



Residential Complex Environmental Performance Analysis

"Home Sweet Home" affordable housing project under Nagpur Smart City Mission

Nagpur Smart City Mission

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1 Executive Summary

In this report, the findings of the analysis performed for MIG, LIG and EWS housing for the Nagpur Smart City mission are presented. Following assessments have been conducted.

1. Solar Shading Analysis

Different combination of external shading devices i.e. angular fins and extended overhangs are analyzed in this report.

It was observed that during summer addition of angular fins and extended shading devices on east and west façade is essential to provide shading over the fenestration. Provision of additional shading devices show complete shading up to 3:00 pm throughout the year over the base case. The proposed shading assembly shows minimal solar exposure during peak summer months.

2. Daylight Analysis

Quality and quantum of daylight entering a space are analyzed in this report for LIG – MIG - EWS Housing Prototype.

It was observed that wall openings/ windows with Visible Light Transmittance (VLT) value of 0.65 or higher is required to meet the daylight factor threshold of 200 lux (2.5%) in occupied spaces like Kitchen and Living room.

3. Cross Ventilation Analysis

4. Access to Light Analysis

2 Introduction

2.1 Background

Under the Nagpur Smart City Mission, around 4000 affordable dwelling units are proposed to be built under the 'Home Sweet Home' project for 3 different income groups (Economically Weaker Section (EWS), Low Income Group (LIG) and Medium Income Group (MIG)). A total number of 1024 dwelling units are planned in the 1st phase of the project and will be built on a identified plot in the areas of Pardi, Bharatwada, Punapur and Bhandewadi, which come under the Area Based Development strategy of Nagpur's Smart City project.

The MIG housing consists of 2 tower with:

- Stilt parking – 2 levels
- Dwelling units – 12 levels

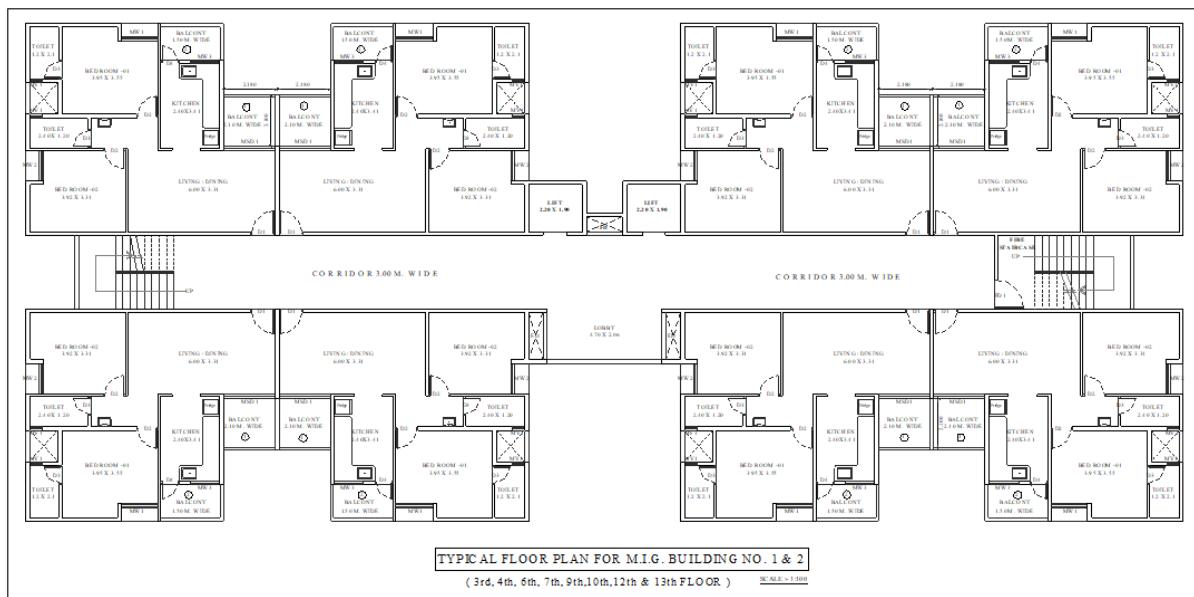


Figure 1 MIG Housing - Typical Floor Layout

3 Solar Shading Analysis

3.1 Methodology

The analysis has been performed for EWS and LIG block. Since the MIG and LIG blocks have similar floor plates, except for the floor area, solar shading analysis was conducted for the EWS and LIG housing block by modeling a typical floor plate on Ecotect based on the proposed design.

The proposed external shading devices in the form of angular fins and extended overhangs are proposed after performing analysis on ecotect and climate consultant software according to proposed design and its location.

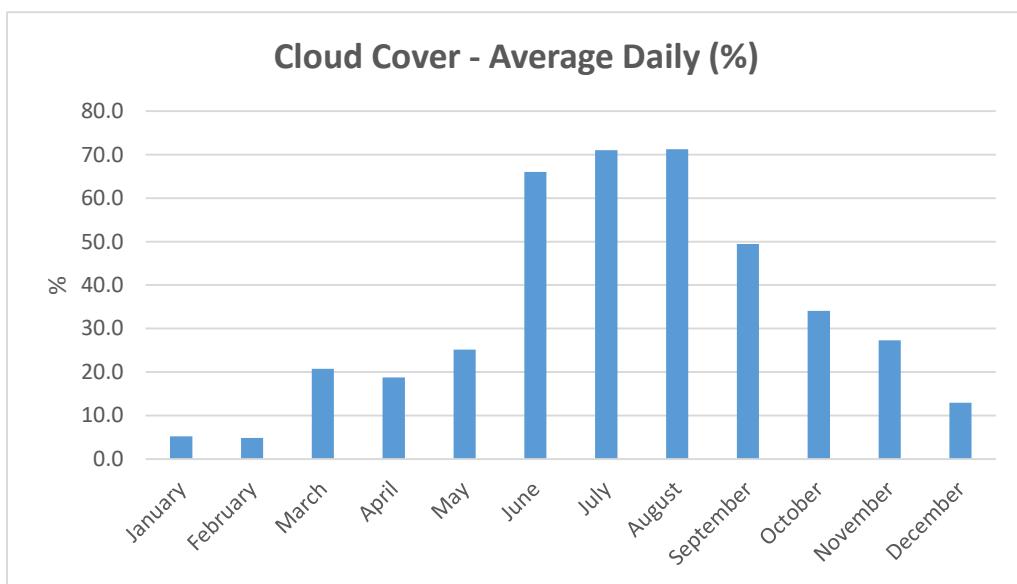
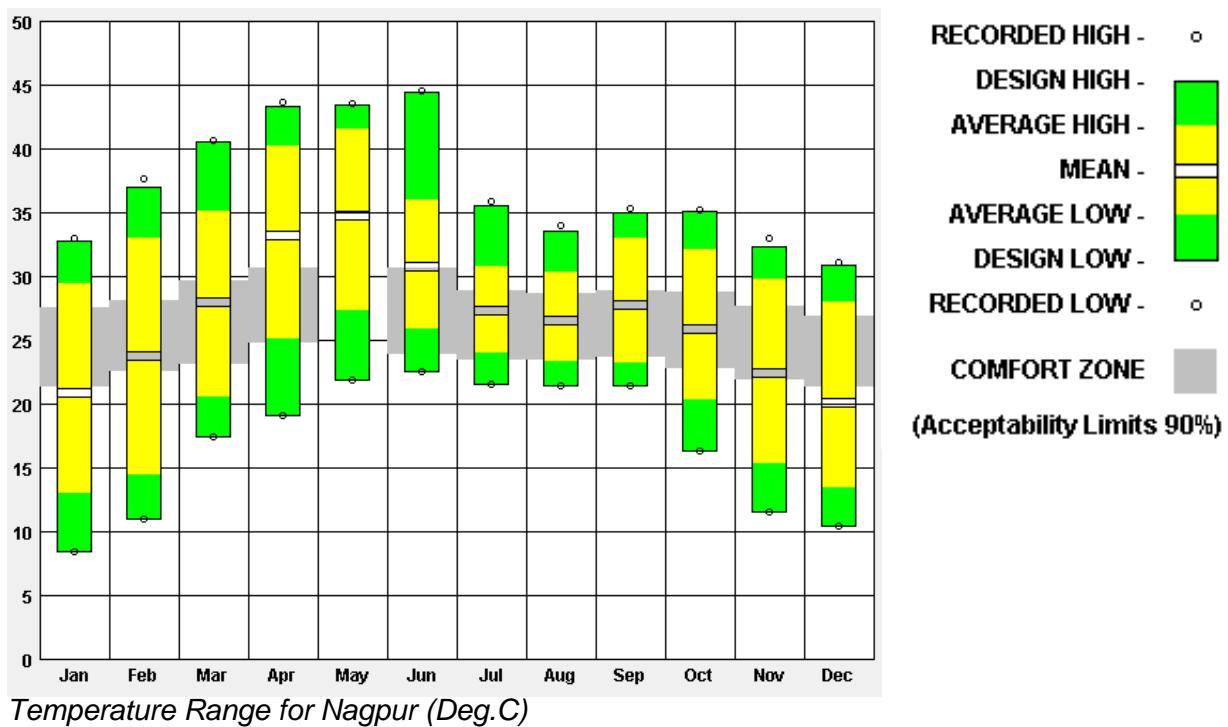
3.2 Solar Shading Analysis

The purpose of this analysis is to understand the impact of external shading devices in obstructing direct solar exposure in the proposed design during peak summer months and throughout the year. The shading devices were added on the building envelope and simulation was conducted on the dwelling units to assess the optimum combination of shading devices required for shading the building during peak summer months and throughout the year. This exercise was performed based on GRIHA's shading requirements. The shading analysis criteria are detailed below:

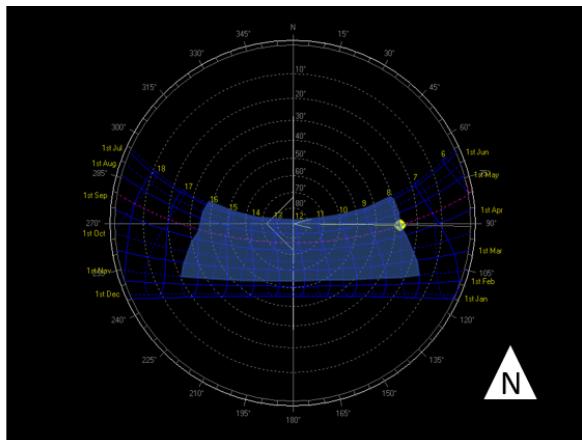
Shading Analysis Criteria:

Site Details	
Location	Nagpur (21.1° N, 79.1° E)
Climate Zone	Composite
Occupancy	Residential
No. of Floors	G + 13
Typical Residential Unit Area	75 sq.m

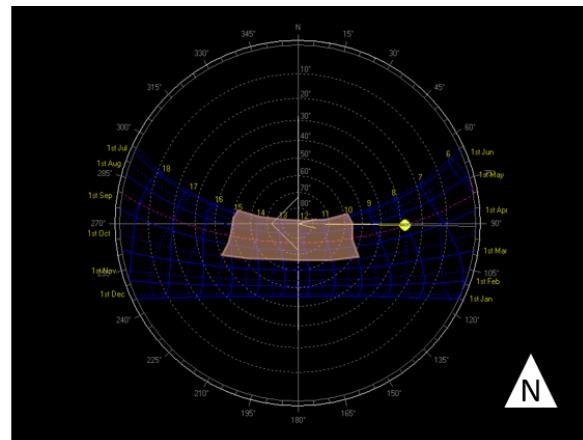
- **Period Analyzed for shading : 08:00 am to 04:00 pm - 1st March to 31st October (Months with higher average temperature range)**
- **GRIHA rating requirement for Shading:**
Complete shading over fenestration between 10:00 am to 03:00 pm – 1st April to 30th September
- **Daily Exposure period analyzed for West Façade - 12:00 pm to 4:00 pm**
- **Daily Exposure period analyzed for East Façade - 08:00 am to 12:00 pm**



