Creating a Sustainable Home

A HANDY MANUAL FOR HOME BUILDERS

CAG

Citizen consumer and civic Action Group

Creating a Sustainable Home: A HANDY MANUAL FOR HOME BUILDERS
First edition: 2020

Author - Jeya Kumar R, Co-author - Balaji.M.K,

Technical support -
Centre for Energy, Environment and Productivity, Chennai
and
Green Evolution, Chennai

Reviewers – K.Vishnu Mohan Rao, Saroja. S, Amudha. V, Padmavathi. S

Illustrations credit - Karunakaran.V

- **About CAG**
  Citizen consumer and civic Action Group (CAG) is a 35-year-old Chennai-based non-profit, non-political and professional organisation that works towards protecting citizens' rights in consumer and environmental issues and promoting good governance processes including transparency, accountability and participatory decision-making.

  Contact details
  Citizen consumer and civic Action Group (CAG)
  New #246, (Old #277B), T.T.K Road (J.J Road)
  Alwarpet, Chennai 600 018
  Tamil Nadu, INDIA
  www.cag.org.in | +91 44 24994458/ 24660387
  Email: helpdesk@cag.org.in ,
  Facebook: www.facebook.com/CAGChennai/, Twitter: @CAGChennai

- **Disclaimer**
  Citizen consumer and civic Action Group (CAG) took reasonable efforts to prepare the booklet but make no representations or warranties about the suitability for any purpose of the contents of this booklet. We recommend taking an expert's opinion where deemed fit. CAG cannot be held responsible for any losses or damages incurred by the participants through their actions. CAG welcomes your suggestions / feedback. If you have queries, please write to us at ecc@cag.org.in or helpdesk@cag.org.in. Please visit www.cag.org.in to know more about CAG.

Preface

Indians have always considered constructing or purchasing a house as an important milestone both for living and secure investment for future generations.

This has fueled the growth of the residential construction sector in India, which has in turn increased the usage of electricity, water, while depleting other resources such as natural green cover in the local surrounding areas. However, this has led to significant environmental impacts such as waste generation, and air pollution, among others and has also affected public health.

The domestic sector, which consumes 25 percent of total electricity generated in the country, is expected to see an increase 6 to 13 times by 2047 when compared to 2012. A large portion of this will account for thermal comfort and lighting. A projection shows that domestic water demand in India will increase to 101 billion cubic metre (BCM) by 2050 when compared to 2000 which was at 34 BCM. The Government of India has formulated several sustainable building techniques aimed at energy efficiency and conservation, and water conservation in the residential sector. However, the consumption of water and electricity have not slowed down despite the initiatives.

In addition, annually 165 to 175 million tonne of Construction and Demolition (C&D) Waste is generated in our country. But the country has only a recycling capacity of 6500 tonne per day which is just about 1.3 % of total generation and the rest of them are being indiscriminately disposed of. India is already generating 1,43,449 metric tonne (MT) of Municipal Solid Waste (MSW) per day, 80-90 % of this is disposed of without following the statutory Solid Waste Management practices, leading to soil, water, and air pollution.

The main purpose of this handy manual is to impart holistic knowledge on building homes using sustainable building techniques, including passive design, construction materials, energy efficiency, water management, green vegetation etc. The target audience for the manual is the public including home owners and local masons. These local masons are the predominant home builders, who build independent homes in cities, towns and rural areas.

The idea for this manual came about while having conversations with a few people from the unorganised construction sector in Tamil Nadu. The unorganised sector includes local masons, electricians, and allied construction workers. The conversations revealed that construction activities and electrical work take place in an uncoordinated manner. It was observed that local home builders from different parts of Tamil Nadu followed varied sustainable construction techniques. Most of them have acquired knowledge of sustainable building practices through experience but lack holistic understanding of sustainable buildings, energy and water conservation.

To create this manual, CAG conducted focused group discussions with masons and electricians to deduce their level of understanding on sustainable building techniques.

This handy manual covers all the sustainability aspects, starting from planning till occupying a home. The importance and benefits of each aspect is explained in a simple manner for easy understanding of the target audience.

The manual consists of 9 chapters as follows:

1) *Site planning*: This chapter highlights the importance of setback, topography, site protection, balance of built vs. open spaces.
2) *General passive design strategy*: This chapter describes building form, orientation and internal spaces planning, natural ventilation, daylight, and shading for both warm and humid, and cold climatic regions. The chapter also speaks about thermal insulation in walls and roofs.
3) *Building envelope*: This chapter explains different types of roofs, and external walls for both warm and humid, and cold climatic regions.
4) *Energy management*: This chapter provides details to ensure improved energy efficiency in buildings. It explains about better planning and layout, standard electrical fittings, energy efficient appliances, energy meters, and renewable energy.
5) *Water management*: This chapter suggests better ways to manage water. It discusses plumbing layout, plumbing materials, water metering, rain water harvesting, and wastewater treatment and reuse.
6) *Resident health and well-being*: This chapter talks about indoor air quality, thermal comfort, and the atmosphere in and around the home; and how these impact residents' health and well-being.
7) *Waste management*: This chapter includes both, construction waste as well as household waste.
8) *Vegetation*: This chapter gives an idea about the types of vegetation that can be grown indoor and outdoor, including the importance of enhancing biodiversity.
9) *Cost efficiency in construction*: This chapter provides details about the different cost effective factors involved in construction.

We hope that this handy manual will add value to home builders and home owners when constructing sustainable houses.

TABLE OF CONTENTS

1. Site Planning

A. Setback

Setback is the minimum distance between a building and its site boundaries on all sides.

Buildings should have minimum setback distances as per regulations. It can be a minimum of 1 metre in the sides and rear; and 1.5 metre in the front from the compound wall / site boundary. (Source: Tamil Nadu combined development and building rules, 2019)

The image below is an illustration of the benefits of providing setbacks.

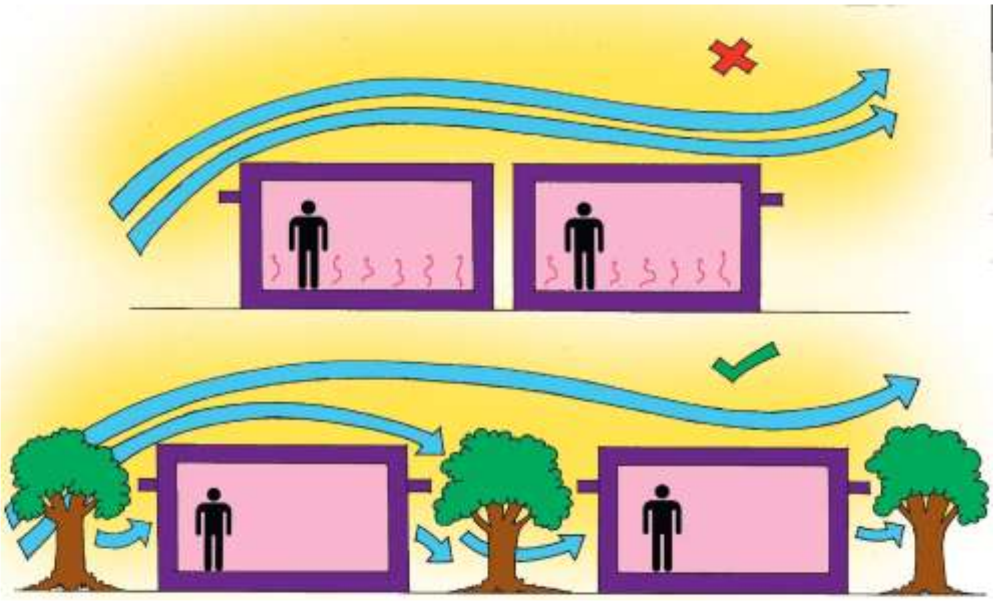


Figure 01: Setback

Benefits:

- The spaces around the building provides natural lighting and ventilation
- It acts as a buffer and helps in reducing the indoor temperature
- It reduces the noise from adjacent buildings and roads
- It provides privacy to the occupants
- Additionally, setback provides ease of access in case of firefighting and reduces the risk of fire spreading to the nearby buildings

B. Topography

Buildings should be designed in such a way that the natural topography is retained as much as possible. In case of sites with steep slopes, flattening of the surface can be minimised by constructing a stepped house.

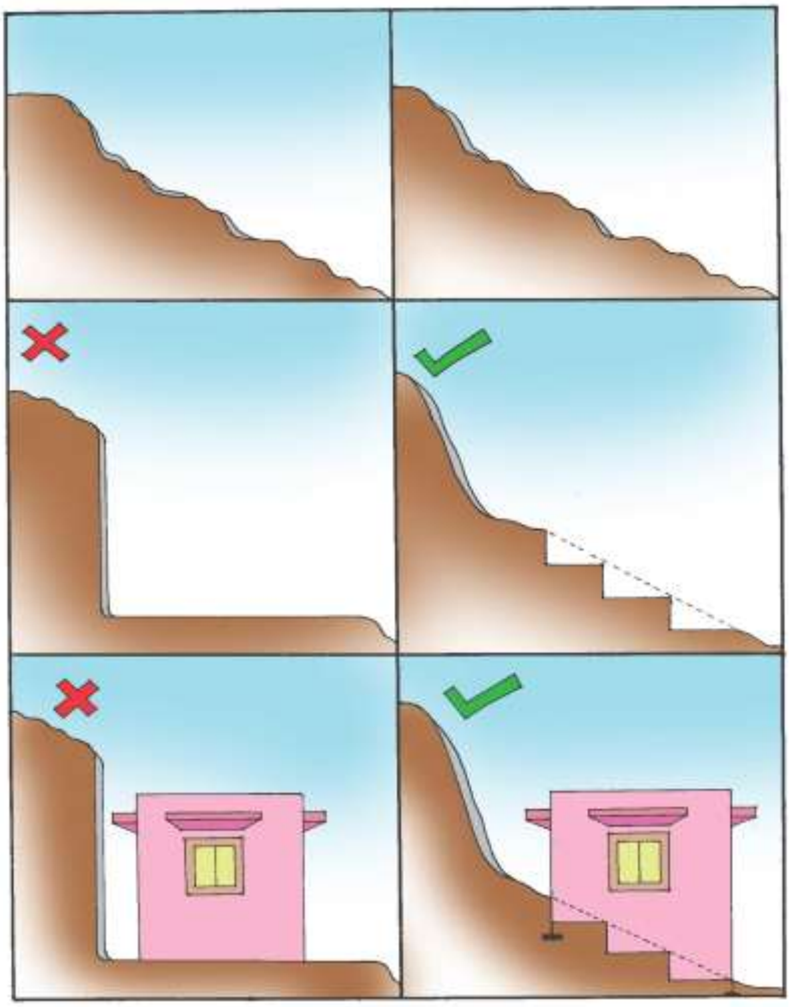


Figure 02: Topography

Benefits:

- Constructing stepped houses in steep slopes, avoids the expensive large-scale earth works (i.e., excavation or filling)
- Also, environmental impacts of large-scale earthworks such as a) risk of erosion by altering soil stability and water run-off patterns, b) sediment run-off during construction and its effects on natural biodiversity by removing soils and plants can be avoided

C. Site Protection

Many localities have been witnessing loss of various species e.g. birds, plants, trees, insects (which plays a major role in balancing the ecosystem) due to unplanned developments.

Minimise disturbance to the site by retaining natural vegetation and water bodies, if any. Cutting down of existing mature trees on the site can be avoided. Protect any existing open wells on the site. The building plan can be altered around existing trees and wells, so that there is minimum site disturbance. The illustration below is an example of site protection.

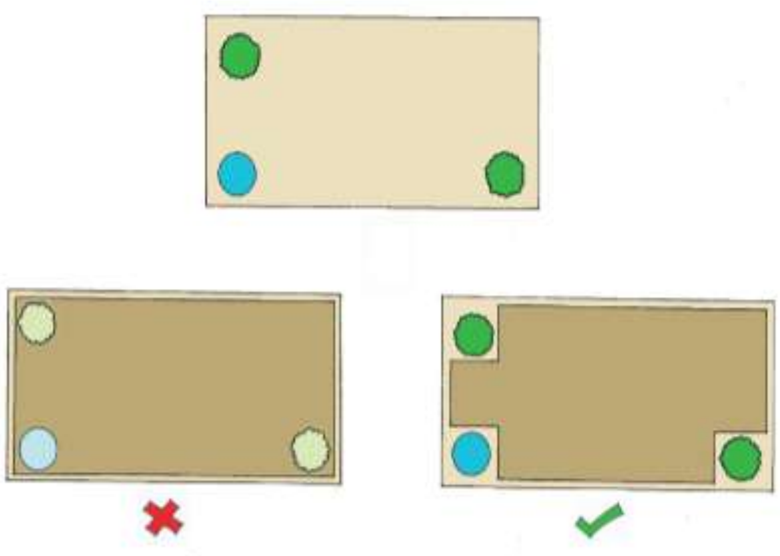


Figure 03: Site protection

During construction, existing trees should be barricaded and protected with a green screen so that the dust and construction debris do not affect them.

Benefits:

- Preserving the natural vegetation and water bodies ensures that the native species are sustained
- Trees help in reducing the heat island effect (increase in temperature due to dense concentration of pavements, buildings and other surfaces that absorb and retain heat)

- Open wells are an important source of water and help reduce the dependence on borewells (which are difficult to recharge due to their greater depths)

D. Balance of Built vs Open Spaces

As per Indian Green Building Council's (IGBC) guidelines, at least 15% of the site area should be provided as open spaces. This can be achieved by providing spaces around the building or pockets of open spaces within the building (e.g. courtyards). Pockets of open spaces within the building, also helps in reducing the indoor temperature.

