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The Use of Earth Tube System as a Means of Improving Indoor Thermal Comfort in South China

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ABSTRACT

This paper reports on an investigation of the use of an innovative earth tube ventilation system designed to improve the internal comfort conditions without the need for mechanical cooling. The numerical model and computer simulation developed for the prediction of air and soil temperatures has been made. The paper demonstrates the accuracy of this model and describes the results of analysis. Preliminary conclusions show that the earth tube ventilation system can make considerable improvements to the indoor thermal comfort within buildings in south China, without the expense and energy implications of installing air conditioning.

KEYWORDS

Earth tube system; Cooling; Ventilation; Thermal Comfort; Energy Saving

INTRODUCTION

In recent years house construction has given considerable stimulation to the national economy. Over the period between 1996-2000 China plans to build 240 million square metres of housing every year, in urban areas and more than twice that amount in the countryside and rural towns. Home construction input will then constitute 13% of the country's total fixed investment. The government has not only asked the construction industry to increase the housing space but also to improve the quality of the housing in order to raise the living standards.

The rapid economic growth that has taken place in the region has led to the demand for a better standard of living and higher levels of thermal comfort within houses. There is therefore an increasing demand for air conditioning in residential buildings and consequently for electrical power. In order to limit this growth and encourage a sustainable housing development, use of renewable energy is encouraged. The government is to give priority to developing new and renewable energy from solar, wind, geothermal and tidal sources in the bid to meet the fast-growing demand for power. So far, the country's annual demand and usage of new and renewable energy has reached 300 million tons of coal equivalent. Seasonal energy storage offers immense opportunities to profit from renewable energy for heating and cooling of buildings.

The climate of China is extremely diverse and variable with a tropical climate in the south and one that is sub-arctic in the north. However, the summer weather conditions are very hot nearly all over China. The average maximum outside temperature in South China is about 34 °C in July and exceeds 25°C for between 75 to 175 days annually. The indoor temperature in buildings without air-conditioning is often over 30 °C throughout

CONCLUSION AND PERSPECTIVES

A neural model for an HVAC system has been developed et compared with a mathematical model and manufacturer data. The black box modelling is faster to produce model than regression model and provides a better accuracy.

However, such a model is designed for one system. It could be useful to have a global model validated for a set of HVAC systems. A model with non dimension inputs in relation to the nominal values (i.e. the values of inputs for Tai = 27°C, h_e = 54.5 kJ/kg and T_e = 35°C), could be a solution, according to our first results. But the design of a global model needs a better knowledge of the system than the black box model. Grey box model (i.e. coupling neural networks and knowledge) could be an interesting tool.

At the design stage, it could be possible, if global models for several sets of systems are available to compare several systems, and then to choose the best ratio between comfort improvment and energetic cost.

NOMENCLATURE

Tanh	*Sigmoid function*	A_M	*Mathematical model prediction for A*
A_{NN}	*Neural network prediction for A*	*HVAC*	*Heating, Refrigerating and Air Conditioning.*
η	*Coefficient of Performance*		
PT	*Total capacity*	*PS*	*Sensible capacity*
h_e	*Indoor air specific enthalpy (kJ/kg)*	T_e	*Outdoor temperature (°C)*
Tai	*Indoor dry bulb temperature*	*Pabs*	*Absorbed capacity*

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the day and night. People often can not bear the heat although fans operate continuously. This not only seriously influences people's working efficiency and daily life but is also harmful to health.

THE EARTH TUBE SYSTEM

The earth tube ventilation system uses relatively simple technology to use earth-to-air heat exchange for cooling in summer and heating in winter. This paper however concentrates on the summer condition demonstrates how internal temperature can reduced to an acceptable 26°C without airconditioning.

It has a great environmental advantage over conventional air conditioning because it uses only a fan and heat exchanger instead of refrigerators with harmful CFCs or HFCs. The technology can be used wherever the subsoil conditions are appropriate and this is the case in large parts of China.

System Description

The system is made of 9 hollow slabs of steel reinforced concrete, which are divided into three sets each parallel to one another. Three hollow slabs in one set are put in series forming the earth tube. The earth tub is 10 m long and is buried at a depth of 1.5 m. The air inlet and outlet are two vertical cylinders. See Fig. 1

