Investigation of the Palestinian overall heat transfer coefficient and comparison with International Building Codes

Hüseyin Çamur

Department of Mechanical Engineering, Faculty of Engineering, Near East University, via Mersin 10, Turkey, Nicosia 99138, Cyprus;
huseyin.camur@neu.edu.tr

Ramez Abdallah

Mechanical Engineering Department, Faculty of Engineering & Information Technology, An-Najah National University, P.O. Box 7, Nablus,

Department of Mechanical Engineering, Faculty of Engineering, Near East University, via Mersin 10, Turkey, Nicosia 99138, Cyprus;

ramezkhaldi@najah.edu

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***Abstract*— The issue of increasing energy consumed in buildings and the need for thermal insulation regulations has become a major concern in Palestine with increasingly alarming warnings of climate change and the depletion of fossil fuels. In this study, the overall heat transfer coefficient U-value in the Palestinian energy-efficient building code was reviewed for walls, floors, roofs, doors, and windows. U-value expresses the amount of heat transfer from the building to the external outside air. U-value was investigated concerning the average value for the U-value (Average U-value), heating degree days, and energy consumption due to the heating load. The investigation in this study suggested a new average U-value of 0.85 W/m^2.K was suggested which can result in approximately 44% energy saving and make the energy consumption in the Palestinian residential buildings comparable to the values of the International Energy Consumption Codes.**

Keywords*— *Palestinian and International Building code, HDD, thermal insulation, U-value, heating load, and building energy efficiency.

I. INTRODUCTION

It has been revealed that the building sector is considered a crucial part of the energy consumed worldwide. This led to applying strict standards to ensure energy efficiency in new buildings and to retrofit old buildings in developed countries. Moreover, it is expected that more energy will be consumed in the building sector in the future to maintain increasing living requirements. It all comes with increasingly alarming warnings of climate change and fossil fuel depletion. Therefore, the issue of low-energy construction has become a major concern for Palestine in light of the environmental impact of the use of fossil fuels and the issue of their depletion [1-6].

Palestine represents a situation different from most of the surrounding countries concerning the energy sector, due to the instability of the political situation there, difficult economic conditions, lack of natural resources, and high population density [1,3,6]. Also, Palestine imports all of its fuel needs and 87% of its electricity from abroad. For all of the above, and bearing in mind that 43% of the Palestinian energy consumption is in the building, it is necessary to design buildings to save energy and incorporate many energy sources[1, 7].

The Palestinian Authority is working hard to reduce energy consumption, so the Palestinian Energy and Natural Resources Authority (PENRA) has improved an action plan for energy efficiency. The goal of this national action plan is to save 384 GWh of energy consumption between 2012 and 2020. 363 GWh of this energy, which constitutes about 94.5%, is consumed in the buildings sector [8]. Despite all these efforts, codes and standards related to Palestinian buildings do not reach the required level, and building insulation is still not required to obtain a building permit [7].

The overall heat transfer coefficient (U-value) can be defined as the quantity of heat transfer between the two air films on both sides of the wall per unit area with one temperature difference. Its unit is (Btu/ ft^2. F) in the USA and the UK and (W/m^2.K) in the rest of the Europium countries [9].

Palestinian energy-efficient building code was issued in 2004 and implemented by the Palestinian Ministry of Local Government (MLG) [10]. The Palestinian energy-efficient building code covers the minimum requirements for the building envelope, which includes external walls, windows, doors, ceilings, and floors, which are the structural elements that separate the internal atmosphere of the building from the external environment surrounding the building. Nowadays, after nearly 17 years, the Palestinian energy-efficient building code must be upgraded to cope with the increase in fuel prices and improve the lifestyle of Palestinians.

In this study, the Palestinian energy-efficient building code will be compared with each of Jordanian building thermal insulation code, building energy codes for Saudi Arabia, European norms, American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), and the Passivhaus construction standard.

In this study, the relations between the construction element U value and the average U value for the whole building were investigated. Moreover, the current study gives a better knowledge of the current Palestinian energy-efficient building code and its influence on the amount of the annual energy consumed in heating load per m^2 in Palestine in relation to international building codes.

