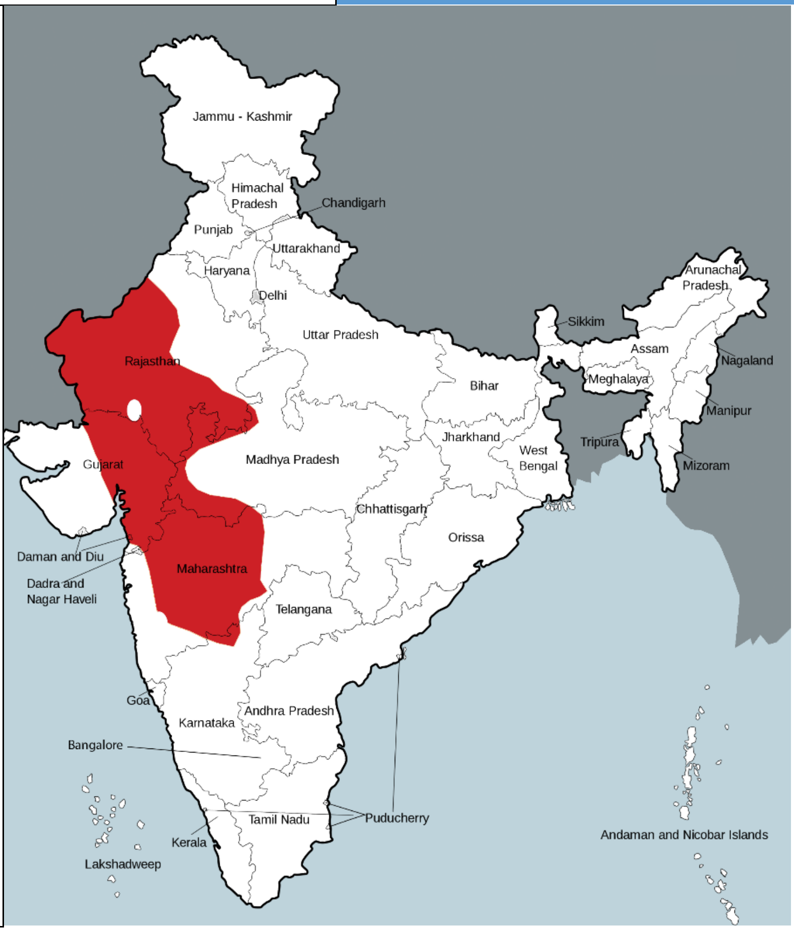
MaS-SHIP

Mainstreaming Sustainable Social Housing in India Project

Guidelines for integrating sustainability in social housing developments in India

October 2018

Hot & Dry 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 learning 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 t*o* enhance the sustainability and quality of life of the residents.

Key principles

- Minimise solar exposure of the building envelope, by optimum orientation (long axis NS), 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 the building during winters.
- The building envelope design should aim at achieving reduction in cooling energy demand, improvement in thermal comfort, and provision of adequate day-lighting in regularly occupied areas such as bedroom, living room, and kitchen.
- Adequate provisions for natural ventilation along with passive cooling strategies are important to enhance thermal comfort in social housing, at a low cost.
- Provide convenient accessibility to basic day to day amenities and proper connectivity to places of work.

Prominent Indian cities within the hot and dry climatic zone (1)

Ahmedabad, Aurangabad, Barmer, Bikaner, Jaisalmer, Kota, Sholapur, Surat, Vadodara

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Climatic characteristics

- Predominance of summer over the year; hot conditions routinely prevail from March to September with April-July being the most intense months.
- High temperatures in summer and low temperatures in winters. Diurnal variations of 15-20°C.
- Mean relative humidity remains very low (25-40%) throughout the year, with low rainfall of <500mm per year.
- Intense solar radiation (800 – 950 W/m²)
- Dust laden local winds often developing into sandstorms throughout the year.
- Sandy/rocky ground with little vegetation and low water level.

