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ENERGY-EFFICIENT RESIDENTIAL BUNGALOW USING PASSIVE COOLING STRATEGIES IN HOT AND DRY REGION: A CASE OF SOLAPUR CITY.

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Abstract: This paper will present various passive cooling strategies suitable for hot and dry regions. Buildings as they are constructed presently use a huge energy resource and other nonrenewable natural resources, with devastating negative environmental effects. It can be seen that 29% of the overall energy is used by the building out of which 20% by residents and 9% by commercial. A hypothetical model will be developed with climate consideration of Solapur city and the implication of passive cooling strategies at the site, building, and component levels. This research aims to see how effective it is to implement chosen climate-responsive technologies to increase energy efficiency and minimize power utilization in individual dwellings in hot and dry climates. The key results of this research have been described and suggested solution from the studies based on the limits of this research has been presented. Hypothetical studies have suggested that using all of the mentioned strategies in buildings can reduce mechanical cooling demand by up to 50% - 70%.

Key Words - Energy Efficient, Passive Cooling Strategies, Hot and Dry Climate, Residential Bungalow, and Thermal comfort.

I. INTRODUCTION

Passive cooling makes use of free, renewable energy sources such as the sun and wind to supply cooling, ventilation, and lighting for a building. This also eliminates the necessity to make use of an artificial cooling system. Using passive cooling implies minimizing temperature differences between outside and inside. Enhancing indoor air performance and making the structure more energy efficient better and more pleasant living or working environment. It will also minimize energy consumption and environmental implications including greenhouse gas emissions. Passive design for cooling or heating has grown in popularity recently, especially in the last decade, as part of a drive toward the sustainable building. In the summer, well-designed buildings optimize airflow and keep the sun away. (1)

It is seen that one-third of the world's energy is consumed by the building out of which 60% is through air conditioning systems. The building sector consumes a large amount of energy to provide thermal comfort to its occupants in India. It can be seen that 29% of the overall energy is used by the building out of which 20% by residents and 9% by commercial. (2)

II. RELEVANCE

The energy-efficient climate response study has been done broadly at the Worldwide level but lagging in developing countries like India. The energy usage pattern may be studied considerably decreased by implementing energy-saving techniques, notably during the project's design stage. When cost-effective insulation solutions were coupled to the building exterior, the space heating stack could be reduced by nearly half.

III. AIM

This research aims at developing an energy-efficient model using passive cooling strategies for a residential bungalow with respect to hot and dry regions, the case of Solapur city.

IV. OBJECTIVES

1) To study passive cooling strategies of hot and dry regions.
2) To study the climatic condition of Solapur city.
3) To develop a hypothetical model
4) To achieve thermal comfort in indoor spaces by reducing mechanical cooling energy with passive cooling strategies.

V. RESEARCH METHODOLOGY

1) The method adopted for the study is exploratory.
2) Background study and problem statement
3) Both qualitative and quantitative methodology tools have been used for the analysis of collected data.
4) Site selection and analysis
5) A hypothetical model has been proposed in Solapur city which has hot and dry climatic conditions. Strategies have been applied at the site, building, and component level for this base case model which impacts in energy efficiency and thermal comfort indoors.
6) Conclusion and recommendation

3.1 The Climate of Solapur City

Solapur city falls in a Hot & Arid climate. The temperature is too high in this region. Hence simple techniques are adequate to take care of the heating and cooling requirements of the building. In summer, the maximum ambient temperatures are as high as 40–45 ºC during the day and 20–30 ºC at night. In winter, the values are between 5 and 25 ºC during the day and 0 to 10 ºCat night. The climate is described as dry because the relative humidity is generally very low, ranging from 25 to 40 % due to low vegetation and surface water bodies. The night is usually cool and pleasant. As the sky is clear at night, the heat absorbed by the ground during the day is quickly dissipated to the atmosphere. Hence, the air is much cooler at night than during the day. (3)

3.2 Model- for Solapur city :

The proposed model is located in Solapur City. A hypothetical model of two-storey residential unit located in the developed region of Solapurcity has been selected as a case study for this research.
The total plot area of the selected residential unit is 812.0 sq.m with a built-up area of 224.2 sq.m that has spread over 2 floors with a height of 3.15m each. The ground floor consists of a formal and informal living room, kitchen with access to store and utility, pooja room, dining, guest room with attached bathroom, common toilet, and courtyard in addition to water body and garden. Thefirst floor consists of a master bedroom with an attached toilet, a children's bedroom, and a lounge area with a balcony and bar.