II. LITERATURE REVIEW

Each country has its own building code that regulates the construction of its own buildings. But these codes have to be revised, updated, and improved over the years.

Rodríguez-Soria, et al. [11] compared inside design temperature, U-value, and the compactness factor in different European countries (The United Kingdom, Germany, Spain, and France) and the United State of America. They also investigated the Passivhaus construction standard which was revealed by the EU as an example of residential buildings in which it consumes almost no energy (approximately zero-energy buildings). Alimohammadisagv, et al. [12] studied the optimal cost solution for a thermal energy storage system in cold climate regions with a ground source heat pump based on demand response (DR) in detached residential houses. Perry and Davidson, [13] investigated economic models to improve building economics by modifying Australia's building code. Echeverría et al. [14] Examined the building energy efficiency from 2006 to 2016 in Spain to meet the challenges resulted from the change of climate. Manu et al. [15] studied improving the thermal comfort life of people by utilizing a newly suggested model named called India Model for Adaptive Comfort (IMAC).

Moral et al. [16] studied climatic zoning to calculate building thermal demand in Extremadura (Spain). They proposed a method consistent with Spanish legislation on the performance of energy to give precise climate zoning.

On the other hand, Nahlek et al. [17] investigated energy simulation and building thermal performance. They proposed a model for energy simulation to calculate how rapidly the inside air temperature variation when the buildings are subjected to extreme heat. Tyagi et al. [18] assessed the energy building efficiency using phase change material to decrease the peak energy demand. The results of this experiment were compared to the theoretical values and there was a good agreement between them. Aïssani et al. [19] evaluated the effect of errors made by the workmanship on the building energy efficiency using both finite element and experimental model.

Khalfan [20] studied two identical buildings, the first building applied the Passivhaus standard and the other applied the normal measures in Qatar. He assessed the thermal performance and comfort levels for the two buildings by simulation and site measurements. He concluded that about 50% reduced water consumption, CO_2 emissions, and annual energy consumption was attained by applying the Passivhaus standards compared to the normal model. He also displayed the difficulties and barriers associated with applying the Passivhaus standards in Qatar.

Jaber and Ajib [21], studied the optimal insulation thickness, building orientation, and windows area for selected residential buildings in the Mediterranean countries. They concluded that nearly 27.59% of the energy consumed annually could be conserved by selecting the optimal insulation thickness, building orientation, and windows area.

Alkhalidi, et al. [9] investigated the overall heat transfer coefficient in Jordanian building thermal insulation code by comparing it to the other international building codes. They proposed a new U value that could reduce thermal energy demand nearly in half.

Alsayed and Tayeh [7] studied the optimum insulation thickness for different cities in Palestine. They concluded that the Payback period for the two insulation materials used and for the different Palestinian cities ranged between 0.9 and 1.6 years and the annual saving is between 4 and 8 \$/m^2/years. This means that wall insulation is very important in Palestine and has a clear economic impact and a short payback period. This is in addition to the excellent environmental impact of reducing carbon dioxide emissions, which is a worrying issue for Palestine and all countries of the world.

This research is the first to analyze and compare the Palestinian energy-efficient building code with other international building codes. This study aims to develop the Palestinian energy-efficient building code and motivate Palestinian decision-makers to improve it and make it a mandatory item. Moreover, the heating degree day (HDD) and the energy consumption in different countries of the world were used as a reference to propose a new U-value to be utilized in the Palestinian building code.

III. METHODOLOGY

The U-value was investigated by three different methods, First method: the construction element U- value for each component (walls, ceilings, floors…etc.) of the Palestinian energy-efficient building code was compared with the other international building codes, Second method: Average (Combined) U-value for the whole building was calculated and also compared with the other international building codes, Third method: the heating degree day (HDD) and the heating demand for the different Palestinian regions are calculated and compared to the other countries of the world.

