MOISTURE BEHAVIOR OF THE SUBSOIL UNDER THE GROUND FLOOR STRUCTURES

Virpi Leivo[1], Jukka Rantala[2], Ralf Lindberg[1], Jorma Hartikainen[2]

[1] Tampere University of Technology, Laboratory of Structural Engineering, Finland
[2] Tampere University of Technology, Geotechnical Laboratory, Finland

ABSTRACT

This paper concentrates on temperatures of the subsoil under ground floor structures, which is a key factor in inspecting the possibility of diffusion in ground floor structures. The paper presents some temperature distributions received from simulation of heat loss from building to subsoil using the FE-modeling and measured under the ground floors of moisture damaged buildings. In the light of these examinations the temperature of the subsoil under the ground floor will in many cases be quite a lot higher than it has been usually assumed. This finding gives a whole new perspective to the moisture-technical design of the ground floor structures.

KEYWORDS: building physics, moisture, soil, diffusion, gravel, modeling

INTRODUCTION

Knowledge of the temperature-dependent moisture behaviour in granular soil is the fundamental basis in development of working ground floor structures. However, the diffusion in gravel fill and capillary suction in subsoil are poorly known.

The objective of the research is to examine the temperature and moisture behaviour in subsoil under buildings.

This paper concentrates on temperatures of the subsoil under the ground floor structures. They are a key factor affecting diffusion in ground floor structures. It is commonly agreed that the relative humidity in the pore air of subsoil is 100%. If the temperature of the subsoil under ground floor is the same as the subgrade, assumed to be about +5 … 8 °C in Finland, the direction of the diffusion will be downwards. On the other hand, if the temperature of the subsoil increases, the direction of the diffusion will be upwards. This paper studies the temperature behaviour of the subsoil under the building and the effect of the heat loss to the ground.

METHODS

Thermal behaviour of the subsoil under the ground floor has been examined using FE-modeling (Finite Element Modeling). Some temperature data for comparison has also been collected from moisture damaged buildings.

The Laboratory of Structural Engineering has made several condition assessments related to moisture damages during the last 10 years. The temperature of the subsoil under the ground floor has been measured using a thermoelement installed inside a steel bar.
The FE-modeling included three different ground floor types: a typical ground floor of a residential house founded on the filling with the thermal insulation below (type A) or above the concrete slab (type B) and a typical industrial building without thermal insulation (type C). The temperature in the surface of the ground floor structure was assumed to be T_{INSIDE} = 21°C throughout the year. The average outside temperatures in Helsinki and Sodankylä were used as temperatures outside the building [1]. Change of the outside temperature was assumed to follow the sinusoidal-shaped curve determined on the basis of the average temperatures [2].

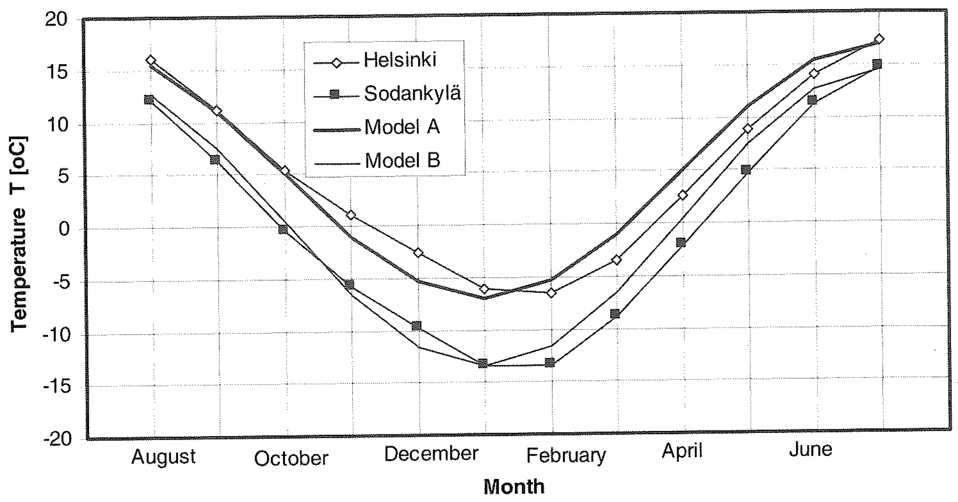

Figure 1. Outside temperatures of the FE-models, A: In Helsinki region, B: In Sodankylä region

