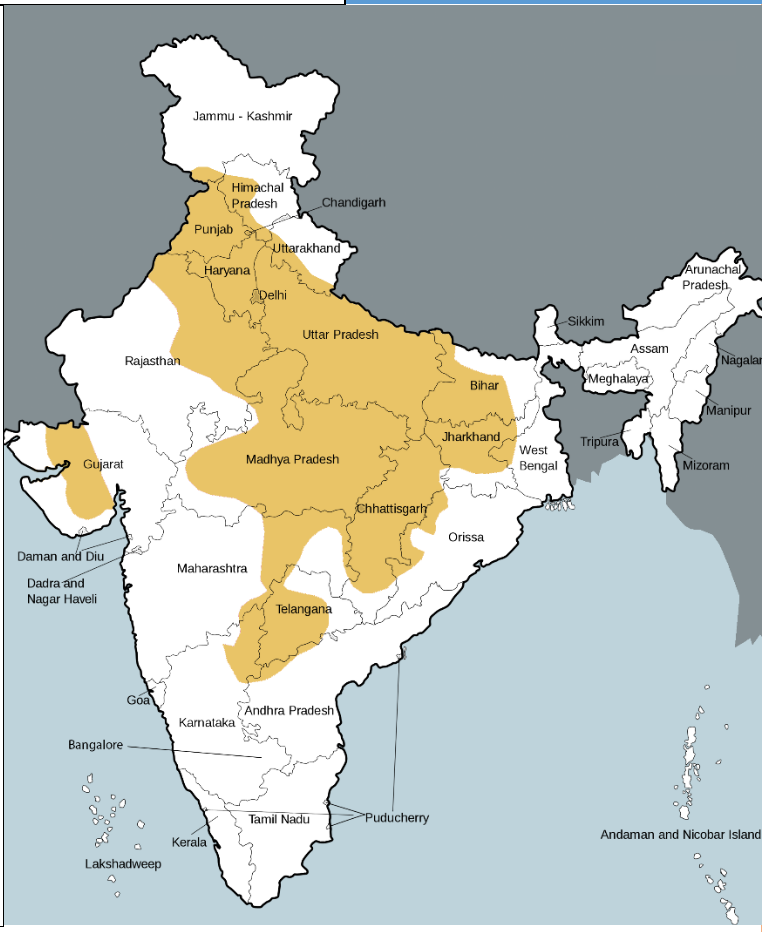
MaS-SHIP

Mainstreaming Sustainable Social Housing in India Project

Guidelines for integrating sustainability in social housing developments in India

October 2018

Composite climate zone



The purpose of this document is to compliment the guidance provided by the Government and Green Building certification bodies in India.

These guidelines are based on learnings derived from the MaS-SHIP project as well as secondary literature.

Insights are also shared from resident surveys conducted in five social housing developments in India.

Incorporating these guidelines in the design and construction of social housing developments will contribute to enhance the sustainability and quality of life of the residents.

Key principles

- Provide convenient accessibility to basic day to day amenities and proper connectivity to places of work.
- Minimise solar exposure of the building envelope, by optimum orientation (long axis EW), built form and mutual shading of building blocks.
- Design & orient the window openings and shading devices, to avoid direct solar gain in summer, but allow for solar radiation to penetrate into the building during winters.
- Windows should allow for sufficient daylight penetration into regularly occupied areas, to avoid internal heat gains due to electrical lighting.
- Maintain quality of construction to developing of cracks, breakage in walls and material joints. Adequate water proofing and good quality plumbing design and installation is imperative to avoid discomfort and damage caused due to occurrence of dampness.
- Adequate provisions for natural ventilation along with passive cooling strategies are important to enhance thermal comfort in social housing, at a low cost.

