TECHNICAL ABSTRACT

Earth-Air Tunnel System for Cooling A Hospital Building at Mathura, India

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The use of earth as a heat source and a sink with buried pipes or underground tunnels as a direct heat exchanger is a concept that has existed in Islamic and Persian architecture for a number of centuries. The systems based on this concept have been repeatedly used in architectural design for natural conditioning of the air to maintain internal comfort. However, the non-availability of performance data on actual systems has restricted the extensive use of the concept.

The earth-air tunnel system exploits the heat-storing capacity of earth, which makes it potentially useful in providing buildings with air-conditioning. Earth has a large thermal capacity, and therefore the heat collected in summer reaches the interior of the earth during early winter, while the winter coolness stays within the earth until the summer. As a result of this, the ground temperature below a certain depth remains constant throughout the year. Therefore tunnels constructed at this depth (equal to 4 m for Delhi-like climates) conditions the passing air, which can then be used for heating and cooling buildings. The tunnels may be especially useful in the context of multistorey buildings where conventional evaporative cooling techniques are not effective.

One such system, designed and built by American missionaries, is situated at the Methodist Hospital, Mathura. This system consists of a big tunnel and a network of smaller tunnels connected with it. A pictorial view of the main tunnel is shown in Fig. 1. The inner walls of the

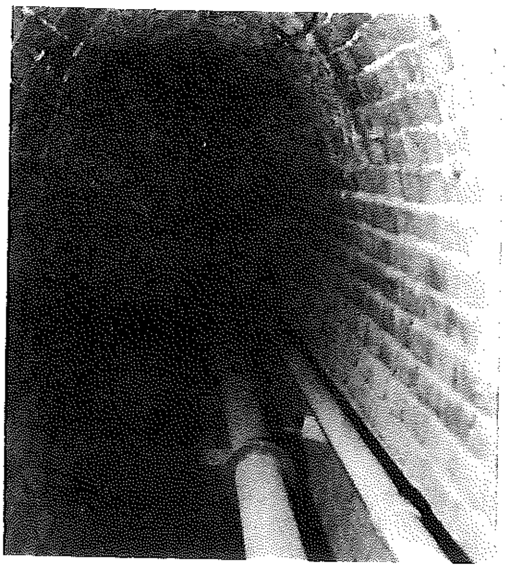

Fig. 1 Internal view of the earth-air tunnel system.

tunnels were made of brick and were made waterproof by using polythene sheet behind the bricks. The combined length of the tunnels is 1 km and the cross-sectional area of the tunnels varies from 3.66 m X 4.57 m to 0.91 m X 0.91 m.

In order to provide natural light inside the tunnel, skylights were provided at regular intervals in the main tunnel. The smaller tunnels run under the buildings and are connected by vertical ducts to each ward and room of the hospital building. Residential flats were also furnished with this system. Dampers were provided in the tunnel at appropriate places, and fans were installed which would draw the tunnel air into the rooms. To supply ambient air to the tunnel an air-intake tower was provided at one end of the tunnel. The schematics of the hospital complex using the earth-air tunnel system are shown in Fig. 2. Unfortunately, the system could not be used because of periodic flooding of the tunnels which left a lot of silt deposition and other wastes

