINT 3

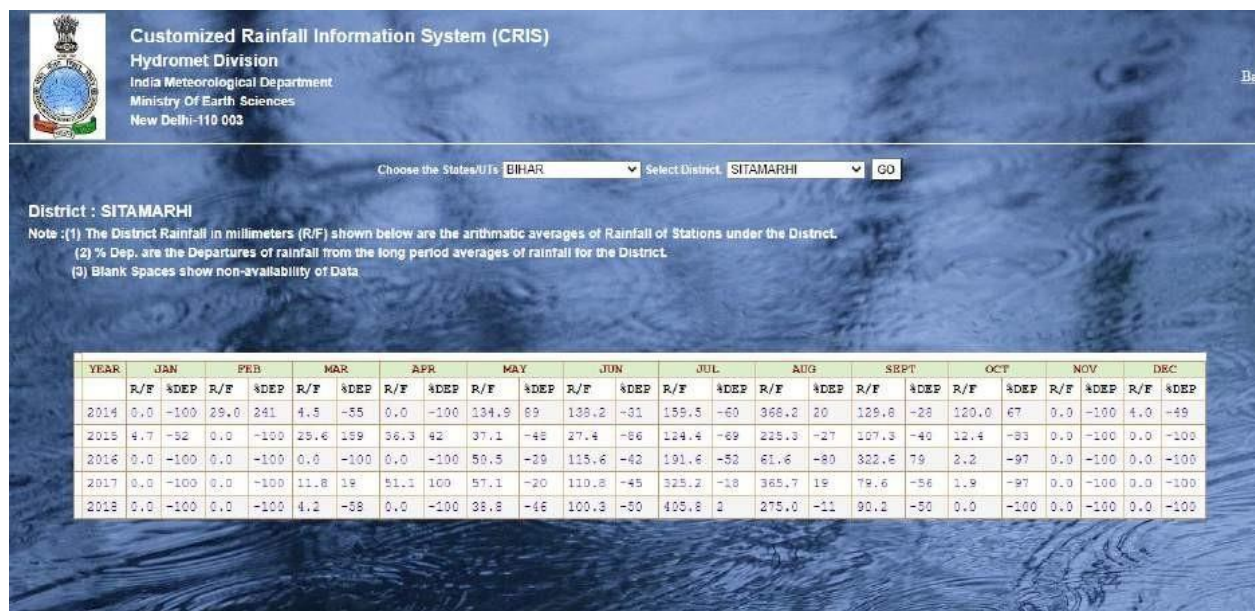
Intent: Implement Rainwater management systems to enhance ground water table and thereby reducing dependence on potable water

Requirements Provide rainwater harvesting system to capture atleast 50% of run-off volumes from roof and non-roof areas. The harvesting system designed should cater to atleast 1 day of normal rainfall* occurred in the last 5 years.

Benefits Anticipated:

1. Harvesting rainwater will reduce dependence on municipal supply of potable water.
2. Rainwater collected could reduce the amount of water being discharged into drains and watercourses thereby reducing the risk of localised flooding.
3. Recharging of aquifers maintains or augments natural groundwater, would conserve surface water and combat progressive depletion of groundwater levels

SITE RAINFALL CALCULATION				
Run- off Calculation				
S.No.	Zone	Area (sq.m.)	Run- off Coefficient	Impervious Area (sq. m.)
1	Bamboo Roof	9286.57	0.80	7429.3
2	Vegetation	22829.07	0.20	4565.8
3	Hardscape (Pathways/ Driveways)	12556.61	0.95	11928.8
4	Open Area (Inside, Outside and Utility area)	6251.00	0.20	1250.2
Net Impervious Area				25174.0
Rainfall Intensity (m/ day) considering 24%of average peak rainfall (2 point)				0.058
Total Run- off Volume (Cu.m.)				1457.64



Year	Peak Month Rainfall	Peak Rainfall (mm)
2014	July	160
2015	July	124.4
2016	July	192
2017	July	325
2018	July	406
Last 5 years average daily rainfall (mm)		241.26

Area cu.m	Liters
1	1000
1457.64	1457637.586

Possible Point IGBC: 3points

Achieved Point: 3points

25.2.3. CREDIT 3 WATER EFFICIENT PLUMBING FIXTURES - POINT

3

Intent: Enhance efficiency of plumbing fixtures, thereby minimising potable water use

Requirements:

Install all water taps with aerators and water closets with dual flush cistern (**Point 1 for each measure**)

- *Aerators fitted for taps (in dwelling units)*
- *Water closets with dual flush (in dwelling units)*
- *Water efficient fixtures in common area toilets*

Benefits Anticipated:

1. Installation of aerators in taps reduces water consumption
2. Reduced water will decrease the load on municipal supply of potable water
3. Water conservation reduces the need to overdraw groundwater resources, which are vulnerable to depletion and contamination
4. Reduces energy consumption for distribution and wastewater treatment systems

For Residence and Public Area								
S.no	Fixtur type	Duration(Minutes)	Daily use per FTE	No . Of Occupants	Baseline		Proposed case	
					Flow rate	Total daily Water	Flow rate	Total daily Water
1	Water closets (Full flush)	1	1	220	6	1320	4	880
2	Water closets (Half flush)	1	1	220	3	660	2	440
3	Faucets	0.15	8	220	6	1584	4	1056
4	Health faucets LPM	0.15	1	220	6	198	4	132
5	Kitchen sink	0.15	6	220	6	1188	4	792
6	Shower head LPM	8	1	220	10	17600	6	10560
					Baseline consumption		22550	Proposed Consumption
								13860
					Percentage savings			

Fixture details

Water Closet Fixture Detail



Product Name: Drizzle

Flush: Dual Flush

Flow Rate: 6 LPF

Rate: 5300rs

Tank Capacity: 6kg

*Local Technique to reduce
flowrate:*

2litre water bottle – 2Kg

The weight of the bottle reduces
the flowrate 6LPF into 4LPF

Types of Fixture	Product company	Image	Flow Rate	Amount
Faucet	DRIZZLE		 Aerator Flow Rate - 4	350
Shower	Hindware		Flow Rate - 6	650
Kitchen Sink	DRIZZLE		 Aerator Flow Rate - 4	645
Health Faucet	MARCOWARE		 Aerator Flow Rate - 4	610

Possible Point IGBC: 3points

Achieved Point: 3points

25.2.4. CREDIT 4 WASTE WATER TREATMENT - POINT 3

Intent: Reduce consumption of potable water and waste water generation to minimize the burden on municipal water supply

Requirements Provide on-site waste water treatment system to treat minimum 50% of the waste water generated to reduce consumption of potable water

50% - 1 Points

75% - 2 Points

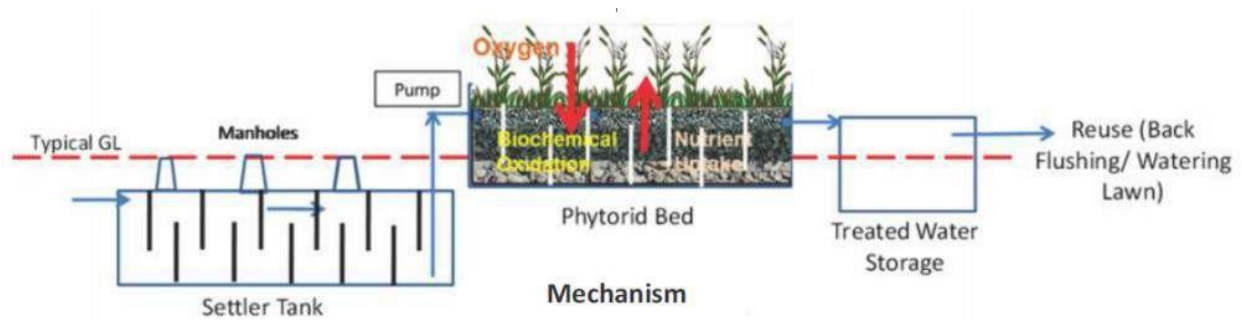
Benefits Anticipated:

1. Self-sufficiency of water needs within the project

2. Saves in maintenance costs
3. Reduces the dependency on municipal water supply
4. Using natural treatment procedures instead of mechanized STP helps reduce energy consumption and other operational and maintenance costs

Waste Water					
Waste Water per day (Litres)	No . Of occupants	Total Waste Water per day (Litres)	Safety Factor	Total KLD	Area Required Cu.m
85	220	18700	2.5	46.750	46.75
					Proposed Area cu.m
					35
					Total Percentage Achieved
					75%

phytoremediation sewage treatment



Non Exotic plant species



Possible Point IGBC: 3points

Achieved Point: 3points

25.2.5. CREDIT 5 TREATED WASTE WATER REUSE - POINT 2

Intent: Encourage use of treated waste water to reduce dependence on potable water

Requirements:

Reuse the treated waste water on-site for reducing the dependency on potable water requirement. Reuse of treated water for the following applications (**Point 2 for each measures**)

- *Flushing*
- or*
- *Landscape*
- or*
- *Vehicle wash applications/ Other appropriate applications*

Benefits Anticipated:

1. Self-sufficiency of water needs within the project
2. Saves in maintenance costs
3. Reduces the dependency on municipal water supply

Declaration: Nearly 14KLD of treated water reused for landscape and cart cleaning purpose “

Possible Point IGBC: 2points

Achieved Point: 2points

**25.2.6. CREDIT 6 MANAGEMENT OF IRRIGATION SYSTEMS - POINT
2**

Intent: Reduce water demand for irrigation through water efficient management systems and techniques to reduce dependence on potable water

Requirements Provide or install highly efficient irrigation systems incorporating the features mentioned below: **(every two features 1 point, maximum points: 2)**

- Central shut-off valve
- Turf and each type of bedding area must be segregated into independent zones based on watering needs
- Sprinklers for turf areas A
- Atleast 50% of landscape planting beds must have drip irrigation system to reduce evaporation
- Pressure regulating device(s) to maintain optimal pressure to prevent water loss
- Any other innovative methods for watering

Benefits Anticipated:

1. About 40 - 60% of potable water savings for landscape irrigation
2. Controlled and optimized irrigation would result in healthier plants

Declaration: Requirements (1-5) will be applied during post construction

Possible Point IGBC: 2points

Achieved Point: 2points

25.2.7. CREDIT 7 WATER METERS FOR DWELLING UNITS- POINT 2

Intent: Encourage water sub-metering to improve the water performance in the project, and thereby save potable water

Requirements:

Provide water meters to all dwelling units

Benefits Anticipated:

1. Water meters can help measure any deviations in the water lines and can be diagnosed or corrected to reduce additional water costs

Declaration: “Water Meter will be installed in all dwelling units”

Water Meter - Product Detail

Company Name: Konarak

Prize: 950rs

Possible Point IGBC: 2points

Achieved Point: 2points



25.3. ENERGY CONSERVATION

25.3.1. CREDIT 1 ENERGY EFFICIENT BUILDING ENVELOPE - POINT 4

Intent: Improve energy efficiency of the building(s) and system(s) to reduce environmental impacts from excessive energy use

Requirements Implement efficient wall, roof and glazing for building envelope measures to improve the energy efficiency. **(1 point for each parameter)**

Wall: The project must ensure that the overall U-value of the wall assembly shall meet the baseline criteria based on climatic zones of India as mentioned in the below table:

Climate Zone*	Maximum 'U'-Value of the overall Wall assembly (W/m ² K)
Composite	≤ 2.5
Hot and Dry	≤ 2.5
Warm and Humid	≤ 2.5
Moderate	≤ 1.1
Cold	≤ 2.5

Material layer	Thickness, <i>t</i> (m)	R- Value - <i>t/k</i> (m ² .K/W)
Bamboo	0.12	0.63
Rice Husk Insulation	0.025	0.31
U - Value		0.86 w/m ² K

Roof: The project must ensure that the U-value of the overall Roof assembly shall meet the baseline criteria based on climatic zones of India as mentioned in the below table:

Climate Zone*	Maximum 'U'-Value of the overall roof assembly (W/m ² K)
Composite	≤ 1.2
Hot and Dry	≤ 1.2
Warm and Humid	≤ 1.8
Moderate	≤ 1.2
Cold	≤ 1.2

Material layer	Thickness, <i>t</i> (m)	R- Value - <i>t/k</i> (m ² .K/W)
Bamboo	0.12	0.63
Rice Husk Insulation	0.025	0.31
U - Value		0.86 w/m ² K

Glazing: The project must ensure that the U-value of the Glazing of all windows shall meet the baseline criteria based on climatic zones of India as mentioned in the below table

Climate Zone *	Maximum U-Value (W/m ² K)
Composite	≤ 5.7
Hot and Dry	≤ 5.7
Warm and Humid	≤ 5.7
Moderate	≤ 5.7

Solar Heat Gain Coefficient (SHGC) of Glazing: The project must ensure that the SHGC of the Glazing of all windows shall meet the baseline criteria based on the window to wall ratio & climatic zones of India as mentioned in the below table

Climate Zone *	Maximum SHGC Value	
	WWR < 20%	WWR > 20%
Composite	0.5	0.42
Hot and Dry	0.5	0.42
Warm and Humid	0.5	0.42
Moderate	0.6	0.48
Cold	0.8	0.8

Proposed Glass Details

Product Name: AIS Ecosense Enhance – Nimbus

Thickness: **6mm** VLT – **0.54%** Internal Reflection – **21%**

External Reflection – **14%** SHGC value : **0.68%** U – Value – **5.4 w/m²k**

Possible Point IGBC: 4points

Achieved Point: 4points

25.3.2. CREDIT 2 SHADING ELEMENTS FOR BUILDING OPENINGS- POINT 2

Intent: Incorporate passive architectural features to improve energy efficiency

Requirements: Implement shading devices over external openings and optimise Window to Wall ratio.

