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Energy Standards for Non-residential Buildings in Arab Countries

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Author's contribution

This work was carried out to develop the final draft for energy efficiency building code for Arab countries. The author was the technical coordinator and the team leader for simulation and training working group. The author added a new chapter in the Egyptian Energy code for Natural Ventilation and Thermal Comfort.

Original Research Article

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ABSTRACT

This paper presents an energy analysis in support of developing an Energy Code for New Commercial Buildings for the Arab Countries. Energy efficiency of buildings is a major consideration of the architectural design. The building used for this study is a twenty-story building with a typical floor area of rectangular shape of 900m^2. Two computer simulation programs (Excel) had been developed. The first to calculate the heating and cooling degree days (DDH & DDC) for the selected Arab cities, and the second to predict the complied energy required for the new buildings based on the weather data of each Arab city, and building materials and construction. The OTTV approach was used to develop appropriate criteria for the building envelope for most commercial buildings in the Arab region. The analysis shows that the OTTV for the exterior walls for most commercial buildings in the Arab region should not exceed 90 W/m^2, and 12 W/m^2 for the roofs. Also, the WWR should be less than 60% with SHGC less than 0.49.

Keywords: Energy Profile; window-to-wall ratio (WWR); glass heat gain coefficient (SHGC); DDH&C; over all transfer value (OTTV).

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ABBREVIATIONS

DD	*Degree Day-difference in temperature between the outdoor mean over 24-hour and base temperature 18.3 or 25°C)*
DD10	*Degree Day Heating based on 10°C*
DD18.3	*Degree Day Heating based on 18.3°C*
DD25	*Degree Day Cooling based on 25°C*
OF	*Window Orientation Factor (non)*
OTTV	*Over all Transfer Value, W/m²*
$OTTV_r$	*Over all Transfer Value for roof,* W/m^2
$OTTV_w$	*Over all Transfer Value for wall,* W/m^2
SC	*Shading Coefficient; ratio of solar heat gain of fenestration system to solar heat gain of single glass.*
SHGC	*Solar Heat Gain Coefficient , (non)*
SF	*Solar Factor,* W/m^2
T_{vis}	*Transmittance of visible light*
U	*Thermal Transmittance,* $W/m^2.°C$
WWR	*Window-to-Wall Ratio (%)*

1. INTRODUCTION

The energy problem is a tremendous task due to rapid population growth, building needs and energy costs. One way to reduce energy expenditure would be the energy efficient building design to limit heat gain into buildings. In Arab Countries, over 60% of the total electricity consumption is attributed to residential, commercial, and institutional buildings; see Table 1. Artificial lighting is estimated to account for about 40% of electricity used in the commercial sector and 45% of electricity used for HVAC system. Building Envelope and fenestration components are considered one of the fundamental design features of energy-efficient buildings. Table 2 shows the total energy consumed in each country, while Table 3 illustrates the electricity consumed. It is clear that Saudi Arabia and Egypt are the top ranking of Energy consumption. A significant increase in electricity demand is expected over the next few years with a growth rate of about 10%. In the last 20 years due to new building construction it has been possible to reduce the cooling energy demand by more than 10% of present cooling energy consumption. This improved building envelope thermal performance means that new buildings are of a higher standard than required by law. To determine the effect of the building envelop on the condition of buildings, the present analysis are carried out for summer conditions of selected cities in the Arab region. The final draft of an energy building code had been developed for new residential and commercial buildings in Arab countries [1]. Envelope Trade-Off Compliance, OTTV Approach [2], is used to determine the effects of building parameters on the total electricity use for typical buildings.

2. METHODOLOGY

2.1 Energy Standards is Effective

From the 1970s many countries throughout the world introduced building regulations aimed at reducing energy consumption in residential and commercial buildings. Typically, these regulations concentrate on aspects of heat loss through the building envelope with minimum levels of insulation required being stated. Worldwide these regulations encompass simple perspective requirements stipulating a minimum resistance for individual opaque building elements. The simple prescriptive nature of most of the regulations reduces the need for complex calculation methods. Table 4 shows a comparison for U-vales for different countries [3].