A. Elemental U- value for each component (walls, ceilings, floors…etc.)

The elemental U-value mentioned in the Palestinian energy-efficient building code [10] will be compared to the Jordanian building thermal insulation code [9], Saudi Arabia building code [9], American Society of Heating, ASHRAE [11], and European Union standard (CEN) [11]. Table 1 shows the elemental U-value for different countries and Table 2 shows the elemental U-value according to the Palestinian energy-efficient building code.

It can be concluded from Table 1 and Table 2 that the elemental U-value specified in the Palestinian energy-efficient building code is more than the U-value specified in the international building codes of other countries.

TABLE 1: ELEMENTAL U-VALUE ($W/M^2.K$) FOR DIFFERENT COUNTRIES.

	Outside walls	Adjacent wall to an unheated space	Outside ceiling	Adjacent ceiling to an unheated space	Door	Window	Outside Floor	Adjacent floor to an unheated space
Jordan	0.57	2	0.55	1.2	2.7	3.1	0.8	1.2
KSA Zone 3	0.455	-	0.27	-	2.84	2.67	0.27	-
UK	0.22	0.25	0.14	0.14	0.9	0.9	0.17	0.17
Germany	0.2	0.35	0.2	0.2	1.8	1.3	0.28	0.28
Spain	0.57	0.74	0.35	0.46	2.7	2.7	0.48	0.62
France	0.36	0.45/a	0.2	0.34	1.8	1.8	0.27	0.36
USA (Avg.)	0.45	0.45	0.36	0.36	1.99	1.99	0.27	0.27
Passivhaus	0.15	0.15	0.15	0.15	0.8	0.8	0.15	0.15

a Loss reduction coefficient for defined unheated spaces

TABLE 2: U-VALUE ($W/M^2.K$) ACCORDING TO THE PALESTINIAN ENERGY-EFFICIENT BUILDING CODE.

	Overall U-value for external*	Adjacent wall to an unheated space	Outside ceiling	Adjacent ceiling to an unheated space	Outside Floor	Adjacent floor to an unheated space
Palestine	1.8	2.2	0.9**	1.2	0.9	1.2

*Overall U-value for external wall combined with windows and doors

** Overall U-value for external ceiling containing skylights equals 1.6

B. *Average (Combined) U-value:*

The U-value for the whole building can be calculated according to the following equation:

$$U_{average} = \sum U_i \times A_i \Big/ \sum A_i \ in\ W/(m^2K) \quad (1)$$

The design of the building in Palestine often follows the planning and organizational laws and can be divided into six main Patterns [6]. The six buildings patterns have an average outside dimensions 20.5 × 16 × 19 m which is approximately equivalent to 1.3 × 1 × 1.2 m. the area of the windows 27% from the wall area, and the door 8% from the wall area. It can be seen from Table 1 that in most of the international building codes the elemental U-value has two values one for the outside wall and the other adjacent to an unheated space. So, In this study The U-value will be investigated in three cases: First, 100% of walls are outside walls, second, 75% of walls are outside walls, and third, 50% of walls outside walls.

TABLE 3: AVERAGE U-VALUE ($W/M^2.K$) FOR 100%, 75% AND 50% OF WALLS ARE OUTSIDE WALLS.

	100% of walls are outside walls	75% of walls are outside walls	50% of walls are outside walls
Palestine	1.51	1.58	1.65
Jordan	1.18	1.34	1.5
KSA Zone 3	0.93	-	-
UK	0.36	0.36	0.37
Germany	0.50	0.52	0.53
Spain	1.03	1.05	1.06
France	0.66	0.67	0.68
USA (Avg.)	0.77	0.77	0.77
Passivhaus	0.30	0.3	0.3

It can be concluded From Table 2 And Table 3 that the Average U value is the highest for Palestine among all the countries. Therefore, it is highly needed to develop both the elemental and the average U-values for Palestinian energy-efficient building code.

It is clear that the U-value of the walls with contact with Unheated wall has the highest value for most of the international building codes. And this is related to temperature differences. As the temperature difference decrease, this allows for increasing the U-value as it can be concluded from the following equation:

$$Q = UA(T_i - T_o) \qquad (2)$$

This leads to the necessity of studying the temperature differences (HDD) for the countries while studying the U-value.

