ISSN 2229-5518

Construction of an Eco-Friendly Building using Green Building Approach

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Abstract— Raipur is the capital of the newly formed state of Chhattisgarh, the environment of Raipur city is very warm. Owing to the increasing population needs, the construction activity is at its boom, resulting in an increase in concrete structures and consequently decrease in green areas. The climate of the city is quiet warm during the months of summer with temperature reaching up to 480C so proper care should be taken to avoid getting any kind of heat related ailment. Also the phenomenon of global warming or climate change has led to many environmental issues including higher atmospheric temperatures, intensive precipitation, and increased greenhouse gaseous emission resulting in increased indoor discomfort condition. Researchers worldwide collectively agreed that one way of reducing the impact of global warming is by implementing "Green Roof Technology" which integrates vegetation, growing medium and water proofing membrane on top of the roof surface. However, none of them have ever studied as to how much the green roof could contribute to lessen the environmental problems. Therefore, this study investigates the effect of green plantation on inclined roof to the indoor temperature on any building in Chhattisgarh climate. The present work emphasizes on use of the Rat trap bond wall technique with insulated cavity wall and room with inclined roof approach having green cover for a residential building. The cavity in wall was filled with wooden powder as insulating material and the outer surface of the wall protected from temperature and rainfall with tile covering. Observations were recorded in two conditions i.e., room with green roof and room with bare roof. The experiment showed a promising result where by the average indoor temperature dropped between 0.6°C to 2.7°C as recorded during the observation for bare roof, while average indoor surface temperatures dropped between 4.8°C to 6.9° C with green roof during daytime.

Index Terms— Green Building, Rat Trap Bond, Cavity Wall, Thermal insulation, Ecofriendly wall, Green Roof & Greenhouse

1 INTRODUCTION

When one mentions about Green building, the reference is specifically made to a structure and the processes involved that are, being environment friendly and resource-efficient throughout the building's life-cycle beginning from site to its design, construction, operation, maintenance, renovation and demolition everything. This actually requires a team work of, the architects, the engineers, and the client at all project stages. Simultaneously with the new technologies constantly being developed, the current practice to compliment this is to create greener structures, the common objective being the design of green buildings to reduce the overall impact of the built environment on human health and the natural environment by:

- Efficiently using energy, water, and other resources
- Protecting occupant health and improving employee productivity
- Reducing waste, pollution and environmental degradation

The green building approach goes beyond reducing energy use or improving indoor air quality, it's actually about addressing the whole system - not just the pieces. The approach towards this should be more comprehensive. Climate change manifested due to global warming has become critical worldwide. High temperature, abundant precipitation and rise of sea level are the indicators of global warming which actually is the outcome of the increase in greenhouse gases.

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Carbon dioxide (CO_2) which is the principal greenhouse gas is said to be the foremost reason for this. With the increase in CO_2 in atmosphere, the ability of earth surface to reradiate heat to the atmosphere is reducing. Thus it acts like a blanket over the surface and keeps the earth warmer. The warmer envelope outside is having an immense effect on the indoor temperature of building. Mentioning the buildings and human comfort level, with an increase in outdoor air temperature, buildings are experiencing indoor discomfort, thus increasing the demand for mechanical ventilation leading to higher energy consumption in buildings. Apart from this the rapid urbanization process which is associated with the deterioration of green areas has created an unhealthy environment becoming a major contributor to climate change. Environmental pollution is thus becoming common in urban areas and resulting in many negative environmental impacts on the society. Urban heat island is the phenomenon due to which the temperature in urban areas is found to be higher than the surrounding areas due to increasing concrete structures, which is the upshot of the rapidly increasing population causing the reduction of green surfaces thus resulting in an increasing heat islands.

Now talking about the climate of Raipur- the hottest months extend from March to June, though the temperatures remains moderate throughout the year .The temperature in April–May sometimes rises even above 48 °C (118 °F), accompanied with hot dry winds. Thus taking into consideration the climate of Raipur, along with the prevailing environmental conditions the population is experiencing, the following approach was made, of making building green by using certain techniques to combat the extremities of the climate in Raipur city.

