International Journal of Civil Engineering and Technology (IJCIET)
Volume 9, Issue 10, October 2018, pp. 1980–1990, Article ID: IJCIET_09_10_196
Available online at http://www.iaeme.com/ijciet/issues.asp?JType=IJCIET&VType=9&IType=10
ISSN Print: 0976-6308 and ISSN Online: 0976-6316

EXTERNAL WALL PERFORMANCE IN RESIDENTIAL BUILDINGS IN HOT CLIMATE COUNTRIES

Ibrahim Varouqa
Assistant Professor Civil Engineering Department, Isra University, Jordan

Taiseer Rawashdeh
Associate Professor Architecture Department, Isra University, Jordan

Shehdeh Ghannam
Assistant Professor, Civil Engineering Department, Jerash University, Jordan

ABSTRACT

It was clearly observed that the temperature in summer period raised every year due to global warming and climate change, this created new problem to keep comfort temperature inside the residential buildings ,which required additional energy to use for mechanical air-conditions and ventilations. External walls in the residential buildings playing major roll to transfer temperature from outside to inside buildings throw building external wall materials.

This paper provides overview of insulation materials and used in the external walls to reduce heat flux throw external walls in the summer and loss heat as well in the winter. In the commercial markets there are many of insulation materials where you can confuse to choose the appropriate material for your region and efficiency of materials used in the construction.

In this paper we will review construction types of external walls in Jordan and check U- Value, study the climate changes for last five years in Jordan and looking for statistics of energy has been spent , also we will illustrate for basic requirements of evaluation of performance insulation materials, technical requirement and compare it with new proposals. This paper is searching only in the residential sector where the area and size of the buildings are limited.

Keywords: Climate change, temperature transfer, insulation materials, heat flux, U- Value , energy, External walls , residential building.

Cite this Article: Ibrahim Varouqa, Taiseer Rawashdeh, Shehdeh Ghannam, External Wall Performance in Residential Buildings in Hot Climate Countries. *International Journal of Civil Engineering and Technology*, 9(10), 2018, pp. 1980–1990.

http://www.iaeme.com/IJCIET/issues.asp?JType=IJCIET&VType=9&IType=10

I. INTRODUCTION

It was clearly observed that the temperature in summer period raised every year due global warming and climate change, this created new problem to keep comfort temperature inside the residential buildings which required additional energy to use for mechanical air-conditions and ventilations. External walls in the residential buildings playing major roll to transfer temperature from outside to inside buildings throw building external wall materials.

This paper provides overview of insulation materials and used in the external walls to reduce heat flux throw external walls in the summer and loss heat as well in the winter. In the commercial markets there are many of insulation materials where you can confuse to choose the appropriate material for your region and efficiency of materials used in the construction.

In this paper we will review construction types of external walls in Jordan and check U-Value, study the climate changes for last five years in Jordan and looking for statistics of energy has been spent as well, also we will illustrate for basic requirements of evaluation of performance insulation materials, technical requirement and compare it with new proposals. However this paper is searching only in the residential sector where the area and size of the buildings are limited.

2. BACKGROUND

For Jordan climate , the requirements for energy has been increased for last 5 years, as per Ministry of Energy and mineral recourses statistic annual report 2013 (1) see (Table 1) the electrical energy consumption has been increased 20.3 % in household sector from 2009 year to 2013 year, comparing with population growth in Jordan as per department of statistics in the statistical year book 2013(2), the population has been increased between 1994 – 2004 by 2.6% and between 2004 -2013 by 2.2%.

Table 1 Sectorial distribution of electrical energy consumption (2009-2013) Giga watt–hour

Sector / Year	Household	Industry	Commercial	Water pumping	Street lighting	Others	Growth rate %
2009	4926	2981	1978	1761	310	-	3.9
2010	5220	3258	2184	1867	315	-	7.4
2011	5441	3478	2260	1938	324	94	5.4
2012	6162	3461	2427	1955	305	-	5.5
2013	6265	3517	2415	2415	391	-	2.0

Source: Ministry of Energy and mineral Recourses - annual report 2013

This gives us how the importance to reduce energy specially in residential sector, good insulation material with good technical.

