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A Study on Low Energy Buildings

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***Abstract*- In this research a study on five Low Energy Buildings has been conducted. The first two buildings are in Bangalore (Office building of M/S Jaisim Fountain- Head, SUVIDHA retirement village). The next two buildings are in Kerala (CHAMAN, THEJAS resort) and the last building is in Pondicherry (Auroville Earth Institute). The climatic conditions in all these places are different. Various methods of construction and materials are used to achieve the comfort temperature and humidity levels of those regions. Using Passive architecture design, maximum availability of daylight and natural wind is obtained inside these buildings, which reduces energy consumption. Uses of recycled and reused materials which are locally available have been practiced here. Materials that are alternative to concrete have been widely used in these buildings, which helped in reducing the temperature levels inside the buildings. Using these methods how these five buildings have succeeded in energy conservation and lowering of carbon emission have been mentioned in this report which makes all these buildings a Low Energy Building.**

INTRODUCTION

A low energy building is a building that reduces the consumption of energy to a low value with the help of passive architecture design, materials used and dependence on renewable energy resources. Passive design helps in bringing in the natural light and fresh air which will be cool. The hot exhaust air will be carried out with the help of proper ventilation and opening provided based on orientation and wind pattern of that area. Open courtyard in building helps to achieve this and even allows rain water to fall inside and creates a cool envelope inside. It also helps in obtaining maximum daylight inside the building which reduces the use of artificial lighting. Materials such as wood, stabilized earth blocks, hollow earth brick help in reducing the interior temperature to a comfort level. Making use of the solar energy by solar panels and heaters helps in saving electricity. All these can help in bringing down the use of non renewable resources which makes all of them sustainable.

LITERATURE SURVEY

Mittal(2009) A study was conducted on Energy efficient buildings features in hotels of Delhi to assess the extent of energy and water conservation measures adopted in the hotels, which are the largest consumers of these resources. Audit of five hotels in New Delhi was carried out to gain insight in to the energy efficient features installed and compare them. Seventy five employees formed a part of the sample to understand their awareness levels regarding energy efficient practices followed in their respective hotels. The findings revealed that many energy efficient feature were installed in all five hotels. All the hotels had efficient HVAC systems with variable speed drive. They also had separate window and split air conditioning units for office use.

However, none of the equipment used in any of the buildings was energy star rated. Well protected building envelopes through proper thermal insulation, water proofing, light colored external walls, fixed windows and shading devices on windows ensured comfort to the guests and occupants. All the hotels used energy savers in their lighting fixtures through CFLs, T5lamps and LEDs, lighting dimmers and lighting timers. ITC was the only buildings with occupancy sensors in all guest rooms and solar panels for external lighting. All the hotels used energy efficient equipment like washer sand dryers in their laundry units except the hotel Maidens, which outsourced its laundry. However, Maidens was the only hotel to have installed a solar water heater to reduce power load. For water conservation, sensor based urinal sand single and dual used flush toilets with reduction in water flow were used. Rainwater Harvesting system, effluent treatment plant for treating kitchen and laundry wastewater were installed in all the hotels. ITC Maurya received the highest score on the checklist used to assess the energy efficient and water efficient features in the hotels.

Wong, 2009 carried out a research on thermal evaluation of vertical greenery systems for building walls. The eight different vertical greenery systems (VGSs)were studies installed in Hort Park, Singapore, to evaluate the thermal impact on the performance of buildings and their immediate environment based on the surface and ambient temperatures. The results reflected the potential thermal benefits of vertical greenery systems in reducing the surface temperature of building facades in the tropical climate, leading to a reduction in the cooling load and energy costs. By limiting the diurnal fluctuation of wall surface temperatures, the lifespan of building facades is prolonged, slowing down wear and tear as well as savings in maintenance cost and replacement of facade parts. The effects of vertical greenery systems on ambient temperature are found to depend on specific vertical greenery systems. Given the importance of wall facades in the built environment, the use of vertical greenery systems to cool the ambient temperature in buildings are promising. Furthermore, the intake of air-conditioning at a cooler ambient temperature helped in saving the energy cooling load.