1.1 Necessity of Eco-friendly housing

Evidence is growing that sustainable buildings provide financial rewards for building owners, operators, and occupants. Sustainable buildings typically have lower annual costs for energy, water, maintenance/repair, churn (reconfiguring space because of changing needs), and other operating expenses. These reduced costs do not have to come at the expense of higher first costs. Through integrated design and innovative use of eco friendly materials and equipment, the first cost of a sustainable building can be the same as, or lower than, that of a traditional building. Some sustainable design features have higher first costs, but the payback period for the incremental investment often is short and the lifecycle cost typically lower than the cost of more traditional buildings. In addition to direct cost savings, eco- friendly buildings can provide indirect economic benefits to both the building owner and society. For instance, eco- friendly sustainable building features can promote better health, comfort, well-being, and productivity of building occupants, which can reduce levels of absenteeism and increase productivity. These features can offer owners economic benefits from lower risks, longer building lifetimes, improved ability to attract new employees, reduced expenses for dealing with complaints, less time and lower costs for project, resulting from community acceptance and support for sustainable projects, and increased asset value. Eco-friendly buildings also offer society as a whole, economic benefits such as reduced costs from air pollution damage and lower infrastructural costs, e.g., for avoided landfills, wastewater treatment plants, power plants, and transmission/distribution lines. The aim of this study is to know the importance and significance of the various factors, involved in construction of the eco-friendly housing, the requirements of which can be listed as below:-

1. To upgrade the construction of sustainable house.
2. To introduce roof gardening.
3. To upgrade the house in maintaining a good thermal comfort inside the building.
4. To demonstrate and popularize the technology of roof gardening and insulated cavity wall.
5. Use of energy efficient materials which consume less energy.

2 GREEN ROOF TECHNOLOGY

One way of reducing the impact of global warming is by implementing Green Roof Technology where roof consists of vegetation and growing medium sometime referred to as Roof Garden. Many researchers have proved that green roof could give many environmental benefits to the buildings and occupants. A Green Roof is a roof of a building that is partially or completely covered with vegetation and a growing medium, planted over a waterproofing membrane. It also includes additional layers such as a root barrier and drainage and irrigation systems. The use of "green" refers to the growing trend of environmentalism and does not refer to roofs which are merely colored green, as with green roof tiles. Also known as "living roofs", green roofs serve several purposes for a building, such as absorbing rainwater, providing insulation, and helping to lower urban air temperatures. There are two types of green roofs: Intensive roofs, which are thicker and can support a wider variety of plants but are heavier and require more maintenance, and Extensive roofs, which are lighter than an intensive green. The term "green roof" is generally used to represent an innovative yet established approach to urban design that uses living materials to make the urban environment more livable, efficient, and sustainable. Other common terms used to describe this approach are eco roofs, and vegetated roofs. Green Roof Technology (GRT) is the system that is used to implement green roofs on a building simultaneously dealing with

- Strength to bear the added weight.
- Seal the roof against penetration of water, water vapour , and roots.
- Retain enough moisture for the plants to survive periods of low precipitation, yet are capable of draining excess moisture when required.
- Provide soil-like substrata to support the plants.
- Maintain a sustainable plant cover, appropriate for the respective climatic region.
- Offer a number of hydrologic, atmospheric, thermal and social benefits for the building, people and the environment.
- Protect the underlying components against ultraviolet rays and thermal degradation.

Advantages of Green Roof:-

- ❖ Roofs represent a large percentage of impervious surfaces; placing vegetation on them can substantially reduce storm water runoff.
- ❖ Green roofs can manage much or all of the runoff that would otherwise be generated by a building's roof area.
- ❖ Green roofs cover normal roofing materials, shielding them from wear and prolonging their life.
- ❖ Rooftop vegetation adds to the insulation of a building, reducing cooling and heating requirements.
- ❖ The collective effect of several buildings withgreen roofs can reduce the "heat island" effect of urban areas, improve the air quality, and reduce dust and other airborne particles.

Researchers from Columbia University Center for Climate Systems Research and NASA Goddard Institute for space studies have discovered that Green roof could potentially reduce energy usage, fossil fuel consumption and green house gas emissions. On an average (5 to 7) °C reduction in indoor air temperatures were measured in building with green roofs during daytime hours and 0.3°C higher at night. Few researces have also confirmed that vegetated surface, green roofs may reduce outdoor air temperature and urban heat island effect through evapo-transpiration, and shading also. Thus the objective of this study is to investigate the effect of potted plants on inclined roof to the indoor temperature reduction inside the building in Indian climatic condition.

2.1 Important Features of the Present Study

The present study was executed with the following strategies as enumerated below showing their positive outcomes and observations:-

Phase I: Eco-friendly Wall Systems a Sustainable Design
Phase II: Inclined Green Roofs
Phase III: Water Harvesting System.

Phase I: Eco-friendly Wall Systems: Sustainable Design.

