IMPACT OF THERMALLY INSULATED FLOORS

E. Al-Sayed Omar
Associate Research Scientist
Kuwait Institute for Scientific Research
P.O. Box 24885, 13109 Safat, Kuwait

F. Alghimlas *
Research Associate
Kuwait Institute for Scientific Research
P.O. Box 24885, 13109 Safat, Kuwait
* fghimlas@kisr.edu.kw

ABSTRACT

Presently in Kuwait the code of practice for energy conservation in the air conditioned buildings implemented by the Ministry of Electricity and Water (MEW) which has been in effect since 1983 has no consideration taken for thermally insulating the floors of residential and commercial buildings with unconditioned basements. As a part of a comprehensive research program conducted by the Building and Energy Technologies Department of Kuwait Institute for Scientific Research for revision of the code this paper analyzes the effect of using un-insulated floors on the peak cooling demand and energy consumption of a middle income residential private villa and a one-bedroom multi-story apartment building in Kuwait. These floors typically separate air-conditioned spaces with ambient environment or un-conditioned spaces. This was done using the ESP-r, a building's energy simulation program, in conjunction with typical meteorological year for Kuwait.

The study compared such typical floors with three types of insulated floors. It was found that using an R-10 floors in multi-story apartment buildings greatly reduce both the peak cooling demand as well as the energy consumption by about 15%, whereas only minimal savings (about 4%) were detected in the case of the residential villas.

Key Words
Energy conservation, code of practice, simulation

INTRODUCTION

In the present Ministry of Electricity and Water (MEW) code of practice, there is no consideration taken for thermally insulating the floors of residential and commercial buildings with unconditioned basements [1]. In most situations when basements are air-conditioned, it is assumed the heat transfer through floors separating basements and upper floors is negligible since the conditioned air temperature is the same. However in other situations, the basements are not air-conditioned. This is evident in the cases of shopping malls with car parking in the basement; as well as the ongoing practice of building multi-story apartment buildings. In such buildings, the ground floor consist of bare columns that are supporting the load of all the other floors in a way leaving the floor of the first level directly exposed to the outside weather conditions. Some residential villas are also built with some spaces in the basement being unconditioned. If the conditioned in basement is similar or close to the outside dry bulb temperature and the heat transfer coefficient is high due to high air movement, then a significant heat flow rate might take place across the basement ceiling and the upper conditioned space.

In this study, analytical evaluations of the peak cooling load and the total electrical energy requirements for cooling in two types of buildings (a private villa and a multi-story apartment building) were performed. A building's energy simulation computer program, the ESP-r [2], was used to simulate the two types of buildings and their prospective scenario cases. The simulation was conducted on three different floor construction types in addition to the base case for each of the two buildings.

BUILDING DESCRIPTION

Private Villa

The middle income residential villa is built on a plot size of 587 m^2. The footprint area of the ground floor is 297 m^2 with an additional 71 m^2 of an annex. The villa consists of a basement, a ground floor, a first floor, and a second floor, along with one level annex. The basement, ground floor, and the first floor are almost similar in shape and size; however, the second floor comprises almost half of the size of any other floor. Fig. 1 shows a rendered image of the whole project assembled together. The long axis of the building is positioned in an east - west direction.

Figure 1. A rendered image of the whole building generated by the RADIANCE lighting simulation program.

The most important construction detail is the floor of the first story. The construction of this layer was described in the model according to the typical floor construction details found around the country. The description is presented in Table 1. The same table also describes an example of the suggested floors later in the study.

It comprises one typical floor representing intermediate floor 2, 3, and 4. The zones above and below that floor shall be scaled up after in the analysis to represent the roof and first floors, respectively.