Shading Devices: (1 point)

- At least 80% of the exterior openings (fenestration) shall have sun shades/ chajjas with a projection factor of 0.5 or more

Or

- Climate responsive concepts and design features as applicable: (1 point) Eg: Extended louvers, punched windows, pergolas, horizontal and vertical landscaping, bamboo chick curtains/blinds

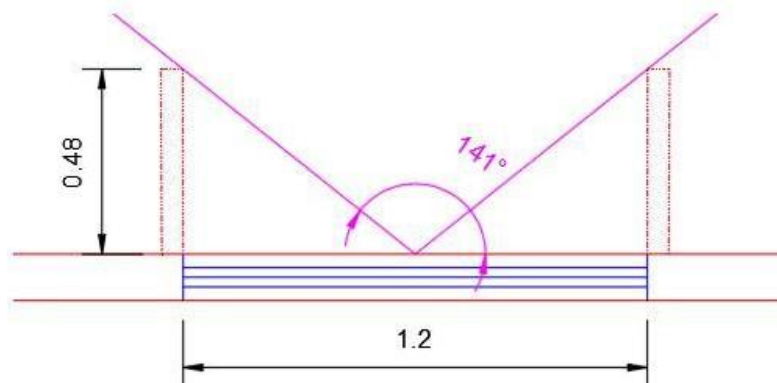
Benefits Anticipated:

1. Reduced energy bills
2. Energy cost saving for up to 20-30%

East & West façade shading

Width of window – 1200 mm

With **HSA -141.44°** and **depth of sunshade 480mm**, window is fully shaded during summer solstice

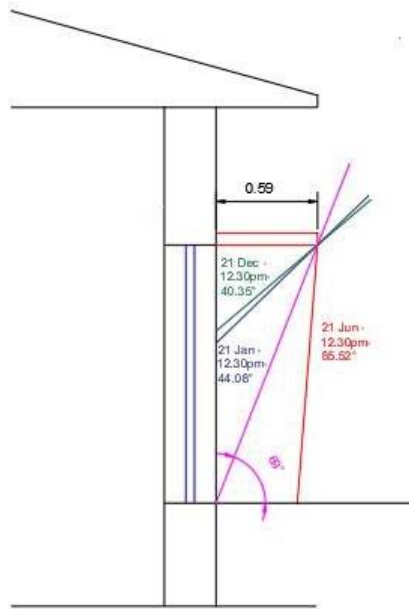


South façade shading

Depth = width / tan (VSA)

$$= 1200 / \tan (68.53) = 1200 / 2.542$$

Depth of vertical sunshade= 590mm



Possible Point IGBC: 2points

Achieved Point: 2points

25.3.3. CREDIT 3 EFFICIENT LIGHTING- POINT 2

Intent: Enhance energy efficiency of the building(s) and system(s) to reduce environmental impacts from excessive energy use

Requirements: Use energy efficient lighting fixtures to reduce the lighting power densities (LPD) in all interior, exterior, common and parking areas. (Any 2 measures, max 2 points)

Install lighting design such that the lighting power density (LPD) shall meet the following maximum values:

Lighting	Applicable Areas	Baseline Lighting Power Density (LPD)
Interior Lighting (for residential units)	Individual dwelling unit, Apartments	$\leq 0.5 \text{ W/ft}^2$
Exterior Lighting, excluding Parking Area (for residential & non-residential units)	Landscaping, Façade, Street lighting, Pathways, Signage's, etc.,	$\leq 0.25 \text{ W/ft}^2$
Common Area Lighting, excluding Parking Area (for residential & non-residential units)	Corridors, Lobbies, Staircases, Terrace, etc.,	$\leq 0.4 \text{ W/ft}^2$
Parking Area	Surface parking (covered & uncovered), Basement parking	$\leq 0.25 \text{ W/ft}^2$

Benefits Anticipated:

1. Reduced energy bills
2. Energy cost saving for up to 20-30%

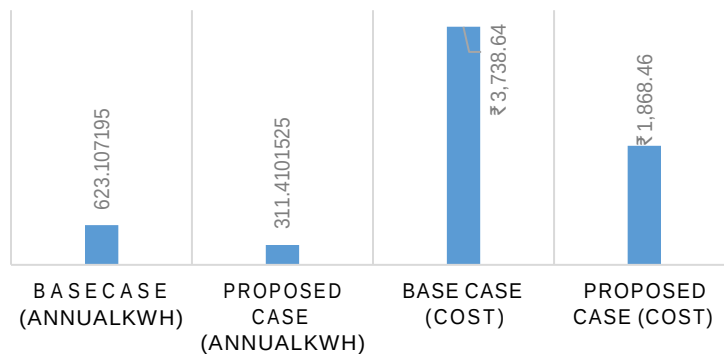
EWS – Lighting Fixture Calculation

Internal Light Fixture EWS (Base Case LPD)					
Typology (EWS)	Area (Sq.m)	Timing(Hrs)	Base Case LPD	Watt	Energy (Annual)Kwh
Living Dining and kitchen	56.2119	6	5	281.0595	615.520305
Toilet	2.0786	2	5	10.393	7.58689
					623.107195

Internal Light Fixture EWS (Proposed Case LPD)											
Typology (EWS)	Area (Sq.m)	Lux Required	Lumens	Efficacy	Watt	LPD	Proposed Fixture (W)	No of Fixture	Timing (Hrs)	Total Watt	Energy (Annual)
Living Dining and kitchen	56.2119	300	16863.57	120	140.52975	2.5		36	4	6	140.52975
Toilet	2.0786	100	207.86	120	1.732166667	0.833333333		5	1.0	2	5
											311.4101525

Internal Light Fixture EWS (Saving)				
	Energy (Annual)	Rate of unit Rs	Total Amount	Percentage
Base Case	623.107195	6	₹ 3,738.64	100%
Proposed Case	311.4101525	6	₹ 1,868.46	50%
		Saving Annual	₹ 1,870.18	

LIGHTING FIXTURE



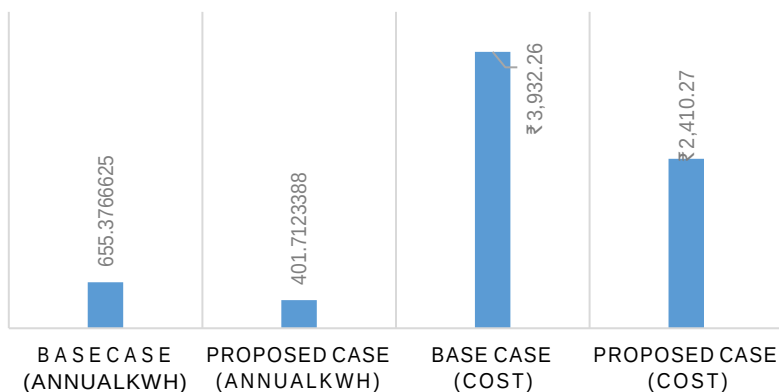
LIG – Lighting Fixture Calculation

Internal Light Fixture - LIG (Base Case LPD)					
Typology (LIG)	Area (Sq.m)	Timing(Hrs)	Base Case LPD	Watt	Energy (Annual)Kwh
Living	15.5113	6	5	77.5565	169.848735
Kitchen and dining	24.3271	5	5	121.6355	221.9847875
Bedroom Area	21.1094	6	5	105.547	231.14793
Toilet Area	8.8754	2	5	44.377	32.39521
					655.3766625

Internal Light Fixture L10 (Proposed Case LPD)											
Typology (EWS)	Area (Sq.m)	Lux Required	Lumens	Efficacy	Watt	LPD	Proposed Fixture (W)	No of Fixture	Timing (Hrs)	Total Watt	Energy (Annual)
Living	15.5113	300	4653.39	120	38.77825	2.5	36	1	6	38.77825	84.9243675
Kitchen and dining	24.3271	300	7298.13	120	60.81775	2.5	36	2	7	60.81775	155.3893513
Bedroom	21.1094	300	6332.82	120	52.7735	2.5	36	1	8	52.7735	154.09862
Toilet	8.8754	100	887.54	120	7.396166667	0.833333333	5	2.0	2	10	7.3
											401.7123388

Internal Light Fixture LIG (Saving)				
	Energy (Annual)	Rate of unit Rs	Total Amount	Percentage
Base Case	655.3766625	6	₹ 3,932.26	100%
Proposed Case	401.7123388	6	₹ 2,410.27	61%
		Saving Annual	₹ 1,521.99	

LIGHTING FIXTURE



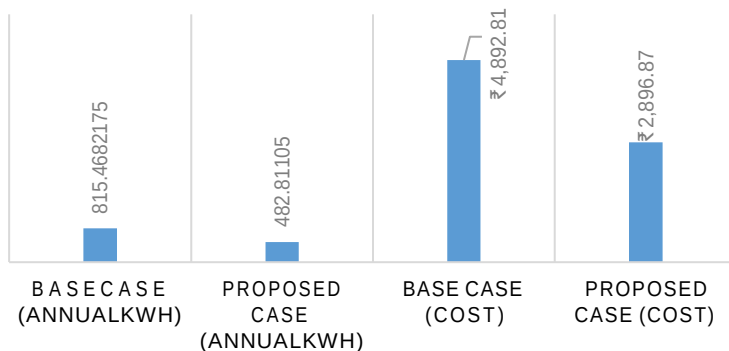
MIG – Lighting Fixture Calculation

Internal Light Fixture - MIG (Base Case LPD)					
Typology (MIG)	Area (Sq.m)	Timing(Hrs)	Base Case LPD	Watt	Energy (Annual)Kwh
Living	21.706	6	5	108.53	237.6807
Kitchen and dining	21.814	5	5	109.07	199.05275
Bedroom Area	13.0381	5	5	65.1905	118.9726625
Master Bedroom Area	22.0725	6	5	110.3625	241.693875
Attached Toilet Area	2.35	2	5	11.75	8.5775
Toilet	2.6002	2	5	13.001	9.49073
					815.4682175

Internal Light Fixture MIG (Proposed Case LPD)											
Typology (EWS)	Area (Sq.m)	Lux Required	Lumens	Efficacy	Watt	LPD	Proposed Fixture (W)	No of Fixture	Timing (Hrs)	Total Watt	Energy (Annual)
Living	21.814	300	6544.2	120	54.535	2.5	36	2	6	54.535	119.43165
Kitchen and dining	13.0381	300	3911.43	120	32.59525	2.5	36	1	7	32.59525	83.2808375
Bedroom	13.0381	300	3911.43	120	32.59525	2.5	36	1	8	32.59525	95.17813
Master Bedroom	22.0725	300	6621.75	120	55.18125	2.5	36	2	9	55.18125	181.2704063
Attached Toilet Area	2.35	100	235	120	1.958333333	0.833333333	5	1.0	2	5	3.65
Toilet	2.6002	100	260.02	120	2.166833333	0.833333333	5	1.0	2	5	3.65
											482.81105

Internal Light Fixture MIG (Saving)				
	Energy (Annual)	Rate of unit Rs	Total Amount	Percentage
Base Case	815.4682175	6	₹ 4,892.81	100%
Proposed Case	482.81105	6	₹ 2,896.87	59%
		Saving Annual	₹ 1,995.94	

LIGHTING FIXTURE



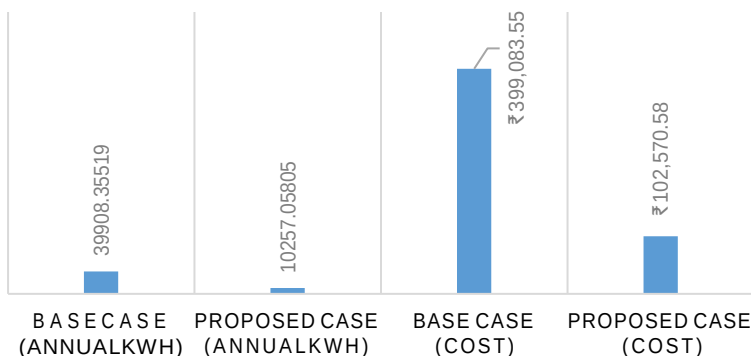
Public Area – Lighting Fixture Calculation

Internal Light Fixture Public Area (Base Case LPD)					
Typology	Area (Sq.m)	Timing(Hrs)	Base Case LPD	Watt	Energy (Annual)Kwh
Library	110.5083	7	12.8044	1414.992477	3615.305778
Day Care	211.1699	5	9.36468	1977.538539	3609.007834
Kioks	246.278	10	13.56264	3340.179854	12191.65647
Multi Purpose hall	365.98	7	13.23972	4845.472726	12380.18281
Primary Health Care	276.9582	7	11.3022	3130.236968	7997.755453
Toilet	31.3553	2	2.5	78.38825	57.2234225
					39793.90835

Internal Light Fixture Public Area (Proposed Case LPD)											
Typology (Public Area)	Area (Sq.m)	Lux Required	Lumens	Efficacy	Watt	LPD	Proposed Fixture (W)	No of Fixture	Timing (Hrs)	Total Watt	Energy (Annual)
Library	110.5083	600	66304.98	120	552.5415	5	36	15	7	552.5415	1411.743533
Day Care	211.1699	300	63350.97	120	527.92475	2.5	36	15	5	527.92475	963.4626688
Kiosks	246.278	500	123139	120	1026.158333	4.166666667	36	29	10	1026.1583	3745.477917
Multi Purpose hall	365.98	150	54897	120	457.475	1.25	36	13	7	457.475	1168.848625
Primary Health Care	276.9582	500	138479.1	120	1153.9925	4.166666667	36	32	7	1153.9925	2948.450838
Toilet	31.3553	100	3135.53	120	26.12941667	0.833333333	5	5	2	26.129417	19.07447417
											10257.05805

Internal Light Fixture Public Area (Saving)				
	Energy (Annual)	Rate of unit Rs	Total Amount	Percentage
Base Case	39908.35519	10	₹ 399,083.55	100%
Proposed Case	10257.05805	10	₹ 102,570.58	26%
		Saving Annual	₹ 296,512.97	

LIGHTING FIXTURE



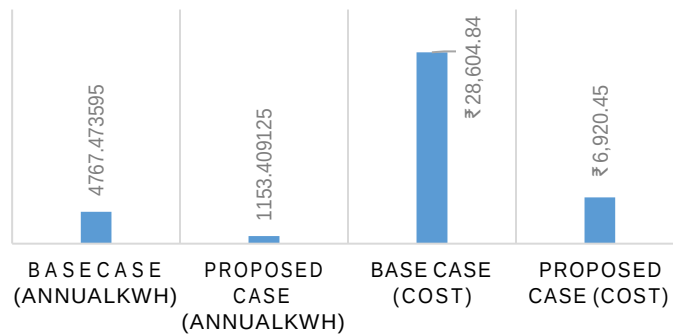
Cattle Shed– Lighting Fixture Calculation

Internal Light Fixture Cattle Shed(Base Case LPD)					
Typology	Area (Sq.m)	Timing(Hrs)	Base Case LPD	Watt	Energy (Annual)Kwh
Cattle Shed	48.199	6	3	166.0204915	363.5848764
Cattle Cleaning Area	583.806	6	3	2010.908091	4403.888719
					4767.473595

Internal Light Fixture Cattle Shed (Proposed Case LPD)											
Typology	Area (Sq.m)	Lux Required	Lumens	Efficacy	Watt	LPD	Proposed Fixture (W)	No of Fixture	Timing (Hrs)	Total Watt	Energy (Annual)
Cattle Shed	48.199	100	4819.9	120	40.16583333	0.833333333	36	1	6	40.165833	87.963175
Cattle Cleaning Area	583.806	100	58380.6	120	486.505	0.833333333	36	14	6	486.505	1065.44595
											1153.409125

Internal Light Fixture Cattle Shed (Saving)				
	Energy (Annual)	Rate of unit Rs	Total Amount	Percentage
Base Case	4767.473595	6	₹ 28,604.84	100%
Proposed Case	1153.409125	6	₹ 6,920.45	24%
		Saving Annual	₹ 21,684.39	

LIGHTING FIXTURE



25.3.4. CREDIT 4 ON-SITE RENEWABLE ENERGY AND SOLAR WATER HEATING SYSTEMS - POINT 2

Intent: Promote self-sufficiency in energy through renewable technologies for on-site power generation and use within the project

Requirements: Install renewable energy systems for at least 50 % of annual energy consumption for common area lighting (AND/OR) for Solar Water Heating, whichever is applicable. (Max 2 points)

Percentage of Annual energy consumption for common area lighting Total on-site renewable energy generated annually	Points
≥ 50 %	1
≥ 75 %	2

Note: Consider hot water requirement as 20 liters per person per day

Benefits Anticipated:

1. Reduces the adverse environmental impacts caused by fossil fuel based energy production and use
2. Ensures energy security for the country

EWS –Solar panel Calculation

Internal Light Fixture EWS (Saving)				
	Energy (Annual)	Rate of unit Rs	Total Amount	Percentage
Base Case	623.107195	6	₹ 3,738.64	100%
Proposed Case	311.4101525	6	₹ 1,868.46	50%
		Saving Annual	₹ 1,870.18	

Internal Equipment EWS					
Appliance	Watt	Timing (Hrs)	No of items	Total Watt	Energy (Annual)
T.v	120	6	1	120	262.8
Fan	36	18	3	108	709.56
Kitchen Fan	150	6	1	150	328.5
Mixer	750	1	1	750	273.75
					1574.61

Solar Panel		
Energy (Annual)	Solar Panel (Kw)	Area (Sq.m)
1886.020153	1.291794625	12.00077207
Proposed Solar Panel 1.5kw = 14 sq.m		

Cost Calculation		
Electric Current	₹ 11,316.12	Rupees
Solar Panel	₹ 112,500.00	Rupees
Return On Investment	10	years

LIG –Solar panel Calculation

Internal Light Fixture LIG (Saving)				
	Energy (Annual)	Rate of unit Rs	Total Amount	Percentage
Base Case	655.3766625	6	₹ 3,932.26	100%
Proposed Case	401.7123388	6	₹ 2,410.27	61%
		Saving Annual	₹ 1,521.99	