Figure 1 Site Location

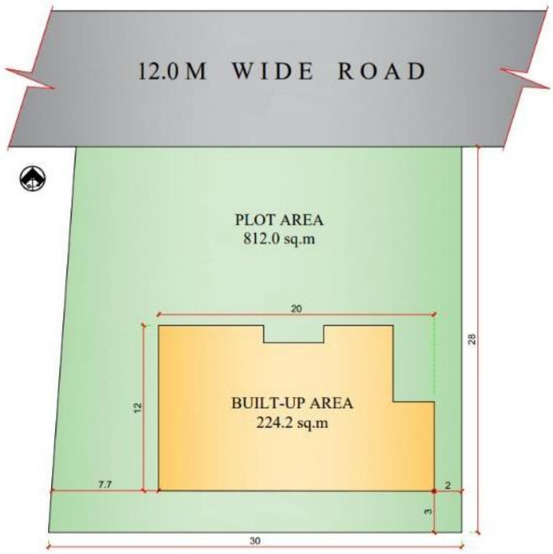

Figure 2 Plot and Built-up Area

Figure 3 Ground Floor Layout

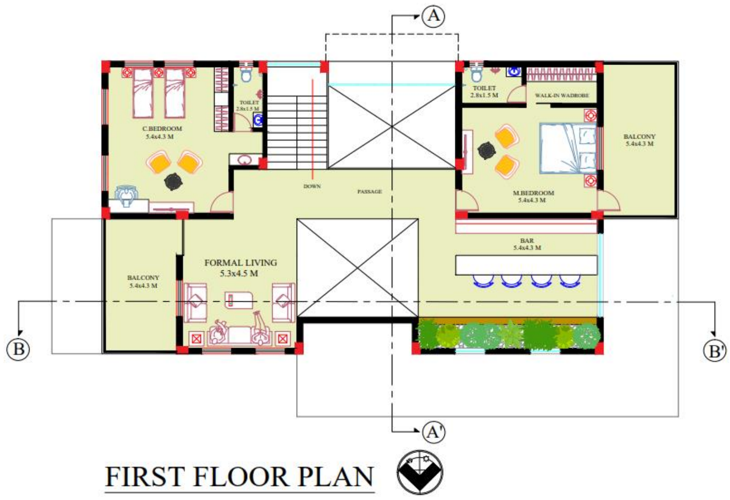

Figure 4 First Floor Layout

IV. RESULTS AND DISCUSSION

A hypothetical model has been developed while considering the sun path diagram also all passive cooling strategies have been incorporated at the site, building, and component levels. Based on case studies and research studies such type of prototype model has been proposed forSolapur region.

Following are the tools which are beneficial in developing the model have been explained briefly.

4.1 Site Level

The focus is on site-specific conditions which have been taken under consideration for the proper designing and development of the model. Tools needed at the site level aremicroclimate consideration, orientation, vegetation, and evaporative cooling.

a) **Microclimate:** Under microclimate, we have studied the local climatic conditions which impact the surrounding parameters.

b) **Orientation:** At the very initial stage orientation has been taken into the picture it has a hugeimpact on indoor thermal comfort. The model has been orientated in such a way that the longest wall faces north-south as it is preferable to achieve north daylight and only the short wall faces east-west as it receives maximum solar radiation during summer.

c) **Vegetation:** In the site surroundings, vegetation and landscaping have been done properly with consideration of the local climate. Deciduous trees are planted to shade the east-westwalls it helps in blocking hot wind in summer and in winter drops the leaves by which solaraccess can be achieved. On the other hand, vines have been used on pergolas to shade the south activity. Vegetation and landscaping have helped in reducing surrounding air temperature by 5 °C.

d) **Evaporative Cooling:** The water body is adjacent to the building’s exterior face and has been designed in a northwest direction. As the summer winds are from the north-west directionin which the air over the land is hotter and rises up to avoid this hot air to flow into the indoor water body and fountain has been placed over there which helps in purifying air when comes in contact with water adds moisture to the air and cool air flows indoors. During the night-time, the process is in reverse. (4)

