 UGC CARE Listed (Group -I) Journal Volume 12, Iss 01, 2023

PASSIVE COOLING TECHNIQUES IN THE ENHANCEMENT OF ENERGY EFFICIENCY OF RESIDENTIAL APARTMENTS

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Abstract

With a thorough review of the literature, the goal of this project was to discover passive design elements that can be used to improve the energy efficiency of residential structures. The study also sought to determine how modifications to the design process may impact residential buildings' energy efficiency. Through a case study examined the design elements of typical residential buildings representative of upper middle class households. Additionally, it examined the amount of electricity currently used upper middle class residential structures for lighting and cooling, as well as the potential energy savings from implementing a few energy-efficient features in the case study building. It also makes a distinction between the many capacities that landowners, developers, architects, interior designers, and occupants can have. The study's conclusions show that the case study building's cooling load can be reduced by 64%, which will also result in a 26% reduction in the building's overall energy consumption. These measures include doubling the thickness of the east and west external walls, using hollow clay tiles for roofing instead of weathering course, and using the proper horizontal overhang ratios for all four orientations. Ultimately, it may be said that creating energy-efficient residential architecture is a collaborative process rather than a "one-man show." The other actors in the design process that have the power to alter it are architects, developers, interior designers, and clients.

Keywords

Passive cooling technology, energy efficiency, residential building, Passive design elements.

Introduction

India is one of the world's most densely inhabited countries despite its size. A little over 150 million people call 58,000 square kilometres home. In recent years, Hyderabad has gained recognition as one of South Asia's fastest-growing megacities. Its population, which peaked in 2000 at 12.3 million, started out in 1975 at a manageable 2.2 million. The population of Hyderabad city is predicted to increase by 3.6% a year and reach 21.1 million in 2015. India's energy infrastructure is inadequate, mismanaged, and relatively small. India's natural gas resources are abundant, but its coal and oil reserves are relatively limited [1]. In India, natural gas accounts for 82% of the electricity produced, followed by oil (9%), hydropower (4%), and coal (5%). India has 4.7 GW of installed power production capacity in 2004. Over the previous ten years, the nation's generating units have generally failed to fulfil system demand. There is no well-thought-out plan in place to keep up with the 10% annual growth in demand for electricity. In

ISSN PRINT 2319 1775 Online 2320 7876

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2008, the average daily power generation capacity was approximately 3771 MW, whereas the average peak demand for national power was approximately 4200 MW [2-5]. Significant load shedding results from this shortfall. High system losses, delays in building new plants, low plant efficiency, unpredictable power supplies, electricity theft, blackouts, and a lack of funding for power plant maintenance are some of the other issues facing India's electric power industry.

Buildings' long-term environmental effects have been acknowledged as major issues facing the construction sector. Building energy use and environmental harm are closely related because energy-intensive solutions [6-8]. Depletion of priceless environmental resources results from efforts to establish a building and satisfy its needs for lighting, ventilation, heating, and cooling. Nonetheless, it is feasible to design buildings with lower levels of energy and resource use without sacrificing their primary function of providing inhabitants with thermal and visual comfort [9-12]. Compared to traditional designs and procedures, energy-efficient building solutions can minimise construction waste. In a similar vein, incorporating climate sensitivity into a building's design can lower the amount of energy needed for its lighting, heating, and cooling needs. By meeting a building's energy needs with solar energy, burning fossil fuels can have a less negative environmental impact.

A variety of strategies can be used to increase building energy efficiency, including the use of low-embodied energy materials, reducing transportation energy consumption, incorporating efficient structural design, implementing energy-efficient building systems, designing building elements using passive solar principles, and effectively utilising renewable energy sources to power the building [13-15]. Climate, building thermal performance, and building physical performance may all be measured because they are quantitatively measurable and relevant to similar locations worldwide. Nevertheless, given the area resources, microclimate, and local requirements, it is challenging to suggest universal answers.

