Sustainability and Technical systems in buildings

Case study: CII – Green Business Centre,

Hyderabad, India

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Note: This article is meant for project managers, architects. Some Technical terms are therefore simplified for better understanding. Efforts have been made to make it interesting for HVAC Engineers as well.

0 Introduction

This article provides a brief overview about the Techno-commercial aspects of use of Wind towers in **Green Business Centre, Hyderabad, India** and a possible application of similar Technology for Modern Residential / commercial Buildings in Indian sub-continent

0.1 Brief Facts:

- Green Business Centre, Hyderabad is recognized as a World's Greenest Building and has a Platinum rating (version II) from LEED (Leadership in Energy and Environmental design, USGBC)
- Wind towers at GBC fall under of Energy and Atmosphere saving / conservation systems of LEED rating. LEED rating system awards 27% importance to Energy and atmosphere.
- Two Wind towers are a part of Air conditioning system of a 300 seat Auditorium at GBC (Green Business Centre, Hyderabad)
- It is unique mix of ancient Indian Air cooling methods and Modern Air conditioning Technology.
- This is an excellent use of Zero-energy Technique (or passive cooling) for Lowering the Fresh air temperature in Air conditioning system

0.2 Thermal comfort: Same Goal, Different Techniques

In Europe / North America, in severe winters, the main aspect of Air conditioning is how to hold the heat IN. Buildings are insulated and have low thermal mass. Comfort is maintained by circulating hot air. Mild summers mean lower cooling load and higher efficiency.

In India and Indian subcontinent, in sweltering summers, the main aspect is how to keep the heat OUT. Buildings are bare and have high thermal mass. This adds to the cooling load. High ambient causes low efficiency of Air conditioning systems. Energy is costly (Considering PPP) and unreliable (Most of the sub-continental countries being either developing or under-developed)

European Interior: Insulating material keeps Heat IN

Indian Exterior: High Thermal mass to keep Heat OUT

0.3 Heritage has the answer

Every culture has evolved its architecture to suit the local environment. In US / Europe thermal comfort means providing heat during cold winter months. Their buildings have low thermal mass and are tightly insulated to prevent cold drafts and heat loss.

In Indian sub-continent thermal comfort means avoiding heat. In a hot dry climate, protection from sun is essential. Builders of past evolved an elegant three pronged formula for thermal comfort.

- **Raise barriers against sunlight / Heat:** Shade from surrounding gardens, tall trees, Verandah ensures that most of the sunrays are resisted from reaching the Main building structure. Greenery in near vicinity ensures that heat rise due to reflection is minimized. Trees are Nature's own evaporative coolers - perfect for the dry climate. Trees also filter blowing dust from the air.

- **Use of mass to delay heat transmission:** Thick walls usually made of material having high Thermal storage capacity ensure that the Heat that reached the walls be absorbed. The walls with reflective surfaces will improve the performance further.

- **Drain out the residual heat:** To flowing water and to the sky by radiation, mostly at night.

None of these processes need energy and are therefore very GREEN.

0.4 Passive cooling: Wind towers

A primary area of energy intensive operations in a typical structure today is that of mechanical cooling. Increasingly, air conditioners, coolers and chilling units are being used to cool urban dwellings. This usage is exacerbated by the fact that predominant housing is mass produced; high rise apartments and residential complexes distance the end user from the construction process, making decisions on material usage and climate control difficult.

The term 'passive cooling' implies a technology in direct contrast to present day cooling technologies which are energy intensive and focus on forced cooling of enclosed spaces. A passive technology is essentially energy efficient, as it uses methods that enable natural cooling of a space, utilizing the natural elements and materials conducive to cooling. The use of moist grass mats over a window, for instance, cools wind blowing into an enclosed space … a cost effective and energy efficient technique. Similarly, the use of rammed earth in walls, and white reflective finishes on exterior walls are all examples of passive cooling systems.

Passive cooling technologies have been in use for over 4000 years in most societies, proving energy efficient as well as cost efficient. With urbanization and the development of mechanical cooling devices, traditional technologies gradually faded away.