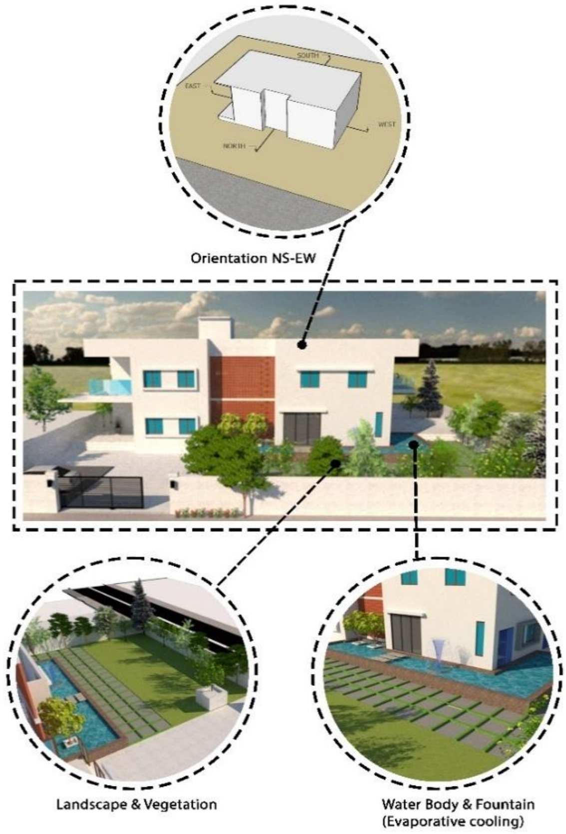

Figure 5 Site Level Strategies

4.2 Building Level

At the building level tools used to achieve thermal comfort are courtyard, double height ceiling, cross ventilation, shading devices, etc.

a) **Courtyard:** Courtyard content is established from ancient times in traditional vernacular architectural style. The courtyard is the best example of natural light, ventilation, heating, and cooling system. The model courtyard has been designed with a mechanically operatingpergola and one of the walls is designed with terracotta block to achieve north light and fresh cool air to flow in also aesthetically appealing.

b) **Cross Ventilation:** In every room of the model window has been positioned in such a way that cross ventilation is achieved. The function of cross ventilation is from one of the windows opening the fresh air enters the room and from another window opening hot air escapes.

c) **Double height ceiling (Skylight):** Sunlight is achieved through a double height ceiling for the dining area. Double height distributor which means fresh air can be distributed allover the building.

d) **Solar PV Panel:** Installation of a Solar PV panel is beneficial in natural water heating through solar radiation and also fulfills energy supply to the entire building and site surroundings. This is very much beneficial in saving excess use of energy consumption. (5)

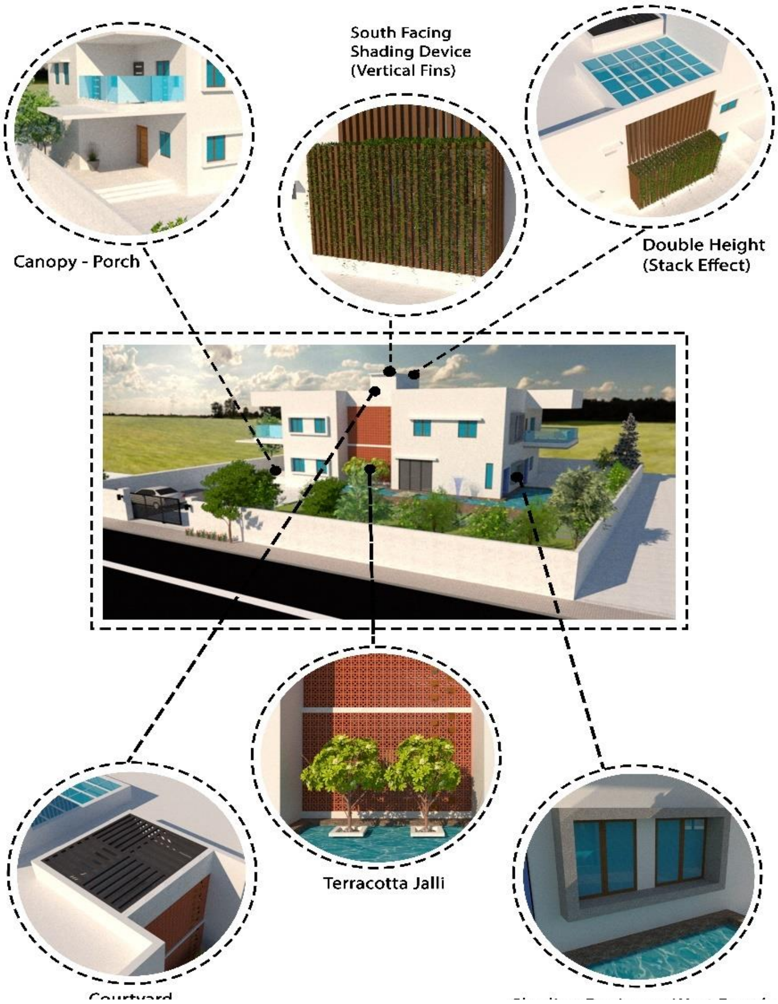

Figure 6 Building Level Strategies

4.3 Component Level

This factor plays a very important role in model formation from the above two factors i.e. site and building level. Under the component level, we will study the wall, roof, window, paint, flooring, etc.