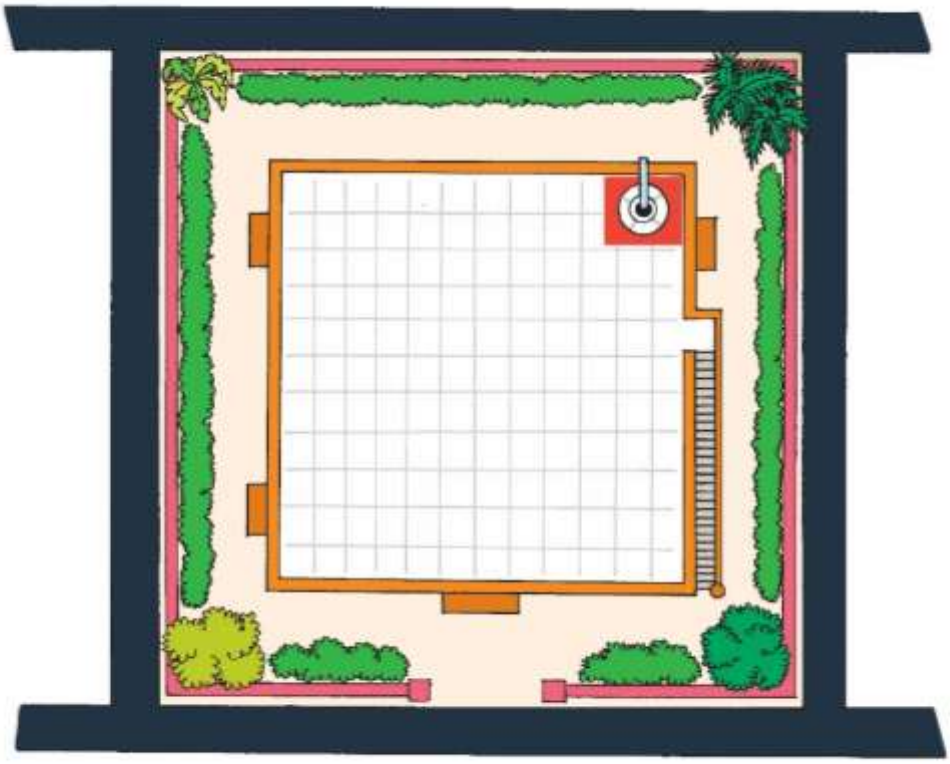


Figure 04: Balance of built Vs open spaces

Benefits:

- Open spaces improve the general health and well-being of the occupants
- They are a good source of natural ventilation
- Moreover, the spaces can be utilised for vegetation, which will provide shade, reduces noise pollution, and improve air quality

2. General Passive Design Strategies

Due to its geographical location, Tamil Nadu receives maximum solar radiation from the west during afternoon hours. This mid-day western radiation heats up and conducts through the western walls of the building and makes the indoor warm during evening and night times. The east builds-up heat and receives natural light as the day advances but also dissipates the heat during the daytime. The south also builds up heat, primarily from the roof due to the sun's positioning at noon. The northern wall receives the least amount of heat along with diffused natural light. The prevalent wind flow direction is from the south-west during the summer and north-east during the winter.

A. Building Form, Orientation and Internal Spaces Planning

Form and orientation constitute two of the most important passive design strategies. It affects the amount of sun rays falling on the building surfaces, enhances day lighting, and directions of wind. The building form determines the volume of space inside a building that needs to be heated or cooled.

In houses with passive solar features, the layout of rooms and interior zones play a key role in increasing comfort levels for the occupants. Ideally, the rooms should be located considering how they will be used in different seasons and at different times of a day.

Three factors that determine the form, orientation and lay-out of the building are:

- Solar radiation
- Prevailing wind
- Topography

Benefits:

- Regulates indoor temperature thereby enhances thermal comfort for the occupants

- Reduces the dependence on air conditioning systems and in turn reduces the energy consumption.

I. Warm and Humid Climatic Regions

Higher temperature and humidity are the most predominant characteristics of this climatic region, hence air movement and protection from sun are vital to give relief from climatic stress. The building form should preferably have elongated plan shapes that favour cross-ventilation and heat emissions at the night.

The longer sides of the building should face south and north. This protects the building from the western heat gain, at the same time traps the southern winds which will bring cross ventilation to the indoor spaces.

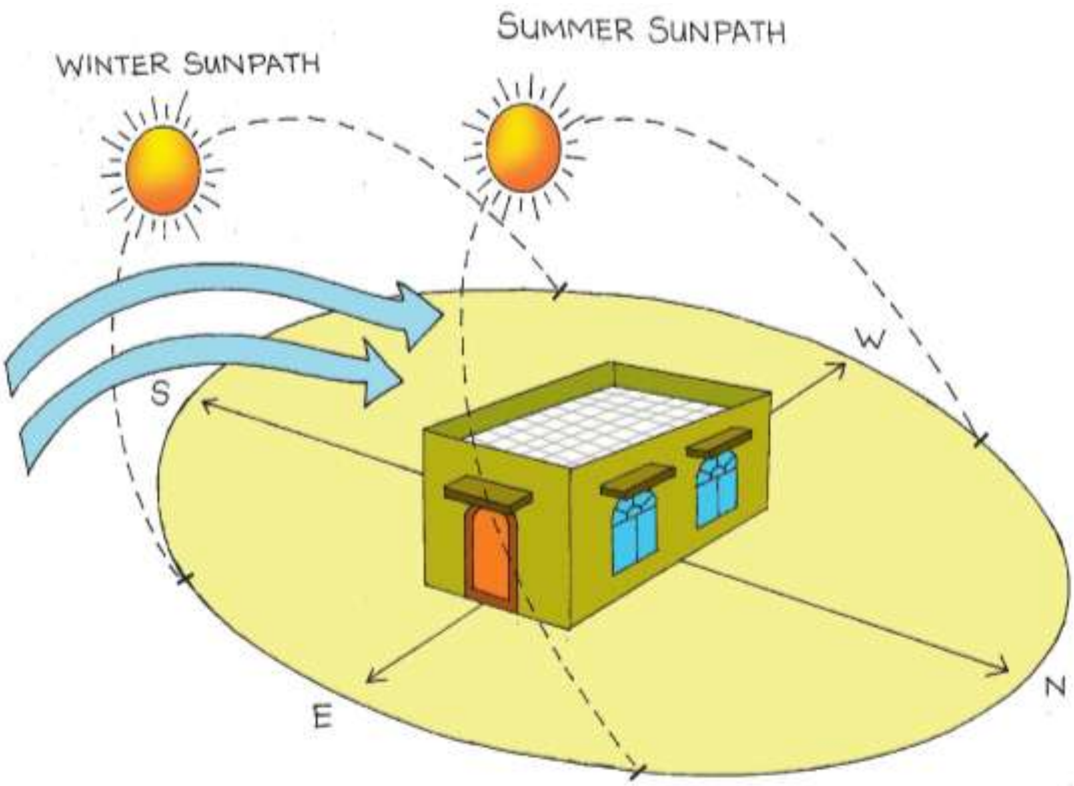


Figure 05: Building orientation – Warm and humid climatic regions

In general, the spaces which will be occupied during the morning hours should be planned on the west, whereas the rooms used during the afternoon should be located on the east side. Spaces on the north and south remain relatively cool, due to the high angle of sun in these orientations, but adequate shading needs to be provided in the south.

Table 1 Warm and Humid Climate - Zoning guide

Space	N	S	E	W	NE	NW	SE	SW
Living	✓	✓✓	✓✓	✗	✓	✓	✓✓	✓
Kitchen	✓	✗	✓✓	✗	✓	✓	✓✓	✗
Bedroom	✓✓	✓	✓	✗	✓	✗	✓	✗
Utility	✓	✓	✓✓	✓✓	✓	✓	✓	✓
Veranda	✓	✓✓	✓	✓✓	✓	✓	✓	✓✓
Storeroom	✓	✓✓	✓	✓✓	✓	✓	✓	✓✓

Legend

✓ - Fair

✓✓ - Best

✗ - Not Ideal

This is a sample ready reconer for ideal zoning of spaces. This might vary depending on the site conditions.

II. Cold Climatic Regions

In the cold climates (in Tamil Nadu this is mostly present in the hilly regions), the main criteria for design is to increase the heat gain into the building. By orienting the building towards south, east, and west, the solar radiations can be trapped in high amount. The building should be sealed and preferably facing away from the cold winds (North-East winds).

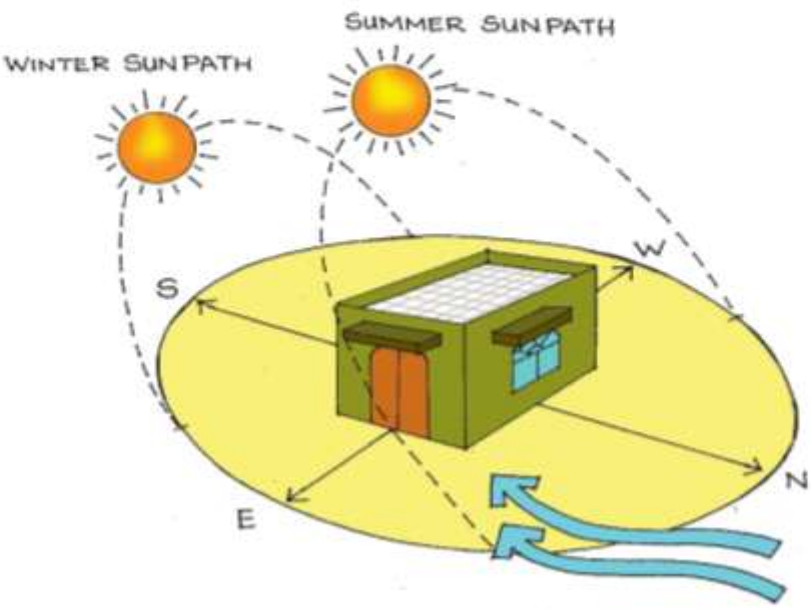


Figure 06: Building orientation – Cold climatic regions

The building form should be compact to reduce the heat losses from the indoors. Buffer spaces should be given on the North orientation which does not receive any heat gain.

Table 2 Cold Climate - Zoning Guide

Space	N	S	E	W	NE	NW	SE	SW
Living	✗	✓✓	✓	✓✓	✗	✓	✓	✓✓
Kitchen	✗	✓	✓✓	✓	✓	✓	✓	✓
Bedroom	✗	✓	✓✓	✓	✗	✓	✓	✓✓
Utility	✗	✓	✓✓	✓	✓	✓	✓	✓
Enclosed Balcony	✓	✓✓	✓	✓✓	✓	✓	✓	✓✓
Storeroom	✓✓	✓	✓	✓	✓	✓	✓	✓

Legend

✓	- Fair
✓✓	- Best
✗	- Not Ideal

This is a sample ready reckoner for ideal zoning of spaces. This might vary depending on the site conditions.

B. Natural Ventilation, Daylight, and Shading

Placement and size of openings (like windows, skylights, ventilators, doors, etc.,) affects greatly the air flow pattern inside the buildings. The building form also influences the natural ventilation and lighting. The width of a building should not be over 20 feet for effective cross ventilation and lighting. In case the building form is wider, cut-outs (i.e. open to sky or courtyards) should be designed appropriately.

Shading from direct sun is important to reduce the glare. Shading can be through shading from neighbouring buildings, self-shading from the building shape, providing vegetation or shading devices. The north and south facades can be protected by simple overhangs. The spaces located on the east and west side of the building requires special shading solutions like veranda or balcony spaces, which are deeper and more effective than simple overhangs. Additionally, vegetation can also be used on the west and the south side to provide shade.

Admission of natural light into a space maximises the visual comfort of the occupant and reduces the reliance on artificial light.

Benefits:

- Enhances indoor air quality
- Increases the thermal comfort level for occupants
- Better health and well-being of occupants
- Better connectivity to the exterior natural environment
- Reduces requirement of artificial lighting and cooling solutions

I. Warm and Humid Climatic Regions

In warm and humid climates, ventilation is required to control the high humidity and warm temperatures inside the building. The building should have larger openings to allow free passage of the southern winds. Appropriate openings should be provided on at least two sides of the space to allow cross-ventilation.

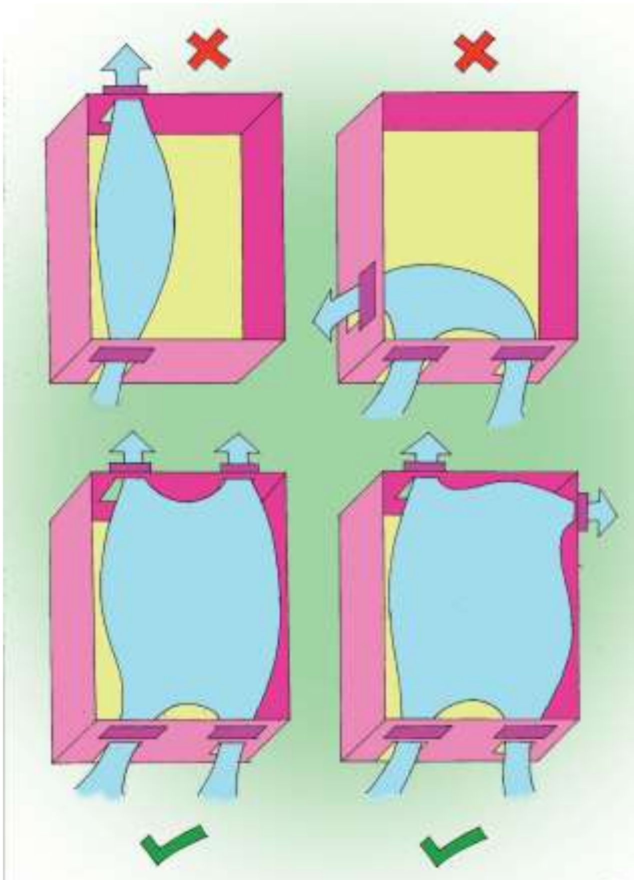


Figure 07: Cross ventilation planning

Broad overhangs should be designed to not only protect the windows but also the walls from the solar radiations. Ventilators should be planned closer to the ceiling or in the roof structure to exhaust hot air. Courtyards also play a major role in cutting down the humidity levels and provide good ventilation and daylight in the indoors. Traditional verandas or *thinnais* provide adequate shading from the sun.

