INTEGRATED GREEN DESIGN

for Urban & Rural Buildings
in Hot-Dry Climate Zone

INTEGRATED GREEN DESIGN

for Urban & Rural Buildings in Hot-Dry Climate Zone

Central Public Works Department

Integrated Green Design for Urban & Rural Buildings
in Hot-Dry Climate Zone

Published by:

Director of General

Central Public Works Department

101 A, Nirman Bhavan, New Delhi-110011
Email: cpwd_dgw@nic.in

Prepared by:
North Zone-III
CPWD, Jaipur
Email:nz3-cpwd-rj@nic.in

Technical Advisory Team:

CPWD - R.K.Singhal, spl. DG;

Mukund Joshi, Chief Engineer;

Rajiv Singhal, Suptd. Engineer ;

Biswajit Bose, Seniour Architect;

D.K. Ujjainia, Executive Engineer;

Consultant
Deependra Prashad Architects & Planners (DPAP)
S-335 (I flr.), Panchsheel Park,
New Delhi- 110017
email: deependra@intbau.in

Printed by:
Kshitiz Enterprises
D-57 south Estension Part-1, New Delhi-110049
ajaymittal1957@gmail.com

Message

सत्यमेव जयते

कमल नाथ
Kamal Nath

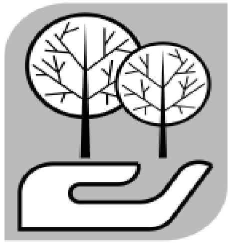
India, a fast developing country, is required to balance the utilisation of resources with the simultaneous need for preserving the environment. To prevent rapid growth from irreversibly degrading the environment and a consequent decay in the quality of life, there is a need to explore options that are low on energy and water use, on pollution and on cost. The planning, construction and utilisation of buildings has to also take options into account.

While the work on sustainable buildings has begun in right earnest, there is scope to do more. While the government and private buildings are gradually adopting practices of energy and environmental efficiency, for these to rapidly bring about visible change, the effort of the entire construction industry which is creating our infrastructure is needed. Since a large part of the built environment is dealing with buildings such as individual residences, schools, health centres, small commerical centres, amongst others, these also need to be included in the sustainable building movement. The cumulative effect of such buildings can make a significant impact on the environmental footprint.

The creation of this manual brings the concept of integrated green design to the common person, wherein certain generic principles and easy to implement methodologies are made available.Architects and engineers who are important decision makers of this construction process will have a much needed ready reckoner with this publication.

I congratulate the Central Public Works Department in bringing out this guide and look forward to the widespread application of the principles.

Shri Kamal Nath
Minister of Urban Development
Government of India




WASTE

Foreword

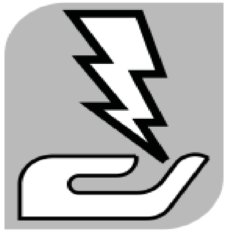
डा. सुधीर कृष्णा
Dr. Sudhir Krishna

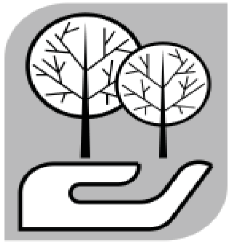
The challenges of growth are many and complex. With development the aspirations of the people are rising. There are competing demands on natural resources such as water and land and on power. Over and above all this are the increasingly evident impacts of global warming induced climate change, wherein temperatures are rising.

India's 2011 Census provides some interesting data that reveals development trends and offers planning opportunities. It shows that one in every third Indian now lives in an urban environment. While the number of million plus cities has shot up to 53 from 35 in 2001, the smaller cities are growing much faster than the larger ones that have a million plus population. The Census houses have increased from 25 crore to 33 crore, of which a third are in urban areas. The challenge then is to meet the necessary and basic needs of all, while maintaining levels of comfort, of using natural resources sustainably and with, minimum impact on the environment. This calls for making simple yet effective and locally relevant changes in the way we develop and construct in our urban and rural habitats, enabling us to reduce our resource consumption. The sheer numbers on widespread adoption will help provide the desired impact.

The publication and widespread dissemination of this simple yet effective user friendly guide on integrated green design for small structures in the hot-dry climate zones in the country by the Central Public Works Department, Ministry of Urban Development, marks another milestone in the journey of reducing our ecological footprints in the urban and rural living spaces, in a manner that will continue, if not enhance comfort levels. I look forward to the adoption of options offered.

Dr Sudhir Krishna
Secretary
Ministry of Urban Development
Government of India






WASTE

About the book

CPWD

अशोक खुराना
Ashok Khurana

India is a country with diverse ecological zones that range from mountains to valleys, dry lands to flood plains and from coastal regions to plateaus. To create infrastructure under these diverse conditions that meet the needs of the people, comply to set norms and standards, use resources and materials that are easily available and with minimum are impact on the environment call for constant innovation and experimentation and engagement with stakeholders.

Over the past several years, the Central Public Works Department (CPWD) has taken significant efforts to move towards the creation of sustainable infrastructure through the adoption of a multi-pronged approach. For example, CPWD is a stringent follower of ECBC (Energy Conservation Building Codes), NBC (National Building Code) and Ministry of Environment and Forests regulations on energy conservation and protection of the environment. The organisation's voluntary efforts and commitments towards sustainability has now transformed into a mandatory and holistic approach, with the declaration that all future buildings to be constructed by CPWD will be minimum 3 star GRIHA rated green buildings. Moving a step further, few buildings being constructed by CPWD are being targeted for highest green building rating i.e. 5 star GRIHA rating after completion.

Our Training Institute at Ghaziabad, has been identified as a centre for excellence in green building initiatives and is imparting training to engineers and architects all over the country and facilitating dissemination of knowledge and technologies among experts in the field.

This guide on integrated green design for buildings in the hot-dry zone is another milestone in this journey. The individual impact of each building may be small. But the cumulative effects of integrating environment concerns right from site selection and its orientation, planning, resource and utilisation, to operation and maintenance, and reaching to buildings constructed by all - in rural and urban areas - will add up to a considerable reduction of the ecological footprint

This practical guide is simple and easy to adopt. The widespread dissemination that has been planned to reach out to various players in the construction industry will go a long way in its adoption across hot-dry climatic zone, adding to our efforts in reducing environmental impact while meeting the needs of the people.

We look forward to your feedback and experiences on using this publication.

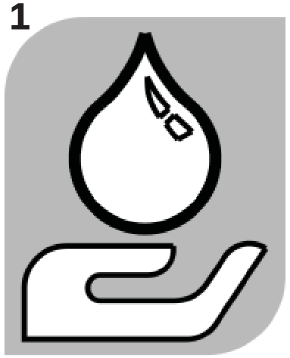
Ashok Khurana
Director General
Central Public Works Department
Ministry of Urban Development

Contents

What is a Green Building?

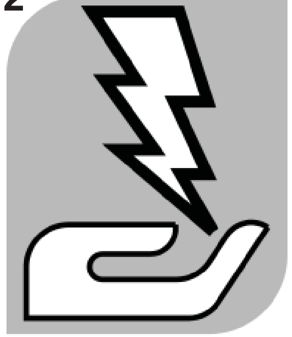
A green building is one which, as compared to a conventional building, has the following properties:

1



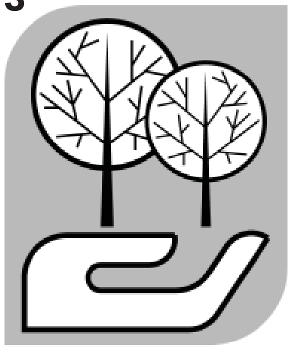
Uses less water

2



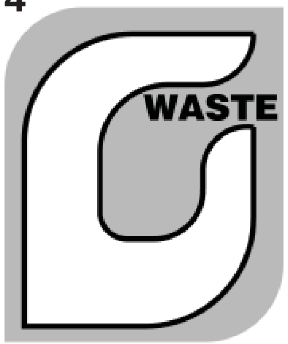
Is energy efficient

3



Conserves natural resources

4



Generates less waste

5

Provides healthier spaces for occupants

WHY GO GREEN?

- Global warming is leading to a rise in temperatures and extreme weather effects.

- Land for building is scarce & Greenfield areas are being depleted to make buildings. The Buildings being made are both energy intensive in construction and usage.

- In case of the environment around buildings, the air is polluted, fresh water is scarce and many water sources are polluted. There is also an Increase in energy usage to compensate for the above.

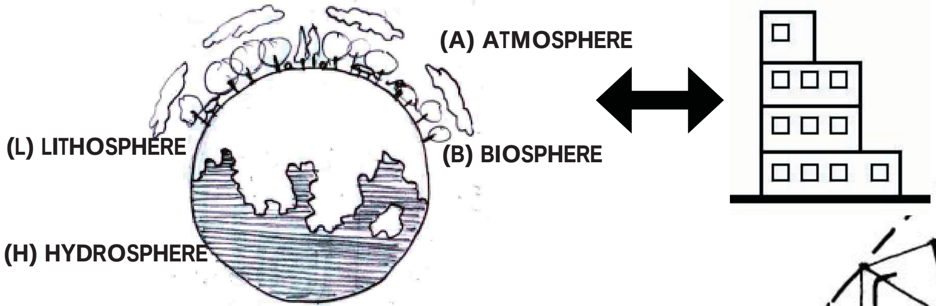
- Deteriorating health of building occupants due to sick building syndrome arising from non-natural and potentially toxic materials.

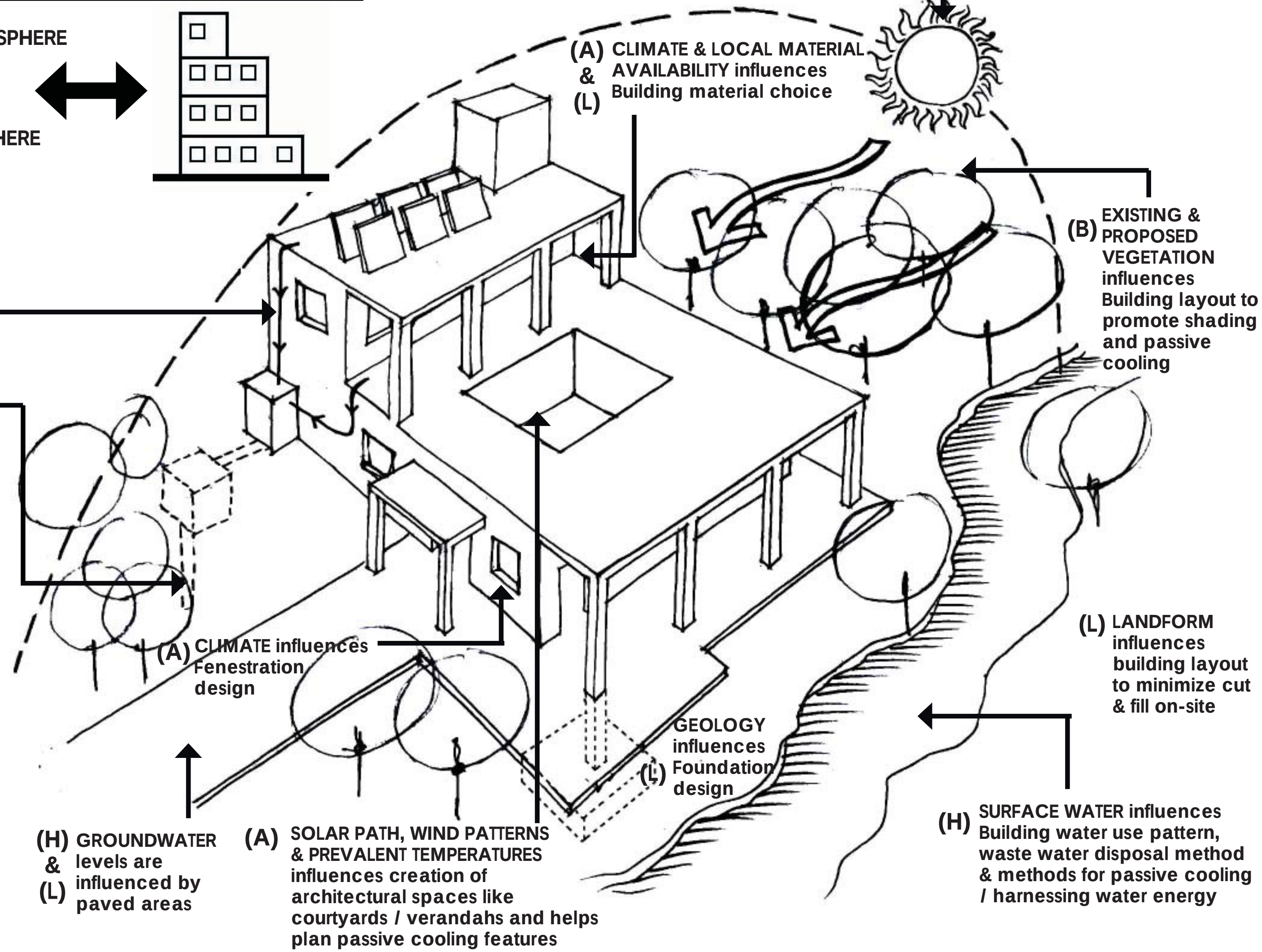
- Increasing energy use for other utilities like transportation due to sprawling cities & towns.

- Large scale depletion of non-renewable energy resources.

Site Context and Environment

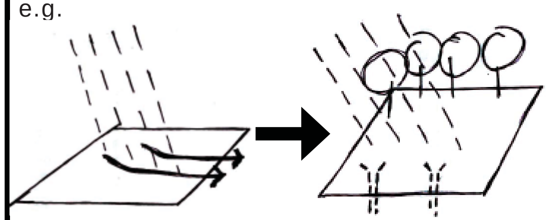
How we build is influenced by, and in turn also influences our surrounding natural environment and its components i.e. atmosphere, biosphere, lithosphere and hydrosphere. This forms our "site context". Responding to this context in building design is essential for a holistic green design approach





REGENERATIVE DESIGN

Regenerative design is of higher value than just efficient green design. This can be termed a "better-than-before" scenario. For. e.g.



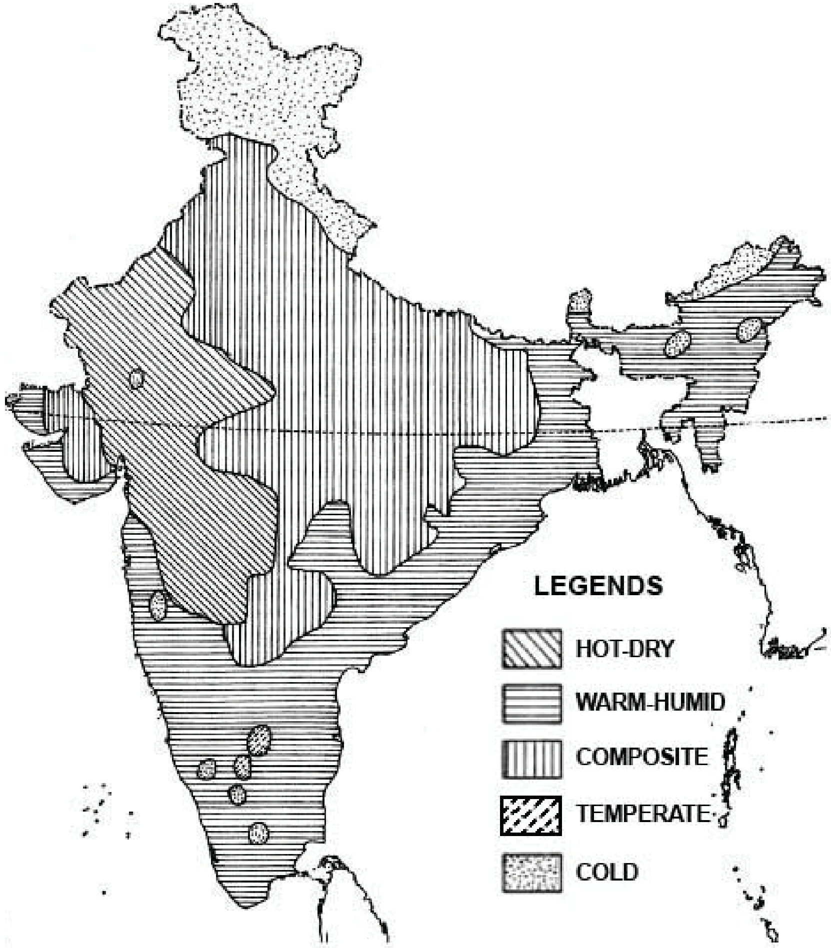
A barren site with water flowing away from it

Recharging water and planting to improve local ecology forms a regenerative approach

Hot-Dry Climate Zone Description

The Indian sub-continent can be broadly categorized into five regions with distinct climates. These climate zones, as shown in the adjoining map, warrant special provisions in each to aid in the functional design of buildings with respect to human thermal comfort and hence energy efficiency. The table below shows the distinct climatic features of the hot - dry climate zone, which is the focus of these guidelines.

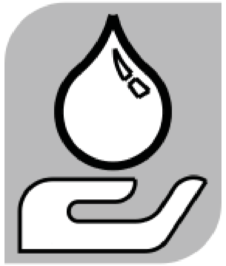
Climatic features		Situation in Hot - Dry Climate	Generic corresponding strategy	Page Reference
Typical landscape & vegetation		Sandy / rocky ground with little vegetation; Low water level	-Preserve vegetation and conserve water	see pg. 12,13,31
Solar radiation		Intense (800 - 950 W/m^2)	- Shade building especially openings as they admit maximum solar radiation - Solar energy generation	see pg. 14-19 see pg. 29
Mean Temp.	Summer midday	40º - 45º C	- Prevent solar access in summer but allow in winters - Insulate building to prevent conduction of heat indoors during the day time - Passive measures to reduce heat gain and promote heat loss through vegetation & water bodies.	see pg. 7-9 see pg. 23-26 see pg.8,9,21
	Summer night	20º - 30º C		
	Winter midday	5º - 25º C		
	Winter night	0º - 10º C		
	Diurnal variations	15 - 20º C		
Mean relative humidity		Very low (25 - 40 %)	-Can use evaporative cooling where water is available	see pg. 21
Annual rainfall		Low < 500mm / yr	-Harvest rainwater for use in dry spells	see pg. 30
Winds		Dust laden local winds often developing into sandstorms	-Prevent wind infiltration; Avoid wind-induced ventilation during overheated times	see pg. 21
Sky conditions		Cloudless skies with high solar radiation causing glare	-Prevent direct radiation ingress and glare into rooms	see pg. 20



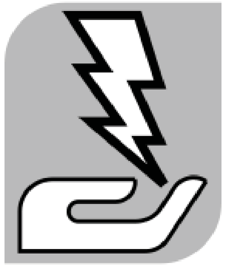
Source: Energy Conservation Building Code, 2007

Integrated Green Design (IGD) Approach

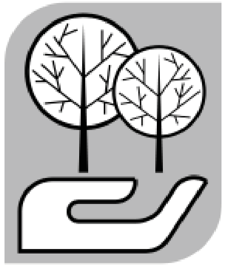
The Integrated Green Design (IGD) approach looks at a building in stages of its planning and design from the broader issues to the details. Each stage within the IGD approach fulfills one or more of the five 'Green' building imperatives.



