

# Evaluation of climate responsive architecture and its strategies based on the ASSOCHAM GEM Sustainability Certification Rating Program –A case of Indore, India

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**Abstract:** Passive design is the integral part of design process. In India modern buildings are majorly depends upon mechanical means for heating and cooling. To reduce the dependency on the artificial means is challenge for designer. This study gives an overview of different passive design strategies used in the buildings of composite climate. A detailed review was conducted on the assessment criteria given in GEM sustainability rating system. These criteria was grouped according to responsive strategies, conservation of water resources, landscape and site plaining Etc. Based on point system given in the ASSOCHAM GEM rating different cases from similar climatic zones were evaluated. A detailed analysis of a live case from composite climate was performed using simulation method and shadow analysis. Quantification of daylight exposure evaluates the impact of size and position of window openings. It is found that basic building configuration and orientation plays an important role in creating balanced thermal environment inside the structure. After relative study of different cases it was found that building with the proper orientation and ventilation fulfill the requirements prescribed by the GEM ratings.

**Keywords:** *Passive Design, daylight, ventilation, orientation*

## Introduction

Climate responsiveness is very important in design of built environment. Understanding the increasing demand of energy in building sector, designing with local climatic condition becomes mandatory for a designer. By using passive design measures designer can minimize heating or cooling load of building. Passive design entirely depends upon micro climate of any particular region. Site plays an important role in which orientation of the site is the starting point in design development [18]. Proper orientation of building the key to maximum thermal comfort for the occupants. In the later stages position of opening, selection of building envelop [48] and position of opening is decided. Different design strategies were identified for different climatic zones. By using appropriate design strategies the architectural solutions will be much energy efficient than conventional buildings which are dependent on mechanical daylighting and ventilation systems. ASSOCHAM (THE ASSOCIATED CHAMBERS OF COMMERCE AND INDUSTRY OF INDIA) has taken a step towards better earth for upcoming generations and formed a Council for Green and Eco-friendly Movement (CGEM) under which a program 'GEM Sustainability Certification Program' was started with the key objective of sustainability in building industry [1]. This paper reviews different criteria of GEM sustainability program and

its application part by studying a live example of a residential building situated in Indore. Indore is situated in composite climatic zone as per ECBC (Energy Conservation Building Code 2017) [35].

### Need of study

In the design process of any building very less importance is given to passive measures the entire design revolves around maximizing built spaces. Unbuilt spaces were neglected and careful investigation of open space is equally important. Careful investigation of performance of any design strategy is a need for maximizing the impact. To review the different strategy and is also important. Combination effect of different studies were also be analyzed.

### Aim

Study aims to understand the key aspects of designing with climate to achieve maximum comfort for the user and minimize the environmental impact of that structure.

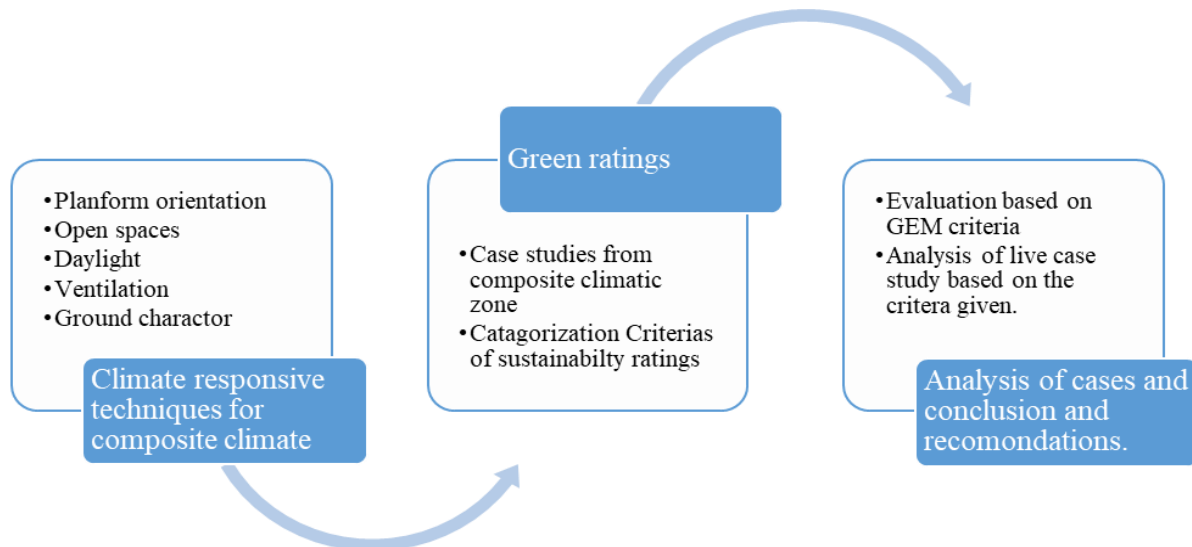
Objectives:

