THERMAL PERFORMANCE OF UNDERGROUND STRUCTURES

By

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Thesis submitted
in fulfilment of the requirements
for the award of the degree of

DOCTOR OF PHILOSOPHY

Department of Physics
INDIAN INSTITUTE OF TECHNOLOGY, DELHI
INDIA

JUNE, 1989

CERTIFICATE

It is certified that the thesis entitled '**Thermal Performance of Underground Structures**' being submitted by Mr. B.C. Jayashankar is worthy of consideration for the award of the Degree of Doctor of Philosophy and is a record of bonafide research work carried out by him under our guidance and supervision. The results contained in this thesis have not been submitted in part or full to any other University or Institute for the award of any degree or diploma.

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ACKNOWLEDGEMENTS

I wish to express my deep sense of gratitude to prof. M.S. Sodha and Dr. R.L. Sawhney for providing me with an opportunity to undertake this research work. I am greatly indebted for the interest, they have shown in this work. But for their encouragements, suggestions, critical discussions, and kind cooperation this work would not have reached the final stage.

It is my great pleasure and privilege to express profound indebtedness to prof. D.P. Tewari, for his invaluable supervision and discussions at all the stages.

My sincere thanks to the principal, S.J. College of Engineering, Mysore for having inspired me into research and sponsored under Quality Improvement programme.

I am highly greatful to prof. I.C. Goyal for his stimulating discussions, unstinted cooperation and help.

Thanks due to Dr. Jugal Kishore, Dr. A.K. Sharma, Dr. Ramchandra and Dr. S.P. Singh for their cooperation and help during research work.

Thanks to my friends and colleagues K.L. Puttabudhi, M.K. Deshmukh, Dr. D. Budhi, Dr. A.K. Goyal, R.S. Adhikari, K.C. Harikumar, P.Sampth, C. Jacob Mathew, Rajesh Agrawal for their encouragement, counsel and assistance throughout the course of this work.

I also thank Mr. Sushil Singh for the nice drawing of figures and Mr. Sudesh kumar Deshbhratar for skillful typing.

Lastly my sincere appreciation to my wife Vijaya and children Divya, Chetan and Chandan for their love, cooperation and encouragment during the development of this work.

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ABSTRACT

The temperature of the earth at a depth of 3 m or more is the mean annual solair temperature of the surface of the earth; it is thus higher than the atmospheric (or even inside building) temperature in winters and lower than the same in the summers. Hence a thermal coupling of the earth with a building provides an inexpensive way of space conditioning; this is possible due to the large capacity for heat storage and insulation provided by a large thickness of earth.

The mean temperature below the surface of the earth (equal to the mean solair temperature of the surface) depends on solar insolation, temperature and nature of the surface. In regions, where the earth temperature is not suitable for an earth coupled structure, it can be suitably modified by appropriate treatment of the surrounding earth surface. For example, in cold regions, the blackening and glazing of the earth's surface can make the coupled buildings warmer and help significantly in improving the performance of a bio-gas digester. In hot climates, subsoil temperatures can be reduced by increasing albedo (by means of whitening agents such as lime or paints, shading the earth surface from direct exposure to the sun and keeping the surface wet; shading by

wet mulches can help in further reducing subsoil temperatures due to additional advantage of their insulating properties. The practicability of modification of subsoil temperatures with different treatments of earth's surface has been theoretically and experimentally investigated by Kusuda, Givoni, Goetsch, and Givoni and Katz. The area of the earth's surface, which is required to be treated for it to become éffective, depends on the shape and depth of the structure below earth's surface and the thermal properties of the soil.

For the evaluation of thermal performance of earth coupled structures (such as slab-on-grade, basement, berm and earth coupled buildings, cold storage, biogas digesters, pipelines, railway tubes etc.), it is essential to estimate the heat transfer between the structure and ground which is in general a complex three dimensional process. The solution of the three dimensional heat conduction equation with appropriate boundary conditions is in general extremely difficult; however the steady state solution of the heat conduction equation can be obtained in a few simple cases, of high symmetry e.g. a sphere and a cylinder with horizontal axis. Numerical Solutions for few other structures with lesser symmetry are also available but require large computational time. Conducting experiments on full size structures to estimate the ground losses is not practicable on account of large variations in their shapes and cost involved. Periodic solution for a cylindrical tube with horizontal axis is also available.

