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Thermal performance of radiant heating floors in furnished enclosed spaces

L. Fontana*

Dipartimento di Progettazione e Studio dell'Architettura, University of Rome "Roma Tre", Piazza della Repubblica 10, 00185 Rome, Italy

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ABSTRACT

The radiant floor heating systems offer distinctive advantages in several special applications and allow to use low temperature heat. A renewed interest has grown in the study of the thermo-physical behaviour of such systems and the influence on health; consequently more accurate design methodologies, taking into account the various relevant parameters, have been developed. However, such methodologies usually refer to "empty spaces" so that working conditions turn out different from those projected.

Preliminary theoretical studies [M. Corcione, L. Fontana, G. Moncada Lo Giudice, Riscaldamento a pavimento radiante. Uno studio teorico sul comportamento termico, CDA Condizionamento dell'aria Riscaldamento Refrigerazione 3 (2001) 51–58.] have shown that the presence of furniture in the environment can cause material changes of the system performance and of the operating temperature obtained in the environment.

In this paper the thermal performance of radiant floor systems is examined in detail through an experimental study, on a scale model. Experimental measures have been conducted in several conditions of thermal insulation of the enclosed space, of floor covering and outside temperature.

For each configuration, tests have been made changing number and typology of the furniture pieces. The furniture influence on the system performance and on the obtained operating temperature has been verified, and the effect of their presence has been evaluated.

1. Introduction

Radiant heating systems usually consist of small pipes, embedded in masonry floors or in prefabricated panels in which hot water flows.

Their growing favour is due to some peculiar advantages offered by these systems, as the possibility of employing low temperature water, the absence of terminal heaters in the heated environment, such as fan-coils, that could cause particulate movement and reduce the air quality, usually required in some important environments, e.g. hospitals.

Furthermore, these systems allow a good flexibility in modifying the internal partitions of the indoor space; above all, in high spaces (e.g. churches, gymnasia, etc.), they allow a good thermal comfort, otherwise difficult to obtain.

Because of the renewed interest about these system solutions, and generally about radiant heating systems, several theoretical and experimental studies have been conducted.

These studies are mainly focused on modelling and simulation of the floor heating systems [1–5]; on the heat exchanges and the systems performances [6–10]; on control strategies and thermal comfort [11–13].

However, although increasingly precise calculation and design procedures have been developed, the radiant floor heating system design practice usually refers to empty spaces, without furniture and accessories; also the European standard [14] refers to this situation. Actually, the furniture presence can produce sensitive changes in thermal exchange processes inside the environment, both convective and radiant, with effects on the system performance, that changes relative to the empty environment case.

2. Theoretical results

A first investigation on the furniture impact has been made in previous numerical studies [15,16], whose results have shown a non negligible decrease in the transferred heat flux, the indoor air temperature and the mean radiant temperature in the furnished environment with respect to the empty space case, other conditions being equal; these effects are different in case of "high" furniture pieces (e.g. tables, chairs shelf or other furniture supplied with legs, whose surface is quite distant from the heated floor) and in case of "low" (e.g. sofa, beds, wardrobes, directly put on the floor), and are emphasized in presence of "low" furniture.

* Tel.: +39 3475403858; fax: +39 6 4880120.
E-mail address: lfontana@uniroma3.it.

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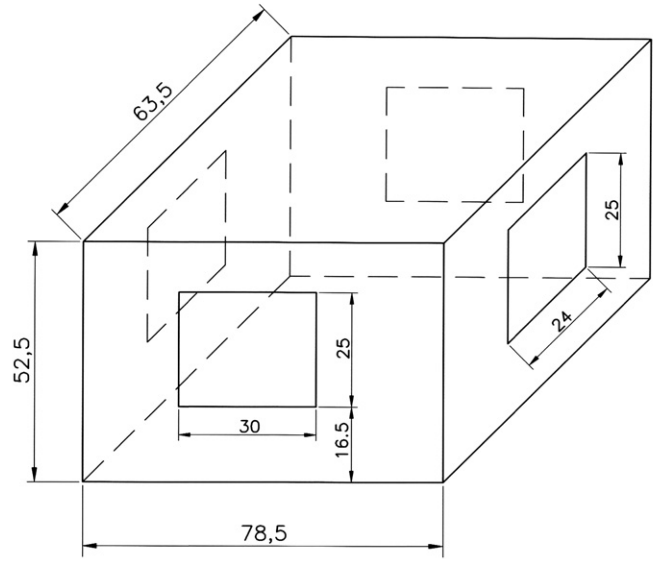

Fig. 1. Sketch of the scale model (dimensions in cm).

In these cases, the theoretical study shows that, to keep the required operative temperature, the average floor temperature should be sometimes significantly raised, even exceeding the limit of 29 °C usually considered for comfort [17,18] and also suggested by the European Standard currently in force.

