Session 3551

THE DESIGNING OF THE "NATURAL HOUSE": A STUDENT'S EXPERIENCE

Radhika Kotha

3rd Yr., Mechanical Engineering Student
Muffakham Jah College of Engineering & Technology
Hyderabad, India

Abstract

"The Natural House", the inspiration of one of our professors and a project of Centre for Environment Studies and Socioresponsive Engineering in our Mechanical Engineering Department, is being designed to "behave" like an "organism" in relation to the surrounding natural environment. Within practical limits it will respond "intelligently" to environmental changes, using the feedback principle of homeostasis. Static geothermal cooling is employed in summer to keep the interior in thermal equilibrium with an underground water tank, using cooling panels attached to the inner walls. Evaporative cooling panels provide additional controlled cooling. The walls, arranged in the form of a polygon, are made up of panels of different materials to meet the overall design objectives of environmental adaptation. The roof is curved and serves as a base for a solar collector and heat shield, designed to capture all the incident solar radiation for use, if needed, and prevent direct solar radiation from heating the roof in summer. In winter some of the hot water from the collector is supplied to the wall panels for warming the house.

I am a member of the undergraduate student team working on this project. Its tremendous educational value may be summarized in the words of A.S. Neil, the founder of Summerhill, an alternative school set up in England in the 1940's: "I hear and I forget. I see and I remember. I do and I understand". Having studied thermodynamics, heat transfer, fluid mechanics, structural mechanics etc. in my courses, this is a wonderful opportunity to put the knowledge immediately into practice and thereby increase it many-fold. By actually doing "real-life" engineering I am finally able to understand what I have learnt in my courses.

My paper describes this exciting and completely novel experience of "learning by doing".

The Designing of "The Natural House": A Student's Experience

I. The context of the Natural House Project

I am a 3rd year (junior) year student in mechanical engineering at Muffakham Jah College of Engineering & Technology, a small, primarily undergraduate private college at Hyderabad, India. In June 2002 one of our professors initiated a novel program, which he named Centre For Environment Studies And Socioresponsive Engineering (CESSE). He was inspired in part by a speech given by Joseph Bordogna, Deputy Director of National Science Foundation, USA, at the MIT Club – in particular, the statement: *Engineering is not only about doing things right but also about doing the right things (1).*

Professor Ansari, the initiator of CESSE, got together a group of students from mechanical and civil engineering and initiated a project in a low-income residential area near our college, where there are serious environmental problems and scarcity of basic resources. The aim of that project is to improve the living conditions of the underprivileged residents through simple engineering inputs by regularly checking the quality of drinking water, devising a better water distribution system, a better garbage disposal and sanitation system, etc. That project is still going on.

Simultaneously, Prof. Ansari drew our attention to the problem of housing and the existing housing design and construction methods in Hyderabad. Since our region tends to have very hot summers and fairly hot weather much of the year, there is a rather large electrical power load due to the use of air conditioners by people who have them. Other people experience considerable thermal discomfort and tend to live with it. All the houses are made of brick and concrete, with no insulation, and reinforced concrete roofs directly exposed to the sun. Due to the high density of population in Hyderabad, a city of about 5 million, there is on average very little space between adjacent houses. There is also a high level of air pollution. Consequently, there is much overheating of the environment. Due to a lack of economic options, most people are willing to tolerate discomfort and do not possess the initiative and enterprise to improve their own living conditions.

Prof. Ansari's Natural House project is based on the visionary idea of tapping the processes used by living organisms to maintain equilibrium conditions – in this case, a stable internal temperature, in the midst of constant environmental fluctuations. This involves the ability to sense and register such changes and respond to them appropriately. It is also to be noted that living systems conserve their own energy and manage to keep themselves comfortably warm in winter and cool in summer with the minimum expenditure of energy.

In our discussions we were all struck by the observation that nature is evidently a superb engineer. Should we not then look to it as a teacher?

II. How a tree does it: Homeostasis and Transpiration

Homeostasis is one of the fundamental characteristics of living things. It refers to the maintenance of the internal environment within tolerable limits. All sorts of factors affect the suitability of an organism's body fluids to sustain life; these include properties like temperature, salinity, acidity, and the concentrations of nutrients and wastes. Because these properties affect the chemical reactions that keep the organism alive, there are built-in physiological mechanisms to maintain them at desirable levels (2).