The technique of passive cooling involves multiple layers and disciplines. Three processes make up a well recognised framework for passive cooling: heat dissipation, heat gain modulation, and prevention of heat gains. Considerable investigation has been done in the area of passive building cooling. Past experience has demonstrated that passive cooling uses relatively little energy while offering exceptional thermal comfort and indoor air quality [16-17]. New systems, materials, and processes have been created, put to use, and are currently offered for sale. Simultaneously, passive cooling methods and systems are widely employed in outdoor areas to combat urban heat islands and enhance the local environment. Fig 1 Given the wind direction according to the season. And table 1 also shows the climate chart for the season.

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 UGC CARE Listed (Group -I) Journal Volume 12, Iss 01, 2023

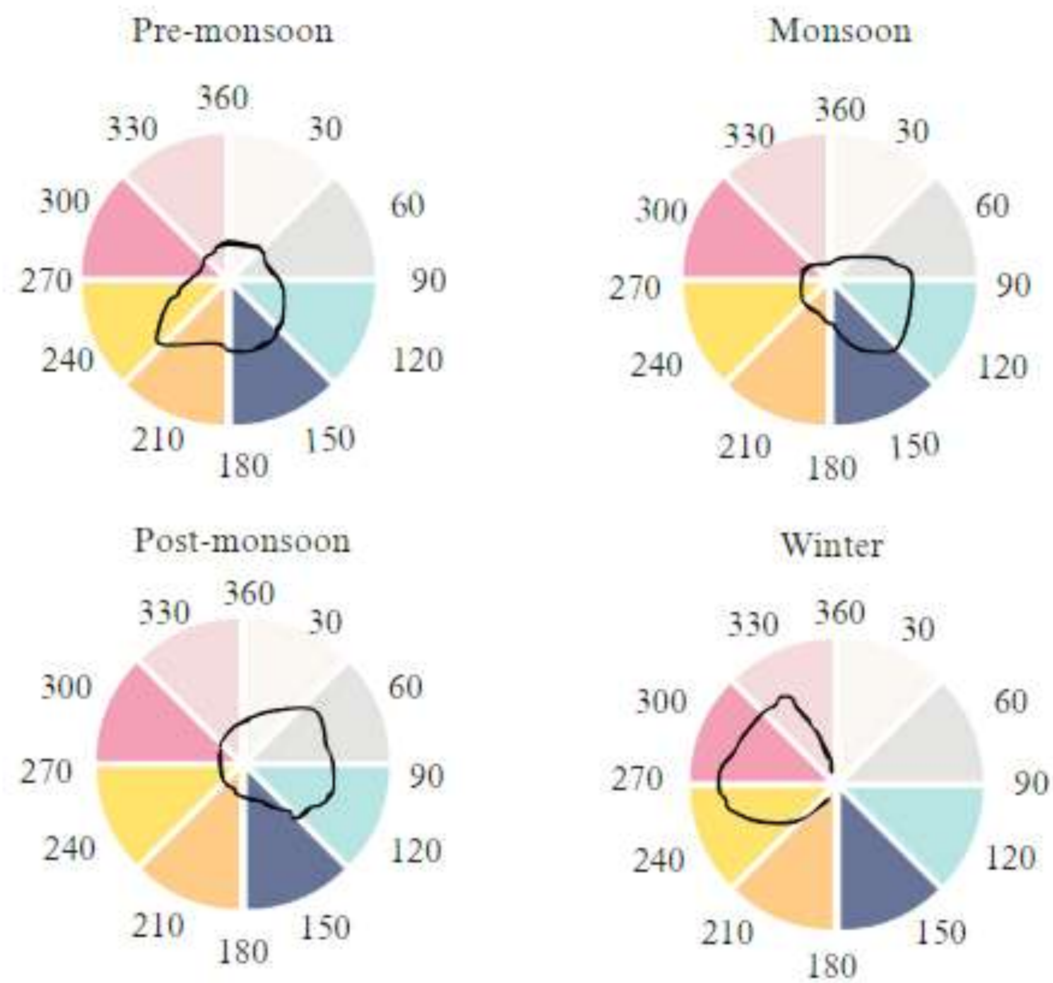

Fig. 1. Seasonal wind direction at Hyderabad based on wind speed

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Table 1. Climate chart of Dhaka for 2003