Cloud Cover (%)

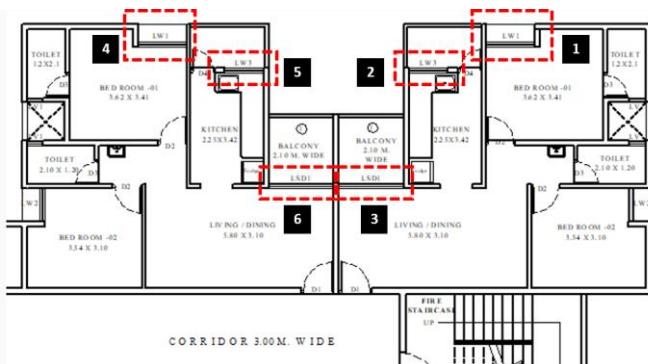


Analysis Range – 8:00 am to 4:00 pm – 1st March to 31st October

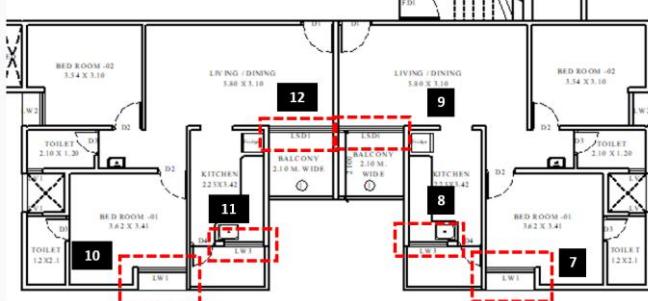


GRIHA Compliance range – 10:00 am to 03:00 pm – 1st April to 30th September

LIG – Housing Prototype – East / West Orientation



- 1** Bedroom – West Facing
- 2** Kitchen – West Facing
- 3** Living Room – West Facing
- 4** Bedroom – West Facing
- 5** Kitchen – West Facing
- 6** Living Room – West Facing



- 7** Bedroom – East Facing
- 8** Kitchen – East Facing
- 9** Living Room – East Facing
- 10** Bedroom – East Facing
- 11** Kitchen – East Facing
- 12** Living Room – East Facing

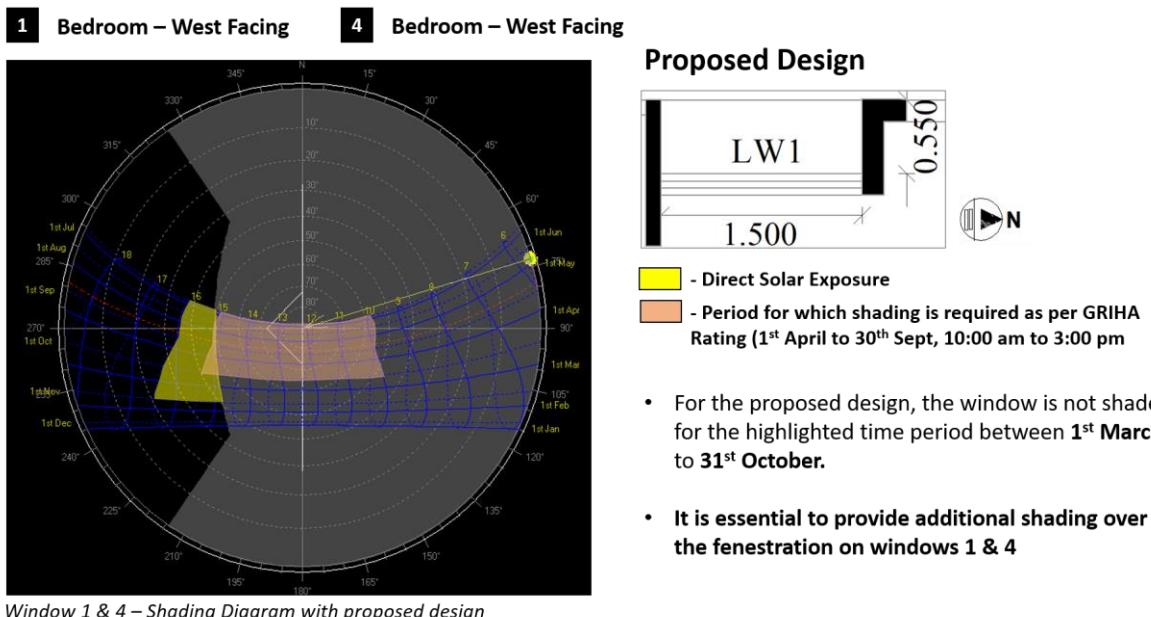
Summary

Window No.	Space	Orientation	Strategy	Exposure between 08:00 am - 04:00 pm from 1st March to 31st October	Exposure between 10:00 am - 03:00 pm from 1st April to 31st September (As per GRIHA requirements)
1	Bedroom	West	Option 1 - Angular fins	N	N
			Option 2 - Extended overhang	Y	N
2	Kitchen	West	-	N	N
3	Living Room	West	-	Y	N
4	Bedroom	West	Option 1 - Angular fins	N	N
			Option 2 - Extended overhang	Y	N
5	Kitchen	West	-	N	N
6	Living Room	West	-	N	N
7	Bedroom	East	Option 1 - Angular fins	N	N
			Option 2 - Extended overhang	Y	N
8	Kitchen	East	-	Y	N

9	Living Room	East	-	Y	N
10	Bedroom	East	Option 1 - Angular fins	N	N
			Option 2 - Extended overhang	Y	N
11	Kitchen	East	-	Y	N
12	Living Room	East	-	Y	N

West Façade Shading Analysis

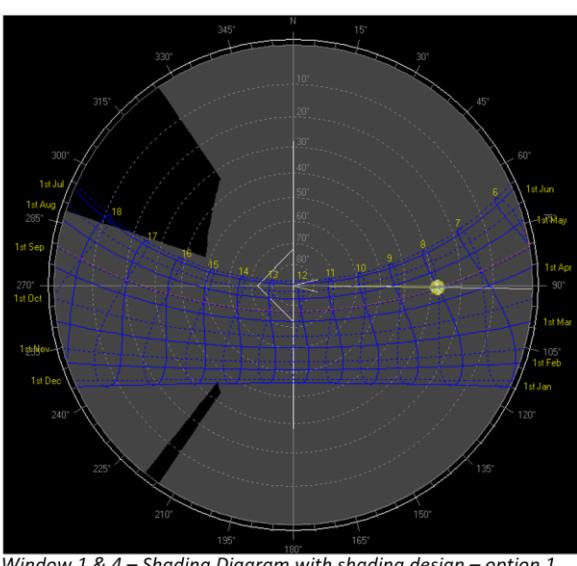
LIG – Housing Prototype – East/West Orientation



It is observed that addition of extended shading is essential during summer days to obstruct direct solar exposure on windows 1& 4.

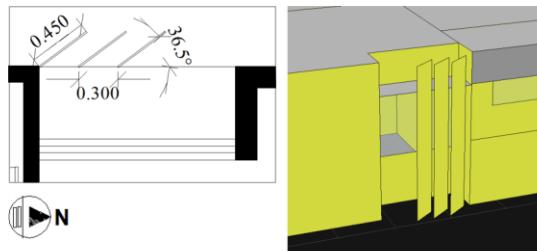
1 Bedroom – West Facing

4 Bedroom – West Facing



Window 1 & 4 – Shading Diagram with shading design – option 1

Shading Design – Option 1

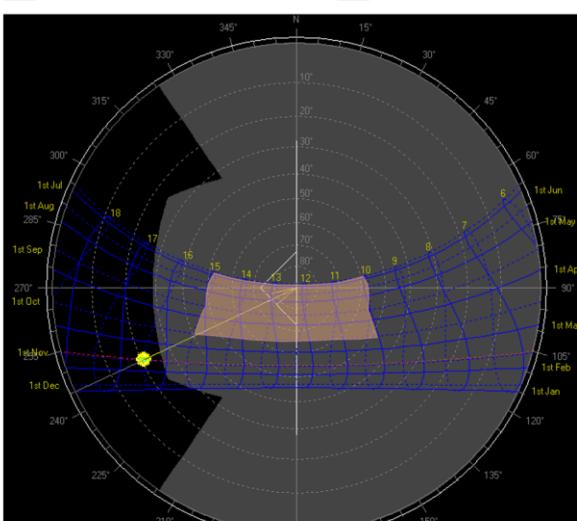


- Provision of 3 nos. vertical fins of 450 mm length, tilted at 36.5° towards north and spaced at 300 mm.
- No solar exposure is seen with this strategy between 12:00 pm to 4:00 pm throughout the year.

It is observed that angular fins obstruct direct solar exposure on windows 1 & 4 throughout the year during 12:00 pm to 4:00 pm.

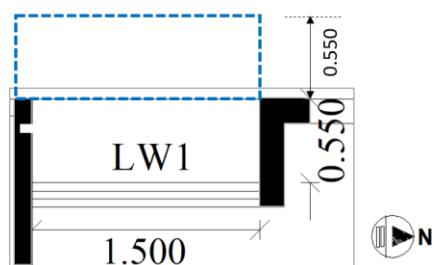
1 Bedroom – West Facing

4 Bedroom – West Facing



Window 1 & 4 – Shading Diagram with shading design – option 2

Shading Design – Option 2

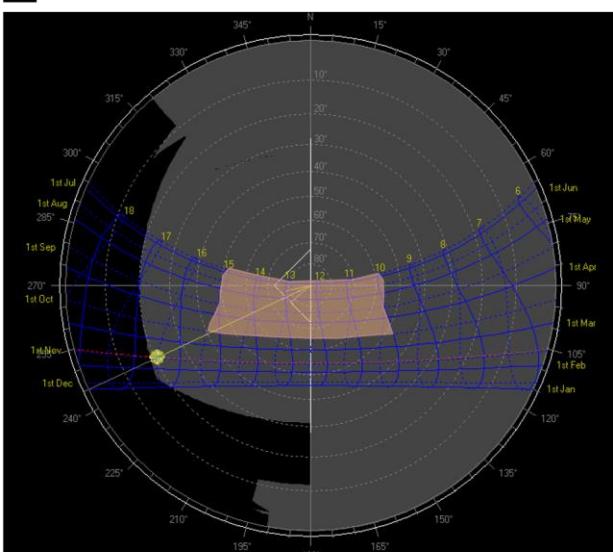


- Period for which shading is required as per GRIHA Rating(1st April to 30th Sept, 10:00 am to 3:00 pm)

- Provision of additional horizontal shading of 550 mm shows complete shading up to 3:00 pm through out the year.

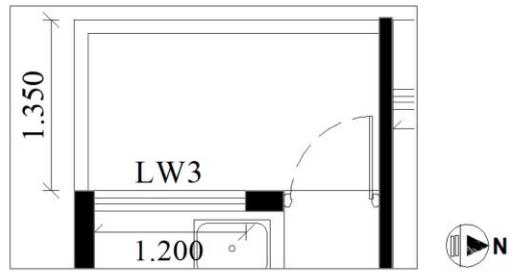
It is observed that on addition of extended shading device of 550 mm the west facing window is completely shaded throughout the year up to 3:00 pm.

