

Air-cooling and Heating System for Tiger in Zoo using Earth Tube Heat Exchanger

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A specially designed air-cooling (and heating) system using Earth Tube Heat Exchanger (ETHE) was installed in the dwelling of a 15-year old white tiger (*Panthera tigris*) named ***Mahesh*** at Kamala Nehru Zoological Garden, Ahmedabad (India) in October 2000. This was done to alleviate the stresses experienced by ***Mahesh*** in summer, which is long and hot; and in winter nights, which can be quite cold. Summer temperatures in Ahmedabad remain around 40°C for a long time and can reach as high as 45°C . Night temperatures in winter can drop to 10°C or below. The system does both--provide cooling in summer and warming in winter. In winter the system warms up the ambient (cold) air by as much as 10°C at night. In summer the system cools the ambient (hot) air also by as much as $8 - 10^{\circ}\text{C}$ during the day.

Tiger Dwellings

There are four separate dwellings at the Zoo for the four tigers it owns. Each dwelling consists of a covered building of 12 m x 4 m x 4 m. Each dwelling can be divided into three sections using movable partitions. The front part is the exhibition section, middle for rest and the rear section is a gallery from which the tiger can go into an open yard bordered with a deep moat. Walls are 45 cm thick made of brick. Roofing is 10-cm RCC slab. Each compartment has two vents--one near the ceiling other one-meter above the floor. Vents have grills but no shutters. Lower vent is 45 x 45 cm, upper vents 60-x 45 cm. The exhibition section has floor-to-ceiling iron gate.

Animal keepers indicated that high summer temperatures cause stress to tigers as a result of which, their intake of food is reduced. Attempts are made to cool the dwellings by hanging wet straw mats and in some cases even using desert coolers. But this makes the inside very humid, which encourages growth of bacteria and pathogen. They also indicated that very low temperatures in winter nights also cause discomfort. During exceptionally cold spells convective electric heaters are used especially for the older animals. But again, it is not quite satisfactory, considerable amount of electricity is consumed. They indicated that it would be good, if a system could be devised that keeps the dwelling within comfort zone both in summer and winter, without requiring that it be closed airtight, and without making the dwelling very humid. Also the solution needs to be cost effective and sustainable.

ETHE works as a dual mode airconditioner--cooling in summer and heating in winter. It does not use water and thus will not increase humidity. Given these features, it was considered that ETHE based system would be most suited. Earth Tube Heat Exchanger is a device that permits transfer of heat from ambient air to deeper strata of soil and vice versa. It is based on the well-known fact that while ambient temperatures are subject to daily fluctuations, temperature of the soil beyond a depth of, say, 2 meter remains virtually constant. Though seasonal variation does occur, the fluctuation in deep soil temperature remains much smaller than that in the ambient. Deeper layers of soil can thus be used both as heat sink (in summer) and heat source (in winter). ETHE is indeed used in Europe and North America to condition (cool and heat) the air for use in livestock buildings and greenhouses. It is also now being considered a good option for human residence.

Prior to designing the system for the Zoo, deep soil temperature was measured for one whole year using a specially devised vertical probe on which sensors were mounted. Measurements indicated that in Ahmedabad region temperature below 2 m depth remains between 25 - 27°C. It appeared quite feasible therefore to design an ETHE system to meet the Zoo stipulations of comfort zone.

System

The system consists of an earth-tube heat exchanger, a high-pressure industrial blower, supply duct, distribution ducts with baffles, grills and diffusers (**Figure-1**). Two parallel tubes (**A**) constitute the heart of the system. Tubes are buried in the floor of the moat. Each tube is 30 m long and made of 20-cm diameter MS pipes. Thickness of the tube wall is 4 mm. Inlet of the tubes is conical (**B**) and covered by wire mesh screen to prevent birds, insects, etc. from being sucked in. The tubes run parallel at the same depth separated by 1.5 m from each other.