Table 1. Ground Level Floor Construction Detail

Element	Layer	Thickness (m)	Conductivity (W/m*K)	Density (kg/m^3)	Specific Heat (J/kg°C)
Existing floor	Cement plaster	0.020	1.00	2085	837
	Heavy mix concrete	0.150	1.77	2297	921
	Kuwait sand	0.040	1.00	2080	840
	Cement mortar	0.025	1.00	2085	837
	Mosaic tiles	0.020	1.04	2284	795
R-10 floor	Cement plaster	0.020	1.00	2085	837
	Heavy mix concrete	0.150	1.77	2297	921
	Kuwait mortar	0.040	1.00	2080	840
	Fibreglass, rigid	0.055	0.04	95	840
	Cement mortar	0.025	1.00	2085	837
	Mosaic tiles	0.020	1.04	2284	795

Multi-Story Apartment Building.

The building functions as a residential one -bedroom apartment building. It is situated on a plot with the size of 802.25 m^2. The building occupies approximately 261 m^2. It consists of six levels, with the top five levels each containing four separate one-bedroom apartments. The remaining ground floor contains only the elevator shaft and the staircase, with the remaining space left open to the outside weather conditions and the building's columns left exposed (a typical construction for apartment buildings in the country).

Each apartment consists of four spaces: a bedroom, a bathroom, a kitchen, and a living and dining area. The total area of one apartment is approximately 48 m^2. The building has one staircase and one elevator shaft with a foyer serving all apartments at any one level. For the purpose of the energy simulation the building was broken down into 19 zones. Fig. 2 shows the ESP-r wire frame model which represents the entire building.

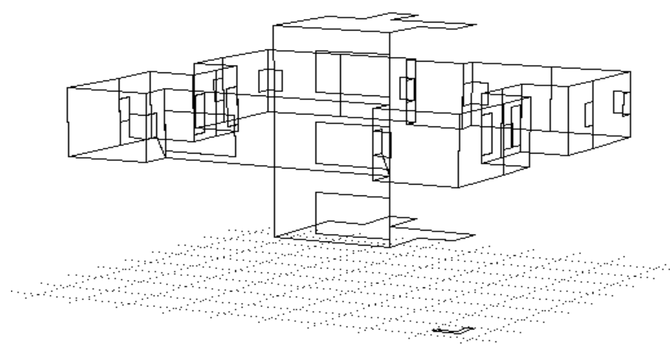

Figure 2. ESP-R Wire Frame Model of an Intermediate Floor with the Scaling Zones

The most important construction detail is the floor of the first story. The construction of this layer was described in the model according to the typical floor construction details found around the country. The description is presented in Table 2. The same table also describes an example of the suggested floors later in the study.

Table 2. First Level Floor Construction Detail

Element	Layer	Thickness (m)	Conductivity (W/m*K)	Density (kg/m^3)	Specific Heat (J/kg°C)
Existing floor	Heavy mix concrete	0.100	1.77	2297	921
	Sand screed	0.060	1.00	2080	840
	Sand cement	0.020	1.00	2085	837
	Mosaic tiles	0.020	1.04	2284	795
R-10 floor	Heavy mix concrete	0.100	1.77	2297	921
	Sand screed	0.060	1.00	2080	840
	Fibreglass, rigid	0.055	0.04	95	840
	Sand cement	0.020	1.00	2085	837
	Mosaic tiles	0.020	1.04	2284	795

GENERAL MODELLING INPUT

The simulation period was set to be from January 1 until December 31. Typical meteorological year (TMY) was used for the coastal areas of Kuwait. The data were provided by KISR weather station at latitude of 29.3°C and longitude of 47.9°C [3]. Table 3 presents the TMY data in terms of monthly values of the significant weather parameters used within the simulation program.