Climate data (1)		
Mean temperature	Summer midday	40 to 45 *deg.*C
	Summer night	20 to 30 *deg.*C
	Winter midday	5 to 25 *deg.* C
	Winter night	0 to 10 *deg.*C
	Diurnal variations	15 to 20 *deg.*C
Relative humidity	Min. 25%	Max. upto 55%
Rainfall	<500 mm/year	

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

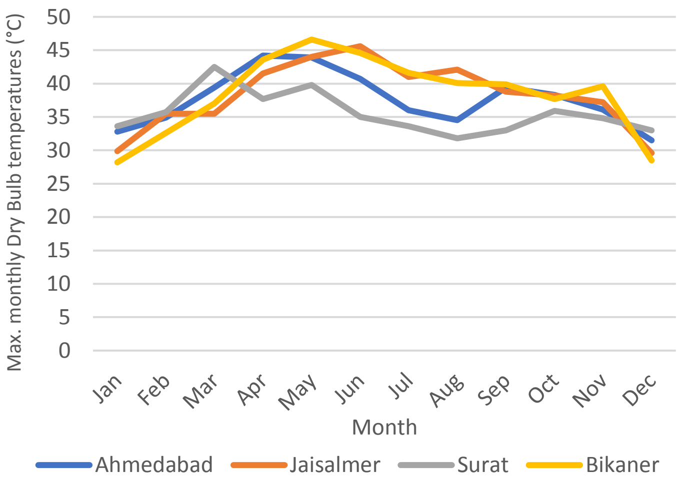

Figure 1: Monthly maximum dry bulb temperature

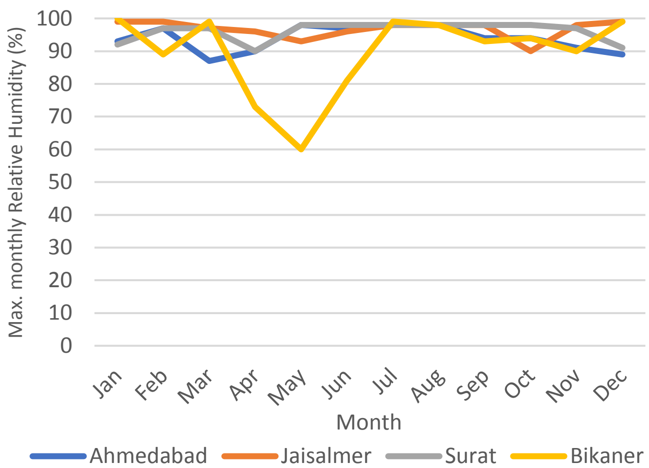

Figure 3: Monthly maximum relative humidity

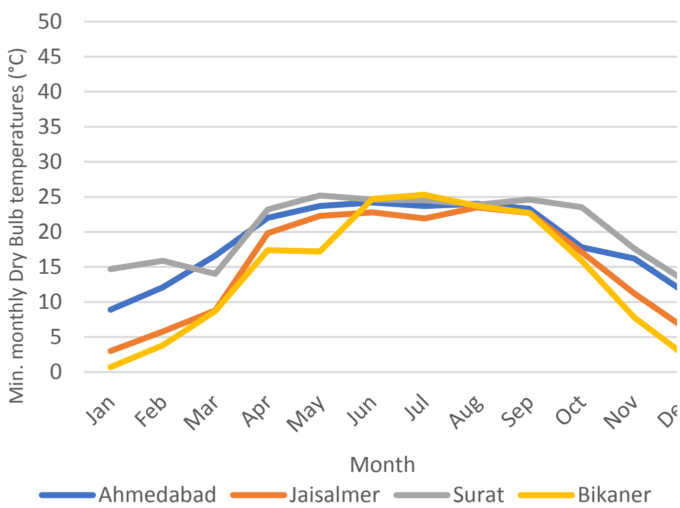

Figure 2: Monthly minimum dry bulb temperature

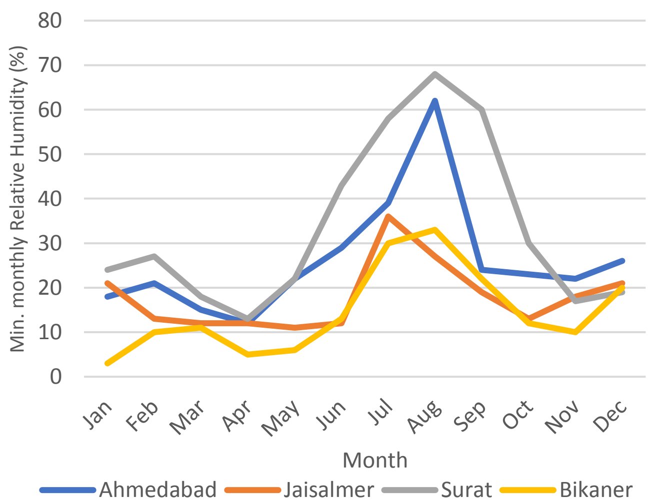

Figure 4: Monthly minimum relative humidity

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).

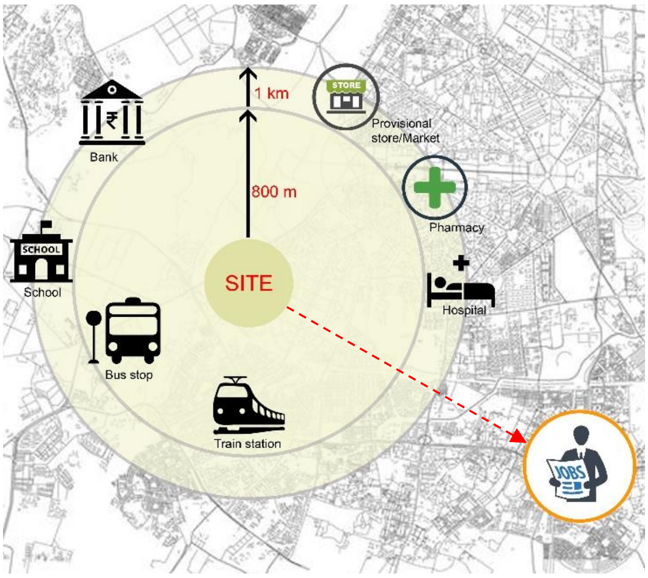

Figure 5: Site location

- 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)