3. AIM OF THE PAPER

The aim of this paper is to select the insulation materials that are used in the external walls to reduce heat flux throw external walls in the summer and loss heat as well in the winter. For the purpose of this investigation, a real case building was selected . An external wall insulation system (or EWIS) is a thermally insulated, protective, decorative exterior cladding procedure involving the use of expanded polystyrene, mineral wool, polyurethane foam or phenolic foam, topped off with a reinforced cement based, mineral or synthetic finish and plaster.

The thickness of thermal insulation is dependent on whatever type is required in order to create a partition with a heat transmission factor of U= 0.25-0.3 W/m^2.K. When calculating the actual insulation requirements, consideration must be given to current Building Regulation standards. Consideration must also be given to exposure and durability, and whether the structure might be subjected to vandalism etc. In many older properties, special attention is required for concrete beams or lintels which act as thermal bridges providing poor insulation.

4. RESEARCH METHODOLOGY

This report summarizes the results of a thermal performance study of traditionally constructed building elements. The study focused on U-values as an indicator of thermal performance, and involved the in situ measurements of U-values and their subsequent comparison with calculated U-values1 . According to the specific research context, a cross-sectional design strategy was adopted. In this study data were collected based on that Jordan has specific types in construction of external walls in residential buildings; from architectural point view the cladding of outer walls must be from white stone with 6-8 cm thickness, some of buildings are not using the white stone.

5. THERMAL TRANSMITTANCE (U-VALUE) & CALCULATION

5.1. what is a U value

A U- value is a measure of heat loss in a building element such as a wall, floor or roof. It can also be referred to as an ‘overall heat transfer co-efficient’ and measures how well parts of a building transfer heat. This means that the higher the U value the worse the thermal performance of the building envelope. A low U value usually indicates high levels of insulation. They are useful as it is a way of predicting the composite behavior of an entire building element rather than relying on the properties of individual materials.

5.2. How to use U values

The other key property you need to obtain is the conductivity of each building material. This is a measure of its inherent ability to facilitate the passage of heat. The U value is defined as being reciprocal of all the resistances of the materials found in the building element. The resistance *R* of a building material is derived by the following formula:

$$R = (1/k) \cdot d \qquad [1]$$

Where ***k*** is the conductivity of the building material and ***d*** is the material thickness. The formula for calculation U- Value is:

$$U \text{ elements} = \frac{1}{Rso + R1 + R2 + R3 + RSi} \qquad [2]$$

Units are: (W/m^2.K - Watt/ Metter square. Kelvin) , (W/m^2.C$_0$ - Watt/ Metter square. Celsius)

Where: ***Rso*** is the fixed external resistance; ***Rsi*** is the fixed internal resistance and ***R1, R2, R3***

Wall elements resistances .(Inverse sum of resistances of each material and surface resistances to the outer and inner faces of the material build up element) see Fig.(1).

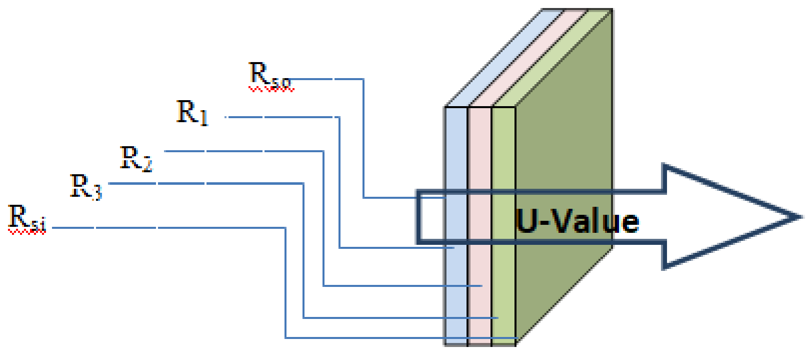


Figure 1 General Wall Layers

6. EXISTING CONSTRUCTION OF EXTERNAL WALLS IN JORDAN

Jordan has specific types in construction of external walls in residential buildings; from architectural point the cladding of outer walls must be from white stone with 6-8 cm thickness, some of buildings are not using the white stone. To calculate U – Value we must know the thermal properties of materials used in construction of external walls.