Wahi (2014) conducted a study on status of green building materials, aimed at finding out the usage, acceptability and awareness of green building materials among building professionals and promotional strategies used by the company's manufacturing these materials. The study also took into account the hindrance and catalysts faced by building professionals while using green building materials. For the study thirty building professionals(architects/builders/civil engineers/green building consultants) who were using green building materials in NCR, Delhi was interviewed. In addition, marketing heads executives of ten companies manufacturing green building materials were interviewed in order to understand the promotional strategies used by them and how useful these strategies had proven for them. It was found that fly ash based materials (fly ash bricks, blocks, AAC blocks, PPC) were most commonly used by the professionals as compared to other materials as these materials were easy to procure at competitive price. Insulation materials, FSC certified wood, salvaged wood and straw board, because of their high prices and low availability were not in much use and were found to be preferred by those professionals whose projects were going for LEED/GRIHA rating. The study showed that availability of some green building materials like FSC certified wood, straw board, insulation materials, pre-fabricated materials was less as compared to conventional building materials because of less demand, less number of manufacturers and high cost. Also, one of the reasons was difficulty in getting these materials in the required form. Delivery time was found to be more in case of green building materials due to less number of manufacturers as compared to conventional building materials and location of the dealers and manufacturers. It was also found that the major catalyst behind using green building materials was reduced environmental impacts and gaining large number of points in LEED/GRIHA certification. As far as hindrances were concerned they were increase in project cost and limited availability of green building materials. The study also provided suggestions to overcome these hindrances which include mandatory usage of green building materials in all new construction, more incentives for building professionals and manufacturers which will encourage more number of manufacturers to manufacture these materials and bring down their cost.

Allen et.al (2015) examined the state of evidence on green building design as it specifically relates to indoor environmental quality and human health. Seventeen research studies that specifically focused on exploring relationships between green buildings and health were searched from internet and reviewed. Overall, the initial scientific evidence published to date indicated better measured and perceived indoor environmental quality and health on green buildings versus non-green buildings. For indoor environmental quality, green buildings had lower levels of VOCs, formaldehyde, allergens, NO2, and PM. Many of these environmental contaminants that have been linked to adverse health effects are explicitly addressed in green building design credits, so these early findings suggest that the design elements targeted at improved IEQ translated to significant reduction in actual exposure. The IEQ benefits in green buildings translate to better self-reported health outcomes across several indicators. This includes fewer sick building syndrome symptoms, fewer respiratory symptoms reports in children, better physical and mental health.

CASE STUDIES

Five case studies on Low Energy Building are dealt with in this chapter. They are,

Office building of M/S Jaisim Fountain- head – Bangalore, Suvidha – retirement village - Bangalore CHAMAN- Kerala, THEJAS resort- Kerala, Auroville Earth Institute- Pondicherry. The first two buildings in Bangalore are designed by Sri. Krishna rao Jaisim who is one of India's leading architects. Most of his works are of eco friendly design with the use of locally available materials such as rocks; clay blocks, and limits the usage of cement and steel. In all his designs the use of passive architectural concept has been highly favored. Preservation of trees, topography, soil, rocks, water body, etc is being given much importance in his work. The two buildings designed by Sri. KrishnaraoJaisim, which are studied in this report are: Office of M/S Jaisim Fountain-Head – Bangalore, Suvidha- retirement village – Bangalore

CASE 1: OFFICE BUILDING OF M/S JAISIM FOUNTAIN-HEAD, BANGALORE

It is located in Jayanagar East 1st block, Bangalore and its co-ordinates are 12056'03.84"N and 77035'12.90"E. This was built in the year 1991. The building is three storied in which the office is below the ground level and above the ground is the Jaisim's residence. The total area of the office alone is around 120 m2. As seen in fig 1 the building has a shape of a quarter circle. It is designed in such a way that the center portion of the building is facing towards east, allowing the daylight to fall on each and every corner of the room. This is a 100% daylight dependent building in which two fluorescent tube lights are being provided inside the office space for extreme cases and has no air conditioning equipment except an exhaust fan. Day lighting and air flow have been used to the maximum in this building. Trees are planted all over the land. This plays a major part in providing natural shade and absorbing the emitted radiation and reduces the temperature both inside and outside the building. The walls of the building are made out of hollow clay blocks, stones, and normal clay bricks. In the residence glass windows have been provided in the entire front area to obtain maximum daylight. The shade from trees situated at the front helps to reduce the problem of heat emitted by absorbing it.