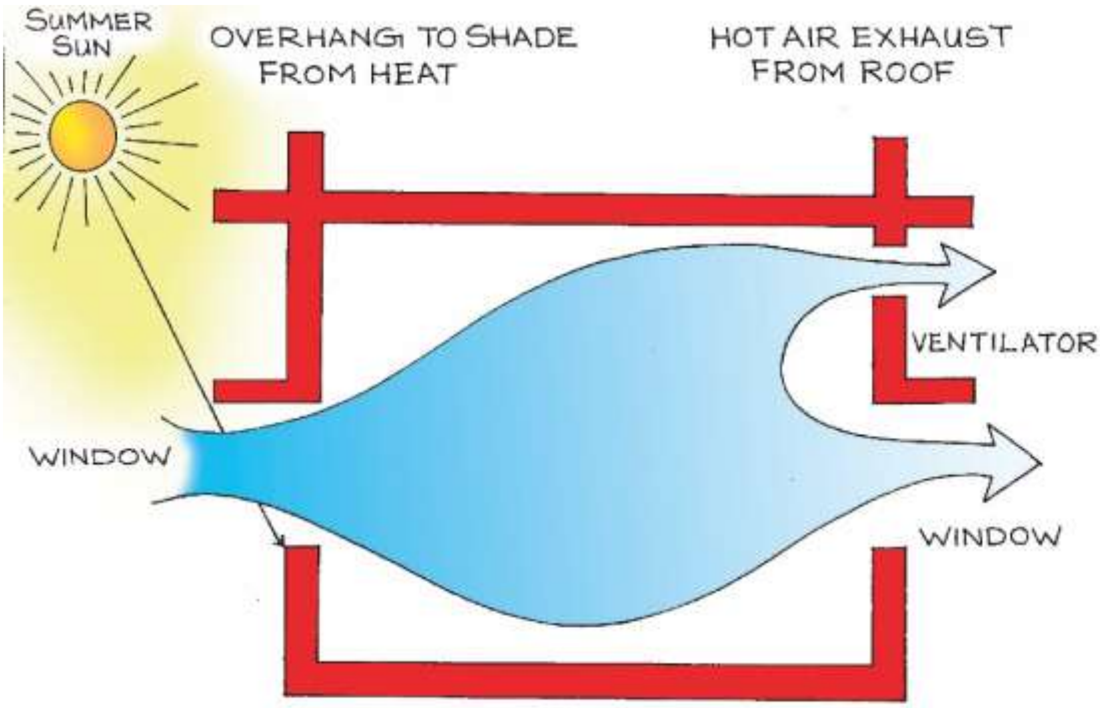


Figure 08: Cross section of a typical cross ventilation

II. Cold Climatic Regions

Natural ventilation is important in cold climates as well, because buildings are often built compactly and allow less natural air leakage. Smaller openings are preferred here to avoid cold winds flowing in to the indoors.

Mites, fungus, viruses, and bacteria can grow in rooms which do not have enough sunlight. Hence, providing large fixed glass windows that are well shaded from the summer solar radiation will help sunlight to enter and purify the interior spaces. This will also help keeping the indoor spaces warmer during the winter and act as a frame to scenic views. Skylights and solar conservatories are effective methods to improve the day lighting without letting in the cold breeze.

C. Thermal insulation

Thermal insulation in walls and roofs reduce heat transfer between the inside and outside and helps maintain comfortable indoor temperature.

A wide range of materials such as fibre glass, mineral wool, rock wool, expanded or extruded polystyrene, cellulose, urethane or phenolic foam boards and cotton can be used for insulation. They are generally in the form of amorphous wool or rigid sheets or require in-situ pouring.

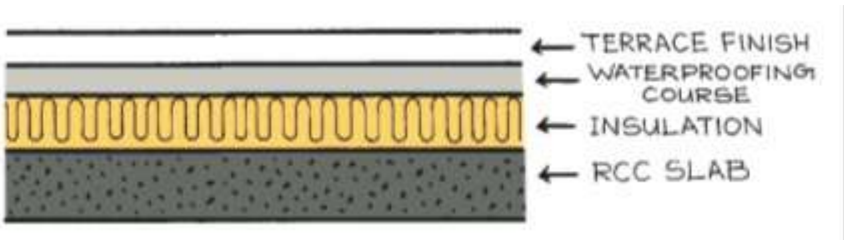


Figure 09: A typical roof section with thermal insulation

Thermal insulation can also be achieved through an air gap left between walls or roofs in a building. The air trapped between two layers, acts as a barrier to heat transfer as it is a poor conductor of heat.

I. Some examples in which air gaps can be provided as insulators in walls:

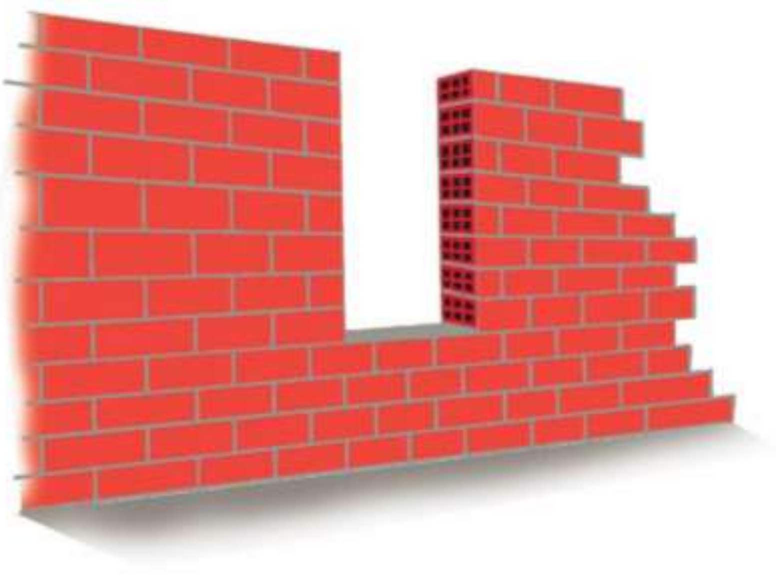


Figure10: Wall insulation – using hollow masonry blocks

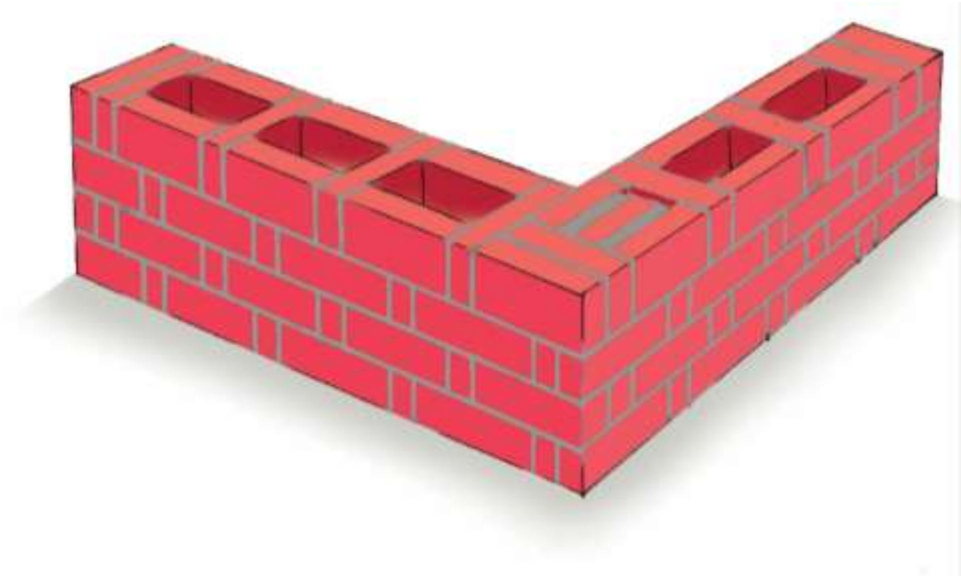


Figure 11: Wall insulation – rat trap bond walls

II. Some examples in which air gaps can be provided as insulators in roofs

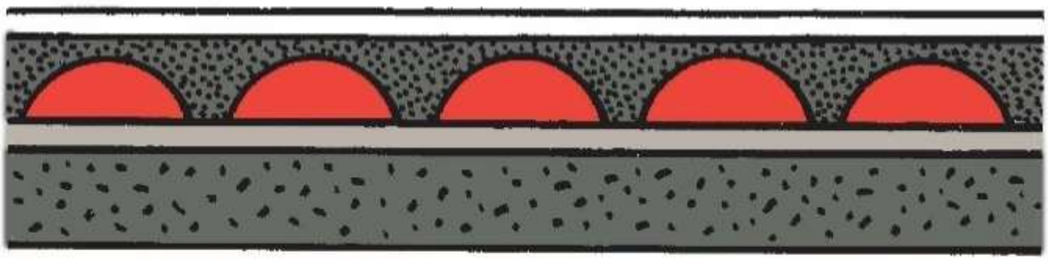


Figure 12: RCC slab + 75mm Inverted earthen pot in lime concrete + 20mm cement mortar finish

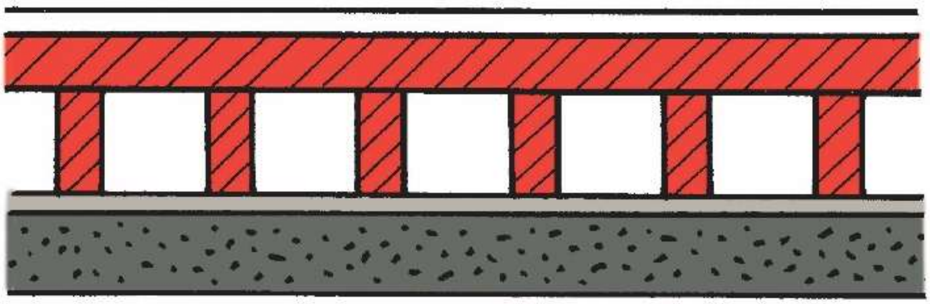


Figure 13: RCC slab + 75mm brick laid at intervals of 230mm c/c+ brick tile covering + 20mm cement mortar finish. ACC (Autoclaved Aerated Concrete) Blocks can be used instead of bricks

Figure 14: Filler slab with hollow blocks or double layered Mangalore tiles

Benefits:

- Thermal insulation helps maintain the indoor temperature at a comfortable level
- They also reduce the amount of electricity required to cool the building by preventing the heat build-up in the roof and walls.

3. Building Envelope

The building envelope, or "skin," consists of structural materials and finishes that enclose a space, separating inside from outside. The envelope must balance requirements for ventilation and daylight, while providing thermal and moisture protection appropriate to the climatic conditions of the site.

The building envelope is a critical component of any facility since it both protects the building occupants and plays a major role in regulating the indoor environment. It controls the transmission of heat between the interior and exterior of the building.

A good envelope design aims to reduce the heat exchange and the building's reliance on active systems for heating and cooling.

Benefits:

- Heat ingress through the building envelope will be minimised
- Minimised dependency on air conditioning appliances will result in reduced electricity bill amounts

A. Roofs

I. Reflective roofs

Reflective roofs as the name suggests, reflects the heat from the sun back to the atmosphere, thus preventing heat build-up. Materials with high solar reflective index (SRI) such as lime coating, white cement tiles, reflective paints, broken china mosaic can be used to make the roof surface reflective.

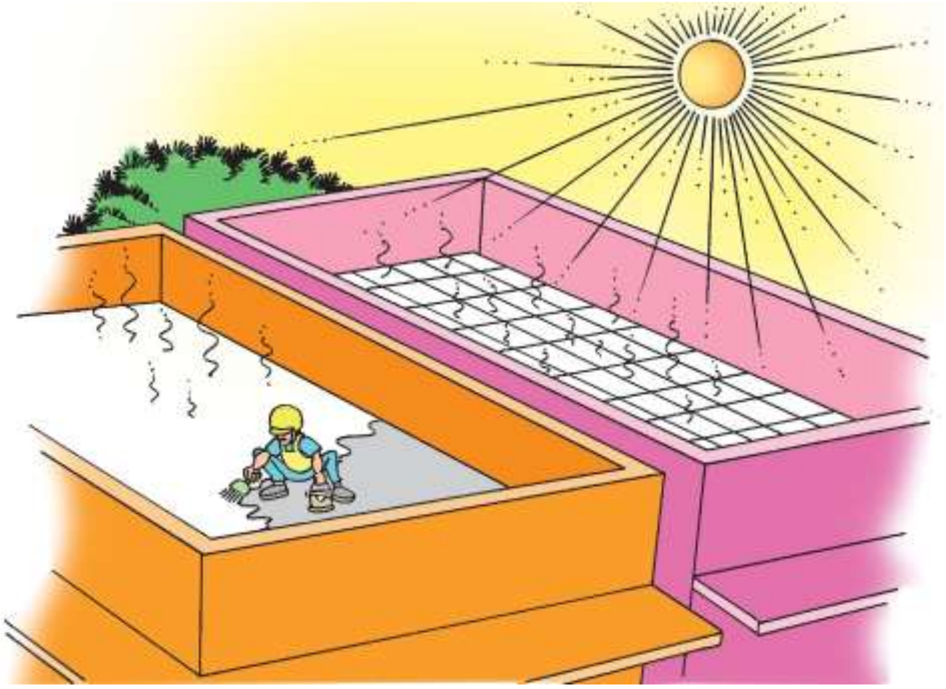


Figure 15: Reflective roofs

II. Shaded roofs

Shading the roof also reduces heat gain. For example, thatches, partial shading by pergolas, bamboo frame, overhanging creepers, photo-voltaic panels shade the roof and prevent it from getting heated up.

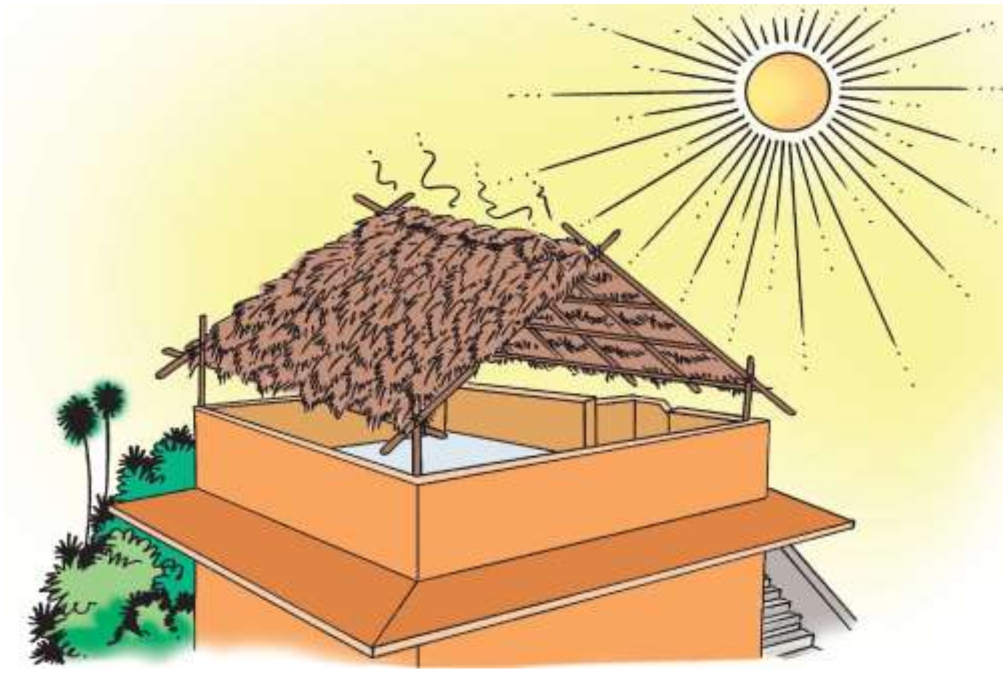


Figure 16: Shaded roofs

III. Green roofs

By providing vegetation on your terrace, about 70% of the heat falling on roof could be avoided from transmitting to the indoor environment. Small trees, shrubs, and plants can be grown on the roof spaces to provide the required shading. It is also a good place to grow vegetables. The plants can be either directly on the roof spaces or grown in large pots or grow bags.

