THE IMPACT OF DWELLING TYPES ON HEATING ENERGY CONSUMPTION IN ISTANBUL

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INTRODUCTION

About half of the energy consumption and similar proportion of carbon dioxide emission is associated with the existing dwelling stock in Istanbul. A significant number of existing residential buildings have insufficient heat resistances and therefore fail to meet performance requirements of either national or international standards for energy conservation, reduction in air pollutants and CO_2 emission. One of the most important goals of Turkey is to develop strategies for enhancing the quality of the built environment and to achieve this the country has to fulfil a number of crucial environmental and ecological requirements besides the others. This will also facilitate the membership of Turkey to the European Union. On this process, the challenge is to create a sustainable environment for achieving an acceptable lifestyle and level of comfort while reducing energy consumption. By considering these facts, a research project was set to investigate the thermal performance of the external envelope of existing dwellings in Istanbul and to develop energy efficient systems for retrofitting external envelope of these buildings [1].

In this study, the impact of dwelling types on heating energy consumption is investigated taking account of the variables such as transparency ratio, floor area, house type (terrace/detached), building height and plan type. The effect of these variables on the heating energy consumption of existing and retrofitted buildings are evaluated and thermal efficiency of each retrofitting system is discussed in terms of energy savings.

THE METHODOLOGY

In the analysis, the representative dwellings are typified and different retrofitting systems are proposed for energy conservation of these buildings. Afterwards, the simulations of the existing and retrofitted dwellings are performed.

Description of the Dwelling Types

In the context of the research project, the current situation of the housing stock was investigated in terms of a field survey in selected settlements. In order to evaluate the thermal performance of the proposed energy efficient systems for retrofitting the external envelope of the dwellings, various dwelling types were specialised by considering the results of the field survey and the municipal regulations for characterising the dwellings in Istanbul. In this study, thirteen typical buildings are selected for the simulations. The main variables of the dwellings are considered as transparency ratio, floor area, house type, building height, and plan type. The main facades of the buildings are oriented to north and surrounding residential buildings in the neighbourhood are also specified. Reinforced concrete structure, exterior non-load bearing brick walls of 13 cm thickness without thermal insulation, single clear glazed wooden windows and tile pitched roof are the typical components of the existing buildings. Cantilevered floors of 1,5 m surround the sides of the buildings. There are four balconies with 1,5×4,0 m size at the corner of each floor. The variables, which characterise the typical buildings, are given in Table 1. The lighting and occupancy schemes are also specified for each building for the internal loads [2].

Description of Retrofitting Systems

Three different retrofitting systems are considered for the rehabilitation of the opaque and transparent components. In the first retrofitting system (R1), the walls, roof and cantilevered floors of dwellings are externally insulated with expanded polystyrene of 5 cm and single glazing is replaced with air filled clear double glazing with a U value of 2,81 W/m^{2}K.

Table 1. The variables that characterise the dwelling types.

	Type	W/L	W	L	F	S	Tr
K1A	D	1,0	15,1	15,1	230	5	35
K2A	D	0,7	12,8	18,0	230	5	35
K2B	T	0,7	12,8	18,0	230	5	35
K2C	D	0,7	12,8	18,0	230	5	25
K2D	D	0,7	12,8	18,0	230	3	35
K2E	D	0,7	12,8	18,0	230	7	35
K2F	D	0,7	12,8	18,0	230	9	35
K2G	D	0,7	12,8	18,0	230	5	45
K3A	D	0,5	11,0	21,5	230	5	35
L1A	D	1,0	17,3	17,3	300	5	35
L2A	D	0,7	14,5	20,7	300	5	35
L2B	T	0,7	14,5	20,7	300	5	35
L3A	D	0,5	12,2	24,5	300	5	35

D: detached, T: terrace, W: width (m), L: length (m), F: floor area (m^2), S: number of storeys, Tr: Transparency ratio (%),

In the second retrofitting system (R2), the roof and the walls are internally insulated with expanded polystyrene of 5 cm and the single glazing is replaced with air filled clear double-glazing. In the third retrofitting system (R3), only the single glazing is replaced with air filled clear double-glazing.

Calculation Method

A PC version of DOE 2.1E computer program, which is comprehensive enough for the energy simulation, has been used to calculate the yearly energy losses of the existing and retrofitted buildings [3]. The overall annual heat losses of the existing buildings and their retrofitted alternatives have been calculated by means of computer simulation. In the evaluations the total heating energy consumption required for heating per m^2 floor area is taken into consideration and it is assumed that the heating system of the buildings have a productivity of 70 %.

RESULTS AND DISCUSSION

The heating energy consumption of the dwelling types is given in Table 2. For the existing situation, the highest energy consumption per m^2 occurred in K2D and K2G buildings while the lowest occurred in L2B and K2B buildings among the selected dwelling types. K2F is the one with the lowest energy consumption among the detached building types, while L2B has the lowest energy consumption among the terrace buildings. (Tables 1-2).

Table 2. Heating energy consumption of the existing and retrofitted dwelling types and energy savings due to existing situation.

