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# Design Requirements for Energy Efficient Buildings and their Effectiveness

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## Abstract

India is one of the fast-developing nations and it's energy consumption in building sector is expected to increase by an average of 2.7% per year between 2015 and 2040. Buildings in India are constantly exposed to solar radiation. Buildings built by using passive cooling approaches can drastically reduce the demand of heating, cooling, and lighting energy required for conditioning the buildings. The energy conservation is motivating the architects to rethink the way buildings are designed and take into consideration such factors as control of building costs, efficient use of space, energy consumption, and health and comfort of building occupants A study was conducted to analyze the most popular passive cooling design techniques employed by architects in design of small buildings in the hot arid region of the Indian sub-continent in order to minimize the use of non-renewable energy resources. The most widely used measures for energy conservation are proper orientation, incorporation of terraces and skylights. The study revealed that with a strong inclination towards the issue of energy conservation and motivation for making more sustainable buildings these measures can be incorporated cost effectively into the design of the buildings.

## Keywords

Design Techniques, Energy Efficient, Sustainable, Buildings, Conservation

## 1. Introduction

Climatic conditions have a strong bearing on the usage of energy in buildings. The demands for energy in a building are primarily for space cooling, heating, lighting, and refrigeration. Significant energy savings can be achieved by designing the building to minimize heat gain indoors and maximizing evaporative cooling. The climatic sensitive and energy-efficient design facilitates the users of these spaces to have adequate thermal comfort, and consequently makes less demand for active energy. In India in 2015, buildings energy consumption represented about 14% of total delivered energy consumption (U.S. Energy Information Administration 2017). The energy consumption for buildings in India is expected to increase by an average of 2.7% per year between 2015 and 2040, more than twice the global average increase (U.S. Energy Information Administration (2017).

Buildings in India are constantly exposed to solar radiation. The demands for energy in the building in this part of the world are primarily for space cooling, heating, lighting, and refrigeration. Hence, building design should aim at minimizing heat gain indoors and maximizing evaporative cooling so that the occupants of these spaces can have adequate thermal comfort, and consequently make less demand for active energy. The effective use of solar energy and various other energy conservation measures can drastically reduce the demand of heating, cooling, and lighting energy required for conditioning the buildings. Energy conservation can be seen as a tangible resource that competes economically with contemporary energy supply options. Energy conservation in buildings can be described as the process and measures that are undertaken to reduce the consumption of energy in buildings through changing the users' behaviors, improving operations and maintenance (Fakhar et al., 2023; Cottone et al., 2015). Passive cooling design approaches have a significant impact on energy conservation. Through passive cooling design approaches buildings can be designed to adapt to local environment conditions and to use natural elements to provide the required thermal comfort to the occupants.

The paper discusses the study conducted to analyze the most popular passive cooling design techniques employed by architects in the design in the hot arid region of the Indian sub-continent in order to minimize the use of non-renewable. The study is related to small buildings in the hot arid region of the Indian sub-continent, where achieving thermal comfort indoor is of prime importance.

## 2. Literature Review

The initial literature survey led to short listing of design approaches based on material use and practices as the most frequently adopted methods by the architects in the small buildings to improve their energy efficiency and life cycle costs. Further studies of the buildings, which were designed for increased energy efficiency revealed that design methods were rated on the incidence of their use and output.

The internal thermal environment within the building results from the response of the building fabric to the changing outdoor conditions of air temperature, solar radiation, humidity, precipitation or evaporation, wind velocity and direction and the clearness of sky (Lin et al. 2023). In hot climates the interception, absorption, and inward transmission of solar radiation can be reduced to minimize the cooling load demand.

The first step in designing passive cooling system is to reduce unnecessary thermal loads in a building. There are usually two types of thermal loads (i) External loads due to climate (ii) Internal loads due to people, appliances, cooking, lighting etc.(Givoni, 1992) Proper zoning of different components and local ventilation of major heat sources can reduce the overall impact of internally generated heat loads. The three major ways thermal loads enter a building are (i) Penetration of direct beam sunlight (ii) Conduction of heat through walls, roof and (iii) Infiltration of outside air (Freewan, 2019).