2.2 Arab Energy Building Codes

The Egyptian energy building code that has been developed recently [5] is very innovative because it specifies minimum building requirements to improve both thermal and visual comfort as well as minimum energy efficiency requirements in conditioned buildings. The Arab Energy Code [1] follows the same procedure as the Egyptian Code issuing minimum performance standards for building windows and openings, natural ventilation and thermal comfort, ventilating and air-conditioning equipment, natural and artificial lighting, and electric power. The final draft of the Energy Code contains the following chapters:

1) scope and compliance
2) general requirements
3) building envelope
4) ventilation
5) heating ventilation and air conditioning
6) service heating system
7) lighting
8) electric power
9) renewable energy
10) whole building performance
11) abbreviations and acronyms definitions

Table 1. Electricity consumption by sector (GWh), 2009 [6]

Arab Countries	Industry	Residential	Commercial and Public Services
S. Arabia	24260	100855	52928
Egypt	38926	47439	18050
UAE	8804	31424	27016
Kuwait	0	22376	11944
Algeria	10560	20155	0
Syrian	10281	13886	3024
Libyan	3722	6117	9037
Morocco	8502	7385	4036
Qatar	5594	5071	3826
Oman	1721	7920	4966
Lebanon	3454	5013	2198
Tunisia	5187	3594	3326
Jordan	2908	4885	2582
Bahrain	1233	5408	3489
Sudan	488	2570	1535
Yemen	0	3001	954

Table 2. Arab energy consumption 2010, [7]

Country	NG Thousand TOE	Petroleum Consumption Thousand toe/day
S. Arabia	1180.0	1820.0
Egypt	600.0	699.9
Qatar	560.0	100.0
Algeria	300.0	348.7
Bahrain	270.0	51.0
Libya	270.0	243.0
Iraq	180.0	500.0
Syria	115.0	318.6
UAE	112.0	357.5
Oman	107.0	66.9
Kuwait	75.0	440.0
Tunisia	59.0	112.0
Jordon	59.0	96.9
Morocco	13.0	186.0

Table 3. Electricity consumption for selected Arab Countries, [7]

Rank	Country	Electricity Consumed GWh
1	S. Arabia	211078
2	Egypt	119400
3	UAE	79346
4	Kuwait	49304
5	Algeria	35677
6	Syria	29685
7	Iraq	26879
8	Qatar	23292
9	Morocco	23280
10	Libya	21139
11	Jordon	12817
12	Tunisia	12850
13	Oman	11448
14	Sudan	5620
15	Lebanon	4852

2.3. Solar and Orientation Factors and Shading Coefficient

Hourly, monthly and annual averages direct and diffuse solar radiations were calculated for eight orientations and for horizontal surface where the Solar Factors (SF) and the Orientation Factors (OF) were also calculated. Orientation Factors (OF) were derived by normalizing the Maximum Solar Heat Gain Factors for June for each selected city in the Arab region, see Table 6. The shading coefficient (SC) of the fenestration system is shown in Table 5 for different Glass Types [4]. The solar factor (SF) is the average hourly rate at which solar radiation incident upon vertical surface; it is expressed in W/m2. Both diffuse and direct radiation is included in the solar factor. The vertical radiation is averaged over the time period 7:30a.m. to 5.30p.m. The solar factor for each Arab city was calculated from a computer program developed specially for this study see Table 7.