2 Kitchen – West Facing



Window 2 – Shading Diagram with proposed design

Proposed Design

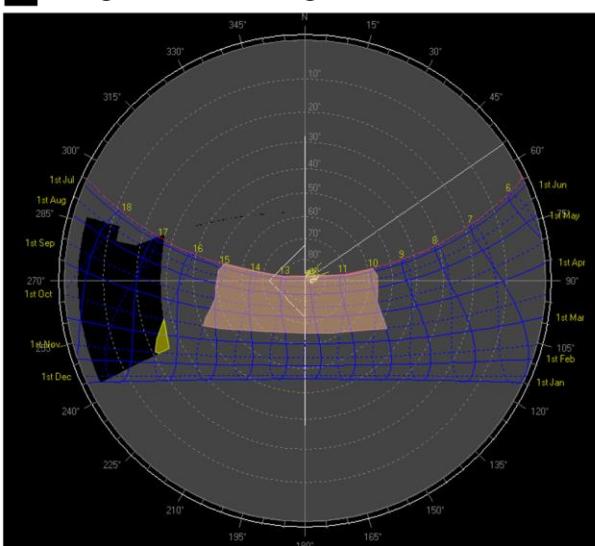


- Period for which shading is required as per GRIHA Rating (1st April to 30th Sept, 10:00 am to 3:00 pm)

- The proposed design for the window shows shading between 12:00 pm to 4:00 pm from 1st March to 31st October.

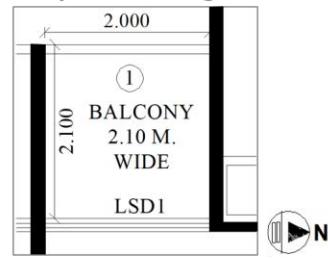
It is observed that proposed design prevents solar exposure during summer between 12:00 pm to 4:00 pm on west facing kitchen window.

3 Living Room – West Facing



Window 3 – Shading Diagram with proposed design

Proposed Design

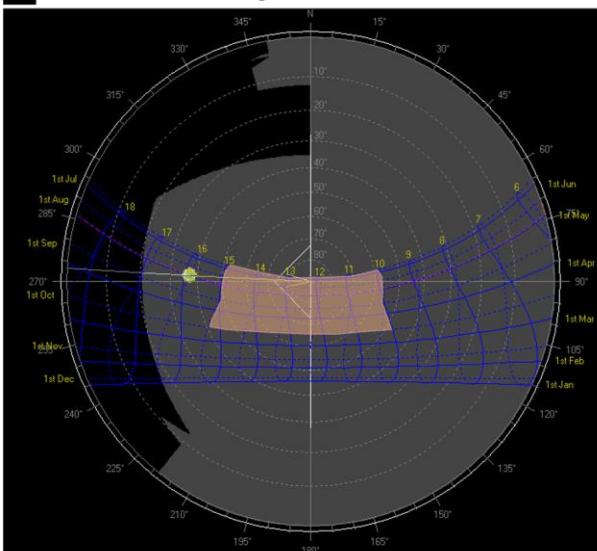


- Direct Solar Exposure

- Period for which shading is required as per GRIHA Rating(1st April to 30th Sept, 10:00 am to 3:00 pm)

- The proposed design for the window shows solar exposure between 1st March to 31st October for the time duration highlighted.
- The proposed shading assembly shows minimal solar exposure but falls within the GRIHA requirements.

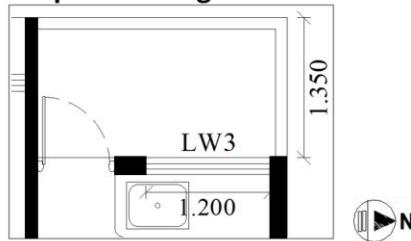
5 Kitchen – West Facing



Window 5 – Shading Diagram with proposed design

It is observed that proposed design provides shading on the west facing kitchen between 12:00 pm to 4:00 pm during summer.

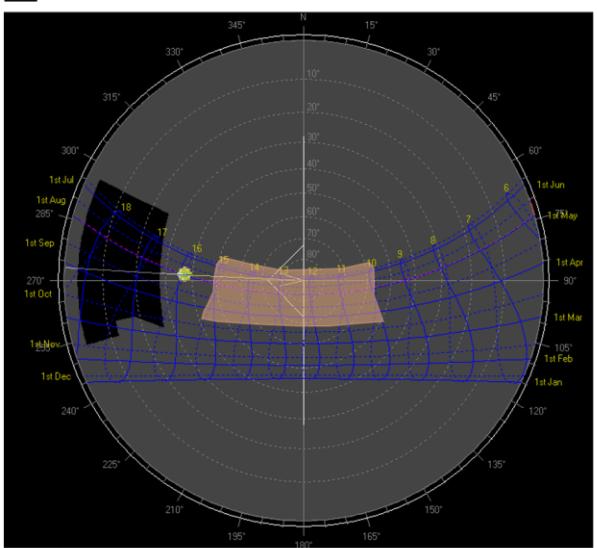
Proposed Design



- Direct Solar Exposure
- Period for which shading is required as per GRIHA Rating(1st April to 30th Sept, 10:00 am to 3:00 pm)

- The proposed design for the window shows shading between 12:00 pm to 4:00 pm from 1st March to 31st October.

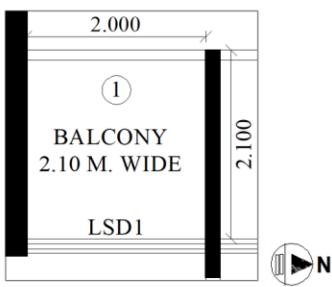
6 Living Room – West Facing



Window 6 – Shading Diagram with proposed design

It is observed that proposed design completely obstructs solar exposure during 12:00 pm to 4:00 pm in summer on the west facing Living room.

Proposed Design

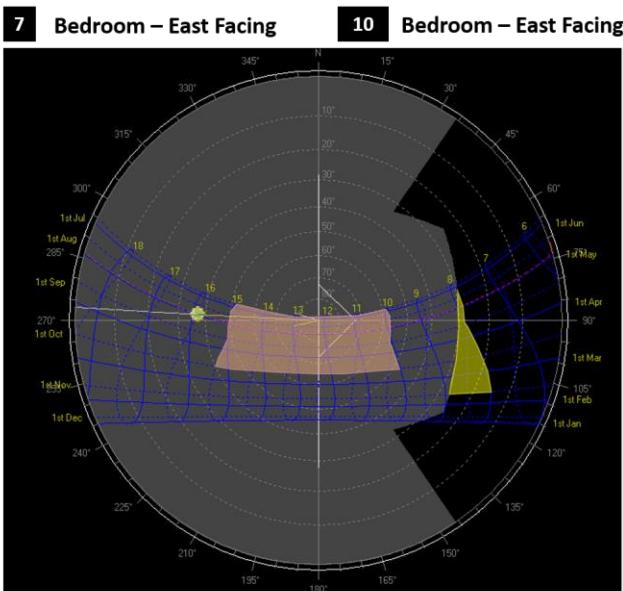


- Direct Solar Exposure
- Period for which shading is required as per GRIHA Rating(1st April to 30th Sept, 10:00 am to 3:00 pm)

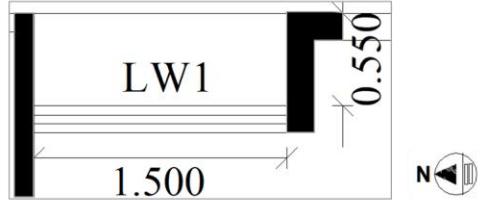
- The proposed design for the window shows complete shading from 12:00 pm to 4:00 pm between 1st March to 31st October.

East – West Façade Analysis

LIG – Housing Prototype – East/West Orientation



Proposed Design

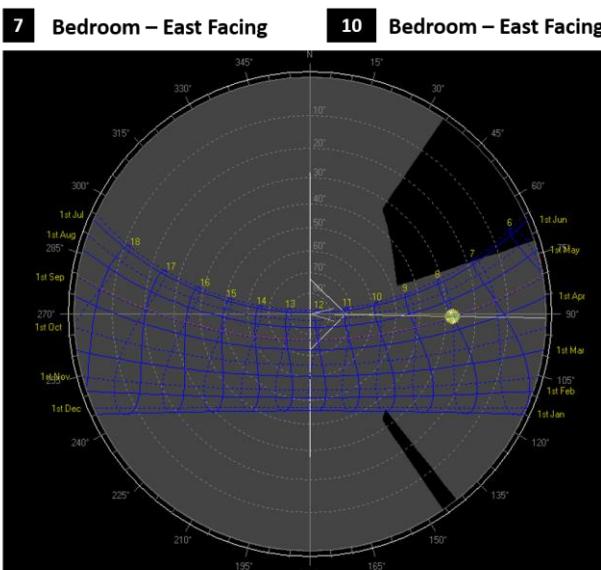


■ - Direct Solar Exposure
■ - Period for which shading is required as per GRIHA Rating(1st April to 30th Sept, 10:00 am to 3:00 pm)

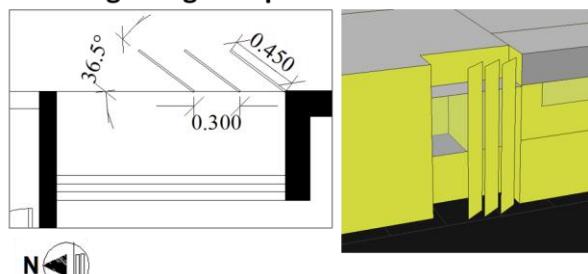
- For the proposed design, the window is not shaded for the highlighted time period between **1st March** to **31st October**.
- **It is essential to provide additional shading over the fenestration on windows 1 & 4**

Window 7 & 10 – Shading Diagram with proposed design

It is observed that additional shading is essential to obstruct solar exposure on east facing bedroom windows during summer.



Shading Design – Option 1

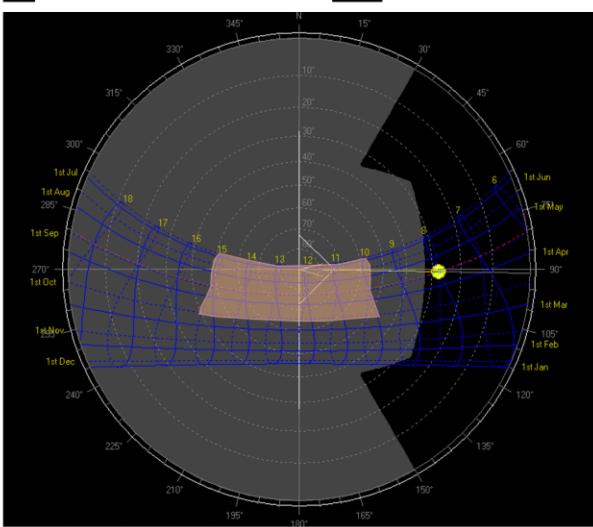


- Provision of **3 nos. vertical fins of 450 mm length, tilted at 36.5° towards north and spaced at 300 mm**.
- **No solar exposure is seen with this strategy between 08:00 am to 12:00 pm throughout the year**.

Window 7 & 10 – Shading Diagram with shading design – option 1

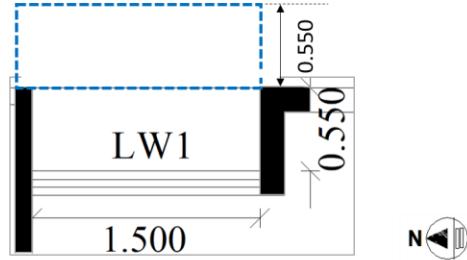
It is observed that 3 vertical fins completely obstruct solar exposure on east facing bedroom windows throughout the year.

