Research Paper Architecture

Explanation of Indian climatic zones and incorporation of passive architectural techniques in buildings

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ABSTRACT

Energy crisis is the major problem in the world due to depleting fossil fuel resources. Moreover the excessive use of fossil fuel is adversely affecting the environment. Therefore its a need to develop techniques to harvest more and more renewable energy to fulfil energy demand of the world. In commercial and residential buildings, main energy consumption is in heating, cooling and illumination. In other words, energy is mainly consumed in maintaining indoor comfort conditions. Nowadays architects are designing buildings, which give comfortable indoor condition with less energy consumption. This can be done by passive architectural techniques. In this paper basic principles of the passive solar architectures are presented. Basically, there are two techniques of the passive architectures, one is simple and the other one is advance. Simple technique is nothing but the factors, which need to be considered before constructing the building. In advance techniques additional features are added in the building to enhance the comfortable level. These techniques are also explained in this paper.

Keywords : Climates, Climatic factors & Passive architectural

1.Introduction:

Energy and architecture form a natural marriage if indoor comfort and respect for environment are secured. Although energy conservation is an important issue in present days but human thermal comfort is the primary concern in case of buildings. But energy conservation becomes a necessity rather than an option in both commercial and residential buildings without compromising the human thermal comfort. The use of day lighting and solar energy for heating and cooling as well as enhanced natural ventilation not only reduce the commercial energy demand but also minimize the negative impact on environment too.

Comfort condition depends on local climatic conditions. Incorporation of passive architectural techniques in buildings improve indoor comfort condition as well as minimize energy consumption.

Indian climatic zones are described in following chapter.

2. Indian Climates, Climatic factors & Passive architectural design concept:

Our country can be divided in 5 climatic zones. All climatic zones along with corresponding climatic values are narrated in table 1.

Design of the building depends on the climate and climatic factors. Following section describe the basic guidelines for designing the building in the different climate.

2.1. Design guidelines:

1.1 Hot and dry climate:

- Decreasing the exposed surface
- Increasing the thermal resistance
- Increasing shading
- Increasing the heat barriers
- Increasing ventilation
- Increasing air exchange rate from the cooler parts of the building
- Evaporative cooling

2.2 Warm and humid climate

- Decreasing exposed surface
- Increasing thermal resistance
- Increasing heat barrier
- Increasing shading
- Increasing ventilation
- Decreasing humidity level

Table 1 (Specification of different bio-climatic zones of India)

Specification of different bio-climatic zones of India

Climatic zones	Ambient temperature	Relative humidity	Rainfall
Hot and dry	Summer: 40-45 °C (day), 20-30 °C (night); winter: 5-25 °C (day), 0-10 °C (night)	25-40%	<500 mm
Warm and humid	Summer: 30-35 °C (day), 25-30 °C (night); winter: 25-30 °C (night)	70-90%	1200 mm
Moderate	Summer: 30-34 °C (day), 17-20 °C (night); winter: 22-25 °C (day), 06-08 °C (night)	20-55% (dry), 55-80% (wet)	Exceeds 1000 mm
Composite	Summer: 32-43 °C (day), 27-32 °C (night); winter: 10-25 °C (day), 4-10 °C (night)	20-25% (dry), 55-95% (wet)	500-1500 mm
Cold and cloudy	Summer: 20-30 °C (day), 17-27 °C (night); winter: 4-8 °C (day), 3-4 °C (night)	70-80%	1000 mm
Cold and sunny	Summer: 17-24 °C (day), 4-11 °C (night); winter: -7-8 °C (day), -14 to 0 °C (night)	10-50%	>200 mm

2.3 Moderate climate:

- Decreasing the exposed surface
- Increasing thermal resistance
- Increasing shading
- Increasing ventilation

2.4 Cold and cloudy and Cold and sunny climate:

- Increasing thermal capacity
- Reducing heat loss
- Decreasing air exchange rate
- Avoiding shading
- Gain maximum solar energy

There are simple and advance methods to achieve comfortable thermal conditions in the buildings. Simple methods are basically the factors which need to be consider before designing the buildings like site condition, building orientation, planform and building envelope. Simple technique is explained in the in the following section.

3. Simple Techniques:

Main principle of solar passive building is to collect, store, distribute and control the flow of thermal energy by the natural heat transfer principle. Flow of thermal energy is controlled by providing dampers, operable windows, moving insulation,

and shading devices.