Table 4. Recommended thermal resistance for different Arab countries [3] (m2.°C/W)

Country	Roof	Walls	Floors
Austria	3.3	2.0-1.4	2.3-1.6
Belgium	2.4-1.3	1.5-1.0	-
Canada	7.0-4.9	3.3-2.1	4.9
Egypt	**1.67**	**1.0**	**----**
Finland	4.4-3.5	3.5-2.9	4.4
France	4.0-2.5	2.0-1.5	1.3-1.0
Jordon	**1.0**	**0.56**	**--**
Kuwait	**2.5**	**1.75**	**--**
Greece	2.0	0.9	2.0-0.3
Italy	2.6	1.7	--
New Zealand	3.0-1.5	1.7-0.6	1.7-0.9
Spain	1.4-0.7	0.7-0.6	1.4-1.0
Switzerland	2.0	1.7	1.7
Turkey	2.63	1.7	--
U K	2.9	1.0	--
USA (various)	7.0-3.5	3.5-2.0	3.5-0.0
West Germany	3.3-2.2	1.2-0.7	1.8-0.8
Saudi Arabia	**1.754**	**1.3**	**--**
Republic of Lebanon	2.27-1.75	1.85-0.48	---

Table 5. Glass types characteristics [4]

Name	U	SC	SHGC	TVIS
Single Glazing_**Clear**	6.17	.95	.81	.88
Single Glazing_**Blue**	6.17	.71	.61	.57
Single Glazing_**Grey**	6.17	.69	.59	.43
Single Reflective (Class A) [1] Clear High Emissivity	5.41	.36	.31	.20
Single Reflective (A) Tint Medium Emissivity	5.11	.29	.25	.09
Double Glazing **BronzeTint**	2.74	.57	.49	.47
Double Glazing **GreenTint**	2.74	.57	.49	.66
Double Glazing Tint Low Emissivity	1.78	.37	.28	.44
Double Glazing, Reflective (A) Clear Medium Emissivity (IG)[2]	2.35	.20	.17	.13
Double Glazing, Reflective (A)Tint, Medium Emissivity (IG)	2.35	.18	.15	.08

1. Class A, inner surface of exposed sheet, 2. Insulated Glass

2.4 Thermal Performance of Building Envelope

For the design and planning of energy efficient buildings, the overall thermal transfer value (OTTV) is one aspect of energy conservation. An OTTV indicates the amount of heat transferred into building through the building façade per unit building envelope area. OTTV is a system performance criterion that allows trade-offs among opaque wall and window areas and their thermal and solar characteristics to achieve an overall minimum performance. It is aimed to reduce heat gain by conduction and solar radiation in order to reduce heat the cooling load of the air conditioning system. The OTTV concept is based on five basic methods of heat gains through the external envelope of a building:

1. Heat conduction through the opaque walls/roof ceiling and floors.
2. Solar heat gain through opaque walls/roof.
3. Heat conduction through windows.
4. Solar radiation through windows.
5. Infiltration through windows and doors.

The total Overall Thermal Transfer Value (OTTV) for the building envelope should not exceed 90W/m2 for hot-arid climate such as Egypt. OTTV is calculated for each individual façade and then for the building taking the weighted average of the individual façade OTTVs. The OTTV for an individual façade is calculated using following formula; where the infiltration/ventilation term is add by the author.

$$OTTV_i = (\alpha A_w OF\ U_w\ (TD_{eqw}-DT_o) + A_w\ U_w\ DT_o + A_g\ U_g\ DT_o + A_g\ SF\ OF\ SC + C_v\ DT_o\ )/A_o \quad (1)$$

Where the terms are defined as:

$$C_v = \text{ventilation/infiltration conductance, } (W/^oC) \cong 0.333 * N*V \quad (2)$$

N = number of air change/hour, and is calculated using the following empirical equations:

$$= 0.49 + 0.09 *V_w \text{ for small cracks or } = 1.03 + 029 *V_w^2 \text{ for open doors} \quad (3)$$

OF = orientation factor of the windows, as given in Table 6.

SF = solar factor, the average hourly value of solar energy on vertical windows, $W/m^2.C$, Table 7.