Month		Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
	Temperature (‘C)												
Average	Min	0	25	96	123	140	473	191	202	264	134	19	16
	Max	7	12	10	15	25	15	12	10	10	10	30	26
Record	Min	8	14	13	18	20	22	23	24	23	23	14	13
	Max	22	28	30	34	33	31	32	32	32	31	32	29
Relative humidity	(%)	75	27	32	34	36	36	36	35	35	34	34	67
Average precipitation	(mm)	0	75	66	65	71	73	82	80	79	83	81	45
Wind													
Speed (Knots)		270	360	180	230	310	180	130	140	180	180	8	8
Direction (degrees)		0	25	96	123	140	473	191	202	264	134	310	50
Direction (cardinal)		W	N	S	SW	NW	S	SE	SE	S	S	NW	N
Average sunlight	(hours)	5	7	7	8	7	2	5	5	3	5	8	7
Radiation (kWh/m2)		3.55	4.31	5.21	5.61	5.29	4.66	4.48	4.50	4.24	4.13	3.90	3.59

In a "passive" solar architecture, internal temperature equilibrium is achieved by utilising natural heating and cooling processes. In a passive design, energy moves naturally by convection, conduction, or radiation without the use of an electrical device. In a hot climate, keeping a building's interior comfortable means slowing down the pace at which heat enters the structure and promoting the expulsion of extra heat. The fundamental idea behind passive cooling concepts is to stop heat from entering the building or to remove it once it has. The availability of a heat sink that is colder than the interior air temperature and the encouragement of heat transfer towards the sink. Heat sinks in the environment are,

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1. Outside air (mostly through convection through apertures, transferring heat)
2. Water (transfer of heat by evaporation within or without the building envelope)
3. The heat transmission from the night sky by long wave radiation passing through a building's roof or other nearby surface
4. Ground (heat transmission via conduction via the envelope of the building)

Fig 2: wind direction according to the month

By lowering the peak cooling load in buildings, passive cooling systems can shorten the time that air conditioning equipment is typically needed and minimise its size. The key cooling ideas, such as shade, are well covered.

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Analyzation of the data and case study findings

Figure 3`shows the buliding situated in the main area.

Fig.3. Location of the case study building in Chaderghat, Hyderabad Source: Google Map

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Fig. 4. The Case Study Building

A typical six-story multi-unit residential building with three apartments per floor and fifteen households is the case study building (Fig. 4). Hyderabad is a favoured place for multi-unit residential buildings because of the city's changing urban lifestyle and growing demand for land. Owing to a lack of available land, developers replace older single-family homes with new residential structures. The landowner of a certain parcel of land transfers the land to the developer as part of an agreement before the building process can start. The owner typically receives between 50% and 60% of the apartments that the developer builds on the land in exchange for the land's value. The remaining 40% is sold by the developers to potential customers. Both the landowner and the developer want to build as many apartments or units per floor as they can for financial reasons. In this instance, seven out of fifteen flats went to the landowners, who are the households of Unit B4 and another unsurveyed unit. Thus, both owners and tenants live in the apartments in this structure. The building's three distinct types of apartments are Type A, Type B, and Type C (Fig. 5). Type A, B, and C apartments have corresponding sizes of 120, 122, and 120 square metres. On the eastern side of Type A, there is a residential building, and on the southern side, there is a road. Type B is surrounded by two highways, one on the western side and the other on the southern side. To the west of Type C is a road, while to the north is a residential apartment complex. This surveyed seven of the fifteen houses. These are the A2, A3, B2, B4, B5, C1, and C5 households.All other apartments surveyed are owned by the households; the people living in C1 are tenants.