- To understand composite climate of India its characteristics.
- To develop understanding of different climate responsive strategies and its effectiveness.
- To evaluate different criteria of GEM sustainability rating.

### Methodology

This article reviews studies based on passive techniques of architectural design for composite climatic zone.

In the later stages some building examples were analysed based on GEM sustainability rating and in the last phase a live case was reviewed based on the GEM sustainable criteria.



### Composite climate

Main characteristics of this type of climatic zone is a combination of hot and dry, humid and cold climates [19]. The temperature ranges in summers from 35 – 45° C in summers and as low as 8° C in winters. Design consideration for this climatic zone is resist heat gain and promote heat loss and proper ventilation is also important in humid weather. For the summer months by providing evaporative cooling and increasing thermal leg will help the structure to cool down. Cavity wall is an important strategy as it will be beneficial for both the summer and winter conditions. Indore is situated on 553 m. above sea level [36].

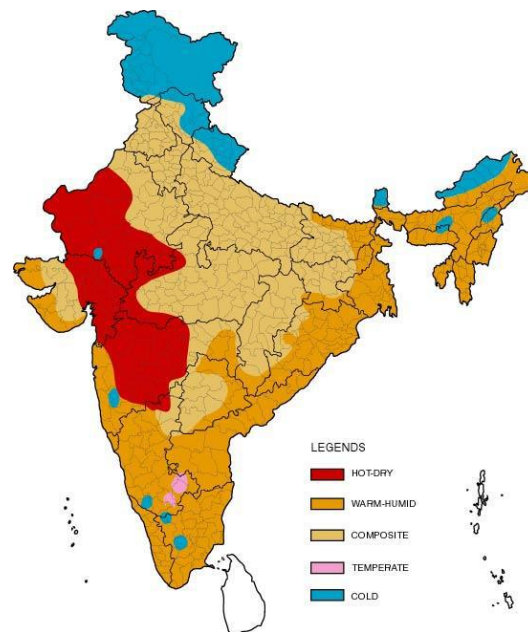


Fig. 1 – Climatic zones of India (Source: ECBC Code India)

#### Climate responsive strategies for composite climate

**Orientation:** For composite climate it is advisable that the longer dimension should be on north and south side. South side receives harsh sun so other strategies should be used with orientation like surface with high thermal mass [20].

**Open spaces:** Open spaces are very important with built spaces. Open spaces are starting point of stack effect process which will help in letting in the cool air. Open spaces work as a climate modifier. [21].

**Ground character:** In the areas where heat gain is a major concern in such areas the ground near the building or in courtyard kept green and hard paved area should be avoided [2].

**Fenestration:** Large opening on the two adjacent walls are preferable for effective air movement. These openings are closed with shutters. In humid periods openings are used to allow monsoon winds. Sunken windows are advisable to minimize solar gain [22].

**Surface Area to Volume Ratio:** surface to volume ratio [23] should be less for composite climatic zone to minimize the exposure of sunrays.

**Self-shading:** Mutual shading is a technique in which one surface element like bricks projected or carvings on external surfaces shade the adjacent element this will minimize the exposed area and make the structure cool [24].

**Building envelop:** The walls and roof of the building acts as barrier between outside environments. Thermal capacity of different building material are different. Use of insulation is also a key addition to building envelops [25].