There are basically two techniques of passive solar building: simple and advance techniques. Simple technique is described in the following section.

3.1 Simple Techniques:
Simple technique is the factors which need to be consider before designing the building to achieve comfortable indoor environment. Which are as follows,

1. Site condition
2. Building Orientation
3. Planform
4. Building envelope

3.1.1. Site condition
Careful selection of the site of the building can help to save considerable amount of the energy and provide comfortable condition through out the year. Site selection mainly depends on the macroclimate and microclimate. Macroclimate includes solar radiation, ambient temperature, air humidity, precipitation, wind and sky condition, which are already explained in the previous section. Whereas microclimate involve following factors:

1. Landform
2. Vegetation
3. Water bodies
4. Street width and orientation
5. Open spaces

3.1.1.1. Landform:
Land at the location may be flat, sloping and undulate. So depending on the climatic condition the building is to be constructed. If the land is flat than the temperature of the wind and velocity of the wind is almost uniform. But if the land is sloping towards north or south than building construction can be different than the flat land. If slope is towards south than building will receive good amount of the solar energy, but if slope is toward northward than building will receive less amount of solar energy. If the land is undulate, like having valleys, than the wind velocity and temperature vary at different places. As in the valley the air is heated and moves upward and cold air rush in the valley and so the temperature of valley drops.

3.1.1.2. Vegetation:
Location of the vegetation near or away form the building is also depends on the climate. In cold climate vegetation should grow away from the building as it reduces the amount of solar energy falling on the building. But in hot climate it should grow nearer to the building.

3.1.1.3. Water bodies:
Location of the building near the water bodies like lake, pond, sea etc. creates comfort and discomfort depending on the climate. In the hot and dry climate building is preferred to locate nearer to the water body, as water provides evaporating cooling and also increases the humidity. But if building is to be constructed in the humid climate than it is preferred to locate building away from the water body as by increasing humidity it creates discomfort.

3.1.1.4. Street width and orientation:
Street width in the hot climate should be such that the building should mutually cast the shadow on each other during the day, so as to reduce the heat gain by the building, where as reverse is true for the cold climate. For good ventilation street should be oriented parallel to the wind flow, and to restrict the flow of air street can be oriented at some angle or normal to the wind flow.

3.1.1.5. Open space:
Depending on the climate open space is covered with the grass or can be constructed with the good finishing surface to reduce or increase the heat gain by the building. In hot climate first case is true where as in cold climate second is true.

3.1.2 Building orientation:
Building orientation should be such that it should gain maximum solar energy in the winter and minimum in the summer. Best orientation of the building is to keep long axis of the building parallel to the east-

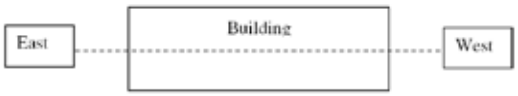


Figure 1

west so that large portion of the building is exposed to the sun in the winter in the northern hemisphere. Where as in the summer sun will move high in the sky and so small portion is exposed to the sun during the day.

3.1.3. Planform:
Planform affect the amount of solar energy received by the building and ventilation, it plays important role in heat gain or loss and in ventilation. When wind is obstructed than it creates pressure difference, and so proper connection between low pressure side and high pressure side should be provided for the good ventilation. The surface to volume ration determines the magnitude of the heat gain or loss, higher the ration higher will be the gain and loss. So I cold climate this ration is kept small.

3.1.4. Building envelope:
Building envelope plays important role in the heat gain or loss by the building, they are as following;

1. Roof
2. Walls
3. Fenestration (opening)
4. External colour and texture
5. Shading

3.1.4.1. Roof:
As roof gain significant amount of solar energy during the day. So it can be constructed with heavy RCC or with thin sheets depending on the climate. With thick roof it delay the transmission of the heat whereas thin sheet increase the heat gain by the building.

3.1.4.2. Wall:
Wall gains large amount of solar energy during the day. It is estimated that 25% of total heat is gain by the load. So wall can be made thick or thin. Thick wall delay the transmission of the solar energy. Also in hot climate wall can be made form the material which has low heat transfer coefficient.

3.1.4.3. Fenestration:
Proper placing of the windows and opening also provide comfort condition. It controls the heat gain by the building, provide ventilation and also admit daylight. But proper location plays important role in comfort condition, as during designing of the window it should keep in mind that hot air will rise and so the location of window should be at a proper height. Glazing of the windows also plays an important role, like by applying high reflective gazing on the window it will admit less amount of light in the building and reduce heat gain by the building.