Prominent Indian cities within the composite climatic zone (1)

Allahabad; Amirtsar; Bhopal; Chandighar; Dehradun; Gorakhpur, Gwalior, Hissar, Hyderabad, Indore, Jabalpur, Jaipur; Jalandhar; Lucknow; Ludhiana; Nagpur; New Delhi; Patna; Raipur; Rajkot; Ranchi; Saharanpur

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Climatic characteristics

- High temperatures in summer and low to very low temperatures in winters.
- Humidity remains low throughout the year, except for monsoon season.
- High direct solar radiation in all seasons except monsoons high diffused radiation.
- Hot winds in summer, cold winds in winter and strong wind in monsoon.
- Clear sky during summer; overcast sky and dull conditions during monsoon.
- Wind direction varies during monsoon season. (Local climatic data should be referred for establishing wind speed and direction)

Climate data (1)		
Mean temperature	Summer midday	32 to 43 deg. C
	Summer night	27 to 32 deg. C
	Winter midday	10 to 25 deg. C
	Winter night	4 to 10 deg. C
	Diurnal variations	35 to 22 deg. C
Relative humidity	Min. 20% to 50%;	Max. upto 95%
Rainfall	Variable - 500 to 1300 mm/year	

Average temperature and relative humidity in five prominent cities (2)

