AIN SHAMS UNIVERSITY

Faculty of Engineering

INFLUENCE OF THERMAL STORAGE, HEAT RECOVERY AND INSULATION ON COOLING AND HEATING LOADS FROM SUNLIT EXTERIOR WALLS OF AIRCONDITIONED BUILDINGS

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بسم الله الرحمن الرحيم

PREFACE

This dissertation is submitted to Ain Shams University for the degree of Master of Science in Mechanical Engineering.

The work included in this thesis was carried out by the author in the Energy and Automotive Department, Faculty of Engineering, Ain Shams University, from November 1982 to August 1988.

No part of this thesis has been submitted for a degree or a qualification at any other University or Institution.

ABSTRACT

In this work, the influence of each of the exterior wall construction, the surrounding buildings, the interior structures, the insulation and its location, the ventilation rate, the wind velocity and the emissivity of both exterior and interior surfaces on the airconditioning cooling and heating load rates from sunlit exterior walls is investigated.

A mathematical model for composite walls, taking these factors into consideration is set and solved by an unconditionally stable, semi-implicit finite difference method whose accuracy and convergence are examined in the present work.

Data compiled for a ten year period of climatic conditions aquired from the Egyptian Meteorological Authority are analyzed, and the design conditions of the dry bulb temperature, the wind velocity and solar radiation intensity for Cairo are determined. Also, the surroundings temperatures are calculated.

These data are used to obtain summer cooling loads and cooling load temperature differences, and also winter heating loads and heating load temperature differences for typical walls and roofs of light, medium and heavy constructions with and without insulation. The results obtained are compared with those obtained using other recommended methods, and it is observed that the former are almost 20% lower than the

latter. Other parameters related to the case under study are also calculated and compared to known design values.

The results show that the periodic variation of both the atmospheric air temperature and the solar intensity in a design day considerably affects the temperature and the temperature-time lag of the exterior walls and roofs of buildings. This periodic nature causes the heat absorbed by the outer surface of exterior slabs of buildings, due to heat exchange with the surroundings including solar radiation, to be partly stored in the exterior slab itself and partly conducted through the slab and transferred to the inside of the airconditioned space. The thermal storage by the exterior slabs and heat recovery from it by the air of the airconditioned space described above decrease the cooling load and shift its peak to occur at hours after that of the maximum of the atmospheric air temperature and of the solar radiation intensity as well.

The results reveal also that the heat exchange between the exterior slab and each of the nearby structures, interior walls, floors and ceilings of the airconditioned space also affects the heat gain rate and the hour of their maxima. It is also observed that the increased wind velocity and the indoor air movement have a significant effect on the above mentioned rates.

Also, the effect of thermal insulation, its thickness and location on the rate of heat inflow is studied. The calculations show that in summer airconditioning the space heat gain and cooling load are minimum when the insulating layer is applied to the outer surface of the exterior slab.

The effect of the various factors mentioned above on the winter heating load is studied as well. Some of these factors are observed to have different effect on the winter heating load than on the summer cooling load such as the thermal insulation and its location where, contrary to the case with summmer cooling, the winter heating load is minimum when the insulation is applied to the inner surface of exterior slabs of airconditioned buildings. Also, the effect of these factors on winter heating load is studied considering a very low atmospheric air temperature.

It is concluded that the influence of insulation location on the summer cooling load should be considered simultaneously with its effect on the winter heating load when deciding the proper location of the insulating layer on an exterior slab of a year-around airconditioned space.

Saving in energy requirements for a building airconditioning is greatly affected by proper location of insulation and utilization of thermal storage and heat release by the structure walls.

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NOMENCLATURE

A	Area of slab under study, m^2
c	Thermal capacity, $J/kg^{o}C$
CL	Cooling load from main slab, W/m^2
CLTD	Cooling load temperatue difference, ^{o}C
D	Thickness of auxiliary slabs , meter
hc_i	Convective heat transfer coefficient at the interior surface , $W/m^{2}{}^{o}C$
hc_o	Convective heat transfer coefficient at the exterior surface , $W/m^{2}{}^{o}C$
HFLUX	Heat flux at external surface, W/m^2
HGAIN	Heat gain from main slab, W/m^2
HL	Heating load from main slab, W/m^2
HLOSS	Heat loss to main slab, W/m^2
HLTD	Heating load temperatue difference, ^{o}C
hr_{i-r}	Radiative heat transfer coefficient between an interior surface and the interior surface number i , $W/m^{2}{}^{o}C$
hr_{o-sk}	Radiative heat transfer coefficient between the exterior surface of the main slab and the sky, $W/m^{2}{}^{o}C$
hr_{o-sr}	Radiative heat transfer coefficient between the exterior surface of the main slab and the terrestial surroundings, $W/m^{2}{}^{o}C$
I_s	Total solar flux incident on the external surface of the main slab, W/m^2
k	Thermal conductivity, $W/m^{o}C$

L	Thickness of slab under study, meter
t	Time, sec
T_a	Dry-bulb ambient temperature, °C
T_d	Indoor air design temperature, °C
T_{ext}	Temperature at the main slab outer surface, °C
T_i	Temperature at the internal surface, °C
T_{int}	Temperature at the main slab inner surface, °C
T_m	Temperature at node m, arithmetic average of U_m and V_m, °C
T_r	Temperatures at internal surface number r , °C
T_{sk}	Sky temperature, °C
T_{sr}	Surroundings temperature, °C
U	Overall heat transfer coefficient, $W/m^2 {}^oC$
U_m	Temperature at node m calculated in direction of increasing x, °C
V_m	Temperature at node m calculated in direction of decreasing x, °C
V_w	Wind velocity, m/sec
x	Distance, meter
y	Distance, meter
α	Thermal diffusivity, m^2/sec
α_s	Absorptivity of exterior surface to solar radiation
ϵ_i	Emissivity of interior surface
ϵ_o	Emissivity of exterior surface
ρ	Density, kg/m^3

Superscripts

n	Integer from 0 to N denoting time level

Subscripts

a	ambient conditions
d	design conditions
i	Denotes internal surface
m	Integer from 0 to M denoting spatial level in the main slab
o	Denotes external surface
r	Integer from 1 to R denoting the number of the internal surface
s	Solar
sk	Denotes sky
sr	Denotes surroundings
w	Integer from 0 to W denoting spatial level in the auxiliary slabs

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