Internal Equipment LIG					
Appliance	Watt	Timing (Hrs)	No of Items	Total Watt	Energy (Annual)
T.v	120	6	1	120	262.8
Fan	36	18	4	144	946.08
Kitchen Fan	150	6	1	150	328.5
Mixer	750	1	1	750	273.75
					1811.13

Solar Panel		
Energy (Annual)	Solar Panel (Kw)	Area (Sq.m)
2212.842339	1.515645438	14.08034611
Proposed Solar Panel 1.75kw = 16sq.m		

Cost Calculation		
Electric Current	₹ 13,277.05	Rupees
Solar Panel	₹ 131,250.00	Rupees
Return On Investment	10	Years

MIG –Solar panel Calculation

Internal Light Fixture MIG (Saving)				
	Energy (Annual)	Rate of unit Rs	Total Amount	Percentage
Base Case	815.4682175	6	₹ 4,892.81	100%
Proposed Case	482.81105	6	₹ 2,896.87	59%
		Saving Annual	₹ 1,995.94	

Internal Equipment MIG					
Appliance	Watt	Timing (Hrs)	No of items	Total Watt	Energy (Annual)
T.v	120	6	1	120	262.8
Fan	36	18	4	144	946.08
Kitchen Fan	150	6	1	150	328.5
Mixer	750	1	1	750	273.75
					1811.13

Solar Panel		
Energy (Annual)	Solar Panel (Kw)	Area (Sq.m)
2293.94105	1.5711925	14.59637833
<i>Proposed Solar Panel 1.75kw = 16sq.m</i>		

Cost Calculation		
Electric Current	₹ 13,763.65	Rupees
Solar Panel	₹ 131,250.00	Rupees
Return On Investment	10	Years

Public Area–Solar panel Calculation

Internal Light Fixture Public Area (Saving)				
	Energy (Annual)	Rate of unit Rs	Total Amount	Percentage
Base Case	39908.35519	10	₹ 399,083.55	100%
Proposed Case	10257.05805	10	₹ 102,570.58	26%
		Saving Annual	₹ 296,512.97	

Internal Equipment Public Area					
Appliance	Watt	Timing (Hrs)	No of items	Total Watt	Energy (Annual)
Computer	200	6	8	1600	3504
Fan	36	8	20	720	6044.4
					9548.4

Internal Equipment Public Area			
Typology	Area Sq.m	Base Case (Kwh Annual)	Energy (Annual)
Public Health Care	276.9582	47	13017.0354
			13017.0354

Solar Panel (Light and Ceiling Fans)		
Energy (Annual)	Solar Panel (Kw)	Area (Sq.m)
32822.49345	22.4811599	208.8499755
<i>Proposed Solar Panel 25kw = 230sq.m</i>		

Cattle Shed –Solar panel Calculation

Internal Light Fixture Cattle Shed (Saving)				
	Energy (Annual)	Rate of unit Rs	Total Amount	Percentage
Base Case	4767.473595	6	₹ 28,604.84	100%
Proposed Case	1153.409125	6	₹ 6,920.45	24%
		Saving Annual	₹	21,684.39

Solar Panel		
Energy (Annual)	Solar Panel (Kw)	Area (Sq.m)
1153.409125	0.79000625	7.339158063
<i>Proposed Solar Panel 800w = 10 sq.m</i>		

“The Entire Community is NET ZERO in energy”

Possible Point IGBC: 2points

Achieved Point: 2points

25.3.5. CREDIT 5 ENERGY SAVING MEASURES IN APPLIANCES & OTHER EQUIPMENT - POINT 2

Intent: Conserve energy in the use of appliances and other equipment, thereby reducing environmental impacts.

Requirements: Provide the following (each application 1 point, Maximum 2 points)

- *Pumps: BEE 4-Star rated pumps or Minimum 60% efficiency for pumps for capacity greater than 3HP and ISI certified pumps for others*
- *Motors: BEE 4-star rated motors (or) Minimum 75% efficiency for motors of capacity greater than 3 HP and ISI certified motors for others*
- *Other energy efficient equipment/ system*

Benefits Anticipated:

1. Reduction in energy consumption, thereby reducing associated adverse environmental impacts

Pump Details

Product Company: Kirloskar

BEE: 4 Star

Rate: 9500

Item Weight: 14 kg

Voltage: 230 Volts



Motor Details

Product Company: V - Guard

BEE: 4 Star

Rate: 5750

Item Weight: 12 kg



Voltage: 300 V

25.4. MATERIAL CONSERVATION

25.4.1. SEPARATION OF HOUSE-HOLD WASTE- MANDATORY

Intent: Facilitate segregation of house-hold waste at source so as to prevent such waste being sent to land-fills

Requirements:

- *Provide separate bins to collect dry waste (paper, plastic, metals, glass, etc.,) and wet waste (organic).*
- *Additionally provide separate bins in a centralized/ common facility to collect waste such as e-waste, medical and paper waste.*
-

Benefits Anticipated:

1. Reduces the burden on landfills

Declaration: Separate household waste disposal bin will be provided for the entire community.



25.4.2. CREDIT 1 ORGANIC WASTE MANAGEMENT- POINT 2

Intent: Ensure effective organic waste management, post-occupancy, so as to prevent waste being sent to landfills

Requirements: Install on-site waste treatment systems Viz. dump-pits, organic waste converter or Vermi-Composting, etc., to treat at least 50% of the organic waste generated and reuse them for landscaping need

- 50% - **1 points**
- 75% - **2 points**

Benefits Anticipated:

1. Reduces the burden on landfills.
2. Encourages the manufacturing industry to re-utilise waste materials. Facilitates local municipal corporations to generate power from waste.
3. Improved hygiene

Organic Waste					
Organic Waste per day per head (kg)	No . Of occupants	Total organic waste (Kg)	Safety Factor	Total Kg	Area Required Cu.m
0.25	220	55	2.5	137.5	1.146
				Proposed Area cu.m	2
				Total Percentage Achieved	175%

Possible Point IGBC: 2points

Achieved Point: 2points

25.4.3. CREDIT 2 HANDLING OF CONSTRUCTION WASTE MATERIALS – POINT 2

Intent: Encourage practices to manage construction waste, thereby, avoiding waste being sent to land-fills.

Requirements: Avoid at least 50% of the waste generated (by either weight or volume) during construction from being sent to land-fills

- 50% - **1 points**
- 75% - **2 points**

Benefits Anticipated:

1. Reduces the burden on landfills and associated environmental impacts.
2. Reduces impacts associated with resource extraction & processing.
3. Facilitates conservation of virgin materials.
4. Better waste management contributes towards mitigating the effects of global climate change

Declaration: 90% of Post construction waste material will be disposed to respective scrapyards

Possible Point IGBC: 2points

Achieved Point: 2points

25.4.4. CREDIT 3 USE OF LOCAL MATERIAL - POINT 3

Intent: Encourage use of building materials available locally thereby minimizing the associated environmental impacts resulting from transportation

Requirements:

Source at least 50% materials which are extracted and manufactured, locally within a distance of 400 kms

Survey and identify building materials which are in the specified distance, in early stages of project design.

- 50% - **1 points**
- 75% - **2 points**
- 95% - **3 Points**

Benefits Anticipated:

1. Decreased transportation costs for the project
2. Encourages vernacular architecture
3. Supports local economy

*Thatch Detail***K Value** - 0.025 w/mK**Rate** : Rs 35 per Sq.ft*Bamboo Detail***K Value** - 0.18 w/mK**Rate** : Rs 60 per sq.ft*Rice Husk Insulation***K Value** - 0.08 w/mK**Rate** : Rs 30 per sq.ft*Mud Flooring Detail***K Value** - 0.25 w/mK**Rate** : Rs 40 per sq.ft***Possible Point IGBC: 3points******Achieved Point: 3points*****25.4.5. CREDIT 4 MATERIALS WITH RECYCLED CONTENT– POINT 3**

Intent: Encourage use of materials which contain recycled content to reduce environmental impacts associated with the use of virgin materials

Requirements:

Use materials with recycled content such that the total recycled content constitutes at least 10% of the total cost of the materials used in the building(s)

Survey the materials with recycled content and locate such local suppliers

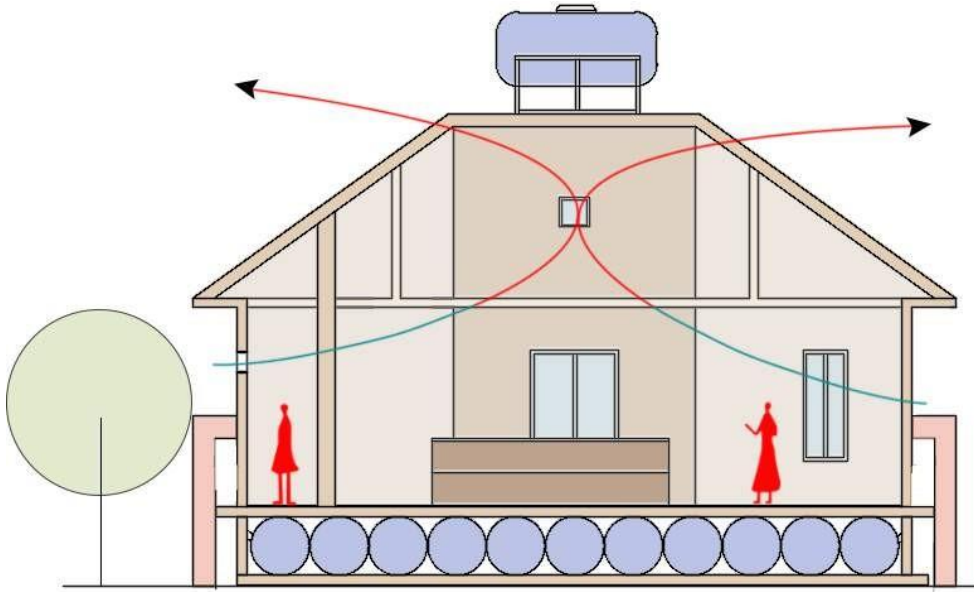
- 10% - **1 points**
- 20% - **2 points**
- 30% - **3 points**

Benefits Anticipated:

1. Eliminates energy use and associated pollution that result from extraction of virgin resources & production of building materials.
2. By diverting recyclable materials, construction waste volumes are reduced, that would otherwise be deposited in a landfill

Declaration: 40% recycled material is used.





Possible Point IGBC: 3points

Achieved Point: 3points

25.4.6. CREDIT 5 APPROPRIATE TECHNOLOGIES- POINT 4

Intent: Encourage use of appropriate and alternative construction technologies to conserve natural resources and thereby reduce environmental impacts

Requirements:

At least 50% (by cost) of the structure should be constructed using appropriate and cost effective technologies without compromising on strength, durability & functional performance and encourage use of alternative technologies.

- 25% - 1 point
- 50% - 2 points
- 75% - 3 points

- 95% - **4 Points**

Benefits Anticipated:

1. Fast track construction
2. Minimum wastage of materials
3. Better strength and durability
4. Provides quality working environment for the Work force

Declaration: By using bamboo as major construction material with simple construction technique nearly 60% of total cost of structure is cut down.

Possible Point IGBC: 4points

Achieved Point: 4points

**25.4.7. CREDIT 6 ALTERNATIVE CONSTRUCTION MATERIALS–
POINT 2**

Intent: Encourage use of alternative construction materials to conserve natural resources and thereby reduce environmental impacts

Requirements:

At least 25% of the alternative materials should be used in the building construction

- 25% - **1 points**
- 50% - **2 points**

Benefits Anticipated:

1. Savings in natural resources consumption. Use of curing compounds will save huge consumption of water for construction
2. Better strength and durability
3. Provides quality working environment for the Work force

Declaration: 100% alternative material is used.

Thatch Detail
K Value - 2.8 w/m²K
Rate : Rs 35 per Sq.ft



Bamboo Detail
K Value - 1.6 w/m²K
Rate : Rs 60 per sq.ft



Rice Husk Insulation
K Value - 3.2w/m²K
Rate : Rs 30 per sq.ft



Mud Flooring Detail
K Value - 0.6 w/m²K
Rate : Rs 60 per sq.ft



Possible Point IGBC: 2points

Achieved Point: 2points

25.5. DAYLIGHT ANALYSIS

25.5.1. CREDIT 1 DAY LIGHTING– POINT 2

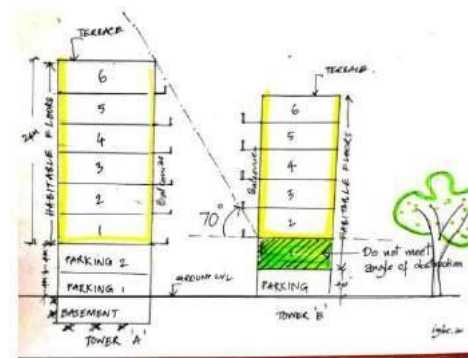
Intent: Ensure connectivity between the interior and the exterior environment, by providing adequate day lighting

Requirements:

Achieve a minimum glazing factor (GF) or lux level for all regularly occupied spaces.

Multiple openings of adequate window sizes to the exteriors, openings in proper orientation preferably north or east facing

- 75% - 1 points
- 95% - 2 points



Option 1:

Prescriptive Approach Achieve minimum glazing factors as listed below in at least 50% of the regularly occupied spaces in each dwelling unit

Option 2: Measurement/ Simulation Approach

Demonstrate through computer simulation that 50% of the regularly occupied spaces in the building achieve daylight IL luminance levels for a minimum of 110 Lux in a clear sky condition on 21st September at 12 noon, at 2 feet 6 inches height

Benefits Anticipated:

1. Lower electricity bills
2. Improves quality of life

3. Connectivity to exterior environment

EWS							
Regular Occupied	Floor area (sq.m)	Window area	VLT	Constant	Glazing Factor Achieved	Glazing Factor Required	Area Meeting
Living Dining and Kitchen	56.21	10.08	0.7	0.2	2.5105	2	56.21

Total Floor Area	56.21
Floor area achieving daylight	56.21
Total Area Achieved %	100%

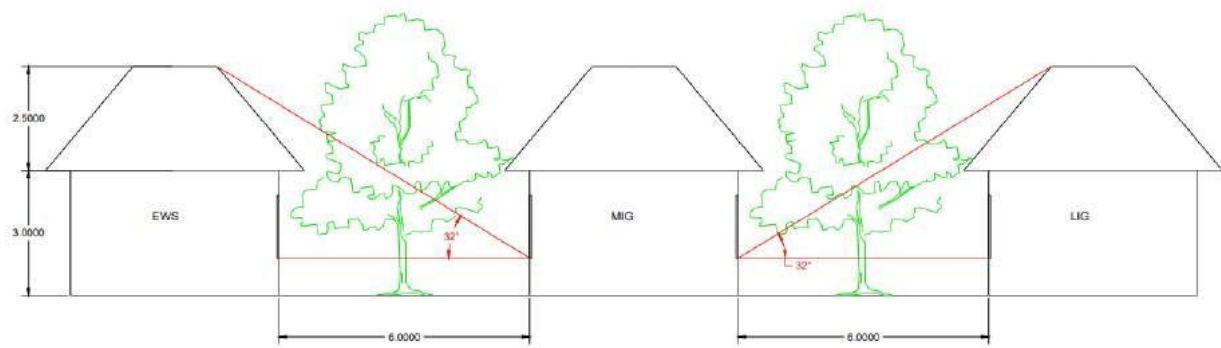
LIG							
Regular Occupied	Floor area (sq.m)	Window area	VLT	Constant	Glazing Factor Achieved	Glazing Factor Required	Area Meeting
Living	15.51	3.60	0.7	0.2	3.24924	1	15.51
Kitchen and Dining	24.33	3.60	0.7	0.2	2.07176	2	24.33
Bedroom	21.11	3.60	0.7	0.2	2.38756	1	21.11
	60.95						60.95