An excellent example of homeostasis, based on positive and negative feedback, can be seen in the process involved in transpiration in plants as shown in the Fig.1.

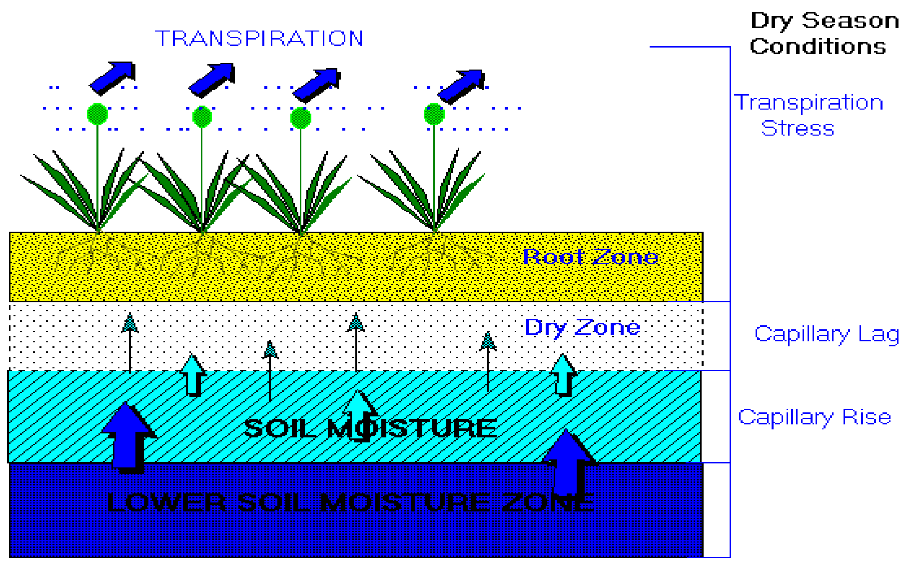

Fig 1. Transpiration Process in Plants

When a leaf's guard cells shrink, its stomata open, and water is lost. This process is called transpiration. In turn, more water is pulled through the plant from the roots. The rate of transpiration is directly related to whether stomata are open or closed. Stomata account for only 1 percent of a leaf's surface but 90 percent of the water transpired. Transpiration is a necessary process and uses about 90 percent of the water that enters a plant's roots. The other 10 percent is used in chemical reactions and in plant tissues. Transpiration is responsible for several things (3):

Transporting minerals from the soil throughout the plant. Cooling the plant through evaporation. Moving sugars and plant chemicals. Maintaining turgor pressure.

III. “The Natural House” Design

A most enjoyable part of the project from my point of view as a student is the opportunity to think creatively in an entirely new way compared to how we are taught to think (or not think at all!) in regular classes. From the beginning Prof. Ansari made it clear to us that, while the designing of the Natural House would involve a great deal of basic engineering science and analysis, it is actually the process of putting it all together to meet the overall design objective of thermal comfort, with the least consumption of external sources of energy, that is the most challenging and interesting part. This helped me to see that a “real life” engineering problem has no single, right or wrong, solution. Many solutions to a problem are possible and each one may represent a particular individual’s own creative process and ingenuity.

About twenty students are working with Prof. Ansari and a junior faculty member, Ms. Mirzana. I am one of the 8 women students in the group. We are expecting a few students from civil engineering to join the group soon as this project has many parts directly related to civil engineering. A little further down the line students from electronics, computer science and engineering and electrical and instrumentation engineering would also be invited to participate. When this happens the experience of doing "real" engineering will become even deeper and more satisfying, since all aspects of an actual house that is designed to behave intelligently like an organism will be covered. I will have the opportunity to not only apply the conventional mechanical engineering knowledge gained from standard courses, but also many "esoteric" or interface areas between mechanical, civil, electronics etc.