3.1.4.4. External colour and texture:
External colour and texture also plays an important role to reduce or to increase heat gain by the building. With good surface finish and white colour reflects more and so reduce the heat gain by the building, and rough texture provides self shading. Whereas dark colour increase the heat gain.

3.1.4.5. Shading:
By providing the shading on the wall and to the windows significant amount of heat gain can be reduced.

In advance technique special construction is done in the building to enhance the thermal comfortable condition. This method is explained in the following sections.

4. Advance Techniques:
In advance techniques some external features and some additional construction is provided for comfortable indoor environment. These techniques are described here.

4.1. Direct gain:
This method is generally used in the cold climate. This technique is cheap and has direct approach to the solar energy. In this technique sun light is directly admitted in the living place and walls and floor is constructed in such a way that it provide appropriate amount of thermal mass.

Figure.2 Direct heat gain technique

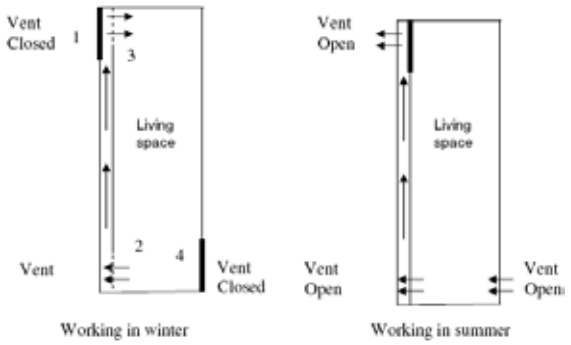
(www.nesea.org)

In this method south facing glazed windows are placed to admit sun light and solar energy is absorbed by the walls and floor which provides thermal storage. And at night this heat is librated by the thermal mass and keeps living space warm. Direct gain can be achieved by different forms like by constructing clerestories, skylights, green house. In summer to provide comfortable condition proper shading devices and insulations are applied to the glazing to reduce the heat gain. Colour of the internal walls and floor also affect the heat gain by the building. For distributing light, lighter shades are preferred. Thus the storage surface should be of medium-dark colour, whereas lightweight material should have light colour to reflect sunlight on the walls and floor. In this technique fluctuation of indoor temperature is very high.

4.2. Thermal storage wall:
In this method thermal wall is placed between the living area and glazing which prevent the sun light to directly entering into the living place. This approach is generally used in the cold climate. There are many ways to construct walls which are as follows:

1. Trombe wall
2. Water wall
3. Trans wall

4.2.1. Trombe wall:
In this method glazing is applied on the out side of the wall. As the sun rays admit from the glazing it heat the air and warm air starts moving upward and cold air enters the space between wall and glazing. In winter vent 1 and vent 4 are kept closed and vent 3 and 2 are kept open which is shown in the figure 4.2



As the air between wall and glazing heats up, it starts moving upward and it enters into the living space. This process continues in the night as wall is warmer than the air. Whereas in summer vent 1, 2, and 4 are kept open. As the air between glazing and wall heats up it starts moving upward and it is discharged into atmosphere from vent 1 and so fresh air drawn in to the living space from the windows and opening. So by this way ventilation and cooling can be done in summer. To reduce the heat transfer from the glazing to outside, insulation is applied outside to the glazing in the winter at the night time.

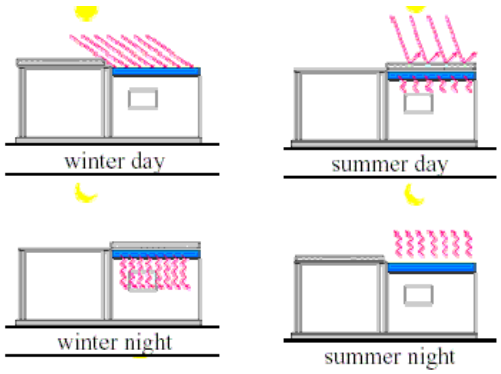
4.2.2. Water wall:
In this method water drums are placed behind the glazing and water is used as a thermal storage. As water has high specific heat it can store large amount of heat, and also in water, temperature distribution is uniform. Heat transfer is also fast in water wall so temperature control is needed and also some times vents are provided to maintain the temperature of living space. Water wall needs less area of wall per square foot of space as compared to the masonry wall. Temperature fluctuation in case of water wall is also less as compared to the masonry wall.