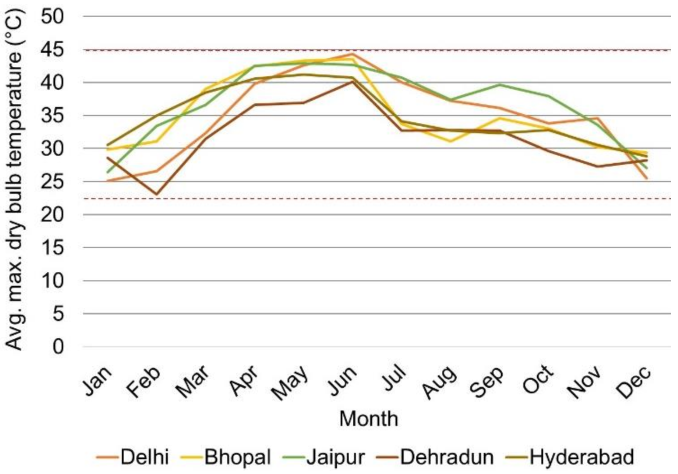

Figure 1: Average maximum dry bulb temperature

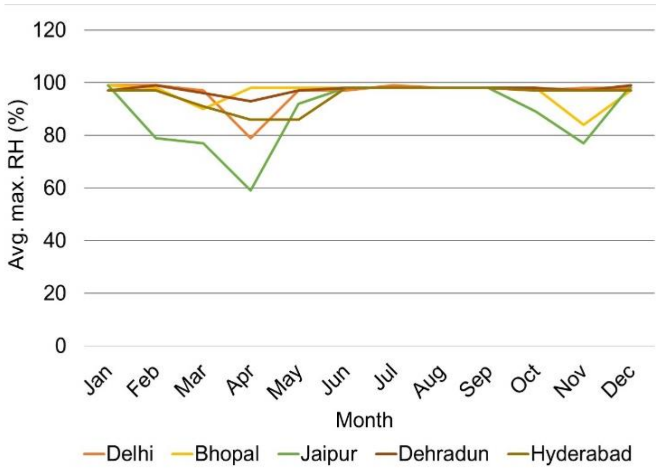

Figure 3: Average maximum relative humidity

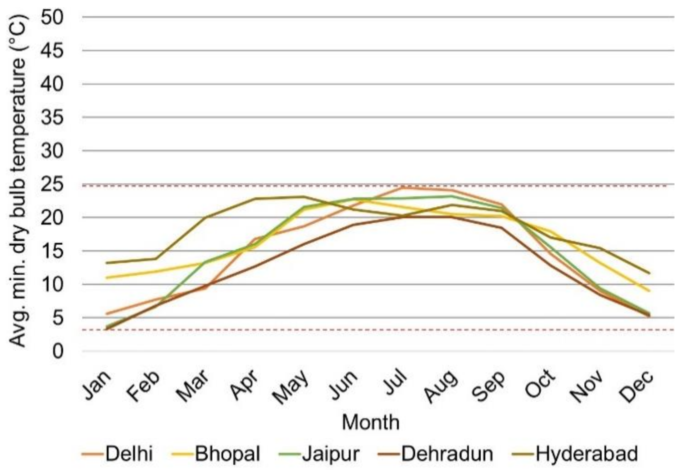

Figure 2: Average minimum dry bulb temperature

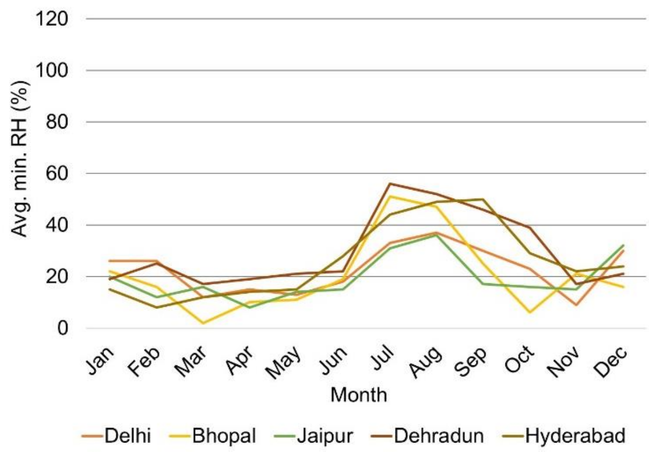

Figure 4: Average minimum relative humidity

Site Location

Convenient access to basic day to day amenities around the development has been identified as an important aspect of approach towards sustainability of a housing development. (3, 4).

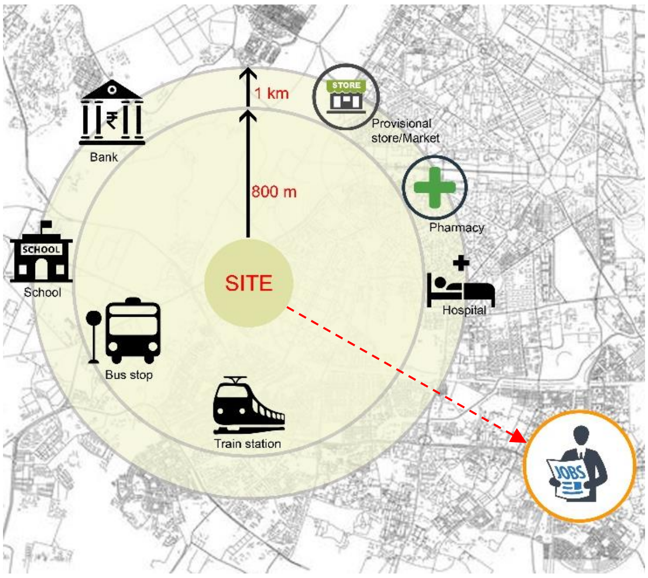

Figure 5: Site location

- Public transport facilities (intra-city station/bus stop/ metro) to be at a max. distance of 800 meters from the development.
- Basic amenities like hospital/clinic, pharmacy, schools, market/provisional store, ATM/bank to be within a walking distance of 1 km from the development.
- The site location should be such that it either provides the residents easy access to job opportunities or is well connected with the city's main commercial/employment centric areas where the residents work/could find work.

Figure 6: View of market near Jakkampudi colony in Vijayawada (Despite being 11km from the city centre, the residents of Jakkampudi colony had easy access basic amenities)