**Daylight:** natural light plays an important role in architectural design. Light in the working plain is very important this will minimize the energy demand of the building. Glare free diffused light is very important in building design [26].

**Vegetation pattern:** In composite climate heat gain is to be minimized. Deciduous trees is to be used to cut of the sun from east, west and south side. In winters these allows the sun to enter in building makes it comfortable for the occupants [2].

Courtyard: courtyard act as a medium to start the process of stalk effect which helps to invite air inside the structure. Building with courtyards consumes 21% less energy in comparison to building without courtyard [44].

Wind catchers: Provision of wind towers helps in catching upper level wind and directs it to inside the building. Provision of evaporative cooling helps to maximize the cooling and creates comfortable conditions [45].

**Factors affecting wind movement**

Different sets of housing units: Different clustered patterns of housing units provides different air movement patterns. Care full arrangements of dwelling unit’s increases or decreases ventilation.

Height and width of the building has a positive or negative impact on the air flowing around the structure. [27].

Passage width and height of the building: Impact of different building heights on velocity of wind.

Building façade combination: study of different façade combination and its impact upon the air movement inside and around the building [28].

Different courtyard configurations: Width, height and position of courtyard and its impact on air movement. Combination of placements of rooms with courtyard also impacts the natural ventilation [29].

Building cross section: Any modification in section of the building, such as giving different volumetric forms, rounding and chamfering building corners and its impacts on air movement [30].

Density of buildings and its impact on velocity.

Analyzing relevance of existing marginal open spaces (M.O.S) [46] prescribed and its effectiveness.

**GEM Sustainability ratings**

Different criteria are joined together on the basis of their common factors. This will provide an entire idea of point distribution and this will help the designer to focus on the key issues while designing and acheave maximum rating for his building.

**Table 2: Categorization of criteria of GEM sustainability certification rating program**

S.No.	Categories of criteria	Principle	Requirement
01	Essential	Government Approved Plans, Fire hazards prevention measures in sustainable buildings [31] Sustainable practices in managing the construction site Adequate parking space	All necessary statutory approvals Certificate of clearance for fire hazards from local administration. Site level interventions, sustainable site development. Parking as per total user capacity as per norms.
02	Climate responsive strategies (Conceptual design stage) (5 points)	Propagating Passive Design Strategies	Implementation of deign strategies at concept development stage to minimize the dependencies of mechanical means,
03	Landscape and site planning preservation of existing flora and fauna (4+2 points)	Appropriate landscape design Use of existing trees in design stage	Maximize natural landscape area and plant

04	Roofing coating materials (6 Points)	High Albedo Materials - Roof and Non-roof [32]	Maximize reflective surfaces
05	Conservation of water resources and reuse of water (4+7+6+3 points)	Harvesting of rainwater and reusing in flushing and other use [38]. Water efficient fixtures. Waste water segregation on site and reuse provisions Irrigation Best Practices	Use of saved rain water in gardening and other activities. Install efficient water fixtures Reusing of water to reduce potable water Use treated water/ rain water for landscape.
06	Quantification of electricity and water usage (6 points)	Measurement of Energy and Water Consumption	Calculation of electricity and water consumption at micro level
07	Waste management (4+4 points)	Waste management system after the building is occupied Use of decomposers to treat organic waste	Post-occupancy waste collection, segregation and disposal Treatment of organic waste through vermicomposting [33]
08	Location of basic amenities to minimize the carbon footprint of user. (6 points)	Amenities for fundamental needs and daily commute	Development of basic amenities within 1 km. distance from site to reduce energy consumption required for procurement of daily essentials.
09	Basic mandatory provisions for differently abled (5 points)	Best Practices for Universal Building Design [43]	Provisions of ramps, braille facilities and other mandatory provision given in NBC
10	Minimize the use of harmful material and gases to reduce the impact on atmosphere (3+2 points)	Minimizing the contact of volatile organic compound [40] Prevention from use of Halogenated Hydrocarbons	Minimizing the use of VOC materials in surface preparations. CFC free refrigeration system, halons free firefighting systems.
11	Sustainable practices in construction methods, techniques and material procurement (12+6 points)	Use of sustainable ways in selection construction techniques and practices [50]. Use of locally available construction materials to minimize carbon footprint [51].	Use of Sustainable alternative is to be promoted rather than conventional materials. Material procurement process and distances is also a main requirement stone is more sustainable in areas where stone is locally available rather than brick.
12	Minimize the use of wood to save trees (4 points)	Minimize the use of different timber material	Use of products alternative to conventional wood like plywood and other recycled material is to