4.2.3. Transwall:
This wall incorporates the features of both the direct gain and trombe wall. Transwall is semitransparent which admit some portion of the solar rays and which provides heating and illuminating the living space. Whereas, some portion of solar energy is stored in the wall and which is transferred latter, which is used in the night.

4.3 Specially added features:
Apart from the thermal wall and direct gain methods, there are some constructions which are constructed into the buildings to enhance the indoor environment, which are described in the following section.

4.3.1. Roof pond:
Roof pond is constructed on the roof which collects the solar energy and stores it in the form of heat in the water, which is filled into roof pond. Roof pond can be constructed, or separate tank is placed on the roof, which consist glazing on the top of it and which consist movable insulation.

Figure 4.3 Roof Pond (www.solarmirror.com)



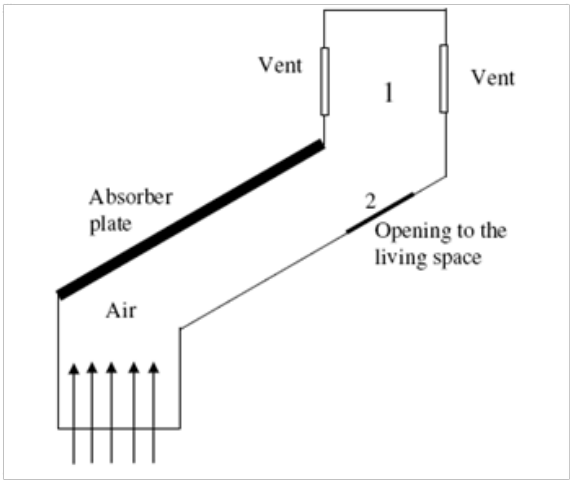
In summer, during day time this insulation covers the glazing whereas in night it is removed and so cooling of water provides cooling effect in the room. In addition to this, water is also sprinkled on the roof to provide evaporating cooling. In winter as the water in the pond heats up during the day this heat is conducted from the roof and which heats up the air in the living space and provide comfortable condition in the winter. And during the night insulation is kept on the glazing of the roof pond to reduce the heat transfer.

4.3.2. Green house:
In the building, green house can be constructed in such a way that green house and living space can have one common wall. By this way green house can be used to grow vegetation in the cold climate and also it can be used as a solar collector and storage. As sun rays fall on the green house common

wall which separates the living space and green house absorb the solar energy which is conducted in the living space. Common wall can be masonry or water wall. If water wall is used then temperature fluctuation of the living space is small as compared to the masonry wall. To increase thermal load water filled container can also be placed in the green house. Thermal storage can also be constructed by means of active rock storage system. In this system warm air is allow to pass through the rock bed which is constructed below the floor or the rock filled wall, which stores the heat and at night it is utilized for heating indoor cool air.

4.3.3. Solar chimney:
This is the new approach to incorporate chimney type construction in the building, which acts as a thermal storage in the building. Solar chimney basically is the construction which is incorporated in the roof of the building, which has one absorber plate which absorbs the solar energy, which is south facing in northern hemisphere and while passing from the solar chimney air gets heated and then it is supplied to the living space by opening the vent 2 . Whereas in summer vent 2 is kept closed and vent 1 of solar chimney is kept open which is shown in the figure 4.4 Figure 4.4solar chimney

So as the air gain heat form the absorber plate it starts moving upward and it goes in to the atmosphere form vent 1 and air enters in the living space from the windows and openings and by this way good ventilation can be provided.



4.3.4. Isolated gain:
In this system solar radiation collection system and storage system is isolated form the living space

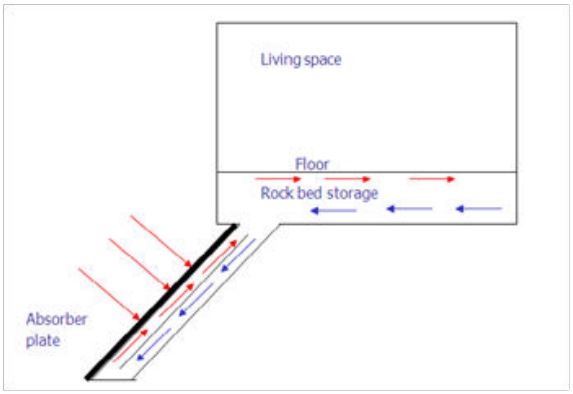


Figure 4.5 Isolated heat gain

It gives great flexibility in construction of the building. And so building orientation can be independent of the solar collecting system. The collecting area required is generally 40% to 60% of total floor area of living space. In this system solar radiation heats up the air or water which is circulated in to the collector system and as it gets warm up it moves up and gives heat to the rock storage and cool water or air comes in to the collector. So by thermo siphoning effect flow takes place in this system.