Massing and space planning

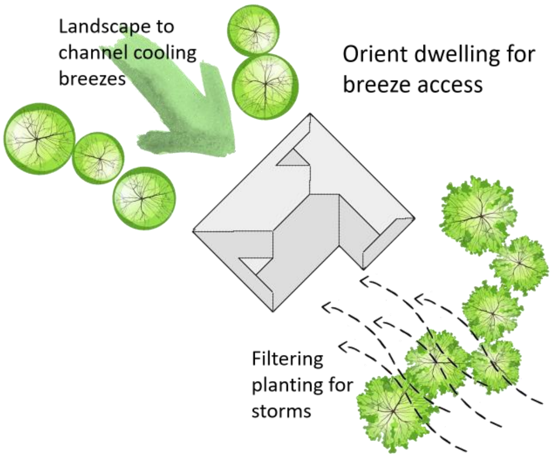

Figure 7: Orienting dwelling for optimum breeze access

- Orient the building with the long axes in the east-west direction so that the longest walls face north & south and only the short walls face east-west, to minimise solar exposure of external walls.
- The prevailing wind direction should also be considered while deciding the building orientation to allow for optimum positioning of windows and to maximise natural ventilation whenever outside temperatures are low.
- Strategically plant vegetation on site to capture and direct the wind flow.
- Preferably compact internal planning in the form of courtyard type (to reduce exposure of external surfaces to solar radiation).
- Balconies and open terrace should be preferably located on the North or South façade of the building. East and West facades can be protected by buffer spaces, such as staircase, corridors etc.
- Building blocks to be arranged to achieve mutual shading, to avoid direct solar heat gain especially during summer. However, adequate penetration of natural light into the regularly occupied areas of the building should also be taken into account.

Building envelope

Thermal performance

The thermal performance of a building envelope i.e. its capacity to regulate heat gain and loss during summer and winter respectively, is one of the most important criterions especially in case of buildings in composite climate zone. The design and material specifications of building envelope should be aimed to achieve:

1. Comfortable indoor temperatures (with minimum possible active measures) during both summer and winter.
2. Healthy indoor air quality, by allowing for adequate natural ventilation.
3. Adequate provision of natural lighting in the regularly occupied areas of the dwellings (5).

- The baseline thermal conductivity (U-value) value for different building components as defined in IGBC Green Affordable housing are provided below (4).

Building component	**U-value (W/m^2K)**
Wall	≤2.5
Roof	≤1.2
Glazing	≤5.7
Glazing (SHGC)	
WWR <20%	0.5
WWR >20%	0.42

- Heat gain from the external walls can also be reduced by using light colours on the exterior surfaces (absorptivity < 0.4).

- Heat gain from roof surface can be reduced by using high SRI roofing materials, like white broken china mosaic, high SRI paints etc on the roof surfaces.

- In case of social housing developments where affordability is of prime concern, while insulating the walls may not prove to be economical, ensuring good quality construction to avoid or minimise air leakage through cracks and joints can contribute in improving the overall indoor comfort.

Window openings and shading

- In composite climatic zone where both cooling and heating of the interior spaces is required, large glazed windows should be avoided to reduce excessive heat gains and loss from the glazing.

- The window to wall ratio (WWR) on each façade should be determined based on the duration of sun exposure.

- Ensure adequate shading on the south side windows to cut-off direct solar radiation during the summer months but permit winter sun.

- Minimum projection factor for external shading should be 0.5 (3).

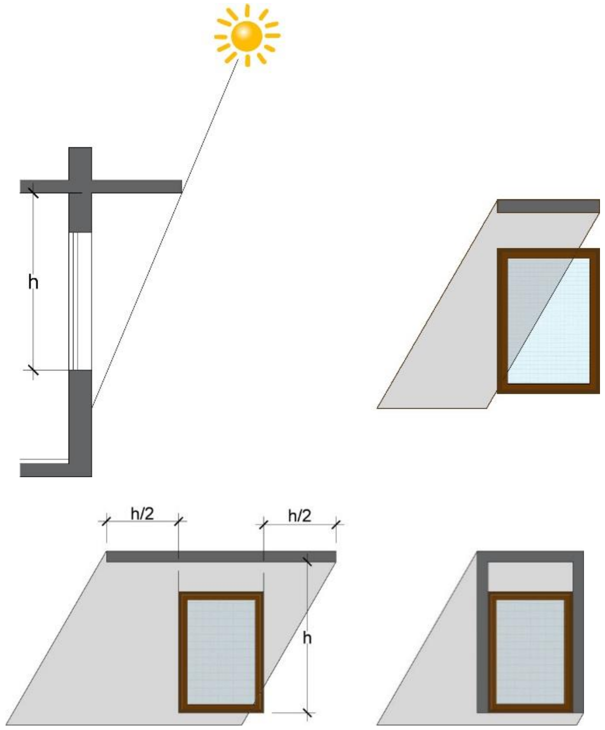

Figure 8: Guideline for designing effective horizontal shading for windows on south façade. Image adapted from: The Carbon Neutral Design Project (11)

Daylighting

- Usually 10%-15% WWR in bedrooms and 30% in living room are needed to provide adequate daylight

- Providing windows with higher lintel levels or use of light shelves can increase the daylight penetration into the building.