a) **Walls:** The material used for wall insulation is AAC blocks 200 mm thick with 15mm plaster on both sides with a U-value of 0.77 W/m²K. It has thermal insulation properties with this we can achieve thermal comfort.

b) **Roof:** First-floor roof has been designed to remain cooler indoors by achievingthermal comfort and escape from direct solar radiation. The terrace has been painted whitewith a double coating of lime as Cool roofs are able to maintain a temperature differential of 6-8 °C between ambient and indoor air temperature due to high thermal emittance and solarreflectance.

c) **Window:** The window has been positioned to achieve daylight and proper cross ventilation through it. It is composed of double glazing with a gap filled with Argon gas having a U-value of 0.21, R-value of 4.76 and SHGC is 62% of solar heat transmitted and VLT is 77%

d) **Paint:** Light color double coat painting with high reflection

e) **Flooring:** Kota Stone is used in site surrounding and is a locally available material

f) **Solar Shading Devices:** On southern facade pergolas with overhang, shrubs have been incorporated to achieve shading through it. It also acts as a semi-open outdoor area. (6)

VI. Conclusion

From the above study, it is observed that passive cooling strategies are significantly important. Various techniques can be adopted to reduce the use of artificial means of energy. Only those strategies have been studied and applied which are applicable to the hot and dry climate of Solapur city. Hypothetical studies have suggested that using all of the mentioned strategies in buildings can reduce mechanical cooling demand by up to 50% - 70%. It is concluded that the model incorporation of these passive cooling techniques would certainly reduce our dependency on artificial means for thermal comfort and minimize the environmental problems due to excessive consumption of energy and other natural resources and hence will evolve a built form, which will be more climate responsive, more sustainable, and more environmentally friendly for future.

The initial cost of the proposed model might be a little expensive. But lots of savings can be done for a lifetime period by utilizing these techniques and making the model energy efficientwithout the emission of greenhouse gases.

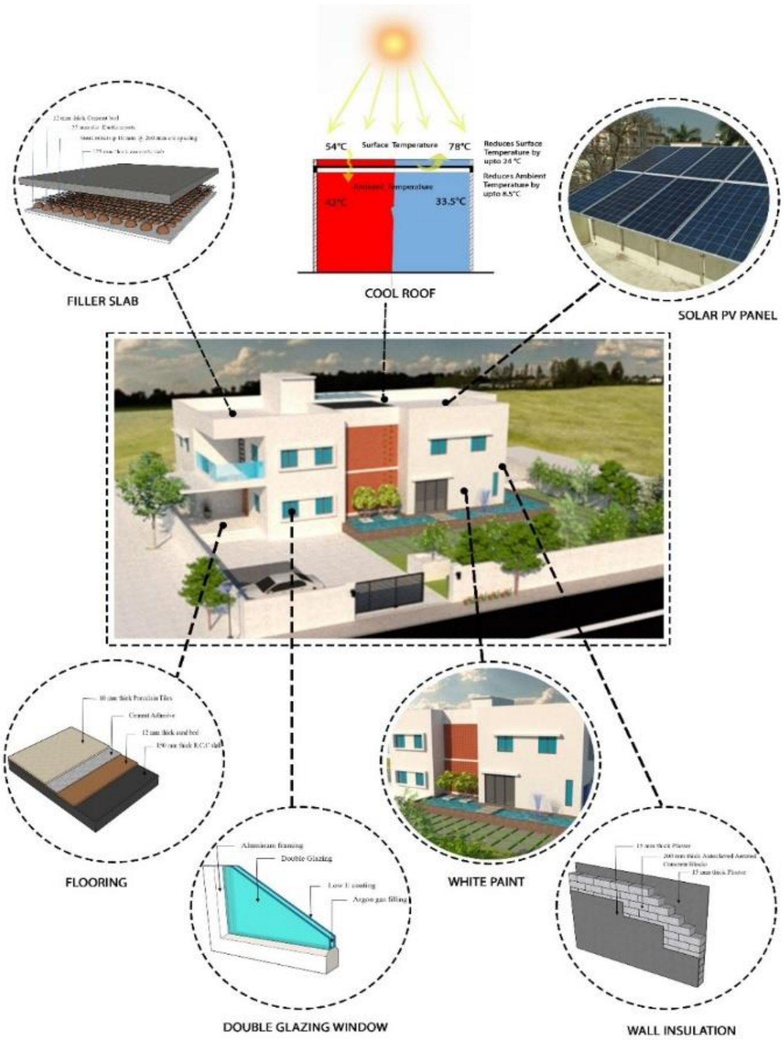

Figure 7 Component Level Strategies

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