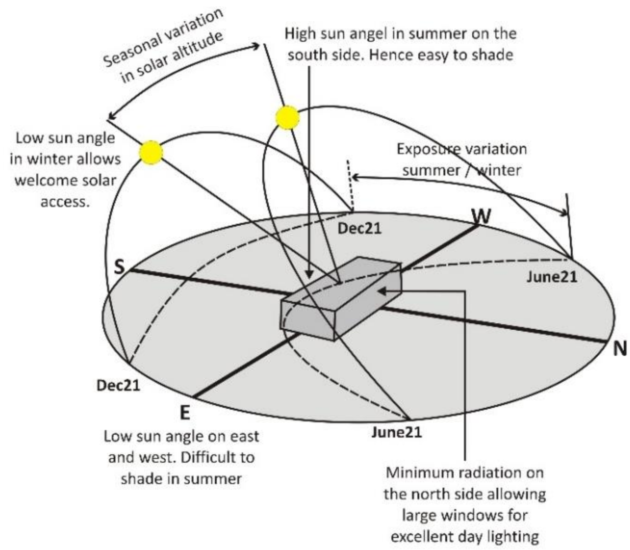

Figure 7: Orientation based on sun path. Source: Adapted from (6)

Massing and space planning

- Orient the buildings to minimise solar exposure on vertical surfaces: a North-South orientation of the longer side of the buildings is preferred, as it allows large windows for day lighting. The high sun angle in summer on the south side is easy to shade, while the low sun angles on east and west side are not.
- Select the building shape to minimise solar exposure on vertical surfaces. In hot-dry climate, a smaller perimeter-to-area ratio (P/A) would result in less area exposed to radiation and lower conduction heat gains. Plan-forms with greater P/A ratio may be applied in certain cases to include features like courtyards, water bodies and vegetation which can modify the micro-climate.