It can be shown that the steady state heat loss from underground structures is given by the relation

$$Q = k_g.a.F.(T_a - T_s)$$

Where a is the characteristic length, F is shape factor (which depends on the shape and not dimensions), k_g is thermal conductivity of the surrounding earth and T_a is the temperature of interior of the structure and T_s Solair temperature of the earth's surface. The shape factors for structures of various shapes can be determined in the laboratory by performing simulation experiments on scaled down models.

Since the distribution of temperature and electrical potential in the steady state are governed by Laplace's equation, it is obvious that the shape factor can also be determined by electrical simulation experiments. Two simple laboratory methods based on electrical and thermal simulation have been devised for experimental determination of the shape factor. The experiments are performed on reduced scale models of the structure made of copper which is chosen on account of large thermal and electrical conductivity. Experiments by the author on structures of various shapes have been used for extending the parametric range and also determination of the shape factors for shapes which have not been investigated.

When a finite area of the earth surface is treated for modifying the temperature of the earth above the underground structure, the heat loss from the structure is given by the relation

$$Q = k_g.a.[(T_a - T_{s1}).F_1 + (T_a - T_{s2}).F_2]$$

Where T_{s1} and T_{s2} are the solair temperature of the treated and untreated earth surfaces and F_1 and F_2 are two dimensionless parameters which depend on the shape of the structure and area of the treated earth surface. Electrical simulation experiments were also performed to determine the dependence of F_1 and F_2 on the area of the treated earth surface for the case of a typical ($8m^3$) bio-gas digester (Chapter 2).

In the northern region of India where the ambient temperature in winters touches zero degree centigrade, the bio-gas production from underground bio-gas digesters gets significantly reduced. This happens because the required optimum temperature of the slurry (at which gas production is maximum) is 35^oC and in winter the subsoil temperature around the digester in these regions is much lower than the required optimum temperature in winters. The slurry temperature can be increased by blackening and Glazing (by plastic sheets) finite area of the ground above a fixed dome digester (Janata model). The author has evaluated the increase in bio-gas production, for different areas of the glazed earth surface above the digester (using the results obtained from electrical simulation experiments); cost analysis was also made to estimate the optimum glazed area. Field experiments on a digester with glazed ground surface were also performed to validate the theoretical model, developed by us (Chapter 3).

The effect of suitable earth surface treatments on the thermal performance of directly coupled partially sunken buildings (assumed to be parallelopiped) for three different climates of the country viz. Cold and dry, hot and humid and composite (cold in winter and hot in summer) has been investigated (chapter 4). For estimating the steady state heat losses from the structure considered, the shape factor of the building was obtained from the thermal simulation experiments.

Chapter 5 analyses the effect of suitable earth surface treatments and various earth air tunnel parameters on the thermal performance of a grade-on-slab room coupled to the earth air tunnel system for each of the three climates mentioned above. The whole work presented in various chapters has resulted in the following publications :

(i) Jayashankar, B.C., Kishore, J., Goyal, I.C., Sawhney, R.L. and Sodha, M.S. (1989), `Solar assisted bio- gas plant IV: Optimum area for blackening and double glazing over a fixed- dome bio- gas plant, Int. J. Energy Research, 13, 193- 205.

(ii) Jayashankar, B.C., Sawhney, R.L. and Sodha, M.S. `Effect of different surface treatments of the surrounding earth on thermal performance of earth integrated buildings, Int. J. energy research. (In press)

(iii) Sodha, M.S., Sawhney, R.L., Singh, S.P. and Jayashankar, B.C. `Electrical simulation of thermal losses from underground structures, Int. J. Energy Research. (In press)

(iv) Sodha, M.S., Goyal, I.C., Kishore, J. and Jayashankar, B.C. `Solar assisted bio- gas plant VA: Experimental validation of numerical model for slurry temperature in a glazed fixed- dome bio- gas plant, Int. J. Energy Research. (In press)

CONTENTS