SC = shading coefficient of the windows = $SC_e * SC_i$, as given in Tables 8 and 9.

DT_o = temperature difference between the indoor and outdoor temperature, (^oC), and is Negative for ventilation when Tai> Tao.

V_w = average wind speed of the city, (**m/s**)

α = solar absorption of the exterior opaque wall, (**non**)

$$OTTV_w = \frac{As*OTTVs + Ae*OTTVe + Aw*OTTVw + ... + An*OTTVn}{As + Ae + Aw + ... + An} \quad (4)$$

Where A_s and $OTTV_s$ are the area and the OTTV for each exposed wall. The OTTV for mass opaque roof (without skylight) is calculated from the equation:

$$OTTV_r = \alpha\ U_r\ (TD_{eqr} - DT_o) + U_r * TD_o \quad (5)$$

Where:

Ur = thermal transmittance for roof, $(W/m^2.^oC)$

TD_{eqr} = Equivalent indoor-outdoor temperature difference through the opaque roof and is calculated from the empirical formula ,i.e.

TD_{eqr} = $29.2 + 5.6*U_r/Tc - 1.12(U_r/T_c)^2$, $T_c = \Sigma\rho C\ L$

2.5 Methodology

The OTTV equations for the walls and the roof were programmed into an Excel spreadsheet, developed by the author. For each city selected the outdoor climatic data changed automatically. Selection for the wall and roof constructions by name and the corresponding physical properties automatically appear on the corresponding cells to facilitate the input and output calculations. The selection for glass type, shading, or color appears directly at the end. The output results were imported to another Spreadsheet to store each run in a separate row for each city. End results were imported to a table containing the selected cells, and the final graph was drawn for comparison.

Table 6. Orientation factors (OF) for Arab countries

City/Orientation	OF_N	OF_{NE}	OF_E	OF_{SE}	OF_S	OF_{SW}	OF_W	OF_{NW}
Cairo	0.65	1.07	1.27	1.04	0.60	1.04	1.27	1.07
Alexandria	0.63	1.05	1.27	1.05	0.63	1.05	1.27	1.05
Aswan	0.77	1.15	1.28	0.94	0.48	0.94	1.28	1.15
Damascus	0.60	1.02	1.26	1.08	0.69	1.08	1.26	1.08
Riyadh	0.76	1.14	1.28	0.95	0.49	0.95	1.28	1.14
Dubai	0.74	1.13	1.28	0.97	0.5	0.97	1.28	1.13
Manama	0.72	1.12	1.28	0.98	0.52	0.98	1.28	1.12
Jeddah	0.86	1.17	1.26	0.90	0.47	0.90	1.26	1.17
Kuwait	0.66	1.08	1.27	1.02	0.58	1.02	1.27	1.08
Amman	0.62	1.04	1.27	1.06	0.64	1.06	1.27	1.04
Beirut	0.6	1.01	1.26	1.08	0.7	1.08	1.26	1.01
Tripoli	0.61	1.03	1.26	1.07	0.67	1.07	1.26	1.03
Tunis	0.57	0.96	1.25	1.12	0.78	1.12	1.25	0.96
Dhahran	0.72	1.12	1.28	0.98	0.52	0.98	1.28	1.12
Damascus	0.60	1.02	1.26	1.08	0.69	1.08	1.26	1.02
Aleppo	0.57	0.97	1.25	1.11	0.76	1.11	1.25	0.97