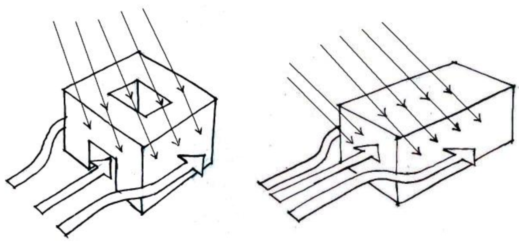

Figure 8: A larger Perimeter-to-Area ratio implies higher heat gain by the building

- Compact planning with courtyards is preferred to reduce exposure of external surfaces to solar radiation. Ventilation in hot-dry climate is only useful if the air is cool, thus the courtyard should be proportioned to be mostly shaded and contain cooling elements like trees, soft paving and water bodies. (Fig. 9) The courtyard can be cooled through shading by keeping a H/W ratio nearing 1:1 (6).
- Arrange building blocks to benefit from mutual shading minimises solar exposure on vertical surfaces during summer months. Mid-rise buildings

are optimal in terms of footprint area, shading and total energy consumed. Row housing are also viable as solar gains are reduced due to common walls.

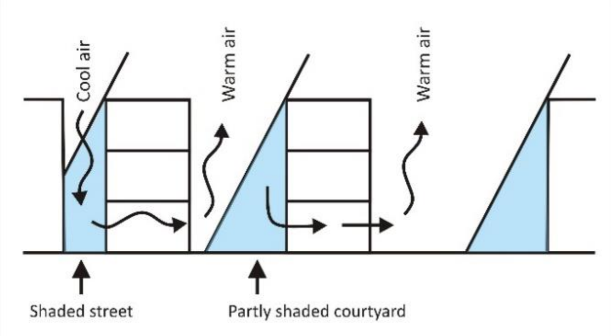

Figure 9: Variable courtyard sizes for ventilation and mutual shading. Source: Adapted from (6)

- Proper choice of building shape for a particular orientation can reduce the solar radiation exposure by 20%–40%. If there is the flexibility of orienting the building correctly (i.e. larger façade in a north and south direction), then the preference of typologies in terms of reduced solar radiation exposure is (5):
    - Preference 1: Linear double-loaded corridor typology
    - Preference 2: Linear typology
    - Preference 3: Tower typology

Building envelope

Thermal performance

The building envelop mainly comprises of walls, windows and the roof. Considering the conditions dominating the hot and dry climate, solar heat gain through the building envelope is the biggest factor influencing indoor thermal comfort. Therefore, 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 for buildings in the hot & dry climate zone. The design and material specifications should aim to:

1. Minimise the amount of heat reaching the building exterior: this can be achieved by a mix of strategies such as orientation, shading, vegetation and heat reflecting exterior treatment of walls.
2. Minimise transmission of heat through building envelope. The cross section of the wall, roof and the properties of glass determine this aspect. Strategies like increasing thermal mass, insulation, cavity in wall section help in minimizing this heat transfer.
3. Reduce the internal heat gain and improve daylight availability.

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 (7)	
WWR <40%	0.25
WWR 40 to 60%	0.2

- Heat gain from the external walls can also be reduced by using overhangs, light coloured finishes/ 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.

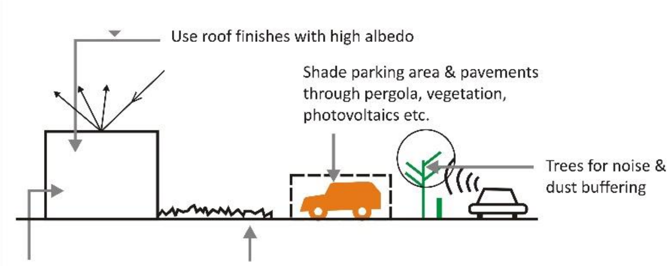

Figure 10: Strategies for reducing heat gain. *Source: adapted from (6)*

- High thermal mass materials, without insulation, can radiate heat all night during summer, or absorb all the heat produced on a winter night. Use of insulation with low thermal mass materials will not be effective in keeping indoor temperatures comfortable.