			be promoted.
13	Operations based on low energy resources [39] (fitting ,fixtures and use of renewable energy) (12+5+8 points)	Management of energy use is to be minimized Maximizing the use of energy efficient lighting and other products Use of solar and other type of energy resources.	ECBC code compliance [49]. Equipment with less energy consumption needs to used Promote alternate energy sources rather than using of fossil fuels.
14	Daylighting (6 Points)	Maximum use of natural lighting [37]	All the habitable areas should be lighted with natural light to minimize the use of electrical lighting equipment's
15	Ventilation and air movement (6 points)	Healthy Indoor Air Quality [41]	Provisions of providing proper ventilation inside the structures.
16	Green rating program awareness (2 points)	Spread awareness about the sustainable practices and rating programs [34] in building design in the team	Promote the energy efficient practices through the use of rating programs and certifications in project development
17	Social responsible (2 points)	Activities for Corporate Social Responsibility	Encouragement to the efforts for social responsibilities by addressing the problems like poverty and hunger.
18	Additional efforts for sustainable development (5 points)	Any additional steps towards sustainable development	Additional steps apart from the criteria mentioned in the rating systems like out of the box idea to minimize the harm to the environment.

### Case studies from composite climate

Case studies were selected on the primary basis of climatic zone to understand the cases from similar climatic conditions. Second criteria is region because climatic criteria is different with different places. Office buildings were selected to understand the similar activity patterns and user groups.

#### Case 1: American institute of Indian studies, Gurugram

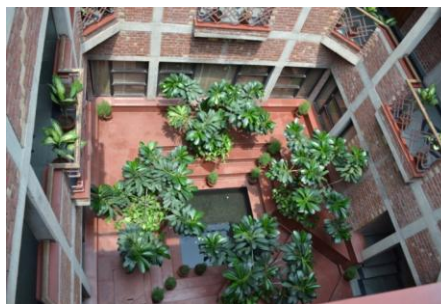
American institute of Indian study is the center to understand Indian art, music and architecture of India. Major built areas of this building is administrative offices, research facilities, archive and library having built up area of 1500 sq. m.

Climate responsive strategies used:

Orientation: maximum surface of the building is oriented NE-SW. Planform is tilted to a certain angle which creates self-shading area and the building surface is constantly changing. Sunken courtyard with landscaping and water bodies are used to minimize the heating effect [4].



**Fig. 2 Plan of building; (Source: Ref. 4)**



**Fig. 3 - View showing courtyard (Source: Ref. 4)**

**Case 2: Solar energy centre, Gurugram**

This building is an office complex with administrative and technical block. The built up area is 6943 sq. m.

Climate responsive strategies used:

Courtyard: courtyard on the entrance with water bod and fountains were used. Mostly the ground is covered with soft grass to regulate the microclimate.

Vaulted roof: Vaulted roofs were used with insulated and reflective materials.

Windows: windows are provides at two different levels lower windows provides ventilation and natural light and lovers with fix glass is used for daylight on working plane [4].



**Fig. 4- (a) Use of reflective material in roofing (b) Use of water in courtyard (c) Openings for lighting (Source: Ref. 4)**

**Case 3: Wipro Technologies, Gurugram**

This building is a corporate office of software professionals.

Climate responsive strategies used:

Compact planning: the compactness ration of building is 9.5. Low surface to volume ratio helps to reduce heat gain from surfaces.

Orientation: The floor plan is oriented 45°. Orientation of the building is according to the sun path, longer building surface oriented to east–west direction to minimize solar heat gain.