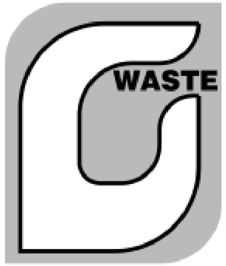
USES LESS WATER



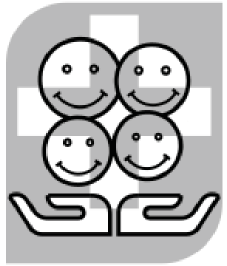
IS ENERGY EFFICIENT



CONSERVES NATURAL RESOURCES



GENERATES LESS WASTE

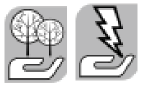


PROVIDES HEALTHIER SPACES

STAGES OF PLANNING & DESIGN

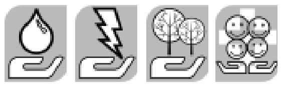
Sustainable Site Planning

Utilizing existing infrastructure, laying out building blocks to benefit from existing landform, sunpath and wind while minimizing damage to prevalent soil, flora, water and air quality.



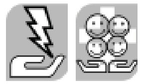
Appropriate Landscaping

Planting the right way to conserve water and improve micro-climate.



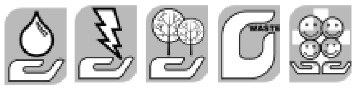
Building Design Details

Detailing building fenestration design and construction details to promote shading, insulation and heat loss.



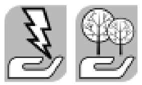
Materials

Choosing materials which are local, durable, utilize waste, have low embodied energy content, use less water for processing and help insulate the building.



Building Energy Use

Efficient electricity usage and usage of clean energy.



Building Water Use

Saving water through efficient fixtures and augmenting water through rain water harvesting & waste water treatment.

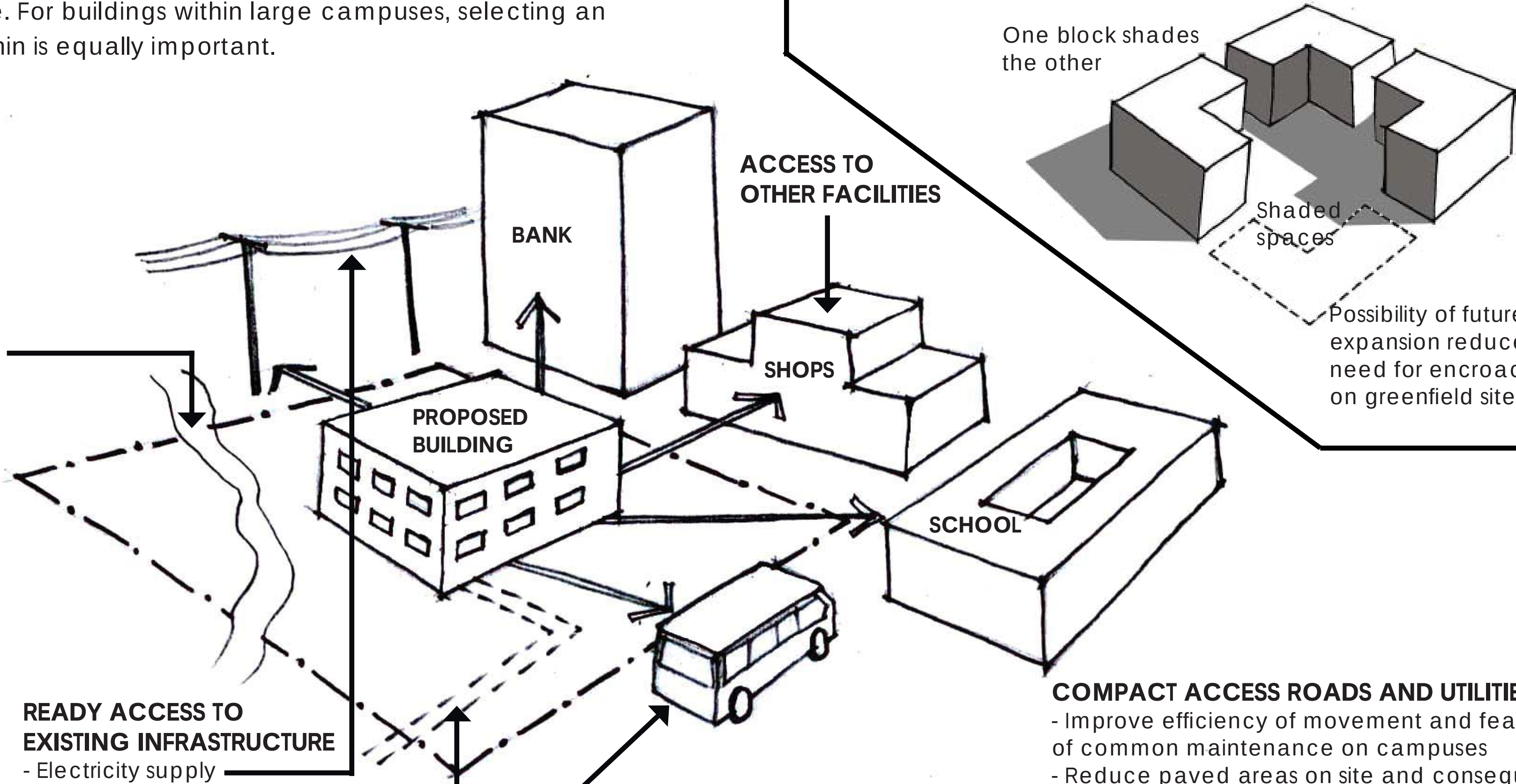
Sustainable Site Planning

SITE SELECTION

The IGD approach starts not from the site layout but from site selection. While not possible in all cases, wherever possible efforts must be made to choose an appropriate site for the proposed use of the building. This would result in less damage of virgin land and less energy expenditure in 'developing' a site. For buildings within large campuses, selecting an appropriate plot within is equally important.

COMPACT CLUSTER PLANNING

Cluster based planning of the building blocks within campuses results in more compact utilities network, reduces damage to existing environment and promotes walkability. Sharing spaces, services and creating a medium-rise, high density development complements this.



AVOID NATURAL DRAINAGE LINES

- Especially important in sloped sites. Obstructing natural drainage lines would involve energy use to drain out storm water or risk site flooding

READY ACCESS TO EXISTING INFRASTRUCTURE

- Electricity supply
- Water supply
- Public transport

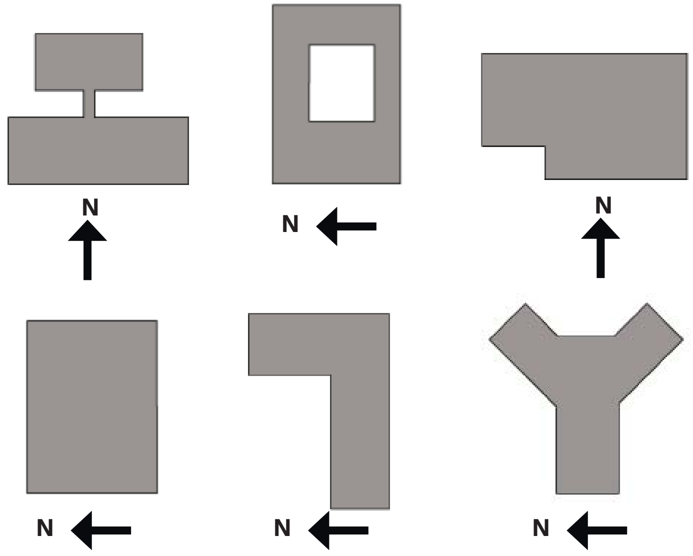
Helps reduce need for new infrastructure

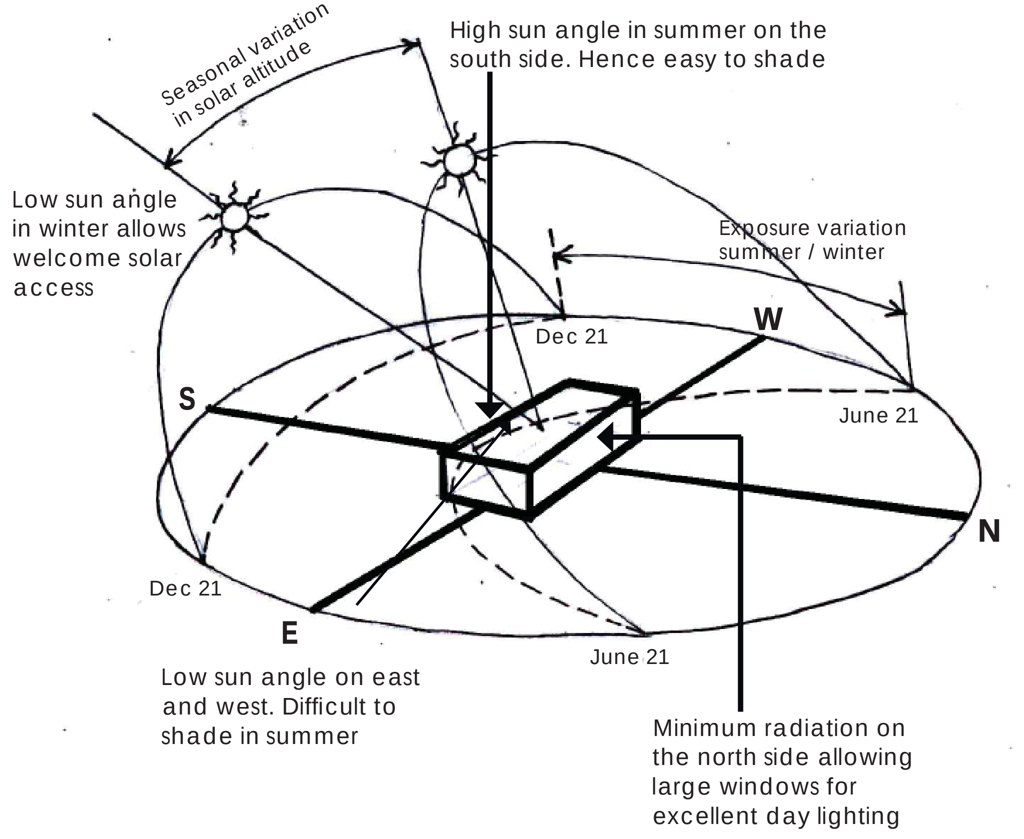
COMPACT ACCESS ROADS AND UTILITIES

- Improve efficiency of movement and feasibility of common maintenance on campuses
- Reduce paved areas on site and consequently reduce heat gain
- Connecting to adjacent structures for common services & access road would reduce servicing costs and improve walkability

BUILDING ORIENTATION

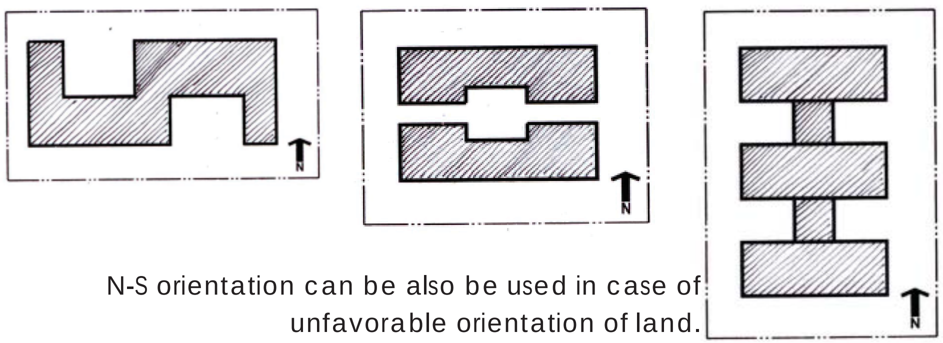
BEST POSSIBLE ORIENTATION OF TYPICAL EXISTING PLANFORMS





ORIENT BUILDING LONG FACES ALONG N-S

N-S orientation can be used in creative ways to generate a variety of built and open spaces.

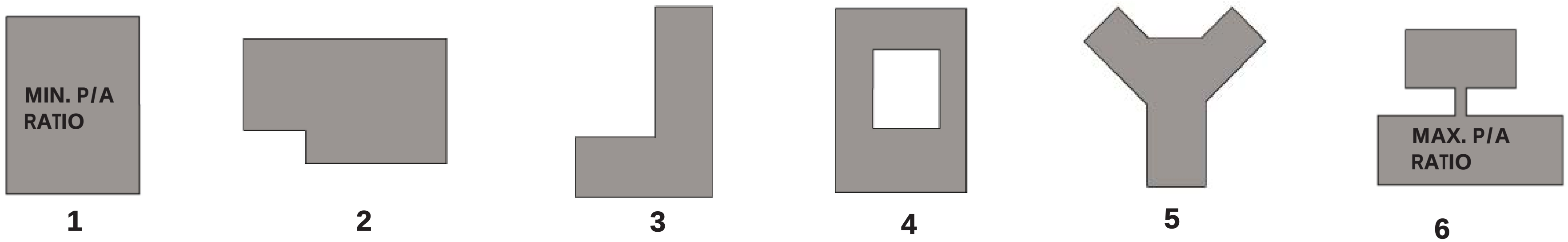


N-S orientation can be also be used in case of unfavorable orientation of land.

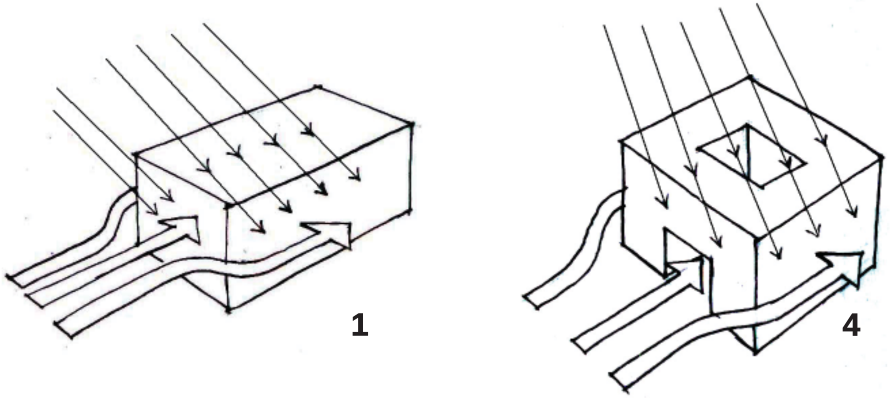
Sustainable Site Planning

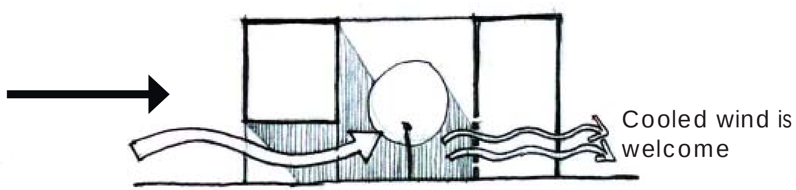
PLANFORM

TYPICAL EXISTING PLANFORMS IN ASCENDING ORDER OF PERIMETER - TO - AREA (P/A) RATIO



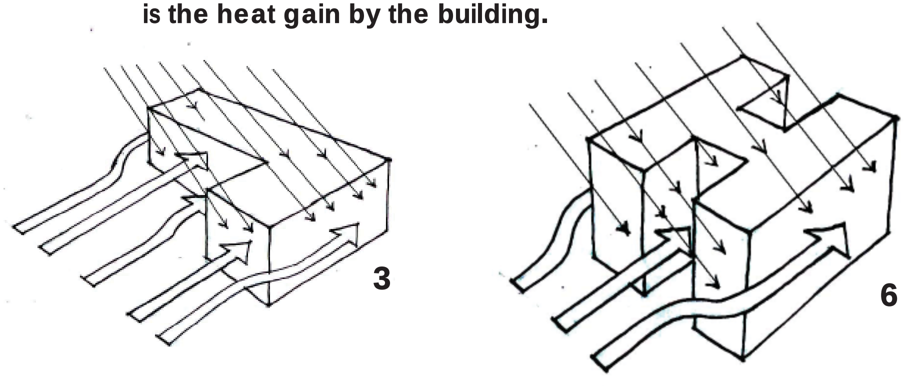
In the hot - dry climate a smaller perimeter-to-area ratio (P/A) would result in less area exposed to radiation and lesser conduction heat gains.

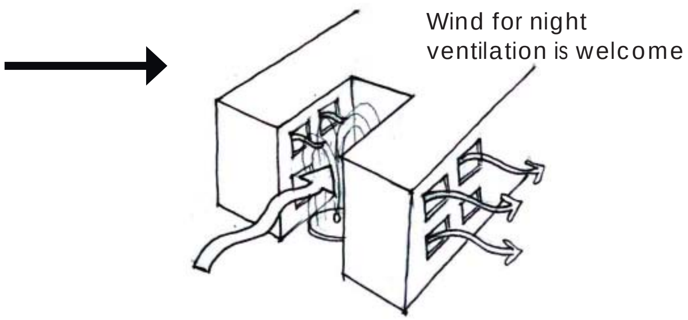




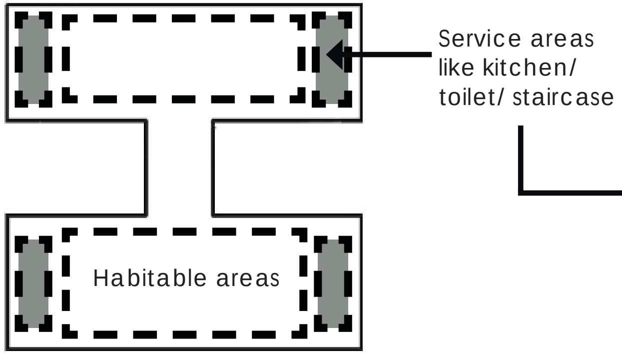
Greater the perimeter - to - area ratio, greater is the heat gain by the building.

Planforms with greater P/A ratio may be applied in certain cases to include features like water bodies & vegetation which can modify the micro-climate. The intermediate spaces can also be effective as interaction spaces

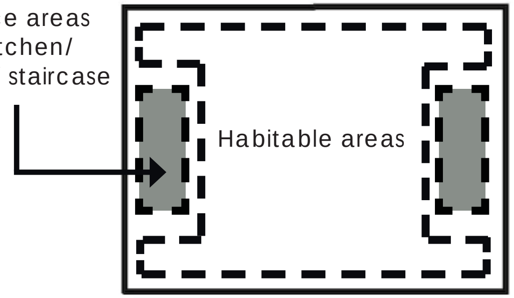




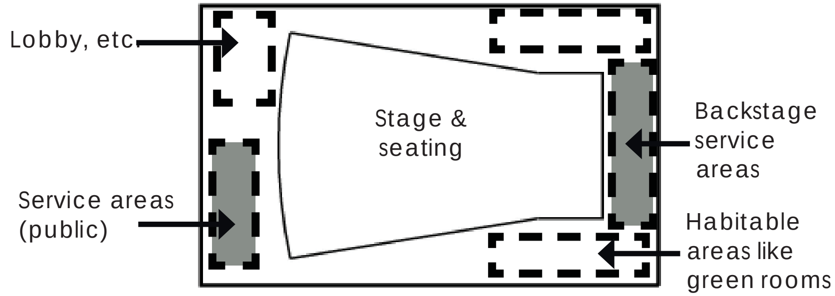
ACTIVITY ZONING FOR VARIOUS PLANFORMS



H-SHAPED PLANFORM

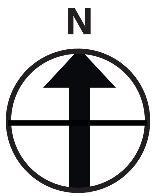


RECTANGULAR PLANFORM

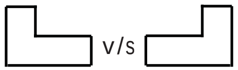


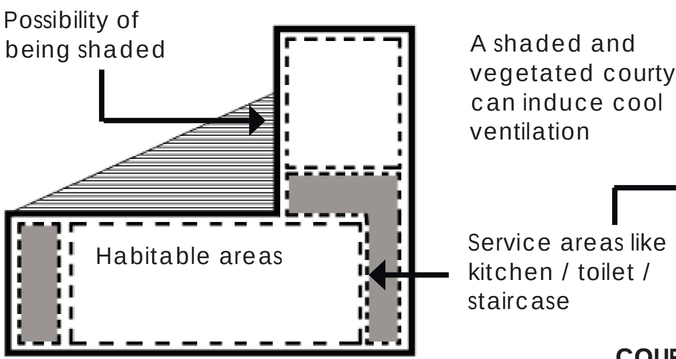
FOR AUDITORIUMS

Most concepts in hot, dry climate focus on decreasing heat gain but adequate daylight is also important. Depending upon the building use, choosing an appropriate planform and proper activity zoning at the initial design stages can ensure heat gain reduction and optimum daylighting.