7 Bedroom – East Facing



10 Bedroom – East Facing

Shading Design – Option 2



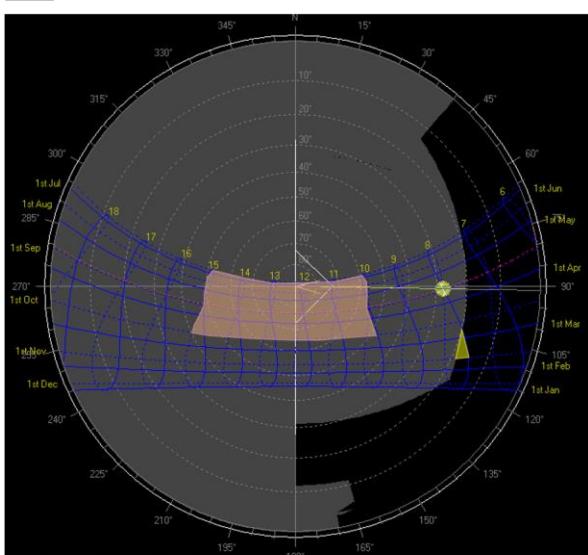
 - Period for which shading is required as per GRIHA Rating(1st April to 30th Sept, 10:00 am to 3:00 pm)

- Provision of additional horizontal shading of 550 mm shows complete shading up to 10:00 am through out the year.

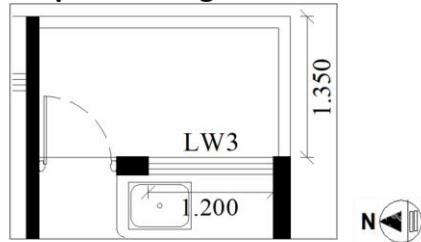
Window 7 & 10 – Shading Diagram with shading design – option 2

It is observed that an extended shading of 550 mm completely shades east facing bedroom window up to 10:00 am throughout the year.

8 Kitchen – East Facing



Proposed Design



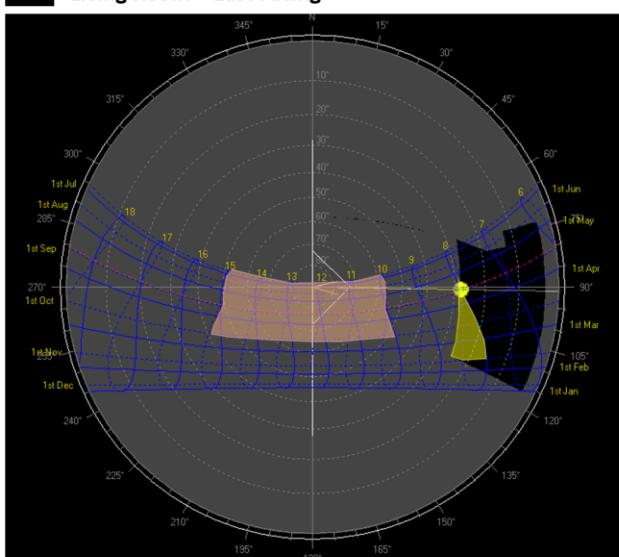
 - Direct Solar Exposure

 - Period for which shading is required as per GRIHA Rating(1st April to 30th Sept, 10:00 am to 3:00 pm)

- The proposed design for the window shows solar exposure between 1st March to 31st October for the highlighted time period.
- The proposed shading assembly shows minimal solar exposure but falls within the GRIHA requirements.

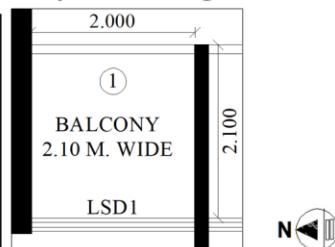
Window 8 – Shading Diagram with proposed design

9 Living Room – East Facing



Window 9 – Shading Diagram with proposed design

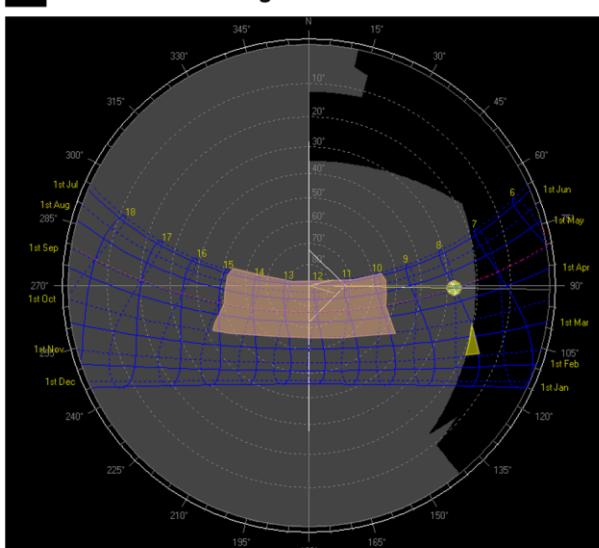
Proposed Design



■ - Direct Solar Exposure
■ - Period for which shading is required as per GRIHA Rating(1st April to 30th Sept, 10:00 am to 3:00 pm)

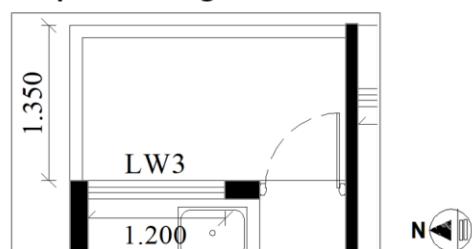
- The proposed design for the window shows solar exposure between **1st March to 31st October** for the highlighted time period.
- The proposed shading assembly shows minimal solar exposure but falls within the GRIHA requirements.**

11 Kitchen – West Facing



Window 11 – Shading Diagram with proposed design

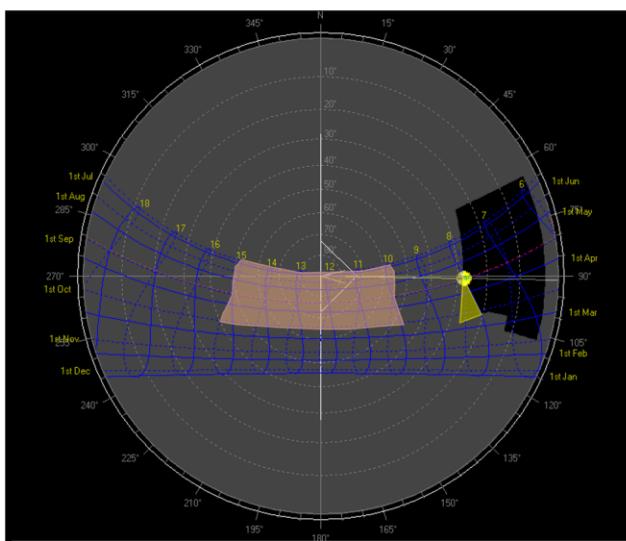
Proposed Design



■ - Direct Solar Exposure
■ - Period for which shading is required as per GRIHA Rating(1st April to 30th Sept, 10:00 am to 3:00 pm)

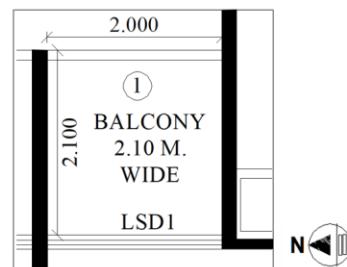
- The proposed design for the window shows solar exposure between **1st March to 31st October** for the highlighted time period.
- The proposed shading assembly shows minimal solar exposure but falls within the GRIHA requirements.**

12 Living Room – East Facing



Window 12 – Shading Diagram with proposed design

Proposed Design



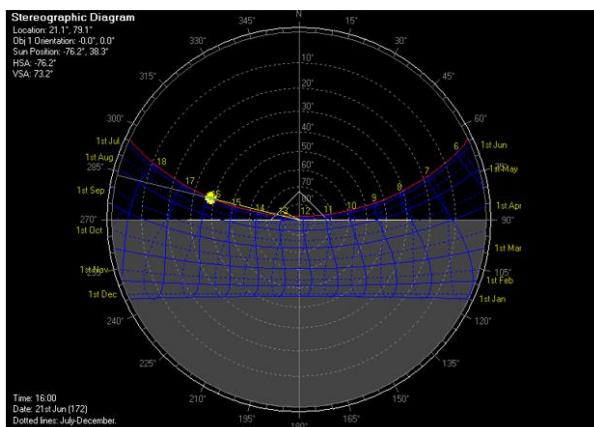
- Direct Solar Exposure
 - Period for which shading is required as per GRIHA Rating(1st April to 30th Sept, 10:00 am to 3:00 pm)

- The proposed design for the window shows solar exposure between **1st March to 31st October** for the highlighted time period.

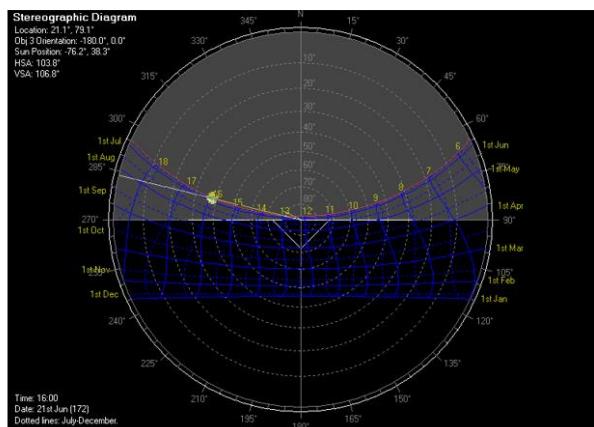
North – South Façade Analysis

LIG – Housing Prototype North/South Orientation

- Location: Nagpur
- Climate: Composite – Hot Dry Summers and Cold Winters
- Primary Fenestration Orientation – **North / South**
- Analysis Period – 1st March – 30th September (Cooling months)
- Analysis Hours:
 - 1) North Façade – 8 am to 4pm
 - 2) South Façade – 8am to 4 pm



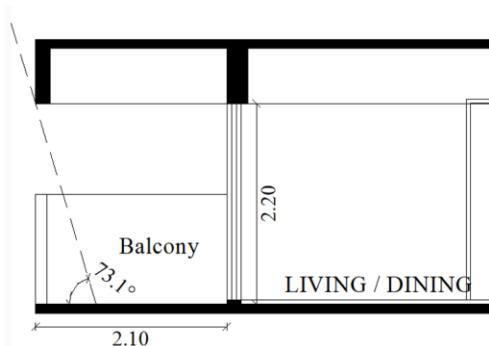
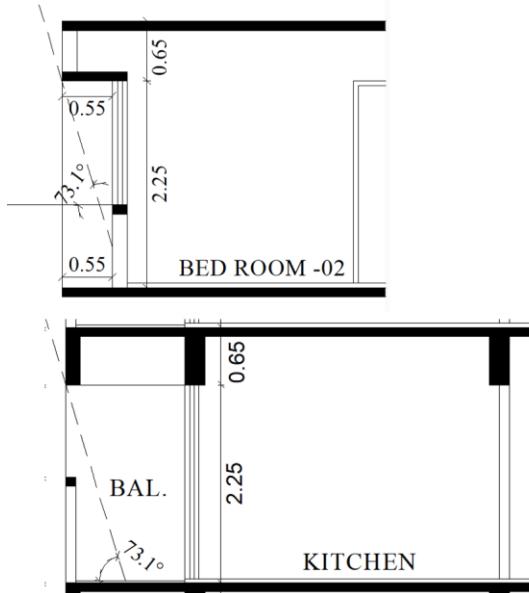
WEST Façade Solar Path