Total Floor Area	60.95
Floor area achieving daylight	60.95
Total Area Achieved %	100%

MIG							
Regular Occupied	Floor area (sq.m)	Window area	VLT	Constant	Glazing Factor Achieved	Glazing Factor Required	Area Meeting
Living	21.71	3.60	0.7	0.2	2.32194	1	21.71
Kitchen and Dining	21.81	3.60	0.7	0.2	2.31044	1	21.81
Bedroom	13.04	3.60	0.7	0.2	3.86559	2	13.04
Master Bedroom	22.07	1.94	0.7	0.2	1.23303	1	22.07
	78.63						78.63

Total Floor Area	78.63
Floor area achieving daylight	78.63
Total Area Achieved %	100%

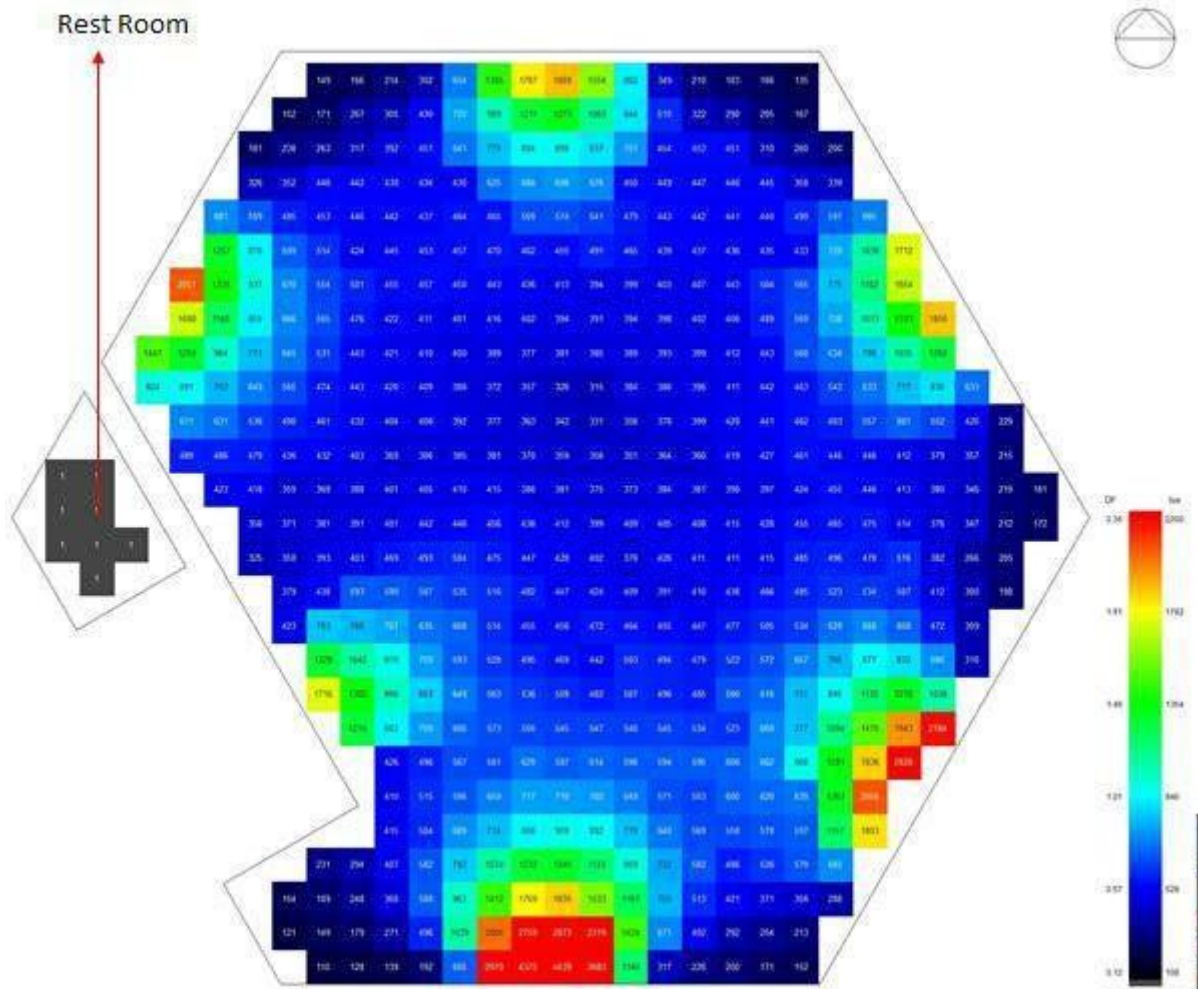
Angle of Obstruction



Possible Point IGBC: 2points

Achieved Point: 2points

EWS – DAYLIGHT ANALYSIS



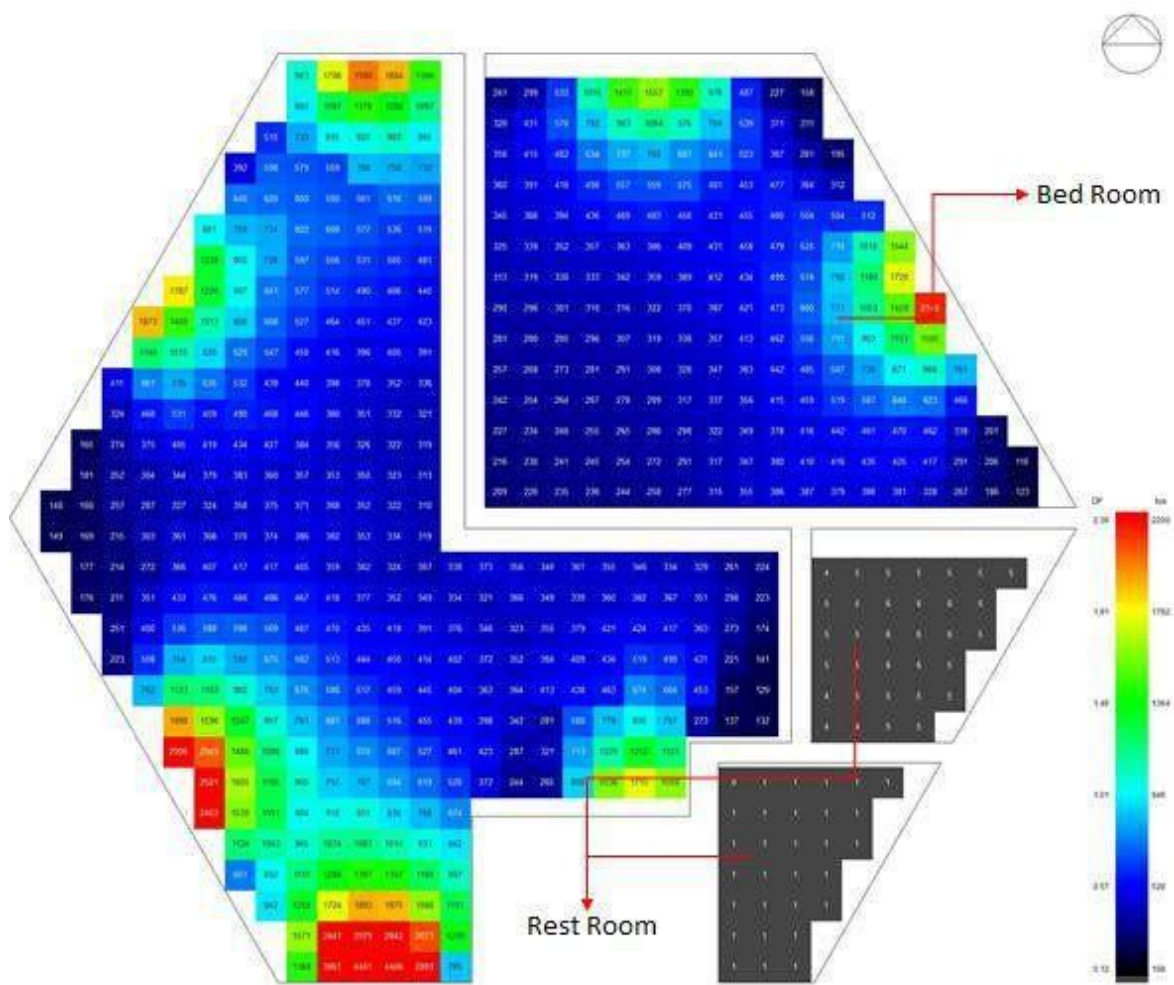
Thickness: 6mm VLT – 0.54% Internal Reflection – 21%

External Reflection – 14% SHGC value : 0.68%

U – Value – 5.4 w/m²k

Typology	Floor Area (m2)	Floor Area above Threshold (m2)	Floor Area above Threshold (%)
Living Bedroom Kitchen and Dining	54.162	53.667	99.086

LIG – DAYLIGHT ANALYSIS



Simulation Approach

At Sep 21 – 12 Pm (Equinox)

Threshold

Minimum Lux – 110 Lux

Maximum Lux – 2200 Lux

Window Wall Area – 20.25 %

Proposed Glass Details

Product Name: AIS Ecosense Enhance – Nimbus

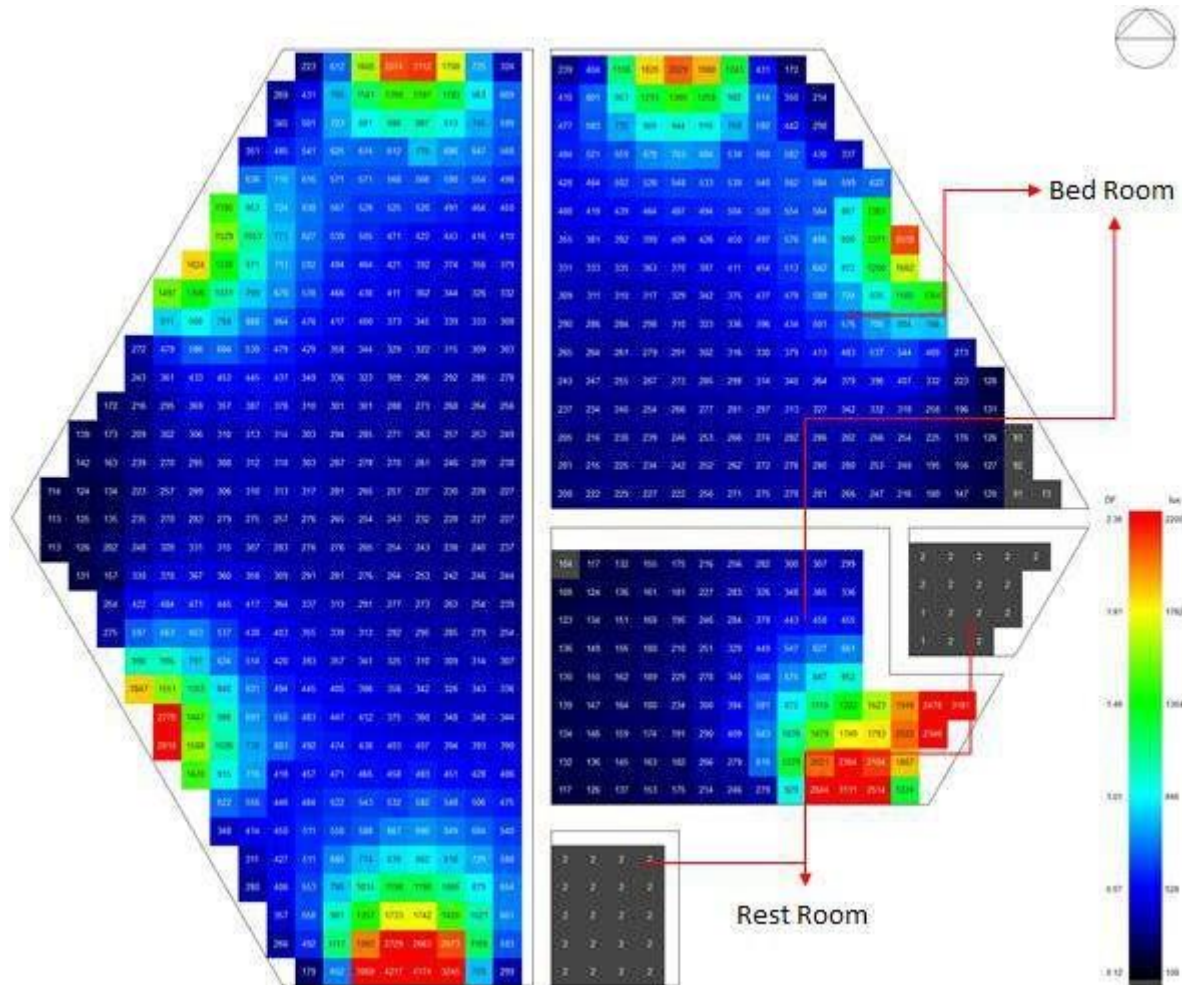
Thickness: **6mm** VLT – **0.54%** Internal Reflection – **21%**

External Reflection – **14%** SHGC value : **0.68%**

U – Value – **5.4 w/m²k**

Typolgy	Floor Area (m2)	Floor Area above Threshold (m2)	Floor Area above Threshold (%)
Living Kitchen and Dining	38.182	38.182	100
Bedroom	20.805	20.52	98.63
Total	58.987	58.702	99.315

MIG – DAYLIGHT ANALYSIS



Simulation Approach

At Sep 21 – 12 Pm (Equinox)

Threshold

Minimum Lux – 110 Lux

Maximum Lux – 2200 Lux

Window Wall Area – 17 %

Proposed Glass Details

Product Name: AIS Ecosense Enhance – Nimbus

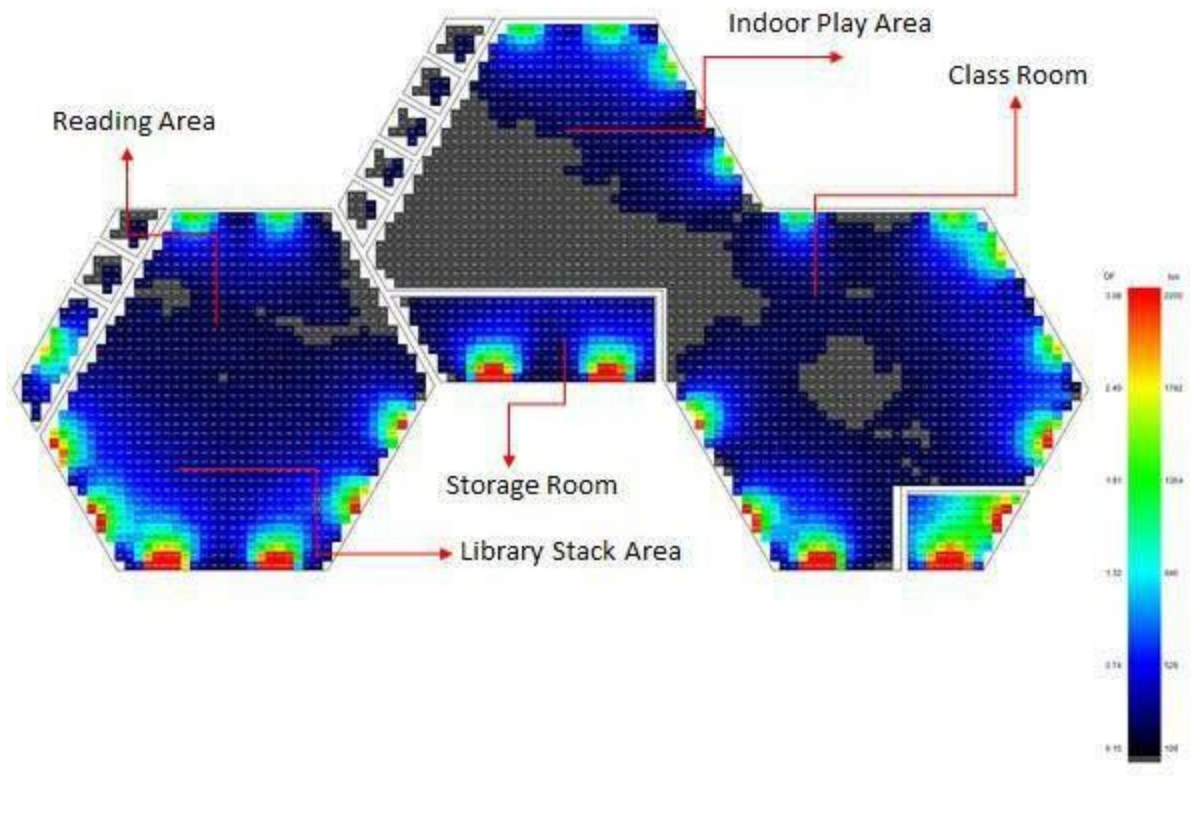
Thickness: **6mm** VLT – **0.54%** Internal Reflection – **21%**