Table 2 Thermal conductivity of some materials used in the wall construction based on density

Material	**Density (kg/m^3)**	**Thermal conductivity λ (w/m.k)**	**Specific heat capacity ($j/kg.c^0$)**	**Thickness *d* (m)**
White Stone	2250	1.70	1000	0.07
Cast concrete	2300	1.75	1000	0.20
Hollow block	1400	0.9	1000	0.20
Hollow block	1400	0.9	1000	0.10
Plaster	2000	1.20	1000	0.02
Thermal insulation	140	0.04	1000	0.03
Air space	1.25	0.28	1000	0.05

Table 3 Materials heat specification of external walls. The internal and external thermal resistance

External wall surface Resistance R_{so}				
Direction of flux	**Element as per Emissivity**	**Thermal resistance $m^2.c^0/w$**		
		Protected surface from sun	**Middle Protected from sun**	**Not protected from sun**
Horizontal	A	0.08	0.06	0.3
	B	0.1	0.7	0.3
Internal wall surface Resistance R_{si}				
Direction of flux	Element as per Emissivity	Thermal resistance $m^2.c^0/w$		
Horizontal	A	0.12		
	B	0.31		

From the above Tables (2) and(3) we can calculate the U- value for any external wall as per formula [2] in Table (3):

U elements = $\frac{1}{Rso + R1 + R2 + R3 + RSi}$

Units are: ($W/m^2.K$ - Watt/ Metter square. Kelvin), ($W/m^2.C^0$ - Watt/ Metter square. Celsius)

The table below Table (4) is showing deferent kinds of external walls and comparison of the

U- value through the layers, we will consider thermal resistance for all surfaces are not

protected from sun 0.3 m^2. .c^0/w and internal surfaces 0.12 m^2. c^0/w.

From the Table (4) we can find that the best type of external wall where the U value is

less than others in type No.2 due to thermal insulation, but there is some defects in this

type like:

1. The thickness of wall is 37 cm, which consider large thickness for residential buildings.
2. The white stone hard to remove if required replacement.
3. Durability of thermal insulation limited 10 – 15 years maximum.

The goal of this research is to

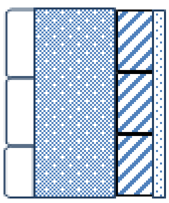
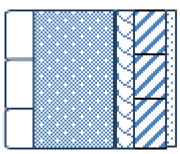
1. Reduce U value through wall elements and materials,
2. Reduce thickness of the wall ,
3. Give more durability for thermal insulation materials,
4. Possibility to remove white stone for maintenance
5. without damaging other parts from the wall.

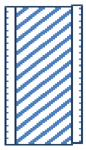
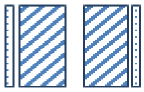
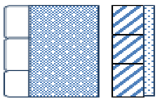
6.1. Thermal insulation material

In the market with thousands of insulation materials, it is very difficult to choose which the

best thermal insulation material. In general all insulation materials are giving nearby numbers of thermal resistances depends on the density and thermal conductivity **λ** , best of them we can find it in the mineral natural sources.