Fig. 5- (a) Building Profile (b) Orientation (c) Plan of building (Source: Ref. 4)

#### Case 4: Indira Paryavaran Bhawan, Delhi

Indira Paryavaran Bhawan, new work place for Ministry of Environment and Forest sets is different from conventional designed buildings. Project area is 9565sq.m.

Climate responsive strategies used:

Orientation: Building is north south oriented, this type of orientation of plan minimize heat gain. Adequate wall to window ratio.

Central courtyard: Courtyard helps in continues airflow because of stalk effect.

Daylight: More than 70% area is naturally lighted helping to reduce artificial lighting.

Landscape: Maximum area outside as well as courtyard area is green area. Soft paving is provided that helps in ground water recharge [6].



Fig. 6- (a) Building Profile (b) Plan of building (Source: Ref. 6)

#### Case 5: Unnati Office, Greater NOIDA

The Unnati headquarter of Gainwell Pvt. Ltd. Project area is 3740 sq. m.

Climate responsive strategies used:



Orientation: orientation northeast- southwest. Volume is cuboid which is good for minimum exposure to the sun.

Landscaping: Native vegetation is used to minimize water requirement. Unbuilt area is 30% of total site.

Green roof: Insulation material is used 13 mm extruded polystyrene insulation and green roof is installed to keep the structure cool.

Daylight: Maximum daylight is achieved because WWR (window to wall ratio) is 30% [7].

**Comparative analysis:**

All the cases are analysed based on the GEM sustainability rating program. All the points of rating system was not considered as different examples has different strategies are used.

**Table 3- Comparative evaluation of case studies according to criteria of gem sustainability**

Criteria	Case 1 American institute of Indian studies, Gurugram	Case 2 Solar energy centre, Gurugram	Case 3 Wipro Technologies, Gurugram	Case 4 Indira Paryavaran Bhawan, Delhi	Case 5 Unnati Office, Greater Noida
Climate responsive strategies (Conceptual design stage) (5 points)	Orientation and courtyard with evaporative cooling (03 points)	Courtyard, reflective roof, Earth sheltered architecture[42], (03 points)	Orientation, Compact volume , courtyard spaces, daylighting (04 Points)	Orientation, Courtyard ventilation , Recycled building material (04 points)	Orientation, daylighting , green walls, roofing insulation (04 points)
Landscape and site planning preservation of existing flora and fauna (4+2 points)	Minimum landscape area ( 2 points)	Minimum landscape area ( 2 points)	10% landscape area (1point)	50% area is covered with native vegetation (04 points)	Built open ratio is 70 and 30 %. Indian landscape verities ae used (04 points)
Roofing coating materials (6 Points)	Roof garden, use of roofing material (02 points)	Reflective surfaces with recycled roofing material (2 points)	(0 points)	High reflective terrace tiles (2 points)	Roof insulation and soil for green roof. (2 points)
Sustainable practices in construction methods , techniques and material procurement (12+6 points)	Use of recycled tils in roofing, local sourcing of building material (6 points)	Use of recycled tils in roofing, use of concrete block, local sourcing of building material (6 points)	Use of locally procured material (4 points)	In plastering fly ash is used and for walls AAC blocks were used (10 points)	Insulated concrete material (4 points)

Above analysis is done based on available data. Points may increase. Points are based on common factors.

3.2 Live case analysis (simulation)

Residence at kamayani nagar rau Indore (Madhya Pradesh, India)

Project by M.P. Housing Board, Extension by Ar. Abhijit Kulkarni

Climate type: Composite

Site area: 1500 Sq. ft.

Built up area: Ground floor-650 sq. ft.

First floor: 450 Sq.ft.