However, a gradual realization of the implications of energy intensive mechanical cooling devices have sent designers and architects back to look at traditional technologies for their potentials in present day application. The last three decades have seen the emergence of innovations and applications based on the traditional systems of passive cooling.

Wind tower has been a traditional cooling device in areas with hot dry climate, such as many parts of North India, Iran and desert countries like Egypt and Morocco.

Cool towers use gravity to move cool air without any fans. They do this by having a wet pad medium in the top of the tower. Since cool air is heavier than warm air, it will fall, creating its own airflow. Wind is not required, but will improve the airflow in a cool tower.

Generally cool towers without fans are from 20 to 30 feet tall and between 5 and 10 feet square (5'x 5', to 10' x 10'). Typically cool towers of this size will require from 10 to 150 watts, and will cool 1,000 to 2,500 square feet. Airflow for these cool towers will range from 2,500 to 8,000 CFM

Breeze towers at GBC; Hyderabad is one such example of improvised design with a little variation for economical purpose. Fans are used to induce the air instead of natural flow. This in effect reduces the size of the towers.

1 Basic Concept

1.1 Breeze Towers (Sheetal Minar)

`Breeze Towers´ 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 evaporative pre-cooled 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.

There are two ways of reducing the temperature:

1. 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 vapor 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.

2. 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 achieved without adding any moisture.

Wind Towers at GBC use both the above processes in sequence. First, evaporative cooling of stones 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.