Fig 1: Office building of M/S Jaisim Fountain-head

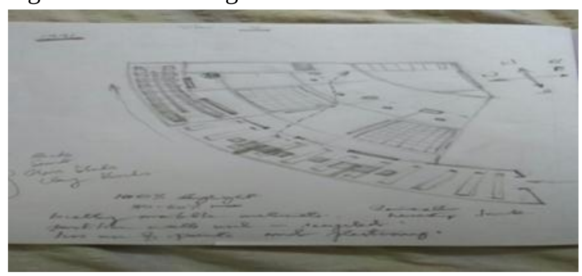

Fig 2: Plan of the Office building of Jaisim Fountain-head

Fig 3: Day lighting obtained inside through pergola design

Fig 5:Rain water harvesting tank

Fig 6: SUVIDHA retirement village

The ceiling of the passage till the visitor's room is provided with pergola with glass boxes fixed in between. Inside the office room there are two glass blocks on the roof of size 90 cm x 90 cm and four open windows and a door facing outwards are provided to obtain maximum day lighting and air flow. In the roof vertical air holes are provided for circulation, through which the air is allowed to enter and enabled to flow through the entire office space and then flow out through these air holes and other openings. Air holes are provided on the walls also. Some amount of air flows upstairs through the passage provided. The walls and floors in the passage and the visitor's room are made with rocks. As the chance of these rock surface getting heated is very much less on account of the shade provided by the trees, the direct falling of sunlight does not increase the surface temperature unduly and it remains cool. All the rocks used here are the ones collected from quarries from where they were thrown out as wastage due to improper shape. Epoxy paints have been completely avoided, instead a coating of hydrated lime has been provided. This helps in cost reduction and provides better indoor air quality as it does not contribute any volatile chemicals. It also keeps away the insects and pests. As most of the materials used were locally available the embodied energy is less than that of a conventional building. Use of recycled and reused materials has been encouraged in this building. Mainly the fuel needed for the transportation has to be accounted in for calculating embodied energy. Apart from the design, the materials used in construction plays a vital role in bringing out the temperature to a comfort level. A few trees growing on the site and found within the premises of the building have not been removed but allowed to grow. This gives enough shade for the building and reduces the temperature inside the rooms. The use of concrete and steel is very much limited as these materials absorbs a lot of heat at day time and emit it during night time. As seen in fig 3, rocks (for both walls and floors), clay blocks and glass blocks have been used which are locally available. The glass blocks used here allows only light to pass through with very little heat energy and reflects the rest of the incident heat back to the atmosphere. The use of salvaged and recycled material has also been highly encouraged. All these measures make the design one of low cost. Partition walls used inside the office space are also of recycled material. Cement plastering is very less. A large value of electric energy is being achieved throughout annually. Along with this energy efficiency water conservation has also been attempted. Rain water falling on the roof is stored in the tank provided as shown in fig 5. From the study of this building we can get a clear picture of how energy efficiency and saving in water consumption is being achieved.

CASE 2: SUVIDHA – RETIREMENT VILLAGE, BANGALORE

'SUVIDHA' retirement village has been set up by Sushruta Vishranti Dhama Ltd, a private company in which most of the investors are doctors of Bangalore Hospital, Jayanagar. It is situated close to Kanakapura road and its co-ordinates are 12051'01.16"N and 77032'02.96"E. The project is located on a 14.2 ha land which consists of one hundred and eighty five retiree's cottages built till now, in which approximately around sixty are occupied. The construction was started in the year 1991. It also comprises of a Club house, Health care center, Sewage treatment plant and a 1.62 ha water body. The water needed for daily use and for construction is taken from here. The recycled water is being used to water the plants all over the area. All the cottage units are single storied. The place is mainly meant for people who would like to spend their retirement in a peaceful manner avoiding the traffic and pollution of the city. The highlight of the project is the preservation of terrain, rocks, trees and soil. Almost 90% preservation of all these have achieved here. Trees have been planted all along the area which gives enough shade to each of the cottages, helps in reducing the inside room temperature. A garden near to the Club house, where the inmates used to spend their evening times has been provided with variety of trees. The cottages were built on floors lifted above the ground on pillars of concrete pipes that are in filled with reinforcement. Fig 7 and fig 8 show some of the pillars that are cylindrical and others with concrete blocks. Below the flooring hollow clay blocks have been fixed in order to reduce the temperature absorbed by the concrete floor slab.