Modeling was made under the temperature conditions of both Helsinki and Sodankylä. The initial temperatures of both soil and structures were assumed to be T = + 5°C at the beginning of the modeling. The effect of the flowing ground water to the temperatures of the subsoil was studied. The temperature of the ground water was assumed to be T_{GWT} = + 7°C. The depth of the ground water was varied in the modeling between 1.1 meter to ∞ below the basement slab. Thermal analyses were done both for a one-year variable heat load and a long-term, 15-year, average heat load.

RESULTS

Following is a short presentation of the results of the modeling for foundation type A (100 mm thermal insulation of polystyrene under the concrete slab) constructed in Helsinki. The depth of the ground water between 1.1 m to ∞ below the concrete slab and thermal conductivity and specific heat capacity of the subsoil were varied in the simulations. The temperatures in the middle of the slab in different variations are presented in Figure 2. The subsoil material was gravel.

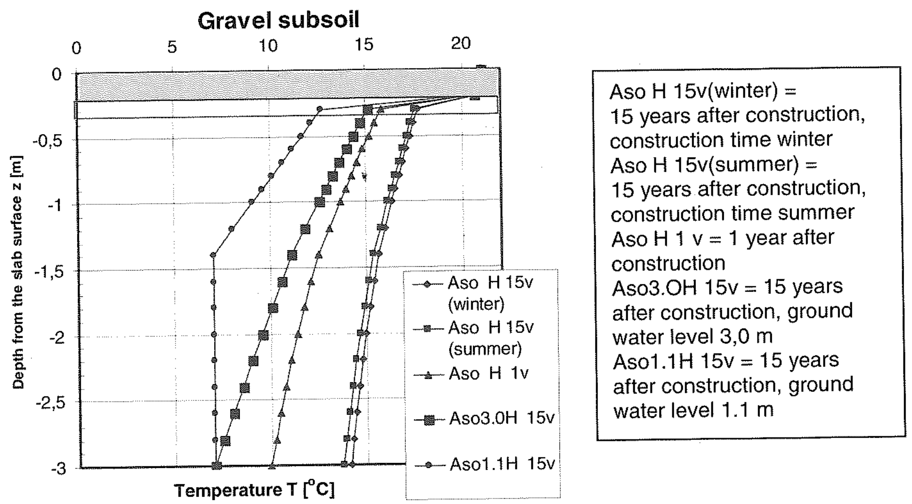

Figure 2. The temperatures in the middle of the slab in different variations.

Figure 3 shows the temperature changes in the subsoil during the 15-year analysis period. The subsoil material was silt.