3. Scale model arrangement

In the mentioned theoretical study, some non negligible simplifications have been made in the furniture model; in particular, the furniture was supposed as a single object, even if with variable surface (wider in case of several pieces). Actually, the numerical method has several limits in investigating more articulated and realistic situations, as the contemporary presence of several objects, of different type and dimension, inside the heated environment.

To be able to extend the study also to these cases, a scale model of an environment heated by floor radiant panels has been realized, and an experimental study has been conducted.

3.1. The heated environment

The scale model (box shaped) is sketched in Fig. 1. To construct the walls and the ceiling, 0.5 cm poplar plywood sheets have been used, insulated with a layer of expanded polystyrene. In order to simulate several heat insulation levels and to obtain walls with different heat transmission coefficients, two kinds of walls have been realized; the first (high *U*-value wall) is insulated by a layer of expanded polystyrene 2 cm thick and has been equipped with a window, whose surface area is equal to about 20% of the total area of the wall: in this case the overall heating transmission coefficient results $U_H \cong 1.8$ W/m^2 °C. The other (low *U*-value wall) is without windows, and in this case the layer of expanded polystyrene is 4 cm thick: the *U*-value results $U_L \cong 0.78$ W/m^2 °C. The ceiling has no windows and the insulating layer is 2 cm thick as well: $U_C \cong 1.3$ W/m^2 °C. Windows are simulated through openings in the polystyrene sheets.

The inner surface temperatures are measured through K-type thermocouples applied to each wall (ten thermocouples for the windowed wall, six for the others) as shown in Fig. 2.

Two additional K-type thermocouples measure the indoor and outdoor air temperature, while the mean radiant temperature is measured by a spherical (7 cm diameter) globe thermometer, (according to the standard UNI EN 27726 [19]), made of 0.4 mm thick copper.

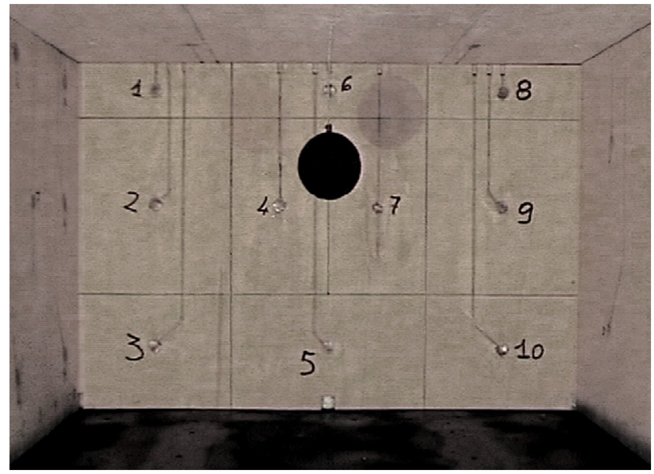

Fig. 2. Sketch of the thermocouples placement.

The outdoor temperature is the temperature of the ambient laboratory. Preliminary measures, periodically repeated, have shown very small differences, inside the range ±0.2 °C (same order of the measure uncertainty), between the mean radiant temperature of the laboratory walls (measured through thermocouples, a pyrometer and a globo-thermometer), and the air temperature, measured near the box. In fact, the environment where the measures are taken is huge (approximately 70 m^2) and high (about 5 m) and bound by heavy masonry walls non confining with the outdoor space. During the measurements the environment temperature remained in the range 26–27 °C.

The measurements have been conducted with two different configurations of the test section; the first configuration provides three high *U*-value walls, the remaining wall with low *U*-value, and the ceiling; the second configuration, more representative of a common room in a flat, provides one high *U*-value wall, the

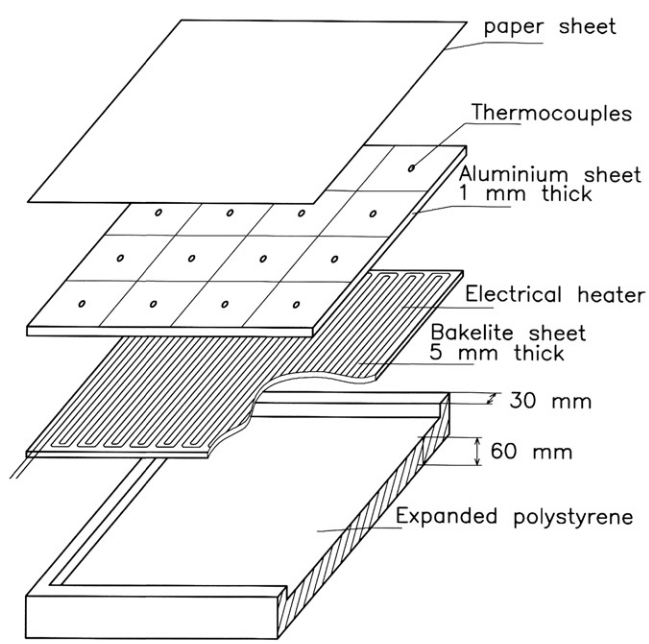

Fig. 3. Sketch of the floor.