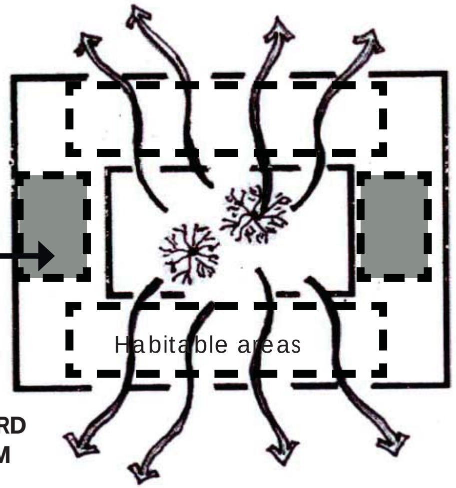
This approach is useful in placing service spaces like toilets/ storage areas / staircase at locations where they can act as thermal barriers. The effect of an unfavorable plan orientation can also be reduced to some extent by zoning.

In comparing L-shapes.. 

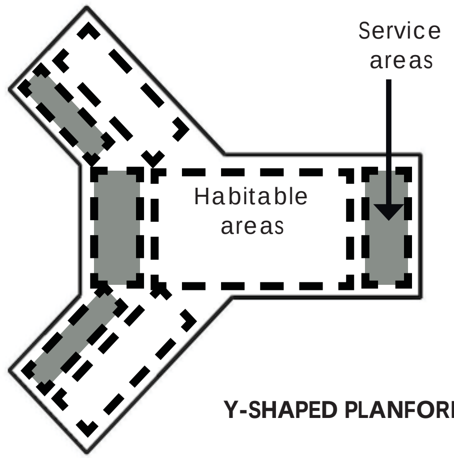


L-SHAPED PLANFORM

A shaded and vegetated courtyard can induce cool ventilation



COURTYARD PLANFORM

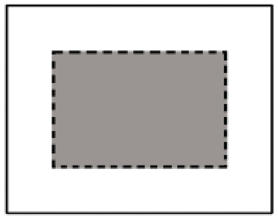


Y-SHAPED PLANFORM

Sustainable Site Planning

BUILDING TYPES

Detached



- High exposure to radiation and wind

- Hence shading through various building elements is vital

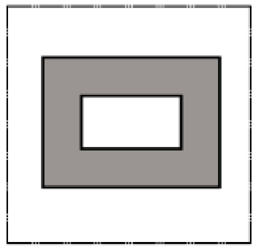
- New buildings should be placed as close as possible to existing buildings for possibility of shading one another.

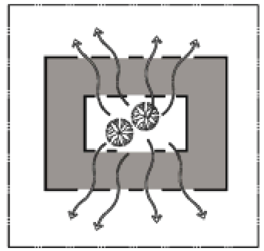
Row

- Solar gains are reduced due to common walls

- Relevant for barracks and housing.

Courtyard

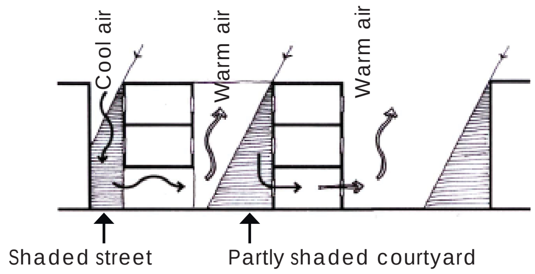




- Courtyards are important for daylight & ventilation and has a cultural significance too

- Ventilation in hot dry climate is useful if the air is cool. Thus the courtyard should
  - be proportioned to be mostly shaded, and / or
  - contain cooling elements like trees, soft paving and water bodies if water is available.

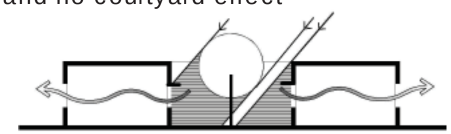
Courtyard effect in traditional settlements



Variable sizes create temperature-pressure differential & can induce cross ventilation

Typical modern courtyards

Courtyard Height- Width (H/W) ratio almost 1:4. Hence courtyard not shaded and no courtyard effect

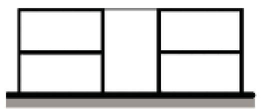


Possible strategies include:
- Cooling the courtyard by shading (H/W ratio nearing 1:1).
- Shading by verandahs / covered passages or by vegetation

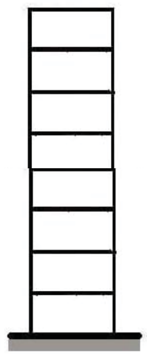
LOW-RISE VS. HIGH RISE

- Higher footprint area
- Foundation embodied energy is more as multiple floors are not sharing the foundation.

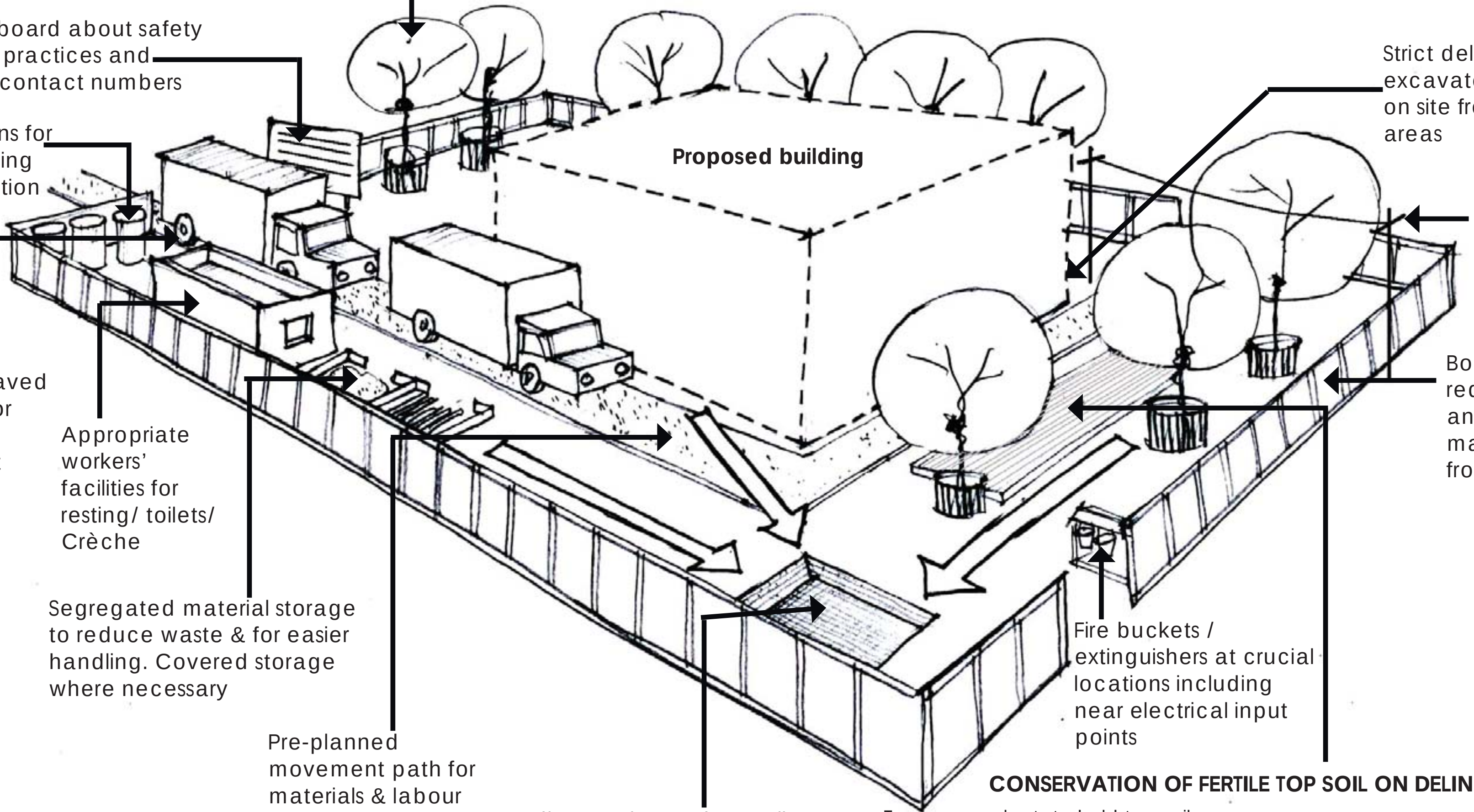
- Lesser footprint
- Could be optimum in terms of total energy and shading



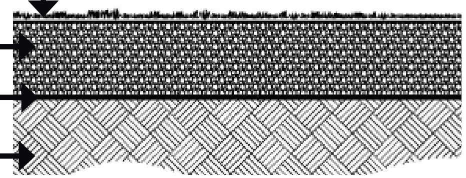
- Least footprint
- Higher service energy to move resources and people up and down.



CONSTRUCTION STAGE PRACTICES

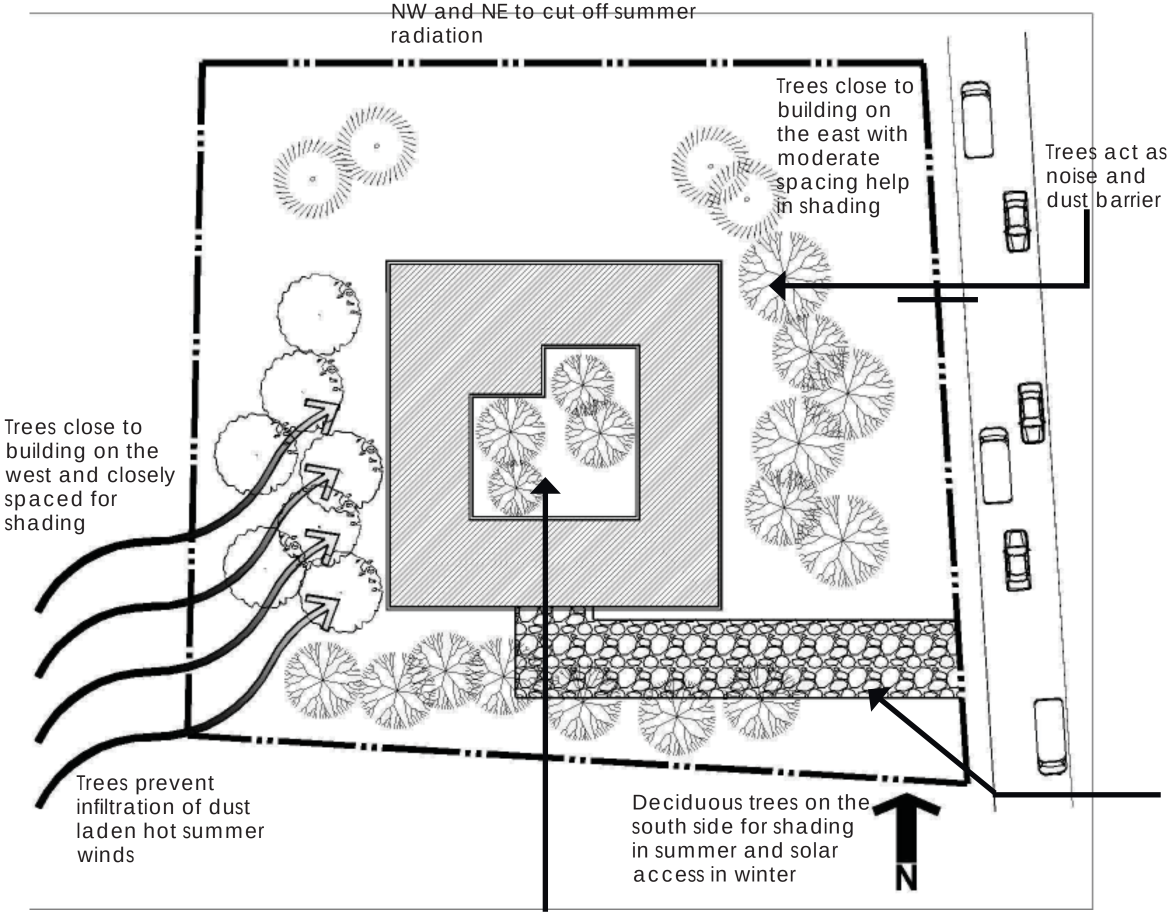


CONSERVATION OF FERTILE TOP SOIL ON DELINEATED SPACE

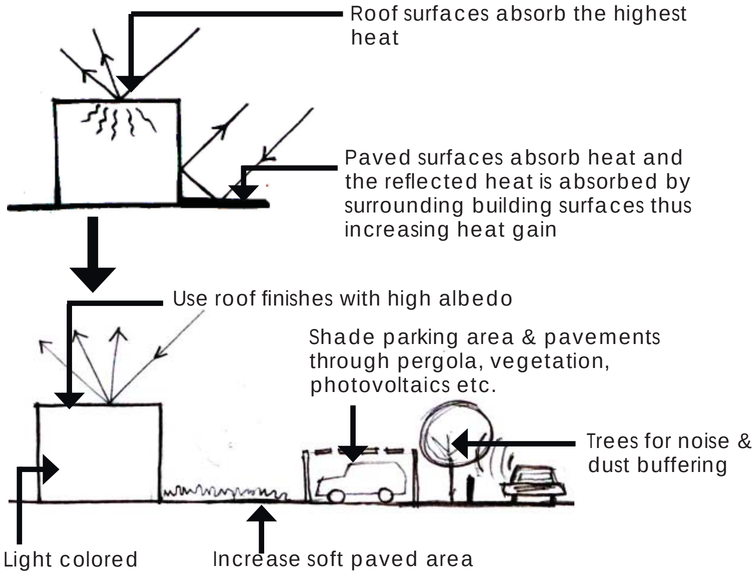


Landscaping for Improving Occupant Comfort

PLANNING PLANTATION



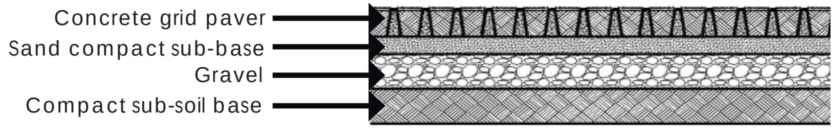
REDUCING URBAN HEAT ISLAND EFFECT (UHIE) TO COOL BUILDINGS & SURROUNDINGS



ALBEDO: refers to surface reflectivity of various materials.
Higher the albedo, more reflective the material.
Dark surfaces: 0.1 - 0.3
White-coloured (e.g. white-washed) surfaces: 0.7 - 0.8
High reflective paints: 0.8 - 0.9
White ceramic tiles: 0.7
Heat resistant terrace tiles: 0.7

PROMOTING GROUNDWATER RECHARGE

Reducing paved areas and using pervious paving reduces UHI effect and improves groundwater recharge. Such paving can be used in walkways, pavements, vehicular roads within the site, ramps, etc.



APPROPRIATE LANDSCAPING

Use of native, low water consuming species, reduction of exotic species & lawns and an efficient irrigation system reduces water consumption.

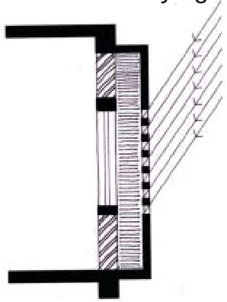
LIST OF SOME NATIVE SPECIES FOUND IN THE HOT-DRY CLIMATE ZONE, INDIA

Common name	Scientific name	Type	Remark
Ronjh	*Acacia leucophloea*	Tree; Deciduous	Native. **Hardy species**. Can grow in the rocky and sandy soils of this zone. Spreading feathery foliage. 12m mature height.
Khejri	*Prosopis cineraria*	Tree; Deciduous	Native. **Adaptable to the harsh conditions of this zone.** Droopy feathery foliage. 12m mature height. State tree of Rajasthan.
Ker	*Capparis aphylla*	Shrub; Deciduous	Native. **Almost leafless with beautiful flowers** but with wide spreading roots. 4m mature height.
Dhau	*Anogeissus pendula*	Tree; Deciduous	Native. **Known as the 'habitat specialist' of the Aravalli hills.** 10 - 15m mature height.
Khair	*Acacia catechu*	Small tree; Deciduous	Native. **5m mature height**.
Baheda	*Terminalia bellirica*	Large tree; Deciduous	Native except for the desert areas. Massive dome shaped crown with broad leaves. **20 - 40m mature height.**
Salai	*Boswellia serrata*	Tree; Deciduous	Native. Light spreading crown with droopy branches. **Drought and frost resistant.** Has medicinal usage. 9 - 15m mature height.
Kankera	*Maytenus emarginata*	Small Tree; Deciduous	Native. **Can have large oval crown.** Considered sacred. 5m mature height.
Desi Babool	*Acacia nilotica*	Tree; Deciduous	Native. **Spreading, open, feathery crown**. 10m mature height.
Ber	*Ziziphus mauritiana*	Small Tree; Deciduous	Native. Dense spreading crown. 8m mature height. **Also cultivated for its fruit**.
Farash	*Tamarix articulata*	Tree; Evergreen	Native. Fast growing. **Salinity tolerant.** 10m mature height.
Rohida	*Tecomella undulata*	Tree; Deciduous	Native. **Loose, open crown.** 8m mature height.
Neem	*Azadirachta indica*	Tree; Semi-evergreen	Drought tolerant. **Good shade tree.** 12m mature height.
Bouganvillea	*Bougainvillea glabra*	Shrub; Deciduous	Good for dry areas. **Low water usage once established**. 4 - 6m mature height.
Peelu	*Salvadora persica*	Small tree; Evergreen	Native in hot, arid areas with water availability. **Tolerant of saline soils.** 7m mature height.
Bada Peelu	*Salvadora oleoides*	Small tree; Evergreen	**Native in hot, arid areas in dry water courses**. 5m mature height.
Thor	*Euphorbia neriifolia*	Shrub; Deciduous	**Native to dry rocky areas.** Spiny, succulent plant. 4m mature height.
Gondi	*Cordia gharaf*	Small tree; Deciduous	**Native but scarce.** 6m mature height.
Bui	*Aerva tomentosa*	Herb	Native. **Good soil binder.**
Guggal	*Commiphora wightii*	Small tree; Deciduous	Native. **Tolerant of poor soil.** Endangered. 4m mature height.
Jujube	*Ziziphus zizyphus*	Small tree; Deciduous	Native. **5 - 10m mature height**.
Sewan	*Lasiurus sindicus*	Grass	Native to the Thar desert. Perennial. **Good soil binder.**

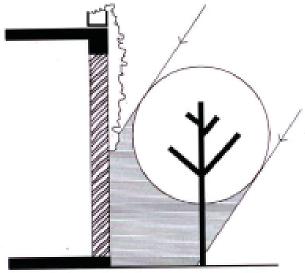
Building Design

SHADING STRATEGIES FOR BUILDING & OPENINGS

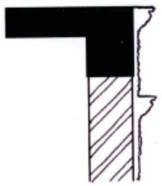
Shading is the most important building design strategy for comfort in the hot-dry climate. Shading of openings like windows is very important and in any case the Window-Wall-Ratio (WWR) should not be more than 60%. Effective day lighting is possible with a much lower WWR.