2 Construction & Operation

2.1 Construction

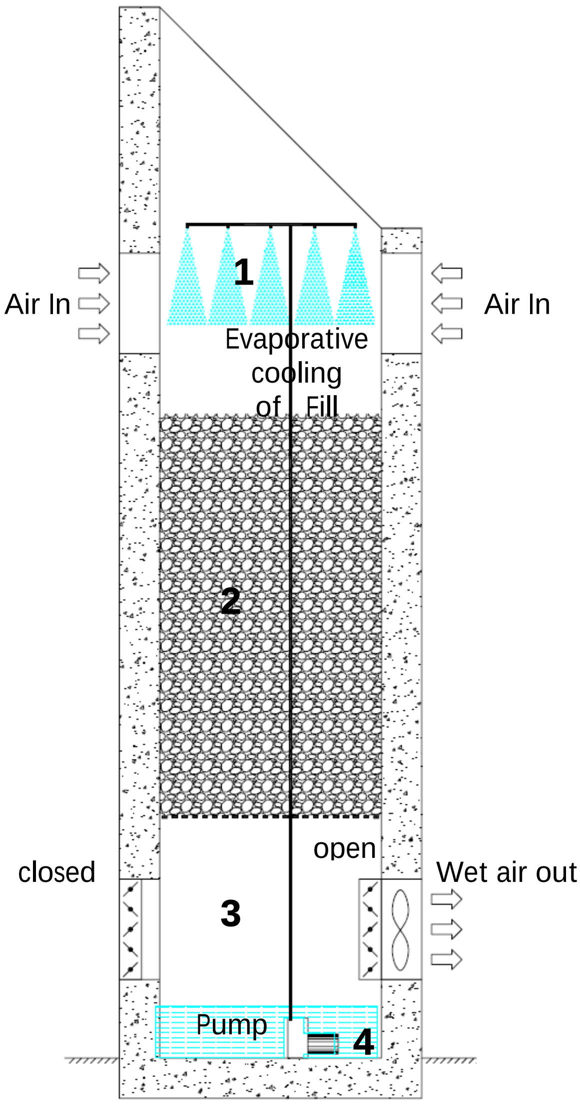


Figure 2.1: Night Cycle

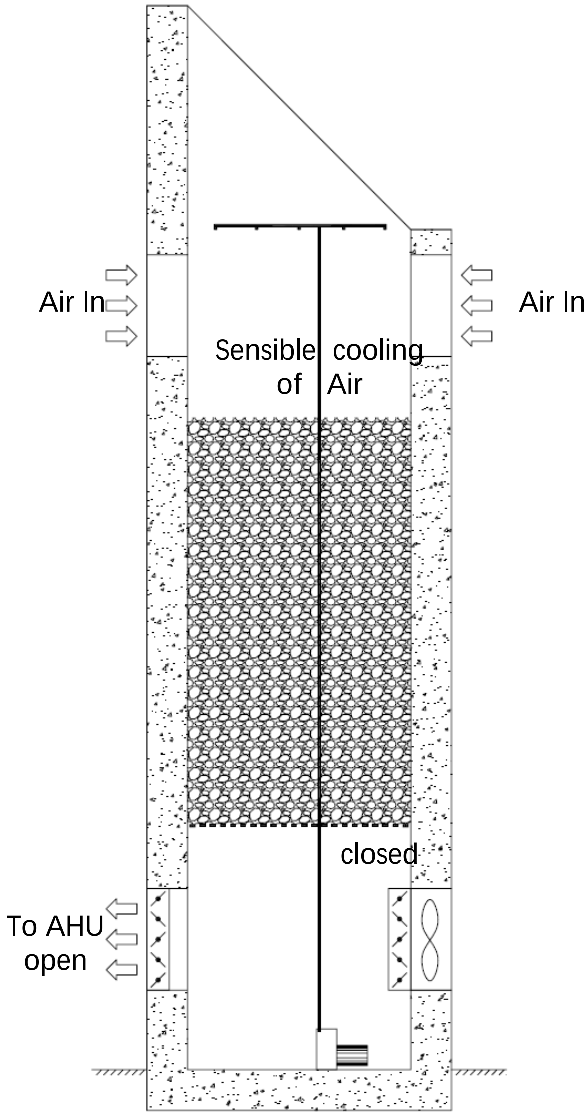


Figure 2.2: Day Cycle

Legend:

1. Spray Chamber
2. Solid fill
3. Air Outlet Chamber
4. Sump

A Wind Tower at GBC is a 14 m High Tower with Air Inlet at the top. It is divided in four sections.

1. Spray Chamber

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 Pipe and Nozzle size is based on the quantity of water required to evaporative cooling.

2. Solid fill

The second section is stuffed with stones or cement blocks (Approximately 100 Ton) arranged so that the air and water pass through easily.

3. Air Outlet Chamber

This chamber contains the two air outlets, a fan and gravity dampers. These dampers ensure Air flow only in one direction

4. Sump

The bottom portion is a Water sump with submerged pump.

2.2 Operation

The heat load in any Room / Building can mainly be attributed to following factors

a. Solar gains
b. Internal sensible load
c. Fresh air and room latent load.

The Wind tower operation is mainly conducted in two cycles. This cycles (Start time, stop time) and related processes can be controlled by automation.

2.2.1 Night Cycle

During this operation, (Refer figure 2.1) at night, the cool dry night air is drawn in at the top (with the help of a fan at bottom of the tower) and is further cooled by evaporation in sprinkler chamber. The stone mass gives away heat to passing air and water and in process cools down substantially. Saturated air is exhausted out; the water drops into the basin for re-circulation.

After the routine for the night starts, say at 2200 HRS, the solenoid valve (Timer) remains `ON´ for 25 min.

During this period, the tank is filled up to its maximum required capacity.

After that, the pump remains ON for 2 min. and OFF for 10 min. until the level of water in the tank drops to the desired level (determined by the Flow Switch). The system functions as per this cycle the whole night depending on the water level.

Fan remains ON continuously during night operation.

If the fresh air inlet temperature to AHU is low (Below the set point of 16 °C), then the pump remains OFF during the night.

2.2.2 Day Cycle

a) During severe summer: (at peak hours, Peak load) with Mechanical cooling

During the day cycle, the pump is off, and the large mass of cool stones remove heat from the hot air going to the AHU, thus saving oodles of energy by reducing the cooling load.