Table 4 deferent kinds of external walls and comparison of the **U-** value

	Construction of Wall	**Thermal Conductance ® w/m.c^0 C = λ/d**	**Thermal Resistance ® (m^2. .c^0/w) R= 1/C = d/ λ**	**U value w/m^2.C^0**
1	 White stone7cm + concrete 15 cm + hollow block 10 cm + Plaster 2cm (Wall thick. 34 cm)	White stone 24.28 Concrete 11.66 Hollow block 9 Internal plaster 60	White stone 0.041 Concrete 0.085 Hollow block 0.11 Internal plaster 0.016	1.479
2		White stone 24.28 Concrete 11.66 Hollow block 9 Internal plaster 60 Polystyrene 1.3 Internal plaster 60	White stone 0.047 Concrete 0.085 Hollow block 0.11 Internal plaster 0.01 Polystyrene 0.75 Internal plaster 0.01	0.698

	White stone 7cm + concrete 15 cm+ thermal insulation 3cm + hollow block 10 cm + Plaster 2cm (Wall thick. 37 cm)			
3	 External plaster 2 cm + hollow block 20cm + internal plaster 2 cm (wall thick. (24 cm)	External plaster 60 hollow block 4.5 external plaster 60	External plaster 0.01 hollow block 0.22 external plaster 0.01	1.515
4	 External plaster 2 cm + hollow block 10cm + air space 5cm + hollow block 10 cm + internal plaster 2 cm (wall thick. 29 cm)	External plaster 6 hollow block 9 air space 5.6 hollow block 9 External plaster 17	External plaster 0.01 hollow block 0.11 air space 0.17 hollow block 0.11 External plaster 0.01	1.204
5	 White stone 7cm + concrete 15 cm + air space 5cm + hollow block 10 cm + Plaster 2cm (Wall thick. 39 cm)	White stone 24.28 Concrete 11.66 Hollow block 9 Internal plaster 60 air space 5.6 Internal plaster 60	White stone 0.047 Concrete 0.085 Hollow block 0.11 Internal plaster 0.01 air space0.17 Internal plaster 0.01	1.17

Earth, naturally, the best insulator is dry immobile air its thermal conductivity factor, expressed in λ, is 0.025 W/(m.K) (watts per meter Kelvin degree). The thermal conductivity of **mineral wool** is close to immobile air as its lambda varies from 0.030 W/(m.K) for the most efficient to 0.040 W/(m.K) to the least, see Fig.(2).

Figure 2 Mineral wool for external walls

We will consider the thermal insulation with λ = 0.04 thermal conductivity to use for our proposals.

6.2. Suspension system for cladding

For white stone as traditional architecture specific for cladding of residential buildings we

must follow, the thickness of white stone 7-9 cm which is very thick for one element of the external wall. We will try to reduce the thickness of stone by using suspension system for cladding. One of the largest company in Germany HALFEN specialized in suspension system for cladding of buildings, one of the system of HALFEN can be matched to reduce the thickness of white stone to 3 cm.

The HALFEN body anchors are 3D adjustable brackets for wall panels made of natural stone

or concrete, which are fixed to the load-bearing structure using HALFEN channels or

approved HALFEN bolts. **The key benefits of Body anchors** are that they are suitable for a

stand-off distance of 30-270 mm with a load capacity up to 1300 N in the standard version, see Figs. (3) ,(4) and (5).