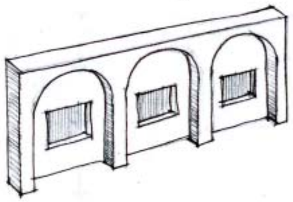
Shading of window and wall surface by jaali screens.



Shading of building surface by vegetation

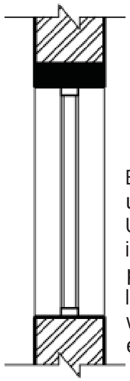


Shading of building surface by surface texture



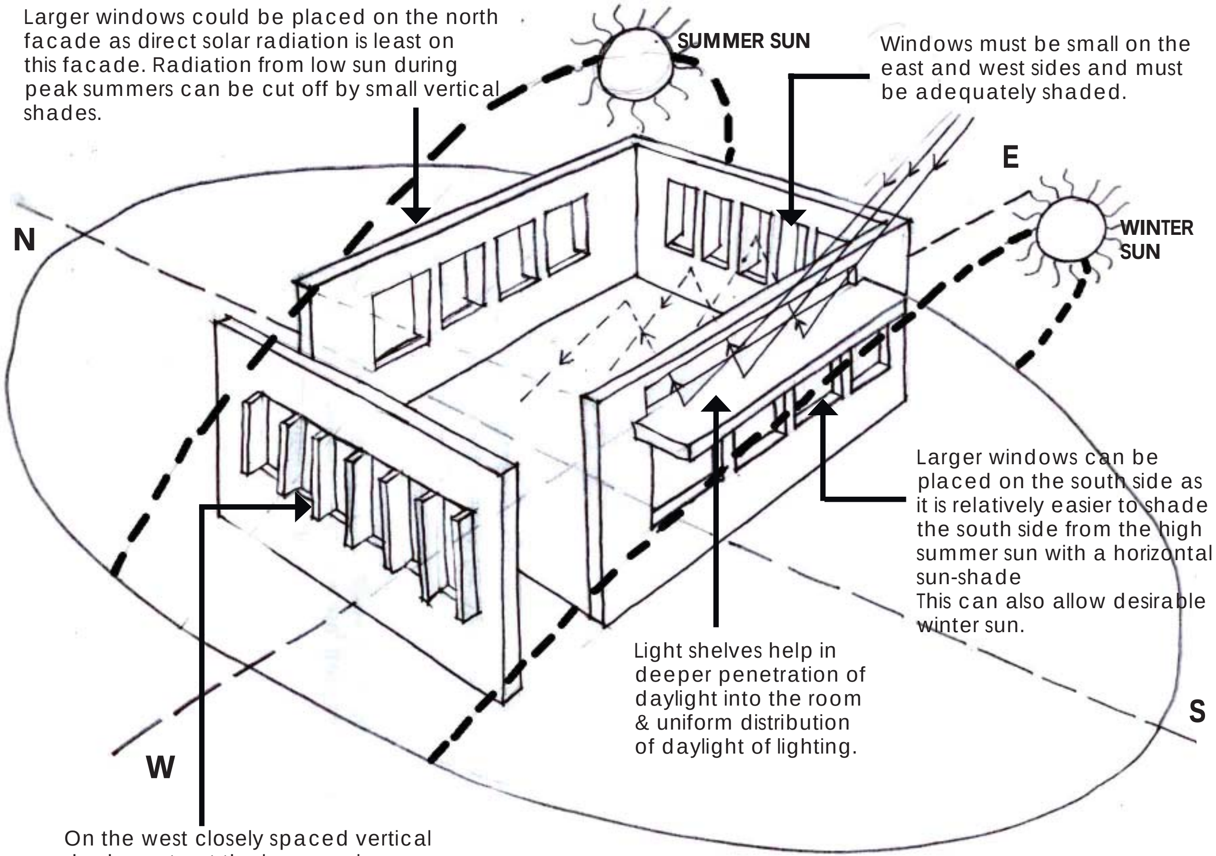
Shading of building surface by architectural projections

Jharokhas are an architectural heritage of the region and provide effective shading. A Jharokha window on the south also cuts out the east-west sun



Besides shading, utilizing Double Glazed Units (DGUs) help insulate the window panel and reduces large heat ingress which would otherwise enter the living space.

ORIENTATION BASED SHADING STRATEGIES



Larger windows could be placed on the north facade as direct solar radiation is least on this facade. Radiation from low sun during peak summers can be cut off by small vertical shades.

Windows must be small on the east and west sides and must be adequately shaded.

Larger windows can be placed on the south side as it is relatively easier to shade the south side from the high summer sun with a horizontal sun-shade
This can also allow desirable winter sun.

Light shelves help in deeper penetration of daylight into the room & uniform distribution of daylight of lighting.

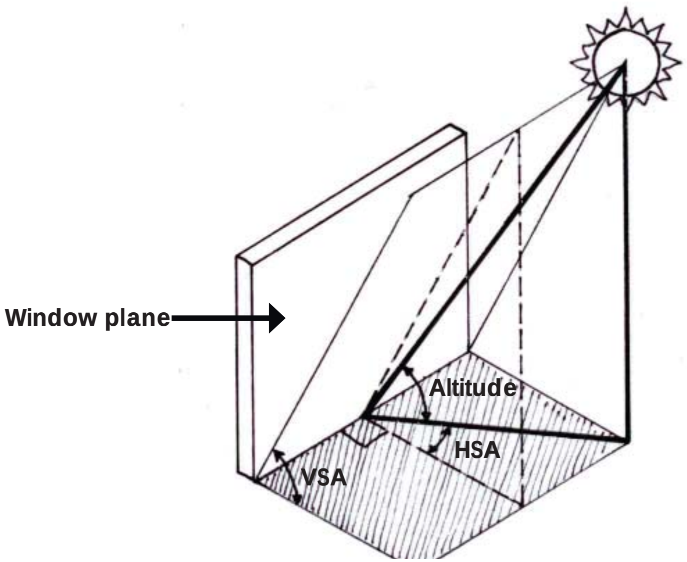
On the west closely spaced vertical shades cut out the low evening sun. As the heat built up during the day is already present, minimization of openings is desirable.

SHADING

Shading from the sun and well designed shading devices are a primary need in the hot-dry climate. It is well established that a majority of the solar heat gain comes from radiation through openings. When designing shading devices for windows, the required horizontal and vertical shadow angles need to be established. They are dependent on both the orientation of the window plane and the sun path.

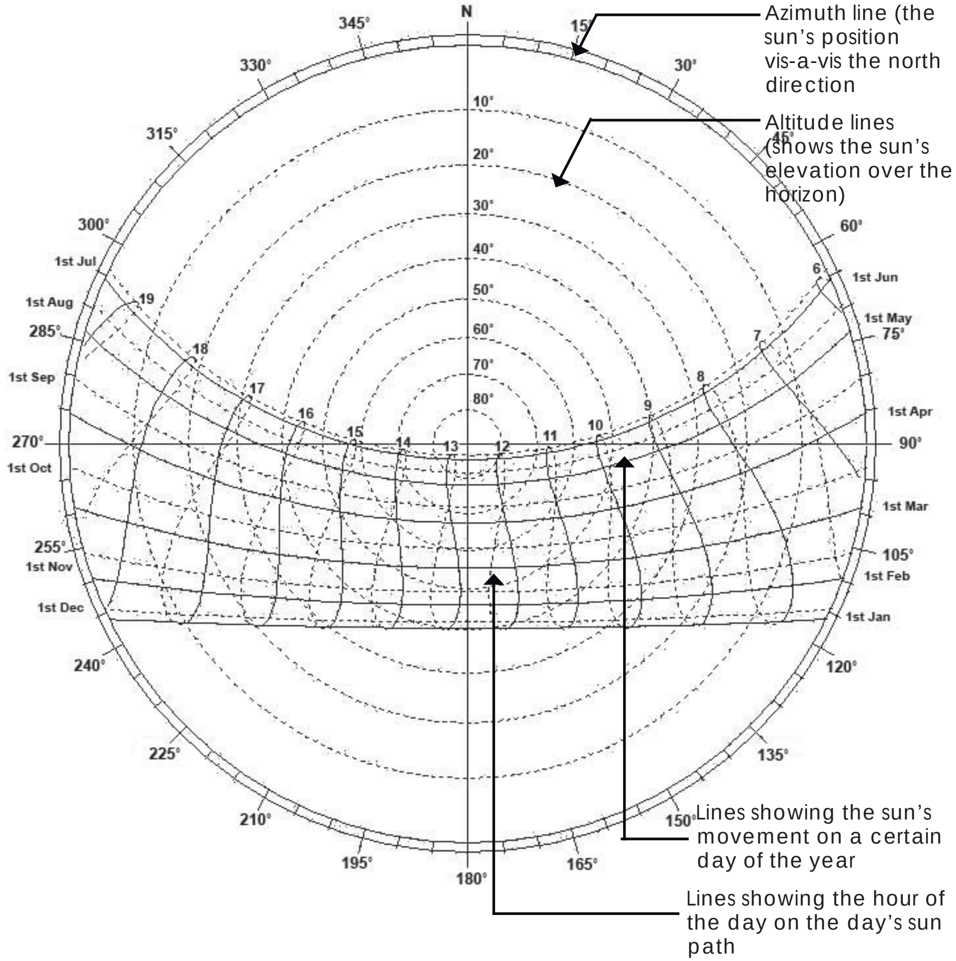
Horizontal shadow angle (HSA: characterizes the vertical shading device)
This is the horizontal angle between the normal of the window pane or the wall surface and the current sun azimuth angle. It is relevant for designing vertical shading devices such as fins.

Vertical shadow angle (VSA: characterizes the horizontal shading device)
This is the angle that a virtual plane containing the bottom two points of the wall/window and the centre of the Sun makes with the ground when measured normal to the window plane. It is required when designing horizontal shading devices such as overhangs.



CALCULATING HSA & VSA FROM SUNPATH DIAGRAM

E.g. Sun path Diagram of Jodhpur, Rajasthan (26.29° N, 73.03° E). The following diagram is also called a stereographic projection which showcases the movement lines of the sun relative to a location on earth.

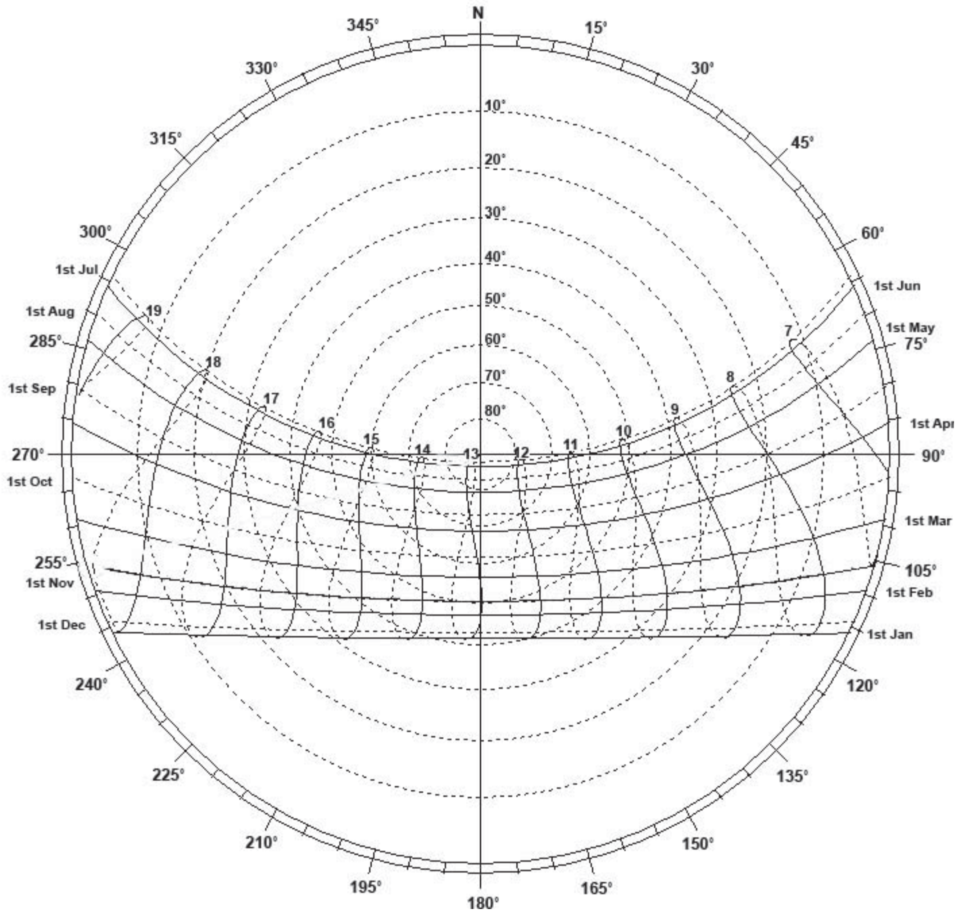


HSA= solar azimuth - window orientation

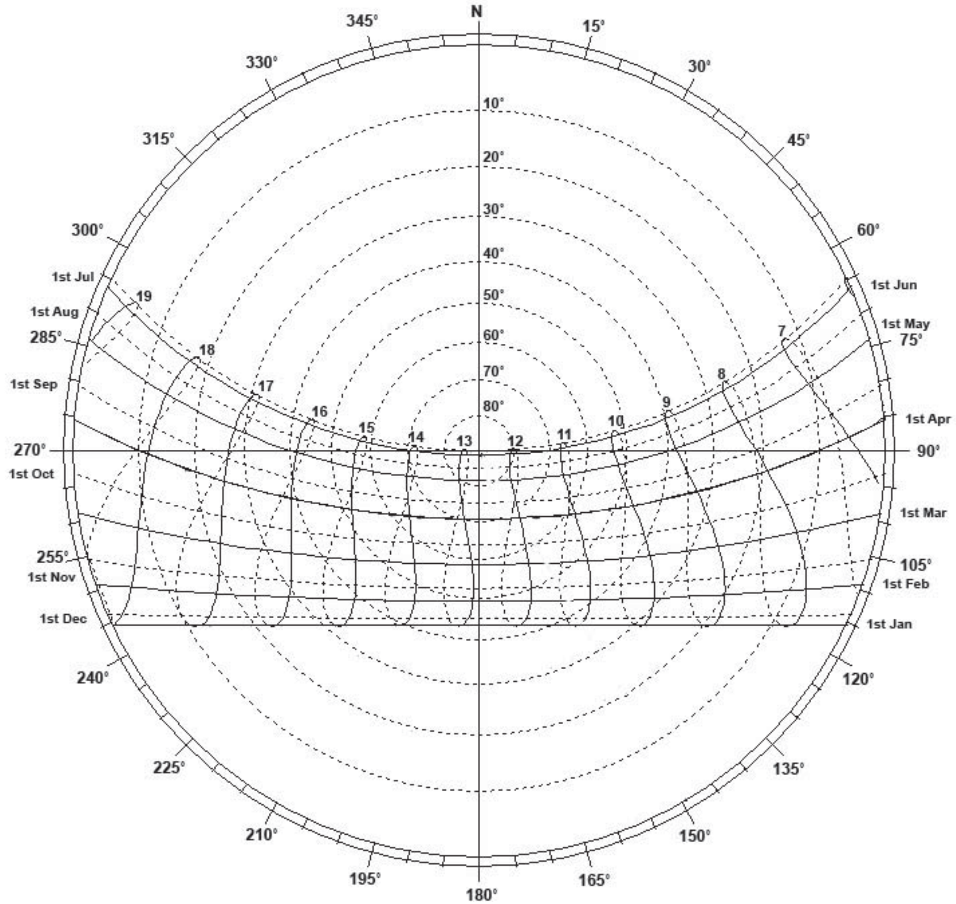
$$VSA = \tan^{-1}(\tan(\text{solar altitude}) / \cos(HSA))$$

SUNPATH DIAGRAMS OF CITIES IN THE HOT- DRY CLIMATE ZONE

Kota, Rajasthan (25.18° N, 75.83° E)

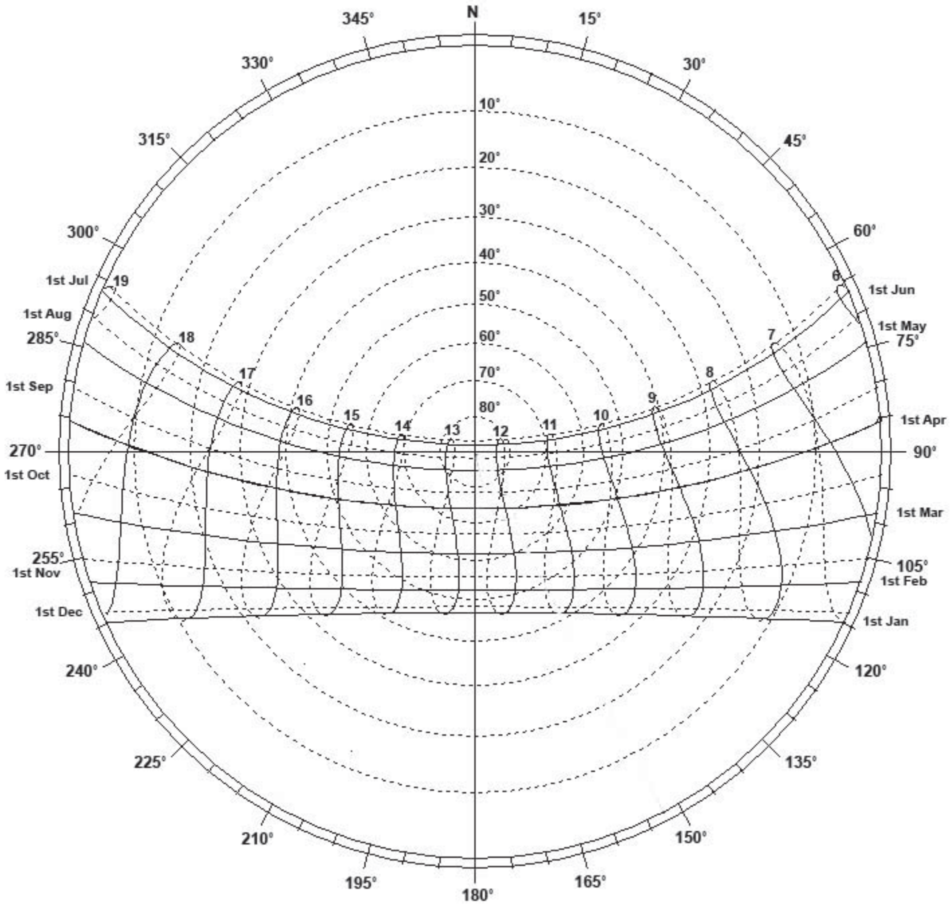


Ahmedabad, Gujarat (23.03° N, 72.62° E)