C. *The heating degree day (HDD) and the heating demand:*

According to the Palestinian energy-efficient building code, Palestine is divided into Seven Climate zones. West bank is divided into five climate zones and Gaza Strip into two climate zones. Table 4 shows the heating degree days for the different climate zones based on the weather data from the Palestinian energy-efficient building code. The heating degree-days (HDD) were calculated based on 18°C. It can be seen that the degree days for all the zones less than 1000 except for climate zone four. Figure 1 shows the main climate zones in Palestine. It worth mentioning that climate zone four that has the highest heating degree days represents the mountain region with the highest population intensity that includes the main cities on the west bank: Jerusalem, Hebron, Bethlehem, Ramallah, and Nablus.

TABLE 4: THE HEATING DEGREE DAYS FOR THE DIFFERENT CLIMATE ZONES IN PALESTINE

Zone (1)	Zone (2)	Zone (3)	Zone (4)	Zone (5)	Zone (6)	Zone (7)
362.2	362.2	853.2	1139.8	471.7	315.3	853.2

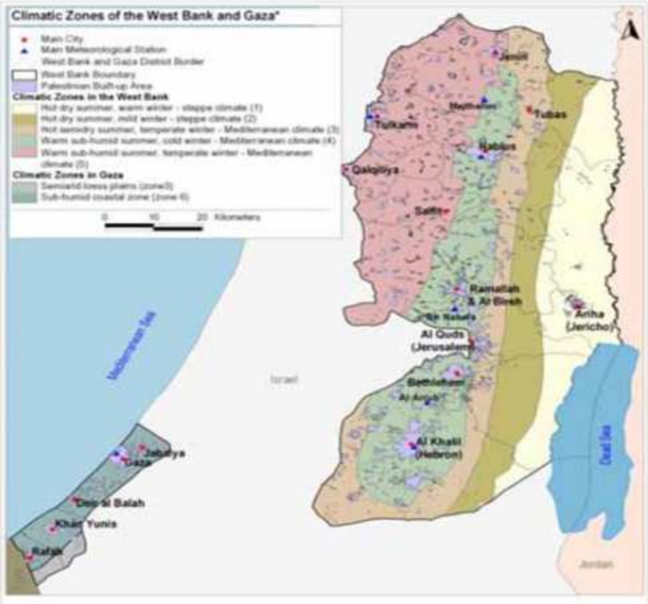

FIGURE 1: THE MAIN CLIMATE ZONES IN PALESTINE [22]

TABLE 5: THE VARIATION OF THE VALUE OF THE HEATING DEGREE DAYS (HDD) FOR THE DIFFERENT COUNTRIES

Country	HDD
Jordan	Less than 1500 [9]
KSA	Less than 1000 [23]
UK	3000-4000 [11]
Germany	2000-6000 [11]
Spain	1000-3000 [11]
France	2000-4000 [11]
USA	1000-9000 [11]
Passivhaus	2000-6000 [11]

To investigate the U-value specified in the Palestinian energy-efficient building code the heating degree days (HDD) for the different countries must be compared to the heating degree days (HDD) for Palestinian climate zones. Table 5 shows the variation of the value of the heating degree days (HDD) for the different countries. It can be concluded from Table 4 and Table 5 that heating degree days (HDD) for climate zone four in Palestine are close to the heating degree days (HDD) in Jordan, KSA, Spain, and the hot Humid region in the USA.

The annual energy consumption for heating per unit area (E_H, KW/m^2) can be estimated by :

$$E_h = \frac{0.024 * U * HDD}{EER} \qquad (3)$$

Where EER is the energy efficiency ratio of the heating system. The U-value must be chosen to make the E_H for Palestine is comparable to the other countries.

IV. RESULTS

E_H for the different Palestinian climate zones and tabulated in Table 6:

TABLE 6: E_H FOR THE DIFFERENT PALESTINIAN CLIMATE ZONES BASED ON THE U-VALUE IN THE PALESTINIAN ENERGY-EFFICIENT BUILDING CODE

Climate Zone	E_H (KW/m^2)*
Zone (1)	3.28
Zone (2)	3.28
Zone (3)	7.73
Zone (4)	10.33
Zone (5)	4.78
Zone (6)	2.86
Zone (7)	7.73

*Based on Average U-value of 100% of walls are outside walls and EER =4.