The main factor which highly affected the room temperature were the walls of the building as it is the wall which is in the direct contact with the surrounding environment and faces the variation of temperature due to climate change. By constructing an eco-friendly or insulated cavity wall using rat trap bond wall technique with the cavity in walls filled by wooden powder which provided thermal insulation helped to reduce the room temperature and provide cooling effect as well. Thus reduction in room temperature was achieved to a great extent

Phase I: Eco-friendly wall Systems

Eco-friendly wall finishes included plaster finishes and paints that are friendly to the environment. These finishes and textures can make quite a statement or provide a subtle background. Many of these finishes will get better with age, all you need is a standard paint. There are several finishes that use natural ingredients and have little or no "off gassing". If there is a need for a softer surface or a special application that calls for wall covering you have some options as well, including natural and recycled products .These eco-friendly wall finishes were provided for all the external walls of the residence.

Insulation Material:

The insulating materials are said to have the following properties

- Long filament fiber recycled textile product
- Tests indicate long filament fibers are not respirable into the lungs
- Not a potential cancer risk as is traditional rotary spun fiberglass
- Excellent sound reduction qualities

Wooden powders were used in this project as in fills of the cavity walls

Phase II: Inclined Green Roofs

The Extensive green roofs, are light-weight with a very thin layer of soil using primarily drought resistant plant species such as sedums and mosses. These roofs survive on natural rainfall and do not need more maintenance than an annual check and a limited feed with nutrients. At the other end of the weight scale is Intensive green roofs with vegetation, roof gardens or even parks which need too much maintenance, watering and weeding just like other gardens. In between these extremes are a wide range of different kinds of roof vegetation with varying soil depths and plant types. Some, like meadows, need occasional maintenance whilst others need more looking after. Green roofs having an inclination of (20^0 to 30^0) were used on top of the house. These actually can be found in many different shapes and sizes. Creating a green roof does many favours to the environment and the user as well. These roofs are attractive and can give urban dwellers a positive view and also an improved microclimate. Animals and plants find habitat on the roofs in the midst of all the asphalt and concrete and these roofs can compensate for lost green space on the ground, to a certain extent. There are also financial benefits to green roofs as the roofing material lasts longer and the cost of heating and cooling the building decreases. Increased green space and more permeable surfaces in the city results in a natural management of much of the rainwater, which leads to decreased costs for drainage and the rainwater does not need to unnecessarily increase the load on the sewage treatment works. Thus these green roofs used had many positive points as said in the previous sentences

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c Fig.2. 1 Green Roof Building

Phase III: Water Harvesting System

Rain water harvesting was also implemented in order to make the project sustainable and eco- friendly. A storage area was made near the house for storage of water. Provision was made to recycle the treated grey water for watering the plants.

3 Constructing Eco-friendly Building With Green Building Aspects

The matter below enfolds the entire considerations made in the project which was experimented, to make an eco-friendly building using green building approach

3.1 Foundation

Though much cannot be done about this part of the construction as everything depends on the soil conditions and

safety of the structure being the priority consideration, it is recommended to adopt a foundation depth of 0.6 m for normal soil like gravely soil, red soils etc., and use the un-coursed rubble masonry with the bond stones and good packing. Similarly the foundation width is rationalized to 0.6m.To avoid crack formation in foundation the masonry shall be thoroughly packed with cement mortar of 1:8 boulders and bond stones at regular intervals.

Fig.3. 1 Foundation

When excavating the trenches for the foundations, it is recommended to shovel the soil inwards like that it will already be where it is wanted for infilling and some of the expense of excavation and infilling will be saved. This practice is usually not followed in day to day construction practice. In case of black cotton and other soft soils it is recommend to use under ream pile foundation which saves about (20% to 25%) cost over the conventional method of construction.

3.2 Plinth

A plinth of height 0.2 m above ground level was adopted, constructed with 1:6 cement mortar. The plinth slab of (100-150) mm which is conventionally provided, was avoided and in its place, in order to take necessary precaution, impervious blanket like concrete slabs or stone slabs was provided all round the building to reduce erosion of soil and thereby avoiding exposure of foundation surface and crack formation.

Fig.3. 2 Plinth

A plinth of height 0.2 m above ground level was adopted, constructed with 1:6 cement mortar. The plinth slab of (100-150) mm which is conventionally provided, was avoided and in its place, in order to take necessary precaution, impervious blanket like concrete slabs or stone slabs was provided all round the building to reduce erosion of soil and thereby avoiding exposure of foundation surface and crack formation.