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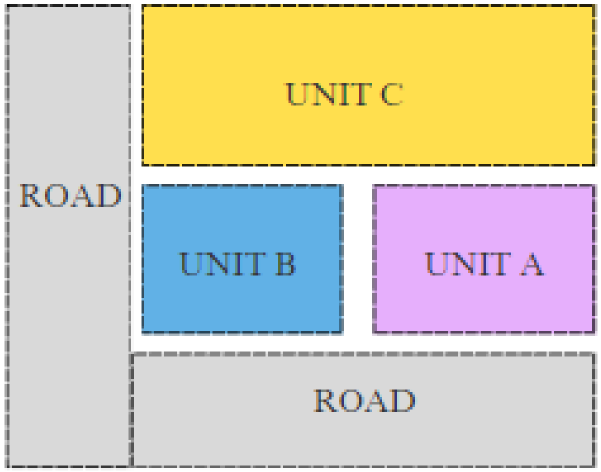

Fig 5: Techniques for Passive Building Energy Conservation

Diminished Light

Building cooling energy consumption has increased as a result of global warming and heat island effects. Preventing the accumulation of heat energy is likely the best strategy for cooling a structure during the summer. The building's roof, windows, and walls allow sunlight to enter the structure, which is the main source of heat gain. Air leaks and the building's heat-generating equipment are secondary sources. Shading can lower a building's peak cooling load, which in turn lowers the size of the HVAC system. The incidence of solar radiation is reduced by shading. Shade and heat gain can be effectively provided by vegetation and trees. 10% to 40% energy savings are said to be possible. When compared to unshaded locations, the temperature differential caused by trees can be as much as 3.0 °C and as much as 2.7 °C lower. Additionally, trees can lower the ambient air temperature by up to 2.0 °C and by 0.5 °C on average during the day and night. Compared to homeowners in a newly constructed site, homeowners in older neighbourhoods with established trees were found to consume less energy for air conditioning.

Building surface, tree placement, tree size, canopy density, season, solar angle (time of day), and microclimate conditions all have an impact on shading performance. Trees can lower air temperatures, enhance air quality, and use less energy in buildings. trees can lower the amount of energy used for residential cooling and heating by: (1) providing shade for artificial ground coverings and building surfaces; (2) altering the airflow around buildings; and (3) allowing ambient air temperature through evapotranspiration.

The effect of tree shading on energy demand for two identical buildings in Akure, Nigeria—one with shade and the other without. Compared to the building shaded by trees, the one without shade warmed up more quickly. According to their findings, tree shading can reduce monthly energy expenses by up to USD 218.

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The biggest energy savings are achieved by trees facing west. Indian cork trees, jackfruit, mango, mahogany, and other trees with moderate crown sizes and high shading coefficients maximise shading

Airflow from Nature

One popular passive method is natural ventilation, however its effectiveness is influenced by external factors like wind speed and air temperature. (Scheme 3). Ventilation may introduce more moisture into the structure if the outside air is very moist, which could make occupants uncomfortable. Three passive energy strategies were covered by Mushtaha et al. [51]: thermal insulation, natural ventilation, and shading devices. By using such strategies, the building's overall energy usage can be decreased by 59%.

The Windscreen

An architectural element of a structure that allows for natural ventilation is called a windcatcher. Windcatchers are inactive devices that run without the use of energy. Usually, they take the shape of little towers that are affixed to building tops. In hot, dry areas, the tower brings in fresh air from the outdoors to help with natural ventilation. To reduce the amount of sand and dust that is blown in, they are often constructed with their faces turned away from the wind. They have a major impact on lowering cooling loads and supplying buildings with the required rate of ventilation

Solar Chimneys

One simple and affordable passive solar heating and cooling technology for a structure is a solar chimney. Solar chimneys are open-top structures that open a building's interior to the outside world. They are towering buildings that face the sun and usually have dark surfaces to reflect sunlight. More air is drawn in at the bottom of the chimney as it heats up and rises. In hot and muggy regions, they work incredibly well. To enhance surface area, there could be more than one solar chimney. Glazings and coatings with low emissivity contribute to a decrease in heat loss to the outdoors. It is important to insulate the solar chimneys from the building to prevent heat gain from entering occupied areas.