Figure 17: Green roofs

B. External Walls

Density and insulation property of the wall material can have a huge impact on indoor temperature. A lot of energy is required to change the temperature of high-density materials like concrete, bricks, and stone.

Refer to Annexure A for a list of materials and their properties

I. Warm and humid climatic regions

Use of high-density material is generally not recommended in this climate due to their limited difference in the maximum and minimum temperatures of a day. Passive cooling in this climate is usually more effective in low mass buildings. In night times, lightweight construction responds quickly to cooling breezes whereas high mass can completely negate these benefits by slowly emitting heat absorbed during the day. Hence, materials with high insulation properties and low density are preferred.

Conductive heat gain through the walls can be significantly reduced by making outer surfaces more reflective. Exterior wall finishes in light colour are beneficial.

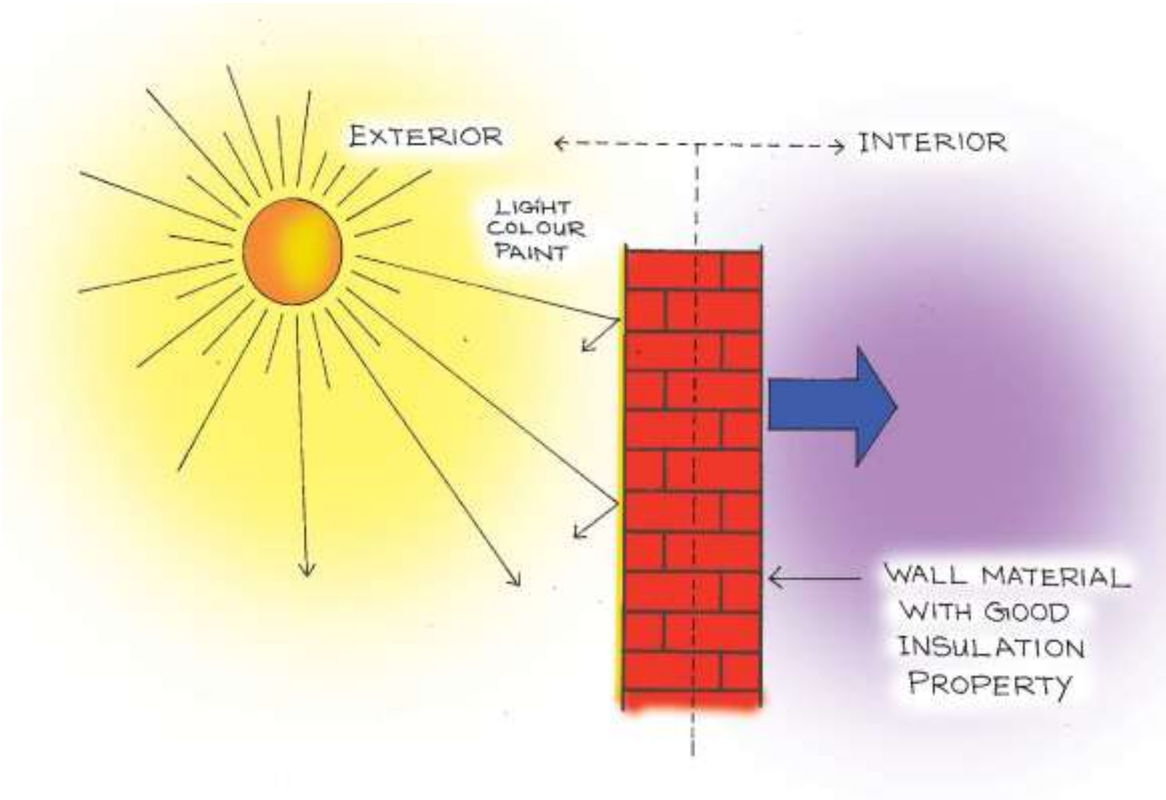


Figure 18: External walls – Warm and humid climatic regions

II. Cold climatic regions

High density wall material with good insulation properties combined with solar passive design is an ideal solution for cold climatic regions. The walls should be exposed to solar radiation during winter to heat it up.

Use a solar conservatory (or closed veranda) along with high thermal mass to increase heat gains. A solar conservatory is a glazed south-facing room that can be closed off from the living spaces at night. Shade the conservatory in summer and provide ventilation to minimise overheating.

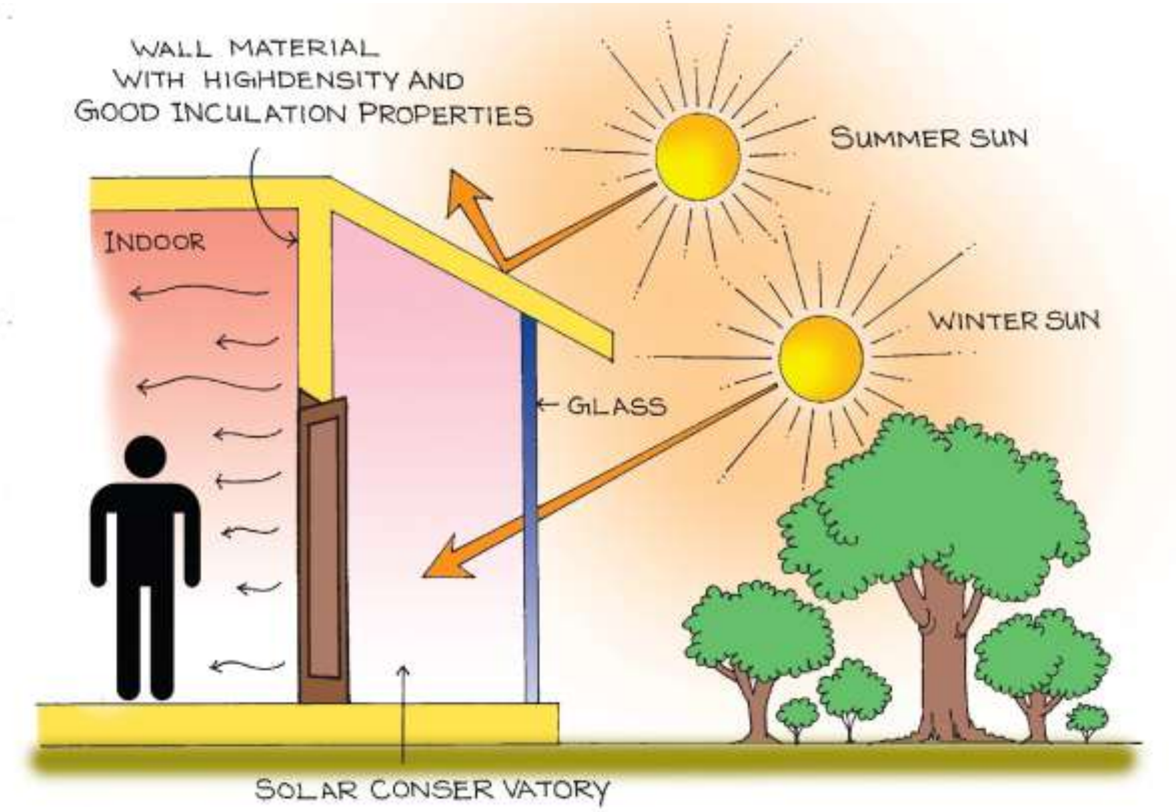


Figure 19: Solar conservatory in cold climatic regions

4. Energy Management

A. Planning and Layout

Proper planning of electrical works can save energy consumption of a building. A planned electrical layout will have streamlined wiring and appropriate placement of appliances. Thoughtfully planned layout also ensures the electrical safety in the buildings.

Lights and fans are the most used appliances in buildings. Lighting should be planned to serve the functional needs. For example, if there is a dining table at the corner, a lamp should be fixed over it. The amount of lighting power required for a given area is termed as Lighting Power Density (LPD).

LPD baselines as per IGBC guidelines are outlined below:

Lighting	Baseline Lighting Power Density (LPD)
Interior Lighting (Living, Bedroom, Dining, Kitchen, Pooja, Study, Library, etc)	5.0 W/m2
Exterior Lighting and Parking Area (Garden, pathways, veranda, portico, etc)	2.5 W/m2
Common Area Lighting, excluding Parking Area	4.0 W/m2

By using LED lights, about 40% energy savings can be achieved over the baseline LPD specified above.

To ensure a good distribution of illumination, the mounting height should be between 1.5 m and 2.0 m above the work plane for a separation of 2.0 m to 3.0 m between the luminaires. Lighter coloured wall finishes reflect more light and enhance the interior brightness. Limit the use of darker colours for interior finishes.

Interference with fan, which produces stroboscopic effect, should be avoided; this happens when fan is below the lamp level and light rays cut the fan’s rotation.

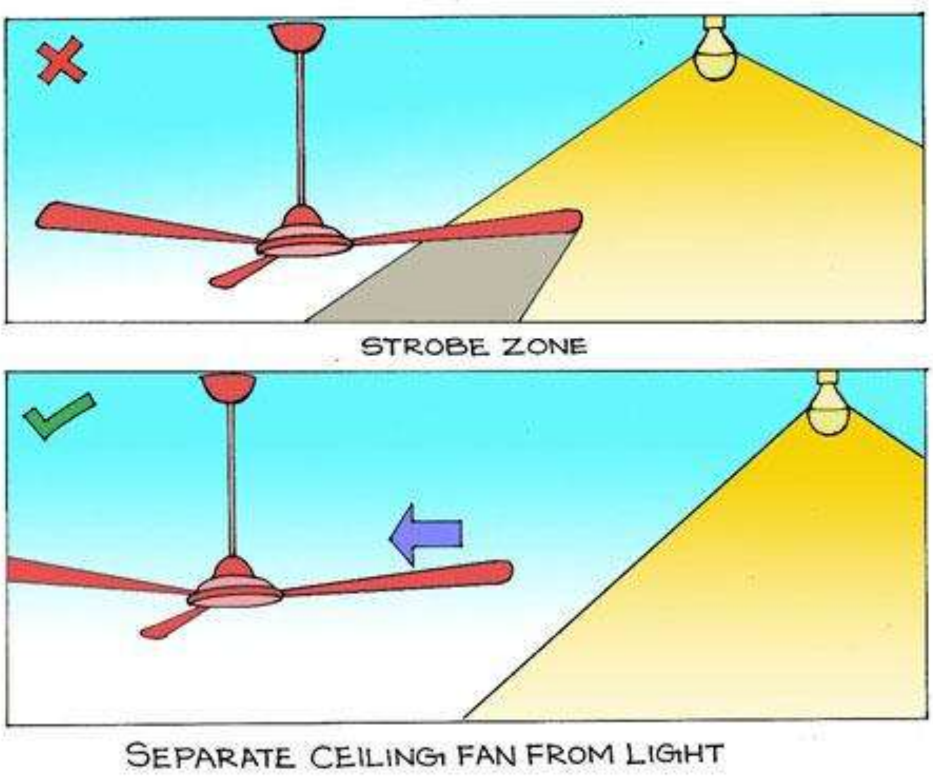


Figure 20: Stroboscopic effect

Ideal fan layout should be 1 fan for every 10 square feet of floor area. The minimum distance between fan blades and the ceiling should be about 1 feet. Likewise, all the appliances should be placed appropriately and based on the necessity.

Benefits:

- Proper electrical layout provides comfortable indoor environment
- It can also save energy by avoiding excessive lighting

B. Electrical fittings

Proper selection of materials is important for ensuring safety, reliability, longevity, and energy efficiency. It is important to buy genuine fittings, preferably ISI certified materials keeping in mind the safety aspects.

Generally, PVC conduits and bends can be used for electrical wiring. The quality of the conduits and bends can be identified by the colourings made on them.

Green markings represent heavy duty conduits, red markings for light duty, and blue markings for medium duty.

Electric wires containing multi-strand wires should be used. Copper wires having electrolytic grade of 99.97% would be better. Heat and fire-resistant wires carry a mark HRFR.

Electrical isolators should be provided in buildings for safe maintenance works. During service and maintenance, isolators will be used to isolate the circuits from the power source.

In addition to isolators, protective devices such as MCB (Miniature Circuit Breaker), RCCB (Residual Current Circuit Breaker) and RCBO (Residual Current Circuit Breaker with Overload protection) should be provided in buildings to protect the electric circuits.

MCBs automatically trip-off in case of high voltage or some other fault in the electric circuit. MCBs can provide protection against short-circuit and overload and are ideal for homes.