	Exist.	R1		R2		R3	
	C	C	S	C	S	C	S
K1A	782	318	59,4	350	55,3	640	18,1
K2A	800	325	59,4	358	55,2	653	18,3
K2B	467	237	49,4	255	45,4	409	12,4
K2C	771	315	59,2	338	56,1	667	13,4
K2D	1011	434	57,0	492	51,3	859	15,0
K2E	716	281	60,7	305	57,4	571	20,2
K2F	670	258	61,5	276	58,9	527	21,4
K2G	828	346	58,3	379	54,3	645	22,1
K3A	827	332	59,8	367	55,6	675	18,3
L1A	718	302	58,0	330	54,0	592	17,5
L2A	729	306	58,0	335	54,0	601	17,5
L2B	435	228	47,5	239	45,0	386	11,3
L3A	730	295	59,5	326	55,4	600	17,8

C:Energy consumption (MJ/m^2), S:Energy savings (%)

The efficiency of the retrofitting systems applied on different dwelling types:

According to the results, the existing situation of all types of the dwellings fails to meet the national heating energy standards. If the retrofitting systems are compared with each other with respect to the heating energy savings in a year due to the existing situation, systems R1 and R2 are more energy efficient than R3 in all dwelling types. Maximum energy savings of 61,5 % and 58,9 % are provided in 9-storey high K2F building improved with R1 and R2, respectively. Minimum energy savings of 47,5 % and 45 % are achieved in 300 m^2-terrace L2B building retrofitted with R1 and R2, respectively. The system R3 provides the maximum and minimum energy savings of 22,1 % and 11,3 % in K2G (Tr:45 %) and L2B (Tr:35 %), respectively (Table 2).

The effect of building variables on heating energy consumption:

The dwelling types are compared with each other taking account of the building variables with respect to the variation in the energy consumption for the existing and retrofitted situations. The variation of energy consumption percentage in a year according to the building variables is given in Table 3.

Table 3. The variation of energy consumption

Building Variables		Type	Exist. %	R1 %	R2 %	R3 %
W/L	1	K1A	0,0	0,0	0,0	0,0
	0,7	K2A	2,3	2,3	2,3	2,0
	0,5	K3A	3,5	2,2	2,6	3,5
W/L	1	L1A	0,0	2,2	1,4	0,0
	0,7	L2A	1,4	3,7	2,9	1,5
	0,5	L3A	1,6	0,0	0,0	1,3
D/T	D	K2A	71,2	37,3	40,4	59,5
	T	K2B	0,0	0,0	0,0	0,0
D/T	D	L2A	67,5	34,2	40,0	55,8
	T	L2B	0,0	0,0	0,0	0,0
Tr	25	K2C	0,0	0,0	0,0	3,5
	35	K2A	3,8	3,3	5,8	1,3
	45	K2G	7,5	9,9	11,9	0,0
S	3	K2D	50,8	68,2	78,5	63,0
	5	K2A	19,3	25,9	29,8	23,9
	7	K2E	6,7	9,0	10,4	8,4
	9	K2F	0,0	0,0	0,0	0,0
F	230	K1A	8,9	5,2	5,9	8,1
	300	L1A	0,0	0,0	0,0	0,0
F	230	K2A	9,7	6,1	6,8	8,7
	300	L2A	0,0	0,0	0,0	0,0
F	230	K2B	7,4	3,7	6,5	6,1
	300	L2B	0,0	0,0	0,0	0,0
F	230	K3A	13,3	12,4	12,7	12,5
	300	L3A	0,0	0,0	0,0	0,0

W/L: width/lenght, D: detached, T:terrace, F: floor area, Tr: transparency ratio, S: number of storeys,

W/R ratio of the dwellings does not influence the amount of the consumed energy significantly. The maximum increase in the energy consumption is calculated as 3.45 % in the buildings with 230 m^2 area while the W/L ratio decrease from 1.0 to 0.5.

The consumed energy increases about 70 % in existing detached buildings compared to the existing terrace buildings with the same area due to the increase in the wall area.

The increase of 20 % in the transparency ratio causes 7.5 %, 9.9 % and 11.9 % of increase in the energy consumption of the existing and dwelling types retrofitted with R1 and R2, respectively. The solar gains from the windows reduce the effect of transparency ratio on the energy consumption.

Building height is very much effective on the amount of energy consumed for heating per m^2 floor area. The energy consumption of an internally retrofitted 3-storey high building is calculated 78.5 % higher than the 9-storey high building. The energy conservation difference between the retrofitted dwelling types becomes more effective by the variation of the storey number of the buildings.

The energy consumed in existing and retrofitted dwellings increase between 3.7 % and 13.3 % with the decrease of 23 % in the floor area.

CONCLUDING REMARKS

The highest energy savings can be achieved by increasing the efficiency of the retrofitting systems in all dwelling types. The system consisting external insulation of the opaque components together with improvement of the transparent components is considered as the most energy efficient retrofitting system in the selected dwelling types.

The most effective building variables on heating energy consumption are the building height and house type (terrace/detached). These variables are directly related with the external wall area of the buildings.

REFERENCES

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