Figure 3 Anchor fixing system

Figure 4 Natural stone with anchor

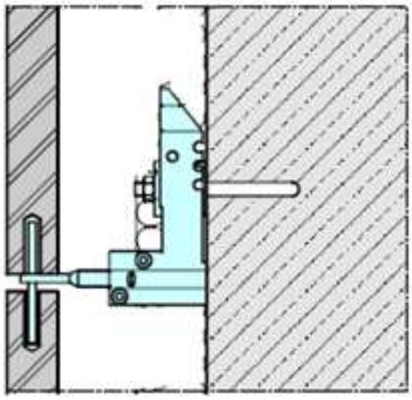


Figure 5 Wall-Cross section

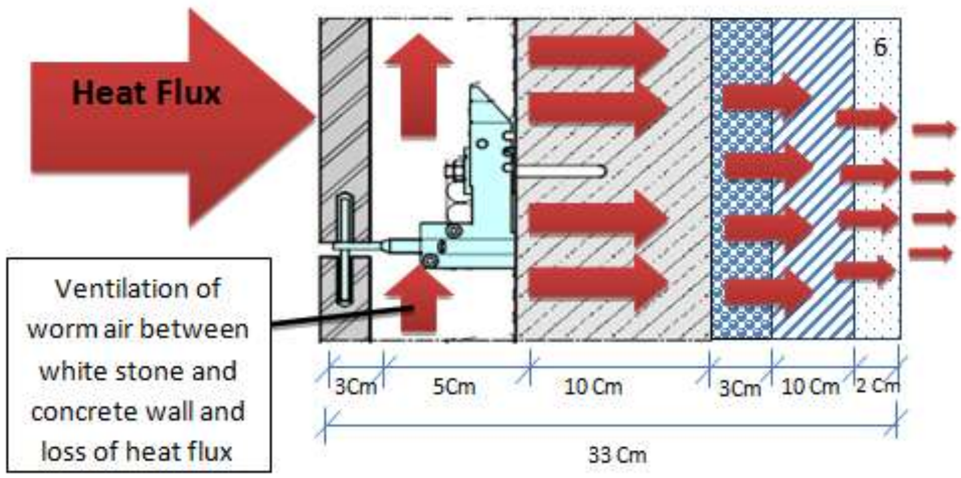
6.3. Proposal of suspension system for cladding white stone.

In the below figure (6) proposal for external wall with insulation material (mineral insulation material), if we calculate the U value for below section:

$$\text{U- Value} = \frac{1}{Rso1 + R1 + RSo2 + R2 + R3 + R4 + R5 + RSi}$$

$$= \frac{1}{56.5 + 5.6 + 0.06 + 17.5 + 1.3 + 9 + 2}$$

= 0.0132 w/m^2.C^0 we can find that the transfer heat is more less than other traditional construction of external walls.



White stone + air space + concrete wall + thermal insulation layer + 10cm hollow block + internal plaster

Figure 6 Proposal of suspension system for cladding white stone

From the above we can see the advantage of using suspension system in the cladding:

a) Reduce the white stone cladding thickness from 8 cm to 3cm.
b) Reduce thickness of the wall.
c) Ventilation space can be controlled and this will help to reduce temperature on the concrete surface.
d) Air space will considered as additional insulation layer.
e) White stone can be removed easily for any maintenance work without damaging any part of the wall.
f) White stone with 3 cm thickness is enough to carry temperature heat in the suspension
g) system and wind load as refer to HALFEN technical data sheet.

6.4. Clay as thermal insulation material

The practical history of clay proves that clay can be used as thermal insulation material the based on international experiments thermal conductivity of clay λ = 0.7 to 0.8 w/m. C^0 and

R0= 0.06 with 2500 density. If we replace the clay when λ = 0.7 w/m. C^0 instead of thermal insulation the U value will be:

$$= \frac{1}{56.5 + 5.6 + 0.06 + 17.5 + 23.3 + 9 + 2} = 8.77 * 10^{-3}\ w/m^2.C^0$$

6.5. Advantage of using clay as thermal insulation

- Available and cheaper than any insulation material
- Durable of material
- Good thermal resistance
- Ecology healthy than insulation material
- High Fire resistant

7. RESULTS AND CONCLUSIONS

For the construction types of external walls in Jordan and the U- Value, as well as the climate changes for last five years in hot climate countries and as statistics of energy that has been spent , we can see according to the basic requirements of evaluation of performance insulation materials, technical requirement and after comparing it with new proposals, the residential sector can use the area and size of the buildings to be limited regarding the thermal conductivity and U-value. **External insulation** systems usually comprise an insulation layer fixed to the existing wall and a protective render or cladding installed on top to protect the insulation from the weather and mechanical damage. The increased depth of an external render or insulation system will require adaptation of roof and wall junctions, window and door openings and rainwater goods. Decorative details such as string courses and quoins may also be affected, and natural materials such as stone or brick will be hidden, effecting a significant change in character.