The thermal gain that occurs through any of the above ways can be reduced by (i) minimization of direct beam sunlight and (ii) conduction of heat through walls/roofs.

Minimization of direct beam sunlight: the entry of direct solar radiation can be controlled through use of vertical, horizontal, and inclined louvers, movable screens, deciduous trees and plants. Additionally, orientation of walls with glazed areas provided in only those portions where effective shading from sun is given.

Conduction of heat through walls/roofs: the conduction of heat into the building through roof/walls is directly proportional to the temperature difference between the outside surface and inside surface. To minimize the conducted heat, the outside surface temperature needs to be minimized. One of the methods for reducing temperature differential is to minimize absorbed radiation (Prieto et al., 2018; Freewan, 2019; Santamouris, 2016). Various methods involved are:

*Shading:* surface shading as part of the building element or as a separate cover, highly textured walls, roof cover of galvanized iron sheets or deciduous plants or creepers, inverted earthen pots and canvas covers.

*Paints:* painting external surfaces of the building with colors that have minimum absorption of solar radiation.

*Evaporative cooling:* methods have been used in places where water is not scarce. Traditionally courtyard fountains and indoor pools have been used to bring down temperatures. Water as a cooler is the simplest strategy working on this principle being used to produce comfortable conditions. But the major problem with this system is minimum efficiency.

*Radiative cooling*: this method involves surfaces that enhance radiative cooling effect.

*Insulation and Cavity walls*: insulating the various building components can decrease amount of heat coming into the building. Cavities also act as good insulators and inhibit the inward transmission of the heat from the component.

*Exploitation of wind, water and earth for cooling*: a characteristic system for cooling with this system is the wind tower.

*Cavity walls/ Vary Therm wall*: the external wall component in this system is made of light material while the internal component is the usual brick or concrete.

*Earth sheltered or earth bermed structures*: this technique involves covering the roof structure under grass and foliage. This helps to block the transmission of heat from or into the building and thus helping to maintain a constant temperature.

*Ventilation*: removal of heat flux. Ventilation is an integral part of vernacular architecture. Air movement relieves heat stress imposed on the human body by humid conditions.

*Photovoltaic panels*: these are silicon panels that convert solar radiations to electricity for domestic needs.

*Building Automation systems*: these are electronic systems that control the cooling in the building and avoid unnecessary load on air conditioning when parts of the building are unoccupied.

**3. Methodology, Data Collection and Analysis**

**3. 1 Methodology and Data Collection**

This study was conducted to identify the most popular techniques used by architects to achieve energy-efficient designs. The study is related to small buildings in the hot arid region of the Indian sub-continent, where achieving thermal comfort indoor is of prime importance.

An exhaustive list of energy efficient buildings in the hot dry regions of northern India was made. These buildings were studied in terms of the design approach followed by the architect to incorporate energy saving means/ devices/ materials.

The key elements of climate, which affect human comfort, and use of buildings are (i) Temperature (ii) Humidity (iii) Precipitation (iv) Sky conditions (v) Solar radiation and (vi) Wind velocity. The climatic data of a typical city in the hot arid region of the Indian sub-continent is represented graphically below (see Fig. 1- 6).