Fig 7: Cottages built on cylindrical concrete pipes

Fig 8: Cottages built on concrete blocks

Fig 9: Solar panels on the roof

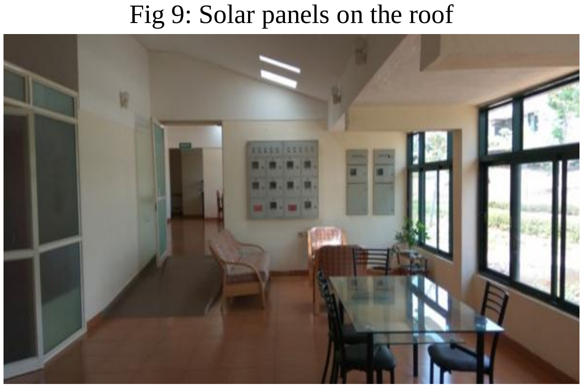

Fig 10: Natural day light obtained using large sliding windows and openings on roof

Fig 11: Front view of Jaisim's cottage

This lifting of cottages above the ground helps in having no direct contact with the ground and allows the circulation of air through the open basement which helps in reducing the inside temperature in the cottages. The external walls are made of hollow clay block which limits the use of plastering and also helps in maintaining thermal comfort. All the units have a concrete sloped roof provided with insulation and water proof coating. Above this roof clay tiles and solar panels have been fixed as shown in fig 9. Solar water heaters are also provided in each cottage. The paint used on the walls also serves the purpose of moisture proofing. Outside every cottage, a small garden has been provided with a variety of plants in it. All these plants are being watered with the recycled water obtained from the sewage treatment plant. Even though the cottages have similar designs, their orientation and the site level of each cottage differs. All the buildings are facing towards different direction. No alterations for leveling of site were allowed. This problem is solved with the help of the passive architecture design. Maximum use of day lighting has been obtained with the help of glass blocks fitted on roofs and walls and with the large sliding windows provided (fig 10). The cottage in which Mr. KrishnaraoJaisim and his wife are currently staying is shown in fig 10. Here the exterior ground is not paved with any material instead has planted with grass which reduces the heat reflected from the ground towards the building. This also helps in the percolation of water into the ground without any run off and maintains the water table level. Inside the building an exhaust fan is provided at the top for removing hot air from inside the room. A seating arrangement made out of rock was laid under the cottage making the space very cool during the mid hot summer days.

Fig 12:The rear view of Jaisim's cottage

Fig 13: Bamboo baskets stuck to the underside of the RCC flooring.

As shown in fig 12, site preservation has been done to the maximum by retaining the rocks and topography of the land as it is. A natural stream was present at the rear side which has dried out due to extreme drought. The walls were built using hollow clay bricks and similar to other cottages maximum use of day lighting has been made. But what made this cottage different from others was the use of bamboo baskets stuck to the underside of the RCC flooring, which gives a cooling effect and an aesthetic appeal too (fig 13).The other main importance about this place is that it is a pollution free area. Inside 'SUVIDHA' travelling is done with the help of electric vehicles. All these vehicles are parked in front of the club house and provision is made to charge all these vehicles. For that electricity is obtained from solar energy which is being stored with the help of solar panels and grids. The other vehicles are parked near to the entrance and club house, from which they can avail the service of these pollution free vehicles.