SIMULATION RESULTS AND ANALYSIS

Private Villa

The simulations were performed on four cases using the ESP-r program. The first case was the base case scenario. In this case, which was labelled Case 0, the conditions were as close as possible to the actual existing conditions of the villa. Other cases were produced and compared with the base case. These cases were as follows:

Table 3. Average Values of TMY Parameters

Months	Avg. db temp. (°C)	Max. db temp.(°C)	Avg. wind sp.(m/s)	Avg. RH (%)	Glob. hor. irr.(kWh/m^2)	Diff. hor. irr. (kWh/m^2)	Dir. norm. irr. (kWh/m^2)
January	13.7	24.6	3.5	63.7	99.5	39.2	127.4
February	15.6	24.0	4.0	71.3	110.2	43.6	118.3
March	18.8	28.2	4.3	60.9	146.7	60.5	132.4
April	25.4	35.6	3.2	59.8	163.6	76.4	123.4
May	31.3	42.3	4.2	46.6	204.8	85.8	156.4
June	33.2	44.6	5.6	44.6	215.3	83.0	175.6
July	36.8	48.0	3.9	45.9	222.3	81.7	184.4
August	37.2	48.3	3.6	49.8	217.2	67.6	203.7
September	33.7	44.4	3.7	41.2	179.7	51.7	189.9
October	27.9	41.1	3.9	50.6	134.0	45.1	148.7
November	20.4	33.1	3.9	64.5	108.7	34.4	143.9
December	15.1	28.7	4.4	69.4	88.6	35.2	115.3

The results of the simulation were compiled in two ways: one at the level of each floor of the villa, and the other was at the villa as a whole. Looking at the results from the first approach (Fig. 3), savings are seen at the ground floor only. Since typically with any villa, the electricity consumption of all the electrical systems is billed as one item, it is unfavorable to examine the results in such a way.

Fresh air intake and ventilation, occupancy, lights, and equipment were set as close as possible according to MEW standards [1]. For this specific report, these criteria are not of major concern as long as they are kept identical in all case scenarios.

- Case 1: Identical to the base case, except for the addition of an insulation material layer within the floor of the ground level to bring up the overall thermal resistance R of the floor to 0.88 m^2K/W (R-5).
- Case 2: Identical to the base case, except for the addition of an insulation material layer within the floor of the ground level to bring up the overall thermal resistance R of the floor to 1.76 m^2K/W (R-10).
- Case 3: Identical to the base case, except for the addition of an insulation material layer within the floor of the ground level to bring up the overall thermal resistance R of the floor to 2.64 m^2K/W (R-15).

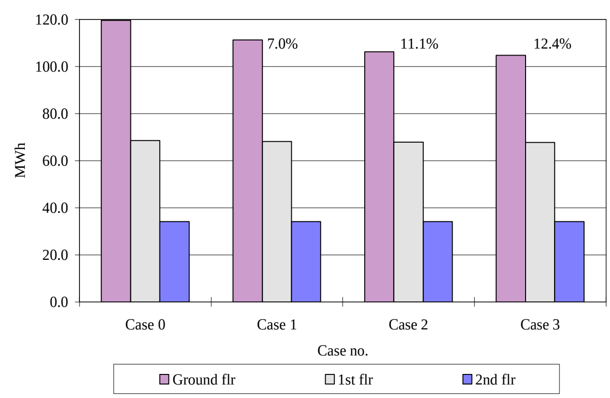

Figure 3. Annual Electrical Requirements for A/C at Each Floor.

Looking at the results of the simulation of the villa as a whole, savings are achieved greatly when using the R-10 floor in place of the existing un-insulated floor. The results are summarized in Table 4.

Table 4. Electrical Requirements for Air-conditioning System

Case	Peak Electric		Consumption		Annual Energy		Consumption	
	kW	savings	W/m^2	savings	MWh	Savings	kWh/m^2	savings
0	43.11	--	57.62	--	232.34	--	310.55	--
1	42.03	2.5%	56.17	2.5%	223.68	3.7%	298.97	3.7%
2	41.33	4.1%	55.25	4.1%	218.51	6.0%	292.06	6.0%
3	41.12	4.6%	54.96	4.6%	216.91	6.6%	289.92	6.6%