External Reflection – **14%** SHGC value : **0.68%**

U – Value – **5.4 w/m²k**

Typology	Floor Area (m ²)	Floor Area above Threshold (m ²)	Floor Area above Threshold (%)
Living Kitchen and Dining	41.861	41.861	100
Bedroom	12.325	11.747	95.313
Master Bedroom	21.785	21.202	97.321
Total	75.971	74.81	97.54466667

PUBLIC AREA (LIBRARY AND DAY CARE) – DAYLIGHT ANALYSIS



Simulation Approach

At Sep 21 – 12 Pm (Equinox)

Threshold

Minimum Lux – 110 Lux

Maximum Lux – 2200 Lux

Window Wall Area – 31 %

Proposed Glass Details

Product Name: AIS Ecosense Enhance – Nimbus

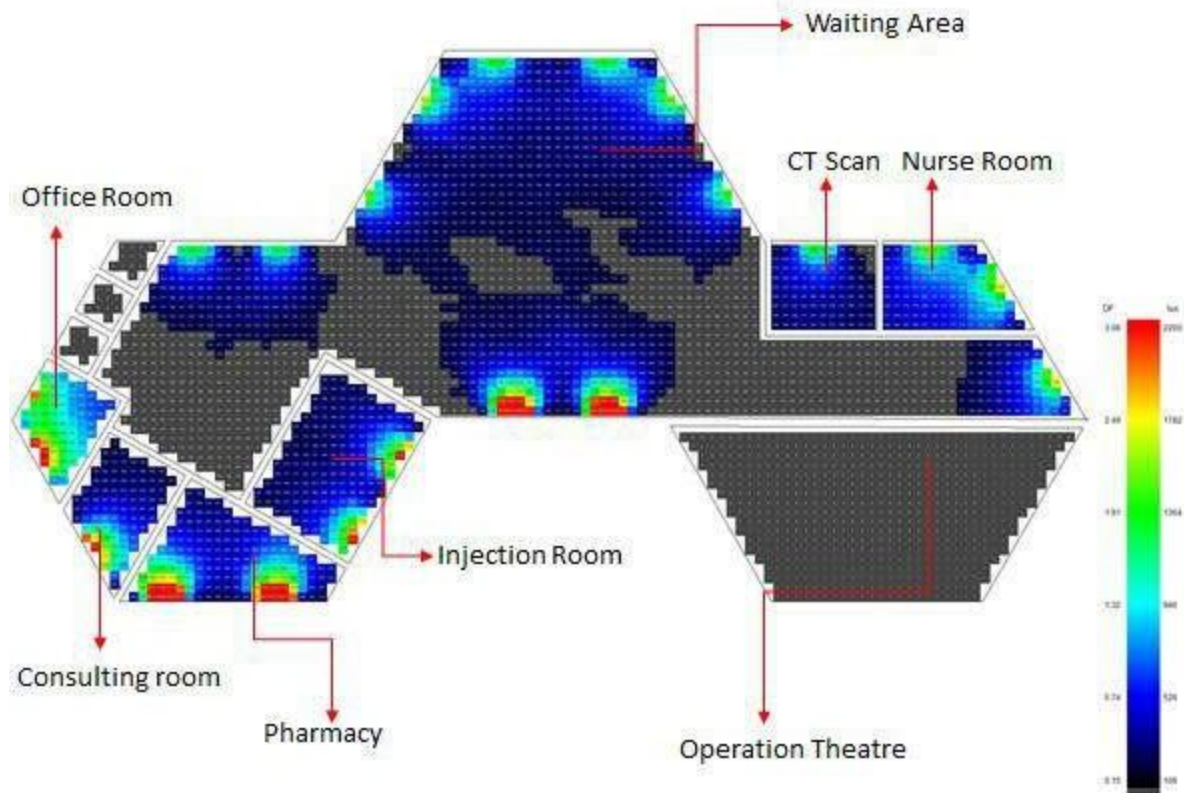
Thickness: **6mm** VLT – **0.54%** Internal Reflection – **21%**

External Reflection – **14%** SHGC value : **0.68%**

U – Value – **5.4 w/m²k**

Day Care			
Zone	Floor Area (m ²)	Floor Area above Threshold (m ²)	Floor Area above Threshold (%)
Classroom and Play area	192.084	133.391	69.444
Staff Room	5.48	5.48	100
Stoarge Room	20.937	19.99	95.475
Total	218.501	158.861	88.30633333
Library			
Library	105.41	99.586	94.475
Stoarge Room	7.866	7.457	94.805
Total	113.276	107.043	94.64

PUBLIC AREA (PRIMARY HEALTH CARE CENTRE) – DAYLIGHT ANALYSIS



Simulation Approach

At Sep 21 – 12 Pm (Equinox)

Threshold

Minimum Lux – 110 Lux

Maximum Lux – 2200 Lux

Window Wall Area – 21 %

Proposed Glass Details

Product Name: AIS Ecosense Enhance – Nimbus

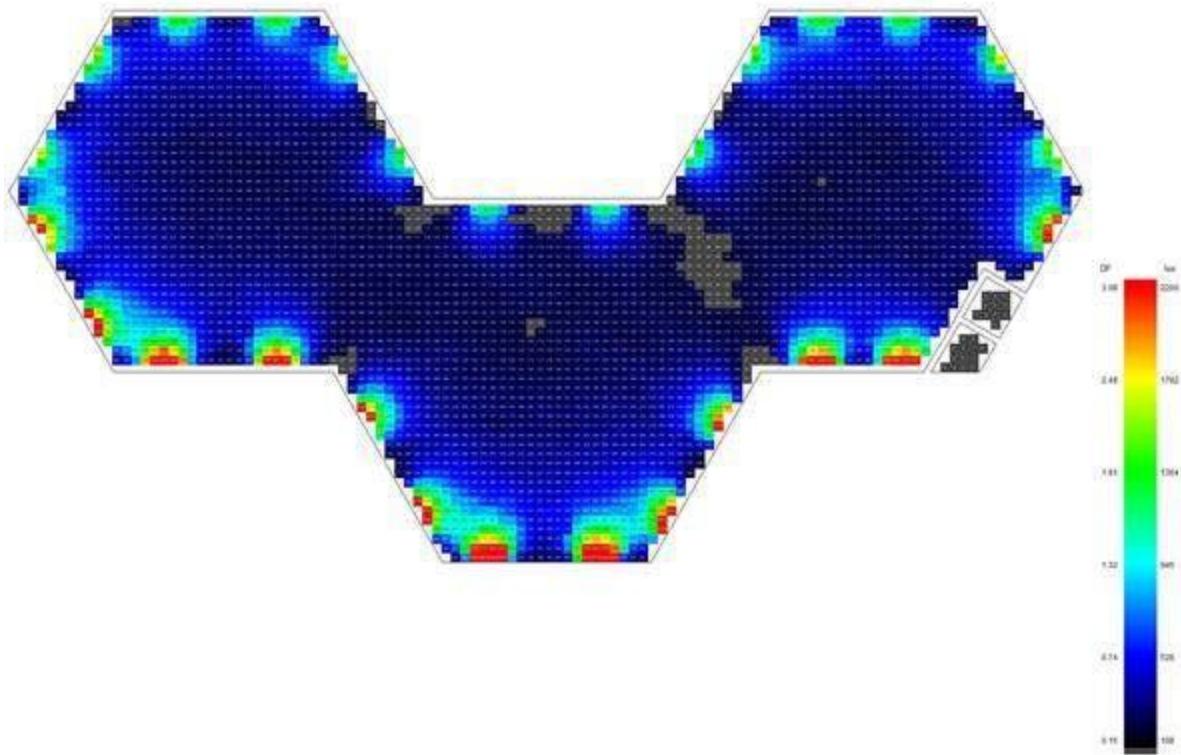
Thickness: **6mm** VLT – **0.54%** Internal Reflection – **21%**

External Reflection – **14%** SHGC value : **0.68%**

U – Value – **5.4 w/m²k**

Typology	Floor Area (m ²)	Floor Area above Threshold (m ²)	Floor Area above Threshold (%)
Waiting Area	204.595	120.805	59.046
CT Scan Room	9.593	9.206	95.96
Office Room	11.407	11.407	100
Injection Room	20.183	20.183	100
Consulting Room	8.215	8.215	100
Nursing Room	10.411	10.411	100
Pharmacy	16.444	15.72	95.597
Total	280.848	195.947	92.94328571

PUBLIC AREA (MULTI PURPOSE HALL) – DAYLIGHT ANALYSIS



Simulation Approach

At Sep 21 – 12 Pm (Equinox)

Threshold

Minimum Lux – 110 Lux

Maximum Lux – 2200 Lux

Window Wall Area – 34 %

Proposed Glass Details

Product Name: AIS Ecosense Enhance – Nimbus

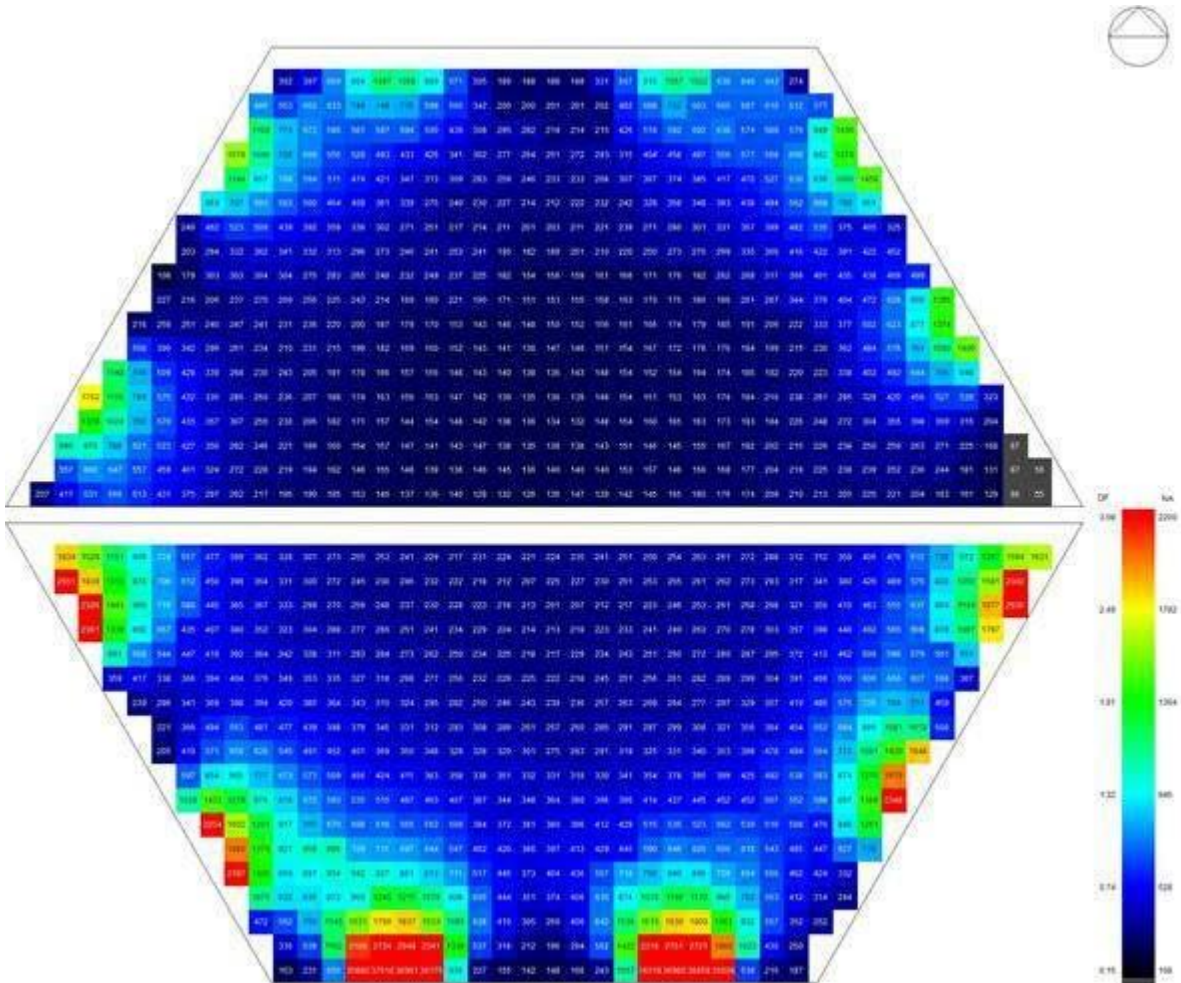
Thickness: **6mm** VLT – **0.54%** Internal Reflection – **21%**

External Reflection – **14%** SHGC value : **0.68%**

U – Value – **5.4 w/m²k**

Typology	Floor Area (m ²)	Floor Area above Threshold (m ²)	Floor Area above Threshold (%)
Multi Purpose Hall	349.611	338.486	96.818

PUBLIC AREA (RETAIL) – DAYLIGHT ANALYSIS



Simulation Approach

At Sep 21 – 12 Pm (Equinox)

Threshold

Minimum Lux – 110 Lux

Maximum Lux – 2200 Lux

Window Wall Area – 32 %

Proposed Glass Details

Product Name: AIS Ecosense Enhance – Nimbus

Thickness: **6mm** VLT – **0.54%** Internal Reflection – **21%**

External Reflection – **14%** SHGC value : **0.68%**

U – Value – **5.4 w/m²k**

Zone	Floor Area (m ²)	Floor Area above Threshold (m ²)	Floor Area above Threshold (%)
Saloon	56.725	56.237	99.139
Vegatable Shop	56.725	55.919	98.579
	113.45	112.156	98.859

25.5.2. CREDIT 2 FRESH AIR VENTILATION– POINT 2

Intent: Avoid indoor pollutants by providing adequate outdoor air ventilation, thereby enhancing the indoor environment quality

Requirements:

Provide openable windows or doors and ventilators to the exteriors in all regularly occupied spaces of each dwelling unit such that the openable area is designed as outlined in the table below

- 50% - **1 points**
- 75% - **2 points**

Space type	Net Openable area as a percentage: of total carpet area*	$\frac{\text{Openable area}}{\text{Total carpet area}} \times 100$
Living Spaces	10%	
Kitchen	8%	
Bathrooms*	4%	

Benefits Anticipated:

1. Enhances indoor air quality
2. Improves quality of life
3. Good health and wellbeing of the occupants

EWS															
Regularly Occupied Spaces	Total Floor Area (Carpet) (Sq.m)	Window type 1	Window type 2	Wooden Doors	Wooden Doors	Operable Window 1 Area	Operable Window 2 Area	Operable Woodern Door Area	Operable Wooden Door Area	Total Operable area	Opening to carpet area ratio	Mandatory Requirement to Meet credit point - Fresh Air	Credit Requirement to Meet credit point	Does it meet MR for Fresh Air	Does it meet CR for Fresh Air
Living,Dining and Kitchen	56.21	W*5	W1	D	D1	8.10	0.97	0.00	0.00	9.07	16.14%	10.00%	10.00%	Yes	Yes