Table 7. Solar factors (SF, W/m^2) for Arab countries

City /Orientation	SF_N	SF_{NE}	SF_E	SF_{SE}	SF_S	SF_{SW}	SF_W	SF_{NW}	SF_{RF}
Cairo	113.5	194.9	330.3	408.1	415.0	408.1	330.1	194.9	629.3
Alexandria	111.4	191.0	326.7	409.1	419.8	409.1	326.8	191.0	620.0
Aswan	125.7	259.9	345.0	395.3	379.8	395.3	345.0	259.9	669.8
Damascus	185.0	310.0	374.0	310.0	186.0	310.0	374.0	310.0	803.0
Riyadh	223.5	337.4	378.3	281.8	144.7	281.8	378.3	337.4	809.5
Dubai	202.0	322.0	372.0	290.0	156.0	290.0	372.0	322.0	799.0
Manama	207.5	325.5	371.7	284.8	149.9	284.8	371.7	325.5	798.3
Jeddah	250.6	341.2	367.5	261.3	137.7	261.3	367.5	341.2	787.1
Kuwait	194.2	316.	373.4	299.8	170.5	299.8	373.4	316.5	801.8
Amman	187.8	316	384.8	321.6	195.7	321.6	384.8	316	821.8
Beirut	178.2	301.1	375.1	322.6	208.6	322.6	375.1	301.1	802.6
Tripoli	180.9	304.9	374.8	317.2	198.4	317.2	374.8	304.9	802.9
Tunis	170.4	290.4	375.5	336.9	236.1	336.9	375.5	290.4	800.0
Dhahran	207.5	325.4	371.5	284.5	149.8	284.5	371.5	325.4	797.8
Damascus	183.4	309.7	384.2	328.4	209.8	328.4	384.2	309.7	819.7
Aleppo	174.4	296.7	380.5	338.2	233.0	338.2	380.5	296.7	810.2

2.6. Study Case

The Base Case used for this study is a twenty-story building with a typical floor area of rectangular shape (A=900m2), as shown in Fig. 1. The dimensions of the building are 45m by 20m with a floor-to-floor height of 4.0m. The perimeter areas (AP) were assumed to have a depth of 6m. Each facade has 10 modules of 3m wide that facilitate the definition of 10 windows on each orientation. It should be noted that the study presented in this paper focuses specifically on the building envelop parameters. The external wall was insulated in the middle between two layers of bricks of 0.12m thick.

Table 8. Internal shading coefficients (Sc_i) and U-value (U_g) for windows

Glass Type	Inside Shade					
	None		Drapery, Venetian Blind or Translucent Roller Shade		Opaque Roller Shade	
	SC	Ug	SC	Ug	SC	Ug
Single	1.00	5.91	0.50	4.60	0.38	4.60
Double	0.88	3.46	0.45	3.12	0.36	3.12
Heat-absorbing	0.58	2.56	0.37	2.50	0.33	2.50
Triple	0.80	2.50	0.44	2.27	0.36	2.27

Table 9. External shading coefficient (Sc_e)

Orientation	Overhangs			Nearby	
	0.6m	1.2m	2.0m	Buildings	Trees
North	1.00	1.00	1.00	1.00	1.00
North East	1.00	0.95	0.90	0.90	0.95
East	0.95	0.90	0.85	0.75	0.80
South East	0.85	0.80	0.75	0.80	0.85
South	0.80	0.70	0.65	0.85	0.90
South West	0.85	0.80	0.75	0.80	0.85
West	0.95	0.90	0.85	0.75	0.80
North West	1.00	0.95	0.90	0.90	0.95

