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A combination of modern technology and heritage techniques

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Our ancestors had used mass and moisture innovatively to pro vide thermally comfortable built environments throughout the long hot Indian summers while using little or no energy. By using it together with new technologies, some buildings in Jaipur, Jalgaon, Vadodara and Ahmedabad have achieved a dramatic reduction in air conditioning costs, while maintaining a better-perceived level of comfort.

This article investigates how a simple but elegant technique, which our master builders of yore had learnt from nature, can reduce cooling load in air conditioned halls. Sheetal Minar at the CII Sohrabji Godrej Green Building Center at Hyderabad, the subject of this article, has virtually eliminated the fresh air load of the air conditioning system.

There are two ways to lower energy bills – increase the efficiency or reduce the load. Much has been written about increasing the energy efficiency; this article is about reducing the load on the air conditioning system. The method described is rooted in our Indian heritage.

Before talking about the solutions, let us understand the problem.

The Problem

When reduced to basics, there are two sources of heat in a building – internal and external. Internal sources are mainly people, lights and equipment. External sources are fresh air and the sun. The problem lies in the difference between the external loads in India and those in the West and in the difference in the construction practices between the two.

In the West, the winters are long and severe; the summers are short and mild. The buildings are insulated and have low thermal mass in order to make them easier to heat and to hold the heat in. In fact, the walls of massive buildings like churches and castles remain cold and uncomfortable and drafty even after absorbing a lot of the room heat.

In India, our massive heritage buildings remain cool and comfortable because they absorb solar heat during the day. Properly designed, the system works very well as can be felt during a visit to the Gol Gumbaz and the Taj Mahal that remain cool throughout the long hot Indian summers. The former, having 10-foot thick walls and measuring 100 feet square topped by a massive dome, depends on its enormous mass to absorb the solar load, while maintaining the 18,000 odd square feet of its interior quite cool.

Those who have visited a heritage building, even the ancestral family home, know that this technique provides thermal comfort at zero energy cost. The reason why these buildings are comfortable is that the entire structure cools down to a temperature that is several degrees below that of the human skin. By contrast, thin modern building walls heat up to several degrees above the skin.

In an air conditioned building, a cool structure will reduce solar load by a good amount and will also shave the peak. It will mean a smaller plant and lower energy consumption. The question was how it could be implemented in modern times.

Heritage Techniques for Cooling Fresh Air

The Hawa Mahal of Jaipur typifies the technique that is repeated in many other heritage buildings. Air is made to pass through fine grillwork carved in thick stone walls that are cooled by water passing through channels built into them during construction. Water and air passages are sealed from one another. Thus, the stones cool the air sensibly by contact and energy is actually removed from the air. In evaporative cooling, of course, sensible heat only changes to latent heat and the energy content remains the same.

Modern Technology

A modern version of this heritage technique is used in the CII Sohrabji Godrej Green Business Center at Hyderabad, in combination with the Moorish wind towers of Spain.

Sheetal Minar is a concept based on the Hawa Mahal of Jaipur and the Moorish wind towers of Spain. It achieves a dramatic reduction in the fresh air load in air conditioned buildings by using the traditional Indian method of cooling the air by passing it through stone work that is pre-cooled evaporatively and allowed to dry. The Moorish tower provides a compact package to combine its components while giving the architect full control of its shape and proportions for integrating it within the overall design statement.

Basic Concept

There are two ways of reducing the temperature:

- **Evaporative Cooling,** where the air makes intimate contact with a flowing stream of water, either in a wet pad or a spray. Here, while the temperature comes down, its total energy content remains the same, as the latent heat of water vapour is added. Thus while this air will cool a warm object such as a human body or some stonework, it will not reduce the air conditioning load.
- **Direct Cooling,** where the air is passed over a cold object such as the cooling coil of an air conditioner or pre-cooled stonework, its energy is actually absorbed by the object. So the cooling is done without adding any moisture.

Sheetal Minar uses both the above processes in sequence. First it cools the stones evaporatively at night and dries them using the dry and cool air at dawn. The cold stones then directly cool the hot outside air during the daytime. This reduces the cooling load of the fresh air using natural processes only.

Figure 1: Tower for pre-cooling fresh air.

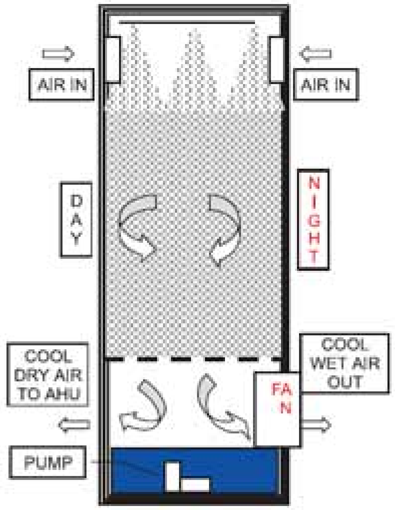

Figure 2: Inside schematic of the fresh air tower.

Design

The tower is divided into three parts. The top portion is a spray chamber with air inlets on all four sides. A pipe header has nozzles that spray water evenly into the next section.

The second section is stuffed with stones or cement blocks arranged so that the air and water pass through easily.

The bottom portion contains the two air outlets, a fan, dampers and a pump that is submerged in the water. In operation, at night, the cool dry night air is drawn in at the top and is further cooled by evaporation. The air and water cool the stone mass. Saturated air is exhausted out; the water drops into the basin for recirculation.

During the day, the pump is off, and about 100 tons of cool stones remove about 100 ton-hours of heat from 4000 cfm of hot air going to the AHU, thus saving oodles of energy by reducing the cooling load.

Operation

There are two towers, one for the Exhibition Hall and the other for the Auditorium. Each tower is a hundred square feet in plan and is 45 feet tall. The concrete blocks filling it are made with high specific heat material such as barites as aggregate. A master clock controls the operation of the pump that runs only at night. The pump runs intermittently to save energy. The 24-inch dia. exhaust fan runs continuously to draw cool dry air from the top and removes the humid air from the bottom. Thus, the water and the air run co-currently. The pump stops at about 4 A.M., but the fan runs for a few hours more so as to dry the stones with the cool morning air. The tower now has about 100 tons of dry blocks cooled to the wet bulb temperature of the night air. The wet bulb temperature goes below 18°C during early morning even in summer.

When the AHU starts, an interlock cuts off the exhaust fan and the pump, if they are running. Automatic non-return dampers allow airflow into the AHU, while blocking the reverse flow from the exhaust fan outlet. Now the 45°C air entering at the top gets sensible cooling of about 100 ton-hours.

While the maximum rate of fresh air is 4000 cfm, CO_2 sensors regulate it to vary with the occupancy. Thus, the fresh air load is almost eliminated. All functions are integrated into the BMS system.

One important point to remember is that the minar must be dried after the evaporative phase in order to avoid fungus growth and its associated stink. This is why the exhaust fan is made to run for a longer time after the pump has stopped. Care must also be taken to prevent mosquitoes and birds from making it their home.

Another point is that this is only the first attempt, so many parameters were chosen empirically. I am sure that the numbers derived during operation will result in a much better design for the next tower that is already on the board.

Conclusion

Our ancestors did not have the technologies of RCC, welding, air moving, pumping or thermodynamics except perhaps in rudiments. Of course, they did not have electricity. By infusing these into their technique of structure cooling, sufficient savings have been achieved to keep AC&R affordable and sustainable. May it be universally adopted.

In the end I wish to acknowledge with thanks the excellent civil design work by Shashikant Shah of Minar Constructions, Vadodra.

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