An example of this is the part concerned with designing a geothermal cooling system for the Natural House. The basic idea behind this is the observation that the temperature of the earth at a depth of one meter in our region (south-central India) remains fairly constant throughout the year in the very comfortable range of 25C to 27C. So, if we could tap a water source situated underground (such as a storage sump, which many homes in Hyderabad, already have in any case), this may provide a natural cooling source in summer, when the outside peak temperature is frequently above 40C. This could be done by designing and attaching to the inside walls cooling panels or jackets, which can be fed by the underground sump. To function properly the temperature of the water in the cooling panels must be tracked by a thermostat, so that when it reaches a limit say, 30C, by absorbing heat generated inside the house and that leaking in through the walls, the thermostat would trigger the process of draining the cooling panel and re-filling it with cool underground water. Hence, along with the cooling load calculations using heat transfer equations; the problem involves designing the sensing and control system, just like the process of self-regulation in nature.

The full group has been divided into several small ones, each one focusing on a particular component or feature of the house. An interesting and important feature is the idea of making the shape of the structure variable and flexible by putting together separate wall sections in the form of a polygon. The house thus need not look like a rectangular box, surrounded by other numerous look-alike rectangular boxes. Some wall sections may be made of brick and concrete and will function as load bearing sections. Other sections may be made of new materials, with high insulation properties, without load bearing requirements. Still other entire wall panels may be all glass to provide an unobstructed view where desired.

Our preliminary calculations indicate that by reducing the direct incidence of solar radiation to practically zero on the walls and the roof, which is protected by a pyramid shaped solar collector- cum-heat shield, and insulating the walls using inexpensive materials, the Natural House will be very easy to keep cool in summer (4). It is expected that the geothermally fed cooling panels may have to be drained and refilled only once every few days under normal summer conditions, and perhaps once or twice in a 24-hr. cycle on very hot days.

A view of the house as conceptualized so far is shown below (Fig.2).

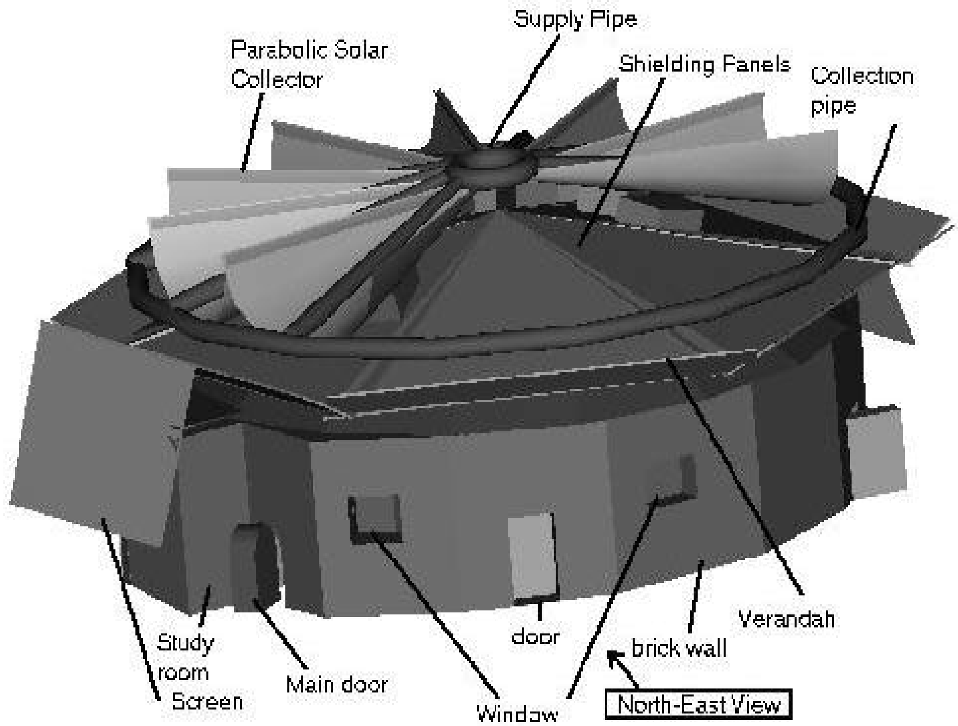

Fig.2. An External View Of The Proposed House

The most distinctive features visible externally are the unconventional shape, the verandah with an upward inclined roof to let in more sun in winter and a view of the sky at night (in summer screens are used on the verandah in the daytime to prevent direct solar incidence), a glass walled sit-out and greenhouse located on the verandah and the pyramid shaped solar collector with parabolic concentrators mounted on the dome roof. It should be mentioned that the pyramid shaped six-sided collector allows the flexibility that the panels on east, southeast, southwest and west sides can all function independently. Depending on the position of the sun in the sky, one or more panels may be made active at any one time and the rest inactive. The panels on the north side have no collector tubes and only serve as a radiation shield for the roof.