3.3 RAT- TRAP BOND WALLING

This technique had been developed by the architect Laurie Baker and has been tested and proven during the past 40 years in India. The rat-trap bond is laid by placing the bricks on their sides have a cavity of (80-100) mm, with alternate course of stretchers and headers. The headers and stretchers are staggered in subsequent layers to give more strength to the walls the main advantage of this bond is the economy in use of bricks, giving a wall of one brick thickness with fewer bricks than a solid bond.

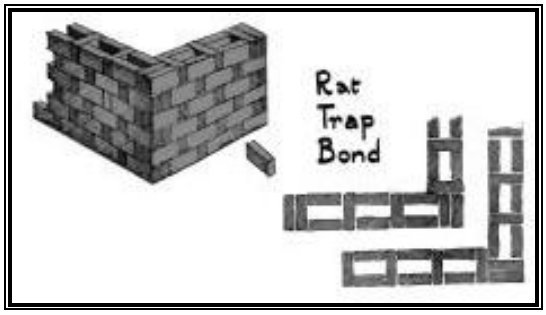

Fig.3. 3.1 Rat- Trap Bond

3.3.1 The Main features of Rat-Trap Bond walls

• Strength is equal to the standard 230 mm. brick wall, but consumes
25% less bricks
• The overall saving on cost of materials used for construction com
pared to the traditional 230 wall is about 26%.
• The air medium created between the brick layers helps in maintain
ing a good thermal comfort inside the building. This phenomenon
is particularly helpful for the tropical climate of South Asian and
other hot countries.
As construction is done by aligning the bricks from both sides with the plain surface facing outwards, plastering is not necessary except in a few places.
It is a cavity wall construction with added advantage of thermal comfort and reduction in the quantity of bricks required for masonry work. By adopting this method of bonding of brick masonry compared to traditional English or Flemish

bond masonry, it was possible to reduce in the material cost of bricks by 25% and about (10% to 15%) in the masonry cost. By adopting Rat-Trap Bond method, one can create aesthetically pleasing wall surface. To determine if you have such a wall cavity, examine the thickness of your walls at the external doors or windows.

3.3.2 Rat- Trap Bond Walling with Insulated Cavity Wall

Houses built before the 1930's had solid walls, but for those walls having cavities, filling the gap with new insulation techniques will always help in not only saving money on fuel bills, but also the temperature of our home will be under control irrespective of the external climatic changes. Mostly fiberglass, cellulose insulation, and polyurethane or polystyrene foam are the materials used to fill wall cavity gaps but here in this project, blow-in and foam fill insulation technique was used nuzzled between the two levels of wall which also helped in keeping the moisture at bay. A hole is located or drilled between the walls and the insulation is pumped or blown in through mechanical means. The process is clean and very quick, and installation also was very easy. The space which was previously filled with air was now occupied, immobilizing airflow and preventing convectional heat transfer. This draft reduction from reduced air movement will thus help in keeping homes warmer in the winter, and the insulation thus helped keeping cooler air inside during the summer. Additionally, CO_2 emissions are also drastically reduced, providing for a green solution to the world's global warming. This thus proved to be one of the most simple and cost-effective techniques for making our home more energy-efficient, saving about (10 % to 40%) of the cost due to home energy heating and air-conditioning bills.

Fig.3. 3.2 Cavity in Wall

In present study wall thickness of 300 mm was provided in the construction of walls all-round the building and 100 mm for inside walls. Burnt bricks were used (which were immersed in water for 24 hours) to construct insulted wall. The cavity of the wall was filled by the wooden powder and other insulating material.

Fig.3.3.3 Wall Cavity filled by wooden Powder

3.4 Doors and Windows

It is suggested to use wooden doors and windows in place of concrete or steel section frames as was done for this project thus achieving good thermal insulation, cause wooden doors and windows have less effect of temperature variations or sun light as compared to the concrete and steel doors and windows and the location of these doors and windows were mostly in northern or southern direction so as not to face the sunlight directly, in the mean time providing sufficient ventilation and air circulation for giving cooling effect.

Fig.3. 4 Door Frame Fitting

3.5 Tiles on The Outer Face of The Wall

In the insulated cavity wall construction, the cavity was filled by wooden powder so there were chances of fire due to the use of wooden materials by short-circuits or any other accidental conditions and also in case of heavy rainfall, chances of water penetration also prevailed into the cavity, Therefore to protect walls from those detrimental conditions, tiles were provided on the outer and inner faces of the walls. Tiles also provided protection to the walls from coming in direct contact of atmospheric heat ensuring the reduction of the temperature as well as increasing the cooling effects as well.