RCCBs are differential current sensing devices used for protecting low voltage circuits in case of leakage fault. It is also known as RCD (Residual Current Device). It has a switch device that switches off in a fraction of a second, whenever the current leaks out and does not return through neutral. RCCBs provides protection from even small electricity leakage arising due to accidental touch by human being or insulation failure, which is not possible by MCBs alone. RCBOs are a combination of MCB and RCCB. It constitutes short circuit, overload and residual current protection features. High voltage due to open neutral can also be avoided. Whereas an MCB protects against short circuits and overload; and a RCCB protects from leakage fault only

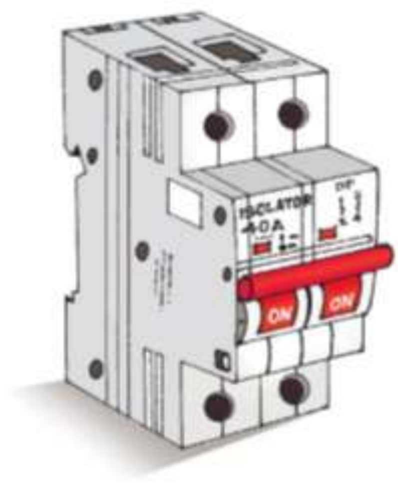


Figure 21: Isolator

Figure 22: RCBO

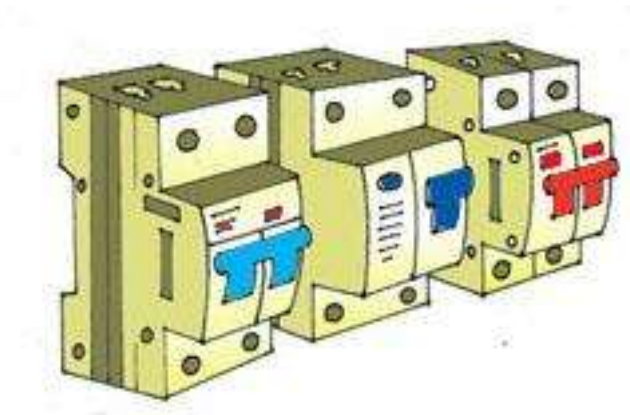


Figure 23: MCB

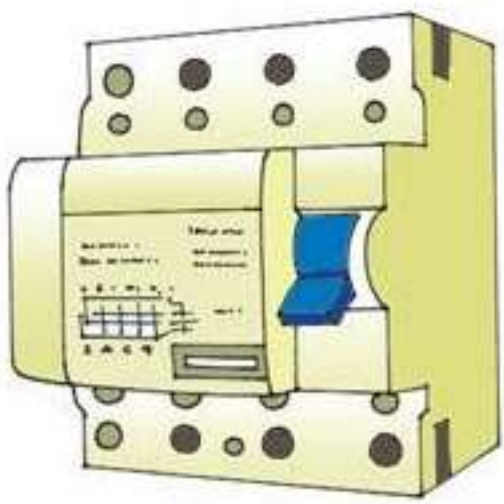


Figure 24: RCCB

C. Appliances

Energy use of a building is based on the amount of energy consumed by the appliances used. The sizing of these appliances is important in optimising the energy use and saving energy. It is highly recommended to use BEE star labelled appliances. Higher star rating represents lesser energy consumption.

Some general tips for saving energy are given below:

- Switch off appliances when not in use
- Refrigerators exhaust a lot of hot air. Hence there must be at least 0.5 to 1 feet gap between the rear side of the refrigerators and the wall.
- In case of using air conditioners, inverter air conditioners are preferred, and the placement should be planned in the layout itself. The outdoor unit should be placed in a way that it is accessible for maintenance and should be protected from direct sun radiation.
- LED (Light Emitting Diode) lamps are much more energy efficient and have a longer life than incandescent or fluorescent lamps.
- New range of fans called BLDC (Brush Less Direct Current) fans are available in the market, which consume about 50% lesser energy compared to normal fans.

D. Energy Meters

Energy meters should be installed to calculate the electricity consumption of a building. Energy meters should be placed in such a way that it is easily accessible to the utility staff. Safety aspects also must be considered.

Figure 25: Energy meter

Separate energy meters also can be installed for the major energy intensive equipment such as pumps and motors, external lighting, and air-conditioning to monitor the energy consumption of each system. Continuous monitoring would help in enhancing the energy performance of a building.

E. Renewable Energy

Renewable energy is energy generated from sources that are naturally replenished e.g. sunlight, winds, tides. Solar energy is the most viable renewable energy source that can be used in buildings such as electricity generation and heating the water. Biogas is another renewable energy which can be produced from kitchen waste.

I. Rooftop Solar system

Solar Photo Voltaic (PV) systems contain numerous solar cells that absorbs the light from the sun and generate electricity. The generated electricity can be used directly by connecting it to the grid or stored in a battery for later use.

The ideal orientation for optimal performance of a solar PV system is facing the south direction at an angle equivalent to the latitude of the place of installation. Area required for installing 1 kW panels is 6 m^2 on an average. The area where solar panel is installed should be free of shade from trees, adjacent buildings, and self-shading.

Figure 26: Rooftop solar system

Benefits:

- Solar energy does not give out any harmful emissions to the environment
- Solar energy reduces the electricity bill. In case of grid-connected solar, the occupant gets paid if export to the utility grid is more.

II. Solar Thermal System

Solar water heating systems, or 'solar thermal' systems, use sun's radiation to heat water. Solar water heaters are available from 100 litre capacity. Flat plate collector and Evacuated tube collector (ETC) are the two predominant types of solar water heaters.

Figure 27: Solar water heater

Benefits:

- Using solar thermal reduces the amount of electricity or gas utilised to heat water

III. Biogas generator

Biogas is a type of biofuel that is naturally produced from the decomposition of organic waste. When organic matters, e.g. food waste and animal waste, break down in an anaerobic environment (an environment without oxygen) they release a blend of gases, primarily methane and carbon dioxide. This gas can be used instead of cooking gas.

Figure 28: A typical household biogas plant

Benefits:

- Biogas can save money spent on LPG (Liquid Petroleum Gas)
- Reduces landfills thereby minimising pollution of soil and groundwater

5. Water Management

Water is a scarce resource and hence should be used efficiently. Conscious efforts are required to reduce water consumption and reuse water wherever possible and minimise dependency on potable fresh water. There is a lot of scope for reduction of water consumption by implementing water saving techniques and fittings, and water efficient landscaping. Rainwater and treated wastewater can be used as alternate sources of water. These measures will help us to overcome water crisis.

A. Plumbing layout

Both water supply and wastewater pipelines should be designed as straight as possible and should have minimum bends. Pipelines should be sized optimally to ensure free flow of water and wastewater. Appropriate slopes in pipelines must be provided to ensure gravitational flow. Placement of water tanks, sumps, rainwater harvesting systems, pumps, closets, taps, water tanks, and wastewater handling facilities should be planned properly in the layout itself.

B. Plumbing materials

Pipes and allied fixtures play a vital role in supplying fresh water to the building facilities as well as carrying wastewater after usage. It is important to choose right type of pipes based on its applications.

Generally, U-PVC (unplasticised polyvinyl chloride) or CPVC (chlorinated polyvinyl chloride) pipes can be used for water supply lines. For hot-water applications CPVC pipes are ideal. PVC pipes can be used for wastewater applications and rainwater harvesting systems.

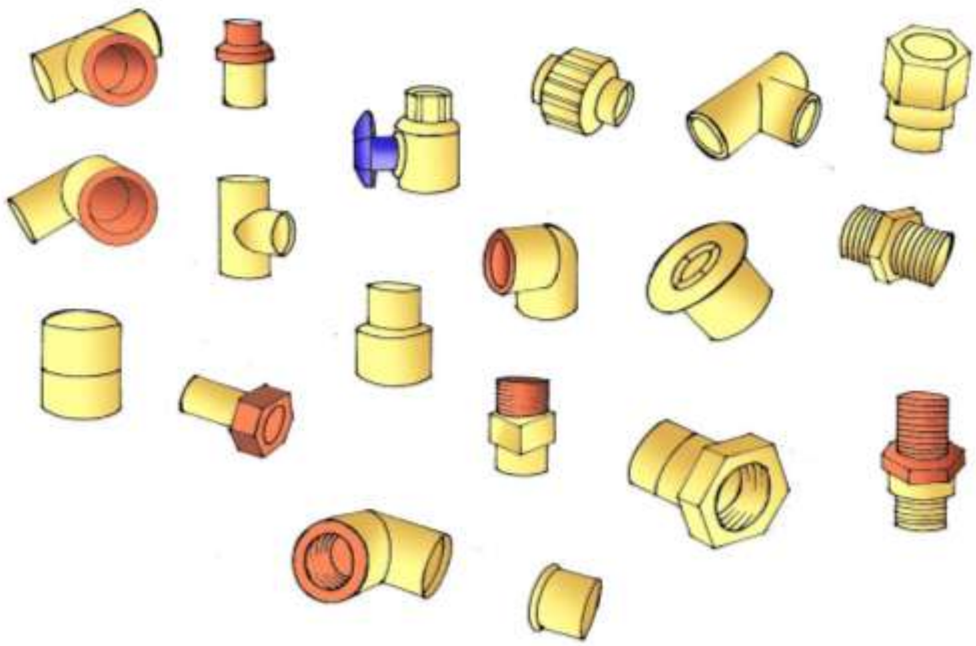


Figure 29: Plumbing fixtures

Non-return valves can be provided next to the pumps to prevent static head of water from creating stress on pump impeller.

Low flow aerators can be provided in the taps as much as possible thereby minimising unnecessary spills while using water.

Figure 30: Low flow aerators

In case of choosing western closets for toilets, a dual flush cistern is preferred since it uses less water compared to a standard one. It has two buttons, one for half flush and other for full flush. A dual flush tank can operate with as low as 4 litres of water in full flush and 2 litres of water in half flush, whereas a standard flush cistern uses 10 litre per flush.

Figure 31: Normal flush cistern and dual flush cistern

A level controller may be provided in water storage tanks for auto ON-OFF control, thus preventing any water wastage due to overflow.

C. Water Metering

Water meters are helpful to continuously monitor and measure the water usage at various points of a building e.g. bore-wells, bathroom, kitchen. It can also help in identifying any deviations (leaks), thus saving resource and money.

Figure 32: Water meter

D. Rainwater Harvesting

Rainwater harvesting (RWH) is the process of collecting and storing rainwater for future use. The rainwater that falls on a roof and site is essentially free. Instead of letting rainwater run-off, if it is collected and stored, it could be an alternative to back up the main water supply especially during the summer months. The collected rainwater may be directly recharged into the ground or stored and utilised in different ways.

Benefits:

- Rainwater harvesting prevents surface run-off and reduces soil erosion
- By percolating the rainwater into the ground, the groundwater level can be raised. Thus, going deeper to access ground water can be reduced and the shallow ground water aquifers can be made easily accessible
- By collecting and using rainwater, dependency on municipal water supply and bore wells can be minimised

Rainwater Harvesting Methodology

In houses with sloped roofs, the rainwater may be collected through half-cut PVC pipes fitted along the sloping sides (or gutters). The down pipes from the terrace should extend till the bottom of the building. Also, rainwater drainpipes should be interconnected if there are more than one. To collect the rainwater in a sump or well, the downpipe should be connected to a filter chamber. The bottom layer of the filter chamber shall be filled either with broken bricks/ blue metal/ pebbles for one feet, followed by one feet of coarse river sand. A nylon mesh can be provided in between the two layers. The filter chamber should be covered with an RCC slab. The inlet rainwater down pipe should be on the top of the filter chamber and the outlet pipe connecting the filter chamber to the sump should be at the bottom. The filtered rainwater can be connected to a sump or well or bore well.

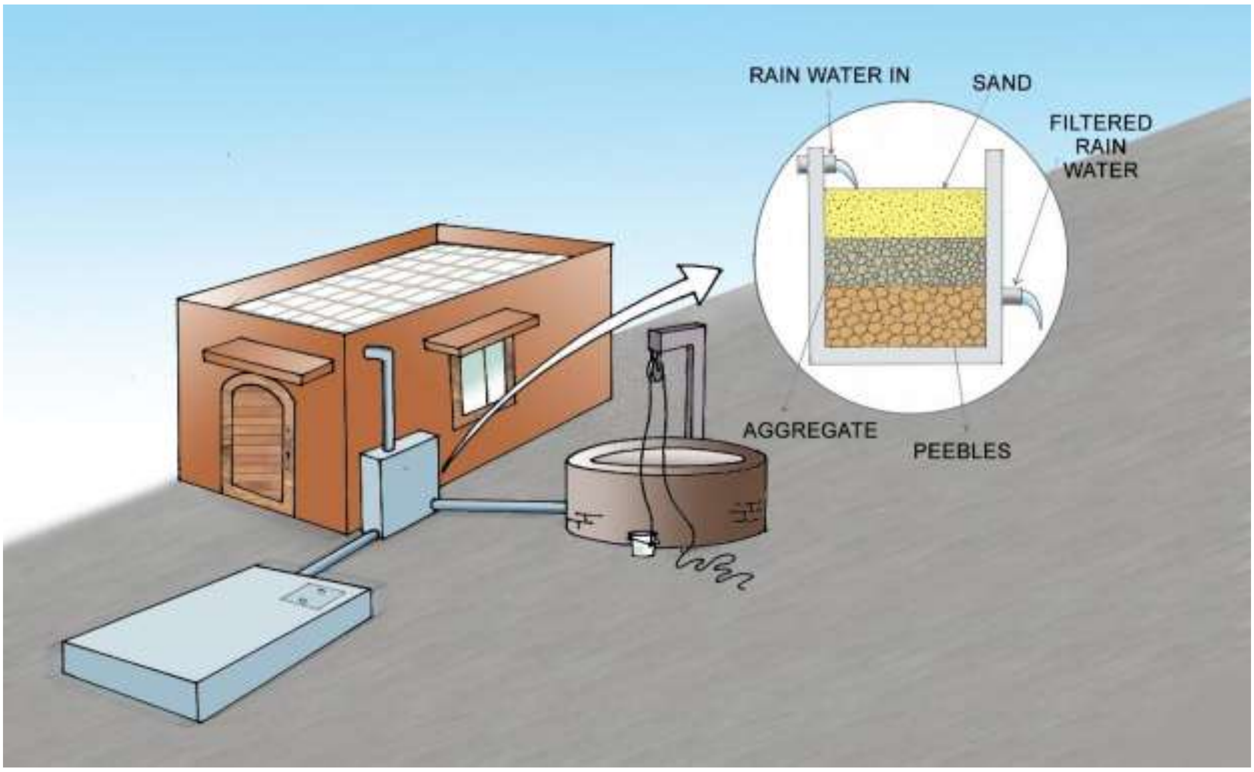


Figure 33: Rainwater harvesting with sand bed filter

Alternatively, a ready-made rainwater filter can be installed.