1. The Pump & Fan system of the Wind tower is shut OFF.
2. The Drain valve is operated to drain off all the water in the tank for 4 hours.

The Fresh air requirement in this system is limited. (In case of GBC, it is 4500 cfm, 15 cfm/person for a 300 seat Auditorium)

b) During Mild summer: (at comparatively low heat load) without Mechanical cooling.

This system can be used without any Mechanical Air conditioning rather with increased Air volume, the cooled air passing over the stone mass can directly be circulated in the conditioned space. In this case the air volume required will be more to cater to the heat load of the Conditioned space. (In case of GBC, 12,000 cfm air (24°C) is circulated to achieve comfort conditions.

In order to avoid the growth of fungus on the blocks, in humid weather conditions & when the offices are unoccupied, the Exhaust fan/AHU fan should operate during the day to dry off the moisture from them.

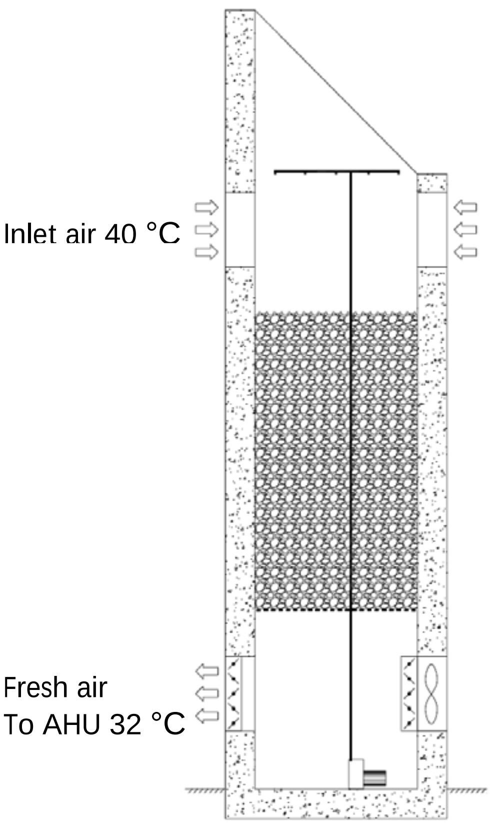


Fig 2.3 Example: Peak summer, Peak load
In tandem with Mechanical cooling system

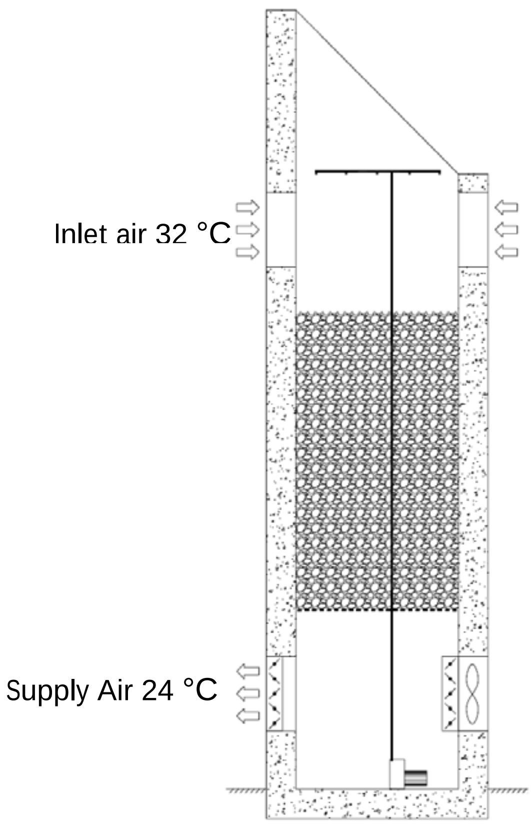


Fig 2.4 Example: Mild summer / Mild heat load
Without Mechanical cooling system

3 Design Basics

3.1 Design Conditions: (GBC, Hyderabad)

General:

Elevation : 545 m
North Latitude : 17.45
East Longitude : 78.47

Summer:

Design max. Temperature : 40.30°C (Standard Deviation 1.1°C)
Mean daily range : 10.5 °C
Relative Humidity : 21.60%
Average Min. Temperature : 12 °C (Standard Deviation 2°C)
Wind Design value : 9 m/s (irrelevant at GBC due to use of fan)

Occupancy : 300 persons (Max)
Fresh air : 15 cfm / person
Total Fresh Air Required : 4500 cfm
(The Table below shows 12000 cfm, Refer 2.2.2 b)

The drop in Air temperature during the day cycle will mainly depend upon following factors

1. Type of material used for fill (Also read section 6.2)
2. Contact factor: This will depend mainly upon the way fill is arranged to provide more contact to air, Height of the fill column, Air velocity in the tower
3. Temperature difference: between Outside Air and fill (Depending upon Night cycle) Here we assume that we do not cool the water Mechanically before spraying)
4. Air volume passing over the fill during the day cycle.

The Height, Cross section area, Fill height will be designed based on system requirement.

Here we shall see sample results taken at GBC Hyderabad. The table below shows Average saving (Tonnage) at peak hours (11:30 Hr – 15:00 Hr) on a normal sunny day.

Table 3.1: Sample Results

SR. NO.	TIME (HRS)	AMBIENT CONDITIONS		AIR FROM WIND TOWER		AIR FLOW	SENSIBLE COOLING	EQUIVALENT TONNAGE
		DBT °F	WBT °F	DBT °F	WBT °F	CFM	BTU/HR	
1	1130	81	73	73	70	12000	103680	**8,64**
2	1215	84	72	72	69		155520	**12,96**
3	1300	82	70	74	68		103680	**8,64**
4	1330	82	71	74	68		103680	**8,64**
5	1400	83	70	74	68		116640	**9,72**
6	1415	85	71	74	68		142560	**11,88**
7	1430	83	71	74	68		116640	**9,72**
8	1445	85	71	74	68		142560	**11,88**
9	1500	83	69	74	68		116640	**9,72**

Original Data from tests carried out by the designers of the GBC Wind Tower, M/s Panasia Engineers Pvt. Ltd., Mumbai, India. Used by permission

4 Analysis

Based on the results mentioned in Table 3.1 we can evaluate the utility of the system as follows:

- For the entire system the average saving is approx. 30 KW / Hr. during the day cycle.
- Considering 6 Hot Hours a day the saving will be approx. 180 KW / day.
- Considering @ 200 hot days a year 36000 kW per year
- Power charges in India are approx. Rs. 4 / KWH

Note: Electricity in India is subsidized by Government. The balance charges are borne by State governments.

- The saving will be Approx. Rs. 1,40,000 / year.
- Low maintenance due to very few number of moving parts in the system
- Most of the fills are stones and concrete blocks (Need no replacement) but only periodic cleaning.
- Initial cost of the system is approx. Rs. 5,00,000/-
- The Break even period will be approx. 4 years.
- *Considering the fact that with the Wind tower system, Air conditioning plant size will reduce (Though this may not be always the case) If the plant size is reduced by 10 TR in GBC, The cost of Wind tower is offset by cost savings due to Reduction in plant size , This makes wind towers profitable from the first day of operation.*