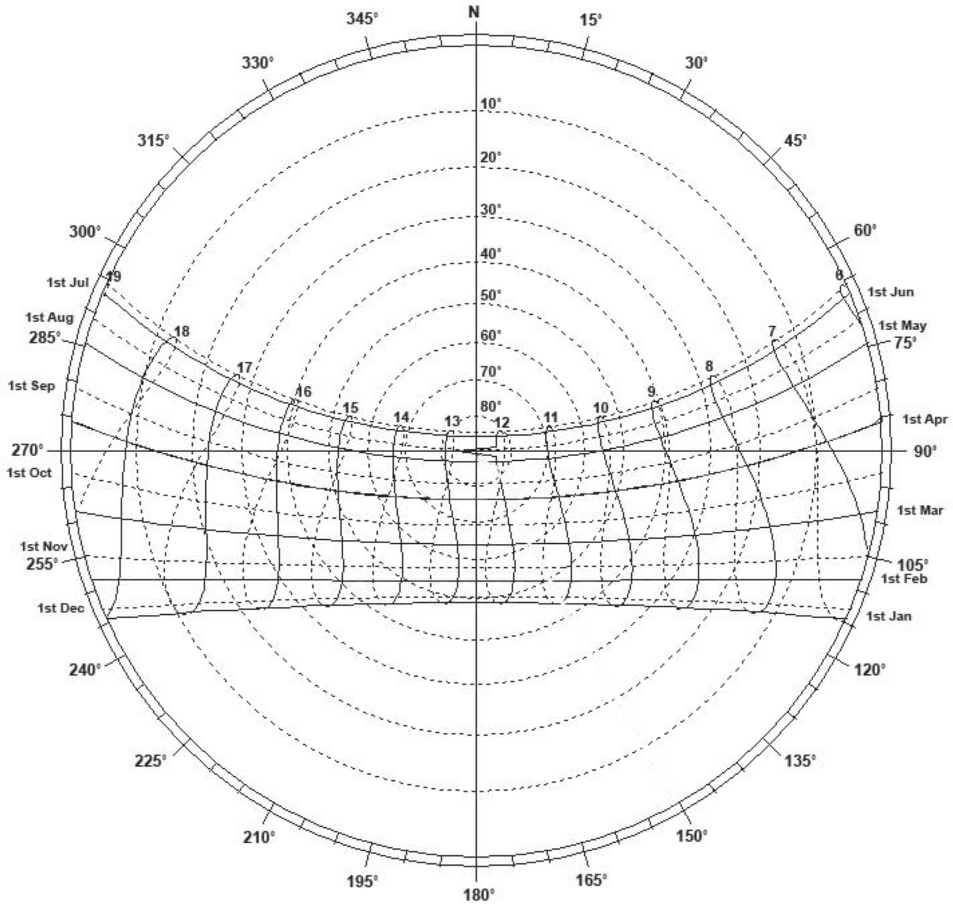


SUNPATH DIAGRAMS OF CITIES IN THE HOT - DRY CLIMATE ZONE

Aurangabad, Maharashtra (19.87° N, 75.33° E)



Solapur, Maharashtra (17.68° N, 75.92° E)



FENESTRATION SHADING DEVICE DESIGN

Example of shading device design on south and west facades of building located in Jodhpur, Rajasthan (26.29° N, 73.03° E)

STEP 1
Determine the cut- off dates i.e. the over-heated period of the year when the window is to be completely shaded. During this period the date of longest and shortest sun-path is recorded, i.e. the two extremities of the sun-path.

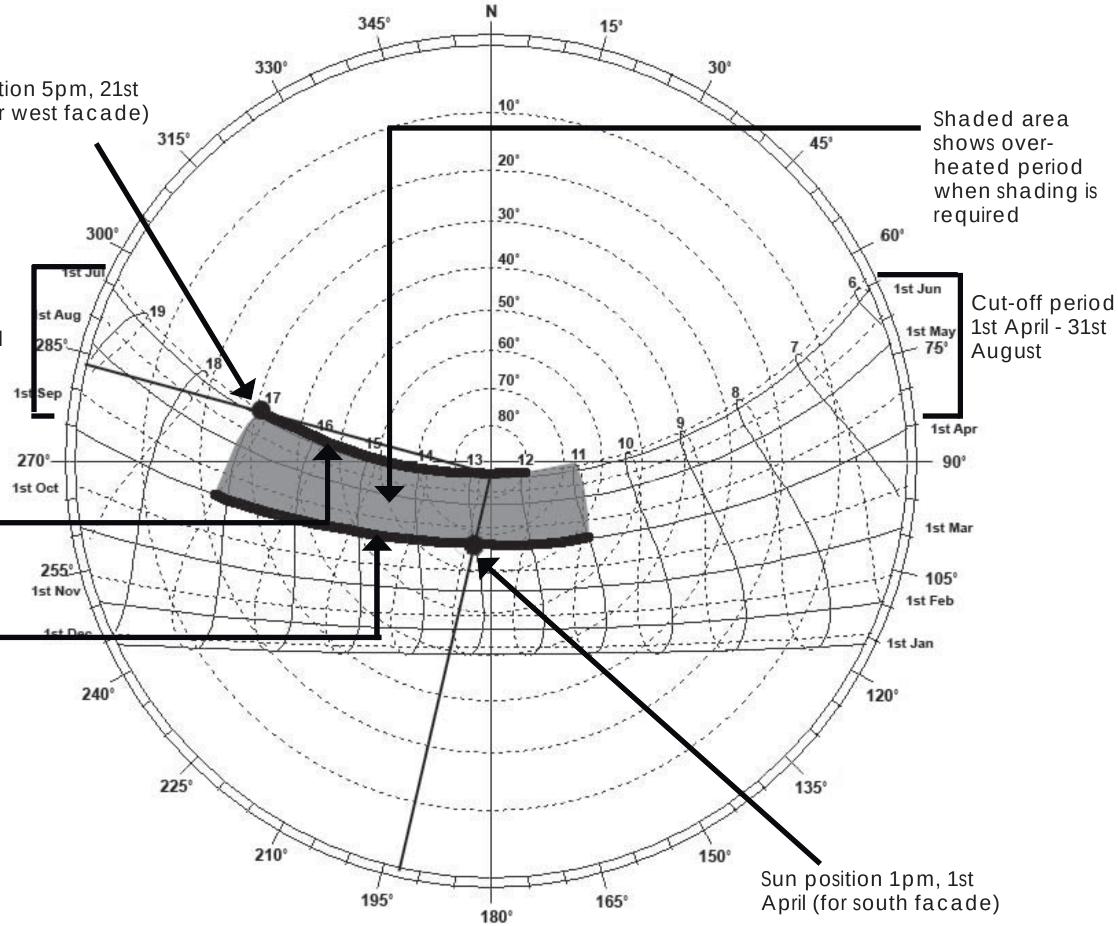
In Jodhpur, for e.g., the cut-off dates are taken as 1st April to 31st August. Within this period, the longest sun path is recorded on 21st June and the shortest sun path on 1st April.

STEP 2
Determine the start and end times representing the times of day between which full shading is required for different facades. It should be kept in mind that the closer to sunrise and sunset these times are, the exponentially larger the required shade.

In Jodhpur, for e.g.,
West facade = 12 noon - 5pm
The shades for this face are designed for the longest sun path within the over-heated period i.e. **21st June**.

South facade= 11am - 5pm
The shades for this face are designed for the shortest sun path (sun travels low in the sky) within the over-heated period i.e. **1st April.**
These two periods together avoid direct sun completely in the overheated period.

STEP 3
Look up the sun position using sun-path diagrams to obtain the azimuth and altitude of the sun at each time on the designated day for facades of different orientations.



In Jodhpur, for e.g., from the sun path diagram
Sun position 5pm, 21st June= -77.4° **or** 282.6°Azimuth / 31.5° Altitude (for designing shading device for the west facade)
Sun position 1pm, 1st April= -165.7° **or** 194.3°Azimuth / 69.5° Altitude (for designing shading device for the south facade)
Similarly, the sun positions are recorded for every half hour interval on the designated day for facades of different orientations.

EFFECTIVE SHADING DEVICE DESIGN	
Orientation	**Effective shading**
South	Fixed horizontal device or window recessing.
West and East	Vertical device/louvres (possibly moveable). East / West faces are difficult to shade with fixed shades as the sun is very low. Hence only small windows are recommended. External moveable shades / rollable blinds are more effective than fixed shades. These also help preserve the view from the windows.
North side	Generally not required except from low evening sun in peak summer when the sun path is long and hits the North from the side. Cutting this out can be is achieved by vertical shades.

STEP 4
Calculate HSA and VSA at different times during designated period for each facade. We need to design a shading device for the lowest possible VSA (horizontal shade) and the lowest possible HSA (vertical shade).

EXAMPLE
In the west facade, one can design vertical shades for which the HSA is calculated. The lowest HSA is found to be at 2:30pm (0.5°). Designing for this HSA would result in very large shades. Hence the shading device is designed for an intermediate sun position. The HSA at 1:30 pm and 5 pm is about 12°. But at 5 pm, the altitude angle of the sun is less (31.5°)and the facade can be shaded by vegetation. Hence, in this case the shades will be designed for the sun position at 1:30 pm.

Sun position 1:30 pm, 21st June= -101.3° **or** 258.7°Azimuth / 78.2° Altitude
HSA = solar azimuth - window orientation
= 258.7 - 270 = -11.3°

In the south facade, we shall design horizontal shades for which the VSA is calculated. The lowest VSA is found to be at 1pm (70.1°).
(These shades are designed for the lowest sun path within the over-heated, summer period. The sun path is lower in winter but during this period solar ingress is preferable)

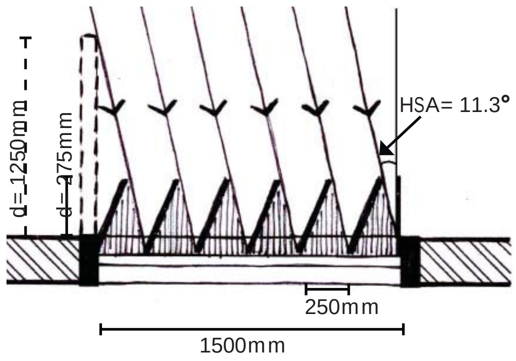
Sun position 1pm, 1st April= -165.7° **or** 194.3°Azimuth / 69.5° Altitude
HSA = solar azimuth - window orientation= 194.3 - 180= 14.3
VSA = $\tan^{-1}$(tan(solar altitude) / cos(HSA))
= $\tan^{-1}$(tan(69.5) / cos(14.3)) = 70.1.

FENESTRATION SHADING DEVICE DESIGN

Step 5
Calculate required depth of shade.

EXAMPLE: Taking a window of width 1500mm and height 1800mm

For west facade

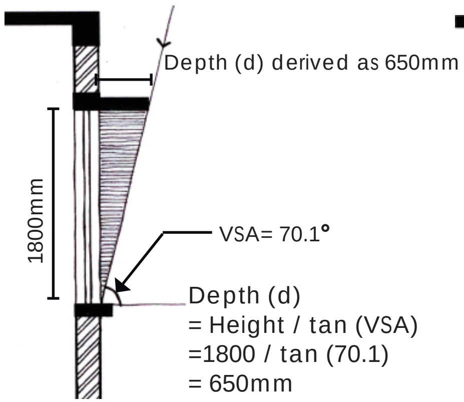


Shading by single vertical shade is not feasible as the shade depth becomes prohibitive. Hence the width is subdivided and several louvres are designed. If 6 divisions are created, i.e. effective width to be shaded is 250mm

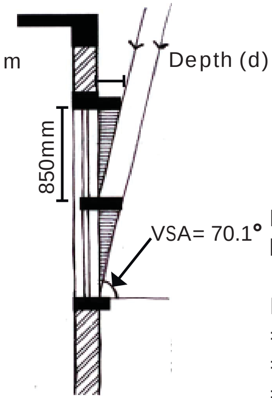
depth (d)= width / tan (HSA)
=250 / tan (11.3°)
= 1250mm

This depth can be reduced much further by designing the louvres at an angle. As mentioned earlier, on the west facade fixed shades will not shade the window at all times. Movable louvers or shading by trees could be better .

For south facade



Depth (d)
= Height / tan (VSA)
=1800 / tan (70.1)
= 650mm



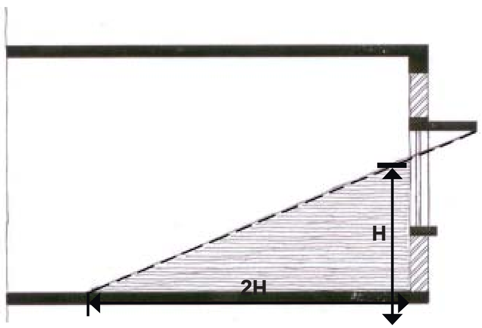
If two horizontal louvres are used then,

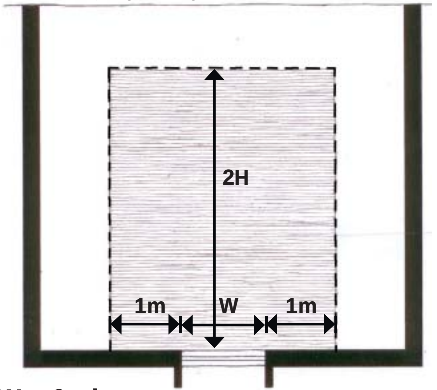
Depth (d)
= Height / tan (VSA)
= 850 / tan (70.1°)
= 300mm

DAYLIGHT DISTRIBUTION

An integrated design approach utilises indirect radiation for day lighting and avoids the heat of direct radiation.

Room & Opening dimensions for appropriate daylighting



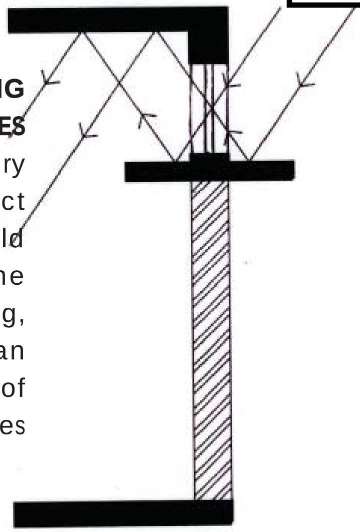


Total daylighted area for window= 2H x (W + 2m)
NBC also recommends that the window area should be atleast 15% of the floor area of the room.

For spaces where regular windows are not required higher clerestory windows can be a suitable daylighting option.

LIGHTSHELVES / SHADING DEVICES

Since in the hot, dry climate a compact building approach would reduce the sky dome available for daylighting, daylight penetration can be enhanced by use of lightshelves



REFLECTANCE OF INTERNAL FINISHES

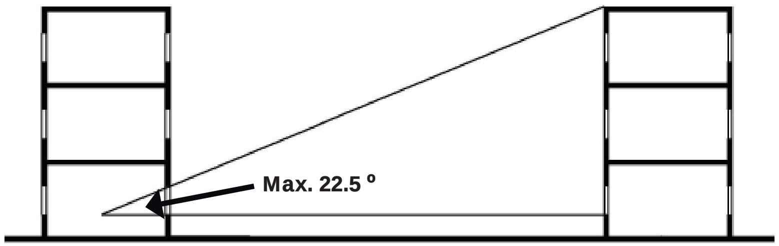
For better daylight distribution, the reflectance of the internal surfaces should be higher. Secondly, full height partitions to be minimized in favour of open office plans where more people can share the natural light & ventilation from a window.

REFLECTANCE OF COMMON SURFACE FINISHES & COLOURS

Typical finishes of surfaces	Reflectance
White wash	0.7 - 0.8
Cream colour	0.6 - 0.7
Light green	0.5 - 0.6
Light blue	0.4 - 0.5
Light pink	0.6 - 0.7
Dark red	0.3 - 0.4
Medium grey	0.3
Cement terrazzo	0.25 - 0.35
Brick	0.4 - 0.5
Vegetation (mean value)	0.25

DISTANCE BETWEEN BUILDINGS FOR DAYLIGHT INGRESS

Ideally for daylight penetration, the lowest floor windows should subtend a maximum angle of 22.5 º with the top of the adjacent building / object. But for regulating heat radiation, a closer fit would help.

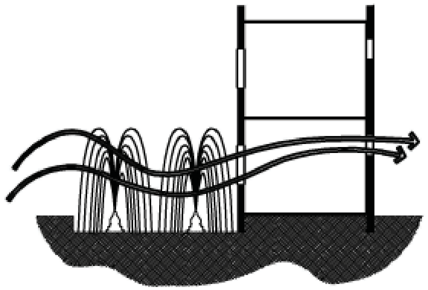


PASSIVE COOLING STRATEGIES

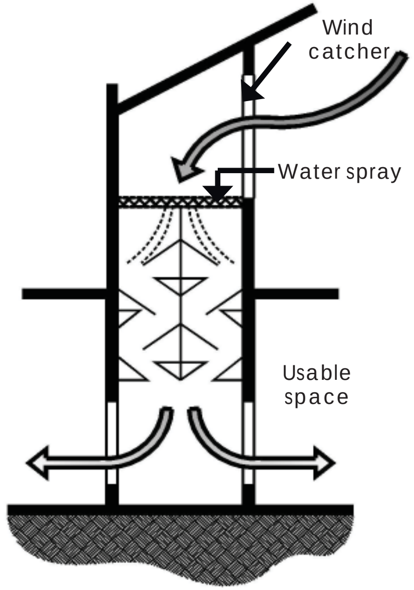
Passive cooling strategies need to be incorporated at the design initiation stage based on the planed organization of spaces in the building. This will ensure minimum HVAC loads even if any active cooling systems are desired.

Evaporative cooling

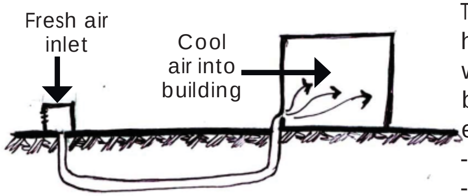
Evaporative cooling works well in the hot-dry climate as humidity is low in this zone. *But water availability needs to be chec*



Water bodies outside or in courtyard for cooling the air. Water bodies should be shaded to minimize evaporation losses.



Central wind tower system with water spray on top. Useful for cooling double loaded corridors. Very acceptable method as humidity is welcome. Water availability needs to be checked.



Care has to be taken in constructing the tunnels to prevent pests etc. from entering the living space.

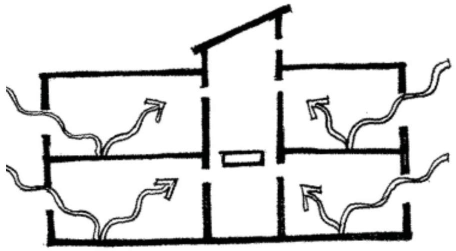
Earth Air Tunnel System

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 (from various existing systems):

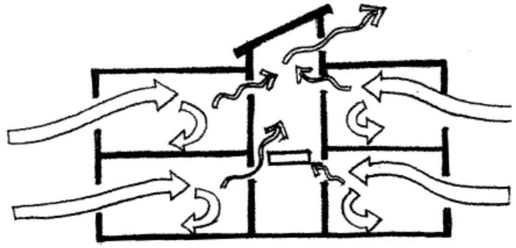
- Pipe depth 4m
- Pipe diameter 0.3 to 0.7m
- Distance between pipes 3m centre-to-centre
- Pipe length depends of air volume required.

Night ventilation

Night ventilation works well in this climatic zone as diurnal variations are high. In this process, buildings are ventilated at night when ambient temperatures are lower to resist heat build-up.



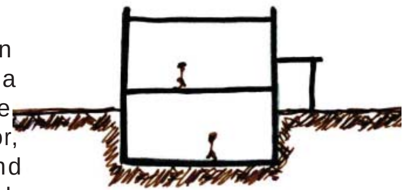
Day-time building heat gain



Night-time ventilation removes the heat gained during the day.