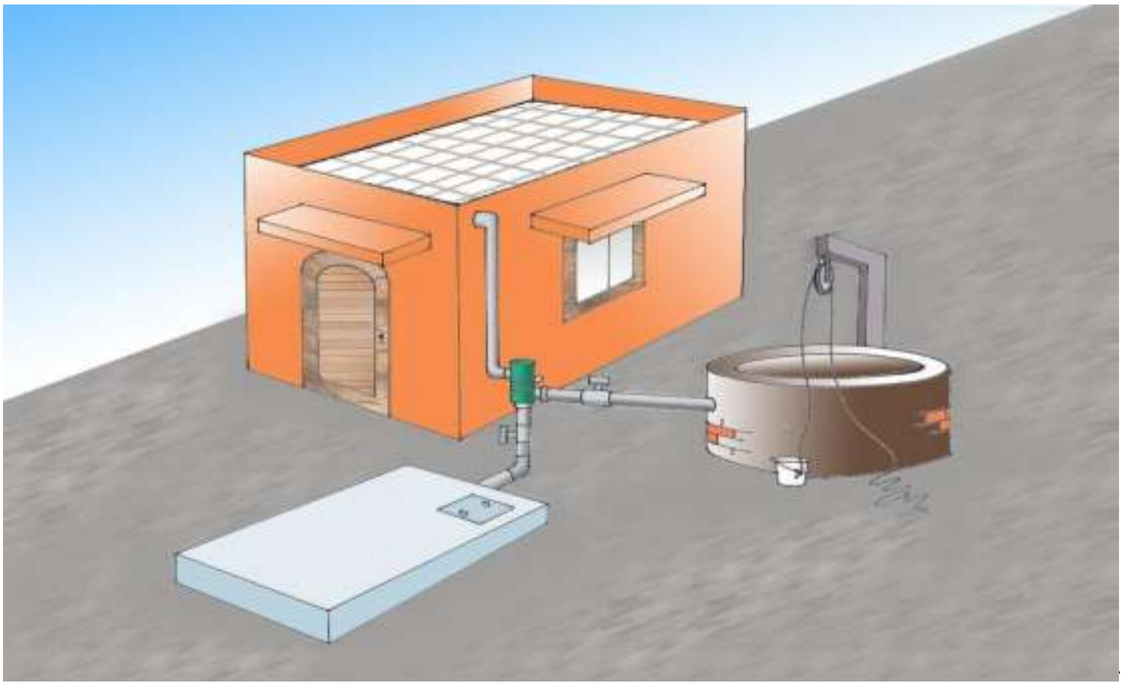


Figure 34: Rainwater harvesting with readymade filter

The rainwater also can be directly percolated into the ground by constructing percolation pits.

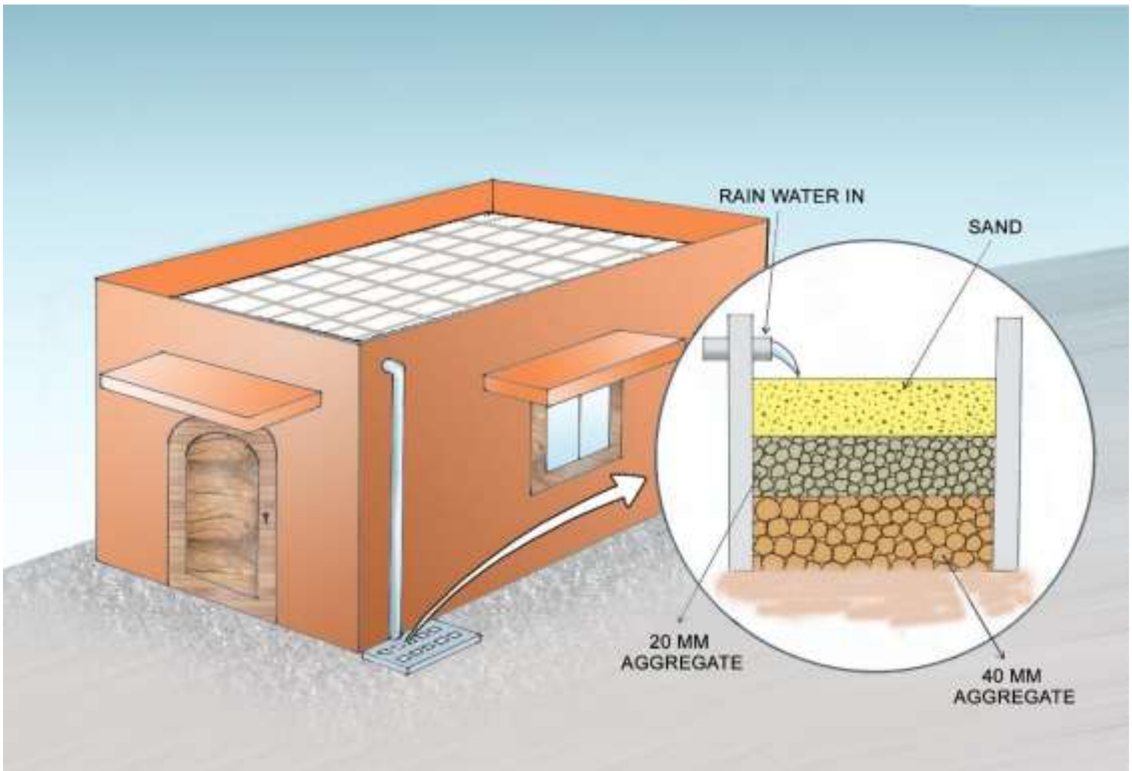


Figure 35: Rainwater harvesting – percolation pit

E. Wastewater Treatment and Reuse

I. Grey Water Treatment

The wastewater from kitchen, laundry, bathroom, and washbasins is known as greywater. A simple plant based grey water treatment system can be set up at each residence. Plants such as Indian Canna, Alocasia, and Reed grass are known to be highly efficient in treating grey water. Treated greywater can be percolated into the ground or reused for flushing, landscaping, floor cleaning, and car washing. The details of a simple grey water treatment system are given below.

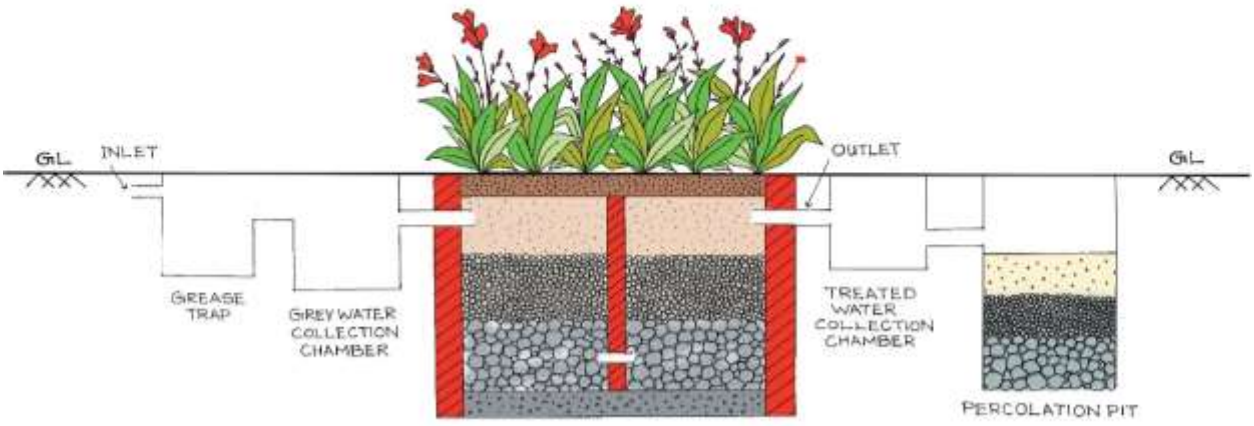


Figure 36: A simple grey water treatment system

Benefits:

- By using treated greywater for secondary uses, the use of potable water can be reduced
- It also minimises the burden on the government in handling wastewater
- When reused to irrigate plants, it provides double benefits as the treated wastewater contains nutrients which help in plant growth.

II. Black Water Treatment

Black water is the sewage water generated from the toilets. Discharging untreated black water into storm water drains or water streams can cause severe health problems. Therefore, proper handling of black water is mandatory. In locations where connection to a main sewer line is not available, a biodigester can be used to handle the black water sustainably.

A biodigester is an eco-friendly and maintenance-free system to manage human waste. Bio-digester utilises an anaerobic process in which bacteria feed upon the faecal matter inside the tank and finally degrades the matter. The bio-digester tank can be bought as a prefabricated tank or built on-site. The output of the biodigester can be used for landscaping or connected to the grey water treatment system for further purification. The treated black water contains micronutrients that enriches plant growth.

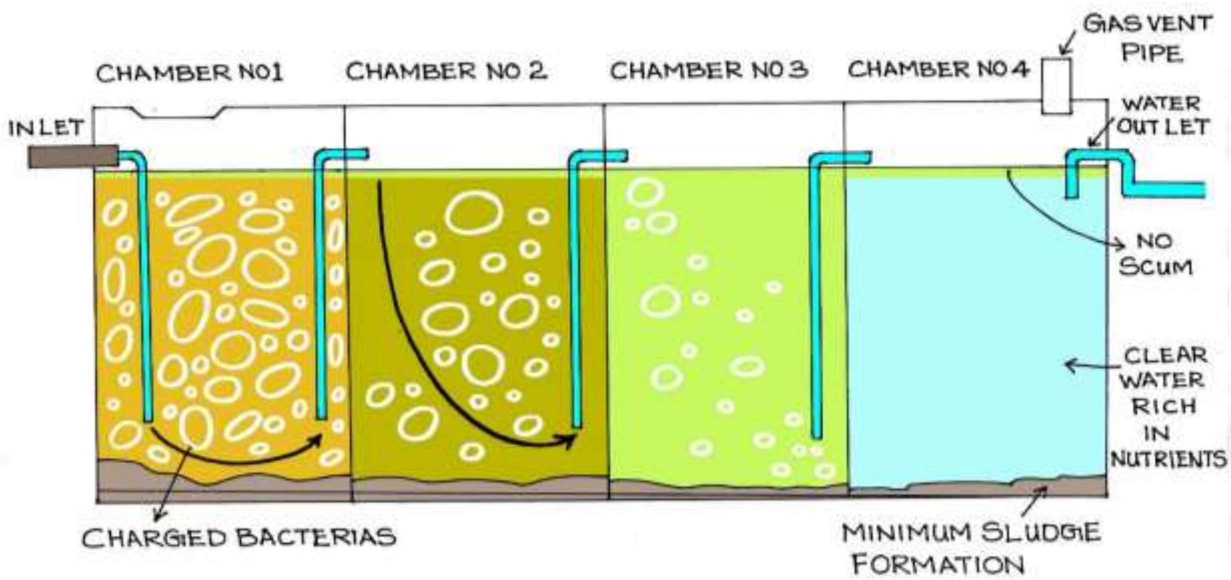


Figure 37: Black water treatment – Biodigester

Alternatively, a septic tank may be constructed to handle the black water locally. A typical section of a septic tank is given below.

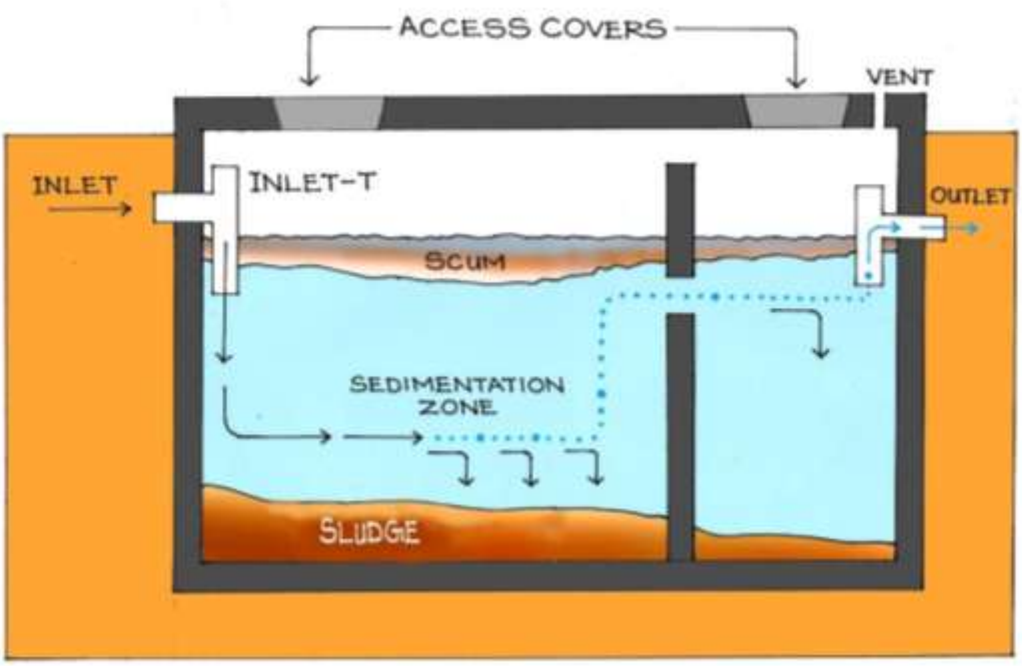


Figure 38: Black water treatment – Septic tank

Benefits:

- Black water treatment is vital to protect the quality of nearby water bodies
- Treated black water can be reused on site to ensure zero water wastage
- It also minimises the burden on the government in handling of wastewater

6. Resident health and well-being

A. Indoor Air Quality

I. Interior finishes

Indoor air pollutants can cause a range of problems from minor respiratory illnesses to major health issues. Many materials used in the building construction and interior fit outs contain Volatile Organic Compounds (VOC), formaldehyde, and other toxins which are harmful to the occupants. Such materials include paints, polish, coatings, varnish, wood & glass sealants, adhesives for plywood, laminate, and veneer applications. However, many alternative low / zero VOC products are available in the market. Products with low VOC should be used for preventing the adverse health risks from exposure to these toxic chemicals. Generally, lighter coloured paints have lower VOC and vice-versa.

The permissible VOC limits for different products are given in Annexure B

Benefits:

- Use of materials with low emissions reduces adverse health impacts on building occupants
- Low VOC finishes have lower odour and reduce the accumulation of allergy-causing toxins in the interiors

II. Building Flush-out

There is a direct link between indoor air contaminants and sick building syndrome. New materials typically have the highest rate of contaminant emission. In order to reduce the potential health risks of the occupants due to these indoor air pollutants a building flush-out should be carried out. A building flush-out can be performed by keeping all windows open for ten days before the building is occupied. Flush-out should be carried out after completing the interior finishes such as painting, varnish, etc.

Benefits:

- Building flush-out improves the indoor air quality by limiting the exposure to an intense contamination period

B. Thermal Comfort

Indoor temperature and relative humidity (RH) levels are the two factors that provides thermal comfort to occupants. Thermal comfort can be experienced differently by individuals at different climatic conditions. The ideal indoor relative humidity for health and comfort is about 40–50% and ideal indoor temperature is 26 ± 2 °C.

There are several ways to achieve the ideal temperature and RH. Natural ventilation and improved circulation of air is a cheap and best way to reduce humidity. Insulation helps keep your home warm in winter and cool in the summer. Shading, building orientation and glazing materials also play an important role in maintaining the ideal indoor temperatures.