- As a rule of thumb- daylight penetrates a room approx. 2.5 times the height of the top of the window.

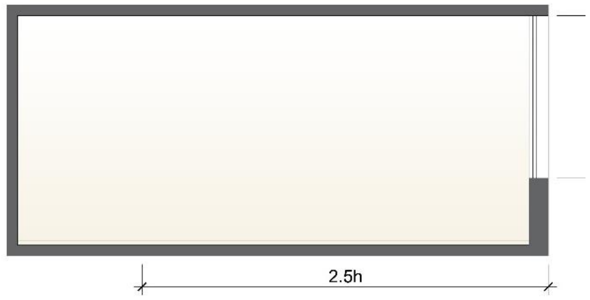

Figure 9: Daylight penetration extent in a space

- External light shelves allow diffused light penetration & shade. Internal light shelves allow deeper light penetration & solar access.

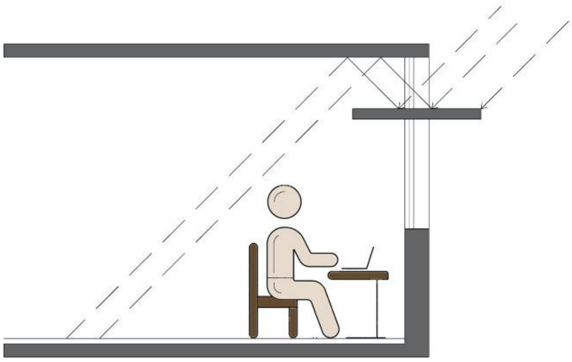

Figure 10: Light shelves

Ventilation and passive cooling

- In the composite climatic zone where external temperatures are high during summer, night time ventilation can be effective in removing the heat stored inside the building mass during the day.

Stack ventilation

- Stack ventilation or convective air movement is a form of cross ventilation that enhances air circulation inside a space by combination of buoyancy and venturi effect. The lighter warm indoor air rises to escape the building through window openings at high level and is replaced by cool night time air or day time air drawn from shaded external areas (north) from inlets at lower level. Stack ventilation can be an effective passive cooling measure when the outside temperatures are relatively cooler (3).

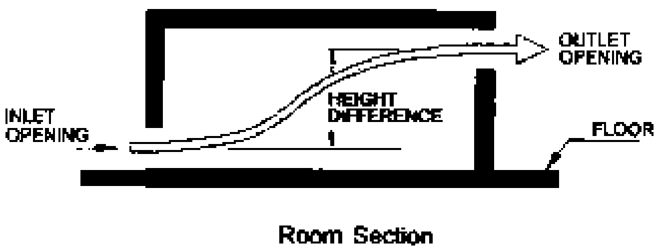

Figure 11: Stack Ventilation. Image adapted from: NBC vol. 2, 2016 (3)

Solar chimneys

- The system can be integrated with the roof or a wall and is a modification over Trombe Wall. Solar Chimney, on an external wall, enhances stack ventilation by providing additional height and well-designed air passages thereby increasing the air pressure differential. Via solar radiation, the chimneys warm the rising air which increases the difference between the temperatures of incoming and outflowing air. These measures increase the natural convection and enhance the draw of air through the building.