4.3.5. Wind tower:
Wind tower is generally used in hot and dry climate for cooling purpose, only the requirement is that site should experience good wind flow. Wind tower is a hollow tower type construction in the building which has opening at the top of the tower. During the day time as the wind tower is heated due to the solar radiation, air also gets heated up and it starts moving up. Due to this, from the windows and ventilation opening air comes into the living space and by this way good ventilation can be provided. During the night as tower gets cool down, air also gets cool down and sinks into the living space. By this way cooling effect can be produce. To enhance the cooling effect during the day time, water sprinkler is kept which humidifies the air as well as it also cools the incoming air. And this air is sinks in to the living space and provides cooling.

4.3.6. Earth wind tunnel:
In this technique, wind tower is attached with the underground tunnel. Openings are provided in to the living space for the air flow. This is generally used in the hot and dry climate for cooling purpose. Below few meters in the earth, the temperature is almost constant, in summer temperature is below the ambient temperature and in winter it is above the ambient temperature. So in winter air while passing through the tunnel, gains heat and which heats up the living space. Whereas, in summer air gets cool down while passing through the tunnel and which provide cooling of the living space. Some times instead of the tunnel pipes are buried in the ground. Also by sprinkling water on the ground and by shading it by growing vegetation temperature of tunnel can also be reduced, which in turn enhance the cooling effect.

These methods are used only when the new building is to be constructed, but there are certain techniques which can be used for the existing buildings. These techniques are discussed in the following section.

5. Retrofitting in the building:
In the existing building, very simply passive solar retrofit could involve without spending much money. Retrofitting is basically the method in which people can make their own decision for the retrofitting, and can bring their own ideas for the retrofitting. It depends on the climate, which is explained in the following section.

5.1. Cold climate:
In the cold climate, main aim is to increase the solar gain, and reduce the heat loss from the building, so in the existing building some arrangement is done to achieve the same. Some methods are as following:

1. To reduce the heat loss from the building, some insulation is provided at the outer surface of the wall.
2. At night heat is lost by the windows, so insulation or shutter is provided for the windows. Shutters are generally placed at the inside surface of the window.
3. To increase solar gain reflectors are placed out side to the windows.
4. Some times reflectors are placed outside the windows on the shady side of the building to increase the solar gain.
5. With a little work, an electric motor can be attached to a reflector to make it rotate incrementally throughout the day allowing a steady beam of light to enter a given window.
6. Some times water filled bottles are placed next to the windows (in side the livings space) to make use of solar gain by it. As sunlight strikes the wall, heat is stored in the water which is then slowly radiated outward.
7. In Australia it is general practice to fit sun lizard, which works on the thermosiphon principle. It mainly consists of black painted absorber surface and glazing on the absorber plate. And it is well insulated from the other sides. It is generally fitted to the south side. As the air gets heat-

ed due to the absorber plate, it starts moving upward and this air is supplied in the living space and cold air form the living space enters in to it. So main principle is just like trombe wall.
8. Green house can also be retrofitted in to the existing house.

5.2. Hot climate:
In hot climate, main aim is to reduce the heat gain. Some methods of retrofitting to reduce heat gain are discussed below:

1. To reduce solar gain during day time reflectors can be placed out side the window glazing, and during night time it can be removed.
2. Roof pond can also be constructed for the cooling in the hot climate.
3. Some times along with roof pond, water sprinkler is also used to spray the water on the roof for providing evaporating cooling.
4. To reduce solar gain internal curtains are also used for the window.
5. To reduce solar heat gain, shading devices are used. These devices are such that its length can be varied as per the sun's motion during the day.
6. Surface of the roof or terrace is so constructed that it reflects the sun rays which falls on it. Sometime roof is painted with white colour.
7. Conduction of the heat is also depends on the colour and texture of the exterior surface. The closer to white colour, and the smoother and shinier, the more reflective the surface and the cooler the building will be.

6. Conclusion:
This paper explains different climatic conditions of India & passive architectural techniques. Explained passive architectural techniques can be used in building, depending on location, at conceptual stage to minimize energy consumption. Individual technique's detail analysis can be done to optimise building construction with respect to climatic zone.

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