- High mass construction with insulation is the most effective strategy to reduce heat gains and should be used with proper shading. In the hot-dry climate, insulation should be on the external side with the high mass material on the inside, protecting it from the summer sun.

Window openings and shading

Shading strategies for building and openings is vital for comfort in hot-dry climate.

- Usually 10%–15% window-to-wall ratio (WWR) in bedrooms and 30% in living room are needed to provide adequate daylighting. The WWR on each façade should be determined based on the duration of sun exposure.

- Openable Window to Floor Area ratio (WFR_{op}) for Hot and Dry climates should be a minimum of 10%.

WFR_{op} is calculated as a ratio between openable areas to built-up area of dwelling units. (8)

- Minimum projection factor for external shading should be 0.5. (3)
- Visible Light Transmittance of the non-opaque building envelope components (glass/transparent/translucent panels) should comply with the requirements given below: (8)

• Window-to-wall ratio	• Minimum VLT
• WWR <20%	• ≥75%
• WWR 20 to 30%	• ≥50%
• WWR 30 to 35%	• ≥40%

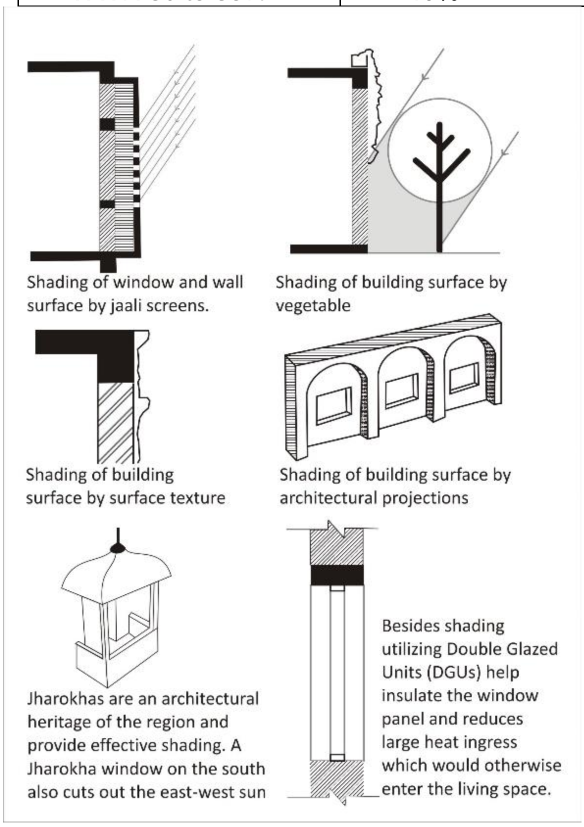

Figure 11: Windows and shading strategies. Source: Adapted from (6)

Daylighting

- Daylight penetrates a room 2.5x the height of the window. NBC recommends a minimum of 15% WWR in living areas.
- Providing windows with higher lintel levels or use of light shelves can increase the daylight penetration into the building. Spaces where regular windows are not required, higher clerestory windows can be a suitable option.
- Heat gain through the windows can also be reduced by simple low-cost means. Extending the overhang on top of the window lintel sideways on both sides by 0.5 m cuts the solar radiation falling on the window. Provision of external shutters is also an effective strategy
- For ideal daylight penetration, the lowest floor windows should subtend a max of 22.5° with the top of the adjacent building, but a closer placement can be used for reducing heat radiation.