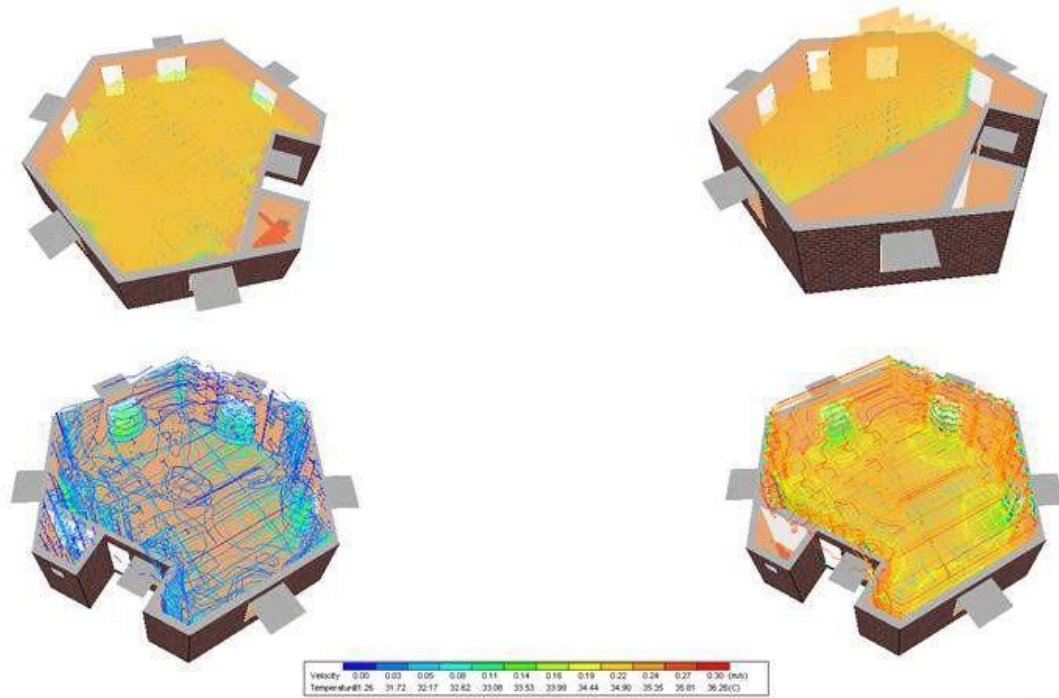
LIO															
Regularly Occupied Spaces	Total Floor Area (Carpet) (Sq.m)	Window type 1	Window type 2	Wooden Doors	Wooden Doors	Operable Window 1 Area	Operable Window 2 Area	Operable Woodern Door Area	Operable Wooden Door Area	Total Operable area	Opening to carpet area ratio	Mandatory Requirement to Meet credit point - Fresh Air	Credit Requirement to Meet credit point	Does it meet MR for Fresh Air	Does it meet CR for Fresh Air
Living	15.51	W*2		D		3.24		0.00	0.00	3.24	20.89%	10.00%	10.00%	Yes	Yes
Kitchen and dining	24.33	W*2	W1		D1	3.24	0.97	0.00	0.00	4.21	17.31%	10.00%	10.00%	Yes	Yes
Bedroom	21.11	W*2				3.24		0.00	0.00	3.24	15.35%	10.00%	10.00%	Yes	Yes

MIO															
Regularly Occupied Spaces	Total Floor Area (Carpet) (Sq.m)	Window type 1	Window type 2	Wooden Doors	Wooden Doors	Operable Window 1 Area	Operable Window 2 Area	Operable Woodern Door Area	Operable Wooden Door Area	Total Operable area	Opening to carpet area ratio	Mandatory Requirement to Meet credit point - Fresh Air	Credit Requirement to Meet credit point	Does it meet MR for Fresh Air	Does it meet CR for Fresh Air
Living Room	21.71	W*2		D		3.24		0.00	0.00	3.24	14.93%	10.00%	10.00%	Yes	Yes
Kitchen and Dining	21.81	W*2				3.24		0.00	0.00	3.24	14.85%	10.00%	10.00%	Yes	Yes
Master Bedroom	22.07	W*2				3.24		0.00	0.00	3.24	14.68%	10.00%	10.00%	Yes	Yes
Bedroom 1	13.04	W	W1		D1	1.62	0.97	0.00	0.00	2.59	19.88%	10.00%	10.00%	Yes	Yes

PUBLIC AREA															
Regularly Occupied Spaces	Total Floor Area (Carpet) (Sq.m)	Window type 1	Window type 2	Wooden Doors	Wooden Doors	Operable Window 1 Area	Operable Window 2 Area	Operable Woodern Door Area	Operable Wooden Door Area	Total Operable area	Opening to carpet area ratio	Mandatory Requirement to Meet credit point - Fresh Air	Credit Requirement to Meet credit point	Does it meet MR for Fresh Air	Does it meet CR for Fresh Air
Library	110.51	W*8		D2		12.96		0.00	0.00	12.96	11.73%	10.00%	10.00%	Yes	Yes
Primary Health Care	276.96	W*21		D2		34.02	0.00	0.00	0.00	34.02	12.28%	10.00%	10.00%	Yes	Yes
Day Care	211.17	W*16		D2		25.92	0.00	0.00	0.00	25.92	12.27%	10.00%	10.00%	Yes	Yes
Multi Purpose Hall	365.98	W*27	W1	D2*2	D1	43.74	0.00	0.00	0.00	43.74	11.95%	10.00%	10.00%	Yes	Yes
Kloeks	246.28	W*20	W1	D2*4	D1	32.40	0.00	0.00	0.00	32.40	13.16%	10.00%	10.00%	Yes	Yes