Benefits:

- A comfortable indoor environment enhances the well-being of the occupants

C. Views

It is said that nature takes away all the stress. Connectivity between the interior and the exterior environment is vital for a relaxed and calm living environment. In regularly occupied spaces, openable windows or glazing should be designed between 0.9 meters (3 feet) and 2.1 meters (7 feet) above the finished floor level for building occupants to provide views into the garden or the sky. Internal courtyards with vegetation can also help in bringing the outdoors in.

Figure 39: View from indoor

Benefits:

- Providing adequate views enhances the aesthetics of the indoor space
- It also improves the mental health and well-being of the occupants

7. Waste management

A. Construction Waste Management

Construction industry is waste intensive, and this waste is generally sent to landfills. Typical construction debris in residential projects include broken bricks, steel bars, broken tiles, glass, wood waste, paint cans, cement bags, packing materials, etc. Construction and demolition waste should be segregated and reused on-site as much as possible or sold to salvage vendors. The objectives of construction waste management plan are to

- Minimise the amount of waste generated as part of the project
- Maximise the amount of material which is sent for reuse or recycling
- Minimise the amount of material sent to landfill.

Preparation of a site management plan and construction waste management plan is the key to manage construction waste. The site management plan should include dedicated storage area for materials, specifically a covered storage area for materials such as cement and sand and a dedicated space for collection of construction waste. Reusing steel bar bits for sunshades, broken tiles for pathways, broken brick and demolition waste for site filling are a few ways to reuse the construction waste on-site. Excavated soil from the site can be used as a construction material, provided it is tested and is fit for construction.

Benefits:

- Reduction of amount of waste sent to landfill, helps in saving lands from becoming dump yards
- Having a construction management plan can save money from being spent on procuring excessive material

B. House-hold Waste Management

I. Waste segregation

Waste segregation is an important step in house-hold waste management. Waste should be segregated at source as dry waste (paper, plastics, metals, glass, etc.,) and wet waste (organic). Dry waste can be sold to scrap vendors or recyclers and wet waste can be decomposed to compost and/or biogas. In addition to dry and wet waste, hazardous waste such as batteries, e-waste, lamps and medical waste, if any must be collected separately and disposed-off properly.

Benefits:

- Reduces landfills, and pollution of soil and groundwater from these landfills
- Recycling waste creates revenue

II. Organic waste management

About 60% of the house-hold waste is organic waste that can be easily decomposed. Decomposition is the 'breaking down' of organic waste and converting it into nutrient-rich compost.

Composting can be done in a pit in the garden or with a dedicated vessel in one’s balcony or backyard. Keep adding organic waste and dried leaves in alternate layers and mix the pile once a week. Once the pit or vessel is full, start a fresh batch. The pile will shrink as it decomposes. Ensure that the compost pile is not too wet as this leads to bad odour and unwanted pests. The decomposing process takes about two to four months to complete. Compost which is ready will be dark in colour and will smell of fresh earth. The compost can be used as a supplement in your garden.

Benefits:

- Reduces landfills, and pollution of soil and groundwater from these landfills
- Compost enriches soil and helps in retaining moisture in the soil.
- Compost reduces the need for chemical fertilisers.

8. Vegetation

A. Indoor Air Purifying Plants

Indoor plants not only provide aesthetics, but they also enhance indoor air quality, thereby improving the health of the occupants. It increases the productivity, concentration and creativity of the occupants and reduces stress and fatigue. It is advisable to have at least one plant in every 100 square feet of carpet area of regularly occupied spaces. Refer to Annexure C for list of Indoor plants.

Benefits:

- Plants purify indoor air by absorbing toxins such as formaldehydes and benzenes
- Plants boost energy and aid in the wellbeing of the occupants

B. Kitchen garden

Fruits and Vegetables can be grown easily in the household premises. Spaces such as balconies and windowsills can be used for this in addition to terrace, back yards, and front yards. Plants can be grown in pots or by planting directly in the garden soil. Herbs can be grown in small containers in the kitchen or utility area. A list of native vegetables, fruits, and herbs have been included in Annexure C.

Benefits:

- Vegetables, and fruits will be fresh, healthy, and free from harmful pesticides.
- Instead of buying from the market, one can save money by growing vegetables and fruits in the kitchen garden
- Roof garden will also provide heat insulation and reduce the indoor temperature

C. Enhancing Biodiversity

Gardens should mimic the natural ecosystems with a wide variety of plants, animals and soil organisms. A biodiverse garden has a variety of plants that attracts birds, butterflies, and other beneficial insects. Placing a birdhouse or a bird feeder, having a small pond or birdbath, growing more native trees and shrubs, growing flowering and fruit-bearing trees and shrubs, using home-made compost instead of chemical fertilisers are some ways of creating and enhancing the biodiversity. A list of native and drought tolerant trees and shrubs can be found in Annexure C.

Benefits:

- Enhancing the biodiversity provides habitat for several species such as birds, butterflies, and bees
- Native plants require less water, are easier to maintain, and will contribute to balancing the local ecosystem
- Gardens in addition to mitigating air and noise pollution also absorb green-house gases and combat climate change

9. Cost Efficiency in Construction

- **Use salvaged materials**

The use of salvaged building materials and products such as windows, doors, pillars, furniture, roof tiles, etc. from existing buildings or demolition sites reduce the demand for virgin materials and reduces waste going to landfills. This also minimises the impacts associated with extraction and manufacturing new construction materials. For example, reusing windows and doors, materials obtained from local demolition contractors, etc.

- **Avoid non-essential elements**

Non-essential elements in construction such as plaster, cladding, and false ceiling can be avoided to reduce the construction cost. Windows can be replaced with *jaali*, mesh, or grill to save cost of woodwork and glass. Blinds and *thattis* made of natural fibre which are available locally can be used for privacy.

- **Use locally available materials**

As per IGBC guidelines, materials which are easily available or extracted on site or within 400 km distance of the project site are called local materials. The use of these materials reduces the transportation cost and the environmental impact associated with it.

- **Minimise wastage**

By designing appropriately, wastage of materials can be minimised. For example, when a half brick is required while building a brick wall, instead of cutting a good whole brick, brick bats or chipped bricks can be used. This can be applied for flooring tiles as well.

- **Reuse construction waste**

Construction waste can be reused on site innovatively. For example, broken floor tiles and stones can be used as pavers in the garden area. Broken bricks and cement debris can be utilised for site filling, while bits of TMT bars can be used for sunshades and other projections.

- **Built-in furniture**

The cost of woodwork spent on interior furniture can be reduced greatly by designing integrated and built-in furniture. *Thinnai* is a classic example of built-in seating in the porch. Built-in wardrobes and kitchen cabinets with stone and brick are cheaper and long lasting than the commercial modular units. Window seaters and raised platforms used as beds are also alternative for furniture.

- **Smart choice of materials**

Choose materials that are best suited for the project, according to site conditions and requirements. On a site that is well shaded, expensive insulation materials for walls may not be required. Using larger blocks such as Porotherm for masonry will reduce the mortar requirement and results in faster construction

- **Simplicity in design form**

Complex design forms tend to have larger outer wall surfaces which consequently increases the material required. Hence, the cost of the construction increases significantly. A simple design form without any wastage of space is ideal for cost-effective construction.

- **Material efficient techniques**

Several construction techniques have proven to be material efficient and effective in providing thermal comfort as well. Rat-trap bond, filler slab, brick lintels are some examples. However, caution must be exercised while opting for these technologies as it may require skilled labour or appropriate structural design.

- **Building Technology**

Identify affordable building technologies that offer cheaper and faster construction. Ferro cement, reinforced thermocol panels, and prefabricated structures are some examples of faster and economical construction technologies.

- **Construction management**

Construction management is a very crucial step to ensure cost efficient construction. Scheduling of construction activities, book-keeping, quality control, and monitoring are some key steps.

- **Integrated Planning and Design**

Ensure structural design, plumbing layouts, electrical layouts, and landscape elements are considered from the design stage itself. The plans and required provisions for these should be made before starting construction works, so that there is no rework.

References

1. *India 2020: Energy Policy Review*. (2020). International Energy Agency.

2. Upali A. Amarasinghe, Tushaar Shah, and B.K.Anand. (2008). *India's Water Supply and Demand from 2025-2050: Business- as- Usual Scenario and Issues*. International Water Management Institute.

3. *Guidelines on Environmental Management of Construction & Demolition (C&D) Wastes*. (2017). Central Pollution Control Board, Government of India.

4. *Municipal Solid Waste Management Manual*. (2016). Central Public Health and Environmental Engineering Organisation, Government of India.

5. Johan Van Lengen. (2008). *The Barefoot Architect: A Handbook for Green Building*. California: Shelter Publications.

6. Laurie Baker. (1999). *A Manual of Construction of Cost Cuts for Storing Acceptable Housing*. Costford Centre of Science and Technology for Rural Development.

7. O.H. Koenigsberger, T.G. Ingersoll, Alan Mayhew, S.V. Szokolay. (1975). *Manual of Tropical Housing and Building: Climatic Design*. Orient Blackswan Private Limited.

8. *Tamil Nadu Combined Development and Building Rules 2019*. (2019). Municipal Administration and Water Supply Department, Government of Tamil Nadu.

9. Knowledge Centre, Net Zero Energy Buildings. https://nzeb.in/knowledge-centre/

10. Energy Conservation Building Code 2017: Design Guide. (2017). Bureau of Energy Efficiency, Government of India.

11. *Green Homes*. Indian Green Building Council. https://igbc.in/igbc/redirectHtml.htm?redVal=showGreenHomesnosign#Resources

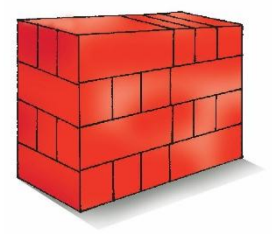
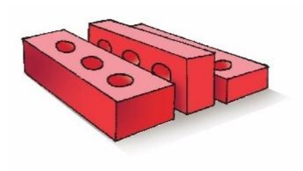
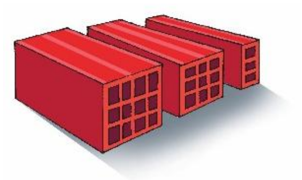
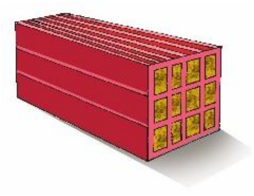
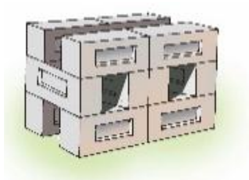
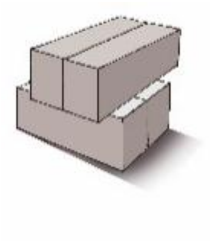
12. Passive Design, Fair conditioning. http://fairconditioning.org/knowledge/passive-design

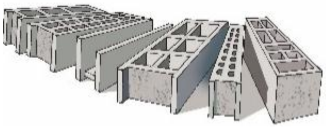
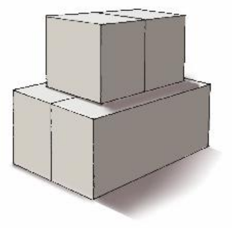
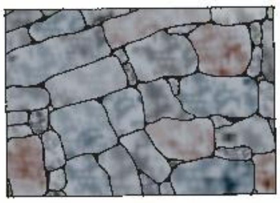
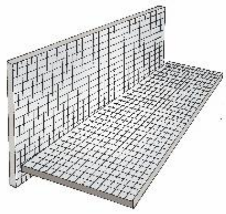
13. Building Materials & Insulation. https://theconstructor.org/

14. Biodigester, Defence Research and Development Organisation. https://www.drdo.gov.in/biodigester#content

15. What is Composting? Green Matters. https://www.greenmatters.com/food/2018/12/07/ZboPlt/what-is-composting

Annexure A – List of Wall Materials and Properties

Wall Materials	Image	Composition	Properties
Fired Clay Bricks		Made by sintering the clay materials	Compressive strength: 10-30MPa; apparent density: 1500-1800kg/m3; thermal conductivity: 0.78W/mK
Fired Hollow Bricks		Made by sintering the clay materials	Compressive strength: 2.0-5.0 MPa; apparent density: 800-1100kg/m3; thermal conductivity: 0.78W/mK
Porotherm Bricks		Made by sintering the clay materials	Compressive strength: 3.5 MPa; apparent density: 750 kg/m3; thermal insulation: 0.6W/(m2K)
Thermo Bricks		Made by sintering the clay materials and the gaps are willed with insulation material	Compressive strength: 3.5 MPa; apparent density: 800 kg/m3; thermal insulation: 0.2W/(m2K)
Fly Ash Bricks		Fly ash, lime, aggregates (slag, and mineral slag) and gypsum	Compressive strength: 7.5-20MPa; apparent density: 1500kg/m3
Solid Concrete Blocks		Manufactured from cement, sand, and aggregate.	high structural capacity, resist fire, easy to be used etc.

Hollow Cement Blocks		Manufactured from cement, sand, and aggregate.	Compressive strength: 3.5 to 15 MPa; Hole-rate: 35% – 50%; Apparent density: 1300 – 1700 kg/m3; Thermal conductivity: 0.26 W/(m*K)
Aerated Concrete Blocks		The porous concrete made by gas-forming and autoclaving ground silicate materials. lime, aluminum powder and water	Compressive strength of 700 grade: 4.2-5.0MPa; thermal conductivity: 0.1 0-0.16W/(m.K)
Natural stone		Undressed pieces of stone or rock	Strength and thermal properties based on Material
Reinforced Thermocol Panel		Polystyrene boards with steel mesh plastered by cement mortar on two sides	Density: 100 – 110 kg/m^3; Thermal Insulation: 0.9 W/m2K
Gypsum Board / Partition Board		Building gypsum, paper boards, glass fibre and water	Apparent density: 600 -1000 kg/m3; Thermal conductivity: 0.2-0.25 W/(m*K)

Annexure B – Low Emitting Materials

A. Paints and Coatings

Paints and coatings (including primers) should have no VOC (volatile organic compounds) or low VOC content as per limits specified below.

S. No.	**Product Type**	**VOC Limit (g / L minus Water)**
1	Interior Flat Coating / Primer	50
2	Interior non-Flat Coating / Primer	150
3	Anti-Corrosive / Anti Rust paint	250
4	Clear wood finish: Lacquer	550
5	Clear wood finish : Sanding Sealer	350
6	Clear wood finish : Varnish	350
7	Clear Brushing Lacquer	680
8	Floor coatings	100
9	Sealers and Under-coaters	200
10	Shellac: Clear	730
11	Shellac: Pigmented	550
12	Stain	250
13	Concrete curing compounds	350
14	Japans / Faux finishing coatings	350
15	Magnesite cement coatings	450
16	Pigmented lacquer	550
17	Water proofing sealers	250
18	Water proofing concrete / masonry sealers	400
19	Wood preservatives	350
20	Low solid coatings	120*
	* VOC Levels for low solids coatings are measured in grams of VOC per litre of material including water	

B. Construction Chemicals

Construction chemicals such as adhesives and sealants should have VOC content within the limits specified below.