EAST Façade Solar Path

Fenestration on North Façade

Solar Angle on 21st June @ 8 am - VSA – 73.1°

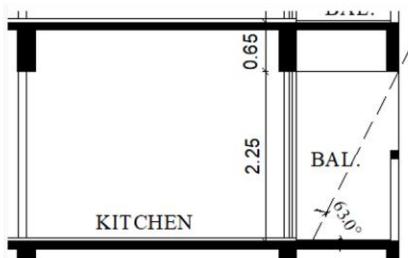
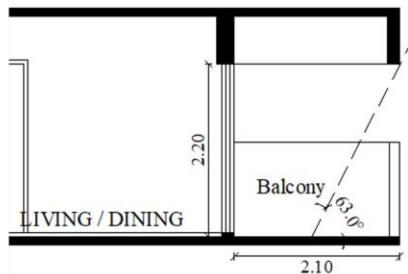
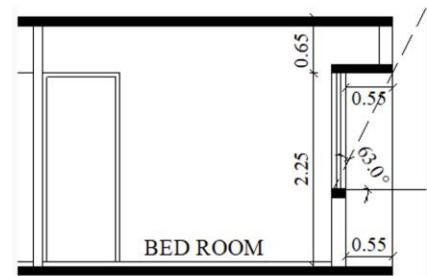


Observations

- No direct solar penetration on the northern façade fenestration with proposed overhangs and balconies

Fenestration on South Façade

Solar Angle on 30th September @ 8 am - VSA – 63°



Observations

- No direct solar penetration on the Southern façade fenestration with proposed overhangs and balconies

Recommendations

Aim

- Nagpur shows Composite Climate – characterized by hot and dry summers and cold winters.
- Essential to block direct solar penetration in the living areas during the cooling period (1st March to 30th September) and allow during the heating period (1st October to 28th February)

Strategy

North Façade

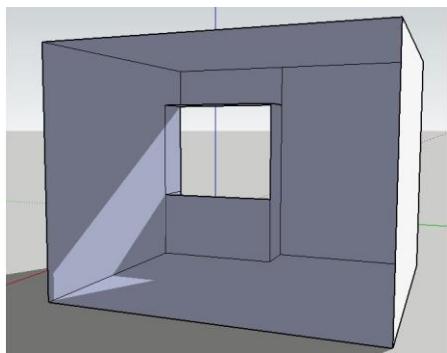
- Fenestrations shaded with proposed overhangs and balconies during the cooling period.

South Façade

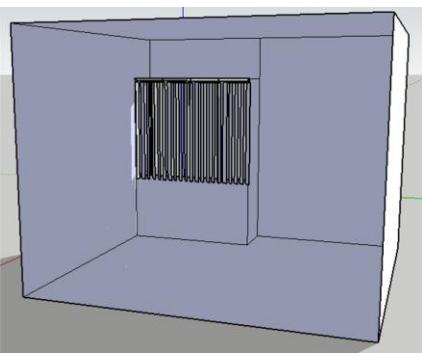
- Fenestrations shaded with proposed overhangs and balconies during the cooling period.

West and East Façade

- Vertical Blinds – Vertical blinds which can be operated internally by the occupant are recommended, instead of fixed vertical louvers. Since the horizontal solar angles are deep (12.8° and 13.9°), blinds with adjustable angle of rotation can block out sun during the cooling months. Moreover, the blinds can be slide-to-open to allow sun during the winter months.



21st June @ 4 pm

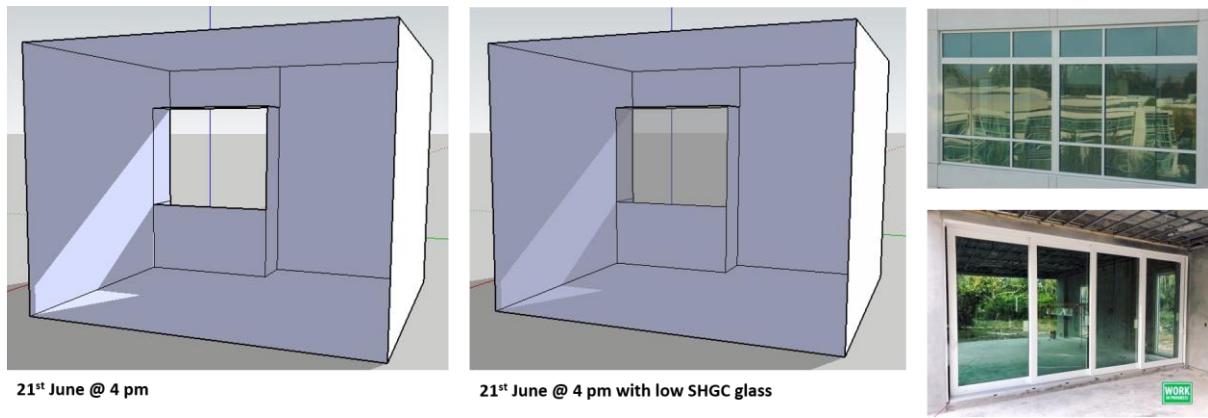


21st June @ 4 pm with vertical blinds



West and East Façade

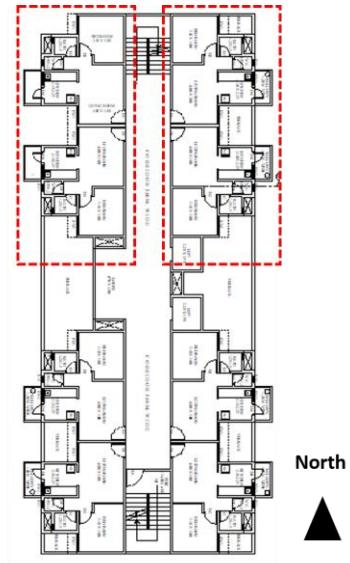
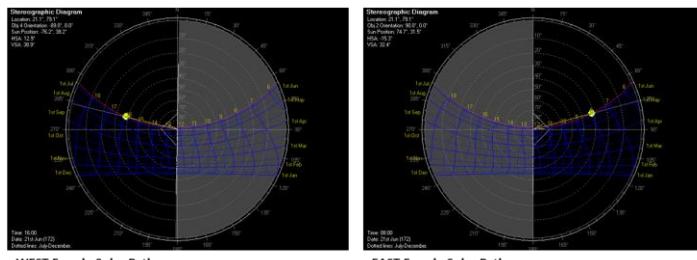
- Use of Glazing with Low Solar Heat Gain Coefficient (SHGC) – Window glazing with a lower SHGC value contributes highly towards reducing the internal heat gain due to direct sun penetration. Glass with SHGC value 0.25 or lower (as recommended by ECBC) will reduce overheating during the cooling months.



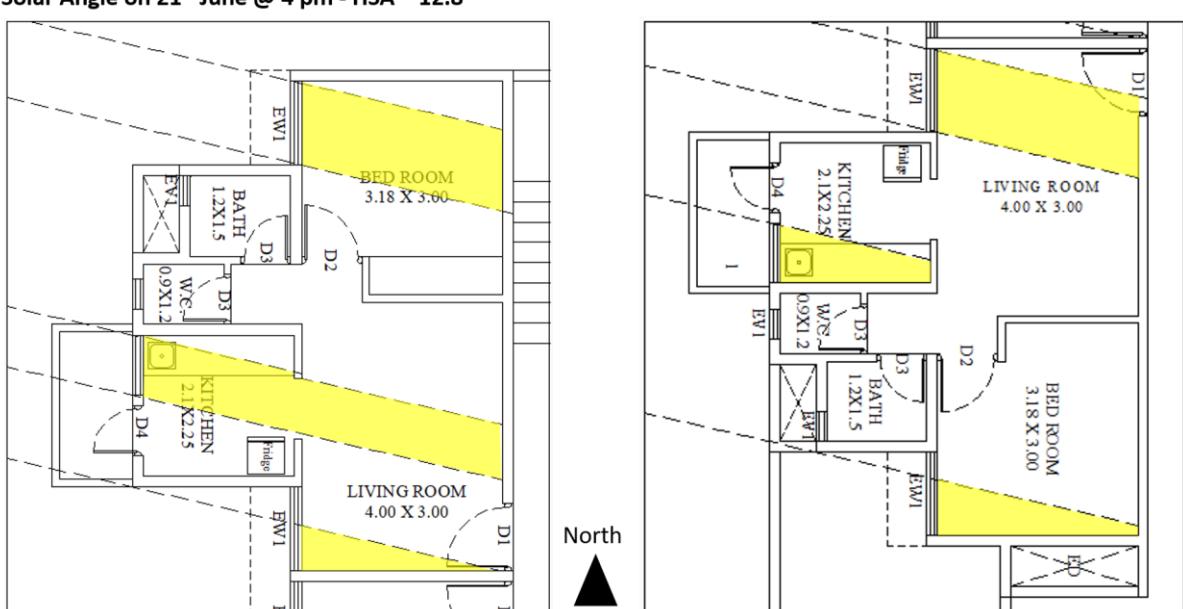
EWS Housing Prototype East/West Orientation

Fenestration on the WEST Façade

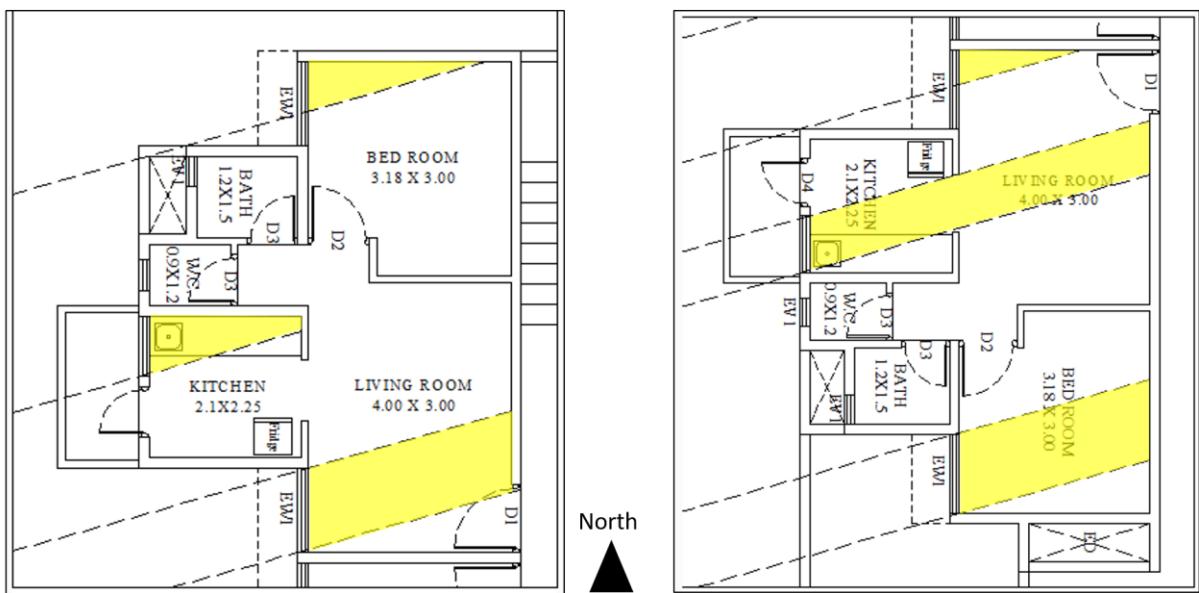
- Location: Nagpur
- Climate: Composite – Hot Dry Summers and Cold Winters
- Primary Fenestration Orientation – **East / West**
- Analysis Period – 1st March – 30th September (Cooling months)
- Analysis Hours:
 - 1) West Façade – 12 pm to 4pm
 - 2) East Façade – 8am to 12 pm