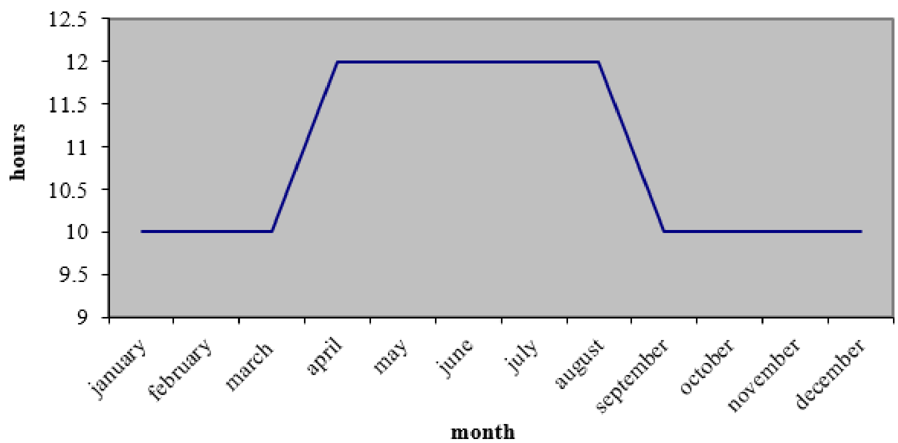


**Fig. 1.** Sunshine hours

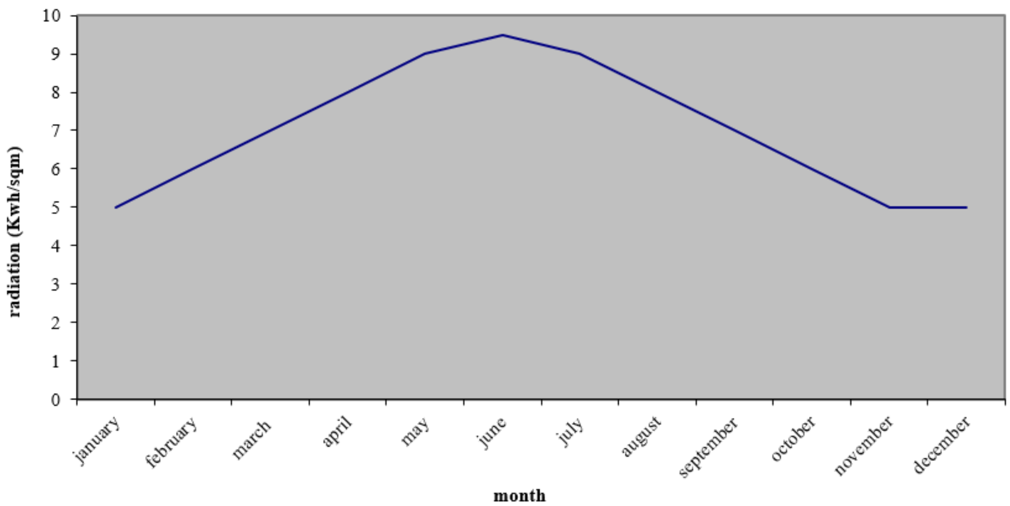


**Fig. 2.** Mean solar radiation (Kwh/sq. m)

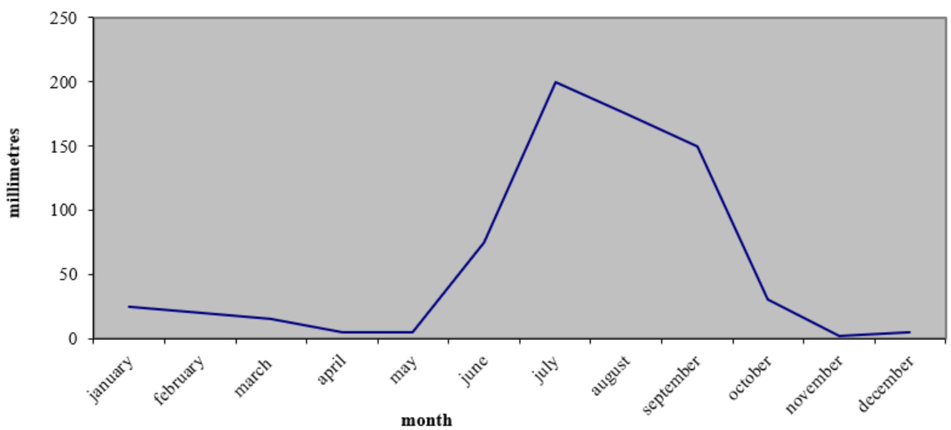


**Fig. 3.** Rainfall

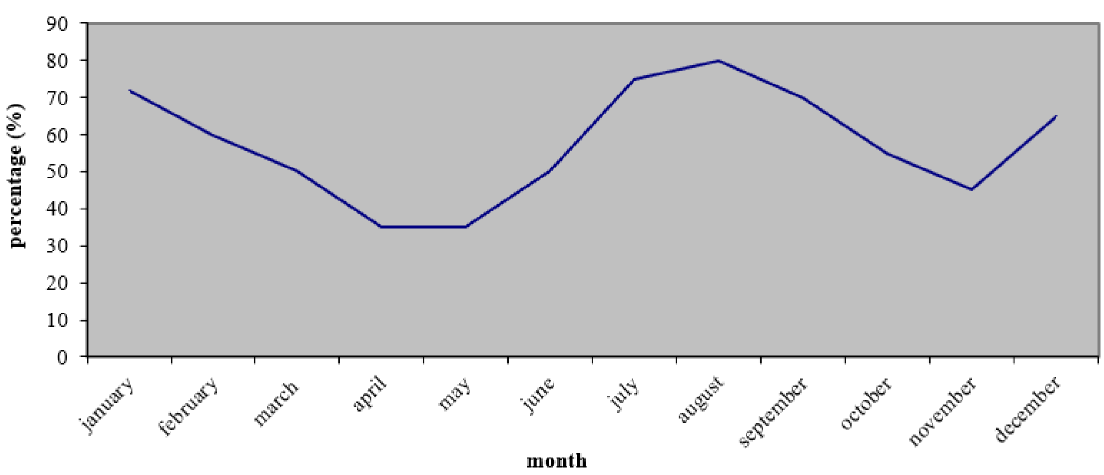


**Fig. 4.** Relative humidity

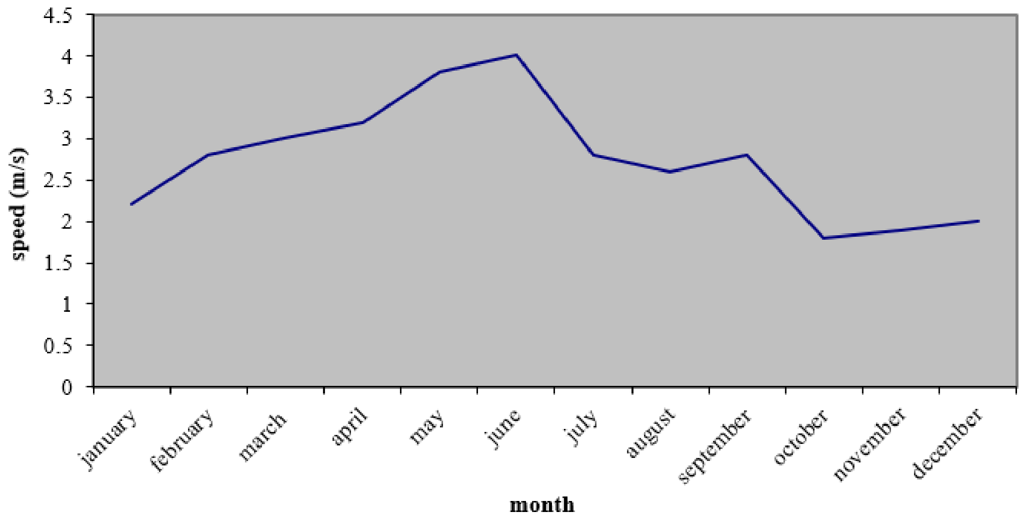


**Fig. 5.** Wind speed

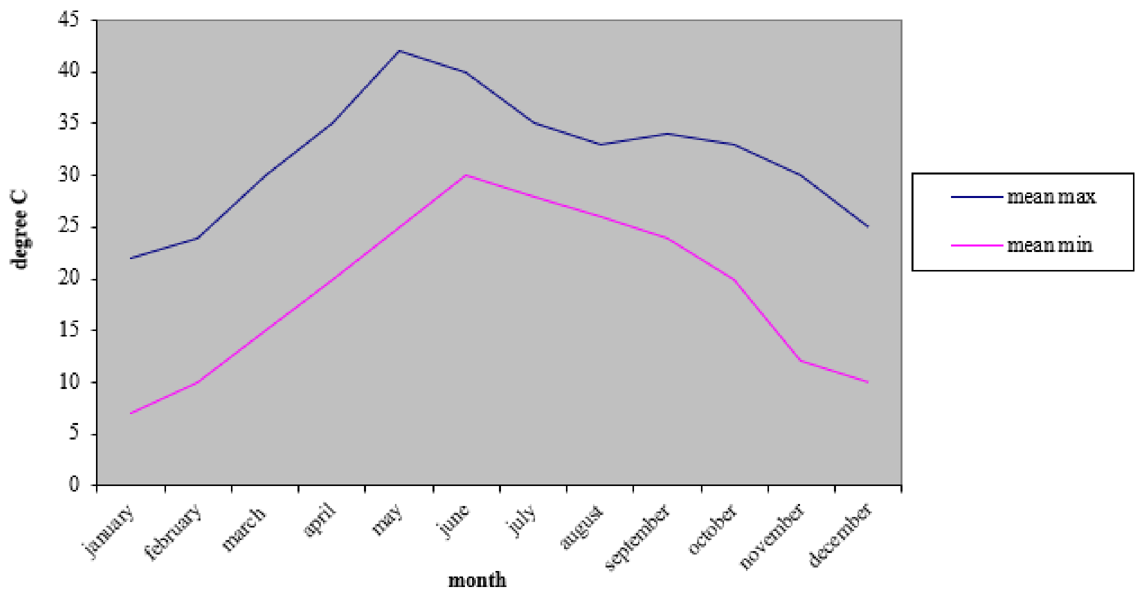


**Fig. 6.** Temperature

### 3.2 Data Analysis

The results are tabulated to determine the most widely used and efficient methods implemented to achieve sustainable