3.6 Roofing and Gardening

Normally 12.5 cm thick RCC slabs are used for roofing of resi dential buildings the roof may it be flat or inclined. But a green roof can be defined as a roof of the building, which is partially or completely covered with vegetation and a growing medium, planted over a waterproofing membrane. It may also include additional layers such as root barriers, drainage and irrigation systems.

Fig.3.6.2 Green Roof

It may also include additional layers such as root barriers, drainage and irrigation systems.

Thus the same concept of green roof was used for this experimental house which fulfilled several purposes for a building, such as absorbing rainwater, providing insulation, and helping to lower urban air temperatures.

4 OBSERVATIONS AND ANALYSIS

In the project discussed above a house which was constructed with conventional methods and another experimental house having green roof and eco-friendly technologies constructed the temperature observations were taken on both the houses and following were the observation found At the time of experiment the following observation were taken on the traditional and green building:-

Normal Temperature Outside = 32.0^0C

Room Temperature of Traditional Building = 31.4^0C

Room Temperature of Green Building = 29.3^0C

Reduction in Temperature for Traditional Building = 0.6^0C

For Green Building = 2.7^0C

Difference between Reductions in Temperature of

Traditional and Green Building = 2.1^0C

After the increase in temperature by the lighting effect

Temperature outside around Traditional and Green Building= 37.0^0C

Room Temperature of Traditional Building = 34.9^0C

Room Temperature of Green Building = 30.1^0C

Reduction in temperature

For Traditional Building = 2.1^0C

For Green Building = 6.9^0C

Difference between Reductions in temperature of

Traditional and Green Building = 4.8^0C

Therefore the result shown above indicate that a Green building will have reduced room temperature and provide more cooling effect as compared to the traditional building.

Fig.4. 1 Temperature Testing on Green Building

Fig.4. 2 Temperature Testing on Traditional Building

Thus the above readings green house has a reduced indoor temperature as compared to the house constructed by the conventional method.

5 CONCLUSION

We are living at a time when the earth is constantly being subjected to UV rays, global warming, and high level of pollution. The disaster is the unhealthy condition in our living. The environment of Raipur city is also very hot in summer as compared to other cities due to the major problem of global warming, green house effect and uncertainty in climatic behavior which is affecting the human beings vastly. So this green building approach as discussed will prove to be very beneficial giving effective result to reduce the extreme heat during the summer thus reducing energy consumption making the building sustainable providing the comfort level for the residents A green building with water harvesting system utilize the natural energy to reduce temperature and increase ground water level hence it saves the additional cost required for mechanical means to reduce temperature. Its advantage can be summarized as stated below: It will absorb CO_2 from atmosphere and reduces the green house effect. The plantation will also give pleasant look to the building and surrounding areas. The collective effective of several buildings with green roof can reduce the "Heat island" effect in urban areas, improve the air quality and reduce the dust and other airborne particles. By providing green roofs, insulated cavity walls and tiles on the outer face of the wall, we will reduce the indoor temperature about 5^0C to 7^0C.

The rain water harvesting system will increase the ground water level which will be utilized in the period of demand. A green building with water harvesting system utilize the natural energy to reduce temperature and increase ground water level hence it will save the additional cost required for mechanical means to reduce temperature. Tiles on the outer face of the wall will reflect sun rays therefore reduce indoor temperature of building. By the provision of tiles on the wall, we will reduce yearly painting or distempering charges of the wall. Tiles protect the wall from the seepage during heavy rainfall. Though the concept of Green Homes in India is new, yet it will help us to put the first step forward in preservation of the earth's natural resources and cutting down on energy consumption and its cost.

REFRENCES

[1] ASHRAE, USGBC, CISBE. (2008). Performance Measurement Protocols for Commercial Buildings
[2] Beall, Frank C., University of California, letter report to Joel Tranmer (May 1994)
[3] Cathy E. Creswell and Linda M. Wheaton Green Building & Sustainability Resources California Department of Housing and Community Development Housing Policy Division
[4] The School of Renewable Natural Resources
[5] N.K.Naik. "Mechanical and Physical-Chemical Properties of Bamboos carried Out by Aerospace "Engineering Dept., IIT – Bombay
[6] Practical Action Walls using the 'rat – trap bond' technology
[7] Wilkes, K., Proceedings of the International Symposium on Roofing Technology (1991)
[8] Yarbrough, D., "Thermal Decomposition of Ammonium Sulfate at Low Temperatures" letter report to the Cellulose Marketing Council (September 1991)
[9] Zane Satterfield, P. E., NESC Engineering Scientist Green Building