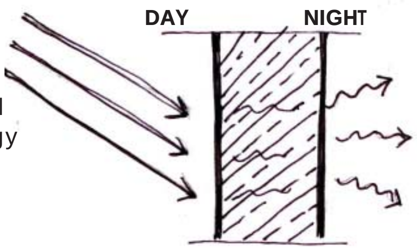
Earth berming

Earth berming reduces outside air infiltration, keeps temperatures cool in summer and warm in winter as the earth's temperature at a depth of a few meters remains almost stable throughout the year. Berms may cover a part of the ground floor, sometimes entire buildings, provided daylight and ventilation requirements are taken care of. Needs adequate water-proofing measures. Basements are similarly cool and preferred spaces.



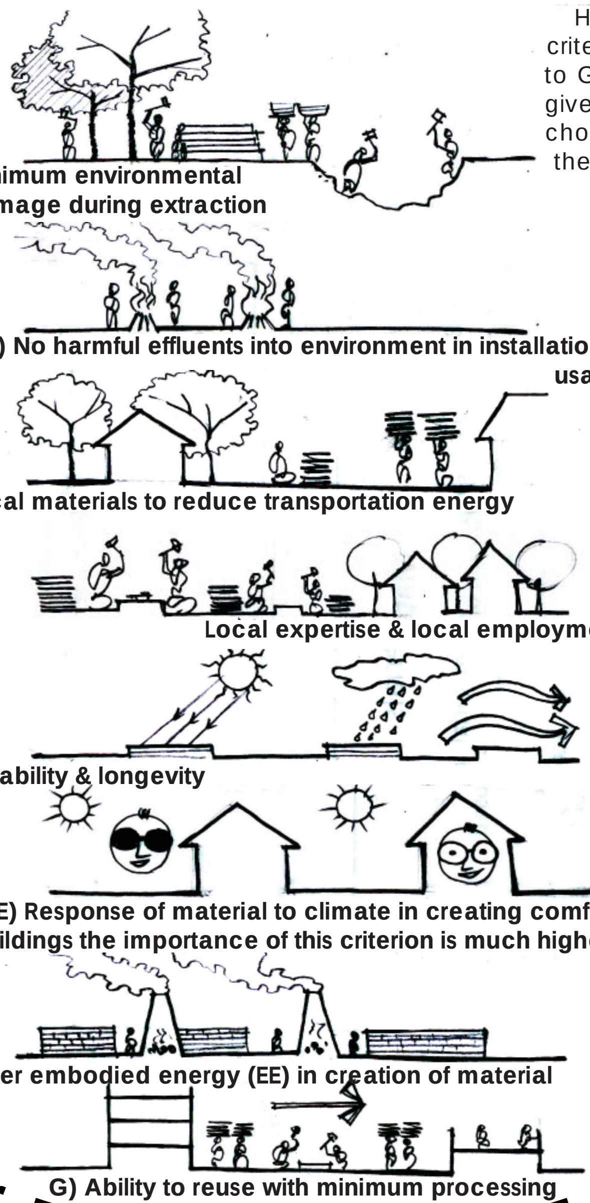
Thermal mass

A building envelope with higher thermal mass will retard heat transfer from the exterior to the interior during the day. When temperatures fall at night, the walls re-radiate the thermal energy back into the night sky. Extensively used in traditional buildings in the region.



HIERARCHY OF SELECTION CRITERIA

How Green a material might be, depends on the selection criterion applied. In utilizing these 8 selection criterion (from A to G) although all are important, but the priority needs to be given for the upper one than the lower one if one needs to choose between the two. See example in boxes which illustrate the criterion in more detail.



A) Minimum environmental damage during extraction

Stones from sustainable mines: The sustainable mining framework of the Govt. of India enunciated better mining practices, less air pollution, reuse of mine waste and mine land.

Reuse of mine waste, like use of stone dust and chips to make concrete blocks, Also helps reduce air & land pollution.

Salvaged timber, reused wood, particle boards etc. reduce use of new wood & saves trees.

B) No harmful effluents into environment in installation & usage

Use of low VOC paints, adhesives and sealants.

Insulation free of CFC and HCFC which have ozone depleting properties.

C) Local materials to reduce transportation energy

EEV of flyash blocks= 2.32 MJ / brick
EEV of stabilised earth block = 2.79 MJ /brick
Even though A flyash block has lesser EEV, it is more efficient only if it travel less than 50 km

Local expertise & local employment

If material unavailable, skills do not help, But if material available, skills can be created by training programs.

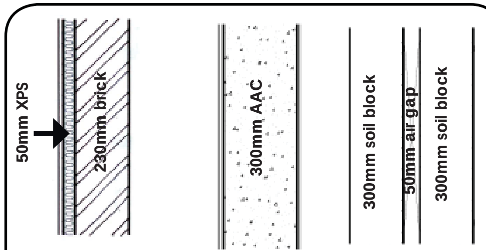
Stone is a local material in Rajasthan and the related expertise and craftsmanship is also available

D) Durability & longevity

EEV of Material 1= 90 MJ / sq.m; Life= 80 yrs.
EEV of Material 2 = 72 MJ / sq.m; Life= 40 yrs.

2x durability of Material 2 means 1/2 energy for extraction, processing, installation & disposal

E) Response of material to climate in creating comfort (For AC buildings the importance of this criterion is much higher)



R value 2.12; High EE due to XPS | R value 2.12; Low EE | R value 2.12; Lowest EE

UPVC windows are more insulating than Aluminium windows

F) Lower embodied energy (EE) in creation of material

PPC has lower embodied energy due to fly ash content which is waste from thermal power plants. It can be used in both structural concrete and plaster mortar.

Stabilised earth block has less embodied energy vis-a-vis bricks as bricks use higher energy for firing.
EEV of CSEB= 138 MJ / sq.m of wall
EEV of brick= 681MJ / sq.m of wall

Waste glass is used in the manufacture of glass. Used marble chips used in the manufacture of terrazzo reduce embodied energy.

G) Ability to reuse with minimum processing

Iron is superior to Aluminum in terms of ease with which it can be recast and reutilized. But recyclability (as different from recycled) is a future hope which might not fructify.

MATERIAL PROPERTIES

Thermal mass:
Thermal mass is the ability of a material to absorb heat energy. This heat storing capacity of building materials helps achieve thermal comfort conditions by providing a time delay to the flow of heat. High density materials, like concrete, brick and stone have high thermal mass. Thermal mass is most appropriate for climates with a diurnal variation of more than 10º C.

Thermal insulation:
Thermal insulation is the reduction of heat transfer through a material. Heat flow is a consequence of contact between objects of differing temperatures. Insulation reduces thermal conduction thus reducing unwanted heat loss or gain

The insulating capability of a material is measured with thermal conductivity (k). Low thermal conductivity is equivalent to high insulating capability (R-value).

Thermal mass & Thermal insulation in Hot-Dry Climate:
High thermal mass materials,without insulation, can radiate heat all night during a summer heatwave, 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. It can trap heat within the building envelope.

High mass construction with high insulation levels *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.*

Thermal conductivity (*k*): *Property denoting a material's inherent ability to conduct heat. It is an intrinsic material property and is temperature dependant.*
Unit: W/m.K

Thermal transmittance(U-value): *Property denoting a material's ability to conduct heat. It is the inverse of R-value.*
Unit: W /m².K

Thermal resistance (R-value): *Property denoting a material's resistance to heat. It is dependant on temperature and the thickness of the material.*
Unit: m².K/W

Relationship between *k*, R-value & U-value:
- *R-value= thickness of material (d)/ k*
- *U-value= 1/ R-value*

MATERIAL R VALUE TABLE

Material	R value (m².K/W)
230mm thk. Brick wall	0.38
300mm thk. Stone wall	0.08
300mm thk. AAC wall	2.08
230mm thk. FAL G wall	0.96
75mm thk. Rockwool	1.56
50mm thk. XPS	1.73
50mm thk. EPS	1.39
50mm thk.PUF	2.08
75mm thk. inverted kulhar in lime concrete	0.30
25 - 100mm air cavity	0.18

Surface Air film resistances:(These are added to the material R value)
- *Outside surface(vertical)= 0.04* m².K/W
- *Inside surface(vertical)= 0.13* m².K/W
- *Outside surface(horizontal)= 0.06* m².K/W
- *Inside surface(horizontal)= 0.16* m².K/W

Note: *Value used are indicative & may very slightly based on exact material properly*

EMBODIED ENERGY TABLE

Material	Embodied Energy (MJ/ m²)
230mm thk. Red clay Brick wall	681.95
300mm thk. Stone wall	630.00
300mm thk. AAC wall	215.70
230mm thk. FAL G wall	201.94
50mm thk. XPS	142.50
50mm thk.PUF	151.50
50mm thk.EPS	66.45

Embodied energy (EE):
It is the sum of all the energy required to produce a material, considered as if that energy was incorporated or 'embodied' in the material itself. Units MJ / kg or MJ / m³.(MJ= Megajoules)

(Note:Values used in this document do not include the energy of transporting materials to site which will vary based on location).

Materials

REDUCING HEAT INGRESS THROUGH WALL

The choice of materials must optimize between the insulation provided & the embodied energy of the material based on its local availability.

R-value calculation example:
Wall assembly 5: 300mm thk. stone wall + 70mm air cavity + 115mm brick Wall + 12mm plaster one side

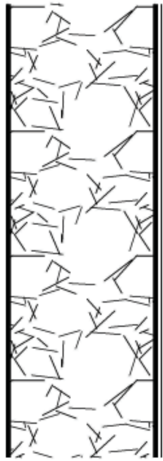
Material	Resistance: R-value (m².K/W)
Outside air film	0.04
300mm thk. stone	0.08
70mm air cavity	0.18
115mm thk. brick wall	0.19
12mm plaster	0.02
Inside air film	0.13

R value of the wall assembly = Sum of the component R-values = 0.64 m².K/W

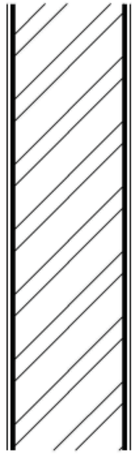
***ECBC recommended R value for wall assembly*= 2.27 m².K/W**

Add-on insulation should be judiciously used especially in the case of non-conditioned buildings with cost constraints and need to keep embodied energy low.

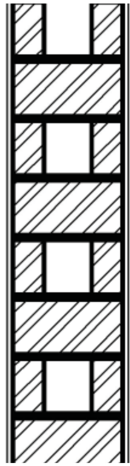
WALL ASSEMBLY 1
300mm thk. stone wall + 12mm plaster one side
EE= 644 MJ / m²
R value= 0.27 m².K/W



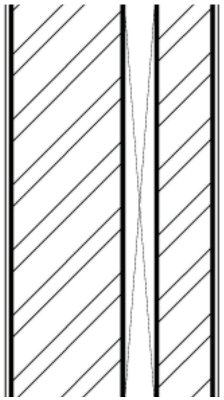
WALL ASSEMBLY 2
230mm thk. brick wall + 12mm plaster both sides
EE= 711 MJ / m²
R value= 0.59 m².K/W



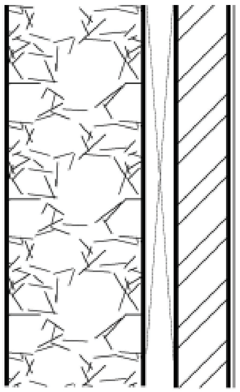
WALL ASSEMBLY 3
230mm thk. brick wall in rat-trap bond + 12mm plaster both sides
EE= 365 MJ / m²
R value= 0.70 m².K/W



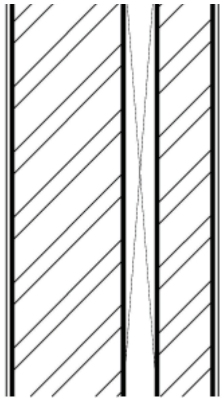
WALL ASSEMBLY 4
230mm bk.wall + 70mm air cavity + 115mm brick Wall+ 12mm plaster both sides
EE= 1052 MJ / m²
R value= 0.95 m².K/W



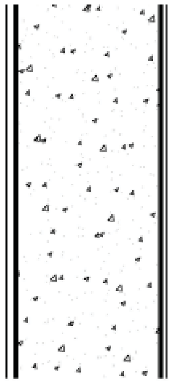
WALL ASSEMBLY 5
300mm stone wall + 70mm air cavity + 115mm brick Wall + 12mm plaster one side
EE= 986 MJ / m²
R value= 0.64 m².K/W



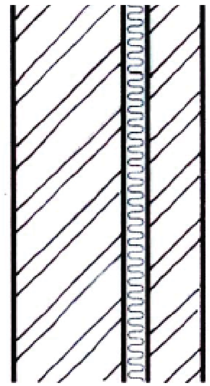
WALL ASSEMBLY 6
230mm FAL G + 70mmair cavity +115mm FAL G + 12mm plaster
EE= 318 MJ / m²
R value= 1.80 m².K/W



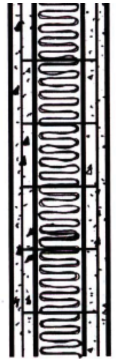
WALL ASSEMBLY 7
20mm stone cladding+ 300mm AAC + 12mm plaster
EE= 272 MJ / m²
R value= 2.27m².K/W



WALL ASSEMBLY 8
230mm bk.wall + 50mm XPS + 115mm bk. Wall + 12mm plaster both sides
EE= 1194 MJ / m²
R value= 2.51 m².K/W



WALL ASSEMBLY 9
3D Eco wall: 50mm shotcrete + 100mm EPS +50mm shotcrete (reinforced with wiremesh)
EE= 470 MJ / m²
R value= 3.00 m².K/W



REDUCING HEAT INGRESS THROUGH ROOF

R-value calculation example:

Roof assembly 1: 100mm RCC slab + 50mm (avg. thickness) brickbat coba + 20mm cement mortar finish

Material	Resistance: R-value ($m^2.K/W$)
Outside air film	0.06
20mm cement mortar	0.03
50mm brickbat	0.08
100mm RCC slab	0.06
Inside air film	0.16

R value of the roof assembly = Sum of the component R-values = 0.39 $m^2.K/W$

ECBC recommended R value for roof assembly
= 3.8 $m^2.K/W$ (24-hr. use buildings)
2.4 $m^2.K/W$ (Daytime use buildings)

Embodied energy (EE) calculation example:

Roof assembly 1: 100mm RCC slab + 50mm (avg. thickness) brickbat coba + 20mm cement mortar finish

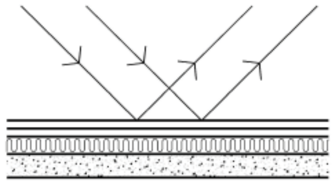
Material	Embodied energy (MJ/ m^2)
20mm cement mortar	36.40
50mm brickbat	148.25
100mm RCC slab	506.44

EE of the roof assembly = Sum of the component EE = 691.1 MJ/ m^2

EE excluding RCC slab= = 184.65 MJ/ m^2

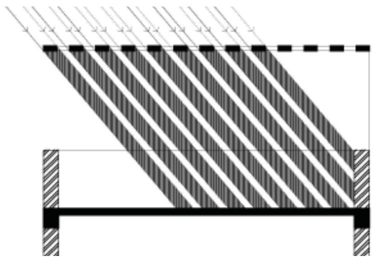
(A) REFLECT

Heat gains can be reduced by using roof finishes with high solar reflective index (SRI), . Examples of high SRI materials include china mosaic, white cement tiles, reflective paints etc. ECBC mandates a minimum SRI of 0.7.



(B) SHADE

Shading the roof also reduces heat gain. For e.g. partial shading by pergolas, bamboo frame, overhanging creepers, Photo-voltaic panels.



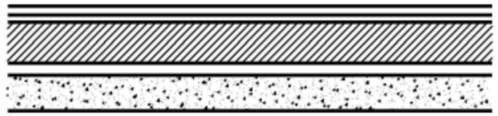
(C) INSULATE

ROOF ASSEMBLY 1 (EE excluding that of 100mm RCC slab = 506.44 MJ / m^2)

RCC slab + 50mm (avg. thickness) brickbat coba + 20mm cement mortar finish

EE= 185 MJ / m^2

R value= 0.39 $m^2.K/W$

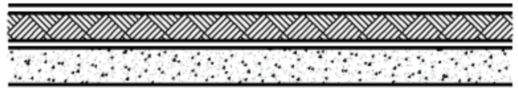


ROOF ASSEMBLY 2

RCC slab + 75mm mud phuska + 20mm cement mortar finish

EE= 36 MJ / m^2

R value= 0.40 $m^2.K/W$

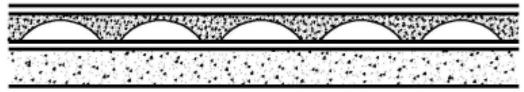


ROOF ASSEMBLY 3

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

EE= 74 MJ / m^2

R value= 0.60 $m^2.K/W$

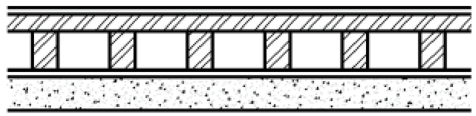


ROOF ASSEMBLY 4

RCC slab + 75mm brick laid at intervals of 230mm c/c+ brick tile covering + 20mm cement mortar finish