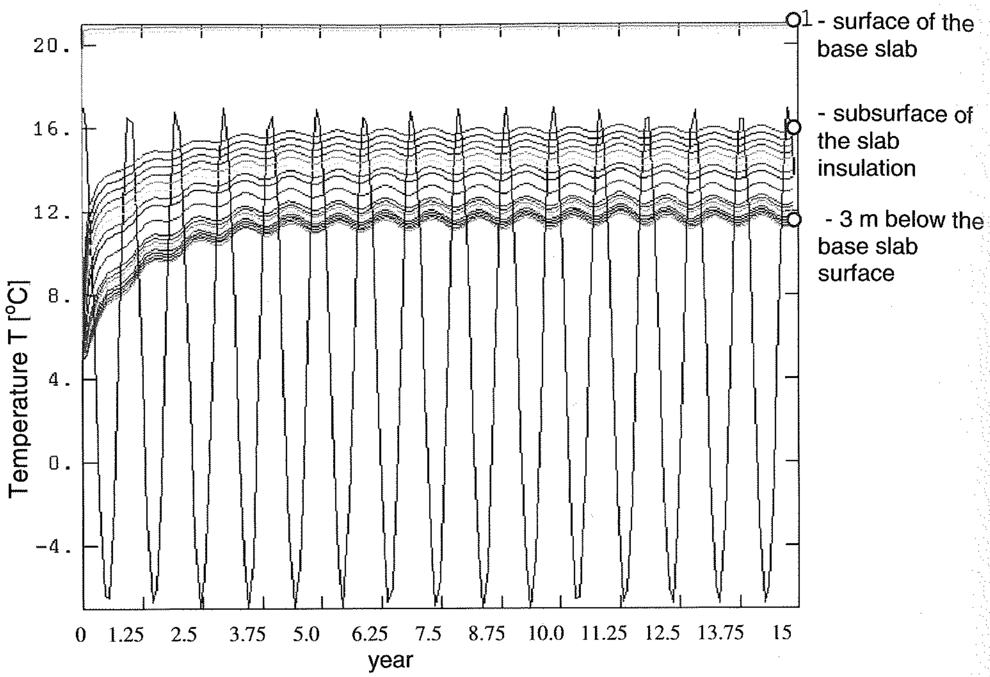

Figure 3. Temperature changes of the subsoil and the base slab during the 15-year analysis period. The subsoil material was silt.

The temperatures of subsoil measured under the ground floor in several moisture damaged buildings correspond to the temperatures received from the FE-modeling.

Table 1 presents some typical temperature distributions measured in moisture damaged buildings. All buildings were constructed more than 10 years ago. Damages are usually observed in the coverings of the ground floor structure.

Table 1. Thermal distributions measured in some real moisture damaged ground floor structures.

Ground floor structure, from above	**Measurement depth mm**	**Measured temperature °C**
Vinyl floor covering or paint, concrete slab 100 mm, thermal insulation polystyrene 150/100 mm	100 mm	15.0 … 22.1°C
	500 mm	13.5 … 19.8°C
	1000 mm	12.9 … 19.9°C
Boarded floor, sawdust insulation 150 mm, concrete slab 60 .. 80 mm, lightweight concrete slab 80 … 100 mm	150 … 200 mm	12.3 … 21.8°C
	650 … 1000 mm	12.7 … 21.7°C
	1250 … 2000 mm	13.5 … 19.0°C
Limestone plates, concrete slab 100 mm, bitumen paper+bitumen coating, thermal insulation polystyrene 50 mm, gravel fill 120 … 200 mm, double plastic sheeting	900 … 1300 mm	12.6 … 16.0°C
Concrete slab 150 mm	900 … 1100 mm	18.6 … 22.5°C
	1500 … 2000 mm	15.4 … 21.5°C
Vinyl floor covering plates, concrete slab 100 mm, double plastic sheeting	200 .. 600 mm	19.2 … 21.2°C
	800 … 1100 mm	20.2 … 21.1°C

DISCUSSION

The temperatures of the subsoil under ground floor received from the FE-modeling and measured in real moisture damaged buildings are higher than it is usually assumed in the moisture-technical design of ground floor structures. Thus the direction of diffusion in the ground floor turns upwards to the living space. In order for the ground floor structure to function properly even in this situation, the coverings material of the ground floor should be able to evaporate the water vapour that is diffusing from the subsoil. Moreover, the thermal insulation should be installed under the whole slab in order to prevent heat loss to the ground and the resulting upward diffusion.

ACKNOWLEDGEMENTS

The research is executed at the laboratory of Structural engineering and the Geotechnical laboratory at Tampere University of Technology. The research is managed by prof. Jorma Hartikainen and prof. Ralf Lindberg. The research is a part of the Healthy Building Technology programme by Tekes (Technology Development Agency). The research is funded by Tekes and enterprises: Lohja Rudus, Soraseula, City of Helsinki/ Department of Geotechnics and Construction Management Division and Innogeo. The authors wish to thank the financiers. The authors also wish to thank researchers of the laboratory of Structural Engineering: M.Sc. Jommi Suonketo, M.Sc. Jyrki Wahlman and M.Sc. Pekka Kokko who have made the field measurements.

REFERENCES

1. Björkholtz, D. Lämpö ja kosteus, rakennusfysiikka. 2. painos. Kustantaja Rakennustieto Oy 1997. ISBN 951-682-432-3. Saarijärvi 1998/8. 150 s. (In Finnish)

2. Hagentoft,C-E. Heat Loss to the Ground from a Building. Department of Building Technology. Lund Institute of Technology, Sweden. Report TVBH-1004. April 1988.