CASE 3: CHAMAN, KERALA

Fig 15: Front view of CHAMAN

Fig 17: open courtyard area

'CHAMAN' the nature blended house is situated at Malaparamba, Calicut, Kerala and its co-ordinates are 11017'10.35"N and 75048'30.89"E. This house was mainly built to meet the climatic conditions in Kerala. The site area in which the house was built was around 160m2. However the entire area has been being utilized for the construction of the house. There are no exterior gardens or open sides provided. Instead all such facilities have been given inside the house. The boundary walls shared with the other plots were taken as walls of the house. And so instead of creating a courtyard inside the building the architect tried to create an interior garden inside with the space he got. The total area of the house alone in this plot is around 140m2. This is an open house facing west from which maximum amount of daylight and natural air are allowed to come into the house with the passive architectural design provided by the architect. As shown in fig15, there is no compound wall or gate provided at the front of the house. Instead on the front wall of the living room a window fully paved with tempered glass has been provided which is kept open always. This allows maximum light and air to pass through it. The plants and creepers grown at the front side and on the walls also reduce the amount of heat, and give shade to the front area. Even the ground is planted with grass instead of concrete pavements consequently, the amount of heat reflected from the exterior space is also very less. The main highlight of this building is that all the materials in this house can be reused after years of use. The amount of cement and concrete is very less and has been used only in the columns, beams and roof. Except the structural frame the rest of the building portion was built with laterite blocks having an average dimension of 360x 190x 230mm was used. These are locally available and are bigger than clay and cement bricks. The laterite stone is used as it is and is given no cement plastering on it. The peculiarity of laterite stones is that it gains strength with time. The masonry used in these building is laterite stone that has been cut with man power only. So the embodied energy in the production of these rocks compared to other building materials can be accounted as almost zero and the only energy utilized here is its transportation from the quarry to the site. After the use in the building this stone can be reused as its strength continues to increase with time and the amount of embodied energy in the future use can be further reduced. Thus it serves a great purpose in making the other materials sustainable and also for the same as it is a reusable material. The characteristic property of this material is that it requires more time to get heated and the heat through it passes slowly. The floor of the living room is lower than that of the ground level and is designed in such a way that, a seating arrangement is made above the floor with the granite blocks. Both the front wall and the opposite one is fully provided with glass windows, in which only two narrow windows are kept open to allow the outside air to flow into the inner space (fig 16). According to the architect as per Bernoulli's theorem, providing a narrow window can increase the pressure acting on the wind, which makes it to enter inside the building with higher velocity. Inside the house after passing the living room (fig 16) a huge open space and an interior garden are provided which is full of various trees, plants and creepers, which give enough shade to the area without trapping the light entering inside. The interesting fact about this area is that the floor is not being paved with any material instead it is kept as itself with jelly chips covering the mud. As rain water falls inside the house the water is not allowed to run off to any other region but is allowed to percolate into the ground to retain the water table level at that region.

Granite stone has been laid on the ground as pavement to walk through the interior garden and even the floors of the house is paved with the same granite stone. Instead of cleaning the floor daily, here the stones are being washed once in a month. In the inner open space created and provided with plants, a fish pond above which lies the staircase, a coffee table, and an open pooja space are provided as shown in fig 18which makes for a comfort ambience.