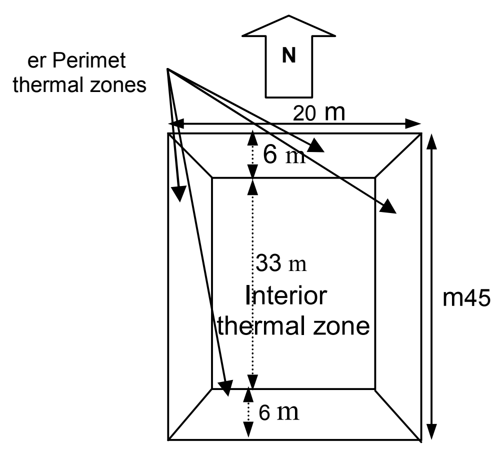

Fig. 1. Lager office typical floor of rectangular plan

The external surface was covered by 25mm thick marble and the plaster from inside by 16mm gypsum layer. The top roof for the building was examined. The U-value of the opaque wall is 0.7W/m2. The roof consists of a concrete slab of 200mm thick with Built-up-cement tiles above it of 70mm. Polystyrene insulation of 75mm was used, above the concrete slab and beneath the roof slab and plastered from inside with 0.016m gypsum. The U-value of the opaque roof is 0.41W/m2. The effect of WWR, Glass Type and shading device will appears directly on the OTTV values. The weather data for the selected cities in the Arab region was downloaded from the Internet and summarized to calculate the DDC10, DDC18.3 and DDH25 for every month and the year using an Excel spreadsheet developed by the author. The results are summarized in Table 10.

3. RESULTS AND DISCUSSION

Table 10 classifies the Arab countries into five regions according to the DDC10, DDC18.3 and DDH25. For example, the first region contains Doha, Dubai and Kuwait where DDC10>6000 where the outdoor weather is very hot and humid. The second region includes Riyadh and Aswan where 4000<DDC10<6000 and the weather is recognized as very hot and dry. The OTTV analysis was applied to each city. The effect of the WWR was analyzed from 0.1 to 0.9.

Fig. 2. shows the variation between $OTTV_w$ and WWR. The variation is linear when WWR increases the

$OTTV_w$ increases. The regression analysis was applied to get the following equations:

OTTV= 296.6.8*WWR+28.39 (Cairo) OTTV= 134.95*SHGC+26.31 (Cairo) (7)
OTTV= 323.94* WWR+21.3 (Kuwait) OTTV= 177.40*SHGC+49.45 (Kuwait)

The general linear equation for all regions was found as follows, i.e,

$$OTTV = 278.0 * WWR + 20.5 \quad (8)$$

Fig. 3. illustrates the variation between the OTTV and glass type. The WWR was chosen as 0.6 since most the commercial buildings designed to appears attractive from outside. The glass type affects the OTTV strongly. The figure shows that it is very difficult to reach the complied values with single glazing without any treatments or using double pane glass with selective coating. The third step is to add external and internal shading device. Fig.4. shows the OTTV versus glazing types at WWR= 0.6 with external shading and light color surface. The shading enhance and lowering the OTTV values and it shows that the OTTV reaches 90 W/m^2 or lower except Riyadh where the WWR must be less than 60%.

Table 10. Degree day heating and cooling for selected Arab cities for different classes

City	Lat, °N	Log, °E	Eleva, m	$T_{ao,avg}$	RH(%)	Ws(m/s)	DDC10	DDC18.3	DDH25	Classification	Category
Doha	25.2	51.6	12.0	28	56	2.9	6579	92	1802		
Dubai	25.3	55.3	5.0	28.1	51	3.0	6620	27	1660		
Dhahran	26.3	50.2	17.0	27.4	50	3.4	6385	205	1840		
Khartoum	15.6	32.5	382	28.6	21	4.1	6796	2	1520	**DDC10> 6000**	**A**
Kuwait	29.2	48.0	55.0	26.3	39	3.1	6005	487	1912		
Manama	26.3	50.7	2.0	26.9	60	3.6	6167	151	1537		
Jeddah	21.7	39.2	12.0	28.3	59	2.8	6683	0	1370		
Aswan	24.0	32..8	194.0	26.2	27	3.3	5908	165	1385		
Riyadh	24.7	46.7	612.0	26.2	29	2.7	5934	340	1161	**4000<DDC10 <5000**	**B**
Laxer	25.7	32.7	88.0	24.7	40	1.8	5397	270	1107		
Baghdad	33.2	44.2	34	23.9	39	2.4	5298	680	1495		
Cairo	30.1	31.4	74.0	21.9	58	2.9	4343	397	409	**3000< DDC10 <4000**	**C**
Mousel	36.3	43.2	216	21.1	47	1.7	4403	1153	1122		
Alexandria	31.2	30.0	7.0	19.9	67	3.2	3639	561	153		
Beirut	33.8	35.5	19.0	20.1	62	2.6	3708	536	174		
Agadir	30.3	9.6W	74.0	19.3	71	2.1	3395	529	26		
Sana'a	15.5	44.2	2190.0	18.4	39	1.5	3074	503	4		
Tunis	36.8	10.2	4.0	19.4	69	2.7	3482	809	202	**3000<DDC10< 4000**	**D**
Tripoli	32.7	13.1	81.0	20.5	57	2.4	3891	686	337		
Latakia	35.5	35.8	7.0	18.4	67	2.3	3108	904	100		
Aleppo	36.2	37.2	393.0	17.6	58	3.6	3139	1570	342		
Algeria	36.7	3.2	25.0	17.9	71	2.6	2977	977	51		
Damascus	33.5	36.5	609.0	16.7	53	4.6	2811	1596	172	**DDC10< 3000**	**E**
Amman	32.0	36.0	773.0	17.1	47	1.9	2828	1504	127		