Multi-Story Apartment Building

For this building type, due to the layout similarity of all floors, re-expressing the actual building design has been altered in a way that matches the requirements of the real problem at hand. The zones located above and below the intermediate floor (Fig. 2) are to enable the results for this intermediate floor to be scaled up to reflect the anticipated difference in energy transfer between the apartments located on intermediate floors (2, 3 and 4) and the roof and first floors with their increased exposure. By using scaling in this manner, it was not necessary to simulate the entire building. The scaling technique was implemented as follows. A zone within the intermediate floor flat was replicated to represent the increased exposure of the top and bottom floors. This zone was chosen to be the living and dining area. The annual simulation results for the building were then obtained by multiplying the results for the intermediate floor by the number of such floors (3 floors) and adding the results for the exposed floors obtained by applying a scaling factor to the intermediate floor results. This scaling factor is established as the ratio of the results for the exposed floor zone to the intermediate floor. Appendix A gives an example.

The ESP-r simulation program was performed on four cases. The first case was the base case scenario. In this case, which was labelled Case 0, the conditions were as close to the actual existing conditions of multi-story apartment building. Other cases were produced and compared with the base case. These cases were as follow:

- Case 1: Identical to the base case, except for the addition of an insulation material layer within the floor of the first level to bring up the overall thermal resistance value to R-5.
- Case 2: Identical to the base case, except for the addition of an insulation material layer within the floor of the first level to bring up the overall thermal resistance value to R-10.
- Case 3: Identical to the base case, except for the addition of an insulation material layer within the floor of the first level to bring up the overall thermal resistance a value to R-15.

Unlike the analysis of the previous example of a private villa, here, only the electrical requirements for the first floor were considered. Granted that all of the apartments are occupied (i.e., the entire floor is conditioned), having insulation in the floor of the first level or not will certainly not affect the other floors from the thermal exchange point of view. Hence, examining the results of the entire building through the different cases would be inappropriate.

Looking at the results of the simulation of the model, savings are achieved greatly when using the R-10 floor in place of the existing un-insulated floor. The results are presented in Table 5.

CONCLUSIONS

From the results of the ESP-r simulation program on the private villa, the implementation of a new code to enforce the use of thermal insulation in such floor is not highly recommended. The savings here were not that substantial (about 4% on peak demand and 6% on electrical consumption). Unlike the other case, the multi-story apartment building, the implementation of a new code to enforce the use of insulation material in such floors is highly recommended. It was shown that there is great opportunity in savings (about 15% on peak demand and electrical consumption). It can be concluded that, for multi-story buildings with the ground level having an exposed floor, such floors should have a thermal resistance value of R-10.

Table 5. Electrical Requirements for Air-Conditioning for the 1st Floor Only

Case	Peak Electric		Consumption		Annual Energy		Consumption	
	kW	savings	W/m^2	savings	kWh	savings	kWh/m^2	savings
0	13.0	--	60.6	--	65,880	--	306.9	--
1	11.6	11.2%	53.8	11.2%	58,575	11.1%	272.9	11.1%
2	11.1	14.9%	51.6	14.9%	56,111	14.8%	261.4	14.8%
3	10.9	16.5%	50.6	16.5%	55,122	16.3%	256.8	16.3%

APPENDIX A

Scaling Example

The following calculations are included to illustrate the process of the scaling used within the project. The figures correspond to the base case results of the apartment building for cooling energy consumption.

All Zones = 69,822 kWh.
Scaling zones (Living_up and Living_1st) = 14,508 kWh.
==> Intermediate floor = 55,314 kWh.
Scaling applied to individual zones:

	kWh	% Difference
Liv_din_a =	6,507	0.0
Living_up =	6,758	3.9%
Living_1st =	7,750	19.1%

Application of scaling factor: scalar value added to intermediate floor

Living_up =	2,135 kWh
Living_1st =	10,566 kWh
Living_up =	57,449 kWh
Living_1st =	65,880 kWh

Calculation for the entire apartment building;

Living_up =	57,449 kWh.
Living_1st =	65,880 kWh.

Intermediate * 3 = 165,941 kWh.

Total Building = 289,271 kWh.

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