Fig 18: A fish pond below the staircase

Fig 19: Glass roofing provided above the passage in open courtyard

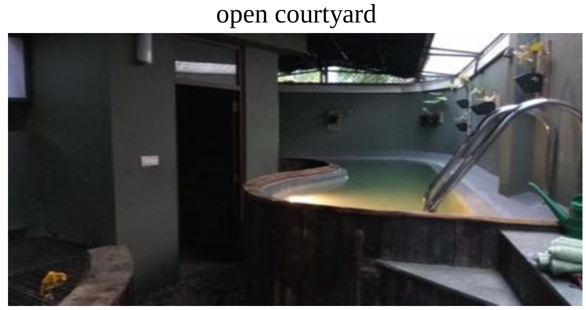

Fig 20: A swimming pool and well provided next to the bathroom

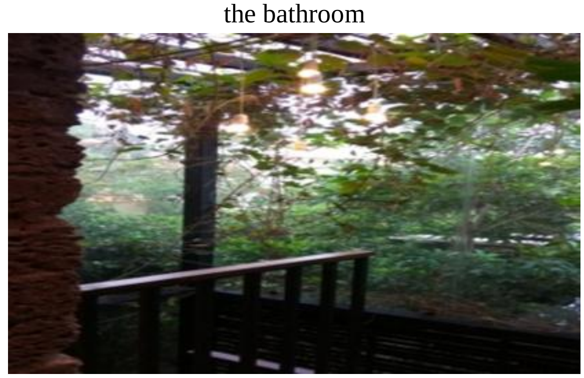

Fig 21: Staircase with side walls and roof made of tempered glass

All these create a cooling effect with the shade obtained from trees in this area, creates a positive feeling inside the building. After this huge inner open space, there comes next the dining area, kitchen and the bed rooms and all these face towards this open space. So the cooling effect obtained in the open space is also passed on to these areas and also direct availability of natural air is ensured. The passage given in the open space which separates the living room and the rest of the building is covered with glass roofing (fig 19). Above the roof creepers have been grown to provide shade. The creepers are grown around the coffee table and its walls too, where birds have even made nest. A small vertical vegetable garden is also being set up on the walls of the open space. Inside the rooms day lighting has been provided with a huge pergola design with glass roofs above which creepers have grown providing shade which reduces heat. The pergola design has been continued till the bathroom where a well and a small swimming pool are provided (fig 20). As a result a cool atmosphere is again created inside the room due to the presence of these water bodies. A naturally existing well has been preserved. Above the well, the roof is kept open with a grill provided for safety, to provide direct fall of rainwater and sunlight into it. On the ground floor lies the master bedroom and in the first floor there are two bedrooms which are separated by a cupboard provided in each of the rooms instead of walls which reduced the cost in construction. The area surrounding the master bedroom and staircase is provided with iron grill gates as a security measure. The staircase is designed in such a manner that the side walls and the roof are made of tempered glass covered with creepers to obtain natural view and light (fig 21). The material used in staircase is steel and reused wood instead of concrete, helped in reducing the cost of construction. The need of lighting till evening is very less. As a result the dependence on electricity is very much less in this building. The average temperature readings taken inside and outside the building from30 April 2017 during the time between 11am till 3pm are given in table 1

Time	Inside temperature (^{0}C)	Outside temperature (^{0}C)
11 am	30.4	35.7
12am	30.7	36.1
1 pm	30.9	36.2
2 pm	31.2	36.6
3 pm	31.0	36.5

Table 1: Temperature readings taken inside and outside of CHAMAN

The maximum temperature measured inside from 30 April 2017 between 11 am till 3 pm was 31.2oC and the minimum was around 30.40C, whereas the maximum temperature measured outside under the shade of a tree opposite to the building was 36.60C and minimum was 35.70C during the same time. So this temperature variance inside and outside the building itself indicates that conditioning can be dispensed with if inmates can make some life style adjustment.

CASE 4: THEJAS RESORT, KERALA: This building is located in Sultan Bathery, Wayanad, Kerala and its co-ordinates are 11040'01.63"N and 76014'58.36"E. The resort has been built in an area of 4000 m2 land which consists of four different types of cottages facing east. The important aspect in this project is mainly site and tree preservation. Almost 70% of the trees have been preserved and are being replanted which contains a wide variety of trees in it. Without undergoing for any site leveling, the existing topography of the site has been maintained. Each of the cottages is at different levels, where stairs are provided for the access to reach.

Fig 22: Front view of THEJAS resort

Fig 23: Salvaged wood obtained from ancient houses in Alappuzha, Kerala

Fig 24: Ancient mural art works present on the wood

Fig 25: Open courtyard which allows natural light, air and rain water inside cottages

As already mentioned about the climatic conditions in Kerala, this building is also designed to counter the problems created due to temperature and humidity. Even in this building the passive architectural design and the materials provided play a vital role in maintaining the comfort level. Maximum use of day lighting and ventilation is made which helps in achieving energy efficiency in this building. The amount of cement used is much less in this building when compared to the amount used in the building 'CHAMAN'. Even the roofs, columns and beams are not built with concrete but with wood. All the cottages are single storied. Only in foundation concrete has been used. In the office building and in kitchen area the walls have been built using laterite rocks. The outside wall has been left as it is and the inside wall has been plastered with mud. The laterite rocks used here have been cut with the help of man power only. So the embodied energy during the production of the stones was very less unless considering about its transportation from the quarry to the site. As the amount of concrete used is also very less, the embodied energy due to usage of cement is also quite less. Instead of giving concrete pavements almost all the ground area has been grown with grass which assists in the percolation of water into ground and to maintain the water table level. Only in certain areas the pavements have been done with laterite stones with spacing given in which grass has been planted. The main interesting fact about this building is that instead of using concrete and other building materials (except laterite stones at certain location) this resort is fully built with wood. Whatever wood used in this building has been salvaged from ancient houses situated in Alappuzha district in Kerala (fig 23). These ancient houses were built around 350 years ago fully with wood. The materials from these houses were dismantled are reused to build the cottages. Even after many years of use these salvaged wood can be again dismantled and reused. As a result man power is the only energy used to obtain these building materials. The main part from where embodied energy can be calculated for this building is the amount of fuel consumed for the transportation of these building materials to bring them to the site. Thus it gives a clear picture of how less is the embodied energy and carbon emission evolved from this low energy building when compared to other conventional buildings, which are mainly depended on concrete in its construction. Paints and cement plastering has been completely avoided in this building, instead at some areas such as in the Office room and kitchen, mud plastering has done. No air conditioning equipment have used here. Instead natural ventilation is provided with the help of open courtyards in each cottage and also the use of skylights provided with glass on roof to enable maximum day lighting as shown in fig 25 which helps in achieving energy efficiency in this building. Rain water is allowed to fall inside the courtyard which gives a cooling effect inside the cottages and it is been diverted to fall into the huge tank provided near to the entrance (fig 26).