As mentioned before Palestine has to have E_H for climate zone four very close to Spain and Zone 3 in KSA. Therefore, the E_H for Spain is 6.18 KW/m^2 and 5.5 KW/m^2 for Zone 3 in KSA. In this study, a new U-value will be suggested to have an annual energy consumption for heating for Palestine comparable to international values.

Therefore, by investigating a typical building in the different Palestinian climate zones, new U- values are proposed: the walls U-value = 0.42. The ceiling U value = 0.45. Floor U-value = 0.45, U-value for door and window = 2.2 W/m^2.K.

The suggested elemental U-values are tabulated in Table 7. Based on the suggested elemental U-values the average U-value can be calculated and equal to 0.85 W/m^2.K. Table 8 shows E_H for the different Palestinian climate zones based on the suggested U-values.

Figure 2 compares the E_H, KW/m^2 for the different Palestinian climate zones based on the suggested elemental U-value and the E_H based on the suggested U-values.

TABLE 7: SUGGESTED ELEMENTAL U-VALUE (W/M^2.K) FOR PALESTINE

100% of walls are outside walls	Area (m2)	Suggested Elemental U
Walls	3.588	0.42
Windows	1.4904	2.2
Doors	0.4416	2.2
Floor	1.3	0.45
Ceiling	1.3	0.45

TABLE 8: THE E_H FOR THE DIFFERENT PALESTINIAN CLIMATE ZONES BASED ON THE SUGGESTED U-VALUES

Climate Zone	E_H (KW/m^2)
Zone (1)	1.85
Zone (2)	1.85
Zone (3)	4.35
Zone (4)	5.81
Zone (5)	2.41
Zone (6)	1.61
Zone (7)	4.35

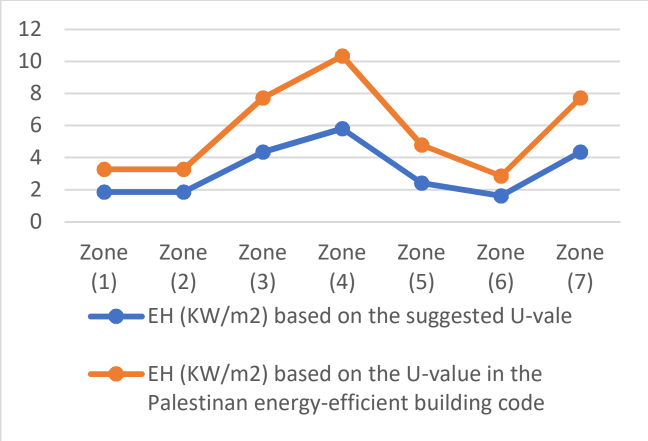

FIGURE 2: COMPARISON OF THE E_H, BASED ON THE U-VALUE IN PALESTINIAN ENERGY-EFFICIENT BUILDING CODE AND THE SUGGESTED U-VALUE

It can be concluded that the average U-value = 0.85 gives a minimum E_H value of 1.61, and a maximum E_H value of 5.81 in different climate zones in Palestine. the annual energy saving is approximately 44% using the new suggested U-value. These numbers are comparable to the international values.

V. CONCLUSION

The comparison of the elemental U-value indicates that Palestine has the highest U-values among all other countries. The exposed and unexposed walls in the Palestinian energy-efficient building code have the highest U-value as compared to all other countries. The average U-value in the Palestinian energy-efficient building code is the highest among all the countries in this study for 100%, 75%, and 50% % outside walls. The minimum annual energy consumption in European countries and the USA climate zones and the maximum annual energy consumption in KSA is comparable to the highest annual energy consumption in Palestine. These values were utilized as a reference to suggest a new value for the U-value in Palestine. The suggested U value limits the annual energy consumption to values comparable to international values.

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