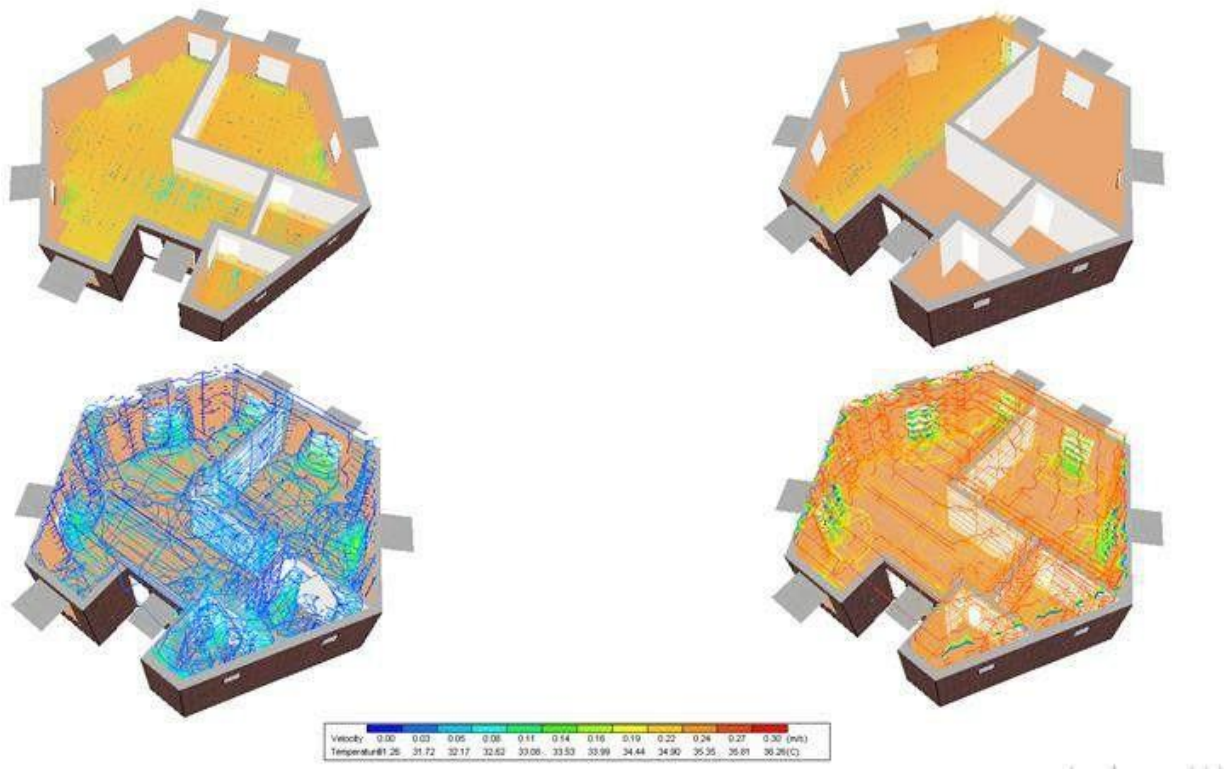
EWS – INTERNAL CFD ANALYSIS

Velocity vs. Temperature



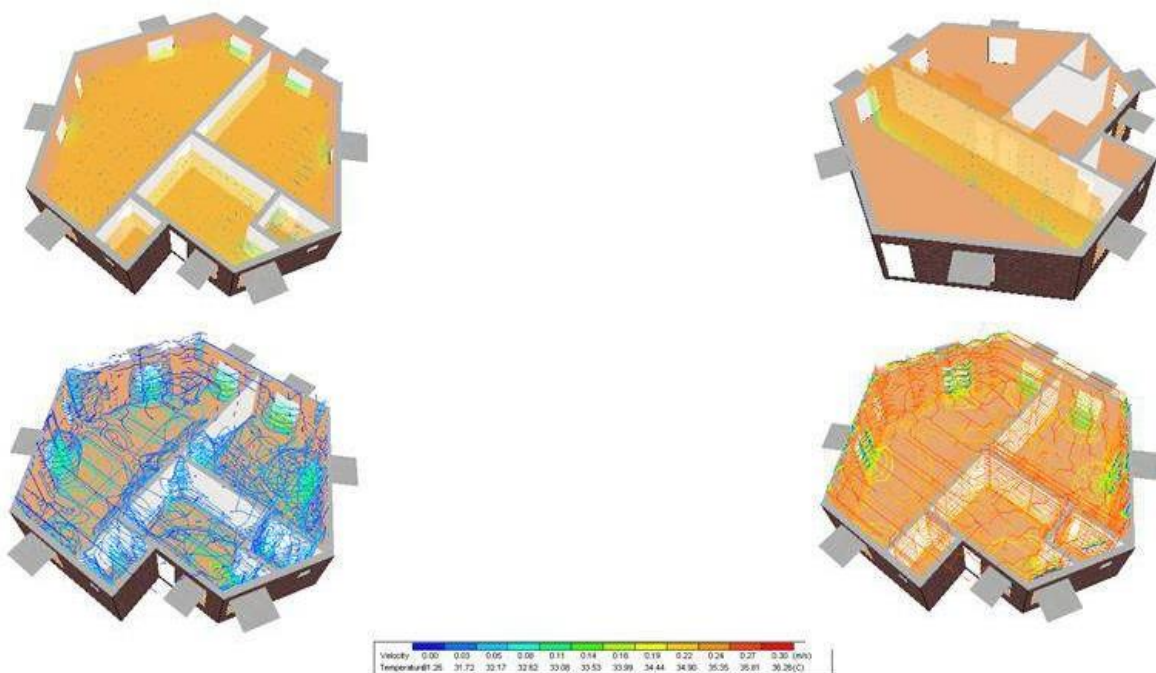
LIG – INTERNAL CFD ANALYSIS

Velocity vs. Temperature



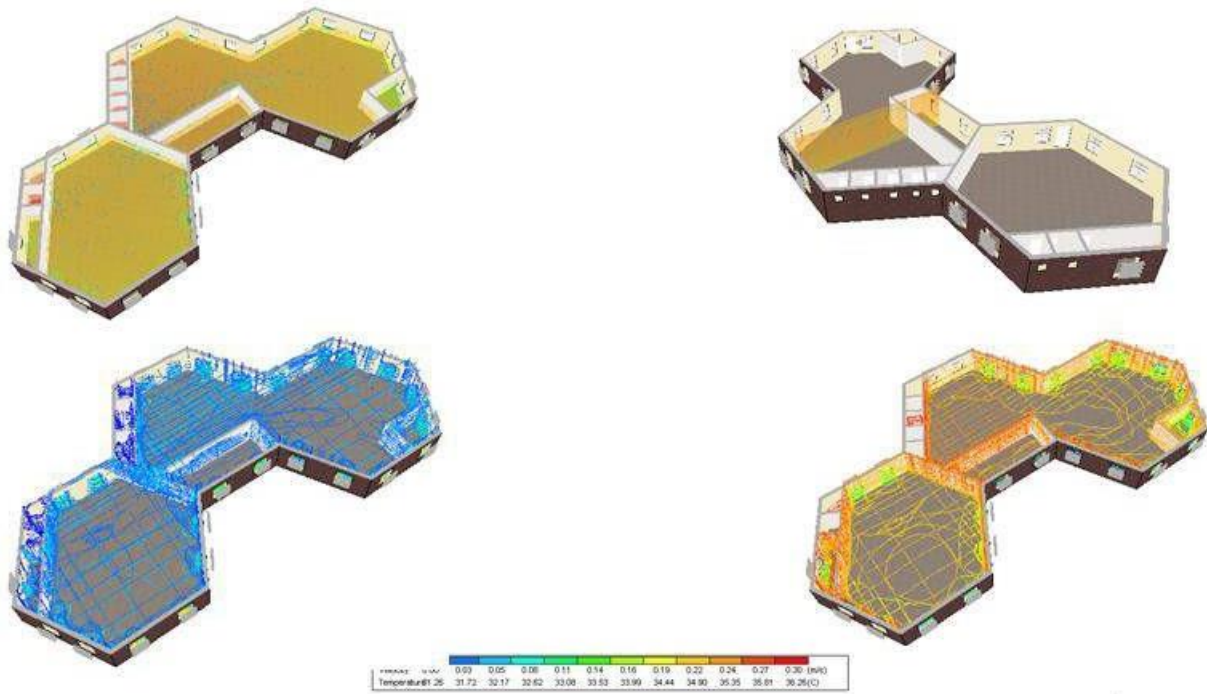
MIG – INTERNAL CFD ANALYSIS

Velocity vs. Temperature



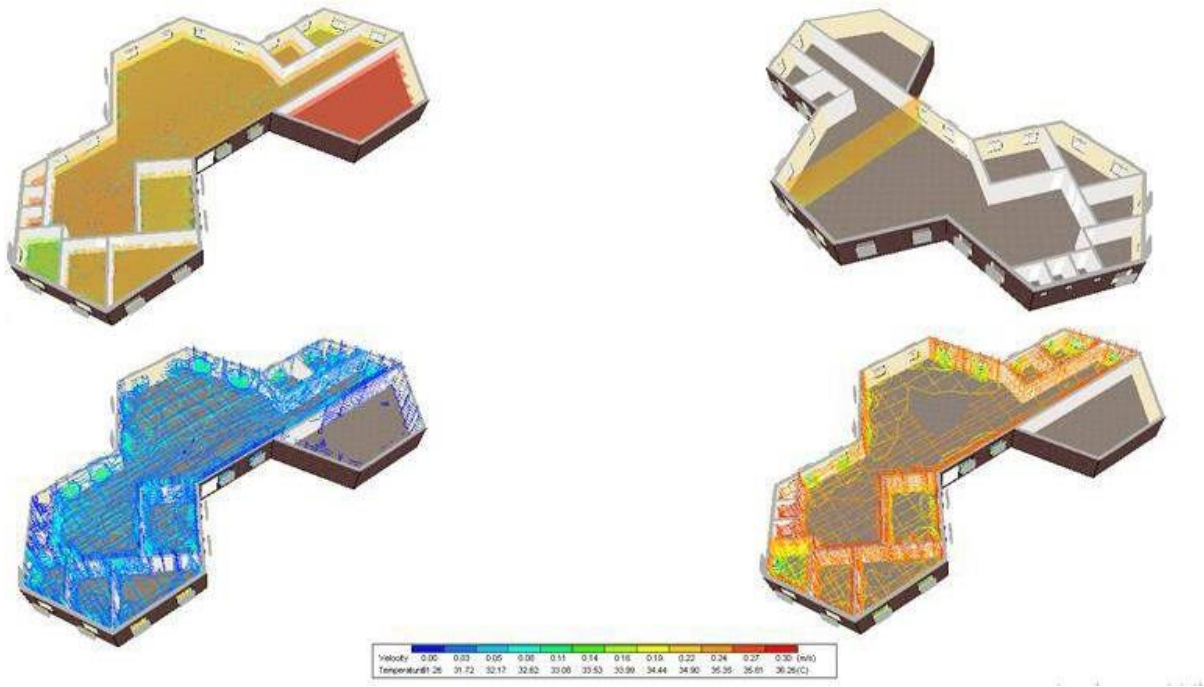
PUBLIC AREA (LIBRARY AND DAY CARE) – INTERNAL CFD ANALYSIS

Velocity vs. Temperature



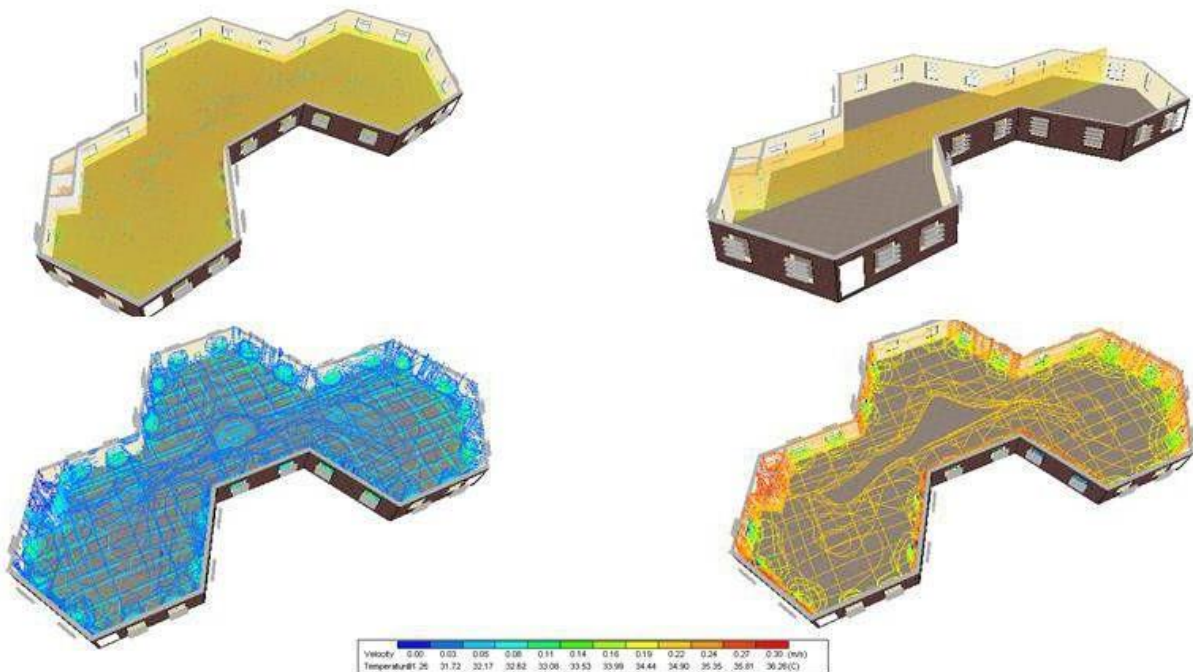
PUBLIC AREA (PRIMARY HEALTH CARE CENTER) – INTERNAL CFD ANALYSIS

Velocity vs. Temperature



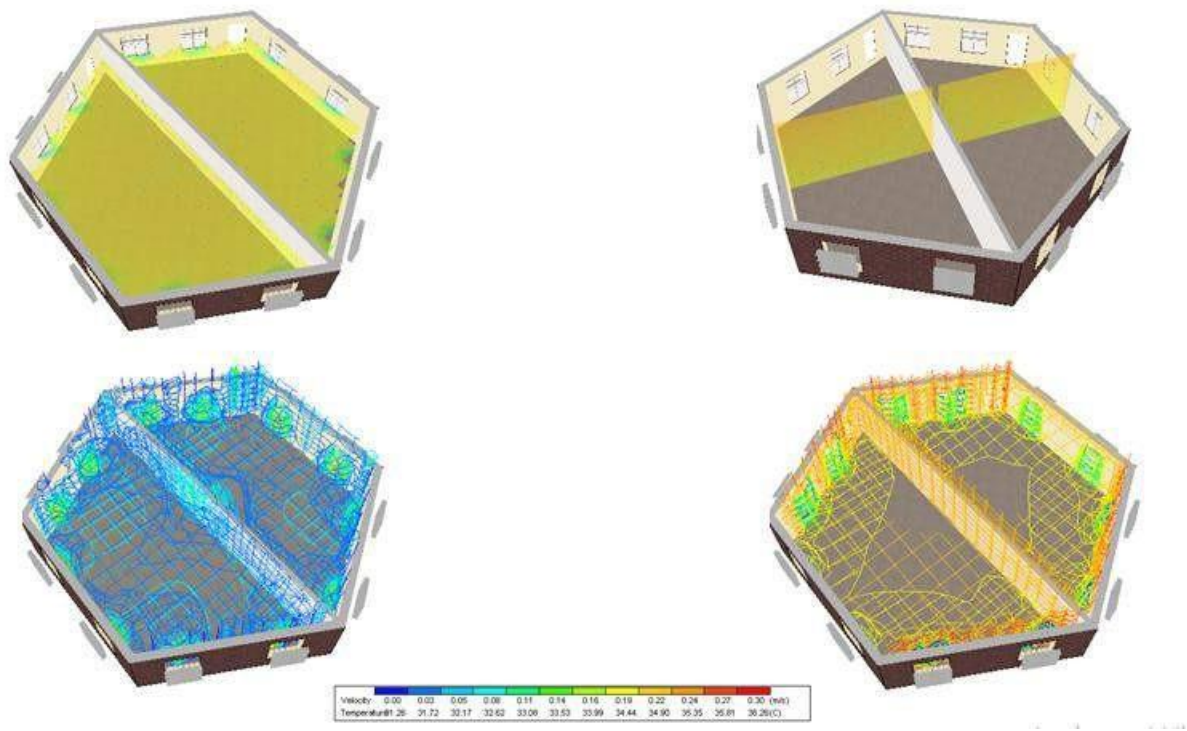
PUBLIC AREA (MULTI PURPOSE HALL) – INTERNAL CFD ANALYSIS

Velocity vs. Temperature

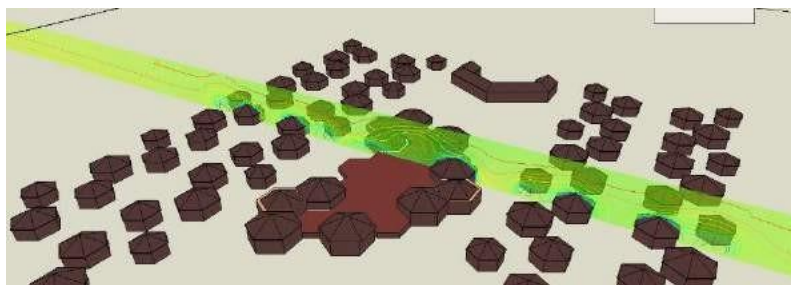
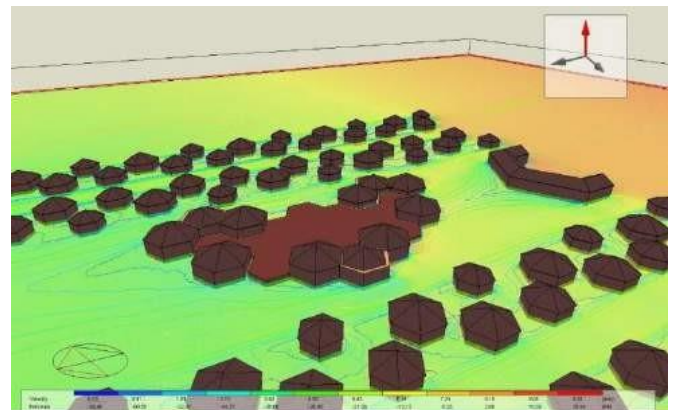
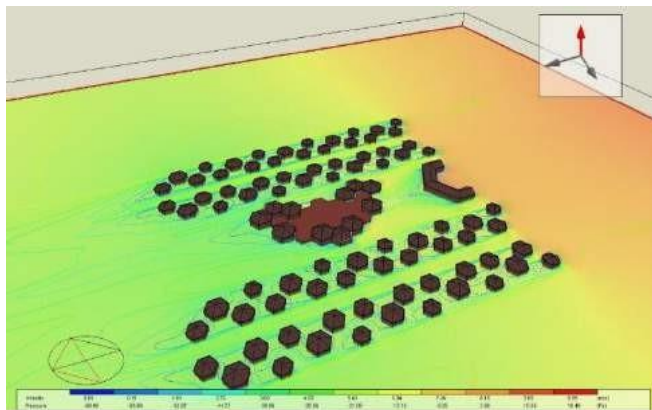
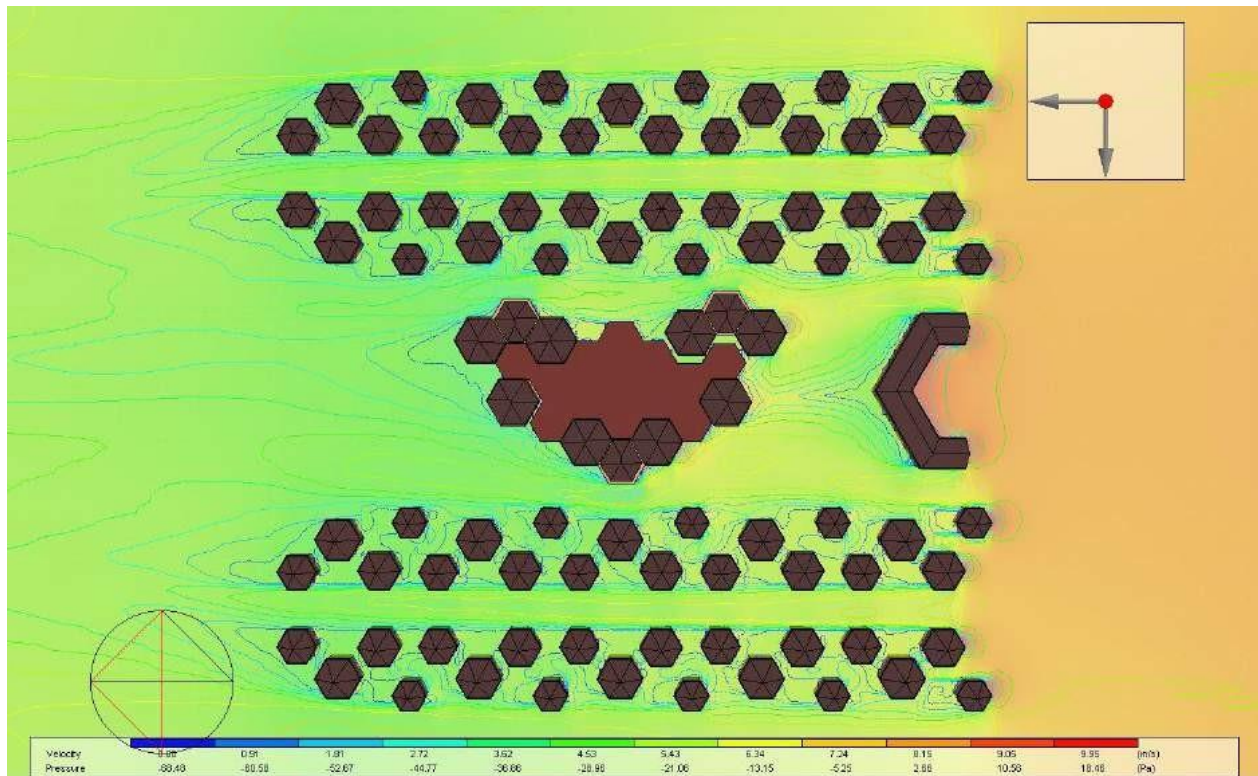


PUBLIC AREA (RETAIL) – INTERNAL CFD ANALYSIS

Velocity vs. Temperature



EXTERNAL CFD ANALYSIS



Simulation Approach

Wind Direction – East 9m/s

Sub Urban

25.5.3. CREDIT 3 CROSS VENTILATION– POINT 2

Intent: Encourage adequate cross ventilation in the design thereby, providing a healthy environment.

Requirements:

Provide openable doors / windows / ventilators to the exteriors in all regularly occupied spaces of each dwelling unit in at least two of the orientations.

- 50% - **1 points**
- 75% - **2 points**

Notes:

- *Regularly occupied spaces include living room, bed room, dining room, study room, kitchen.*
- *The windows/ ventilators should not have any obstruction within 2 m from outside surface.*
- *The openings considered should meet IEQ Credit 2.*
- *Regularly occupied spaces with an opening to the outdoors only in one orientation can also be considered for calculations, if there is a permanent opening to the adjoining room which meets cross ventilation criteria*

Benefits Anticipated:

1. Enables good circulation of fresh air
2. Flushes out contaminants and provide a better indoor environment

Cross Ventilation - EWS				
Regularly Occupied spaces				
Regularly Occupied Spaces	Total Floor Area (Carpet) (Sq.M)	Window/Door type	Satisfies Cross Ventilation Criteria	Area Which Satisfies Cross Ventilation Criteria
Living,Dining and Kitchen	56.21	W,W1.D,D1	Yes	56.21

Total Floor Area	56.21
Floor area achieving Cross Ventilation	56.21
Total Achieved %	100%

Cross Ventilation - LIG				
Regularly Occupied spaces				
Regularly Occupied Spaces	Total Floor Area (Carpet) (Sq.M)	Window/Door type	Satisfies Cross Ventilation Criteria	Area Which Satisfies Cross Ventilation Criteria
Living	15.51	W,W	YES	15.51
Kitchen and Dining	24.33	W,D	YES	24.33
Bedroom	21.11	W,W	YES	21.11

Total Floor Area	60.95
Floor area achieving Cross Ventilation	60.95
Total Achieved %	100%

Cross Ventilation - MIG				
Regularly Occupied spaces				
Regularly Occupied Spaces	Total Floor Area (Carpet) (Sq.M)	Window/Door type	Satisfies Cross Ventilation Criteria	Area Which Satisfies Cross Ventilation Criteria
Living	21.71	W,W	YES	21.71
Kitchen and Dining	21.81	W,W,D	YES	21.81
Bedroom	13.04	W,W	YES	13.04
Master Bedroom	22.07	W,W1,D1	Yes	22.07

Total Floor Area	78.63
Floor area achieving Cross Ventilation	78.63
Total Achieved %	100%

25.5.4. CREDIT 4 EXHAUST SYSTEMS – POINT 2

Intent: Ensure that bathrooms and kitchen are adequately ventilated, so as to improve the quality of the indoor environment

Requirements:

Design exhausts systems in bathrooms as per the requirements provided in the table below:

Location	Floor Area	Minimum Airflow
Bathroom	≤ 4.64 sq.m (50 sq.ft)	50 cfm
Kitchen	≤ 9.3 sq.m (100 sq.ft)	100 cfm

- *Mechanical Exhaust system: (1 point)*
- *Ventilators or openings above lintel level: (1 point) . Incorporated with mesh to keep insects out*

Kitchen Exhaust Vent Details
 Product Company : Urban king
 Cfm : 120
 Rate : 1050
 Item Weight : 2900 Grams
 Wattage : 60W



Bathroom Exhaust Vent Details
 Product Company : DIGISMART
 Cfm : 55
 Rate : 720
 Item Weight : 720 Grams
 Wattage : 45W



Possible Point IGBC: 2points

Achieved Point: 2points

25.5.5. CREDIT 5 LOW VOC MATERIALS, PAINTS & ADHESIVES— POINT 2

Intent: Encourage use of materials with low emissions so as to reduce adverse health impacts on building occupants

Requirements:

Use low VOC paints, sealants and adhesives to reduce adverse health impacts on building occupants.