As most suitable external insulation systems will also need to be protected from rain and mechanical damage, they should normally be considered as a two-component system where all layers must work together. Materials are available which can be used as a single coat, such as insulating lime renders which contain expanded vermiculite, but these tend to give significantly lower insulating values. They can, however, sometimes be applied in circumstances where other types of external insulation would be unacceptably detrimental to the character of a historic building. Again, whatever insulation material is used, the improved wall will need to achieve a U-value of no more than 0.30 W/m^2K.

8. DEFENITIONS AND KEY WORDS

Thermal conductivity (λ)

The quantity of heat transmitted through a unit thickness of a material - in a direction normal to a surface of unit area - due to a unit temperature gradient under steady state conditions, measured in watts per meter per kelvin (W/(m.k). Symbol: λ

Thermal Resistivity (R0)

The Inverse of thermal conductivity is thermal resistivity. $R_0 = 1/\lambda$

Thermal resistivity is used for evaluating the thermal quality of materials for use in component packaging applications. Thermal resistance is a figure of merit for evaluation of the thermal transport capability of component packaging. Measured (M.K/W)

Thermal Conductance (C)

A measure of the ability of an object to allow the flow of heat from its warmer surface through the object to its colder surface, determined as the heat energy transferred per unit of time divided by the temperature difference between the two surfaces, expressed in watts per kelvin / Celsius. The conductance of an object equals the conductivity of its material times its surface area (cross-section) divided by the distance between the two surfaces (thickness). $C = \lambda / d$ where d is the thickness of object or material

Thermal Resistance (R)

The Inverse of thermal conductance is thermal resistance R = 1/C, measured (m^2.k/W)

Surface Thermal Conductance (f)

The amount of the thermal current flowing vertically between on the surface and the air in contact with him. Measured (W/ m^2.k)

Surface Thermal Resistance (Rs)

The Inverse of thermal conductance is thermal resistance is the Surface thermal resistance

Rs =1/f measured (m^2.k/W).

Cavity Thermal Conductance (C_c)

The amount of the thermal current flowing vertically throw unite area of cavity due deference between two surfaces. Measured (W/ m^2.k)

Cavity Thermal Resistance (R_c)

The Inverse of cavity thermal conductance is cavity thermal resistance. Rc= 1/Cc

Thermal Transmittance (U)

Also known as U-value is the rate of transfer of heat (in watts) through one square meter of a structure divided by the difference in temperature across the structure. It is expressed in watts per meters squared kelvin, or W/M^2K.

Air to Air Thermal Resistance (R_a)

Also known as total thermal resistances from air to air, and the inverse of thermal transmittance Ra = 1/ U

Emissivity (E)

Is a measure of the efficiency in which a surface emits thermal energy. It is defined as the fraction of energy being emitted relative to that emitted by a thermally black surface (a black body). A black body is a material that is a perfect emitter of heat energy and has an emissivity value of 1

REFERENCES

[1] The Ministry of Energy and Mineral resources, Annual Report 2013, Jordan – Amman.

[2] Department of statistic, Annual Report No 64 – 2013, Jordan – Amman.

[3] External wall insulation, London Borough of Havering - Climate Consulting Ltd.

[4] External Wall insulation in traditional buildings – Research report 2014- English

[5] Heritage Research report 2014.

[6] Quad-Lock Concrete Building Solutions, 2015, http://www.quadlock.com/retrofit_insulation

[7] Channel sub-Structure for Natural Stone Facades-HALFEN FSU98.2 ,Version1.3.

[8] Thermal Conductivity and density of clay pastes at various water contents for polytherapy use, Applied Clay Science, journal homepage – ELSEVIER- 2014