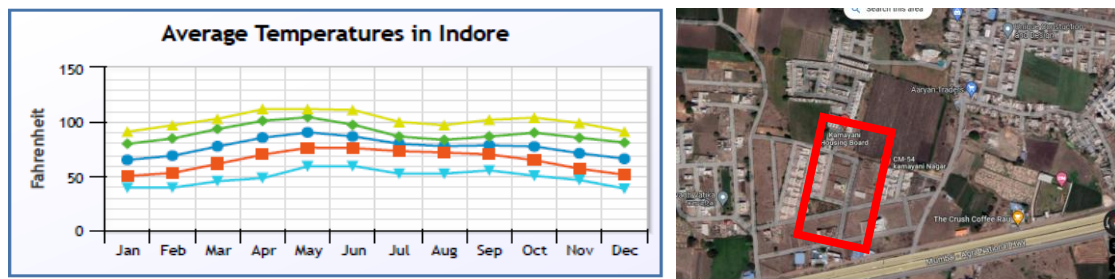


Fig. 7- (a) Showing temperature ranges of Indore (b) Site location (Source: Google earth)

Climate responsive strategies used:

Orientation: Plan is oriented towards east-west. North side is open and south side wall is common between two houses. Minimum exposure in west side wall minimize the heat gain all openings of ground and first floor provided in northern side to minimize direct sun rays.

Open spaces: More than 50 % of the area is left open. These open spaces used as a vegetable garden and flower gardens. Open spaces are provided in west and north directions.

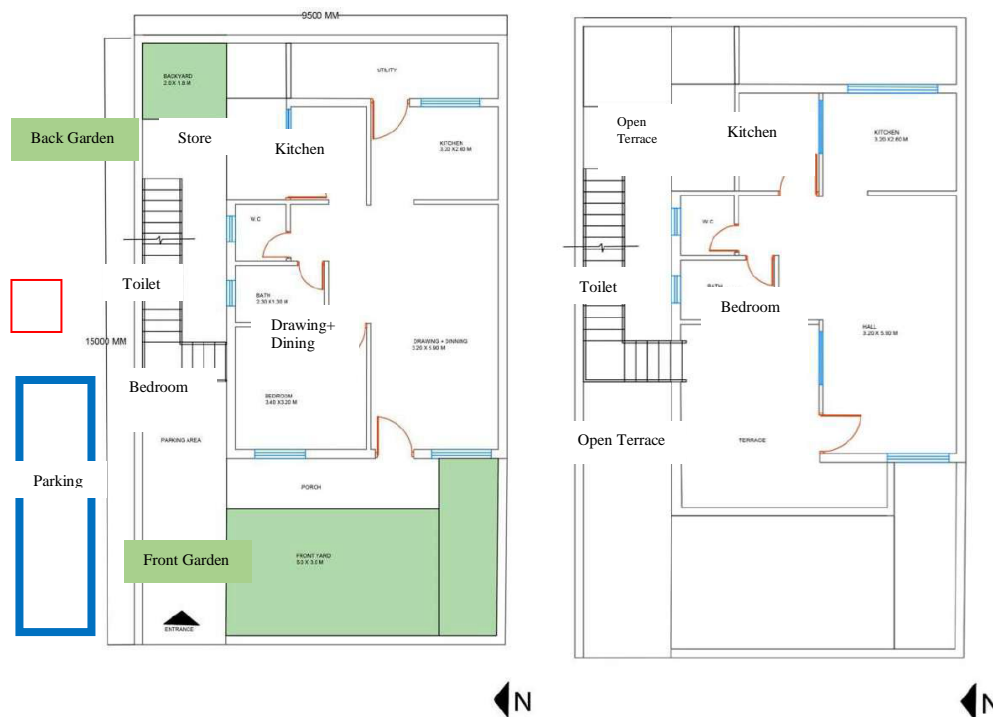


Fig. 8- (a) Ground floor plan (b) First floor plan (Source: Author)

Soak pit in red, parking paved area in blue and green spaces showing open areas

Landscape: Minimum hard areas are provided for parking purpose only that also in northern exposure. Native plants [47]. And fruit plants are used in landscape area. Soil cover helps rain water to perferate in. Use of cow dung as a traditional techniques to regulate thermal comfort.

Brick jail wall: Brick jali is used in compound wall to maximize air flow and aesthetic purposes.