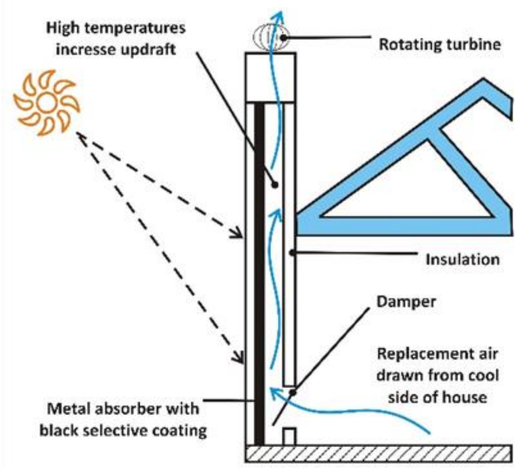

Figure 12: Solar chimney-wall

Drainage & Waste management

- The site plan should be developed so as to minimize the disturbance caused to the existing natural habitat at the site. Detailed guidelines for providing and developing green areas at site are available in NBC vol 2, 2016.
- Segregation and disposal of organic waste through natural process like dump-pits, vermi-composting etc. should be incorporated in the design and planning of the project to encourage cleanliness at site. A regulatory body can be formed from among the residents to oversee the regular disposal of garbage. This will help provide them with a sense of responsibility and also assist in job creating.

Water conservation

Rainwater Harvesting

- Capturing and preserving rain water is an efficient way to reduce portable water consumption and address water crisis.
- Rainwater harvesting can be done either for-

  I. Storage (underground or over-ground tanks) and direct use of rain water, or

II. Charge into the ground – Ground water recharge.

- Rainwater harvesting system for a minimum of 20% of run-off volume from impervious surfaces (both site & roof) should be provided.

Or

- If the ground water table is less than 4m, rainwater harvesting storage tanks for a minimum of 7.5% system for a minimum of 20% of run-off volume from impervious surfaces (both site & roof) should be provided (4).

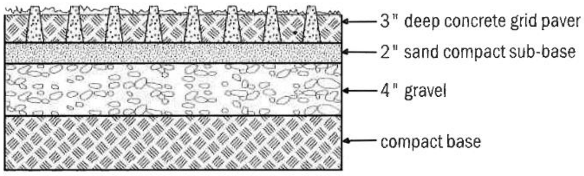

Figure 13: Performed lattice unit grids for storm run-off control, pedestrian pathways and soil conservation. Image adapted from: Sustainable Building Design Manual, Vol.2 (7)

- Providing pervious &/or semi-pervious surfaces on site, in the form of grass pavers, pebble beds etc. can also lead to less run-off and allow for ground water recharge through a larger area.

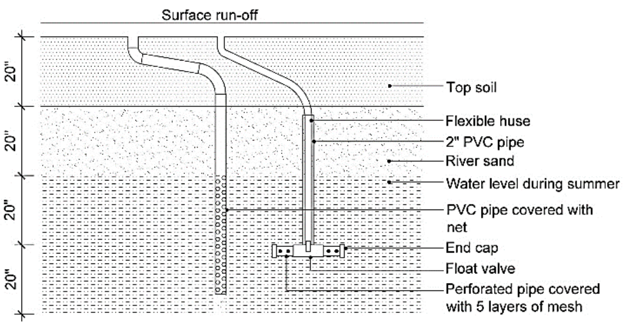

Figure 14: Rainwater harvesting mingled with a pavement design at an interval dependent on the run-off. Image adapted from: Sustainable Building Design Manual, Vol.2 (7)

- The type & amount of rainwater harvesting suitable for a development varies and depends on the climatic zone, rainfall intensity, soil conditions, run-off volume and site design. NBC and Local Building Byelaws must be referred for planning and detailing RWH system in a development.

Building materials

Selection of materials in composite climate should be done primarily to minimize heat gain through the building envelope. The selection criteria for material should fulfil:

- Reduced heat ingress
- Dissipate humidity during monsoons
- Local availability to reduce transportation energy.
- Lower embodied energy (EE).
- Higher durability of material (2x durability means ½ energy for extraction, processing, installation and disposal).