Use lime based surface treatments / Low VOC paints (1 point)

(AND / OR)

For adhesives and sealants used within the interiors, ensure that the VOC content does not exceed the limits as specified in the table below (1 point)

Benefits Anticipated:

1. Reduces impact on health of occupants
2. Eliminates sick building syndrome.

Type of material	VOC Limit (g/L less water)
Paints:	
Non-flat (Glossy) paints	150
Flat (Mat) paints	50
Anti-corrosive/ anti-rust paints	250
Varnish	350
Adhesives:	
Glazing adhesive	100
Tile adhesives	65
Wood adhesive	30
Wood flooring adhesive	100

Declaration: Material selection is based on the low VOC Limits.

Possible Point IGBC: 2points

Achieved Point: 2points

25.5.6. CREDIT 6 OCCUPANT WELL-BEING FACILITIES– POINT 1

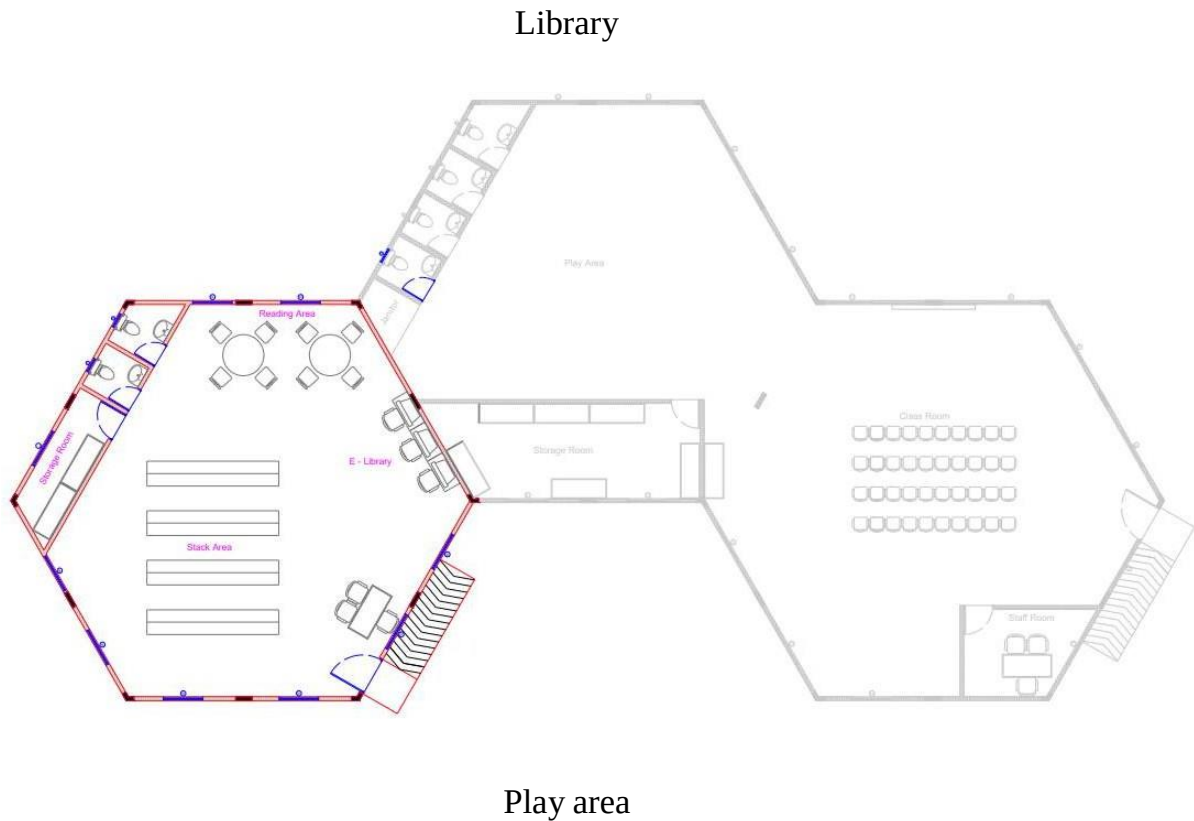
Intent: Provide occupant well-being facilities, so as to enhance physical, emotional and spiritual well-being of building occupants

Requirements:

Demonstrate that the project has community well-being facilities of appropriate size (such as yoga/ meditation room/ reading room or any gathering space and common seating spaces)

Benefits Anticipated:

1. Enhance social connectivity
2. Promote health & wellbeing



Possible Point IGBC: 1points

Achieved Point: 1points

25.6. INNOVATION & DESIGN PROCESS

25.6.1. CREDIT 1 INNOVATIVE PRACTICES– POINT 2

Intent: Provide design teams and projects an opportunity to attempt for innovative performance in green building categories not specifically addressed by the IGBC Green Affordable Housing Rating System

Requirements:

Credit 1.1: Innovative practices (1 point for each of the credits; maximum 2 points)

The projects can also identify the innovation strategies those are not addressed by any existing credits in the rating system. Identify the intent of the proposed innovation credit, to achieve significant, measurable environmental performance requirements for compliance of the credit.

Credit 1.2: Innovative practices Same as credit 1.1

Benefits Anticipated:

1. Leads to more sustainable design/ practices thereby benefiting the environment

Declaration: The proposal will address innovative solution for flood and earthquake by using different construction technique.

Possible Point IGBC: 2points

Achieved Point: 2points

25.6.2. CREDIT 2 EXEMPLARY PERFORMANCE– POINT 2

Intent: Exemplary performance strategies result in performances that greatly exceed the performance level or expand the scope required by an existing Green Affordable Housing credit. To earn exemplary performance credits, teams must meet the performance level defined by the next step in the threshold progression. For credits with more than 1 compliance path, an Innovation and Design Process point can be earned by satisfying more than 1 compliance path if their benefits are additive

Requirements:

Credit 2.1: Exemplary Performance (1 point for each of the credits; maximum 2 points)

Identify the intent of the proposed Exemplary Performance credit, the proposed requirement for compliance and the proposed documentation to demonstrate compliance and the design approach used to meet the required measures.

Credit 2.2: Exemplary Performance Same as credit 2.1

Benefits Anticipated:

1. Leads to more sustainable design/ practices thereby benefiting the environment

Case 1: Exemplary Performance: The project team may earn an Innovation and Design Process credit point (for exemplary performance) by **showing 40%** or above of the site as Green Cover (existing vegetation/ landscaped area/ roof gardens) post construction

Spaces	Area Sq.m	Percentage
Total Landscape Area	22829.0663	100%
Case 1:		
Turf Area	1200	5%
Case 2:		
Plant Area (Native Species)	5945	26%
Tree Area (Native Species)	15684.0663	69%
Summary		
Total Site Area	56276.9111	100%
Total Landscape Area	22829.0663	41%

Required Percentage: 40%

Achieved Percentage: 41%

Case 2:

Exemplary Performance: The project team may earn an Innovation and Design Process credit point for exemplary performance by installing on-site waste treatment systems to treat at least 90% of the organic waste generated and reuse them for landscaping needs.

Organic Waste					
Organic Waste per day per head (kg)	No . Of occupants	Total organic waste (Kg)	Safety Factor	Total Kg	Area Required Cu.m
0.25	220	55	2.5	137.5	1.146
			Proposed Area cu.m		2
			Total Percentage Achieved		175%

Required Percentage: 90%

Achieved Percentage: 175%

Case 3:

This credit is eligible for exemplary performance under ID Credit 2 - Exemplary Performance, if rainwater run-off from roof & non-roof areas is captured and/ or recharged, as listed below

Sl.No.	Average Peak Month Rainfall (in mm)	One-day Rainfall (% of Average Peak Month Rainfall)	
		Case A	Case B
1.	Upto 250	24%	18%
2.	251 – 350	20%	15%
3.	351 – 500	16%	12%
4.	501 – 700	12%	9%
5.	701 & above	8%	6%

SITE RAINFALL CALCULATION				
Run- off Calculation				
S.No.	Zone	Area (sq.m.)	Run- off Coefficient	Impervious Area (sq. m.)
1	Cemented Roof	9286.57	0.80	7429.3
2	Vegetation	22829.07	0.20	4565.8
3	Hardscape (Pathways/ Driveways)	12556.61	0.95	11928.8
4	Open Area (Inside, Outside and Utility area)	6251.00	0.20	1250.2
Net Impervious Area				25174.0
Rainfall Intensity (m/ day) considering 24%of average peak rainfall (2 point)				0.058
Total Run- off Volume (Cu.m.)				1457.64

Possible Point IGBC: 2points

Achieved Point: 2points

25.6.3. CREDIT 3 IGBC ACCREDITED PROFESSIONAL– POINT 1

Intent: Support and encourage involvement of IGBC Accredited Professional in green affordable housing projects, so as to integrate appropriate design measures and streamline certification process

Requirements:

At least one principal participant of the project team shall be an IGBC Accredited Professional

Benefits Anticipated:

1. Hand holding the project team in designing green buildings.
2. Impart knowledge to other team members about green buildings

Possible Point IGBC: 1points

Achieved Point: 1points

25.7. CHECKLIST AFFORDABLE HOUSING VER2.0 – IGBC

Check List Affordable Housing Ver2.0 - IGBC			
Credit	Criteria	Points	Points Achieved
Site Measures (SM)		Possible Points: 16	
SM Mandatory Requirement 1	Local Building Regulations	Mandatory	
SM Mandatory Requirement 2	Site Selection	Mandatory	
SM Credit 1	Proximity to Public Transport	1	0
SM Credit 2	Top Soil Preservation	2	2
SM Credit 3	Access to Social Infrastructure	2	2
SM Credit 4	Green Cover on-site	2	2
SM Credit 5	Heat Island effect-Non Roof	2	2
SM Credit 6	Heat Island effect-Roof	2	2
SM Credit 7	Parking Facilities for Tenements	1	0
SM Credit 8	Design For differently abled	2	0
SM Credit 9	Basic Facilities for construction workforce	2	2
	Sub Total	16	12
Water Conservation (WC)		Possible Points: 15	
WC Credit 1	Availability of Potable Water	1	1
WC Credit 2	Rainwater Harvesting	3	3
WC Credit 3	Water Efficient Plumbing Fixtures	3	3
WC Credit 4	Waste water treatment	3	3
WC Credit 5	Treated waste water Reuse	2	2
WC Credit 6	Management of Irrigation Systems	2	2
WC Credit 7	Water meters for dwelling units	1	1
	Sub Total	15	15

Check List Affordable Housing Ver2.0 - IGBC			
Credit	Criteria	Points	Points Achieved
Energy Conservation (EC)		Possible Points:	12
EC Credit 1	Energy Efficient Building Envelope	4	4
EC Credit 2	Shading Elements for Building Openings	2	2
EC Credit 3	Efficient Lighting	2	2
EC Credit 4	On-site Renewable Energy	2	2
EC Credit 5	Energy Saving Measures in Appliances & other Equipment	2	2
Sub Total		12	12
Material Conservation (MC)		Possible Points:	16
MC Mandatory 1	Segregation of House-hold waste		Mandatory
MC Credit 1	Organic Waste Management	2	2
MC Credit 2	Handling of construction waste materials	2	2
MC Credit 3	Use of local Materials	3	3
MC Credit 4	Material with Recycled content	3	3
MC Credit 5	Appropriate Technologies	4	4
MC Credit 6	Alternate Construction Materials	2	1
Sub Total		16	14
Indoor Environment Quality (IEQ)		Possible Points:	12
IEQ Mandatory 1	Tobacco Smoke Control		Mandatory
IAQ Credit 1	Day Lighting	2	2
IAQ Credit 2	Fresh air ventilation	2	2
IAQ Credit 3	Cross Ventilation	2	2
IAQ Credit 4	Exhaust Systems	2	2
IAQ Credit 5	Low VOC Material, Paints & Adhesives	2	2
IAQ Credit 6	Occupant Well-being Facilities	1	1
Sub Total		11	11
Innovation & Design Process		Possible Points:	5
INN Credit 1.1	Innovation & Design Process	4	4
INN Credit 2	IGBC Accredited Professional	1	1
Sub Total		5	5
Total Available Points		75	70

Rating	Points
Certified	38 – 45
Silver	46 – 52
Gold	53 – 60
Platinum	61 – 75

Achieved Points: 70 Points

Award: IGBC Platinum



26.CHECKLIST AFFORDABLE HOUSING VER2015 – GRIHA

Check List Affordable Housing Ver2015 - GRIHA			
Credit	Criteria	Points	Points Achieved
Site Planning	Possible Points:	16	
SP Credit 1	Low Impact Design	6	4
SP Credit 2	Design to mitigate UHIE	3	3
SP Credit 3	Preservation and Protection of Landscape during Construction	3	3
SP Credit 4	Storm Water Management	2	2
SP Credit 5	Reduction in Air and Soil Pollution during Construction	2	2
	Sub Total	16	14
Energy & Occupant Comfort	Possible Points:	25	
EO Credit 1	Envelope Thermal Performance	8	8
EO Credit 2	Occupant Visual Comfort (Daylight)	5	5
EO Credit 3	Efficient Lighting	2	2
EO Credit 4	Energy Efficient Equipment	2	2
EO Credit 5	Renewable Energy	6	6
EO Credit 6	Energy Metering	2	2
	Sub Total	25	25
Water Savings	Possible Points:	19	
WS Credit 1	Efficient use of water during construction	2	2
WS Credit 2	Optimization of building & Landscape water demand	9	7
WS Credit 3	Water reuse	7	7
WS Credit 4	Water Metering	1	1
	Sub Total	19	17

Check List Affordable Housing Ver2015 - GRIHA			
Credit	Criteria	Points	Points Achieved
Waste Management	Possible Points:	7	
WM Credit 1	Construction waste management	1	1
WM Credit 2	Post construction waste management	6	4
	Sub Total	7	5
Sustainable Building Material	Possible Points:	17	
SBM Credit 1	Reduction in environmental impact of construction	Mantory	
SBM Credit 2	Use of low-environmental impact materials in building interiors	2	2
SBM Credit 3	Use of recycled content in roads and pavements	2	2
SBM Credit 4	Low VOC paints, adhesives, sealants and composite wood products	2	2
SBM Credit 5	Zero ODP materials	2	2
	Sub Total	12	8
Social Aspects	Possible Points:	16	
SA Credit 1	Facilities for Construction workers	1	1
SA Credit 2	Universal accessibility	2	
SA Credit 3	Proximity to Transport and Basic Services	10	4
SA Credit 4	Environmental awareness	2	2
SA Credit 5	Tobacco Smoke Control	Mantory	
SA Credit 6	Water Quality	Mantory	
SA Credit 7	Provision of access to clean sources of cooking fuel	1	1
	Bonus Point	4	4
	Sub Total	20	12
Total Available Points		104	81

Rating	Points
*	25 - 40
**	41 - 45
***	56 - 70
****	71 - 85
*****	86 - Above

Achieved Points: 81
Points Award: Four
Star Rating

27. ACHIEVEMENT OF PROPOSAL

- 1: ECBC Eco Nivas Residential
- 2: IGBC – Platinum
- 3: GRIHA – 4 0Star



“The Solution”

Thank You

“Climate Change is the reason”

“Save Trees Save Earth”

28. REFERENCES

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