designs. Table -1 and Figure 1 shows energy saving measures used in buildings and number of projects using these techniques.

**Table 1.** Analysis of the results

| Sl. No. | Energy saving measures used in the buildings | Use of these techniques | | |
|---|---|---|---|---|
| | | No. of projects using | Percentage of use (%) | Mean /normal values |
| 1 | Orientation | 15 | 40.5 | 11 |
| 2 | Appropriate zoning | 11 | 29.7 | 8 |
| 3 | Location of doors/windows | 6 | 16.2 | 4 |
| 4 | Double glazing in windows | 5 | 13.5 | 4 |
| 5 | Photo-voltaic panels | 6 | 16.2 | 4 |
| 6 | Energy-efficient lighting systems with daylight controls | 8 | 21.6 | 6 |
| 7 | Insulated cavity walls | 14 | 37.8 | 11 |
| 8 | Energy intensive material use | 14 | 37.8 | 11 |
| 9 | Shading devices | 7 | 18.9 | 5 |
| 10 | Incorporating terraces and skylights courtyards etc. as design elements | 16 | 43.2 | 12 |
| 11 | Evaporative cooling | 6 | 16.2 | 4 |
| 12 | Waste water management | 5 | 13.5 | 4 |
| 13 | Varied roof design | 9 | 24.3 | 7 |
| 14 | Building automation system | 5 | 13.5 | 4 |
| 15 | Other specific system (Ventilation) | 5 | 13.5 | 4 |