Materials

Materials suitable for Composite climate are:

1. Autoclaved Aerated Concrete Blocks
2. Ferrocement Channels
3. Sustainable mine waste such as stones, stone dust and chips to make concrete blocks.
4. Fly-ash bricks (more efficient if travel is less than 100 km)
5. Compressed Stabilized Earth Blocks
6. Hollow core concrete blocks
7. Perforated brick masonry, Rat-trap Bond
8. UPVC windows, to provide better insulations in comparison to Aluminium windows.
9. Marble chips used in manufacturing of terrazzo
10. Low VOC paints, adhesive and sealants.
11. Sandstone Roofing

Insulation

Use of cavities and cheap insulation material such as polystyrene in walls can help achieve desired U-values. A typical 9-inch (230 mm) brick wall has a U-value of 2.28 $W/m^2 \cdot K$ (9), while a value of 0.7 W/m^2K can be achieved by using 200-mm thick autoclaved aerated concrete (AAC) block or hollow concrete blocks filled with insulation material.

Impact on cooling load

- Simulations were carried out to estimate the annual energy consumption per unit area due to cooling, in a 4 storey building using DesignBuilder software. The Bhawana housing case study was used as a reference to model a social housing project in the context of India. The simulations were run for a single dwelling unit of 22.35 Sq. M. area situated on the top floor (4th floor). A split air-conditioning HVAC system (COP-3.26) was modelled and the set-point for the operative room temperature was assigned in accordance with the EN 15251 standards of adaptive thermal comfort.

- Occupancy and activity schedules were assumed from national standards, similar research work and homeowner's survey data collected as part of MaS-SHIP. A total of 16 existing and emerging building construction systems were assessed in comparison to the base-case. Comparative analysis between the annual cooling load per Sq. M. shows the savings potential for each of these systems as enlisted in the table below.

Composite			
	Base Case	**Cooling energy (kWh/m²/yr)**	
	Walling (12.5 mm cement plaster + 225 mm brick + 12.5 mm cement plaster)	**50.2**	
	Roofing (100 mm RCC + 100 mm lime concrete)		
		Savings from Base Case	**Savings**
		(kWh/m²/yr)	**In %**
	Improvements - Walling		
1	Fly-Ash brick work	1.77	4
2	AAC block masonry	14.22	28
3	Rat-trap Bond brickwork	2.68	5
4	Hollow concrete block masonry	1.85	4
5	Solid concrete block masonry	-3.17	-6
6	CSEB walling	2.25	4
7	Stonecrete blocks masonry	-4.24	-8
8	GFRG Panel System	-3.74	-7
9	Precast Large Concrete Panel system	0.90	2
10	Reinforced EPS Core Panel System	19.78	39
11	LGSFS-ICP	-3.53	-7
12	Monolithic Concrete Construction	-4.01	-8
	Improvements - Roofing		
1	Reinforced Brick Panel roofing	0.78	2
2	RCC Filler Slab roofing	-3.61	-7
3	Pre-cast RCC Plank & Joist roofing	3.61	7
4	Ferro Cement channel roofing	2.48	5

Note- Negative sign signifies that the building system impacts to a higher cooling load than the base case.

- While AAC Block and ferrocement channels have the highest savings potential, Stone-crete blocks perform the worst. The simulation has been run for a dwelling unit with exposed roof, hence the most drastic changes in cooling load were observed in cases where the construction of roof changes.

Sustainability Index

- The Sustainability Assessment Tool (SAT) is built on a Multi-Criteria Decision support system to provide the targeted beneficiaries with evidence based performance information. This would aid decision making in their choice of building materials and construction technologies, both walling and roofing, for social housing projects in India.

- A total of 17 building materials and systems have been evaluated on the basis of 18 attributes categorized under 4 main criteria – Resource Efficiency, Operational Performance, User Experience and Economic Impacts

- The link to the SAT is: https://teriindia-my.sharepoint.com/:x:/g/personal/megha_behal_teri_res_in/EYFFmyuT1sdDjvod8oZqlK4BVw-OKPkVGVlnUn-8Rsro4g?e=sZrveE

- The SAT would enable the user to make an informed choice by providing:

    - Order of preference of 17 walling & roofing building systems across all 18 attributes
    - Order of preference of 17 walling & roofing building systems across selected attributes
    - Customized results based on the location selected
- The SAT outputs are represented in the form of graphs which provide '**scores**' of the building materials and systems with respect to the selected attributes. The scores have been calculated on the basis of absolute data gathered for 17 building materials and systems across 18 weighted attributes.
- Higher score of a building material or system with respect to others is an indicator of its better performance. Precisely, higher the score, better the building material or system.