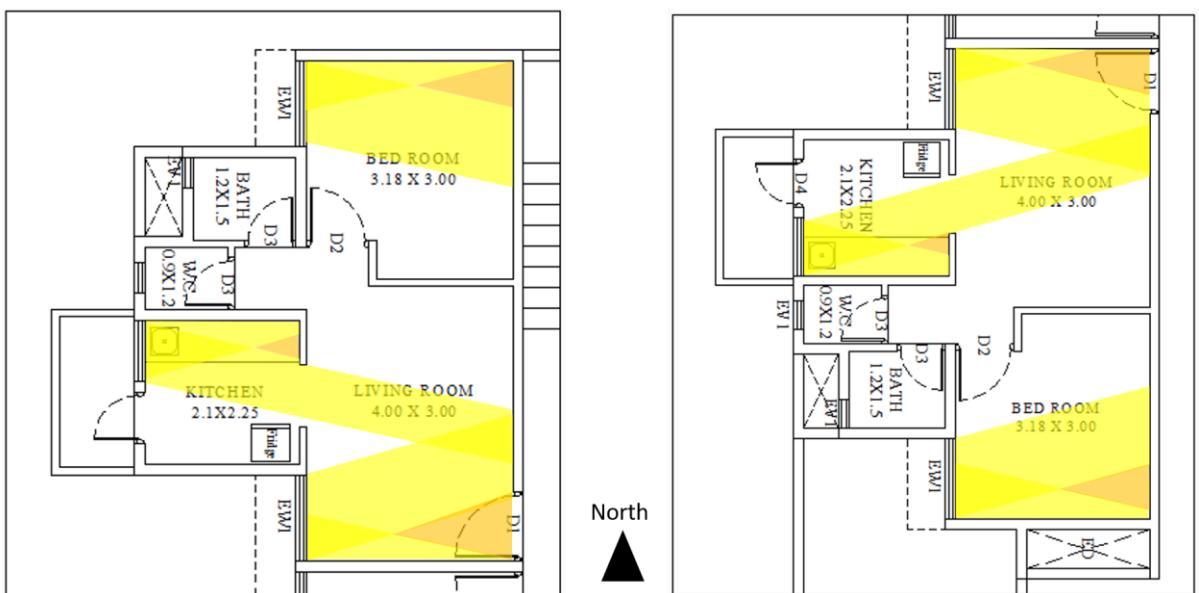
Solar Angle on 21st June @ 4 pm - HSA – 12.8°



Solar Angle on 30th September @ 4 pm - HSA – 15.7°



For 1st March to 30th September (Cooling Months)



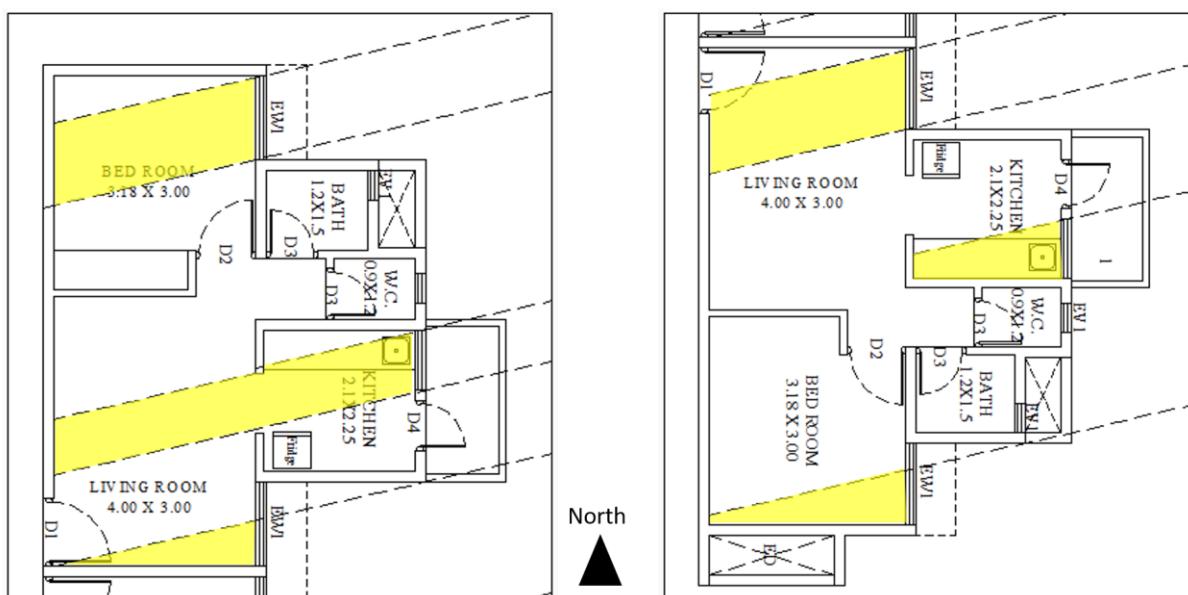
Observations

West Façade

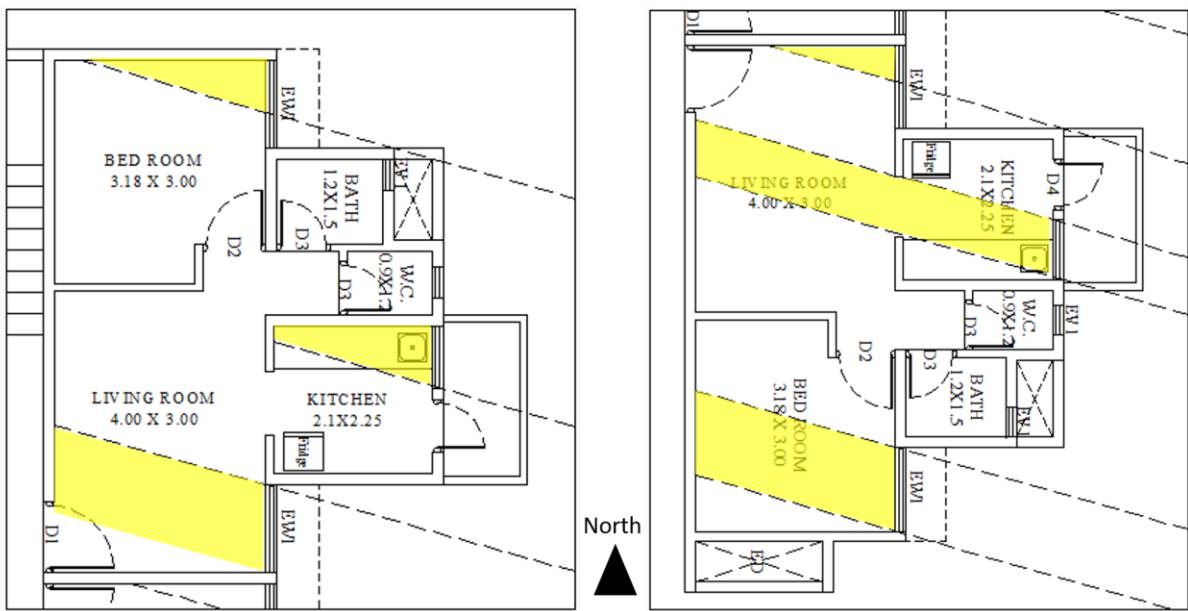
- Maximum Horizontal angle of the sun on the west façade is -12.8° , which will penetrate the most inside the living areas of the apartment. This occurs on 21st June (summer solstice) at 4:00 pm.
- The horizontal angle of the sun on 30th September i.e the end of cooling period is 15.7° at 4.00 pm, on the west façade.
- Thus the range of horizontal solar penetration extends from -12.8° to 15.7° . This range has been highlighted in the above outputs in Yellow
- This solar penetration during the cooling periods is not desirable as the temperatures are high in Nagpur and hence must be blocked.

Fenestration on East Façade

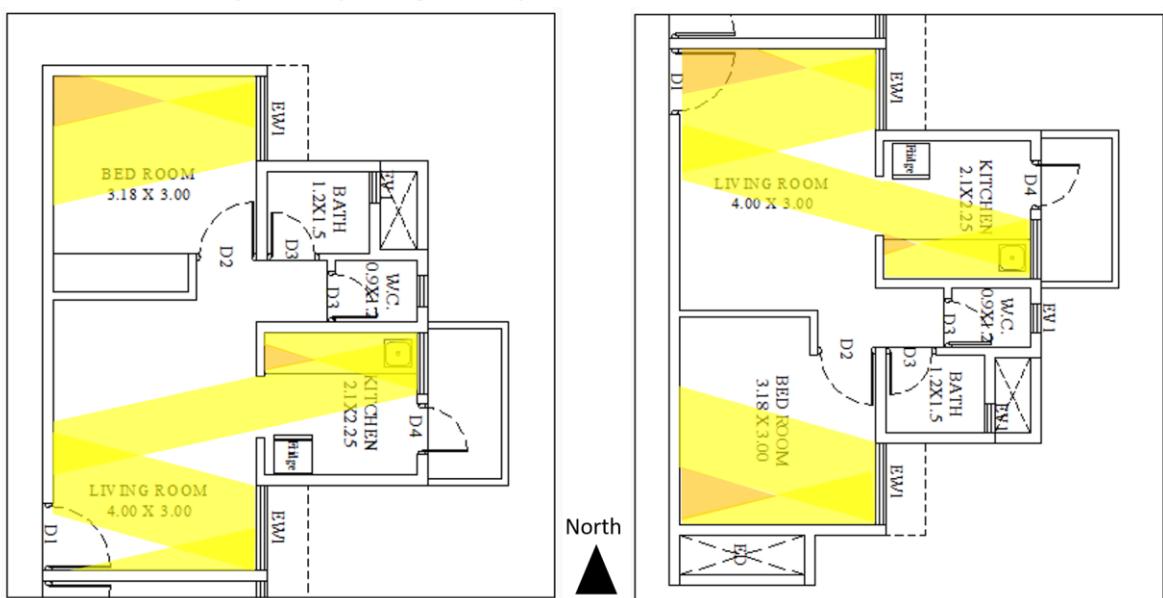
Solar Angle on 21st June @ 8 am - HSA – 15.3°



Solar Angle on 30th September @ 8 am - HSA – 13.9°



For 1st March to 30th September (Cooling Months)



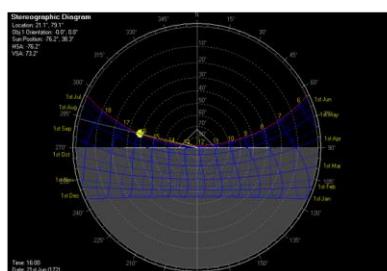
Observations

East Façade

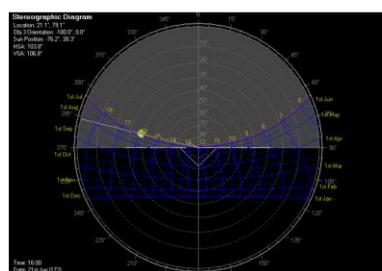
- Maximum Horizontal angle of the sun on the east façade is 13.9° , which will penetrate the most inside the living areas of the apartment. This occurs on 30th September at 8:00 am.
- The horizontal angle of the sun on 21st June (summer solstice) is -15.3° at 8.00 am, on the east façade.
- Thus the range of horizontal solar penetration extends from 13.9° to -15.3° . This range has been highlighted in the above outputs in Yellow
- This solar penetration during the cooling periods is not desirable as the temperatures are high in Nagpur and hence must be blocked.