Fig. 9- (a) Front open space (b) Back open space (c) Native plants (d) Brick Jali (Screen wall) (Source: Author)

Fenestration control: Windows are provided in staggered configuration and positioned in such way that will help in maximize cross ventilation.

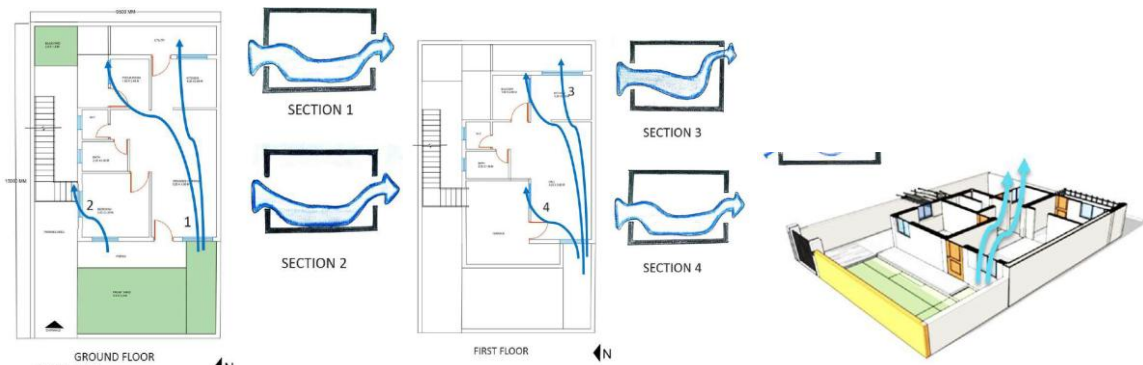


Fig. 10- (a) Ground floor plan with air movement (b) First floor plan (d) Brick Jali (Screen wall)

(Source: Author)

Water harvesting: Maximum rain water and overflow water is connected to soak pit.

Daylight Factor: Satisfactory daylighting in all the habitable zones minimize the requirement of artificial lighting.

Maximum areas having daylight factor of 4.80 which is satisfactory.

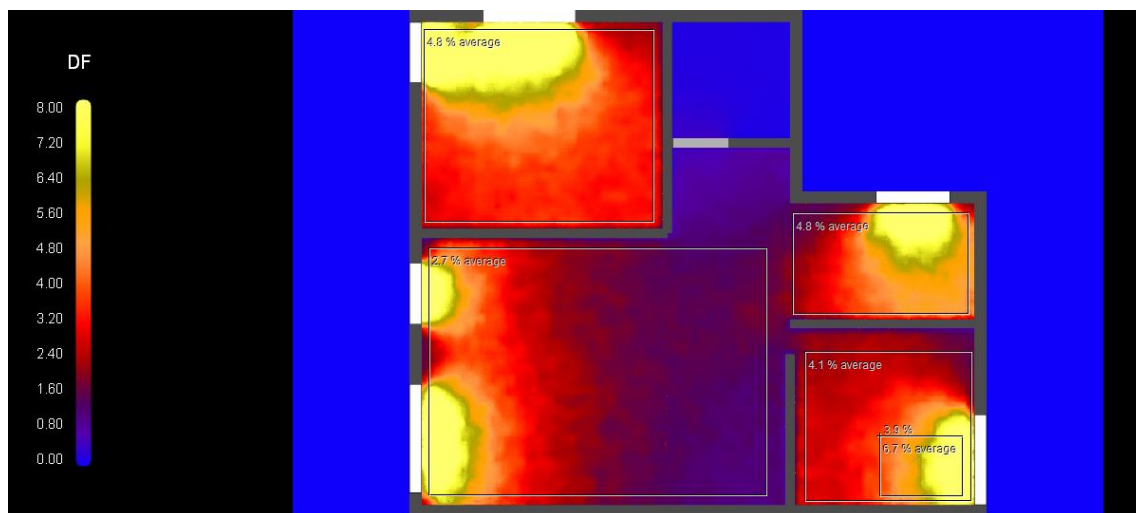


Fig. 11- Daylight simulation is done by Velux daylight visualizer 3

Mutual shading: Because of orientation mutual shading takes place this will help in minimizing heat gain.