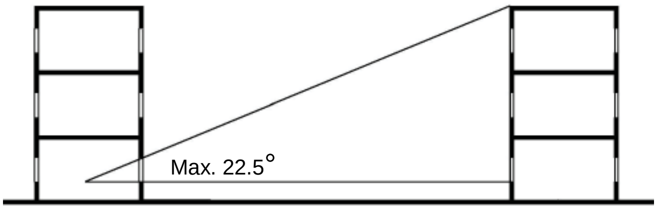

Figure 12: Distance between buildings for daylight ingress. Source: Adapted from (6)

- External light shelves allow diffused light penetration & shade. Internal light shelves allow deeper light penetration & solar access. Light shelves can be added inside to increase daylight penetration

Ventilation and passive cooling

Passive cooling strategies need to be incorporated at the design initiation stage based on the planed organisation of spaces in the building.

- Variable sized courtyards create temperature-pressure differential and can thus induce cross-ventilation.
- Evaporative cooling works well in the hot-dry climate as humidity is low in this zone. But for this technique, water availability needs to be in check.
- Central Wind Tower System
- Earth Air Tunnel System and Earth Berming
- Night ventilation works well as the diurnal variations are high. Buildings are ventilated at night when the ambient temperatures are lower to resist heat build-up.

These will also ensure minimum HVAC loads if any active cooling systems are desired in the future.

Wind Tower System

A central wind tower system with water spray on top is useful for cooling double loaded corridors and a very acceptable method in hot & dry regions as humidity is welcome. The introduction of 10m high wet columns may reduce the inside temperature by 12°C for hot arid areas (10). For windy areas, new installation of wind towers

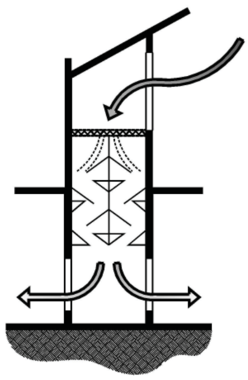

Figure 13: Cooling wind tower (6)

can be aligned with the predominant wind direction. (11)

Earth Air Tunnel System

This system is viable if the ground below has good thermal capacity, for e.g. soil with adequate water content. The design basics generally followed are: pipe depth of 4 m, pipe diameter of 0.3 to 0.7m, distance between 3m c/c. Care has to be taken in constructing the tunnels to prevent pests etc. from entering the living space.

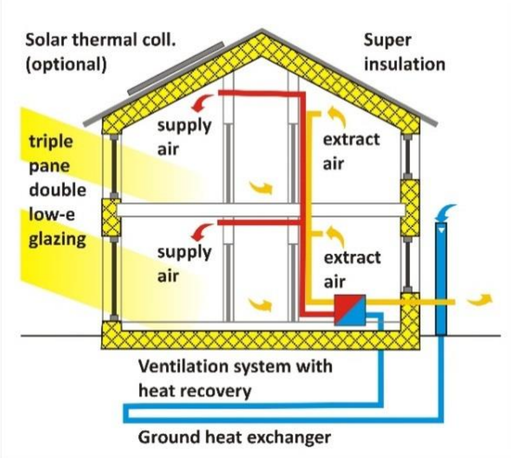

Figure 14: Earth air tunnel system. Source: Passivhaus Institute, Germany

Drainage & Waste management

- The site plan should be developed 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.
- Zero discharge is possible by creative treatment and reuse of water, thus reducing load on municipal drains through:
    - Improved Septic Tanks
    - Effective Micro-organisms
    - Decentralized wastewater treatment system (DEWATS) can be incorporated longitudinally within the setback.

Water conservation

Rainwater Harvesting

Water conservation and reuse is of utmost priority in the hot-dry climate. It can be done through:

- Water efficient landscaping. Use of native, low water consuming species in site landscaping and reduction of exotic species and lawns with an efficient irrigation system reduces water consumption.
- Rainwater harvesting, where the rainwater is used for groundwater recharge instead of direct use, as rainfall in hot-dry areas is low and infrequent and the groundwater table is usually low.
- Rainwater harvesting potential is calculated as catchment area (m^2) x Annual rainfall (m) x Surface run-off co-efficient. A thumb rule for estimating tank size is to store 15 minutes of peak rainfall.
- 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).