Fig 26: Rain water harvesting tank provided

Fig 27: Lamps provided on pavements which works on solar energy

Along with water conservation, energy conservation and efficiency have been attempted as well. All the electrical equipment works on electricity generated from solar panels employing on photovoltaic and water is heated using solar water heaters. Small lamps which are provided along the walkways and pavements work on solar energy (fig 27). Even though energy efficiency is maintained very well in this low energy building the use of air conditioning equipment is neglected. This is mainly because of the materials which have been used for the construction especially wood. The maximum and minimum average temperatures measured during the time between 11 am to 3pm, from17 April 2017 inside the building and outside under a tree at the garden are mentioned in table 2

Time	Inside temperature (^{0}C)	Outside temperature (^{0}C)
11 am	28.8	35.6
12 am	29.1	36.0
1 pm	29.4	36.3
2 pm	29.6	36.5
3 pm	29.4	36.2

Table 2: Temperature readings taken inside and outside of THEJAS resort.

Time	Inside temperature (°C)	Outside temperature (°C)
11 am	33.7	35.6
12 am	34.1	36.1
1 pm	34.5	36.4
2 pm	32.9	36.6
3 pm	32.7	36.3

Table 3: Temperature readings taken inside and outside of a conventional building

These readings were compared with the readings obtained from a normal conventional building on the same time and day which is situated in the adjacent site (Table 3), This comparison shows the difference created in comfort levels between a low energy building and a conventional building due to the difference in the methods and materials used in both the constructions.

CASE 5: AUROVILLE EARTH INSTITUTE, PONDICHERRY

Fig 28: Office building of Auroville Earth Institute

Fig 29: Inside view of the Office room

The Auroville Earth Institute (AVEI) was founded in the year 1989 by Government of India. The Institute is situated at Auroville, Pondicherry and its co-ordinates are 12001’00.13”N and 79048’36.55”E. This is a non - profit organization which mainly deals with earth architecture and its technologies. It also conducts awareness programs and workshops for the people about earth construction, which are eco friendly, cost effective and are sustainable. In the construction of a building the institute aims to limit the use of concrete (even in flooring and roofing), instead uses Compressed Stabilized Earth Blocks (CSEB), Stabilized Rammed Earth Foundations (SREF), Stabilized Rammed Earth Walls (SREW), CSEB, vaults, arches and domes, etc. The Auroville Earth Institute has built many houses and buildings all round India and in many other countries. In this report a brief study of the Office of Auroville Earth Institute has been reported which is a perfect example of a low energy building. The building covers an area of 135 m2 which consists of an office room, meeting room, library, photocopy room and a store room. Since the building is situated at Pondicherry, which is a coastal area, the temperature and humidity at that region are very high. But the passive design and the materials used in this building have made a drastic difference in temperature within the building. The whole building was constructed using compressed stabilized earth blocks with 5% cement content. As seen in fig 28 and 29, instead of concrete roofs, domed shaped roofs and arches were built using CSEB. Opposite to the office building there is a small exhibition hall where they have exhibited various specimens of soils, stones, concrete products, compressed stabilized earth blocks which have been collected from all round the world. Some of them are shown in fig 30 and fig 31.