5 Wind Towers Improvisation

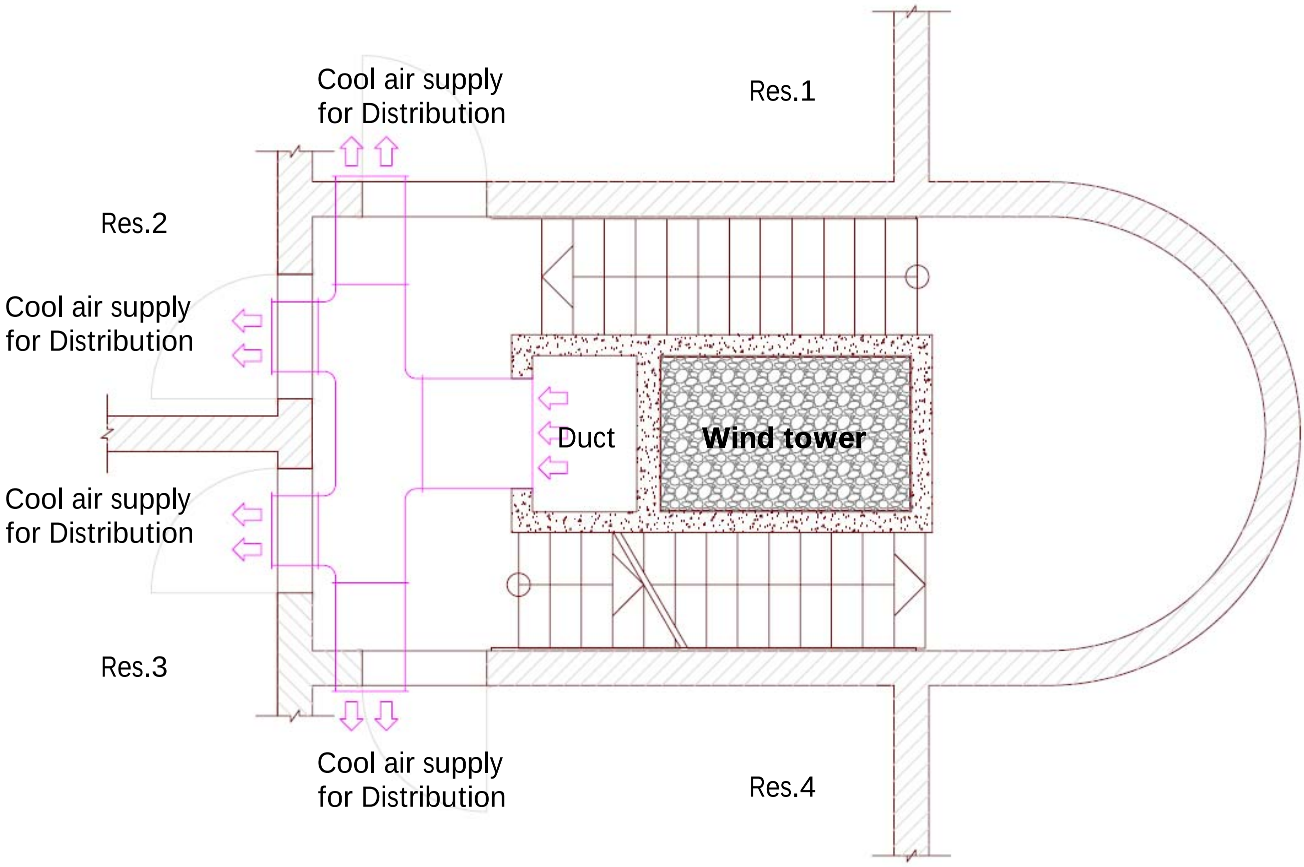
5.1 Wind towers in Residential / commercial buildings

Wind Towers were being used successfully for a very long period. A blind adaptation of western construction styles during last century has made this system a thing of past.

A very simple and inexpensive alteration in present day buildings can

- Reduce use of Mechanical cooling in residential / commercial buildings.
- For majority of Indian population who can not afford to install Air conditioners at house, summers will still be 7 – 9 °C cooler and no extra cost burden

Figure 6.1 shows an example of improvised wind tower in a typical 3-4 storey residential building.



5.2 Fill materials

There are various alternatives for fill material. The basic criteria for selecting a fill material are

- Good specific heat capacity
- Easily available
- Economical
- Ease of maintenance (corrosion, disintegration free) Hazard free

The specific heat of a substance is defined at the amount of heat that must be absorbed or lost for 1 g of that substance to change its temperature by 1º C.