IV. Simulating natures cooling process

Using another unconventional approach, we are investigating the possibility of attaching evaporative cooling panels to the ceiling at certain places. These will provide latent heat cooling and cool the air circulating in a channel surrounding the panels. The cooled air will circulate gently into the house from above and eliminate thermal stratification. The system, depicted in Fig.3, is conceived as a simulation of the cooling effect provided by the shade of a tree.

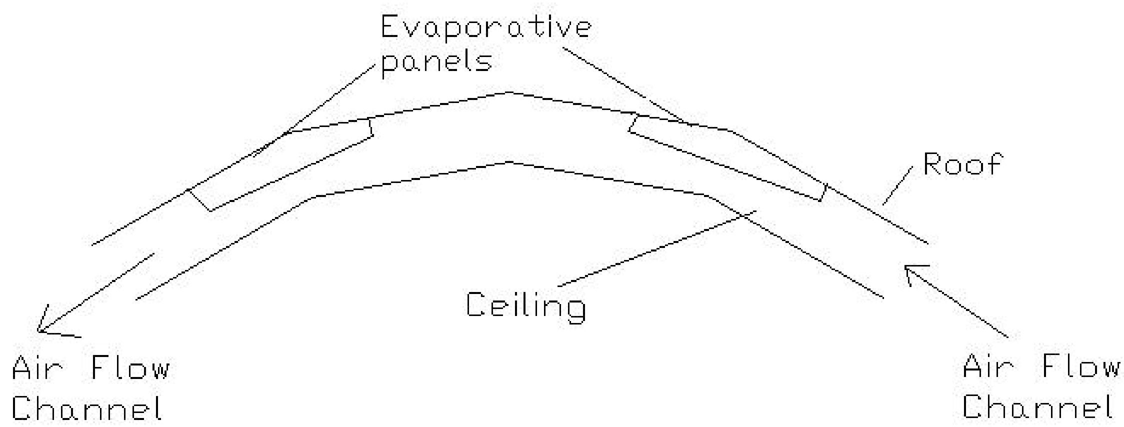

Fig.3. Evaporative Cooling System

One more feature worthy of mention that is on the same lines is the possibility of using evaporatively cooled air from the greenhouse and supplying it inside as a cool, refreshing oxygenated source of ventilation – once again, simulating the natural refreshing cooling effect of a tree shade.

V. A novel experience of "doing" Engineering

It is extremely rare for an engineering junior to have the opportunity to learn so much engineering in a single project. I think this has become possible in this particular project because Prof. Ansari has encouraged us to transcend traditional boundaries. Even though he gave us a well-defined framework, as implied by the name, The Natural House, the emphasis all along has been to do our own research and apply our own problem solving skills to the objective of designing a thermally comfortable, aesthetically beautiful house which would function with a very low expenditure of energy.

What is even more exciting is the prospect of actually building a Natural House. That would be the culmination of a long and rich educational experience. After doing the calculations and the mathematical modeling we plan to do a computer simulation of the house under various environmental conditions. The next step will be to build a working scale model for laboratory testing under actual outdoor conditions. The design can then be modified and improved as needed.

The last step, which we are eagerly looking forward to, is the construction of a small Natural House. We plan to do most of the work ourselves as a group. And we hope to be able to present to the world not only a work of inspired engineering but also a work of art.

REFERENCES

1. Bordogna, J. *Next Generation Engineering: Critical Trajectories, Holistic Approaches*, Speech at MIT Club, Sept. 12, 1997, www.nsf.gov/od/lpa/forum/bordogna/jbchat2.htm

2. http://www.uwsp.edu/geo/faculty/ritter/images/biosphere/transp2.gif

3. The World Book Encyclopedia (Transpiration T-pg 346)

4. Krishan, A. et. al. Ed., *Climate Responsive Architecture: A Design Handbook for Energy Efficient Buildings*, Tata McGraw-Hill (New Delhi, 2001)