Fig 30: Specimens of stones and concrete products


Fig 31: Compressed stabilized earth blocks


Fig 32: Various types of CSEB

The main difference between this exhibition hall with the office building is that the exhibition hall has a flat roof made with Ferro cement instead of Stabilized earth dome. But this difference creates an increase in temperature of 10C to 20C inside the exhibition hall than the Office building. But the rest of the building was constructed using earth blocks. For both these buildings the foundations were made using rammed earth. The use of this earth construction is the main reason for the substantial temperature difference between the interior and the exterior of the building. This creates a cooling effect inside the building without using any air conditioning equipment and so reduces the use of electricity. The CSEB are made using natural soil, which is slightly moistened and is poured into a steel press which is then either compressed with a manual or motorized press. The Auram Press 3000, which is a manual press, has been used here. This was designed and developed by the Auroville Earth Institute and is renowned worldwide. It delivers a compressive force of fifteen tons on the block and can produce one hundred and twenty five blocks per hour. It consists of seventeen moulds with which can produce seventy five different types of blocks. Soil stabilization provides high compressive strength and water resistance. As cement stabilization is done using 5% of cement, the blocks must be cured for four weeks after manufacturing. After drying under the sun, they can be used as common bricks. 1 m3 of CSEB requires 1.3m3 to 1.5m3 of natural soil from the ground. Amount of water required for the production of one CSEB block including mixing and curing is about six to eight liters. Energy efficiency is one of the main advantages of CSEB when compared to other building materials. It only uses sunlight for drying (no need for burning) and man power for pressing the blocks. The embodied energy for the production of these can be accounted only for the transportation of materials and for the percentage of cement (5%) used. Embodied Energy and Carbon Dioxide Emission obtained for CSEB, Kiln fired Brick and Country Fired Brick are given below in table 4 and table 5. Dimension of CSEB used are 240x240x90 mm.i.e.192 blocks per m3.

Material	Embodied Energy (MJ/m^3)	Embodied Energy (MJ/ block)
CSEB	1112.36	5.79
Kiln Fired Brick	2247.28	11.70
Country Fired Brick	4501.25	23.44

Table 4: Embodied Energy comparison

Material	Embodied Energy (MJ/m^3)	Embodied Energy (MJ/ block)
CSEB	110.11	0.57
Kiln Fired Brick	202.25	1.05
Country Fired Brick	441.12	2.29

Table 5: Carbon Emission comparison

From the above values obtained we get an idea of how much less energy is used and how much less pollution it creates due to Carbon Dioxide emission during the production of CSEB when compared to the other bricks

Fig 33: Soil for the production of CSEB being covered with plastic sheet

Time	Inside temperature (°C)	Outside temperature (°C)
11 am	33.2	45.4
12 am	33.7	45.9
1 pm	34.1	46.3
2 pm	34.4	46.7
3 pm	34.1	46.4

Table 6: Temperature readings taken inside and outside of office building, AVEI

Along with embodied energy reduction, energy efficiency is also given high preference. The maximum and minimum average temperature measured inside and outside the building under the tree near the CSEB production unit (fig 33) during the time between 11 am to 3 pm, from 25 May 2017 are mentioned in table 6, The maximum and minimum average temperature readings taken in the exhibition hall on the same date are mentioned in table 7

Time	Inside temperature (°C)
11 am	35.3
12 am	35.6
1 pm	36.1
2 pm	36.5
3 pm	36.2

Table 7: Temperature readings taken inside exhibition hall

Fig 34: Anemometer

This shows the difference in temperature created due to the difference in materials used for roofing in both the buildings, though the rest of both these are built with CSEB. When compared with the outside temperature a huge variation is noted. All these measurements are taken with the help of Anemometer (fig 34). Along with energy efficiency, water conservation is also given high preference. Rain water harvesting tanks and ponds are provided for the collection of rain water. A sewage treatment plant is also provided from which the recycled water is taken for watering the plants. All these features such as Energy efficiency, low embodied energy, low Carbon emission, Water conservation and Passive architecture design contributes to the fact that the Office of Auroville Earth Institute is a good example of Low Energy Building.

CONCLUSION

All the five Low Energy Buildings have been studied and how these buildings have achieved in maintaining the comfort level in climate in those regions is discussed. The use of cement in construction is increasing every day and there by the amount of Carbon dioxide emitted into the atmosphere is also high, which the main cause for global warming. During cement production a lot of energy and natural resources are being heavily used in which most of them are nonrenewable. The replacement and reduced use of cement with alternatives such as earth construction and materials like fly ash can make other resources sustainable. Conventional buildings with cement as the main building component, have an inside minimum temperature difference of 30C greater when compared to a low energy building. In all these five building the use of concrete is limited. Availability of maximum daylight and fresh air inside the buildings through pergola and open windows provided makes the use of artificial lighting and air conditioning equipment very less. This helps in providing better indoor environment quality. Reducing the use of paints with high VOC content can also help in attaining better IEQ along with the reduction in cost of construction. Wood, Steel, Aluminum, Glass, etc can be re used and recycled which makes other materials sustainable and reduces the use of energy or fuel consumed for its production. The use of locally available and ecofriendly materials which reduces the embodied energy, carbon emission during production and the passive design helped in achieving all these building to be Low Energy Building.

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