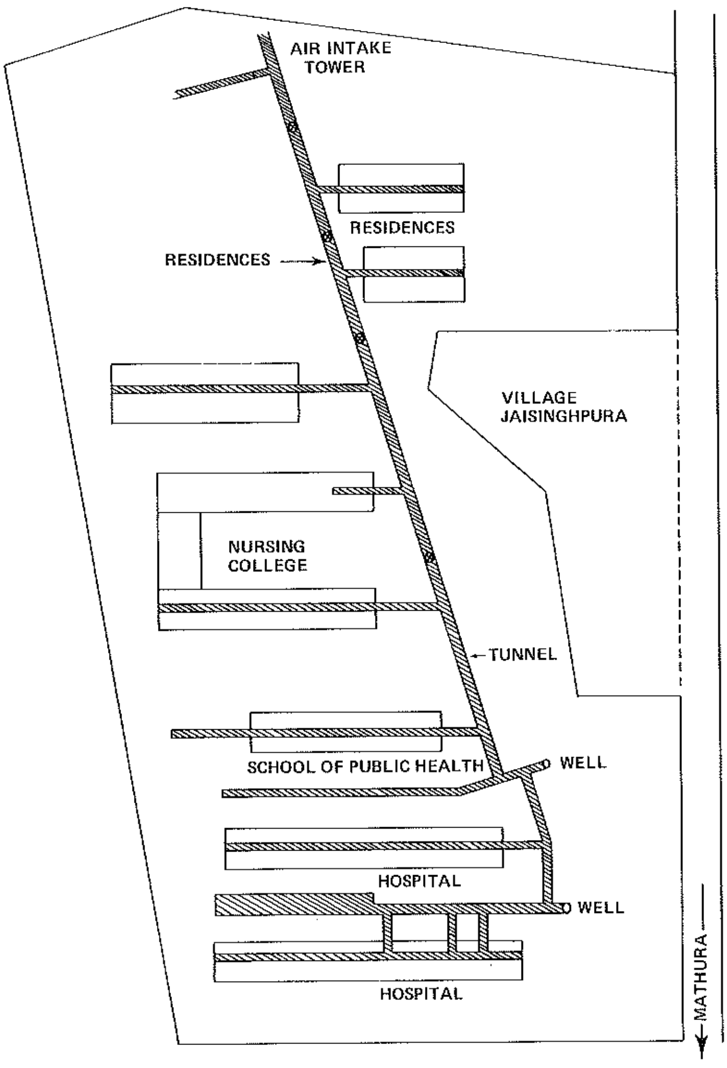

Fig. 2 Schematics of the earth-air tunnel system at Mathura.

inside the tunnel. In February, 1981, a team of scientists and architects from the Indian Institute of Technology (IIT), New Delhi, and the School of Planning and Architecture, New Delhi, visited the tunnel and decided to test the system, provided financial grants were made available. Later, a proposal was submitted to the Indian Government's Department of Non-Conventional Energy Sources in New Delhi, which awarded a grant to conduct the tests to IIT in December 1982. The principal investigators for the project were Professor M.S. Sodha and Dr. N.K. Bansal.

In view of insufficient facilities and the restricted time period allocated for the execution of the project, the experiments were carried out with only a part of the tunnel system. The damaged part of the tunnel had to be repaired and sealed against the infiltration of undesirable air prior to the experiments. The length of the experimental portion was 300 m. The air temperature, the surface temperature of the tunnel, and the humidity of the air were measured as a function of tunnel length using resistance thermometers (Pt-500) and thermocouples from March 1983 to June 1984. Observations were made throughout 24 hours at one-hour intervals. From the extensive experimental data on the earth-air tunnel system it has been established that the system provides sufficient summer cooling (Table 1) and partial winter heating (Table 2). In winter, the temperature of the air was in the order of 17°C. This heating was inadequate in view of the low ambient air temperatures (≅ 10°C), and it was realized that auxiliary heating was necessary.

In summer, the average temperature of the air at the outlet of the tunnel was 26-28°C and remained almost constant. The humidity of the air varied between 75-85%.

In the light of these investigations, the following remarks can be made:

i) It should be ensured that the water-table level is below 6-7 m from the ground surface because the tunnel has to be located at about 4 m depth from the ground surface.

ii) Preferably mechanical fans should be used, as these result in a better performance than the natural airflow system provides.

Table 1. Performance of the earth-air tunnel system in summer

Day June-83	Air Temperature* (°C)			
	Inlet		Outlet	
	Dry bulb temperature	Wet bulb temperature	Dry bulb temperature	Wet bulb temperature
15	32.8	21.5	26.0	23.0
16	29.1	22.7	24.3	21.7
17	29.8	20.5	26.6	22.3
18	30.9	21.7	24.8	23.1
19	33.0	22.5	25.7	23.0
20	34.4	23.7	26.6	24.3
21	35.0	22.7	26.2	23.3
22	35.0	22.9	26.2	23.0
23	36.1	24.7	26.6	23.7
24	31.8	22.8	25.7	23.9