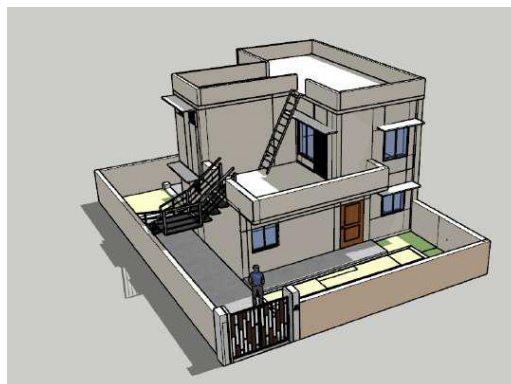


Fig. 12- Mutual Shading analysis (May 12 pm.)

Table-4 Gem energy efficiency criteria fulfilment for live case

Principles	Description	Maximum Points	Points earned
01	Government Approved Plans Certificate of clearance for fire hazards from local administration. Site level interventions, sustainable site development. Parking as per total user capacity as per norms.	Essential	Essential
02	Climate responsive strategies (Conceptual design stage)	5 points	03 points

03	Landscape and site planning preservation of existing flora and fauna	6 points	03 points
04	Roofing coating materials	6 points	00 points
05	Conservation of water resources and reuse of water	20 points	11 points
06	Calculation of electricity and water consumption at micro level	6 points	2 points
07	Waste management	8 points	8 points
08	Location of basic amenities to minimize the carbon footprint of user.	6 points	0 points
09	Basic mandatory provisions for differently abled	5 points	0 points
10	Minimize the use of harmful material and gases to reduce the impact on atmosphere	5 points	02 points
11	Sustainable practices in construction methods , techniques and material procurement	18 points	06 points
12	Minimize the use of wood to save trees	4 points	02 points
13	Daylighting	6 points	06 points
14	Ventilation and air movement	6 points	06 points
15	Efficient Electric Equipment and Systems	5 points	02 points
16	Energy Management Best Practices	12 Points	06 Points
		Total points	<b>57 Points</b>

Project is compliant for GEM 2 level certification, this rating may increase after the detailed study of all the factors.

#### Guidelines

- Orientation of the building is first step towards occupants comfort. Proper orientation minimize the solar exposure of surface. According to this study orientation of the building is the first important and influential strategy in the design process.
- Surface thermal mass plays an important role in heat transmission of the building glazing in incorrect direction creates discomfort for the user.

- Maximizing open spaces and proper use of water courts and green courts helps in controlling the site level conditions.
- Wind movement inside the building and changing the path of wind by creating negative pressure in the opposite face reduces the cooling load of the building.

### Conclusion

Continues increase in energy demand is a major concern for the humanity. Building sector is a major stakeholder in energy demand on global level. Land is an important resource and it is limited and population increase is the major challenge for the society. Understanding demand of the society and providing sustainable solutions is the major role of a designer. This research helps in understanding the climatic features of composite climate which has a major land share in Indian context. Different design strategies are analyzed and suitable set of strategies are enlisted in this paper. In earlier studies major focus is given to building envelop and impact of solar radiation on it. In this research neighborhood level wind patterns and macro to micro level wind analysis is taken into consideration and how it will impact the ventilation pattern inside the building is reviewed. GEM sustainability rating systems are reviewed and different literature cases were analyzed based on the criteria given. Analysis of literature case studies are done on the basic of strategies which are mentioned in the studies actual rating of the building may increase after the detailed investigation. A live example from composite climate was also analyzed and found compliant for GEM 2 certification. This study will continue in the sector of integration of different design strategies at building envelop level and wind movement for composite climate to provide a framework to design with climate and detailed analysis of effective wind flow.

### Future course of work

Different building typologies needs to be analyzed from different climatic zones and according to different functions. Effectiveness of different strategies individually need to be analyzed and categorization according to impact of each strategies on thermal comfort is to be identified. Air movement is also an area in which accurate modelling is required for Indian context. Combination of multiple strategies need to be analyze in future.

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