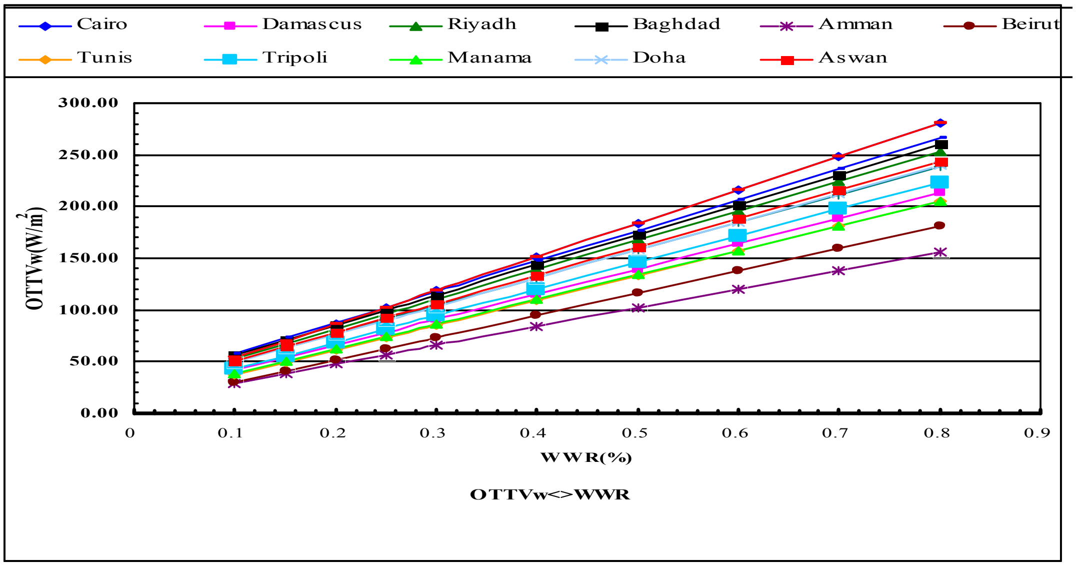

Fig. 2. Relation between OTTV & WWR

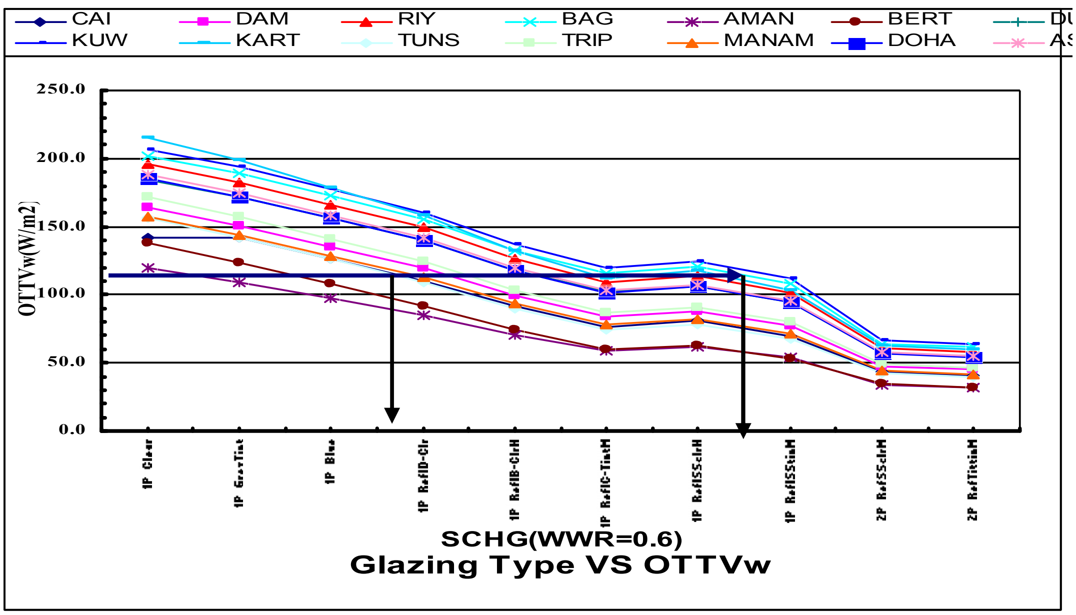

Fig. 3. Relation between OTTV & SHGC

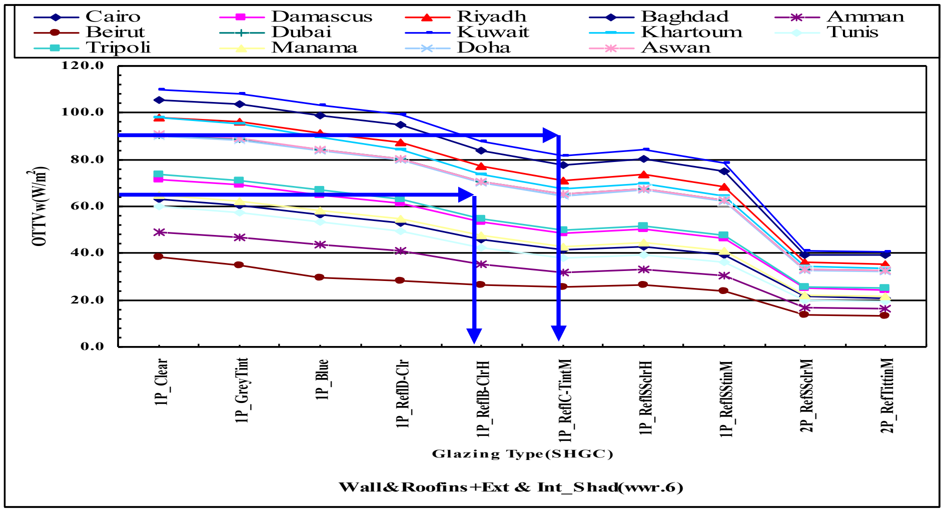

Fig. 4. Relation between OTTV and building envelope characteristics for WWR (60%)

4. CONCLUSION

It has been proven that increasing the glazing efficiency of the façade increases the WWR and the building thermal efficiency. The Total Overall Thermal Transfer value (OTTV) for the exterior walls should not exceed $90W/m^2$, ranges from $60W/m^2$ to $90W/m^2$ for the five climatic regions. The $OTTV_r$ should not exceed $12W/m^2$ and could be taken as $10W/m^2$.

COMPETING INTERESTS

Author has declared that there is no competing interests exit.

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