EE= 300 MJ / m^2

R value= 0.60 $m^2.K/W$

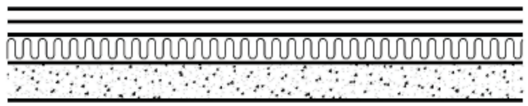


ROOF ASSEMBLY 5

RCC slab + 100mm PUF +waterproofing + Marble crazy

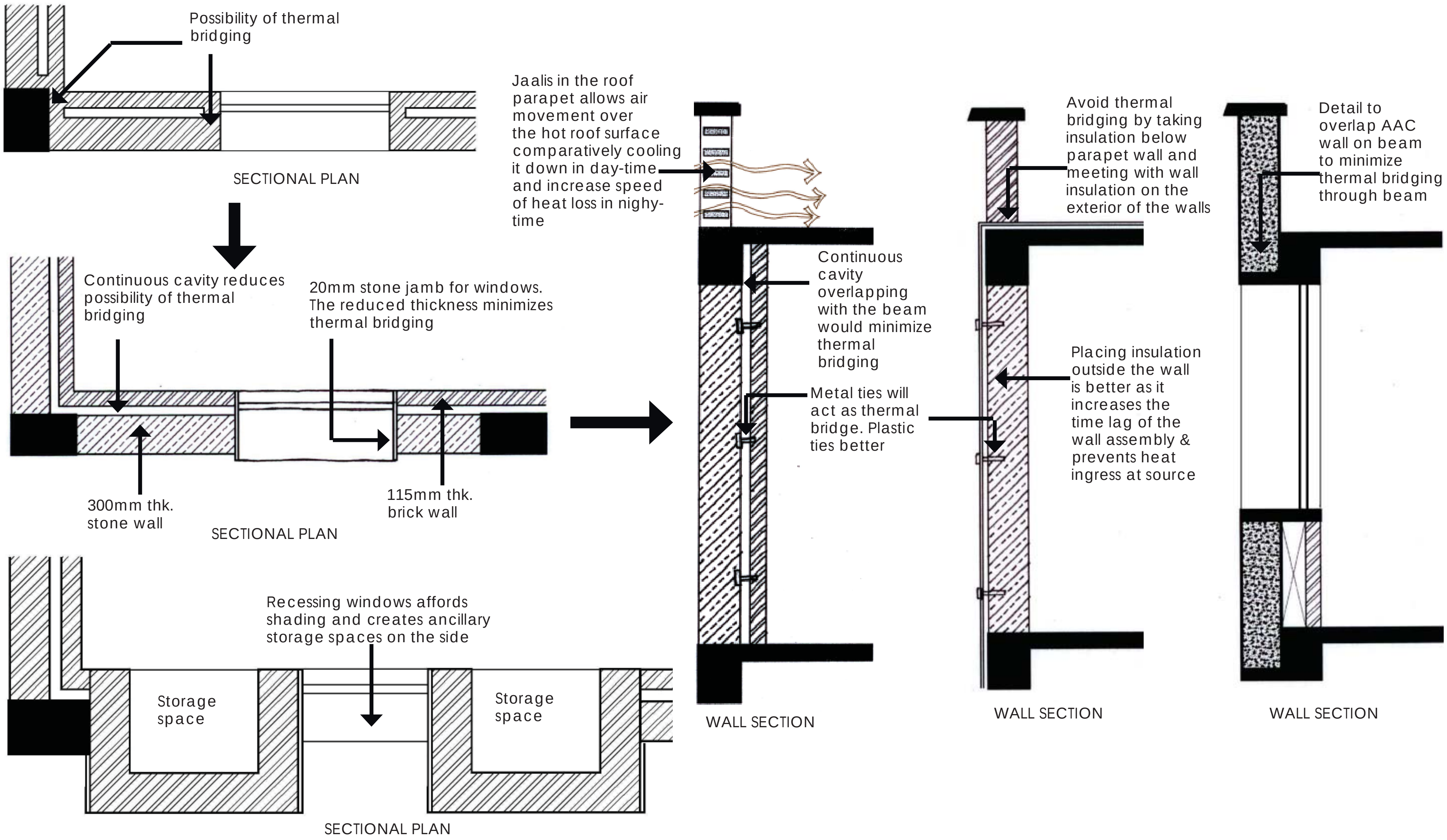
EE= 419 MJ / m^2

R value= 4.48 $m^2.K/W$



Materials

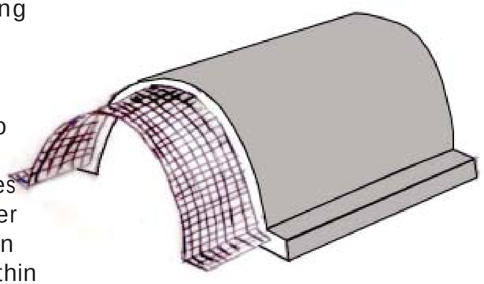
MATERIAL USAGE: GOOD PRACTICES



ALTERNATIVE LOW ENERGY OPTIONS

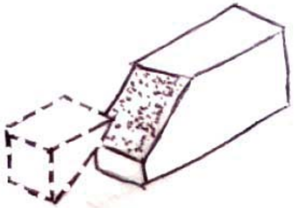
FERROCEMENT

(EE= 111 MJ / m²)
A versatile form of RCC possessing unique properties of strength and durability. Made up of rich cement mortar and wire mesh reinforcement, it has a high ratio of strength to weight. A cost-effective material, it also enables faster construction and has lower embodied energy in comparison to conventional RCC due to its thin section & minimization of steel



CLC (CELLULAR LIGHTWEIGHT CONCRETE) & AAC (AERATED AUTOCLAVED CONCRETE) BLOCKS

(EE= 215 MJ / m² for wall thickness 300mm)

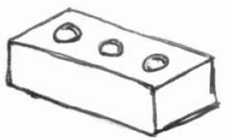


CLC and AAC blocks are air-cured lightweight concrete with fly-ash as a major ingredient. The difference lies in the process of generation of air bubbles. In CLC the air bubbles are generated in the form of a foam while in AAC they are produced from a reaction that uses aluminum powder.

These light-weight blocks reduce structural steel requirement and provides higher thermal insulation. As it uses fly-ash which is a waste material it leads to substantial material saving and has lower embodied energy.

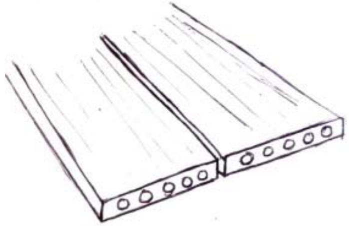
PERFORATED BRICK MASONRY

These are high strength hollow bricks with 50-60 percent perforations. These perforations act as sound and heat insulators and saves materials.



PRE-STRESSED SLAB

This helps in reduction of section of slab. Pre-stressed slabs are up to 25% lighter than conventional RCC slabs due to a reduction in section size.

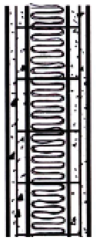


SANDSTONE ROOFING

(EE= 196 MJ / m²) An extensively used material, this consists of 25mm thick stone slabs on pre-cast RCC beams or iron sections.

3D ECO WALL

(EE= 470 MJ / m²)
This wall assembly consists of a 100mm EPS panel finished with 50mm shotcrete on both sides, reinforced by wiremesh. The 200mm thk. panel saves space and provides excellent insulation.
This may be used both for walling & roofing.
The EPS can be reduced to 100mm for interior walling.

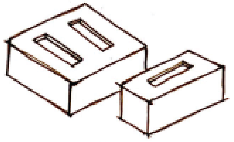


GEOPOLYMERS

Geopolymers are a class of synthetic aluminosilicate materials with potential use essentially as a replacement for Portland cement. Fly ash based geopolymer concrete has superior strength and mortar / plaster made from it does not require curing. GPC (Geo Polymer Cements) use a host of waste and virgin materials in feedstock. Besides Structural Concrete, GPC can be used also for Building Blocks and Paver Blocks.

CSEB (COMPRESSED STABILISED EARTH BLOCKS)

(EE= 138.6 MJ / m² for 230mm thk. wall)
Blocks made of mud stabilised with 5% cement lime and compacted in block-making machines without firing. Compressive strength equal to red clay fired bricks.



FAL G (FLY ASH- LIME GYPSUM) BLOCKS

(EE= 202 MJ / m² for 230 thik wall)
These blocks require less mortar, plastering can be avoided, are cost effective and environment-friendly as it avoids use of fertile top soil.

PRE-CAST STONE BLOCKS

Blocks manufactured using waste stone pieces of various sizes with lean cement concrete.

Please note: The embodied energy values are indicative. They do not include transportation energy to deliver material on-site. Values will vary as per exact construction detail utilized.

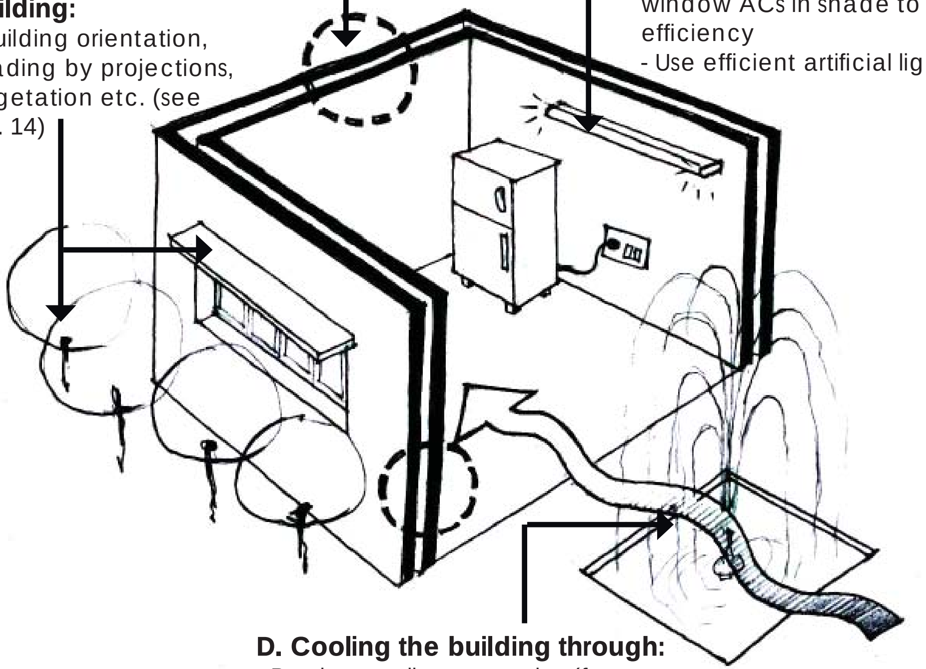
Building Energy Efficiency

ORDER OF STRATEGIES FOR ENERGY EFFICIENCY

A. Control amount of heat reaching building:
- Building orientation, shading by projections, vegetation etc. (see pg. 14)

B. Minimize carriage of heat through building skin:
- Insulation (see pg. 24,25,26)

C. Reduce internal heat gain and improve daylight (for detailed design refer to daylighting code SP41)
- Usage of fixtures and appliances with low equipment power density and with efficient BEE rating.
- Keep outdoor equipment like window ACs in shade to improve efficiency
- Use efficient artificial lighting



D. Cooling the building through:
- Passive cooling strategies (for non-AC buildings) (see pg. 21)
- Low energy HVAC technologies (for AC buildings)

ARTIFICIAL LIGHTING EFFICIENCY

1) Use of optimum Lighting Power Density (LPD): *It is the amount of electrical power used to illuminate a space. (Expressed in Watts per unit of area)*

Exterior building LPD (ECBC 2007)	
Application Area	**LPD**
Building entrance with canopy	13 W / m^2 of canopied area
Building entrance without canopy	90 W / m of door width
Building exit	60 W / m of door width
Building facades	2 W / m^2 of vertical facade area

Indoor LPD of common building types (ECBC 2007)	
Building type	**LPD (W / m^2)**
Residential	7.5
Office	11.8
Dining facility	15 - 17.2
Clinic	10.8
School	12.9
Hostel	10.8

2) Selection of efficient lighting fixture on the basis of efficacy (ratio of lumen output to energy input)

Lamp efficacy of different lamps

Type	Lamp wattage (W)	Ballast power loss	Total Power (W)	Lamp flux (lumen)	Efficacy (lumen / W)
Incandescent	100			1340	13
TL-D 36W	36	4	40	3250	81
TL5 HE 14W	14	2	16	1350	84
TL5 HE 28W	28	2	30	2900	97
CFL 18W	18	4	22	1200	54

3) Use of controls where possible like master switches, timers, occupancy sensors etc.

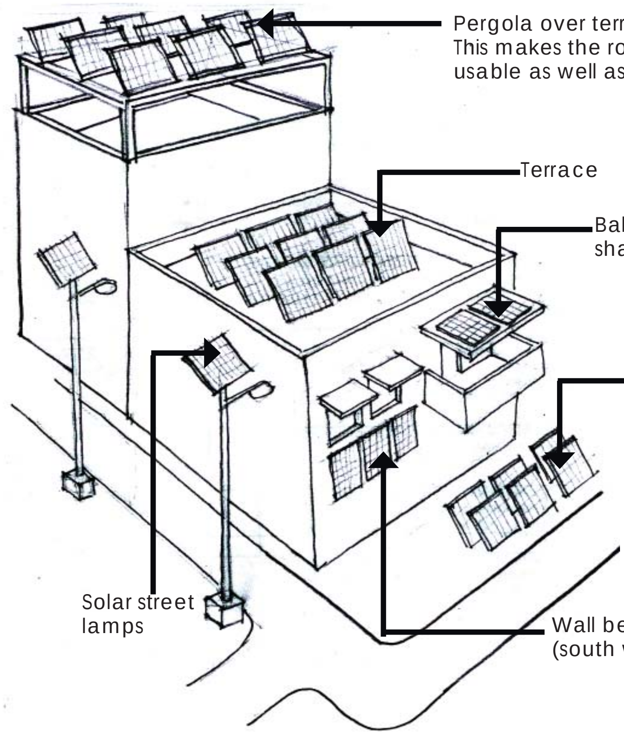
RENEWABLE ENERGY FOR ELECTRICITY GENERATION

With the high solar radiation available in the hot, dry climate zone, it is highly recommended to use solar energy to meet atleast some part of the building's electricity demand. The simplest way to generate solar energy is by using stand-alone photo-voltaic (PV) systems with or without storage battery.

SOLAR PHOTO-VOLTAICS INSTALLATION

The ideal orientation for optimal performance of a solar cell is at an angle equivalent to the latitude of the place of installation. Area required for generation of 1 kWp electricity is on an average 12 m^2 for 15 % efficiency panels

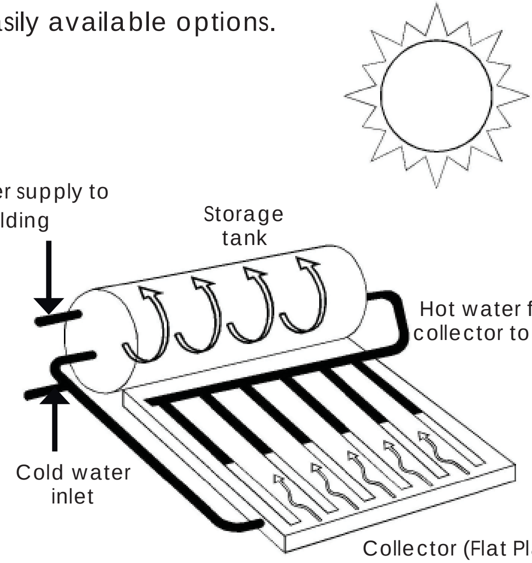
POSSIBILITIES OF PV PANEL PLACEMENT



ENERGY EFFICIENCY & RENEWABLE ENERGY

SOLAR WATER HEATER

Use of solar energy for water heating is one of the most commercialized and easily available options.



Typical hot water consumption in different buildings (varies as per local criterion)	
Residential	100 litres / day / family
Office	4 litres / person / day
Hostel	30 litres / person / day
Dispensary	30 litres / bed / day

FLAT PLATE COLLECTOR (FPC) VS. EVACUATED TUBE COLLECTOR (ETC)

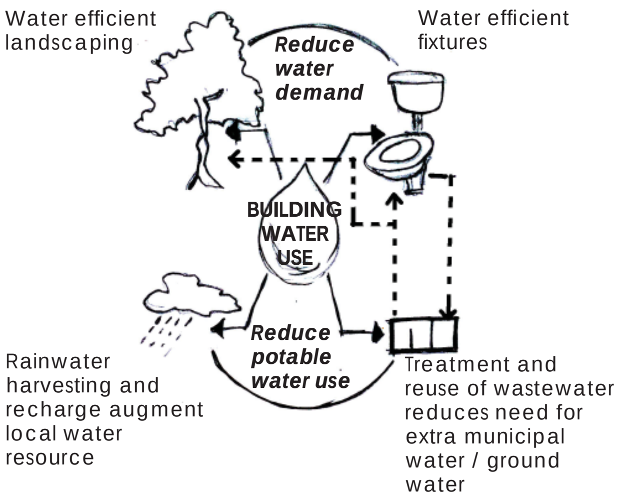
ETC, though more expensive, is generally more efficient due to better heat absorption and less heat losses. The circular tubes also allows better sun tracking and are better suited for hard water.

Commonly, units are available for 200 litres per day, 500, 1000 and more.

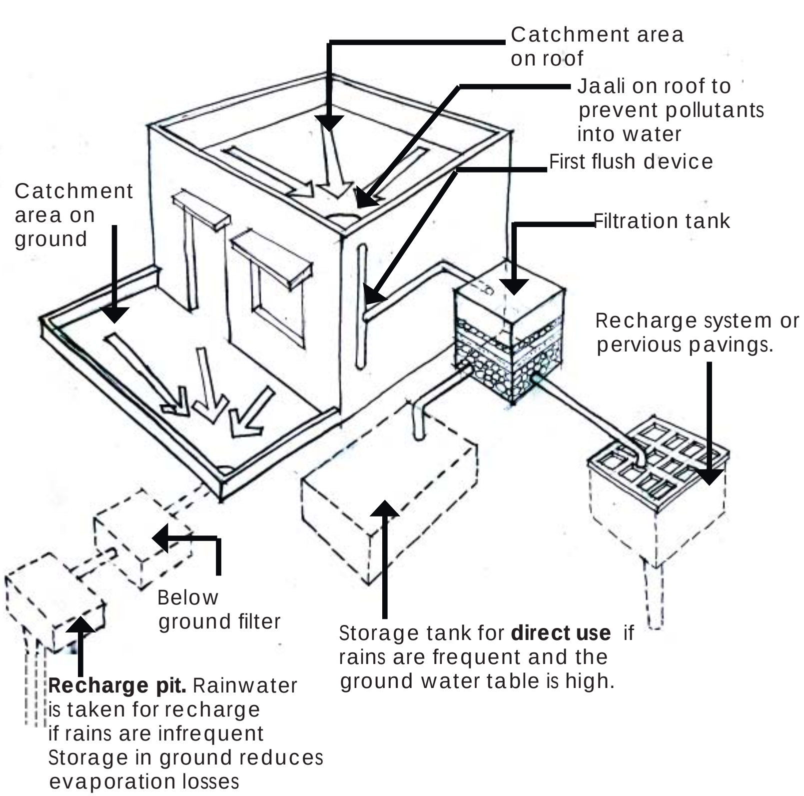
RAINWATER HARVESTING (RWH)

Water conservation and reuse is of utmost priority in the hot-dry climate.

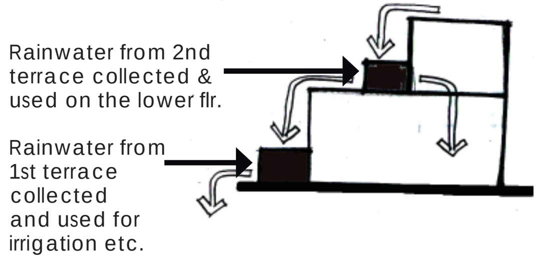
STRATEGIES FOR WATER EFFICIENCY



RAINWATER HARVESTING AND RECHARGE SYSTEM



CASCADE SYSTEM RWH FOR RAINWATER REUSE



COMPARISON BETWEEN DIRECT RAINWATER USE & RECHARGE INTO GROUNDWATER

Direct use	Recharge
Used if rainfall frequent	Used if rainfall infrequent
Used if groundwater table is high	Used if groundwater table is low to augment groundwater resource

RUN-OFF CO-EFFICIENTS FOR VARIOUS SURFACES

Surface type	Run-off co-efficient
Roofs conventional concrete	0.95
Concrete / Kota paving	0.95
Gravel	0.75
Brick paving	0.85
Vegetation	0.2 - 0.3 (depending on slope)
Turf slopes (Lawn)	0.25 - 0.45 (depending on slope)

RAINWATER HARVESTING POTENTIAL=

Catchment area (m^2) x Annual rainfall (m) x Surface run-off co-efficient

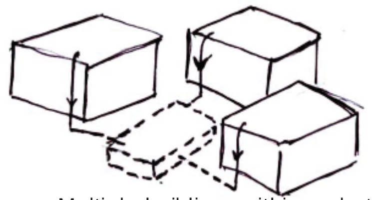
A thumb rule for estimating tank size is to store 15 minutes of peak rainfall. So, if peak rainfall= 90mm / hr., then in 15 minutes rainfall= 22.5mm

Hence, (22.5mm x collection area x run-off co-efficient) would be the optimum tank size for storage.