S. No.	Adhesive	VOC (g/L)
(I) Architectural Applications		
1	Carpet pad adhesives	50
2	Ceramic tile adhesives	65
3	Dry wall and panel adhesives	50
4	Multi-purpose construction adhesives	70
5	Rubber flooring adhesives	60
6	Structural glazing adhesives	100
7	Subfloor adhesives	50
8	VCT and asphalt tile adhesives	50
9	Indoor carpet adhesives	50
10	Wood flooring adhesives	100
(II) Adhesive Substrate Specific Applications		
1	Adhesives for fibreglass	80
2	Adhesives for metal	30
3	Adhesives for plastic foams	50
4	Adhesives for porous material	50
5	Adhesives for wood	30
6	PVC welding	510
7	Top & trim adhesive	250
8	Special purpose contact adhesive	250
9	Contact adhesives	250
(III) Sealants		
1	Architectural	250
2	Non membrane roof	300
3	Roadway	250
4	Other	420

C. Other Materials

Composite wood and Agri-fibre materials should not contain added urea formaldehyde resins. The recommended threshold limits of TVOCs, Formaldehyde and total aldehydes for the products and materials such as Gypsum ceilings, Carpets, Furniture are specified below.

Chemical Component	**Emission Limits**
TVOC	0.5 mg/m3
Formaldehyde	50 Parts Per Billion (Ppb)
Total aldehyde	100 Ppb

Annexure C – List of Plants

A.Indoor Plants

S. No	Common Name	Scientific Name
1	African Violet	*Saintpaulia ionantha*
2	Air Plant	*Tillandsia spp.*
3	Aloe Vera	*Aloe barbadensis miller*
4	Anthurium / Tail Flower	*Anthurium Andraeanum*
5	Aralia Ming	*Polyscias Fruticosa*
6	Areca Palm	*Dypsis lutescens*
7	Arrowhead	*Syngonium podophyllum*
8	Asparagus Fern	*Asparagus densiflorus sprengeri*
9	Blushing BromeLiad	*Neoregelia Carolinae*
10	Boston Fern	*Nephrolepis exaltata*
11	Buddhist Pine	*Podocarpus macrophyllus*
12	Chinese Evergrenn	*Aglaonema spp.*
13	Cornstalk Plant	*Dracaena fragrans*
14	Dragon Tree	*Dracaena marginata*
15	Earth Star	*Cryptanthus spp.*
16	English Ivy	*Hedera helix*
17	Flaming Sword plant	*Vriesea Splendens*
18	Flaming Torch	*Billbergia Pyramidalis*
19	Foxtail Fern	*Asparagus Densiflorus Meyersii*
20	Gerbera Daisy	*Gebera jamesonii*
21	Golden Pothos / Money Plant	*Epipremnum aureum*
22	Heart leaf Philondendron	*Philodendron hederaceum*

S. No	Common Name	Scientific Name
23	Janet Craig	*Dracaena deremensis*
24	Kentia Palm	*Howea forsteriana*
25	Lady Palm	*Rhapis excelsa*
26	Matchstick Plant	*Aechmea gamosepala*
27	Mottled Imbe	Philondendron Imbe
28	Mums	*Chrysanthemum spp.*
29	Peace Lily	*Spathiphyllum wallisii*
30	Purple hearts	*Tradescantia pallida*
31	Purple Waffle	*Hemigraphis alternata*
32	Pygmy Date Palm	*Phoenix roebelenii*
33	Queensland Umbrella	*Schefflera actinophylla*
34	Rubber Plant	*Ficus elastica*
35	Scarlet Star	*Guzmania lingulata*
36	Snake Plant	*Sansevieria trifasciata*
37	Song of India	*Dracaena reflexa*
38	Spider Plant	*Chlorophytum comosum*
39	Split leaf Philondendron	*Philondendron xanadu*
40	Ti Plant	*Cordyline fruticosa*
41	Velvet leaf philondendron	Philondendron Micans
42	Waxy leaved Plant	*Hoya carnosa*
43	Weeping Fig	*Ficus benjamina*

B. Vegetables and fruits

I. Vegetables

S. No	Common Name	Scientific Name
1	Apple gourd / tinda	*Praecitrullus fistulosus*
2	Ash gourd	*Benincasa hispida*
3	Banana / Plantain	*Musa spp.*
4	Beans	*Phaseolus vulgaris*
5	Beetroot	*Beta vulgaris*
6	Bitter Gourd	*L. Momordica charantia*
7	Bottle Gourd	*Lagenaria siceraria*
8	Brinjal	*Solanum melongena*
9	Brocolli	*Brassica oleracea var. italica*
10	Cabbage	*Brassica oleracea var. capitata*
11	Capsicum	*Capsicum annuum*
12	Carrot	*Daucus carota*
13	Cauliflower	*Brassica oleracea*
14	Celery	*Apium graveolens*
15	Chilli	*Capsicum frutescens*
16	Cluster beans	*Cyamopsis tetragonoloba*
17	Corn	*Zea mays*
18	Cucumber	*Cucumis sativus*
19	Drumstick	*Moringa oleifera*
20	Elephant Foot yam	*Amorphophallus paeoniifolius*
21	Garlic	*Allium sativum*
22	Hyacinth Beans (Broad Beans)	*Lablab purpureus*
23	Ivy gourd	*Coccinia grandis*

S. No	Common Name	Scientific Name
24	Lemon	*Citrus limon*
25	Lettuce	*Lactuca sativa*
26	Mirliton squash (*Chow Chow*)	*Sechium edule*
27	Okra (Lady's Finger)	*Cucumis melo*
28	Onion	*Allium cepa*
29	Peas	*Pisum sativum*
30	Pointed gourd	*Trichosanthes dioica*
31	Potato	*Solanum tuberosum*
32	Pumpkin	*Cucurbita pepo*
33	Raddish	*Raphanus sativus*
34	Ridge gourd	*Luffa acutangula*
35	Snake beans (Legume)	*Vigna unguiculata ssp.*
36	Snake gourd	*Trichosanthes cucumerina*
37	Spinach	*Spinacia oleracea*
38	Spring Onion	*Aaluum cepa*
39	Sweet Potato	*Ipomoea batatas*
40	Tapioca	*Manihot esculenta*
41	Taro	*Colocasia esculenta*
42	Tomato	*Lycopersicon esculentum*
43	Turnip	*Brassica rapa*
44	Veldt grape (*Pirandai*)	Cissus quadrangularis
45	Yam	*Dioscorea alata*

II. Fruits

S. No	Common Name	Scientific Name
1	Apple	*Malus domestica*
2	Apricot	*Prunus armeniaca*
3	Avocado	*Persea americana*
4	Banana	*Musa spp.*
5	Cashew	*Anacardium occidentale*
6	Cherry	*Prunus avium*
7	Custard Apple	*Annona reticulata*
8	Fig	*Ficus carica*
9	Grapefruit	*Citrus × paradisi*
10	Grapes	*Vitis vinifera*
11	Guava	*Psidium guajava*
12	Honeydew Melon	*Cucumis melo L.*
13	Indian Goose Berry	*Phyllanthus emblica*
14	Indian Jujube	*Ziziphus mauritiana*
15	Indian Sherbet Berries	*Grewia asiatica*
16	Jackfruit	*Artocarpus heterophyllus*
17	Jamun	*Syzygium cumini*
18	Kiwi	*Actinidia deliciosa*
19	Langsat	*Lansium parasiticum*
20	Litchi	*Litchi chinensis*

S. No	Common Name	Scientific Name
21	Mango	*Mangifera indica*
22	Mangosteen	*Garcinia mangostana*
23	Mosambi	*Citrus limetta*
24	Musk Melon	*Cucumis melo*
25	Orange	*Citrus X sinensis*
26	Papaya	*Carica papaya*
27	Passion Fruit	*Passiflora edulis*
28	Peach	*Prunus persica*
29	Pear	*Pyrus communis*
30	Pineapple	*Ananas comosus*
31	Plum	*Prunus subg. Prunus*
32	Pomegranate	*Punica granatum*
33	Sapota / Chikoo	*Manilkara zapota*
34	Starfruit	*Averrhoa carambola*
35	Strawberry	*Fragaria × ananassa*
36	Sugar palm	*Palmyra palm*
37	Tamarind	*Tamarindus indica*
38	Tangerine / Santra	*Citrus reticulata*
39	Watermelon	*Citrullus lanatus*
40	Wood Apple	*Limonia acidissima*

C. Herbs and Greens

I. Herbs

S. No	Common Name	Scientific Name
1	Aswagandha	*Withania somnifera*
2	Bay Leaves	*Laurus nobilis*
3	Betel	*Piper betel*
4	Black Nite shade / Manathakkali	*Solanum nigrum*
5	Black Pepper	*Piper nigrum*
6	Brahmi	*Bacopa monnieri*
7	Carrom / Ajwain	*Trachyspermum ammi*
8	Chives	*Allium schoenoprasum*
9	Citronella	*Cympobogan nardus*
10	Corriander	*Coriandrum sativum*
11	Curry leaf	*Murraya koenigii*
12	Fennel / Saunf	*Foeniculum vulgare*
13	Fenugreek	*Trigonella foenum-graecum*
14	Ginger	*Zingiber officinale*
15	Jeera	*Cuminum cyminum*
16	Karpooravalli / Oregano	*Origanum vulgare*
17	Khus / Vetiver	*Chrysopogon zizanioides*
18	Lavendar	*Lavandula angustifolia*
19	Lemon grass	*Cympobogan citratus*
20	Mango Ginger	*Curcuma amada*
21	Mint	*Mentha*
22	Mustard	*Brassica*
23	Rosemary	*Salvia rosmarinus*
24	Tulsi	*Ocimum tenuiflorum*
25	Turmeric	*Curcuma longa*

II. Greens

S. No	Common Name	Scientific Name
1	Agathi Keerai / Agathi Leaves	*Sesbania grandiflora*
2	Arai Keerai / Amaranthus tricolor	*Amaranthus aritis*
3	Gongura / Brown Indian hemp	*Hibiscus cannabinus*
4	Kalyana Murungai	*Erythrina variegata*
5	Karisilangkanni	*Eclipta prostrate*
6	Kodi Pasalai / Malabar Spinach	*Basella alba*
7	Kuppai Keerai / Reen amaranth	*Amaranthus viridis*
8	Mudakkathan Keerai	*Cardiospermum halicacabum*
9	Mulai Keerai / Purple amaranth	*Amaranthus blitum*
10	Mulli Keerai / Prickly amaranth	*Amaranthus spinosus*
11	Musumusu Keerai /	*Mukia maderaspatana*
12	Nachukottai / Thorny amaranth	*Pisonia alba*
13	Pannai Keerai	*Celosiaargentea*
14	Parattai Keerai / Kale	*Heteranthera ipomoea-reniformis*
15	Paruppu Keerai / Common purslane	*Portulaca oleracea*
16	Palak	*Spinacea oleracea*
17	Poduthalai keerai / Turkey tangle	*Phyla nodiflora*
18	Ponnakanni keerai / Dwarf copper leaf	*Alternanthera sessilis*
19	Siru Keerai / Tropical amaranth	*Amaranthus tricolor*
20	Sukkan Keerai / Bladder dock, Sorrel	*Rumex vesicarius*
21	Thandu Keerai / Foxtail Amaranth	*Amaranthus gangeticus*
22	Thoothuvalai Keerai / Thai night shade	*Solanum trilobatum*
23	Thoyya Keerai / False amaranth	*Digera muricata*
24	Thuthik Keerai / Indian mallow	*Abutilon indicum*
25	Vallarai Keerai / Indian pennywort	*Centella asiatica*

D. Native and Drought tolerant Plants

I. Warm and Humid Climatic Regions

TREES

S.No.	Common Name	Scientific Name
1	Crape-myrtle	*Lagerstromia Lanceolata*
2	Ashoka	*Saraca Ashoka*
3	Banyan	*Ficus bengalensis*
4	Shisham, Indian Rosewood	*Dalbergia latifolia*
5	Kindal	*Terminalia paniculate*
6	Mahua	*Madhuca indica*
7	Plantain	*Musa paradisiaca*
8	Cornbeef wood	*Barringtonia racemose*
9	Indian Laburnum, Amaltas	*Cassia fistula*
10	Kabuli keekar	*Prosopis julifora*
11	Coconut	*Cocos nucifera*

SHRUBS

S.No.	Common Name	Scientific Name
1	Bamboo	*Bambusa Sps.*
2	Tulasi	*Ocimum sanctum*
3	Jupa	*Hybiscus rosasinensis*
4	Vetiver grass, Khas	*Vetiveria zizanioides*
5	Assamese ginger	*Alpinia sps.*
6	White ginger lily	*Hedychium coronarium*
7	Song of India	*Pleomele reflexa*
8	Bougainvillea	*Bougainvillea sps.*
9	Copperleaf	*Acalypha wilkesiana*
10	Bringaraja	*Eclipta alba*
11	Chrysanthem	*Chrysanthem Indicum*

II. Cold Climatic Regions

TREES

S.No.	Common Name	Scientific Name
1	Himalayan Silver fir	*Abies pindrow*
2	Teak	*Tectona grandis*
3	Deodar	*Cedrus deodara*
4	Indian Willow, Bilsa	*Salix tetrasperma*
5	Sal	*Shorea robusta*
6	Chir pine	*Pinus roxburghii*
7	Walnut, Akhrot	*Juglans regia*
8	Parijat	*Nyctanthes arbor-tristis*
9	Mulberry	*Morus*
10	Brahmakamal, Queen of the night	*Epiphyllum oxypetalum*
11	Indian Laburnum, Amaltas	*Cassia fistula*
12	Shisham, Indian Rosewood	*Dalbergia latifolia*
13	Kachnar	*Bauhinia variegate*

SHRUBS

S.No.	Common Name	Scientific Name
1	Tulasi	*Ocimum sanctum*
2	Jasmine	*Jasminum multiflorum*
3	Winter cherry	*Withania somnifera*
4	Alpenrose	*Rhododendron*