EWS Housing Prototype North/South Orientation

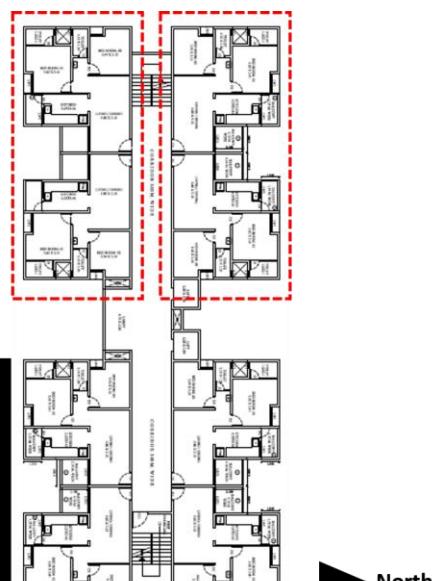
- Location: Nagpur
- Climate: Composite – Hot Dry Summers and Cold Winters
- Primary Fenestration Orientation – **North / South**
- Analysis Period – 1st March – 30th September (Cooling months)
- Analysis Hours:
 - 1) North Façade – 8 am to 4pm
 - 2) South Façade – 8am to 4 pm



WEST Façade Solar Path

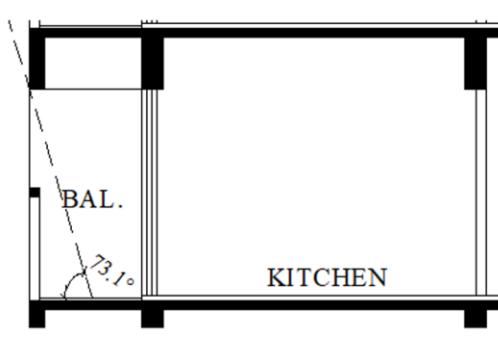
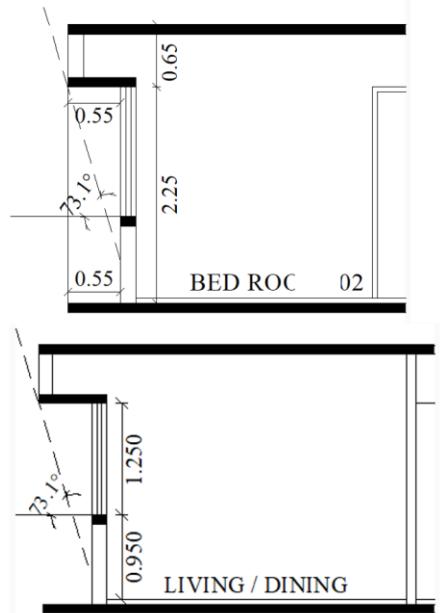


EAST Façade Solar Path



Fenestration on the North Façade

Solar Angle on 21st June @ 8 am - VSA – 73.1°

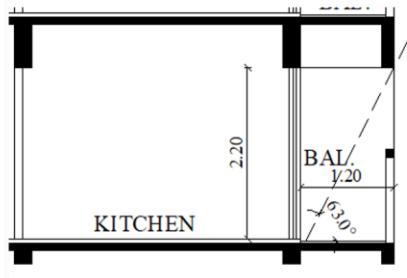
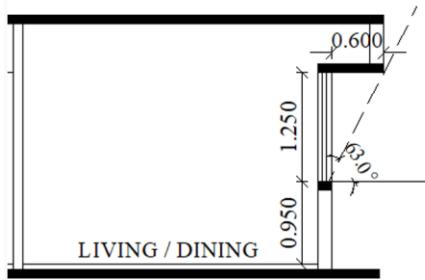
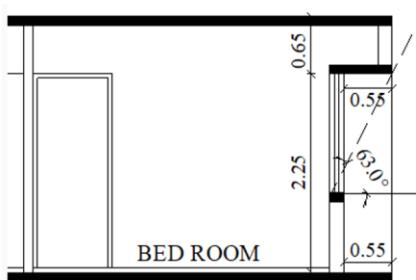


Observations

- No direct solar penetration on the northern façade fenestration with proposed overhangs and balconies

Fenestration on South Façade

Solar Angle on 30th September @ 8 am - VSA – 63°



Observations

- No direct solar penetration on the Southern façade fenestration with proposed overhangs and balconies

Recommendations

Aim

- Nagpur shows Composite Climate – characterized by hot and dry summers and cold winters.
- Essential to block direct solar penetration in the living areas during the cooling period (1st March to 30th September) and allow during the heating period (1st October to 28th February)

Strategy

North Façade

- Fenestrations shaded with proposed overhangs and balconies during the cooling period.

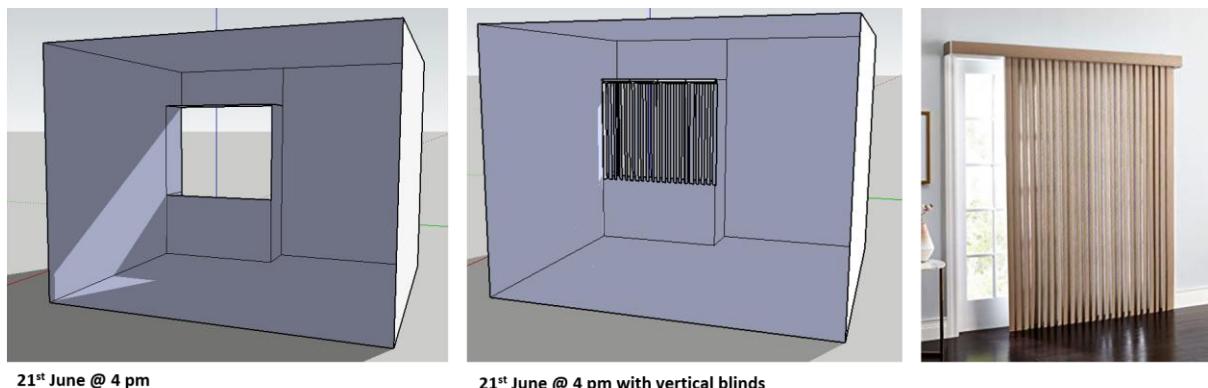
South Façade

- Fenestrations shaded with proposed overhangs and balconies during the cooling period.

Recommendations

West and East Façade

- **Vertical Blinds** – Vertical blinds which can be operated internally by the occupant are recommended, instead of fixed vertical louvers. Since the horizontal solar angles are deep (12.8° and 13.9°), blinds with adjustable angle of rotation can block out sun during the cooling months. Moreover, the blinds can be slide-to-open to allow sun during the winter months.



4 Daylight Analysis

4.1 Methodology

The analysis has been performed for EWS and LIG block. Since the MIG and LIG blocks have similar floor plates, except for the floor area, daylight analysis was conducted for the MIG housing block by modeling a typical floor plate in the Daylight Analysis software – DesignBuilder based on the proposed design.

The proposed glazing for wall openings/ window is with VLT value of .65 or higher after assessing a base case with VLT value of .50.

4.2 Daylight Analysis

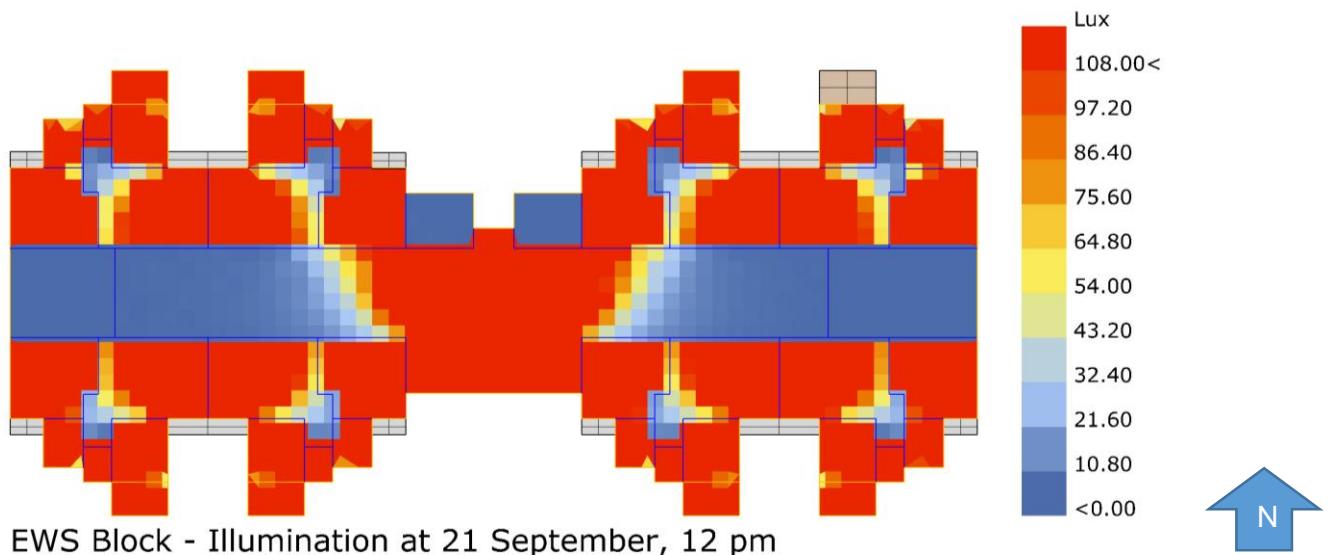
The purpose of this analysis is to understand the presence of natural light in occupied spaces during day time in the proposed design. The glass parameter i.e. VLT value was assigned to the windows and simulation was conducted on the dwelling units to assess the illuminance and daylight factor in all occupied spaces. This exercise was conducted by testing glazing used for openings/ windows in the proposed design. The options for assessment were based on IGBC – Green Homes and GRIHA green rating system. Simulations include 2 options as listed below:

Sn No.	Standard	Unit	Minimum Req.	Maximum Req.
Option 1	IGBC – Green Homes	Lux	108 Lux in 50% of regularly occupied area	-
Option 2	GRIHA Option 1 (SP-41)	Daylight Factor	<ul style="list-style-type: none">Kitchen – 2.5Living Room – 0.625Study Room – 1.9Circulation – 0.313	-

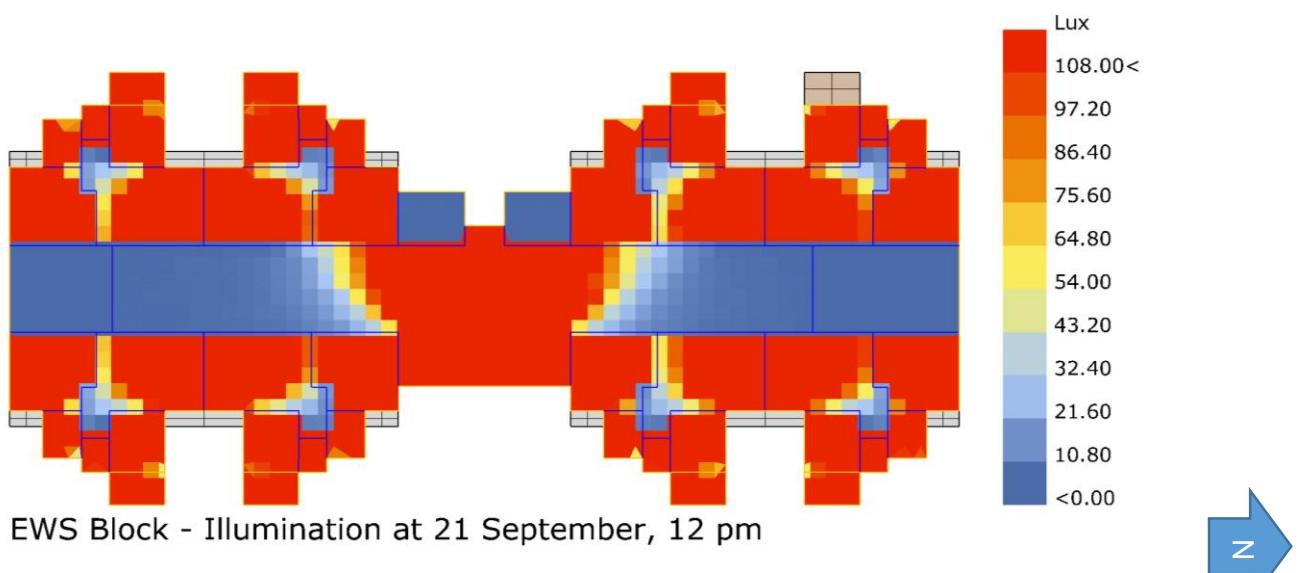
4.2.1 EWS Housing Analysis – Option 1 – illuminance (lux)