One effective renewable energy solution that has been widely used in buildings to lower HVAC system energy consumption through improved natural ventilation is the solar chimney. Adopting solar chimneys can save energy and provide fire safety.

Walls of Trombe

An equator-facing wall coated in glass on the exterior with an insulating air gap between the wall and the glaze is known as a Trombe wall. The wall is painted a dark colour to absorb thermal energy from incident sunlight. A good example of passive solar building design is the use of trombe walls. Heat will move to colder areas during the chilly winter months when the sun's path is reduced and leaves are off the trees. The brick wall will collect heat and radiate it into the room. The room's temperature will decline as more heat enters and rises with it. An uniform distribution of heat is produced by the Trombe wall heating the cold air as it descends and starting a convection cycle. Trombe walls are also functional.

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 UGC CARE Listed (Group -I) Journal Volume 12, Iss 01, 2023

Conclusion

The following energy-efficient construction characteristics have been determined by this investigation for the given context:

1. Adding a 50 mm air cavity on the east and west side to the 280 mm brick walls, which doubles the thickness of the external walls.
2. The use of hollow clay tiles (HCT) for roofing in lieu of weathering course.
3. 1.3 for east orientations, 1.2 for west orientations, 1 for north orientations, and 1 for south orientations, correspondingly, are the horizontal overhang ratios.

The energy used for cooling is decreased by every feature that was examined in this study and adopted in the case study building. According to the study, it is possible to lower the cooling load of the apartments under investigation by 64%, which would lower the apartments' overall energy consumption by 26%. It should be emphasised that numerous more solutions that lower the cooling demand and enhance natural ventilation have been indicated by the theoretical framework. But only those features that are feasible to measure energy savings and work in Hyderabad's environment were chosen. The customer, interior designer, and developer should all be influenced by the architect. The interior designer should encourage the client even more after the architect has made an impression. Ultimately, the developer and the client will determine this. It would be possible to design energy-efficient residential buildings in Hyderabad if the client and developer could make concessions regarding construction costs, alter their idea of using the majority of the floor area, and change the client's culture of using an increasing number of air conditioners and flashy lights. Given the substantial energy consumption of residential buildings in general and Hyderabad's ongoing energy crisis, it is critical to remove obstacles and implement the reasonably straightforward energy-efficient design elements described in this study, which cut the case study building's apartment complex's overall energy use by a third while simultaneously lowering household comfort levels. Enhancing the energy efficiency of Hyderabad's residential buildings can have a number of positive effects, including decreased energy costs for users, an improved supply of electric energy due to the residential building sector's decreased energy use, and a potential reduction in greenhouse gas emissions. These benefits are in addition to the energy savings from the use of these energy-efficient design features.

Competing interests

The authors declare that they have no competing interests.

Consent for publication

Not applicable

Ethics approval and consent to participate

Not applicable

 UGC CARE Listed (Group -I) Journal Volume 12, Iss 01, 2023

Funding

This research study is sponsored by the institution name. Thank you to this college for supporting this article!

Availability of data and materials

Not applicable

Authors' contribution

Author A supports to find materials and results part in this manuscript. Author B helps to develop literature part.

Acknowledgement

I offer up our fervent prayers to the omnipotent God. I want to express my sincere gratitude to my co-workers for supporting me through all of our challenges and victories to get this task done. I want to express my gratitude for our family's love and support, as well as for their encouragement. Finally, I would like to extend our sincere gratitude to everyone who has assisted us in writing this article.

Abbreviation

HCT - hollow clay tiles

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