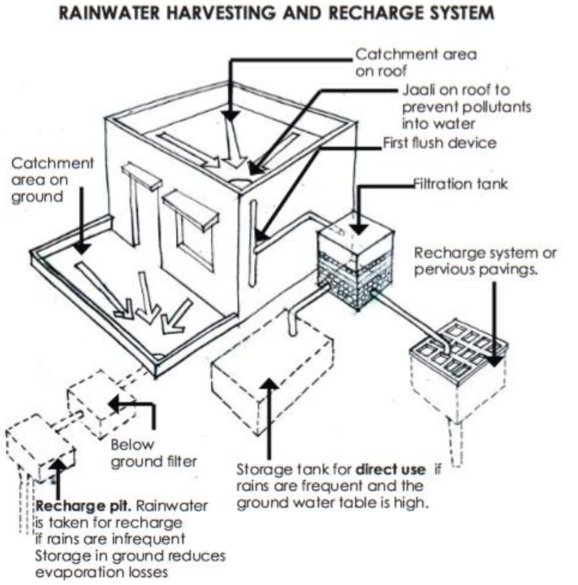

Figure 15: Rainwater harvesting and recharge system. Source: Adapted from (6)

- 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.

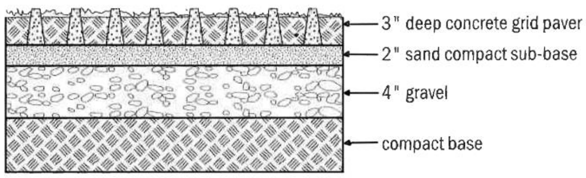

Figure 16: Perforated lattice unit grids for storm run-off control, Image adapted from: Sustainable Building Design Manual, Vol.2 (10)

Building materials

Selection of materials in hot and dry climate should be done primarily to minimize heat gain through the wall and roof. The selection criteria for material should fulfil:

- Reduced heat ingress
- 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 Hot and Dry 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 technologies 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 technologies as enlisted in the table below.

Hot & Dry			
	Base Case	**Cooling energy ($kWh/m^2/yr$)**	
	Walling (12.5 mm cement plaster + 225 mm brick + 12.5 mm cement plaster)	**46.5**	
	Roofing (100 mm RCC + 100 mm lime concrete)		
		Savings from Base Case ($kWh/m^2/yr$)	**Savings In %**
	Improvements - Walling		
1	Fly Ash brick	1.84	4
2	AAC Block	13.75	30
3	Rat-trap bond	2.75	6
4	Hollow concrete block masonry	1.92	4
5	Solid concrete block masonry	-3.64	-8
6	Compressed Stabilised Earth Block	-2.51	-5
7	Stonecrete Blocks	-6.03	-13
8	Glass Fibre Reinforced Gypsum (GFRG) panel	-4.39	-9
9	Precast Large Concrete Panel System	0.97	2
10	Reinforced EPS Core Panel System	-6.03	-13
11	Light Gauge Steel Frame (LGSF)	-6.21	-13
12	Monolithic Concrete Construction using Plastic/Aluminium Formwork	-6.22	-13
	Improvements - Roofing		
1	Reinforced Brick Panel Roof	7.11	15
2	RCC Filler Slab	-2.35	-5
3	Plank & Joist Roof (60 mm tile above + 60 RC plank + 75 mm mud phuska)	3.55	8
4	Ferrocement Roof Channel	11.46	25

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

- While AAC Block and Ferrocement channels have the highest savings potential, Stonecrete, Monolithic concrete construction and LGSFS perform the worst. The simulation has been run for a dwelling unit with exposed roof, the most drastic changes in cooling load were observed in cases where the construction of roofs changes.

Sustainability Assessment Tool

- 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 technologies 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 technologies across all 18 attributes
    - Order of preference of 17 walling & roofing building technologies 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 technologies with respect to the selected attributes. The scores have been calculated on the basis of absolute data gathered for 17 building materials and technologies across 18 weighted attributes.
- Higher score of a building material or technology with respect to others is an indicator of its better performance. Precisely, higher the score, better the building material or technology.

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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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