North – South Orientation Results

Modelling Parameters	Results
Location: Nagpur	
VLT: 50%	
Ceiling Reflectance – 0.8 (white)	
Floor Reflectance – 0.2 (Dark colours)	
Wall Reflectance – 0.6 (Light colours)	> 50% of Regularly occupied Areas with 108 lux and Higher

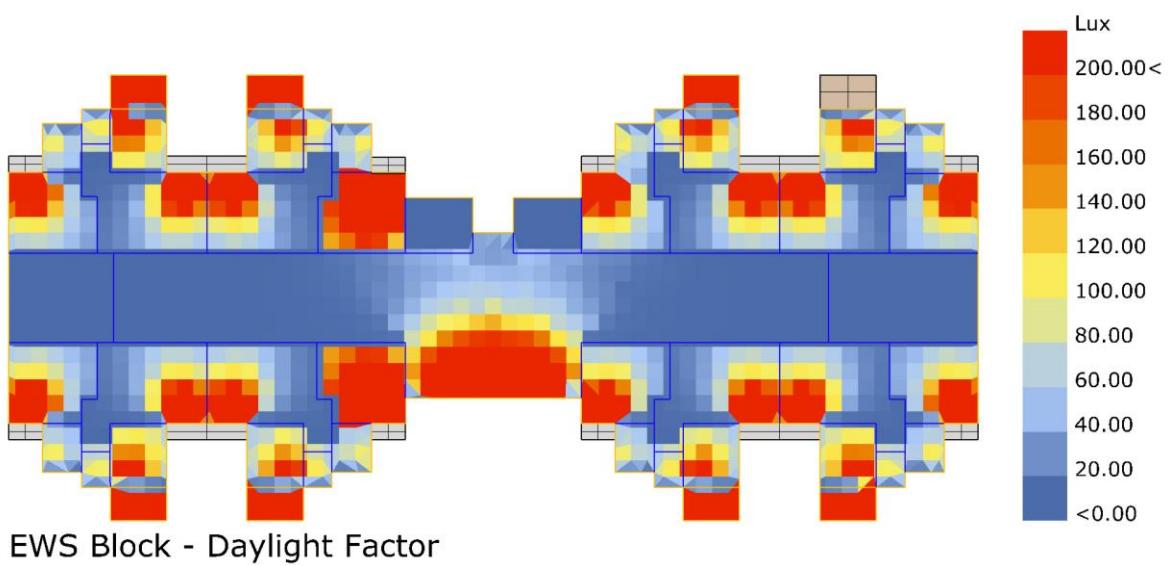


East – West Orientation Results



4.2.2 EWS Housing Analysis – Option 2 – Daylight Factor

Modelling Parameters	Results
Sky Lux: 8000 Lux	Kitchen – Not Complaint
VLT: 50%	Living Room – 0.625
Ceiling Reflectance – 0.8 (white)	Study Room – NA
Floor Reflectance – 0.2 (Dark colours)	Bedrooms - 0.625
Wall Reflectance – 0.6 (Light colours)	

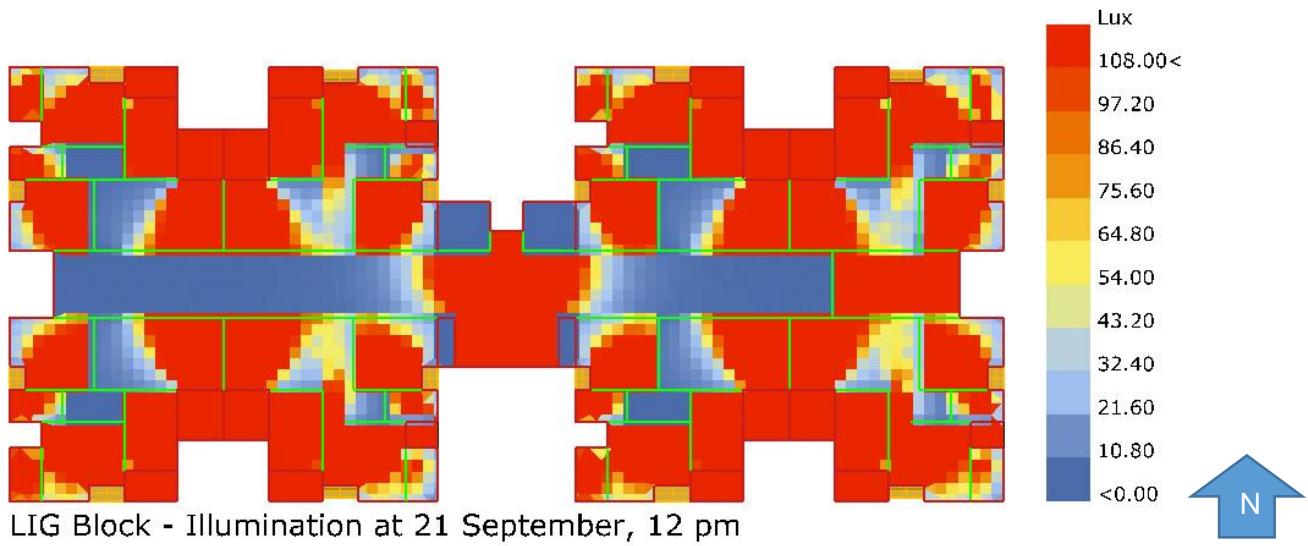


For EWS Block it is observed that Daylight factor is lower than the required threshold of 200 lux (2.5%) in the center of the room in Kitchen. Hence it is recommended that the glass in the kitchen area should have a higher visible light transmittance (VLT) value of 0.65 or higher.

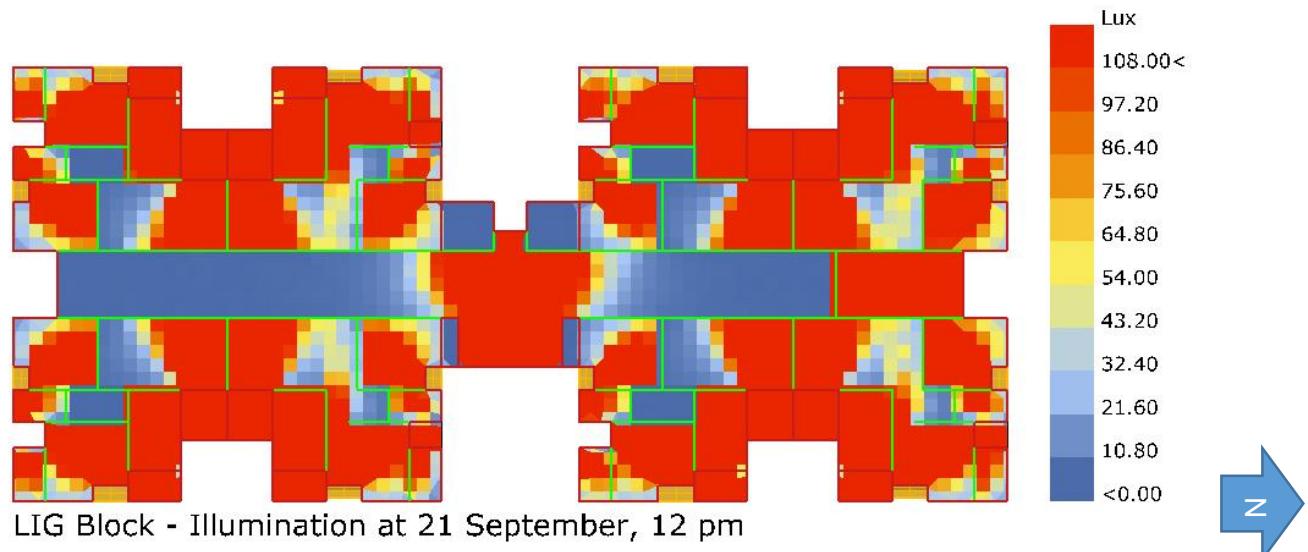
4.2.3 LIG Housing Analysis – Option 1 – illuminance (lux)

North – South Orientation Results

Modelling Parameters	Results
Location: Nagpur	
VLT: 50%	
Ceiling Reflectance – 0.8 (white)	
Floor Reflectance – 0.2 (Dark colours)	
Wall Reflectance – 0.6 (Light colours)	
	> 50% of Regularly occupied Areas with 108 lux and Higher

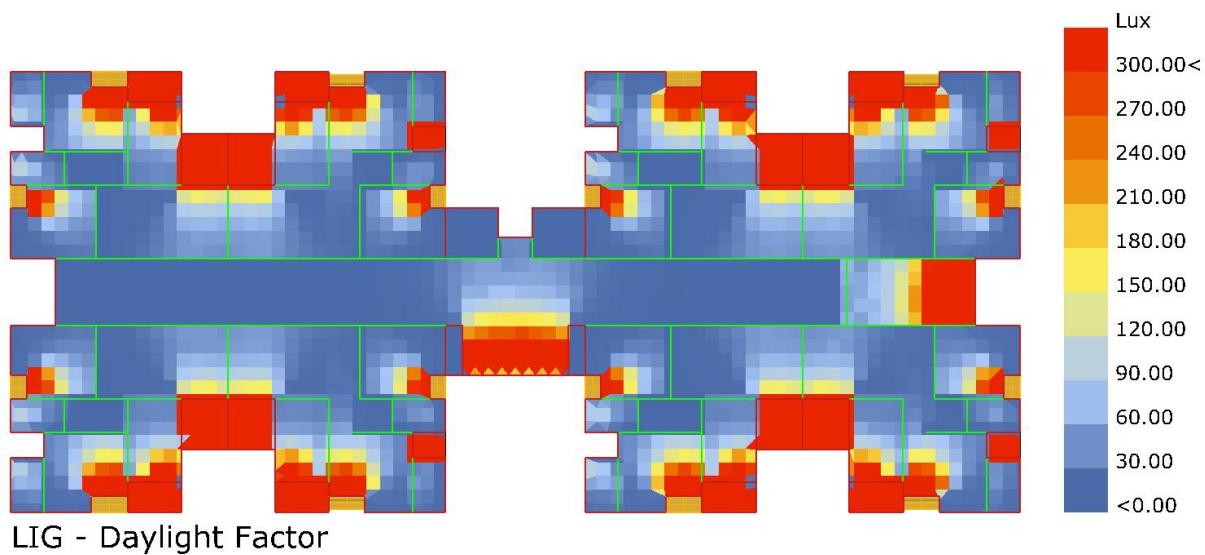


East – West Orientation Results



4.2.4 LIG Housing Analysis – Option 2- Daylight Factor

Modelling Parameters	Results
Sky Lux: 8000 Lux	Kitchen – Not Complaint
VLT: 50%	Living Room – Not Complaint
Ceiling Reflectance – 0.8 (white)	Study Room – NA
Floor Reflectance – 0.2 (Dark colours)	Bedrooms - 0.625
Wall Reflectance – 0.6 (Light colours)	



For LIG Block it is observed that Daylight factor is lower than the required threshold of 200 lux (2.5%) in the center of the room in Kitchen. Whereas for living room it is lower than the required threshold of 50 lux (0.65%) in the center of the room. Hence it is recommended that the glass in the kitchen and living area should have a higher visible light transmittance (VLT) value of 0.65 or higher.

5 Cross Ventilation Analysis

5.1 Methodology

The analysis has been performed for EWS and LIG block. Since the MIG and LIG blocks have similar floor plates, except for the floor area, cross ventilation analysis

5.2 Cross Ventilation Analysis

The purpose of this analysis is to understand the impact of

6 Access to Light Analysis

6.1 Methodology

The analysis has been performed for EWS and LIG block. Since the MIG and LIG blocks have similar floor plates, except the floor area, access to light analysis

6.2 Access to Light Analysis

The purpose of this analysis is to understand the impact of

7 Appendix – A

Analysis Software

1. EnergyPlus with DesignBuilder interface – Building Daylight Analysis
2. Ecotect – Daily Shadow Range
3. Climate Consultant