Both tubes are connected to a header (**C**), which in turn is connected to the suction end of the blower. Blower is made of aluminum and has radial blades. A 30 cm diameter HDPE pipe (**D**) connected to the delivery end of the blower takes the conditioned air to supply duct near the dwellings. Three diffuser inlets supply the air to each of the three compartments of the dwelling. Inlets are fitted with louvered diffuser.

The HDPE pipe is buried at 1 m depth. It is not intended to play any role in conditioning the air. It is buried only so as to be out of the way of the tiger and functions only as a conveyor of conditioned air. Had the moat been nearer the dwelling, this would not have been necessary at all. Vertical air inlets, blower housing and supply ducting and other parts exposed to ambient are insulated with glass-wool.

Air flow rate has been set to 1600 cubic feet per minute (cfm). This is the volume required to remove heat gained by the dwelling in summer from exterior walls, roof, partitions, vents (sensible and latent) and that generated by animal. Heat generated by the single animal is negligible. Tigers are always housed singly. In cases where groups of animals are housed together, cattle for instance, this component will be important. The airflow arrangements are so made that air velocity near animal body surface does not exceed about one foot per second.

Performance

System was commissioned in October 2000. Its performance was first tested in January 2001 at night. System was turned on at 10:00 P.M. when the ambient air was at 20°C. It declined steadily as night progressed. By early morning it was 12.3°C. The ETHE delivered 24°C air to the dwelling. After 8 hours of continuous operation, through the night, it declined only to 22°C. In other words the ETHE could warm the ambient air by as much as 10°C. This is a very satisfactory performance. System was used almost each day for 5 to 6 hours during the summer of 2001, from April to June. Measurements were similarly made. In cooling mode also the reduction in temperature was found to be nearly 10 degrees, from 42°C ambient to 32°C at the dwelling.

The project was undertaken due entirely to the initiative of the Zoo authorities. To our knowledge, this is first such application in India. Zoo authorities here are keenly aware of the need to improve the environment in which animals live. They have been experimenting with and improvising various ways to achieve that. They had indicated that the system would be under observation for a year. If the performance was satisfactory, it would be expanded. In anticipation, provision has already been made in the basic design. Extension to adjoining dwellings can be possible with minimal additional expenditure.

A Comparison of ETHE Based Systems and Others

ETHE based systems are not a substitute for conventional air-conditioning systems. But these have some features that are highly desirable from the viewpoint of impact on environment and sustainability.

ETHE systems utilise deeper layers of soil as heat sink and source. This opportunity is created by nature and is available most everywhere. Being a natural phenomenon it is sustainable indefinitely.

ETHE does not use any water. Evaporative air coolers consume large quantities of water, which is scarce in many places. For the same reason, ETHE air does not become excessively humid and is accordingly healthier for both animals and humans. Breathing excessively humid air reduces the resistance of animals to diseases. Conventional (refrigeration) air-conditioning is expensive, especially the running cost. Moreover, it would require that the dwellings be closed. This is not convenient in zoos. Lions, tigers, leopards frequently urinate to mark their territory. Their urine contains high amount of urea. In order to remove the odour, it is necessary that the zoo dwellings be well ventilated. ETHE makes this easily possible.

In addition, one can use the system as an easy means to provide to the animals inhaling medication when they suffer from cold or respiratory problems. Eucalyptus oil gauge for instance can be placed near the air inlet, which will spread it to all the dwellings connected to the system.

ETHE does not degrade the environment as the refrigerants, in the long run do. Compared to the conventional air-conditioning. ETHE system uses much less electricity and is economical to install and run.

ETHE is a dual mode air-conditioner that is it works as a cooler in summer and a heater in winter. This feature is not found in the so-called desert coolers or conventional air-conditioners.

Some animals, especially reptiles are cold-blooded animals. They can not survive extreme climates. In cold winter months, if heating is not provided, they become less active, sluggish and mortality is increased. Reptiles go into hibernation, which makes the visitors wonder if they are alive. ETHE based systems are good option for such situation. In short, such systems can greatly help animal conservation in zoos and enable them to carry out their other functions--education and research on endangered species--better.

Figure 1 : ETHE System at Zoo (schematic diagram)