5.2.1 Concrete Blocks

Considering the depth of the fill, the pressure drop might be too high. At GBC, regular hollow cement blocks are arranged with their cavities aligned vertically to provide a generous air passage area. Since the cooling is by water, the heat transfer is much better. In the day cycle, the temperature difference, and the rough surface of the blocks provide adequate cooling.

5.2.2 Stones / Rocks

As a heat / cold storage material, stones are cheap and readily available, have good heat transfer characteristics with air (the transfer medium) at low velocities, and act as their own heat exchanger. Rock storage is the more reliable because of its simplicity. Once the system is installed, maintenance is minimal and few things can decrease the performance of the storage.

Although size of stones selected will be determined primarily upon cost, in general, the larger the size the better for storage purposes. The main reason is that it takes less power to force the heat transfer air through large stones than through small ones. Stones less than an inch in diameter are usually too small; whereas ones more than 4-6 inches in diameter are too large, because of insufficient heat transfer surface area.

If gathering your own stones for storage, look for round field stones in the 4- to 6-inch diameter range. If buying commercially from a stone quarry, the largest size available is probably "septic gravel", which is 1-3 inches in diameter. But don't be overly concerned about size; settle for a 2-inch septic gravel if you'd have to pay a premium for larger rock. Probably more important than stone size is uniformity of size. If there is too much variation, the smaller stones will fill in the voids between the larger stones, thus increasing the air blower power requirement. Also, avoid those types of rock that tend to scale and flake, such as limestone. The resulting "dust" is picked up by the heat transfer air and either clogs the filters or, is blown directly into the conditioned area.

Since air must be drawn through the rock bed, it's necessary to know the amount of power needed. In general, the faster the air flow and / or the smaller the rock size, the greater the power requirement.

Before filling the storage facility, consider washing or screening out "fines" which might otherwise fill in the voids. The rock storage should allow some way for accumulated moisture to be discharged. Also, consider ways to prevent mold and bacteria growth.

5.2.3 Water

The cooling capacity of the wind tower can be improved by using alternate fill materials with higher specific heat.

One such material which is freely (almost) available in nature is water. The specific heat of water is 1.00 cal/g ºC. Compared to stone (0.20 cal/g ºC) it is 5 times higher.

Water as a storage material has the advantages of being inexpensive and readily available, of having excellent heat transfer characteristics. Because of the good heat storage-to-volume ratio Water collection and storage systems can be very practical:

- Where close maintenance is available (such as in multiple-residence or industrial buildings),
- Where water storage system can be directly coupled with an existing system as in residential systems.

Thinking out of the box can provide solutions that are much cheaper than the cement block system.

5.3 Combination of Sensible cooling and Evaporative cooling

In extreme dry atmosphere, combination of wind tower and evaporative cooling can be used to further reduce the indoor temperature. HVAC Engineers should check the possibility and offer the right solution.

6 Operation and Maintenance

- In order to avoid the growth of fungus on the blocks, in humid weather conditions & when the offices are unoccupied, the Exhaust fan/AHU fan should operate during the day to dry off the moisture from them.

- Periodic cleaning of fill by cleaning agent shall be planned

- Mechanical components (e.g. Fan, Pumps, valves, Dampers) need periodic maintenance

- Electronic components, timers, sensors, flow switches need periodic replacements

- Nozzles, spray pipes may need replacement

- With proper Automation, system shall not require an operator

7 Conclusion:

Most of the heritage buildings of Ancient India such as Taj Mahal, Gol Gumbaz, hawa-Mahal, use some simple systems to keep away scorching Indian heat.

All our heritage buildings and even rooms ancestral homes remain cool in the worst of summer. Our ancestors had evolved a three-pronged technique to provide thermally comfortable built environment — Barriers, Mass and Water Body.

That this zero energy technique works well is self-evident. The tragedy is that it was trashed as impractical by the That this zero energy technique works well is self-evident. The tragedy is that it was trashed as impractical by the Western educated Indian technologists who never bothered to apply the huge pool of new technologies to this technique so as to adapt it to modern times.

Results show that our heritage has far better answers for Green Technology.

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