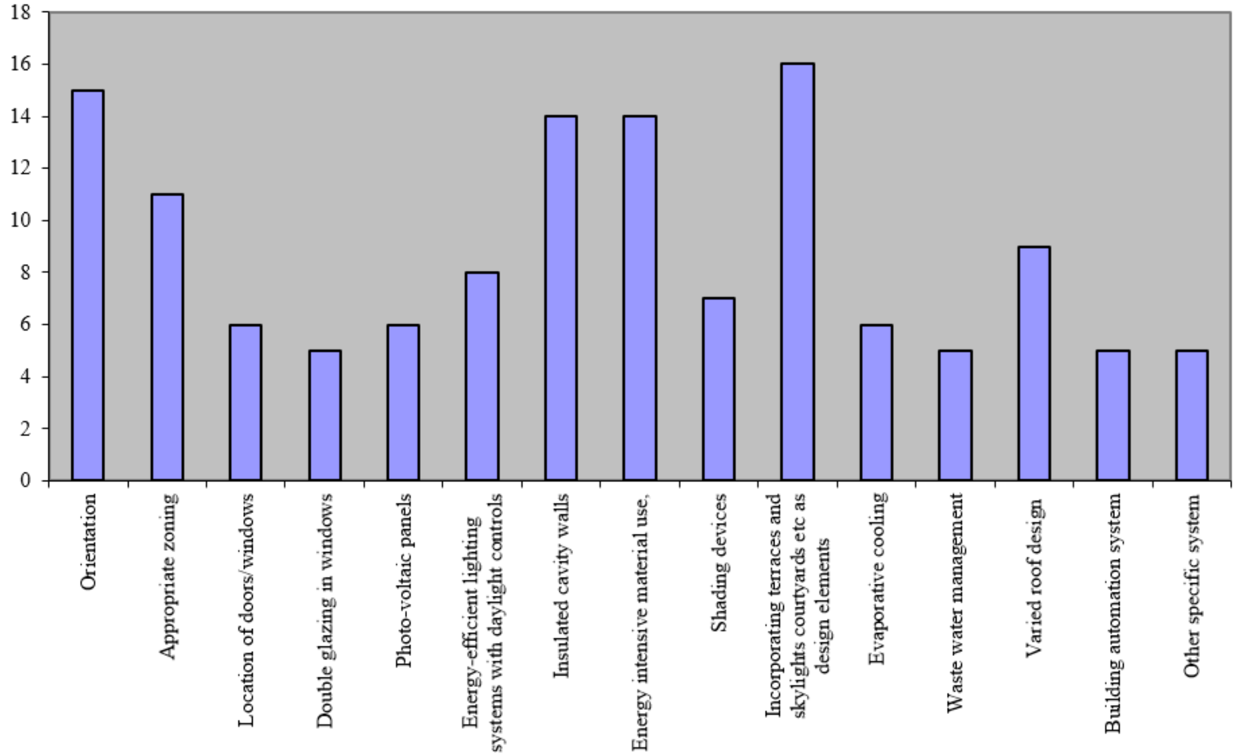


**Fig. 7.** Energy saving measures used in the buildings.

## 4. Conclusion & Recommendations

### 4. 1 Conclusion

It is clear from the above figures , the most used methods for energy conservation are proper orientation, incorporation of terraces, skylights etc. and energy intensive material use. These techniques are easy to incorporate with design and prove to be more effective in the long run. Also, after personal interviews with architects it was revealed that these measures do not add to the construction cost when compared to the conventional methods of building. All that is required is a strong inclination towards the issue of energy conservation and motivation for making more sustainable buildings.

From the results it is concluded that in today's scenario it is advisable for architects to give strong consideration to the most used design methods. The following measures are recommended to promote energy efficiency and more sustainable practices for the building industry.

- Comprehensive energy audits for identification of energy saving audits and evaluation.
- Mandatory energy audit services
- Energy management techniques
- Project appraisal for incorporation of energy efficiency parameters
- Water consumption audit and optimization techniques
- Evaluation of economically viable alternatives for energy efficiency
- Specification of energy efficient and more cost effective finishes and equipment
- Training programs to conduct energy audits, their implementation methodologies
- Education and awareness programs for design professionals

### 4. 2 Recommendations for future studies

A simulation study of energy consumption comparisons between two identical buildings with and without energy efficient design, could be carried out to determine the cost effectiveness on a lifecycle basis. Such studies would promote more sustainable buildings.

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