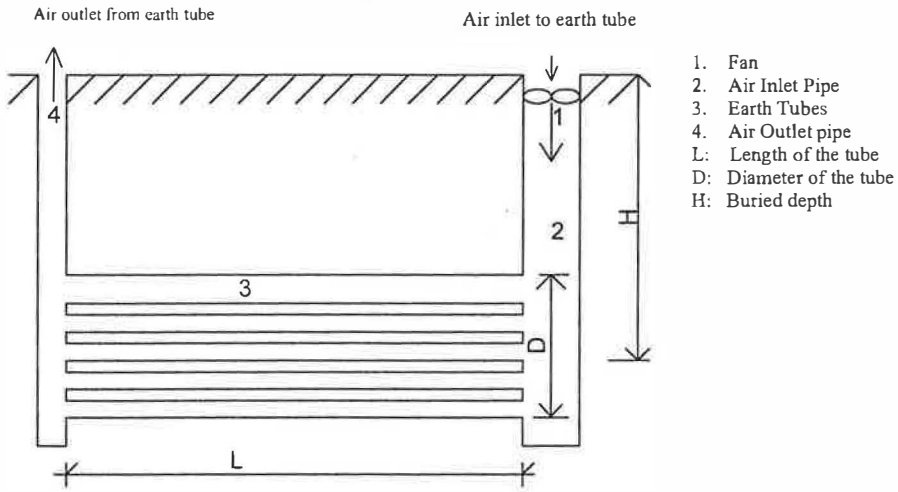

Fig. 1. Earth Tube System

Modelling for the pipe's heat transfer

Computer simulation for the transient earth-to-air heat transfer of soil, pipes and air are based on standard energy balance equations and a full description of the development of the model can be found in Feng (1994). Fig.2 shows the accuracy of the model demonstrating good correlation between actual and predicted results for a flow rate of 455 m^3/hr.

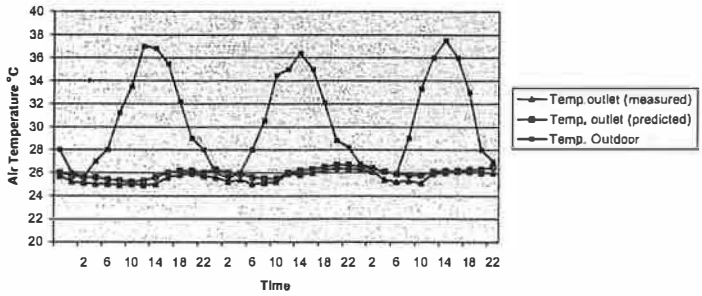

Fig. 2. Predicted and measured air temperature

The developed model enables investigation of a wide range of parameters including climate conditions, buried depth of the pipes, length of the pipe and air velocity through the pipe.

THERMAL COMFORT BY EARTH TUBE VENTILATION

Thermal comfort

In the absence of its own thermal comfort standard China uses the ISO-DIS7730 PPD-PMV index Standard. However the results of field studies on thermal comfort in many countries show that different groups of people are comfortable at different temperatures and that people are tolerant of diurnal and seasonal variations of room temperatures in naturally ventilated buildings. It was suggested (CBSRI, 1989) that residential buildings in China should not exceed a Predicted Mean Vote of between plus and minus 1.5, which is equivalent to a PPD (Predicted Percentage Dissatisfied) of less than 50%.

A computerised fluid dynamics (CFD) model has been adopted to analyse the airflow and comfort conditions within a building. This model used in conjunction with the results of the simulation of the earth tubes, enable prediction of the internal comfort condition (Yao, 1997).

Figures 3 and 4 show the comparison of the PPD within the same room under summer conditions when the outside temperature reached 37°C with and without the use of the earth tube system. Overall the PPD has been reduced by over 30% by using the earth tube system.

CONCLUSION

A computer simulation model has been developed to predict the outlet air temperature from an earth tube system for cooling buildings in south China. The results of this model, used in conjunction with CFD simulation results have show that while outdoor air temperature is 37 °C, the indoor air temperature is about 26 °C and the PPD is less than 25%. Most Chinese people would accept this condition of improved comfort which is achieved at small cost and minimal additional energy demand.

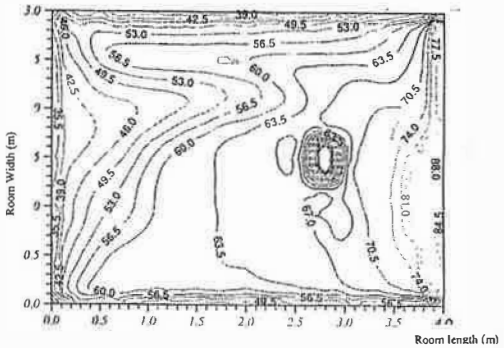

Fig.3. Prediction of PPD without earth tube ventilation

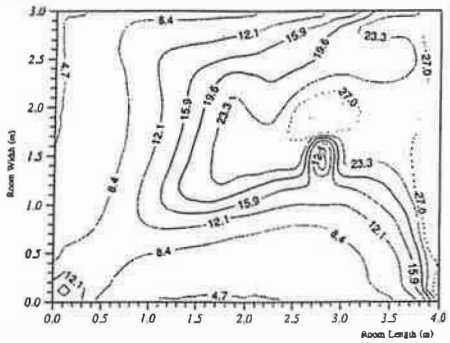

Fig. 4. Prediction of PPD with earth tube ventilation

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