PRECAUTIONS TO BE TAKEN WHILE HARVESTING RAINWATER

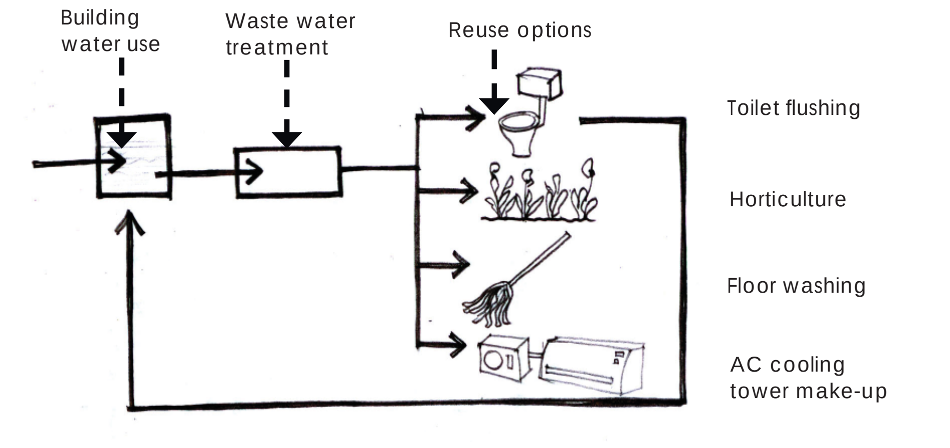
- Filtration and first flush system esssential to prevent entry of contaminants
- Cleaning of tank at the beginning of summer and winter rainfalls

RAINWATER HARVESTING FOR MULTIPLE BLOCKS



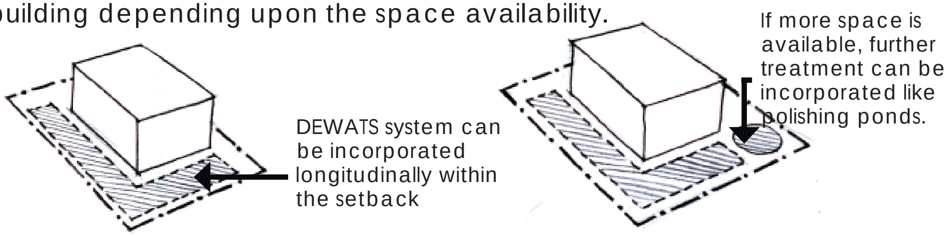
Multiple buildings within a cluster can have a common rainwater harvesting system

WASTE WATER USE STRATEGY



LOCATION:

The treatment systems can be located within the setbacks around the building depending upon the space availability.



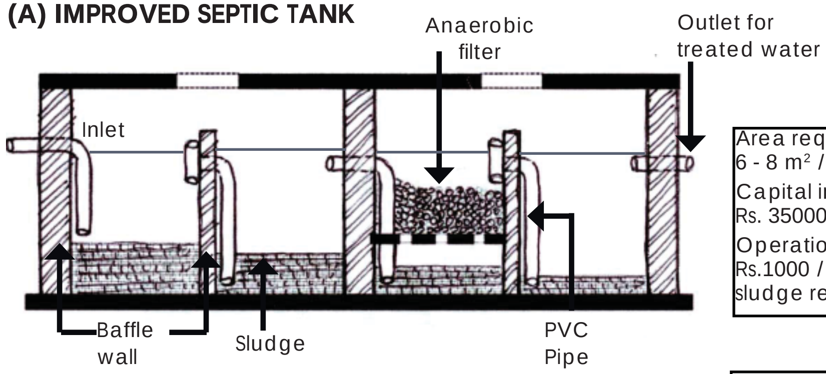
Multiple buildings can combine their water treatment systems. In a campus, this is all the more feasible.

WASTE WATER USAGE

Zero discharge is possible by creative treatment and reuse of water, thus reducing load on municipal drains

TECHNOLOGIES FOR SMALL STAND-ALONE PROJECTS:

(A) IMPROVED SEPTIC TANK



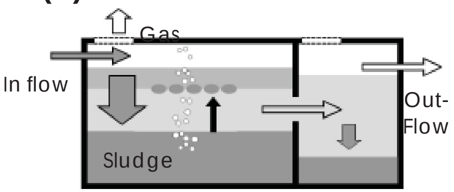
Area required (sq.m.)= 6 - 8 m^2 / m^3
Capital investment= Rs. 35000 - 50000 / m^3
Operation cost= Rs.1000 / year for sludge removal

(B) EFFECTIVE MICRO-ORGANISMS

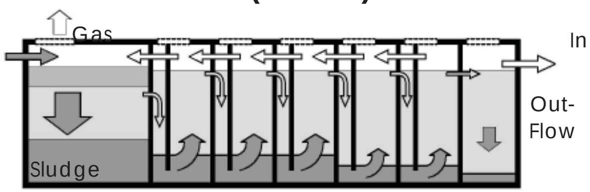
Effective micro-organisms(EM) system has anareobic organisms introduced to waste water after primary treatment to remove organic content. Using EM reduces sludge in the secondary treatment.

Area required (sq.m.)= 3 m^2 / m^3
Capital investment (EM + baffled tank)= Rs. 6700 / m^3
Operation cost= Rs.12/ m^3 (cost of EM solution)

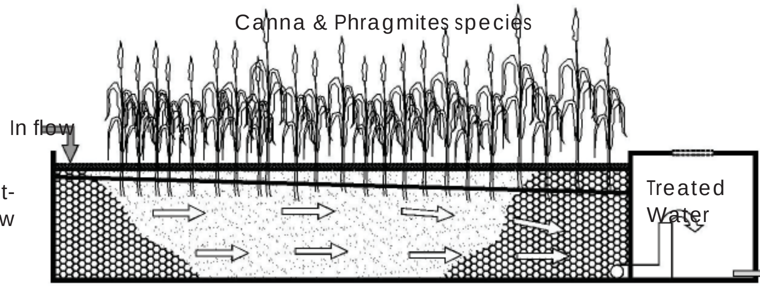
(C) DECENTRALIZED WASTEWATER TREATMENT SYSTEM (DEWATS)



PRIMARY TREATMENT (Septic tank)



SECONDARY TREATMENT (Anaerobic baffled tank reactor)
tank reactor)



Out-flow for reuse

TERTIARY TREATMENT (Reed bed system / Planted gravel filter)

Area required (sq. m.)= 7 -8 m^2 / m^3
Capital investment= Rs. 25000 - 50000 / m^3
Operation cost= Rs. 1000 / year for sludge removal

Modifying Existing Buildings

STRATEGIES FOR MODIFYING SMALL SCALE EXISTING BUILDINGS

STRATEGIES FOR MODIFYING EXISTING SMALL SCALE BUILDINGS

(A) Add-on Insulation on wall and roof

(B) Energy Audits

(C) Window Retrofitting

(D) Shading

(E) Add-on Cooling Devices

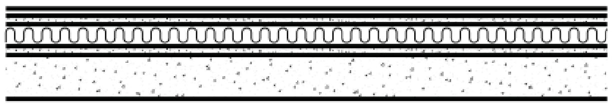
(A) ADD-ON INSULATION ON WALL AND ROOF

Insulation can be added on to the wall and roof, as shown in the examples, to reduce heat ingress into the building.

Insulation added on existing roof

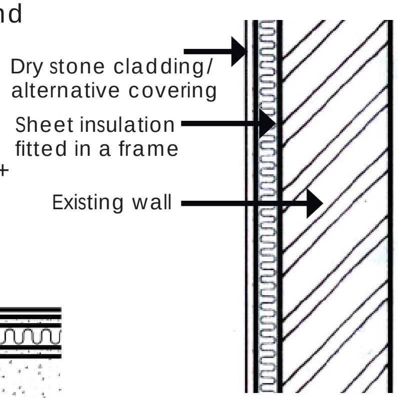
RCC slab + 50mm sloping screed + 75mm XPS + china mosaic

R value= 2.97 m².K/W



Insulation below-deck possible & usually the case in existing buildings but preventing heat ingress from outside is preferable.

Insulation & cladding added on existing wall



If 50mm XPS is used as insulation material, then

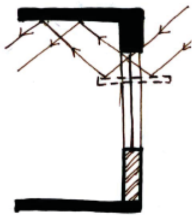
R value= 2.31 m².K/W

(B) ENERGY AUDITS for replacing existing electrical fixtures with efficient ones. This includes...

- Lighting fixtures with higher lumen output and lower heat output
- Lighting fixtures with electronic ballasts
- Other efficient appliances as per the ECBC 2007

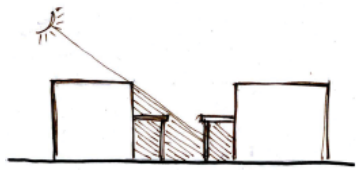
(C) WINDOW RETROFITTING involves

- Cleaning out blocked openings which afford natural light
- Shading the window glazing to prevent heat ingress by add-on projections on East, West and South sides
- Adding light shelves, in the interior or exterior, for better daylight distribution

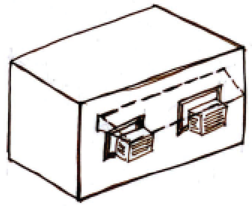


(D) SHADING

- Using spaces like courtyards for add-on shading features. For e.g. adding a shaded porch into the courtyard helps shade the building surface and openings.

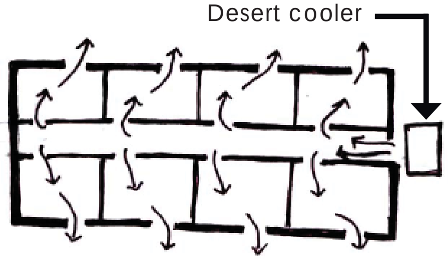


- Shading the window ACs also helps provide better performance.



(E) ADD-ON COOLING DEVICES

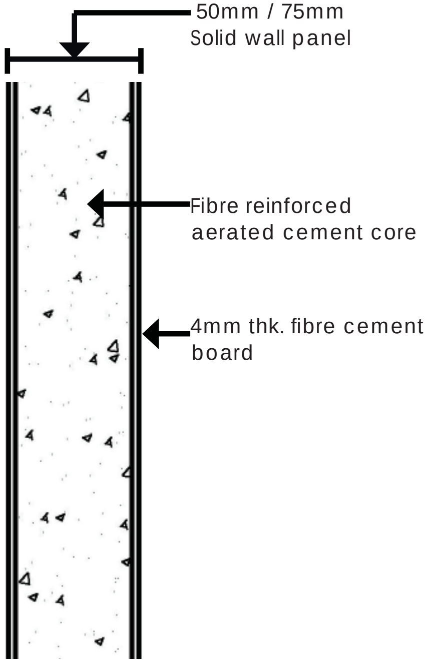
Passive cooling devices, which consume less energy as compared to air-conditioners, can be incorporated into the building even at a later date. For e.g. Desert coolers / Evaporative coolers



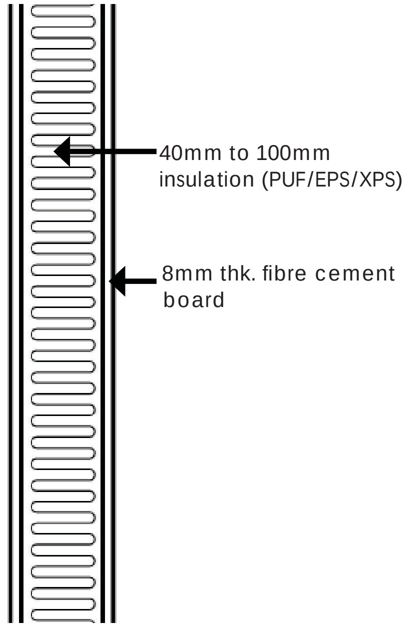
Use of desert coolers is another way of evaporative cooling. Adequately placed coolers can affect the temperatures of large contiguously ventilated spaces.

MATERIALS FOR ENERGY EFFICIENCY IN TEMPORARY CONSTRUCTION

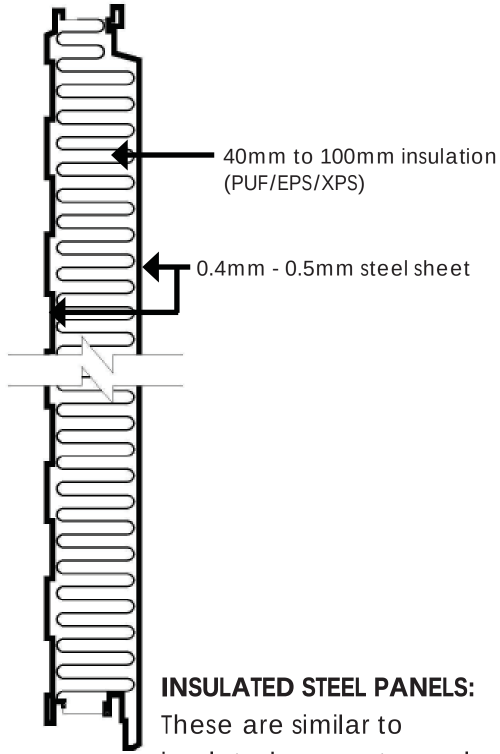
Temporary structures are frequently used for site offices, temporary installations and additional building area requirements, and in many cases they are air conditioned as well. For these to be energy efficient certain option are available as follows.



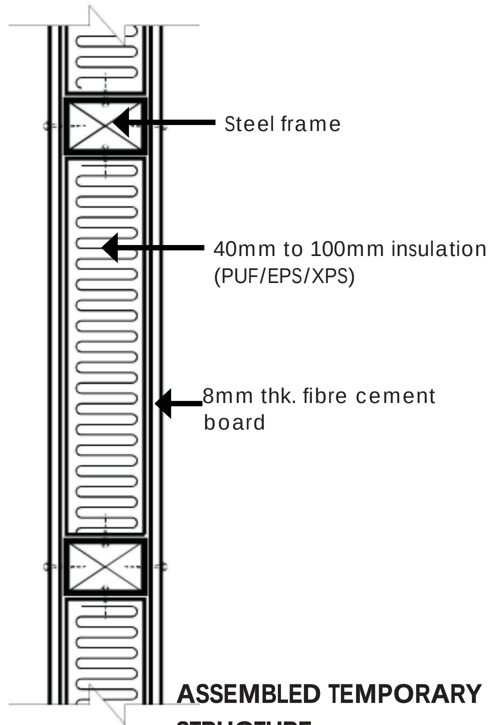
AERATED CEMENT SOLID WALL PANELS:
These have good insulation properties. Additionally, flyash used in both the aerated cement core and the cement board ensures that the embodied energy also remains low.



INSULATED CEMENT BOARD PANELS:
These panels ensure higher insulation. These lightweight panels can be reused, thus reducing overall embodied energy. Stone and timber finishes are also available for insulated panels.



INSULATED STEEL PANELS:
These are similar to insulated cement panels except for the facing material. These lightweight panels also result in better air-tightness, and are reusable.



ASSEMBLED TEMPORARY STRUCTURE:
Better insulation in temporary structures can also be achieved by introducing insulation between cement boards. The insulation and boards are supported on a steel framework.

Abbreviations and References

ABBREVIATIONS:

AAC: Autoclaved Aerated Concrete

CLC: Cellular Lightweight Concrete

CSEB: Compressed Soil Earth Blocks

DEWATS: Decentralised Water Treatment System

ECBC: Energy Conservation Building Code

EE: Embodied Energy

EEV: Embodied Energy Value

EM: Effective Micro-organisms

EPS: Expanded Polystyrene

ETC: Evaculated Tube Collector

FAL G: Fly-Ash Lime Gypsum

FPC: Flat Plate Collector

HVAC: Heating Ventilation and Air Conditioning

HSA: Horizontal Shadow Angle

IGD: Integrated Green Design

LPD: Lighting Power Density

NBC: National Building Code

P/A Ratio: Perimeter-to-Area Ratio

PPC: Portland PozzolanaCement

PUF: Polyurethane Foam

SPV: Solar Photo-voltaic

UPVC: Unplasticised Polyvinyl Chloride

VOC: Volatile Organic Compound

VSA: Vertical Shadow Angle

WWR: Window-to-Wall Ratio

XPS: Extruded Polystyrene

UHI: Urban Heat Island

REFERENCES:

Centre for Science and Environment (2008). Do-it-yourself: Recycle and reuse wastewater. New Delhi: Centre for Science and Environment.

Auroville Earth Institute (2008). Embodied Energy of various materials and technologies. Auroville: Auroville Earth Institute.

Bureau of Energy Efficiency (2007). Energy Conservation Building Code 2007. New Delhi: Bureau of Energy Efficiency, Ministry of Power, Govt. of India.

Bureau of Indian Standards (2005). National Building Code. New Delhi: Bureau of Indian Standards.

Enzen Global Solutions; Greentech Knowledge Solutions (2011, November 8). Strategies for Cleaner Walling Material in India. Retrieved June 27, 2012, from Enzen Global Solutions Web site: www.enzenglobal.com

Greenspec (2002, January 1). Embodied energy: Materials: manufacture, use & impact: GreenSpec. Retrieved June 23, 2012, from GreenSpec Web site: http://www.greenspec.co.uk/

Prashad, D. (2011) Optimizing Embodied Energy of Materials in various Building Envelope Configurations

Krishan, A., Baker, N., Yannas, S., & Szokolay, S. V. (2001). Climate Responsive Architectute: A design handbook for energy efficient buildings. New Delhi: Tata Mcgraw-Hill.

Krishen, P. (2006). Trees of Delhi: A field guide. New Delhi: Dorling Kindersley.

Prashad, D. (2012). Prioritizing Materials in Sustainable Design. New Delhi.

Reddy, B. V., & Jagadish, K. S. (2001). Embodied Energy of common and alternative building materials and technologies.

Tetali,S. Assessment of Cool Roof Technology for its energy performace in buildings, (2011) IIIT Hyderabad

Chetia, S. (2012) Enviornmental Performance of Urban Form, SPA Delhi

Sustainable Design Manual (2004). New Delhi: TERI.

TERI & MNRE, Govt. of India (2010). GRIHA Manual. New Delhi: TERI.

Acknowledgements

The idea to have a booklet for hot-dry climate originated during a meeting between me and Spl. DG NR, CPWD based on the vision and approach of Hon'ble MOUD Shri Kamal Nath and Secretary Ministry of Urban Development Dr. Sudhir Krishna. The work on booklet was started by NZ-III, CPWD, Jaipur in June, 2012 when consultant DPAP got associated with CPWD.

We would like to thank the Hon'ble MOUD Cabinet Minister Shri Kamal Nath for agreeing to release this booklet so that concepts of Green Buildings benefit the common man in the hot-dry regions of country. We are also thankful to the Secretary, Ministry of Urban Development Dr. Sudhir Krishna for his vision, support and endorsement of the Booklet for its widespread usage across the country. We are thankful to Shri Ashok Khurana, Director General, CPWD for his keen interest in studying the contents of booklet, making contribution in a short span of time and ensuring its release from an appropriate forum so that the benefits of the booklet reach beyond CPWD.

We are thankful for endorsement and support received from Shri A.K.Jain, former Spl. DG (NR), Shri R.K. Singhal, Spl. DG (NR) and Shri Sudhir Kumar, ADG(NR-I).

We are also thankful to CPWD officers; Shri Kamalpreet Singh (Chief Architect), Shri P.K. Parmar (SE), Shri BL Meena (SE), Shri K.K. Agarwal (SE), Shri P.K. Gupta (EE) who closely interacted with S/Shri Deependra Prashad, Saswati Chetia and Arpan Mazumdar of DPAP and helped to bring out this booklet for use by not only professionals but also the common man.

Over and above thanks are due to all individuals and organisations who support the cause of green building construction. I wish that the book should reach the masses and fulfils the dream of building green across the country.

Mukund Joshi
Chief Engineer, NZ-III, CPWD