Insights from resident experiences of living in social housing developments in composite climate

- Relocating the urban poor from the heart of the city to the outskirts is one of the causes of number of dwellings remaining unoccupied in such developments. Due to unavailability of adequate job opportunities around the developments the residents are forced to relocate in order to retain their jobs in the city.

- Residents living in housing developments in remote locations lack adequate public transport facilities, making it increasingly difficult for them to access basic day-to day amenities like market place and hospitals.

- Dwellings in social housing developments fail to provide comfort indoor environment especially in summer (in the absence of air–conditioning).

- Air movement plays a significant role in influencing the perception of indoor environmental conditions in naturally ventilated dwellings. Poor design and layout resulted in inadequate air movement in many of these homes.

- The housing projects aimed to address the needs of people from the economically weaker sections of the society often face cost constrains and therefore focus on using cost-effective affordable building materials and technologies. Consequently, the quality of construction and workmanship gets compromised.

- The nail-ability of the walls and difficulty in accessing the plumbing pipe works for repair and maintenance where the primary concerns expressed by the householders.

- The lack of maintenance and up-keep of the common areas and the site was a common sight in all the surveyed developments. In some developments incomplete or poorly planned drainage system lead to water logging around the dwellings, while absence of cleanliness and proper garbage disposal system resulted in unhygienic streets and surroundings.

References

1. BEE (2009). *Energy Conservation Building Code User Guide*. New Delhi: Bureau of Energy Efficiency, p.E.2.
2. Energyplus.net. (2018). *Weather Data by Region | EnergyPlus*. [online] Available at: https://energyplus.net/weather region/asia_wmo_region_2/IND%20%20 [Accessed 14 Aug. 2018].
3. Bureau of Indian Standards (2016). *National Building Code of India.* New Delhi: Bureau of Indian Standards, p.14.
4. IGBC (2017). *IGBC Rating System for Green Affordable Housing Pilot Version*. Hyderabad: Confederation of Indian Industry, pp.9,11,21 *Available at: https://igbc.in/igbc/html_pdfs/abridged/IGBC%20Green%20Affordable%20Housing.pdf*
5. BEE (2014). *Design Guidelines for Energy-Efficient Multi-Storey Residential Buildings (Composite and Hot-Dry Climates)* (2014) [PDF], pp.17,18, 31. Available at: https://www.beepindia.org/case-studies-n-resources/ [Accessed 8 Aug. 2018].

Others

6. Degreedays.net. (2018). *Heating & Cooling Degree Days - Free Worldwide Data Calculation*. [online] Available at: http://www.degreedays.net/ [Accessed 14 Aug. 2018].
7. Sustainable Building Design Manual. V2- Sustainable building design practices. (2004). 1st ed. New Delhi: Energy and Resources Institute, pp.33,34.
8. CPWD (2014). *CPWD Guidelines for Sustainable Habitat*. New Delhi: Central Public Works Department.
9. Ashok.B Lall Architects & Greentech Knowledge Solutions Pvt. Ltd (2017). *Position paper on Low Carbon Resource- Efficient Affordable Housing*. New Delhi. Available at: http://capacitiesindia.org/position-paper-on-low-carbon-resource-efficient-affordable-housing/
10. Rainwaterharvesting.org. (2018). *Rainwater Harvesting - Solution to water crisis - System and Systems*. [online] Available at: http://www.rainwaterharvesting.org [Accessed 14 Aug. 2018].
11. The Carbon Neutral Design Project | Society of Building Science Educators | American Institute of Architects - Carbon Neutral Design Strategies http://www.tboake.com/carbon-aia/strategies1b.html

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MaS-SHIP

Mainstreaming Sustainable Social Housing Project in India (MaS-SHIP) is a two-year research developed to promote sustainability in terms of environment performance, affordability and social inclusion as an integral part of social housing. Funded by United Nations Environment Programme (UNEP) 10 Year Framework of Programme on Sustainable Consumption and Production (10YFP).

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